

CE EN 547 – BRIGHAM YOUNG UNIVERSITY

MODFLOW – Part 2

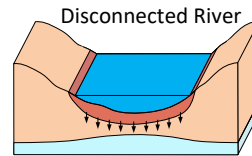
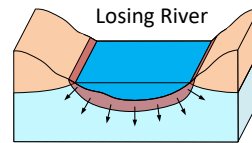
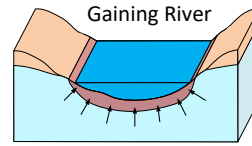
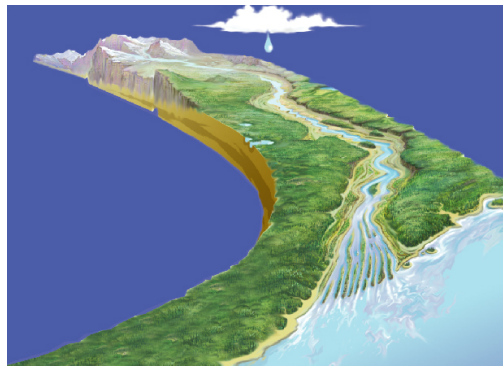
Advanced Packages

Additional Packages

- RIV - River
- STR - Stream-Aquifer Interaction
- SFR - Stream Flow Routing
- GHB - General Head
- CHD - Changing Head Boundary
- HFB - Horizontal Flow Barrier
- EVT – Evapotranspiration

There are several additional packages that we will not cover. These are just some of the more commonly-used packages

Stream-Aquifer Systems



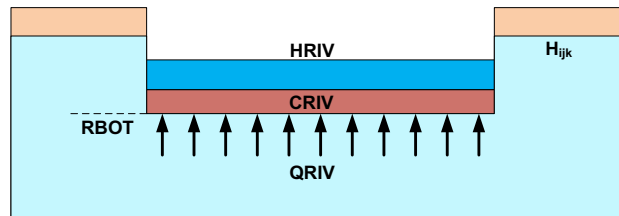
River Package

If head is above river stage, flow is from aquifer → river
 If head is below river stage, flow is from river → aquifer

I	J	K	Stage (ft)	Conductance (ft ⁻² /d)	Elevation (ft)
45	7	1	761.19759442151	236.07211283546	756.19759442151

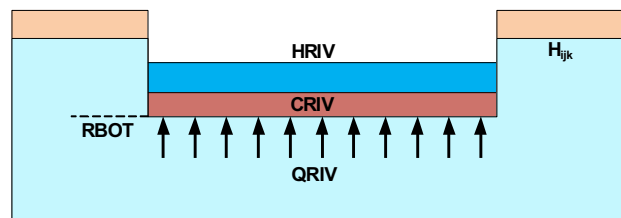
Buttons: Add BC, Delete BC, Delete All BCs, OK, Cancel

Idealized Representation



H_{ijk} = Head in cell
HRIV = Stage in river
CRIV = Conductance of river bottom sediments
RBOT = Elevation of bottom of sediments
QRIV = Flow between aquifer and river

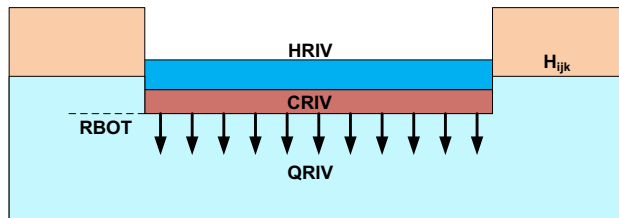
Case #1 – Head Above River Stage



$$QRIV = CRIV * (HRIV - H_{ijk})$$

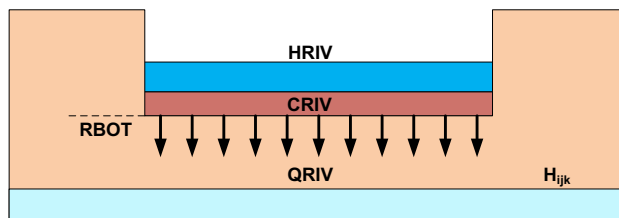
(-Q signifies flow out of cell)

Case #2 – Head Below River Stage But Above River Bottom



$$QRIV = CRIV * (HRIV - H_{ijk})$$

Case #3 – Head Below River Bottom



$$QRIV = CRIV * (HRIV - RBOT)$$

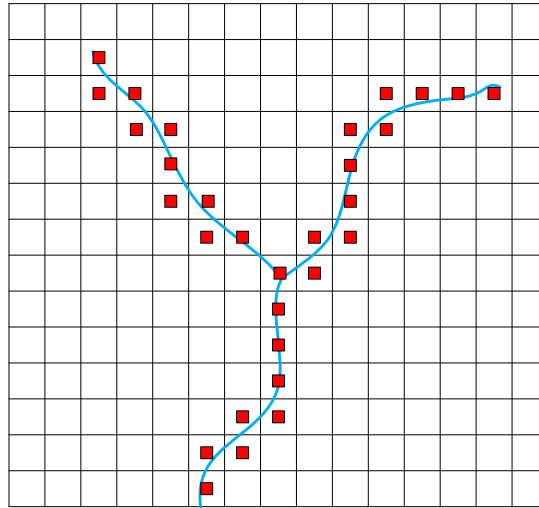
River Conductance

Length of reach in each river cell is computed

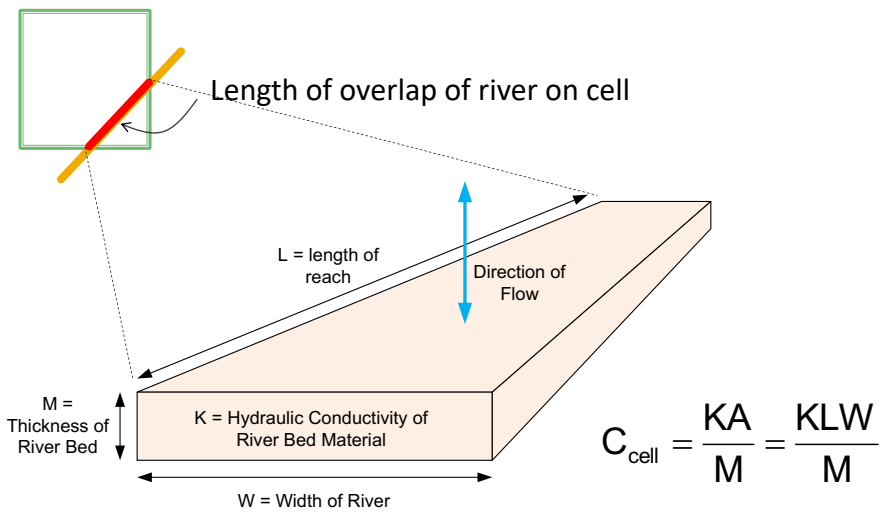
River Network



River Cells



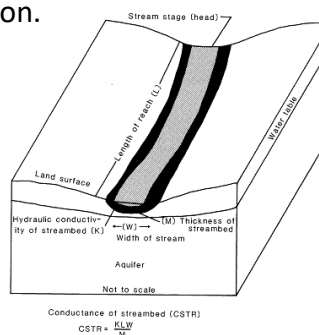
River Conductance Calculation



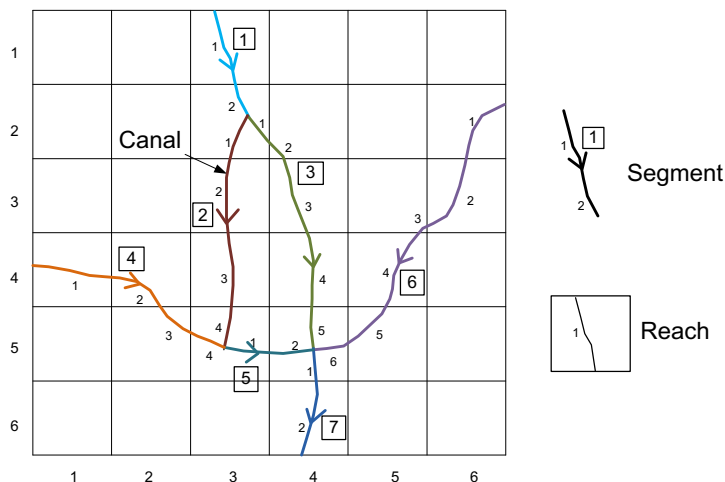
STR - Stream-Aquifer Interaction Package

- Like the River Package, water can flow from aquifer to stream or vice versa.
- Unlike the River Package, stage is not specified. Rather, flow is routed using simple channel hydraulics and a stage is computed using Manning's equation.

$$Q = \frac{u}{n} A R_h^{2/3} S_o^{1/2}$$



STR Package - Segments and Reaches

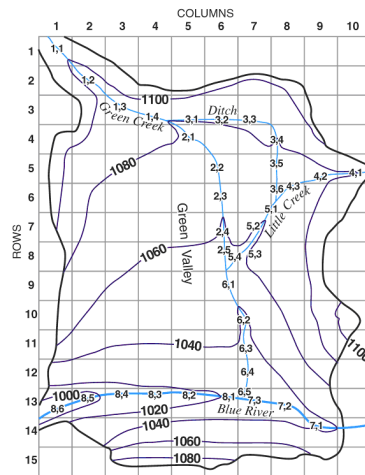


STR Package - Required Attributes

- Segments
 - Incoming flow (for top segments and diversions)
 - Width
 - Slope
 - Manning's roughness coefficient
- Reaches
 - Conductance
 - Elevation of the bottom of the streambed
 - Elevation of the top of the streambed

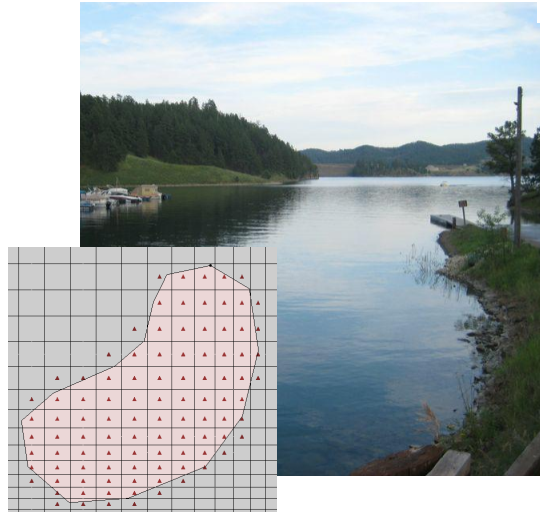
SFR - Stream Flow Routing Package

- More advanced stream package
- More options for inputs to streams
- Interaction with the Unsaturated Zone Flow package

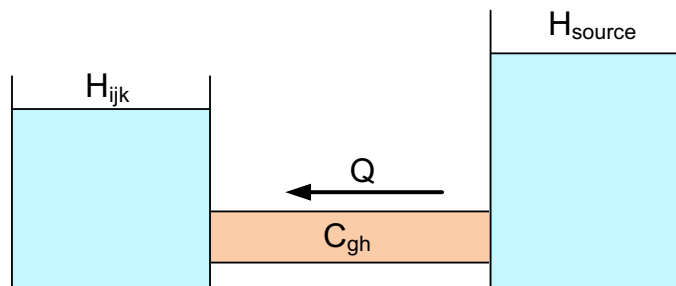


GHB - General Head Package

- Often used to simulate lakes, reservoirs
- Required parameters:
 - Head
 - Conductance

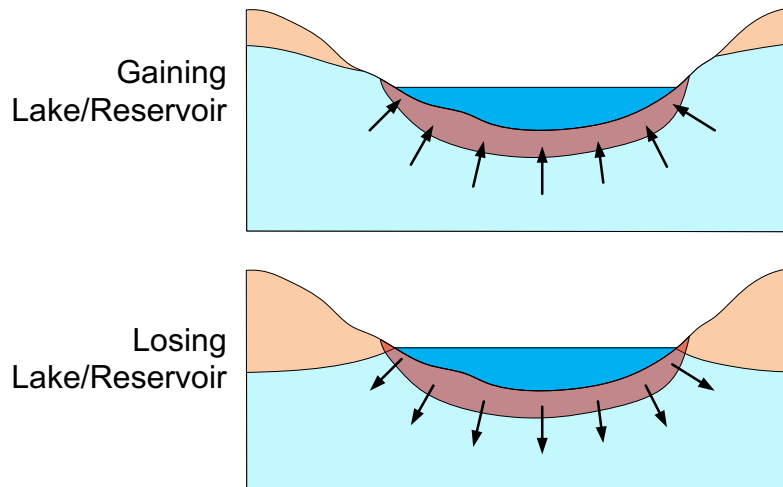


General Head

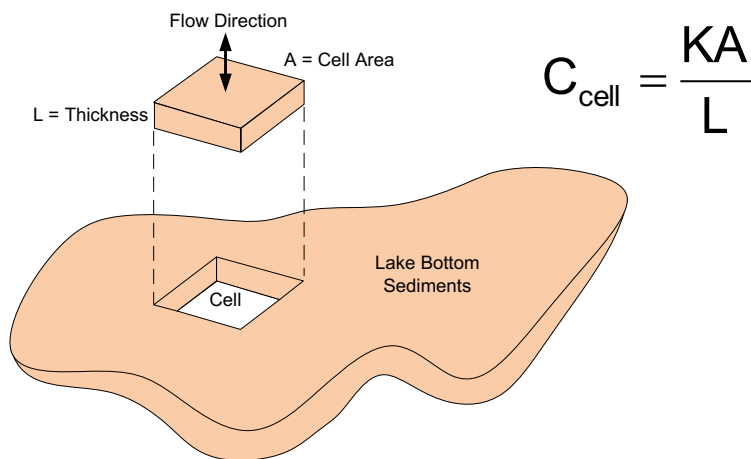


$$Q = C_{gh} * (H_{source} - H_{ijk})$$

General Head Boundary



Lakes and Reservoirs

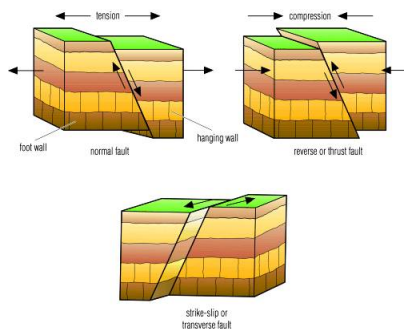


CHD - Time Variant Specified Head Package

- CHD = Changing Head
- Original method for defining specified heads, works for static (steady-state) heads only
 - IBOUND
 - Starting Heads Array
- CHD later added to allow for transient specified head boundary conditions
- Can be used for steady-state case also

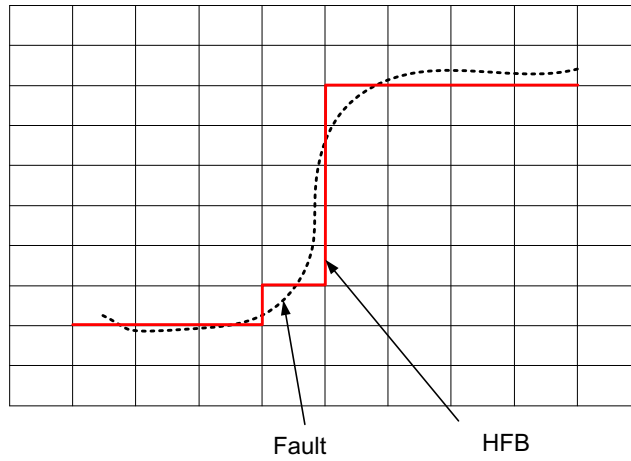
HFB – Horizontal Flow Barrier Package

Used to simulate low permeability barriers such as faults, sheet pile walls, and slurry trenches

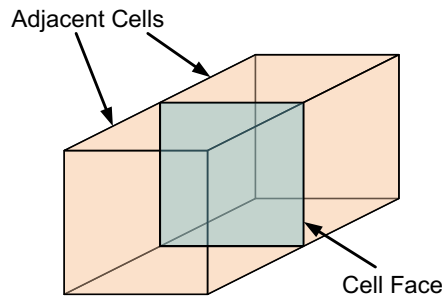


HFB Cell Boundaries

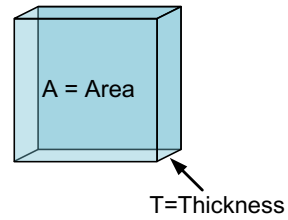
Plan View



HFB – Hydraulic Characteristic



Each instance is assigned a "hydraulic characteristic"



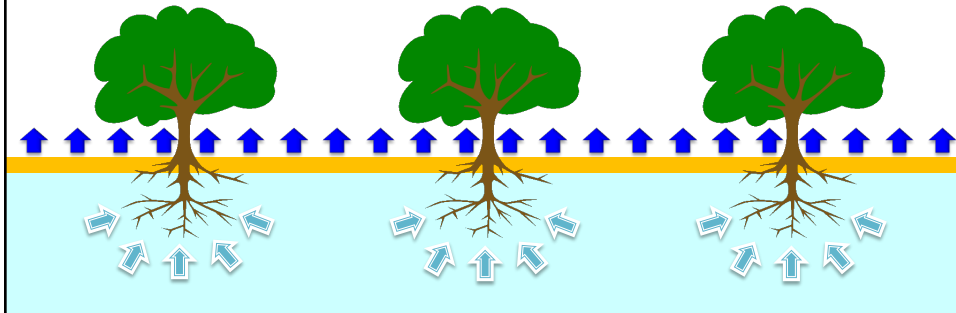
$$HC = \frac{K}{T}$$

$$Q = HC \cdot A \cdot \Delta H$$

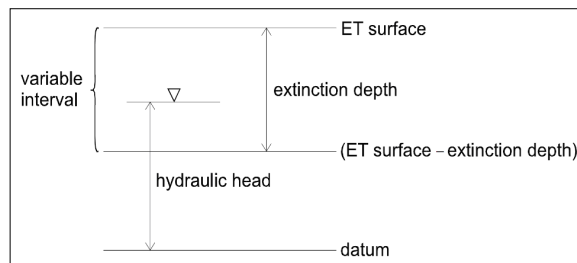
$$Q = \frac{KA}{T} \cdot \Delta H$$

EVT – Evapotranspiration Package

- Simulates groundwater loss from evaporation and transpiration
- User specifies:
 - Maximum ET rate
 - Surface elevation (usually ground surface)
 - Extinction depth



EVT – Evapotranspiration Package



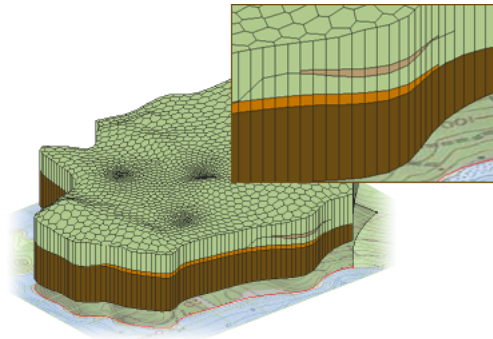
User specifies:

- Maximum ET rate
- Surface elevation (usually ground surface)
- Extinction depth

- ET rate = 0.0 when head below (ET surface – ext. depth)
- ET rate = Max. ET rate when head above or equal to ET surface
- ET rate varies when head between ET surface and ext. depth

MODFLOW-USG

New version of MODFLOW that allows for unstructured grids (no rows/columns/layers). Uses finite volume formulation.



Allows for more efficient grid refinement around features where rapid head change occurs.

