Farm Challenge Report

Homework 7

HWRS 482

Compiled by Abigail Kahler

March 17, 2022

University of Arizona

*Introduction*

This report details the results of a MODFLOW model examining how the introduction of ACME Farming Corp. will impact the groundwater supply to Wildcat Farm. The farms cultivate alfalfa and cotton. Located in southern Arizona, crop consumptive use and evapotranspiration losses can significantly draw down regional aquifers to the detriment of multiple users.

*Conceptual Model*

Chart, bar chart

Description automatically generated

The conceptual model of the system identifies four observation wells at the edges of the domain. Data from these wells provide the framework for determining plausible constant head boundaries and hydraulic conductivities (K). The system contains three gradients of gradient hydraulic conductivity representing the distribution of measured K at four observation wells. Grid resolution is 100 square meters, which is great enough to generate a representative scale without a prohibitive computational draw.

*Model Parameters*

* Hydraulic conductivity, zone 1: 1 m/d

Chosen as a conservative representation of the measured K at observation wells one and three.

Kobs1 = 1.5 m/d

Kobs2 = 1 m/d

* Hydraulic conductivity, zone 2: 6 m/d

A median value between the zones of greatest and lowest hydraulic conductivities

* Hydraulic conductivity, zone 3: 11 m/d

Chosen as a representative value between the measured K at observation wells two and four.

Kobs2 = 13 m/d

Kobs4 = 8 m/d

* Coordinates, areas, and crops for each farm were given in the provided materials.
  + Wildcat Farm: 30 acres of cotton, approximately square, southwest corner latitude and longitude: (1500,125)
  + ACME Farming Corp: 500 acres of alfalfa, approximately rectangular, southwest corner latitude and longitude (0,700)

*Pumping Rates*

Wildcat Farm pumps 348 m3/d

Cotton consumptive use \* farm area = (.003 m/d \* 121,410 m2)

ACME Faming Corp pumps 10,462 m3/d between two wells

Alfalfa consumptive use \* farm area = (.0052 m/d \* 2,023,500 m2)

*Evapotranspiration*

Background: 5e-5 m/d

Cultivated areas:

Wildcat Farm: .0039 m/d derived from average ET in arid Southwest (Hanson 1991)

ACME Farming Corp: .0031 m/d adjust to reflect multiple harvests of alfalfa

*Recharge*

Net recharge in non-irrigated areas in this domain is 1e-4 m/d

* Wildcat Farm: 0.001 m/d

Total irrigation \* (1 – efficiencycotton) = .003 m/d \* (1 – 0.80)

* ACME Farming Corp: 0.0008 m/d

Total irrigation \* (1 – efficiencyalfalfa) = .0052 m/d \* (1 - 0.85)

*Boundary Conditions*

Constant head boundaries were derived from provided water table depth (WTD) at each observation well.

Obs1 WTD = 4.8 m

Obs2 WTD = 5.4 m

Obs3 WTD = 50.2 m

Obs4 WTD = 51.6 m

WTDleft boundary = 5 m

WTDright boundary = 51 m

Constant head boundaries = Thickness of domain – WTD

Left boundary = 995 m

Right boundary = 949 m

*Assumptions*

1. Hydraulic conductivity can be represented by homogenous zones distributed throughout the system
2. ACME Farming Corp wells are placed with greatest benefit to Wildcat Farm
3. Average southwestern agricultural evaporation rates are applicable to this situation (Hanson 1991)

*Scenario 1 – Reasonable Guess*

Chart, bar chart

Description automatically generatedIn the first case (conceptual model pictured above) hydraulic conductivities are represented in three horizontal layers. This is the simplest distribution of the ranges measured at the observation wells (Fig. 1). Wildcat farm pumps from a single well located in its center; this location remains constant among all three cases. This instance places one ACME well in the moderate-K zone and one in the high-K zone.

Figure 1 First Scenario: The heterogeneous system is represented by three homogenous zones

QWildcat = 348 m3/d

QACME1 = 4731 m3/d

QACME2 = 5731 m3/d

Recharge for Wildcat Farm and ACME Farming Corp. are adjusted to .0003 m/d. These differ from initial values calculated by the greater efficiency of alfalfa, which did not work in the model. The values used here, and holding them constant for both crops (Fig. 2) is an assumption of this scenario.

Chart, bar chart

Description automatically generatedThis realization allows both farms to pump without depleting the water table below maximum screen depth for either farm. The left side of the domain, where the Wildcat screen depth is only 20 meters, comes close to running dry but remains in an acceptable range. The distribution of head equipotentials and location of flow vectors (Figure 3) align with expected flow through each K zone.

Figure 2 A single recharge value is applied over both farms

Chart

Description automatically generated

Figure 3 Flow vectors showing three distinct zones of hydraulic conductivity

*Scenario 2 – Worst Case*

Chart, bar chart

Description automatically generated

For the worst-case-scenario, hydraulic conductivities were simplified into two homogeneous zones, with the largest area assigned low K. As anticipated, this drained the entire domain (Fig. 4). These structural choices were extreme for a specific purpose. In general, results such as this would prompt revisiting parameters to ensure they were representative of the real system. Figure 5 shows what the flow vectors across the K domains would be.

Chart, radar chart

Description automatically generated

Figure Pumping exceeds what the aquifer can support and returns a negative head value at the bottom of the well

Chart, scatter chart

Description automatically generated

Figure Flow vectors illustrating K distribution

*Scenario 3 – Best Case*

Chart, bar chart

Description automatically generated

The best case scenario is built on the most specific K values of the three situations explored. Specifically, a median K zone extends across both farms and contains two wells, while the second ACME well is contained in a zone of slightly higher K. Both ACME wells are pumping the same amount. Depth to water table remains sufficient for Wildcat farm and experiences only a moderate decrease in the lower right quadrant where ACME well 2 is located (Fig. 6).

Chart

Description automatically generated

Figure Water table depth reflects the ACME well pumping in a zone of high K

This case is the only one to generate an informative 3D head plot (Fig. 7), again highlighting that pumping has a significant impact on the water table but does not compromise Wildcat Farm. The head differences from a linear table and plan view head plots show how the proximity of the wells affect the local water table (Fig. 8).

Chart, surface chart

Description automatically generated

Figure This profile shows the impact of the ACME pumping wells on head gradient

Diagram

Description automatically generated

Figure The best-case reasonable scenario shows that the wells are on the edge of affecting each other

Given the assumptions required in hydrgeologic modeling, I think this best-case scenario is also the most plausible. It would be a good basis from which to explore other, more negative outcomes.

Reference

Hanson, R.L., 1991, Evapotranspiration and Droughts, in Paulson, R.W., Chase, E.B., Roberts, R.S., and

Moody, D.W., Compilers, *National Water Summary* 1988-89--Hydrologic Events and Floods and Droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 99-104.