Boundary and Initial Conditions for 2D Modeling

Eric Tichansky

Senior Hydraulic Engineer

USACE, Institute for Water Resources, Hydrologic Engineering Center

US Army Corps of Engineers

IWR

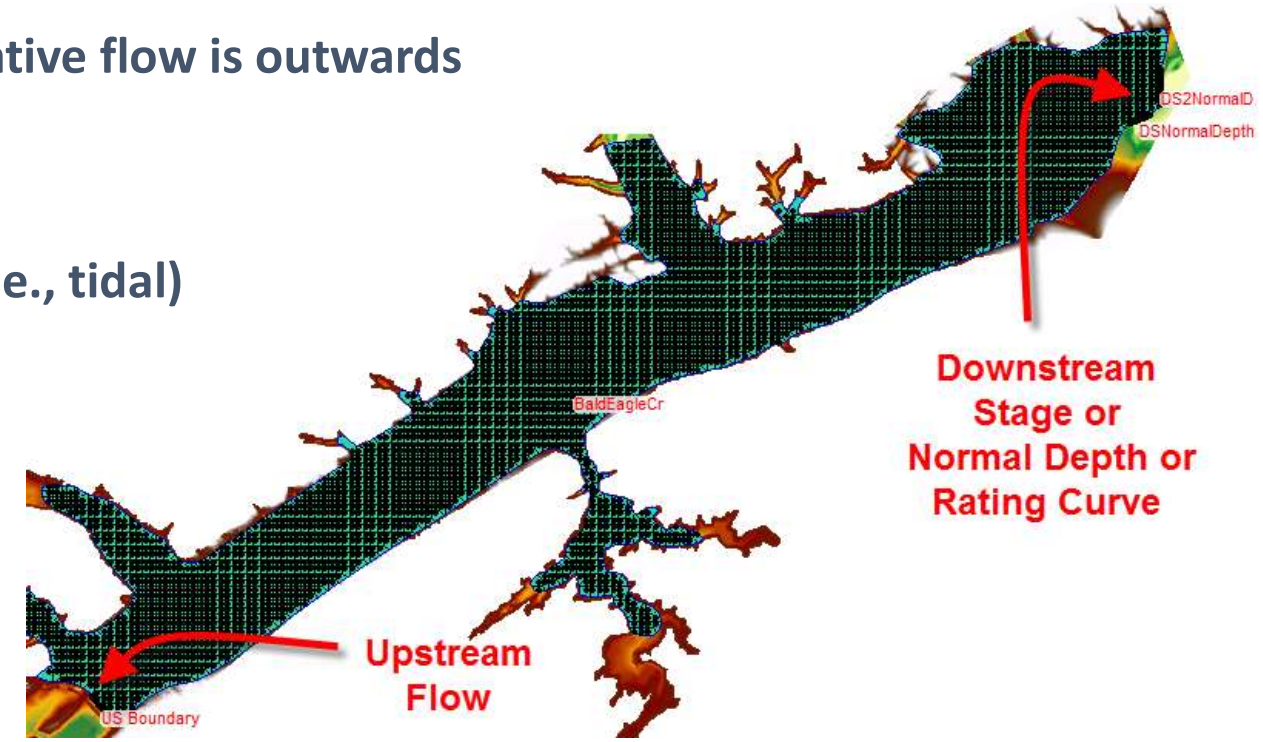
HEC

Overview

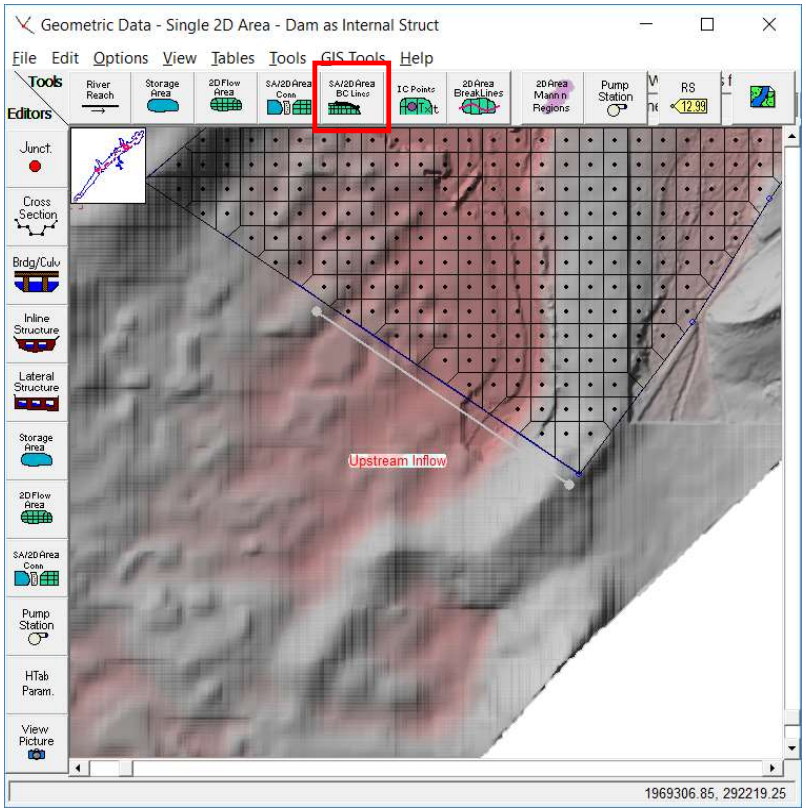
- Boundary Conditions (BC)
  - External
  - Internal
  - Global
- Initial Conditions (IC)
  - User-Specified
  - Ramp Up and Warm Up Periods
  - Restart File
  - Interpolate from Previous Results

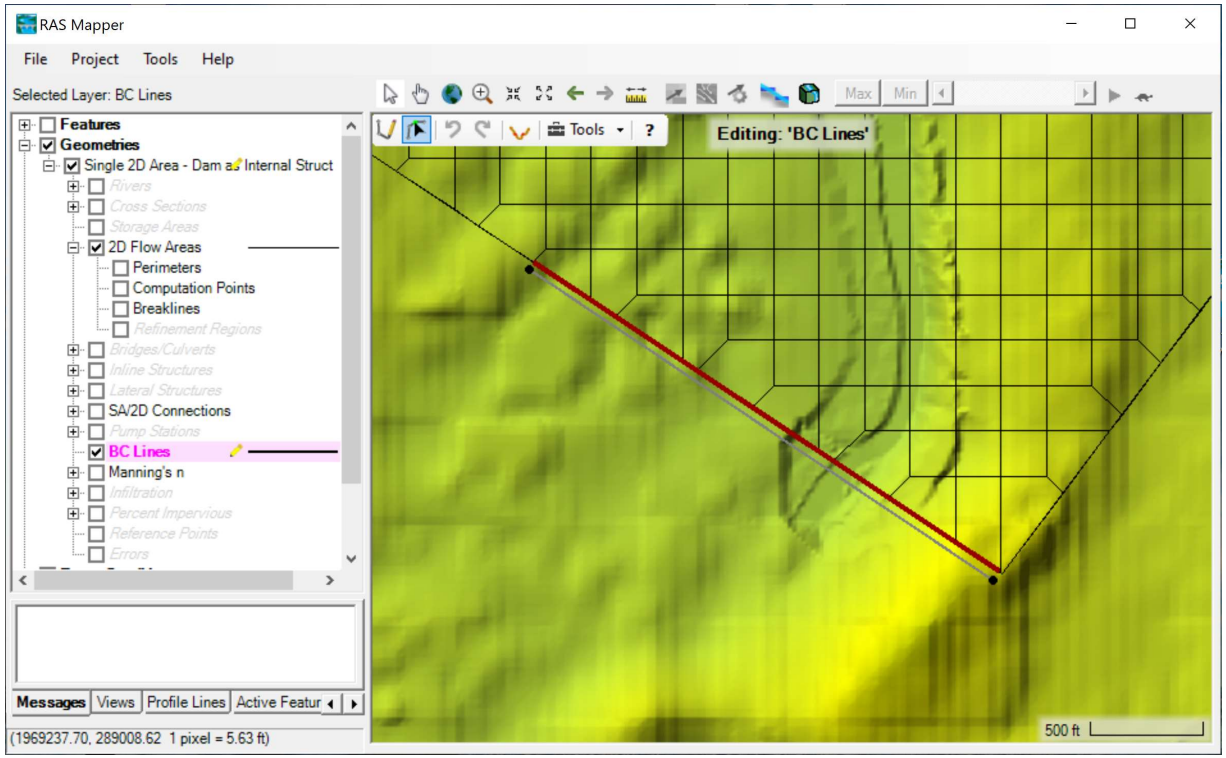
External Boundary Conditions

- Flow Hydrograph
  - **Usually for inflow (upstream/lateral)**
  - **Can also be used for outflow**
  - **Positive flow is inwards; Negative flow is outwards**
- Stage Hydrograph
  - **Usually for outflow**
  - **Can also be used for inflow (i.e., tidal)**
- Normal Depth (outflow only)
- Rating Curve (outflow only)

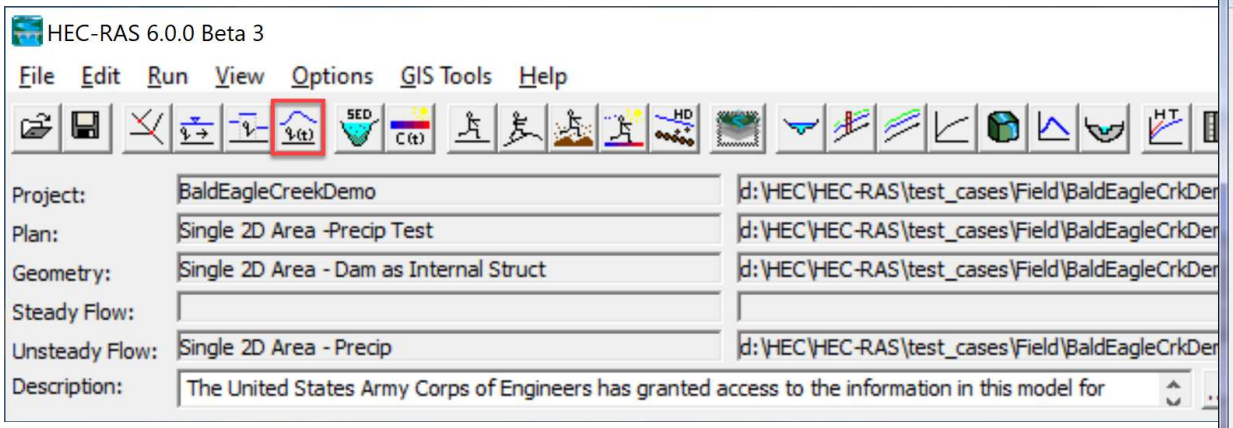


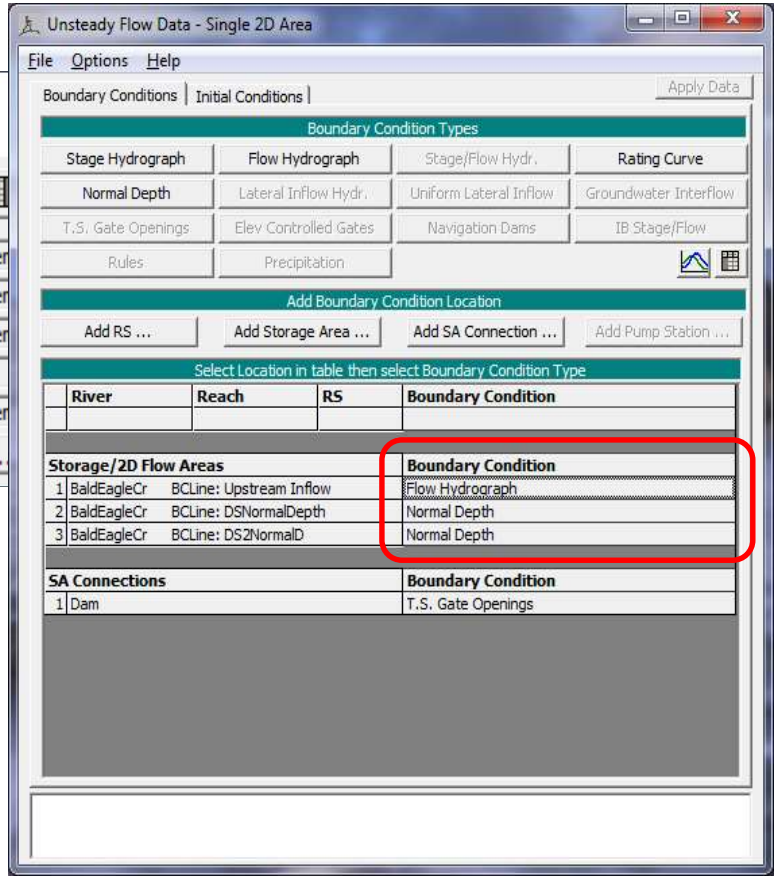
Creating External Boundary Condition Lines





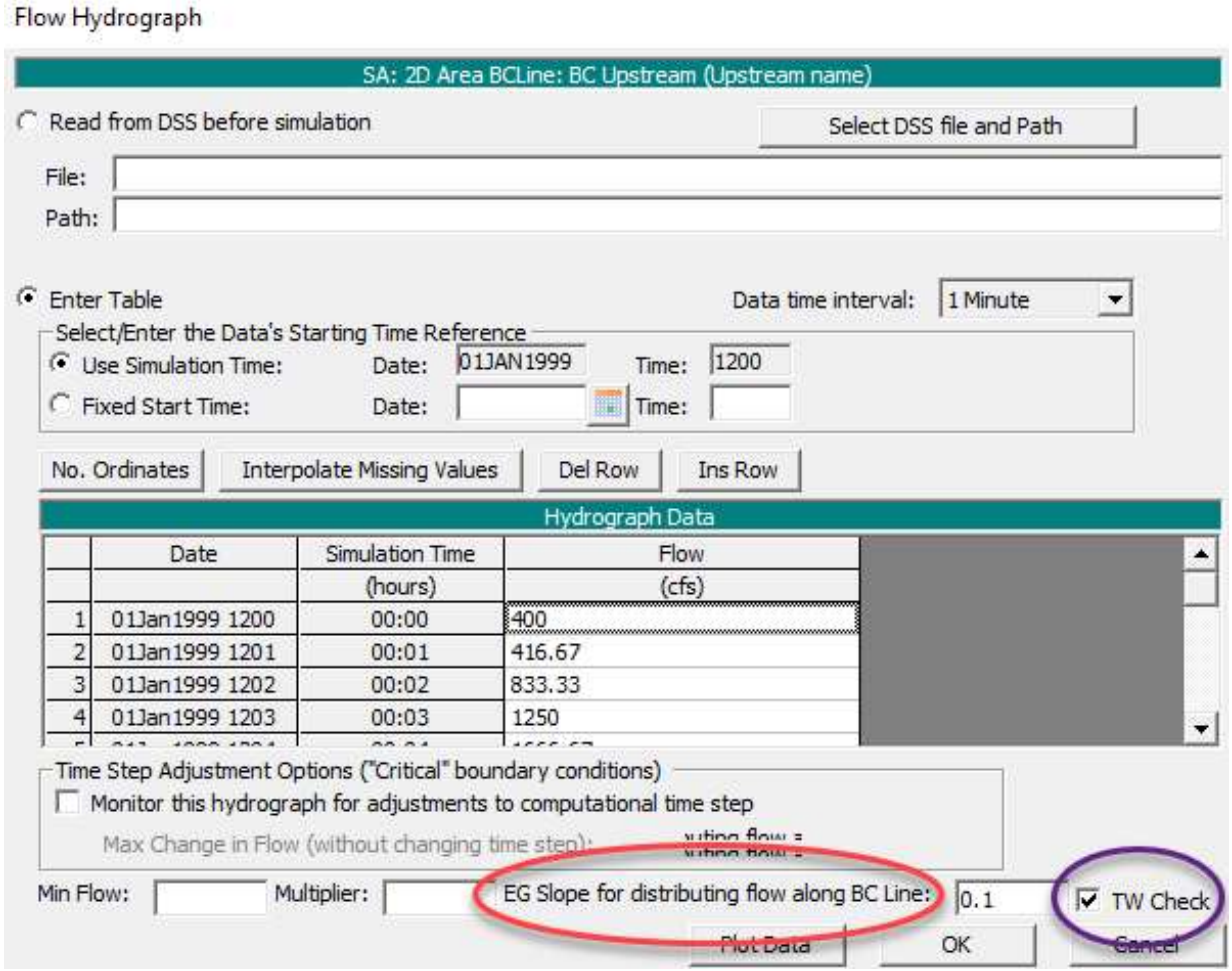
External Boundary Condition Data





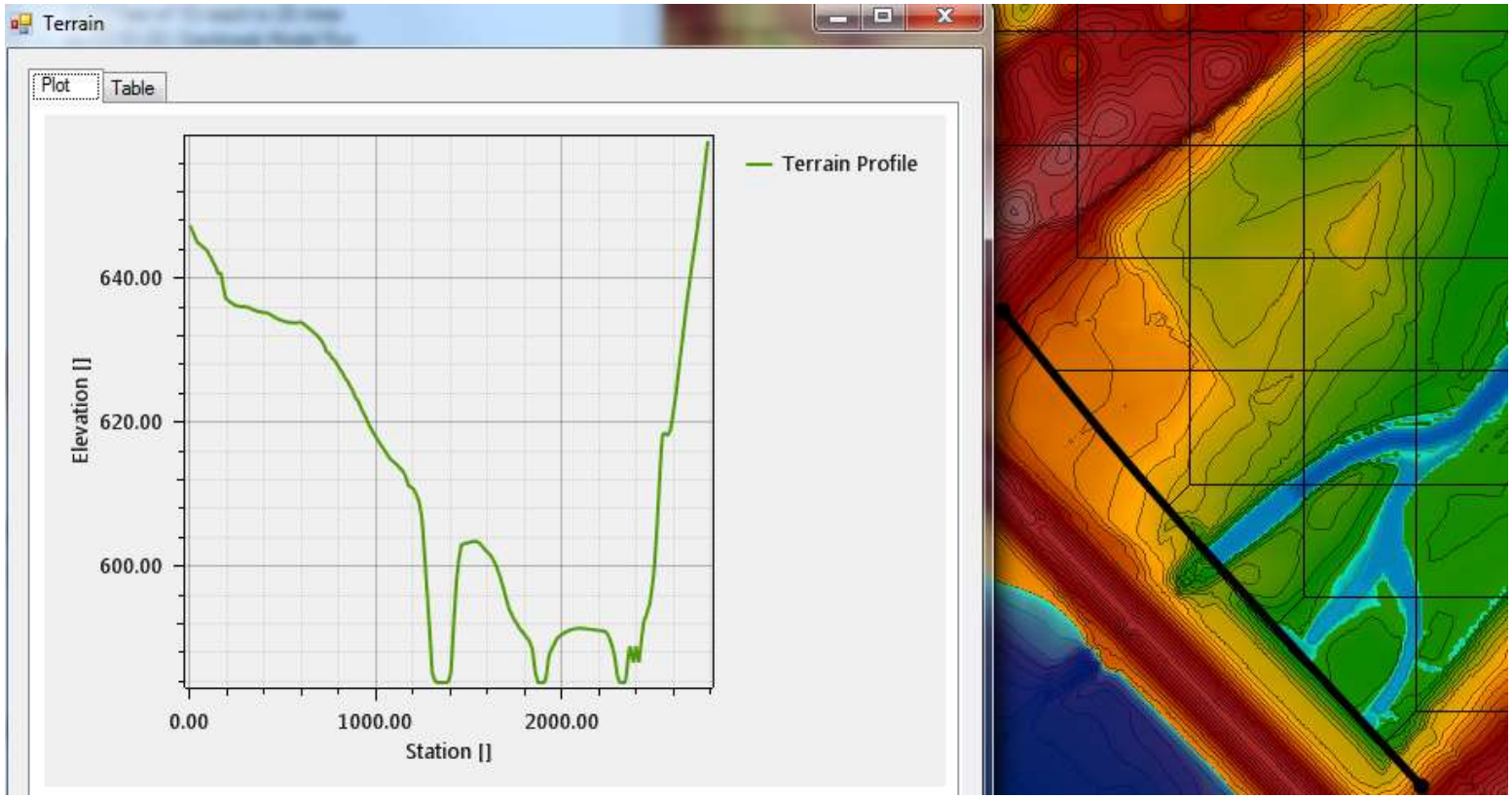
- Open Unsteady Flow Data editor
- Required BC's appear automatically

Flow Hydrograph & EG Slope



- Time series can specified from DSS file or entered as a table
- **EG Slope** required to compute normal depth
- Flow distributed along boundary based on conveyance
- **TW Check** option uses higher of TW and normal depth
- Face velocities computed for shallow water equations

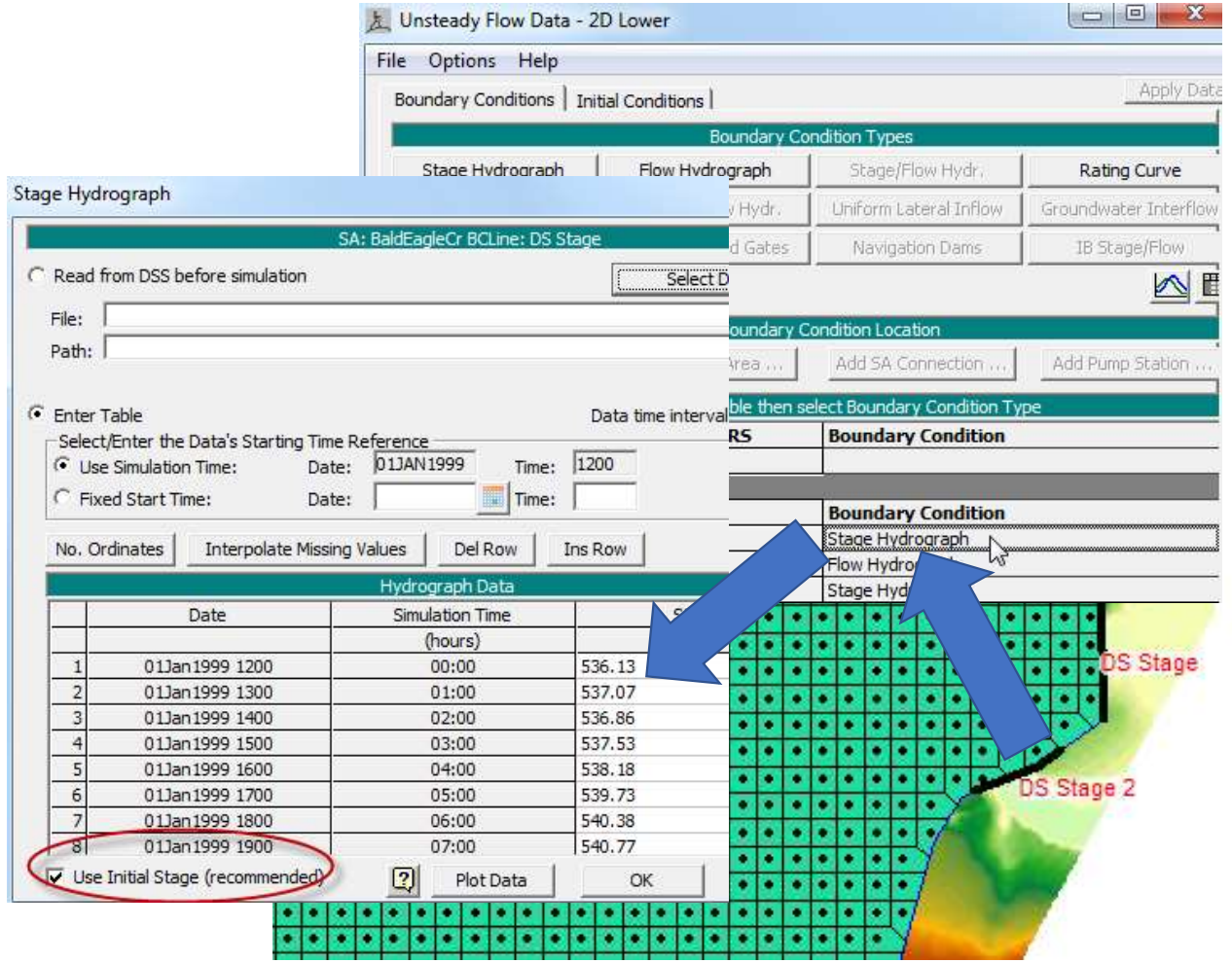
Flow Distribution along Boundary



- Flow is distributed to the appropriate cells based on EG Slope Conveyance or actual water surface

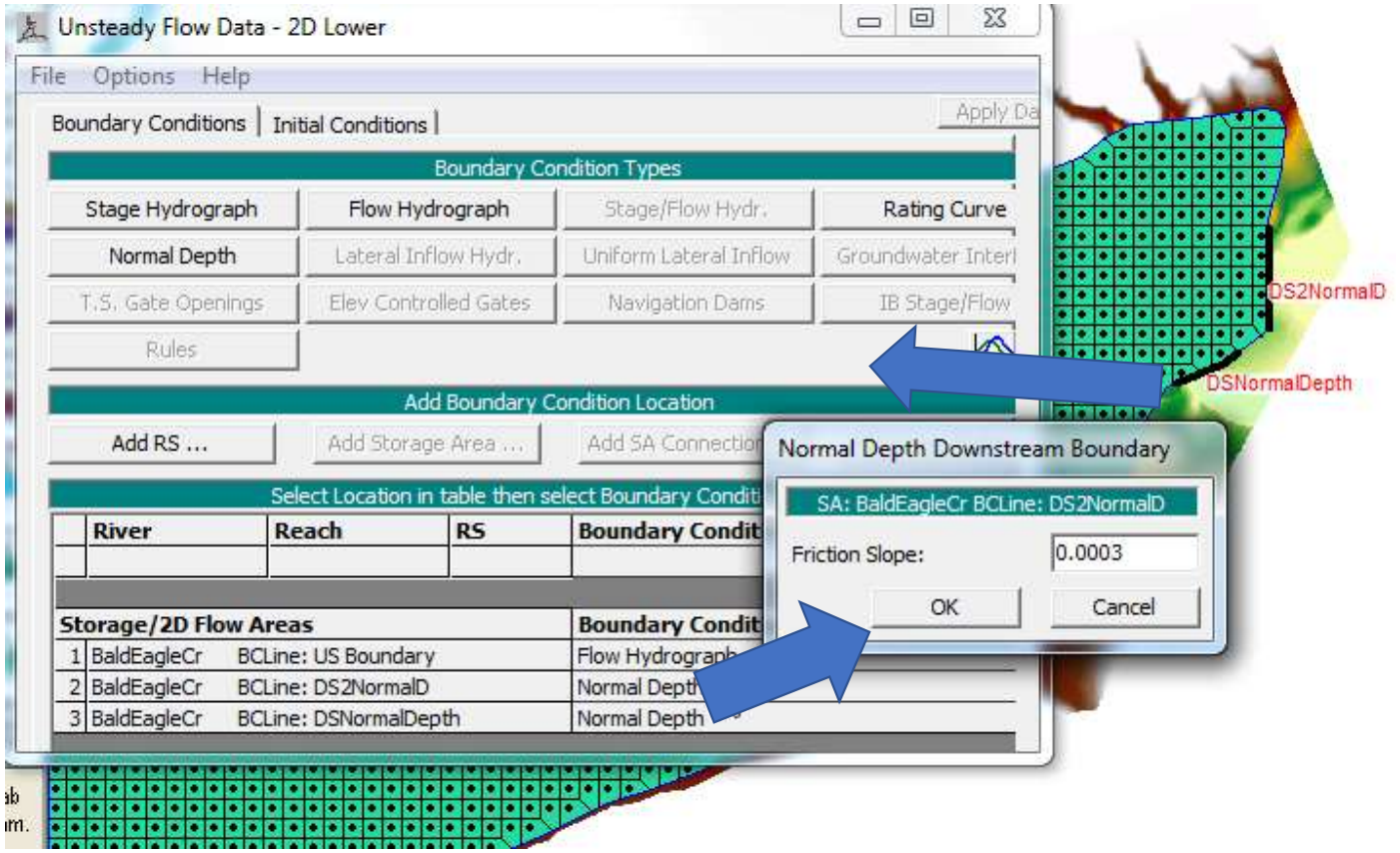
Stage Hydrograph

- DSS or Table
- **Use Initial Stage** option applies a horizontal water level from the boundary inwards
- All wet faces at the boundary assigned the same value
- Stage specified at boundary faces

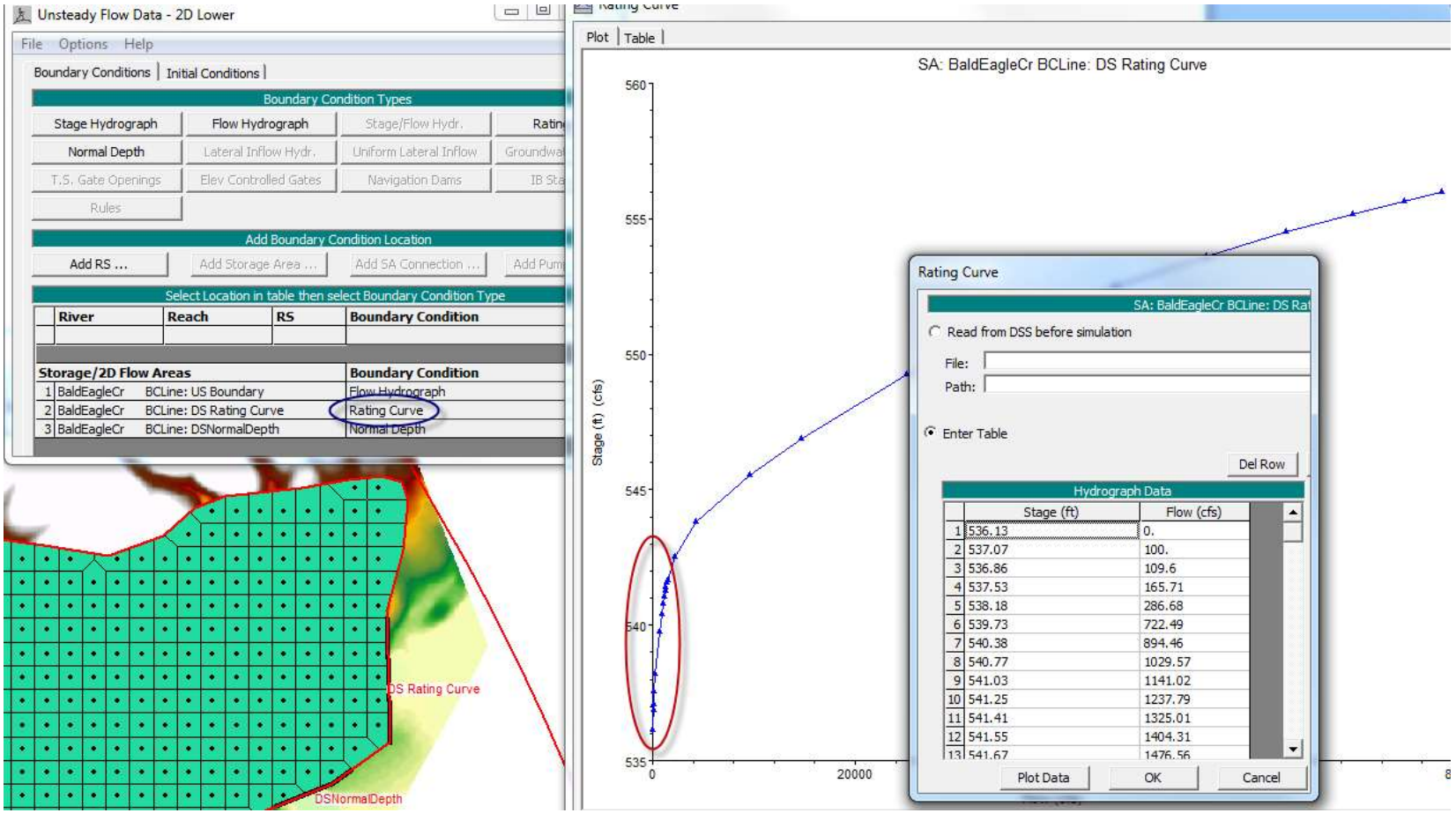


Normal Depth

- Only for outflow
- Friction slope constant for entire boundary
- Manning's Eq. used to compute flow per face
- Boundary stage can vary
- Should be reserved for situations where no other data is available
- Placed away from project area



Rating Curve



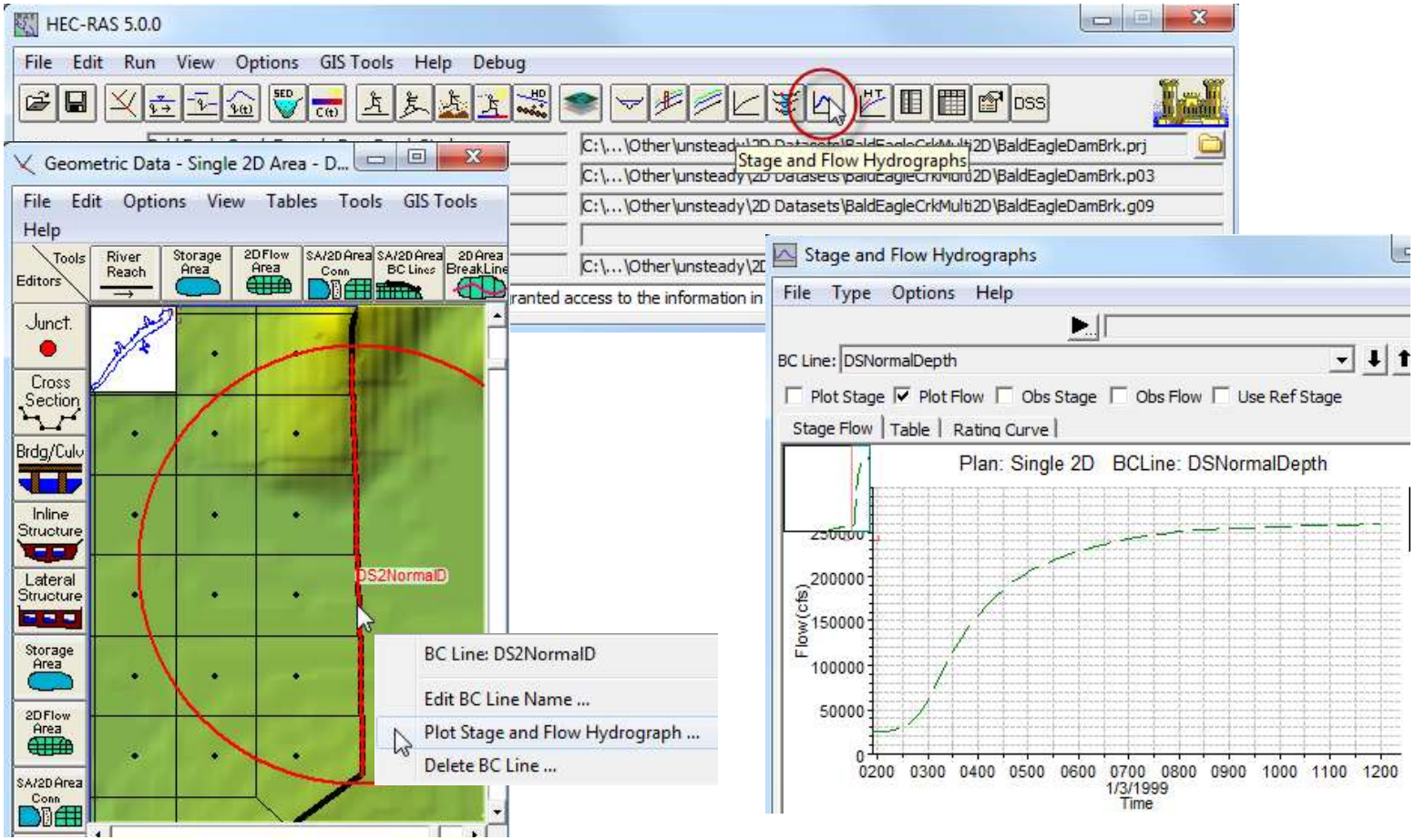
Rating Curve Considerations

- Flow based on conveyance-averaged WSE
- Flow distribution based on conveyance
- Watch out for a steeply sloped curve and/or sharp transitions in the curve
- Watch out for “bad” low flow curve
- Zero flow point on Rating Curve does ***NOT*** have to be at invert (could be higher)
- Can have initialization problems
  (when RC is not consistent with cold-start conditions)

External Boundary Locations

- Extend boundary condition locations away from study area of interest
  - **Normal Depth is an approximate boundary**
  - **Stage creates a horizontal WSE along the boundary cells (place normal to flow)**
  - **Rating curve does not take into for changes in flow for rising and falling-limbs of hydrograph**

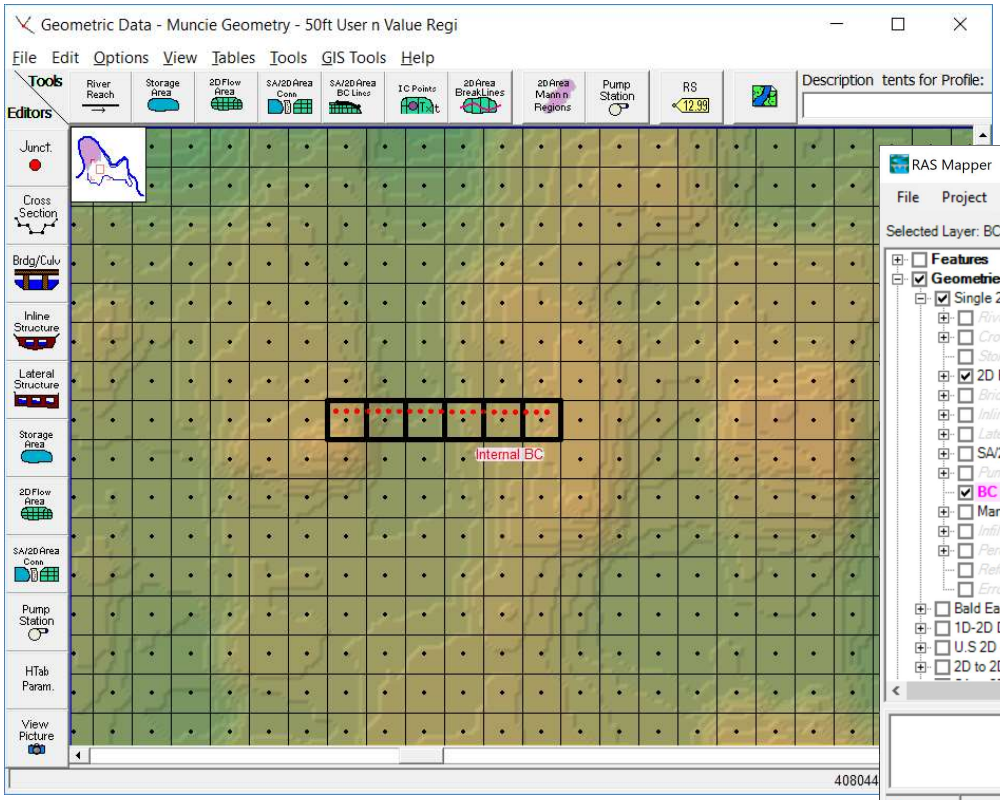
Boundary Output

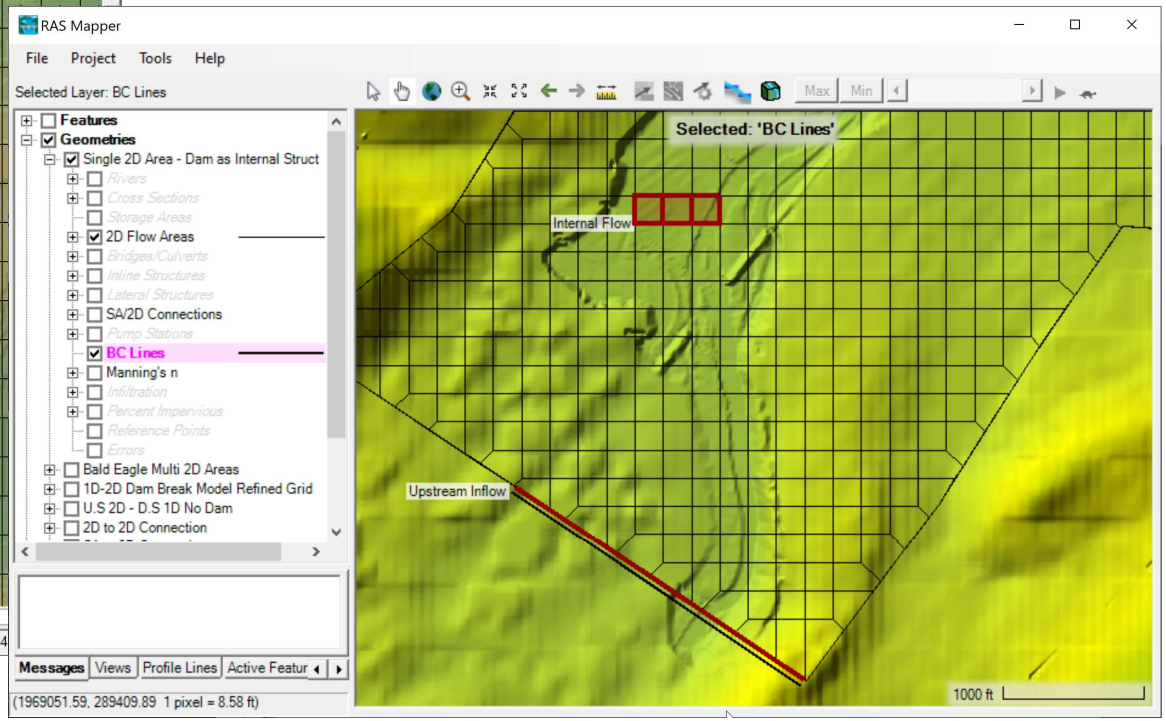


Internal Boundary Conditions

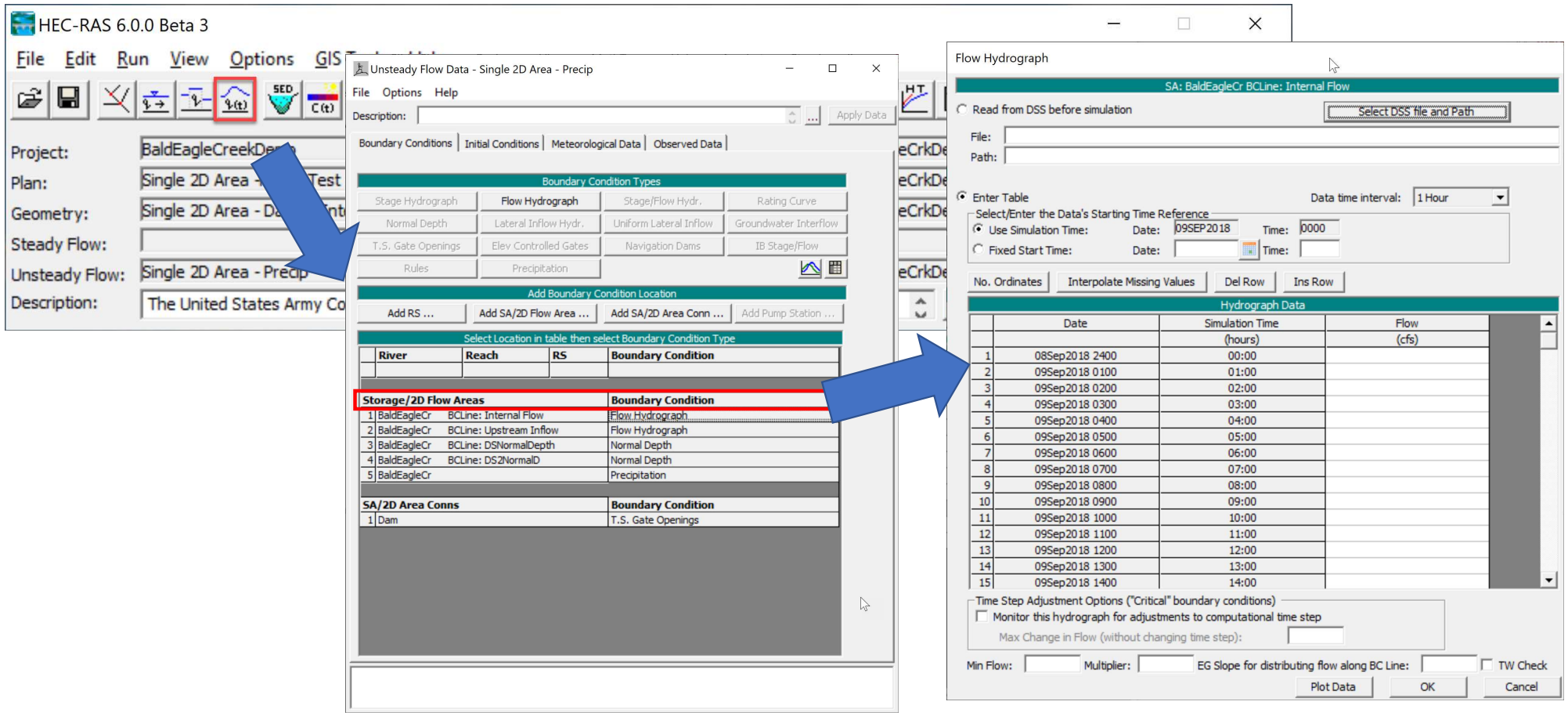
- Flow Hydrographs
  - Must be completely inside of the 2D Flow Area
  - Can have positive and/or negative flows
  - No flow direction; Flow is only in Continuity Equation and not Momentum Equations
  - Flow is allocated to each cell based on length of line in cells
- Precipitation
  - Time-series applied to individual 2D areas
  - Precipitation rates constant for every cell
  - Specified as period cumulative depths

Internal Flow Boundary Condition

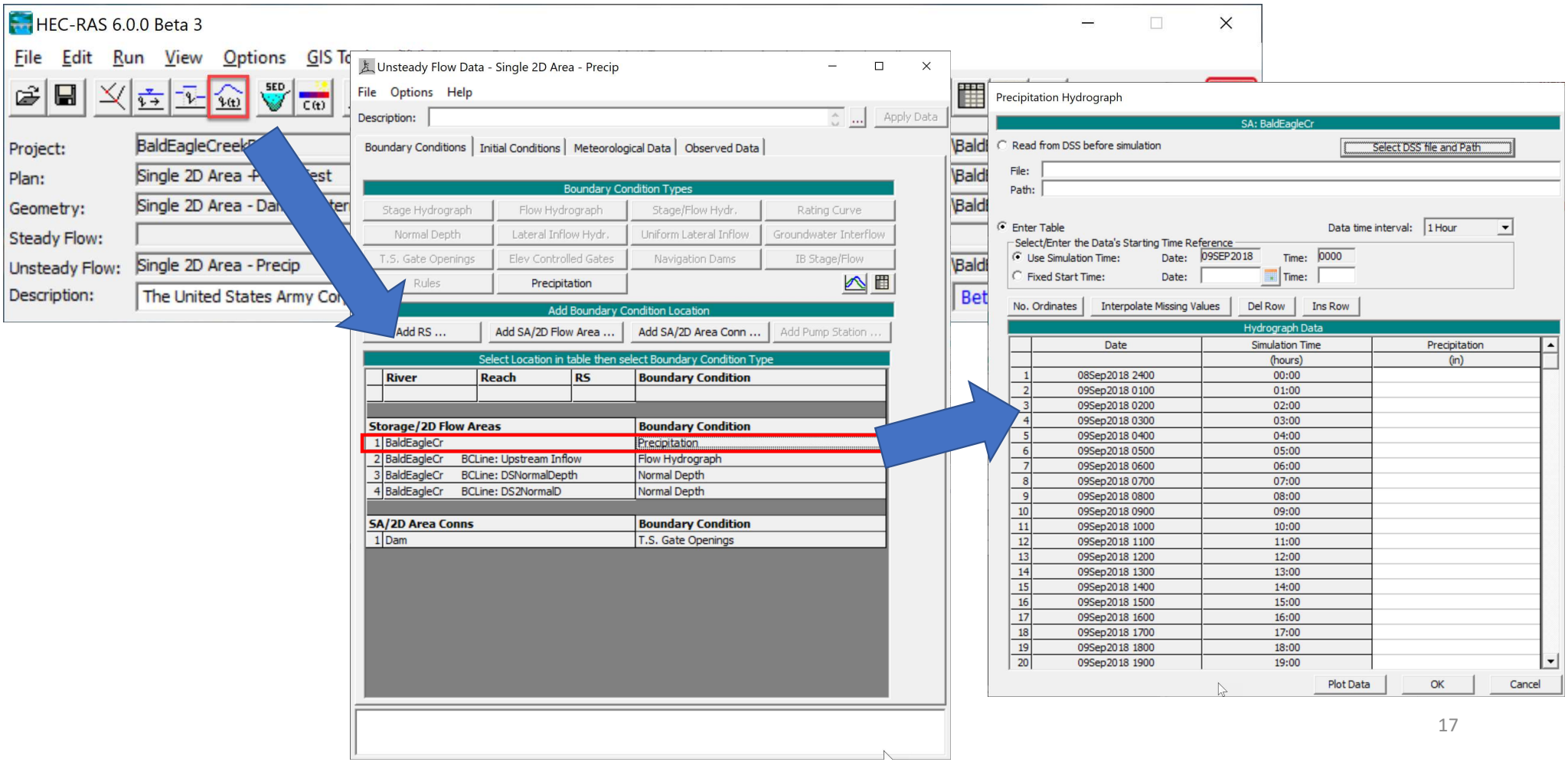




Internal Flow Boundary Condition

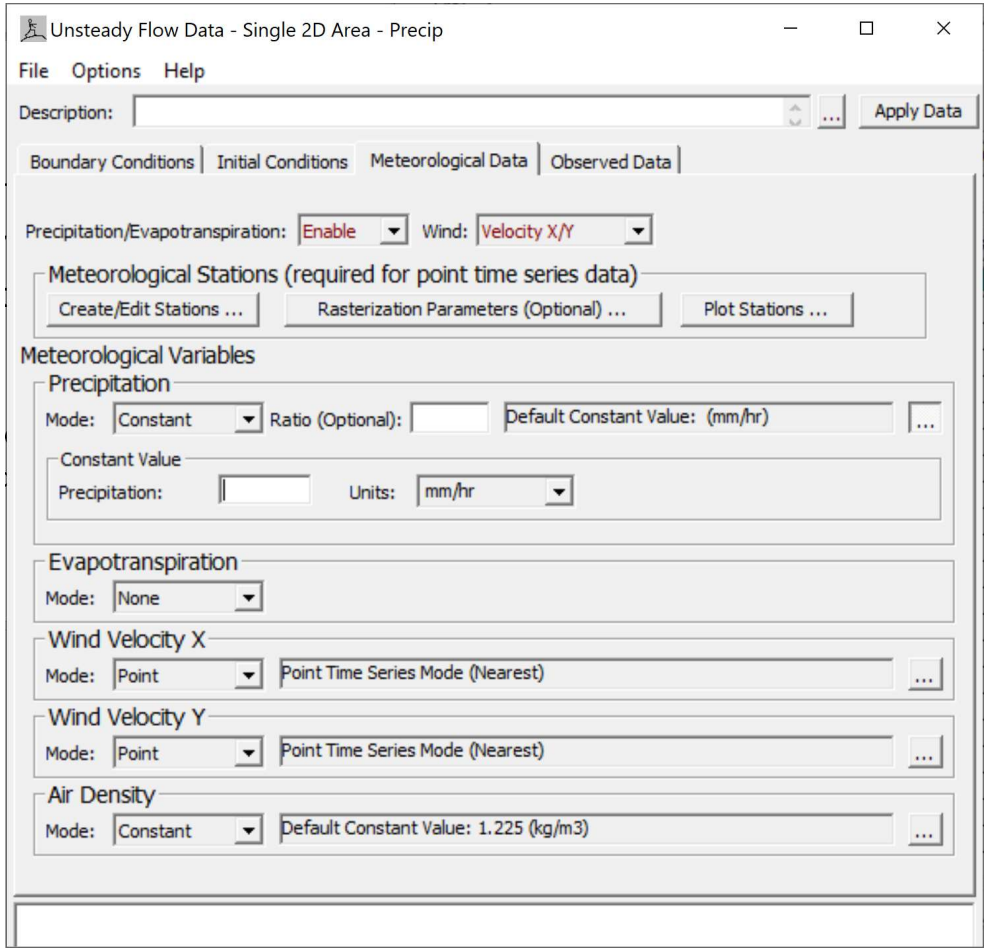


Internal (2D Area) Precipitation BC



Global Boundary Conditions

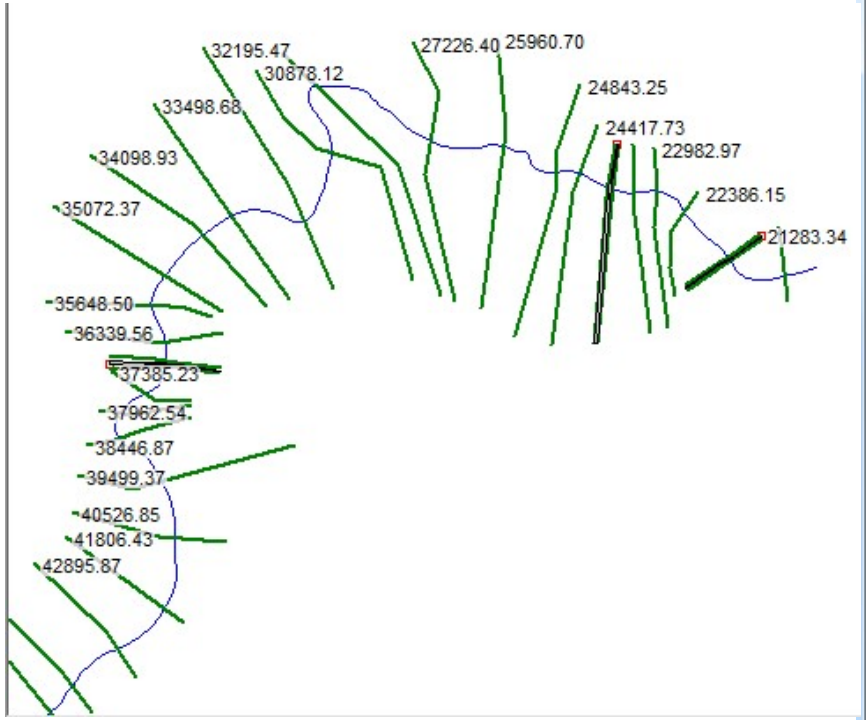
- Applied to the entire project
- Specified in **Meteorologic Data** tab of **Unsteady Flow Data** editor
- Types of Boundaries:
  1. Precipitation
  2. Evapotranspiration Potential
  3. Wind
  4. Air Density
- Types of Data
  1. Point
  2. Constant
  3. Gridded

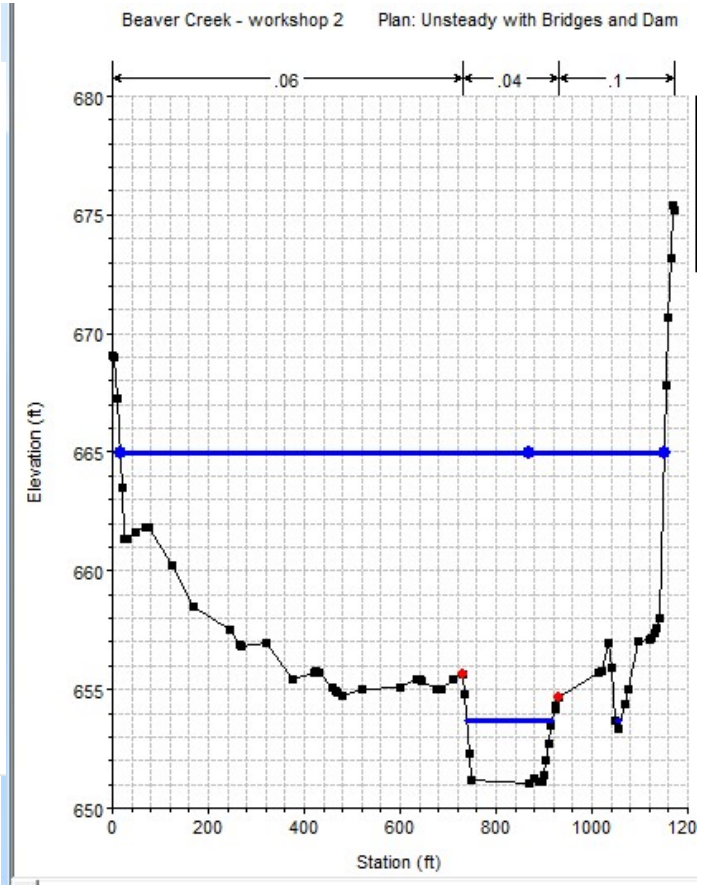


2D Initial Conditions Overview

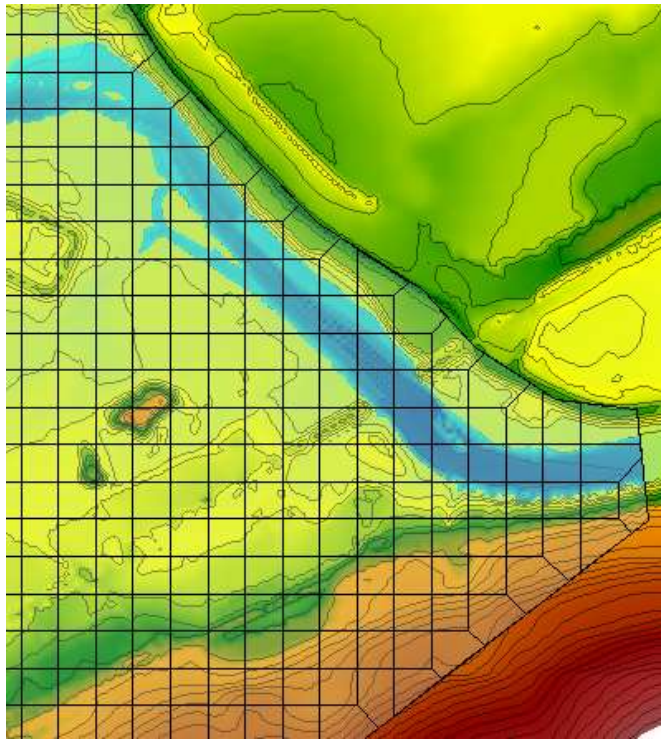
- User Specified Initial Conditions
  - Dry Initial Conditions
  - Single Horizontal WSE
  - Option to apply initial stage boundary values horizontally into domain
  - 2D **Initial Condition Time** (Optional)
    - **Allows each 2D area to compute an initial profile**
    - **Somewhat similar to 1D initial backwater**
  - Optional entire model **Warm Up** period to settle simulation
- Use **Restart File**
  - Restart File created by previous run
- Interpolate from Previous Results
  - Interpolates wse, velocity, and flows for 1D and 2D
  - Geometries do not have to be the same

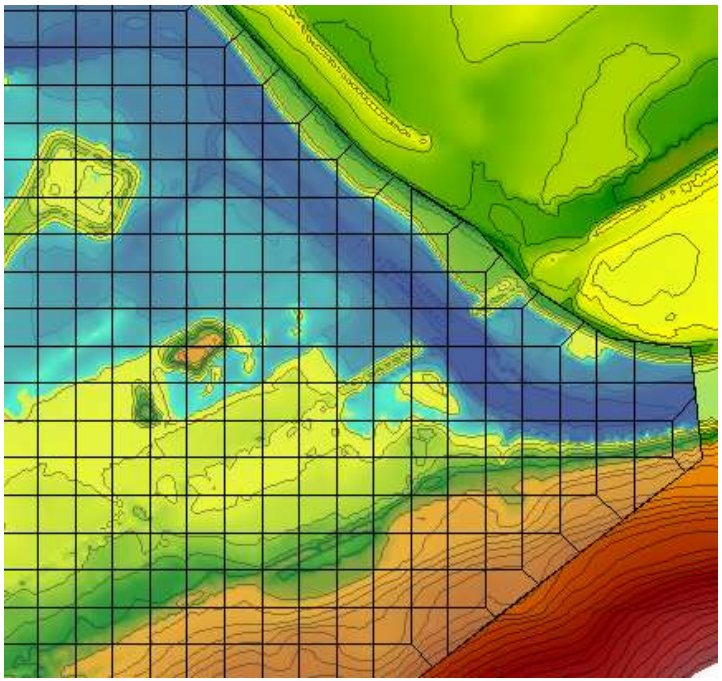
1D Finite-Difference Stays Wet





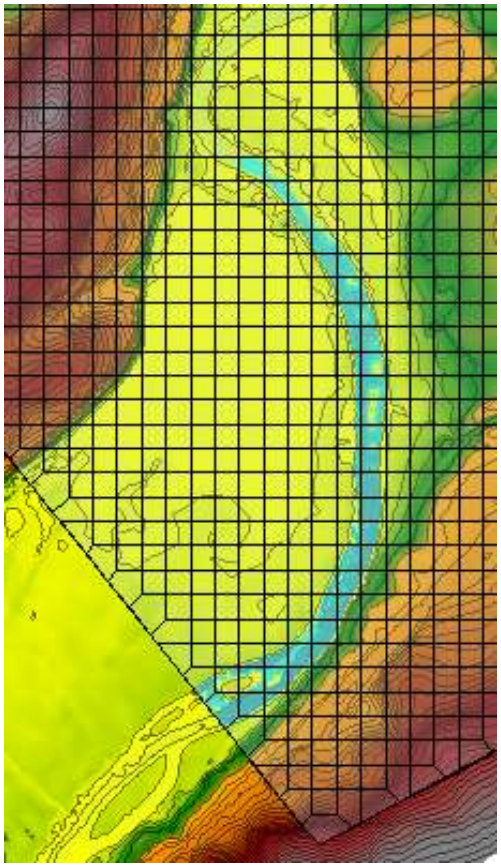
2D Wetting/Drying





Filling 2D Channel

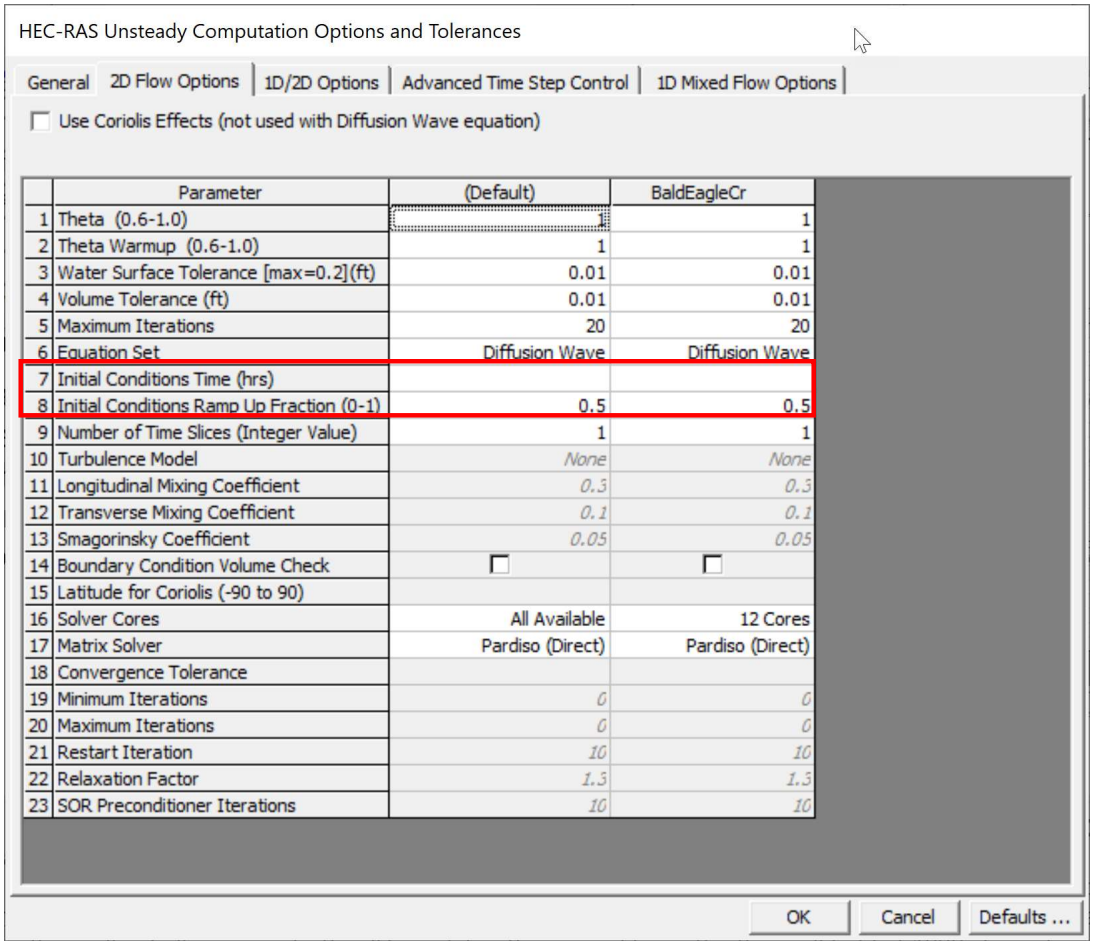
- Use Initial Conditions Time to fill channel



- Upstream flow will eventually fill channel
- May take a long time to fill, especially reservoirs
- Initial [horizontal] WSE can be used to speed things up
- A Restart File can save time

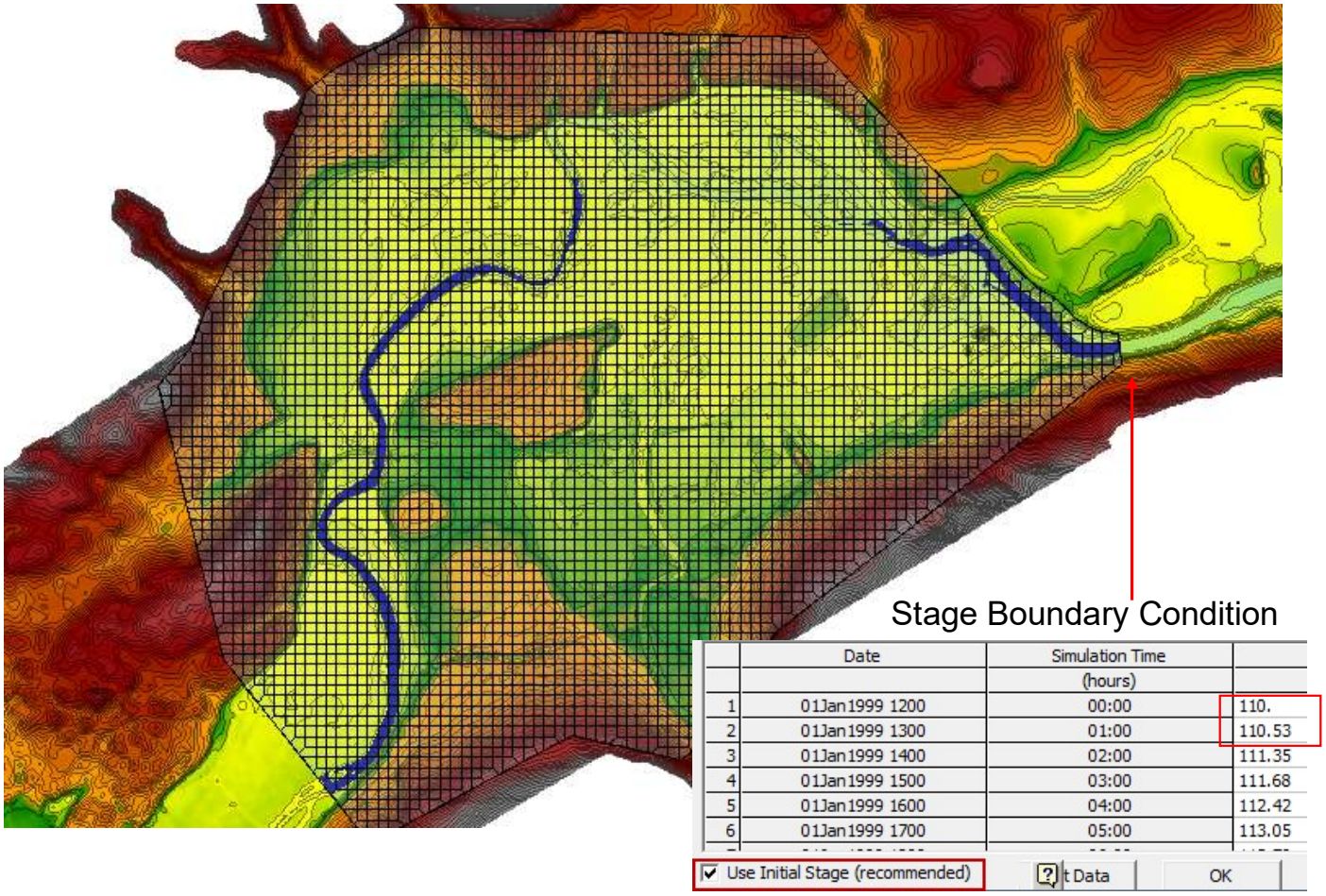
Initial Conditions Ramp Up

- Ramp Up Period run before Warm Up Period
- Specified for each 2D area
- Ramp Up Fraction determines the period over which flow and stage are ramped up from the initial condition and then held constant

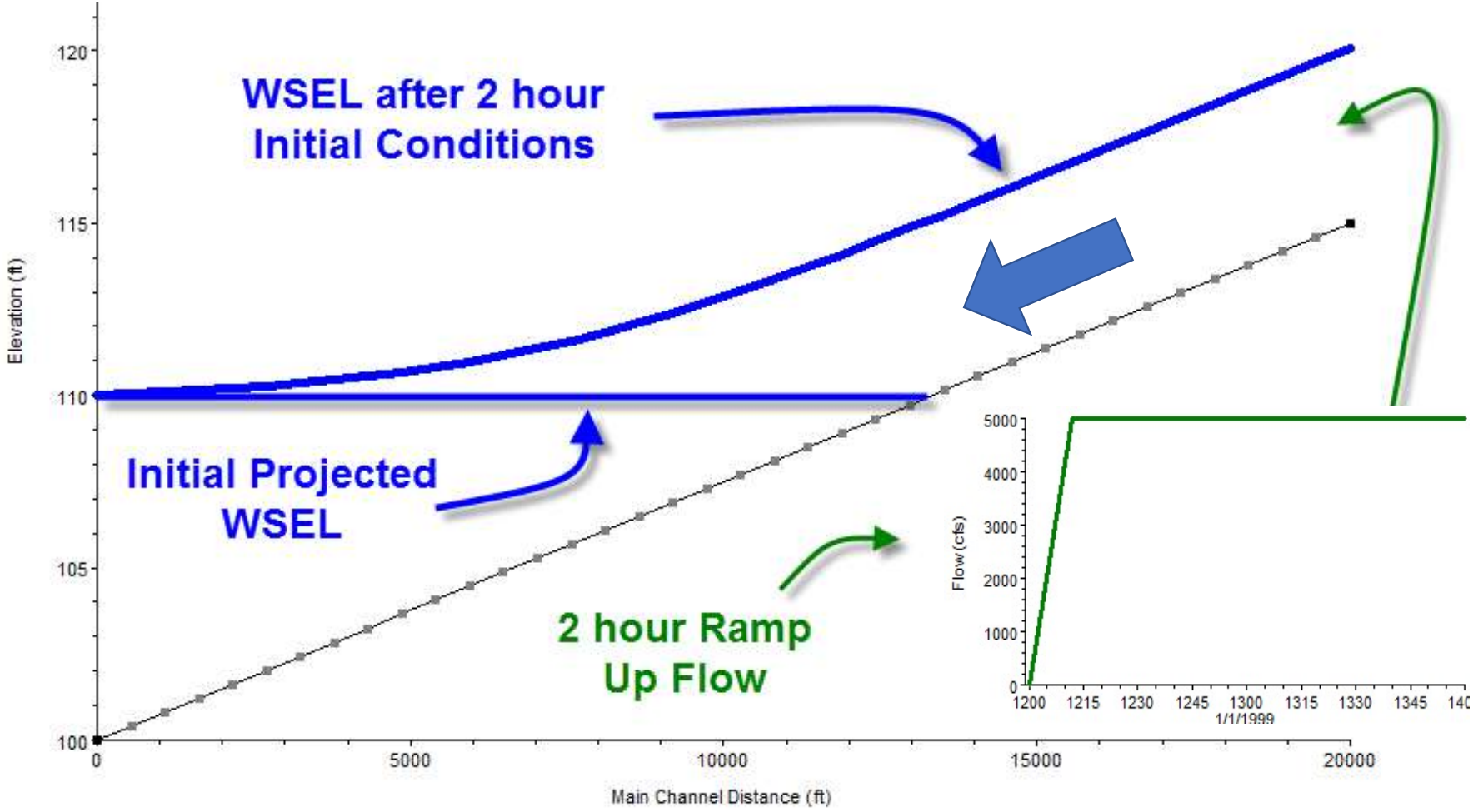


	Parameter	(Default)	BaldEagleCr
1	Theta (0.6-1.0)	1	1
2	Theta Warmup (0.6-1.0)	1	1
3	Water Surface Tolerance [max=0.2](ft)	0.01	0.01
4	Volume Tolerance (ft)	0.01	0.01
5	Maximum Iterations	20	20
6	Equation Set	Diffusion Wave	Diffusion Wave
7	Initial Conditions Time (hrs)		
8	Initial Conditions Ramp Up Fraction (0-1)	0.5	0.5
9	Number of Time Slices (Integer Value)	1	1
10	Turbulence Model	None	None
11	Longitudinal Mixing Coefficient	0.3	0.3
12	Transverse Mixing Coefficient	0.1	0.1
13	Smagorinsky Coefficient	0.05	0.05
14	Boundary Condition Volume Check	☐	☐
15	Latitude for Coriolis (-90 to 90)		
16	Solver Cores	All Available	12 Cores
17	Matrix Solver	Pardiso (Direct)	Pardiso (Direct)
18	Convergence Tolerance		
19	Minimum Iterations	0	0
20	Maximum Iterations	0	0
21	Restart Iteration	10	10
22	Relaxation Factor	1.3	1.3
23	SOR Preconditioner Iterations	10	10

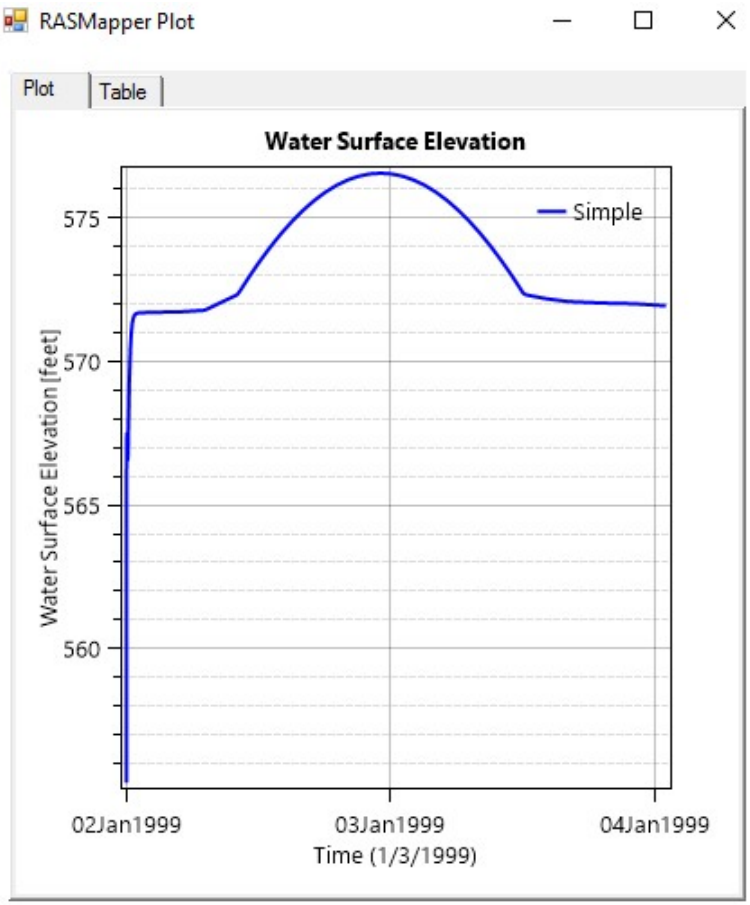
2D Initial Conditions Warm Up in Progress

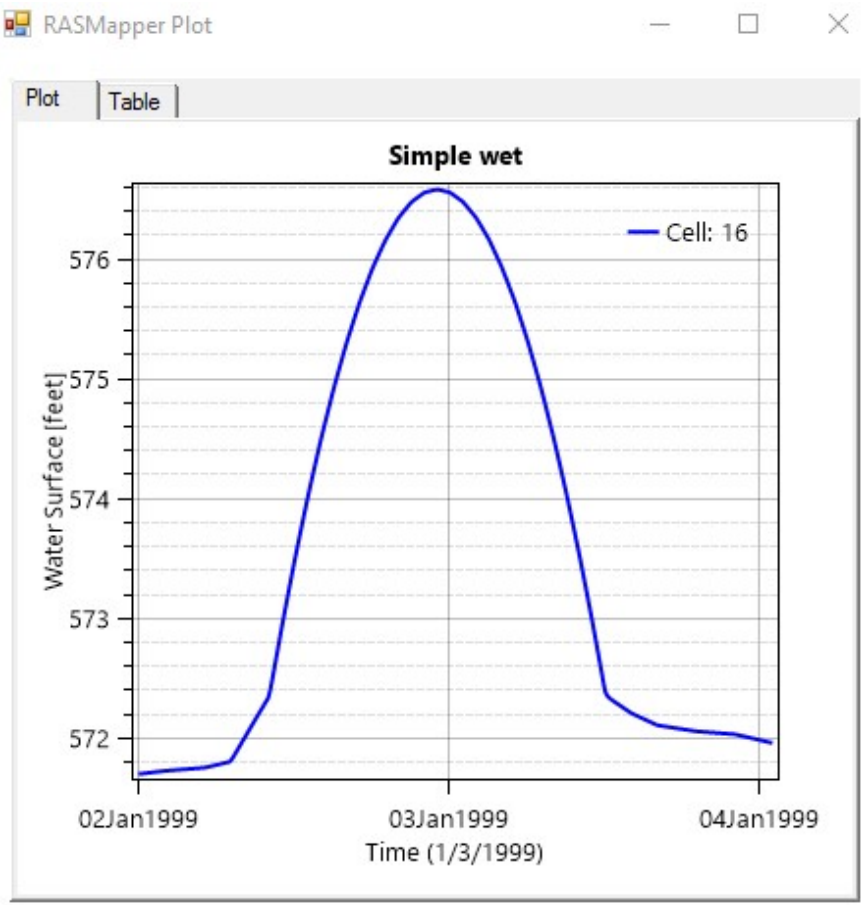


2D Initial Conditions Profile



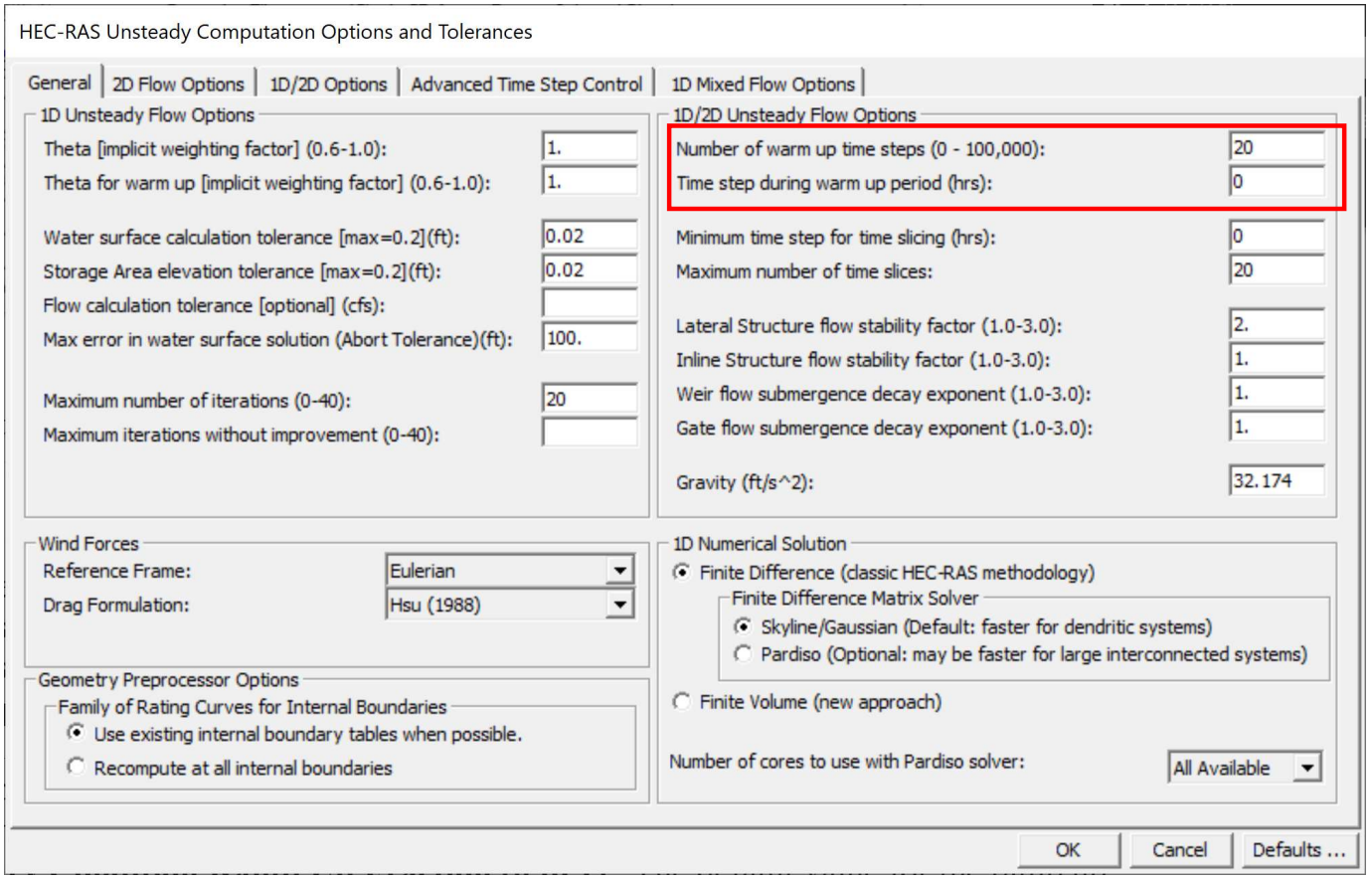
Dry vs Wet Start





Initial Conditions Warm Up Period

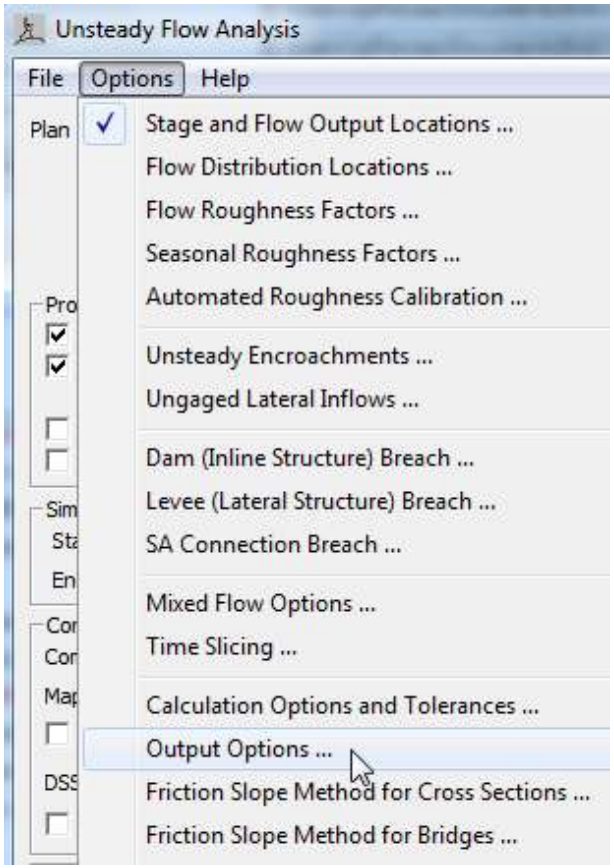
- Run after Initial Conditions Period
- Length specified as number of time steps
- Time step is optional
- Hold all the BC's constant and allows the model to stabilize

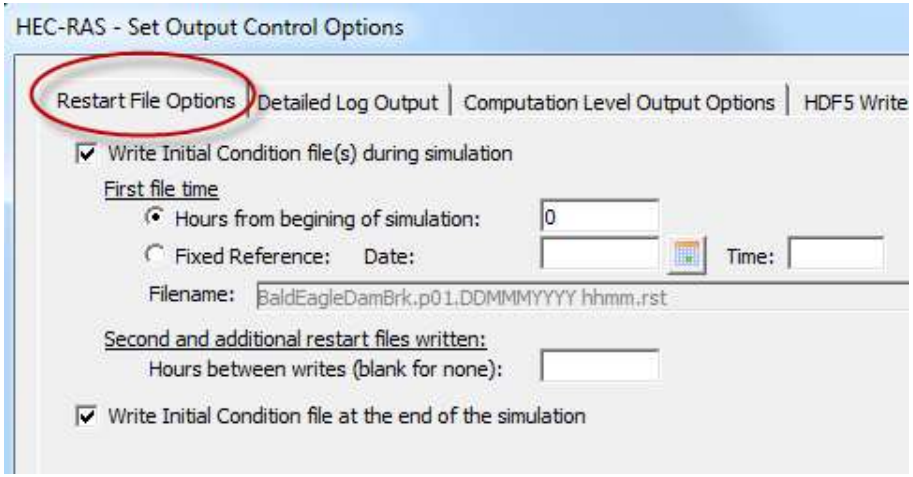


Using a Restart File

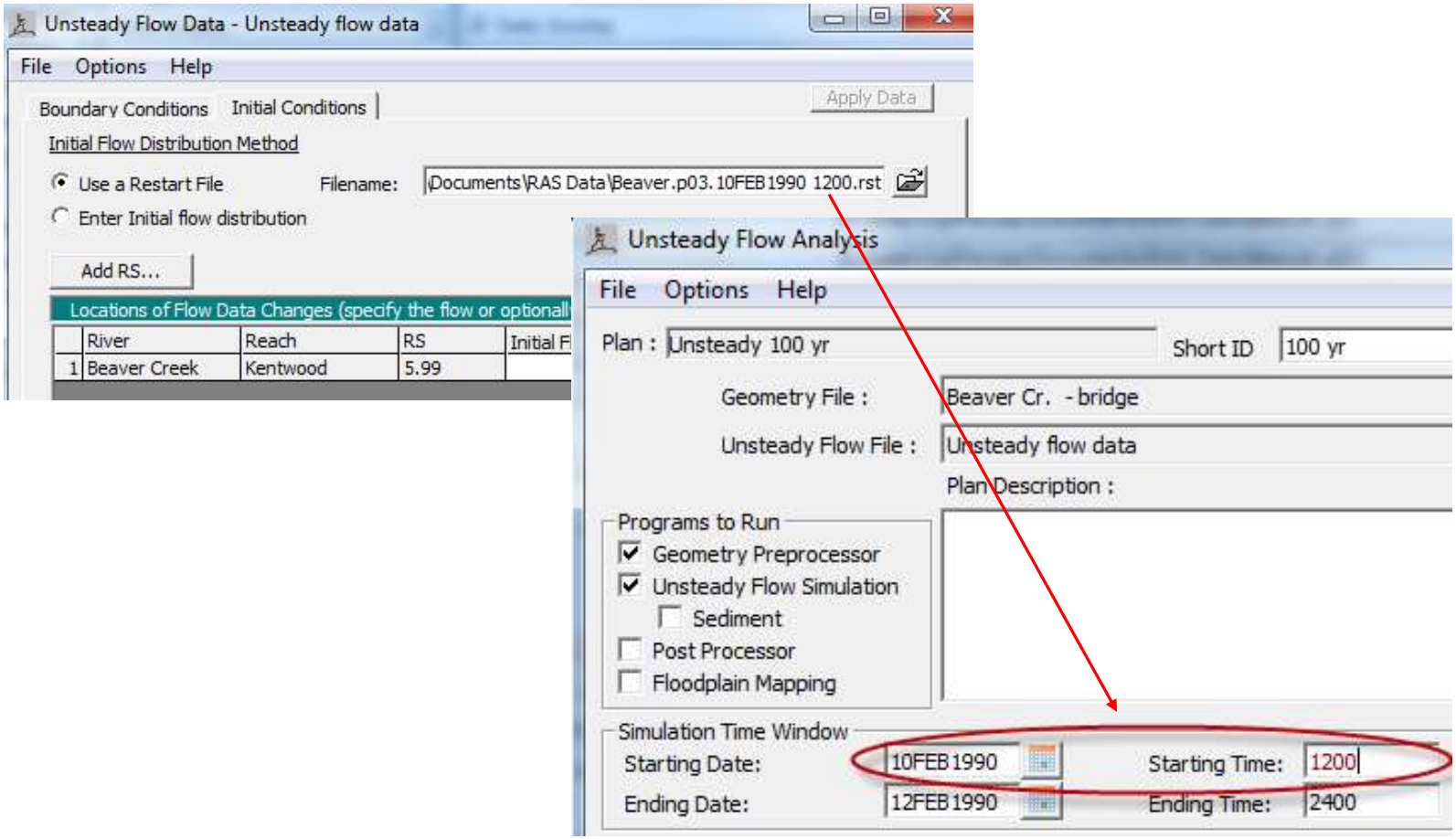
1. Write **Initial Condition File** out
2. Create a new **Unsteady Flow Plan** (“Save As…”)
3. Select **Use a Restart File** option in **Unsteady Flow Initial Conditions Tab**
4. Adjust starting date, and any hydrographs, if needed (if you start model later than previous run).

Write Initial Condition File

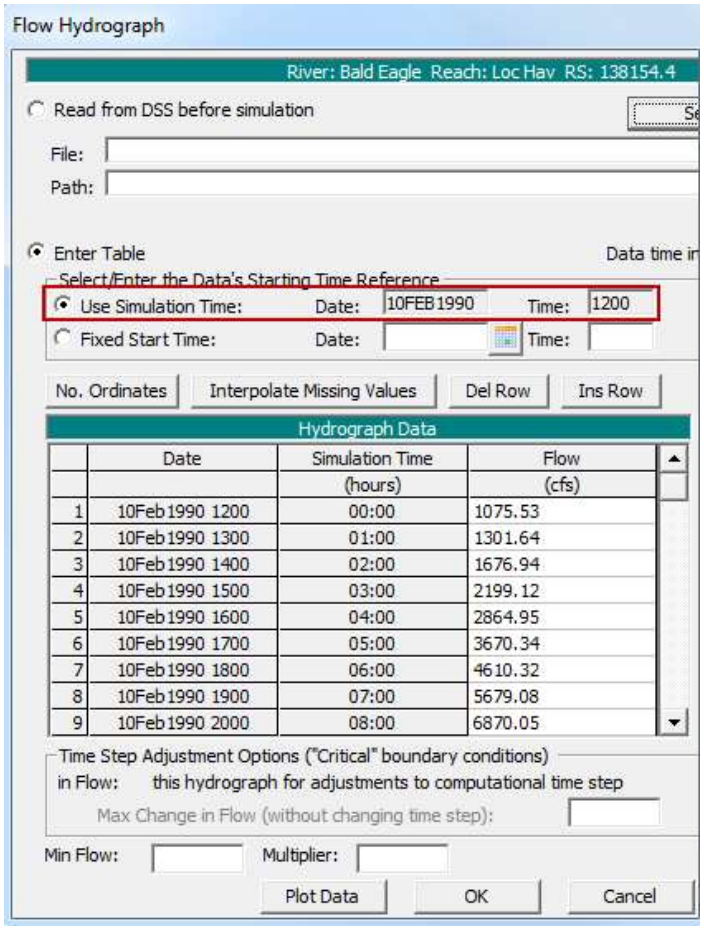




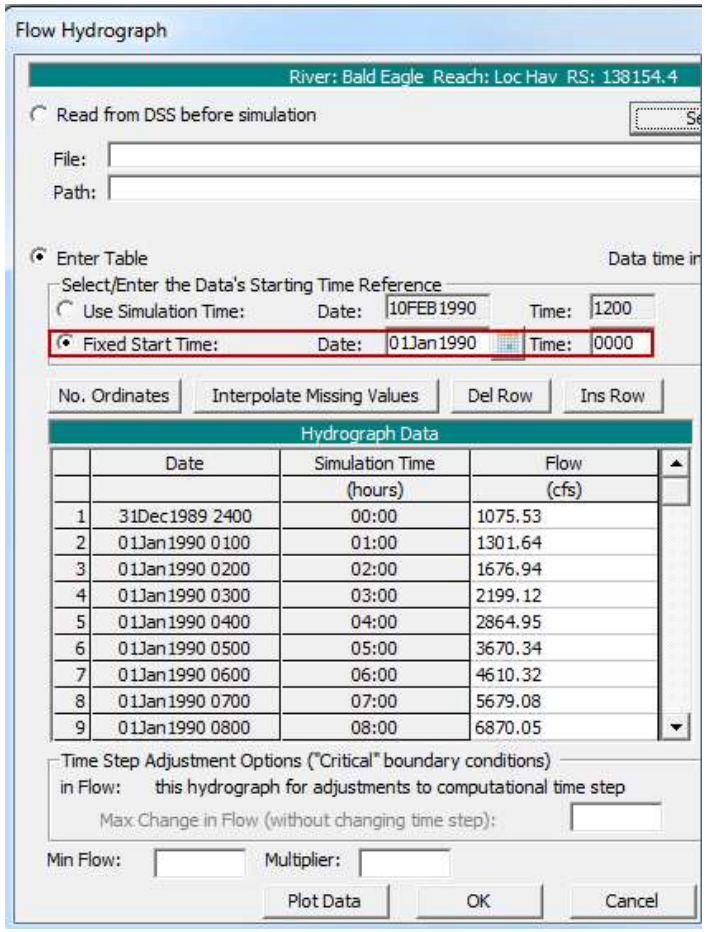
Select Restart



Hydrograph Starting Time



	Date	Simulation Time (hours)	Flow (cfs)
1	10Feb1990 1200	00:00	1075.53
2	10Feb1990 1300	01:00	1301.64
3	10Feb1990 1400	02:00	1676.94
4	10Feb1990 1500	03:00	2199.12
5	10Feb1990 1600	04:00	2864.95
6	10Feb1990 1700	05:00	3670.34
7	10Feb1990 1800	06:00	4610.32
8	10Feb1990 1900	07:00	5679.08
9	10Feb1990 2000	08:00	6870.05



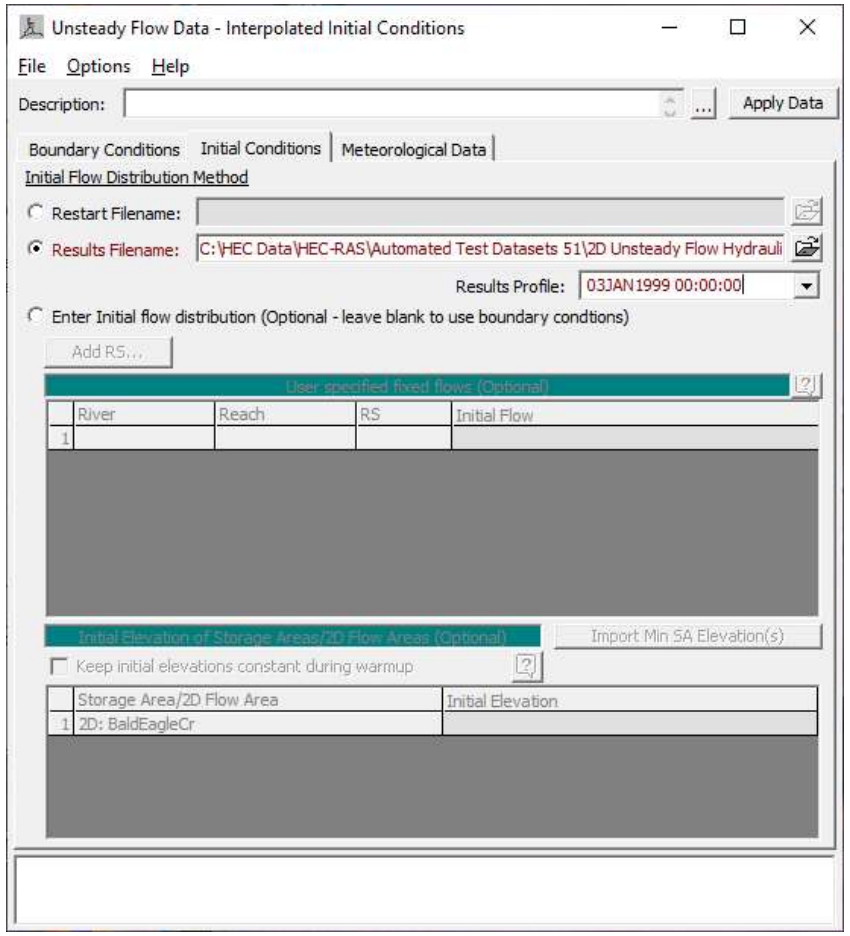
	Date	Simulation Time (hours)	Flow (cfs)
1	31Dec1989 2400	00:00	1075.53
2	01Jan1990 0100	01:00	1301.64
3	01Jan1990 0200	02:00	1676.94
4	01Jan1990 0300	03:00	2199.12
5	01Jan1990 0400	04:00	2864.95
6	01Jan1990 0500	05:00	3670.34
7	01Jan1990 0600	06:00	4610.32
8	01Jan1990 0700	07:00	5679.08
9	01Jan1990 0800	08:00	6870.05

Restart File Notes

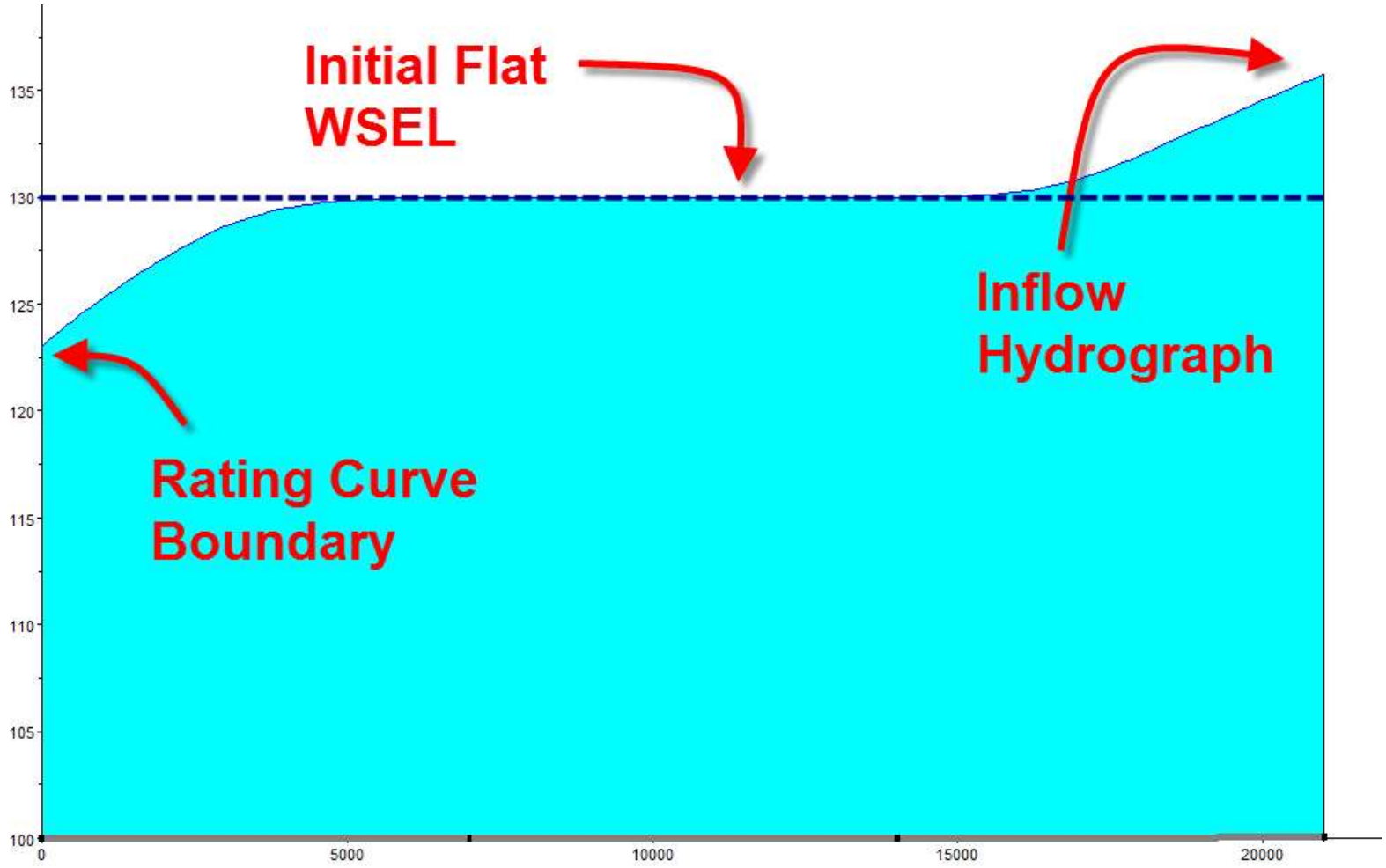
- Geometry must be the same
- Can switch 2D equation if desired
  - **Use to run DWE to create Restart for SWE**
- Can change the time step
- Can change the output interval
- Can (generally) change flow and plan data

Interpolate From Previous Results

- New for Version 6.0
- User selects a previous plan results file (ProjectName.p##.hdf)
- Geometry does not have to be the same
- Interpolates water levels, velocities, and flows
- Works for 1D and 2D



Flat WSEL vs Momentum



Questions?

US Army Corps of Engineers