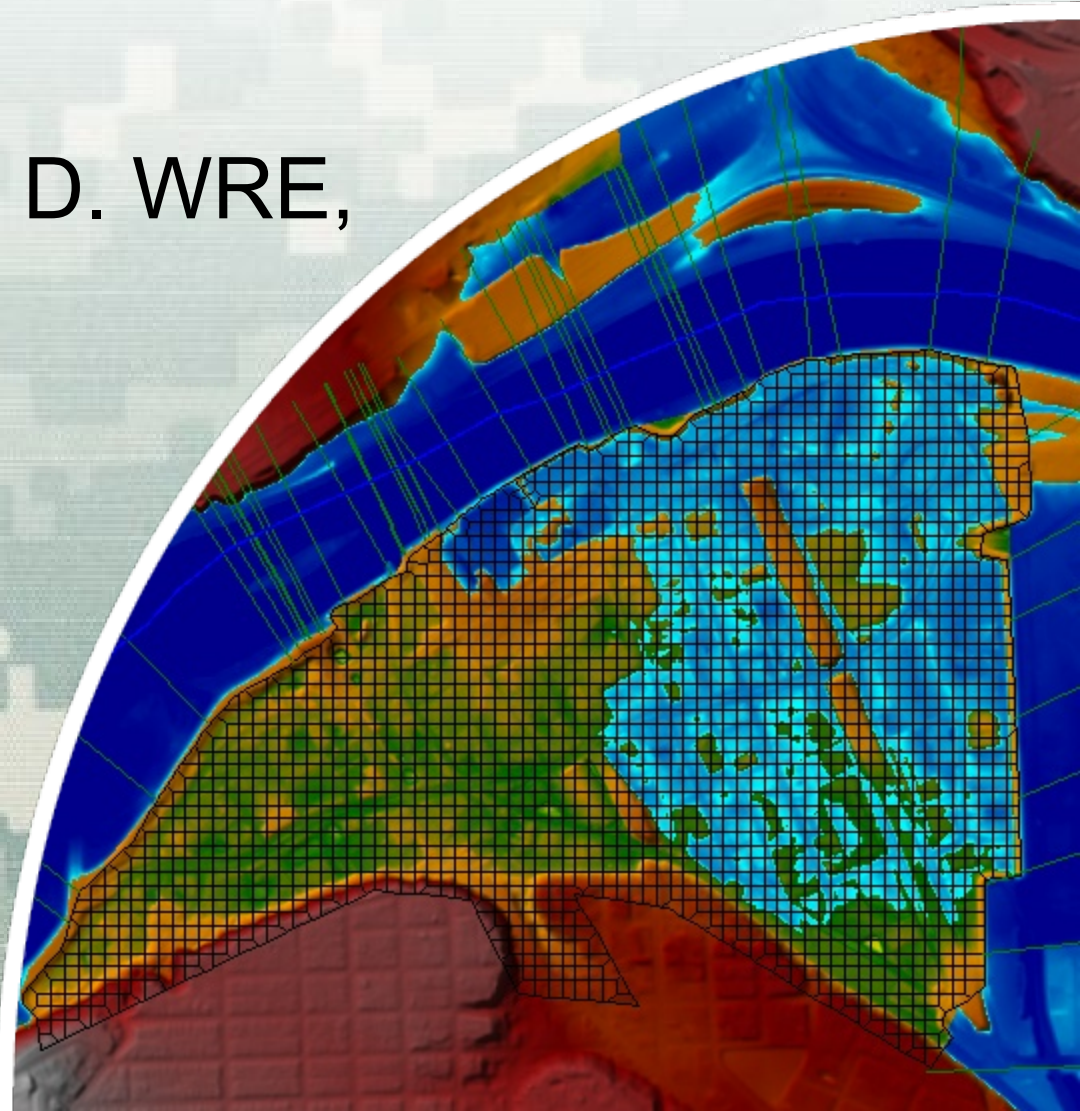


What's New with HEC-RAS 5.1

Gary Brunner, P.E., D. WRE,
M.ASCE



Major New Hydraulics Features for HEC-RAS 5.1

- Spatial Precipitation
- Spatial Infiltration
- Wind Forces
- 1D Finite Volume solver
- New 2D full momentum solver with greater Momentum conservation properties
- Pump stations inside 2D Flow Areas
- 1D Bridge Hydraulics inside 2D Flow Areas
- Computational speed improvements
- 3D Visualization tool

Spatial Precipitation

- Gridded Data
 - HEC-DSS file format (from HEC-MetView)
 - GRIB - NWS
 - NetCDF - NWS
- Point Gage Data
 - HEC-DSS time series
 - Regular Interval
 - Irregular Interval
 - User Entered into a Table

Unsteady Flow Boundary Conditions

[illegible]

Gridded Data

Boundary Conditions | Initial Conditions | Meteorological Data |

Precipitation: Wind Forces: Air Density:

Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode: Ratio (Optional): ...

Gridded Data

Source:

Filename:

Path:

Projection Override (Optional):

Units Override (Optional):

Gridded Precipitation example

HEC-RAS



Point Gage Data

Unsteady Flow Data - Point Precipitation Data 1972

File Options Help

Description ...

Boundary Conditions | Initial Conditions | Meteorological Data

Precipitation: Wind Forces: Air Density:

☐ Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode: Ratio (Optional): Point Time Series Mode (Nearest)

Meteorological Stations

Detailed View | Summary View

	Station Name	Height	Project X	Project Y	Longitude	Latitude
1	ALVIN BUSH DAM	2	1922740.6	431189.94	-77.9166667	41.35
2	DRIFTWOOD	2	1863234.88	427128.04	-78.1333333	41.3383333
3	HOLLIDAYSBURG 2	2	1790610.4	95591.73	-78.3888889	40.4272222
4	MILROY 2 WNW	2	2012703.14	199422.25	-77.5905556	40.7138889
5	PHILIPSBURG 8 E	2	1838408.6	266227.39	-78.2205556	40.8963889
6	RAYSTOWN LAKE 2	2	1896963.52	97268.31	-78.0069444	40.4333333
7	TYRONE	2	1832952.79	183975.72	-78.2386111	40.6705556
8	WILLIAMSPORT RGNL	2	2197049.88	394058.28	-76.9188889	41.2452
9	CRESSON 1 SE	2	1734232.01	104373.03	-78.5916667	40.45
10	CURWENSVILLE LAKE	2	1786461.52	322534.71	-78.41	41.05
11	DU BOIS 7 E	2	1690689.7	349266.08	-78.7583333	41.1208333
12	MADERA 2 SE	2	1778927.51	241828.17	-78.435	40.8283333
13	MILLHEIM	2	2044073.29	263969.12	-77.4766667	40.8908333
14	RENOVO 6 S	2	1968271.12	422543.08	-77.7508333	41.3263889
15	SAYERS DAM	2	2007191.2	321872.44	-77.6097222	41.05
16	STATE COLLEGE	2	1943600.61	248985.51	-77.84	40.85

Point Gage Data

Unsteady Flow Data - Point Precipitation Data 1972

File Options Help

Description ...

Boundary Conditions | Initial Conditions | Meteorological Data |

Precipitation: Wind Forces: Air Density:


Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode: Ratio (Optional): Point Time Series Mode (Nearest)

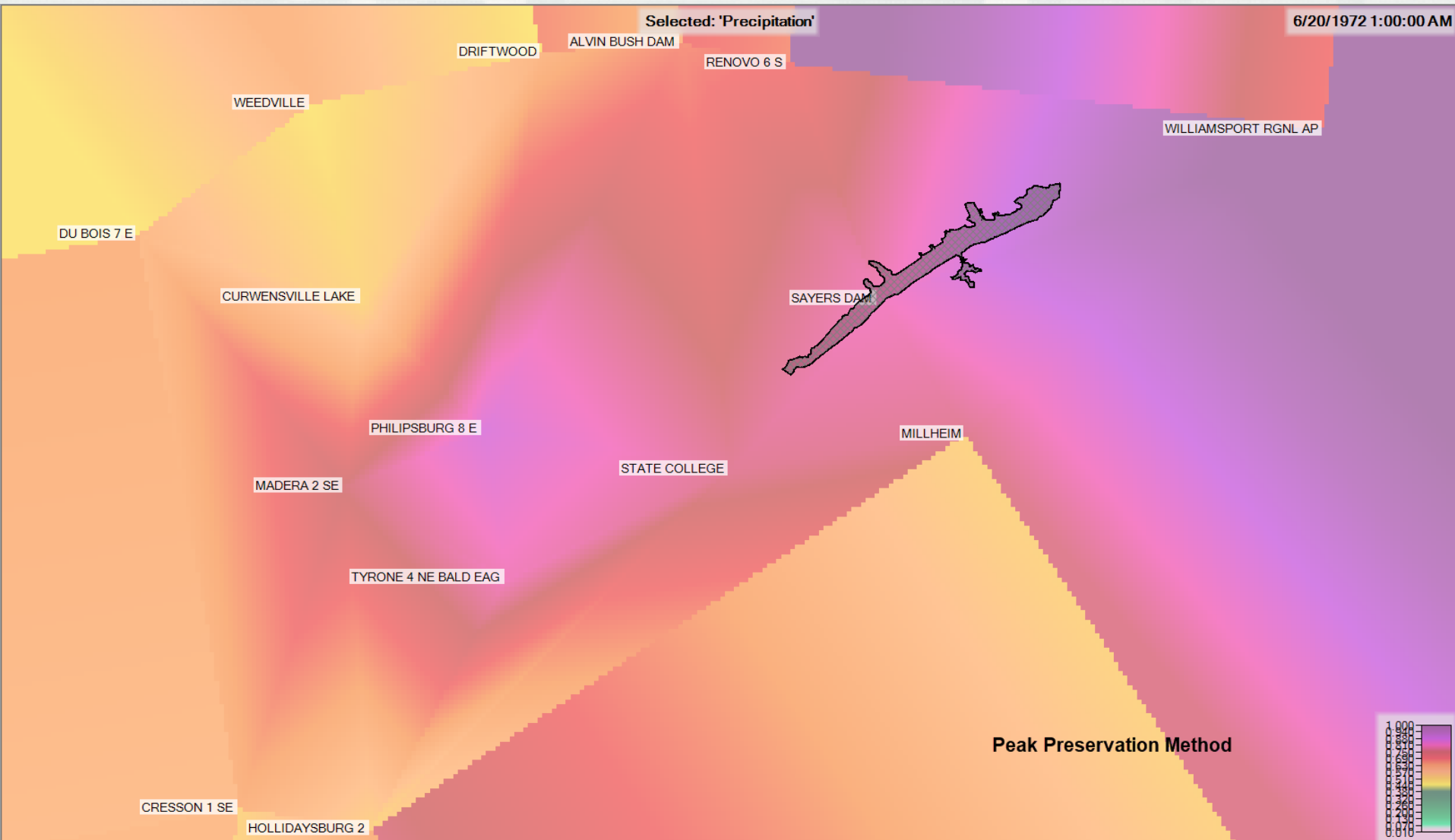
Point Time Series Data

Interpolation Method: 

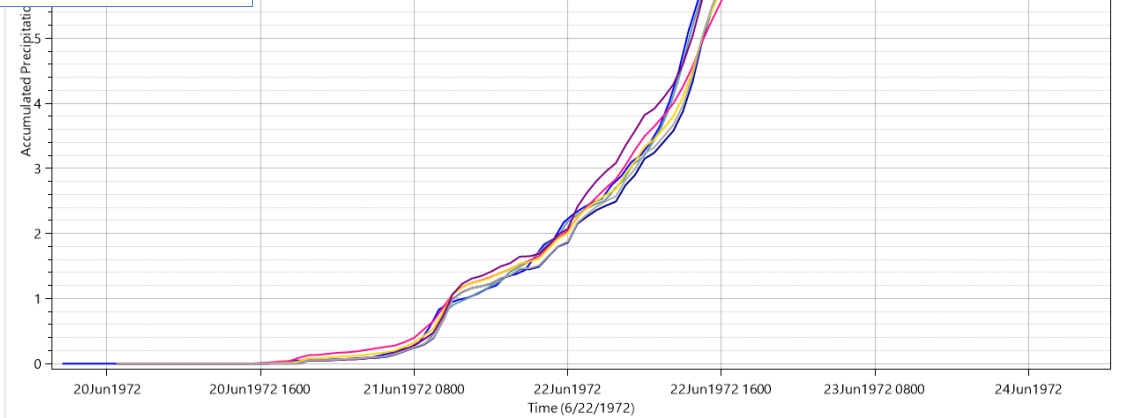
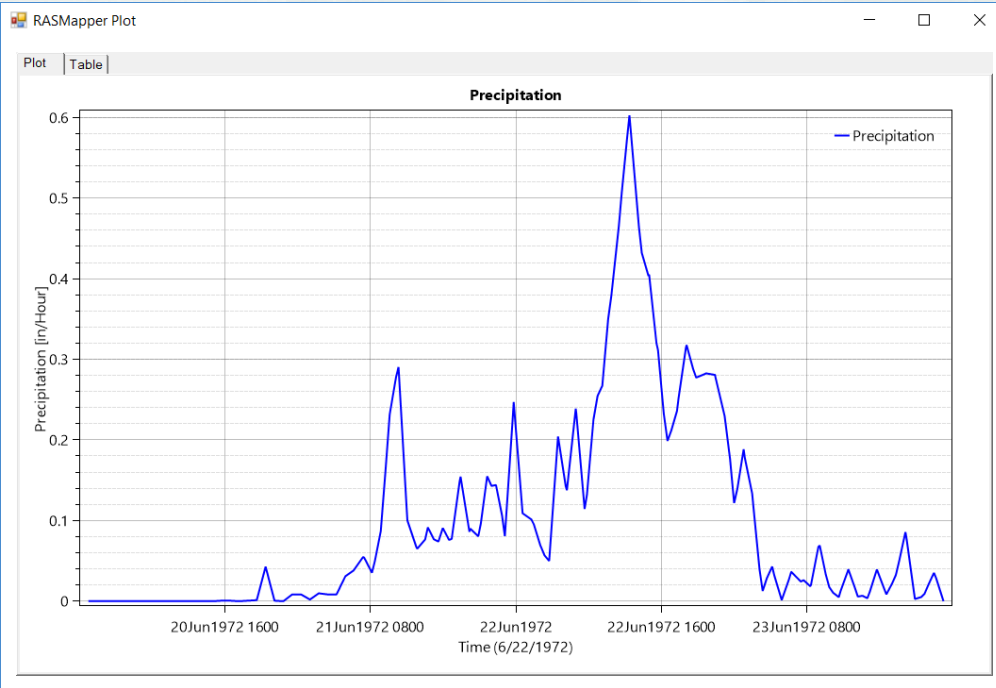
	Station Name	Interpolation Method	Distance	Edit
	1 ALVIN BUSH DAM	Inverse Distance	to 0.500 (inches)	...
	2 CRESSON 1 SE	Inverse Distance Squared	to 0.470 (inches)	...
	3 CURWENSVILLE LA	Inverse Distance Squared Restricted	to 0.300 (inches)	...
	4 DRIFTWOOD	Triangulation	to 0.390 (inches)	...
	5 DU BOIS 7 E	Peak Preservation	to 0.510 (inches)	...
	6 HOLLIDAYSBURG 2	Shape Preservation	to 0.510 (inches)	...
	7 MADERA 2 SE	Laplace	2.90 (inches)	...
	8 MTI HFIM	DSS: data range = 0.000 to 0.500 (inches)		...

DSS: data range = 0.000 to 0.510 (inches)

Cumulative Rainfall



Rainfall Time Series Plots



Spatial Infiltration

- Three Methods
 - Deficit – Constant method
 - SCS Curve Number
 - Green and Ampt
- Spatial Data
 - Soils
 - Land cover
- Other Optional Data
 - Evapotranspiration
 - Mean Monthly Pan evaporation data

Wind Forces

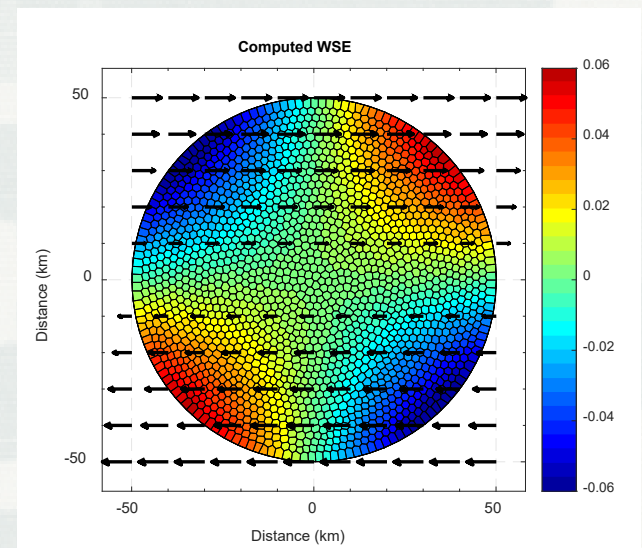
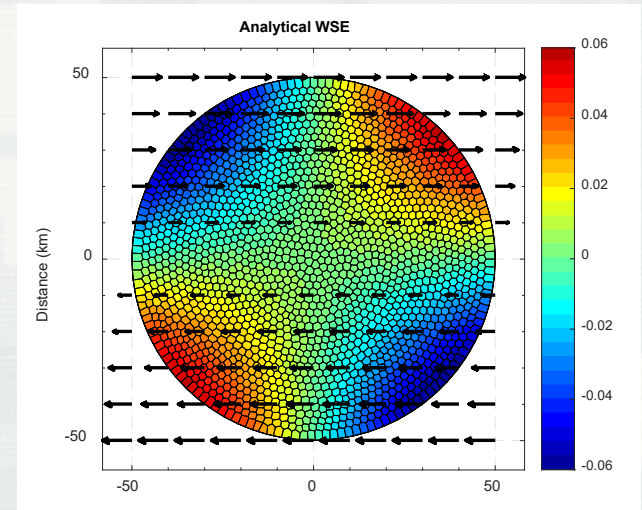
- Added to 1D and 2D solution algorithms
 - 1D Finite Difference and 1D Finite Volume SWE
 - 2D SWE - current and new equation solver.
 - **Not** in 2D Diffusion Wave solver

1D Momentum Equation
$$\frac{\partial Q}{\partial t} + \frac{\partial(VQ)}{\partial x} + gA \left(\frac{\partial \eta}{\partial x} + S_f + S_h \right) = T_w \frac{\tau_{sR}}{\rho_w}$$

- Data Sources
 - Gridded Data
 - Gaged Point data
 - User Entered Table

Wind Verification

- Flat circular basin
- Spatially variable wind forcing in the x-direction only
- Linear bottom friction
- Polygonal mesh



Wind Application - Animation



Wind 1D Profile Animation

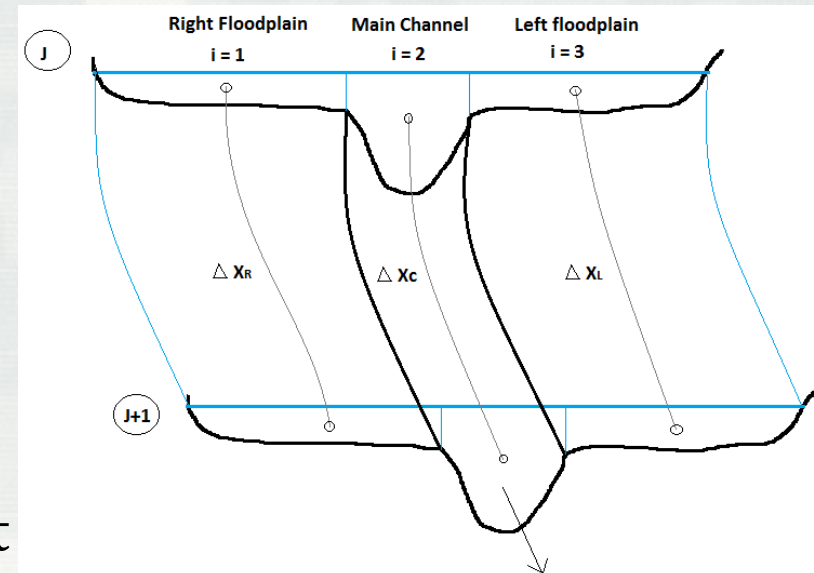


1D Finite Volume Solution Algorithm

- **The new 1D Finite Volume algorithm has the following positive attributes:**
 - Can start with channels completely dry, or they can go dry during a simulation (wetting/drying)
 - Very stable for low flow modeling
 - Can handle extremely rapidly rising hydrographs without going unstable
 - Handles subcritical to supercritical flow, and hydraulic jumps better – No special option to turn on.
 - Junction analysis is performed as a single 2D cell when connecting 1D reaches (continuity and momentum is conserved through the junction)

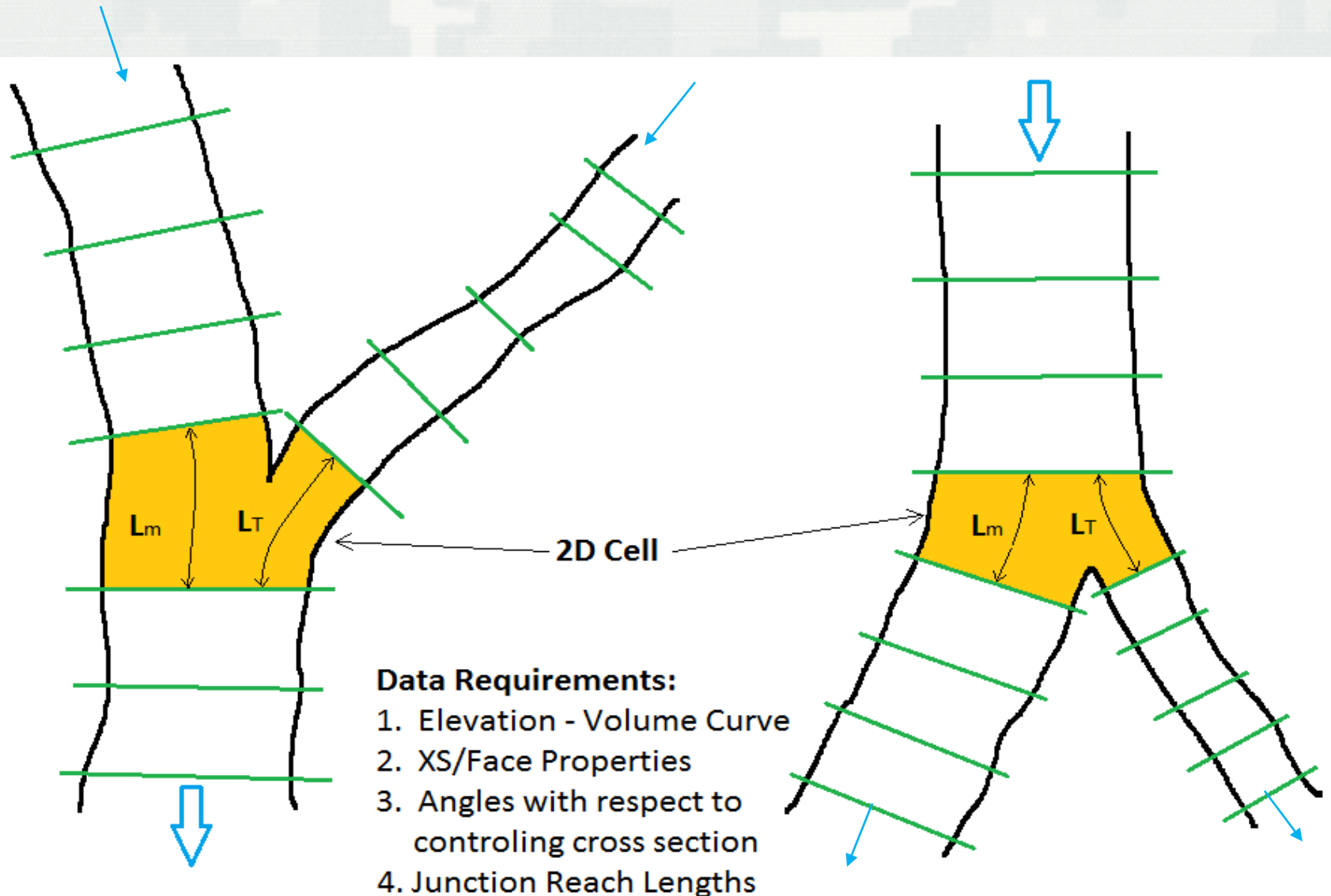
Partial Cells

Left floodplain, Main channel, Right floodplain

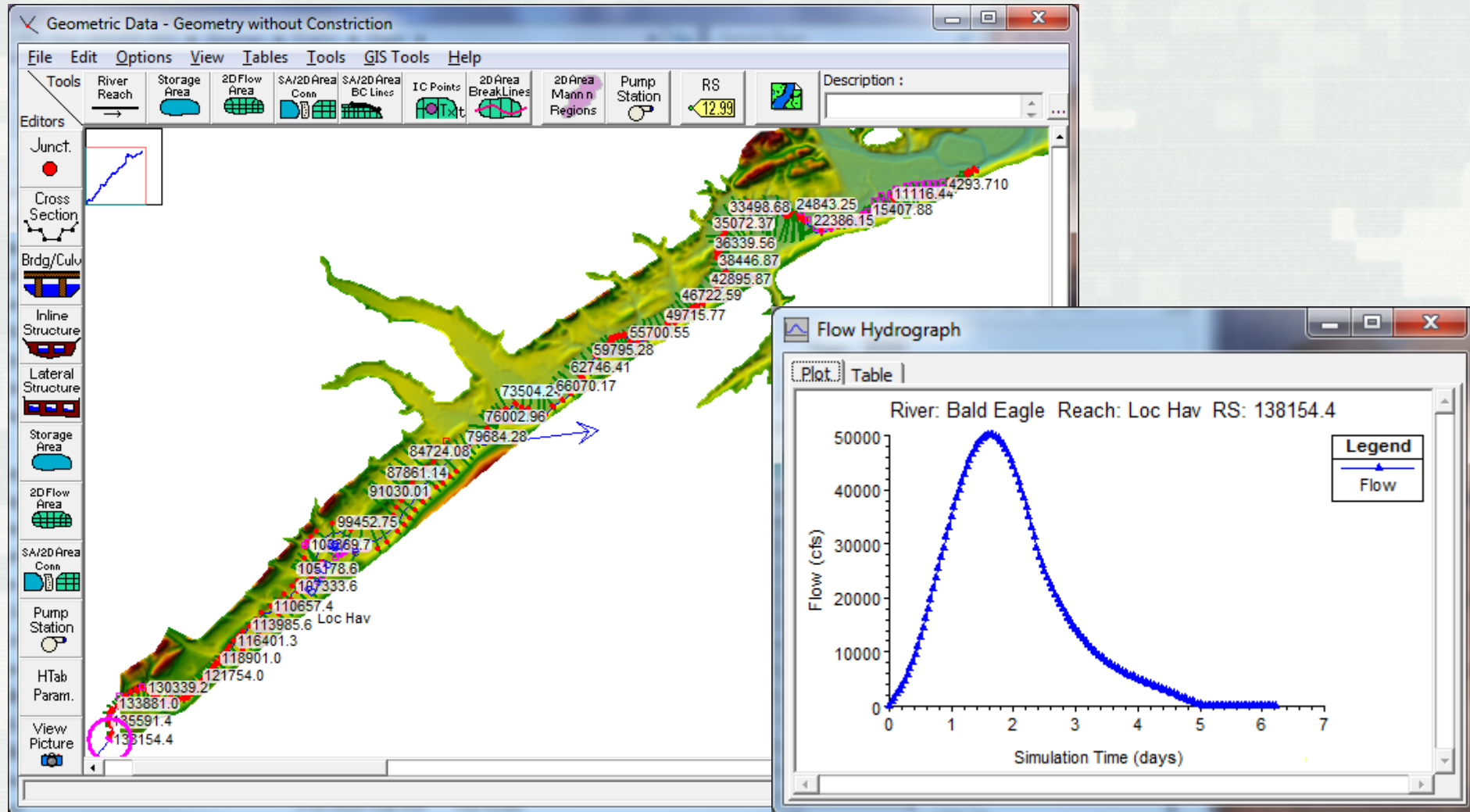


- Separate cells for main channel, left floodplain and right floodplain.
 - Current Finite Difference uses only two flow areas: channel & floodplain
 - Notation: Partial cells indexed by i
 - u_{ji} = channel or overbanks velocities at
 - A_{ji} = channel or overbanks partial areas for cross-section j
 - $A_j = \sum_i A_{ji}$ cross-section total area
 - Cross-section partial conveyance $K_{ji} = \left(A_{ji} R_{ji}^{2/3} \right) / (n_{ji} / k)$
 - Cross-section total conveyance $K_j = \sum_i K_{ji}$
-

Junctions

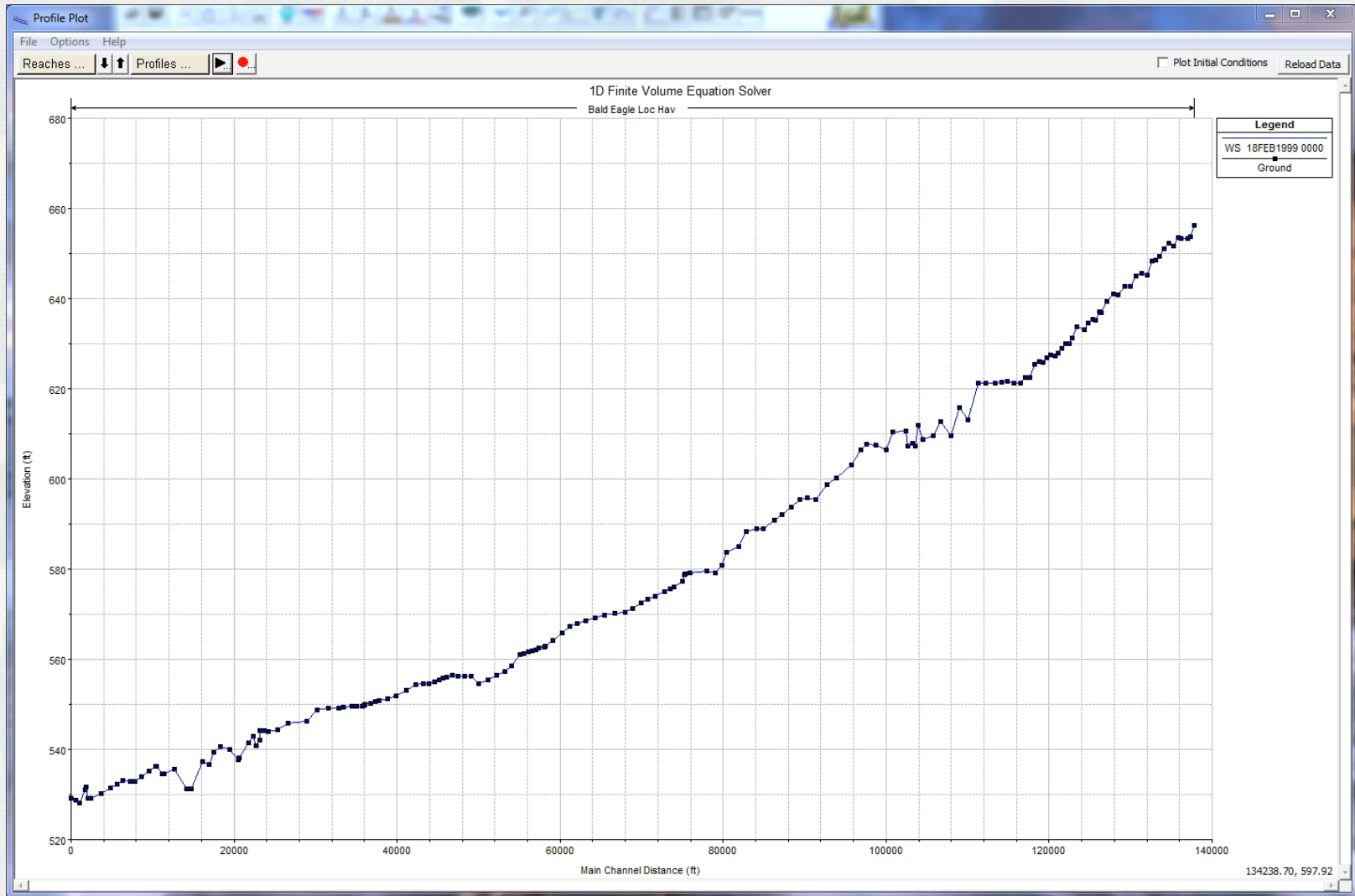


Natural River – No Connections Starting Dry, then wet, then dry



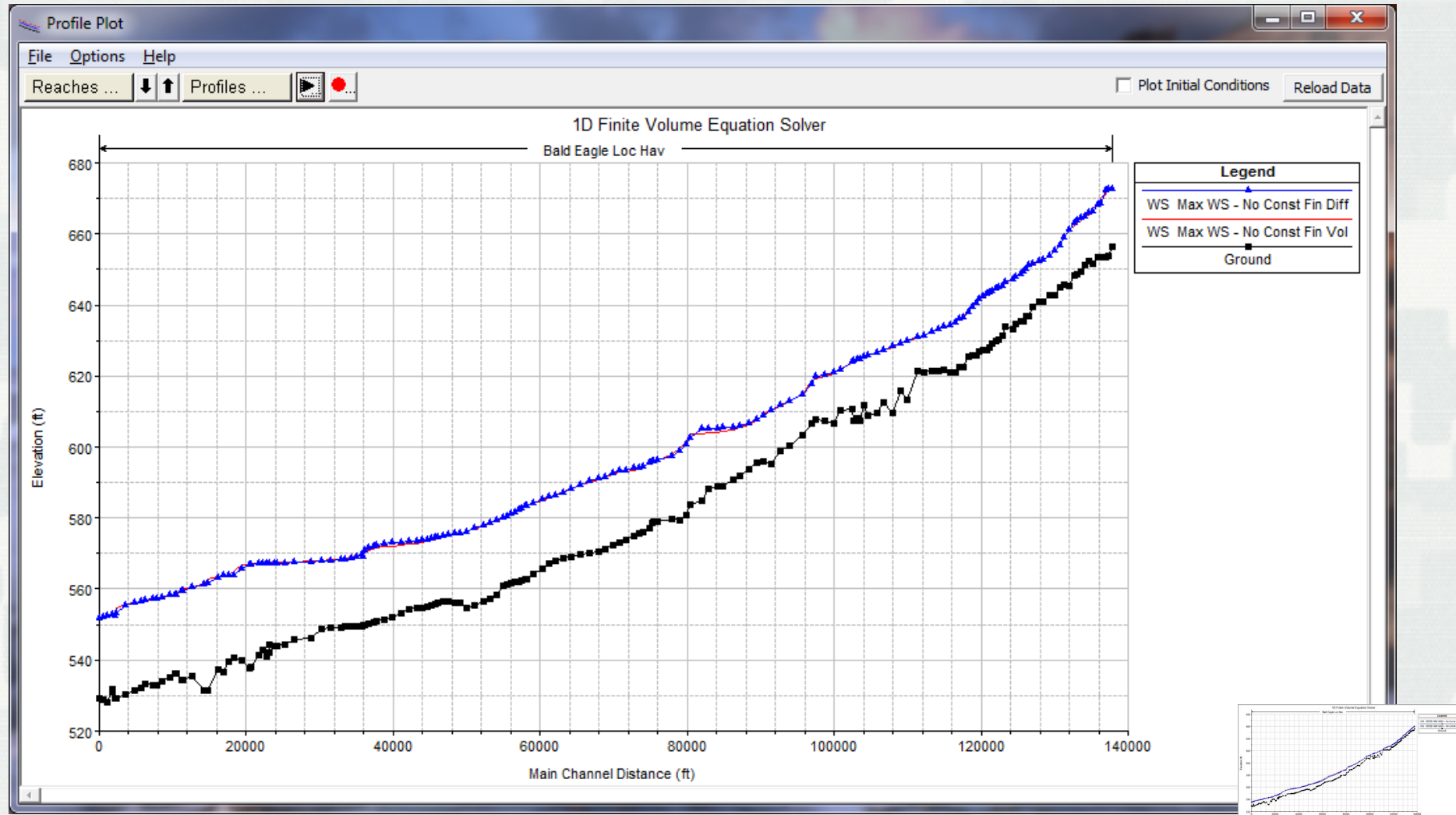
Natural River — Continued

Animation - Finite Volume - Dry to Wet to Dry

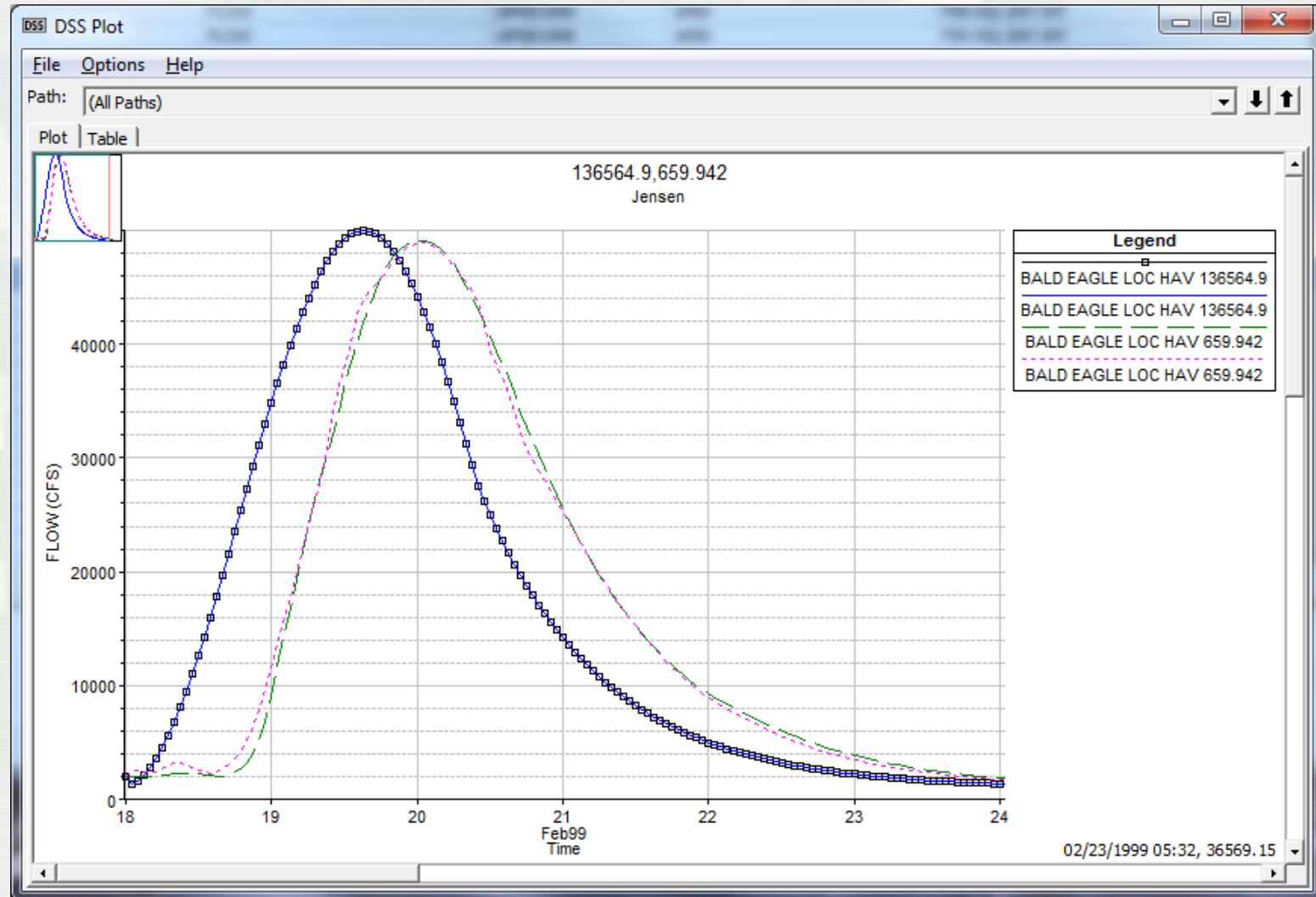


Natural River — Continued

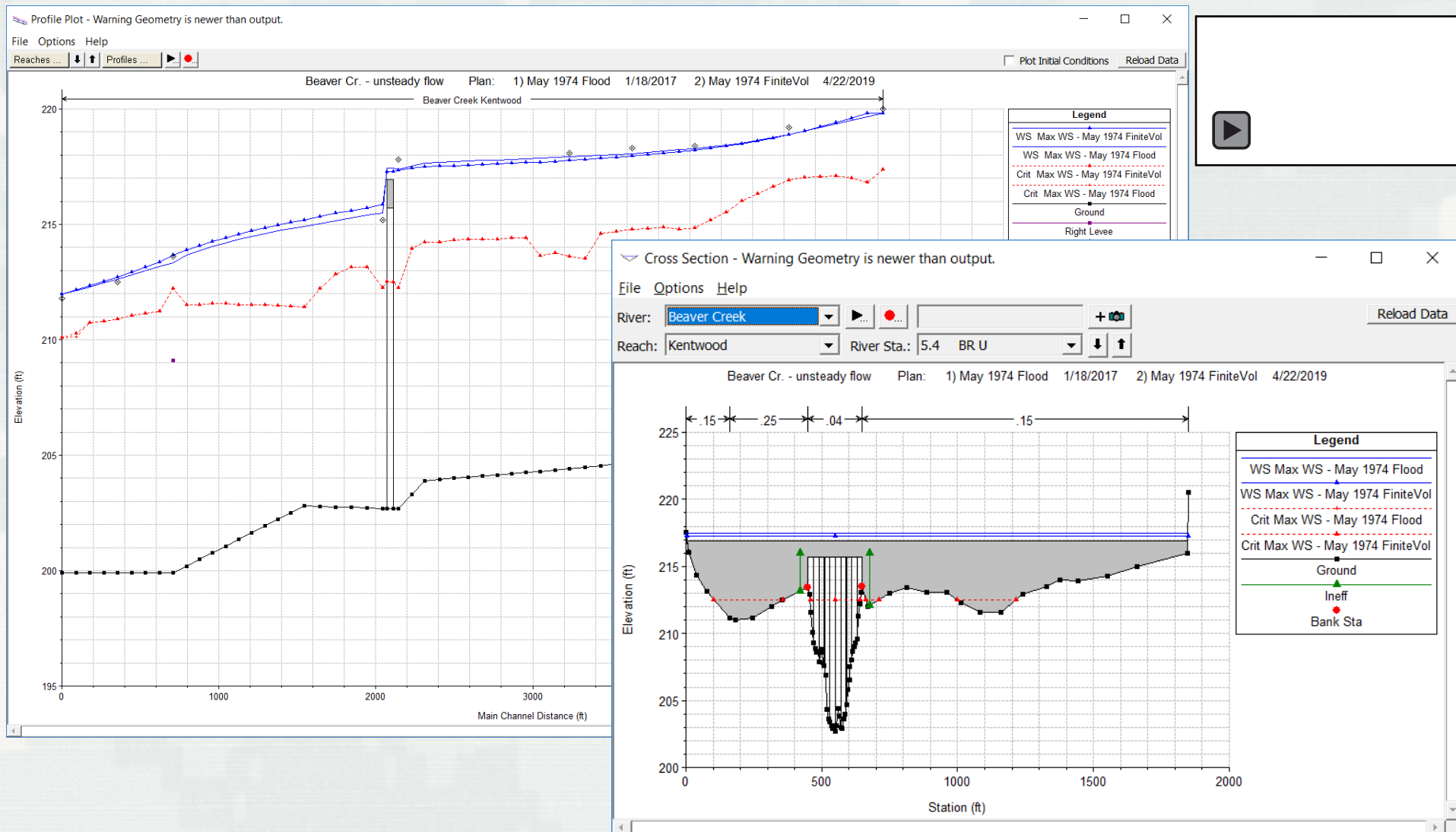
Finite Volume vs Finite Difference – Starting Wet



Natural River — Continued Upstream Inflow and Downstream Outflows



1D Bridge Hydraulics Beaver Creek



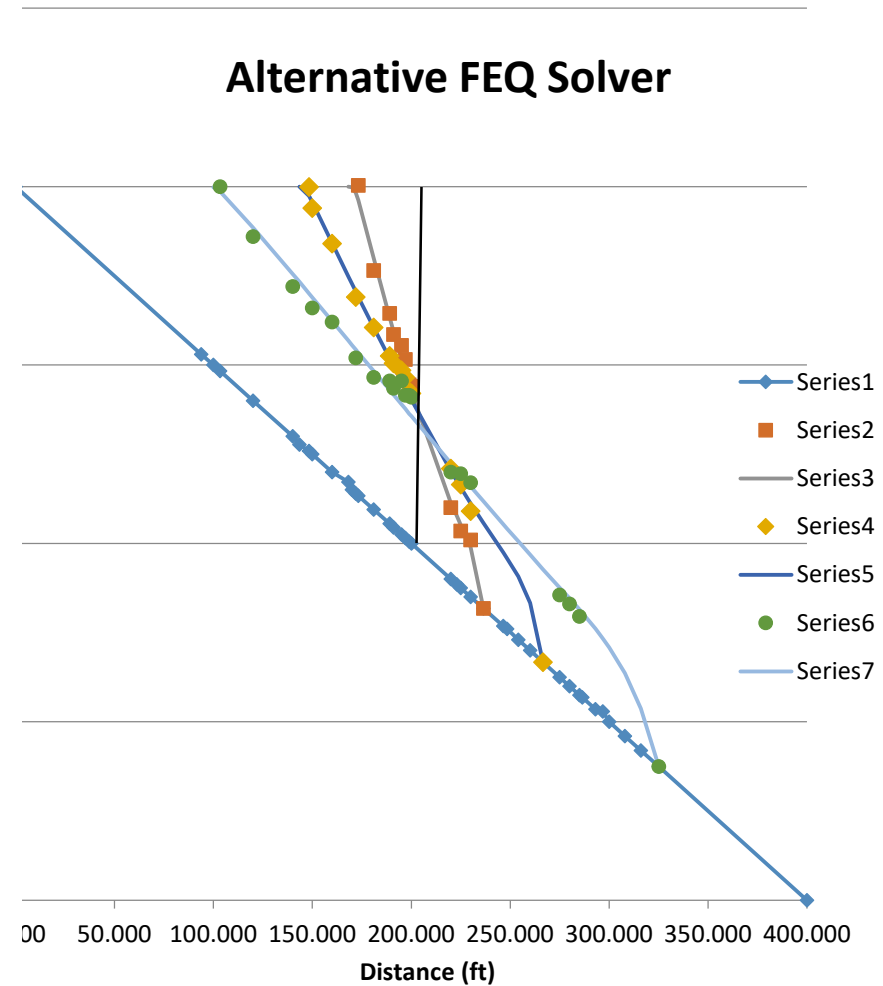
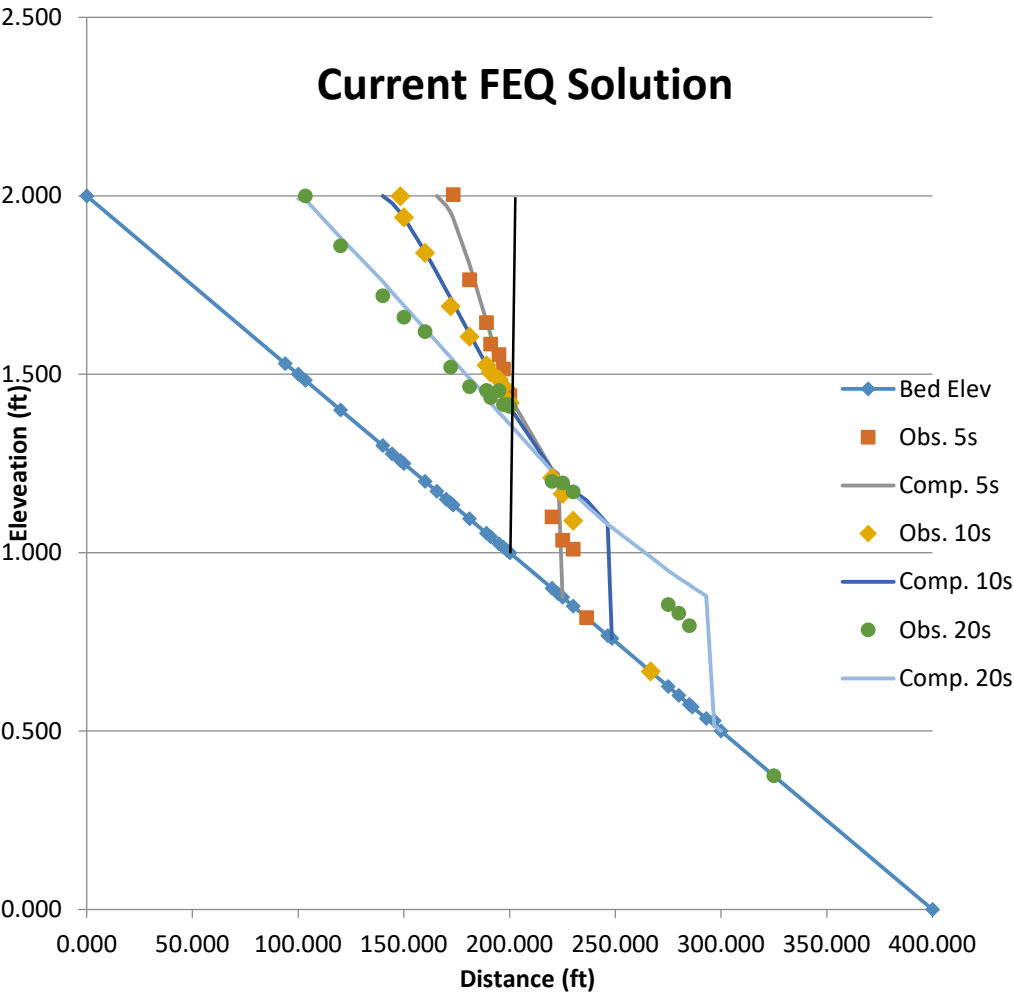
Bald Eagle Creek with Bridges



Alternative Solution Scheme for Shallow Water Equations

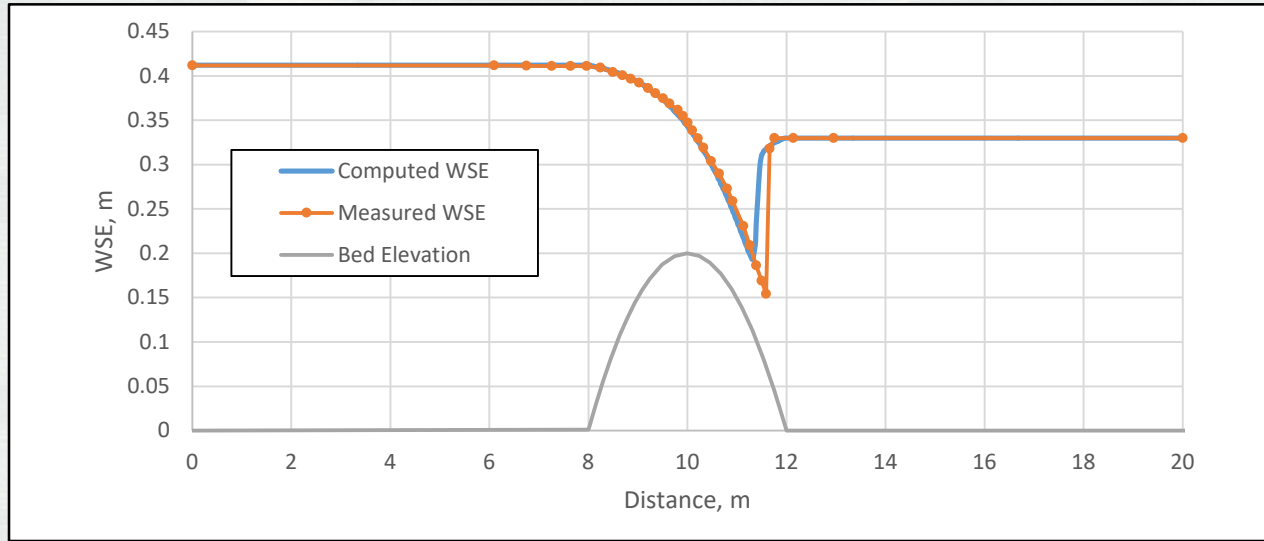
- Momentum - conservative discretization of the acceleration terms
 - Greater momentum conservation than current solver in current version
- Semi Explicit – Time step is somewhat limited by the Courant condition
 - Generally requires smaller time steps and more computational time to run

Sudden Dambreak in a Flume (WES Data Set and report from 1960)

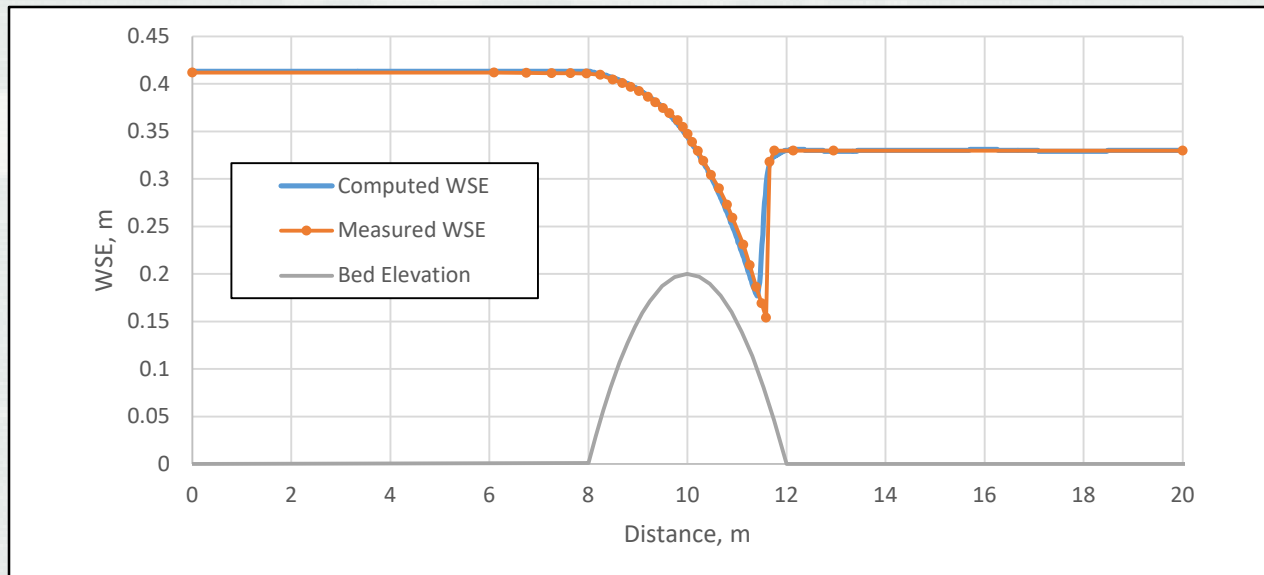


Flow over a Bump assuming no Friction

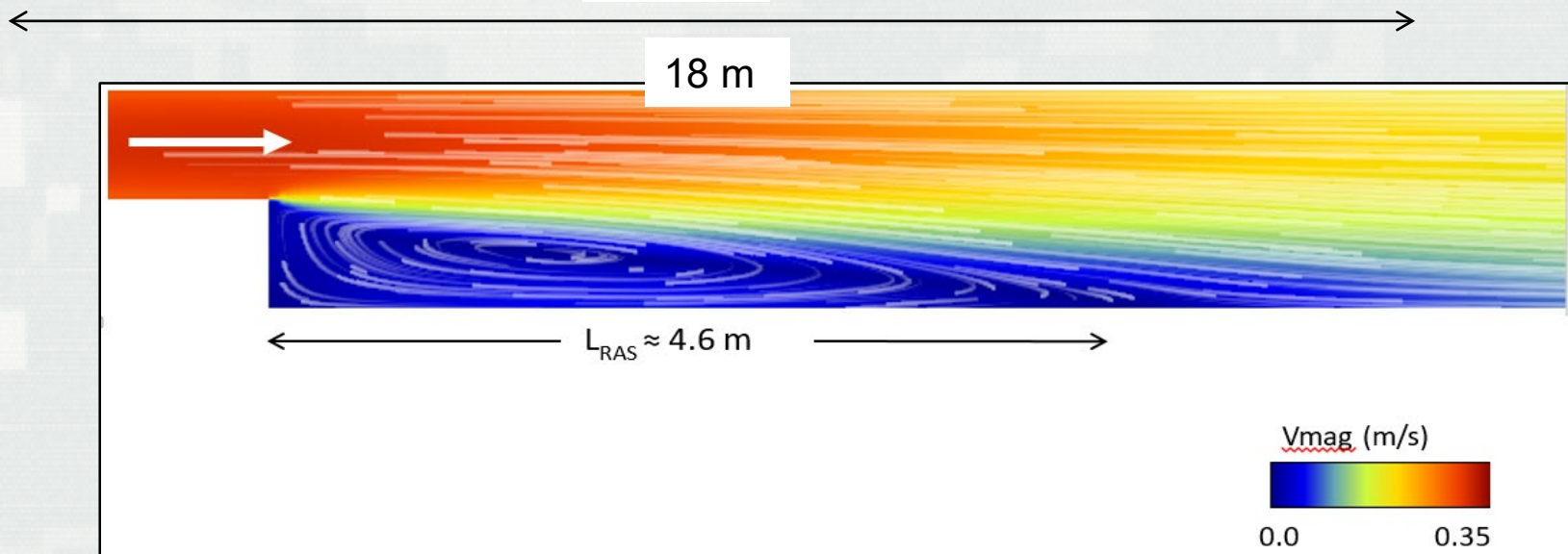
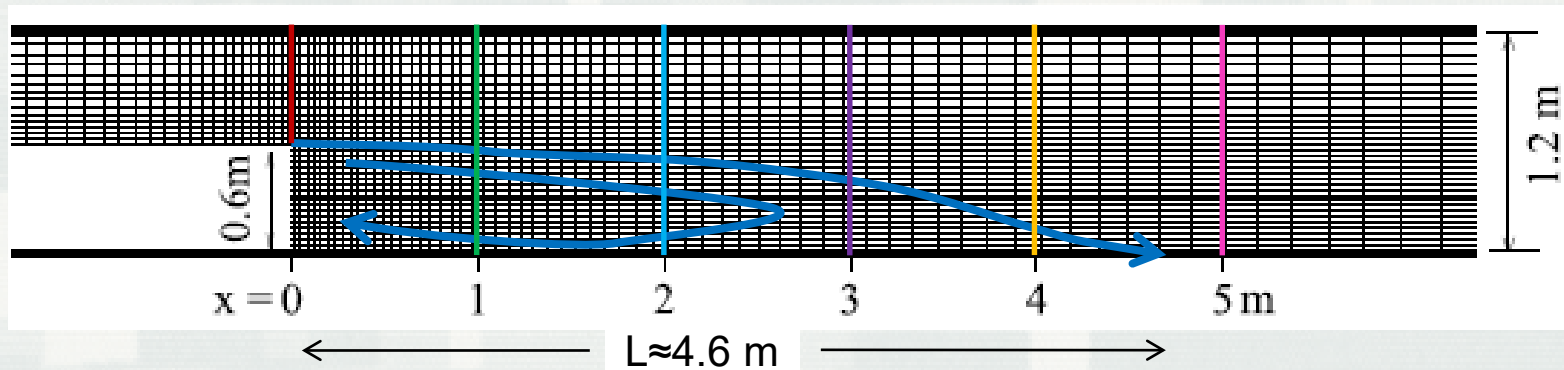
Current Solver:



New Solver:

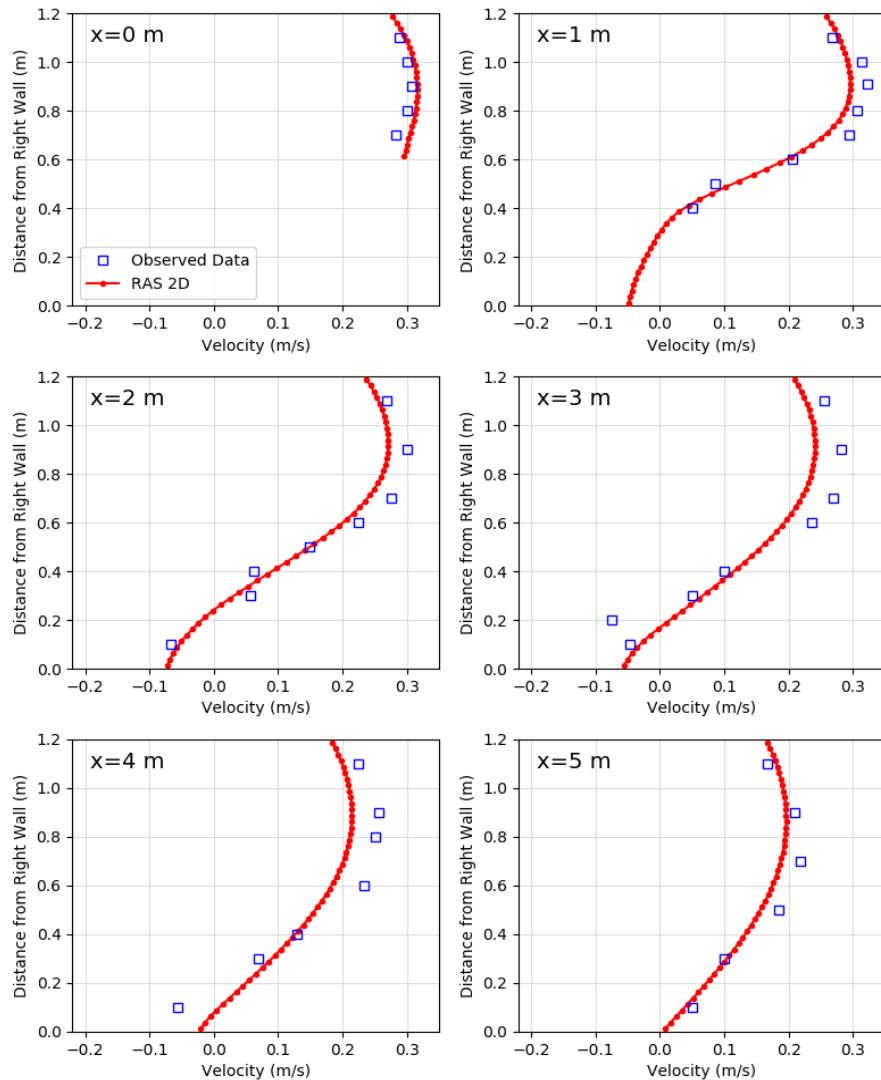


Sudden Expansion – Lab Data

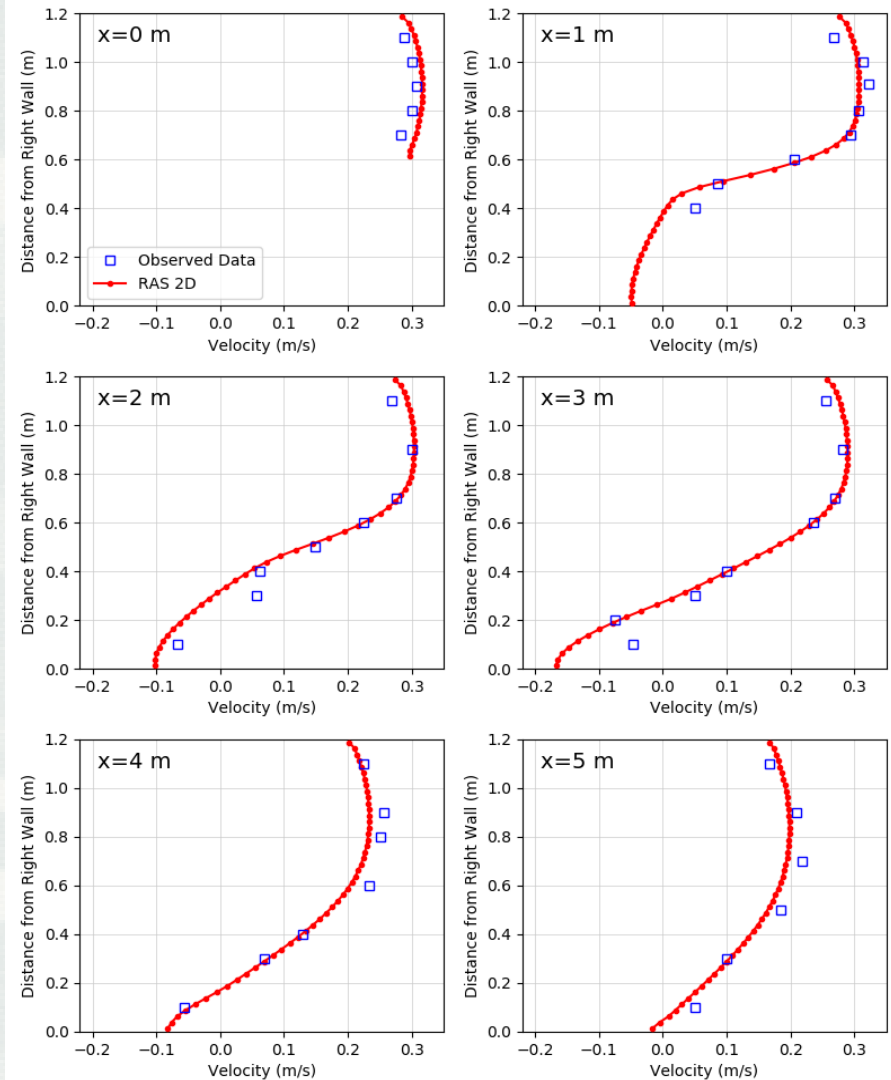


Sudden Expansion

Current Solver (D=1.4):



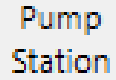
New Solver D=0.4:



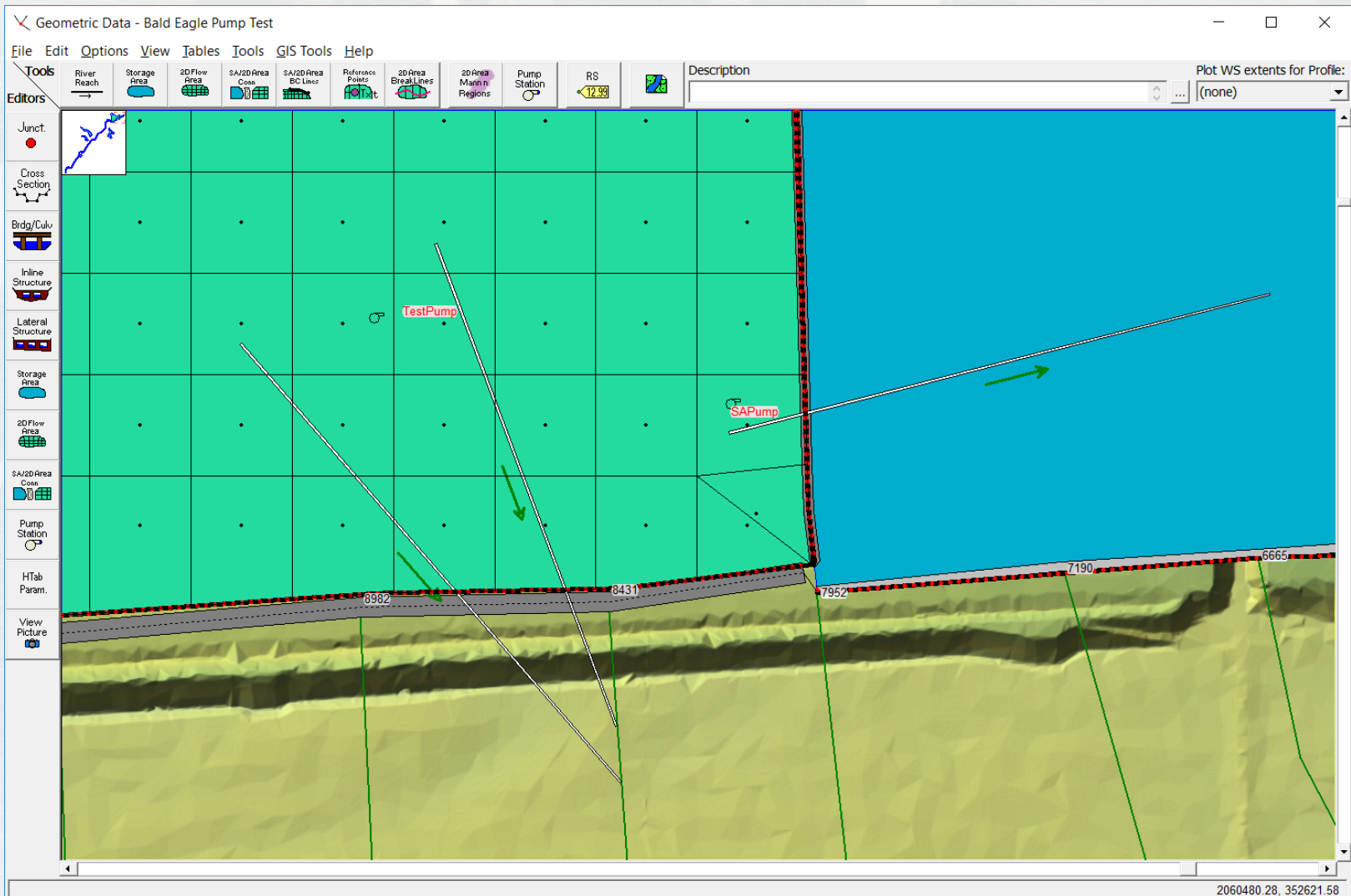


Pump Stations Connected to 2D Flow Areas

- Pump Stations now how spatial connections
 - X, Y coordinates for too and from locations
- Can now connect to 2D flow areas
 - 2D cell to another 2D cell
 - 2D cell to Storage Area
 - 2D cell to 1D river reach (XS location)



Pump Stations Example





Pump Station

Pump Stations Example

RAS Mapper

File Tools Help

Selected Layer: Depth

Features

- Geometries
- Event Conditions
- Results
 - PMF Multi 2D
 - 1D-2D Refined Grid
 - 2D to 1D No Dam
 - 2D to 2D Run
 - SA to 2D Dam Break
 - Single 2D
 - 2D Levee Struc
 - Detailed 2D to 2D
 - MeshGenProb
 - 1D-2D ND Test
 - Culvert Test
 - PMF Multi 2D NC
 - SA2D Conn Tests
 - PolygonTool
 - PolygonTool V-DT
 - PMF Multi 2D V-DT
 - 1D-2D Vel at BC
 - 1D to 2D Conn
 - Precip Test
 - Pump Test
 - Event Conditions
 - Geometry
 - Depth (Max)
 - Velocity (01JAN1999 12:00:00)
 - WSE (03JAN1999 20:30:00)

Map Layers

- LandUse
- MainChannelBanks
- USGS Imagery
- Google Hybrid
- street100k_L_pa027
- street100k_L_pa035
- NLCD_2016_Impervious_L48_20190
- NLCD 2016 Land Cover L48 20190

Messages Views Profile Lines Active Featu

(2050014.46, 351039.80 1 pixel = 5.99 feet)

Selected: 'depth'

Pump Station Data Editor

Pump Station Name: UpTheHill

Pump Connection Data Pump Group Data Advanced Control Rules

Pump Group: Group #1

☐ Bias group operations to On (at start of simulation)

Startup Time (min): 1

Shutdown Time (min): 1

Width: 5

Number of pumps in this group: 2

Pump Efficiency Curve

	Head(ft)	Flow(cfs)
1	0	500
2	1	475
3	10	400
4	20	350
5	30	300
6	50	200
7	60	150

Pump Names and Base WSEL On/Off

	Pump Name	WS Elev On (ft)	WS Elev Off (ft)
1	Pump #1	557	555
2	Pump #2	560	558

Pump GIS Data: Pump #2
Length: 6276.3

	X	Y
1	2053057.4	351219.88
2	2051849.49	350828.12
3	2050158.42	350971.76
4	2049048.46	350913
5	2048193.13	351167.64
6	2046972.16	350958.71
7	2046050.11	350802.41

Plot Pump Efficiency Curves ...

OK Cancel



1D Bridge Hydraulics inside of a 2D Flow Area

- Develop a family of Headwater – Tailwater - Flow curves from 1D bridge hydraulic calculations
- Option to compute flow over the top of the bridge as weir flow or normal 2D flow equations
- Flows through the bridge opening will take into account momentum transfer
 - Flow and Velocity Boundary condition

Computational Speed Improvements

- New Matrix Format

- Previous versions allowed the matrix to be Non-Symmetric
- Version 5.1 uses a Symmetric matrix format
- This allowed us to use a faster solver - Symmetric Positive Definite Solver

- Boundary Condition Cells

- Previous version had B.C. cells along entire boundary of 2D area
 - Done for simplicity and consistency (.i.e. keep the code simple)
- Version 5.1 only has extra cells a user defined boundary condition locations
 - Fewer cells means less computations – Faster solution

5.0.7 vs 5.1 2D Computational Speed

2D Test Name	Number Cells	Equation Type	5.0.7	5.1	Speed Factor
Bald Eagle Detailed	87,022	FEQ	1 hr 29 min 55s	59 min 37s	1.51
Muncie 2D 50ft Grid	5,376	FEQ	1 min 15s	55s	1.36
Saint Paul 2D	2,251	Diff	1 min 32s	1 min 01s	1.51
EU Test No 2	10,000	FEQ	40s	22s	1.82
EU Test No 4	80,000	FEQ	56s	40s	1.40
EU Test No 5	7,460	FEQ	50s	36s	1.39
EU Test No 6	36,492	FEQ	1 min 18s	50s	1.56
EU Test No 7 20m grid	16,590	FEQ	12 min 25s	10 min 26s	1.19
EU Test 8A 2m grid	97,000	FEQ	1 hr 10 min 36s	48 min 26s	1.45
Yolo Bypass2	17,129	FEQ	9 min 34s	8 min 11s	1.17
Boise River	10,423	FEQ	10 min 46s	6 min 57s	1.55
Truckee River 1D/2D	162,805	Diff	1 hr 18 min 27s	47 min 6s	1.67
400 sq mi Watershed	2,033,190	Diff	16 hrs 45 min 14s	9 hrs 53 min 55s	1.69
Average Speed Increase					1.50

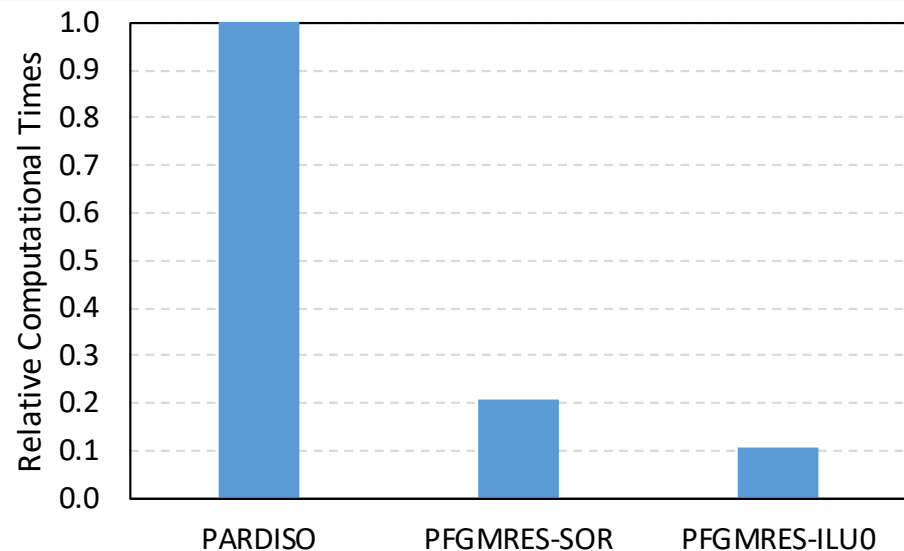
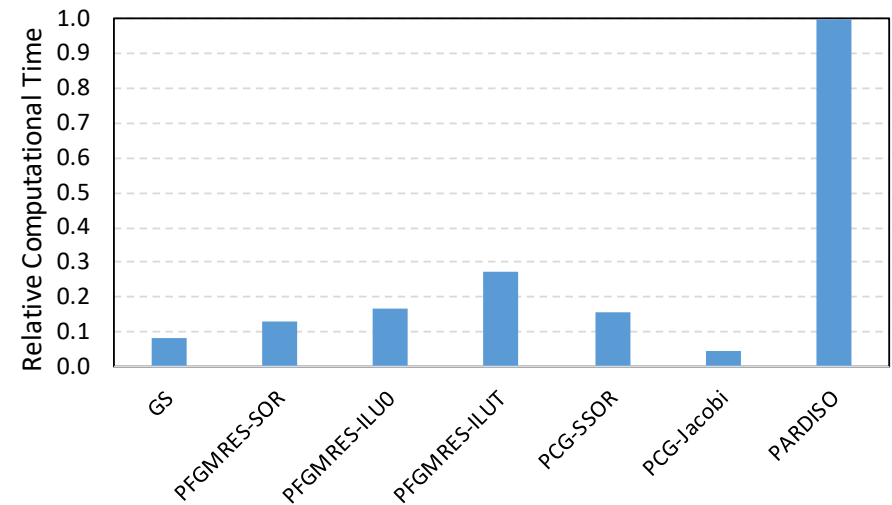
2D Iterative Matrix Solvers

- HEC-RAS 5.0.7 uses a solver called **PARDISO - direct solver**
 - Better for model stability and volume accounting
 - Slower
- For HEC-RAS 5.1 we have added optional **Iterative Solvers**
 - Potentially faster
 - Requires user-based solution tolerance
 - Potentially less stable

Iterative Matrix Solvers

Note: Times are only for matrix solution

- Channel constriction and expansion
- Upper North Bosque River Watershed



5.0.7 vs 5.1 with Iterative Solvers

2D Test Name	Number Cells	Equation Type	5.0.7	5.1	5.1 Iter Solv	Speed Factor
Bald Eagle Detailed	87,022	FEQ	1 hr 29 min 55s	59 min 37s	51 min 47s	1.73
Muncie 2D 50ft Grid	5,376	FEQ	1 min 15s	55s	51s	1.47
Saint Paul 2D	2,251	Diff	1 min 32s	1 min 01s	1 min 52s	0.82
EU Test No 2	10,000	FEQ	40s	22s	13s	3.08
EU Test No 4	80,000	FEQ	56s	40s	25s	2.24
EU Test No 5	7,460	FEQ	50s	36s	24s	2.08
EU Test No 6	36,492	FEQ	1 min 18s	50s	37s	2.11
EU Test No 7 20m grid	16,590	Diff	12 min 25s	10 min 26s	6 min 57s	1.79
EU Test 8A 2m grid	97,000	FEQ	1 hr 10 min 36s	48 min 26s	15 min 2s	4.69
Yolo Bypass2	17,129	FEQ	9 min 34s	8 min 11s	5 min 41s	1.68
Boise River	10,423	FEQ	10 min 46s	6 min 57s	4 min 50s	2.23
Truckee River 1D/2D	162,805	Diff	1 hr 18 min 27s	47 min 6s	1 hr 10 min 30s	1.1
400 sq mi Watershed	2,033,190	Diff	16 hrs 45 min 14s	9 hrs 53 min 55s	11 hr 3 mins 43s	1.52
Average Speed Increase						2.04

3D Visualization tool

