**\*\*Please know that planning El Dia and Earth Week sessions is taking a toll on my quality of work in all classes and research. Spring break will help some, will carve out more time to dive deeper with HW7 model\*\***

**Challenge 1**

1. **Chart, line chart

   Description automatically generatedPlot the flow across the left and right boundaries. Explain what you see and why it makes sense. (Figure 1)**

The left boundary experiences its greatest flux at the bottom (y=0) but takes a parabolic dip to a minimum at y=1600. The right boundary has less fluctuation with a slight increase along the y-axis. ET occurs across the whole domain at an order of magnitude lower than the recharge, which is localized in the upper left quadrant of the domain. This manifests in a reduction of flow because the head gradient decreases.

1. **Plot equipotentials and flow vectors in plan view and outline the area that would be affect by recharge if contaminated. Explain what you are seeing and why. (Figure 2)**

Figure 1 Flow across left and right boundaries

**Chart

Description automatically generated**Flux is driven by hydraulic gradient, dh/dl. The reduced head at the localized point of recharge decreases the amount of lateral flow and allows it to spread tangentially until it is far enough from that point. Then the flow vectors become parallel again as the head gradient increases and becomes more even. So, the contamination zone is dictated by the rate of recharge and distribution of head equipotentials. The zone stops growing when the head gradient becomes more even again.

Figure 2 Equipotentials and flow vectors for extinction depth 1 meter

1. **Plot ET, recharge, and water table depth and explain what you are seeing and why. (Figure 3)**

Background ET is constant at 5e-5 m3/day. The whole domain would be yellow if there were no recharge. The gradient shown is the introduction of recharge and how it reduces ET loss. The water table depth corresponds to this distribution; closer to the ground surface where recharge is occurring, and deeper where it is not.

Chart

Description automatically generated**Challenge 2: Calculate the water balance for the model (Figure 4) and explain what controls each term in your water balance.**

Figure 3 ET, Recharge, and WTD for extinction depth 1m

Sources: Q\_in and Recharge

Sinks: ET

Q\_in is controlled by the assigned constant head gradient. Q\_in plus recharge equals the total flux introduced into the system. ET is a sink that, with Q\_out, balances the equation.

**Table

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Figure 4 Water balance for extinction depth 1 m

**Challenge 3: Change the extinction depth in the model (changed to 1 m)**

1. **Report the new water balance numbers (Figure 5)**
2. **Plot the new head contours and fluxes (Figure 6)**
3. **Explain what changed and why**

Extinction depth defines the water level at which ET will become zero. In our first run of the model the extinction depth was 3 meters. Now, it is one meter. This means that ET will have less impact on the domain because the water table will quickly trigger the change to zero ET.

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Figure 5 Water balance for extinction depth 8m

**Chart

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Figure 6 Equipotentials and flow vectors for extinction depth 1m

**Challenge 4: Pumping well at -20 m3/day, extinction depth at 8 meters to compare**

1. **Plot equipotentials and flow vectors in plan view and outline the area that would be affected by recharge if contaminated (Figure 7)**
2. **Plot ET, recharge, and water table depth and explain the patterns (Figure 8)**

A picture containing chart

Description automatically generatedExtinction depth = 8m, pumping = -20 m3/day, ET = 5e-5, recharge = 5e-4

The change in extinction depth significantly increases the amount of loss to ET because it remains active for as long as it takes the water table to drop the additional 7 feet. The relationship between ET and water table depth also increases the rate of water table decline.

1. **How does the well change the zone that is affected by the recharge area?**

The well captures only a small portion of the contamination and is largely circumnavigated by the recharged flow. For full remediation there would need to be a line of two to three wells transecting the domain. Chart

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Figure 7 Extinction depth of 8m for contrast; equipotentials and flow vectors

Figure 8 ET, recharge, and WTD for extinction depth 8m

1. **How does the well affect the ET map?**

The well creates a localized zone of reduced ET, likely because the drawdown accelerates the water table exceeding the extinction depth and reaching zero ET.

**Challenge 5: Write a mass balance for the well**

Total ET = -131.88 m3/day

Total recharge = 80.0 m3/day

Left flux = 88.13 m3/day

Right flux = 140.01 m3/day

**Glossary**

1. **Define evapotranspiration**

Evapotranspiration is the combined water loss both directly from the surface and indirectly through plant processes.

1. The components are evaporation: phase change of water from liquid to gas and, and transpiration; release through plants
2. The water can be pulled from the ground surface and down to a depth determined by soil composition and vegetation type and distribution.
3. Capillary forces drive evaporation from soils at depth, and advection and cohesion forces cause water to travel through a plant column and reach flowers, leaves, or other broad surfaces that allows it to diffuse
4. **Describe how the evt package in MODFLOW models ET. List the assumptions and simplifications that this package is making.**

The evt package simulates a head-dependent flux out of the domain. It multiplies the ET rate by the horizontal area of activated cells to calculate the volumetric flux rates.

Assumptions:

* The EVT package only includes ET from the saturated zone
* ET from unsaturated zone is assumed to be a term in the recharge calculation: Recharge = precip – losses between surface and water table

Simplifications:

* ET is calculated only for one cell in each vertical column (NEVTOP variables).

1. **What is a land surface model?**

Land surface models simulate energy exchanges at the land surface-atmospheric interface.

* **What are the differences between GW models like MODFLOW and the land surface models that also simulate the shallow subsurface?**

Land surface models (LSM) can be used independently or coupled with general circulation models. LSMs efficiently provide direct analyses of how changes to the earth’s surface will impact the hydroclimate.

GSFLOW is a coupled ground water and surface water flow model that integrates the Precipitation Runoff Modeling System (PRMS) and MODFLOW.

PRMS:

1. Simulates land-surface hydrologic processes
2. Can be used to analyze effects of urbanization on spatial distribution of GW recharge
3. Can be used with other models
4. Has a modular design which allows substitution of other processes

MODFLOW:

1. 3D saturated GW flow and storage
2. 1D unsaturated flow and GW discharge to the land surface
3. GW interactions with streams

**When is each preferred over the other?**

Reading the [documentation on GSFLOW](https://pubs.usgs.gov/tm/tm6d1/pdf/tm6d1.pdf), it seems like surface and GW models should always be used together. But, this would be time extensive and computationally heavy. Though there is overlap at the land surface, the two types of models have distinct parameters that could indicate which to use. 3D saturated GW flow and storage is specific to MODFLOW and can provide important information about the effects of surface processes.