GAM Run 05-38

by Andrew C. A. Donnelly, P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 463-3132
January 27, 2005

REQUESTOR:

Mr. Ray Brady on behalf of the Collingsworth County Underground Water Conservation District (UWCD).

DESCRIPTION OF REQUEST:

Mr. Brady requested a Groundwater Availability Model (GAM) run to evaluate the impact of uniform pumping rates of 0.25, 0.5, and 0.75 acre-feet per acre per year in a particular area of interest in Collingsworth County on water levels and the amount of water in storage in the Seymour aquifer over periods of 5, 10, and 25 years.

METHODS:

To determine the impacts of pumping on water levels and the amount of water in storage in Collingsworth County, we used the GAM for the Seymour aquifer. Mr. Brady provided a map of an area of interest, shown in Figure 1, where the District wanted to evaluate the impact of uniform withdrawal rates from the Seymour aquifer. In this area of interest the District wanted to simulate uniform pumping of 0.25, 0.5, and 0.75 acre-feet per acre per year.

For the predictive model runs, we used the most recent historic estimate of pumpage as the basis for the predictive pumpage. The calibration/verification model runs done for the GAM calibration were for the 1975 to 1999 time period using monthly stress periods. Therefore, we totaled the pumpage for January to December 1999 and used this as the basis for the predictive model runs.

It is important to note that the 1999 estimates contained a significant amount of pumpage in the District's area of interest. Table 2 provides a summary of 1999 pumpage in the Seymour GAM model cells in the area of interest. This table indicates that approximately half of the cells in the area of interest have pumpage in 1999 that is greater than 0.25 acre-feet per acre per year. In order to create pumpage inputs for the desired uniform withdrawal rates, the District decided that these withdrawal rates would replace the existing pumpage only if the new pumpage was greater than the existing pumpage. If the desired rate (0.25, 0.5, or 0.75 acre-feet per acre per year) was less than the existing pumpage in a cell, we used the existing 1999 pumpage for that cell in the pumpage data set. Therefore, for example, pumpage was increased to 0.25 acre-feet per acre per year in only half of the cells in the area of interest for the first model run because the other half of the cells already contained pumpage of more than 0.25 acre-feet per acre per year.

Table 1. Summary of 1999 Estimated Pumpage in Area of Interest in the Seymour GAM

Total Number of Model Cells in Area of Interest	110
Number of cells with < 0.25 acre-feet per acre per year	54
Number of cells with 0.25 – 0.50 acre-feet per acre per year	29
Number of cells with 0.50 – 0.75 acre-feet per acre per year	25
Number of cells with > 0.75 acre-feet per acre per year	2

PARAMETERS AND ASSUMPTIONS:

- See Ewing and others (2004) for assumptions and limitations of the GAM for the Seymour aquifer.
- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) in the entire GAM for the period of 1990 to 2000 is between 13.3 and 20.5 feet, or approximately one to two percent of the range of measured water levels (Ewing and others, 2004).
- The GAM includes two layers, representing the Seymour aquifer (Layer 1) and the underlying Permian units (Layer 2). The Permian units include the Blaine aquifer, as well as the Wichita, Clear Fork, Pease River, and Whitehorse groups and the Quartermaster and Ogallala formations.
- We simulated a 25-year time period for the predictive model runs.
- We used an average annual recharge based on recharge determined through the calibration of the transient model covering the years 1975 to 1999.
- We used 1999 pumpage rates as the baseline pumpage for the runs. Uniform withdrawal rates of 0.25, 0.50, and 0.75 acre-feet per acre per year were used in the District's area of interest.
- The Seymour GAM uses the MODFLOW stream package to simulate discharge to streams. For the predictive runs, we used average stream flow conditions for this package based on stream flows for the transient calibration run covering the years 1975 to 1999.
- The Seymour GAM uses the MODFLOW drain package to simulate discharge to springs. All documented springs were attempted to be included in the GAM. Springs that were coincident with stream cells were not included in the model because the streams provide a sufficiently similar type of boundary condition.

- The baseline run includes pumpage representing rural domestic, municipal, industrial, irrigation, and livestock uses. Pumping for the other runs may represent any combination of use categories.

RESULTS:

Water levels at the beginning of the 25-year predictive model runs are shown in Figure 2 and initial saturated thicknesses are shown in Figure 3. These figures indicate that large portions of the aquifer, including some of the District's area of interest, are simulated by the transient GAM model run to be dry at the start of the predictive time period (2000). Most of the smaller area of interest in the southeastern corner of Collingsworth County is dry at the start of the predictive runs, as well as the southwestern edge of the larger area of interest in the west-central portion of the county. Saturated thicknesses in the remainder of the area of interest range from zero to greater than 100 feet, with an area of greater saturated thickness in the northwestern portion of the larger area of interest (Figure 3).

Four predictive model runs were done for this study:

1) *Baseline Run*—A baseline simulation was done using the 1999 annual pumpage estimates for the entire 25-year model run. This run was done to give an estimate of the impact of just the existing pumpage on water levels and resulting saturated thicknesses without any modifications to the pumpage requested by the District.

2) *Increasing pumpage in the area of interest to 0.25 acre-feet per acre per year*—Pumpage in model cells in the area of interest was increased to 0.25 acre-feet per acre per year. As noted above, pumpage in cells in which the 1999 estimated pumpage was greater than 0.25 acre-feet per acre per year was not changed, and therefore pumpage was not changed in half of the cells in the area of interest for this model run.

3) *Increasing pumpage in the area of interest to 0.50 acre-feet per acre per year*—As noted above, pumpage in model cells in the area of interest was increased to 0.50 acre-feet per acre per year. Pumpage in cells in which the 1999 estimated pumpage was greater than 0.50 acre-feet per acre per year was not changed.

4) *Increasing pumpage in the area of interest to 0.75 acre-feet per acre per year*—As noted above, pumpage in model cells in the area of interest was increased to 0.75 acre-feet per acre per year. Pumpage in the two cells in which the 1999 estimated pumpage was greater than 0.75 acre-feet per acre per year was not changed.

Table 2 indicates the annual rate of pumpage in the District's area of interest for each of these four model runs. Table 3 provides a summary of the estimated volume of groundwater remaining in the Seymour aquifer in the area of interest for these four model runs after 5, 10, and 25 years. This table indicates that the volumes lost over time increases with increasing amounts of pumpage. However, the decrease in the remaining volume in storage does not correlate directly with the amount of pumpage, indicating that the model is simulating that groundwater is moving laterally into the area of interest and more significantly is migrating upward from the underlying Blaine aquifer.

Table 2. Summary of annual pumpage rate (in acre-feet) in the area of interest for each of the four model runs.

Model Run	Annual Pumpage in Area of Interest (acre-feet)
Baseline—1999 Estimated Pumpage	20,824
0.25 acre-feet/acre/year	26,928
0.50 acre-feet/acre/year	37,991
0.75 acre-feet/acre/year	53,113

Table 3. Summary of volumes of groundwater (in acre-feet) remaining in storage in the Seymour aquifer estimated by the Seymour GAM after 5, 10, and 25 years of pumpage.

Model Run	Initial Volume	5 Years	10 Years	25 Years
Baseline—1999 Pumpage	308,858	273,145	249,115	210,220
0.25 acre-feet/acre/year	308,858	262,917	232,797	187,774
0.50 acre-feet/acre/year	308,858	241,468	201,677	145,911
0.75 acre-feet/acre/year	308,858	211,710	158,698	99,840

The water levels and saturated thicknesses remaining after 25 years for the baseline model run are shown in Figures 4 and 5, respectively. These results indicate that numerous additional cells, including within the District's area of interest, go dry during the 25-year simulation without any additional pumpage above the baseline 1999 pumpage. This is because the 1999 estimated pumpage for many cells in the area of interest are significant, as noted above.

Figures 6 and 7 show the water levels and saturated thicknesses for the model simulation run with increasing pumpage in all cells in the area of interest to 0.25 acre-feet per acre per year. These figures indicate that, when compared to the baseline run, several additional cells in the area of interest dry up during the 25-year model run, and saturated thicknesses in the remaining cells decrease slightly.

Figure 8 and 9 show the water levels and saturated thicknesses for the model simulation run with increasing pumpage in all cells in the area of interest to 0.50 acre-feet per acre per year. These figures indicate that several more cells in the area of interest dry up in the 25-year model run, and saturated thicknesses in the remaining cells decrease, in particular in the northwestern portion of the area of interest, where saturated thicknesses started out the greatest. Although this area still contains the greatest saturated thicknesses, some portions of this area are decreasing in saturated thickness.

Figure 10 and 11 show the saturated thicknesses for the model simulation run increasing pumpage in all cells in the area of interest to 0.75 acre-feet per acre per year. These figures indicate that numerous additional cells in the area of interest dry up in the 25-year model run, and saturated thicknesses in the remaining cells decrease. Cells in the northwestern portion of the area of interest contain substantially lower saturated thicknesses that at the start of the 25-year run, and saturated thicknesses in the rest of the area of interest in cells that have not gone dry are generally less than 40 feet.

Although not included as part of this GAM run request, water budgets for the three model runs (0.25, 0.50, and 0.75 acre-feet per acre per year) after 25 years are provided in Tables 4, 5, and 6, respectively. It is important to note that the outflow to wells in these budget tables do not match the annual pumpage rates in Table 2 due to the presence of dry cells in the model. When a cell goes dry during the model run, the pumpage that was assigned to that cell is eliminated from the model.

It is important to note that an analysis of the water budgets indicates that some portions of the area of interest are not drying up due to a significant increase in the upward migration of groundwater to the Seymour from the underlying Blaine aquifer. Because little information exists on the vertical connectivity between the Seymour aquifer and the underlying units, it is unknown whether this amount of upward migration of groundwater from the Blaine can be expected with increased pumpage in a localized area. In other words, we are unsure whether this is an accurate representation of what will happen in the area of interest with this amount of pumpage from the Seymour. However, even if the water can continue to be produced from the Seymour at the rates indicated in these GAM runs due to the influence of Blaine groundwater, the water being produced will be of a much poorer quality. Groundwater in the Blaine is typically brackish in quality (contains over 1,000 milligrams per liter in total dissolved solids) and largely unsuitable for any purposes except irrigation to salt tolerant crops (LBG-Guyton, 2003). Therefore, even though the GAM for the Seymour aquifer indicates that portions of the area of interest may not dry up due to the withdrawal rates being applied, the groundwater being produced will eventually be of much poorer quality than is typically produced from the Seymour.

Table 4. Summary of water budgets (in acre-feet per year) for the model run simulating a uniform pumping rate of 0.25 acre-feet per acre per year.

	Inflow	Outflow
Springs*	0	120
Wells	0	18,731
Streams	181	2,156
Recharge	24,799	0
Evapotranspiration	0	431
Storage	2,798	431
Lateral flow from Oklahoma	0	139
Lateral flow from Childress County	0	848
Flow between Blaine aquifer	25,161	11,650
* - Springs were modeled using the MODFLOW drain package		

Table 5. Summary of water budgets (in acre-feet per year) for the model run simulating a uniform pumping rate of 0.50 acre-feet per acre per year.

	Inflow	Outflow
Springs*	0	82
Wells	0	21,937
Streams	181	2,017
Recharge	23,513	0
Evapotranspiration	0	423
Storage	3,329	351
Lateral flow from Oklahoma	0	135
Lateral flow from Childress County	0	843
Flow between Blaine aquifer	42,169	9,437
* - Springs were modeled using the MODFLOW drain package		

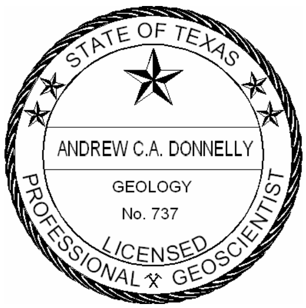
Table 6. Summary of water budgets (in acre-feet per year) for the model run simulating a uniform pumping rate of 0.75 acre-feet per acre per year.

	Inflow	Outflow
Springs*	0	73
Wells	0	25,491
Streams	181	1,862
Recharge	21,758	0
Evapotranspiration	0	360
Storage	3,914	309
Lateral flow from Oklahoma	0	132
Lateral flow from Childress County	0	839
Flow between Blaine aquifer	51,810	8,909
* - Springs were modeled using the MODFLOW drain package		

REFERENCES:

Ewing, John E., Toya L. Jones, John F. Pickens, Andrew Chastain-Howley, Kirk E. Dean, Aubrey A. Spear, 2004, Groundwater Availability Model for the Seymour Aquifer: Texas Water Development Board, Final GAM Report, 533 p.

LBG-Guyton Associates, 2003, Brackish Groundwater Manual for Texas Regional Water Planning Groups: Texas Water Development Board Report, 186 p.



The seal appearing on this document was authorized by Andrew C.A. Donnelly, P.G. 737, on January 27, 2006.

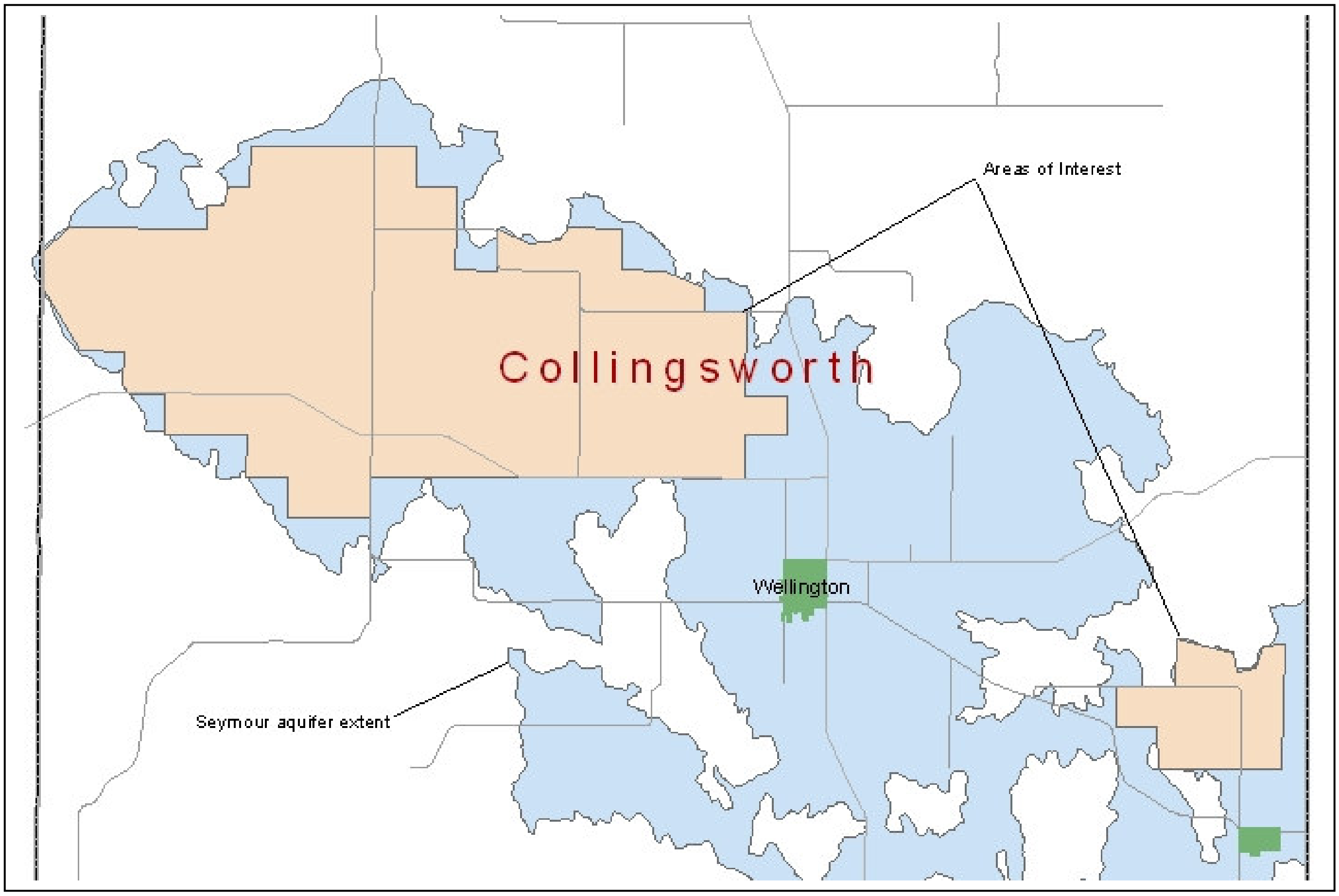


Figure 1. Map of the model area in Collingsworth County. The District's area of interest is indicated in tan. The extent of the Seymour aquifer in the area is shown in blue. The figure is oriented with north to the top.

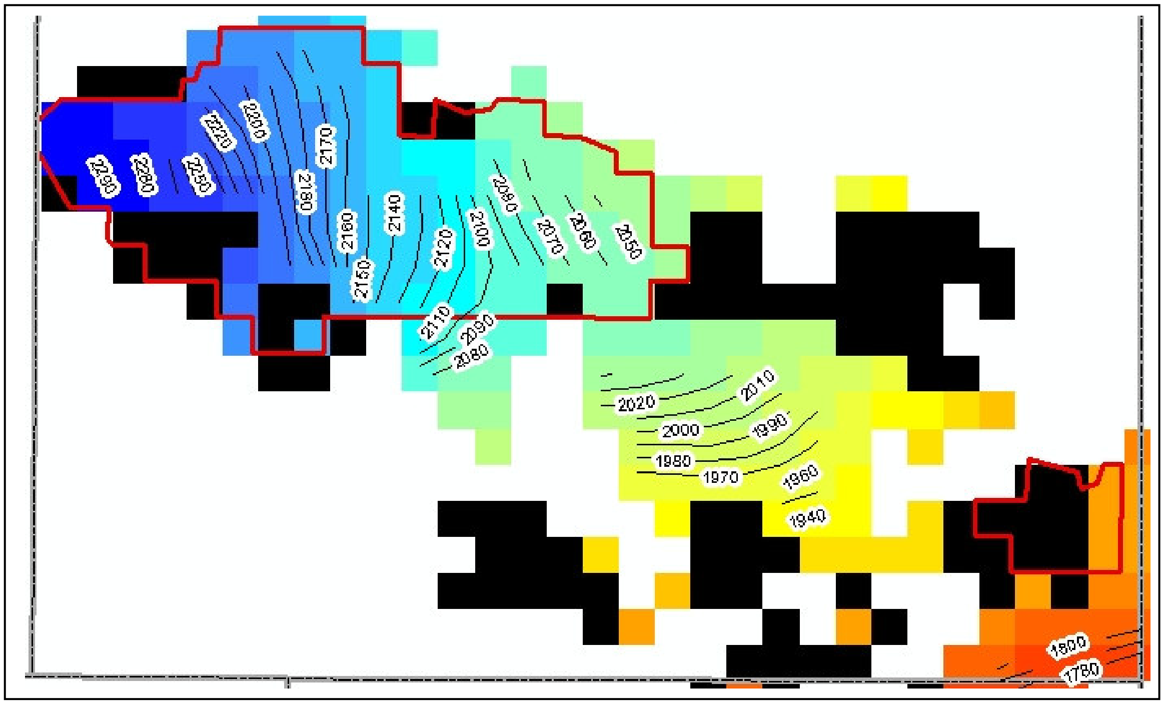


Figure 2. Initial heads (water levels) used in the model runs for the Seymour aquifer. Cells in black are those that began the predictive simulation as dry cells. Contour interval is ten feet. The areas of interest are outlined in red. The figure is oriented with north to the top.

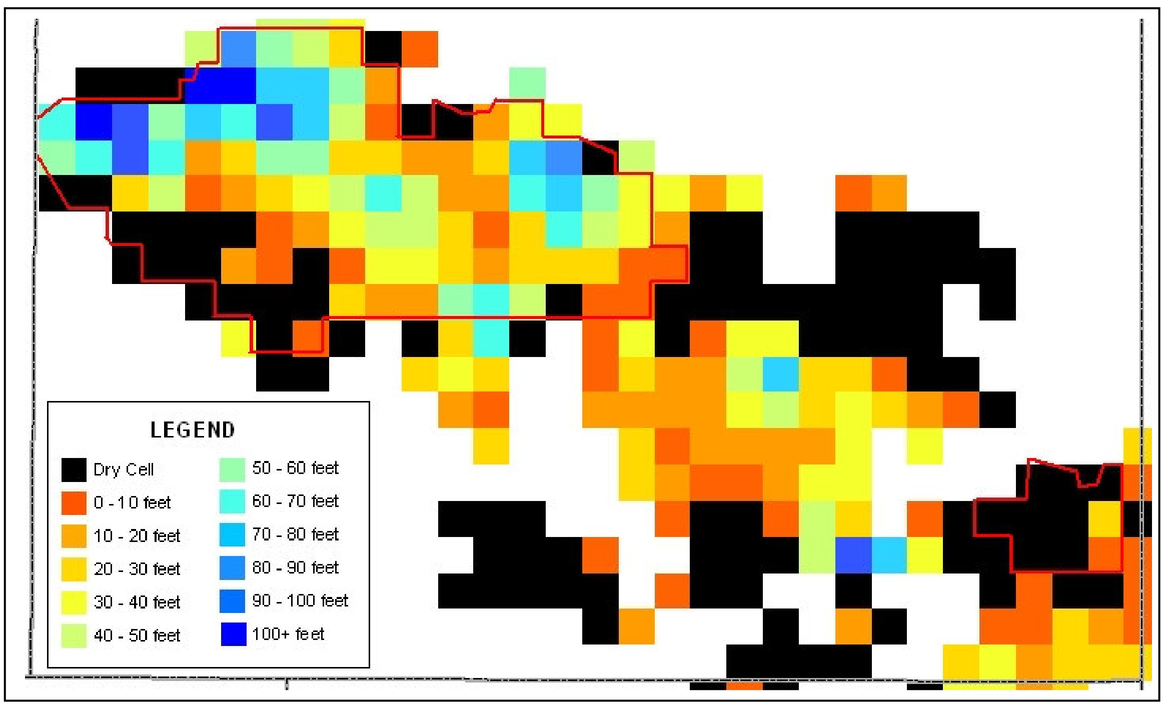


Figure 3. Initial saturated thicknesses of the Seymour aquifer in the model runs. Cells in black are those that began the predictive simulations as dry cells. The areas of interest are outlined in red. The figure is oriented with north to the top.

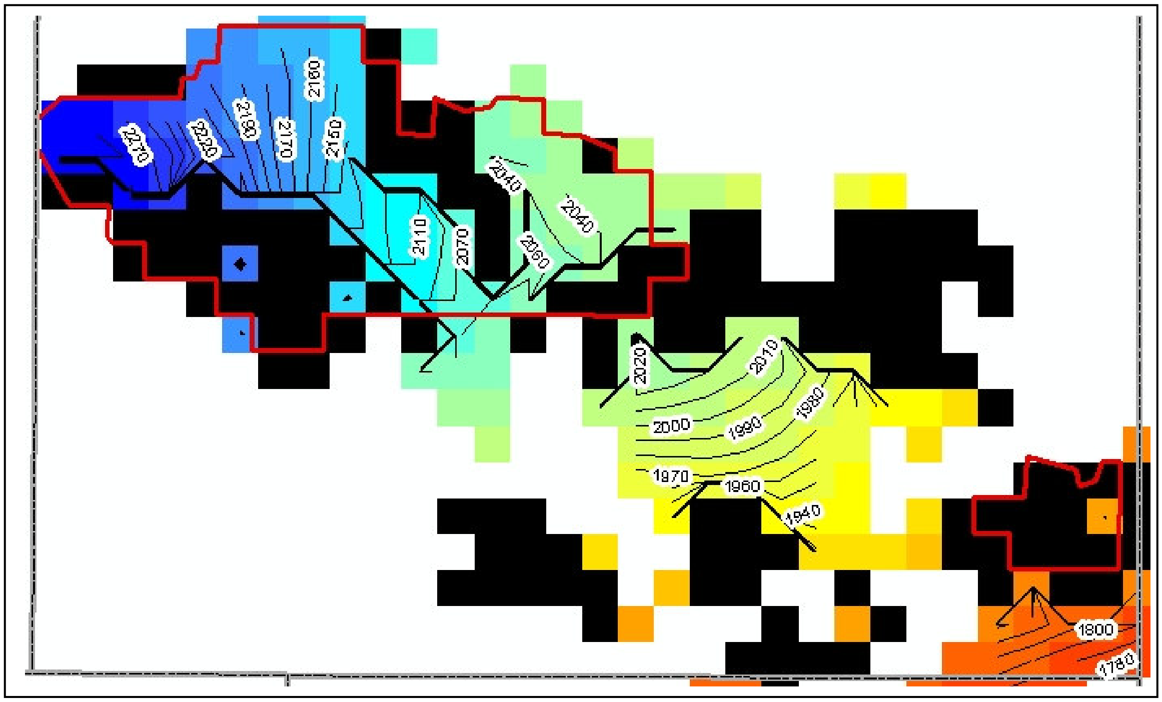


Figure 4. Water Levels in the Seymour aquifer after 25 years of pumping using 1999 annual pumpage. Cells in black are those that are dry at the end of the 25-year simulation. Contour interval is 10 feet. The areas of interest are outlined in red. The figure is oriented with north to the top.

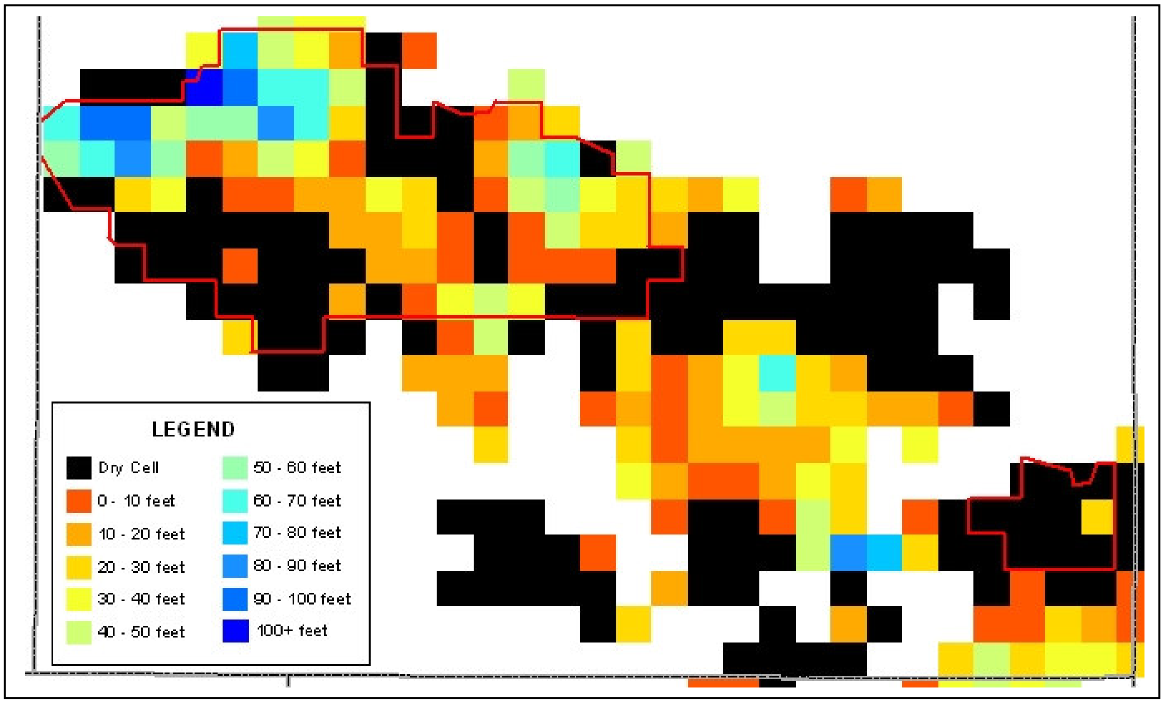


Figure 5. Saturated thicknesses of the Seymour aquifer after 25 years of pumping using 1999 annual pumpage. Cells in black are those that are dry at the end of the 25-year simulation. The areas of interest are outlined in red. The figure is oriented with north to the top.

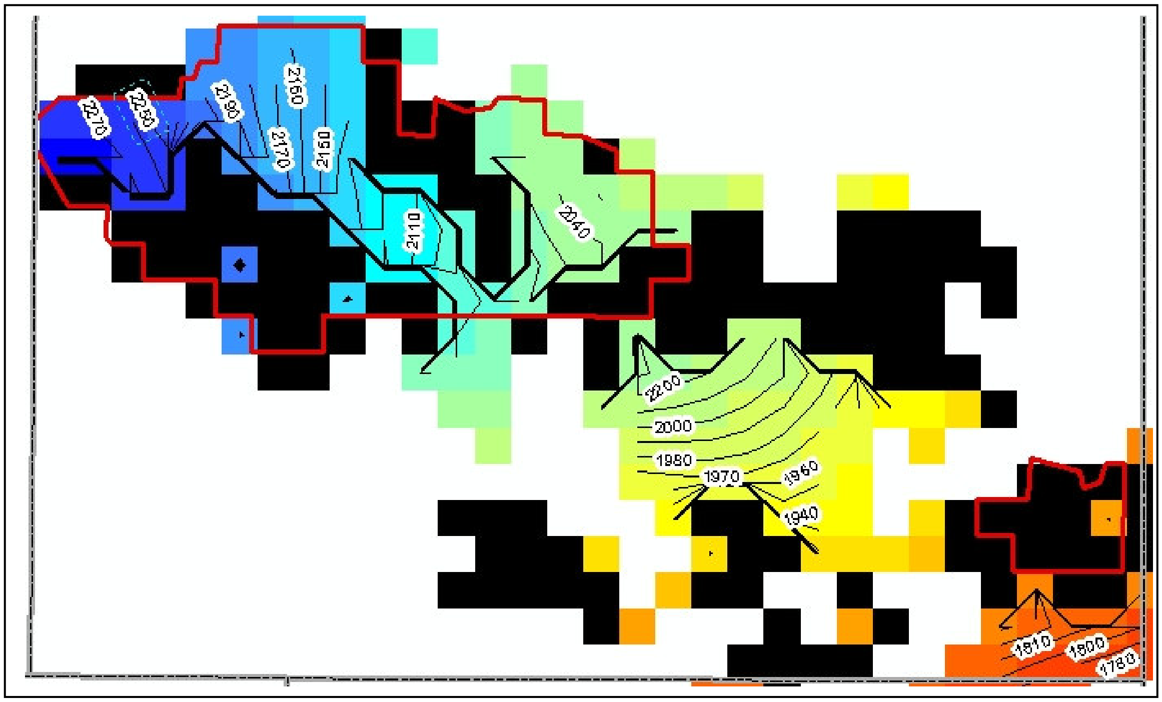


Figure 6. Water Levels in the Seymour aquifer after 25 years of pumping using 1999 annual pumpage with pumpage increased to a minimum of 0.25 acre-feet per acre per year in the area of interest. Cells in black are those that are dry at the end of the 25-year simulation. Contour interval is 10 feet. The areas of interest are outlined in red. The figure is oriented with north to the top.

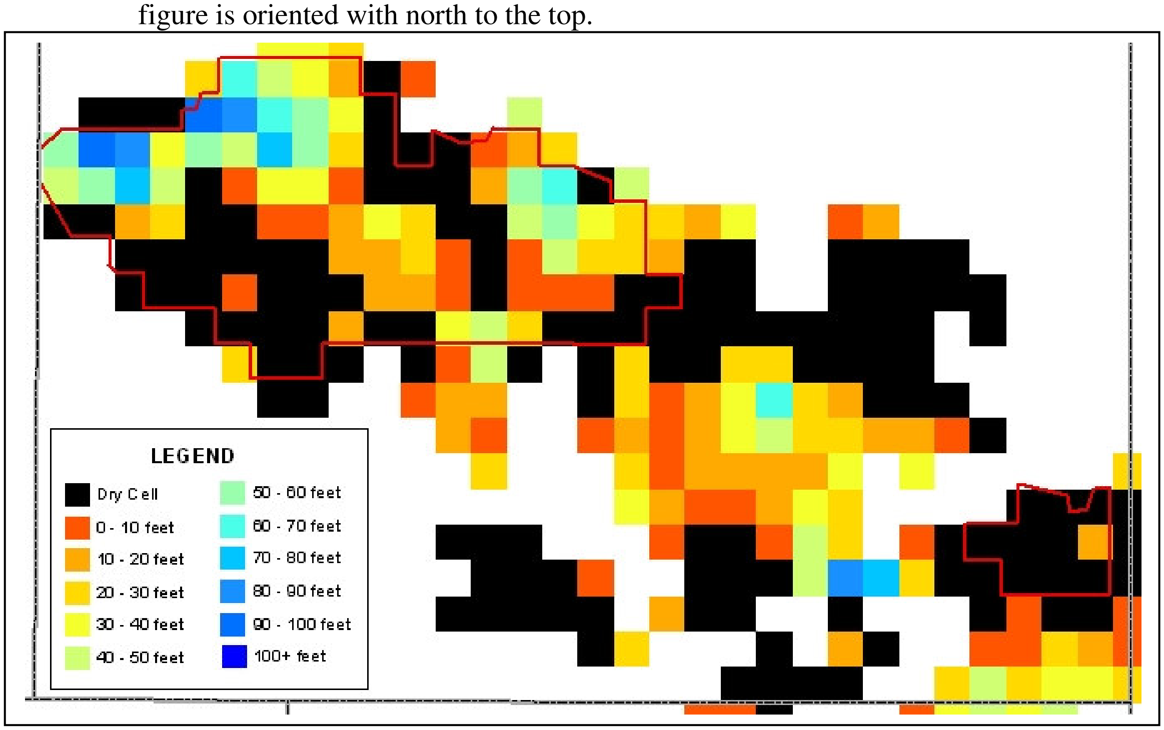


Figure 7. Saturated thicknesses of the Seymour aquifer after 25 years of pumping using 1999 annual pumpage with pumpage increased to a minimum of 0.25 acre-feet per acre per year in the area of interest. Cells in black are those that are dry at the end of the 25-year simulation. The areas of interest are outlined in red. The figure is oriented with north to the top.

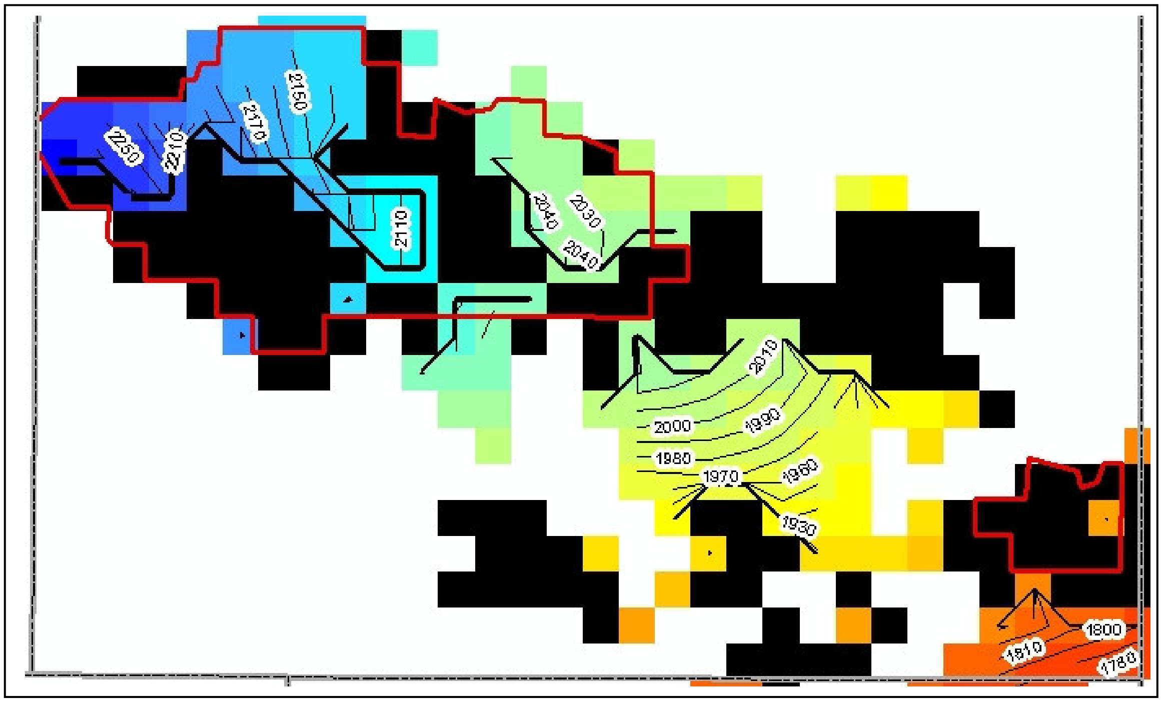


Figure 8. Water Levels in the Seymour aquifer after 25 years of pumping using 1999 annual pumpage with pumpage increased to a minimum of 0.50 acre-feet per acre per year in the area of interest. Cells in black are those that are dry at the end of the 25-year simulation. Contour interval is 10 feet. The areas of interest are outlined in red. The figure is oriented with north to the top.

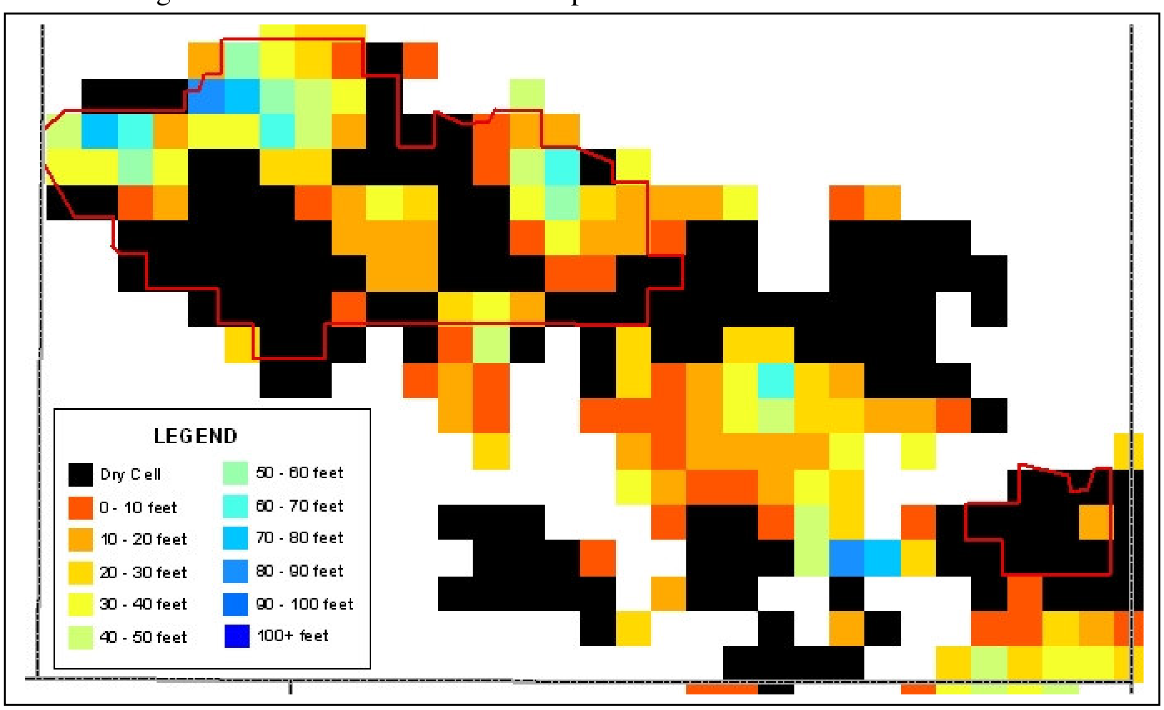


Figure 9. Saturated thicknesses of the Seymour aquifer after 25 years of pumping using 1999 annual pumpage with pumpage increased to a minimum of 0.50 acre-feet per acre per year in the area of interest. Cells in black are those that are dry at the end of the 25-year simulation. The areas of interest are outlined in red. The figure is oriented with north to the top.

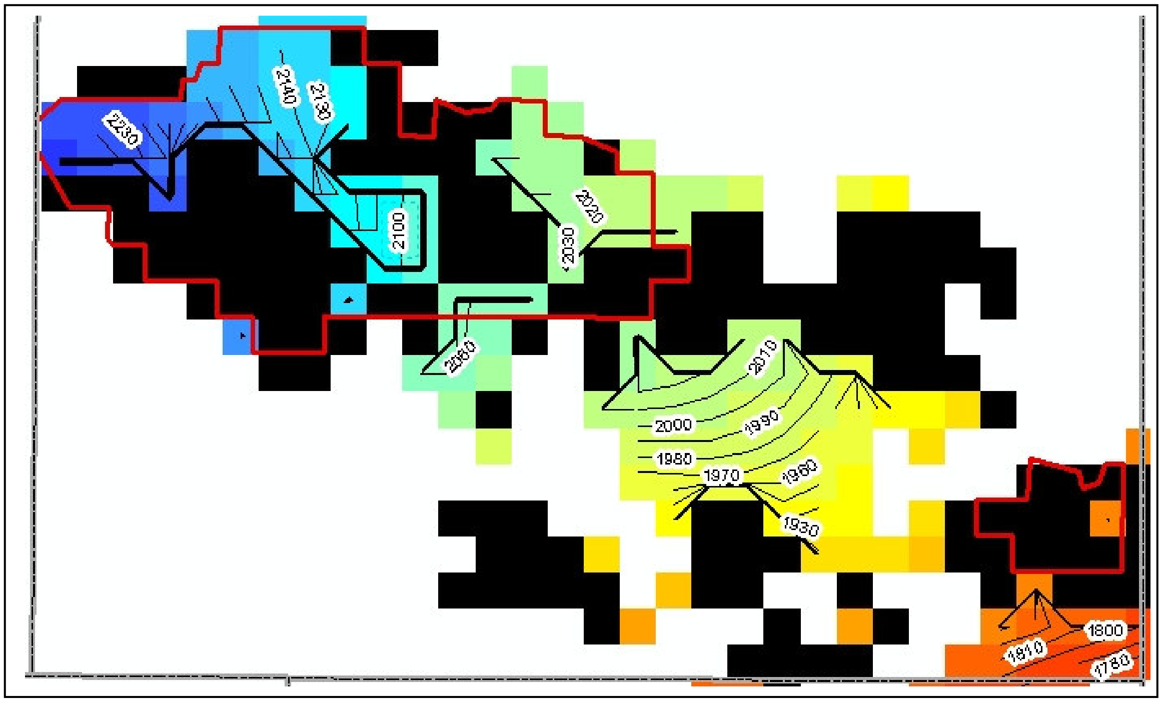


Figure 10. Water Levels in the Seymour aquifer after 25 years of pumping using 1999 annual pumpage with pumpage increased to a minimum of 0.75 acre-feet per acre per year in the area of interest. Cells in black are those that are dry at the end of the 25-year simulation. Contour interval is 10 feet. The areas of interest are outlined in red. The figure is oriented with north to the top.

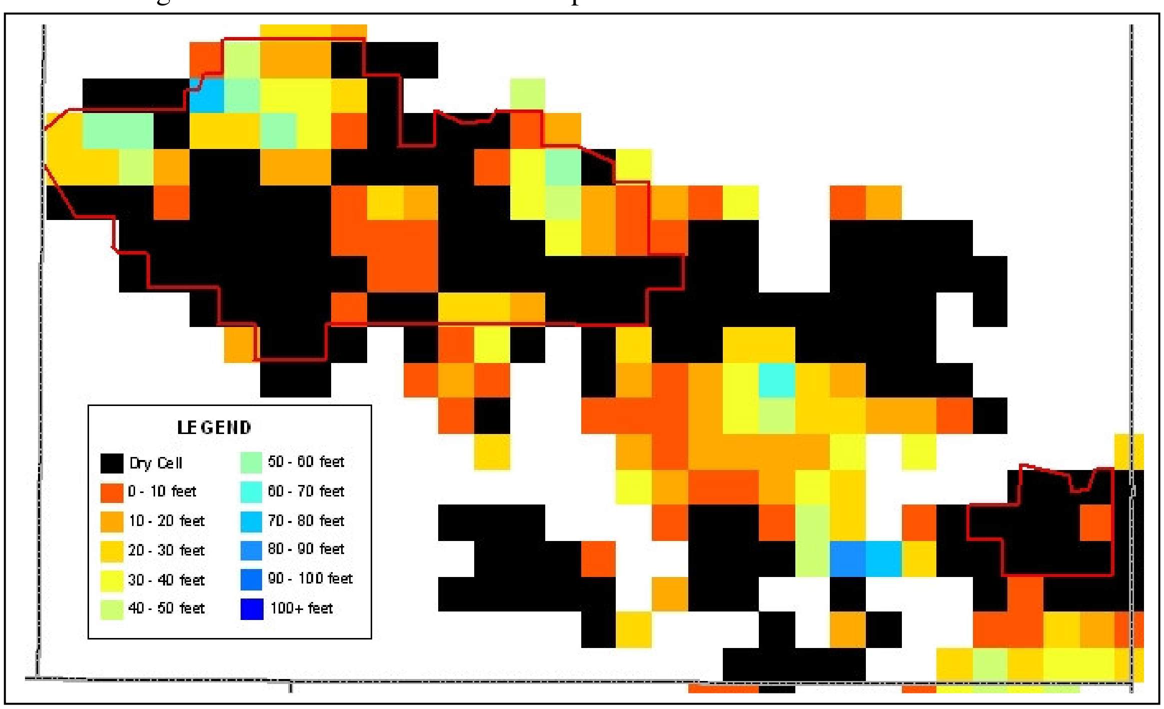


Figure 11.Saturated thicknesses of the Seymour aquifer after 25 years of pumping using 1999 annual pumpage with pumpage increased to a minimum of 0.75 acre-feet per acre per year in the area of interest. Cells in black are those that are dry at the end of the 25-year simulation. The areas of interest are outlined in red. The figure is oriented with north to the top.