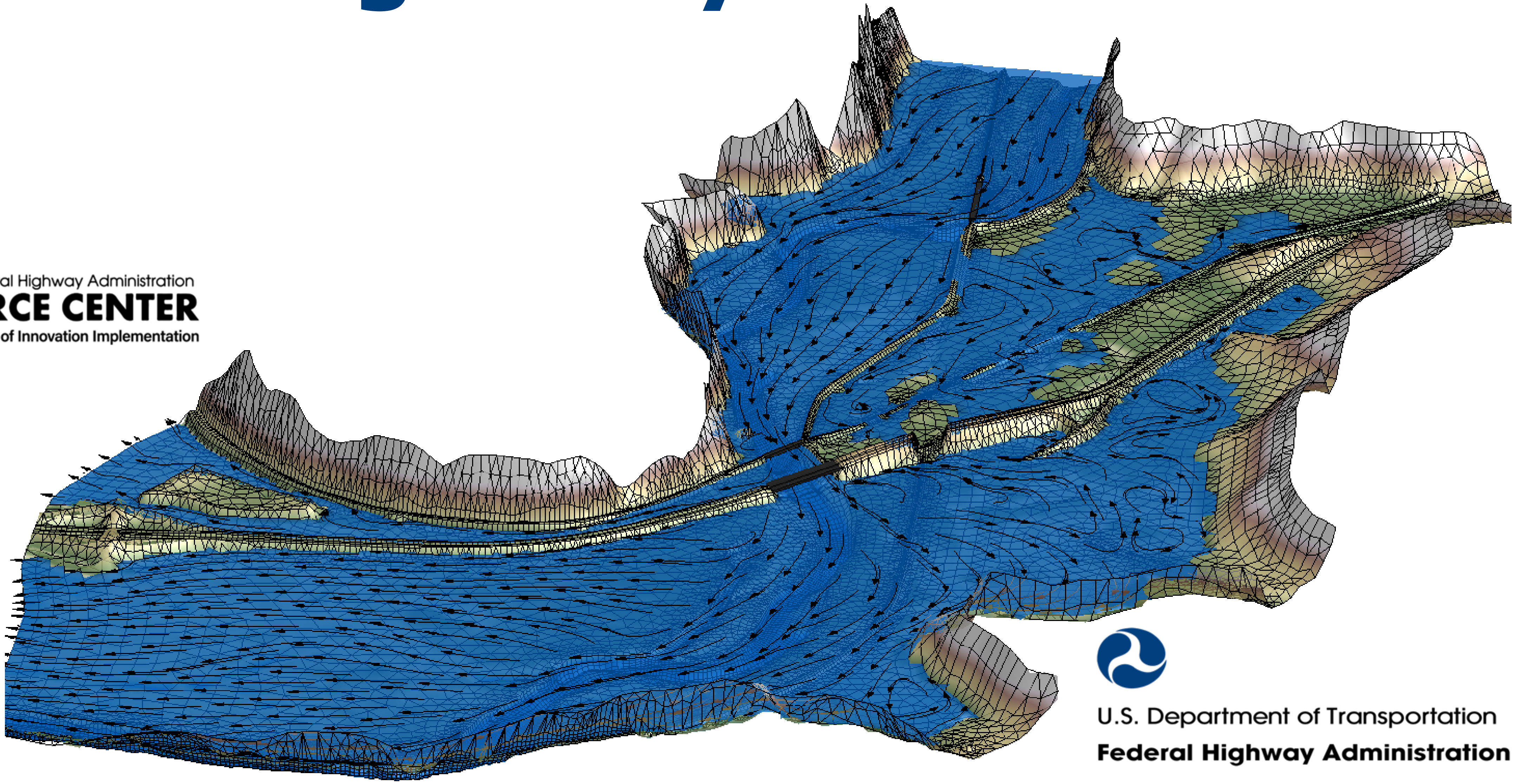
Getting Your Feet Wet with Reviewing 2D Hydraulic Models



Federal Highway Administration
RESOURCE CENTER
Office of Innovation Implementation

U.S. Department of Transportation
Federal Highway Administration

Instructor

Scott Hogan

Senior Hydraulic Engineer
FHWA Resource Center
Fort Collins, CO

- **Background & Experience:** 11 years FHWA Resource Center, 7 years Central Federal Lands Hydraulics Team Lead, 14 years consulting engineering
- **Current Duties:** **T**raining,**T**echnical Support, **T**echnology Development and Deployment
- **Hydraulic Modeling Background:** HEC-2, HEC-RAS 1D, FESWMS, RMA-2D, TUFLOW Classic and FV, SRH-2D, HEC-RAS 2D
- **Education:** B.S Civil Engineering 1991 (Colorado State University) M.S. Hydraulics 1993 (Colorado State University)

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2D Hydraulic Model Review Training

Learning Objectives

- Identify key aspects of a 2D hydraulic model review
- Request the relevant information required for conducting a review
- Conduct cursory or detailed reviews of hydraulic models
- Recognize acceptable or reasonable ranges for the key parameters of a 2D model.
- Spot common modeling errors and other issues that warrant further investigation.
- Understand the hydraulic modeling variables needed for bridge scour analyses and how they can be extracted from a 2D model

2D Model Review Training Agenda

Session 1

- Overview of 2D Modeling and Available Resources
- Information to Be Reviewed, Model Review Spreadsheet and Best Practices
- Project Information and Model Background Data
- 2D Mesh
- *Assign Exercise 1*

Session 2

- *Review Exercise 1*
- Boundary Conditions
- Material Roughness
- Hydraulic Structures
- Simulation Parameters
- *Assign Exercises 2 & 3*

Session 3

- *Review Exercises 2 & 3*
- Reviewing Model Results
- Hydraulic Variables for Bridge Scour Analyses
- Wrap-up

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Image from PowerPoint online images by Peter Baumgartner

Introduction

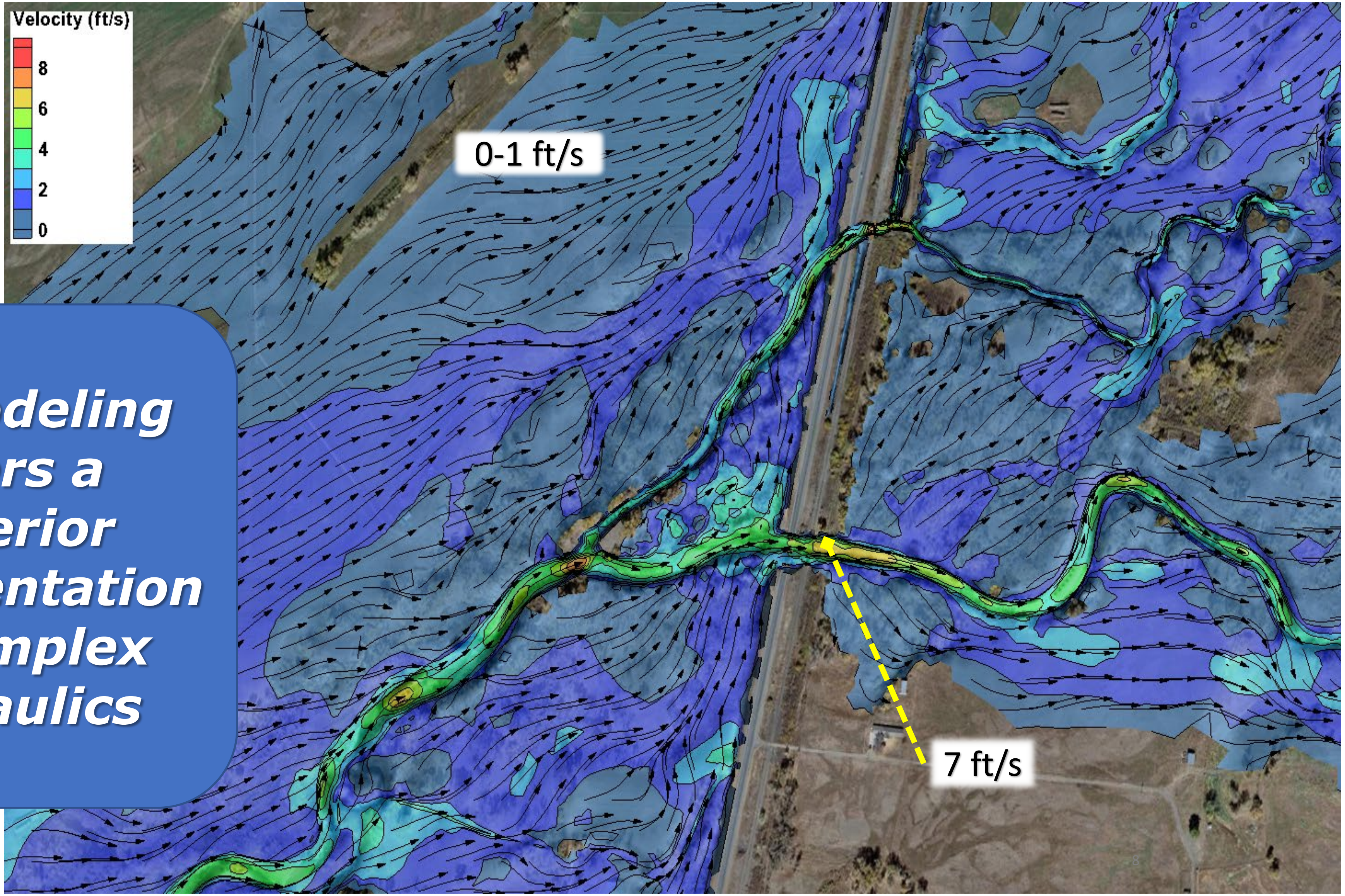
Why 2D Modeling?

1D vs. 2D Hydraulic Modeling Assumptions / Limitations

Hydraulic Variables	One-dimensional (1D) Modeling	Two-dimensional (2D) Modeling
Flow direction	Assumed by user	Computed
Flow paths	Assumed by user	Computed
Channel roughness	Assumed constant between cross sections	Represented at each element
Ineffective (blocked) flow areas	Assumed by user	Computed
Flow contraction and expansion through bridges	Assumed by user	Computed
Flow velocity	Averaged at each cross section Assumed in one direction	Magnitude and direction Computed at each element
Flow distribution	Computed based on conveyance	Computed based on continuity
Water surface elevation	Assumed constant across cross sections	Computed at each element

Introduction

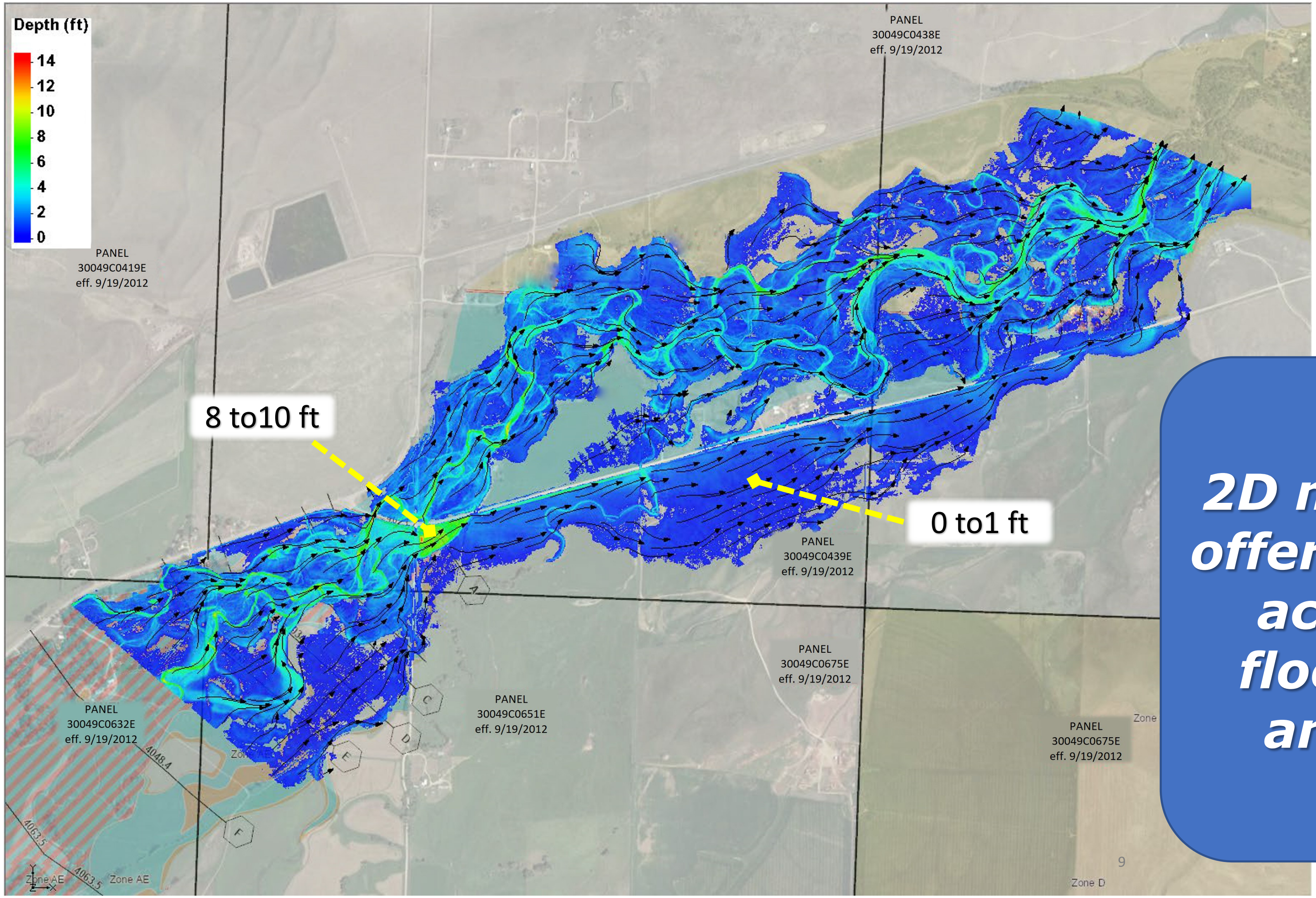
Why 2D Modeling?



2D modeling offers a superior representation of complex hydraulics

Image Sources: CDOT / Earthstar Graphics (Aerial Image)

Introduction
Why 2D Modeling?

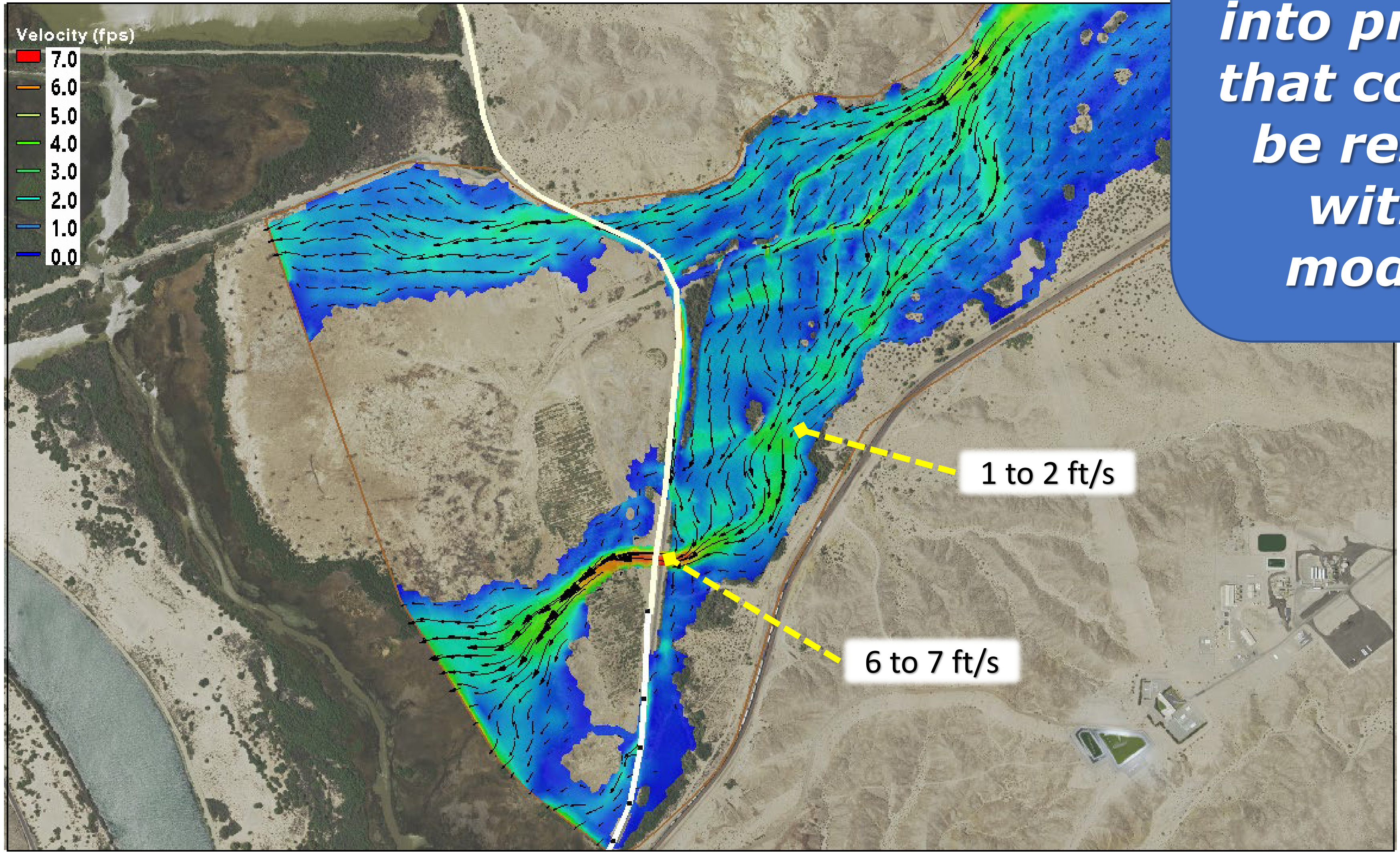


2D modeling offers a more accurate floodplain analysis

Image Sources: FHWA / Earthstar Graphics (Aerial Image)

Introduction

Why 2D Modeling?

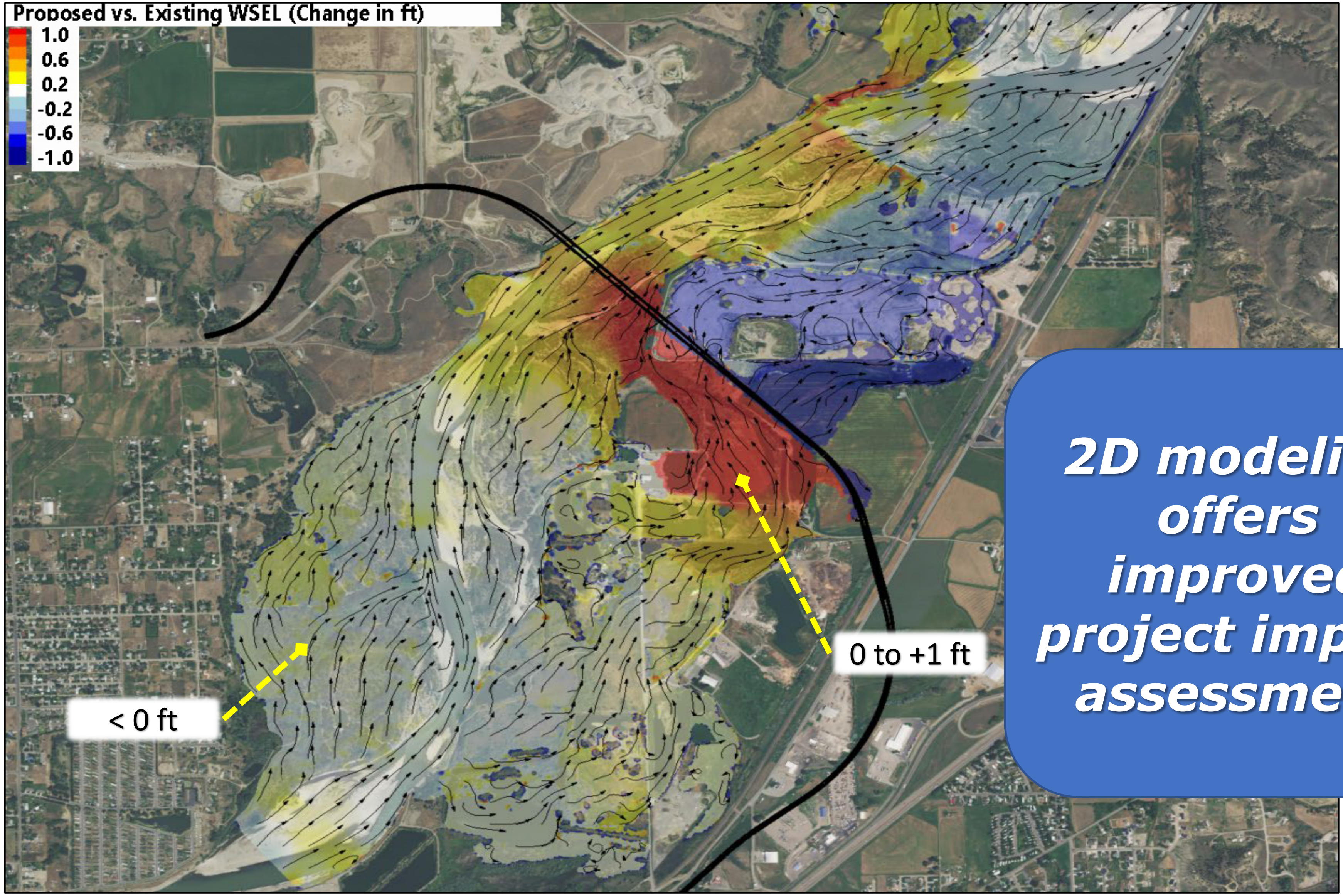


2D modeling offers insight into problems that could not be resolved with 1D modeling

Image Sources: FHWA / Earthstar Graphics (Aerial Image)

Introduction

Why 2D Modeling?



2D modeling offers improved project impact assessment

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

Introduction

Why 2D Modeling?

2D modeling more accurately depicts flow distribution and variability in WSEL

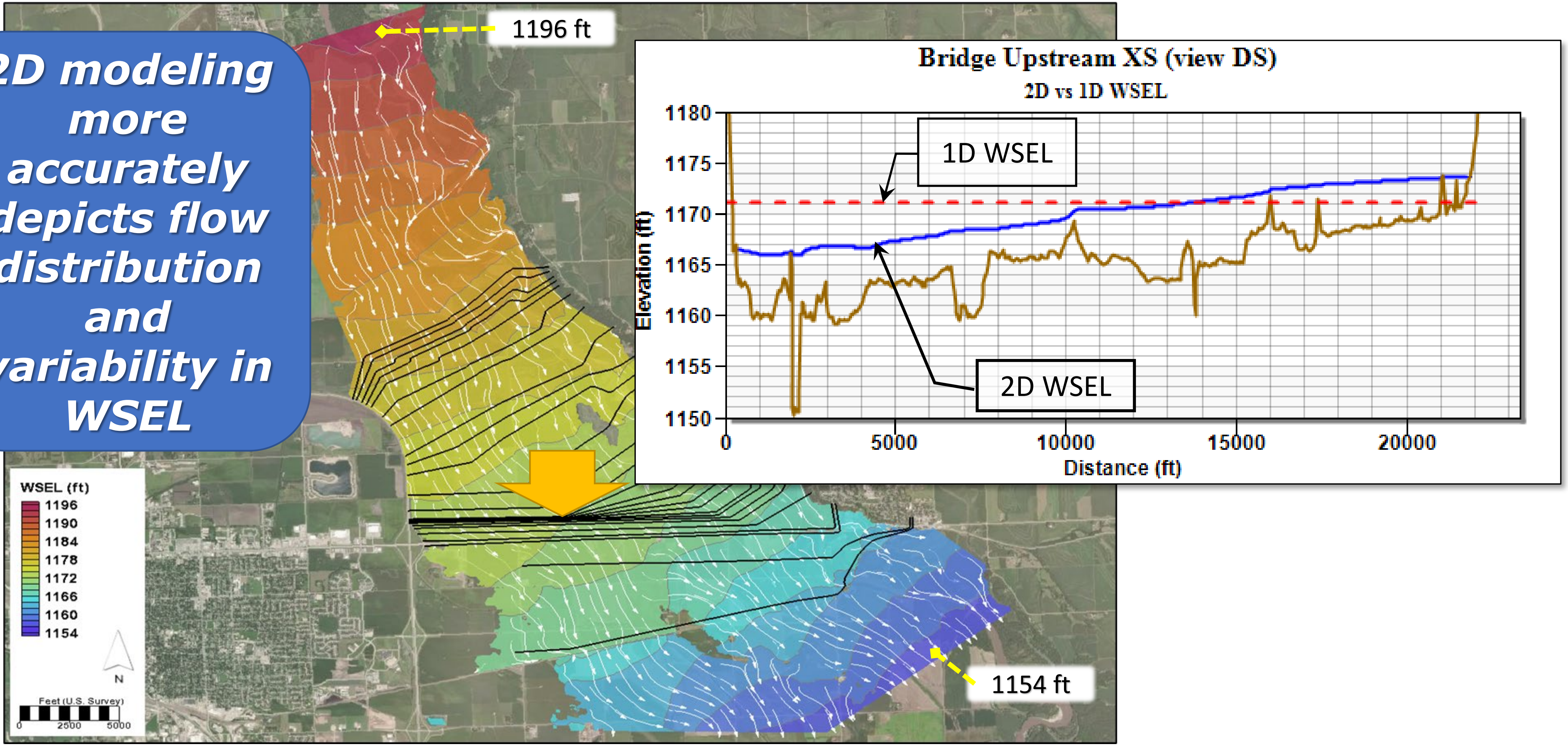
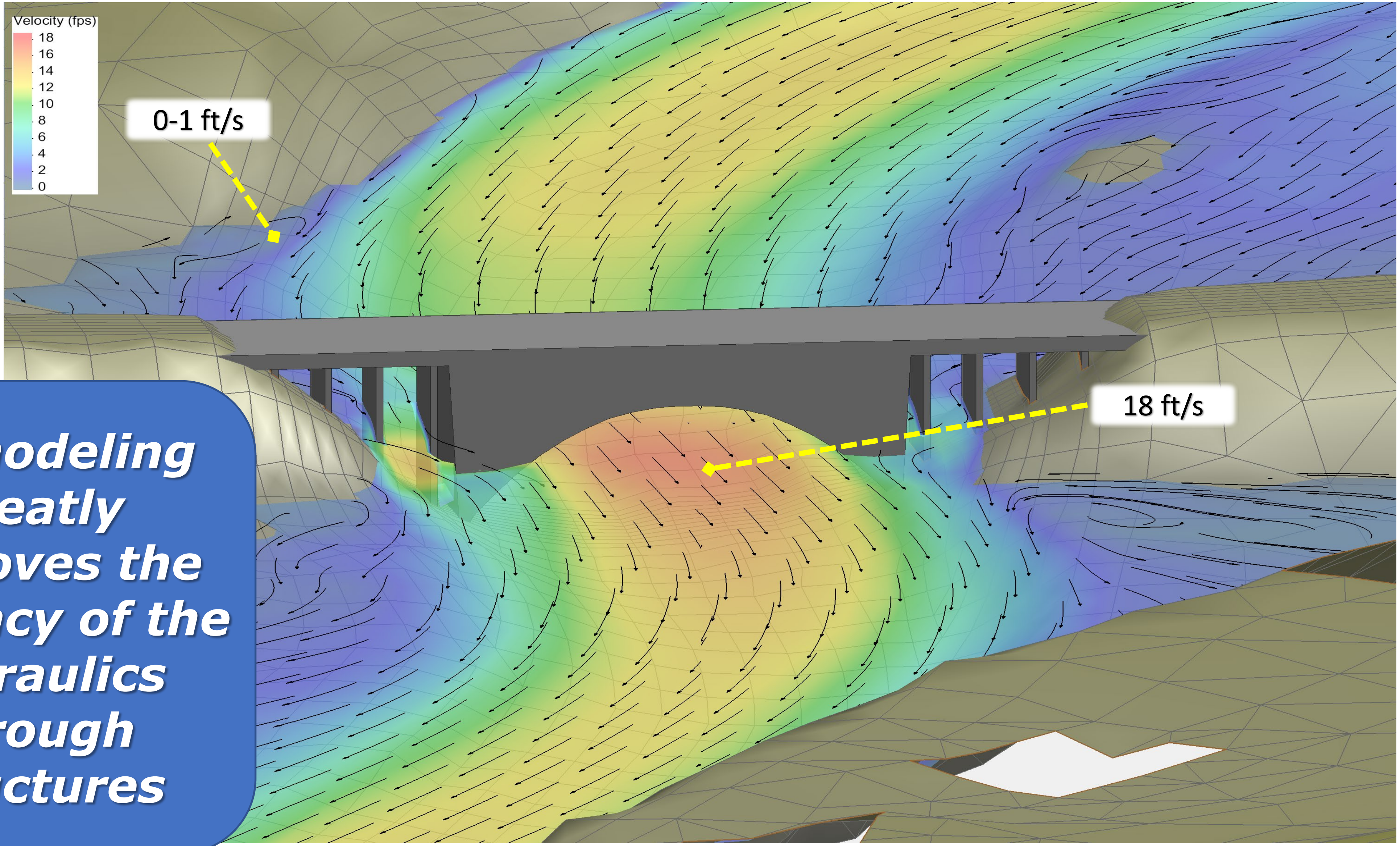


Image Sources: Alaska DOT/ WFL / Earthstar Graphics (Aerial Image)

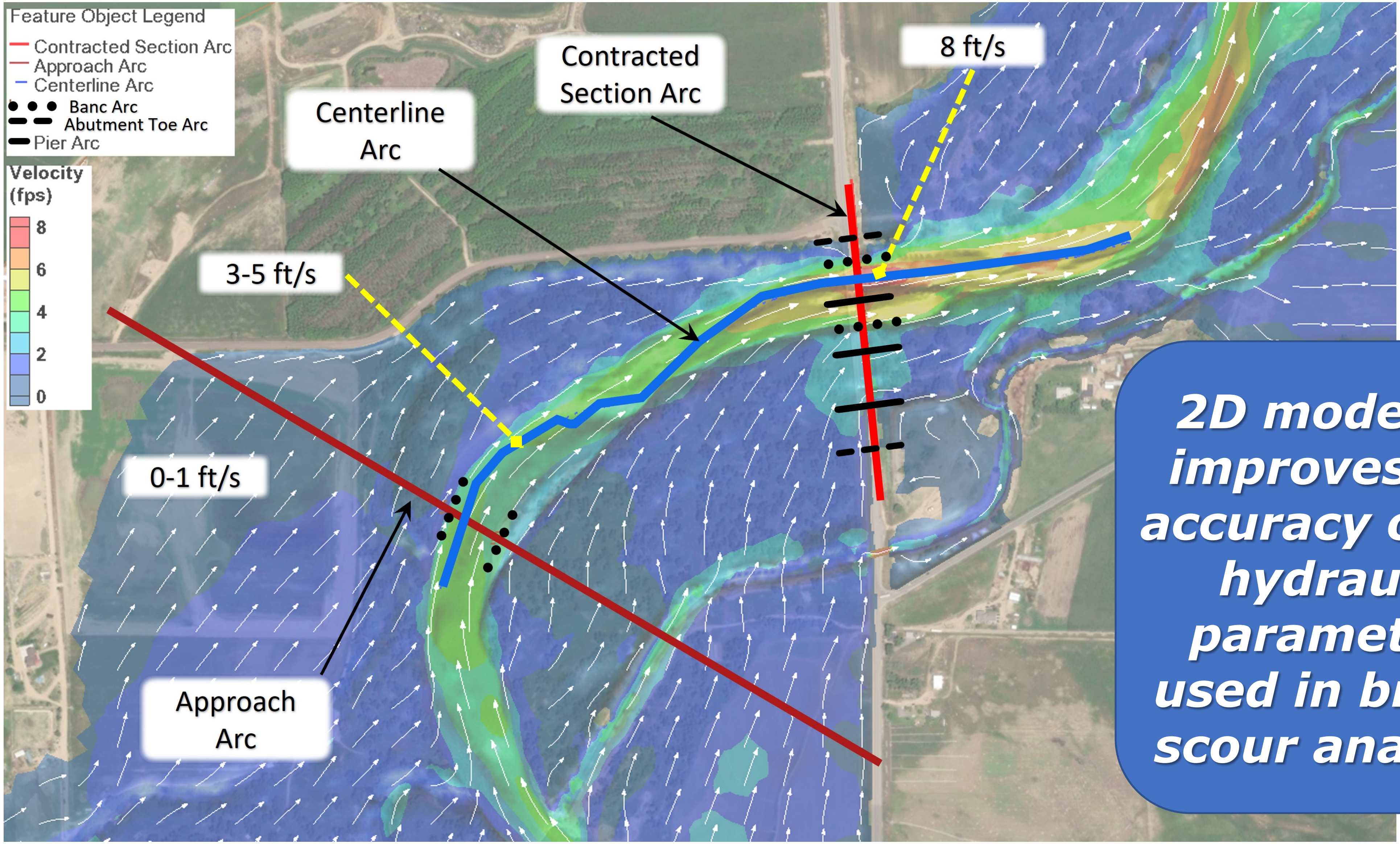
Introduction

Why 2D Modeling?



2D modeling greatly improves the accuracy of the hydraulics through structures

Introduction
Why 2D Modeling?



2D modeling improves the accuracy of the hydraulic parameters used in bridge scour analysis

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

Introduction

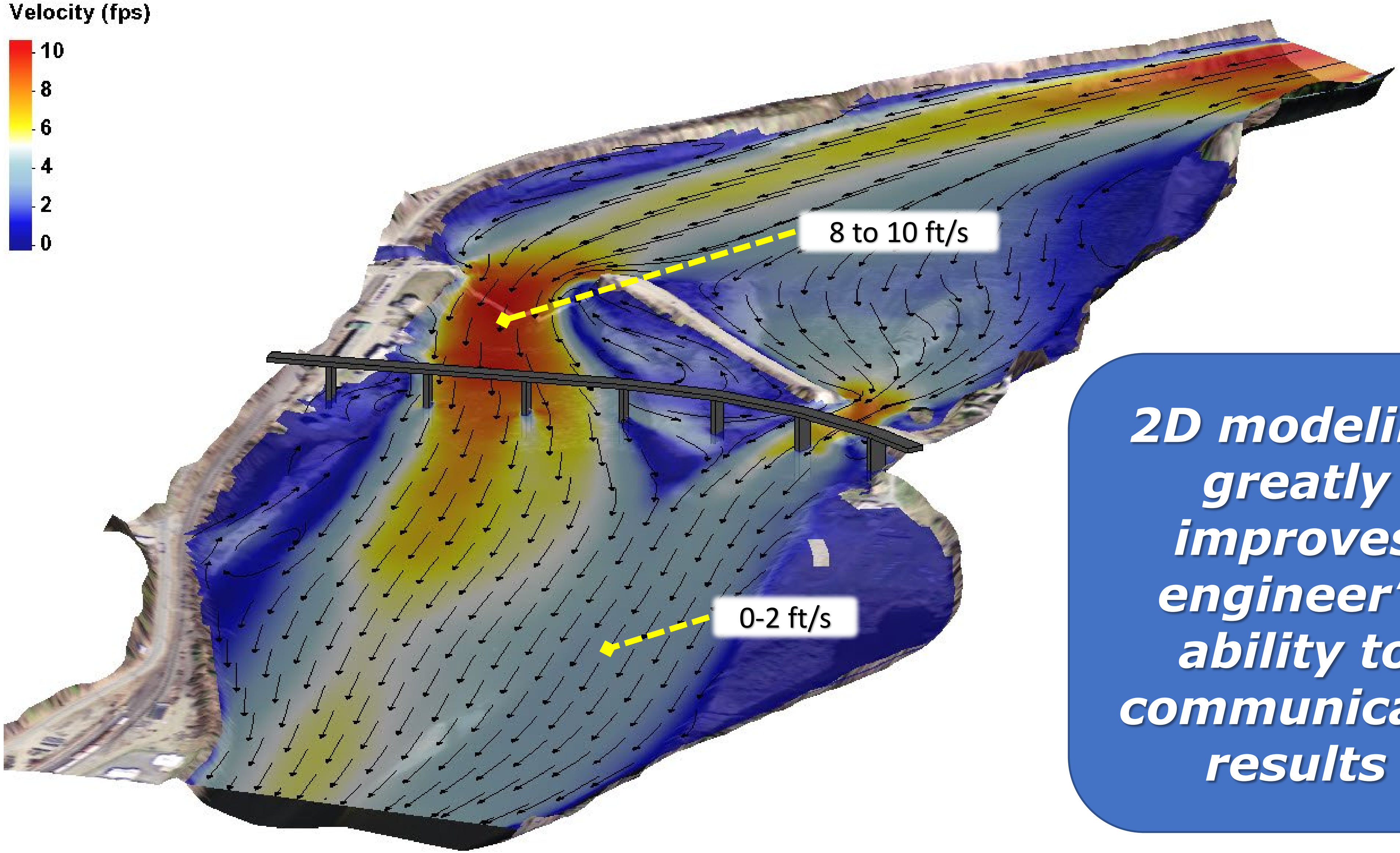
Why 2D Modeling?

2D modeling allows more realistic delineation of a FEMA floodway

Image Sources: Larimer County / FHWA / Earthstar Graphics (Aerial Image)

Introduction

Why 2D Modeling?



2D modeling greatly improves engineer's ability to communicate results

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

Introduction

Resources and Information

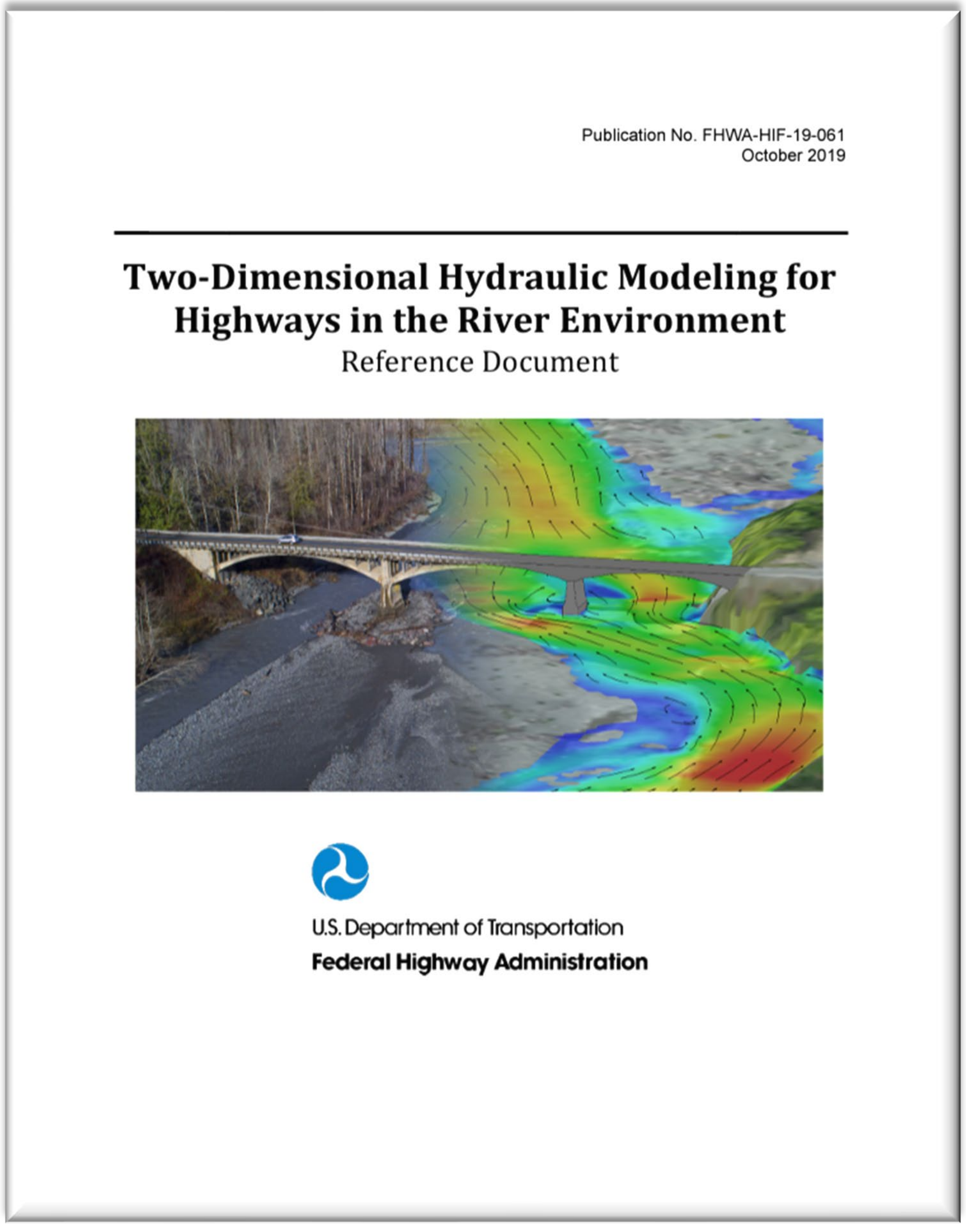
Software Download and Licensing

- Review website for current release and notes
- Community license (**free to all**)
    - No license code needed
    - Includes all features needed to perform SRH-2D simulations
- Pro-version
    - Request/Renew from SMS Menu: *Help → Register→ Request License*
    - Includes technical support
    - DOT/FHWA staff contact *scott.hogan@dot.gov or laura.Girard@dot.gov*
    - All others contact *support@Aquaveo.com*
- **Reviewers License – Pro-Version**
    - Complete form and Contact Aquaveo

Introduction

Resources and Information

- [2D Hydraulic Modeling for Highways in the River Environment]
- Modeling fundamentals
- Data requirements
- Model development
- Model review and calibration
- SMS/SRH-2D User Interface
- Sample report outline
- Survey request form


Publication No. FHWA-HIF-19-061
October 2019

Two-Dimensional Hydraulic Modeling for Highways in the River Environment
Reference Document

U.S. Department of Transportation
Federal Highway Administration

Introduction

Resources and Information

NHI Training Courses

- In-person training (NHI Course 135095)
- Virtual training available (NHI Course 135095V)
- Virtual Training (NHI Course 135095A) SRH-2D Model Data files, Diagnostics & Verifying 2D Model Results
- Virtual Training (NHI Course 135095B) Model Terrain Development with Various Data Sources

Introduction

Resources and Information

2D Modeling Tutorials

- Tutorial Link
- Over 75 SMS/SRH-2D Tutorials, including:
  - Data importing, processing, and conversions
  - Raster data features and tools
  - Display and Visualizations
  - Mesh development tools
  - Culverts and other 1D hydraulic structures
  - Bridge and culvert pressure flow
  - Floodway tools
  - Sediment transport
  - Calibration and advanced simulations

Introduction

Resources and Information

Online SMS Wiki Page and Other Resources

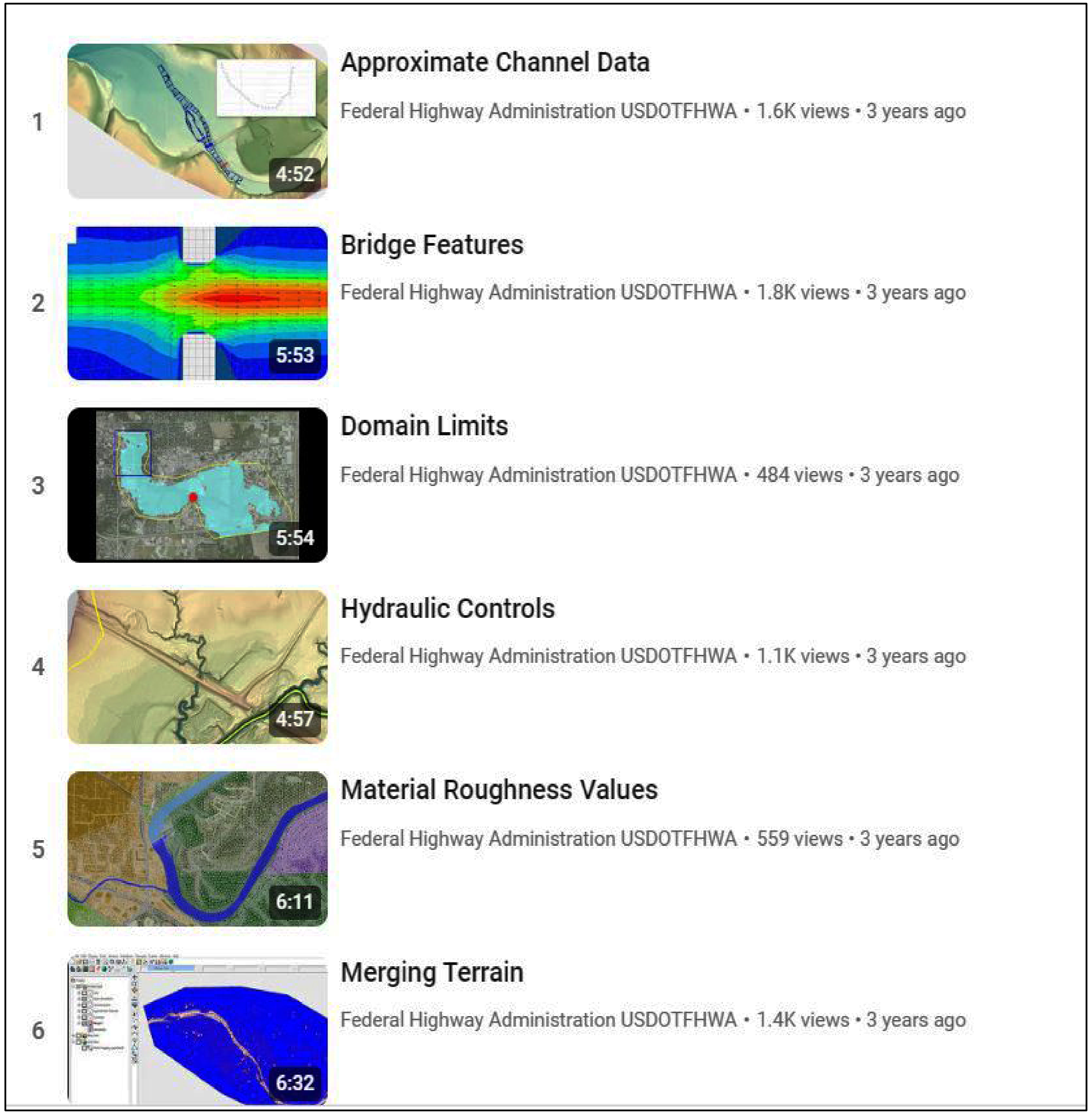
- SMS Workflows Overview
- Table of SRH-2D Errors and Solutions
- SMS Blog

Introduction

Resources and Information

Short YouTube Training Videos – 2D Hydraulic Modeling

- 2017 Videos (11)
- 2020/2023 Videos (12)
- Other SMS Learning Videos
- NHI 2D Hydraulic Modeling Course Demonstration Videos (13)

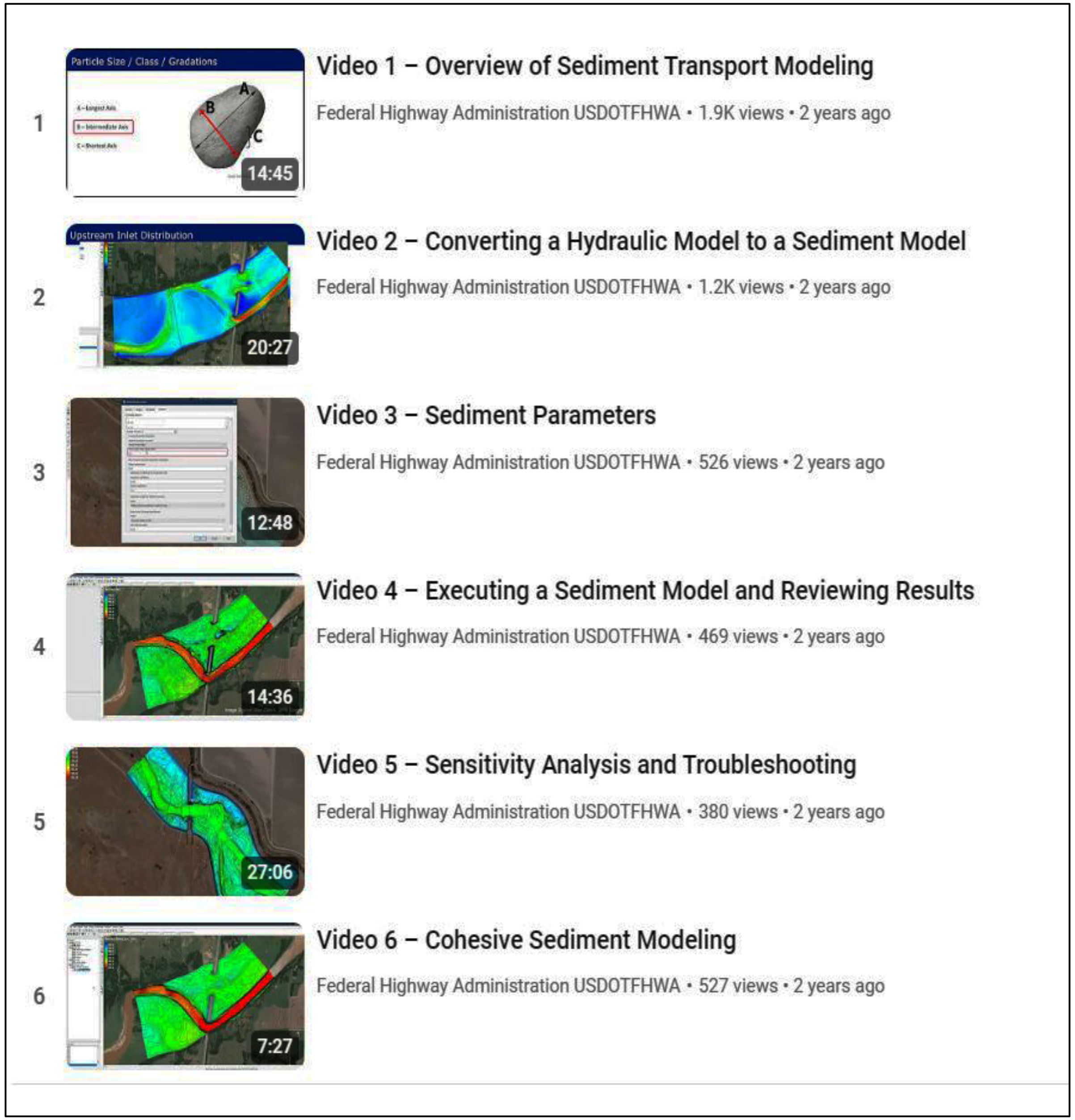


Introduction

Resources and Information

Short YouTube Training Videos – 2D Sediment Transport Modeling

- SRH-2D User's Manual: Sediment Transport and Mobile-Bed Modeling
- Overview of SMS/SRH-2D Sediment Transport Modeling YouTube Videos (6)



Introduction
Resources and Information

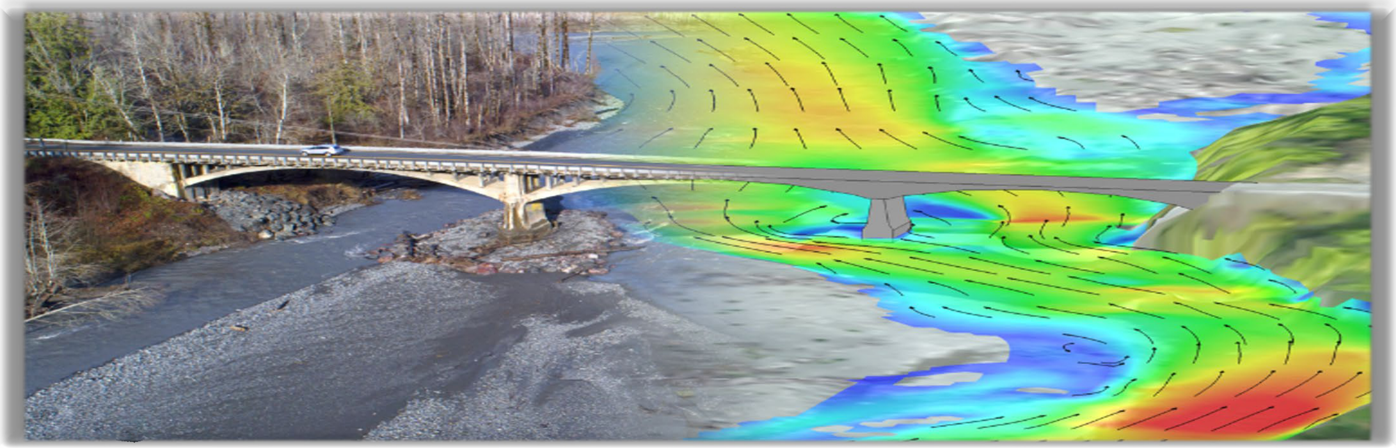


Image by John Gussman

FHWA 2D Hydraulic Modeling User's Forum

- Subscribe to receive web meeting invites
- Web meetings held roughly every few months
- Updates on the latest SRH-2D and SMS developments
- 2D modeling best practices
- Tips and tricks in SMS
- Access to past eight years of web meeting recordings
- Contact Scott Hogan for more information

Scott Hogan
FHWA Resource Center
Scott.hogan@dot.gov
(720) 576-6026

Questions?

2D Model Review Training Agenda

Session 1

- Overview of 2D Modeling and Available Resources
- **Information to Be Reviewed, Model Review Spreadsheet and Best Practices**
- Project Information and Model Background Data
- 2D Mesh
- *Assign Exercise 1*

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2D Hydraulic Model Review

Levels of Model Review and Key Elements of a Review

Cursory and Detailed Reviews

- Project objectives
- Software used and version
- Data sources and accuracy
- Project datum and units
- Model extents
- Mesh resolution and element size
- Mesh accuracy
- Mesh representation of hydraulic controls (key features)
- Mesh quality
- Boundary condition type, location, and values
- Material roughness values /assignments
- Modeling approach (steady/unsteady)
- Hydraulic structure details
- Simulation parameters
- Stability verification
- Continuity verification
- Adequate simulation length verification
- Results - range of values
- Hydraulic variables used for bridge scour analyses

2D Hydraulic Model Review

What information should be requested for a review?

- **Project Hydraulic Report**
  - Project information and area description
  - Project horizontal and vertical datums, local adjustments or scale factors
  - Flooding history and background
  - Project objective
  - Source of hydrologic data
  - Source(s) of terrain data
  - Source of land use data and roughness values
  - Hydraulic structure summary and geometry details
  - Summary of modeling approach and assumptions

2D Hydraulic Model Review

What information should be requested for a review?

- **Hydraulic model summary**
  - Hydraulic model and version used to complete the analyses
  - Changes to previous models and reasons for change
  - Number and type of flow conditions modeled
  - Description of scenarios modeled
  - Mesh development summary (element resolution, size, and breaklines)
  - Modeling approach for hydraulic structures (1D, 2D, overtopping, etc.)
  - Summary of simulation parameters
  - Calibration and sensitivity analyses performed
  - Modeling challenges

2D Hydraulic Model Review

What information should be requested for a review?

- **Summary of results**
  - Include only required simulations
  - Verification of flows/continuity/stability
  - Summary of the range of depths and velocities
  - Explanation of any highlights or areas of concern
- **Optional (but valuable) information**
  - Modeling notes and info included in model metadata
  - Comparison of mesh surface with original terrain
  - Cross section plots at key locations
  - Profile plots
  - Bridge scour hydraulic variables and location of extracted values

2D Hydraulic Model Review

SRH-2D/SMS Summary Report

- Project Summary
- Software version
- Project datums
- Terrain data information
- Mesh summary
- Boundary condition summary
- Monitoring points and lines summary
- Simulation parameters summary
- Solution plots
- Solution dataset summary

2D Hydraulic Model Review

Model Review Spreadsheet

Project Description: **Reviewer:**

Stream Name(#) / Reach

Project File Name: **Date:**

Additional Information:

FHWA: 2D Hydraulic Modeling Reference Document: www.fhwa.dot.gov/engineering/hydraulics/pubs/hif19061.pdf

Item	Reviewed/ Completed	Comment	Action Needed (blank=none)	Response to Comment/Resolution	Screen Shot
Pre-Review/Submittal Best Practice Considerations					
Use the Merge Triangles option to reduce the number of mesh elements and CPU time					
Trim the model domain to exclude large areas outside of the floodplain					
For steady flow models use the Simulation End output option to avoid large file sizes					
Clean up and organize map project data to include only what is needed for review					
Name simulations and other coverages with short, easy to understand labels					
Complete the project metadata and notes to provide explanations where needed					
Consider using the Advanced Simulations option to run multiple flows for the same mesh					
Use the Steady Flow option for steady flows, unless the unsteady option is needed to improve stability					
Consider using initial conditions for each simulation to minimize runtime. Starting with a restart file or initial WSEL can significantly reduce runtime.					
Consider using an initial and secondary timestep to optimize runtimes (Model control/advanced settings)					
Optimize simulation timestep and simulation time to minimize CPU time					
Use restart or WSEL initial conditions to minimize CPU times					
Provide a copy of the simulations Summary Report					
Internal Quality Control (QC) review should be performed prior to submittal					

Other Tabs in the Spreadsheet: Model Review | Topographic Data | Mesh | Boundary Conditions | Materials | Culverts | Bridges_Structures| Monitor lines| Froude |

2D Hydraulic Model Review

Model Review Checklist

1. Pre-Submittal Best Practices
2. Project Information
3. 2D Mesh
4. Boundary Conditions
5. Material Roughness
6. Hydraulic Structures
7. Simulation Parameters
8. Model Results
9. Bridge Scour Analysis Hydraulic Variables

2D Hydraulic Model Review Checklist

1. Pre-Review / Submittal Best Practices Considerations

- ☐ Use the Elements - Merge Triangles option (Top menu) to reduce the number of mesh elements by 25-30% and save CPU time.
- ☐ Trim the model domain to exclude large areas outside of the floodplain.
- ☐ For steady flow models use the Simulation End output option to avoid large file sizes
- ☐ Clean up and organize map project data to include only what is needed for review.
- ☐ Name simulations and other coverages with short, easy to understand labels.
- ☐ Complete the project metadata and notes to provide explanations where needed.
- ☐ Consider using the Advanced Simulations option to run multiple flows for the same mesh (helps to declutter simulation list).
- ☐ Use the Steady Flow option for steady flows, unless the unsteady option is needed to improve stability.
- ☐ Consider using initial conditions for each simulation to minimize runtime. Starting with a restart file or initial WSEL can significantly reduce runtime.
- ☐ Consider using an initial and secondary timestep to optimize runtimes (Model control/advanced settings)
- ☐ Optimize simulation timestep and simulation time to minimize CPU time.
- ☐ Use restart or WSEL initial conditions to minimize CPU times.
- ☐ Run the simulation Summary Report (rt click on any sim, select Tools – Summary Report) and provide electronic files to reviewer (In SMS all the files are contained in a Reports folder in the project directory)
- ☐ Perform internal Quality Control (QC) review prior to submittal.

2D Hydraulic Model Review

Common Pitfalls in 2D Hydraulic Modeling

- Insufficient or inadequate terrain data
- Lack of breakline use with sparse data or mix of data
- Insufficient domain length and/or width
- Inappropriate element size (too large or too small) at key features
- Too little or too much mesh resolution
- Poor representation of or exclusion of hydraulic structures
- Failure to identify hydraulic controls along element edges
- Simulation times not sufficient for specified boundary conditions
- Overlooked results that indicate instability

Questions?

2D Model Review Training Agenda

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- Overview of 2D Modeling and Available Resources
- Model Review Spreadsheet and Best Practices
- **Project Information and Model Background Data**
- 2D Mesh
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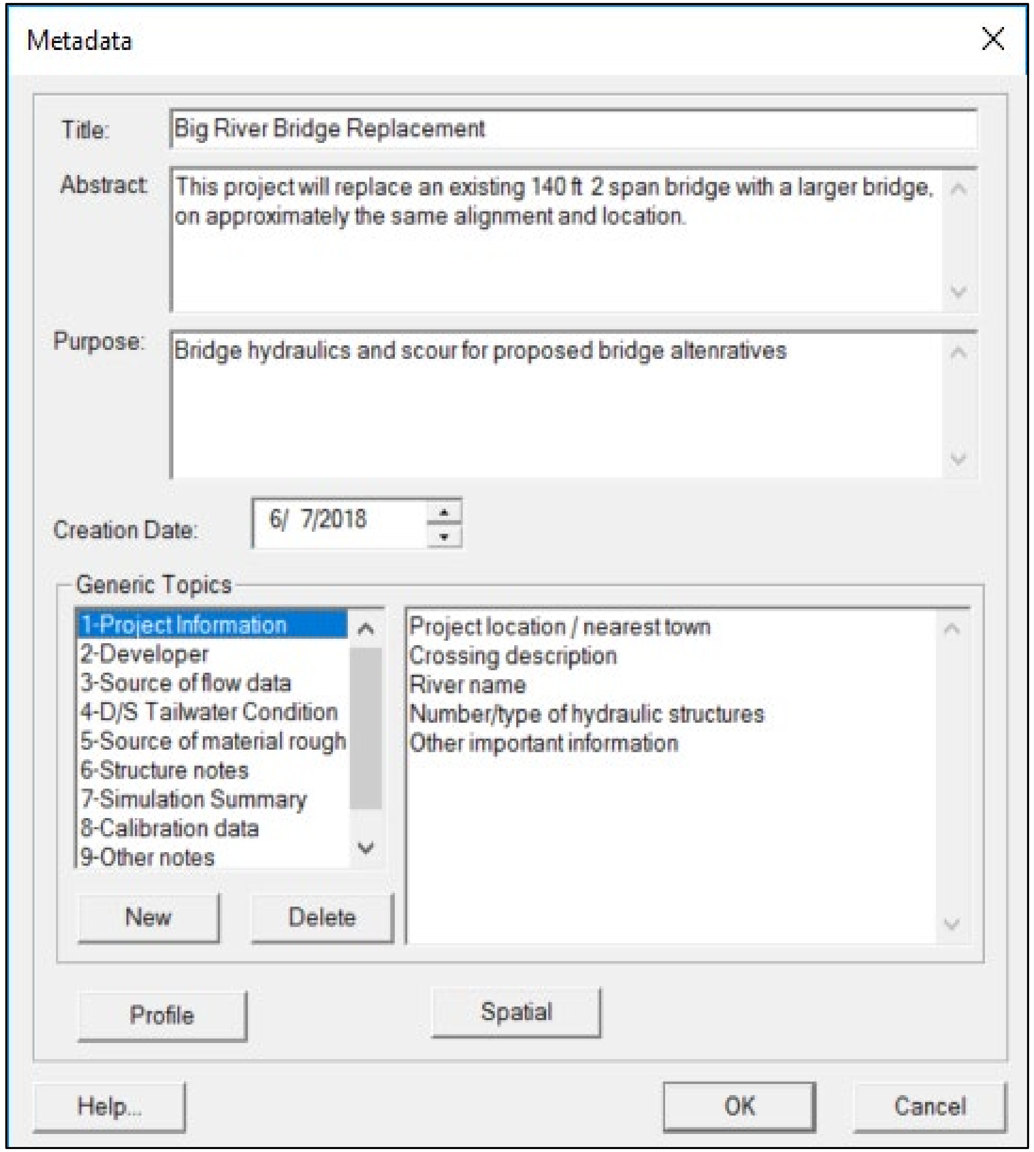
Reviewing Project Info and Background Data
Top 3 Things

1. Review the project objective
2. Check the quality and source of terrain data
3. Confirm terrain data coverage for the entire model domain

Project Information and Background Data

General Information

- Project name and location
- Project objective
- Model and version used
- Modeler name and title
- Modeler’s qualifications (brief)
- List of project files and simulations to be reviewed
- Modeling approach and assumptions



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Project Information and Background Data

Sources of Data

- What are the data sources and stated accuracies?
- What are the horizontal and vertical datums?
- Is aerial imagery included? If so, what date was it taken?
- Does the date of the imagery match the date of the terrain data?
- Was channel bathymetric data used?
- What is the source of hydrologic data, and what flows are simulated?
- What is the source of any structure data?
- What units are the data in and are all consistent?

Key Question:

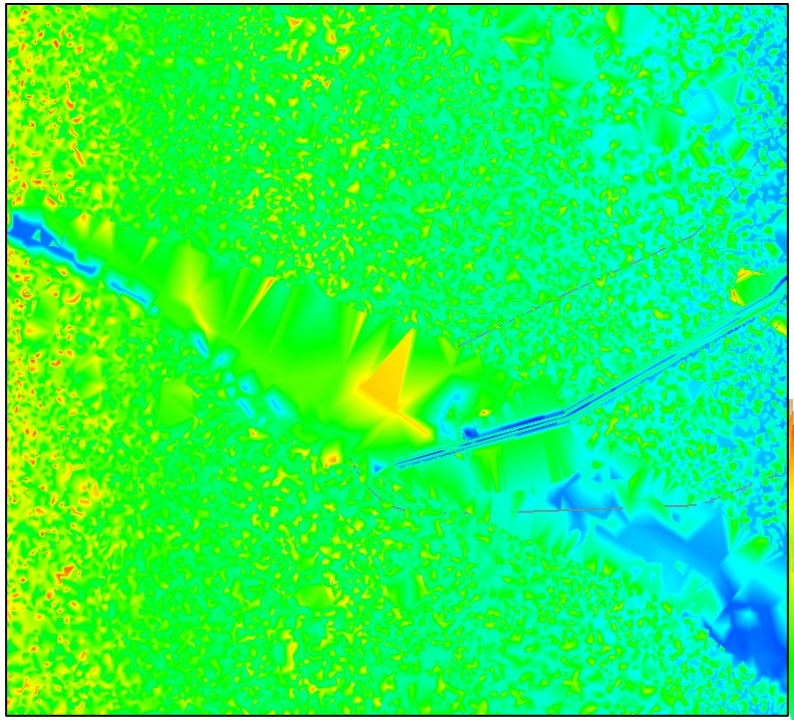
Are data sources consistent and do they cover all modeled areas?

Project Information and Background Data

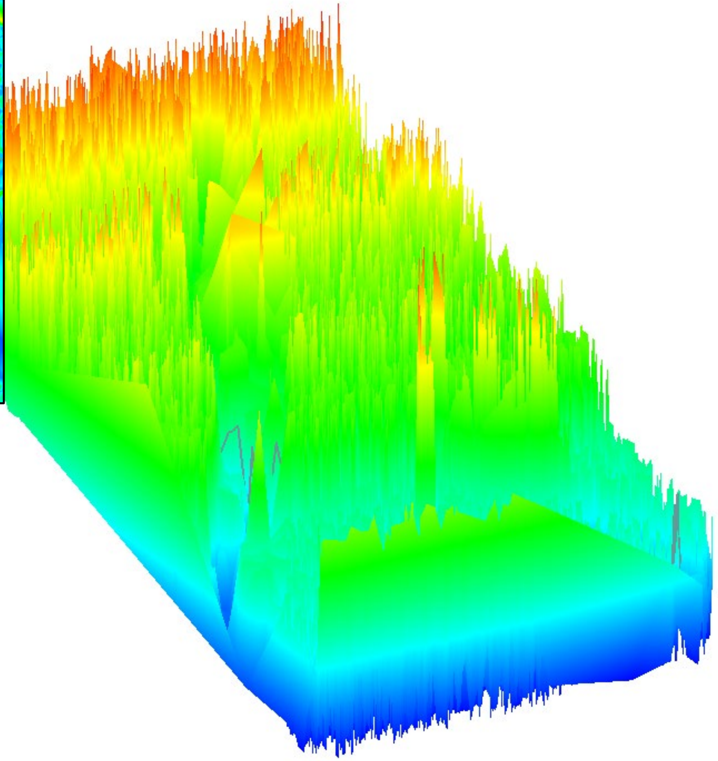
Terrain Data – Lidar Data

Key Question:

Has the terrain data been processed to remove unwanted features? (i.e. vegetation, structures, etc.)



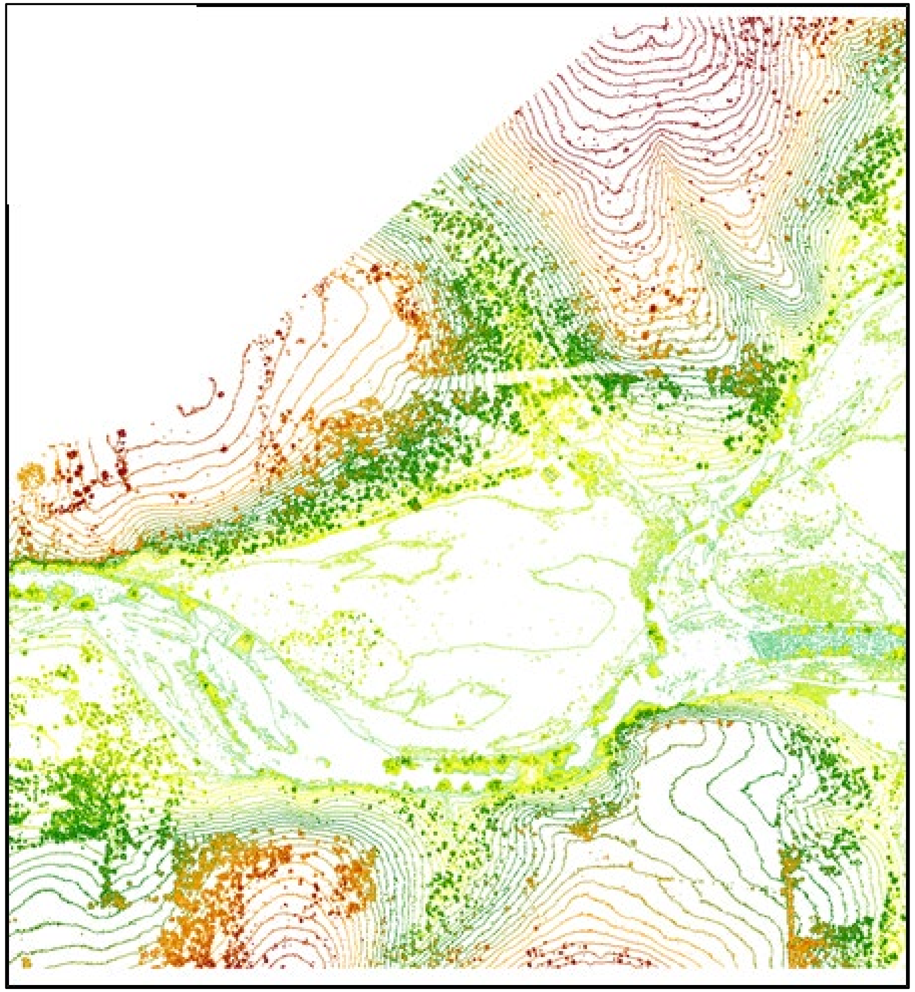
Plan View of elevation contours



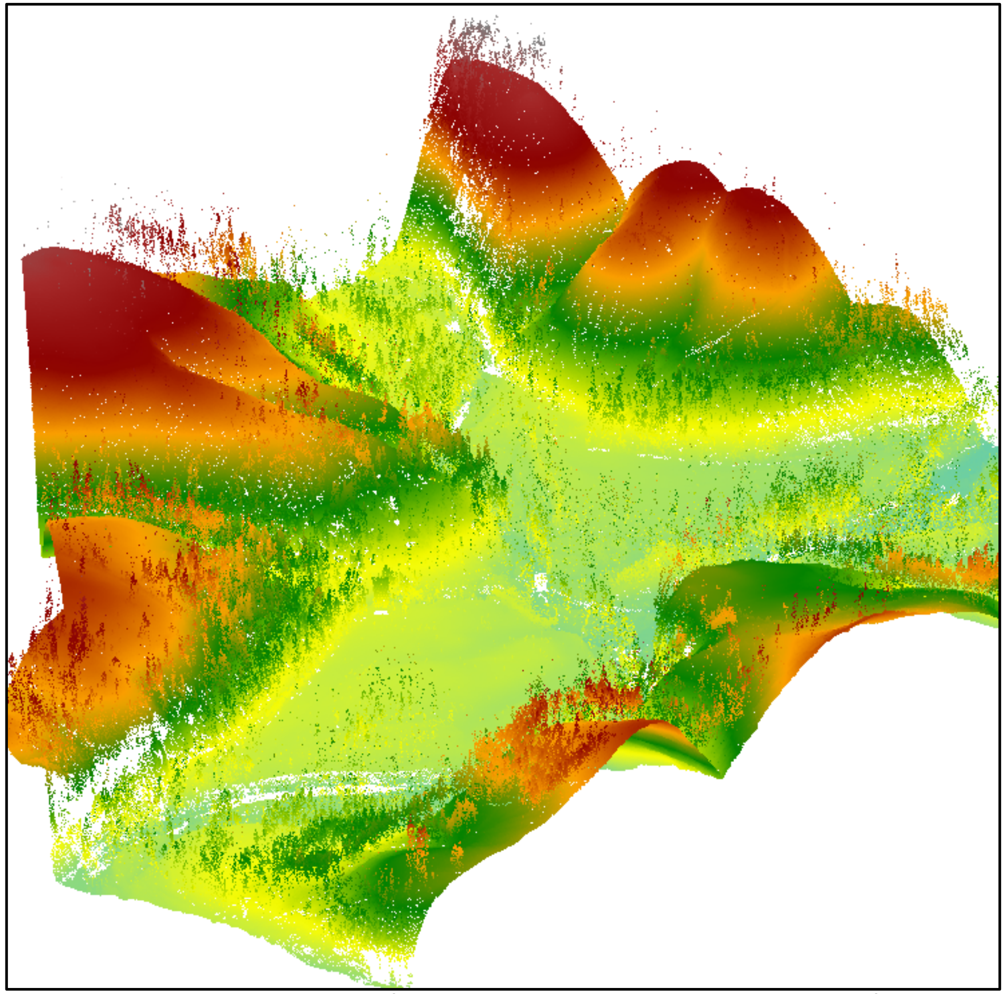
Oblique View (Trees not removed)

Project Information and Background Data

Terrain Data – Lidar Data



Plan View of elevation contours

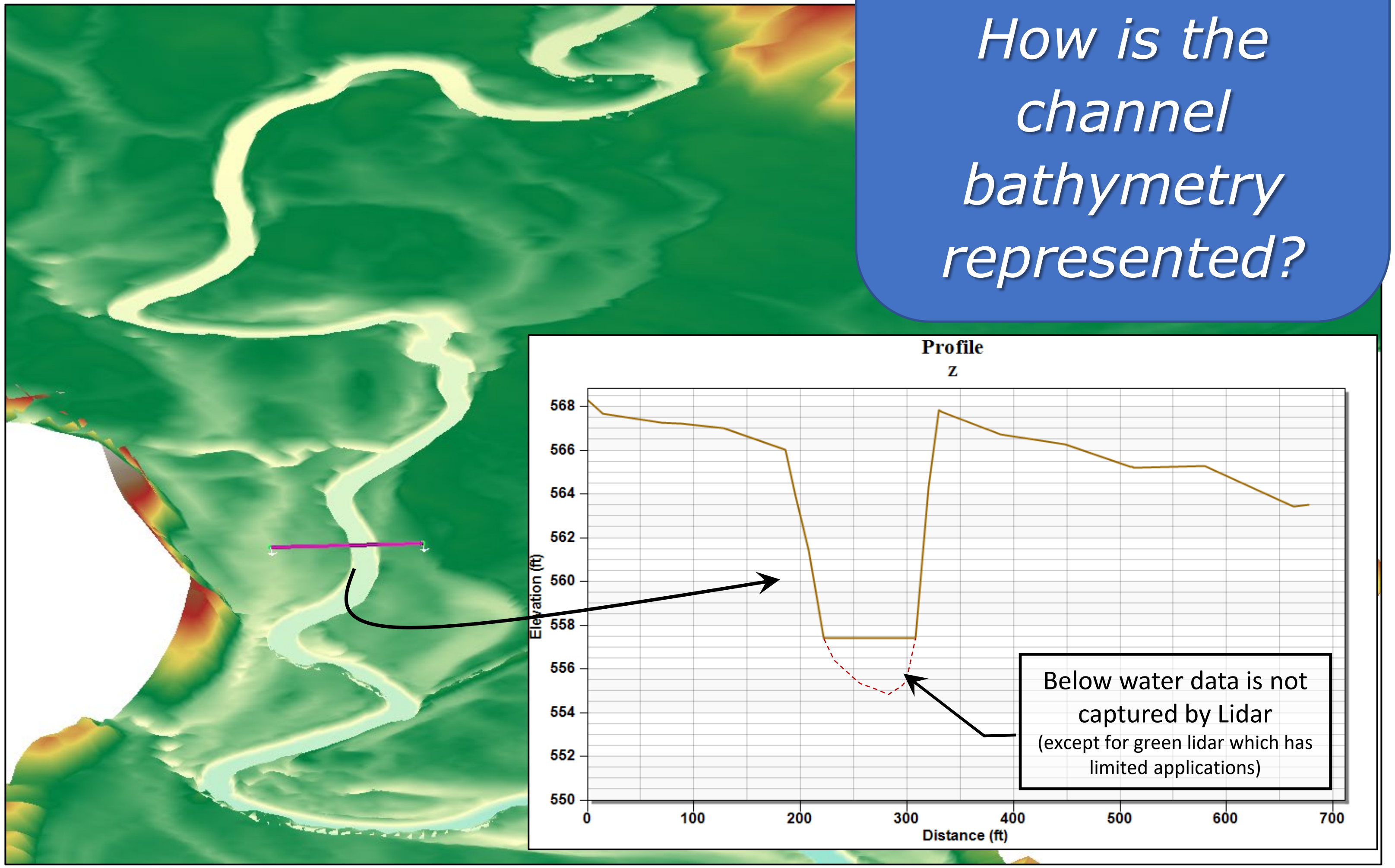


Oblique View (Vegetation not removed)

Project Information and Background Data

Terrain Data

- Channel bathymetry is often overlooked
- It is best to have surveyed data (cross sections) in the vicinity of the project
- Approximated channel data (stamped channels) are acceptable in other areas
- If multiple data sources were used, verify agreement at seems



Key Question:

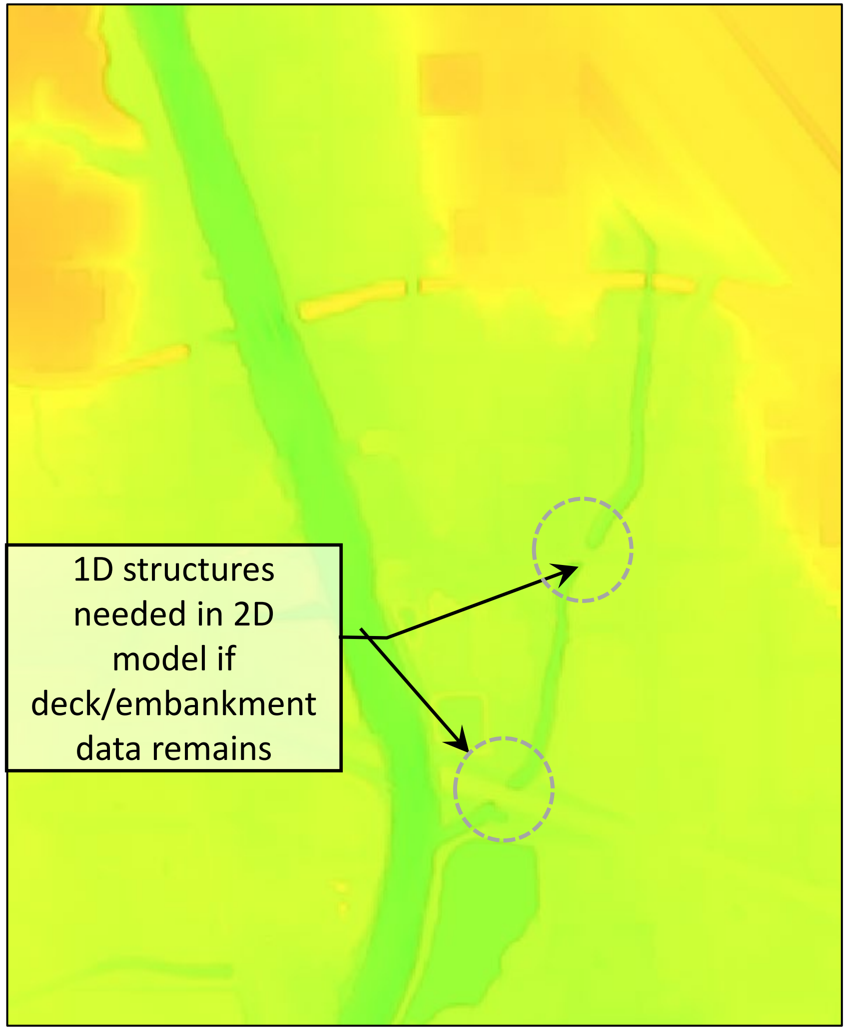
How is the channel bathymetry represented?

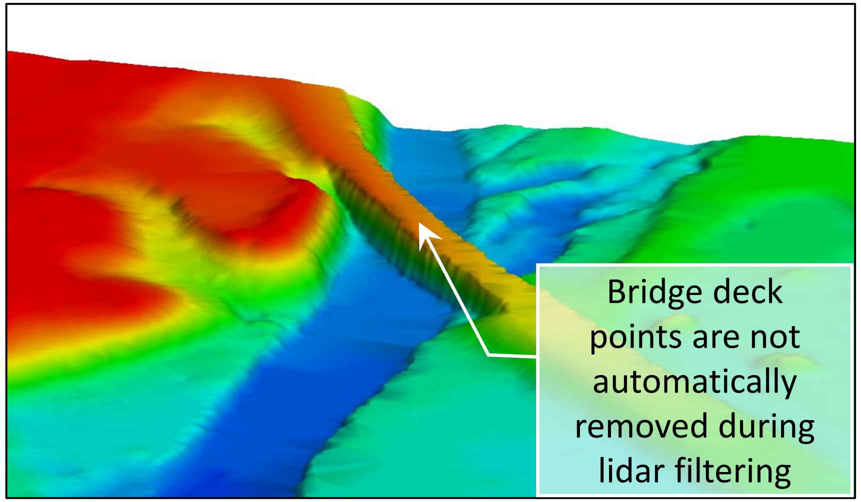
Project Information and Background Data

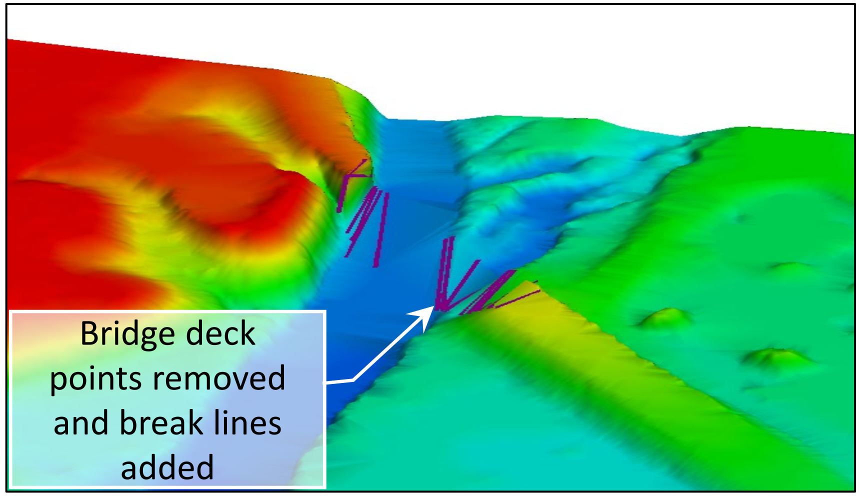
Terrain Data – Correct representation of crossings

Have bridge decks been removed?

Embankments crossing channels will act as dams, unless 1D structures are added to the 2D model





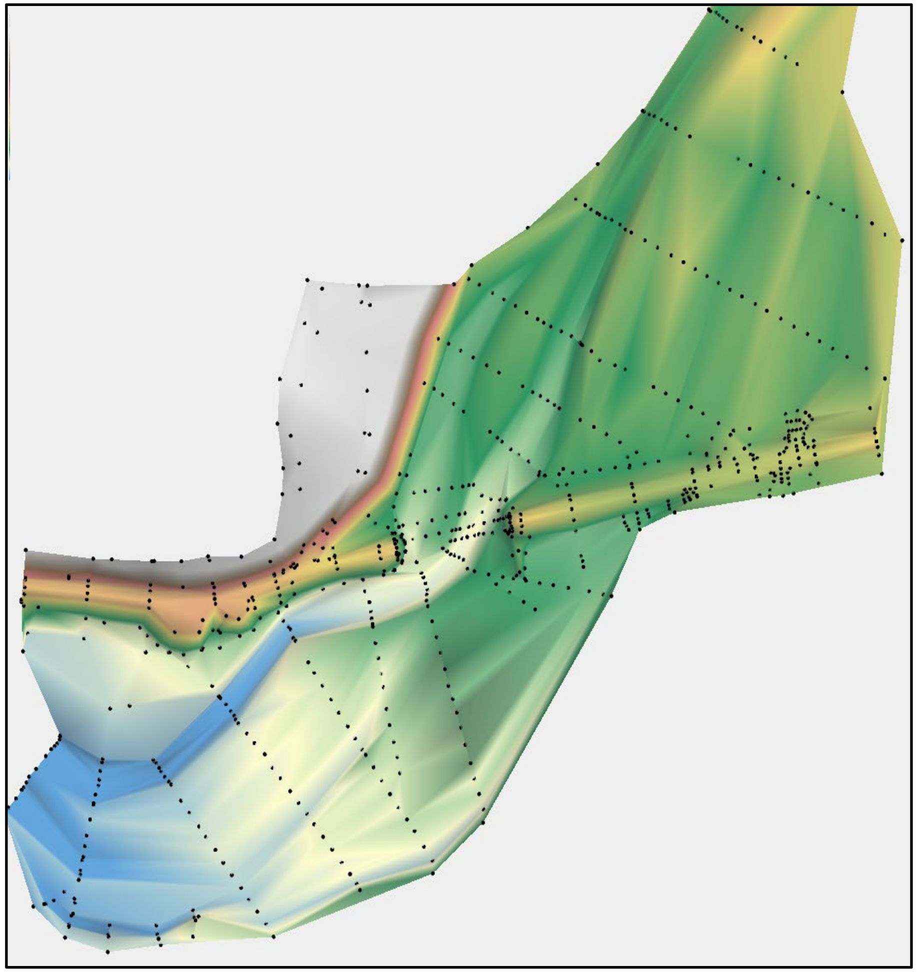


Project Information and Background Data

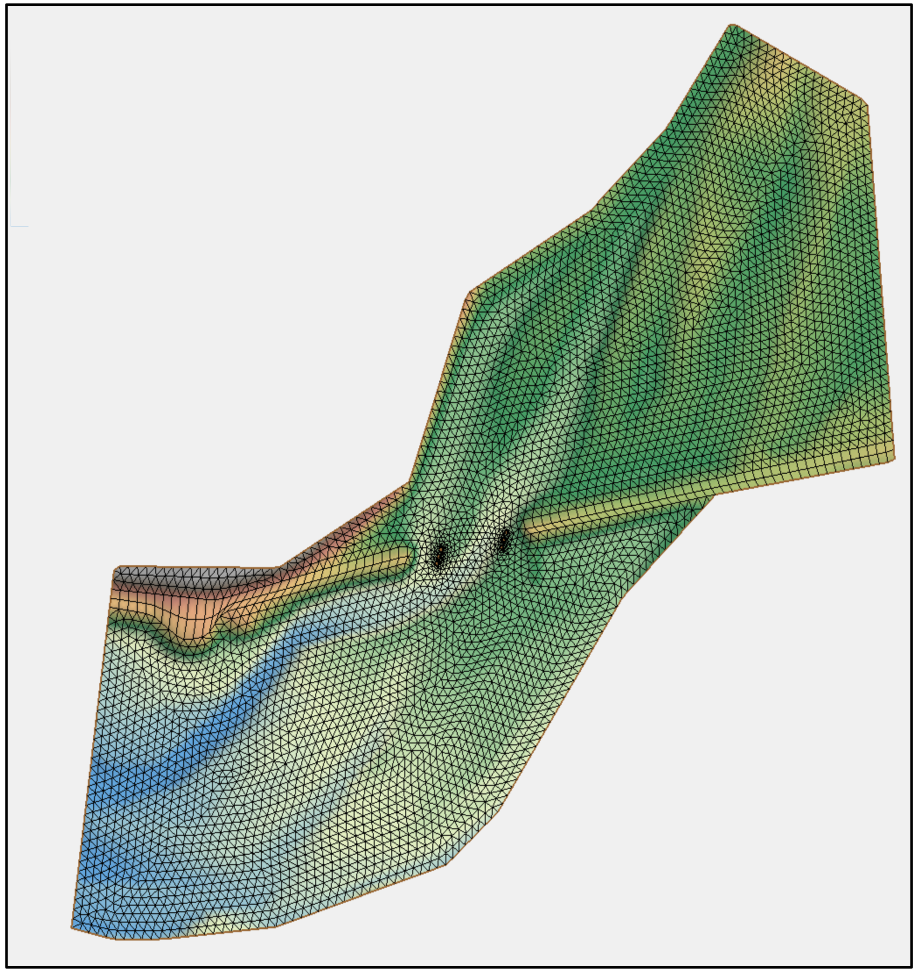
Terrain Data Resolution

Key Question:

Is the terrain data resolution sufficient to support the project detail and objectives?



Terrain Data



Mesh

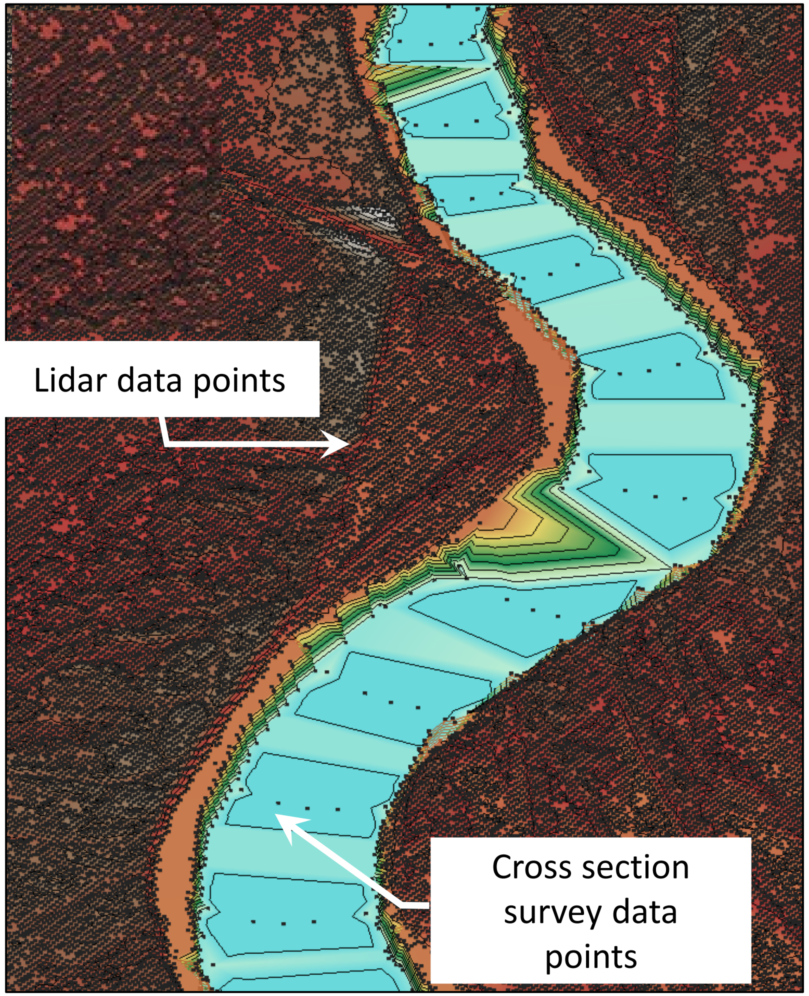
Project Information and Background Data

Terrain Data – Use of breaklines

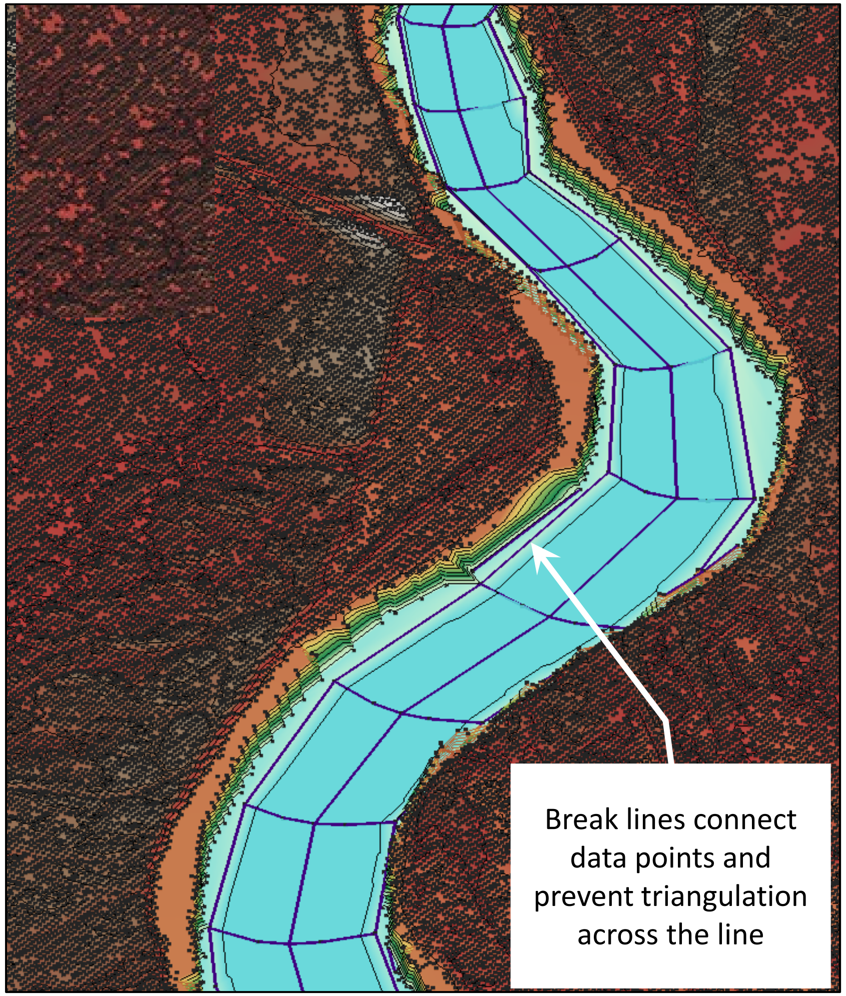
Key Question:

Have breaklines been used where needed?

- Breaklines are important to prevent errors in triangulation
- Breaklines are essential when incorporating cross section data



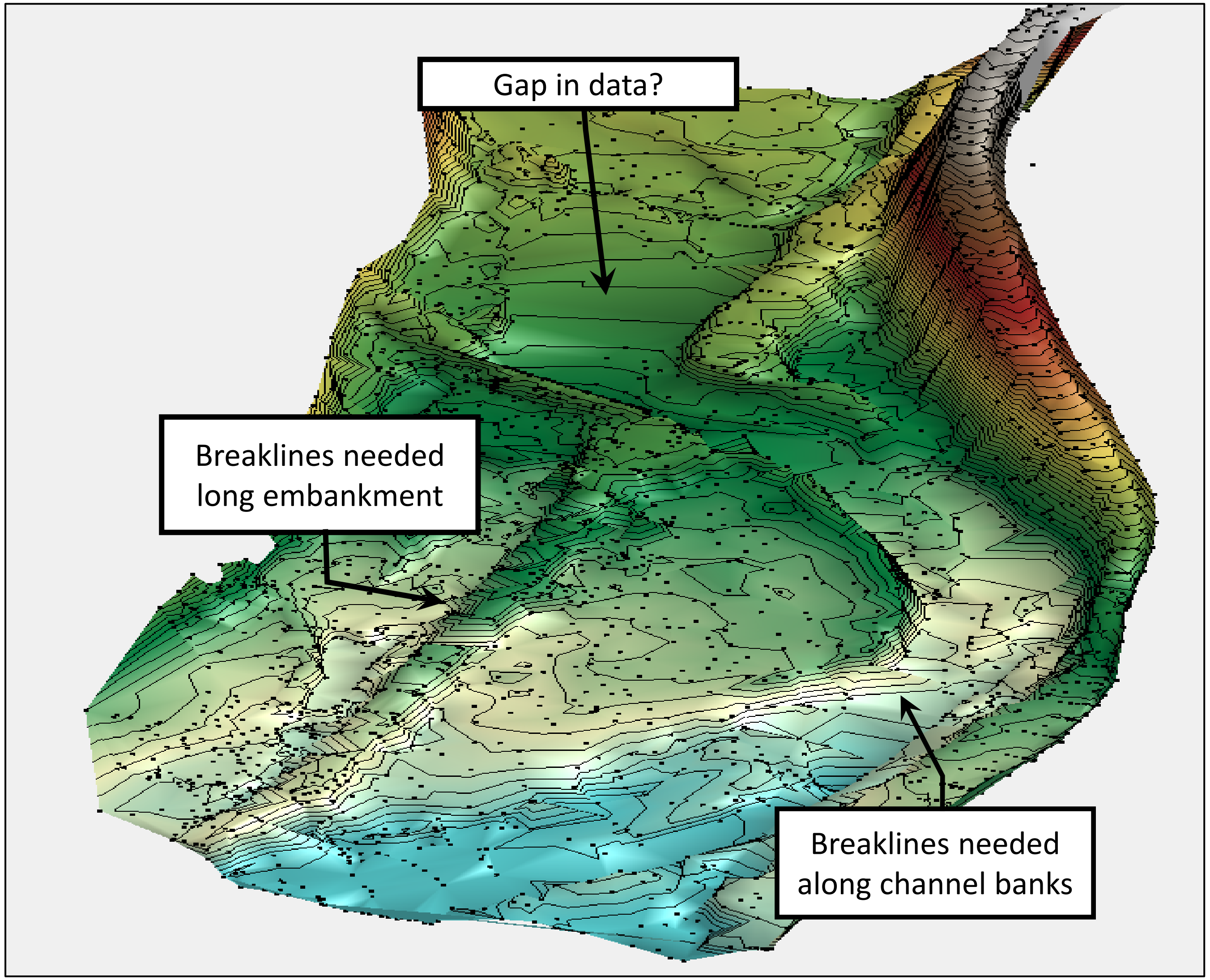
Lidar and cross section data w/o break lines



Break lines added and forced

Project Information and Background Data

Terrain Data Consistency



- Review spacing of data points
- Look for good representation of hydraulic controls (embankments, channel banks, other features)
- Look for gaps in the data
- Review transition zones between data sets

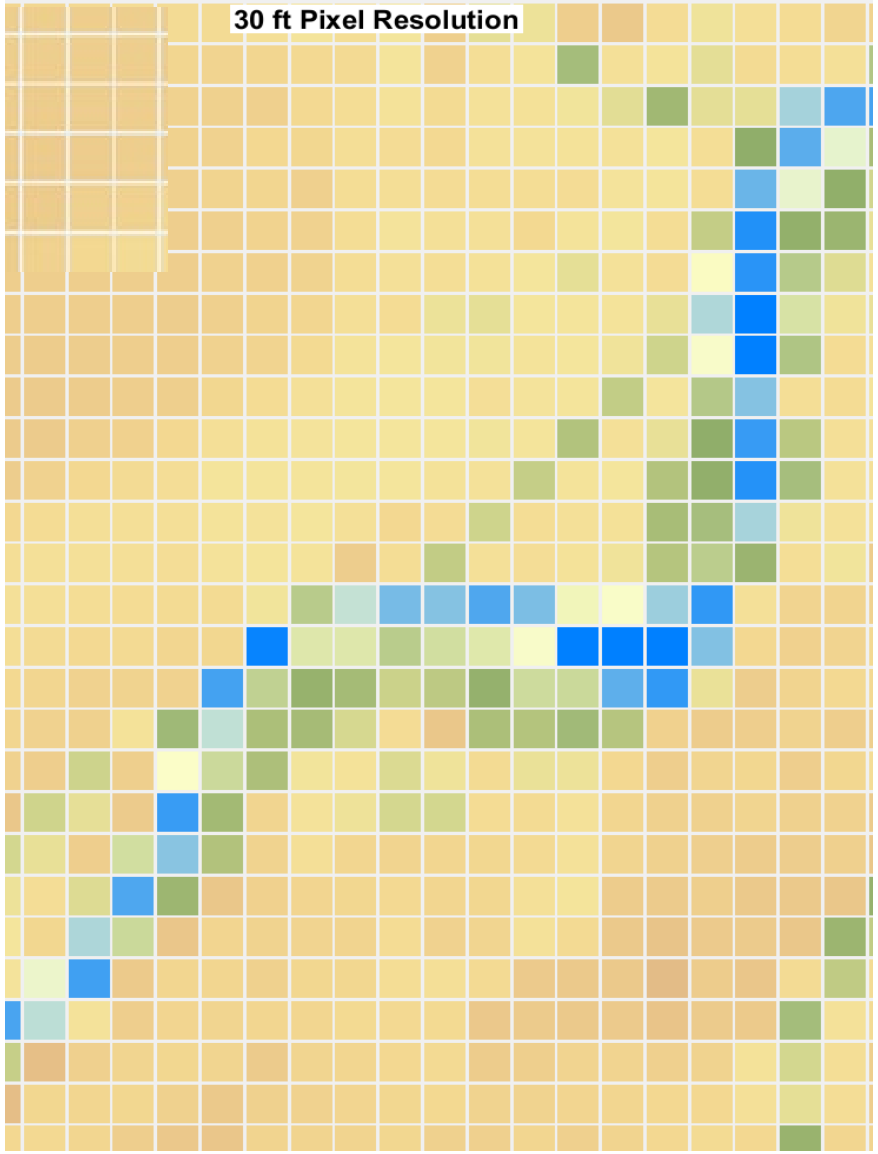
Project Information and Background Data

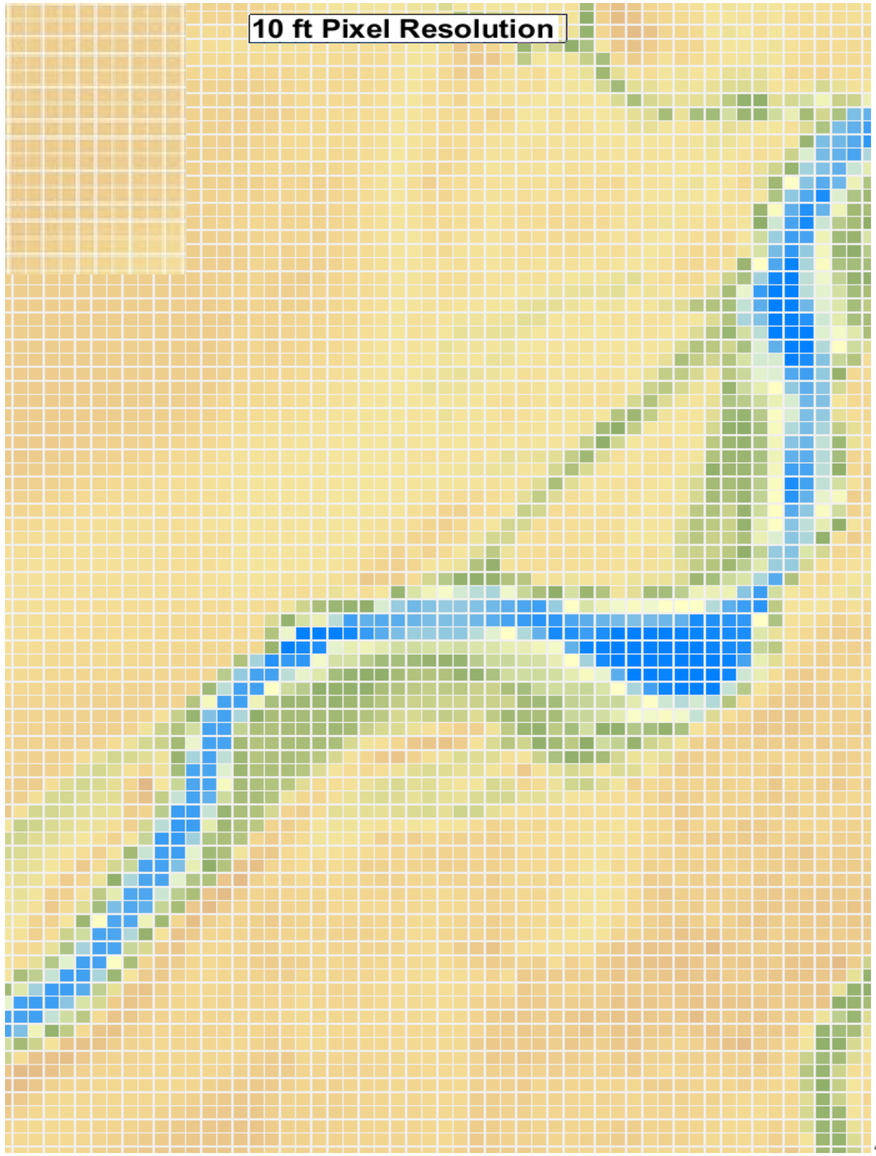
Terrain Data – Raster Data

What is the pixel size in the raster image?

What size is needed to provide sufficient detail?

30 ft? 10 ft?



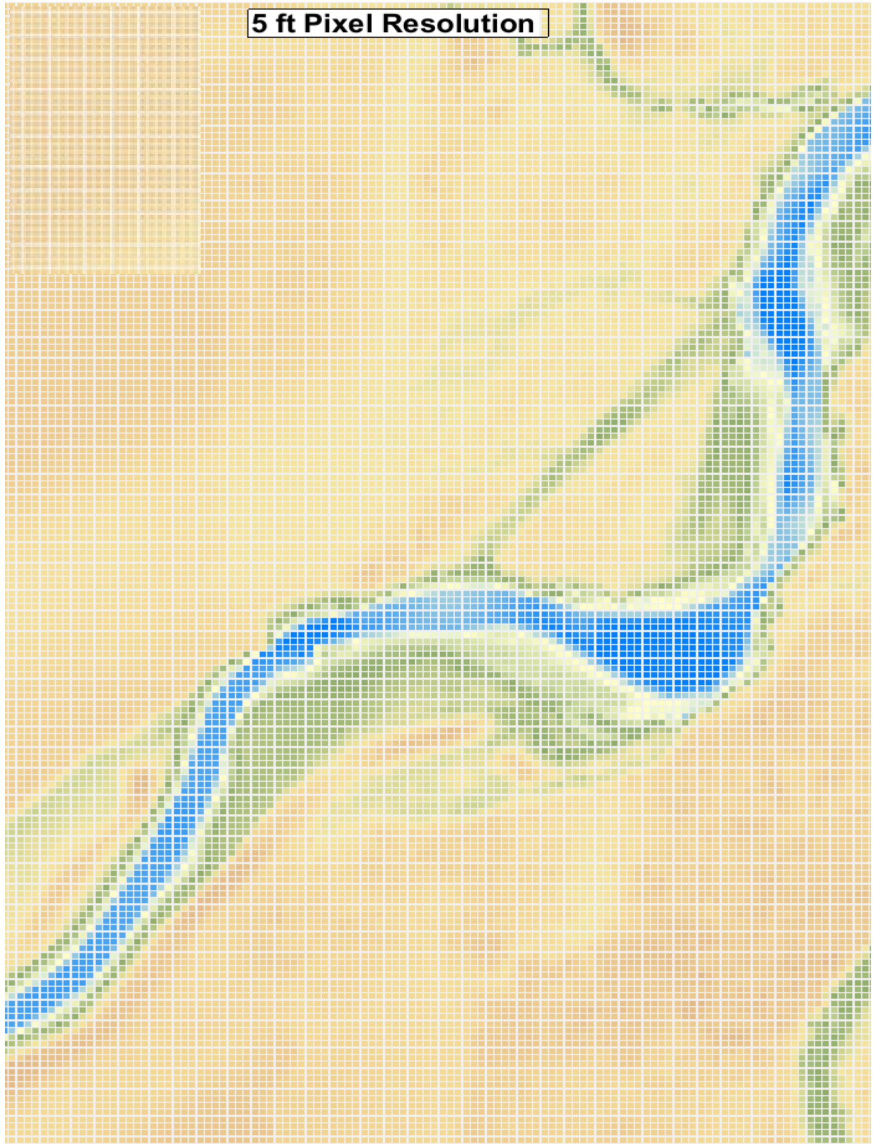


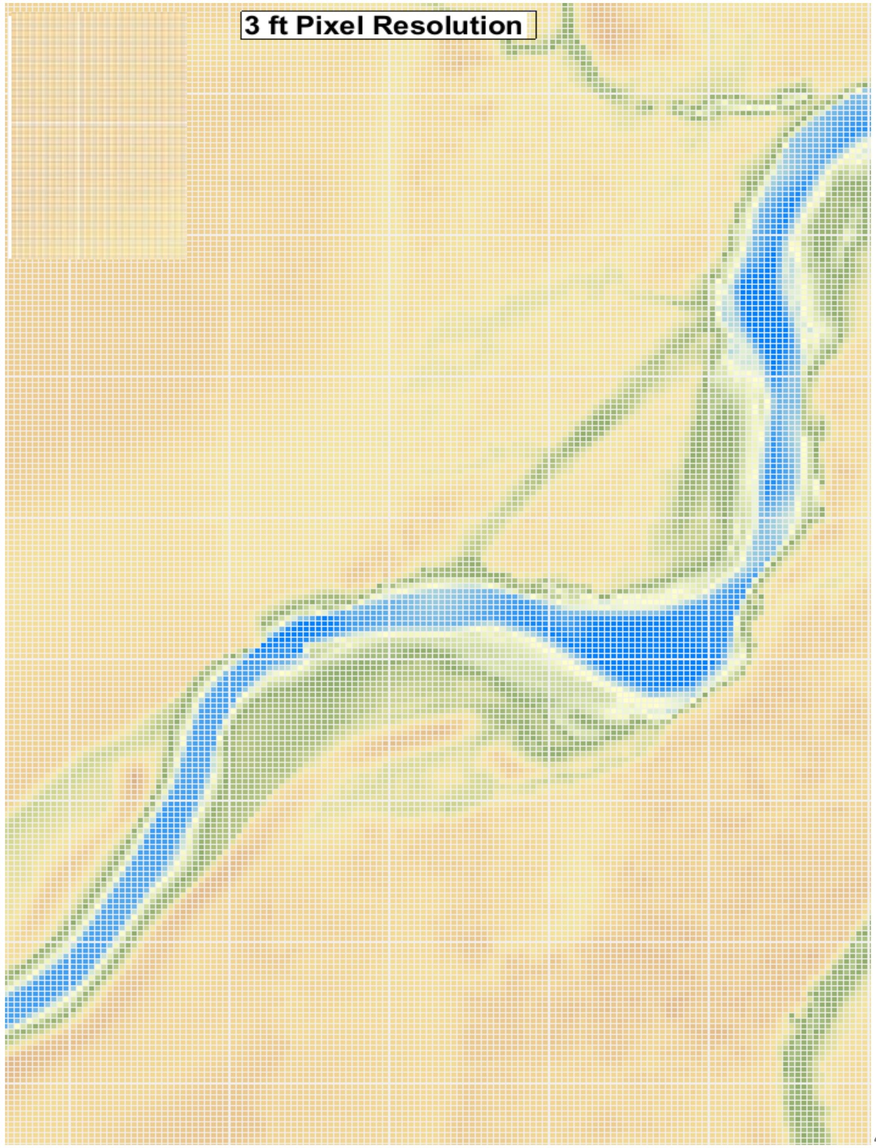
Project Information and Background Data

Terrain Data – Raster Data

3-5 ft is optimal.

Larger pixel sizes will not represent linear features well.



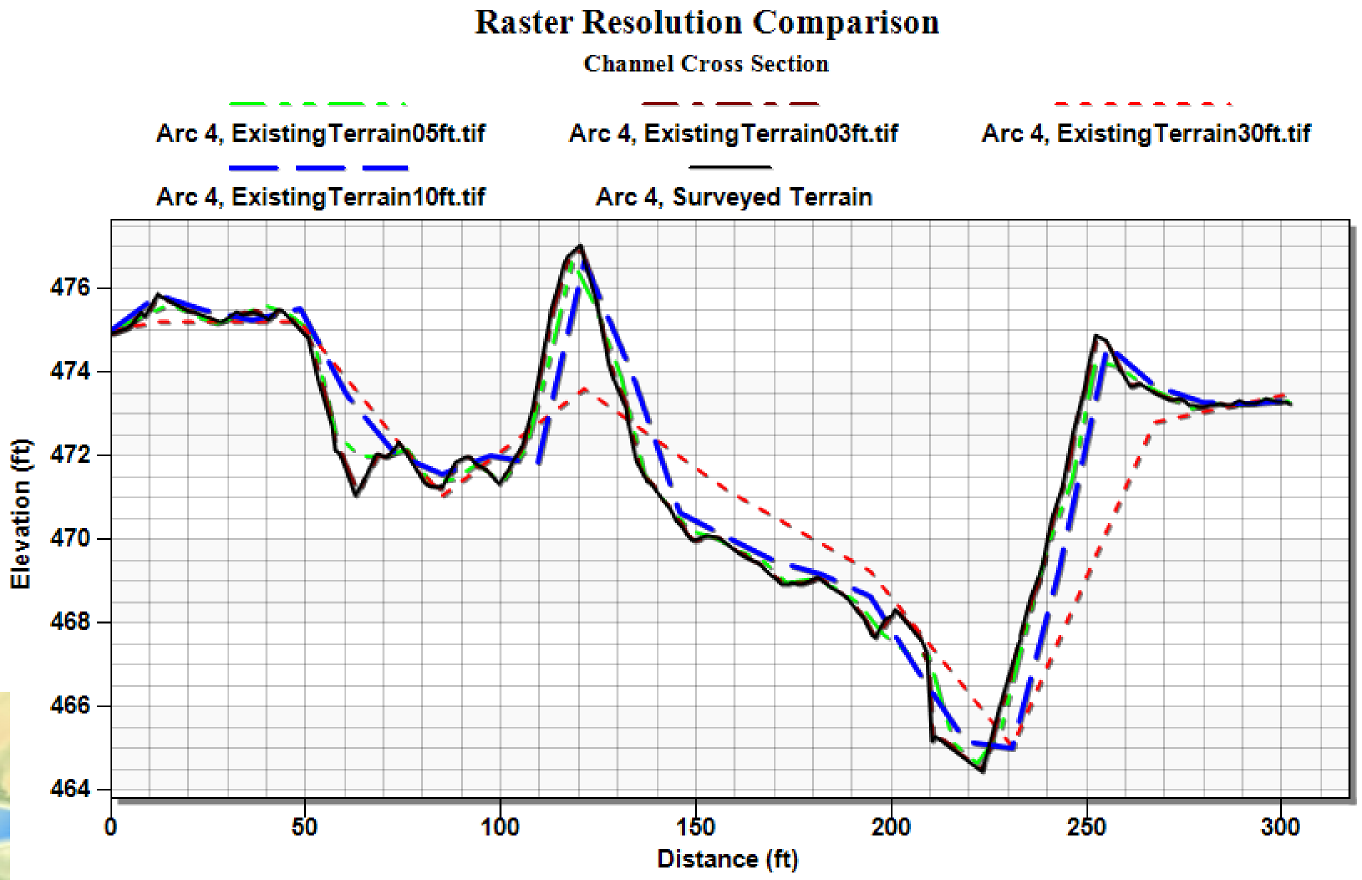


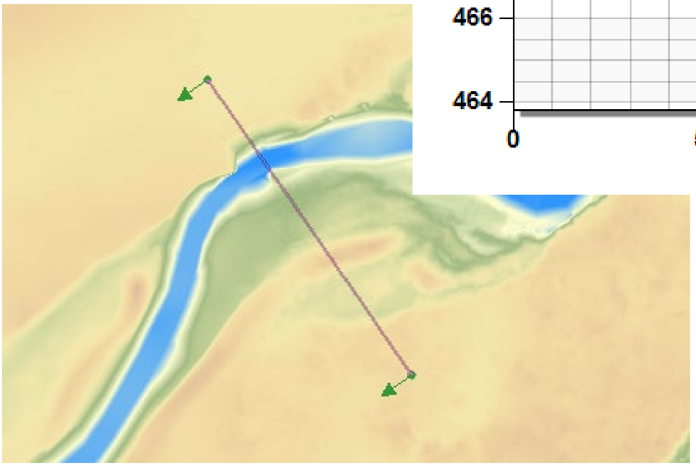
Project Information and Background Data

Terrain Data – Raster Data

Key Question:

How well does the terrain data define features? (Using plotted cross sections throughout the domain)





Key Project Info and Background Data Review Questions

- Are data sources consistent and do they cover all modeled areas?
- Has the terrain data been processed to remove unwanted features? (i.e. vegetation, structures, etc.)
- How is the channel bathymetry represented?
- Is the terrain data resolution sufficient to support the project detail and objectives?
- Have breaklines been used where needed?
- How well does the terrain data define features?

5 Minutes

2D Model Review Training Agenda

Session 1

- Overview of 2D Modeling and Available Resources
- Model Review Spreadsheet and Best Practices
- Project Information and Model Background Data
- **2D Mesh**
- *Assign Exercise 1*

Image from PowerPoint online images by Peter Baumgartner

Reviewing a 2D Mesh
Top 3 Things

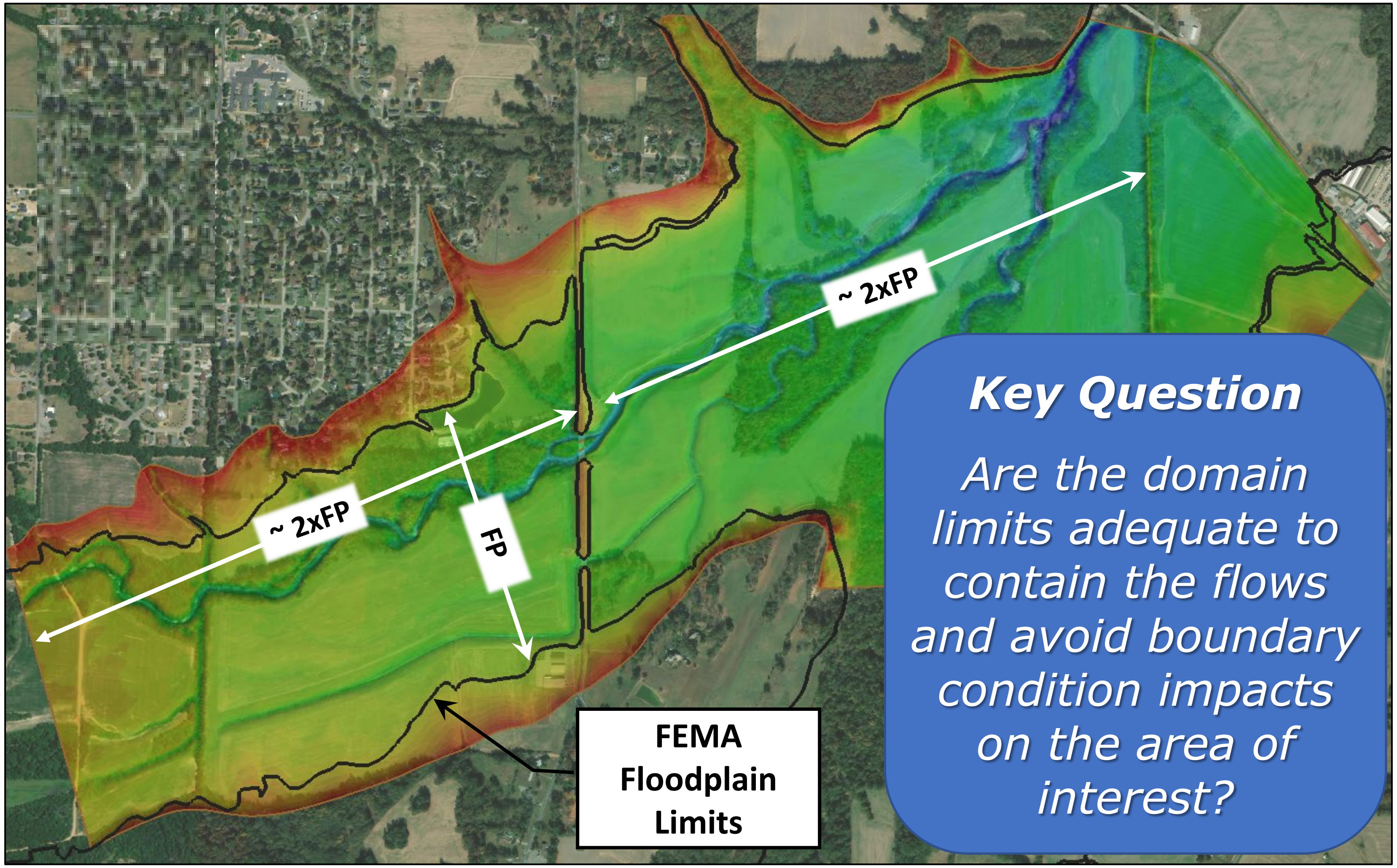
1. Confirm the domain limits are adequate
2. Compare the mesh with the original terrain and key features
3. Assess the number and size of mesh elements

2D Mesh

Mesh Extents (Domain Limits)

<u>Upstream considerations</u>

- More contracted, simple geometry locations are preferred (best practice)
- Terrain features that affect flow distribution
- Distance needed to establish natural flow distribution
- Sensitivity analyses are needed when boundaries are in close proximity to the area of interest



Key Question

Are the domain limits adequate to contain the flows and avoid boundary condition impacts on the area of interest?

2D Mesh

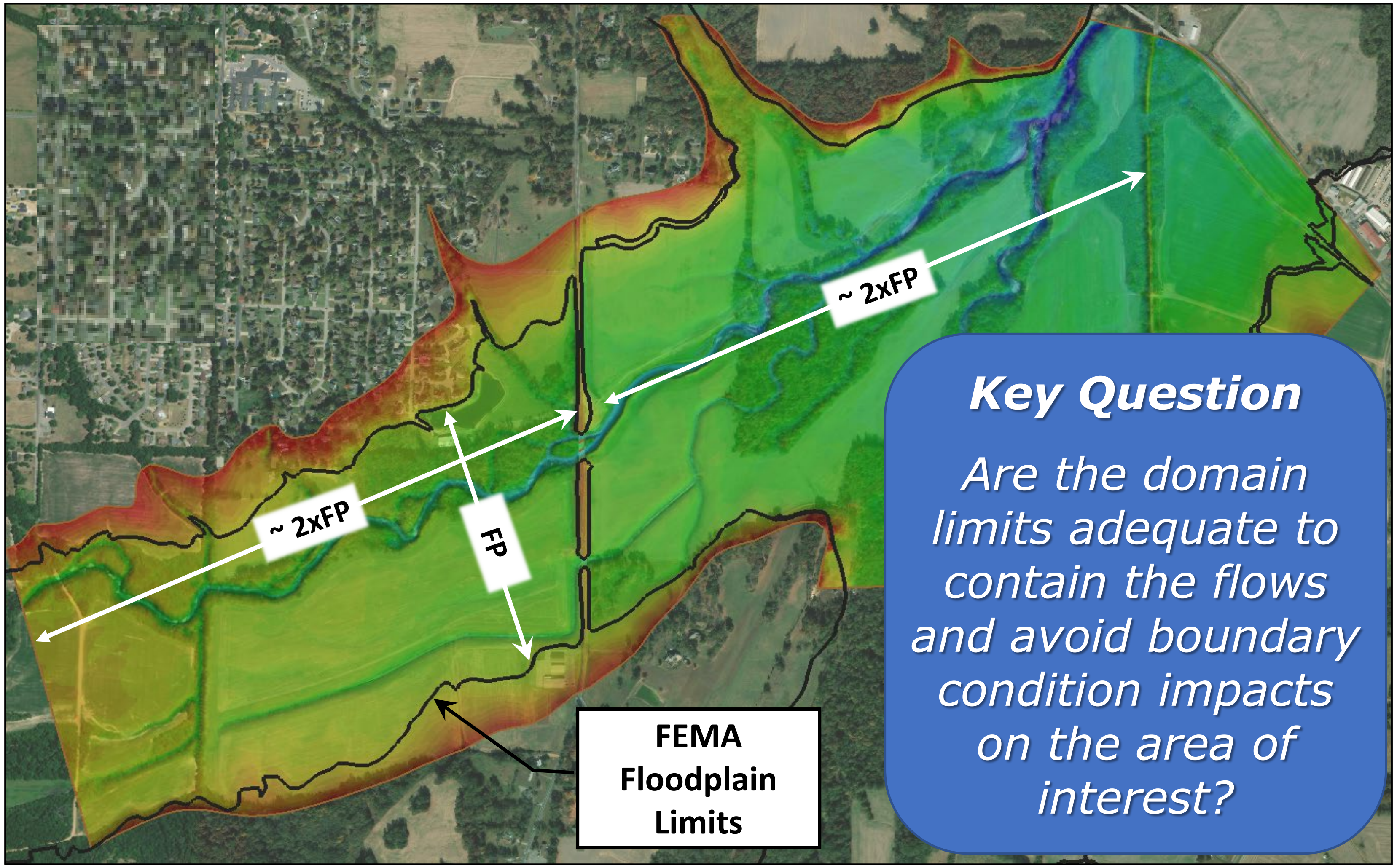
Mesh Extents (Domain Limits)

Downstream considerations

- Terrain features that affect flow distribution
- More contracted, simple geometry locations are preferred
- Influence of possible errors in estimating tail water elevation

Lateral limits

- Should extend beyond floodplain limits
- Vertical wall assumed when flow contacts boundary



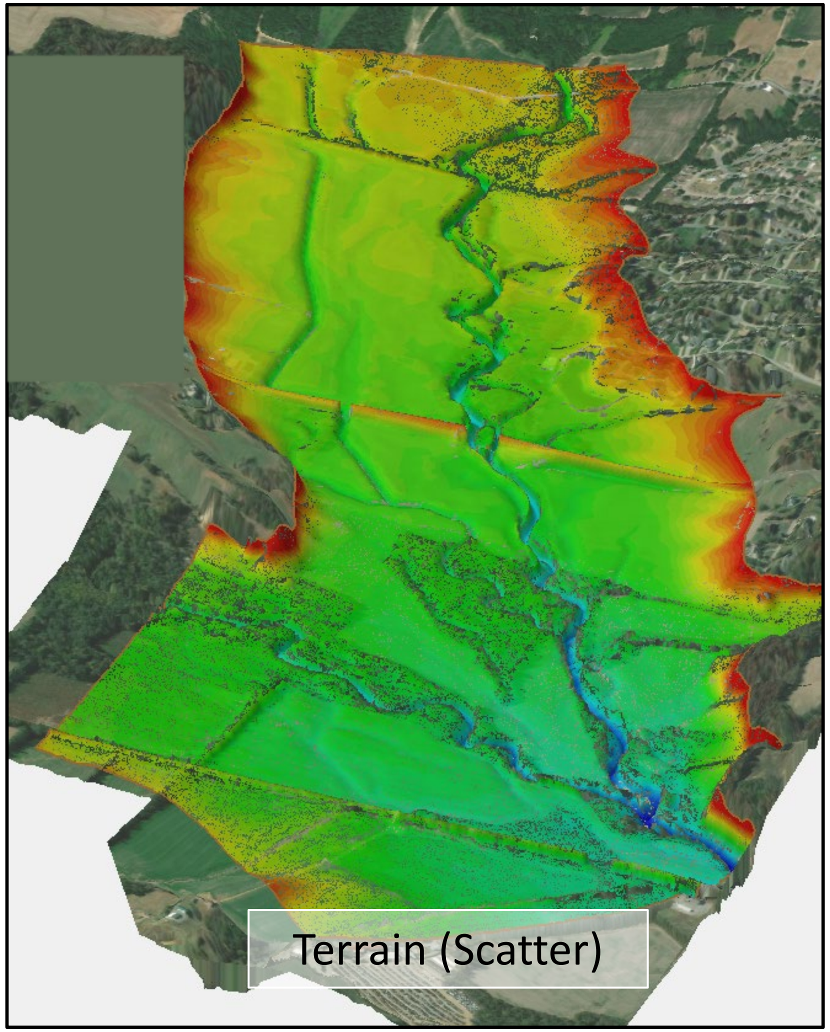
2D Mesh

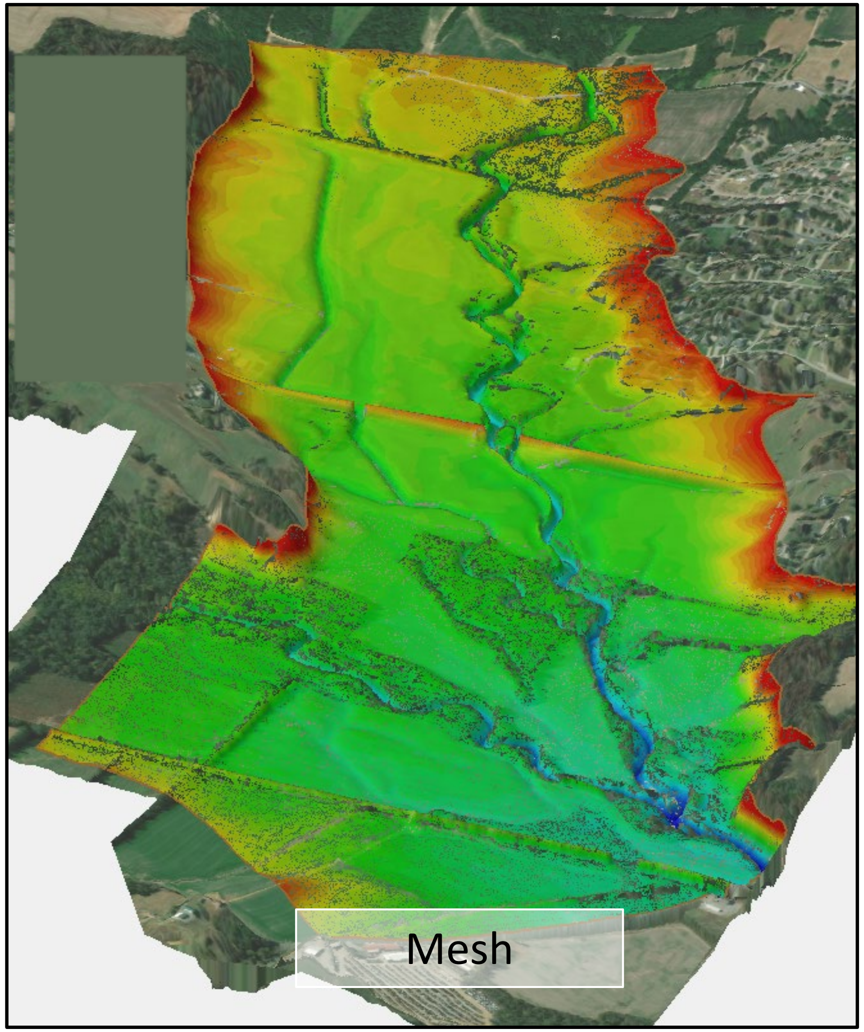
Terrain Representation and Hydraulic Controls

Key Question:

Does the mesh provide an accurate representation of the terrain?

- Compare key features in mesh vs terrain
- Compare along cross sections and profiles



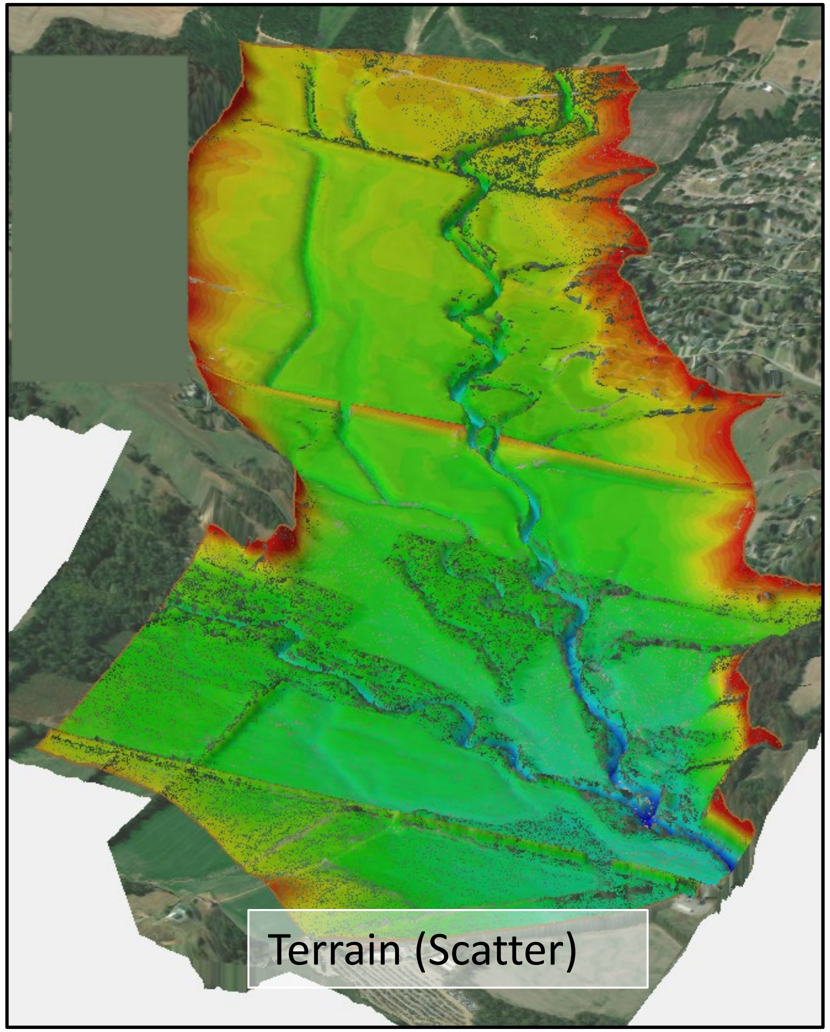


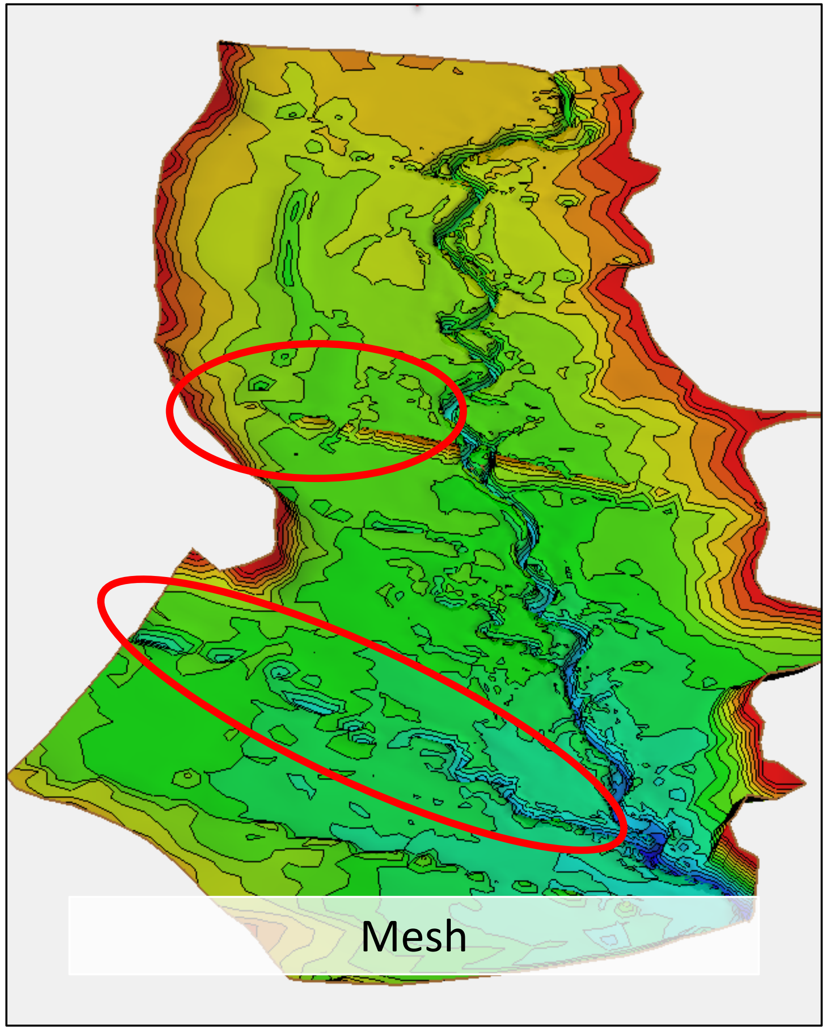
2D Mesh

Terrain Representation and Hydraulic Controls

Key Question:

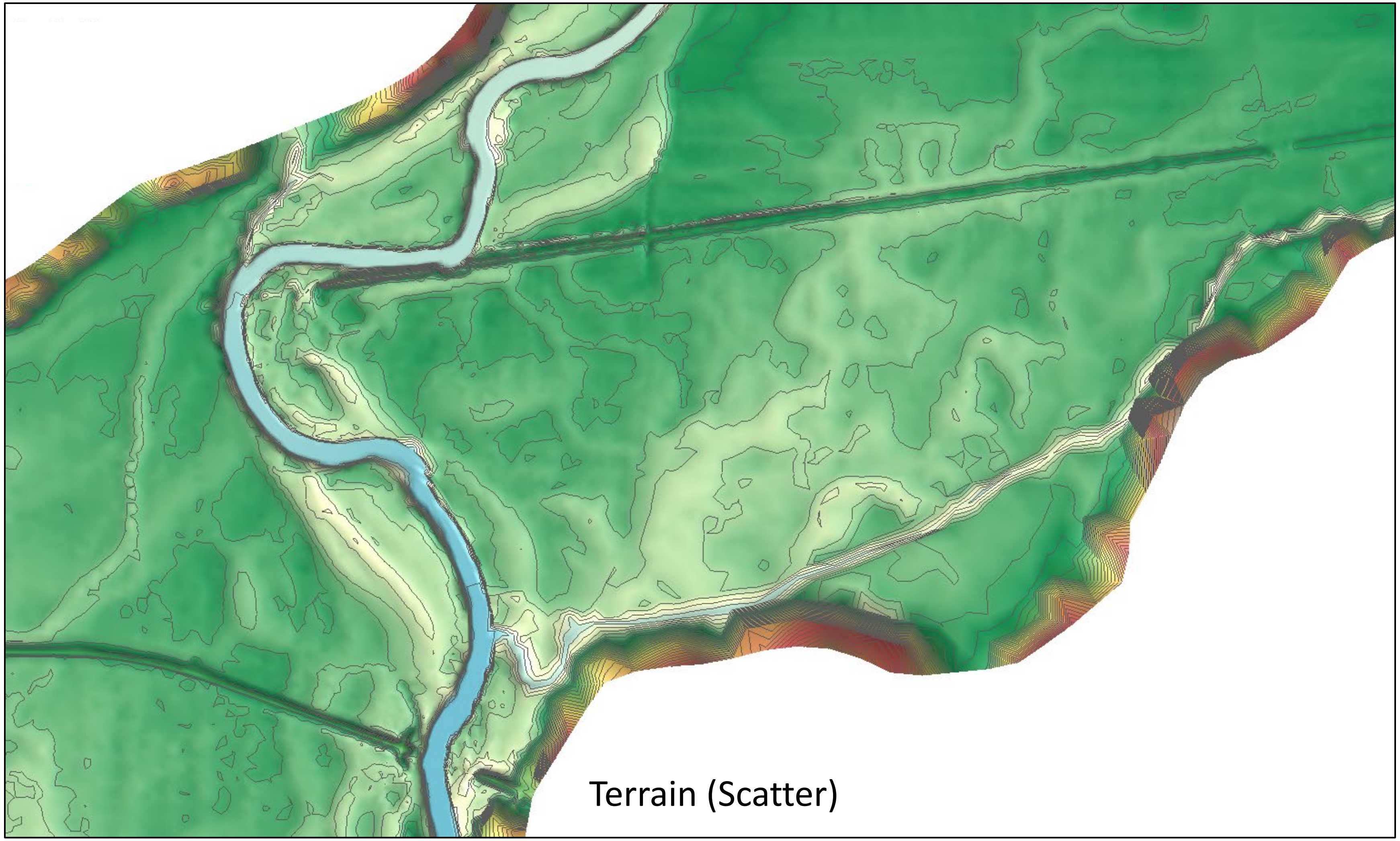
Are key features accurately represented (embankments, channels, etc.)?





2D Mesh

Terrain Representation and Hydraulic Controls

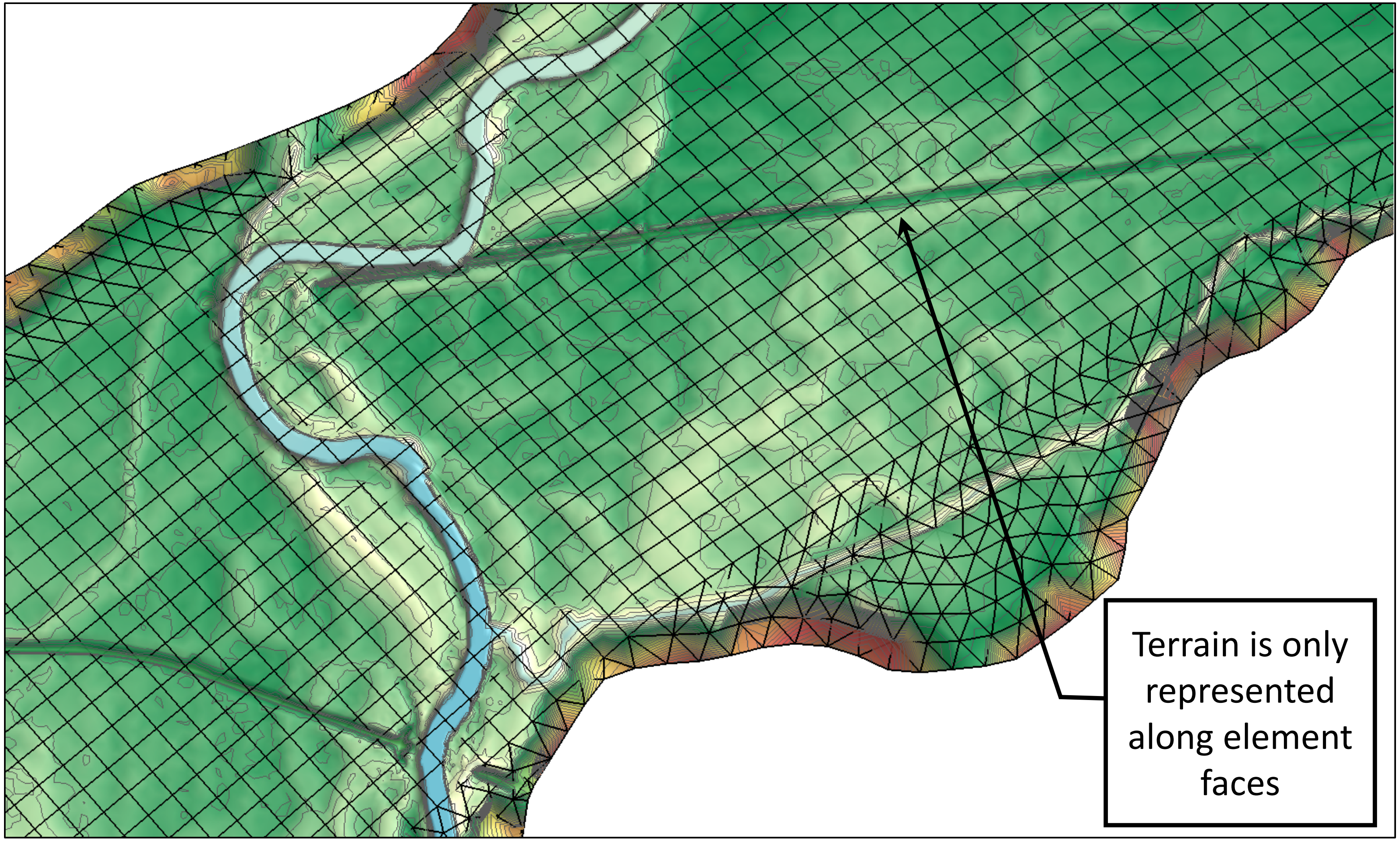


Key Question:

Do element faces align with key features (hydraulic controls)?

2D Mesh

Terrain Representation and Hydraulic Controls



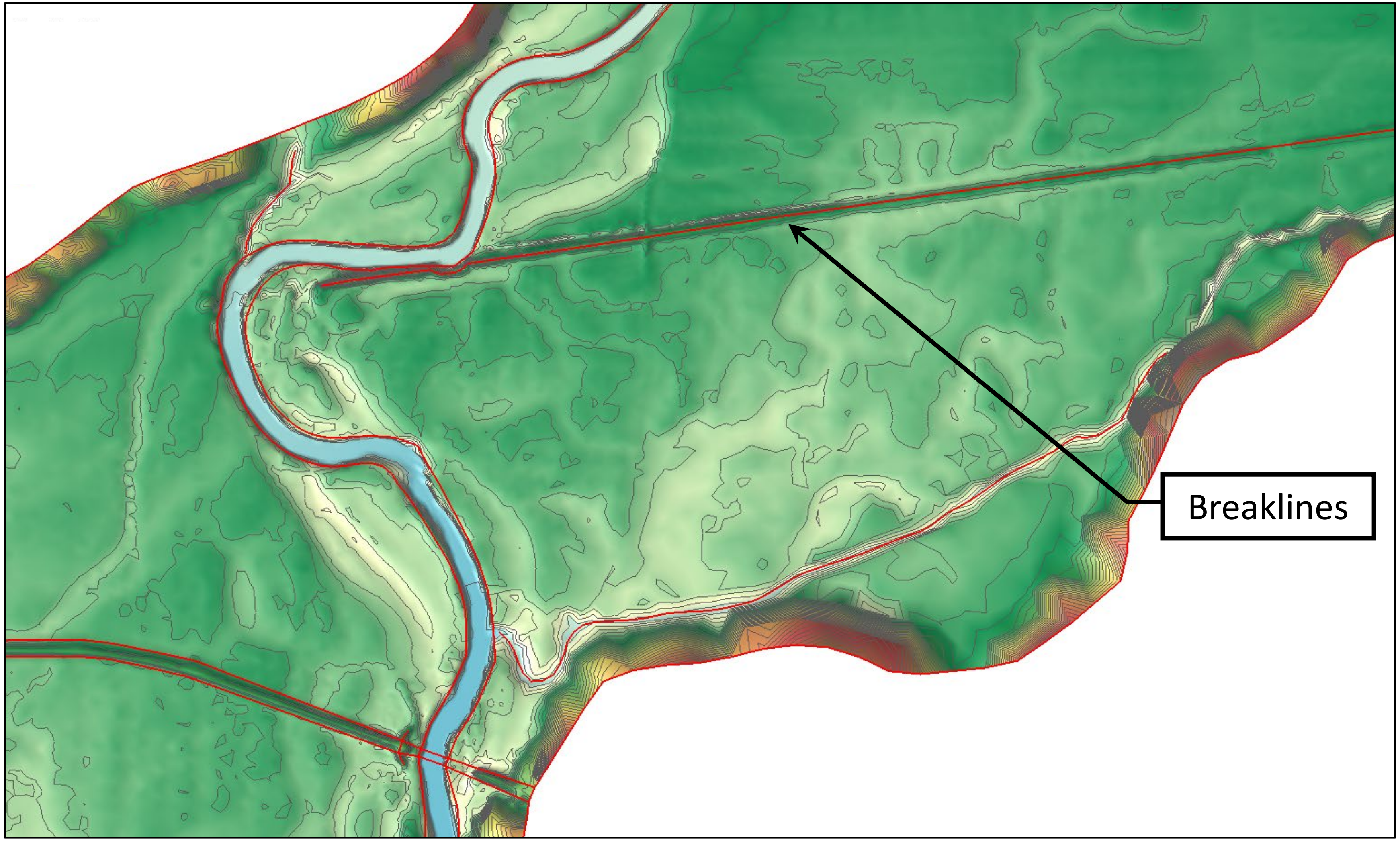
Key Question:

Do element faces align with key features (hydraulic controls)?

- This mesh would not correctly represent the embankment or channel banks.

2D Mesh

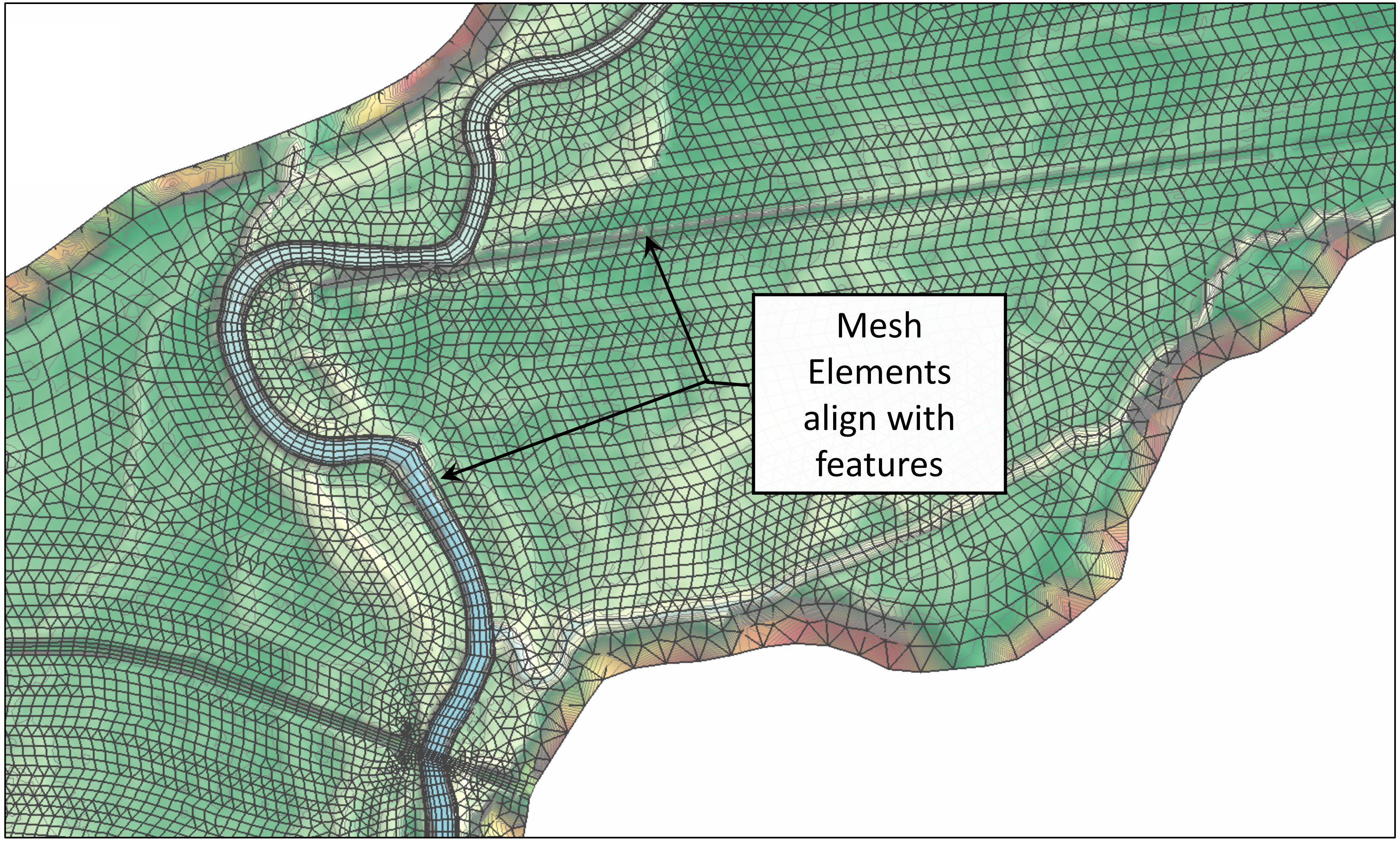
Terrain Representation and Hydraulic Controls



- Breaklines must be used when generating the mesh to force element edges to align with key features and controls
- Channel bank breaklines are recommended when there is notable flow between the main channel and overbanks

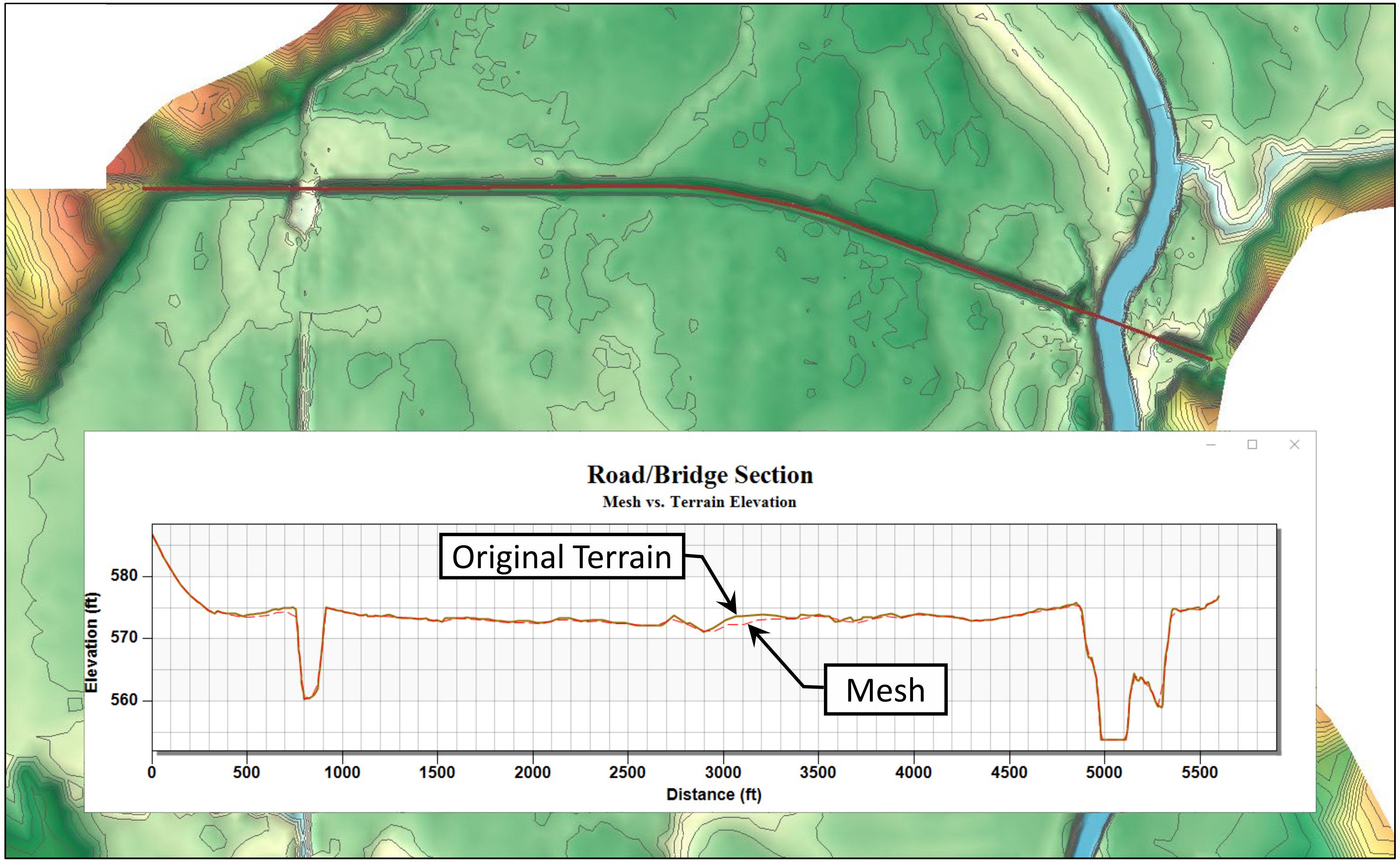
2D Mesh

Terrain Representation and Hydraulic Controls



2D Mesh

Terrain Representation of Hydraulic Controls and Key Features



Plotted profiles along key features comparing original terrain to the mesh terrain are helpful in model review

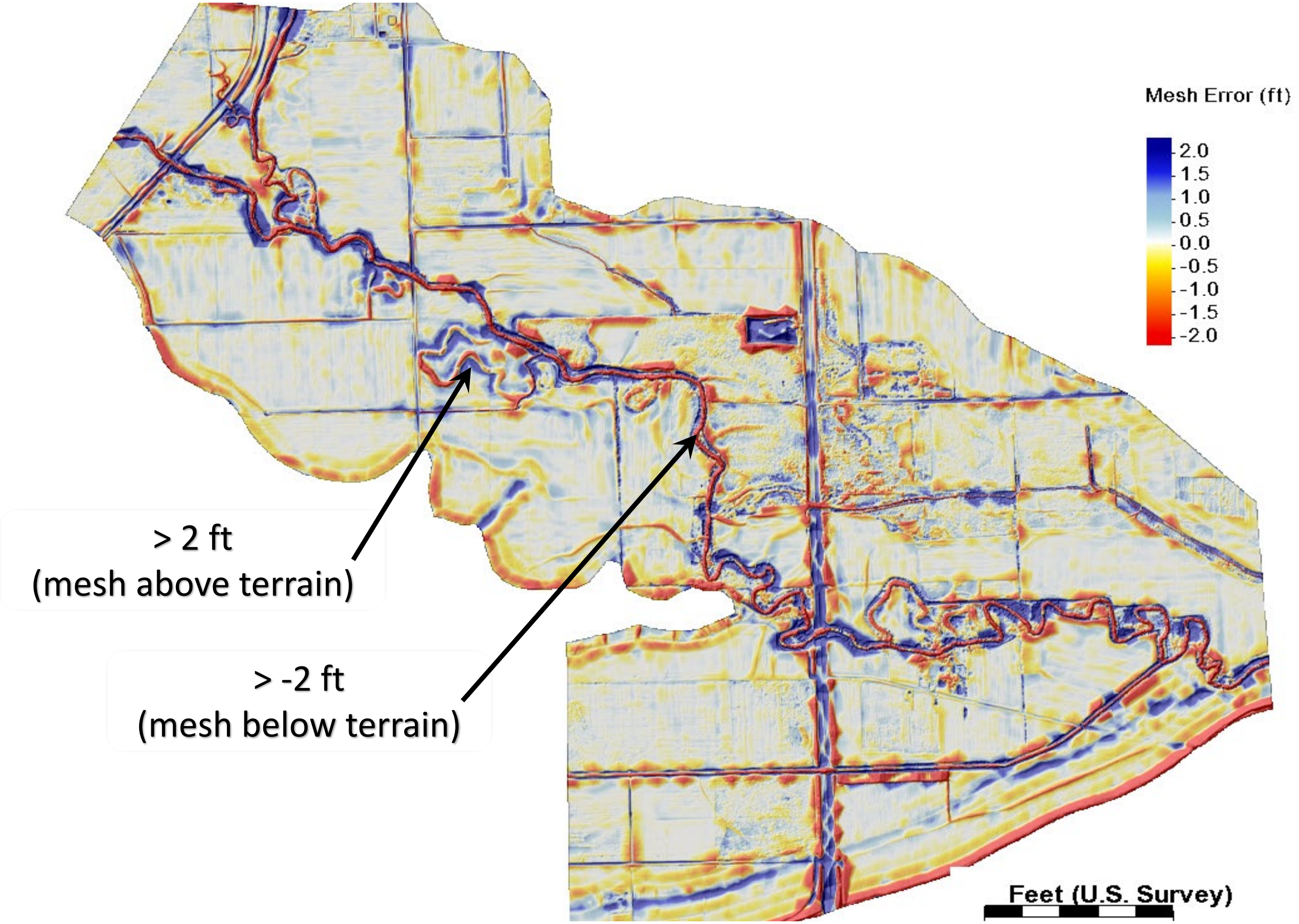
2D Mesh

Terrain Representation of Hydraulic Controls and Key Features

A differential surface plot can be very helpful in assessing how well a mesh represents the terrain.

The plot is generated by subtracting the mesh surface elevations from the terrain surface.

Significant differences may highlight areas that are not represented well



2D Mesh

Mesh Resolution, Element Size, and Quality

Key Question:

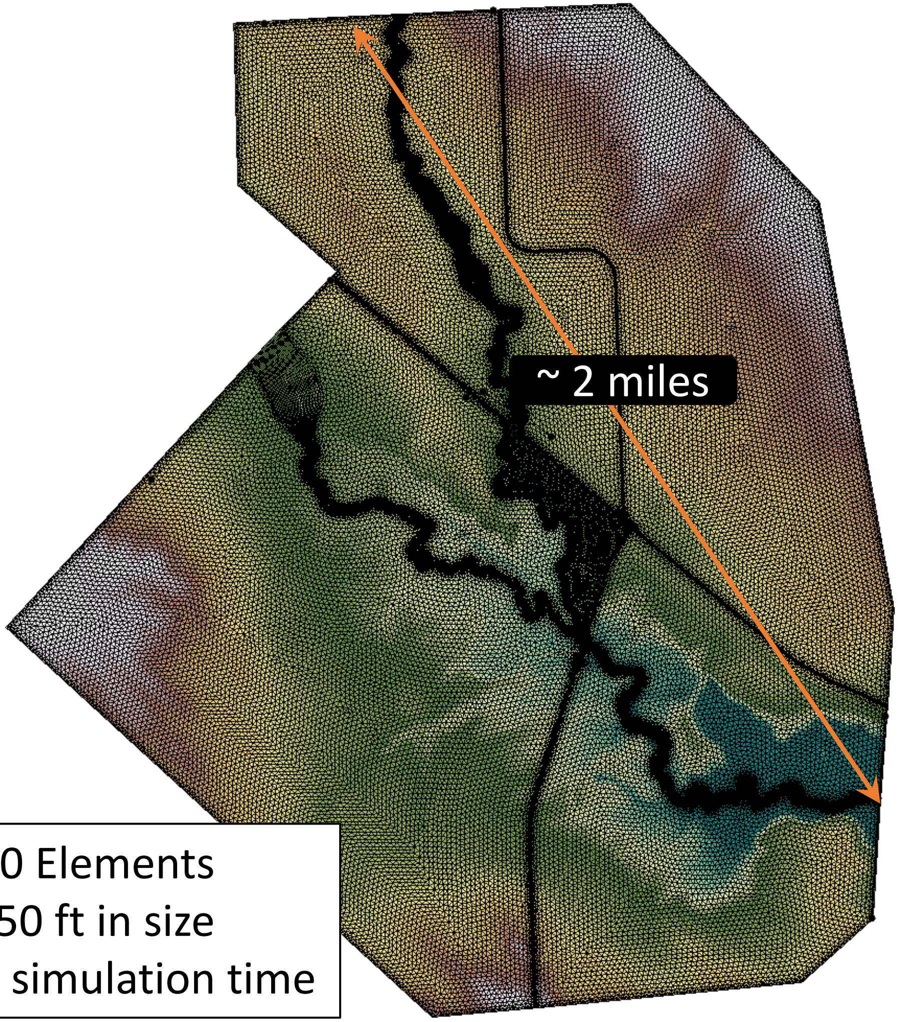
Is the number of mesh elements appropriate?

- In general, most detailed study projects can be accomplished with fewer than 100,000 elements, depending on complexity
- The level of detail should be consistent with modeling objectives
- More elements are not always better
- Model efficiency is generally important

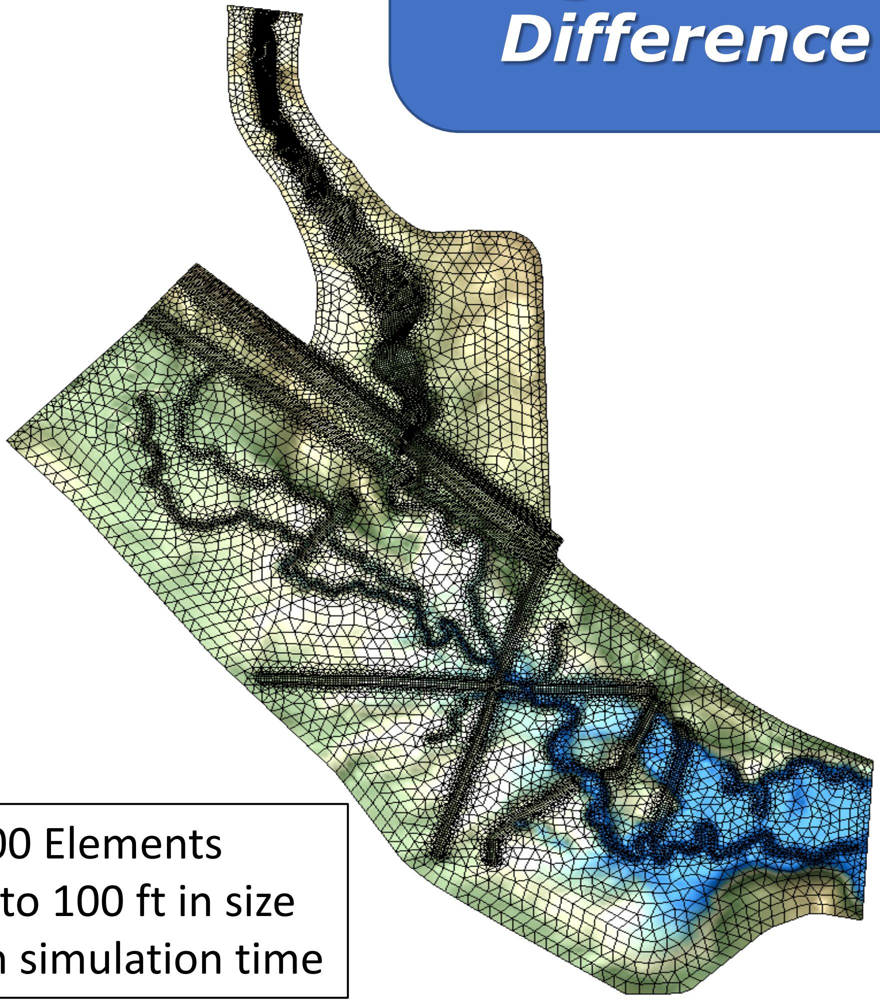
2D Mesh

Impacts of Mesh Resolution

Best Practices Make a Significant Difference



140,000 Elements
1 ft to 50 ft in size
36 min simulation time



26,000 Elements
10 ft to 100 ft in size
1 min simulation time

2D Mesh

Mesh Resolution, Element Size, and Quality

- Is the element size reasonable relative to the terrain data resolution?
- Is the mesh resolution sufficient to represent areas with complex hydraulics? (Changes in flow direction, flow splits, rapid drops in WSEL, etc.)
- To avoid stability issues, element **length** should generally be equal to or greater than the flow depth, except in limited areas (i.e. piers)

Key Question:

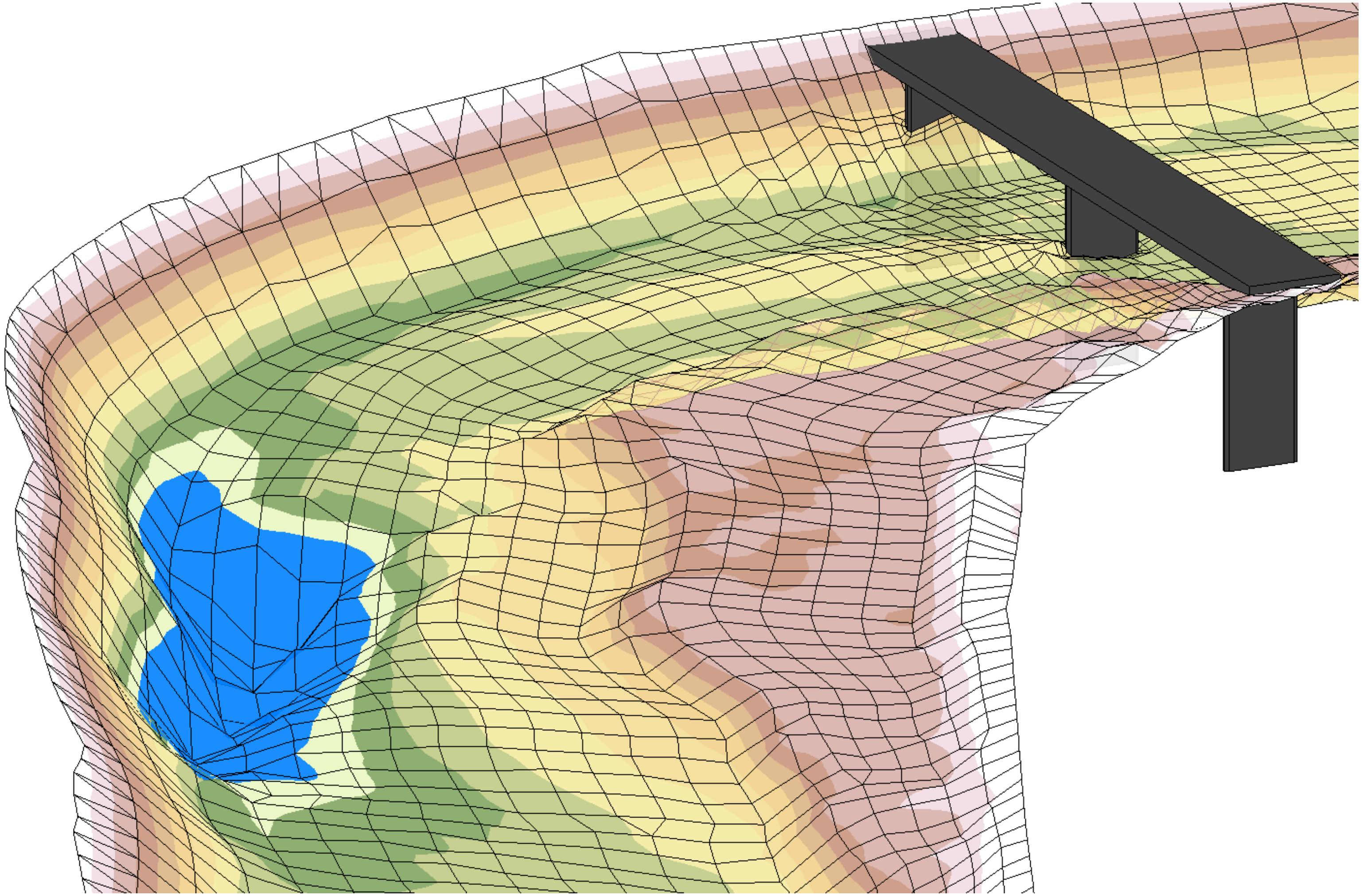
Is the size of mesh elements appropriate?

2D Mesh

Mesh Resolution, Element Size, and Quality

Multiple elements should be used to represent channel bed and banks, and embankment slopes where detailed flow distribution, velocity distribution results are needed.

Only one WSEL and velocity solution is computed for each element (centroid). All other values in a solution are interpolated.

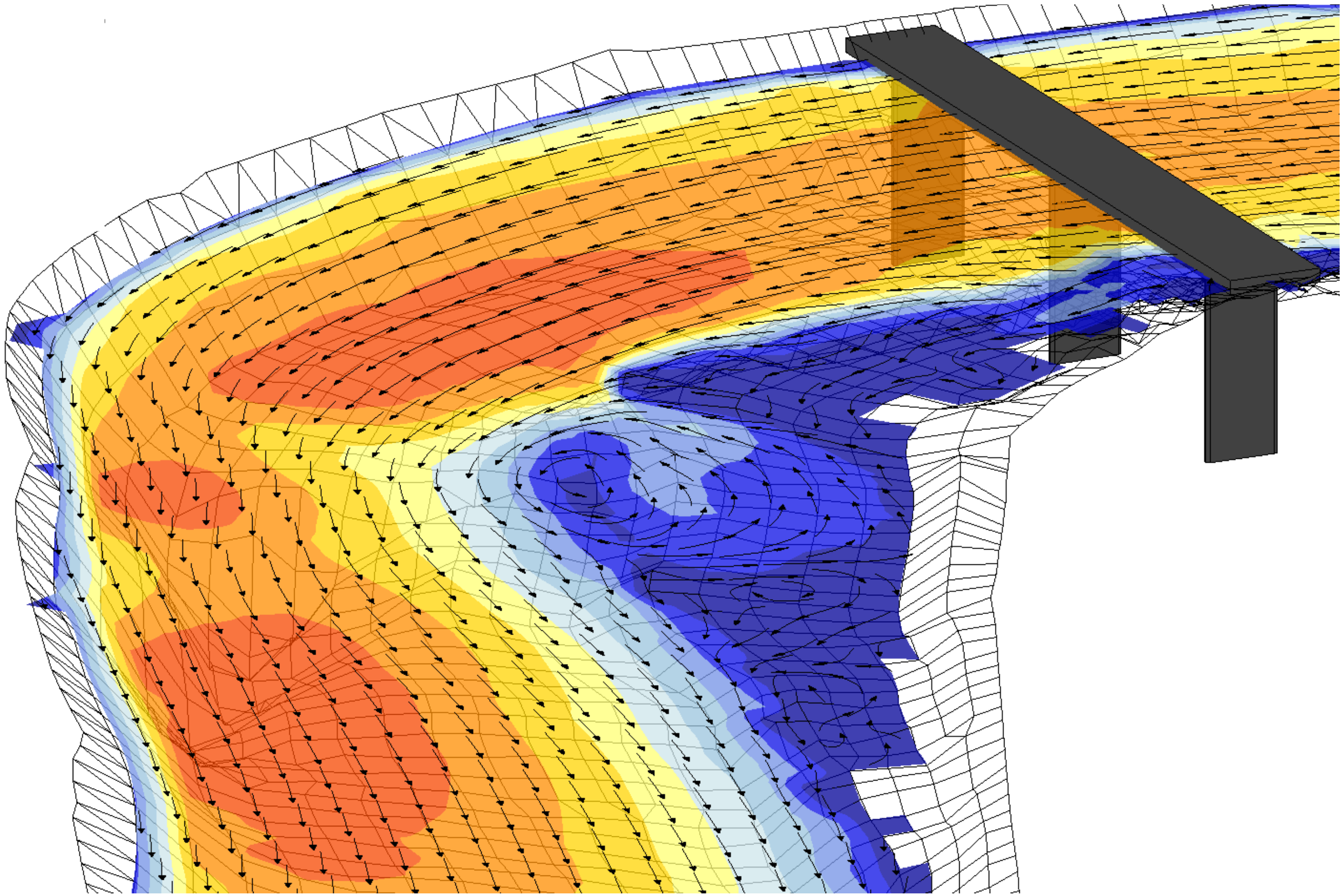


2D Mesh

Mesh Resolution, Element Size, and Quality

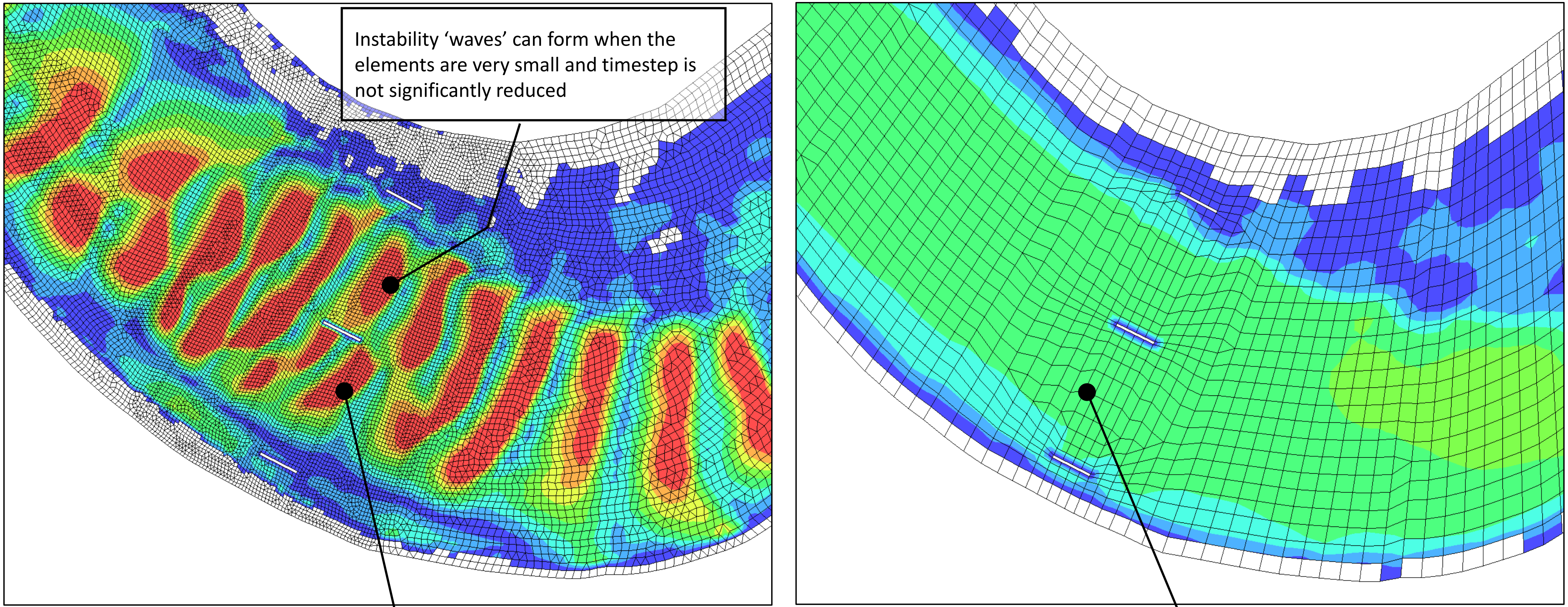
Without adequate mesh resolution, detailed velocity and flow distributions cannot be computed accurately.

This is especially important when representing flow splits and rapidly varied flow, as well as using results for design purposes (counter-measure design, bridge scour analyses, etc.)



2D Mesh

Impacts of Mesh Resolution



Average flow depth = 28 ft
Average element length = 10 ft

Average flow depth = 28 ft
Average element length = 26 ft

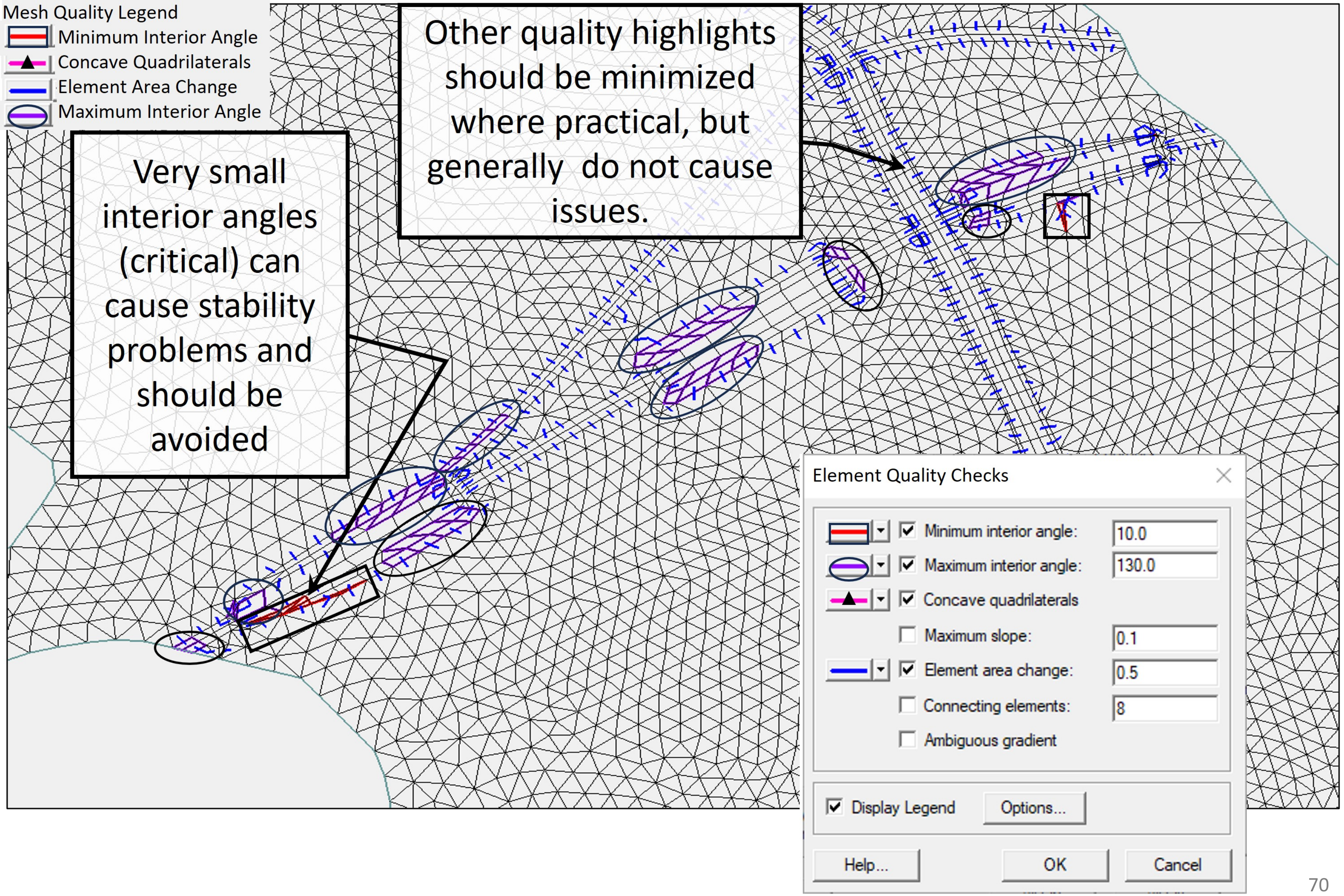
Velocity Contours

2D Mesh

Mesh Resolution, Element Size, and Quality

Key Question:

Does the mesh have any critical quality issues?



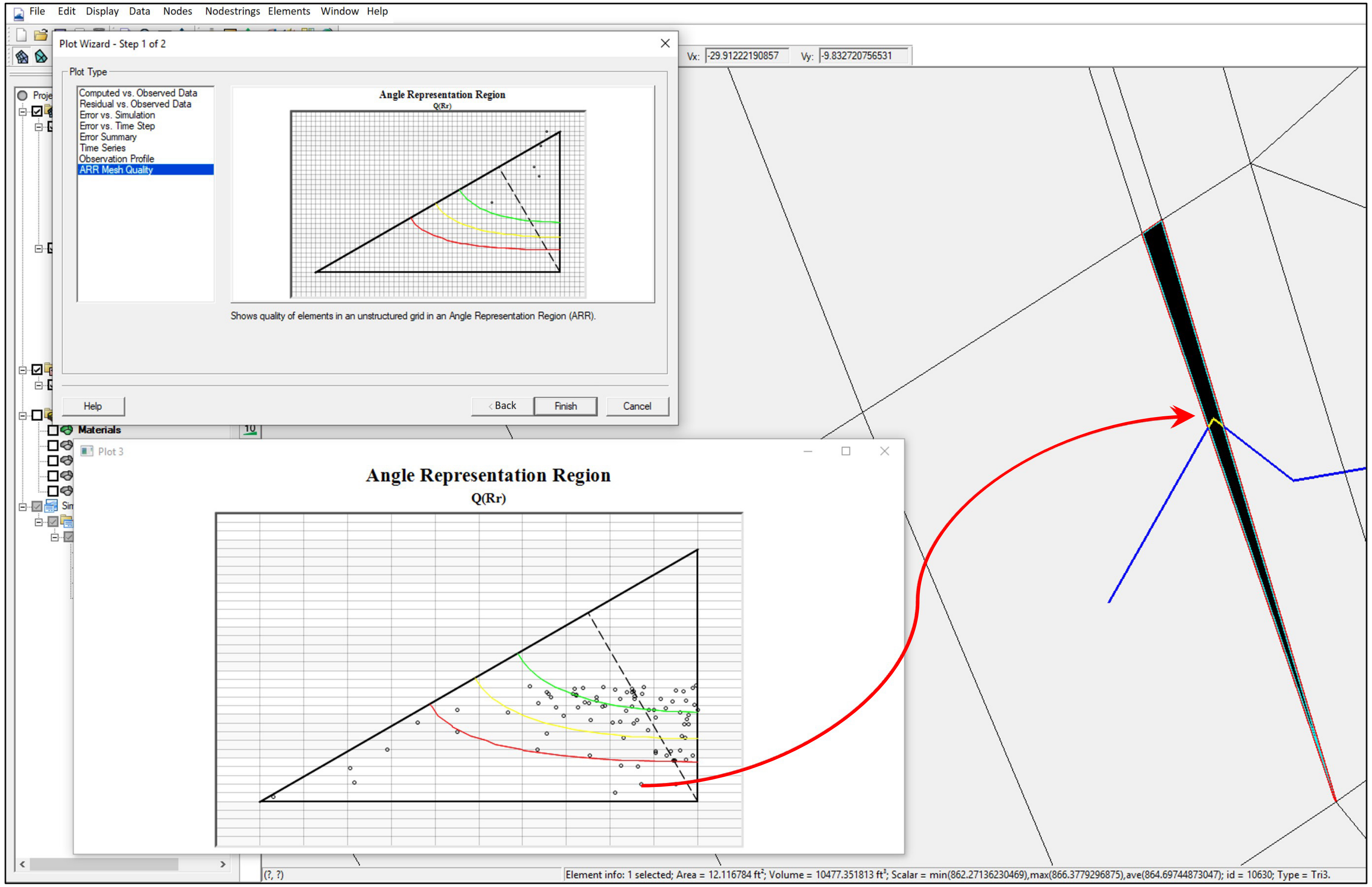
2D Mesh

Mesh Resolution, Element Size, and Quality

The ARR plot in SMS is helpful in assessing the quality of a mesh.

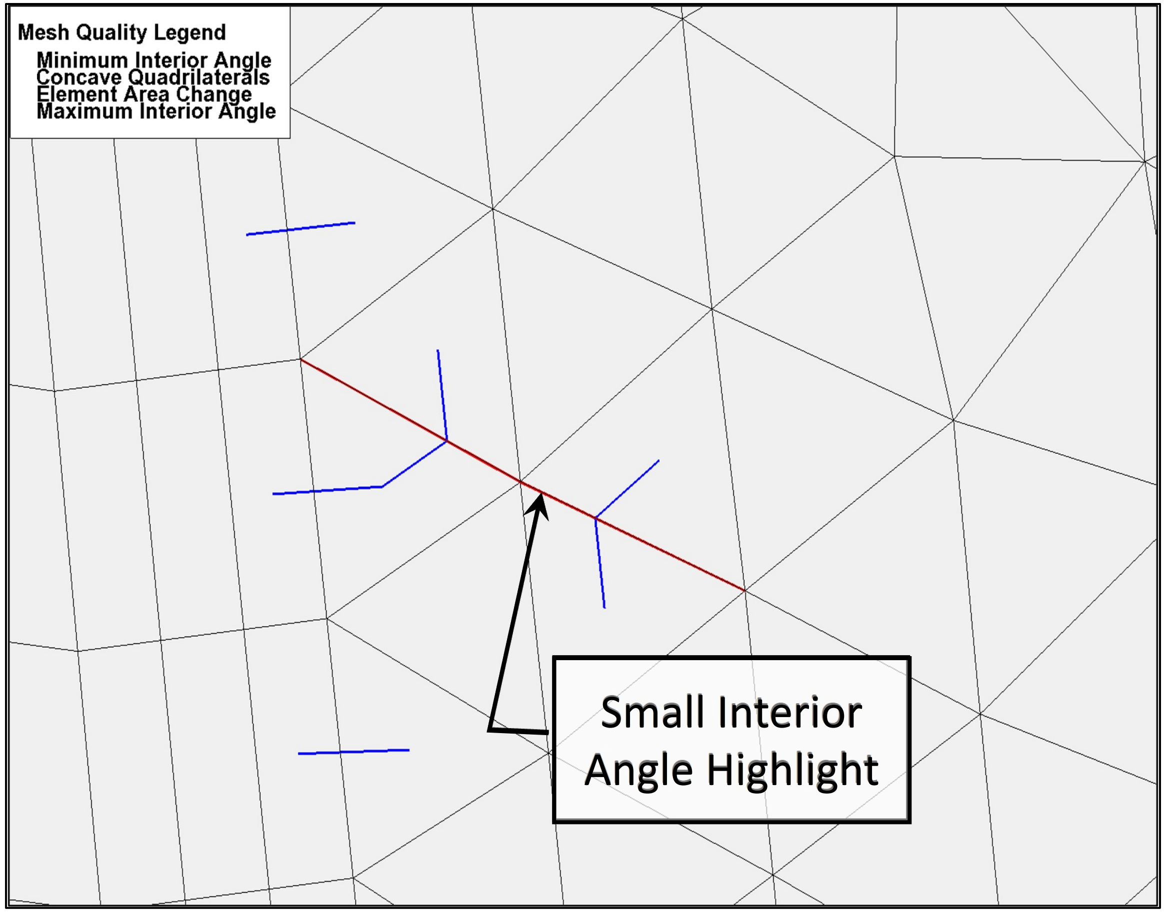
Elements with potentially poor quality fall below the red line and should be reviewed

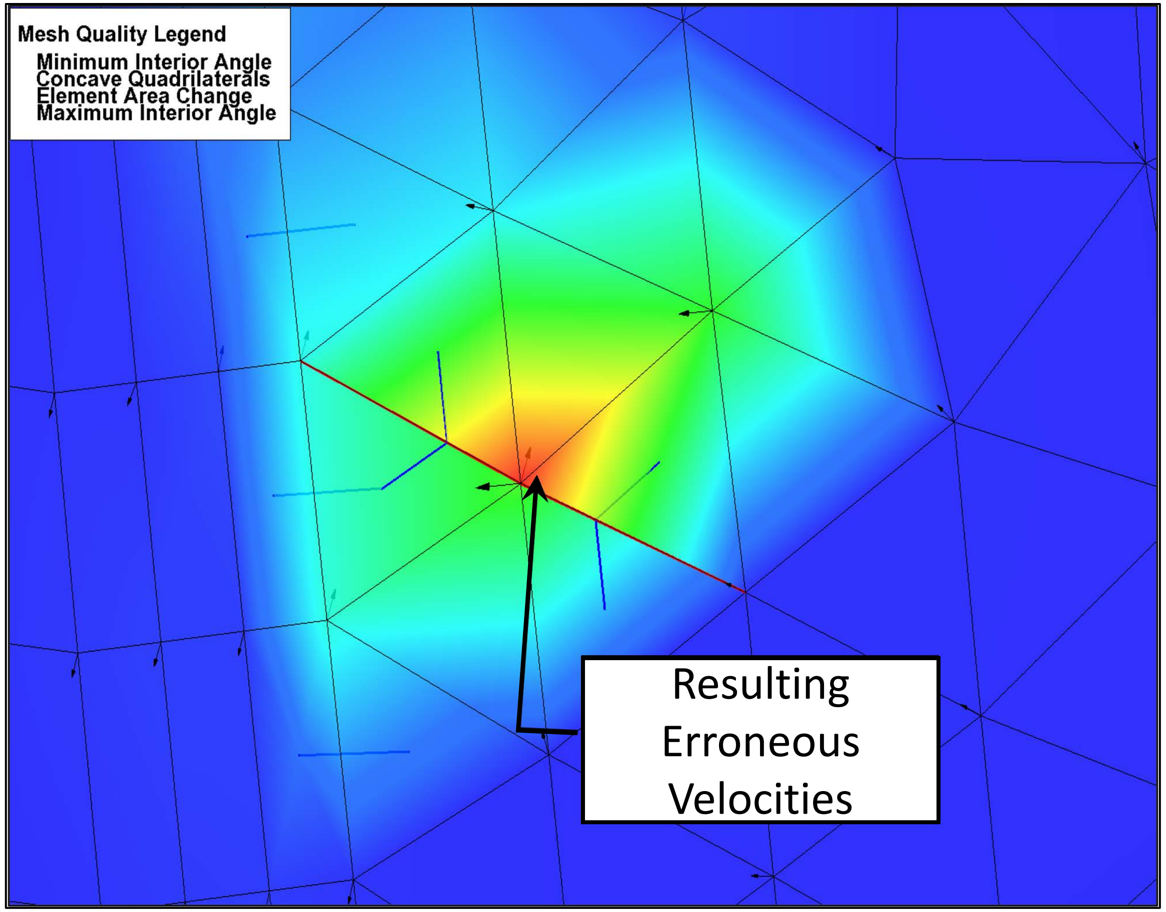
The ARR plot is also included in the SMS Simulation Summary Report



2D Mesh

Impacts of Poor Mesh Quality





Key 2D Mesh Review Questions

- Are the domain limits adequate to contain the flows and avoid boundary condition impacts on the area of interest?
- Does the mesh provide an accurate representation of the terrain?
- Are key features accurately represented (embankments, channels, etc.)?
- Do element faces align with key features (hydraulic controls)?
- Is the number of mesh elements appropriate?
- Is the size of mesh elements appropriate?
- Does the mesh have any critical quality issues?

2D Model Review Training Agenda

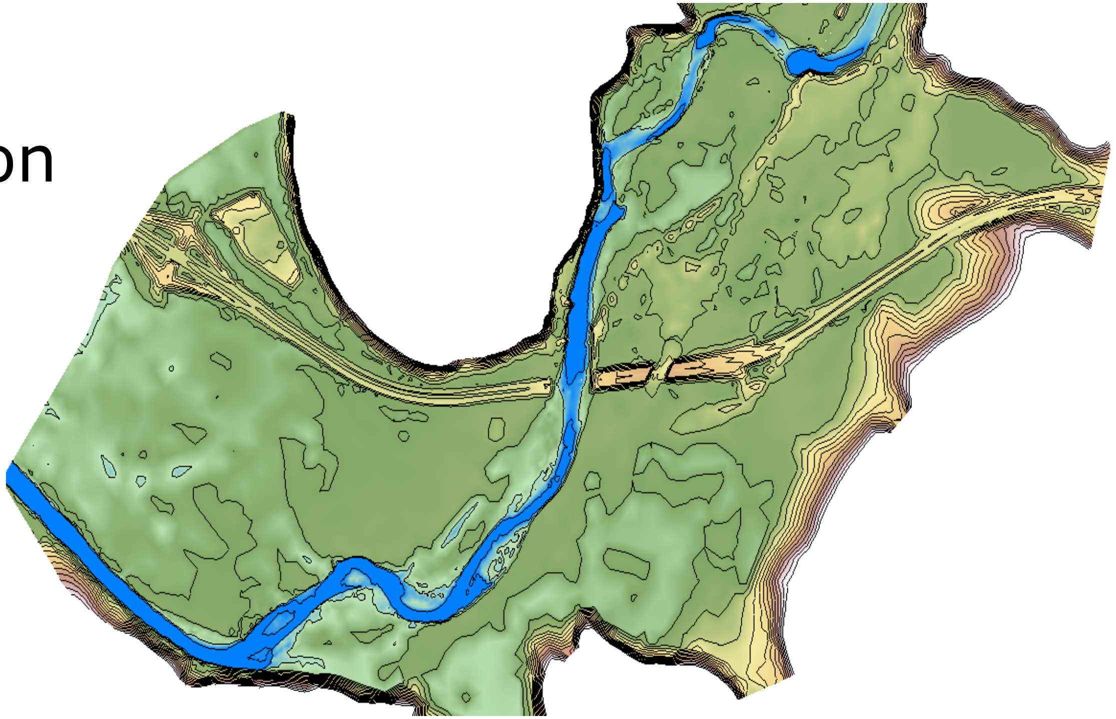
Session 1

- Overview of 2D Modeling and Available Resources
- Model Review Spreadsheet and Best Practices
- Project Information and Model Background Data
- 2D Mesh
- ***Assign Exercise 1***

Image from PowerPoint online images by Peter Baumgartner

Model Review Exercise 1

- Focus on the **Terrain Data** and the **2D Mesh**
  - Note the key features (controls) contours in the terrain data set
  - Compare with the mesh elevation contours
  - Review mesh quality
  - Review terrain difference plot (tif image)
  - Review mesh resolution and element size
- Note observations for group discussion in Session 2



End of Session 1

Session 2

- *Review Exercise 1*
- Boundary Conditions
- Material Roughness
- Hydraulic Structures
- Simulation Parameters
- Assign Exercises 2 & 3

2D Model Review Training Agenda

Session 1

- Overview of 2D Modeling and Available Resources
- Information to Be Reviewed, Model Review Spreadsheet and Best Practices
- Project Information and Model Background Data
- 2D Mesh
- *Assign Exercise 1*

Session 2

- *Review Exercise 1*
- Boundary Conditions
- Material Roughness
- Hydraulic Structures
- Simulation Parameters
- *Assign Exercises 2 & 3*

Session 3

- *Review Exercises 2 & 3*
- Reviewing Model Results
- *Bridge Scour Analysis Review*
- Wrap-up

Image from PowerPoint online images by Peter Baumgartner

2D Model Review Training Agenda

Session 2

- ***Review Exercise 1***
- Boundary Conditions
- Material Roughness
- Hydraulic Structures
- Simulation Parameters
- Assign Exercises 2 & 3

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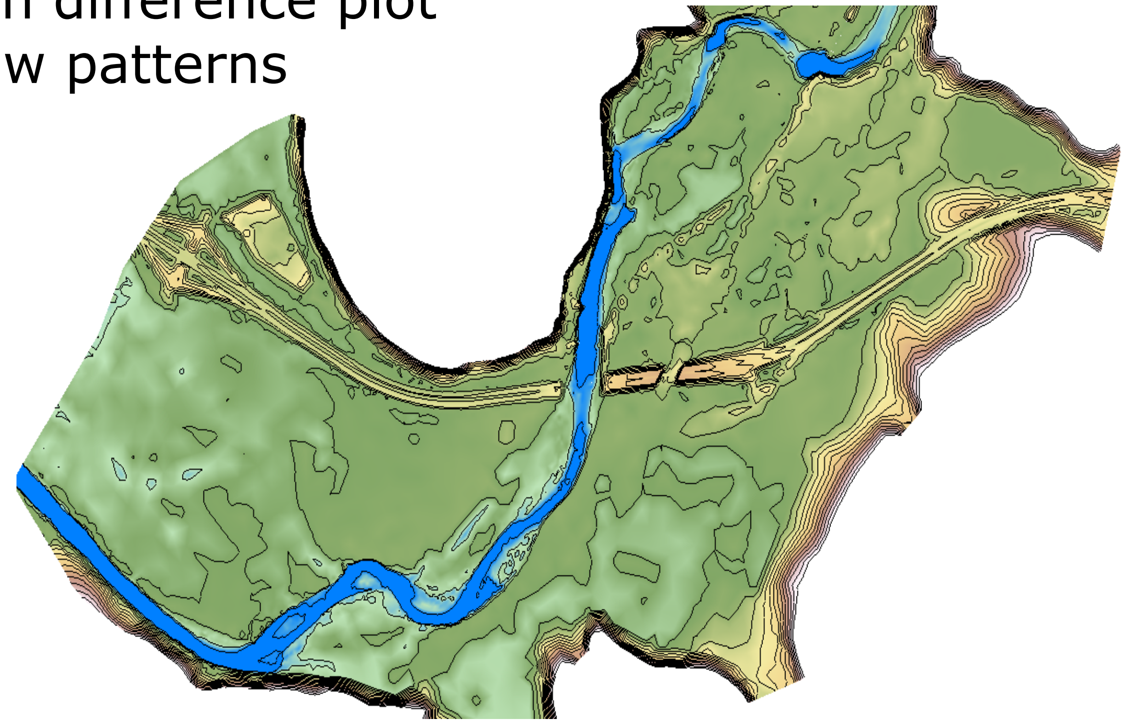
Model Review Exercise 1

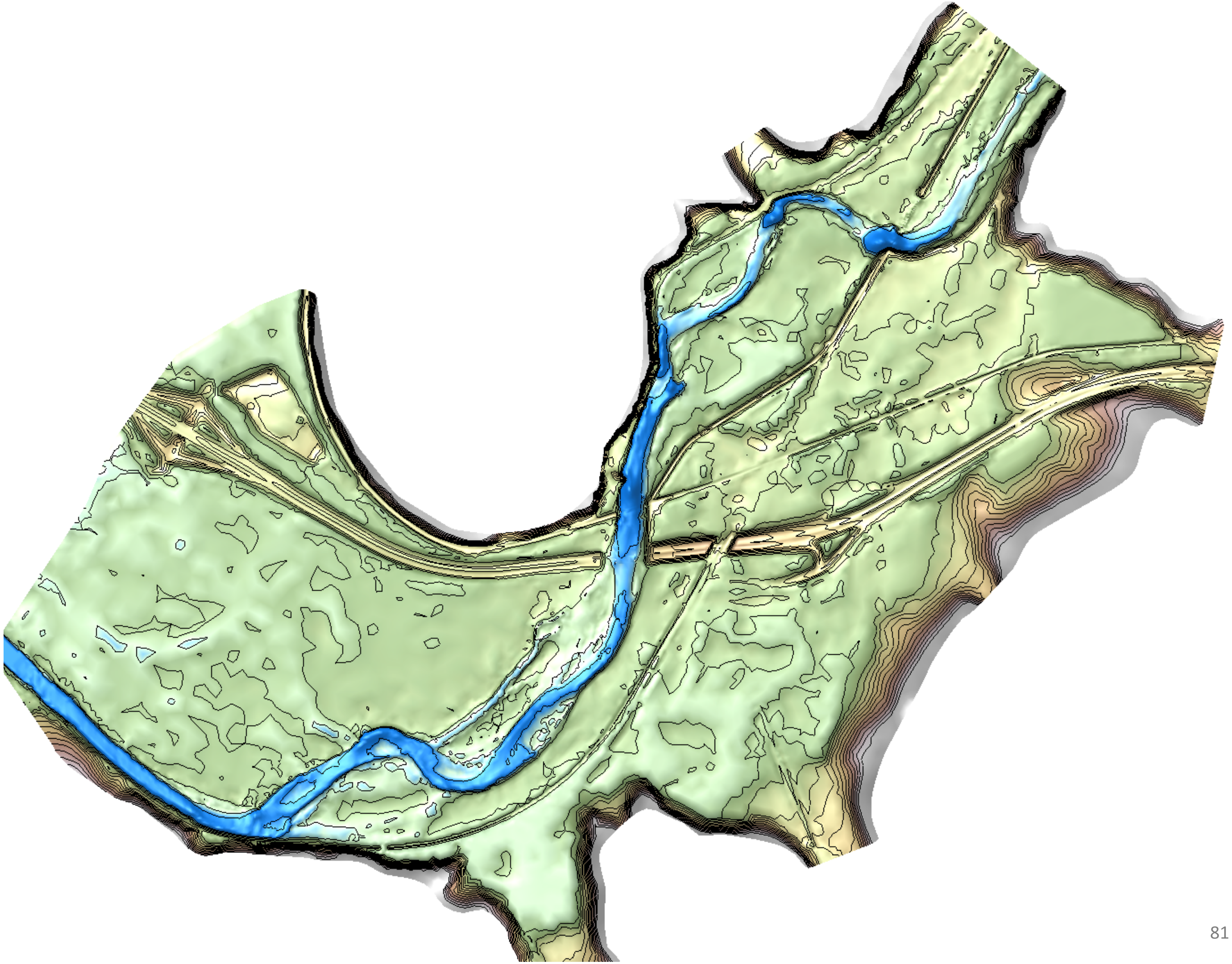
Discussion

Model Review Exercise 1

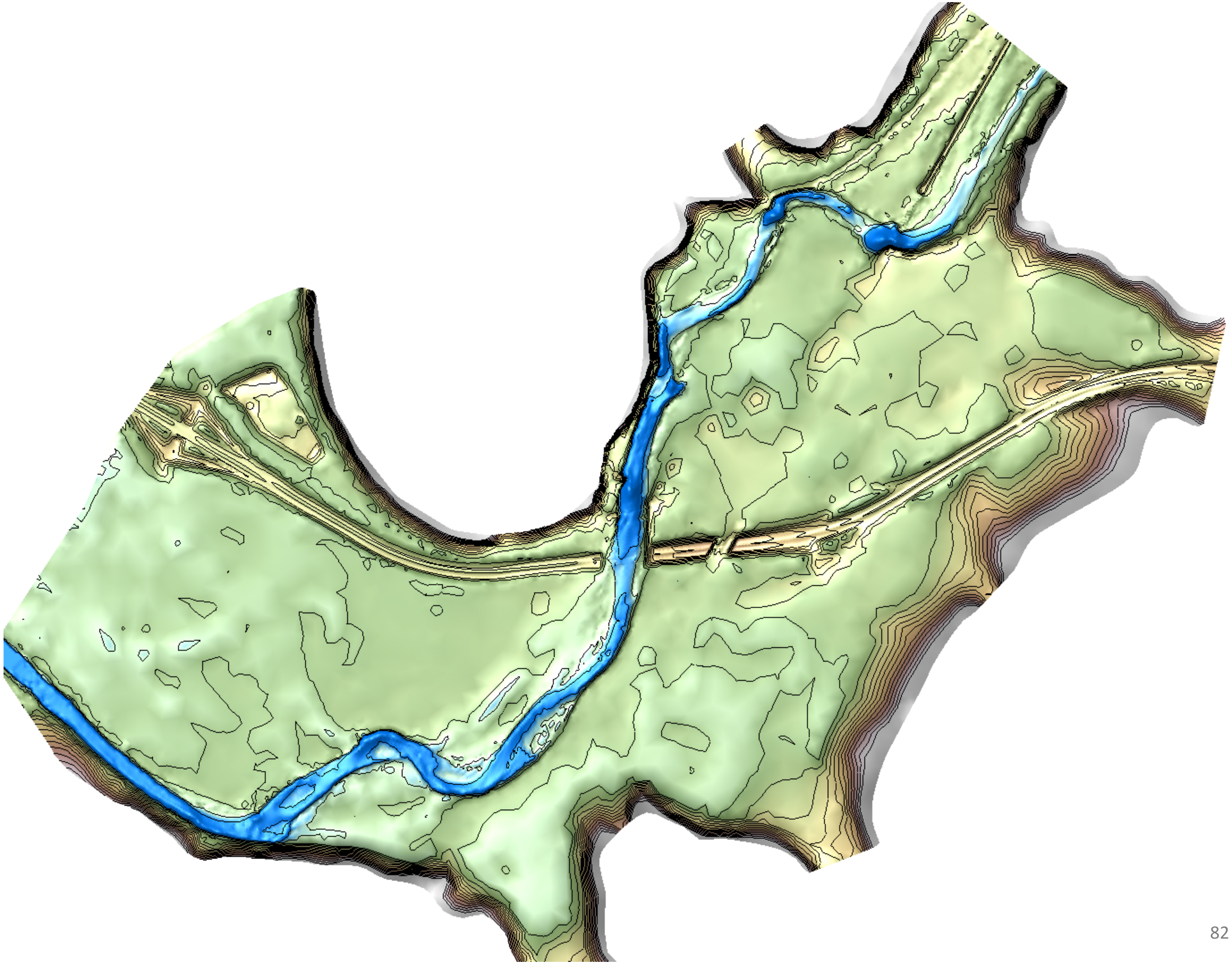
- Focus on the **Terrain Data** and the **2D Mesh**
  - Key linear features (controls) are not represented along element faces
  - Mesh quality could be improved
  - Significant differences shown in the terrain difference plot
  - Review of mesh element resolution for flow patterns



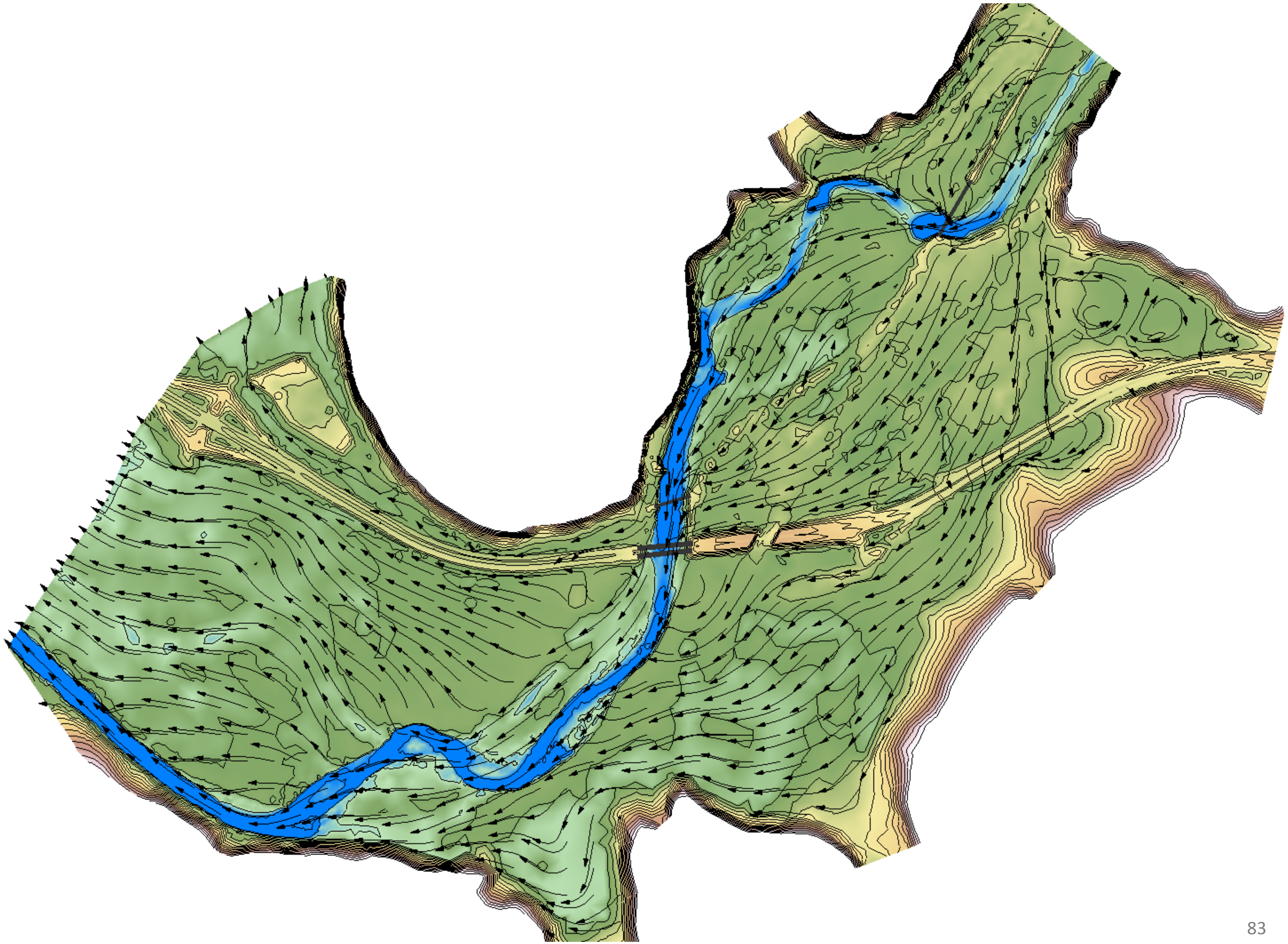
Original Terrain Contours



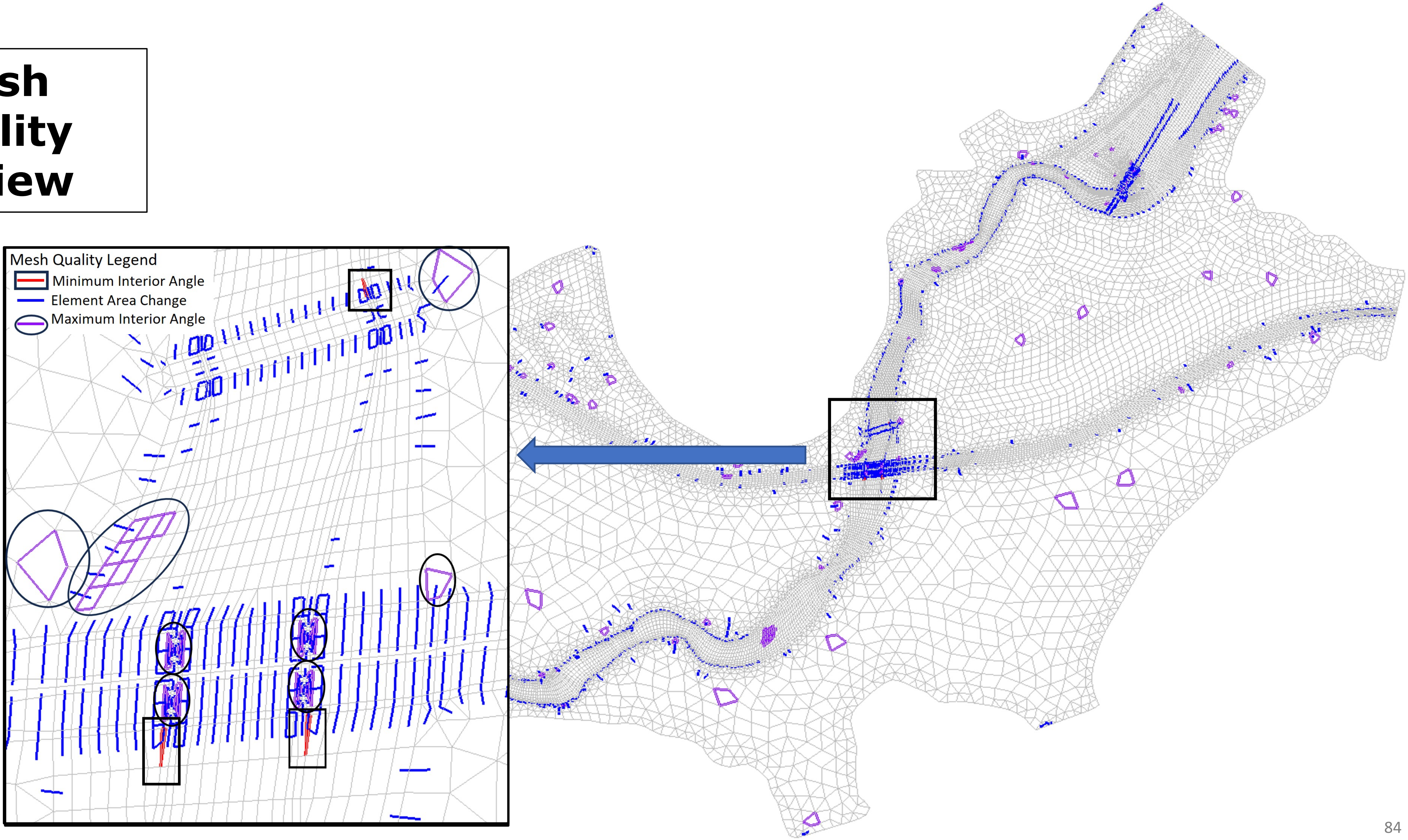
Mesh Elevation Contours



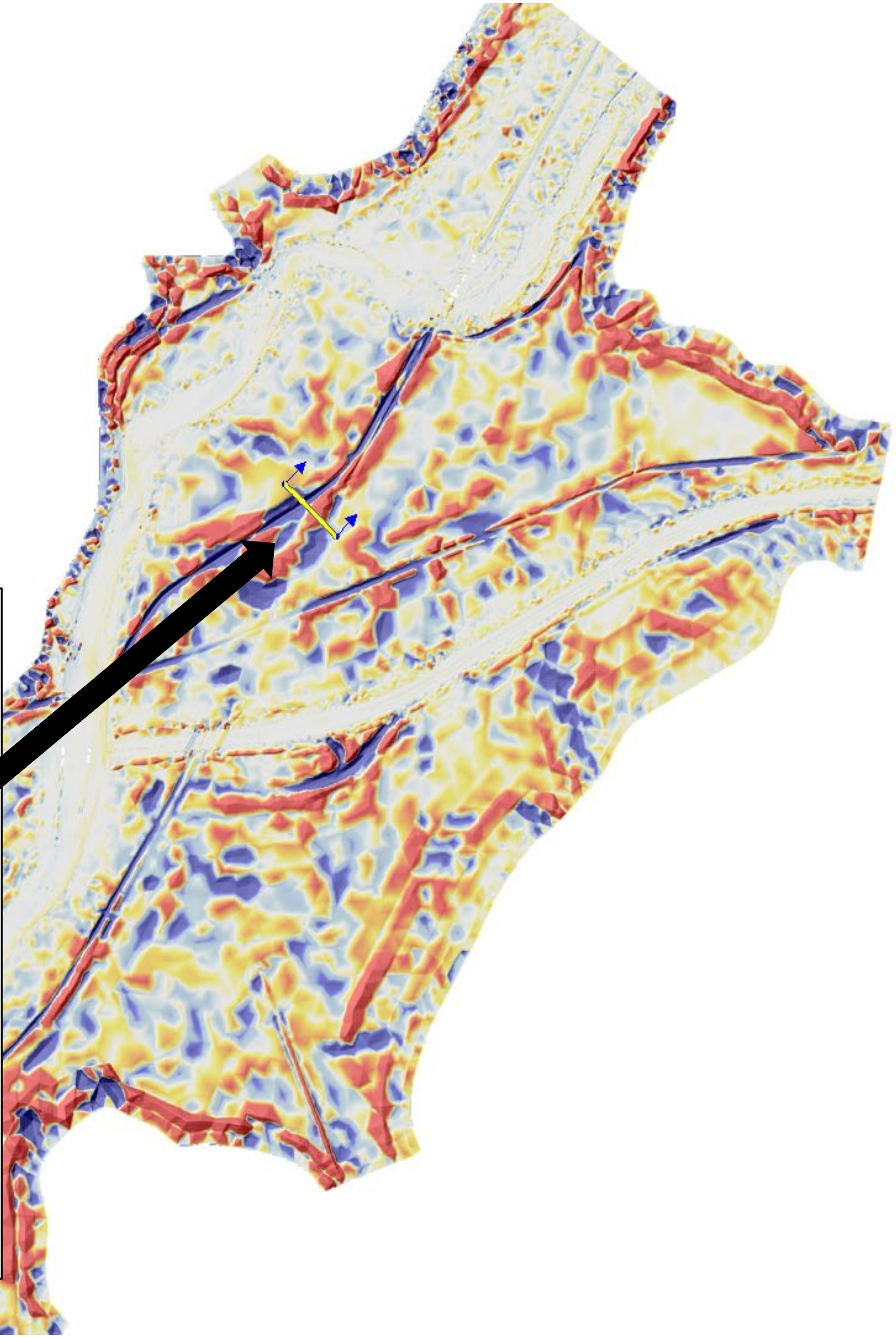
Mesh Elevation Contours

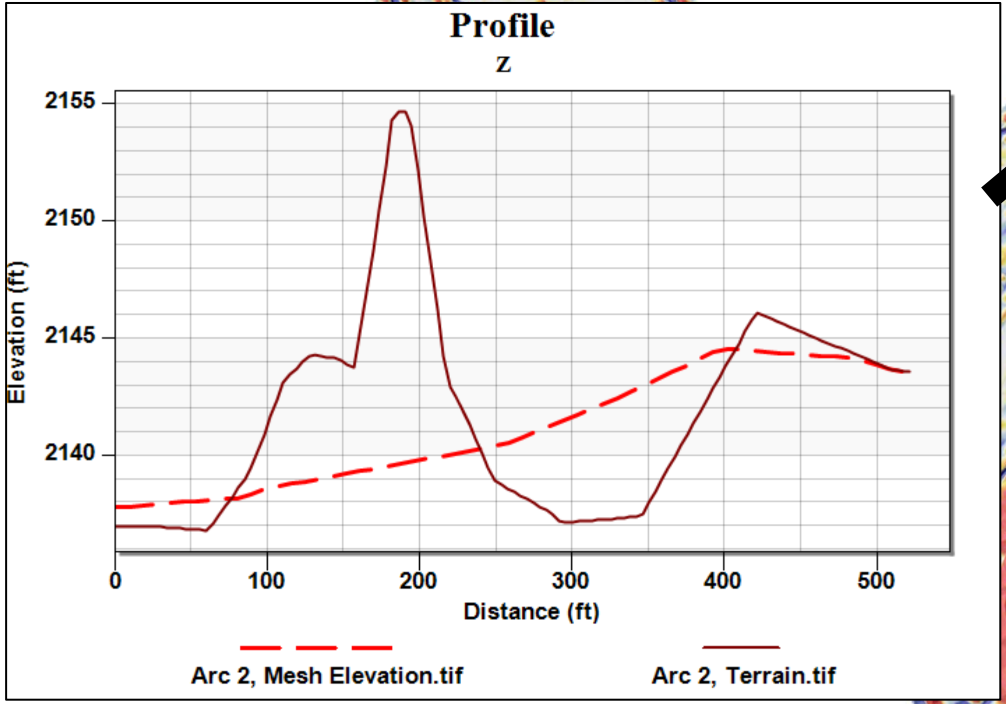


Mesh Quality Review

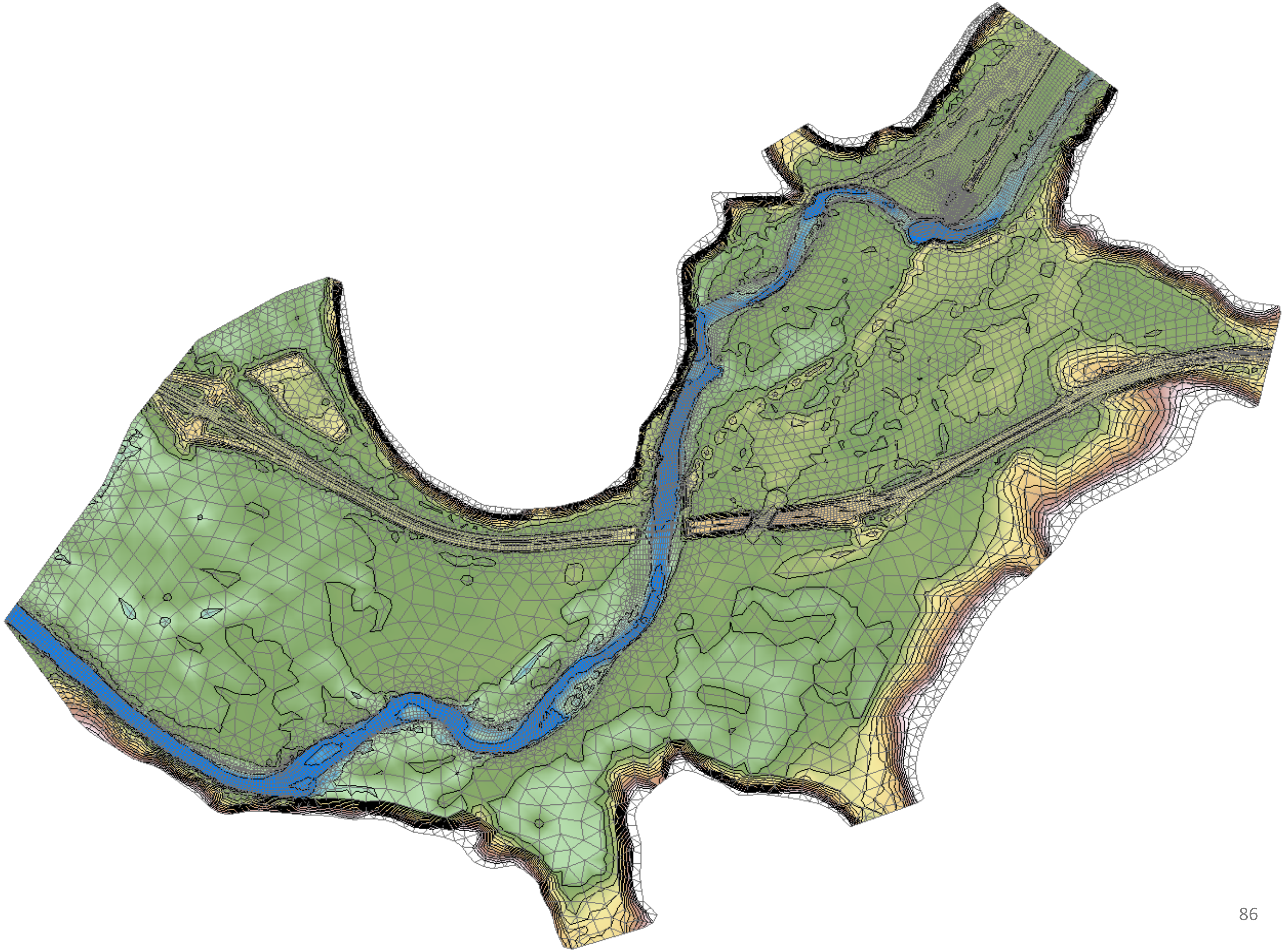


Raster Elevation Difference in SMS

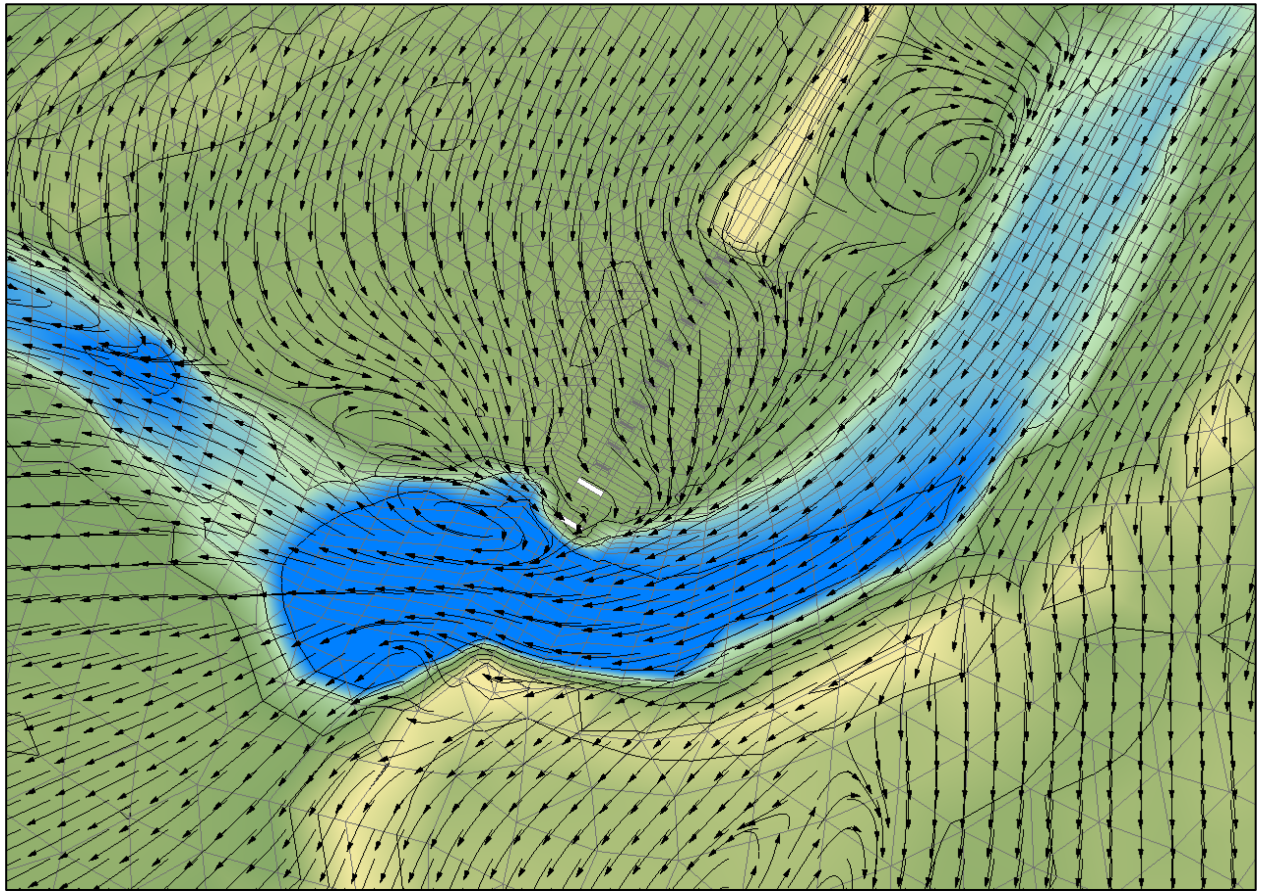


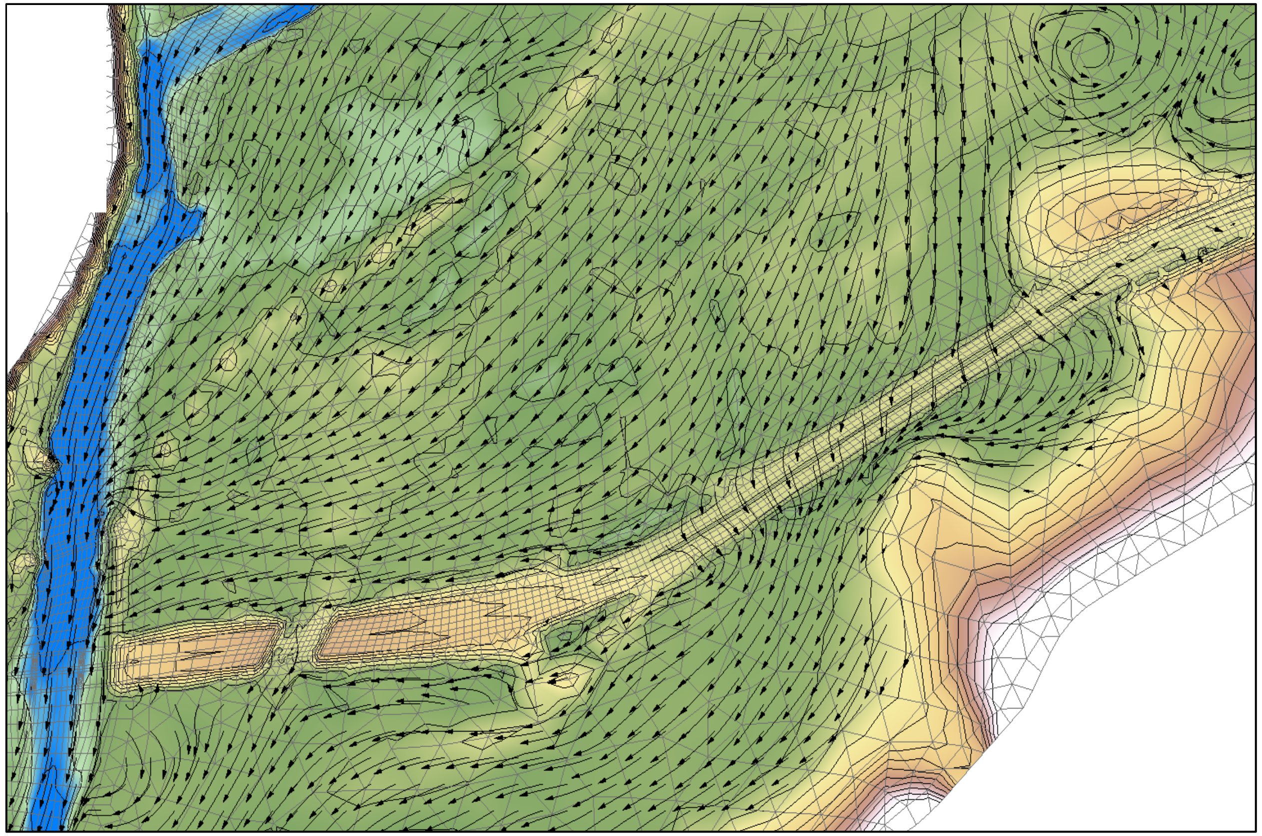


Mesh Element Resolution



Mesh Element Resolution





2D Model Review Training Agenda

Session 2

- *Review Exercise 1*
- **Boundary Conditions**
- Material Roughness
- Hydraulic Structures
- Simulation Parameters
- Assign Exercises 2 & 3

Image from PowerPoint online images by Peter Baumgartner

Reviewing Boundary Conditions Top 3 Things

1. Verify inflow values and locations
2. Check downstream controls
3. Review other boundary conditions (inc. 1D structures)

Boundary Conditions

Source of Flow Information

Key Question:

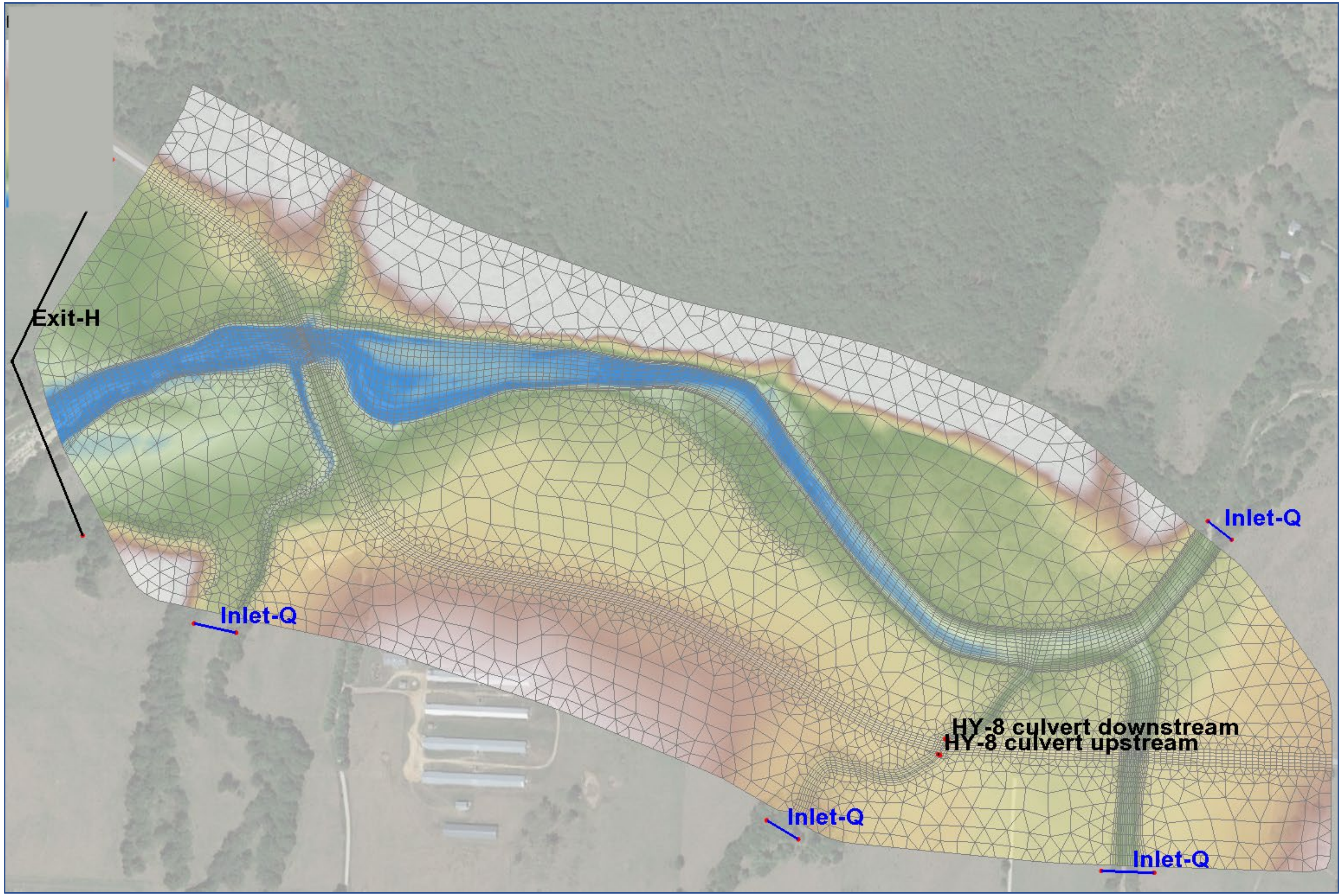
What flow events and scenarios were modeled and what is the source of info?

Q10
Q50
Q100
Q500
Qovertopping

Natural Condition
Existing Condition
Proposed Condition

Boundary Conditions

Types of Boundary Conditions



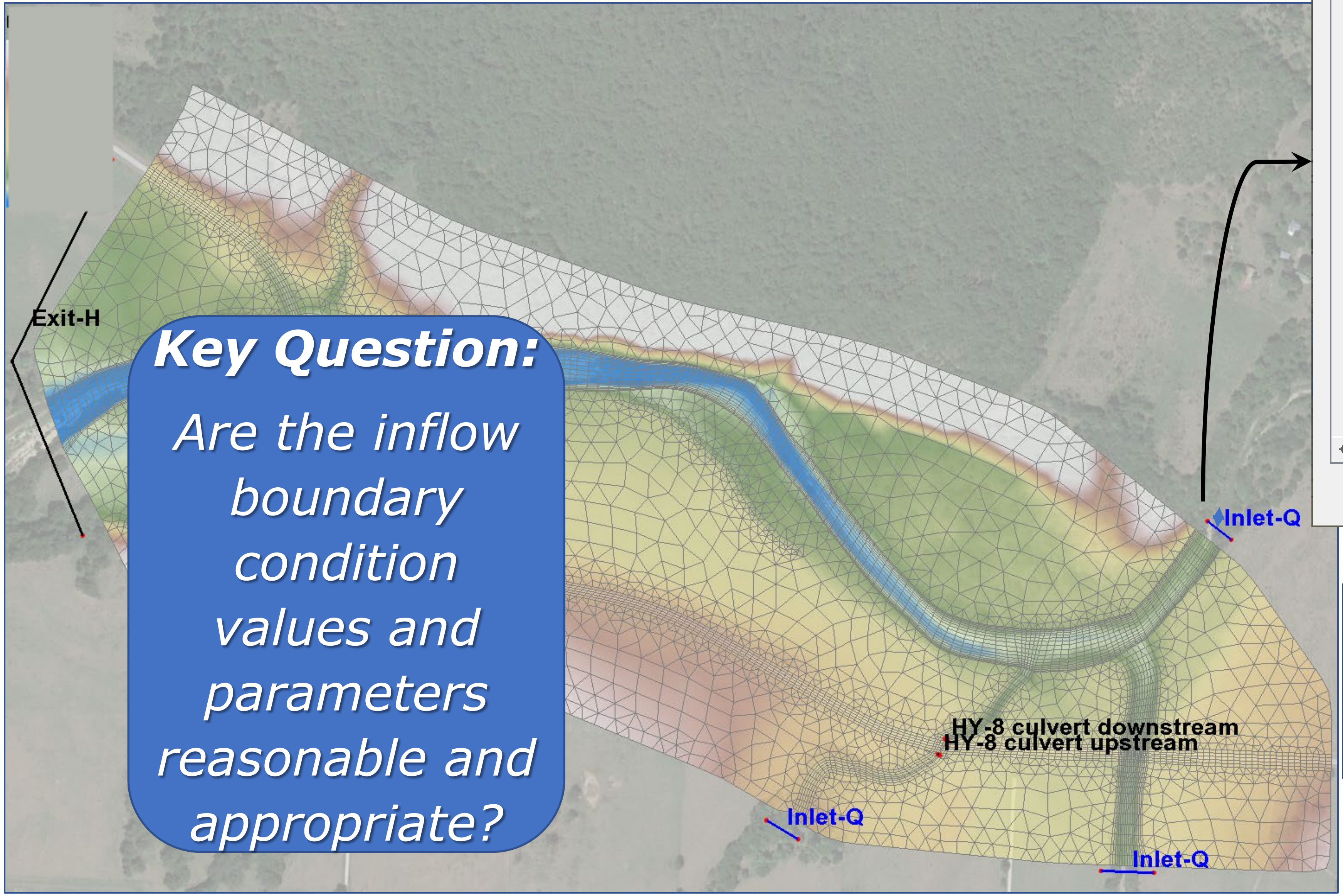
Key Question:

How many boundary conditions and what type?

Boundary arcs should be placed across the maximum floodplain width to be modeled

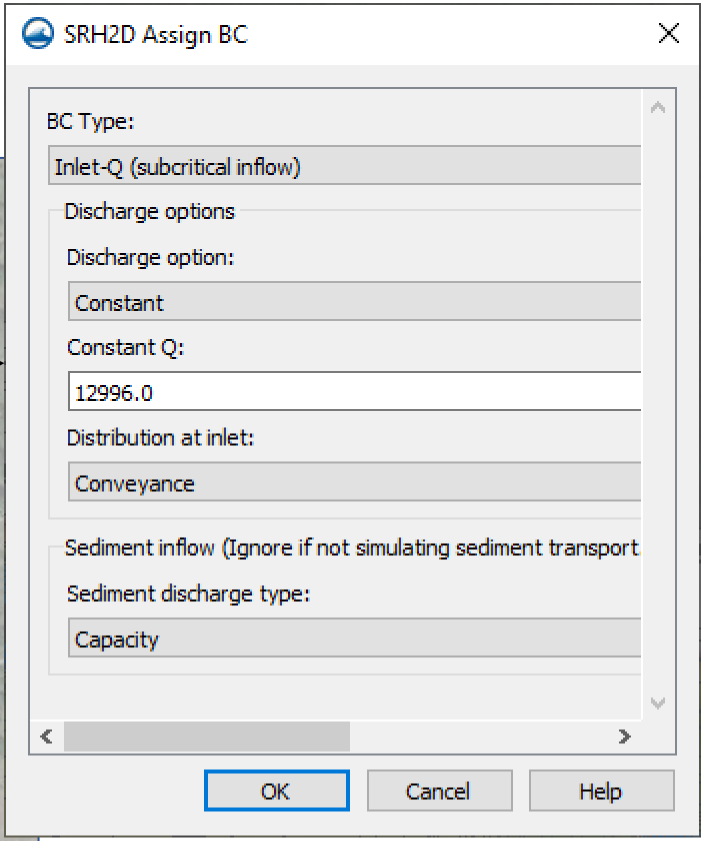
Boundary Conditions

Inflow Boundary Conditions



Key Question:

Are the inflow boundary condition values and parameters reasonable and appropriate?



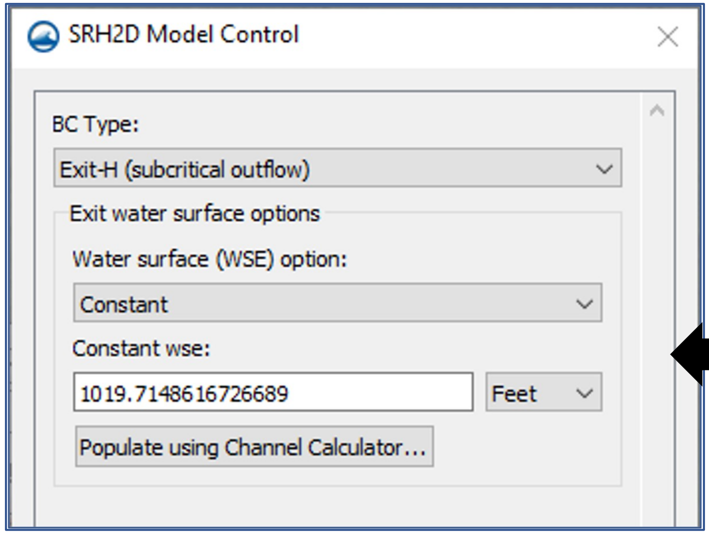
- Constant (steady) or time-series (hydrograph)
- Conveyance distribution is the most common

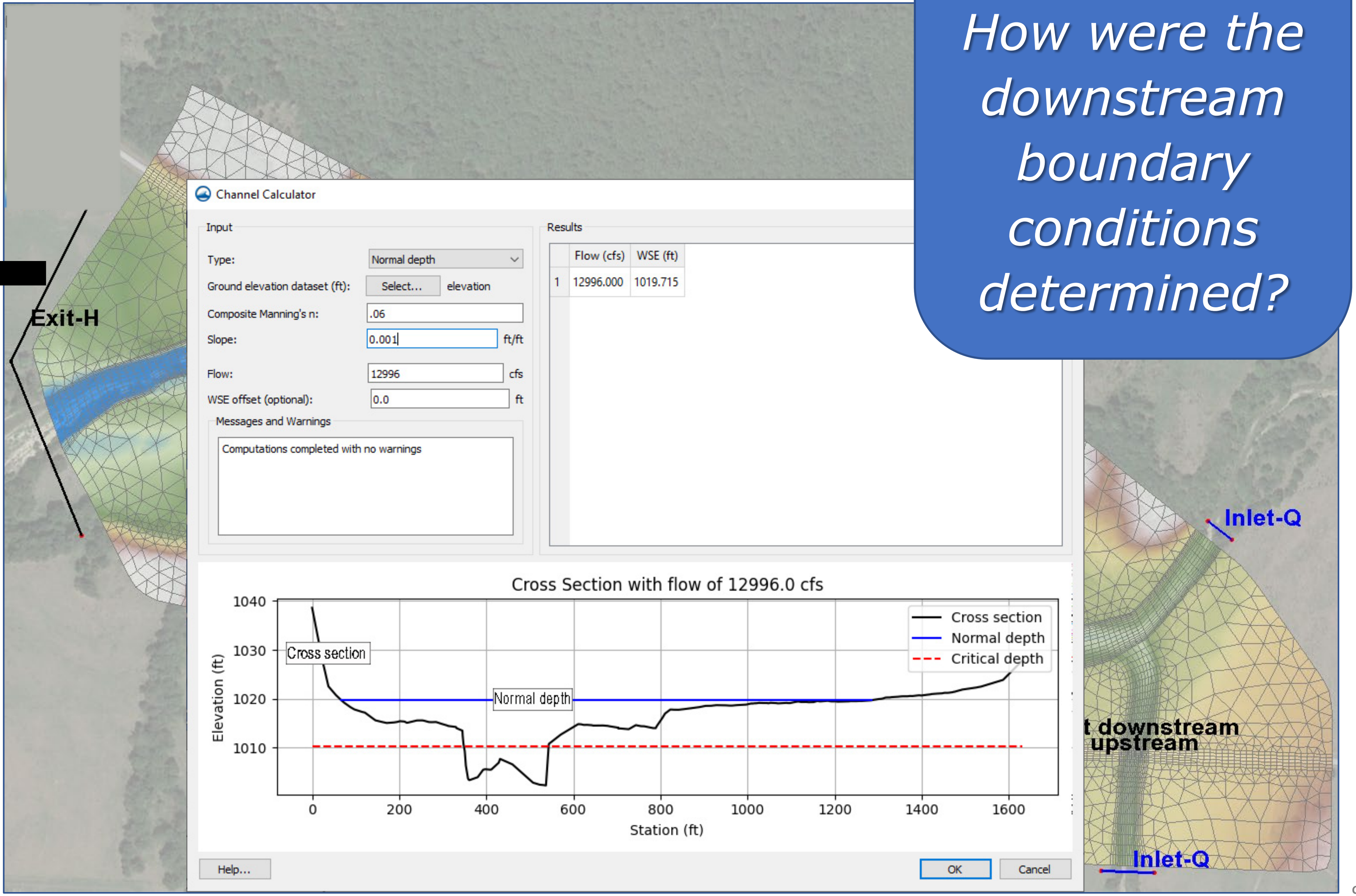
Boundary Conditions

Downstream Boundary Conditions

Key Question:

How were the downstream boundary conditions determined?





Options:

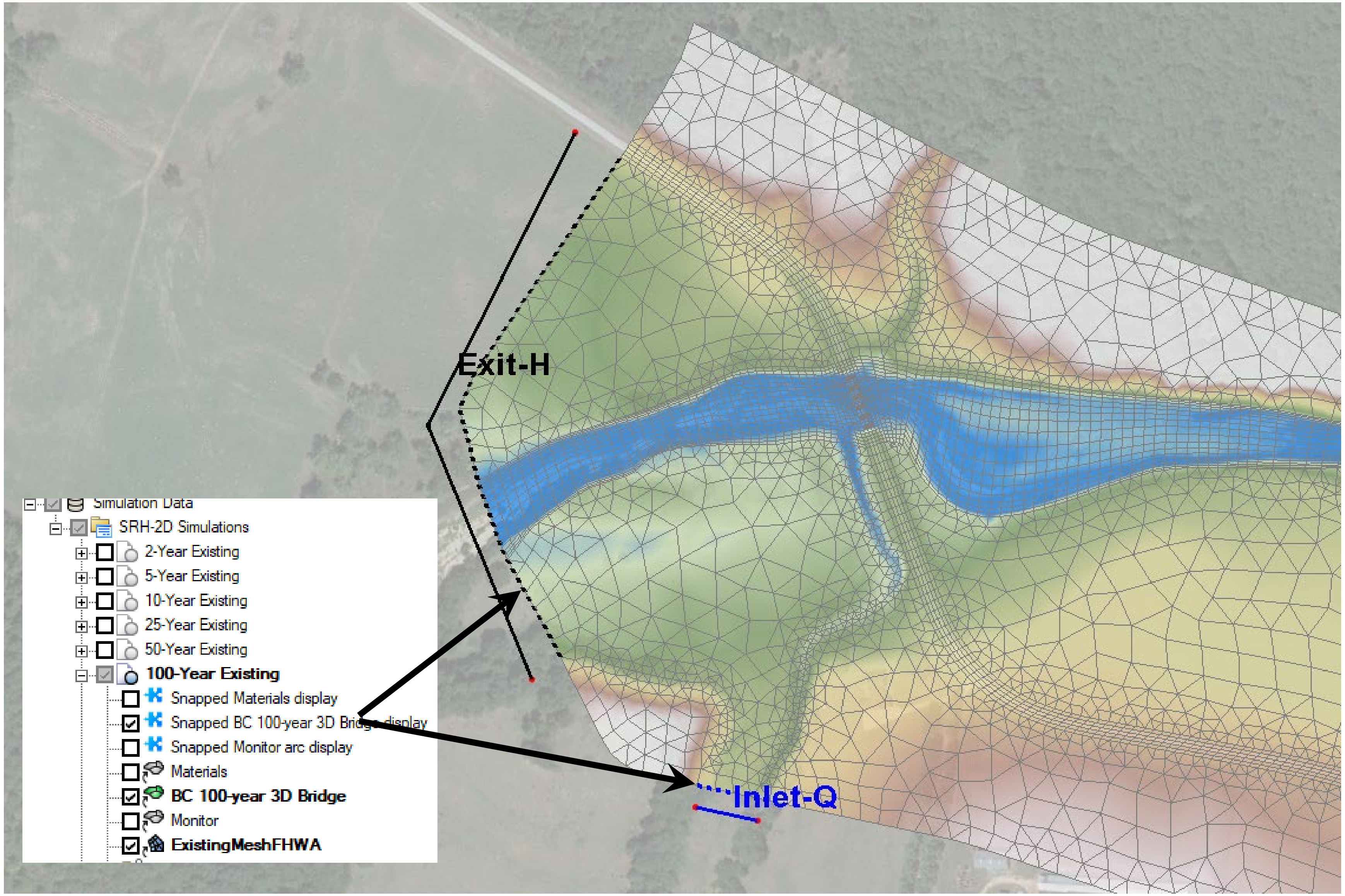
- Constant (steady), time-series (hydrograph), or rating curve
- Normal depth
- Critical depth
- Known WSEL

When using a rating curve, confirm that the curve covers the range of modeled flows

Boundary Conditions

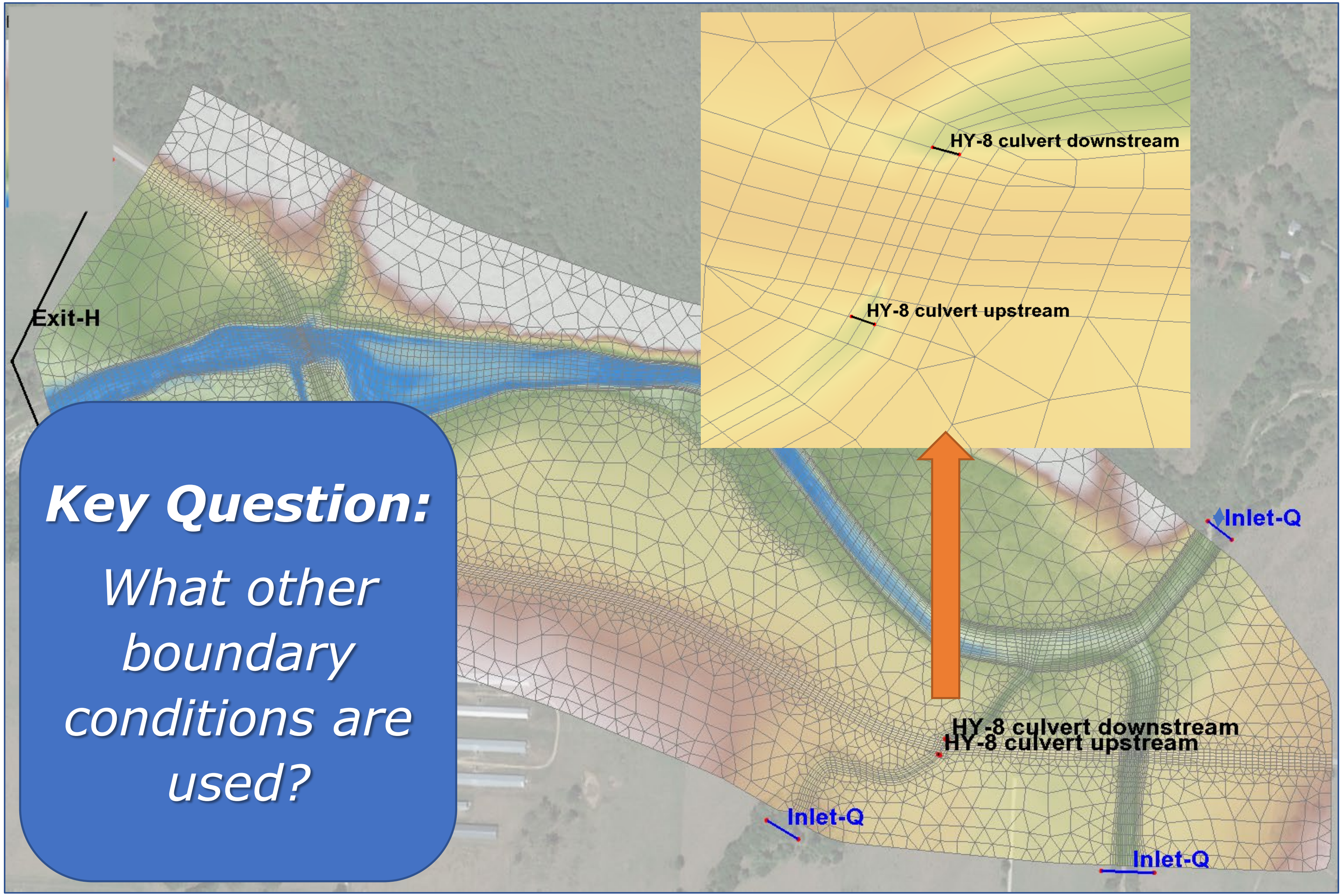
SMS Snap Preview

The SMS Snap Preview feature may be used to review how boundary arcs are mapped to a mesh



Boundary Conditions

1D Boundary Conditions



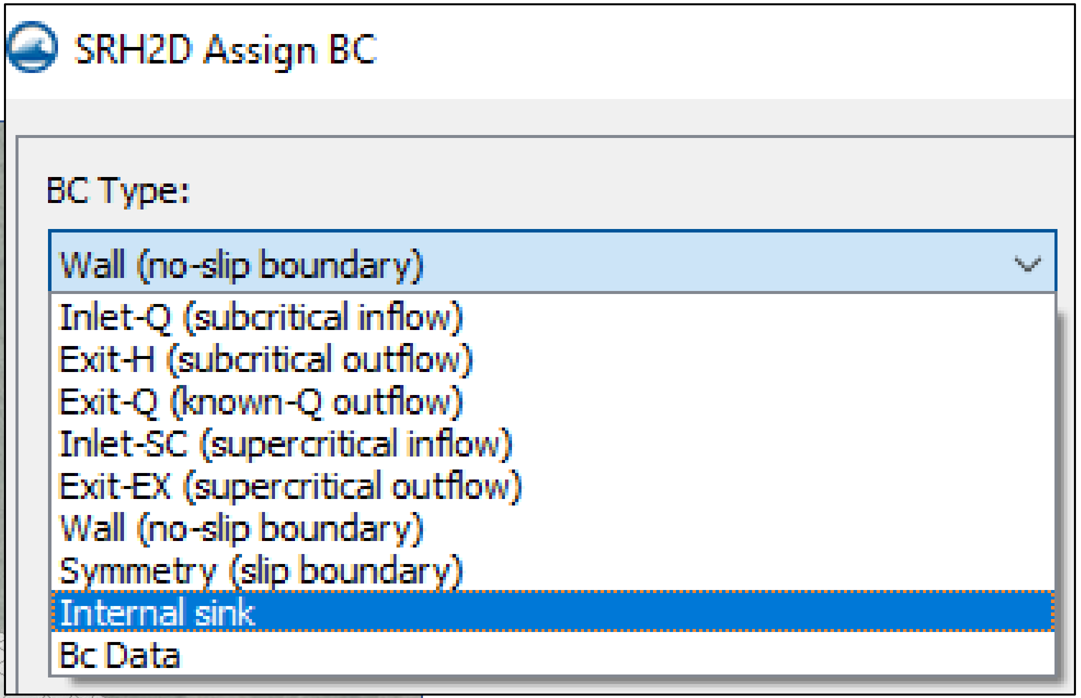
Key Question:

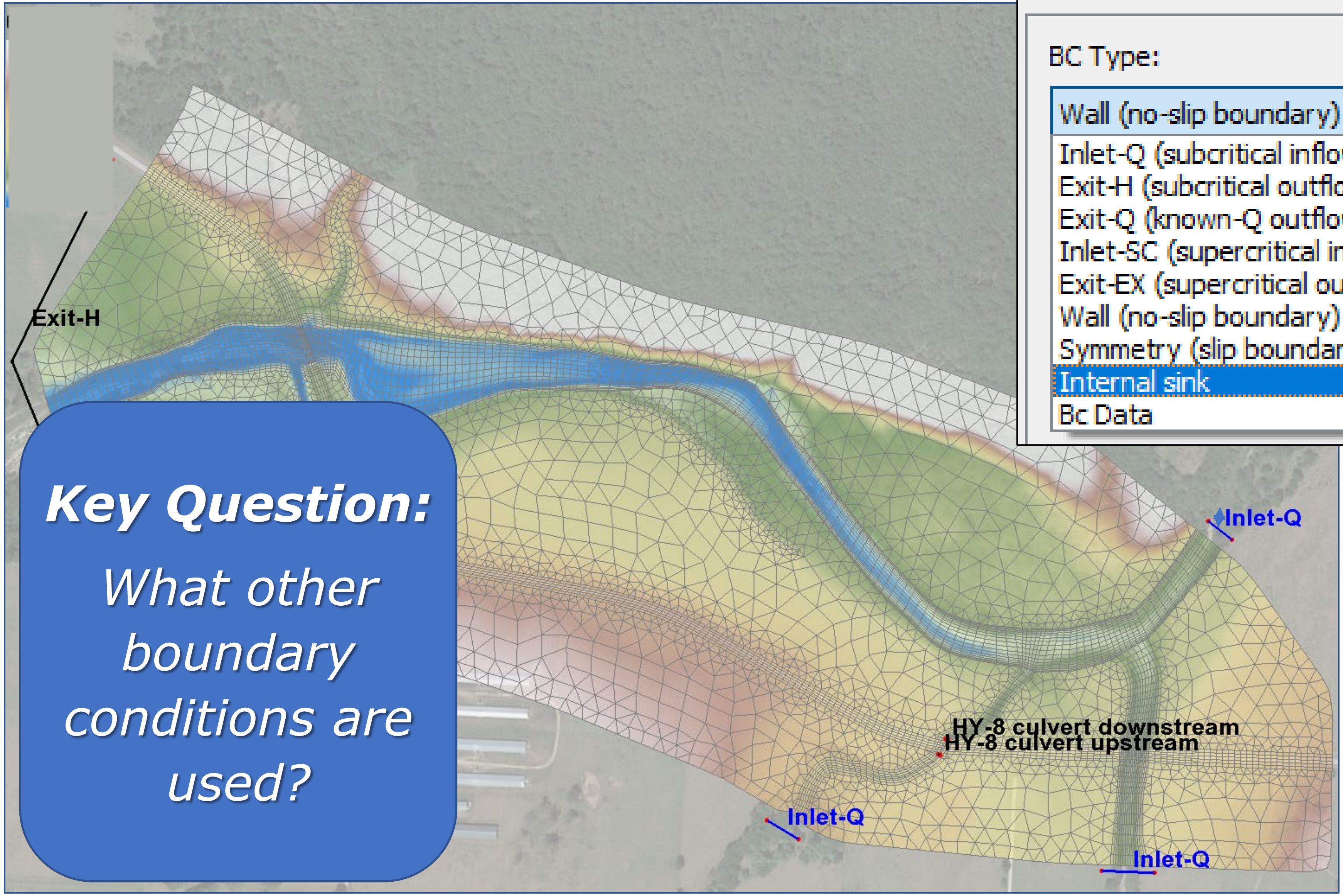
What other boundary conditions are used?

- All 1D structure BCs are represented with two arcs (upstream/downstream)
- Confirm correct up- and downstream BC arc assignments.
- Quadrilateral elements aligned with the structure between the arcs are recommended (link BCs and culverts with 2D overtopping excluded)
- Two or more elements across the width of a 1D structure are recommended

Boundary Conditions

Other Boundary Condition Types





Key Question:

What other boundary conditions are used?

All model domain boundaries are treated as Wall types unless another type is specified

Key Boundary Condition Review Questions

- What flow events were modeled and what is the source of info?
- How many boundary conditions and what type?
- Are the inflow boundary condition values and parameters reasonable and appropriate?
- How were the downstream boundary conditions determined?
- What other boundary conditions are used?

2D Model Review Training Agenda

Session 2

- *Review Exercise 1*
- Boundary Conditions
- **Material Roughness**
- Hydraulic Structures
- Simulation Parameters
- Assign Exercises 2 & 3

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Reviewing Material Roughness Top 3 Things

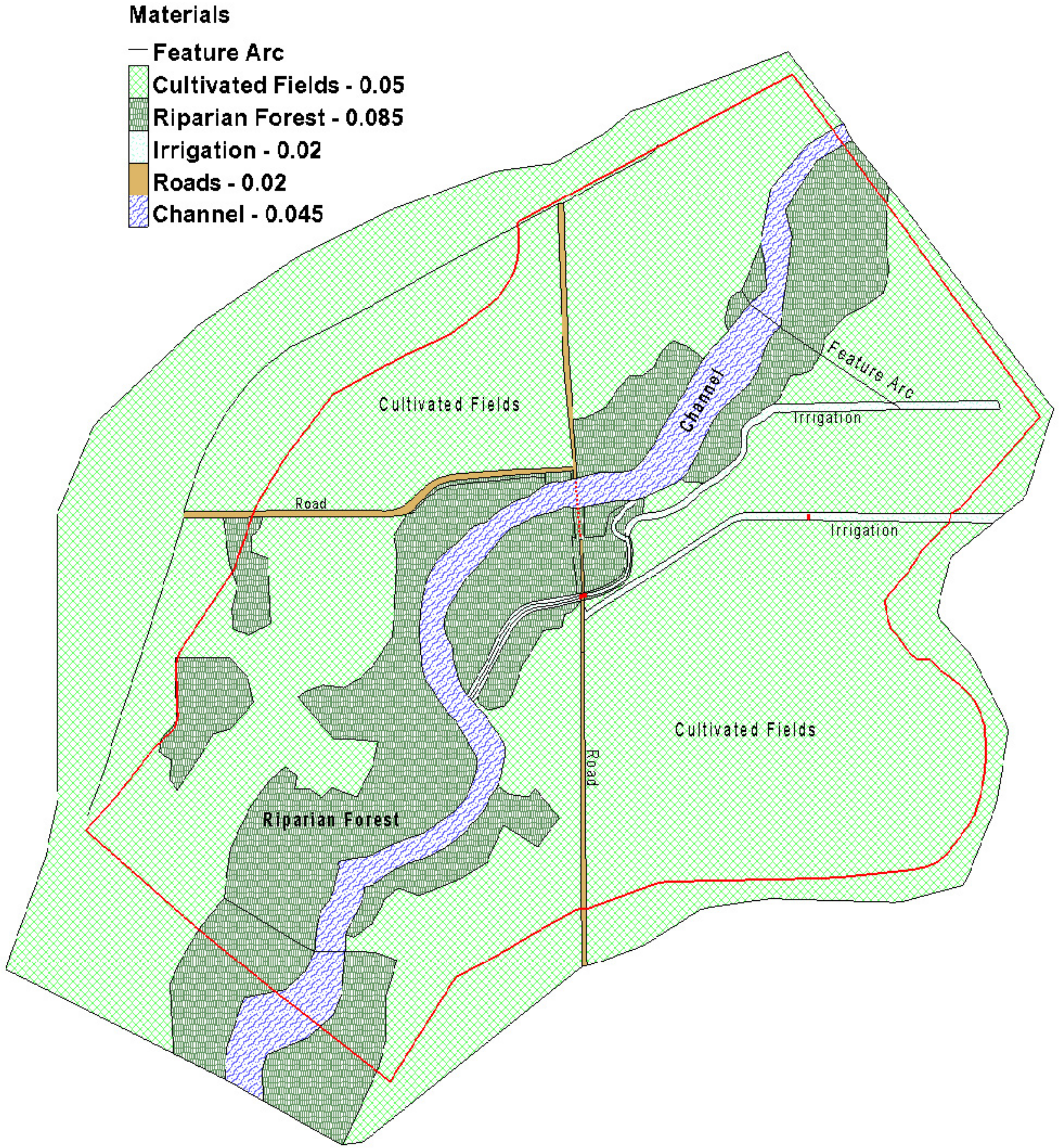
1. Review the number and type of materials
2. Confirm a reasonable range of values were used
3. Look for calibration or sensitivity testing

Material Roughness

Number and Types of Materials Used

Key Question:

Are an appropriate number and type of material types used?



Material Roughness

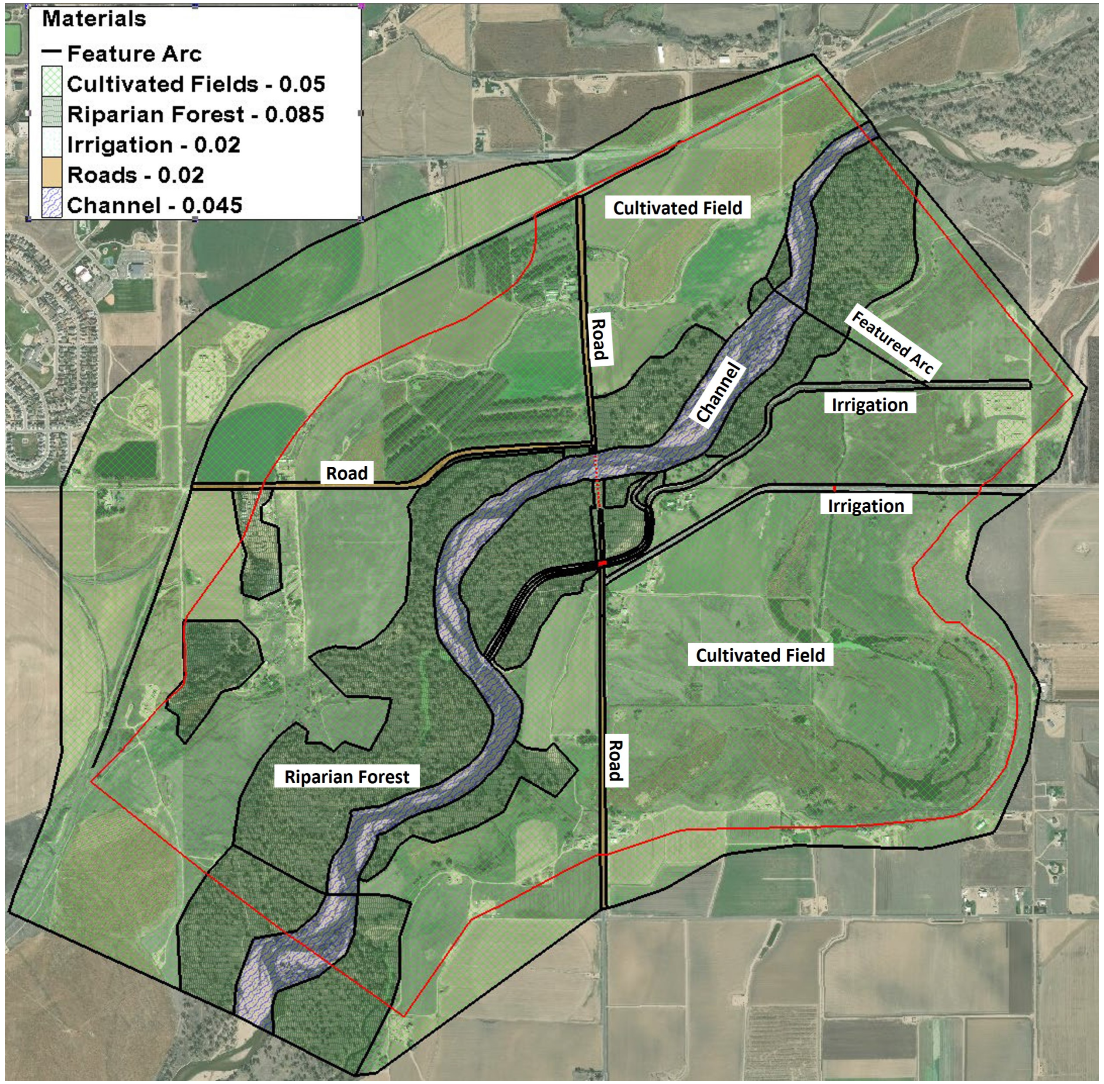
Source of Manning's n values

Key Question:

What was the source of material roughness zones and values?

The most common sources of material roughness delineation are 1) digitized from and aerial image, or 2) extracted from a GIS land use file.

Was a field visit conducted?



Material Roughness

Number and Types of Materials Used

Key Question:

Are the roughness values within reasonable ranges?

Manning's n for Channels (Chow, 1959).

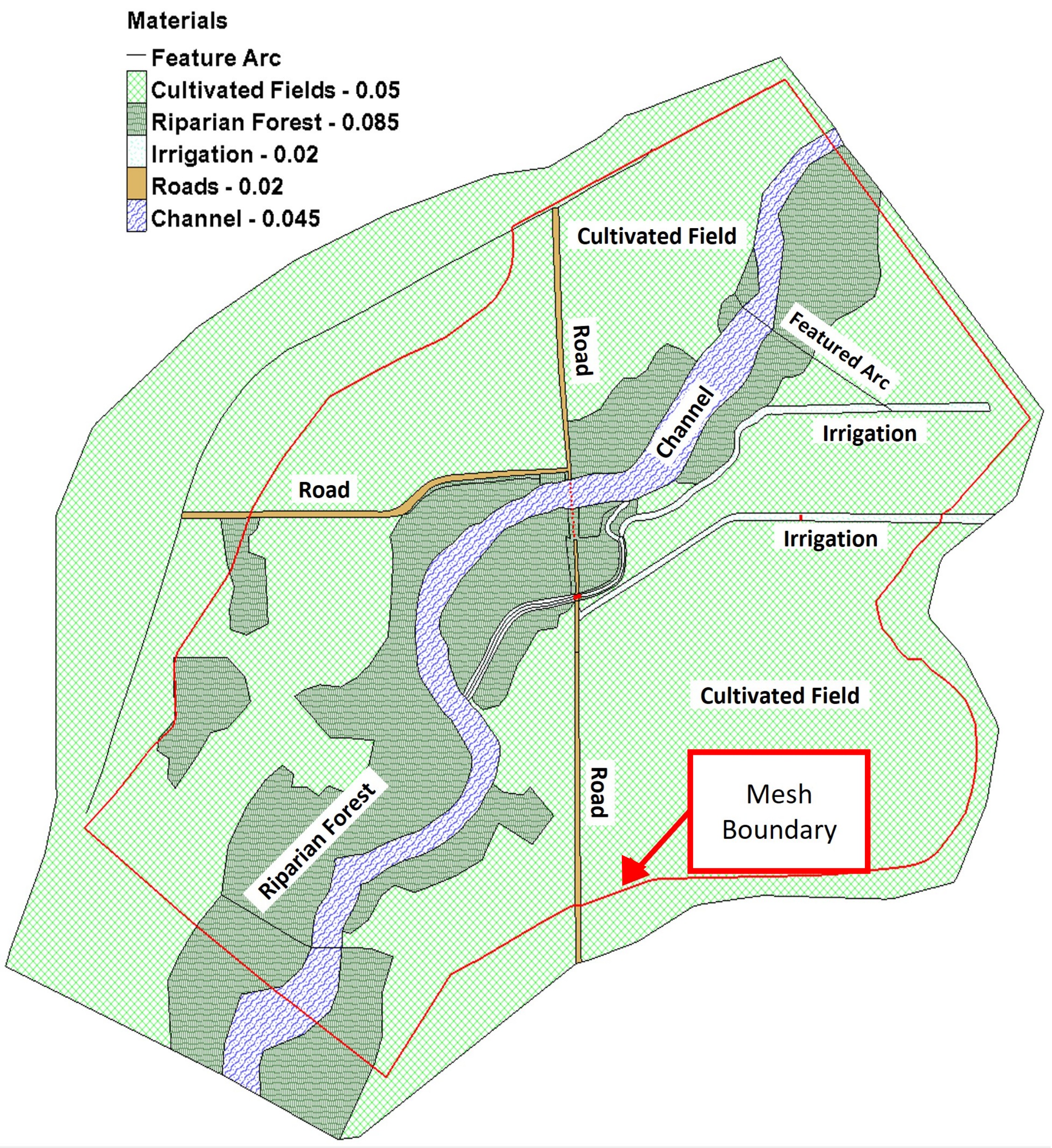
Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110
5. medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. dense willows, summer, straight	0.110	0.150	0.200
2. cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. same as 4. with flood stage reaching branches	0.100	0.120	0.160

Material Roughness

Manning's Roughness Values

Key Question:

Do the material limits cover the extents of the mesh?

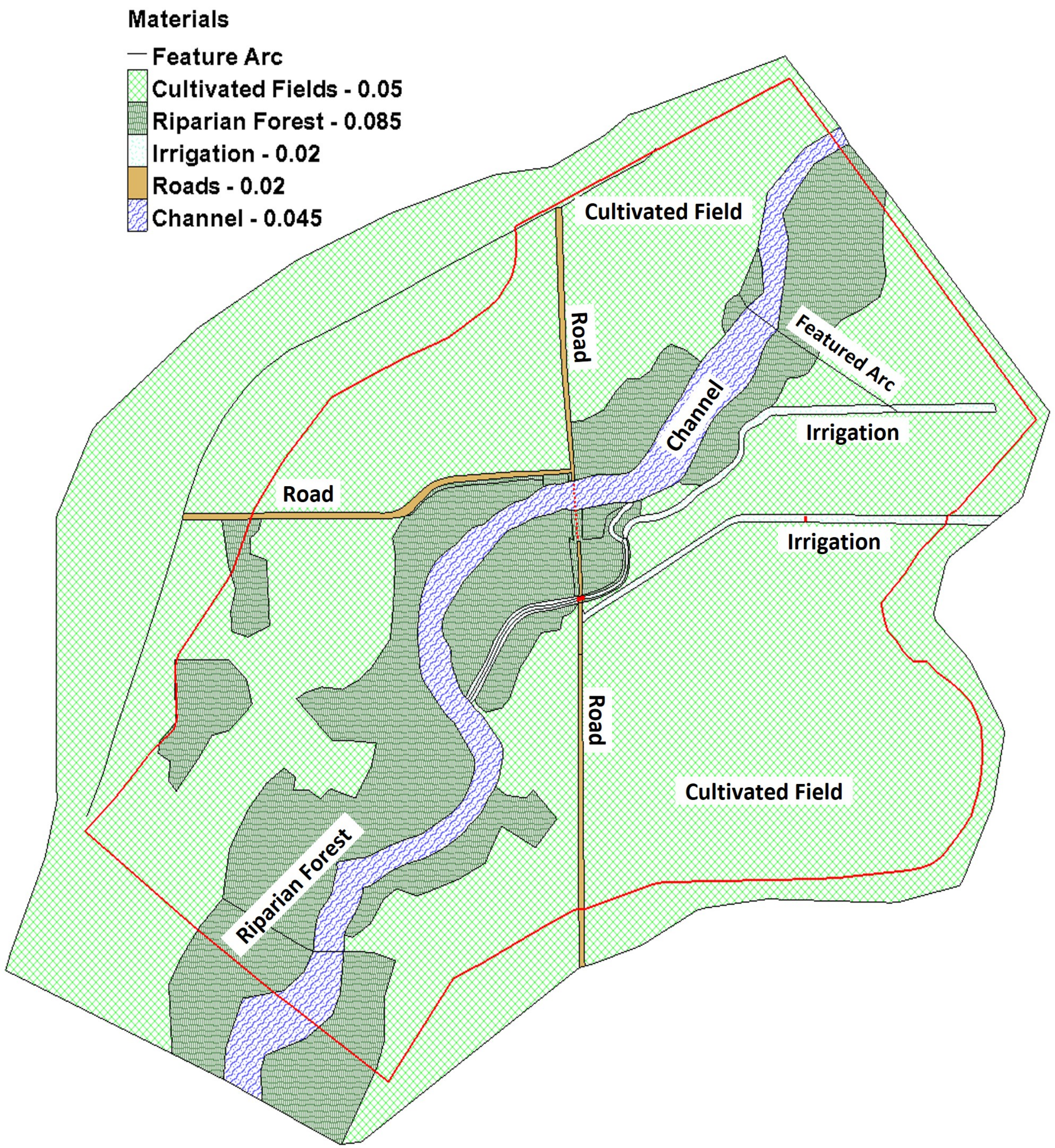


Material Roughness

Manning’s Roughness Values

Key Question:

Are the roughness values assigned correctly?

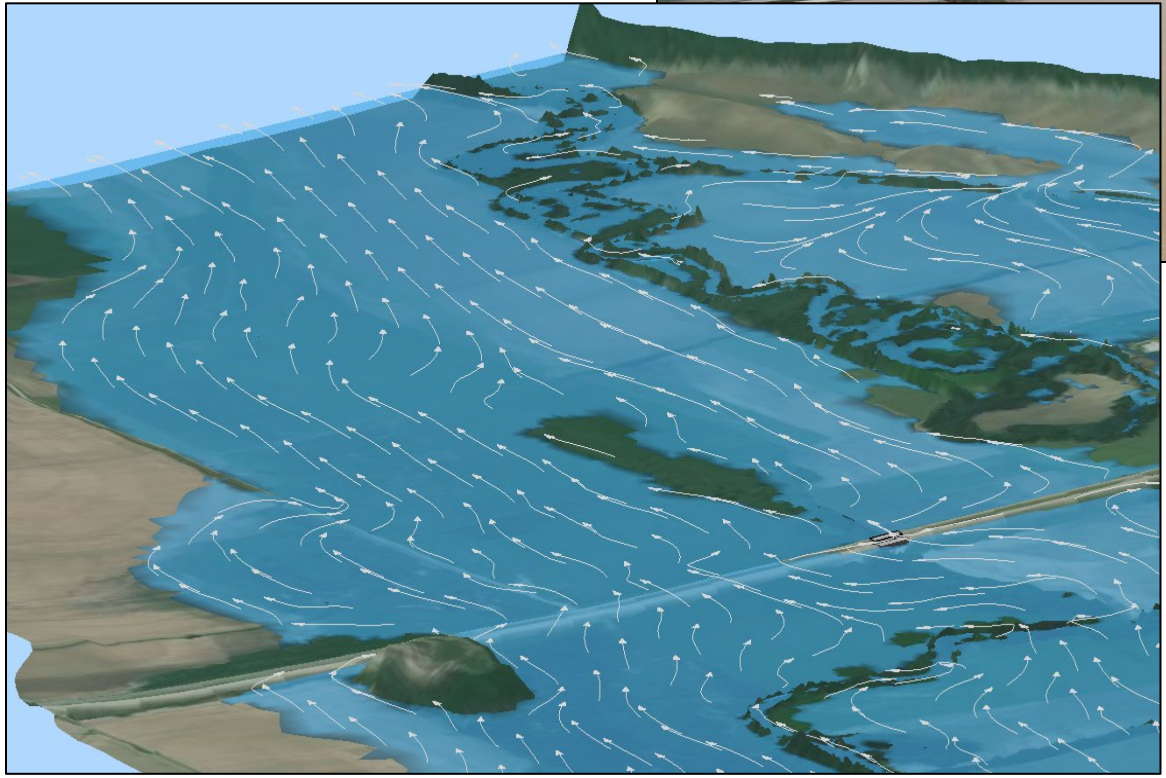


Material Roughness

Calibration and Sensitivity Analyses

Key Question:

Were the Manning's n values calibrated or verified with a measured event?

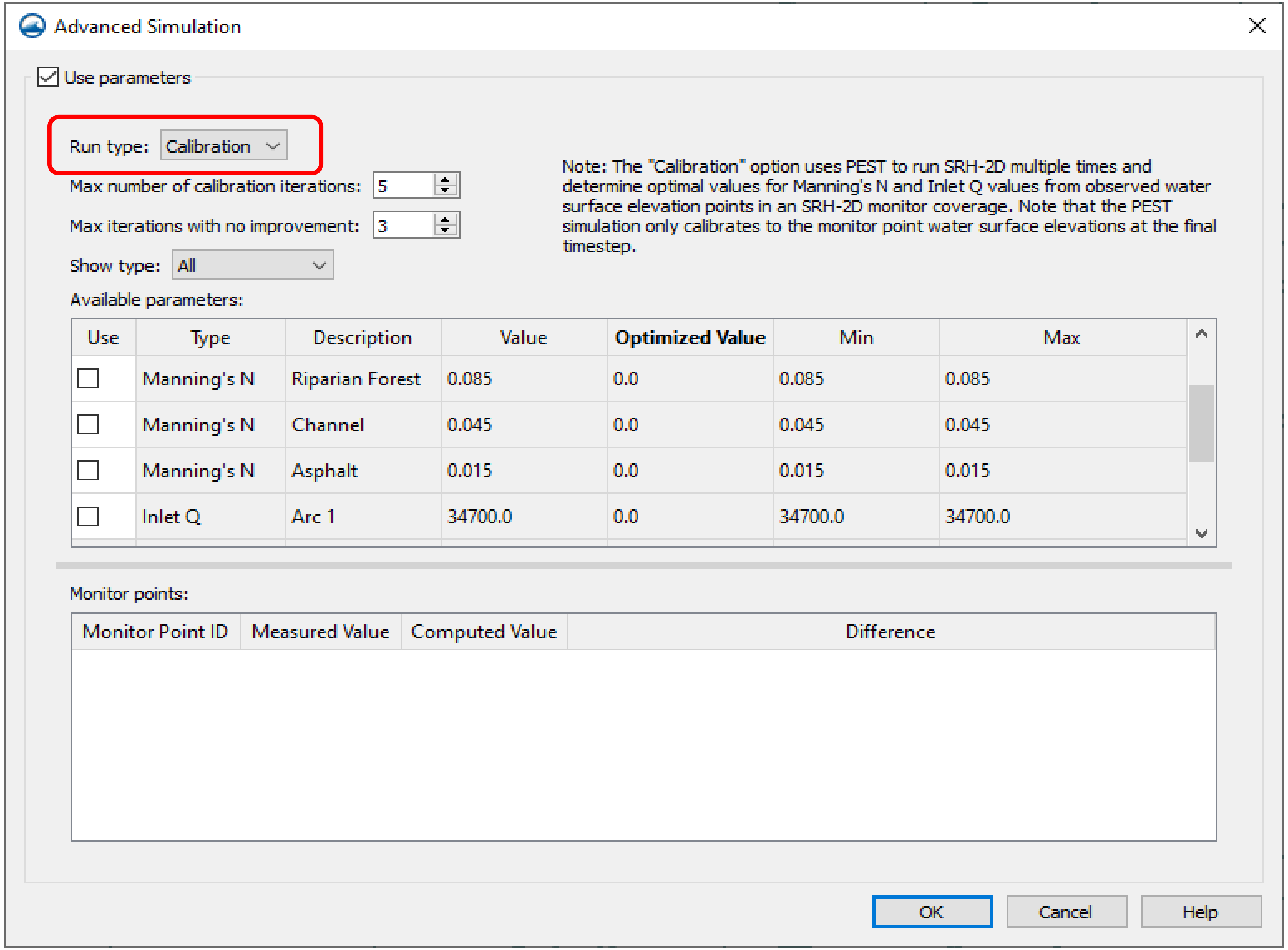


- Gage data
- High water marks
- Aerial imagery of flood
- Anecdotal reports of flooding / overtopping

Material Roughness

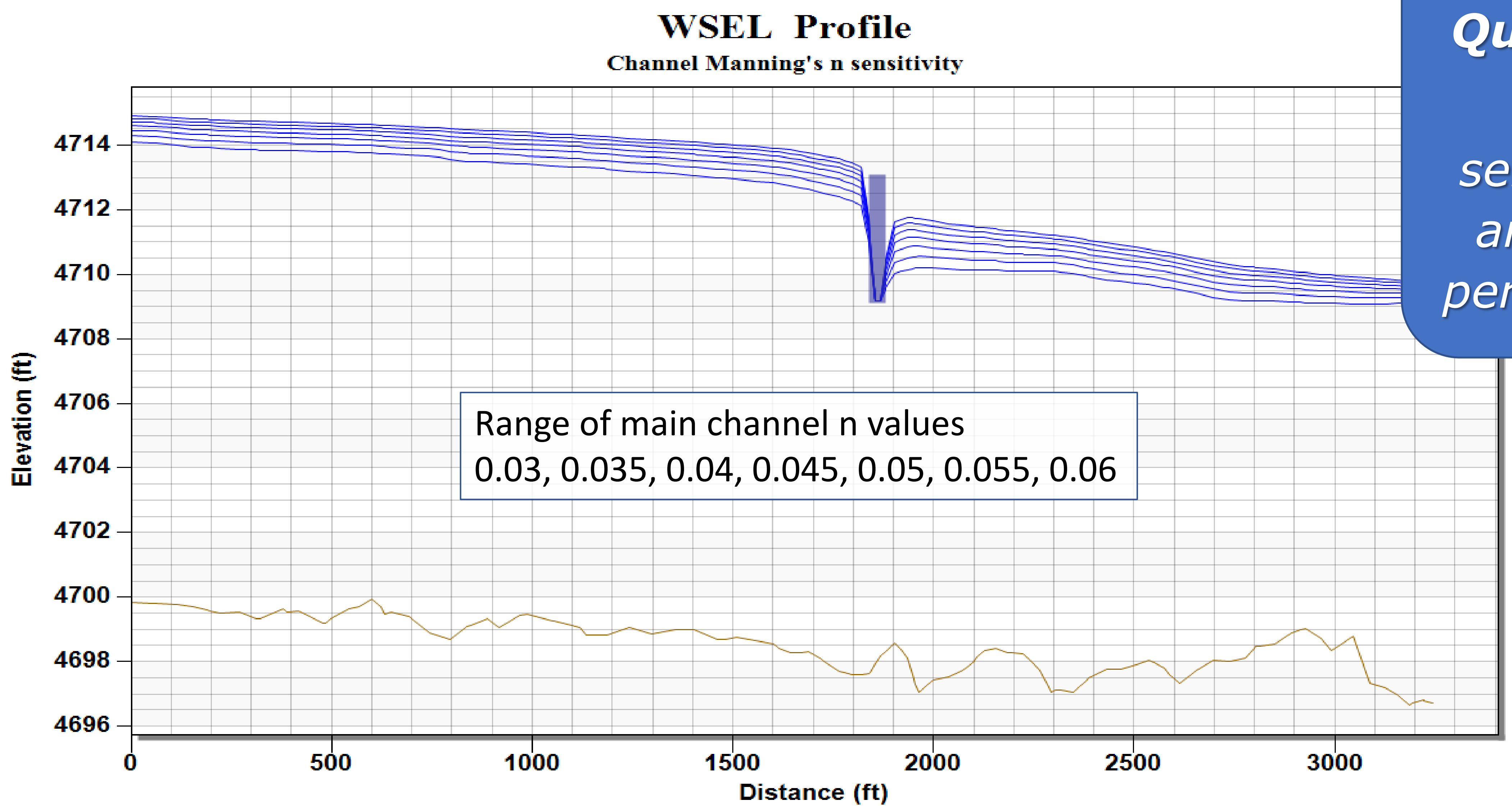
Calibration Tools

SMS/SRH-2D Calibration Tool can calibrate multiple Manning’s n values for measured WSELs and discharge



Material Roughness

Sensitivity Analyses



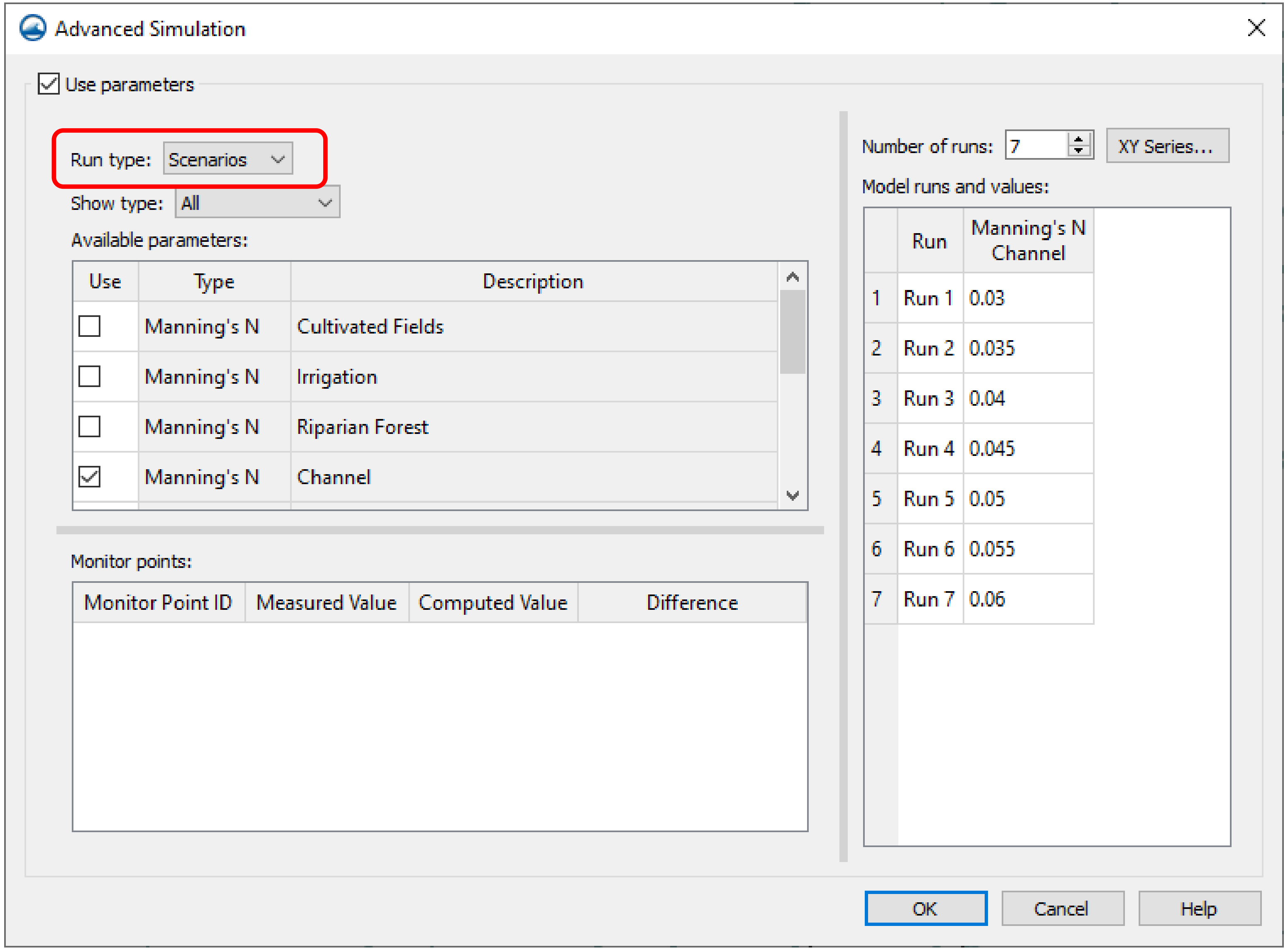
Key Question:

Was sensitivity analyses performed?

Material Roughness

Sensitivity Analyses

SMS/SRH-2D Advanced Simulation Tool can run several concurrent simulations with a range of values to assess sensitivity



Key Material Roughness Review Questions

- Are an appropriate number and type of material types used?
- How were the roughness values determined?
- Are the roughness values within reasonable ranges?
- Do the material limits cover the extents of the mesh?
- Are the roughness values assigned correctly?
- Were any calibration or sensitivity analyses performed?

10 Minutes

2D Model Review Training Agenda

Session 2

- *Review Exercise 1*
- Boundary Conditions
- Material Roughness
- **Hydraulic Structures**
- Simulation Parameters
- Assign Exercises 2 & 3

Image from PowerPoint online images by Peter Baumgartner

Reviewing Hydraulic Structures Top 3 Things

1. Verify elevations and extents
2. Assess mesh resolution at each structure
3. Check pressure flow and overtopping parameters

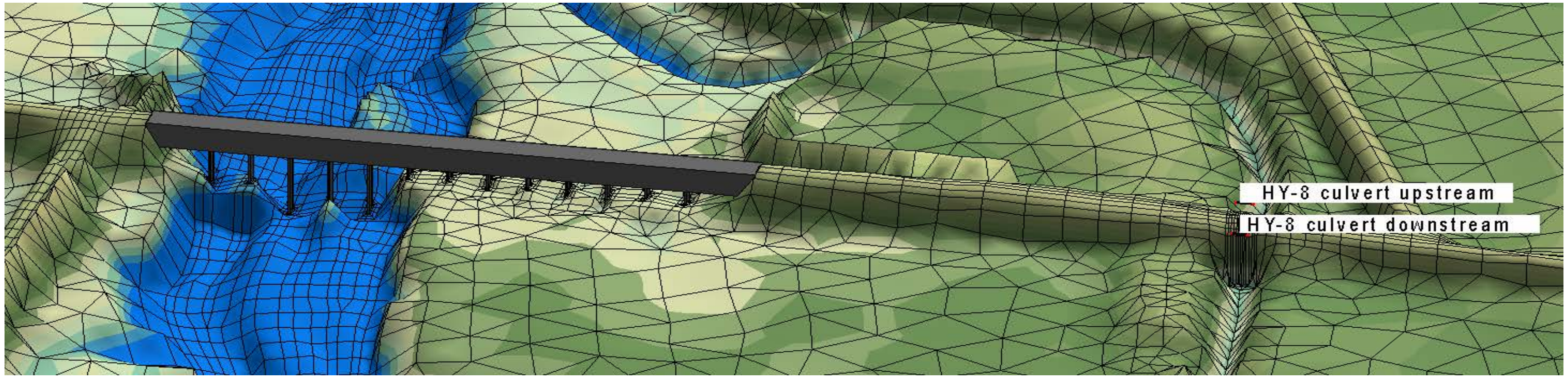
Hydraulic Structures

Structure Summary

Key Question:

How many and what type of structures are represented?

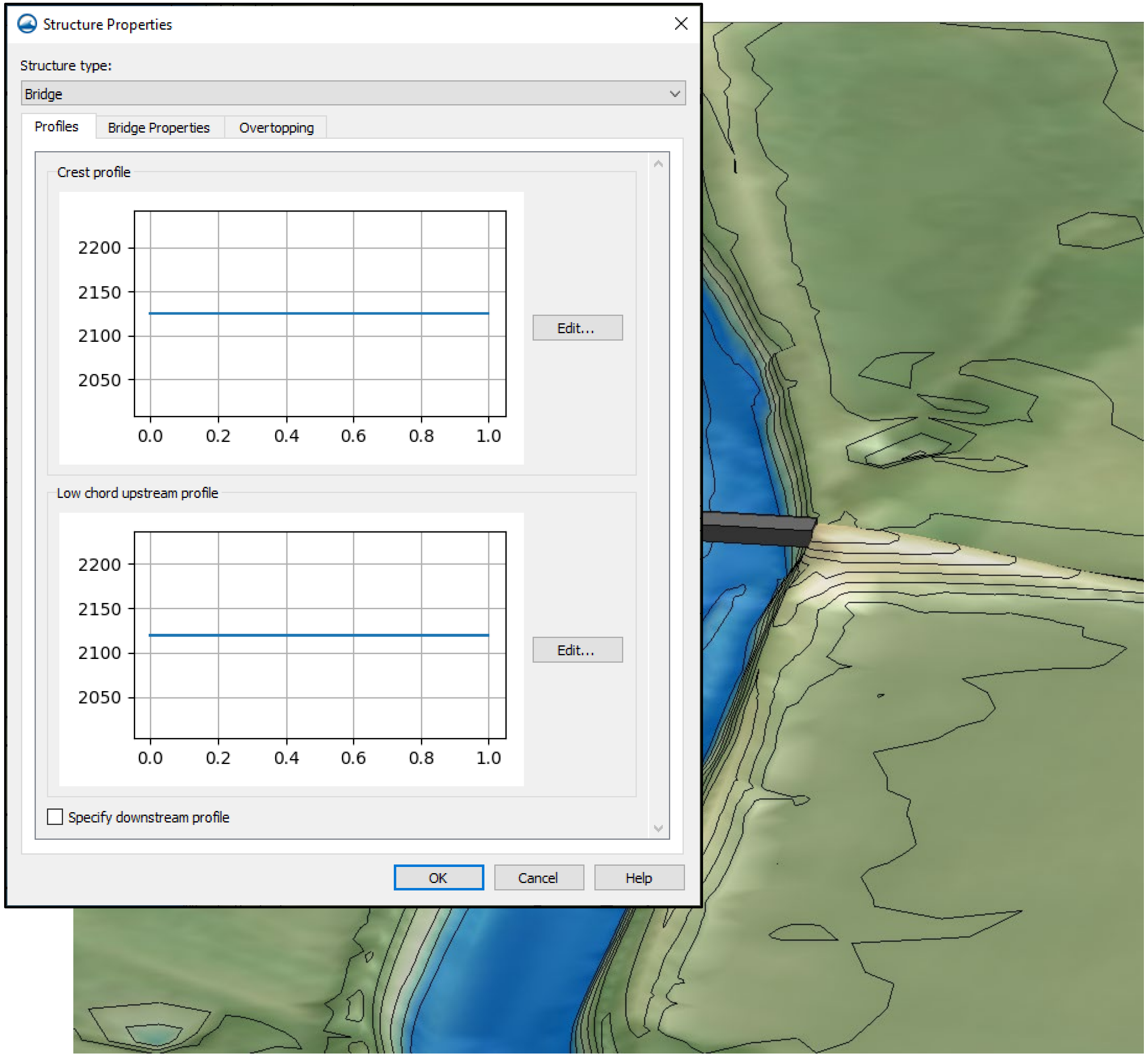
Structure ID / Name	1D or 2D	Type	Dimensions	# of Piers or # of barrels	Elevations
Main Bridge	2D	14-Span	45'W x 775'L	13 piers 2.5' x 20'	Crest 4713.1' Low Chord 4709.1'
Box Culvert	1D	3 RCBC	8'x8'x80'	3 barrels	US 4704.0' DS 4703.5' Crest 4713.0'
Circular Culvert	2D	CMP	7'	1 barrel	US 4701.5' DS 4700.0' Crest 4709.0'



Hydraulic Structures

3D Structures (Bridges and Culverts)

- Crest profile (bridge deck crown or parapet) defines deck overtopping elevation
- Low chord profile defines the pressure flow ceiling
- Overtopping should only be selected if flow is likely to overtop the bridge deck (affects computation time)
- Overtopping of the approach embankments is evaluated in the 2D computations



Hydraulic Structures

3D Structures (Bridges and Culverts)

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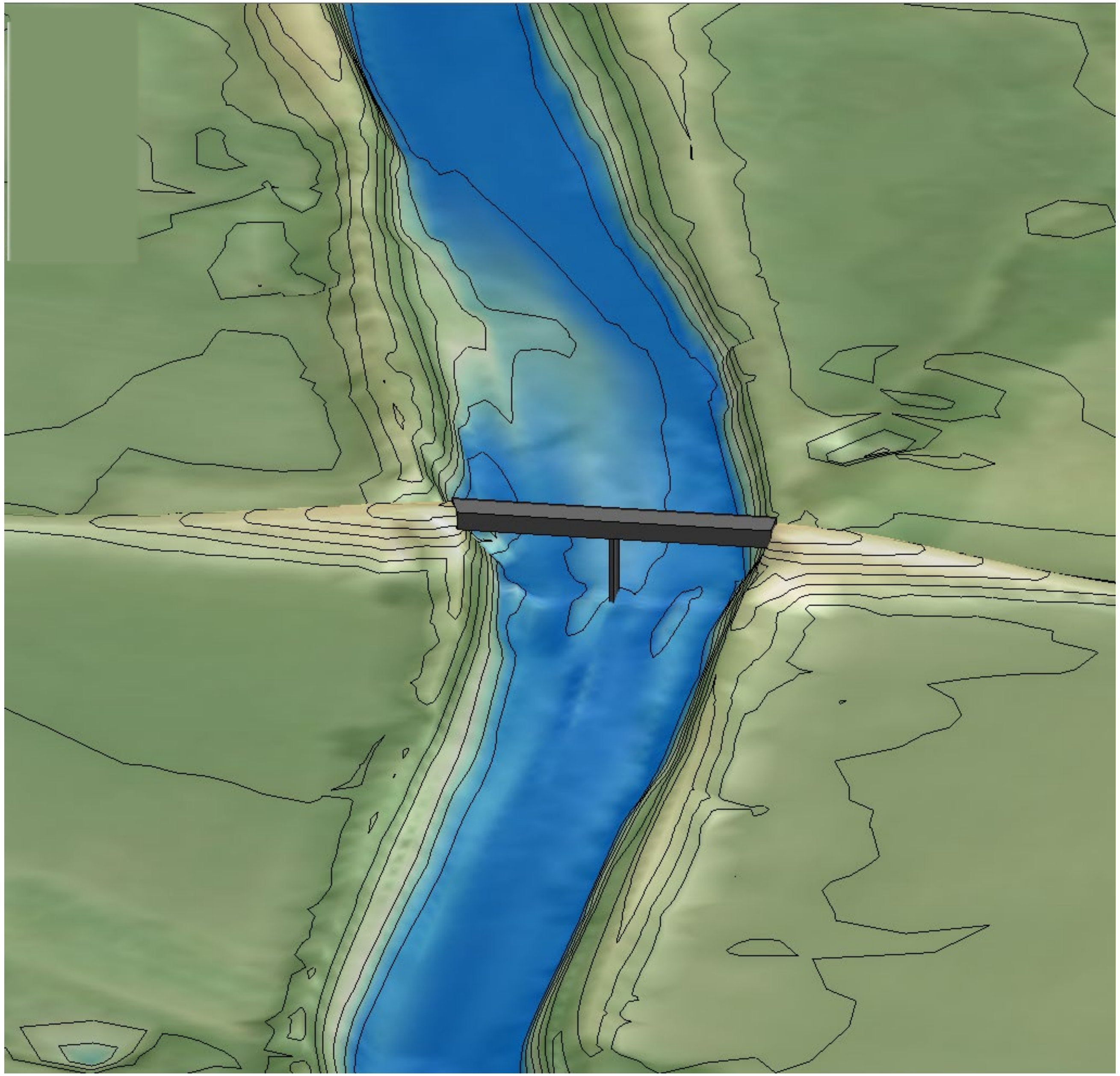


Hydraulic Structures

Structure Extents and Elevations

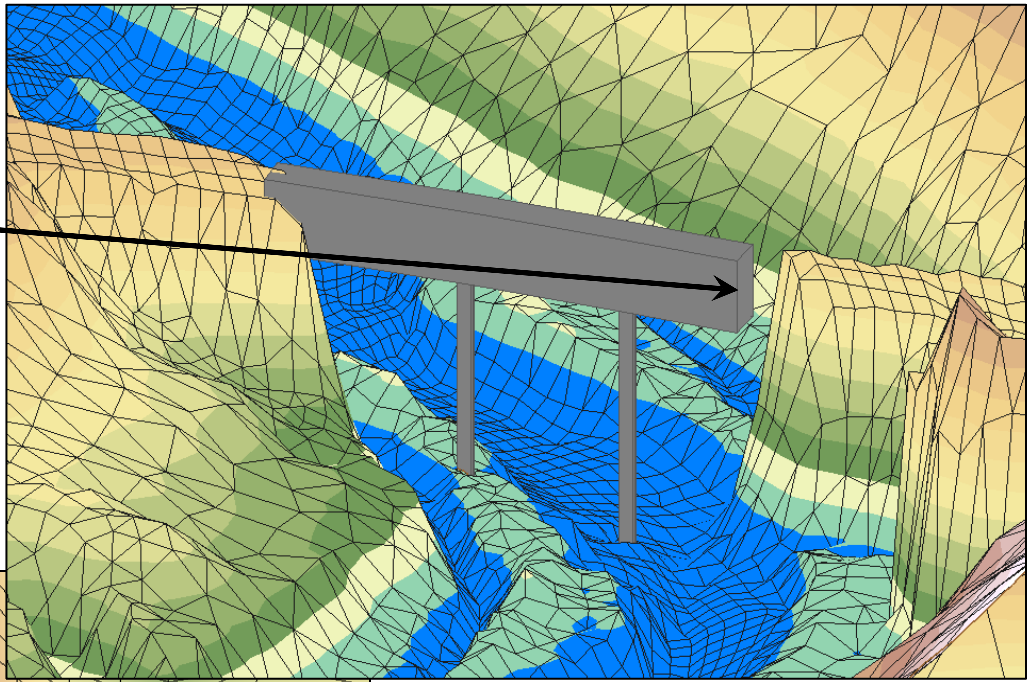
Key Question:

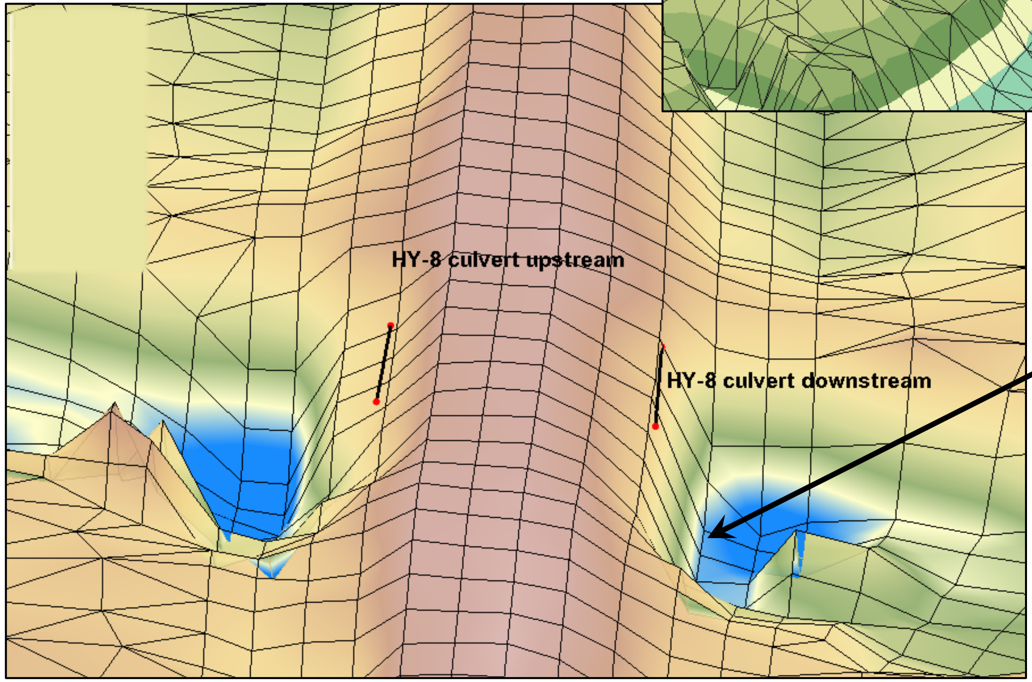
Do the structures align vertically and horizontally with the mesh?

Review 3D structure geometry and surrounding mesh

Review 1D structure elevations and mesh around BC arcs

3D Structures should extend into the terrain

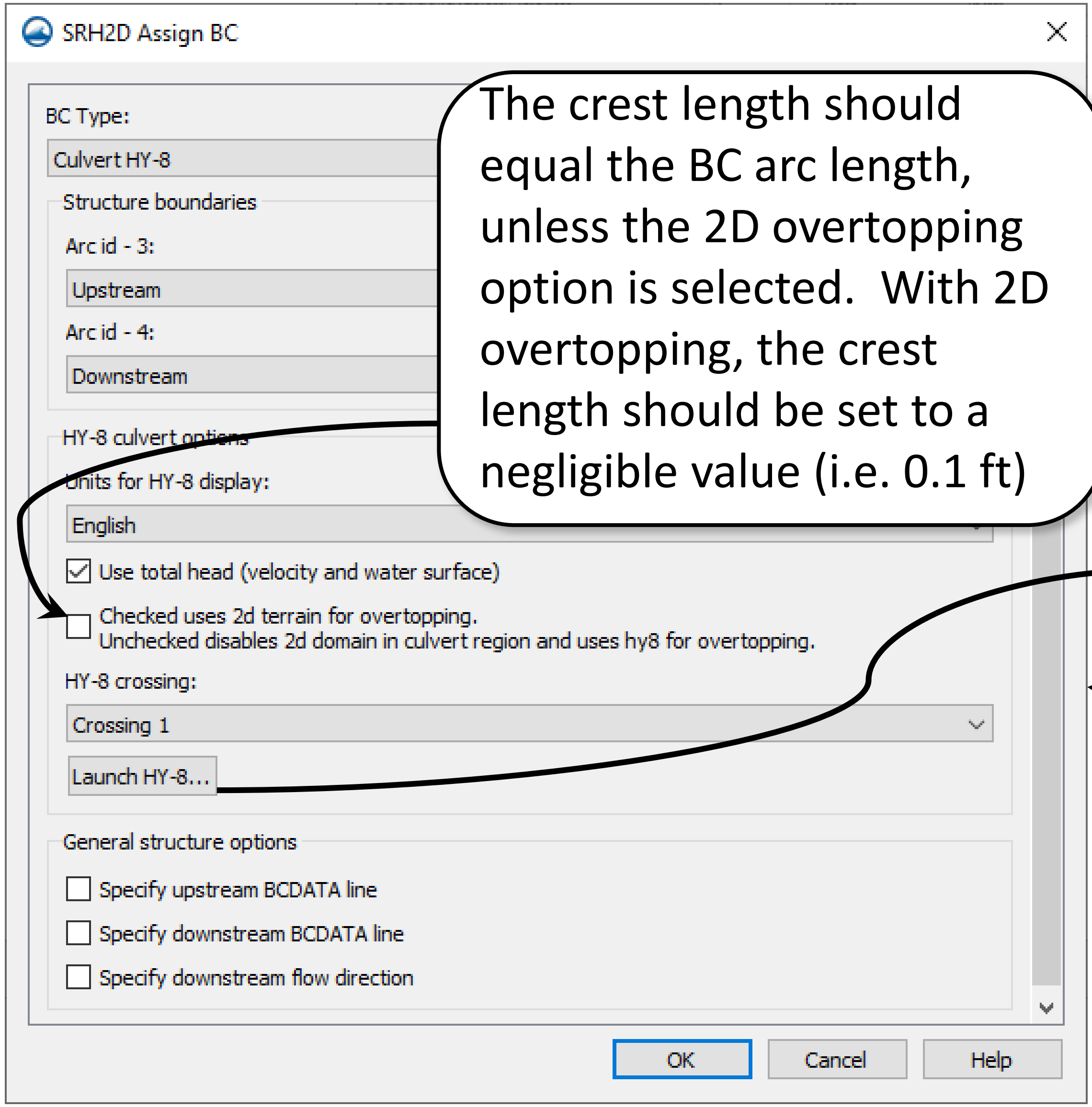




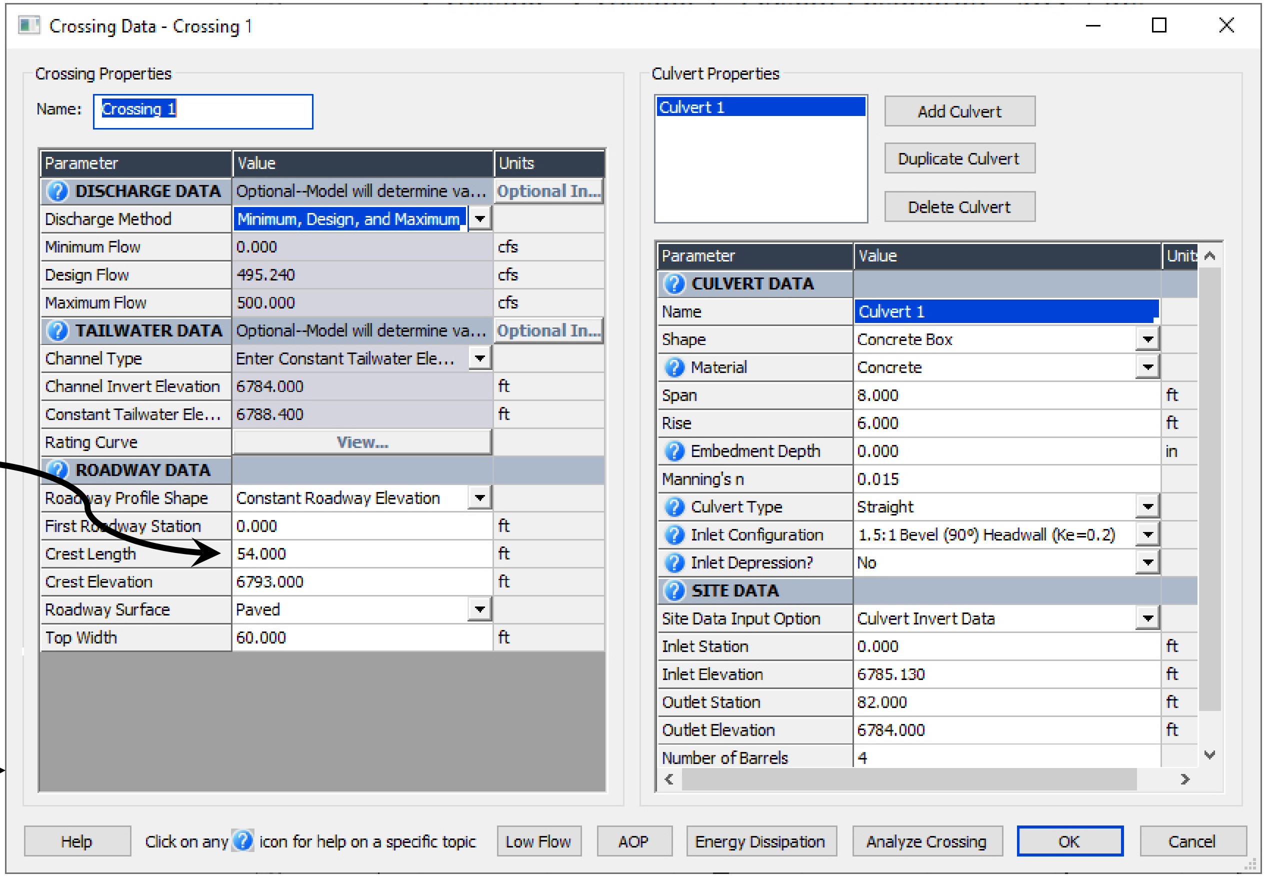
BC arcs should be at culvert invert locations

Hydraulic Structures

HY-8 Culverts



The crest length should equal the BC arc length, unless the 2D overtopping option is selected. With 2D overtopping, the crest length should be set to a negligible value (i.e. 0.1 ft)



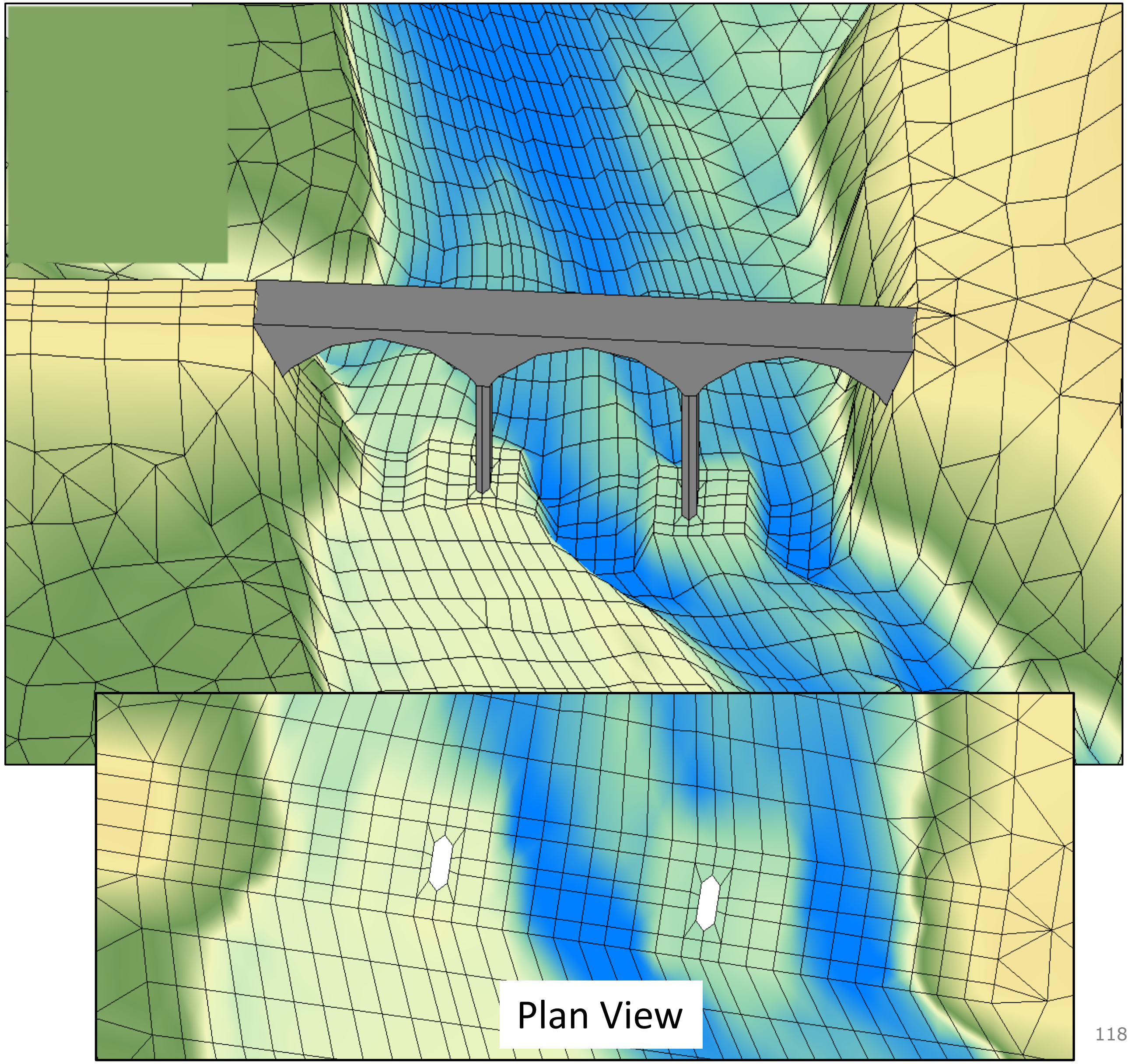
To review 1D structures, select both BC arcs in the BC coverage, rt click and select *Assign BC*.

Hydraulic Structures

2D Mesh through structures

Mesh geometry recommendations for detailed bridge hydraulic analysis:

- 5-7 elements per bridge span
- Piers as holes in the mesh
- Element width around piers between 0.5 to 1 times the pier width
- 2-3 elements along each side slope
- Vertical abutments are best represented as holes in the mesh
- Element length up and downstream should be of similar length as the depth



Hydraulic Structures

Types of Structures

1D

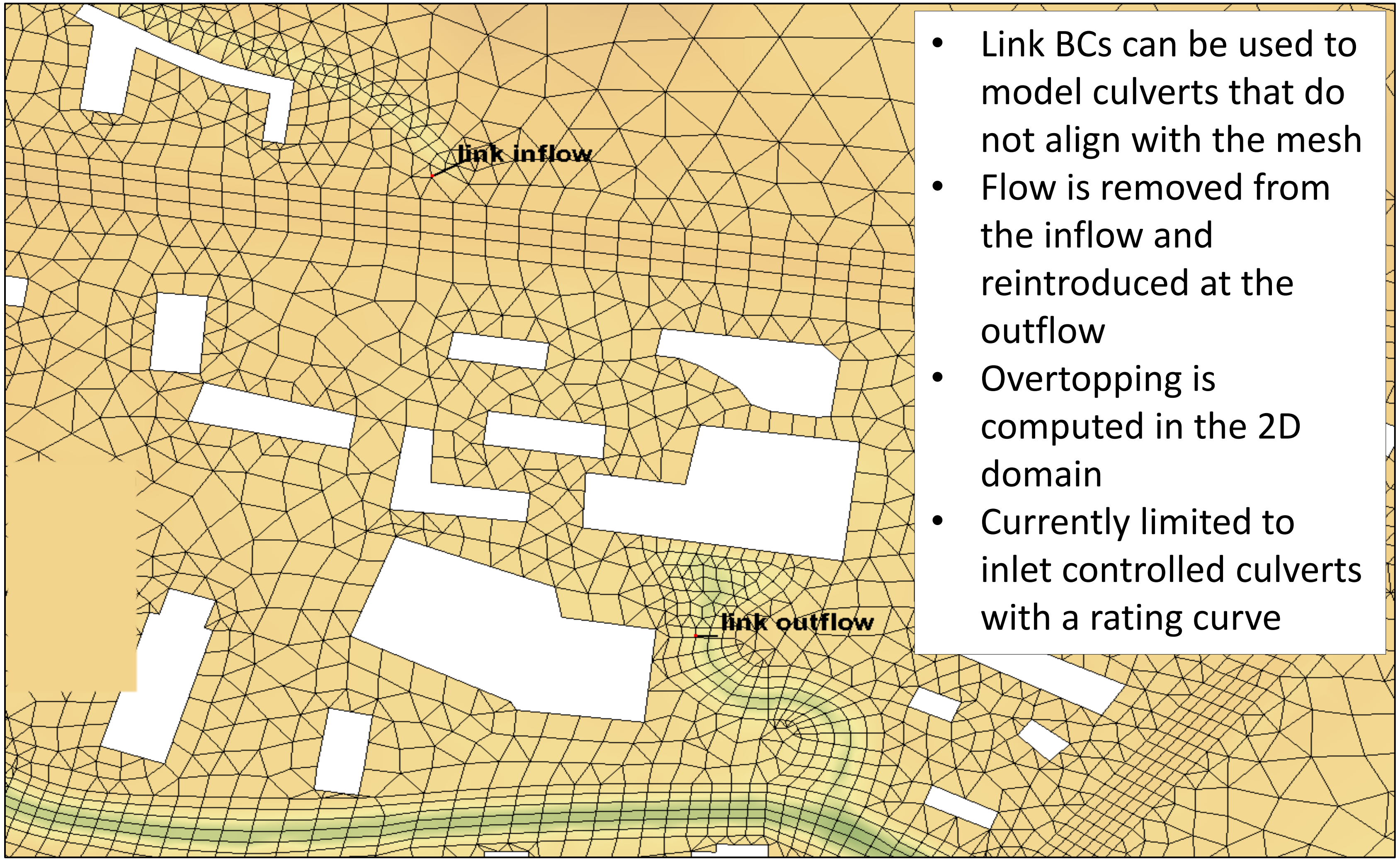
- HY-8 Culverts
- Weirs
- Gates
- Sources / Sinks

2D

- Bridge (Pressure Flow)
- Box culverts
- Cylindrical culverts
- Embankments

Hydraulic Structures

Other Structures



- Link BCs can be used to model culverts that do not align with the mesh
- Flow is removed from the inflow and reintroduced at the outflow
- Overtopping is computed in the 2D domain
- Currently limited to inlet controlled culverts with a rating curve

Key Hydraulic Structure Review Questions

- How many and what type of structures are represented?
- Do the structures align vertically and horizontally with the mesh?
- Is structure overtopping modeled correctly?
- Is the mesh resolution and configuration through the structure appropriate for the application?
- Are the 1D structure parameters correct?

2D Model Review Training Agenda

Session 2

- *Review Exercise 1*
- Boundary Conditions
- Material Roughness
- Hydraulic Structures
- **Simulation Parameters**
- Assign Exercises 2 & 3

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Reviewing Simulation Parameters Top 3 Things

1. Check timestep
2. Verify adequate simulation time
3. Review initial conditions

Simulation Parameters

Labels and Components

Key Question:

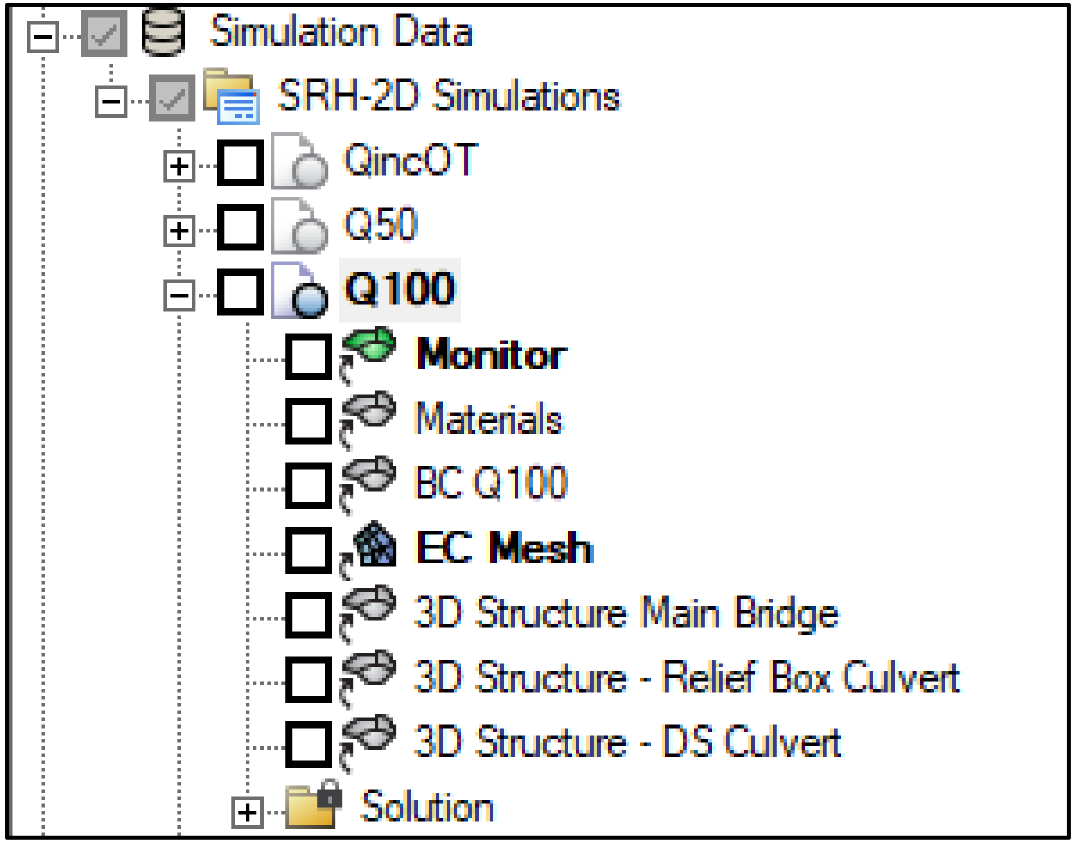
Are simulations labeled clearly and contain all the correct components?

Each SRH-2D simulation must include:

- Boundary Conditions
- Materials
- Mesh
- Monitor Lines and Points

But may also include:

- Obstructions
- Individual 3D structures

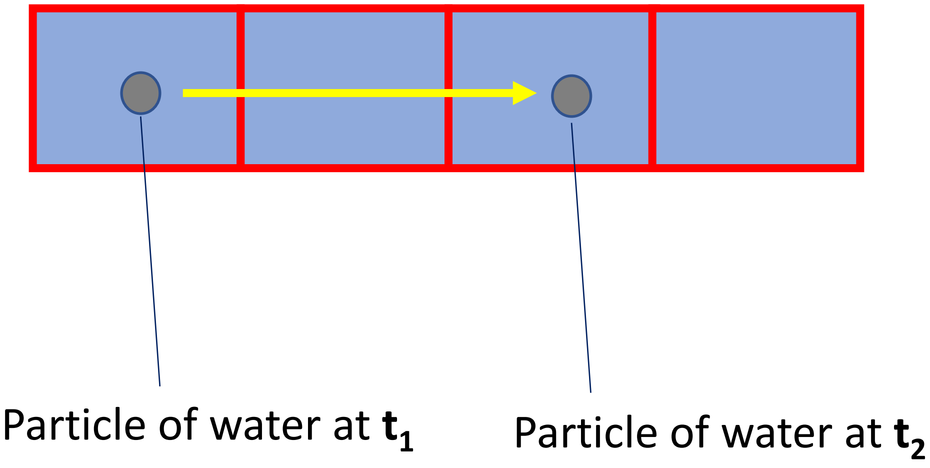


Simulation Parameters

Time Step

Key Question:

Is the timestep reasonable?



SRH-2D uses a fully implicit numerical solver and the timestep is not limited by the Courant Condition.

The recommended timestep is between 1 and 10 seconds.

When the timestep needs to be <1s to achieve a stable solution, this is usually an indicator of other problems (very small elements or poor mesh quality)

The Courant criterion essentially states that a particle of water should not pass more than one element in a given time step.

Some models (explicit schemes) require that the criteria be strictly adhered to.

Simulation Parameters

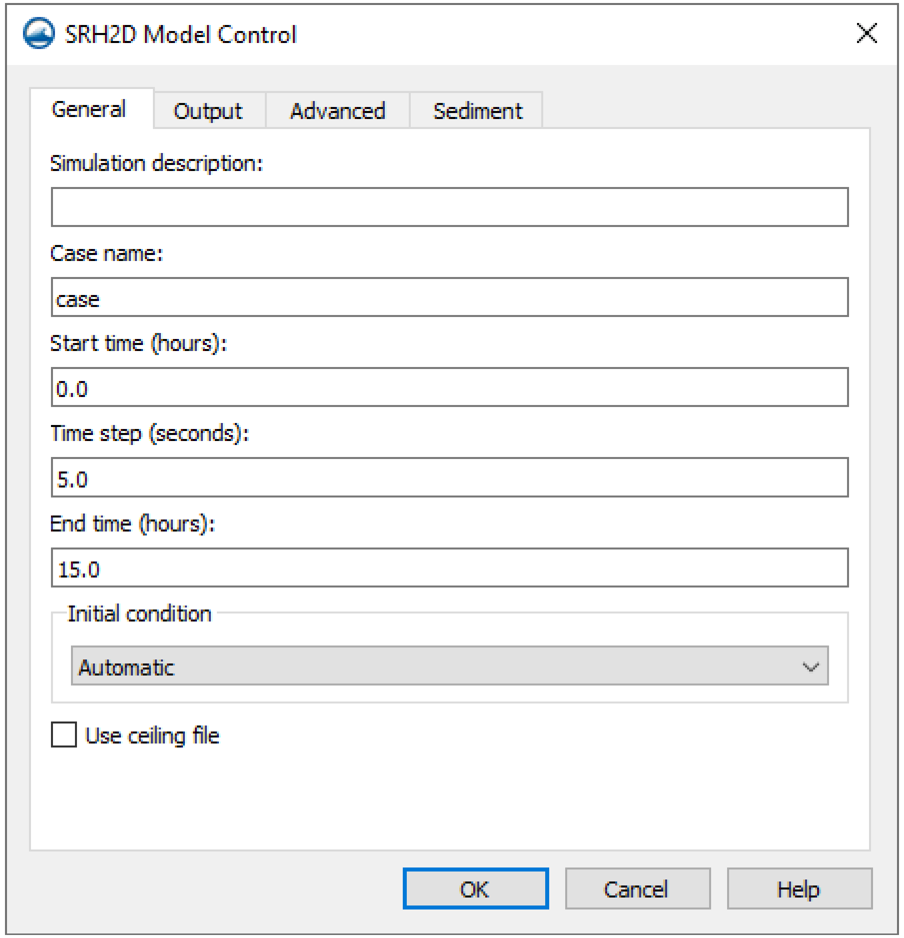
Simulation Time

Key Question:

Is the simulation time long enough?

For a steady simulation, the simulation time must be sufficient for flow to fill the domain and reach a steady condition.

For unsteady simulations, the simulation time should be long enough for the peak flow to reach the downstream end of the domain.



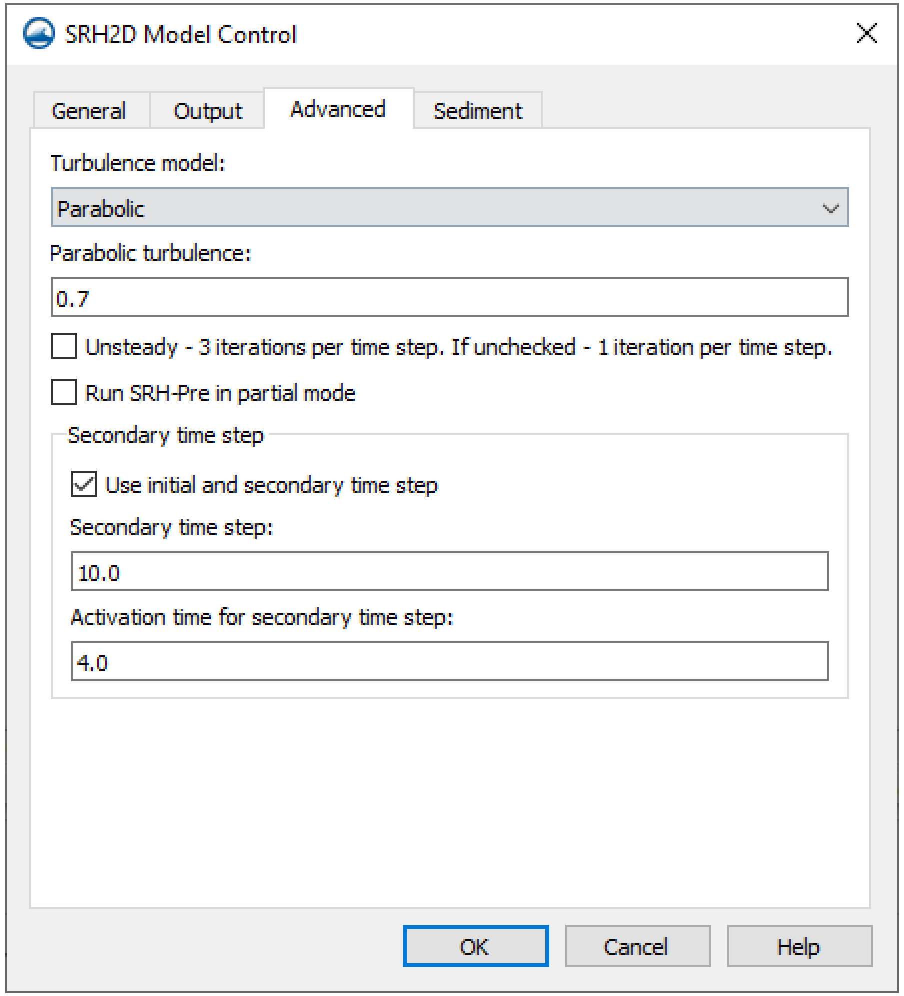
Simulation Parameters

Other parameter options

The default Parabolic Turbulence coefficient of 0.7 should be used for all natural channels.

Unsteady vs. Steady option

To improve run-time, a larger timestep can often be used following the initial filling of the domain.



Key Simulation Parameter Review Questions

- Are simulations labeled clearly and contain all the correct components?
- Is the timestep reasonable?
- Is the simulation time long enough?
- Have the turbulence model or coefficient been changed?

2D Model Review Training Agenda

Session 2

- *Review Exercise 1*
- Boundary Conditions
- Material Roughness
- Hydraulic Structures
- Simulation Parameters
- **Assign Exercises 2 & 3**

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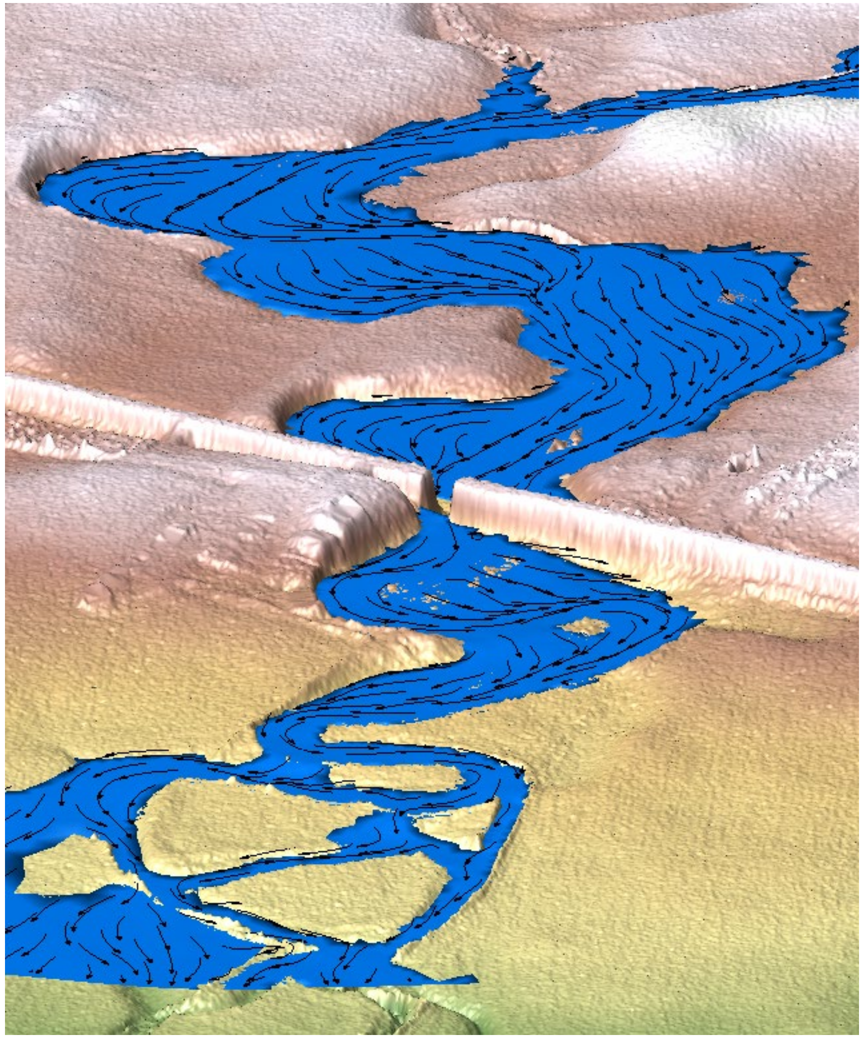
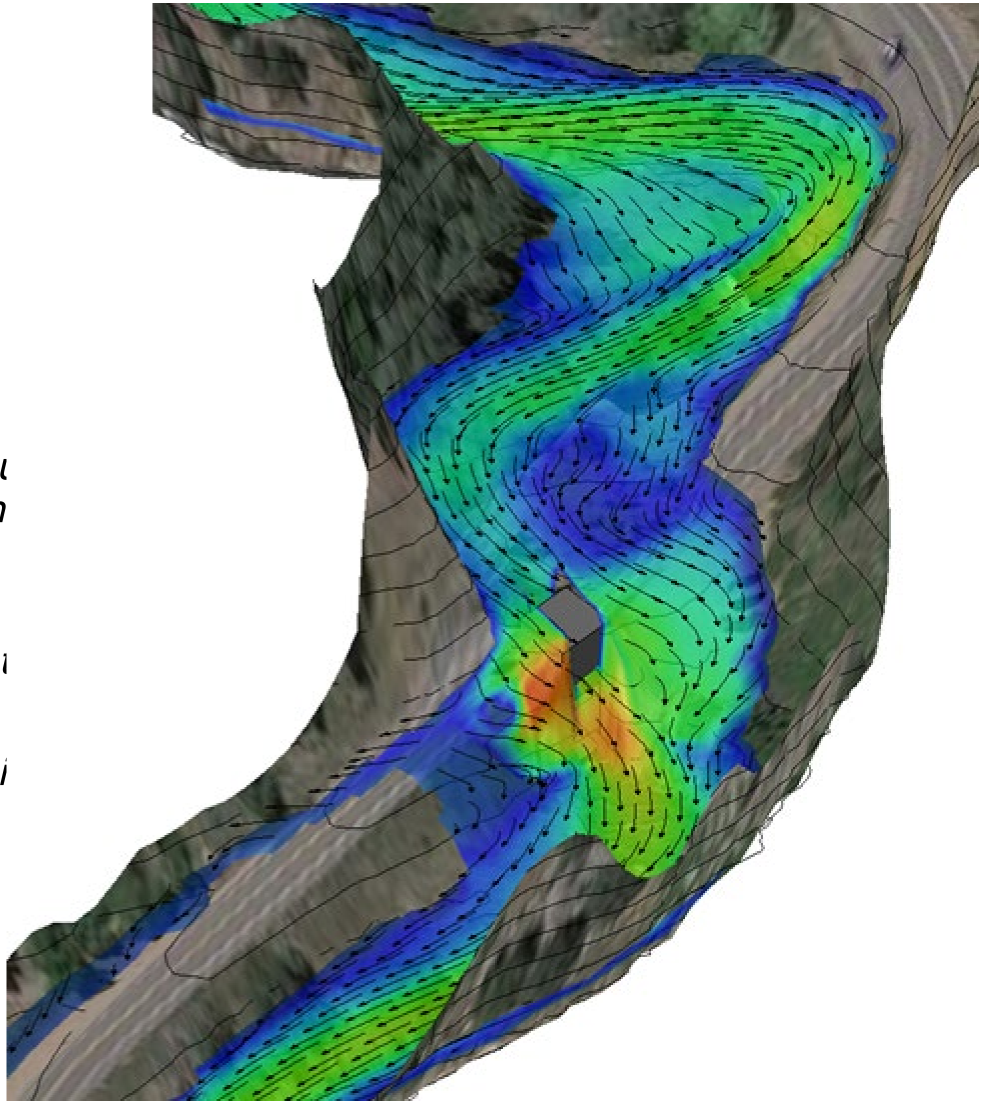
Model Review Exercise 2

- Focus on **Materials Coverage** and **Boundary Conditions**
- Prepare a list to share with the group in Session 3



Model Review Exercise 3

- Focus on **Hydraulic Structures and Simulation Results**
  - Review simulation plots *(rt click on simulation→ Select Tools → View Simulation Plots) – Confirm continuity and stability*
  - Review SRH-2D Structure Plots *(rt click on 3D Structu Culvert (under Map Data)→ SRH Structure Plots (Discharge curren only shows overtopping)*
  - Review Monitoring Line Plots *(Select the Monitor coverage → select a monitoring line, rt click → Monitoring Line Plot*
  - Review HY-8 structure information *(Select the BC Q500 HY-8 Culvert, select one of the HY-8 BC arcs, rt click → Assi BC → Launch HY-8 to review culvert information)*
  - Review ranges of results *(Select a dataset, rt click → Properties)*



End of Session 2

Session 3

- ***Review Exercises 2 & 3***
- Reviewing Model Results
- *Bridge Scour Analysis Review*
- Q&A
- Wrap-up

2D Model Review Training Agenda

Session 1

- Overview of 2D Modeling and Available Resources
- Information to Be Reviewed, Model Review Spreadsheet and Best Practices
- Project Information and Model Background Data
- 2D Mesh
- *Assign Exercise 1*

Session 2

- *Review Exercise 1*
- Boundary Conditions
- Material Roughness
- Hydraulic Structures
- Simulation Parameters
- *Assign Exercises 2 & 3*

Session 3

- *Review Exercise 2*
- Reviewing Model Results
- *Review Exercise 3*
- Hydraulic Variables for Bridge Scour Analyses
- Wrap-up

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2D Model Review Training Agenda

Session 3

- ***Review Exercise 2***
- Reviewing Model Results
- ***Review Exercise 3***
- Hydraulic Variables for Bridge Scour Analyses
- Wrap-up

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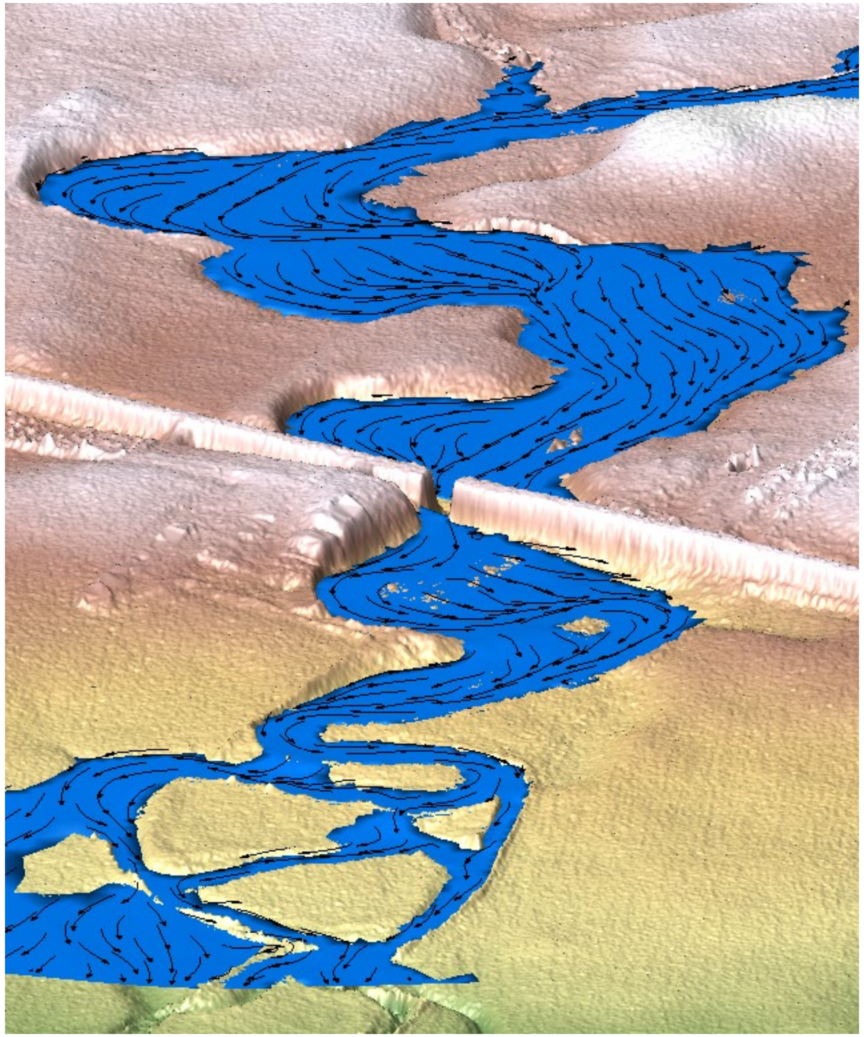
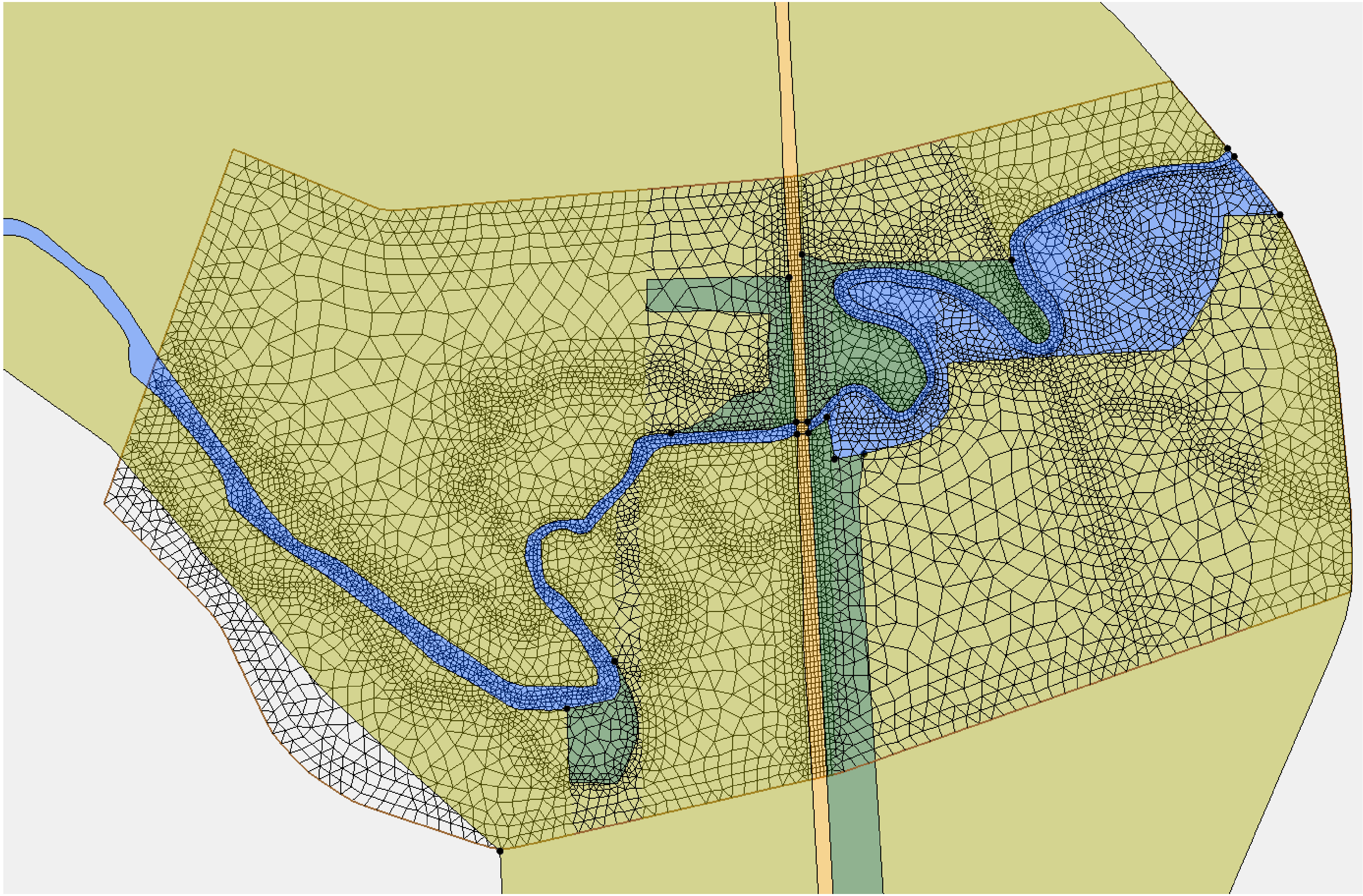
Model Review Exercise 2

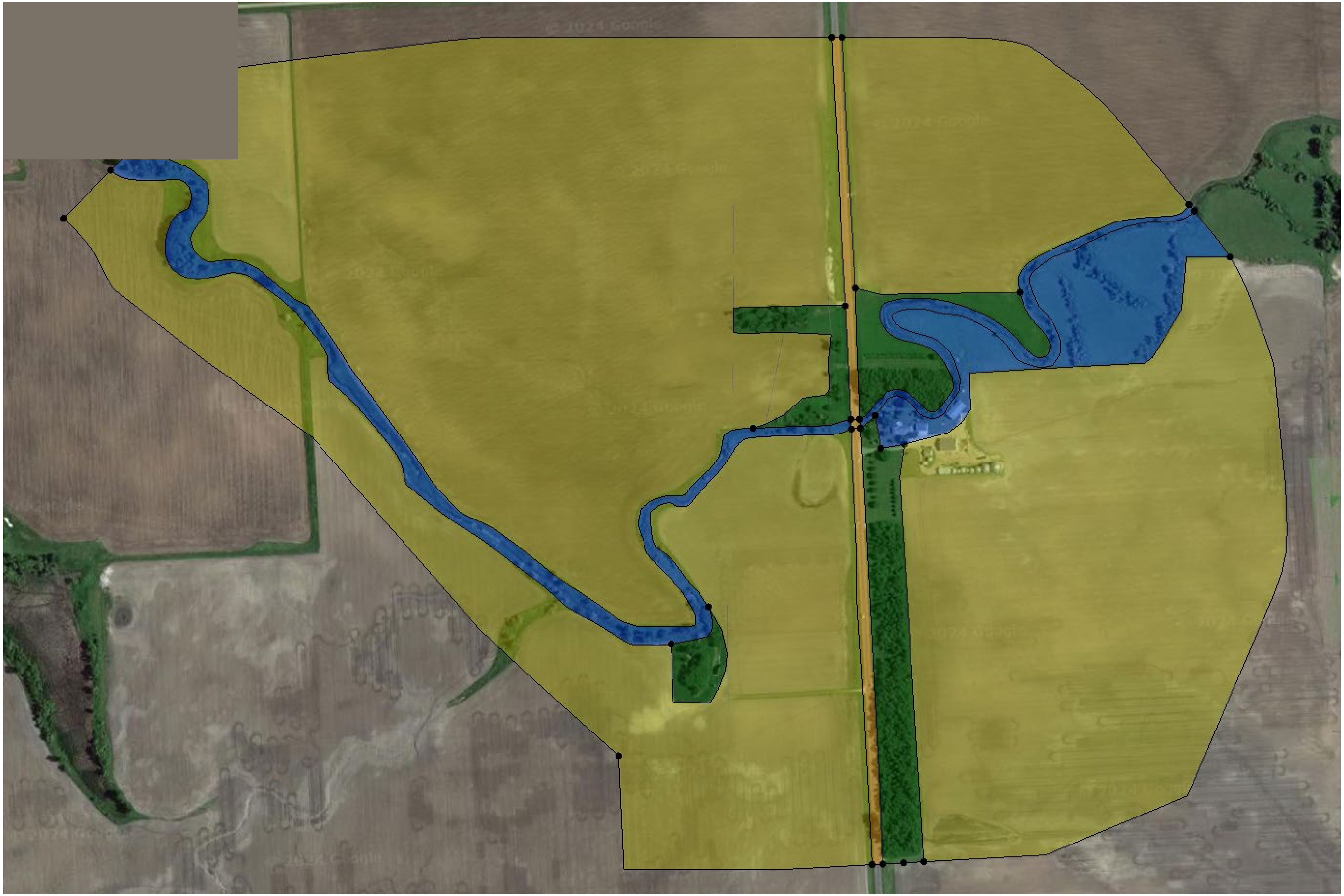
Discussion

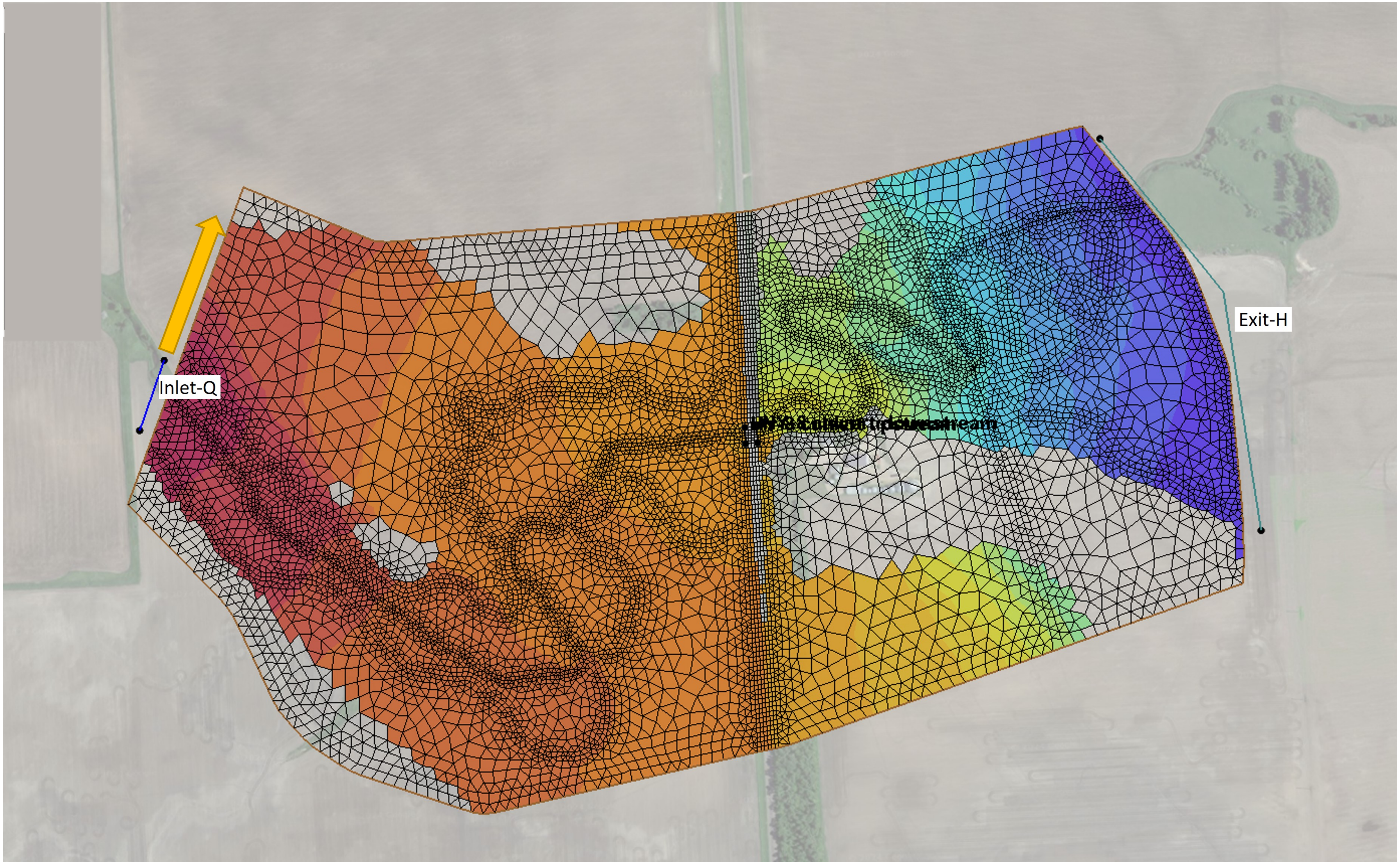
Model Review Exercise 2

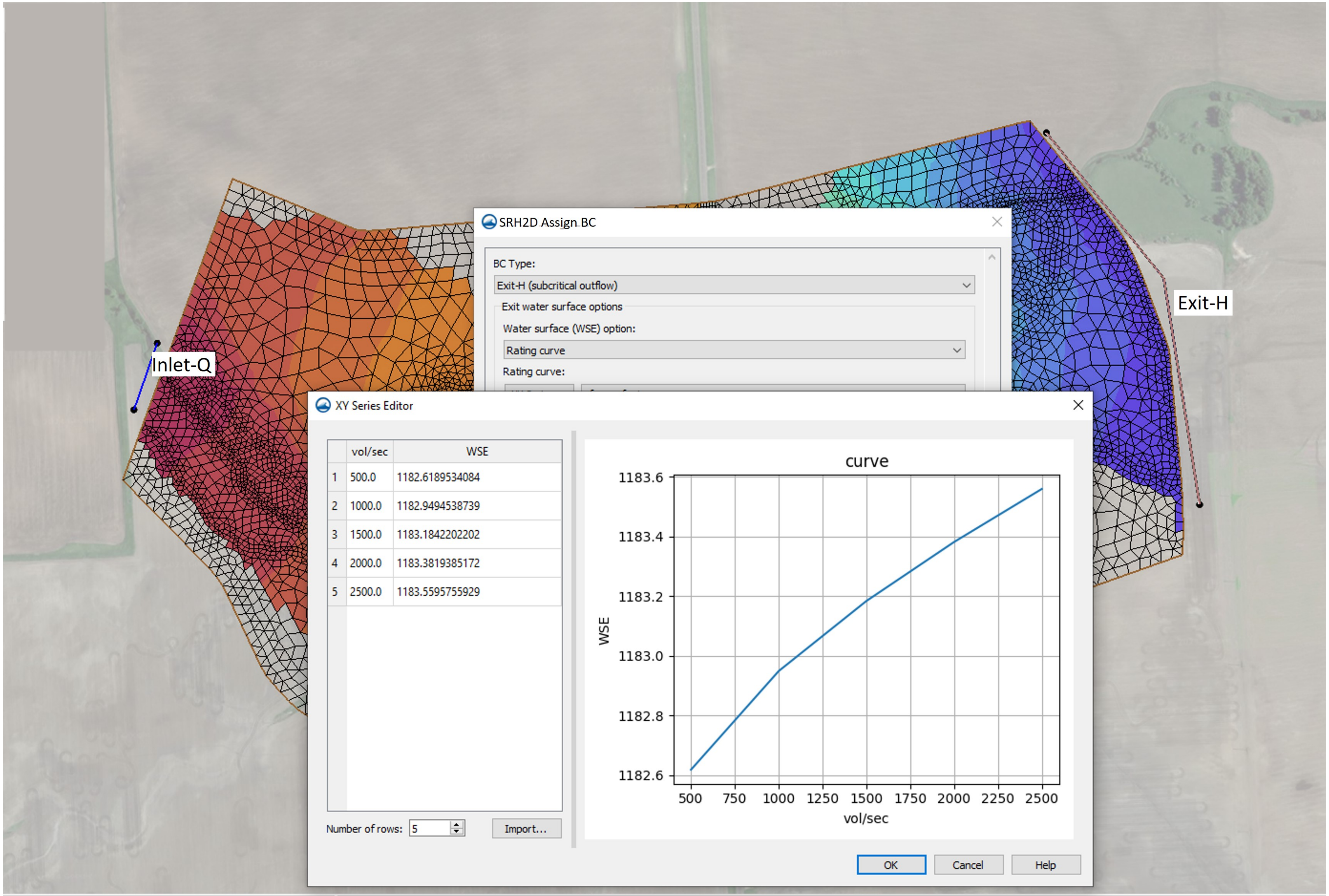
- Focus on **Materials Coverage** and **Boundary Conditions**
  - Materials zones do not extend to mesh
  - Wrong materials type assigned to overbank (channel)
  - Inlet Q – Arc does not extend across FP width
  - Exit-H – Rating curve ends at 2500 cfs
  - HY-8 culvert weir issue -Overtopping length is set too long

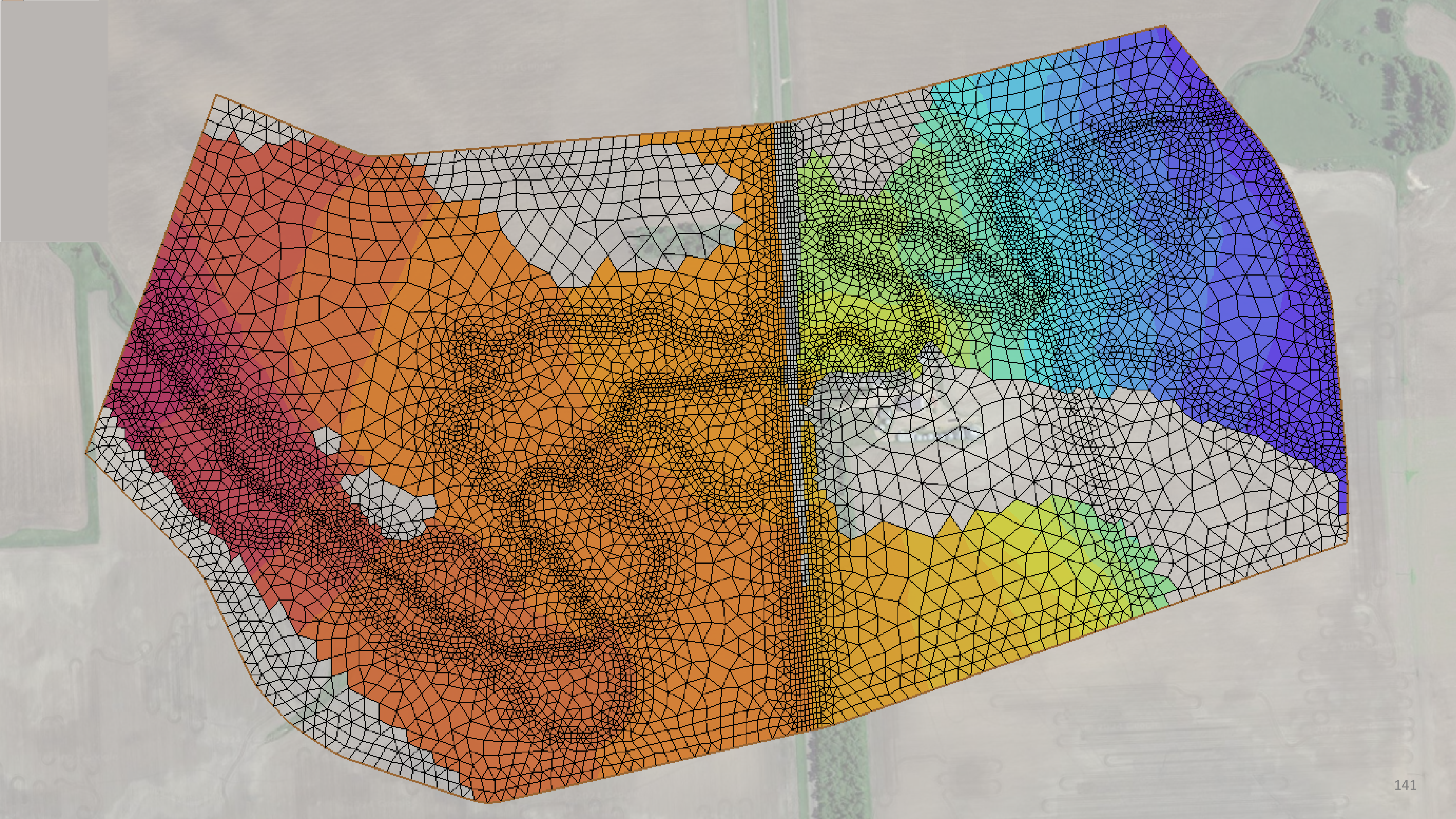


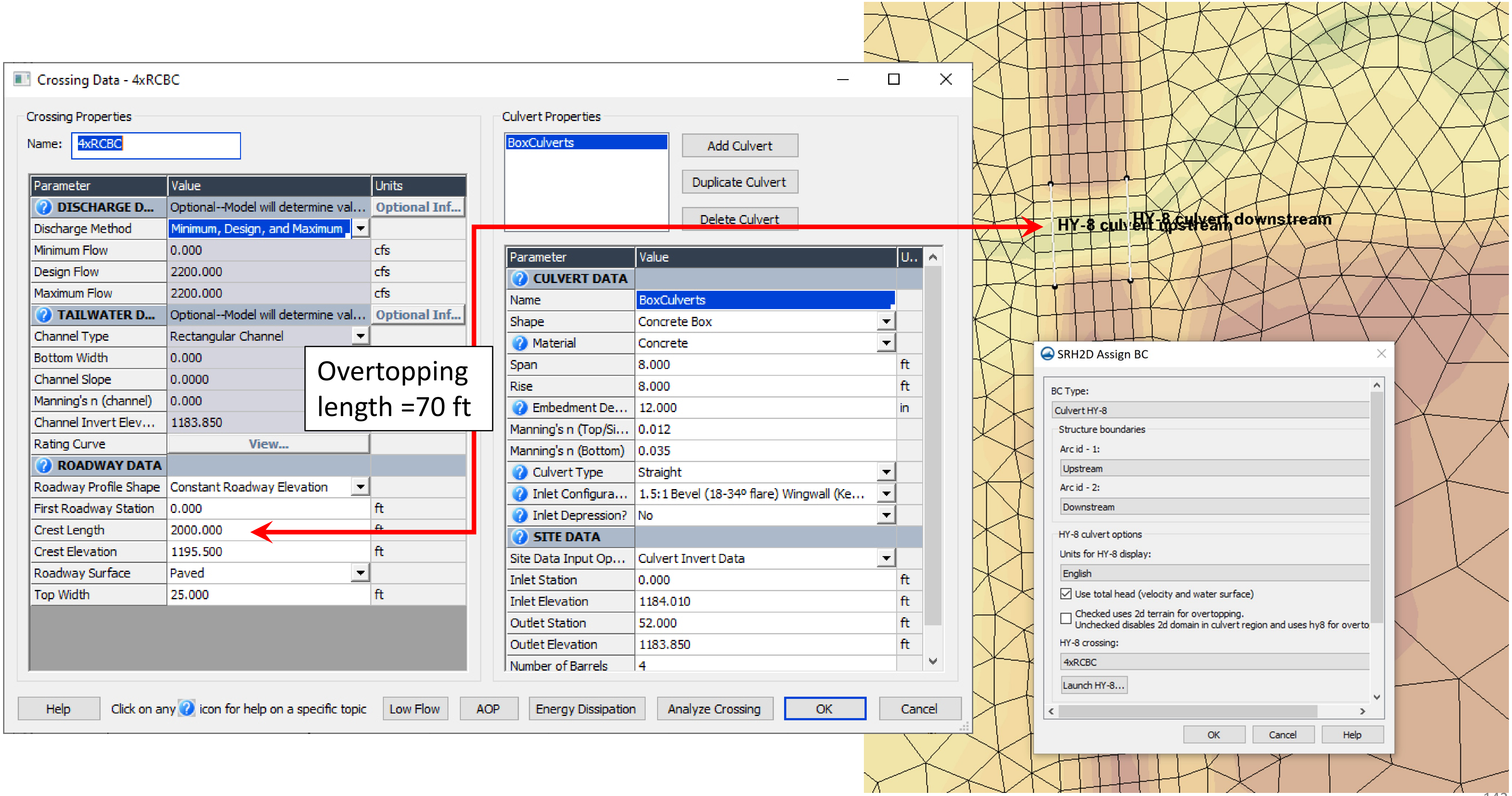





Inlet-Q
Exit-H


Inlet-Q
Exit-H
SRH2D Assign BC
BC Type:
Exit-H (subcritical outflow)
Exit water surface options
Water surface (WSE) option:
Rating curve
Rating curve:
XY Series Editor
vol/sec
WSE
1 500.0 1182.6189534084
2 1000.0 1182.9494538739
3 1500.0 1183.1842202202
4 2000.0 1183.3819385172
5 2500.0 1183.5595755929
Number of rows: 5
Import...
curve
WSE
vol/sec
OK
Cancel
Help





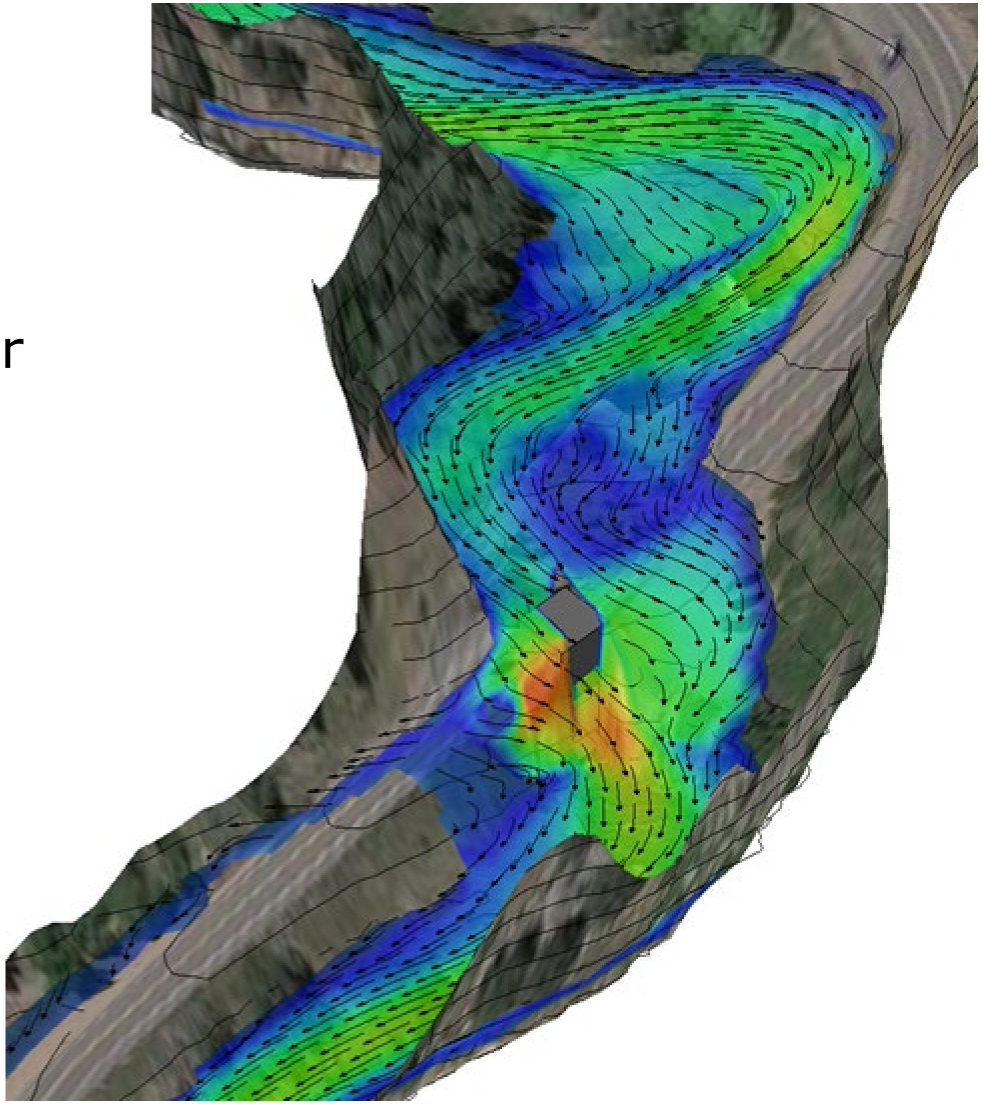
Crossing Data - 4xRCBC
Crossing Properties
Name: 4xRCBC
Parameter | Value | Units
DISCHARGE D... | Optional--Model will determine val... | Optional Inf...
Discharge Method | Minimum, Design, and Maximum
Minimum Flow | 0.000 | cfs
Design Flow | 2200.000 | cfs
Maximum Flow | 2200.000 | cfs
TAILWATER D... | Optional--Model will determine val... | Optional Inf...
Channel Type | Rectangular Channel
Bottom Width | 0.000
Channel Slope | 0.0000
Manning's n (channel) | 0.000
Channel Invert Elev... | 1183.850
Rating Curve | View...
ROADWAY DATA
Roadway Profile Shape | Constant Roadway Elevation
First Roadway Station | 0.000 | ft
Crest Length | 2000.000 | ft
Crest Elevation | 1195.500 | ft
Roadway Surface | Paved
Top Width | 25.000 | ft
Overtopping length =70 ft
Culvert Properties
BoxCulverts
Add Culvert
Duplicate Culvert
Delete Culvert
Parameter | Value | U..
CULVERT DATA
Name | BoxCulverts
Shape | Concrete Box
Material | Concrete
Span | 8.000 | ft
Rise | 8.000 | ft
Embedment De... | 12.000 | in
Manning's n (Top/Si... | 0.012
Manning's n (Bottom) | 0.035
Culvert Type | Straight
Inlet Configura... | 1.5:1 Bevel (18-34º flare) Wingwall (Ke...
Inlet Depression? | No
SITE DATA
Site Data Input Op... | Culvert Invert Data
Inlet Station | 0.000 | ft
Inlet Elevation | 1184.010 | ft
Outlet Station | 52.000 | ft
Outlet Elevation | 1183.850 | ft
Number of Barrels | 4
Help
Click on any icon for help on a specific topic
Low Flow
AOP
Energy Dissipation
Analyze Crossing
OK
Cancel
HY-8 culvert upstream
HY-8 culvert downstream
SRH2D Assign BC
BC Type:
Culvert HY-8
Structure boundaries
Arc id - 1:
Upstream
Arc id - 2:
Downstream
HY-8 culvert options
Units for HY-8 display:
English
Use total head (velocity and water surface)
Checked uses 2d terrain for overtopping.
Unchecked disables 2d domain in culvert region and uses hy8 for overto
HY-8 crossing:
4xRCBC
Launch HY-8...
OK
Cancel
Help

Model Review Exercise 3

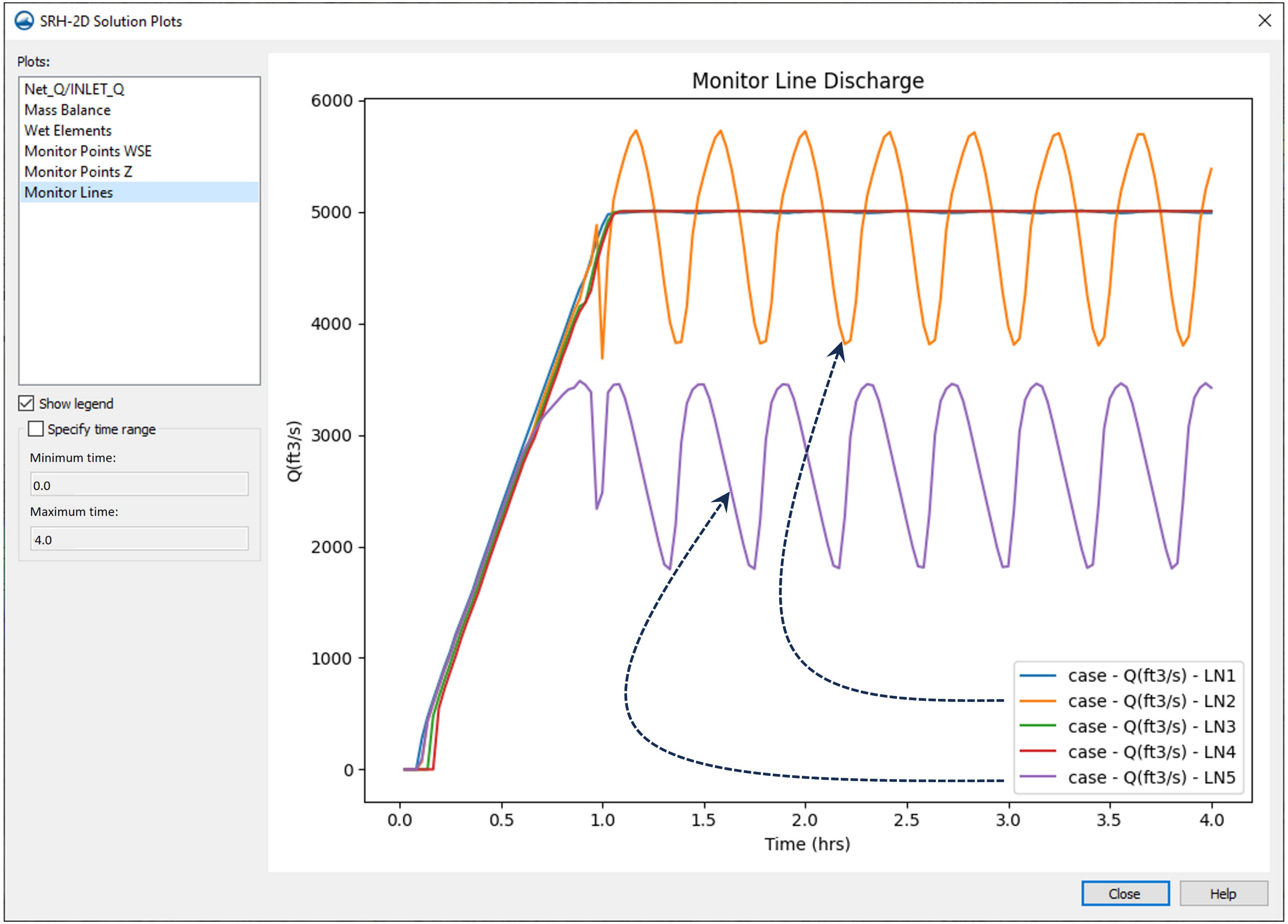
Discussion

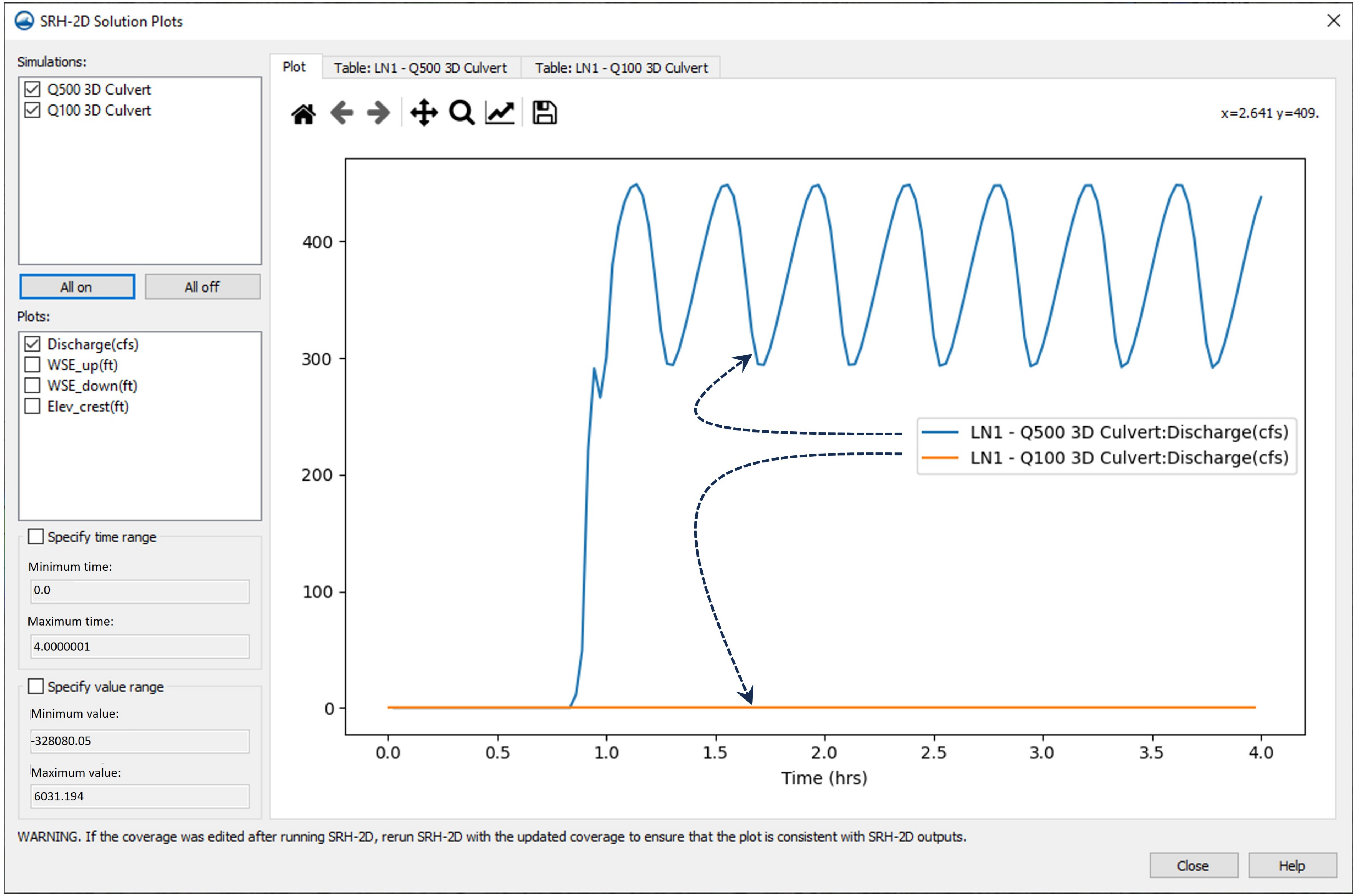
Model Review Exercise 3

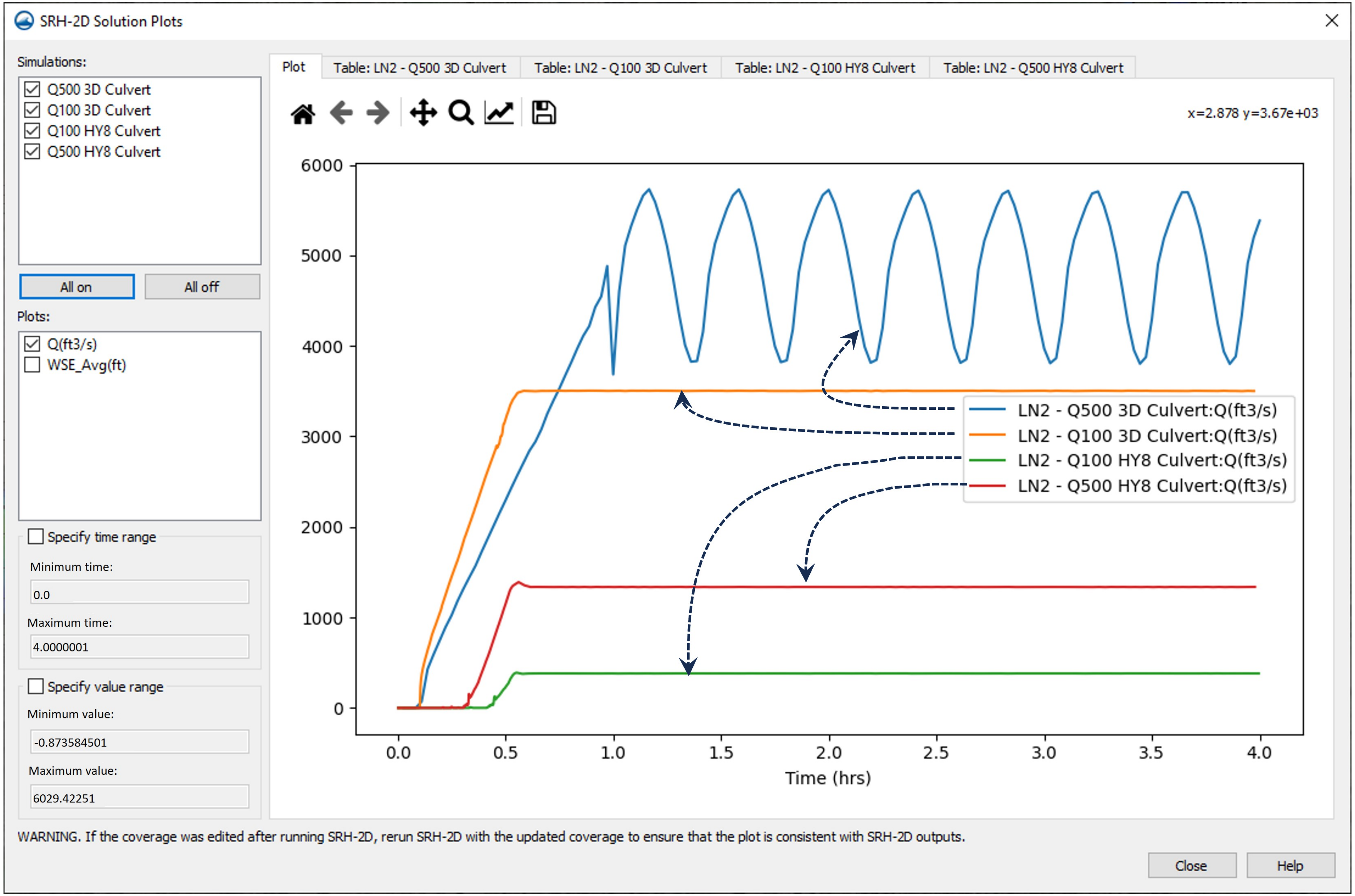
- Focus on **Hydraulic Structures and Simulation Results**
  - Simulation plots show discharge oscillations for the Q500 at the culvert (3D Culvert)
  - SRH-2D Structure Plots show oscillations in Q and WSEL (Q500 3D Culvert)
  - HY-8 weir crest is set too long
  - Review results ranges

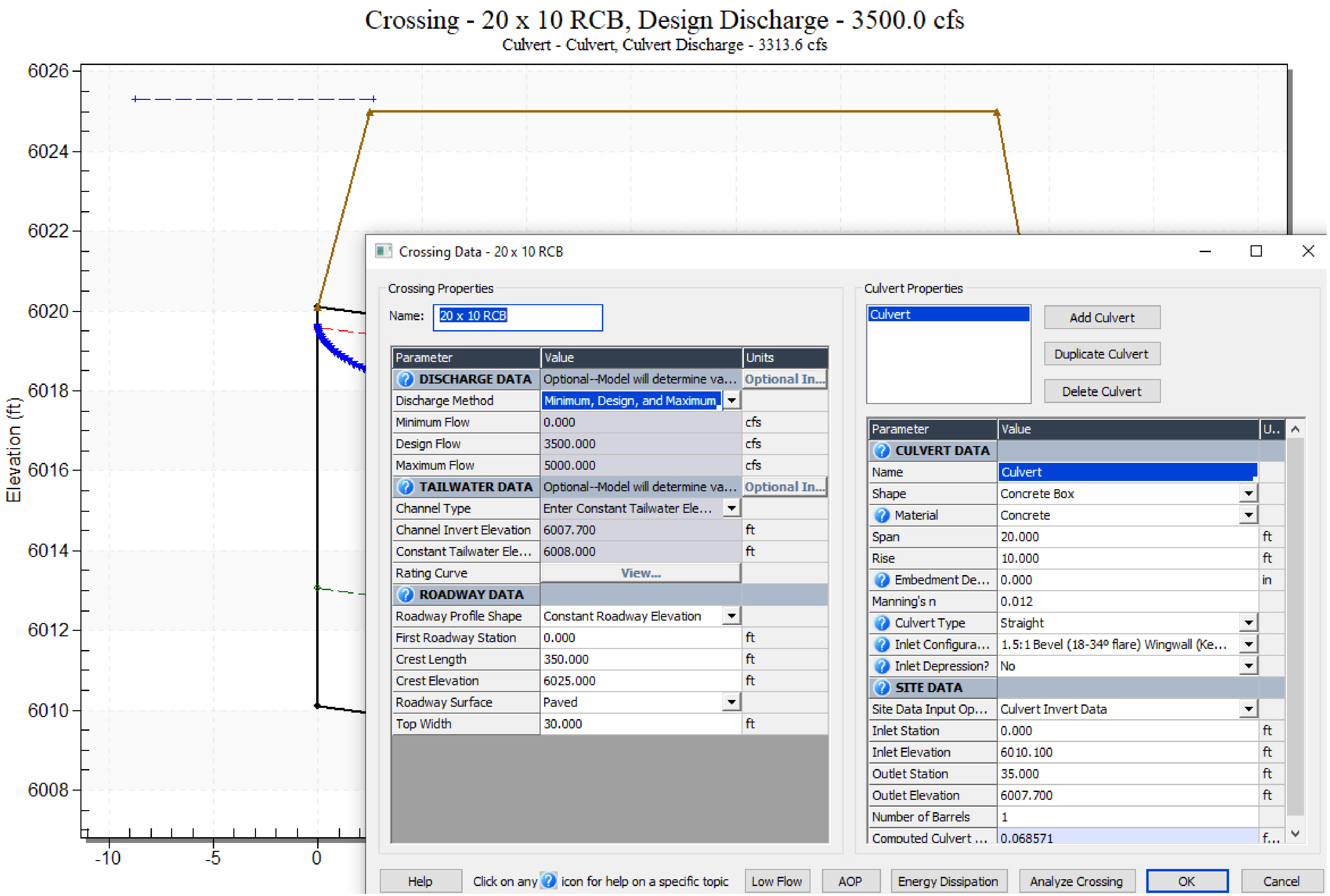


Q500 3D Culvert




SRH-2D Solution Plots
Simulations:
Q500 3D Culvert
Q100 3D Culvert
All on
All off
Plots:
Discharge(cfs)
WSE_up(ft)
WSE_down(ft)
Elev_crest(ft)
Specify time range
Minimum time:
0.0
Maximum time:
4.0000001
Specify value range
Minimum value:
-328080.05
Maximum value:
6031.194
Plot
Table: LN1 - Q500 3D Culvert
Table: LN1 - Q100 3D Culvert
x=2.641 y=409.
400
300
200
100
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (hrs)
LN1 - Q500 3D Culvert:Discharge(cfs)
LN1 - Q100 3D Culvert:Discharge(cfs)
WARNING. If the coverage was edited after running SRH-2D, rerun SRH-2D with the updated coverage to ensure that the plot is consistent with SRH-2D outputs.
Close
Help


SRH-2D Solution Plots
Simulations:
Q500 3D Culvert
Q100 3D Culvert
Q100 HY8 Culvert
Q500 HY8 Culvert
All on
All off
Plots:
Q(ft3/s)
WSE_Avg(ft)
Specify time range
Minimum time:
0.0
Maximum time:
4.0000001
Specify value range
Minimum value:
-0.873584501
Maximum value:
6029.42251
Plot
Table: LN2 - Q500 3D Culvert
Table: LN2 - Q100 3D Culvert
Table: LN2 - Q100 HY8 Culvert
Table: LN2 - Q500 HY8 Culvert
x=2.878 y=3.67e+03
6000
5000
4000
3000
2000
1000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (hrs)
LN2 - Q500 3D Culvert:Q(ft3/s)
LN2 - Q100 3D Culvert:Q(ft3/s)
LN2 - Q100 HY8 Culvert:Q(ft3/s)
LN2 - Q500 HY8 Culvert:Q(ft3/s)
WARNING. If the coverage was edited after running SRH-2D, rerun SRH-2D with the updated coverage to ensure that the plot is consistent with SRH-2D outputs.
Close
Help


Crossing - 20 x 10 RCB, Design Discharge - 3500.0 cfs
Culvert - Culvert, Culvert Discharge - 3313.6 cfs
Elevation (ft)
6026
6024
6022
6020
6018
6016
6014
6012
6010
6008
-10
-5
0
Crossing Data - 20 x 10 RCB
Crossing Properties
Name: 20 x 10 RCB
Parameter
Value
Units
DISCHARGE DATA
Optional--Model will determine va...
Optional In...
Discharge Method
Minimum, Design, and Maximum
Minimum Flow
0.000
cfs
Design Flow
3500.000
cfs
Maximum Flow
5000.000
cfs
TAILWATER DATA
Optional--Model will determine va...
Optional In...
Channel Type
Enter Constant Tailwater Ele...
Channel Invert Elevation
6007.700
ft
Constant Tailwater Ele...
6008.000
ft
Rating Curve
View...
ROADWAY DATA
Roadway Profile Shape
Constant Roadway Elevation
First Roadway Station
0.000
ft
Crest Length
350.000
ft
Crest Elevation
6025.000
ft
Roadway Surface
Paved
Top Width
30.000
ft
Culvert Properties
Culvert
Add Culvert
Duplicate Culvert
Delete Culvert
Parameter
Value
U...
CULVERT DATA
Name
Culvert
Shape
Concrete Box
Material
Concrete
Span
20.000
ft
Rise
10.000
ft
Embedment De...
0.000
in
Manning's n
0.012
Culvert Type
Straight
Inlet Configura...
1.5:1 Bevel (18-34º flare) Wingwall (Ke...
Inlet Depression?
No
SITE DATA
Site Data Input Op...
Culvert Invert Data
Inlet Station
0.000
ft
Inlet Elevation
6010.100
ft
Outlet Station
35.000
ft
Outlet Elevation
6007.700
ft
Number of Barrels
1
Computed Culvert ...
0.068571
f...
Help
Click on any icon for help on a specific topic
Low Flow
AOP
Energy Dissipation
Analyze Crossing
OK
Cancel

2D Model Review Training Agenda

Session 3

- *Review Exercises 2 & 3*
- **Reviewing Model Results**
- Hydraulic Variables for Bridge Scour Analyses
- Wrap-up

Image from PowerPoint online images by Peter Baumgartner

Reviewing Model Results
Top 3 Things

1. Verify continuity
2. Check stability through structures and areas of interest
3. Confirm reasonable ranges of values

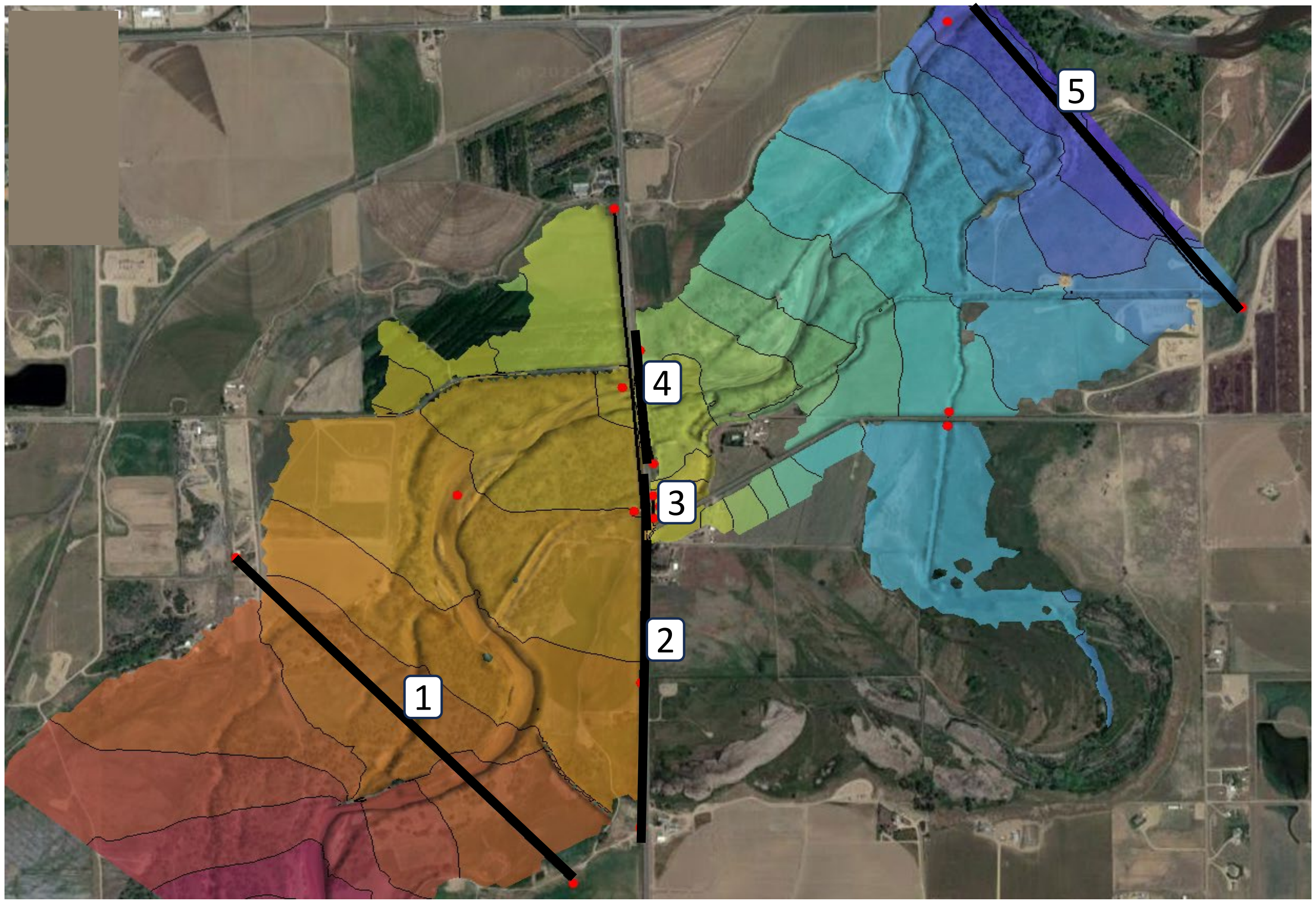
Reviewing Results

Continuity and Stability

Key Question:

Are continuity and stability preserved throughout the model domain?

Review simulation plots or monitoring line plots to confirm continuity and stability.

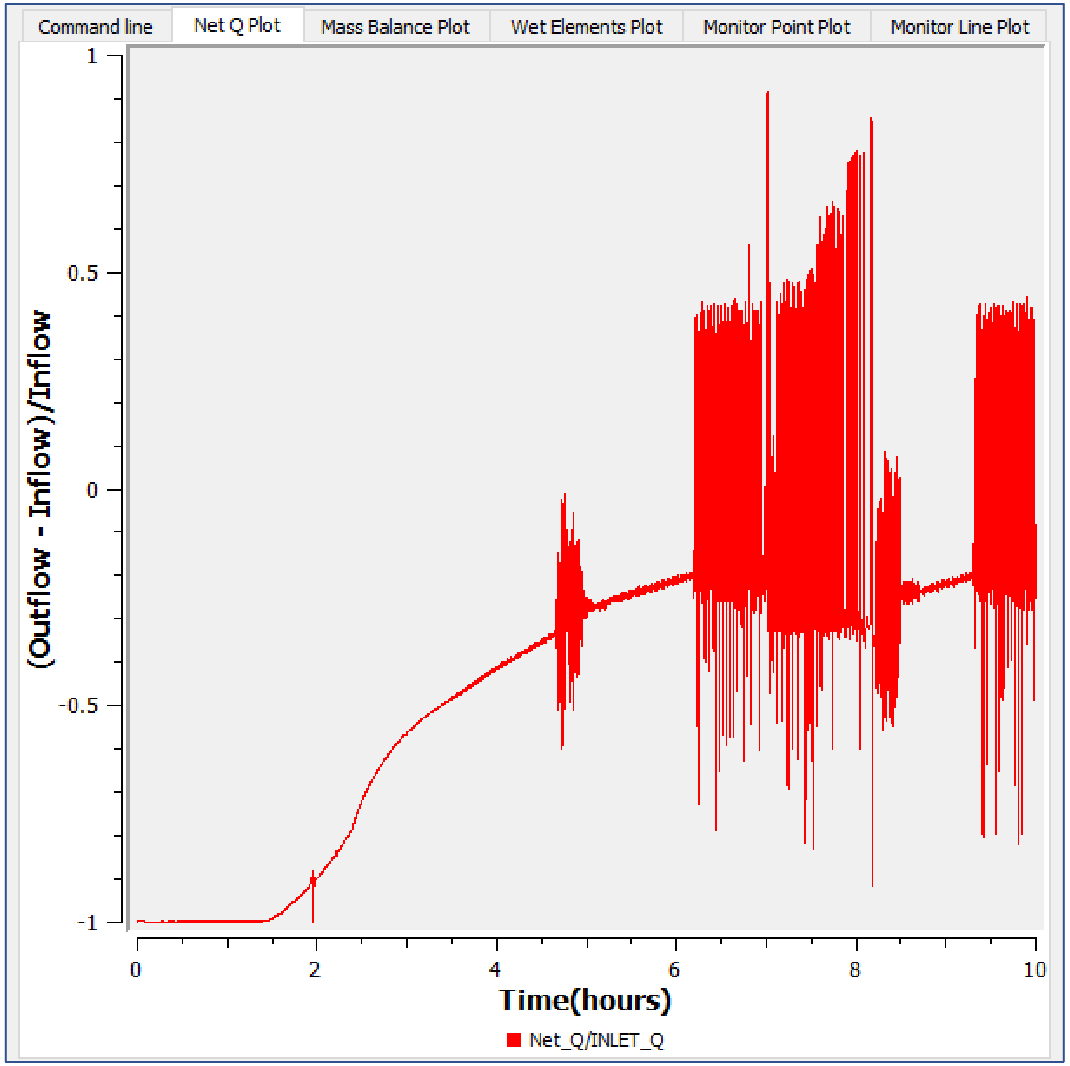


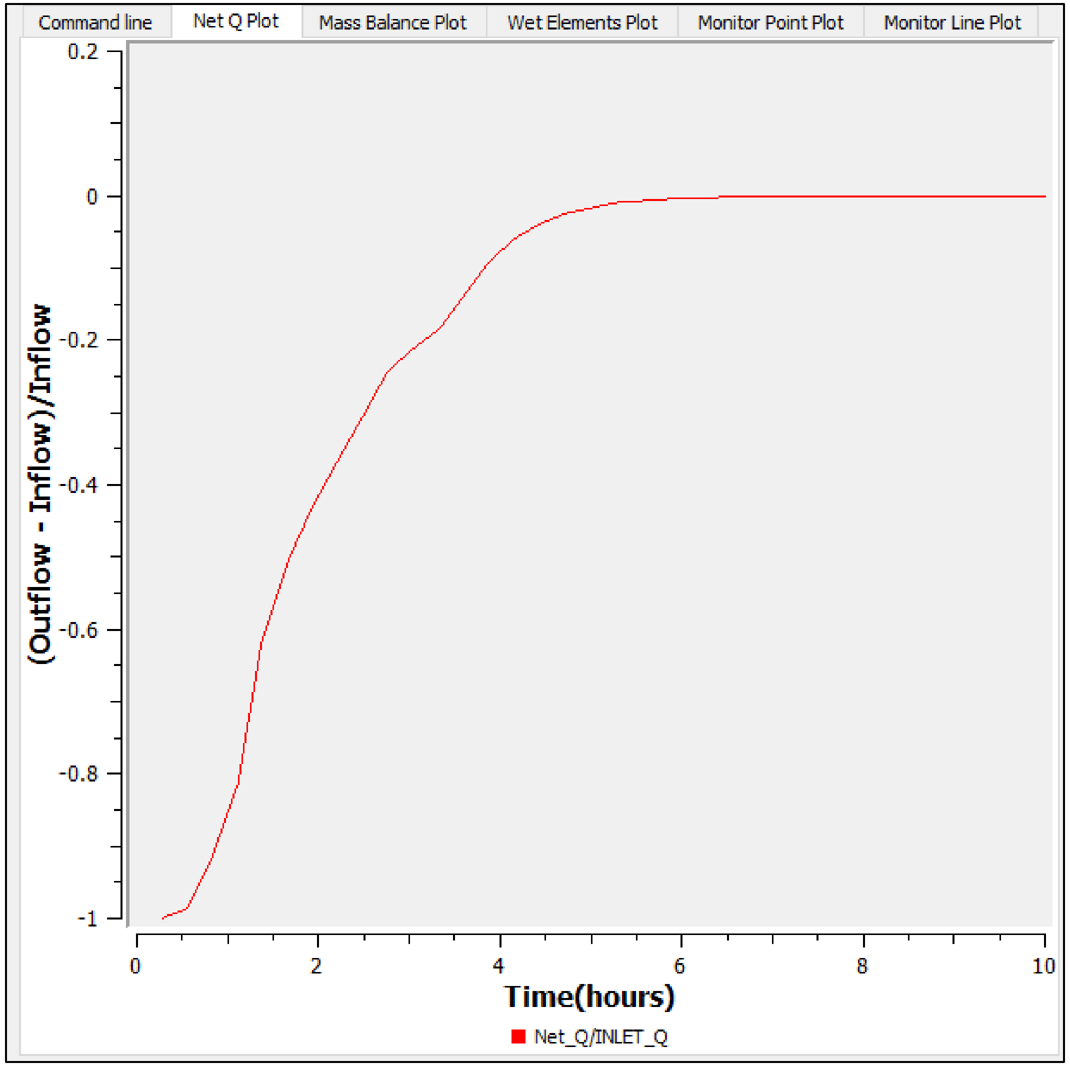
Monitor Line	1	2	3	4	5
Discharge (cfs)	22000	21920	1208	20634	21835
Difference (cfs)	0	-80 (0.3%)	-158 (.7%)		-165 (0.8%)

*Check continuity for a steady state/constant discharge

Reviewing Results

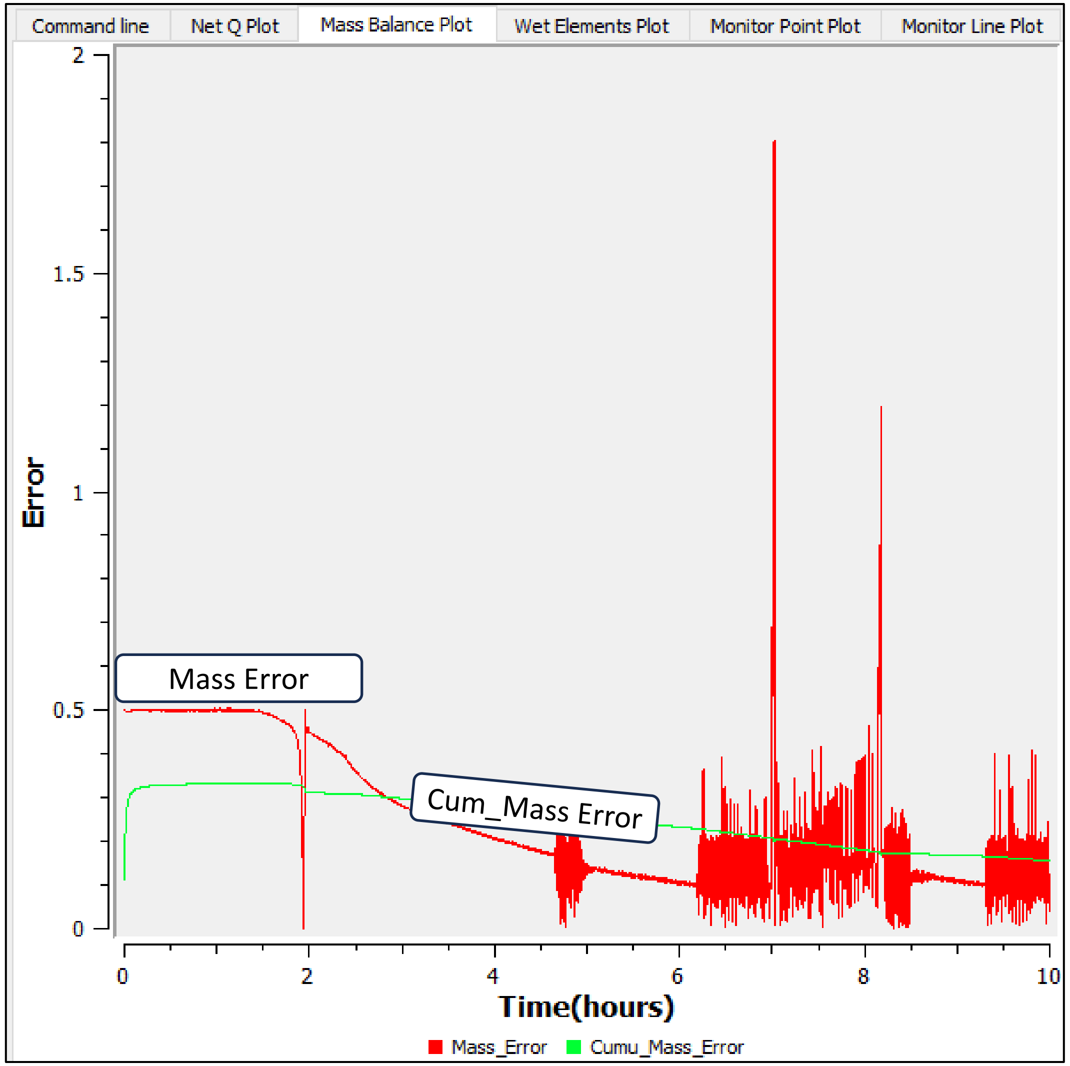
Continuity and Stability

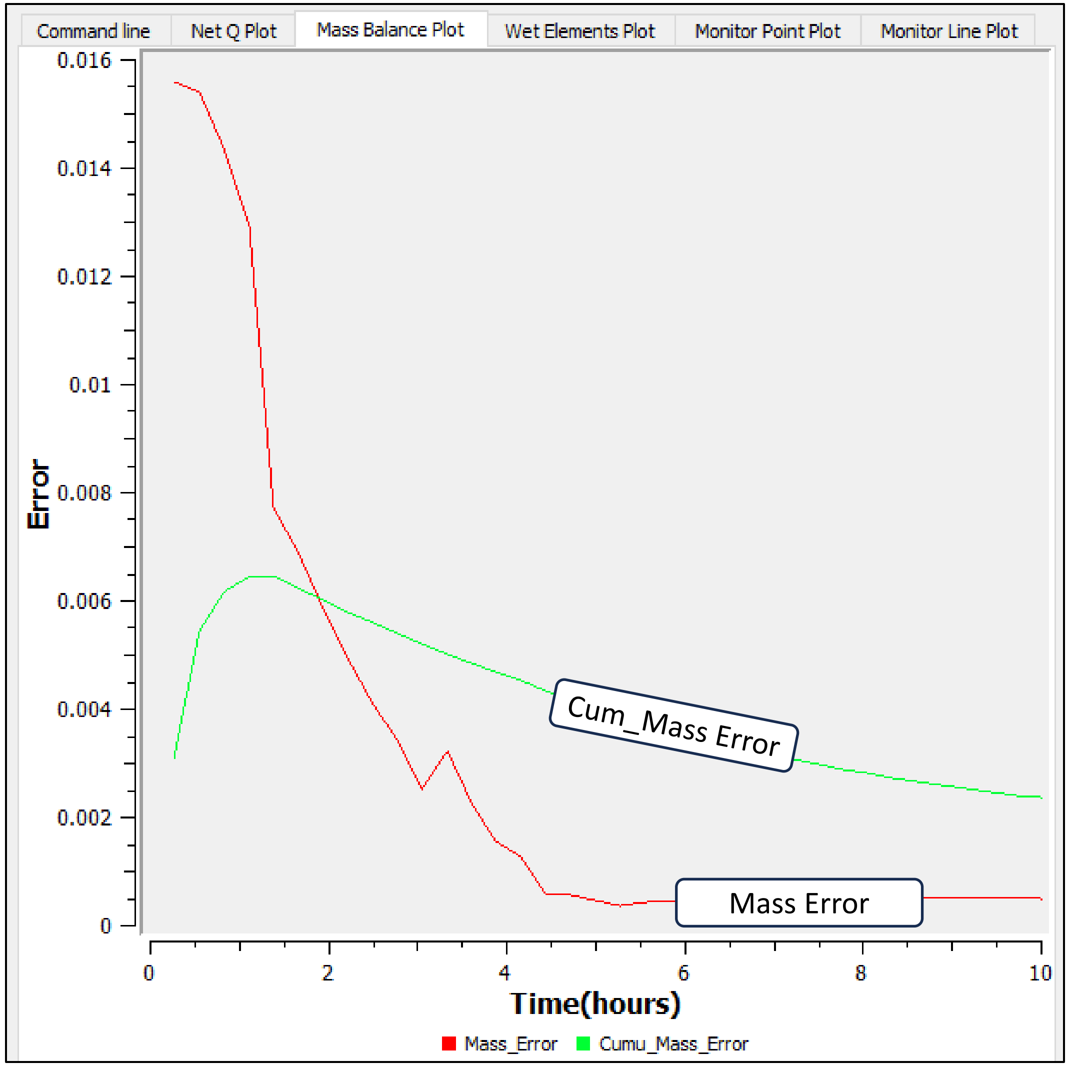




Reviewing Results

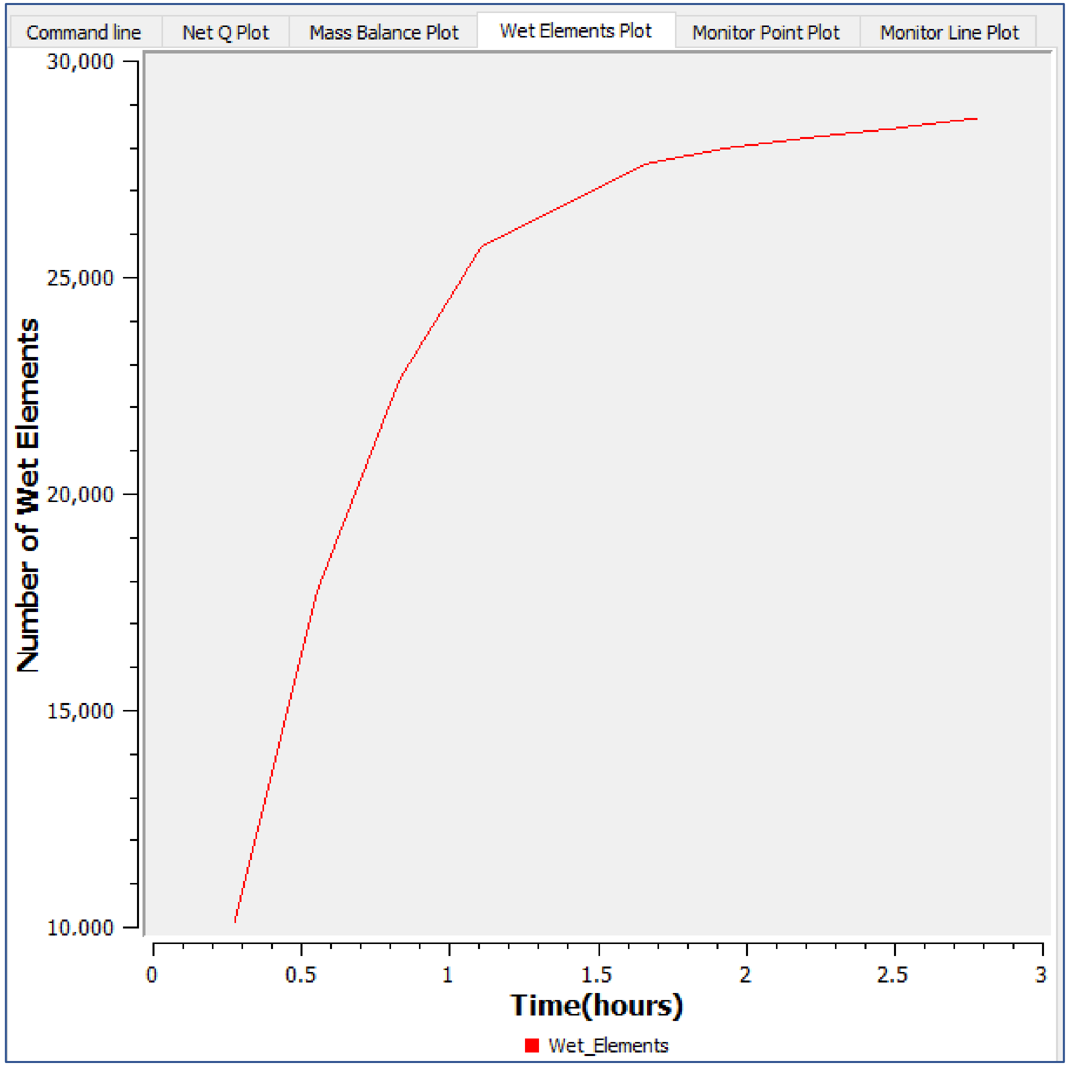
Continuity and Stability

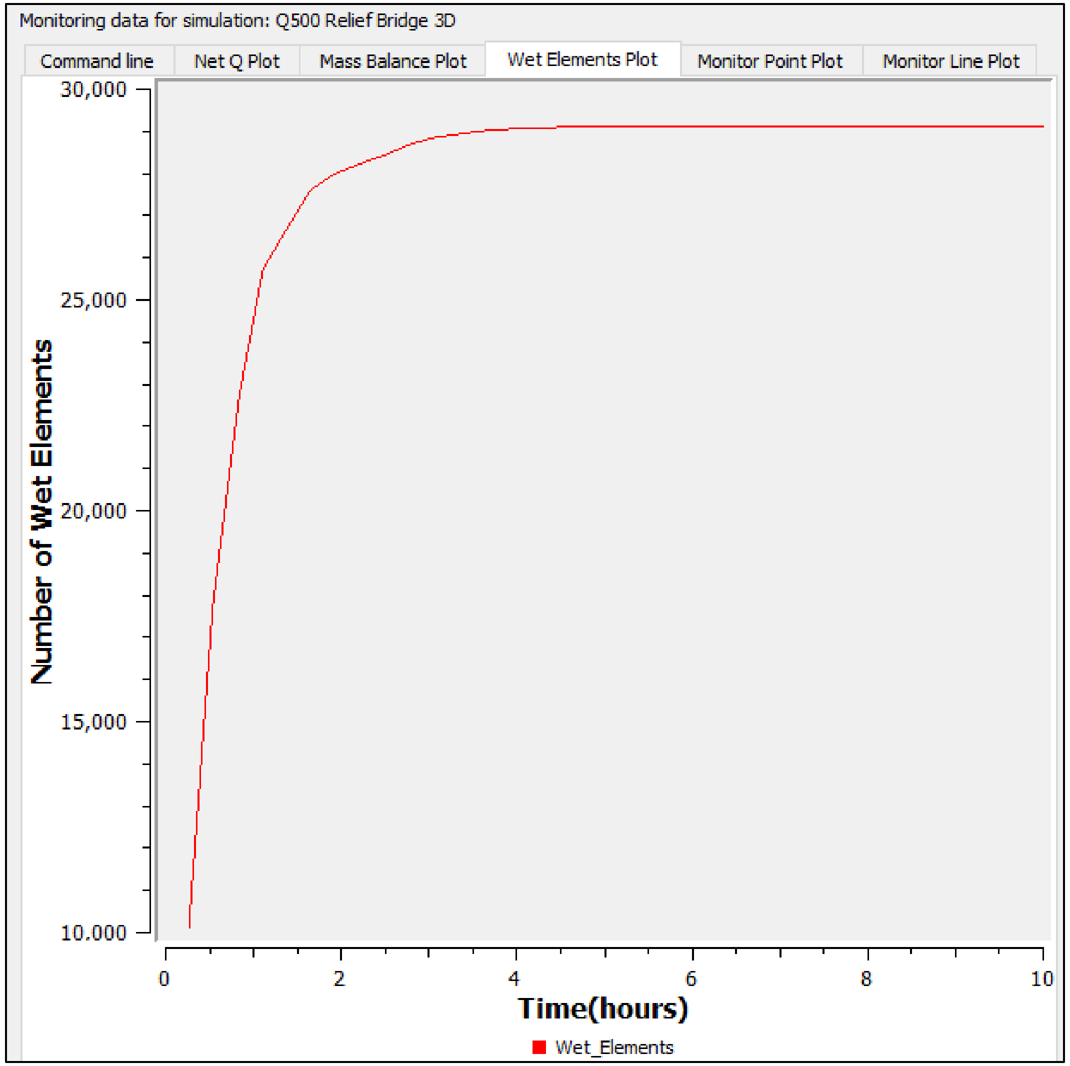




Reviewing Results

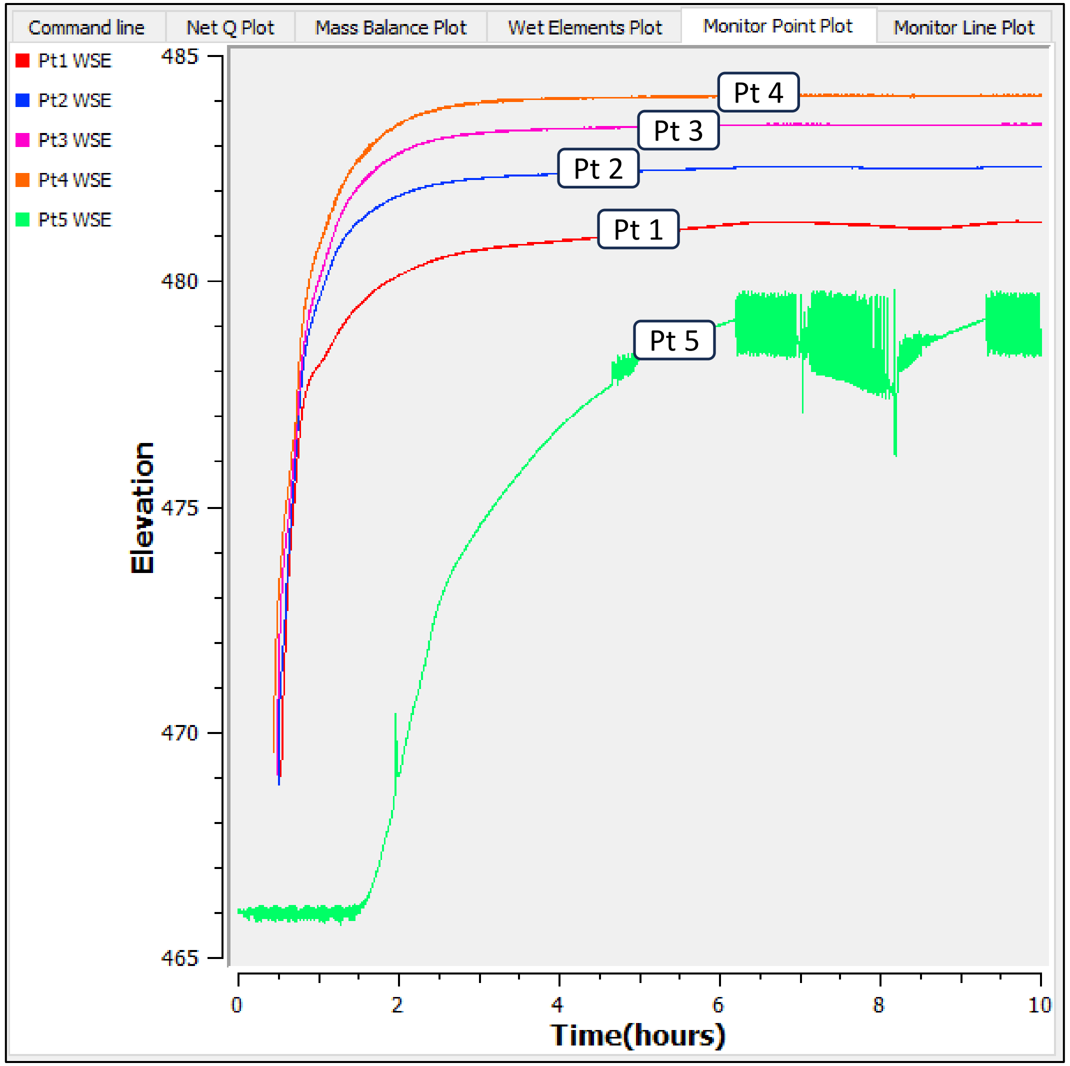
Continuity and Stability

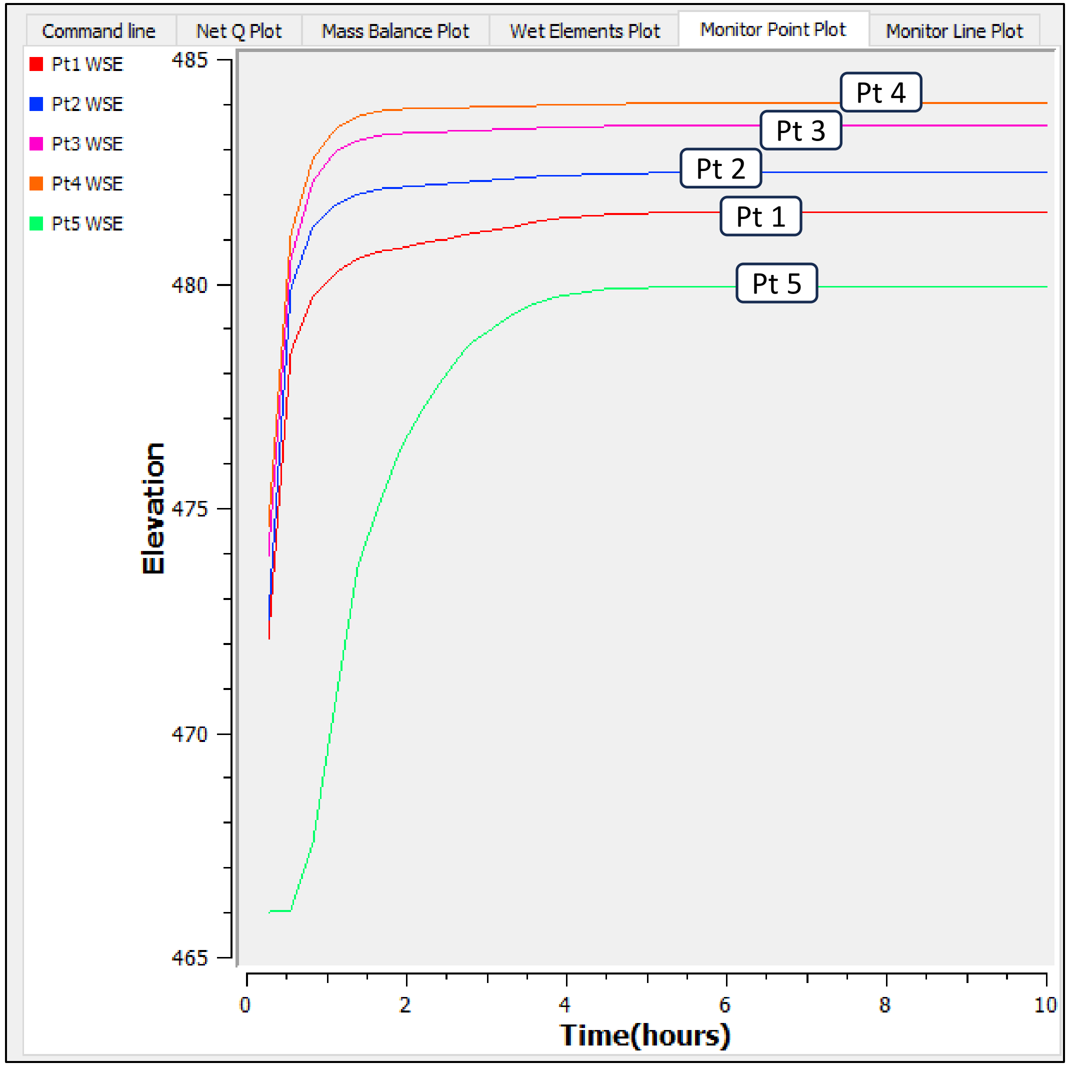




Reviewing Results

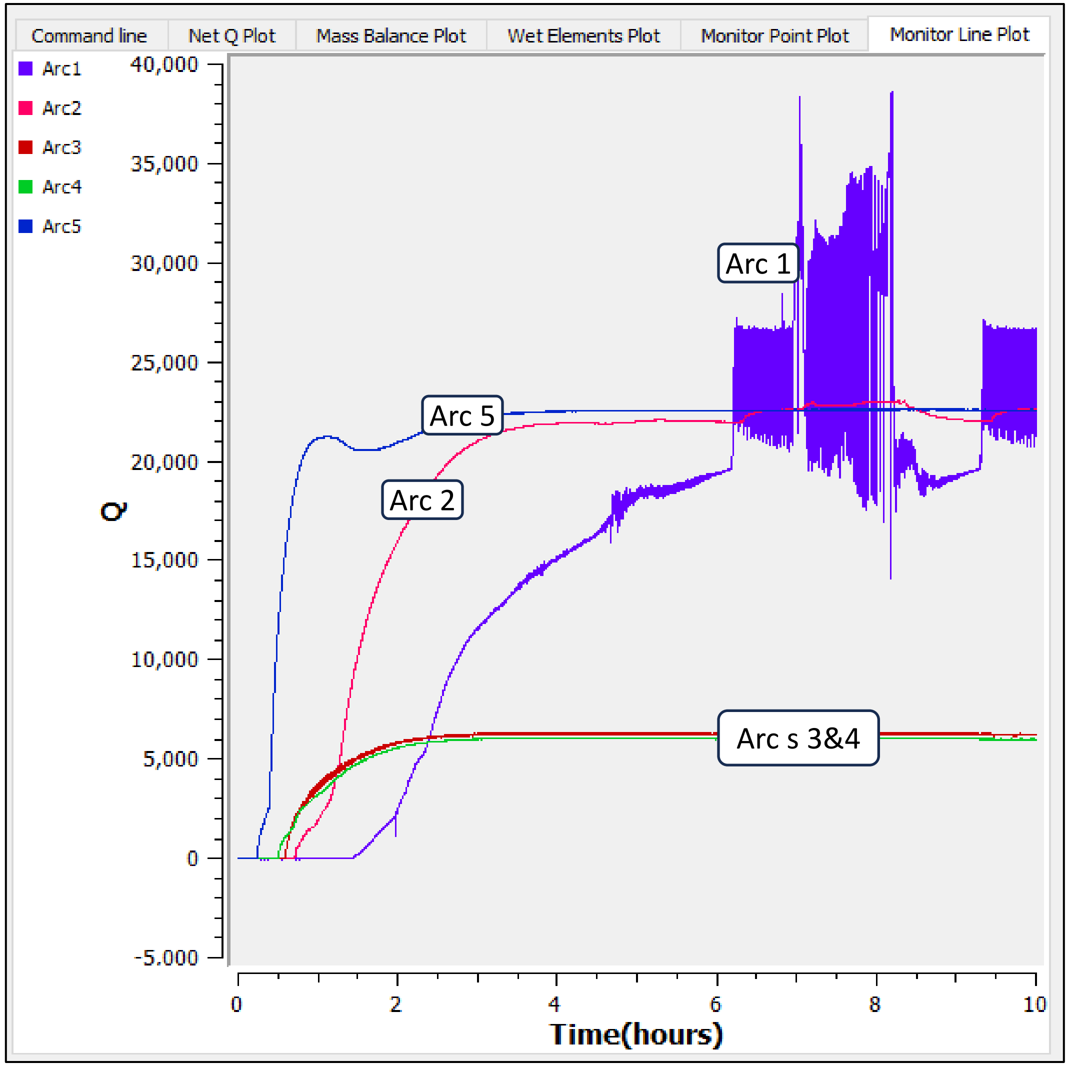
Continuity and Stability

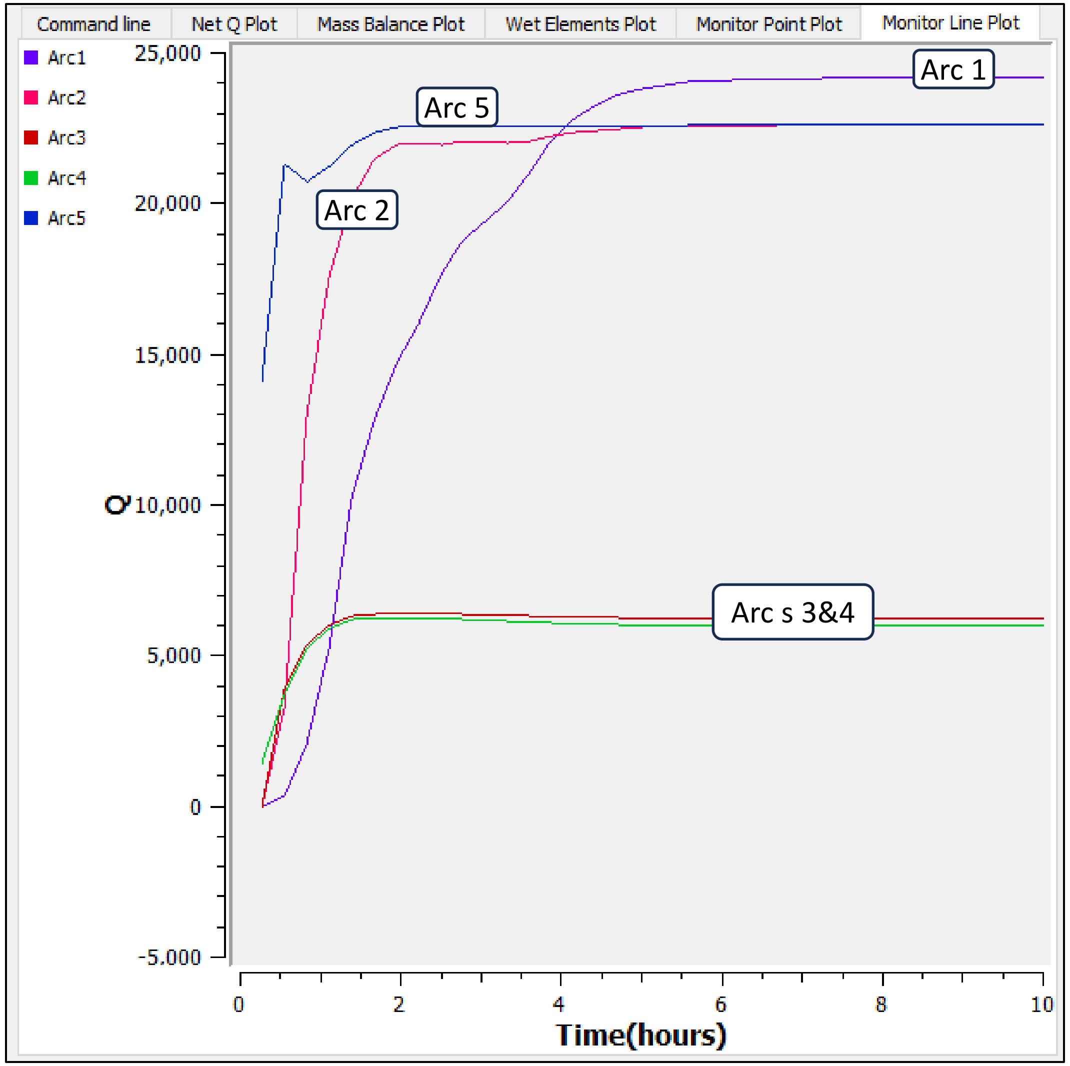




Reviewing Results

Continuity and Stability





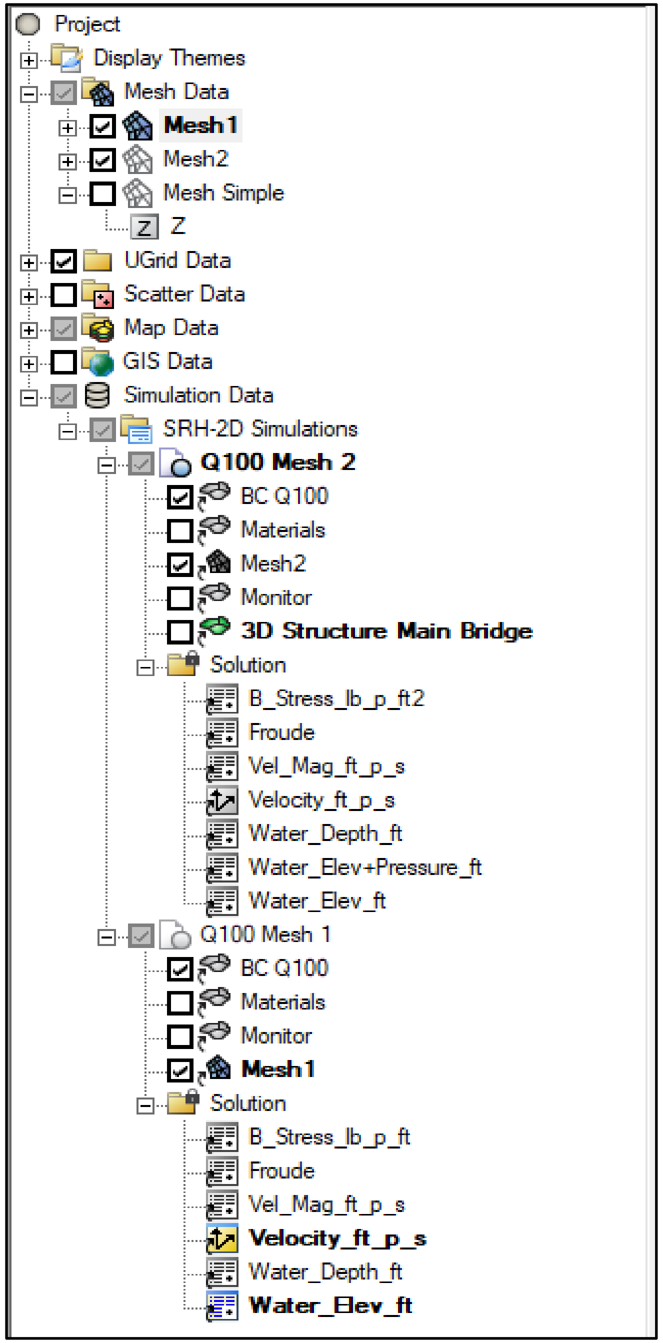
Reviewing Results

Continuity and Stability

Key Question:

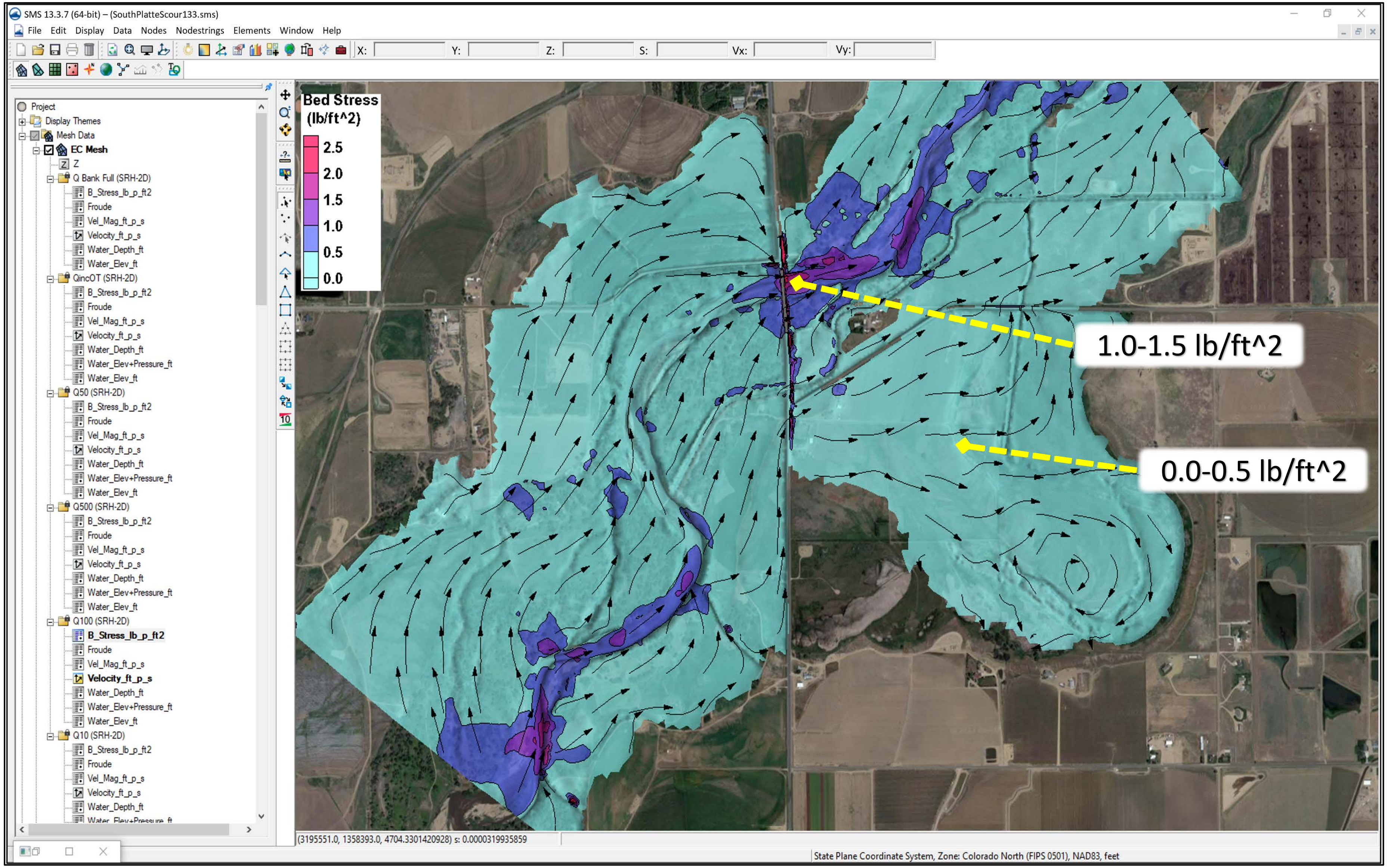
Are the data set results within expected ranges, with no anomalies?

Review the standard SRH-2D simulation output (shear stress, Froude #, velocity, depth, and WSEL)



Reviewing Results

Shear Stress

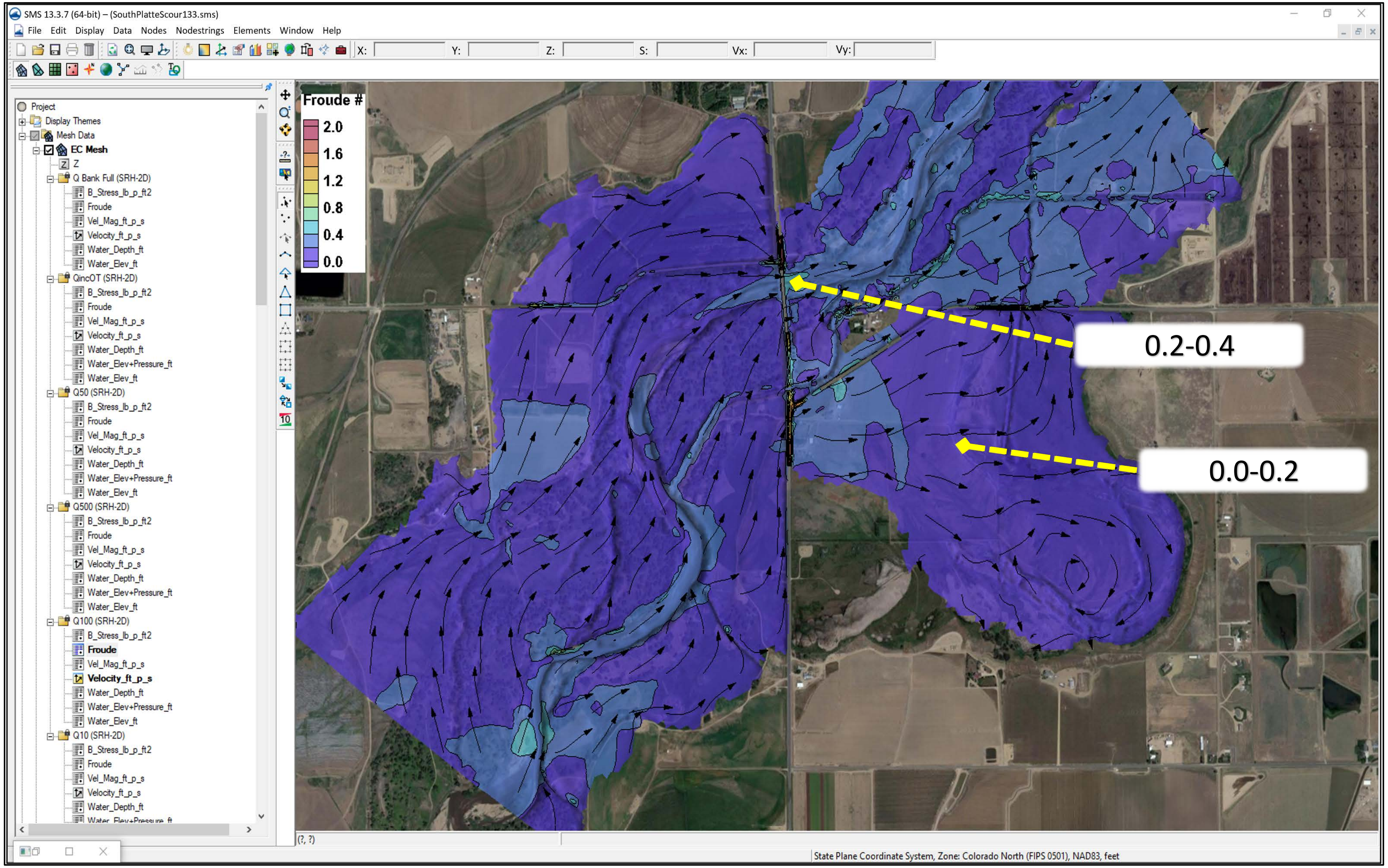


Review min/max values shown in the Simulation Summary Report

Reasonable Ranges of Shear Stress = <5 psf for mild slopes

Reviewing Results

Froude

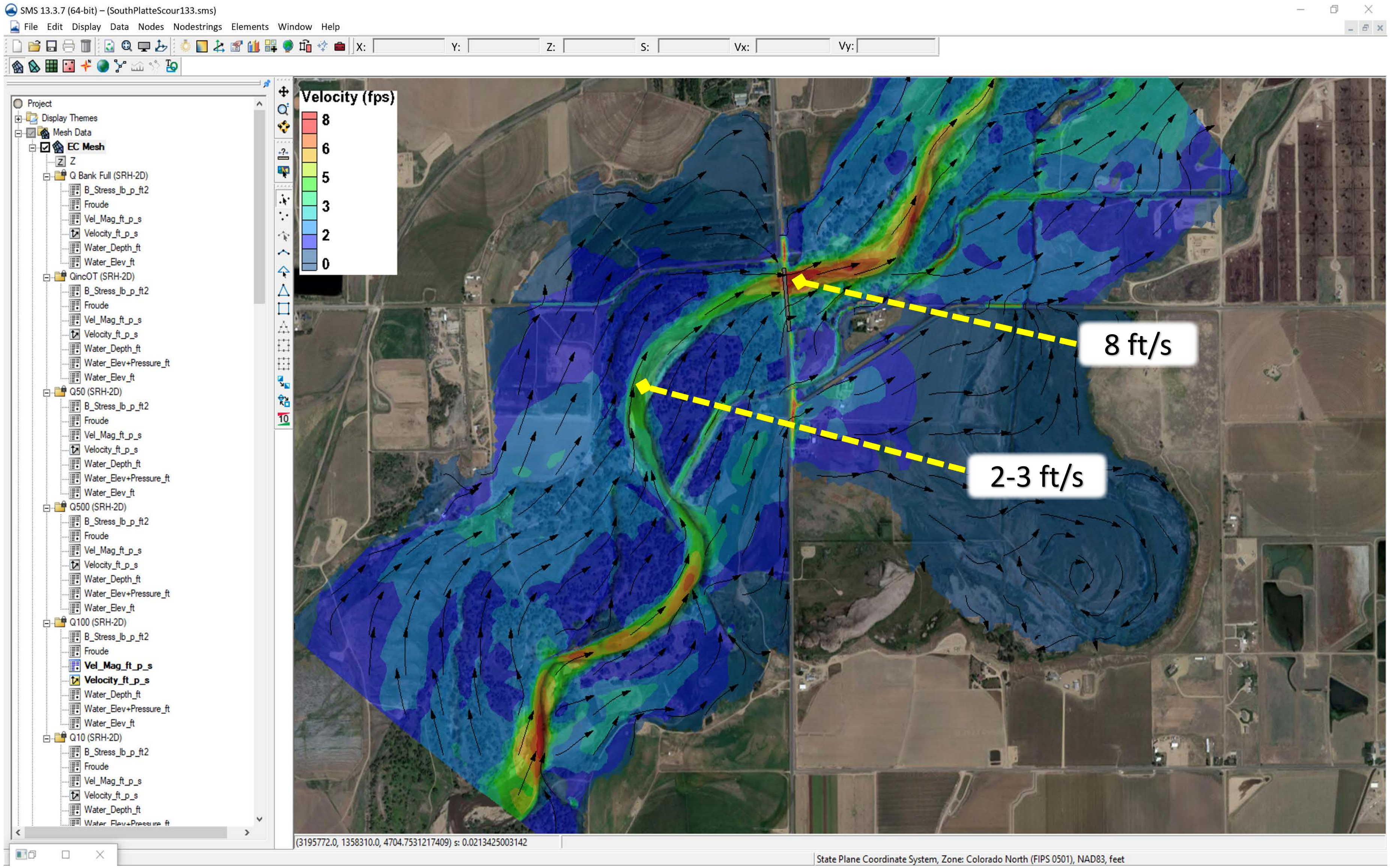


In natural channel Froude #s are generally <1.0 (subcritical), with short sections >1.0 supercritical.

Longer reaches with Froude >1.0 likely indicate a need to use greater the Manning's n values.

Reviewing Results

Velocity



Review min/max values shown in the Simulation Summary Report

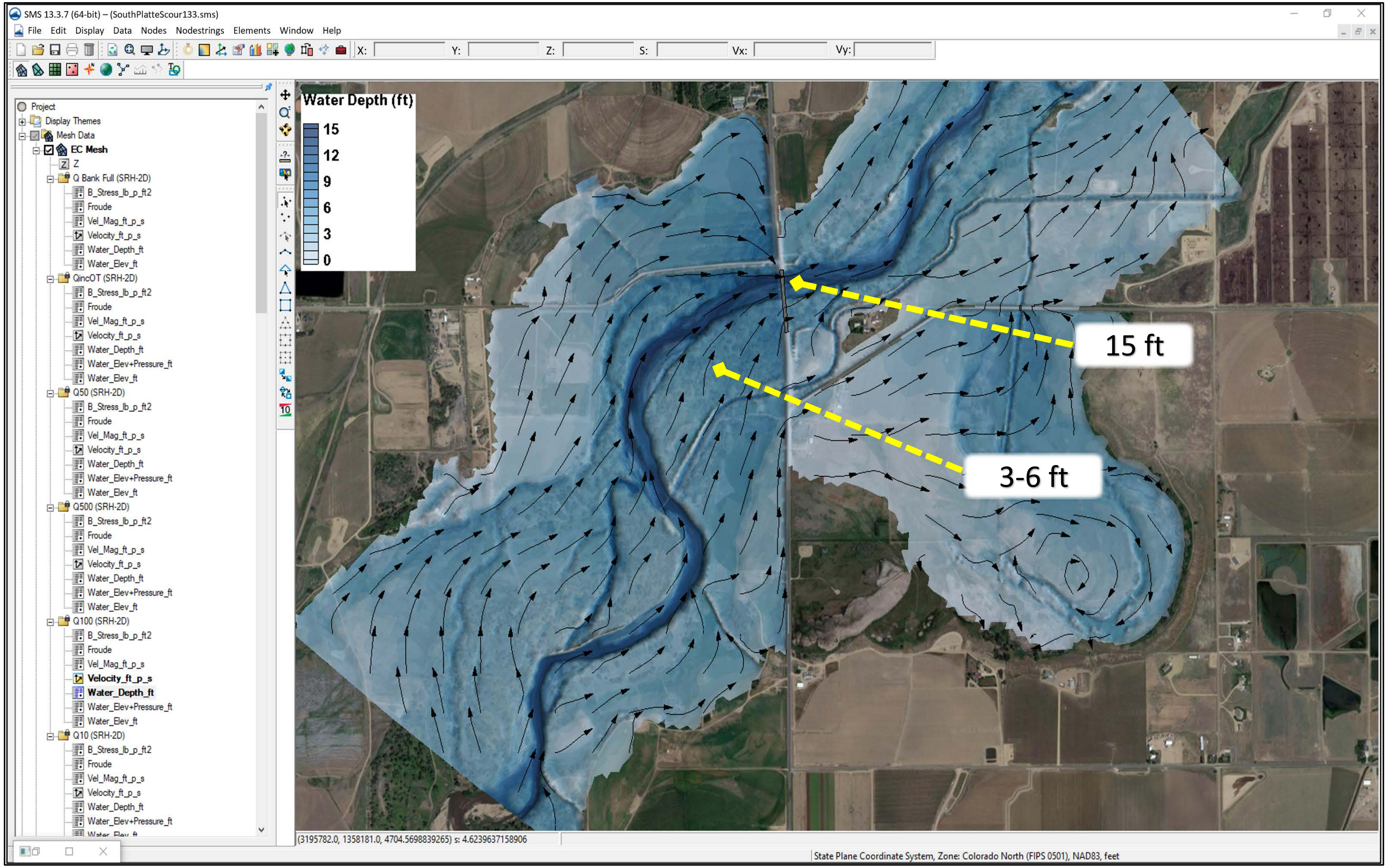
Reasonable velocity range:

0-20 ft/s

Do velocity vectors follow expected flow patterns?

Reviewing Results

Depth



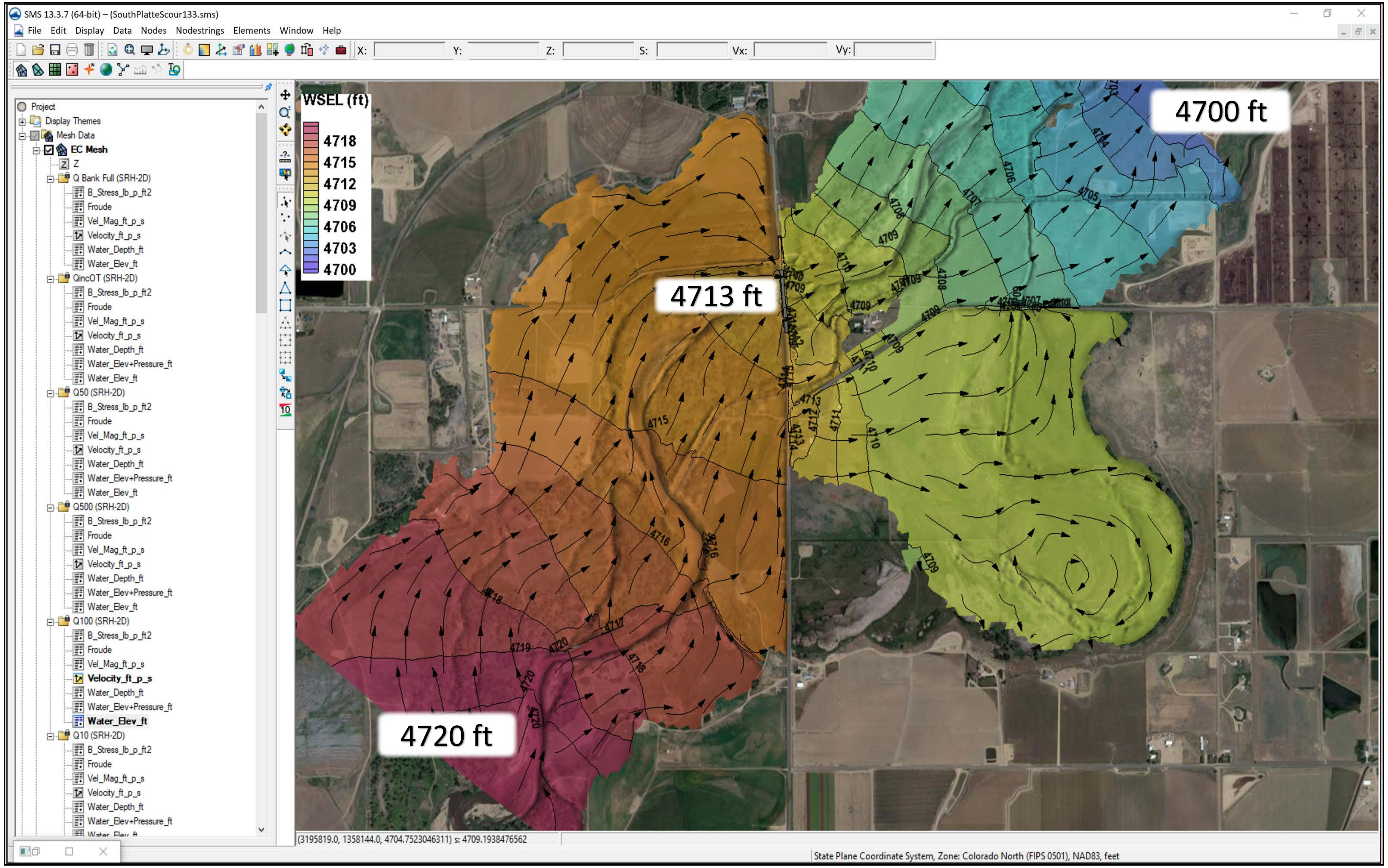
Review min/max values shown in the Simulation Summary Report

Reasonable depth ranges?

Are there any abrupt depth changes in unexpected areas? Indicates possible issue in merging terrain data.

Reviewing Results

Water Surface Elevations



Review min/max values shown in the Simulation Summary Report

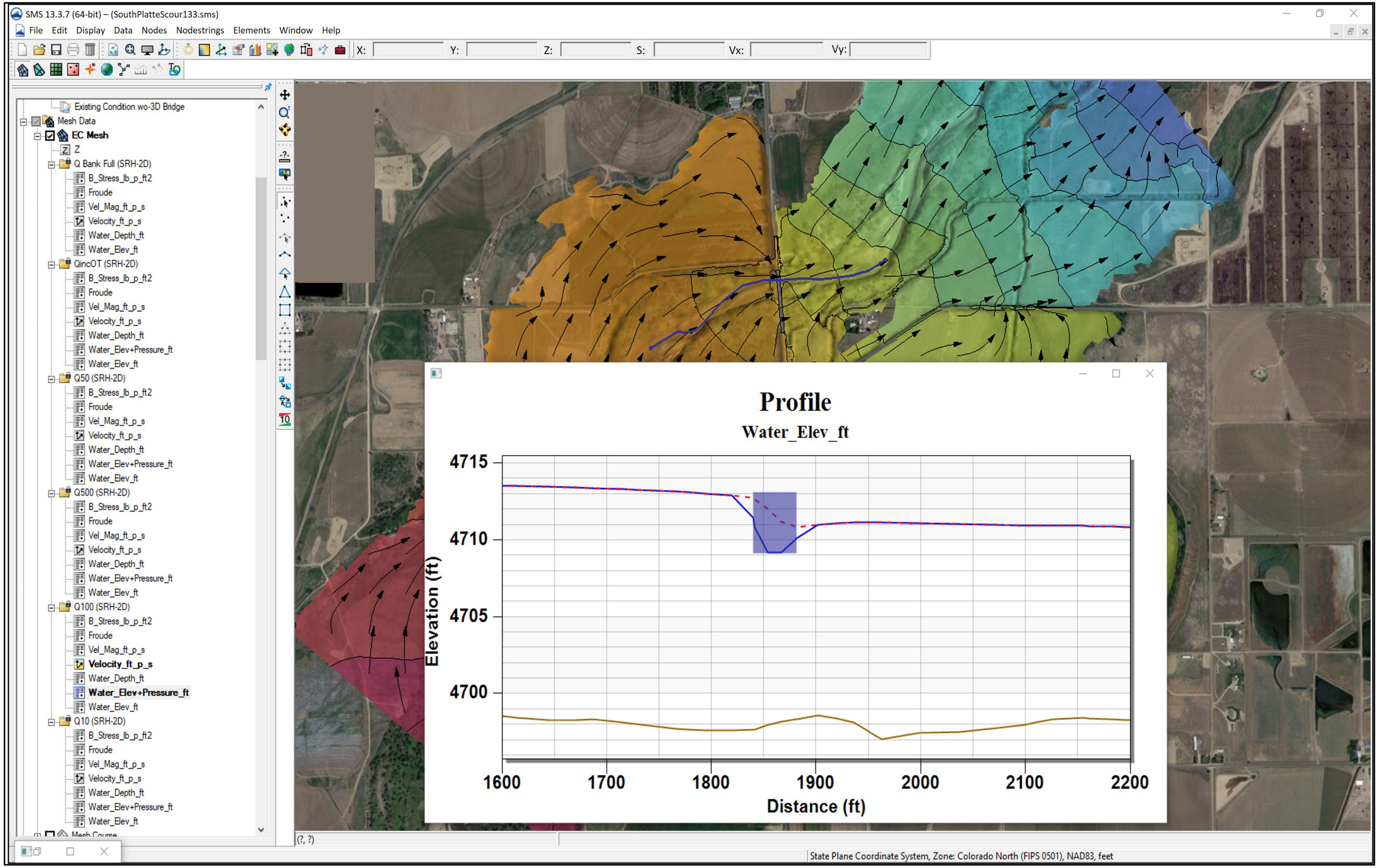
Reasonable WSEL ranges?

Project specific

Look for odd undulations.

Reviewing Results

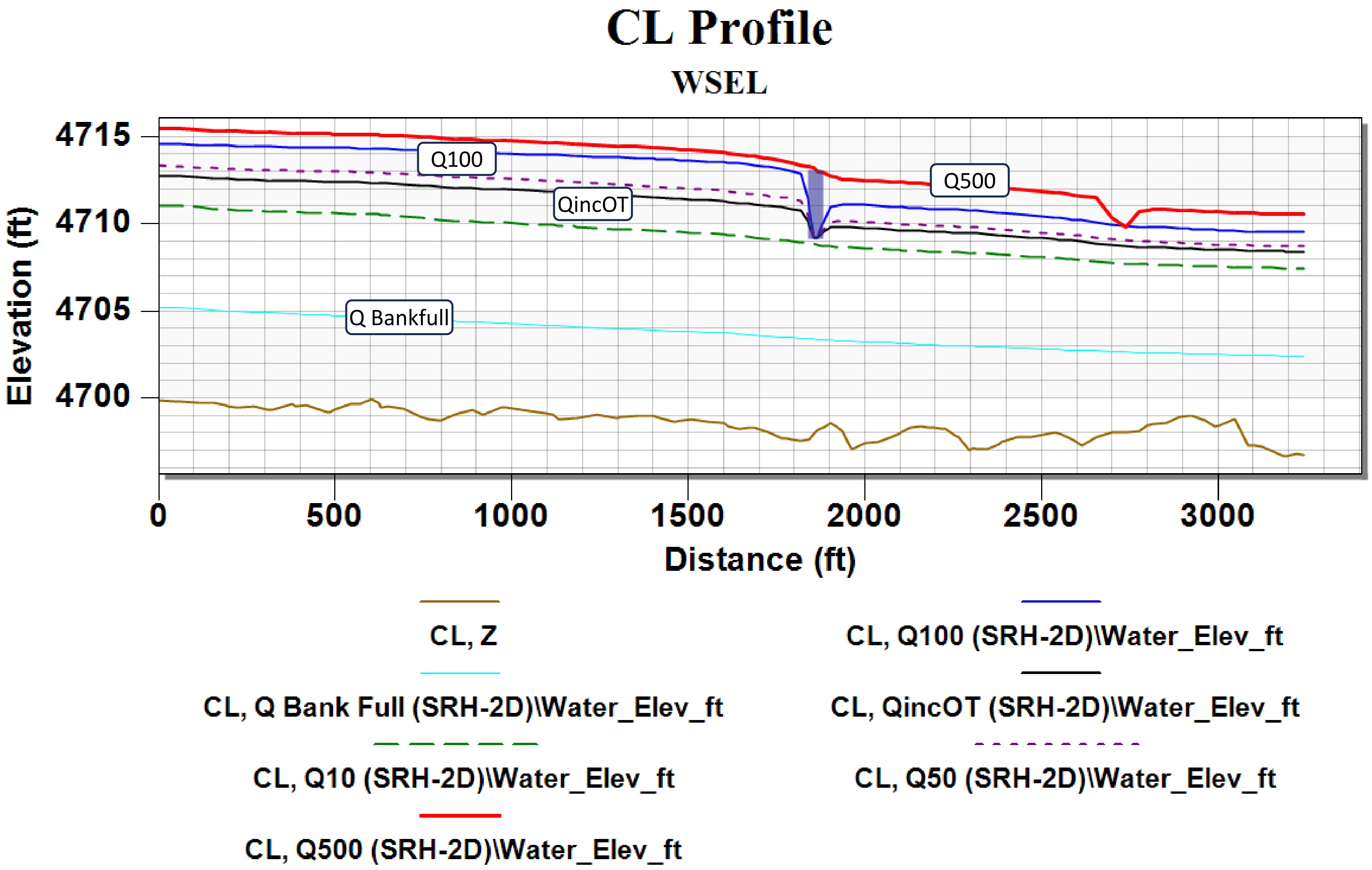
Water Surface Elevations + Pressure



When pressure flow exists, an additional dataset is added to represent the pressure head.

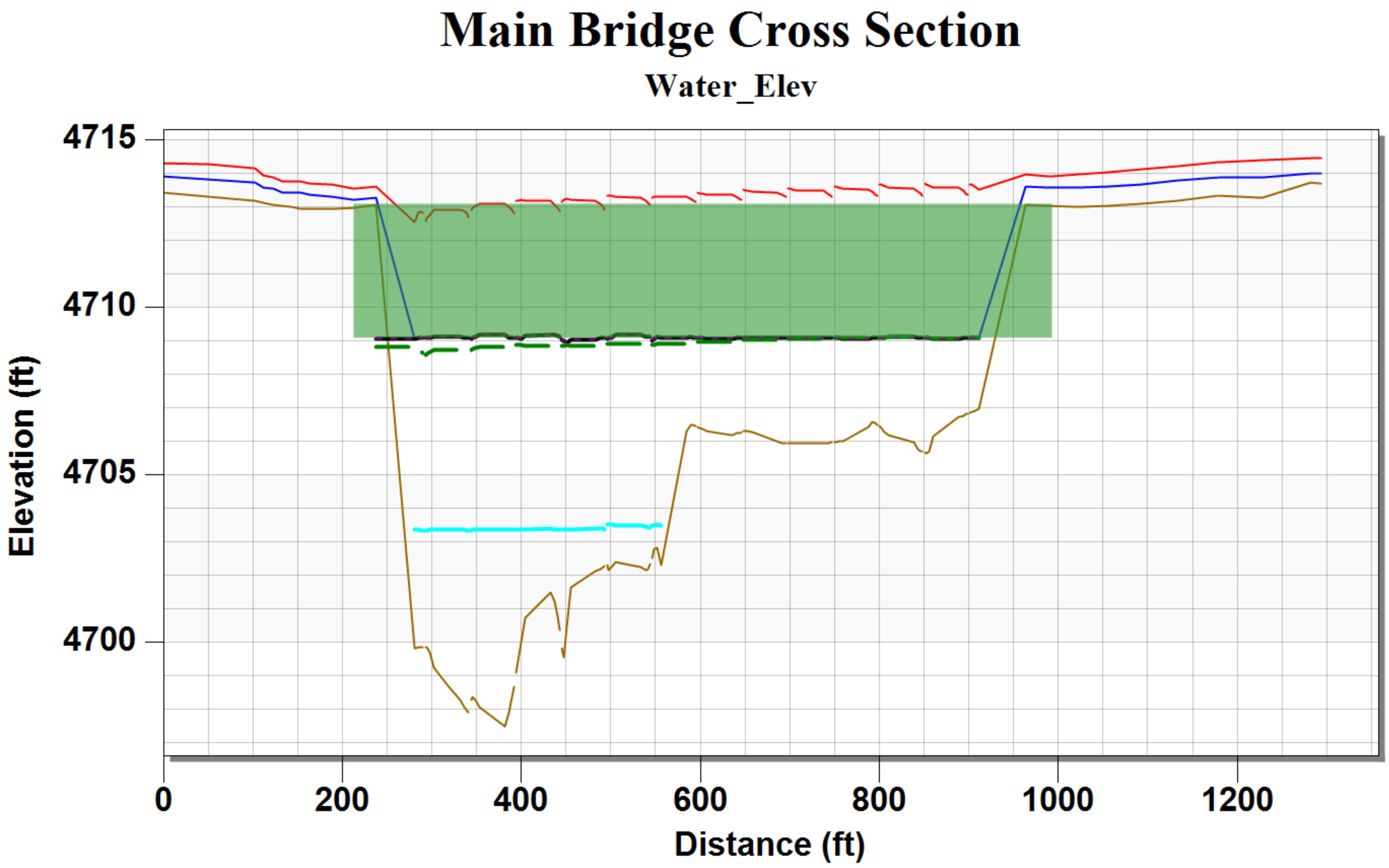
Reviewing Results

Profile and Cross Section Plots



Reviewing Results

Profile and Cross Section Plots



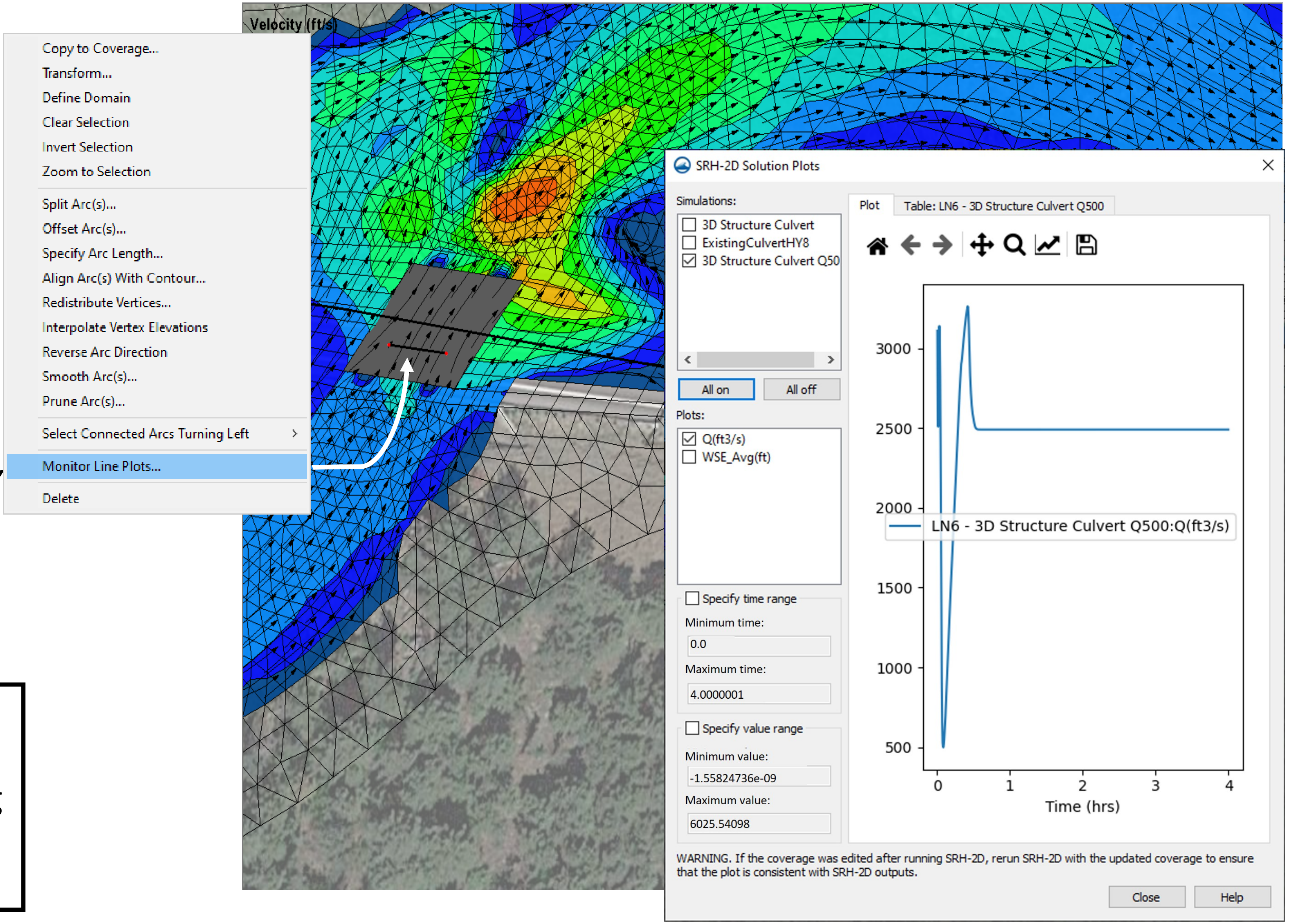
Reviewing Results

Hydraulic Structures – 3D Bridges and Culverts

Review velocities, depths, and WSELs

Confirm flow continuity:

- Structure opening flow
- Structure overtopping flow
- Embankment overtopping flow



To view the flow through the structure opening rt click on a monitoring line crossing the structure opening and select Monitor Line Plots

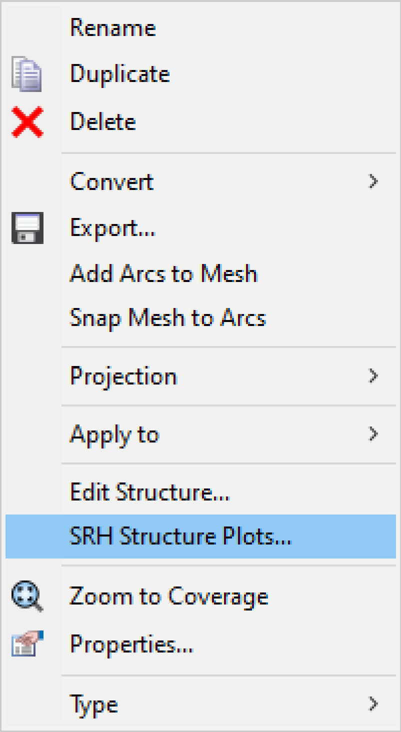
Reviewing Results

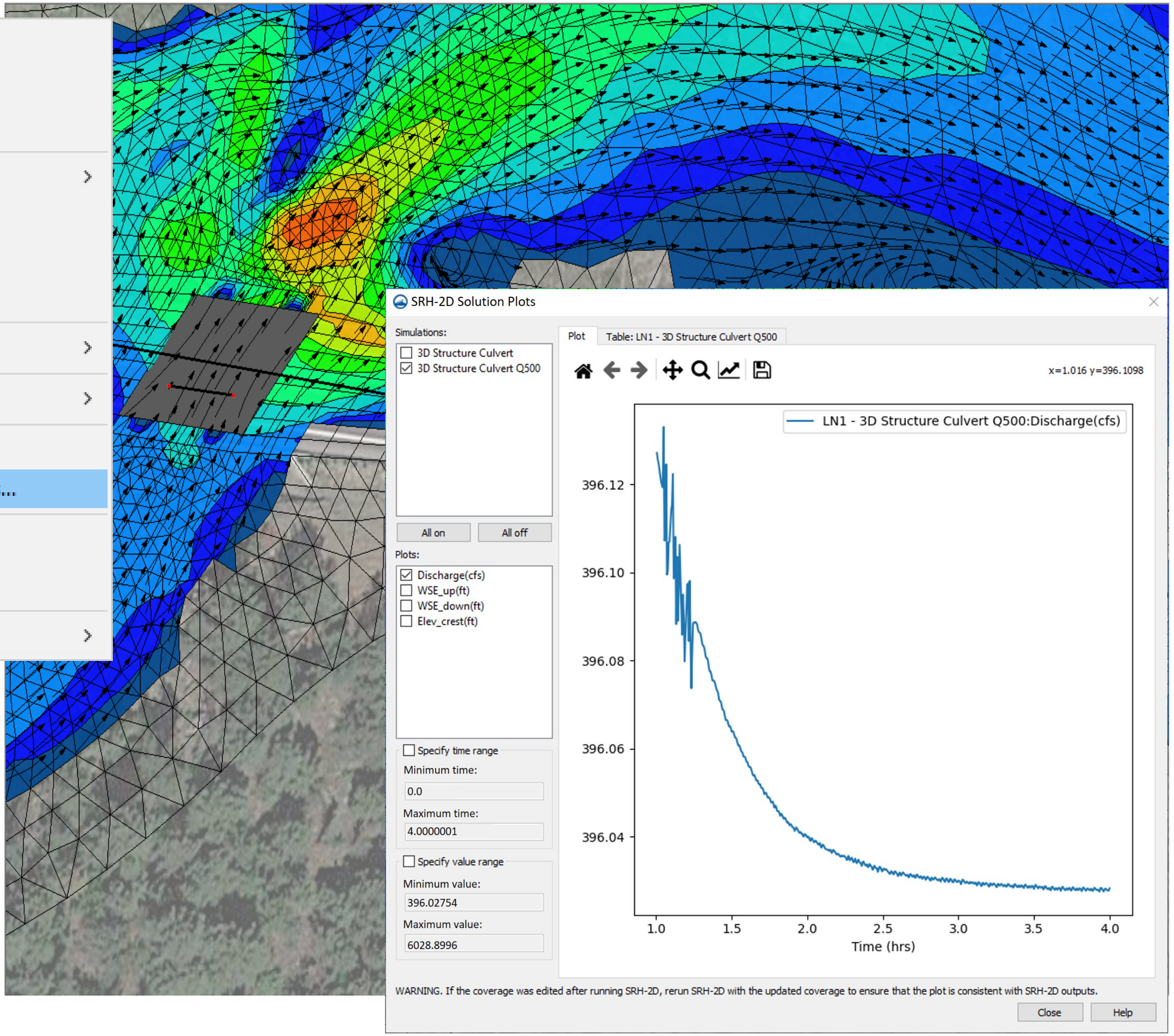
Hydraulic Structures – 3D Bridges and Culverts

Review velocities, depths, and WSELs

Confirm flow continuity:

- Structure opening flow
- Structure overtopping flow
- Embankment overtopping flow





To view the structure overtopping flow
rt click on the 3D structure coverage and select SRH Structure Plots

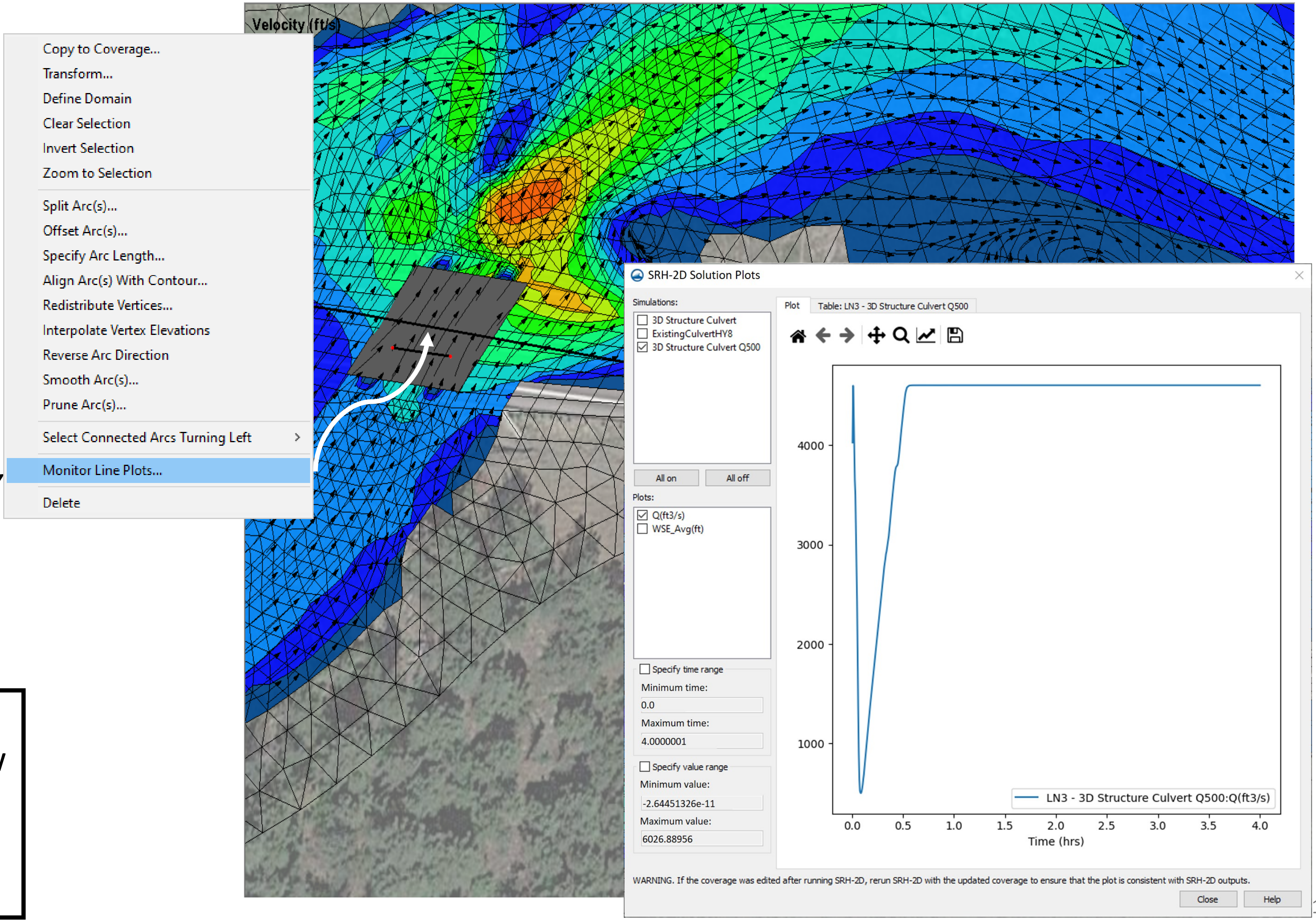
Reviewing Results

Hydraulic Structures – 3D Bridges and Culverts

Review velocities, depths, and WSELs

Confirm flow continuity:

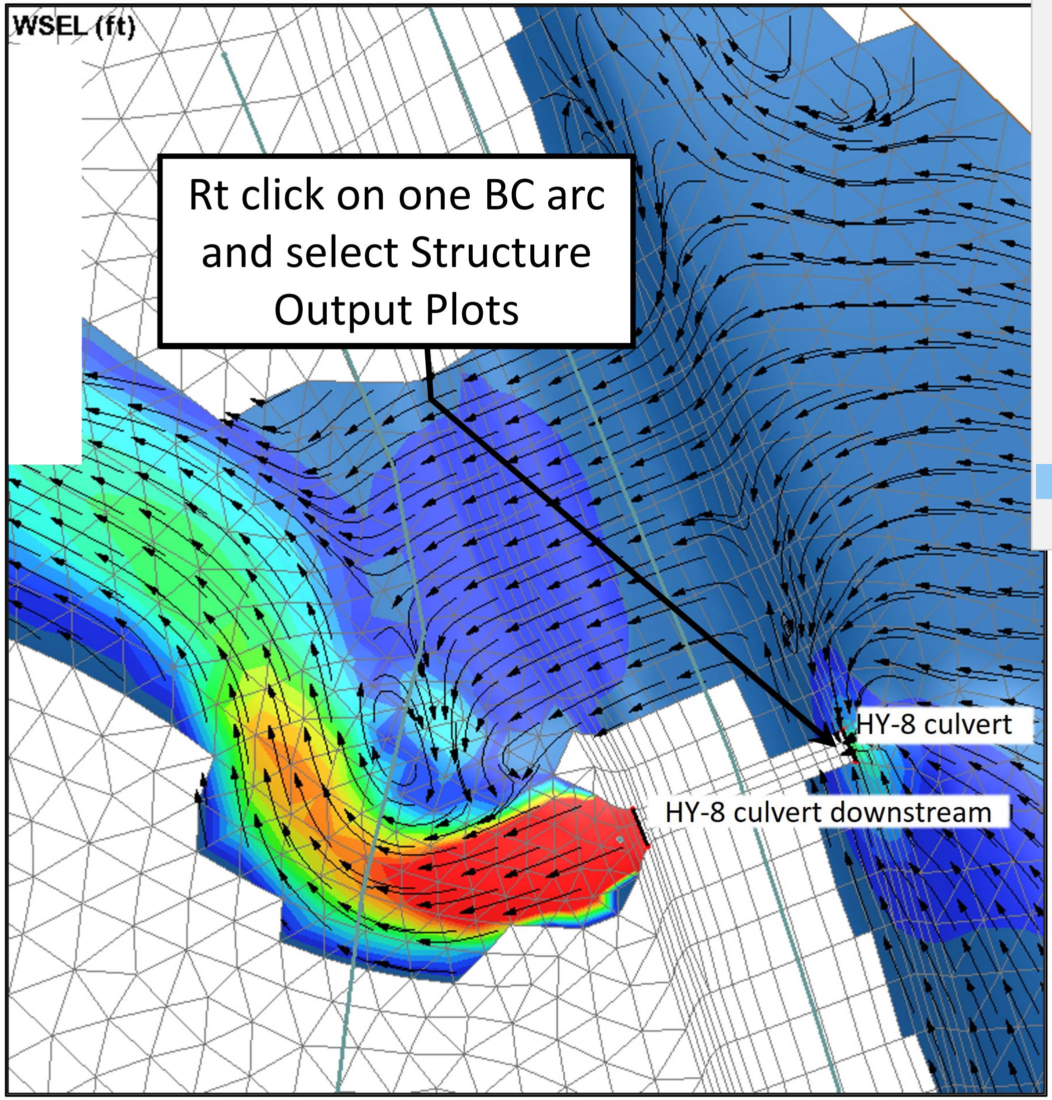
- Structure opening flow
- Structure overtopping flow
- Embankment overtopping flow

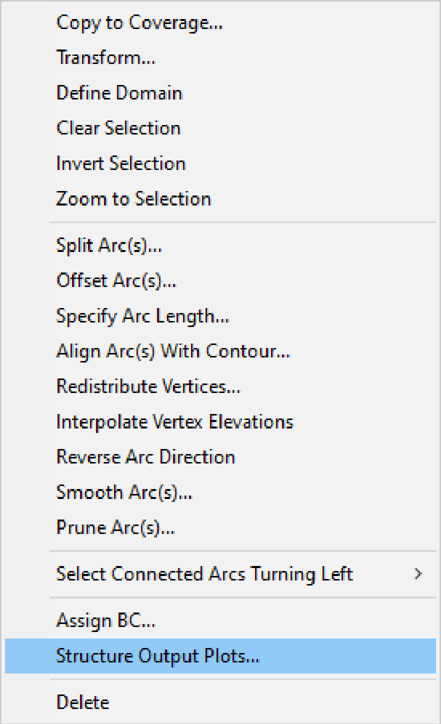


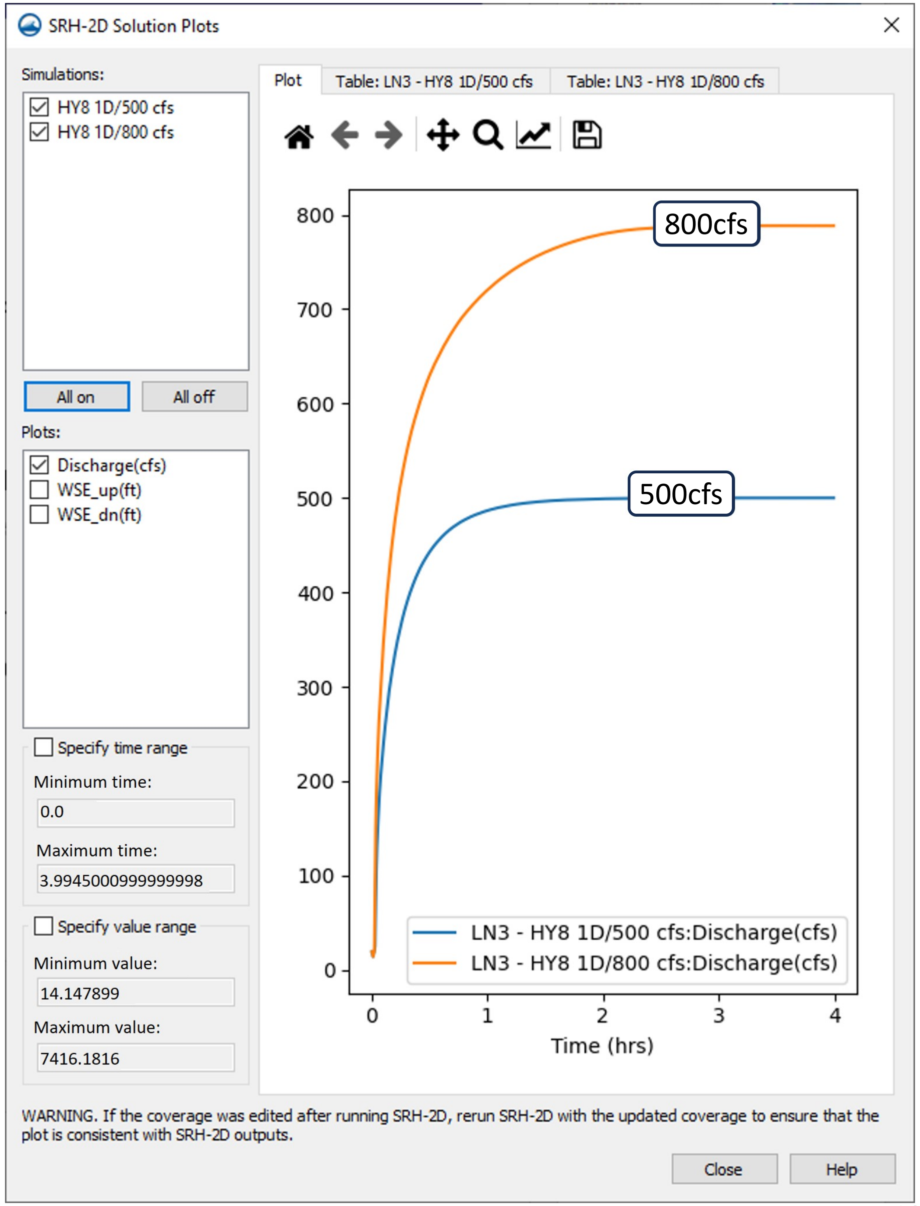
To view the embankment overtopping flow + the opening flow rt click on a monitoring line along the embankment and select Monitor Line Plots

Reviewing Results

Hydraulic Structures – HY-8 Culverts

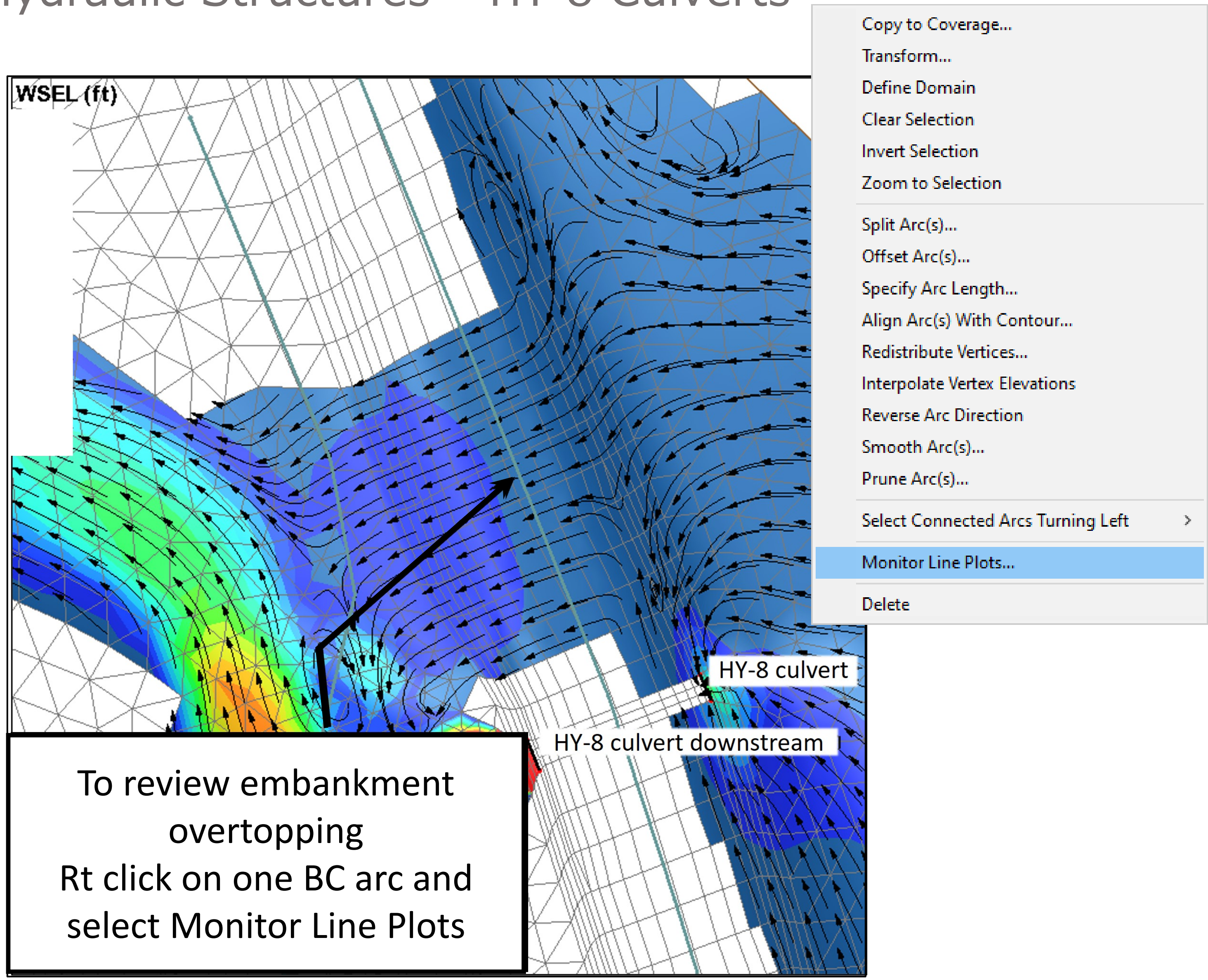




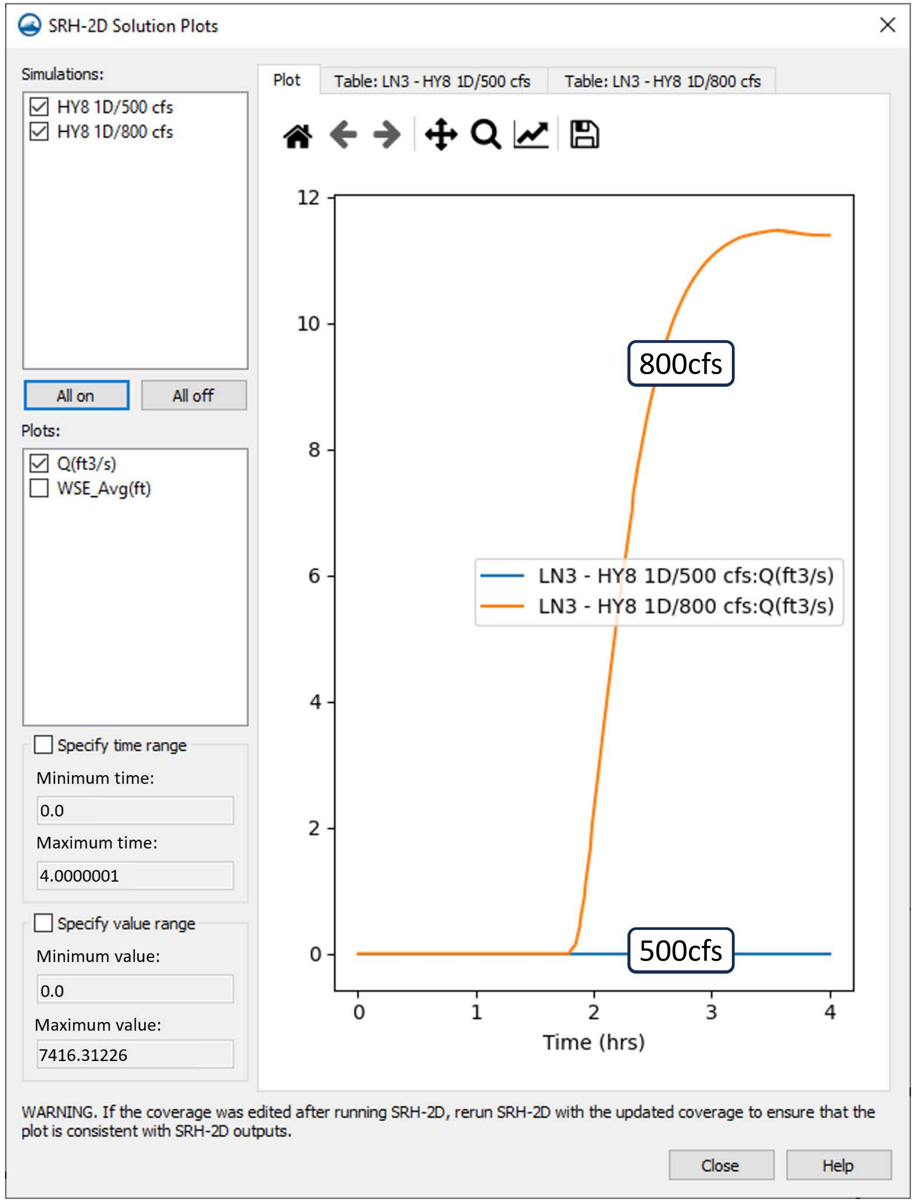


Reviewing Results

Hydraulic Structures – HY-8 Culverts



To review embankment overtopping
Rt click on one BC arc and select Monitor Line Plots



Key Results Review Questions

- Are continuity and stability preserved throughout the domain?
- Are the data set results within expected ranges, with no anomalies? (velocity, depth, WSEL, Shear Stress, and Froude#)
- Water surface / ground profile and cross section plots
- Data set comparisons (existing vs. proposed, baseflow vs. floodway, etc.)

2D Model Review Training Agenda

Session 3

- *Review Exercises 2 & 3*
- Reviewing Model Results
- **Hydraulic Variables for Bridge Scour Analyses**
- Wrap-up

Recommended Training:

- FHWA Bridge Scour Workshop – 8-hour refresher course
- NHI 135046 Stream Stability and Scour at Highway Bridges

Image from PowerPoint online images by Peter Baumgartner

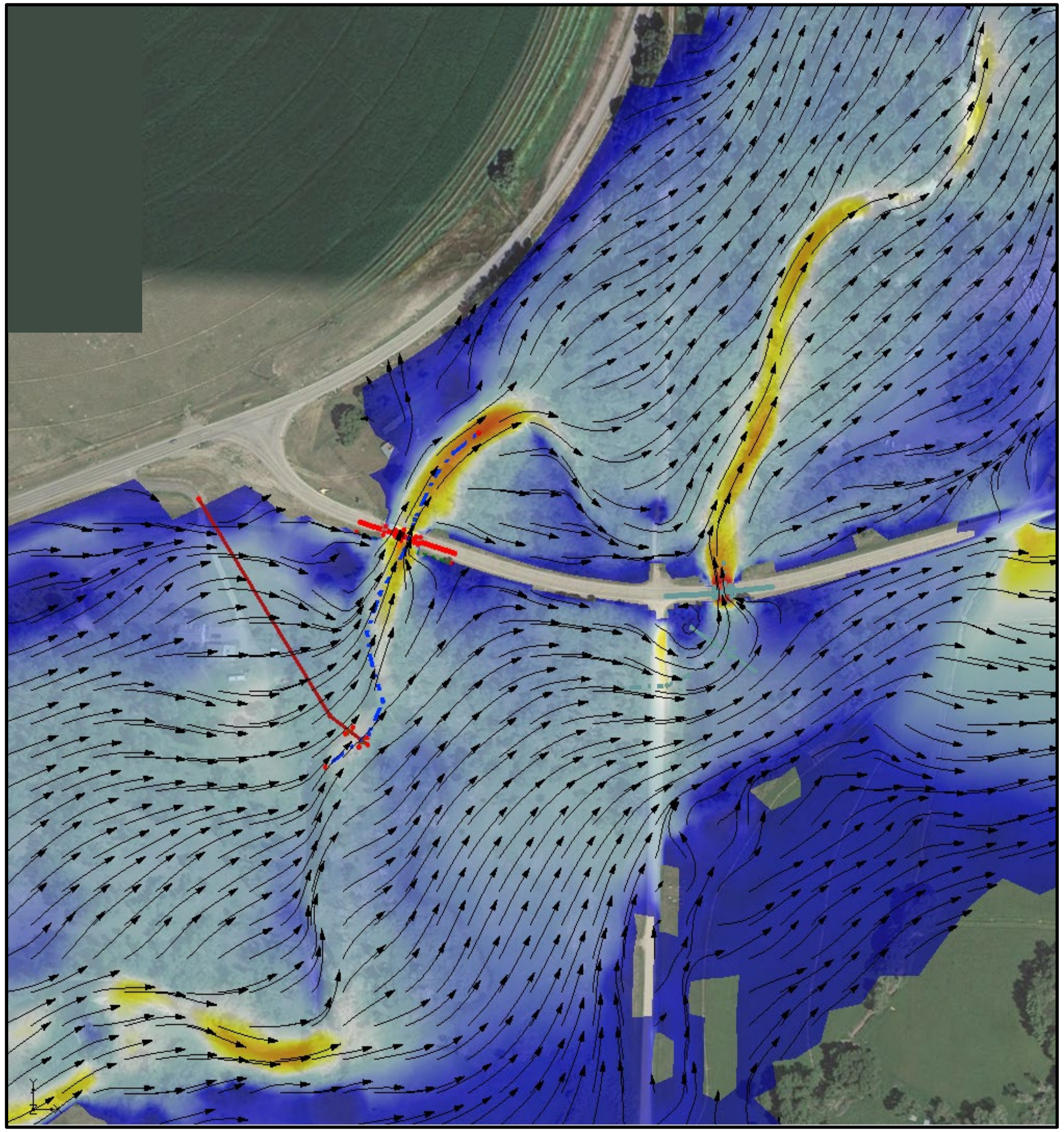
Reviewing Bridge Scour Hydraulics Top 3 Things

1. Review sources of material gradations
2. Verify approach and contracted section locations
3. Confirm that averaged hydraulic conditions are used (except for pier scour)

Bridge Scour Hydraulic Variables Review

Recommended Information

- Multiple events (3-5) are recommended to assess the worst- case scour potential.
- The Q50, Q100 and Q500 should be evaluated for most analyses. Incipient embankment overtopping could also be considered, and others that may result in worst-case conditions.
- Channel bed gradations are needed for the contracted section and the approach section.
- A channel bed sample at the contracted section may be used to represent the approach section if field investigations conclude they are similar.



Bridge Scour Hydraulic Variables Review

Overview of Hydraulic Variables

Critical Velocity $V_c = K_u \mathbf{y}^{1/6} D^{1/3}$

Contraction Scour

Live Bed Condition

$$y_s = \mathbf{y_1}\left(\frac{\mathbf{Q_2}}{\mathbf{Q_1}}\right)^{6/7}\left(\frac{\mathbf{W_1}}{\mathbf{W_2}}\right)^{\mathbf{k_1}} - \mathbf{y_0}$$

Clear Water Condition

$$y_s = \left(\frac{K_u \mathbf{Q}^2}{Dm^{2/3}\mathbf{W}^2}\right)^{3/7} - \mathbf{y_0}$$

Abutment Scour

$$y_{max} = \alpha_{A/B}\mathbf{y_1}\left(\frac{\mathbf{q_{2c}}}{\mathbf{q_1}}\right)^{6/7}$$

$$y_{max} = \alpha_{A/B}\left(\frac{\mathbf{q_{2f}}}{K_u D_{50}^{1/3}}\right)^{6/7}$$

Pier Scour

$$y_s = 2.0\, K_1\, K_2\, K_3 \left(\frac{a}{\mathbf{y_p}}\right)^{0.65} Fr_1^{0.43} \qquad \left(Fr_1 = \frac{\mathbf{V_p}}{(g\mathbf{y_p})^{0.5}}\right)$$

y=average depth
Q = discharge
W = width of flow
q = unit discharge

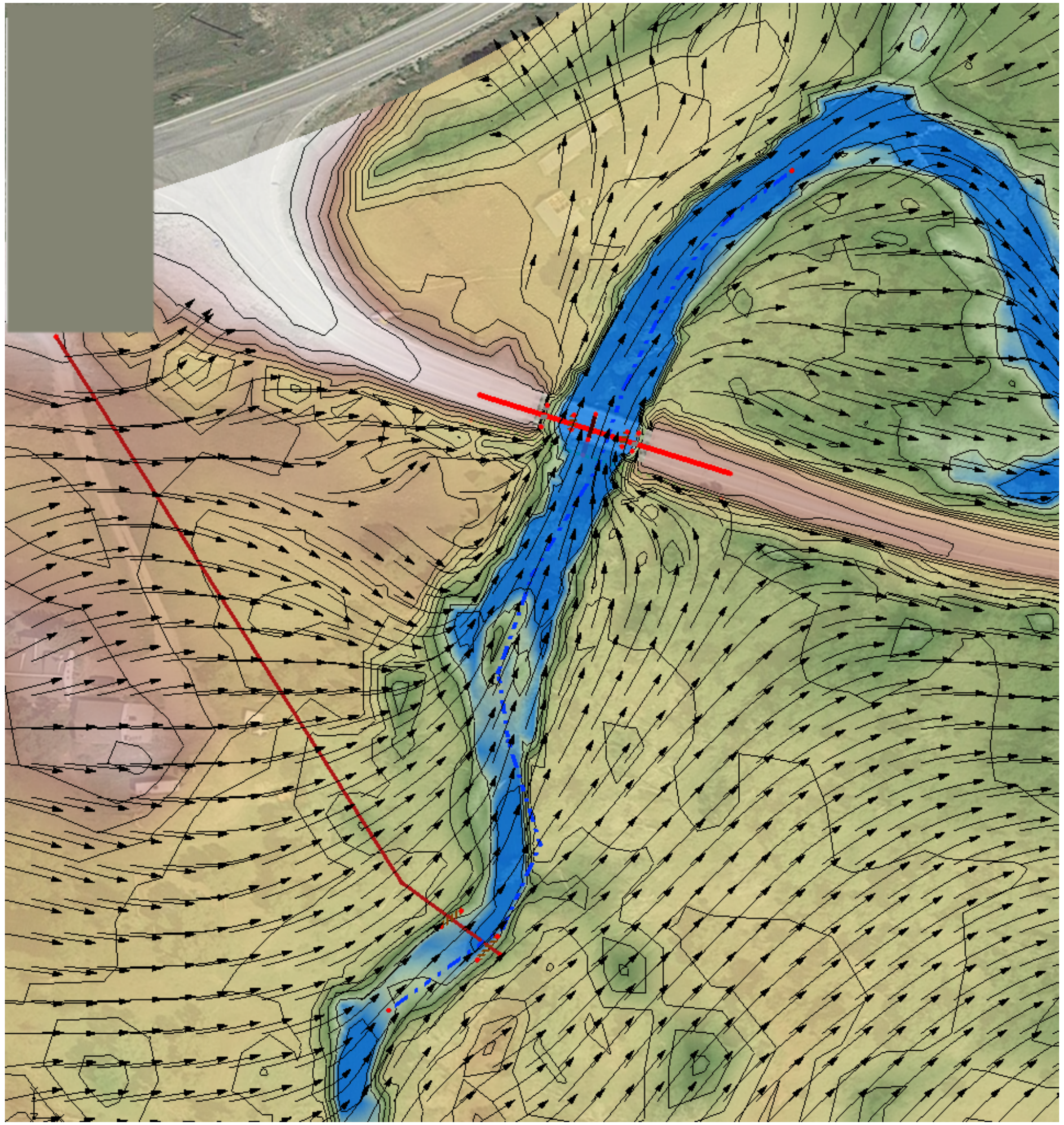
1 = Approach Section
2 = Contracted Section

Reference: HEC-18 5th Edition

Bridge Scour Hydraulic Variables Review

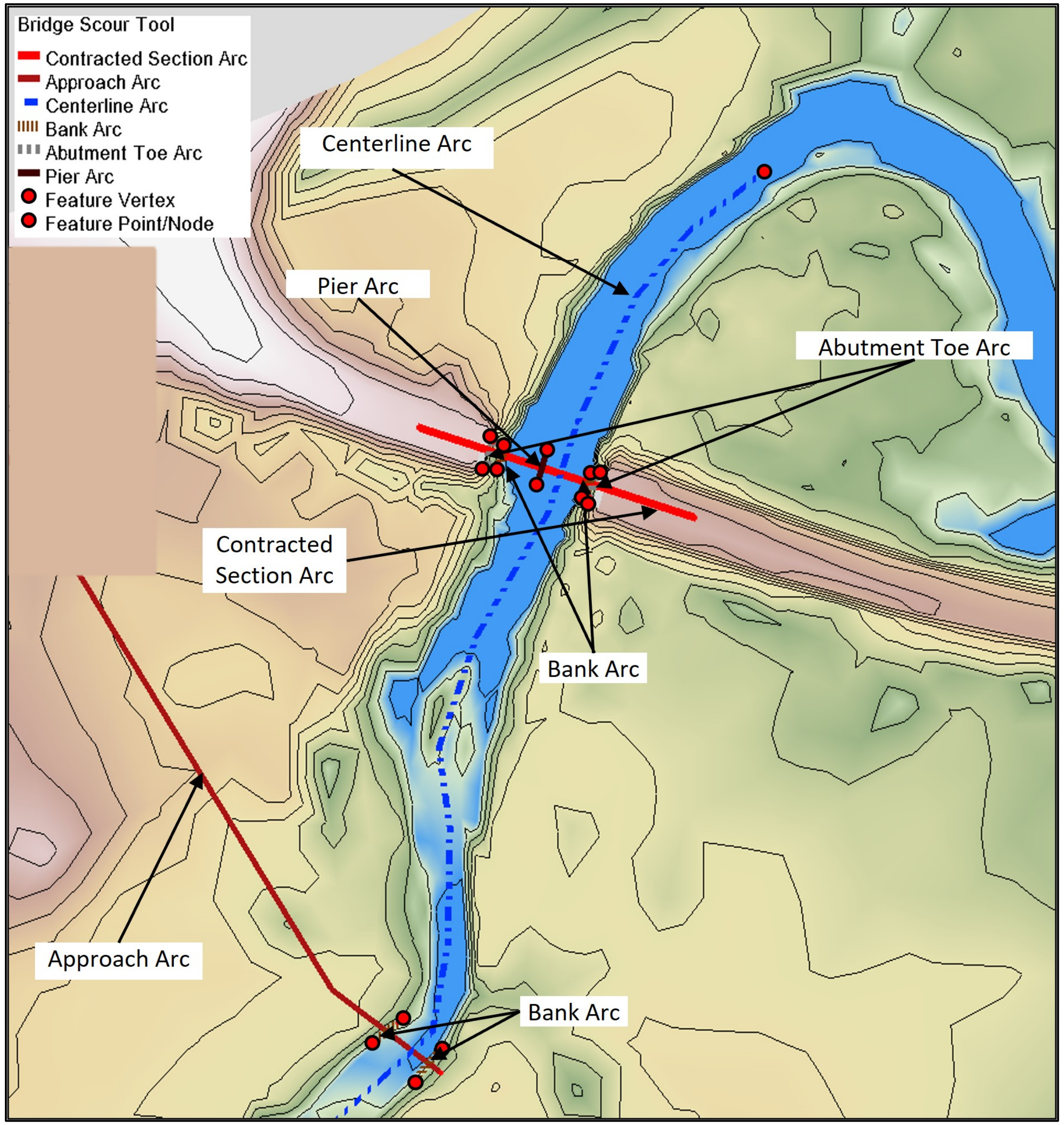
Contracted and Approach Sections

- **Contracted section** represents the flow characteristics and channel section at the maximum constriction (Bridge location)
- **Approach section** represents the hydraulic conditions and sediment transport approaching the bridge, prior to the overbank being redirected toward the channel
- The approach section should span the width of flow contributing to each bridge
- The hydraulic conditions in the main channel at the approach section determine a live-bed or clear-water scour condition



Bridge Scour Hydraulic Variables Review

Defining Main Channel and Overbanks

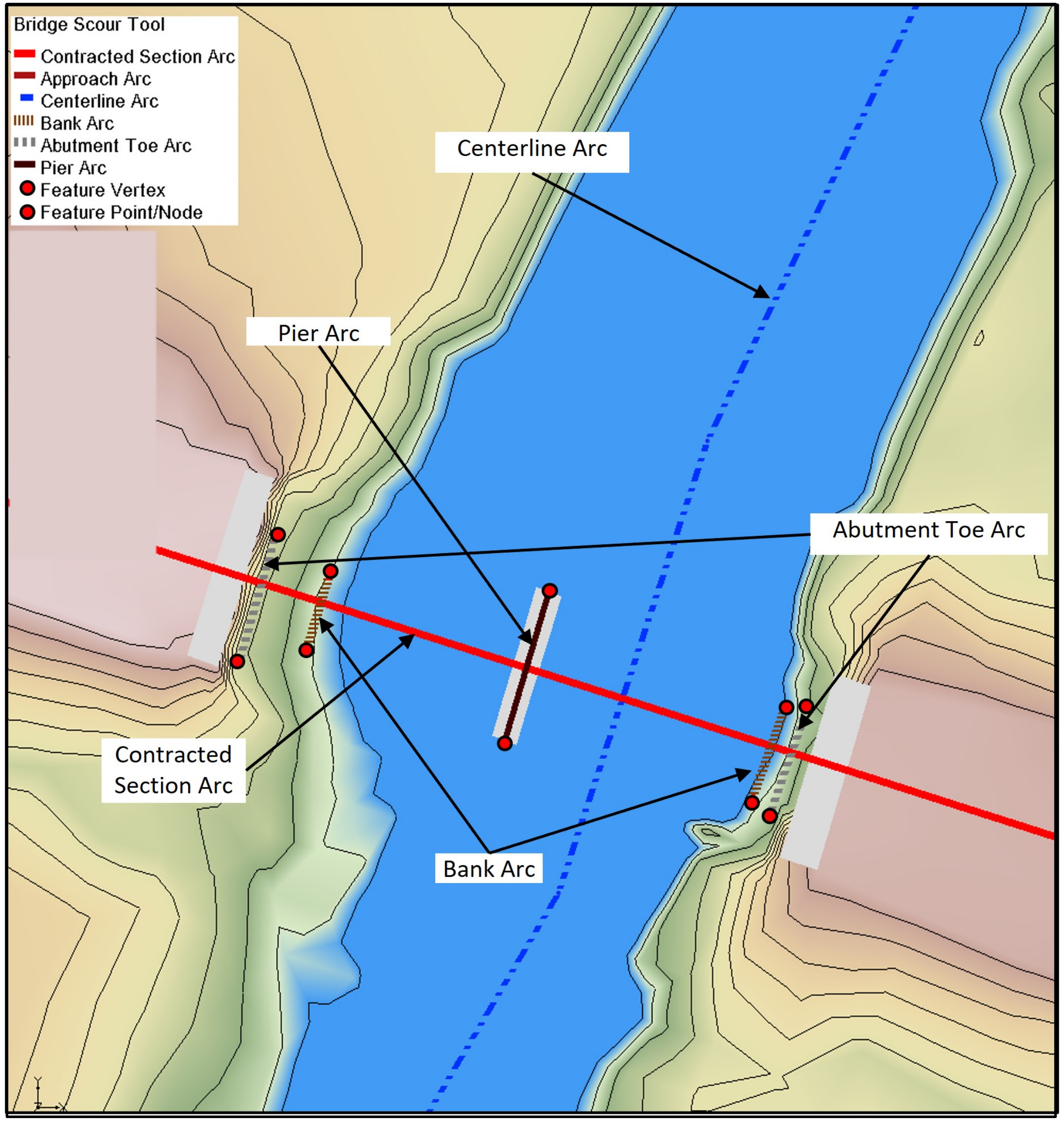


- The main channel is defined by the width of flow that could be transporting sediment (Typically toe to toe or bank to bank)
- The same main channel reference should be used at the approach and contracted sections.
- The average depth and d_{50} in the main channel at the approach section are used to determine if there is a live-bed condition ($V>V_c$) or clear-water condition ($V<V_c$)
- Overbank areas rarely transport significant sediment consistently.
- Averaged hydraulic parameters for the main channel and each overbank area are used for scour computations.

Bridge Scour Hydraulic Variables Review

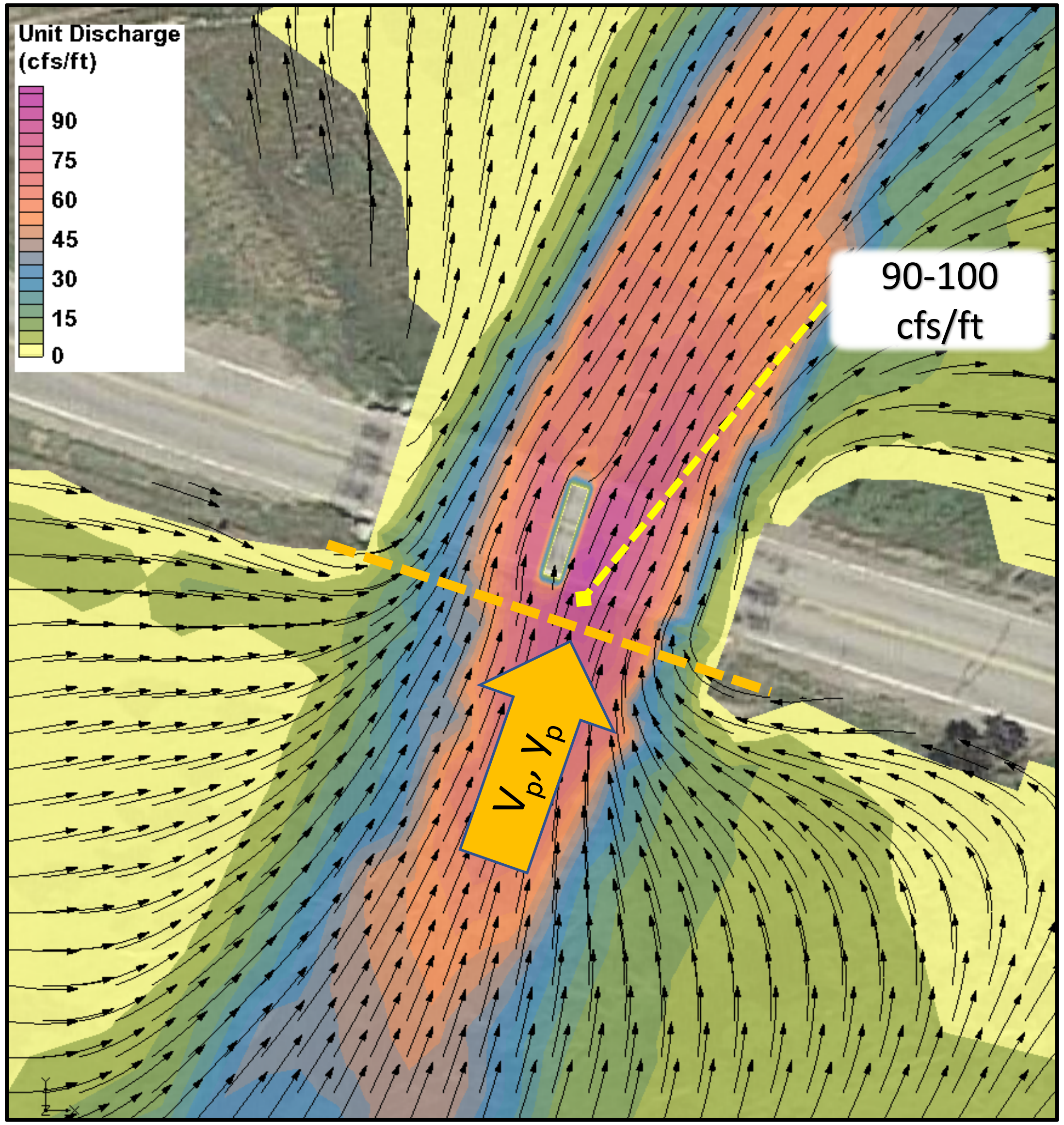
Contracted Section Adjustments

- The contracted width of flow must be adjusted by the effective width of the piers, including skew.
- The contracted width of flow must be adjusted for the bridge skew relative to the main channel.



Bridge Scour Hydraulic Variables Review

Pier Scour Variables

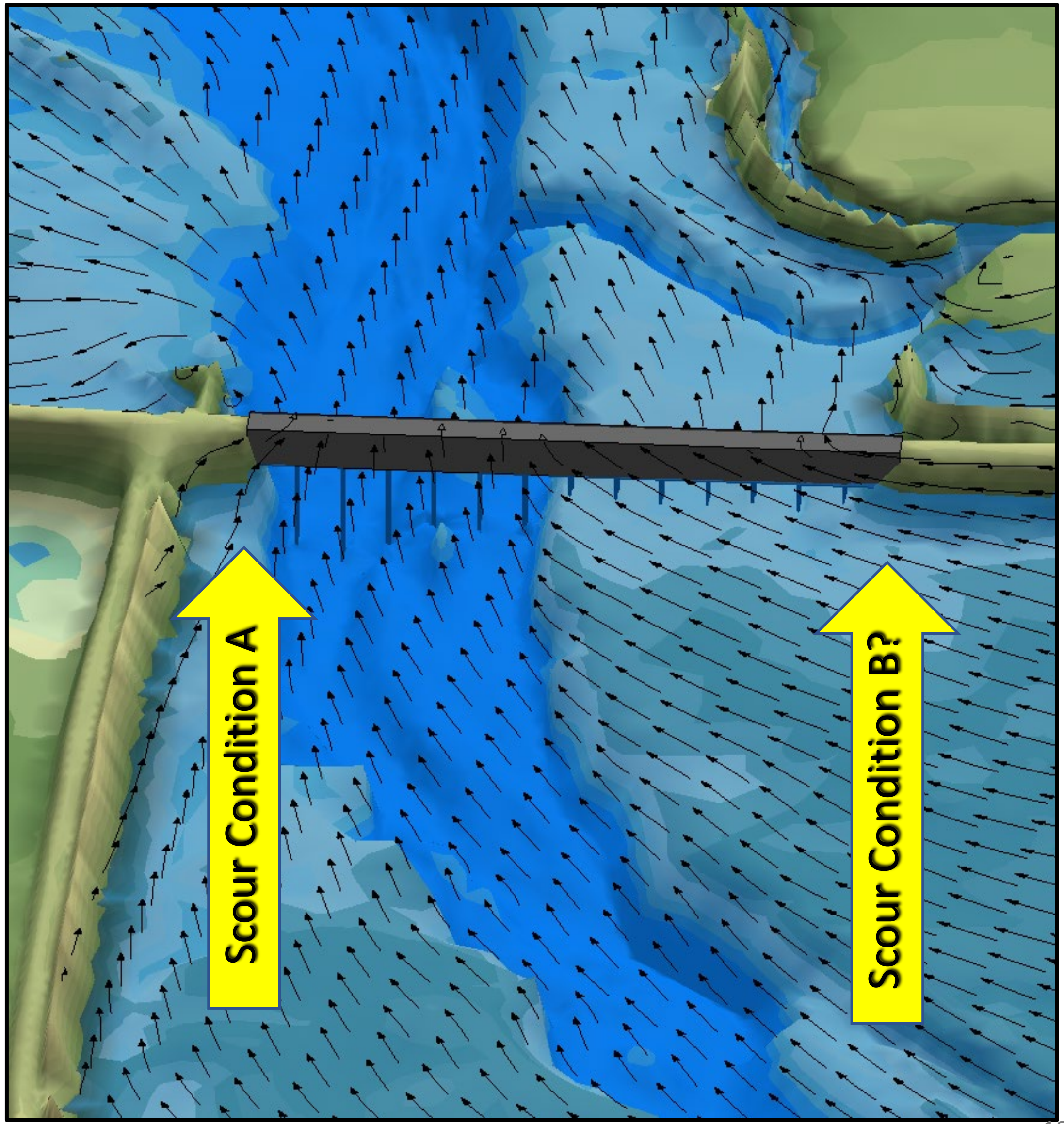


- The velocity, depth, and angle of attack for pier scour represent the flow approaching each pier.
- For design applications, the potential for thalweg and channel migration over the life of a bridge should be considered.
- The velocity and depth at the location of maximum unit discharge represent the worst-case hydraulic conditions that may impact a pier with channel/thalweg migration
- Changes in the angle of attack with potential channel changes should be considered

Bridge Scour Hydraulic Variables Review

Abutment Scour Variables

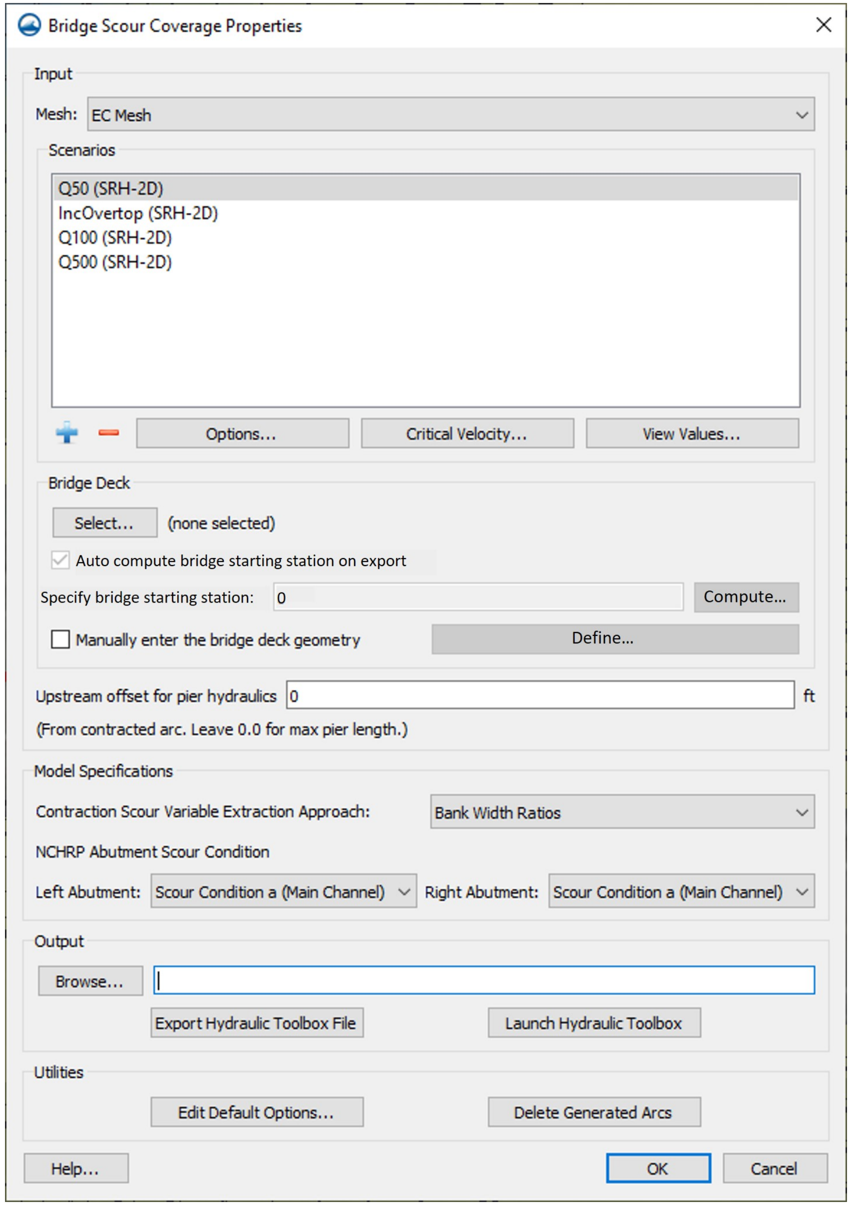
- Abutment location relative to the main channel over the life of the bridge determines the scour estimate approach.
- The HEC-18 NCHRP Abutment Scour method is recommended.
- **Scour Condition A** assumes the abutment may be impacted by main channel hydraulics over the life of the bridge.
- **Scour Condition B** assumes the abutment will not be impacted by the main channel and uses overbank hydraulics for computing scour.



Bridge Scour Hydraulic Variables Review

SMS Bridge Scour Tool

- Average hydraulic parameters exported for multiple simulations (for main channel & overbanks)
- Bridge cross section and pier geometry adjusted for skew
- Pier and abutment parameters exported
- Velocity and depth at the maximum unit discharge are exported by default
- Measured angles of attack are exported unless specified by user
- Long Term Degradation needs to be considered (use HEC-20)



Questions?

2D Hydraulic Model Review Training

Learning Objectives

- Identify key aspects of a 2D hydraulic model review
- Request the relevant information required for conducting a review
- Conduct cursory or detailed reviews of hydraulic models
- Recognize acceptable or reasonable ranges for the key parameters of a 2D model.
- Spot common modeling errors and other issues that warrant further investigation.
- Understand the hydraulic modeling variables needed for bridge scour analyses and how they can be extracted from a 2D model

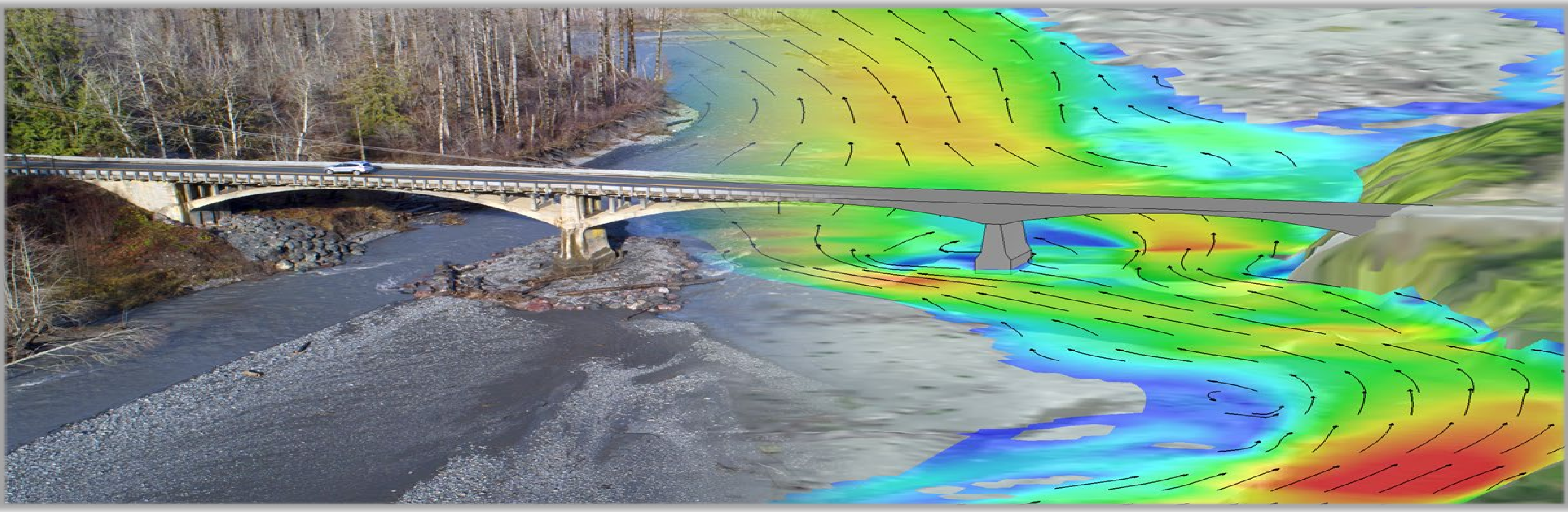


Image by John Gussman

THANK YOU!
Please contact me with any questions

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