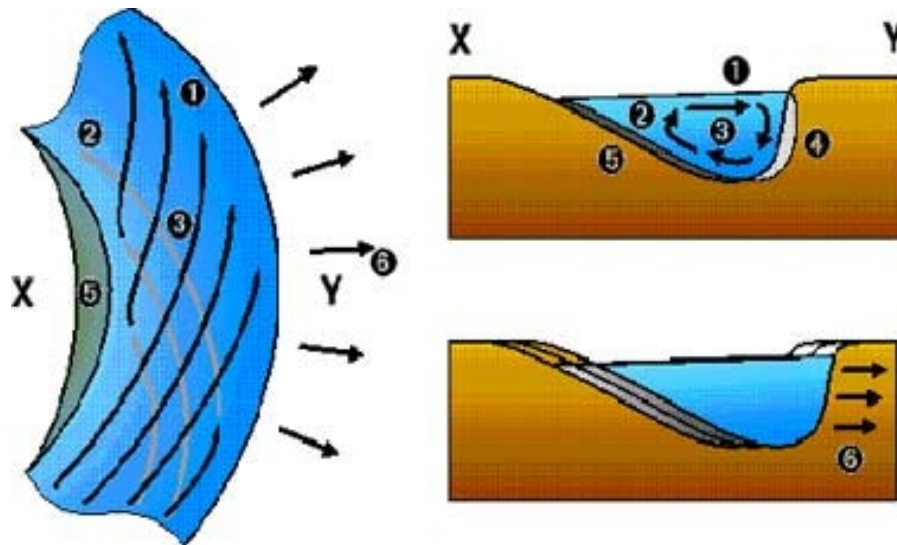


Simulating Stream Flow in GSSHA



- Concentrated, dynamic flow
- 1D, 2D, and 3D flow patterns, depending on stream size, shape, flow



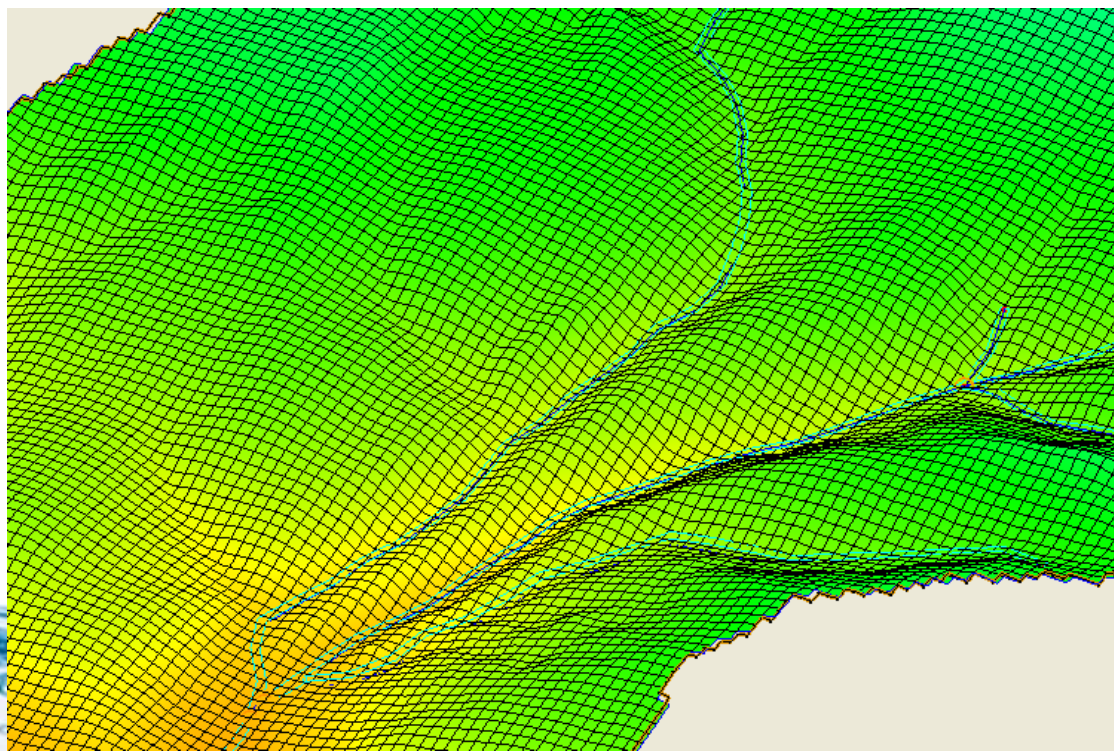
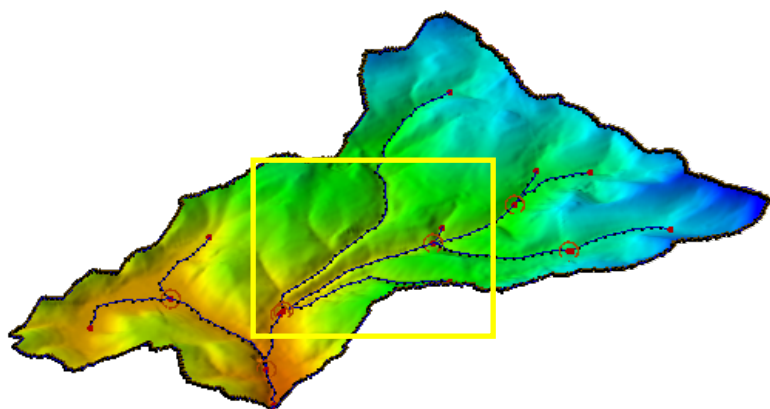
Stream Flow Generation Mechanism

- Overland flow
- Groundwater/interflow
- Storm surge, tidal cycles



Stream Flow in GSSHA

- 1D network of links (reaches) containing nodes (cells)
- Links represent stream reaches of uniform properties.
- Computations are performed on the nodes.



Stream Networks in GSSHA

- 1D channel flow
 - Trapezoidal
 - Natural (Break-point)
- Detention basins / reservoirs
- Hydraulic structures
 - Broad crested weirs
 - Culverts
 - Rating curves
 - Rule curves
 - Scheduled releases



- Shallow water wave equations in one direction (x)

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial x} \left[\frac{q^2}{h} \right] + \frac{gh \partial (h + z)}{\partial x} + \frac{gn^2 q^2}{h^{7/3}}$$

q = unit flow

h = depth

z = elevation

n = roughness

t = time

x = distance

Acceleration Advection

Pressure

Friction

- If the pressure term is large compared to the other terms then

$$\frac{gh \partial (h + z)}{\partial x} = 0$$

- Which can be rearranged to put into what is called the diffusive wave equation



- Manning's Equation
(Uniform open channel flow)

$$Q_{i-1/2} = \frac{1}{n} A_{i-1} R_{i-1}^{2/3} S_{f_{i-1/2}}^{1/2}$$

- Friction Slope (Diffusive Wave)

$$\frac{\partial h}{\partial x} = S_o - S_f$$

$= \Delta x (\text{node size})$

- Continuity

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = S$$

$= \Delta t (\text{time step})$



- Does not require continuous media (avoiding wet/dry issues)
- Avoids problems with shocks found in dynamic and kinematic flow equations
- Diffusion smooths transitions in flow
- Captures backwater effects
- Can be used to bring in outside boundary conditions (tidal surge)
- Has some issues
 - Manning roughness is not constant with depth
 - Can smear the water surface profile near transitions
 - Because the flow has no momentum, flow direction can change due to only small changes in water surface elevation, can become a problem



- Shallow water wave equations in one direction (x)

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial x} \left[\frac{q^2}{h} \right] + \frac{gh \partial (h + z)}{\partial x} + \frac{gn^2 q^2}{h^{7/3}}$$

Acceleration Advection Pressure Friction

- If we ignore advection, this can be rewritten as:

$$q_{t+\Delta t} = \frac{q_t - gh_t \Delta t S_f}{1 + gh_t \Delta t n^2 / h_t^{10/3}}$$

- Substituted for q based on the Manning formula for the continuity equation
- In theory, is more stable for flooded conditions because giving the water momentum should reduce rapid flow direction changes



- Finite volume method
- Forward weighted (dependent on flow direction)
- Variable time step dependent on stability criteria
- Predictor-corrector method
 - Fluxes estimated from initial heads
 - Intermediate heads estimated from flow
 - Fluxes calculated with new heads
 - Two fluxes averaged
 - Heads updated with new fluxes
- Picard iterations until flow areas converge

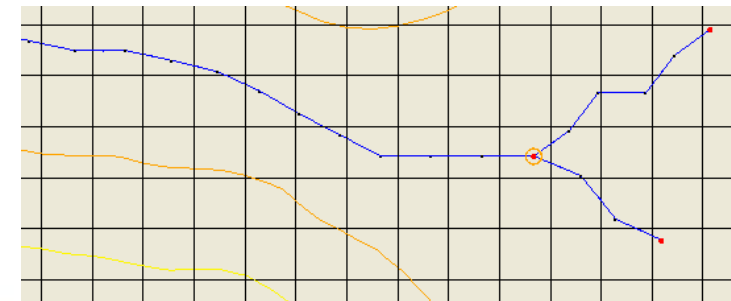
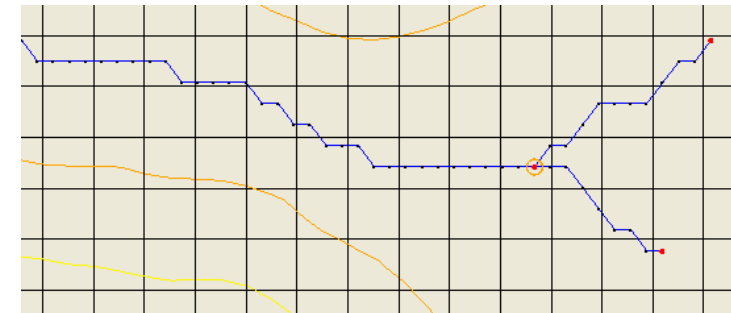
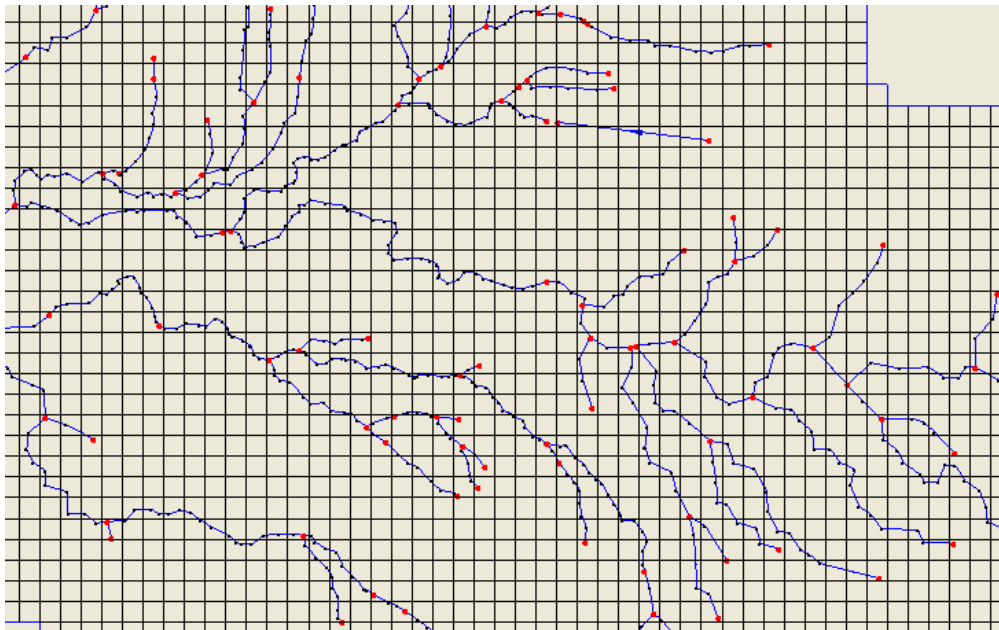


- Links represent a stream reach of uniform area.
- Transitions between cross sectional areas in links should be smooth.
- Include enough links to avoid abrupt changes in cross section or slope.



Selecting Node Size

- Small enough to capture required sinuosity.
- Large enough for numerical efficiency.
 - Channel flow tends to be a limiting factor in computational considerations



- Channels
 - Cross-section profile
 - Thalweg profile
 - Roughness
- Detention Basins
 - Min, Max, Initial water surface elevation
- Hydraulic Structures
 - Geometry, hydraulic coefficients

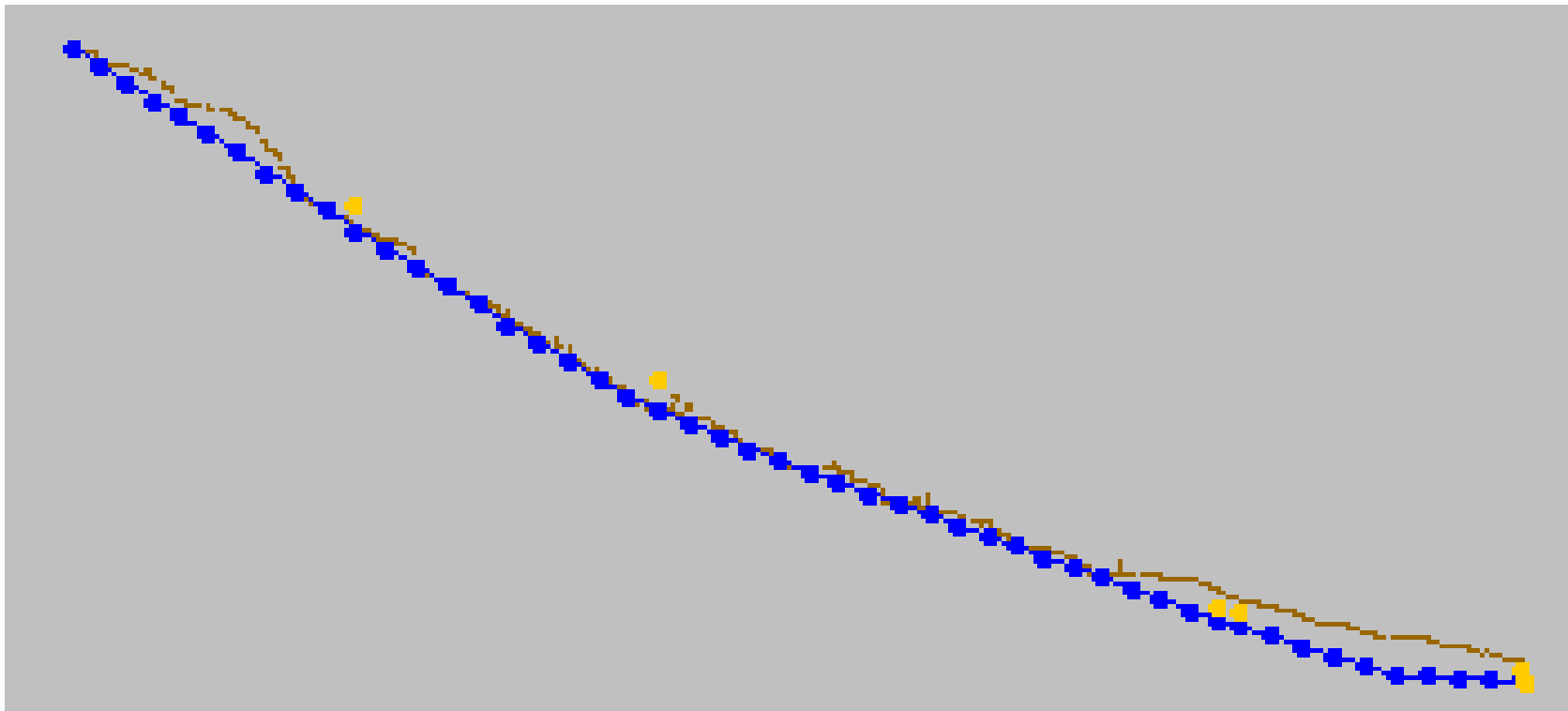


- Stream locations
 - GIS data
 - Derived from DEM data
- Stream shape
 - Surveyed data
 - Estimated
- Stream Roughness
 - Estimated from photos, calibrated



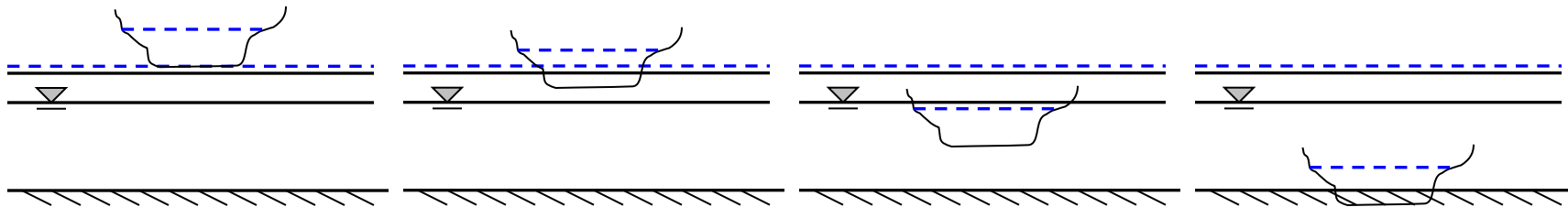
Vertical Thalweg Profile

- Can be estimated relative to the land surface
- Must be relatively smooth, may contain small adverse slopes



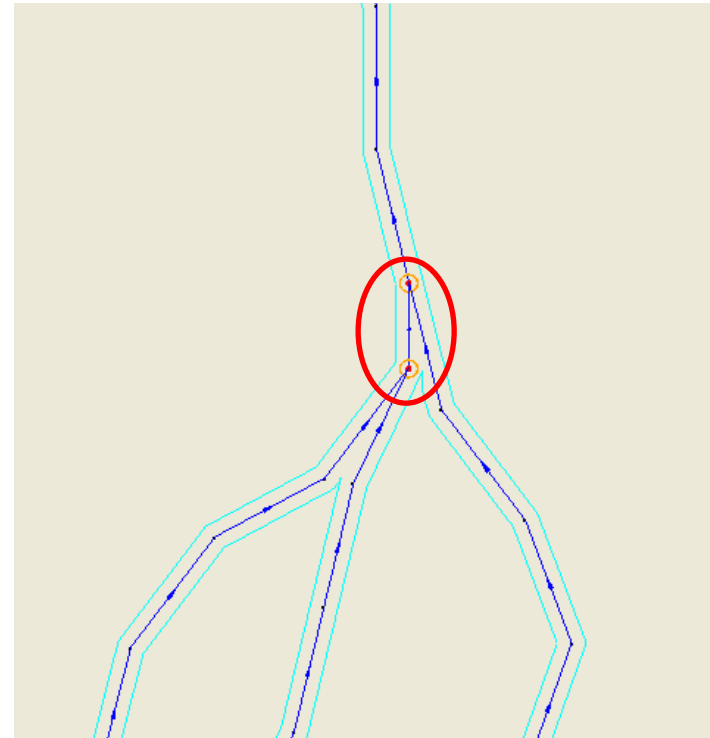
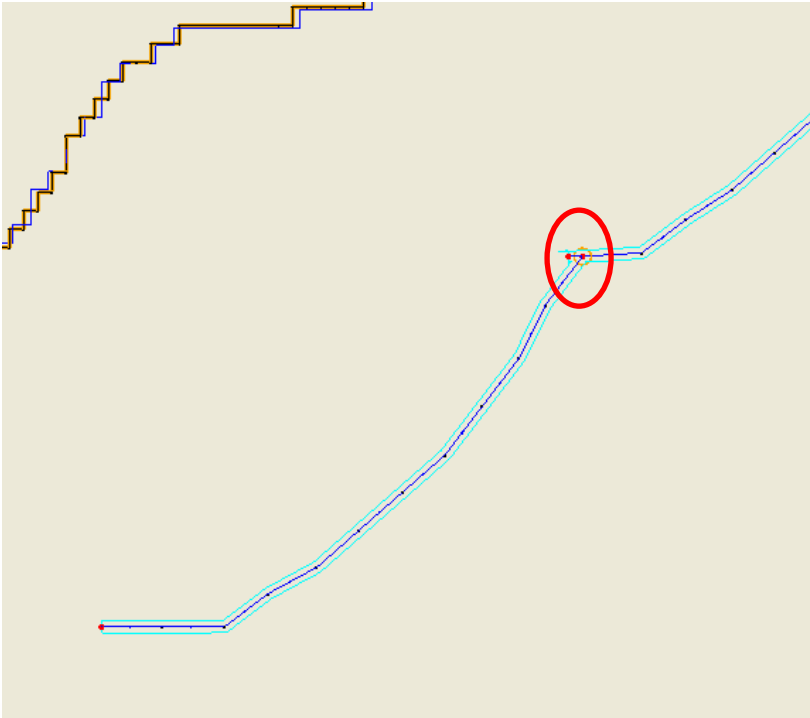
Integrating the Channel Model: Vertical Location

- Full interaction with:
 - Overland flow
 - Groundwater



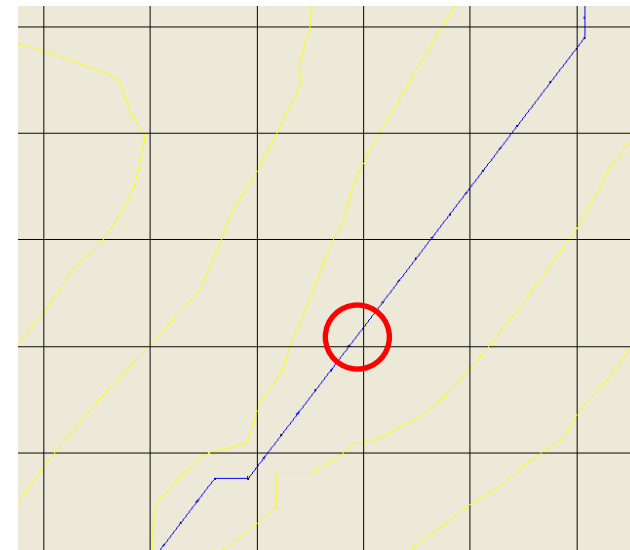
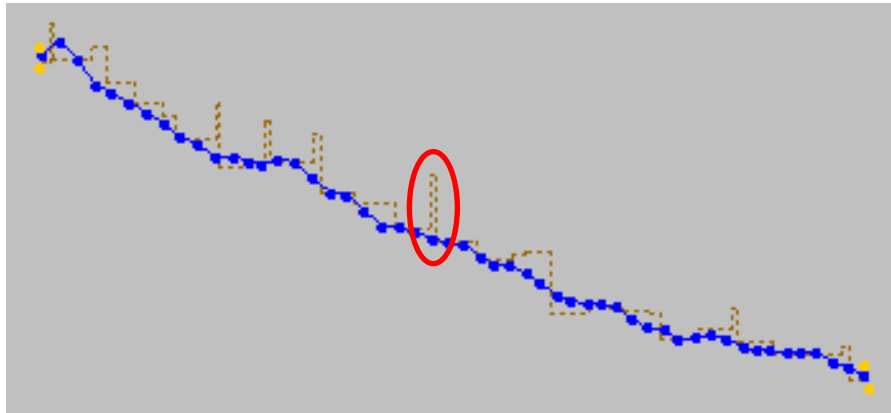
Integrating the Channel Model: Horizontal Location

- Remove very short streams (1 node streams)



Integrating the Channel Model: Horizontal Location

- Adjust nodes laterally to lie in lowest nearby cells
- Caused by cell size differences between DEM and GSSHA grids.



Start Simple, Build on Success

- Start with the main channel.
- Add lower order streams as necessary.
- Stop adding lower order streams when the addition of more streams no longer affects the observations of interest.



Eau Galle River, Wisconsin

