**The Challenge**

1. Plot the heads (or WTD) of the initial steady state condition. The gradient is not uniform for the initial steady state conditions - discuss the influences of recharge and the unconfined condition on this nonlinearity

Unconfined conditions allow aquifer thickness to vary. This causes hydraulic head to become a function of area; making the gradient nonlinear (Fig. 1). This also means that recharge, though distributed evenly across the domain, is nonlinear.

Table

Description automatically generated with low confidence

Figure Heads of initial steady state condition

1. Determine if the system has reached steady state after 10 years - consider a point at the well and another at the center of the domain.

This system is not at steady state after 10 years. The ‘bow’ in the head gradient when the pump is turned off for the last time could reflect continuing aquifery recovery; in unconfined conditions the pressure gradient does not immediately equalize when pumping ceases (Fig. 2). Head values at the well and the center point show that both return to initial values, but they do not balance (Fig. 3). This confirms that the system is not in steady state.

Chart, line chart

Description automatically generated

Figure Heads through cross section of well in time

Chart, bar chart, histogram

Description automatically generated

Figure Head fluctuations through full time series

1. Repeat your run this time for 100 years and reconsider question 2 again.

The system does return to steady state after 100 years (Fig. 4). Given enough time and an infinite supply of water, this can be expected for unconfined aquifers. Pumping tests use this assumption to treat unconfined aquifers as confined in calculating drawdown (Theis curve). In this example, the system returns to steady state in the last ten years (Fig. 5).

Chart, histogram

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Figure 5 The fluctuation in head is approximately equal at the end of 100 years

Figure Heads along well cross section align with stead state condition

1. Find the zone of influence of the well defined in two ways:
   * Based on the drawdown from the initial steady state to the end of simulation time (end of final no-pumping stress period). (Figure 6)

Diagram, histogram

Description automatically generated

Figure 6 Drawdown occurring over timespan of ten years

* + Based on the drawdown from the end of the last pump-on stress period to the end of simulation time. (Figure 7)

Chart

Description automatically generated

Figure 7 Drawdown for time period from final pumping stop to end of time series for 10 year span

**Glossary questions:**

1. *Explain the concept of stress periods in MODFLOW. How should you determine stress periods when setting up your model? How do they differ from timesteps?*

Stress periods are an attribute for applying transient conditions in MODFLOW. A stress period indicates the span of time over which specific conditions will be applied (pumping, different porosity, etc.). These conditions are held constant through the duration of a stress period. To determine stress periods in model setup, the modeler should consider:

* 1. Units of time
  2. Duration of total time
  3. Duration of each different temporal condition (period length)

Timesteps differ from stress periods in that they dictate at what interval the model will solve. Small timesteps create high temporal resolution in the model, making it computationally expensive in the same way as high spatial resolution.

1. *What is the period length in MODFLOW? How does the meaning of the period length differ for a steady state vs non steady state solution?*

Period length and the amount of time assigned to each stress condition. In a steady state model we have no stress conditions, so there is no time dependency and period length does not apply. A non-steady state solution changes in time. The period length describes how these changes will be applied in the solution.

1. *What does the nstep variable signify in MODFLOW and how does it relate to the stress periods and period lengths? List the pros and cons of taking large timesteps vs. small timesteps. Is there any limit to how large a time step you can take and if so what determines this limit?*

The nstep variable controls how many times the model will solve in each stress period.

Large timesteps decrease computational draw but create a low temporal resolution that may not capture fluctuations that are happening in the model.

Small timesteps provide a higher resolution that provides more detail of the system but is computationally expensive. One of the challenges of modeling is to determine an appropriate time step with the type of process being modeled, the data available, and the model purpose.

The default value for nstep is 1. The maximum value may be controlled by the solver package capabilities.