

CE EN 547 – BRIGHAM YOUNG UNIVERSITY

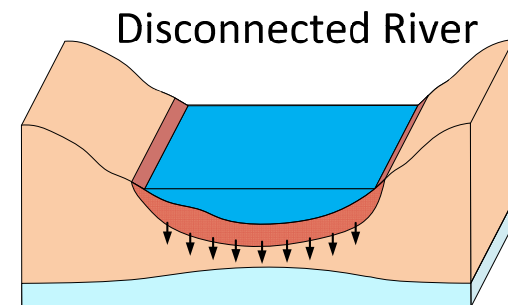
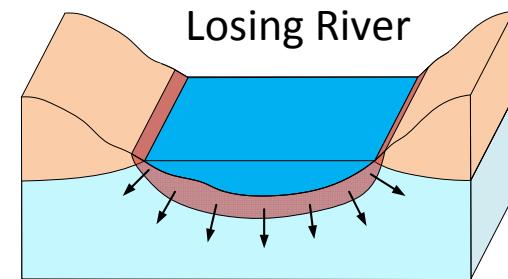
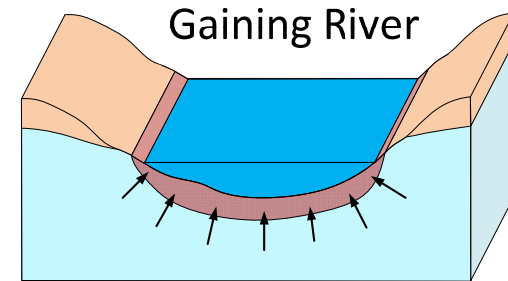
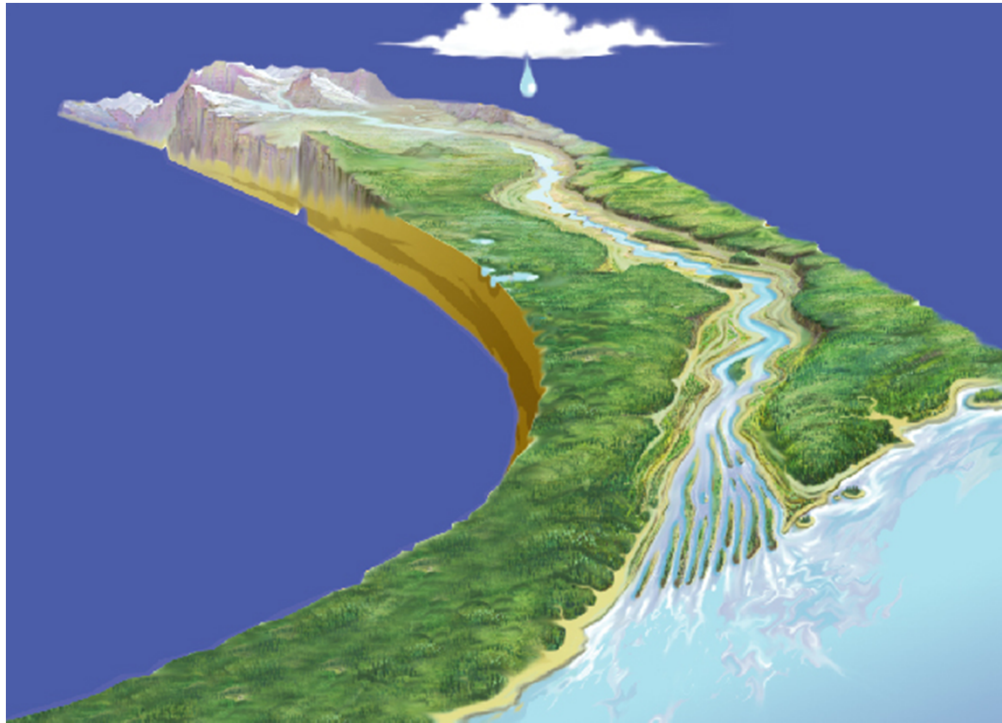
MODFLOW – Part 2

Advanced Packages

Advanced Packages

- River
- Stream-Aquifer Interaction
- General Head
- Changing Head Boundary
- Horizontal Flow Barrier

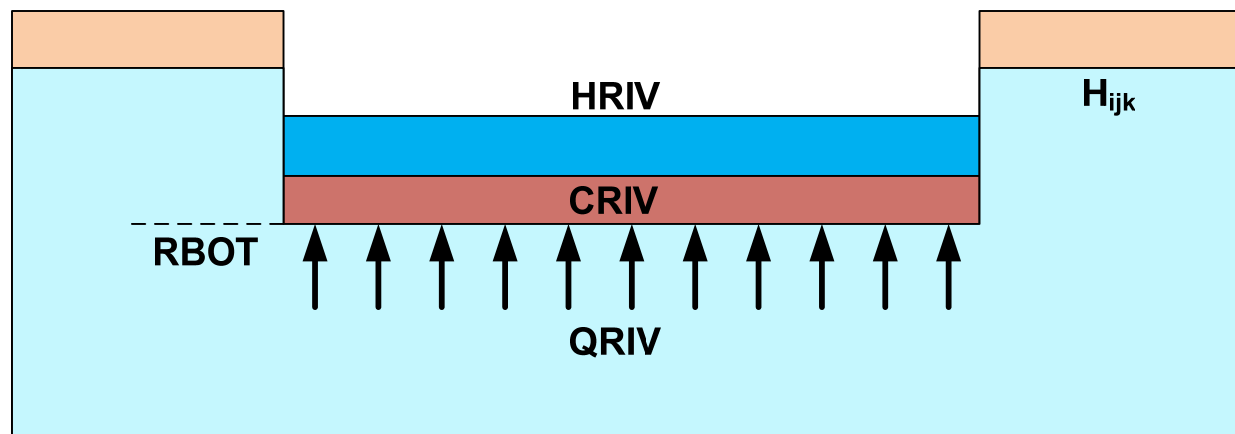
Stream-Aquifer Systems



River Package

- Assigned to individual cells
- If head is above river stage, flow is from aquifer to river
- If head is below river stage, flow is from river to aquifer
- Required parameters
 - Conductance
 - Bottom elevation
 - Stage

Idealized Representation



H_{ijk} = Head in cell

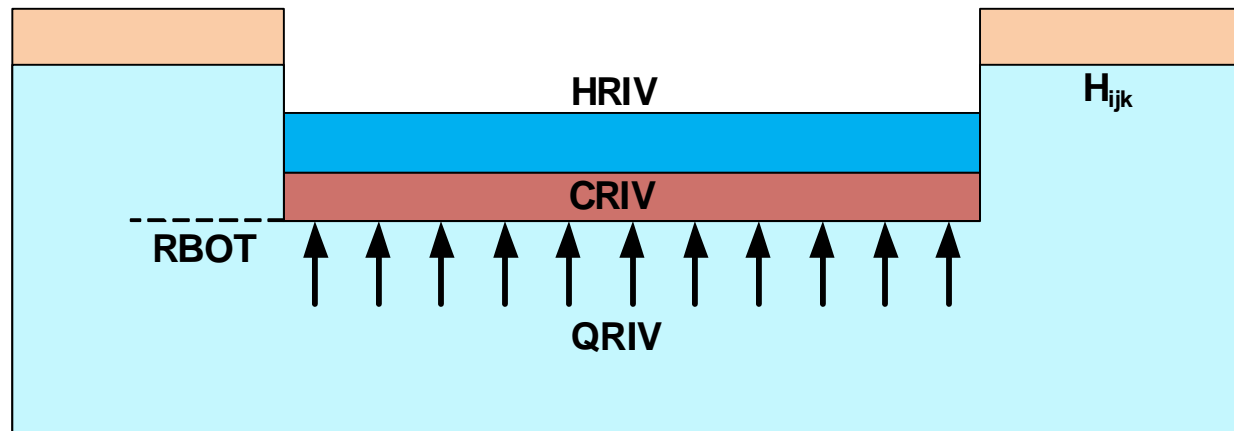
HRIV = Stage in river

CRIV = Conductance of river bottom sediments

RBOT = Elevation of bottom of sediments

QRIV = Flow between aquifer and river

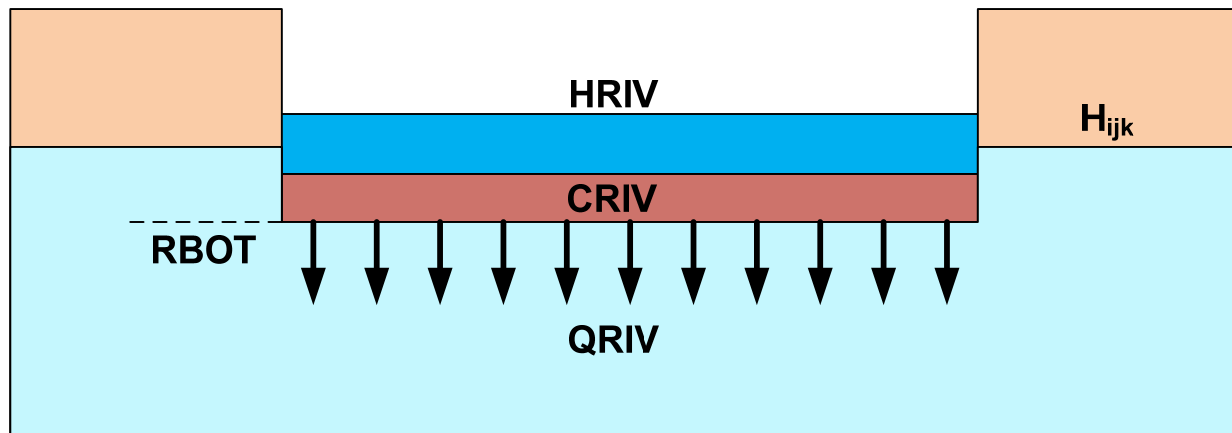
Case #1 - Head Above River Stage



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

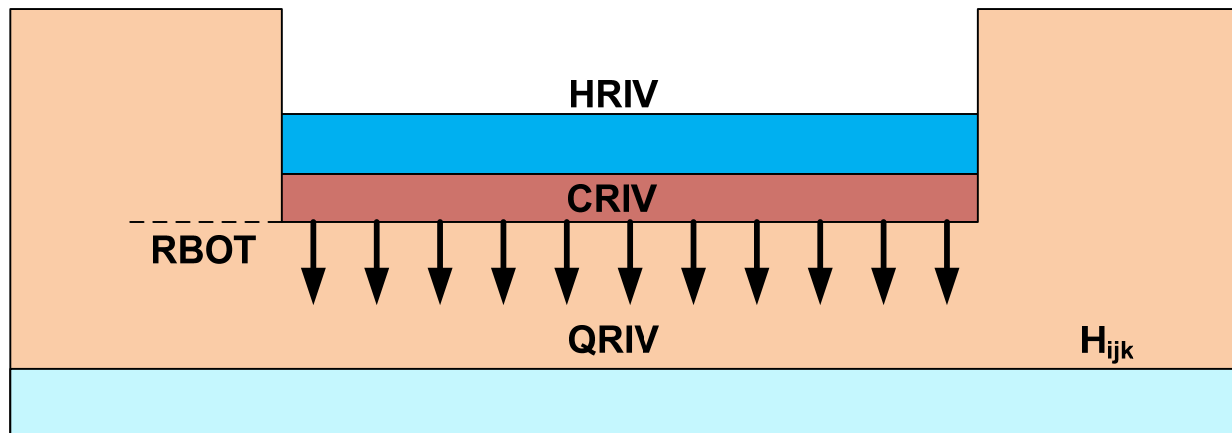
(-Q signifies flow out of cell)

Case #2 - Head Below River Stage but Above River Bottom



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

Case #3 - Head Below River Bottom



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

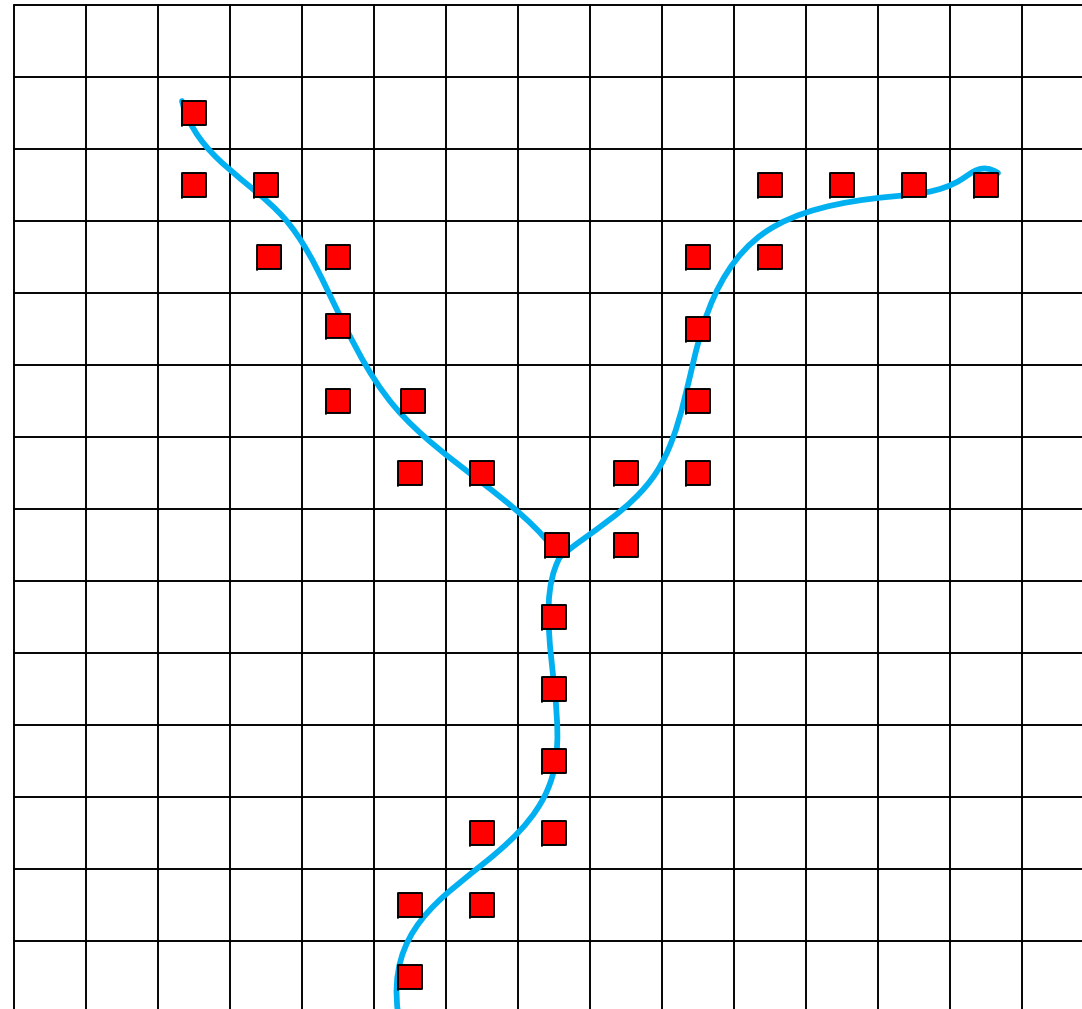
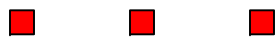
River Conductance

Length of reach in each river cell is computed

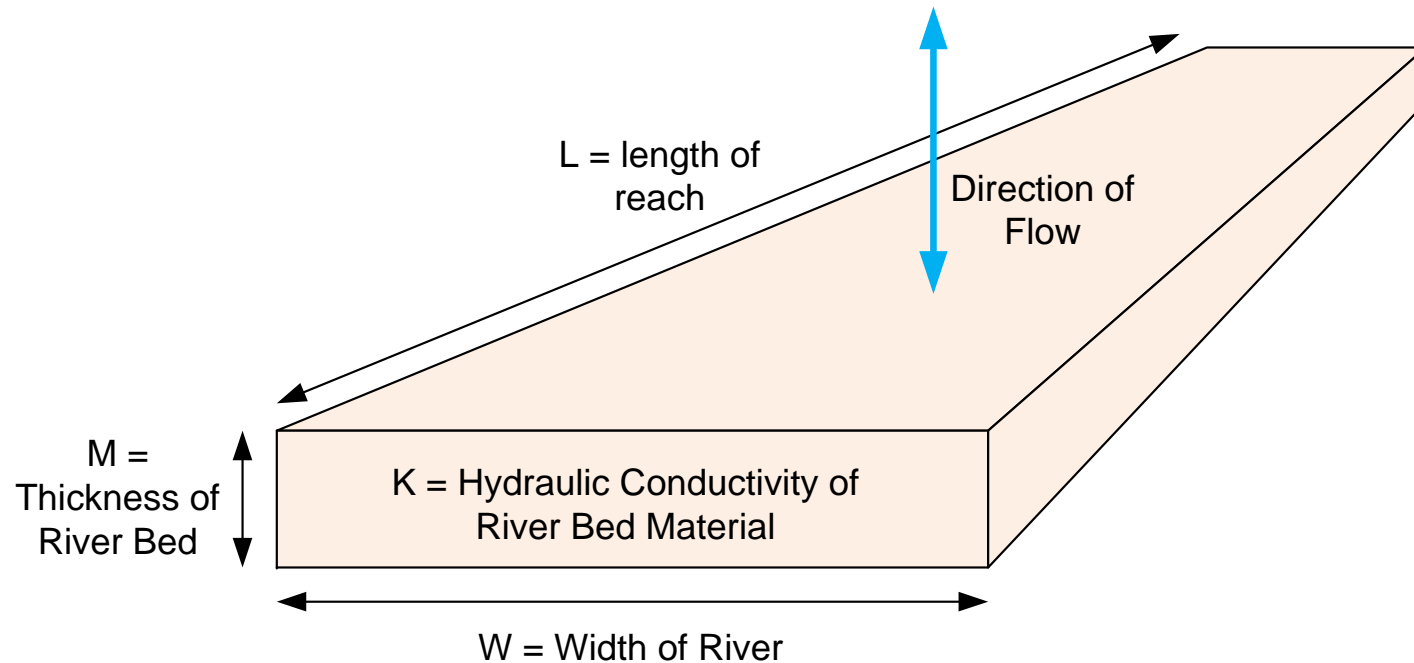
River Network



River Cells



River Conductance



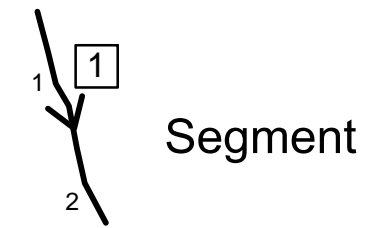
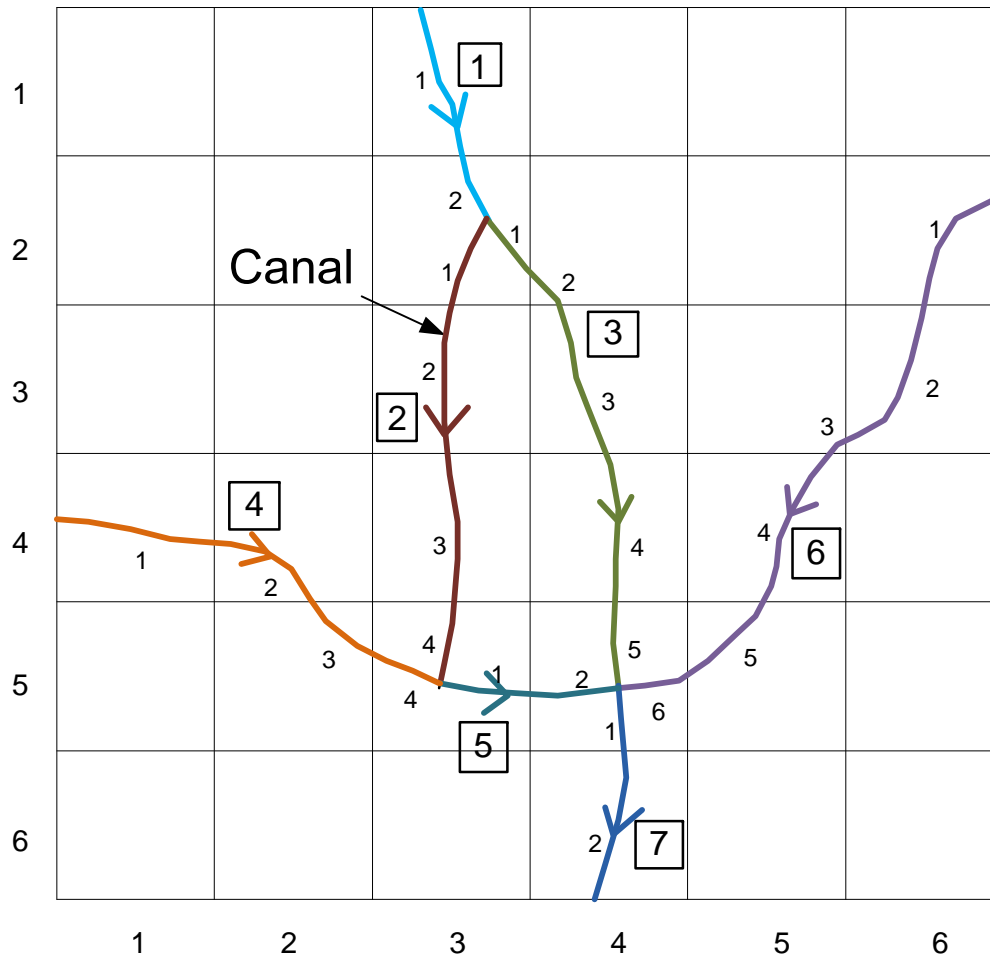
$$\text{Cond} = \frac{K * (\text{area of flow})}{(\text{length of flow})} = \frac{KLW}{M}$$

Stream-Aquifer Interaction Package

- Not part of original MODFLOW packages.
- 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.

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

Segments and Reaches



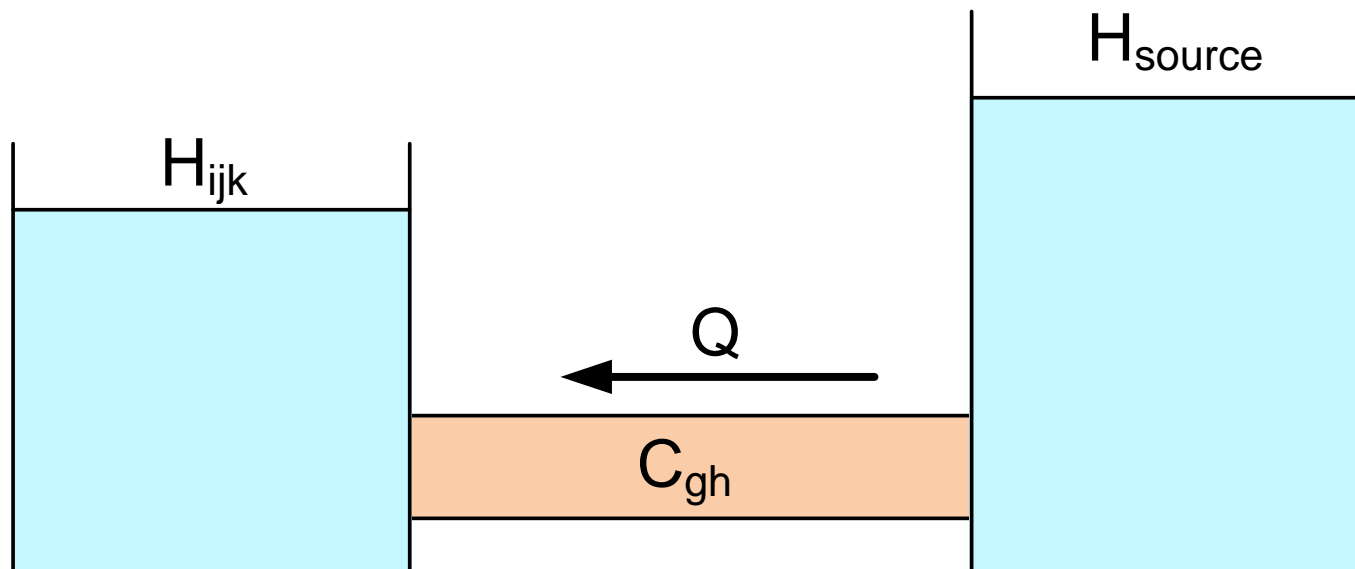
Attributes

- 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

General Head Package

- Assigned to individual cells
- Often used to simulate lakes, reservoirs
- Required parameters
 - Head
 - Conductance

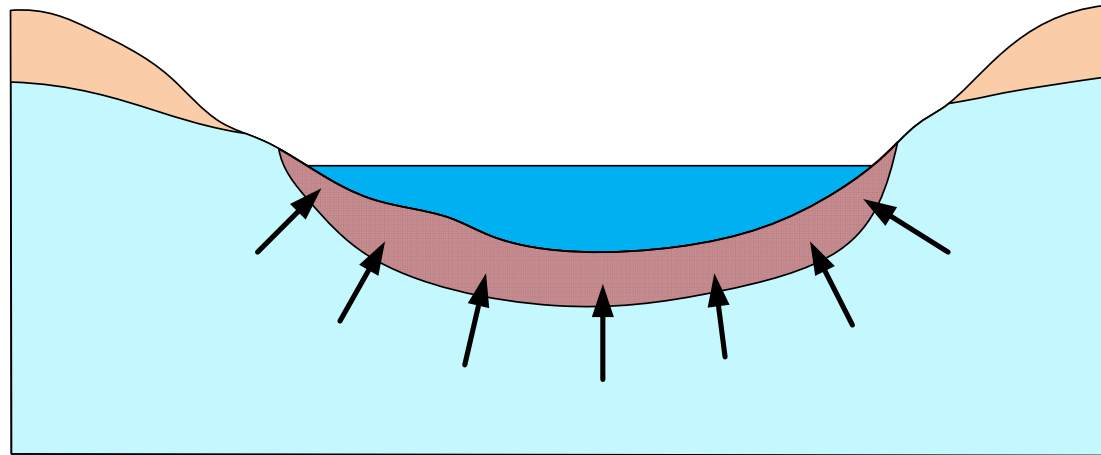
General Head



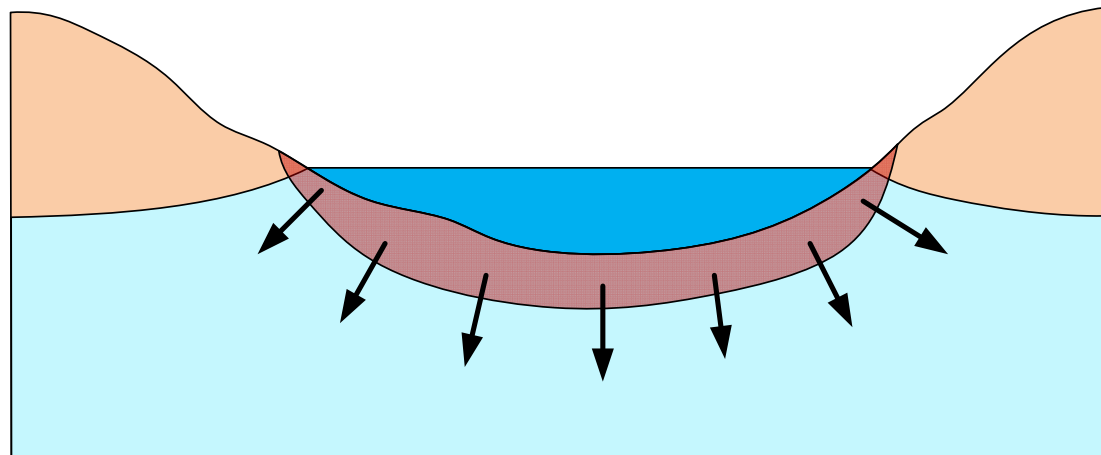
$$Q = C_{gh} * (H_{source} - H_{ijk})$$

General Head Boundary

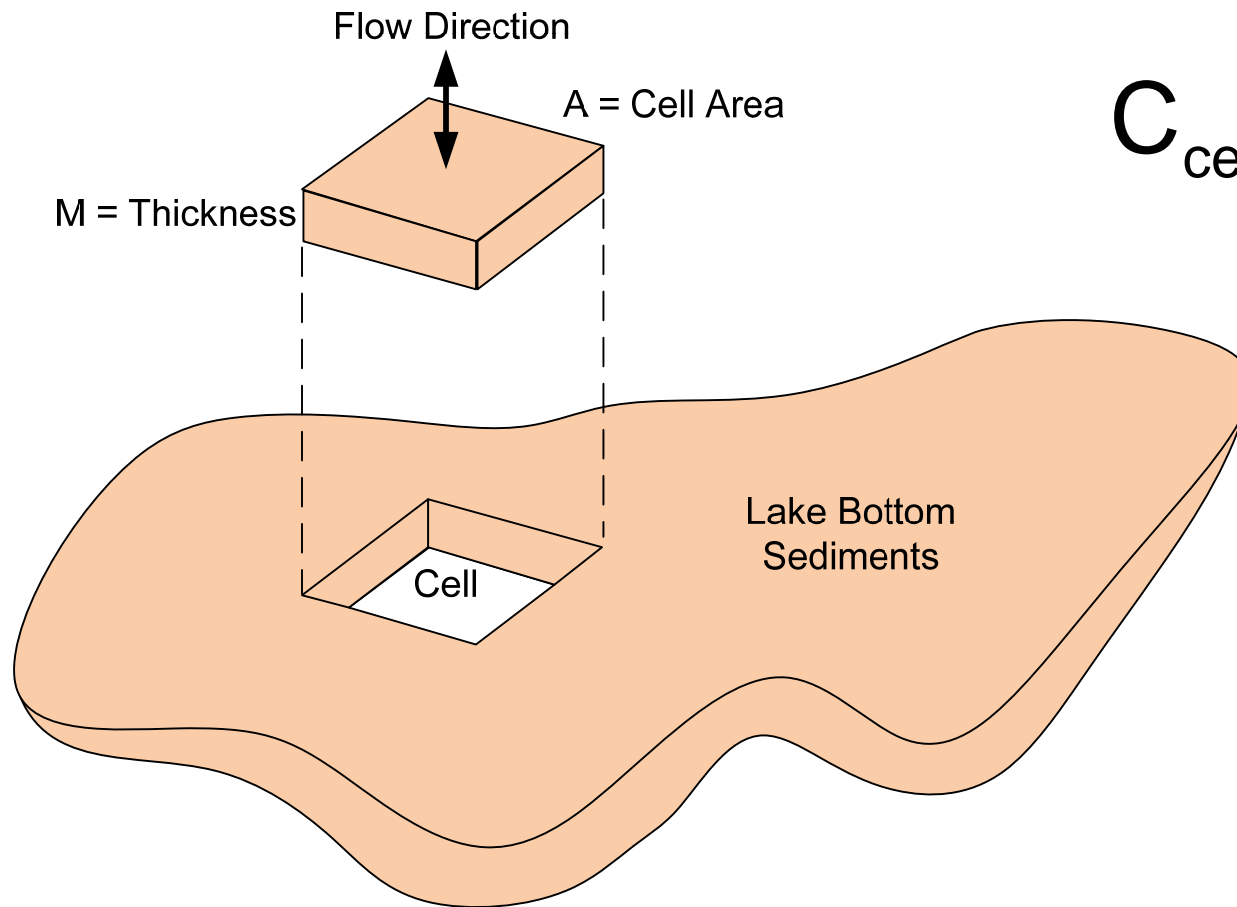
Gaining
Lake/Reservoir



Losing
Lake/Reservoir



Lakes and Reservoirs



$$C_{\text{cell}} = \frac{KA}{M}$$

CHD Package

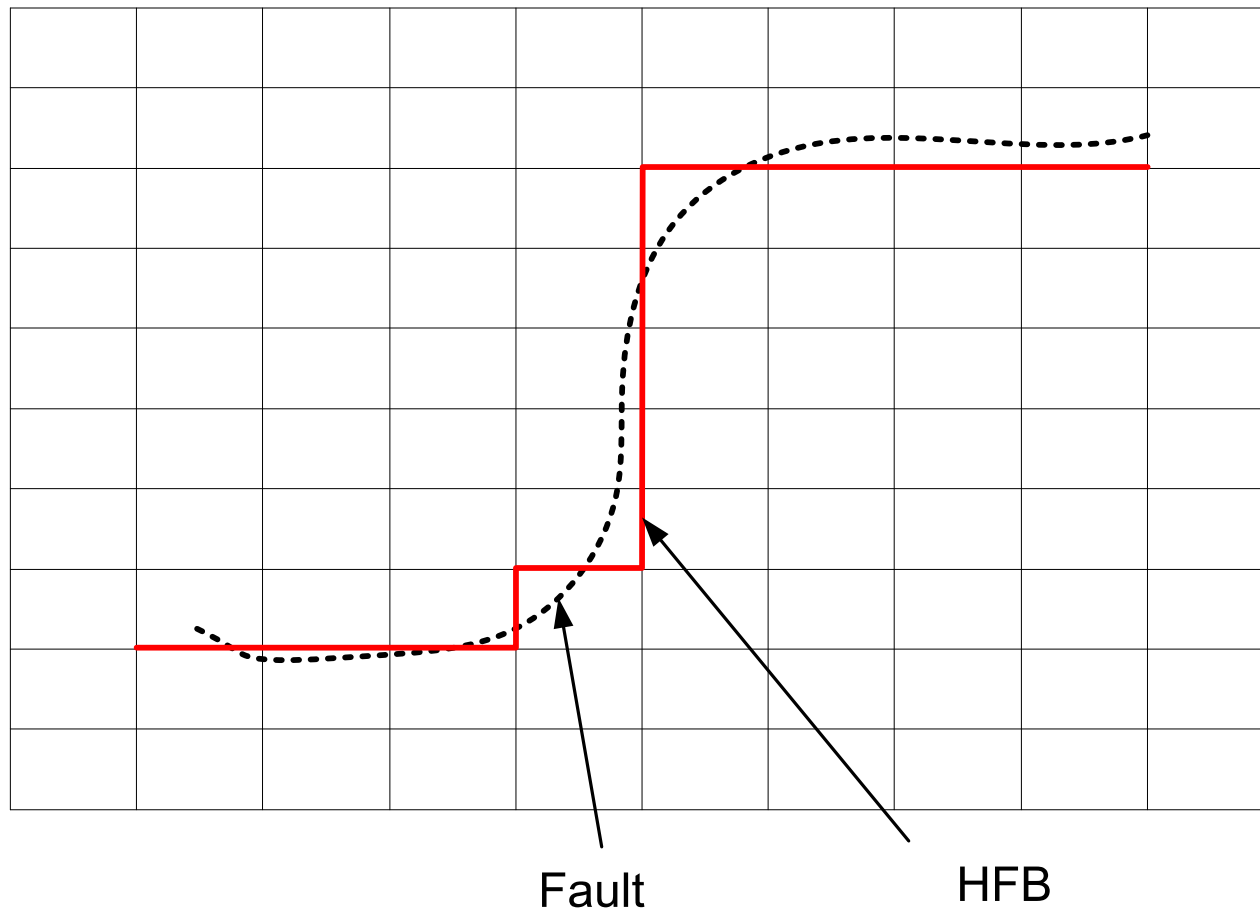
- CHD = Changing Head
- Original method for defining specified heads works for static (steady state) heads only.
 - IBOUND
 - Starting Heads Array
- CHD later added to allow for transient specified head boundary conditions
- Assigned to individual cells
- Can be used for steady-state case also

Horizontal Flow Barrier Package

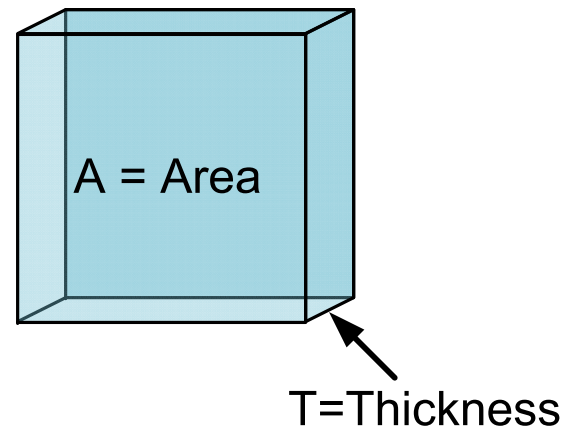
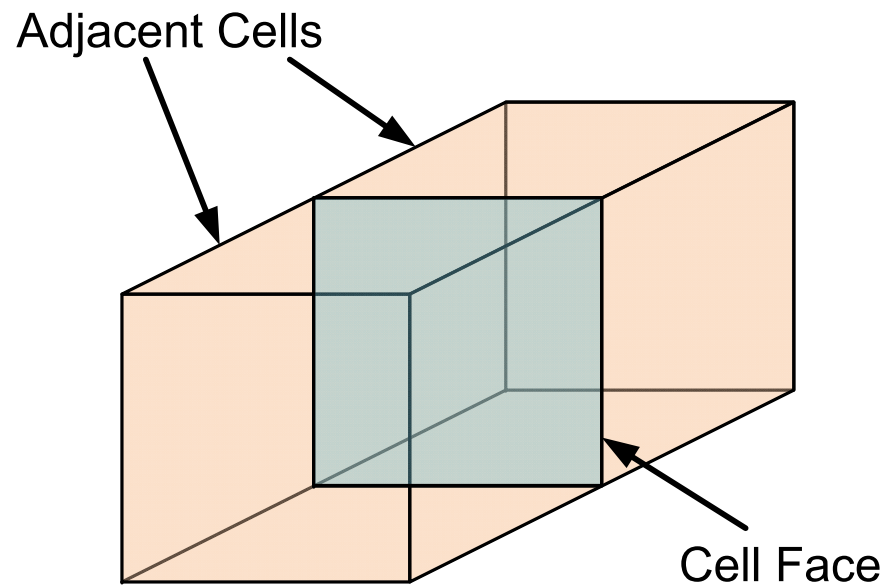
- Not part of original MODFLOW packages
- Used to simulate low permeability barriers such as sheet pile walls or slurry trenches.
- Assigned to cell boundaries (pairs of cells)
- Each instance is assigned a hydraulic characteristic = $K/\text{thickness}$

HFB Cell Boundaries

Plan View



HFB



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

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

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