

Combined 1D River and 2D Floodplain/Levee Areas

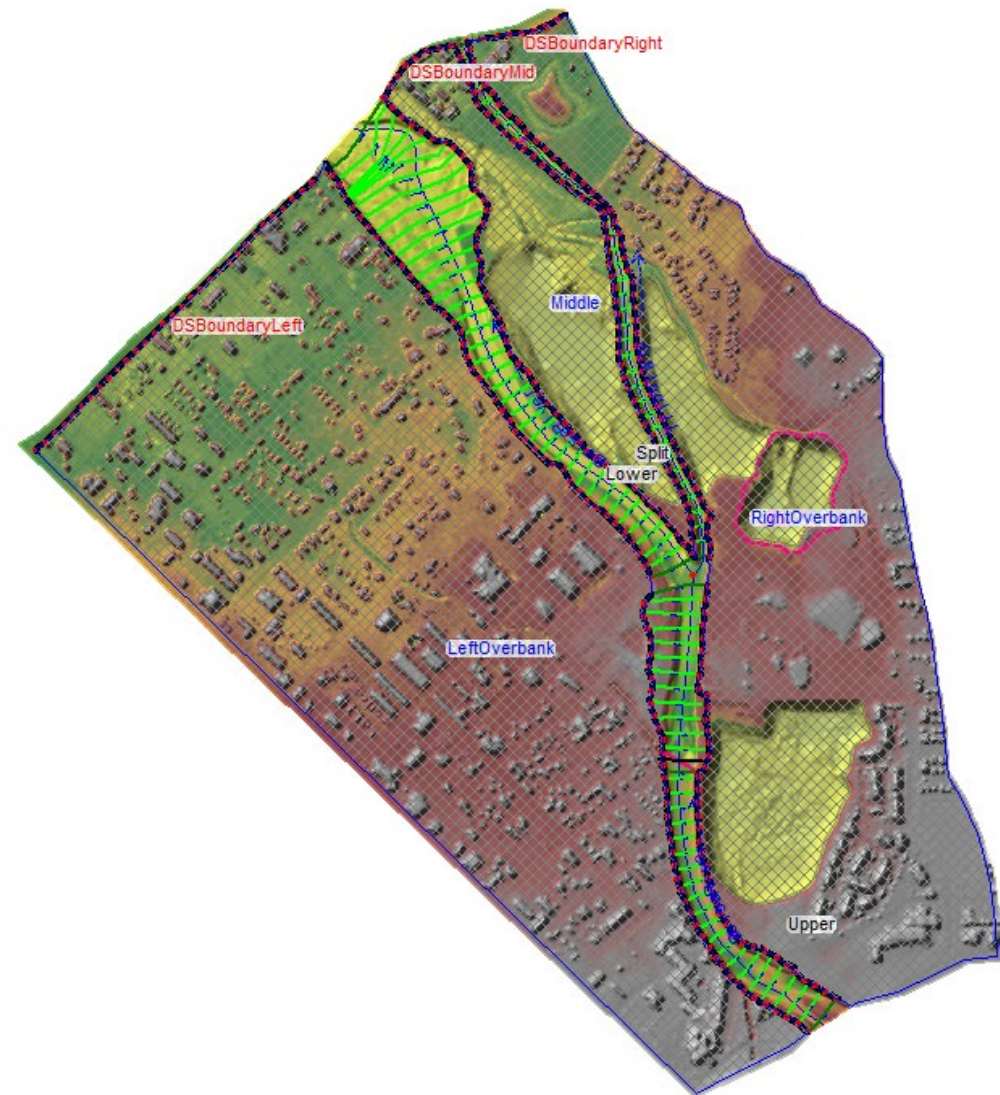
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USACE, Institute for Water Resources, Hydrologic Engineering Center





1D/ 2D Unsteady Flow



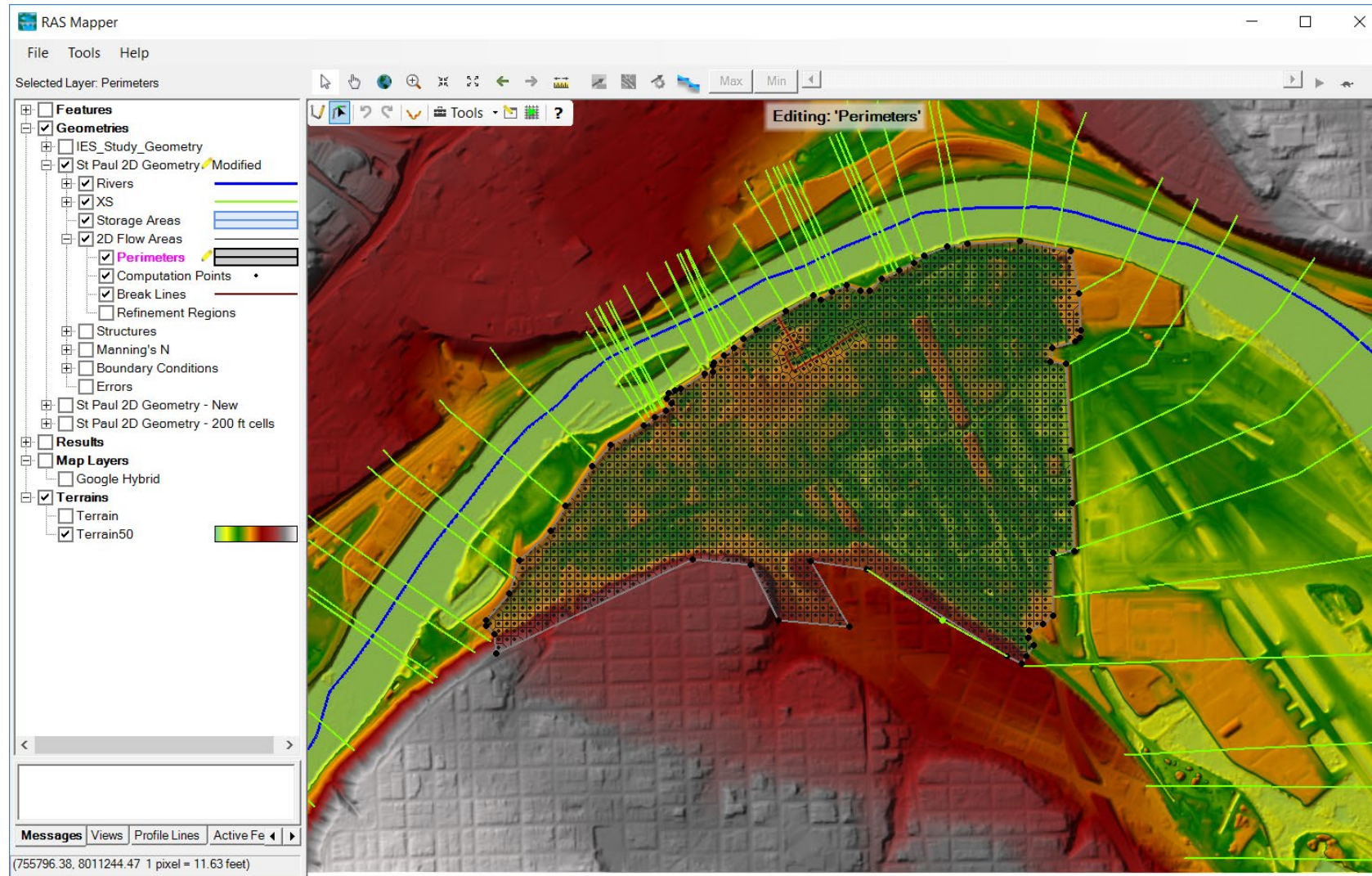


Overview

- Connecting 2D overbanks to 1D channels with lateral structures
- Selecting appropriate parameters
- Selecting appropriate computation options

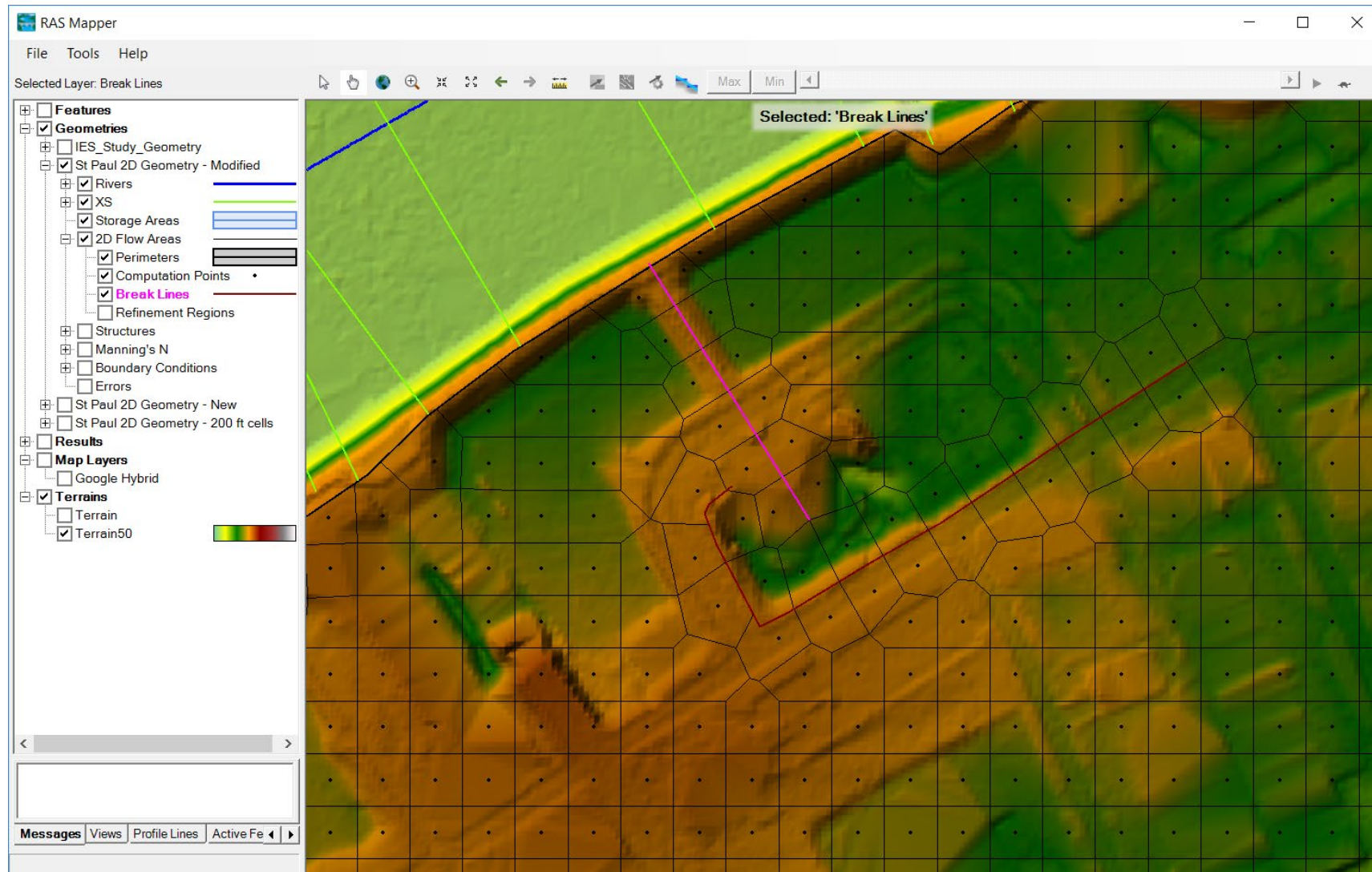


Modeling a Leveed Area in 2D





Modify The Mesh as Needed





Connecting a 2D Flow Area to a 1D River Reach with Lateral Structures

RAS Mapper

File Project Tools Help Debug

Selected Layer: Lateral Structures

- Features
 - Geometries
 - IES_Study_Geometry
 - St Paul 2D Geometry - Modified
 - St Paul 2D Geometry - New
 - Rivers
 - Cross Sections
 - Storage Areas
 - 2D Flow Areas
 - Bridges/Culverts
 - Inline Structures
 - Lateral Structures
 - Gate Openings
 - Culvert Barrels
 - Rating Curve Outlets
 - Outlet Time Series
 - SA/2D Connections
 - Pump Stations
 - Boundary Condition Lines
 - Initial Condition Points
 - Reference Points
 - Reference Lines
 - Reference Areas
 - Pipe Networks
 - Manning's n
 - Infiltration
 - Percent Impervious

Terrain Contour: 2 (Selected)

Messages Views Profile Lines Active Features Layer Values

Geometric Data - St Paul 2D Geometry - Modified

File Edit Options View Tables Tools GIS Tools Help

Tools: River Reach, Storage Area, 2D Flow Area, SA/2D Area Conn, SA/2D Area BC Lines, 2D Area Break Lines, 2D Area Mann n Regions, Pump Station, RS (12.99)

Editors: Junct., Cross Section, Brgd/Culv, Inline Structure, Lateral Structure (highlighted), Storage Area, 2D Flow Area, SA/2D Area Conn, Pump Station, HTab Param., View Picture

Description



Lateral Structure Editor

Lateral Structure Editor - St Paul 2D Geometry - Modified

File View Options Help

River: MissRiver Apply Data + [Camera Icon]

Reach: thru_St_Paul HW RS: 151400 [Down Arrow] [Up Arrow]

Description [Text Box] [Up Arrow] [Down Arrow] [More Icon]

HW Position: Right overbank Plan Data Optimization ... Breach ...

Tailwater Connection
Type: Storage Area/2D Flow Area
SA/2DFA: 2D flow area: 2DArea Set SA/2DFA ... Weir Length: 671.42
Centerline Length: 671.42

Overflow Computation Method
 Normal 2D Equation Domain Use Weir Equation 2D Boundary Use Velocity Centerline GIS Coords...

All Culverts: No Flap Gates Terrain Profile ...

Structure Type Weir/Gates/Culverts/Diversion Rating Curves Clip Weir Profile to 2D Cells...

Legend
Lat Struct
Ground
Bank Sta
TW Cell Min Elev
LS Terrain

HW and TW Connections Determined Geo-Spatially

The plot shows a cross-section of the lateral structure. The y-axis is Elevation (ft) ranging from 640 to 720. The x-axis is Station (ft) ranging from -200 to 1000. Key stationing points are marked at 0, 151438.4, 151084.4, and 150854.0. The structure is shown as a shaded area with a top boundary and a bottom boundary. A legend on the right identifies the elements: Lat Struct (shaded area), Ground (dotted area), Bank Sta (red dots), TW Cell Min Elev (black dots), and LS Terrain (solid line).

Edit lateral structure description



Weir/Embankment

Lateral Weir Embankment

Weir Data

Weir Width:

Weir Computations:

Standard Weir Equation Parameters

Weir flow reference:

Weir Coefficient (Cd):

Weir Crest Shape:

Weir Stationing Reference

HW - Distance to Upstream XS:

Embankment Station/Elevation Table

	Station	Elevation
1	0	717.52
2	160.9	717.328
3	217.23	716.861
4	239.07	716.825
5	297.36	716.253
6	477.08	716.183
7	556.99	716.042
8	671.42	716.046
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		

Lateral Structure Editor - St Paul 2D Geometry - Modified

File View Options Help

River:

Reach: HW RS:

Description:

HW Position:

Tailwater Connection

Type:

SA/2DFA:

Weir Length:
Centerline Length:

Overflow Computation Method

Normal 2D Equation Domain Use Weir Equation Use Velocity

2D Boundary

Use Velocity

All Culverts:

Structure Type:

HW and TW Connections Determined Geo-Spatially

structure description



Weir Length vs GIS Length

The screenshot displays the HEC-RAS software interface. The main window is titled "Geometric Data - St Paul 2D Geometry - Modified". The "Lateral Structure Editor" is open, showing a 2D terrain profile with a weir structure. The "Lateral Structure Editor" dialog box is open, showing the following settings:

- River: MissRiver
- Reach: thru_St_Paul
- HW RS: 151400
- HW Position: Right overbank
- Type: Storage Area/2D Flow Area
- SA/2DFA: 2D flow area: 2DArea
- Overflow Computation Method: Use Weir Equation
- Structure Type: Weir/Gates/Culverts/Diversion Rating Curves

The "Weir Length" and "Centerline Length" are both set to 671.42. The "Centerline GIS Coords..." button is highlighted. The "Lateral Structure Centerlines GIS Coordinates" dialog box is also open, showing the following data:

Names (Select one or Many)	X (ft)	Y (ft)
MissRiver thru_St_Paul 151400		
1	753174.2	8014682.58
2	753286.49	8014792.07
3	753444.65	8014913.72
4	753713.22	8015078.42

The "HW and TW Connections Determined Geo-Spatially" plot shows the elevation (ft) versus station (ft) for the weir structure. The plot includes a legend for Lat Struct, Ground, Bank Sta, TW Cell Min Elev, and LS Terrain. The plot shows the weir structure with a length of 671.42 ft and a centerline length of 671.42 ft. The plot also shows the ground elevation and the weir structure elevation. The plot is titled "HW and TW Connections Determined Geo-Spatially".



Lateral Weir Headwater Connections (HW)

HW Lateral Structure Connections

Computed Default Weir Stationing User Defined Weir Stationing

Default Computed Weir Stationing		
	XS RSs	Weir Station
1	151436.4	-22.92
2	151354.9	156.84
3	151084.4	373.92
4	150654.0	803.62
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

User Defined Weir Stationing		
	XS RSs	Weir Station
1	151354.9	5692
2	151084.4	5909
3	150654.0	6435
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

7 User Specified Connections
8 Option will not be used
9 because the lateral structure
10 has a geo-referenced
11 centerline.

OK Cancel

Geometric Data - St Paul 2D Geometry - Modified

File Edit Options View Tables Tools GIS Tools Help

Tools: River Reach, Storage Area, 2D Flow Area, SA/2D Area Conn, SA/2D Area BC Lines, 2D Area Break Lines, 2D Area Man n Regions, Pump Station, RS

Editors: Junct., Cross Section, Brdg/Culv, Inline Structure, Lateral Structure, Storage Area, 2D Flow Area, SA/2D Area Conn, Pump Station, HTab Param., View Picture

Description: [] Plot WS ex: (none)



Lateral Weir Tailwater Connections (TW)

TW Lateral Structure Connections

Computed Default Weir Stationing User Defined Weir Stationing

Default Computed Weir Stationing		
	2D Face Points	Weir Station
1	456	-34.3083
2	412	28.59606
3	368	174.9681
4	319	314.8326
5	322	479.7218
6	325	521.3957
7	2408	663.5559
8	239	725.6677
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

User Defined Weir Stationing		
	2D Face Points	Weir Station
1	454	5470.98
2	411	5537.3
3	368	5703.08
4	319	5861.57
5	322	6048.15
6	325	6095.38
7	User Specified Connections	
8	Option will not be used	
9	because the lateral structure	
10	has a geo-referenced	
11	centerline.	
12		
13		
14		
15		
16		
17		
18		
19		

OK Cancel

Geometric Data - St Paul 2D Geometry - Modified

File Edit Options View Tables Tools GIS Tools Help

Tools: River Reach, Storage Area, 2D Flow Area, SA/2D Area Core, SA/2D Area BC Lines, 2D Area Break Lines, 2D Area Mann n Regions, Pump Station, RS

Editors: Junct., Cross Section, Brg/Culv, Inline Structure, Lateral Structure, Storage Area, 2D Flow Area, SA/2D Area Core, Pump Station, HTab Param., View Picture

753713

Overflow Computations

- Weir Equation
 - $Q = CLH^{3/2}$
 - Good for free fall conditions
 - Not great for submerged weir
- 2D Equation
 - Simply modifies cell face properties
 - Good for highly submerged conditions

Lateral Structure Editor - St Paul 2D Geometry - Modified

File View Options Help

River: MissRiver Apply Data +

Reach: thru_St_Paul HW RS: 151400

Description

HW Position: Right overbank Plan Data Optimization ... Breach ...

Tailwater Connection

Type: Storage Area/2D Flow Area

SA/2DFA: 2D flow area: 2DArea Set SA/2DFA ...

Weir Length: 671.42

Centerline Length: 671.42

Overflow Computation Method

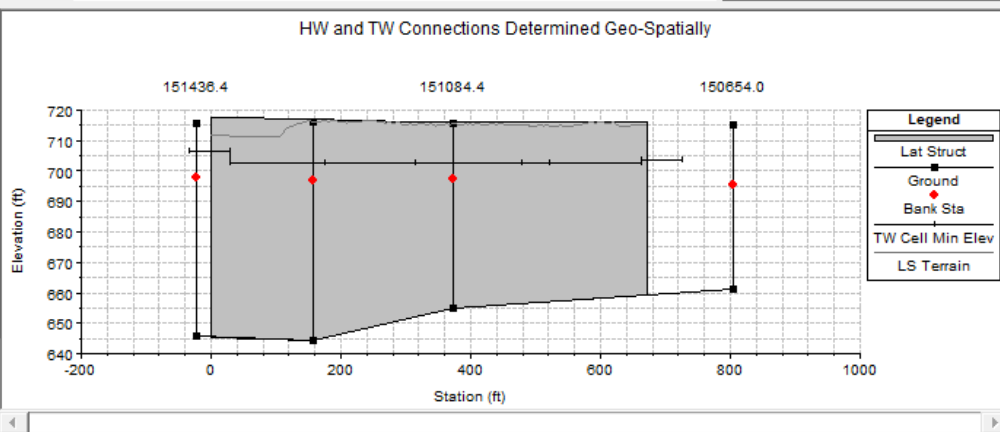
Normal 2D Equation Domain Use Weir Equation 2D Boundary Use Velocity

Centerline GIS Coords... Terrain Profile ... Clip Weir Profile to 2D Cells...

All Culverts: No Flap Gates

Structure Type Weir/Gates/Culverts/Diversion Rating Curves

HW and TW Connections Determined Geo-Spatially



Legend

- Lat Struct
- Ground
- Bank Sta
- TW Cell Min Elev
- LS Terrain

Edit lateral structure description



Weir Coefficients for Lateral Structures

What is being modeled with the Lateral Structure	Description	Range of Weir Coefficients
Levee/Roadway – 3ft or higher above natural ground	Broad crested weir shape, flow over Levee/road acts like weir flow	1.5 to 2.6 (2.0 default) SI Units: 0.83 to 1.43
Levee/Roadway – 1 to 3 ft elevated above ground	Broad Crested weir shape, flow over levee/road acts like weir flow, but becomes submerged easily.	1.0 to 2.0 SI Units: 0.55 to 1.1
Natural high ground barrier – 1 to 3 ft high	Does not really act like a weir, but water must flow over high ground to get into 2D area.	0.5 to 1.0 SI Units: 0.28 to 0.55
Non elevated overbank terrain. Lat Structure not elevated above ground	Overland flow escaping the main river.	0.2 to 0.5 SI Units: 0.11 to 0.28

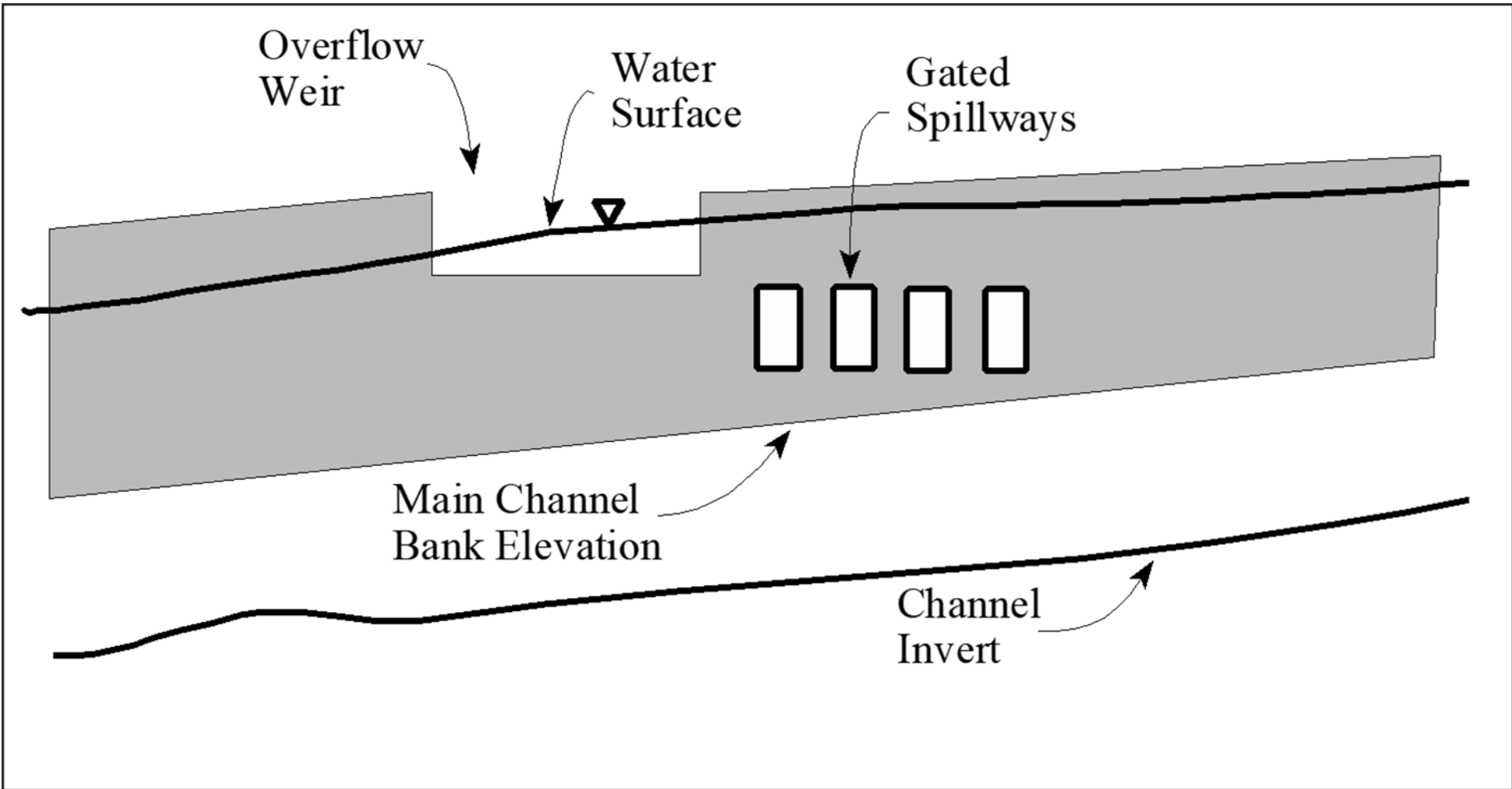


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Weir Computation





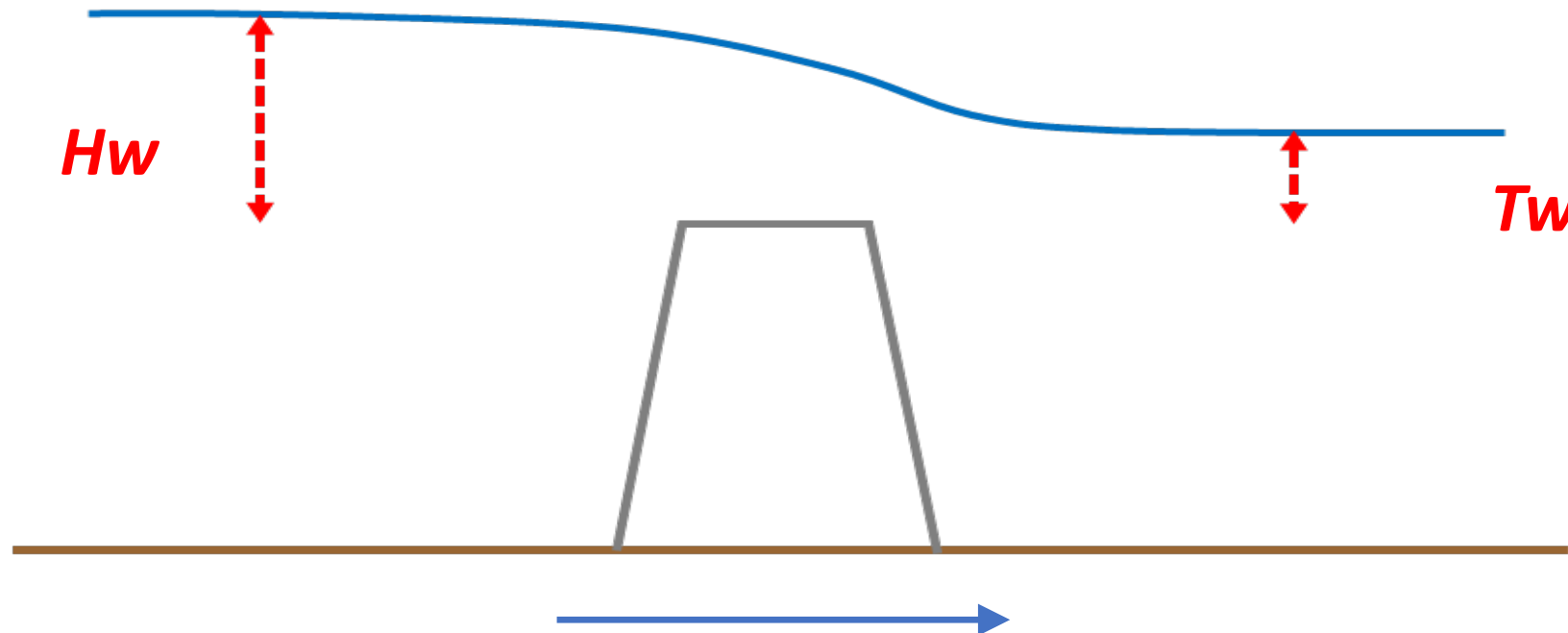
Computation Considerations

- Flow is assumed constant over the timestep
 - Long timesteps can transfer too much volume and oscillate
- Order of computations
 - 1D computes first then 2D
 - Weir flow is computed with current HW (1D) and previous TW (2D)
- Tailwater elevations
 - TW elevations of each connected cell is used
- Weir submergence



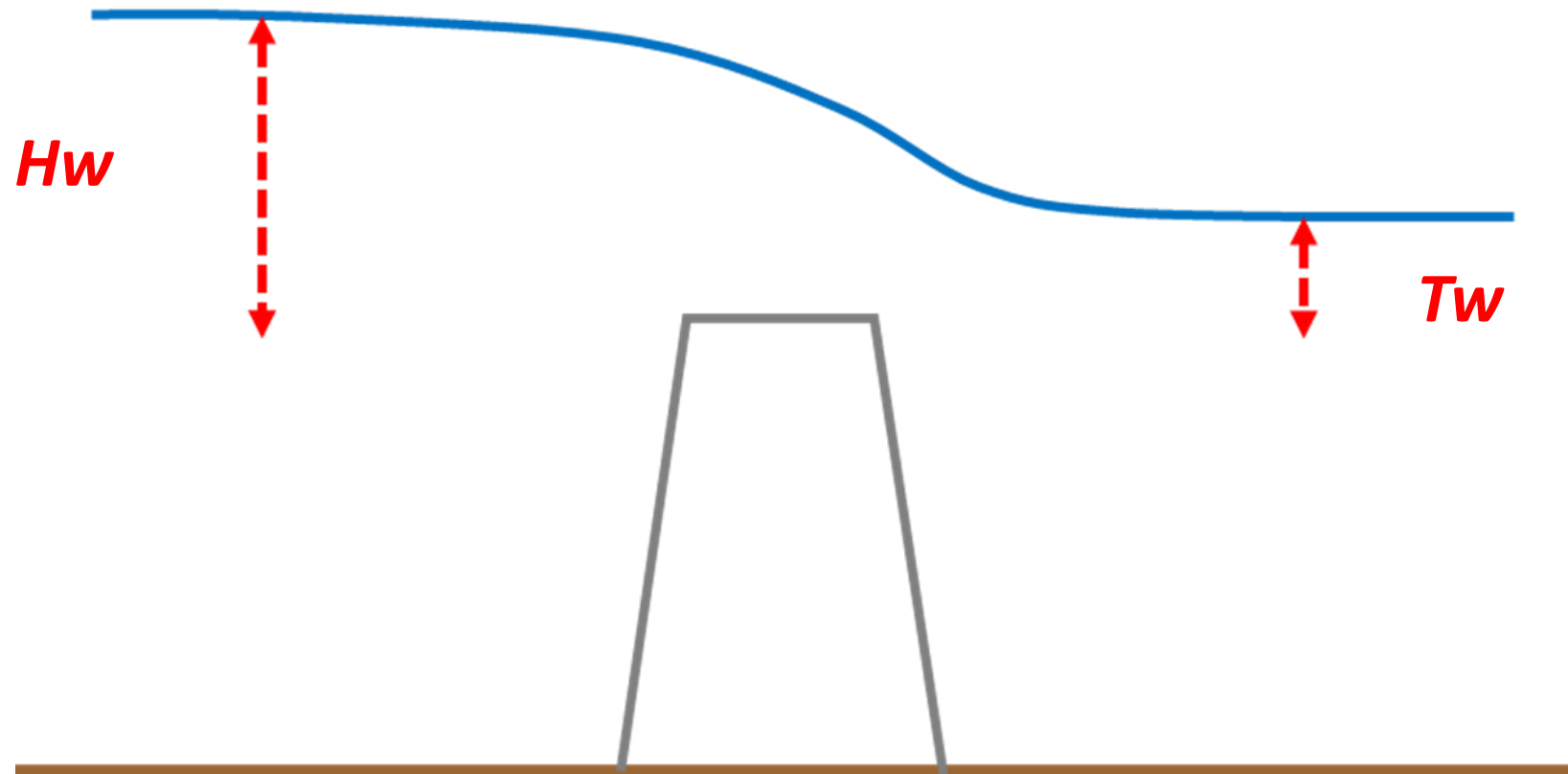
Weir Submergence

- Tailwater begins to impact weir flow
- A weir submergence curve is used to compute the reduction in flow
- This can be a dramatic reduction





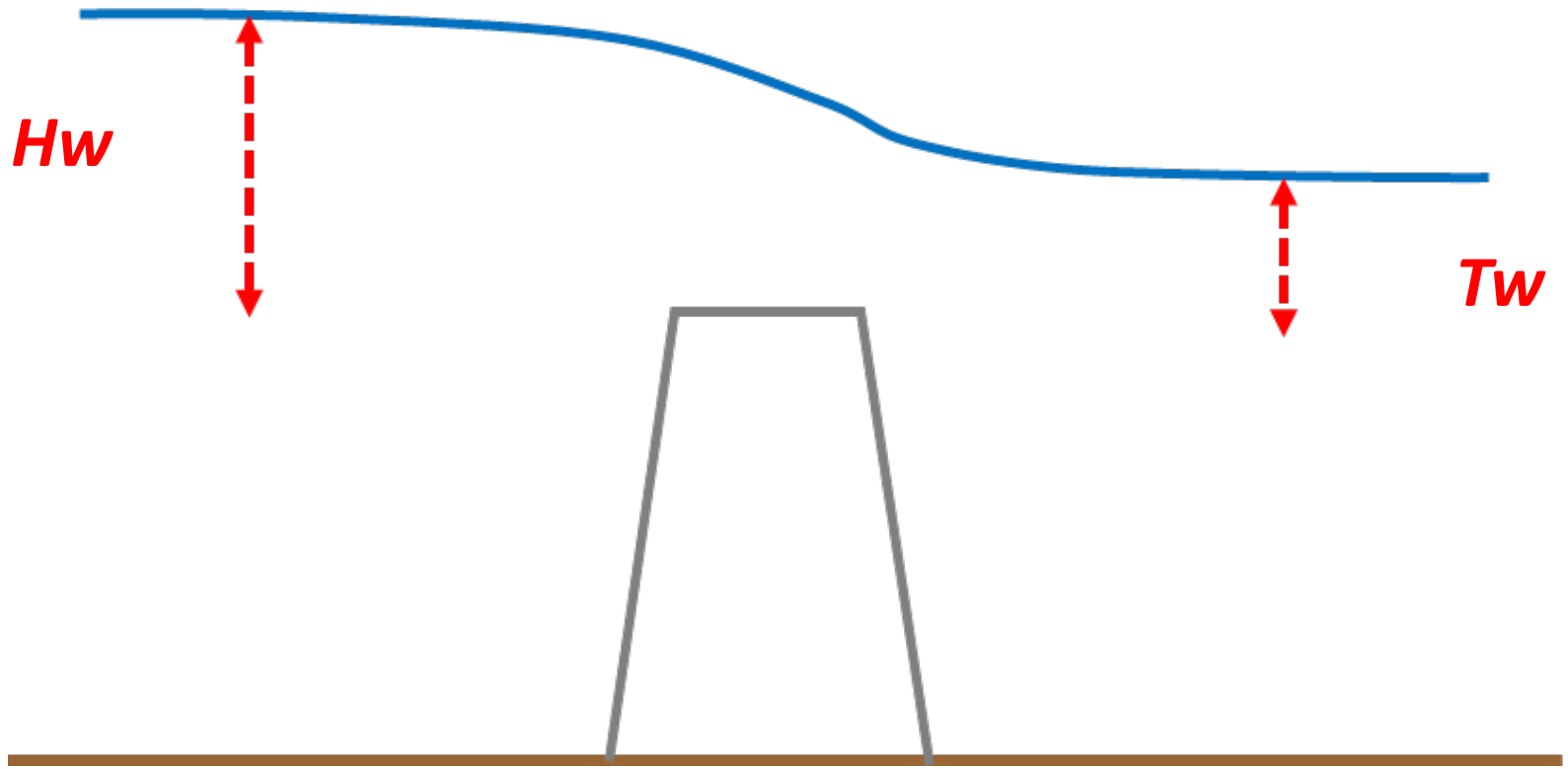
Will Weir Submerge?



$$T_w / H_w = 0.25$$



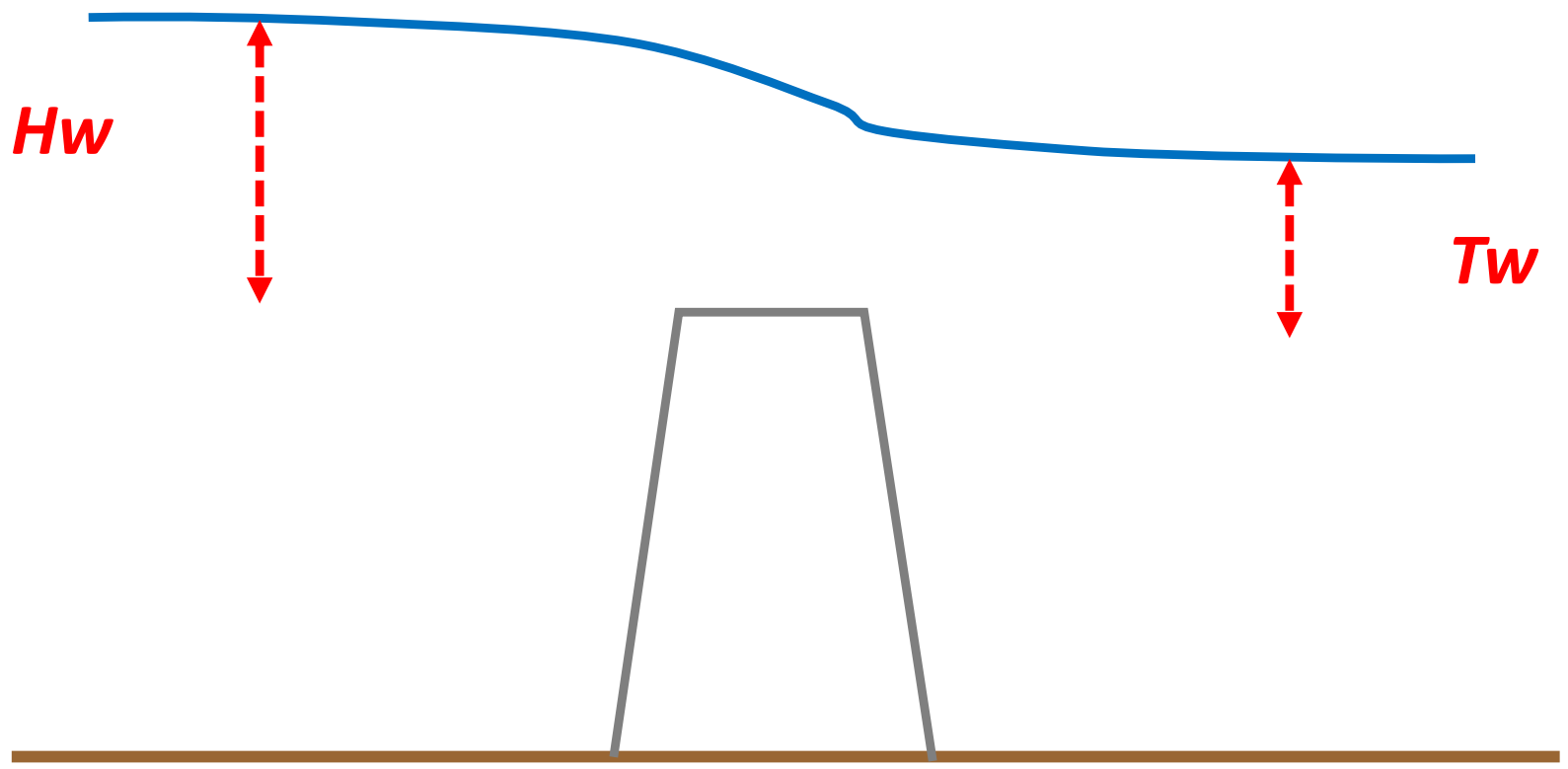
Will Weir Submerge?



$T_w / H_w = 0.5$



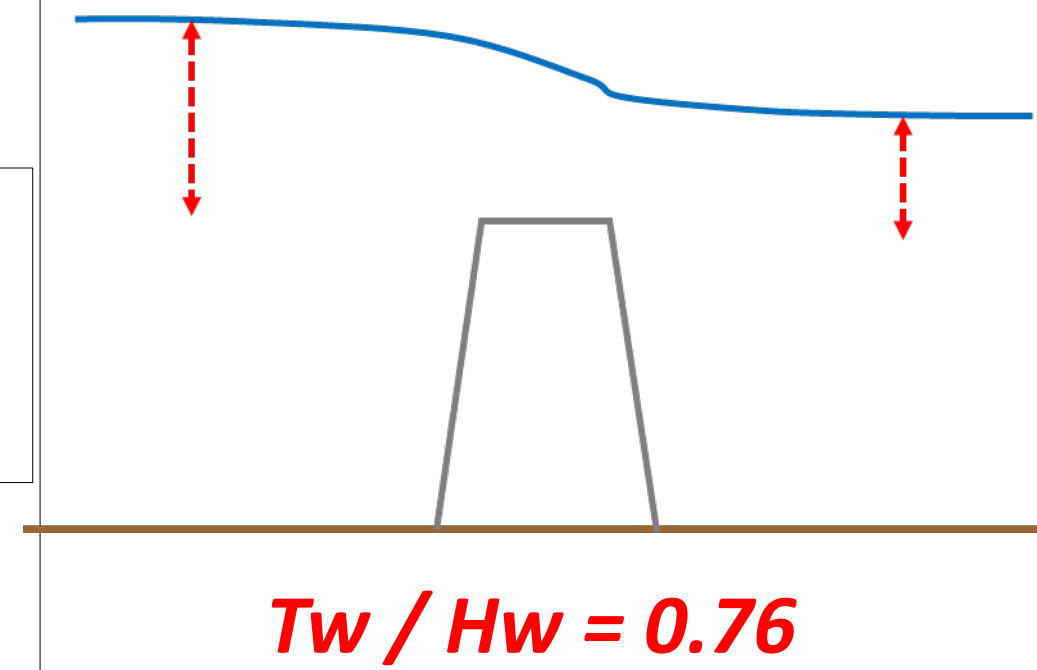
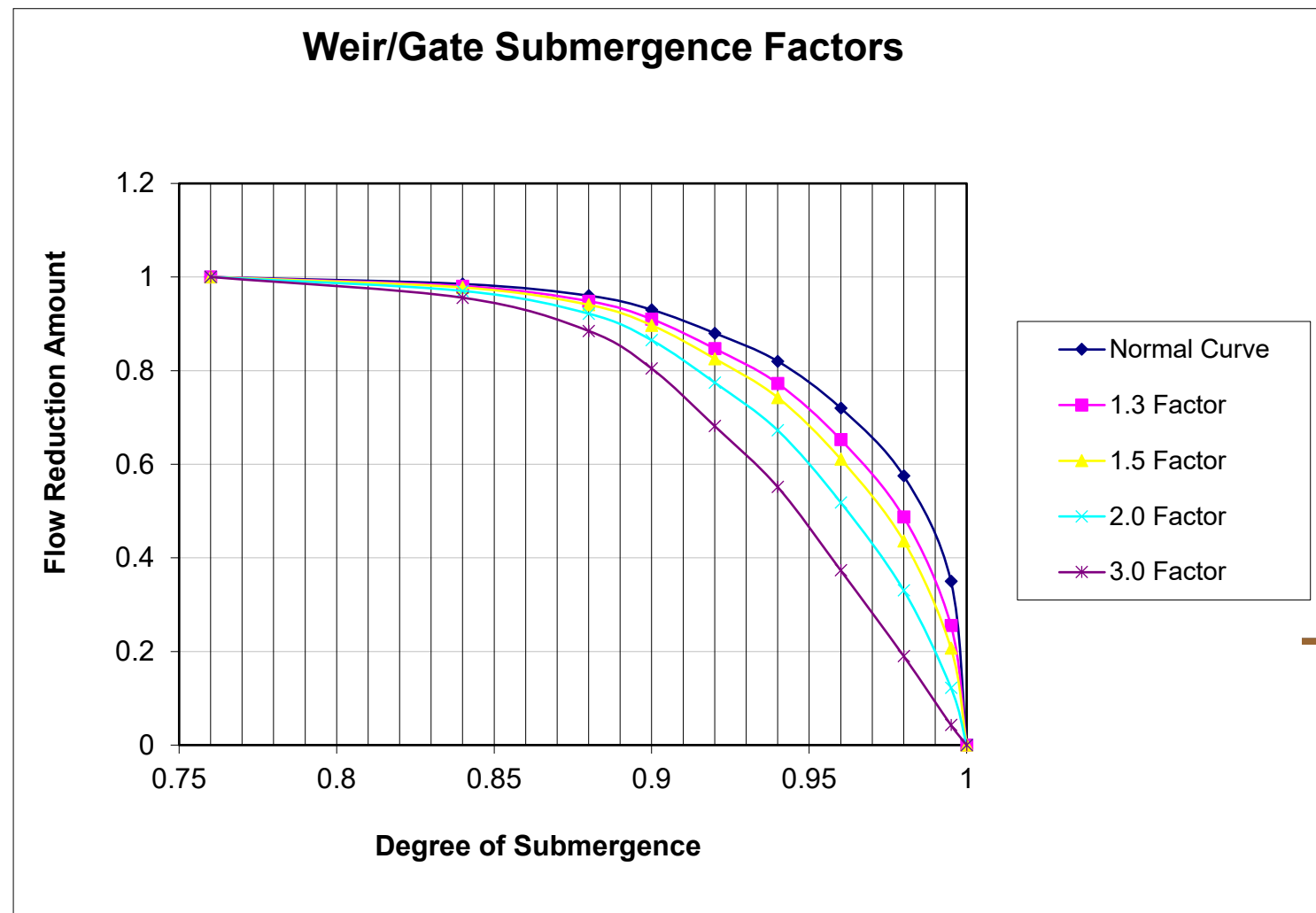
Will Weir Submerge?



$T_w / H_w = 0.75$



Weir Submergence Curves





Lateral Structure Computational Options

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

1D Unsteady Flow Options

Theta [implicit weighting factor] (0.6-1.0):	1.
Theta for warm up [implicit weighting factor] (0.6-1.0):	1.
Water surface calculation tolerance [max=0.2](ft):	0.02
Storage Area elevation tolerance [max=0.2](ft):	0.05
Flow calculation tolerance [optional] (cfs):	
Max error in water surface solution (Abort Tolerance)(ft):	100.
Maximum number of iterations (0-40):	20
Maximum iterations without improvement (0-40):	

1D/2D Unsteady Flow Options

Number of warm up time steps (0 - 100,000):	0
Time step during warm up period (hrs):	0.05
Minimum time step for time slicing (hrs):	0
Maximum number of time slices:	20
Lateral Structure flow stability factor (1.0-3.0):	3.
Inline Structure flow stability factor (1.0-3.0):	1.
Weir flow submergence decay exponent (1.0-3.0):	3.
Gate flow submergence decay exponent (1.0-3.0):	1.
DSS Messaging Level (1 to 10, Default = 4)	4

Geometry Preprocessor Options

Family of Rating Curves for Internal Boundaries

- Use existing internal boundary tables when possible.
- Recompute at all internal boundaries

1D Numerical Solution

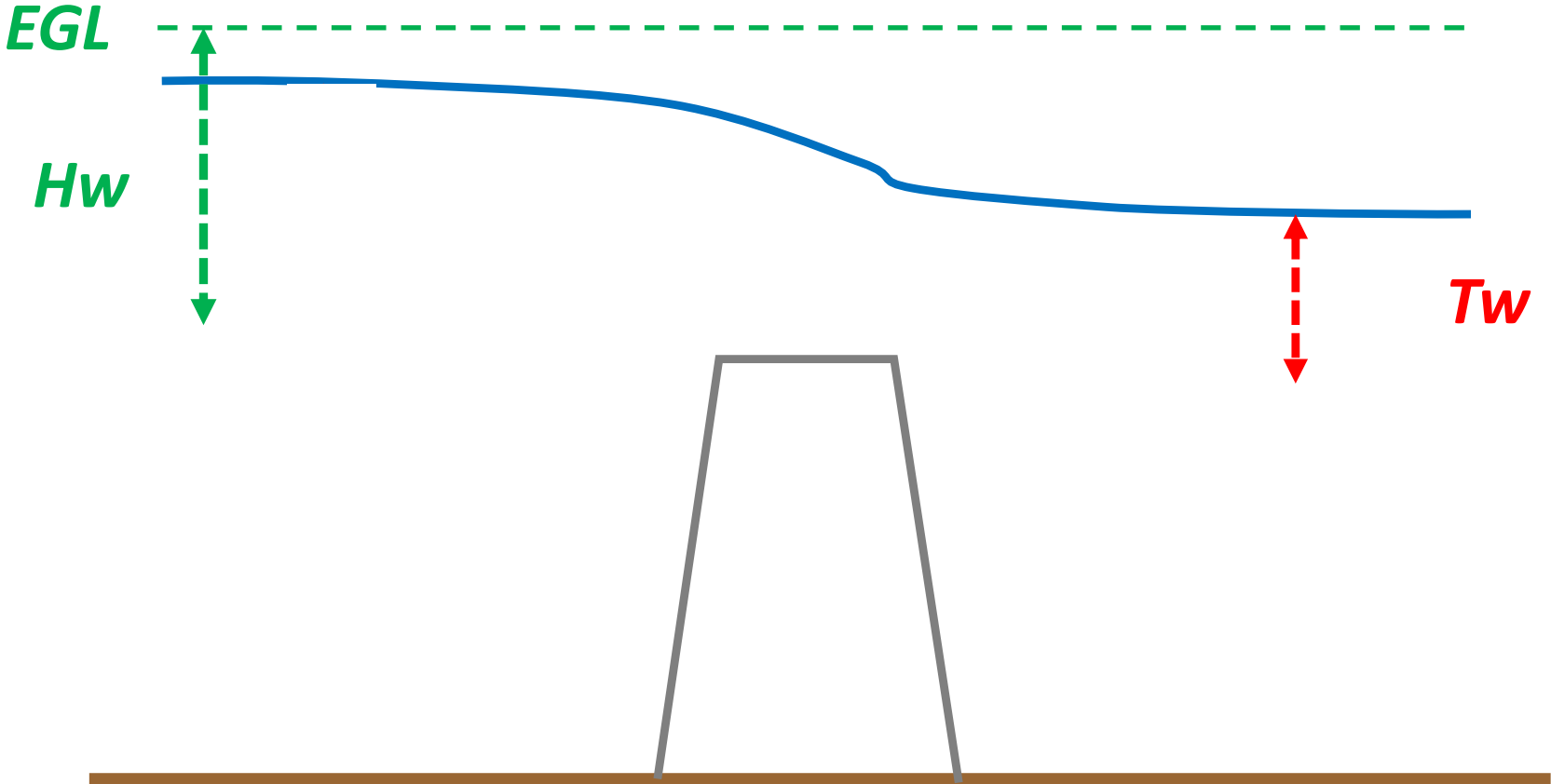
- Finite Difference (classic HEC-RAS methodology)
 - Finite Difference Matrix Solver
 - Skyline/Gaussian (Default: faster for dendritic systems)
 - Pardiso (Optional: may be faster for large interconnected systems)
- Finite Volume (new approach)

Number of cores to use with Pardiso solver: All Available

OK Cancel Defaults ...



Hw : EGL or WSEL?





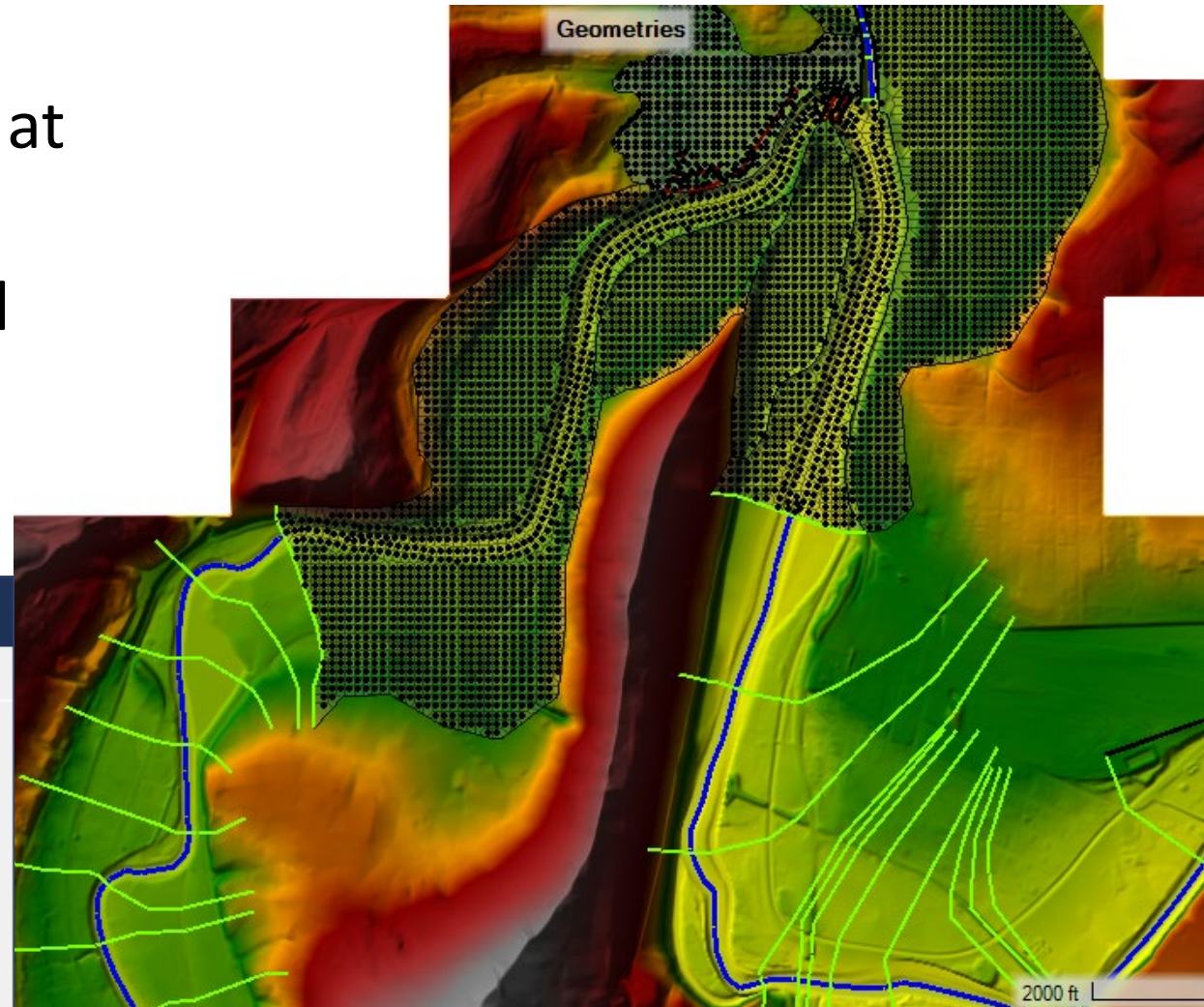
1D/2D Iterations Option

- Monitors WSEL and Flow Tolerance at boundaries
- Iterates the 1D and 2D domain until tolerances are met
- Off by default (0 iterations)

HEC-RAS Unsteady Computation Options and Tolerances

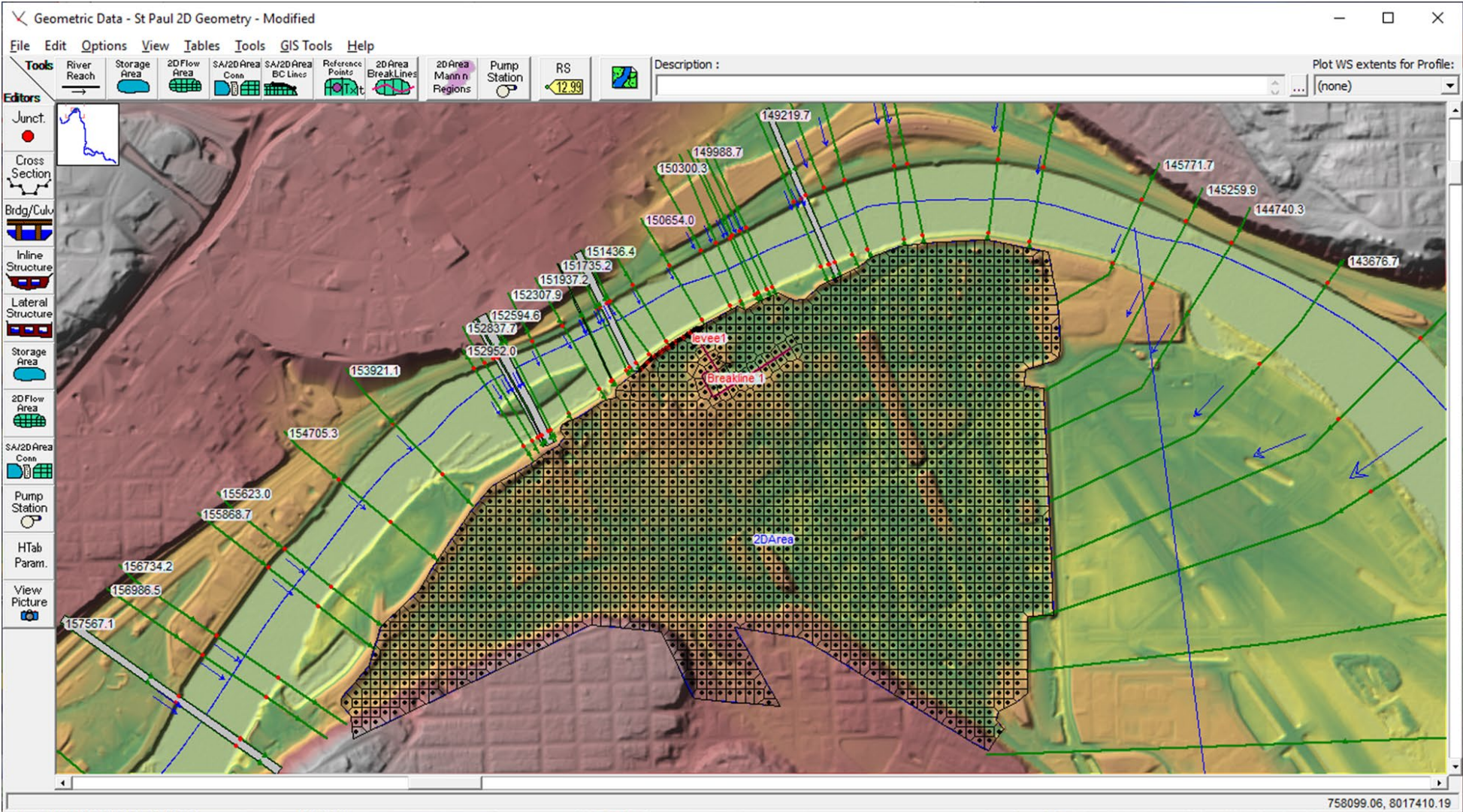
General | 2D Flow Options | **1D/2D Options** | Advanced Time Step Control | 1D Mixed Flow Options

Maximum iterations between 1D and 2D (0=off, 1 to 20):	<input type="text" value="0"/>
Water surface tolerance (ft):	<input type="text" value="0.01"/>
Flow Tolerance (%)	<input type="text" value="0.1"/>
Minimum flow tolerance (cfs):	<input type="text" value="1."/>





1D/2D Modeling Computational Time Step





2D Time Slicing

- Use fraction of computation interval

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

Use Coriolis Effects (not used with Diffusion Wave equation)

Parameter	(Default)	BaldEagleCr
1 Theta (0.6-1.0)	1	1
2 Theta Warmup (0.6-1.0)	1	1
3 Water Surface Tolerance [max=0.2](ft)	0.01	0.01
4 Volume Tolerance (ft)	0.01	0.01
5 Maximum Iterations	20	20
6 Equation Set	Diffusion Wave	Diffusion Wave
7 Initial Conditions Time (hrs)		4
8 Initial Conditions Ramp Up Equation (0-1)	0.5	0.5
9 Number of Time Slices (Integer Value)	1	1
10 Turbulence Model	Non-Conservative (original)	Non-Conservative (original)
11 Longitudinal Mixing Coefficient		
12 Transverse Mixing Coefficient		
13 Smagorinsky Coefficient	0	0
19 Minimum Iterations		10
20 Maximum Iterations		10
21 Restart Iteration	10	10
22 Relaxation Factor	1.5	1.5
23 SOR Preconditioner Iterations	10	10

Computation Settings

Computation Interval: 30 Second ... Hydrograph Output Interval: 30 Minute

Mapping Output Interval: 30 Minute Detailed Output Interval: 1 Hour

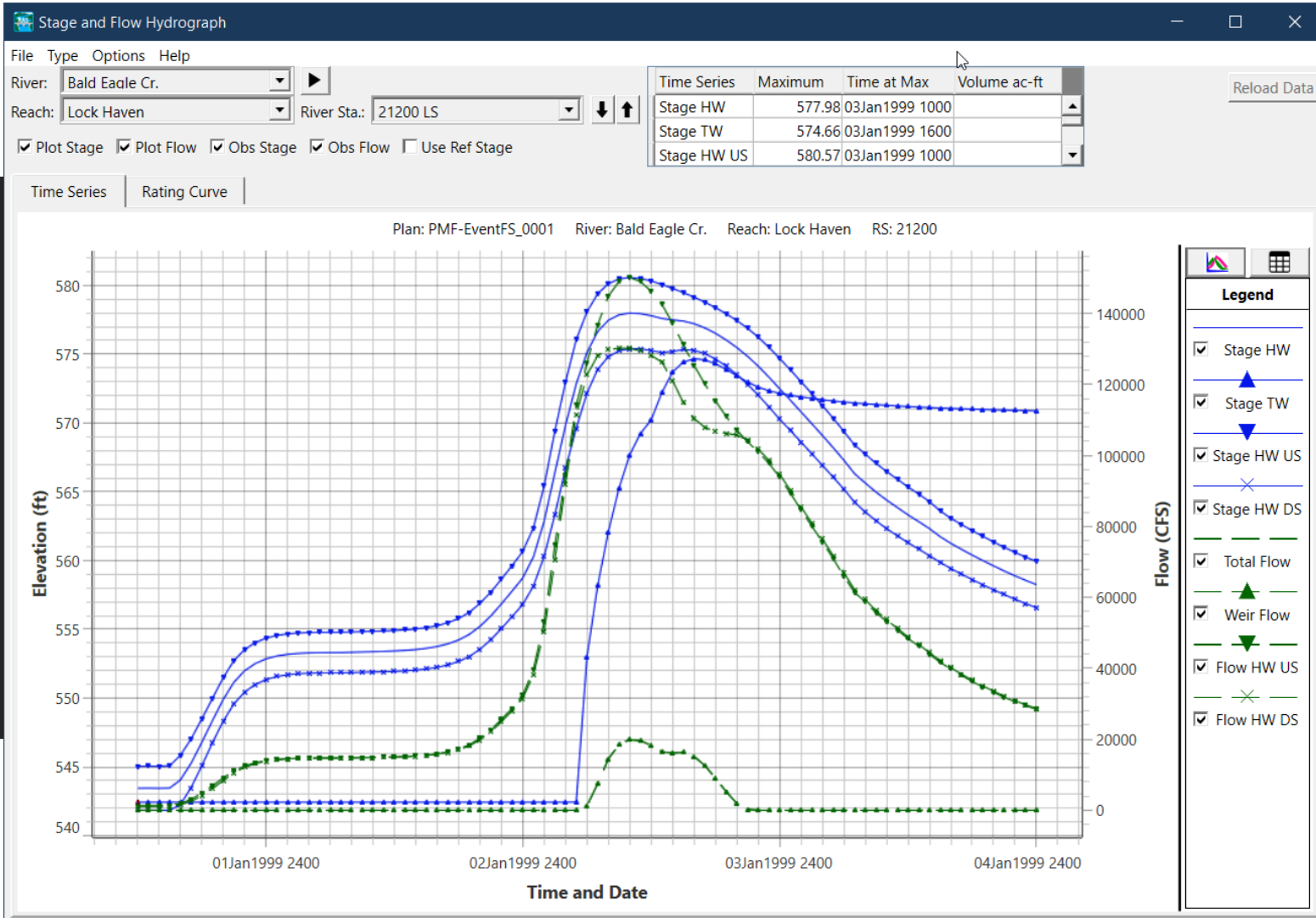
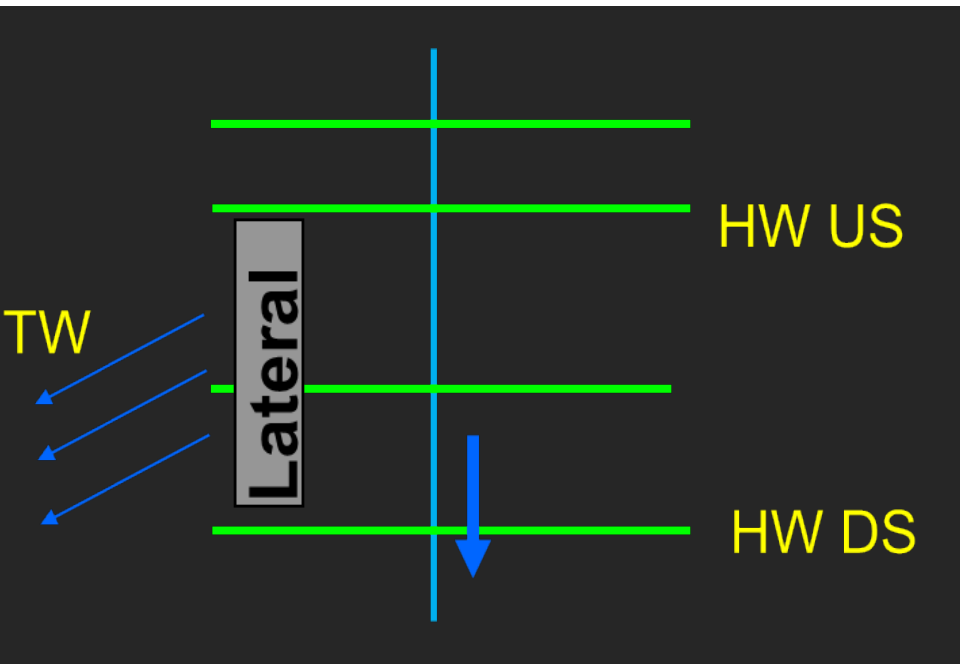
Project DSS Filename: C:\Computational Investigations\Testing\Upper Chickasawh...

6 Cores PARDISO (Direct) 6 Cores PARDISO (Direct)

OK Cancel Defaults ...

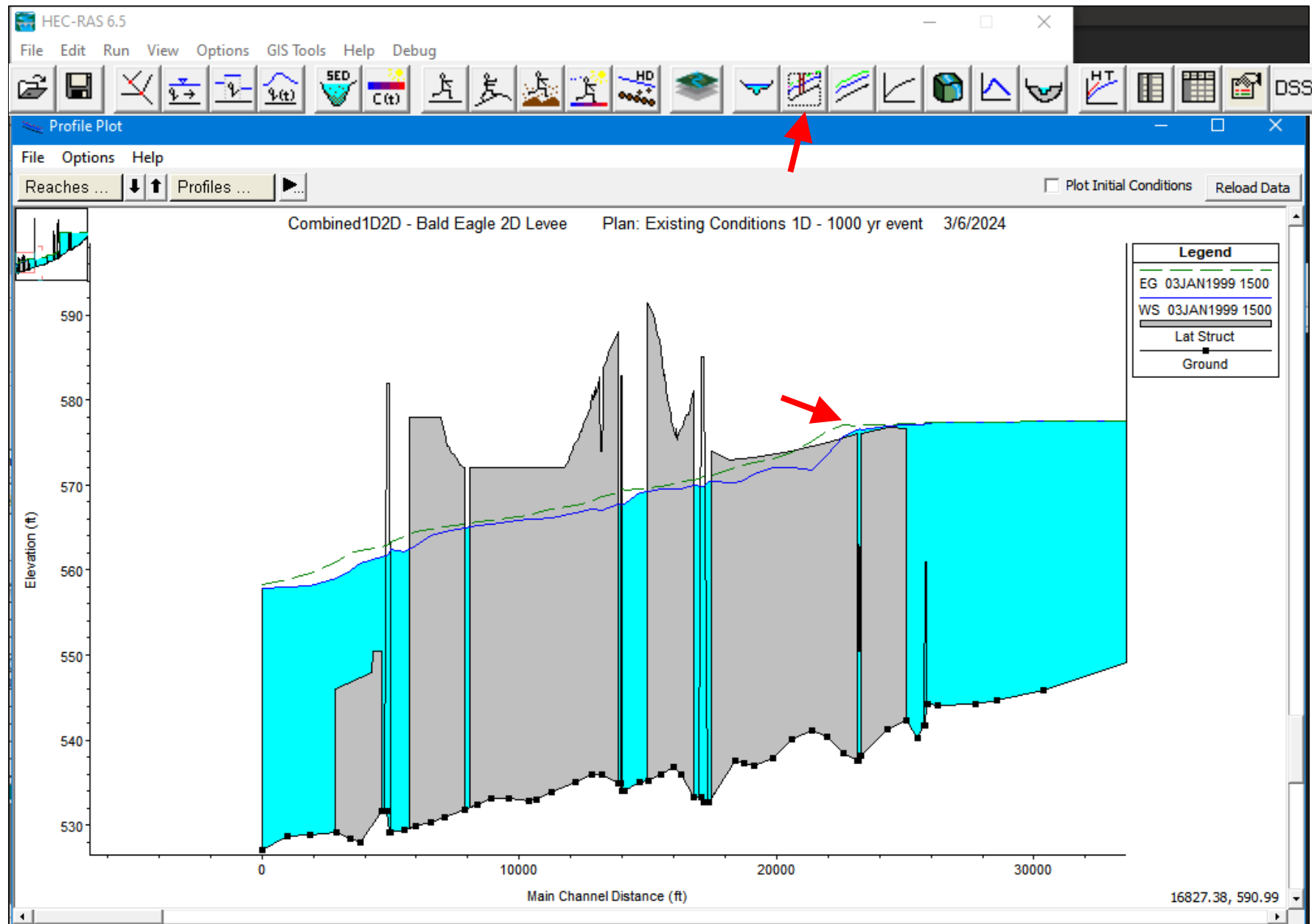


Hydrograph – Lateral Structure





Profile Plot





Lateral Structure Detailed Output

Lateral Structure Output

File Type Options Help

River: MissRiver Profile: 13FEB2099 0600 Lateral Structure

Reach thru_St_Paul RS: 151400 Plan: 2D Run Modified

Plan: 2D Run Modified MissRiver thru_St_Paul RS: 151400 Lateral Structure Profile: 13FEB2099 0600

E.G. US. (ft)	716.10	Weir Sta US (ft)	5750.00
W.S. US. (ft)	715.28	Weir Sta DS (ft)	5850.00
E.G. DS (ft)	716.08	Min El Weir Flow (ft)	704.00
W.S. DS (ft)	714.80	Wr Top Wdth (ft)	100.00
Q US (cfs)	281458.70	Weir Max Depth (ft)	11.22
Q Leaving Total (cfs)	4332.12	Weir Avg Depth (ft)	11.14
Q DS (cfs)	277159.10	Weir Flow Area (sq ft)	1113.82
Perc Q Leaving	1.54	Weir Coef (ft ^{1/2})	2.600
Q Weir (cfs)	4332.12	Weir Submerg	0.95
Q Gates (cfs)		Q Gate Group (cfs)	
Q Culv (cfs)		Gate Open Ht (ft)	
Q Lat RC (cfs)		Gate #Open	
Q Outlet TS (cfs)	0.00	Gate Area (sq ft)	
Q Breach (cfs)	4332.12	Gate Submerg	
Breach Avg Velocity (ft/s)	3.89	Gate Invert (ft)	
Breach Flow Area (sq ft)	1113.82	Gate Weir Coef	
Breach WD (ft)	100.00		
Breach Top El (ft)			
Breach Bottom El (ft)	704.00		
Breach SSL (ft)	0.00		
Breach SSR (ft)	0.00		

Errors, Warnings and Notes

Average flow velocity through a breach.



Levee Breaching

Levee (Lateral Structure) Breach Data

Lateral: MissRiver thru St_Paul 151400

Breach This Structure

Breach Method: User Entered Data

Center Station: 284

Final Bottom Width: 100

Final Bottom Elevation: 704

Left Side Slope: 0

Right Side Slope: 0

Breach Weir Coef: 2.6

Breach Formation Time (hrs): 1

Failure Mode: Overtopping

Piping Coefficient: 0.5

Initial Piping Elev:

Trigger Failure at: Set Time

Start Date: 12feb2099

Start Time: 2400

Breach Plot | Breach Progression | Simplified Physical | Parameter Calculator | Breach Repair (optional)

StPaulIES Plan: Fail Middle - 2D Run Modified FEQ Jan17 7/17/2018

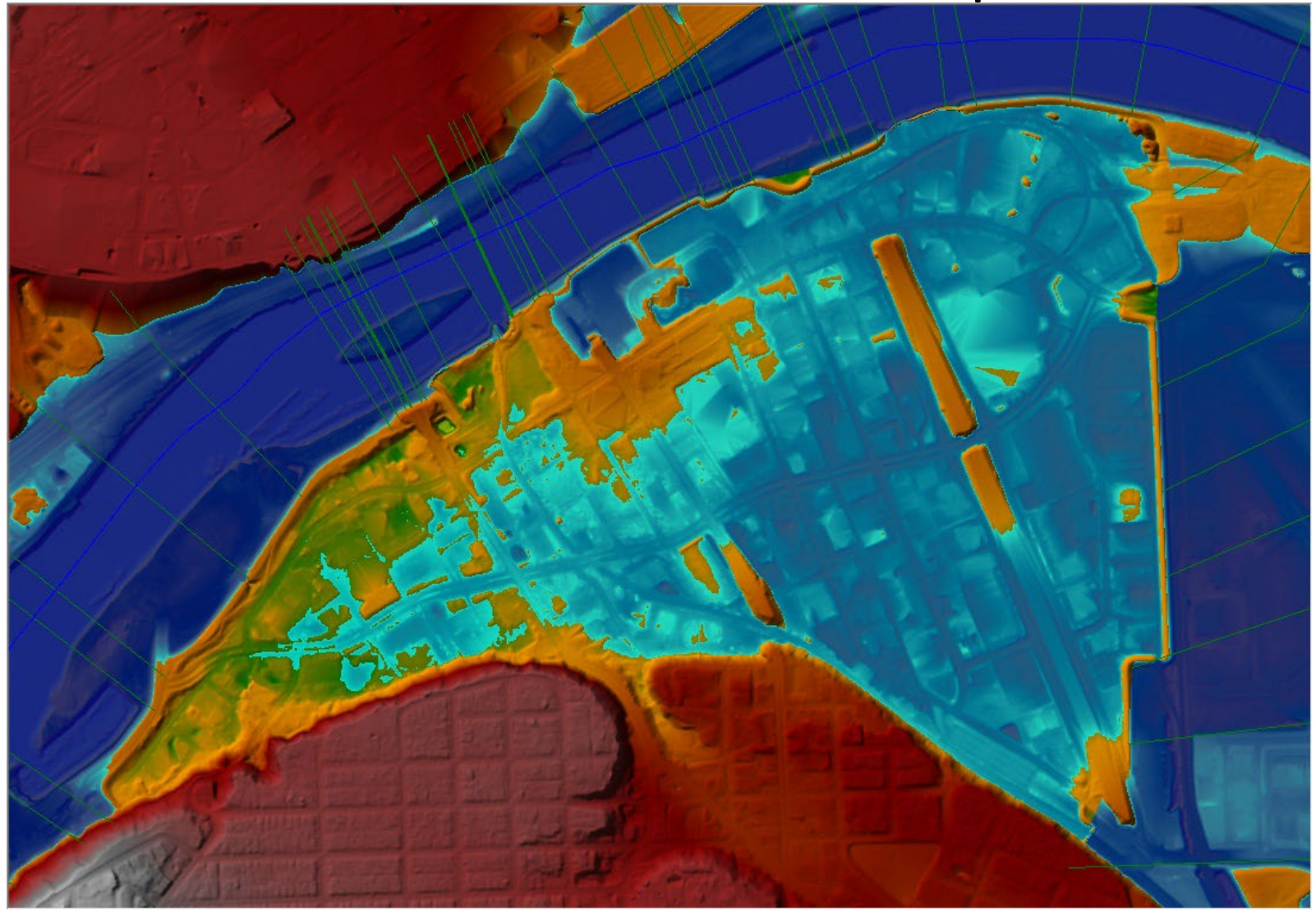
Legend

- Lat Struct
- Centerline Terrain
- Final Breach

OK Cancel



Saint Paul Levee Breach Example



Questions?