

CWEMF

IWFM v4.0 Workshop

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West Yost Associates, Davis, CA

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California Department of Water Resources

Session 3:

Tile Drains, Subsidence, Pumping and Recharge

Tile Drainage

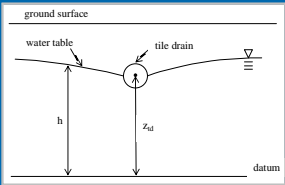
- Used to control the elevation of the groundwater table where drainage is a problem and to promote vertical flow in farmlands for leaching
- Does not interfere with farming operations
- No loss of farming area due to drainage system

Tile Drains

- Simulated as general head boundary conditions:

$$Q_{td} = C_{td}(z_{td} - h) \leq 0$$

Q_{td} = tile drain flow, [L³/T]
 C_{td} = conductance, [L²/T]
 z_{td} = tile drain elevation, [L]
 h = groundwater head, [L]


- Tile drain flows can be directed into specified stream nodes or outside the model area

Subsurface Irrigation

- Used in arid areas to irrigate deep rooted crops to minimize evaporation
- Simulated as general head boundary conditions:

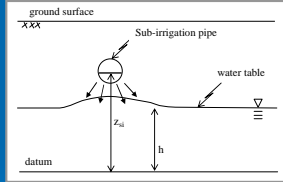
$$Q_{si} = C_{si}(z_{si} - h) \geq 0$$

Q_{si} = subsurface irrigation, [L^3/T]

C_{si} = conductance, [L^2/T]

z_{si} = head in the subsurface irrigation pipe elevation, [L]

h = groundwater head, [L]

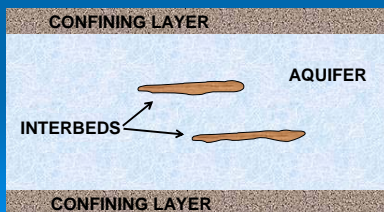


Land Subsidence

- Large amounts of water extraction from the groundwater may cause compaction of the aquifer material
- Elastic compaction or expansion of the aquifer material; soil structure is not changed permanently
- Inelastic compaction of the aquifer material; soil structure is changed permanently

Land Subsidence

- Land subsidence due to compaction of interbed lenses
- Ground surface elevation and aquifer thickness are not modified during simulation



Land Subsidence

- Modeling elastic change in the interbed thickness

$$\Delta b_{se} = -\Delta h S_{se} b_o \quad \text{if } h \geq h_c$$

- Modeling inelastic change in the interbed thickness

$$\Delta b_{si} = -\Delta h S_{si} b_o \quad \text{if } h < h_c$$

$\Delta b_{se}, \Delta b_{si}$ = elastic and inelastic compaction, (L);
 S_{se}, S_{si} = elastic and inelastic specific storage, (1/L);
 Δh = change in groundwater head, (L);
 h_c = pre-compaction head, (L);
 b_o = initial interbed thickness, (L).

- Interbeds cannot be compacted beyond a minimum thickness

Land Subsidence

- The following term is added to groundwater flow equation to incorporate the storage changes due to subsidence:

$$q_s = S_s' \frac{\partial h}{\partial t}$$

q_s = rate of flow into storage due to compaction of interbeds, (L/T);

$$S_s' = \begin{cases} S_{se} b_o & \text{if } h > h_c \\ S_{si} b_o & \text{if } h \leq h_c \end{cases}$$

= skeletal storativity of interbeds, (dimensionless).

Pumping / Recharge

- Pumping / recharge by well:
 - Exact location of wells and pumping/recharge rates are known
- Pumping / recharge by element:
 - Exact locations of wells are not known or modeling every single well is impractical
 - A general knowledge of region where a cluster of wells are located is available and regional pumping/recharge rates can be estimated

Pumping / Recharge

- Distribution of well pumping to vertical layers:
Kozeny Equation (Driscoll, 1986)

$$f_m = T \ell_s \left[1 + 7 \sqrt{\frac{r}{2b\ell_s}} \cos\left(\frac{\pi \ell_s}{2}\right) \right]$$

f_m = fraction of pumping from aquifer layer m, (dimensionless);
 T = aquifer transmissivity, (L^2/T);
 ℓ_s = well screen length as a fraction of the
aquifer thickness, (dimensionless);
 r = well radius, (L);
 b = aquifer thickness, (L).

- Distribution of element pumping to vertical layers:
 - Distribution coefficients are supplied by the user



Pumping to Meet Water Demand

- Well and element pumping can be
 - Used at the same element that the pumping occurs
 - Delivered to a subregion
 - Delivered to a single grid cell
 - Delivered to a group of grid cells
 - Sent outside the model area



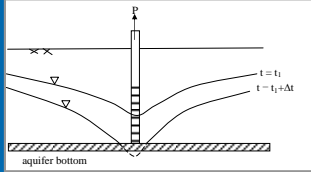
Distribution of Regional Pumping Among Wells and Elements

- Regional pumping can be distributed among wells and elements based on
 - Fractions supplied by the user
 - Total area of the delivery destination multiplied by user-defined factor
 - Total agricultural and urban area in the delivery destination multiplied by user defined factor
 - Agricultural area in the delivery destination multiplied by user defined factor
 - Urban area in the delivery destination multiplied by user defined factor



Pumping at Drying Wells / Elements

- To compute actual supply to urban and agricultural lands, it is necessary to calculate the actual amount of pumping at a well / element that goes dry



- An iterative procedure is used to compute actual pumping at a drying well / element

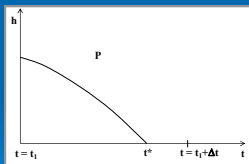
- Pumping rate at a drying well / element is modified iteratively to find the rate that will dry the well / element at the end of the time step



Pumping at Drying Wells / Elements

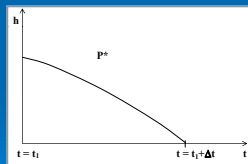
- Inverse problem

$$\text{Amount pumped} = P \times (t^* - t_1)$$

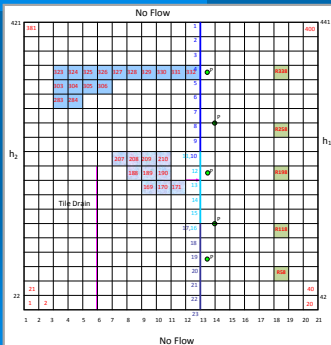


- Approximate solution

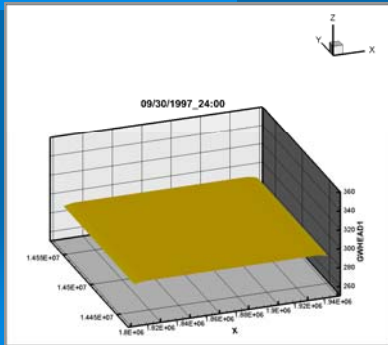
$$\text{Amount pumped} = P^* \times \Delta t$$



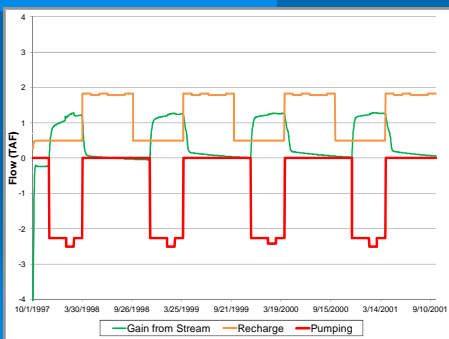
Example 3: Tile Drains, Subsidence, Pumping and Recharge



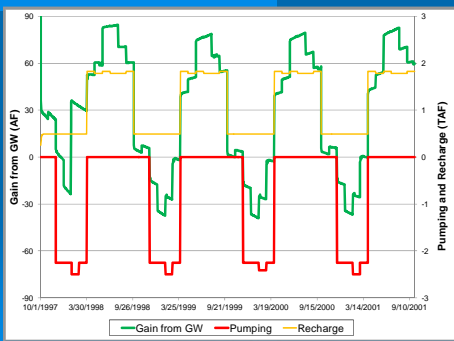
Example 3: Results



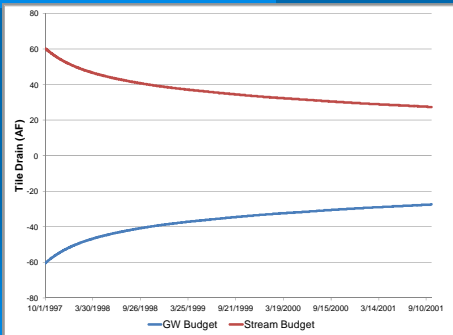
Example 3: Stream-Groundwater Interaction



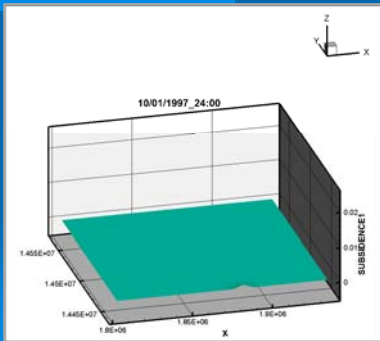
Example 3: Lake-Groundwater Interaction



Example 3: Tile Drains



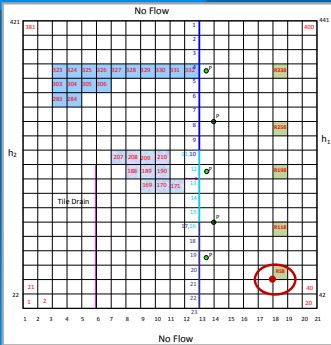
Example 3: Subsidence



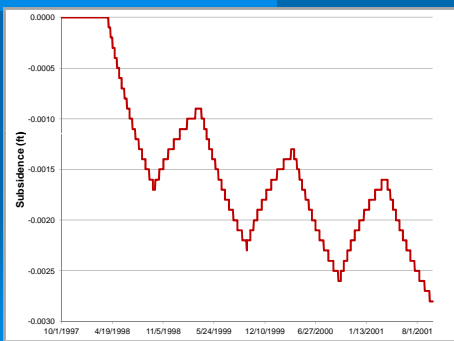
Example 3: Cumulative Subsidence versus Net Recharge



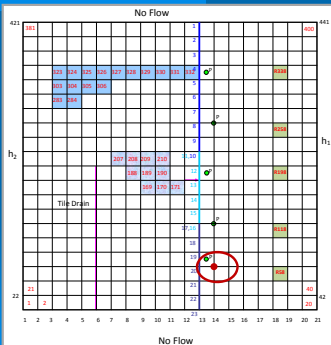
Example 3:
Subsidence at Node 60



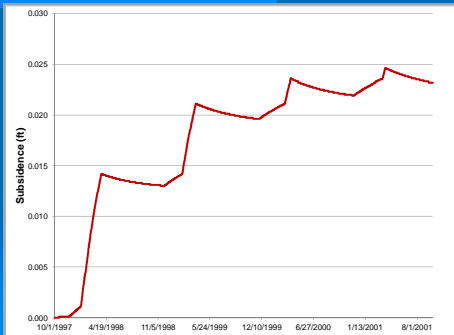
Example 3:
Subsidence at Node 60



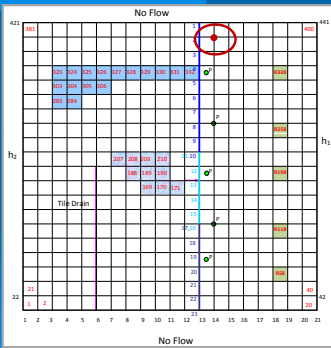
Example 3:
Subsidence at Node 77



Example 3:
Subsidence at Node 77



Example 3:
Subsidence at Node 413



Example 3:
Subsidence at Node 413

