GAM Run 05-39

by Andrew C. A. Donnelly, P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 463-3132
January 3, 2006

REQUESTOR:

Mr. Sam Beaumont on behalf of the Fox Crossing Water District in Mills County.

DESCRIPTION OF REQUEST:

Mr. Beaumont requested a Groundwater Availability Model (GAM) run to estimate the availability of groundwater from the Trinity aquifer based on desired future conditions that allow the loss of 15, 30, and 50 percent of current saturated thicknesses at the end of a predictive model run.

METHODS:

To determine the water budgets for Mills County, we used the GAM for the northern part of the Trinity aquifer (Harden & Associates and others, 2004). We ran the model for a 50-year predictive simulation (2000 through 2050) using average recharge conditions. We assumed existing pumpage from the last year of the calibrated transient model period (1999) remained constant throughout the predictive simulation for our baseline analysis. We then evaluated drawdowns and remaining saturated thicknesses in Mills County by increasing pumpage evenly throughout Mills County until the desired future conditions were met.

In order to increase pumpage in Mills County, we first evaluated the existing pumpage in the GAM from the calibrated transient model (Figure 1). Table 1 summarizes how the pumpage was distributed to each layer in the GAM for the year 1999.

Table 1. Percent of projected pumpage from each layer in the GAM for the Northern Trinity aquifer in Mills County

Layer	Aquifer	Percent Pumpage
1	Woodbine	0
2	Washita and Fredericksburg Series	0
3	Paluxy	0.2
4	Glen Rose	2.7
5	Hensell	39
6	Pearsall/Cow Creek/Hammett/Sligo	0
7	Hosston	58

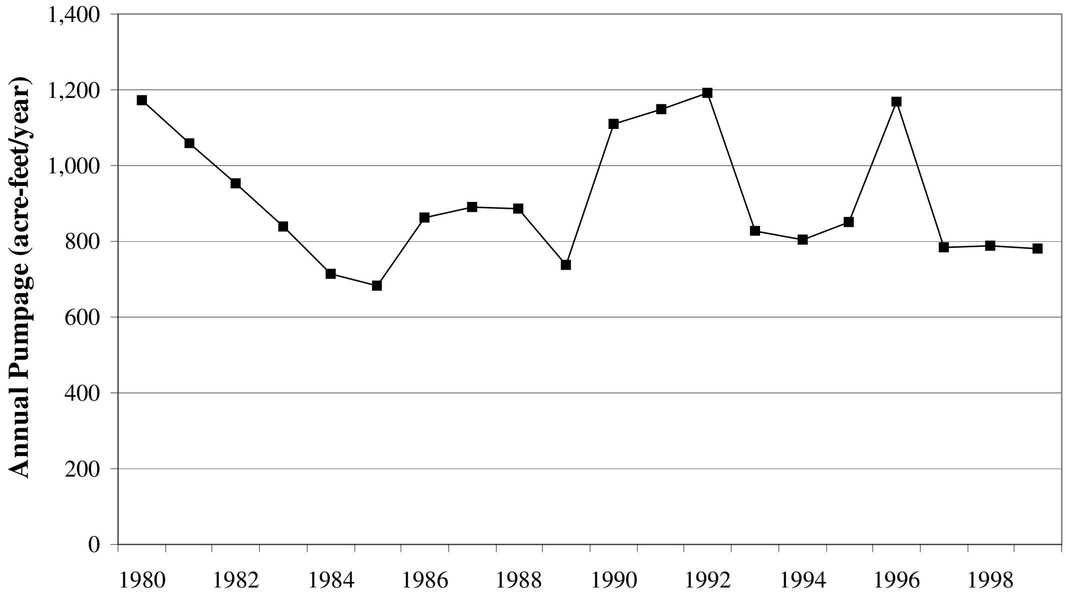


Figure 1. Annual pumpage in Mills County from the northern part of the Trinity aquifer for 1980 to 1999.

We based the amount that we increased pumpage in each of these aquifers and model layers on the amount required to reach the percent of saturated thickness remaining in 2050 for the desired future conditions specified by the District. After discussions with Mr. Beaumont, we agreed we would evenly distribute pumpage throughout Mills County instead of assuming pumpage would just increase at existing well fields.

PARAMETERS AND ASSUMPTIONS:

- Based on the distribution shown in Table 1, we assumed that additional pumpage in Mills County would come from the Hensell and Hosston layers. We assumed that no additional pumpage would come from the other layers because little pumpage currently exists in those layers, presumably due to quantity and/or quality issues. We also assumed pumpage in the surrounding counties would remain the same as the pumpage that was included at the end of calibrated transient model, both spatially and volumetrically.

- See Harden & Associates and others (2004) for assumptions and limitations of the GAM.

- The model includes seven layers, representing the Woodbine aquifer (Layer 1), the Washita and Fredericksburg Series (Layer 2), the Paluxy aquifer (Layer 3), the Glen Rose Formation (Layer 4), the Hensell aquifer (Layer 5), the Pearsall/Cow Creek/Hammett/Sligo Formation (Layer 6), and the Hosston aquifer (Layer 7).

The Woodbine, Paluxy, Hensell, and Hosston layers are the main aquifers used in the region. All layers except the Woodbine are present in Mills County.

- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) for the four main aquifers in the model (Woodbine, Paluxy, Hensell, and Hosston) for the calibration and verification time periods (1980 to 2000) ranged from approximately 37 to 75 feet. The root mean squared error was less than ten percent of the maximum head drop in the model (Harden & Associates and others, 2004).

- We used average annual recharge conditions based on climate data from 1980 to 1999 for each of the simulations.

- The model uses streams to simulate the interaction between the aquifer(s) and major intermittent streams flowing in the region. Flow both from the stream to the aquifer and from the aquifer to the stream is allowed, and the direction of flow is determined by the water levels in the aquifer and stream during each stress period in the simulation. The only stream or river included in the model in Mills County is Cowhouse Creek.

RESULTS:

Results are shown for the Hensell and Hosston aquifers only because these are the two aquifers that additional pumpage was added to in order to complete these model runs. The following parameters are evaluated for the results.

1. Drawdown—Drawdown is the difference in water levels between two time periods. The drawdown in an aquifer is primarily due to the response of the aquifer to pumpage and the amount of drawdown that occurs is based on the amount of pumpage and the hydraulic properties of the aquifer. We used water levels from the beginning of the year 2000 as our baseline and then subtracted water levels from the end of the 50-year predictive simulation to estimate drawdowns.

2. Saturated Thickness—Although the saturated thickness of an aquifer does not include water levels above the top of the aquifer, for the purposes of this evaluation, the saturated thickness of an aquifer is the difference between the water level and the bottom of the aquifer. Therefore, the term saturated thickness in this report refers to the hydraulic head above the bottom of the aquifer. This was done to evaluate the model results based on our understanding of what the requestor desired to show with these model runs.

3. Percent of Saturated Thickness Remaining—The percent of saturated thickness remaining is the saturated thickness at the end of the simulation divided by the saturated thickness at the start of the model run (that is, in 2000) multiplied by 100 percent. The targeted percent of saturated thickness remaining was the maximum for the county, rather than an average.

Initial water levels and saturated thicknesses in the Hensell and Hosston aquifers in 2000 are shown in Figures 2 and 3, respectively. Water–level elevations in both aquifers (Figure 2) range from 1,450 feet in the outcrop areas to approximately 1,100 feet in the eastern corner of the county, and groundwater flow in both aquifers is away from the outcrop areas and to the east. Saturated thicknesses in the Hensell range from less than ten feet in some of the outcrop areas to approximately 140 feet in the eastern corner of the county. An area of lower saturated thicknesses in the Hensell aquifer is found in the central part of the county, as shown in Figure 3. Saturated thicknesses in the Hosston aquifer in 2000 are substantially greater than in the Hensell aquifer, as shown in Figure 3. Hosston saturated thicknesses range from less than 30 feet in some of the outcrop areas, to more than 240 feet in the eastern corner of the county and are greater than 90 feet throughout most of the county. These figures provide a reference point for all results because the desired future conditions have been specified to be a certain percent of original saturated thickness remaining in the aquifer, which are based on the saturated thicknesses at the start of the simulation (that is, in 2000).

The drawdowns, saturated thicknesses, and the percent of original saturated thickness remaining in the Hensell and Hosston aquifers in 2050 using the existing projected pumpage for Mills County are shown in Figures 4 to 6, respectively. Drawdowns in both the Hensell and Hosston aquifers are less than 5 feet for the entire county using the existing projected pumpage for the county, which ranges from 1,257 to 1,134 acre-feet per year for 2000 to 2050,. The Hosston aquifer shows some recovery of water levels in the eastern portion of the county, presumably due to our assumptions of pumpage in areas outside of the county over the 50-year predictive time period. Because drawdowns are small with this amount of pumpage, saturated thicknesses are very similar to saturated thicknesses in 2000, and the percent of saturated thickness remaining is greater than 95 percent for the entire county for both aquifers.

Existing predictive pumpage was increased by 2,550 acre-feet per year for the Hensell aquifer and 950 acre-feet per year for the Hosston aquifer, which resulted in a maximum of 15 percent of the saturated thickness to be lost over the 50-year model run. The drawdowns, saturated thicknesses, and the percent of original saturated thickness remaining in the Hensell and Hosston aquifers in 2050 using this amount pumpage are shown in Figures 7 to 9, respectively. Drawdowns are as large as 8 feet in the Hensell aquifer and 15.5 feet in the Hosston aquifer and are much greater across a larger portion of the county in the Hosston aquifer (Figure 7). The resulting saturated thicknesses for the Hensell aquifer are very similar to the simulation using existing projected pumpage because the larger drawdowns in this aquifer are in the eastern part of the county, where saturated thicknesses were much larger. The saturated thicknesses for the Hosston aquifer decrease for much of the county but are greater than 80 feet for most of Mills County.

Existing predictive pumpage was increased by 5,500 acre-feet per year for the Hensell aquifer and 2,000 acre-feet per year for the Hosston aquifer, which resulted in a maximum of 30 percent of the saturated thickness to be lost over the 50-year model run. The drawdowns, saturated thicknesses, and the percent of original saturated thickness remaining in the Hensell and Hosston aquifers in 2050 using this amount pumpage are shown in Figures 10 to 12, respectively. Drawdowns are as large as 11.5 feet in the

Hensell aquifer and 32 feet in the Hosston aquifer, and are much greater across a larger portion of the county in the Hosston aquifer (Figure 10). The resulting saturated thicknesses for the Hensell aquifer are as low as 20 feet in the central portion of the county but remain above 50 feet for most of the county. The saturated thicknesses for the Hosston aquifer decrease for much of the county but are greater than 70 feet for most of Mills County.

Existing predictive pumpage was increased by 11,000 acre-feet per year for the Hensell aquifer and 3,400 acre-feet per year for the Hosston aquifer, which resulted in a maximum of 50 percent of the saturated thickness to be lost over the 50-year model run. The drawdowns, saturated thicknesses, and the percent of original saturated thickness remaining in the Hensell and Hosston aquifers in 2050 using this amount of pumpage are shown in Figures 13 to 15, respectively. Drawdowns are as large as 18 feet in the Hensell aquifer and 53 feet in the Hosston aquifer and are much greater across a larger portion of the county in the Hosston aquifer (Figure 13). The resulting saturated thicknesses for the Hensell aquifer are as low as 13 feet in the central portion of the county but remain above 40 feet for most of the county. The saturated thicknesses for the Hosston aquifer decrease for much of the county but are greater than 50 feet for most of Mills County.

These results show several items of note.

- The areas with maximum drawdown do not correspond with the areas with maximum percent loss of original saturated thickness. The areas that dictate the amount of pumpage that can be added to meet the desired future condition of 15, 30, or 50 percent loss of the original saturated thickness are those with the lowest saturated thicknesses in 2000. For the Hensell aquifer this is an area in the central portion of the county, and for the Hosston aquifer this is an area in the northern portion of the county (Figure 3).

- Drawdowns, and therefore loss in saturated thickness, are limited in the outcrop areas of either aquifer. This is due to the large amount of recharge to the model, which is applied directly to these outcrop areas.

- Although additional pumpage is much higher in the Hensell aquifer, drawdowns are much lower for Hensell aquifer than for the Hosston aquifer. This is mainly due to the fact that groundwater being produced from the Hensell aquifer is coming from unconfined storage, while groundwater produced from the Hosston aquifer is coming from confined storage. When water is produced from unconfined storage, it is from the physical dewatering of the aquifer, sometimes referred to as "mining" the aquifer. When water is produced from confined storage, it is from the expansion of water due to a decrease in fluid pressure and the compaction of the aquifer. Aquifers produce far larger volumes of water from unconfined storage than from confined storage with the same drawdowns. It is important to note that once drawdowns in the Hosston aquifer reach the top of the aquifer, this aquifer will also begin to produce groundwater from unconfined storage.

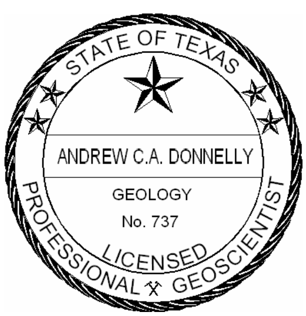
- Total pumpage from the Hensell and Hosston aquifers in Mills County that result in the desired future conditions are summarized in Table 2. Please note that the total pumpage for each aquifer is the sum of the additional pumpage summarized above plus the existing pumpage already included in the projected pumpage data set.

Table 2. Summary of pumpage in 2050 resulting in desired future conditions in Mills County (in acre-feet per year)

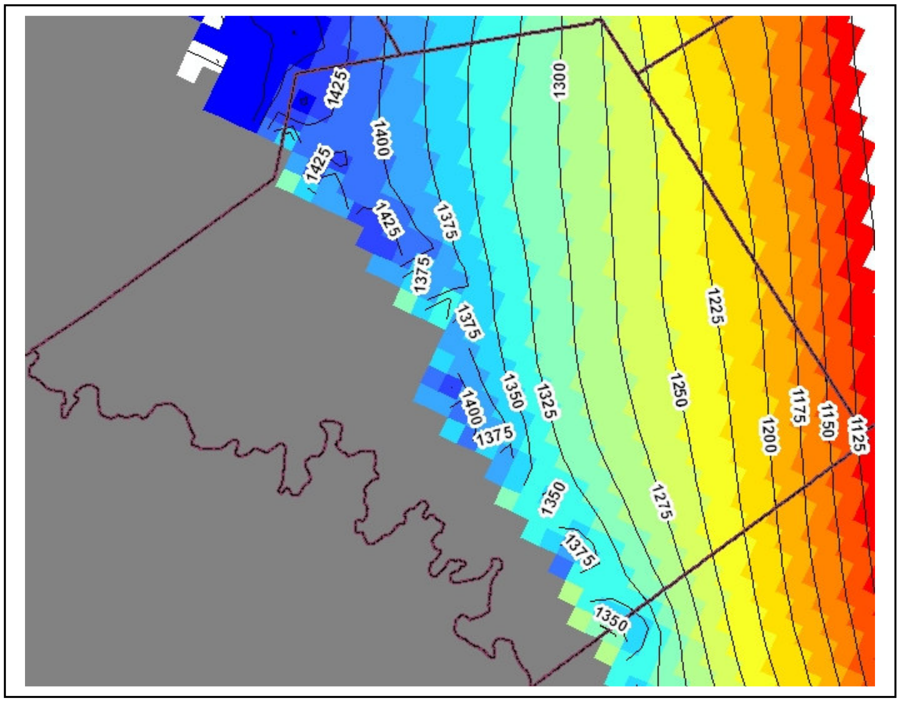
Condition	Total pumpage	Original Hensell pumpage	Additional Hensell pumpage	Original Hosston pumpage	Additional Hosston pumpage
Baseline- existing projected pumpage	1,109	446	0	663	0
Loss of 15 percent of original saturated thickness	4,609	446	2,550	663	950
Loss of 30 percent of original saturated thickness	8,609	446	5,500	663	2,000
Loss of 50 percent of original saturated thickness	15,509	446	11,000	663	3,400

REFERENCES:

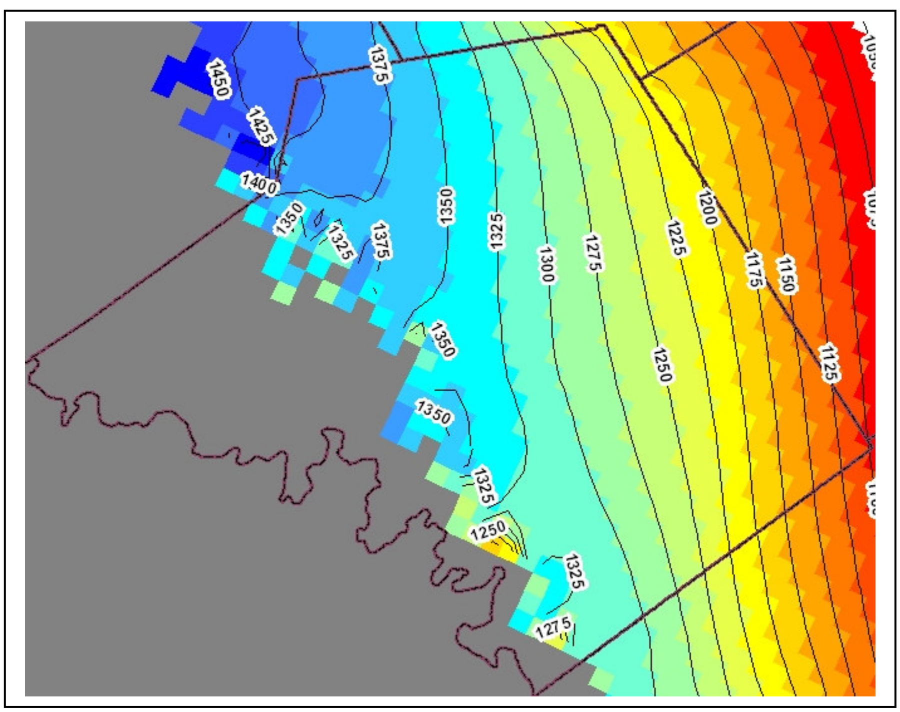
Harden, R. W. & Associates, Freese and Nichols, HDR Engineering, LBG-Guyton Associates, the U.S.G.S., and Yelderman, Joe, 2004, Northern Trinity/Woodbine Groundwater Availability Model: Texas Water Development Board, GAM Report, 391 p.



The seal appearing on this document was authorized by Andrew C.A. Donnelly, P.G. 737, on January 3, 2006.

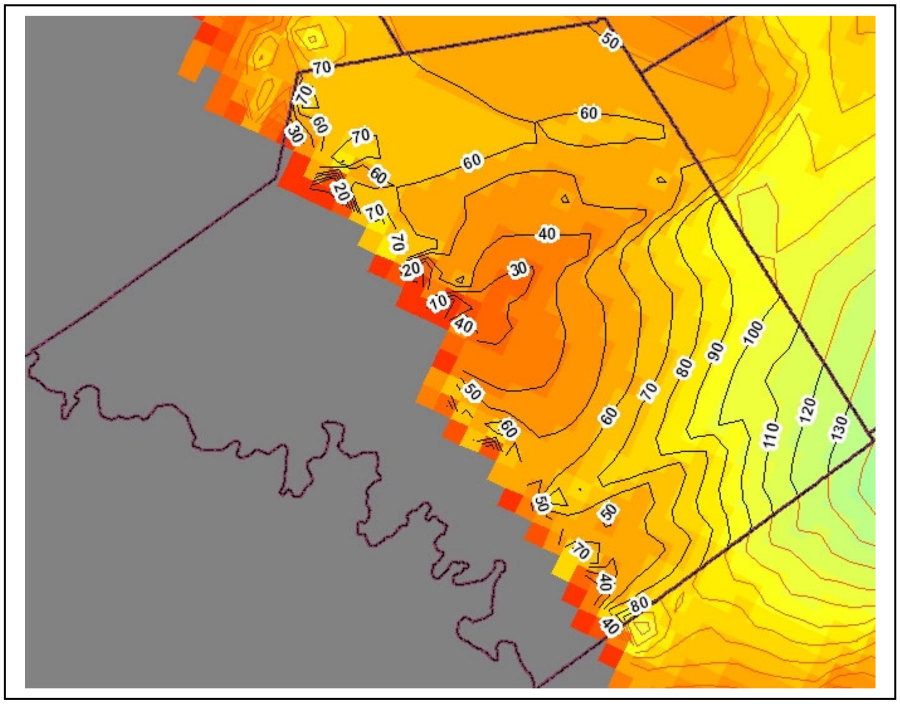


Hensell

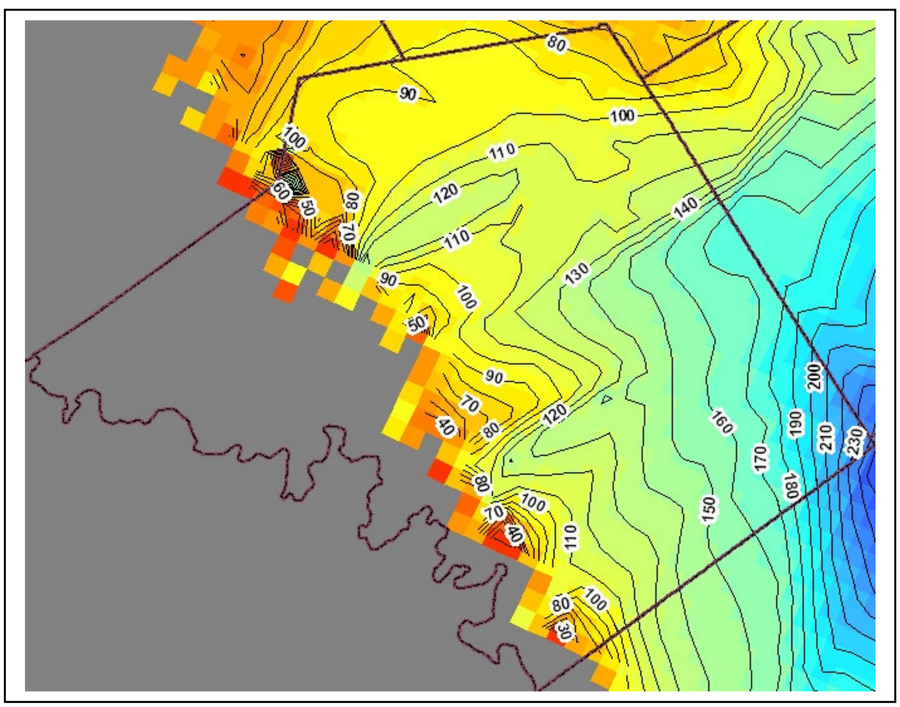


Hosston

Figure 2. Modeled water levels (in feet above mean sea level) in 2000 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston). Inactive (no-flow) areas are gray. Contour interval is 25 feet. Color shading is based on model cells and so is not smooth.

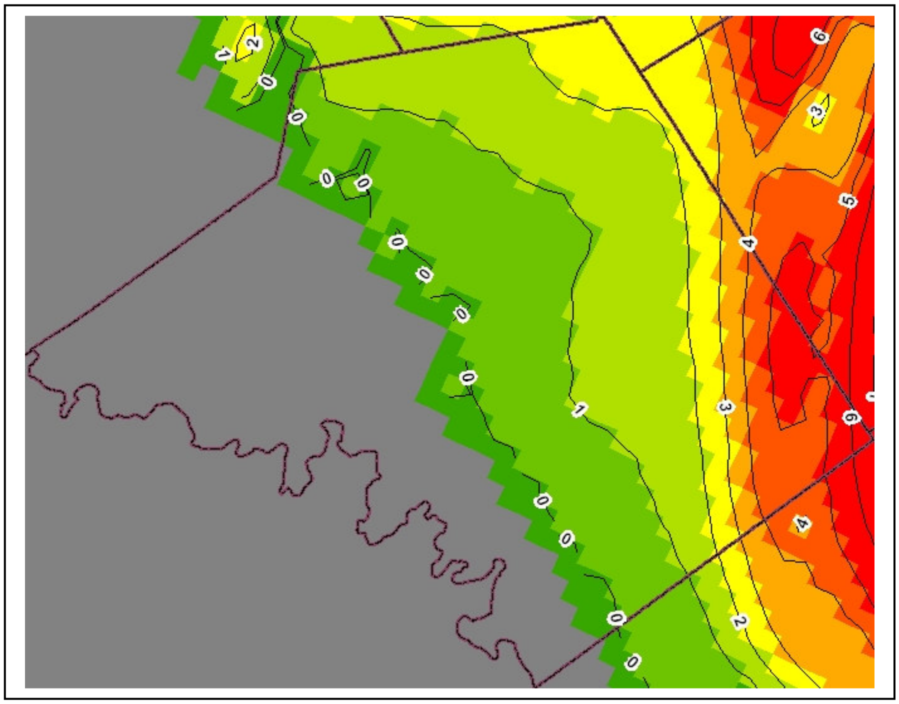


Hensell



Hosston

Figure 3. Modeled saturated thicknesses (in feet) in 2000 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston). Inactive (no-flow) areas are gray. Contour interval is 10 feet. Color shading is based on model cells and so is not smooth.



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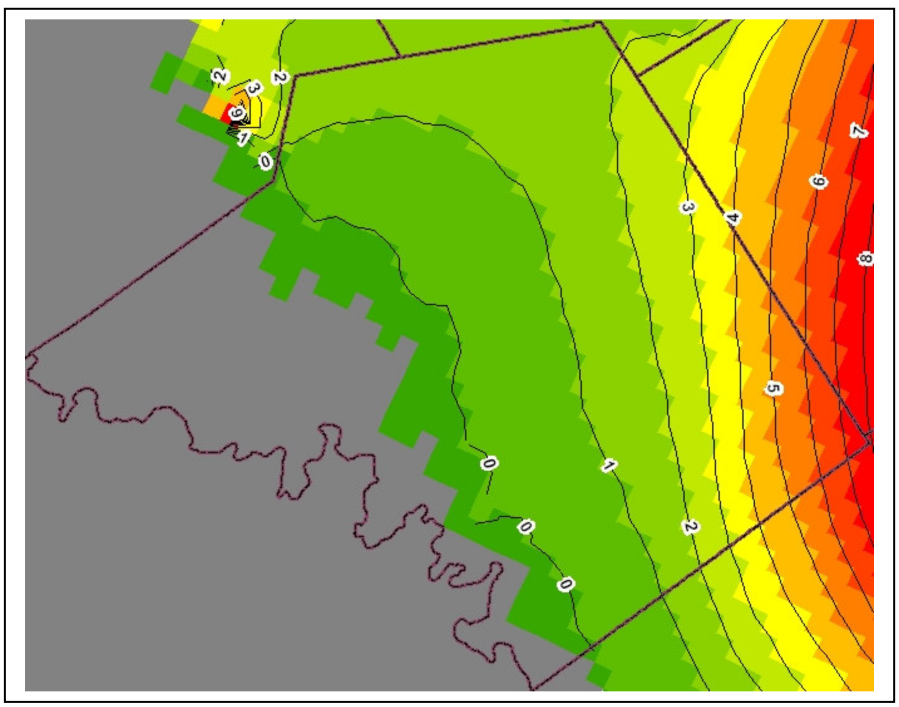
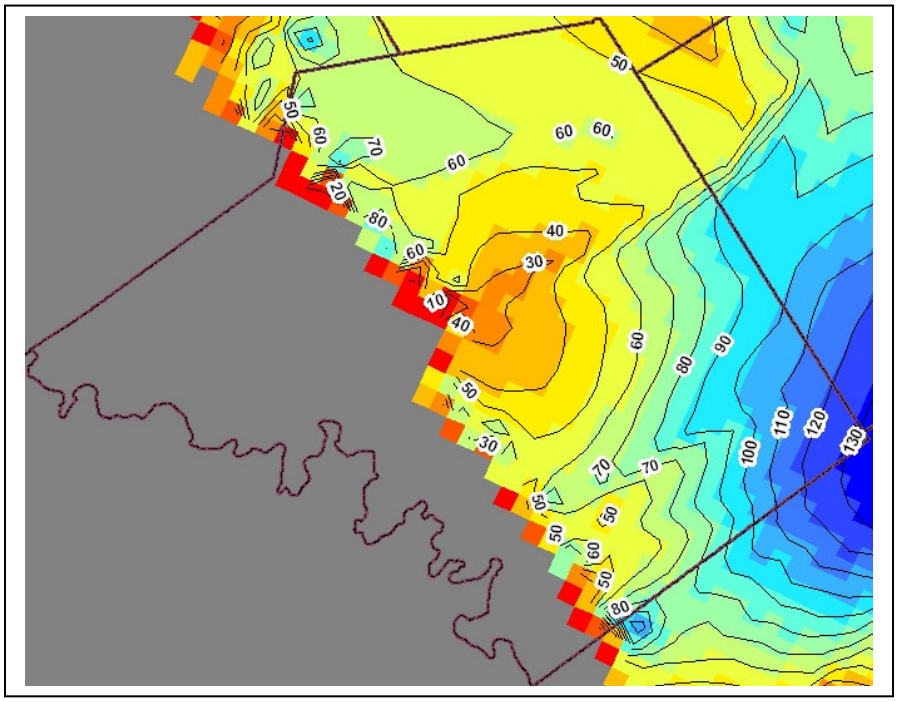


Hosston

Figure 4. Modeled drawdowns (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage. Inactive (no-flow) areas are gray. Contour interval is one foot. Color shading is based on model cells and so is not smooth. Negative drawdown areas represent areas of water level recovery.



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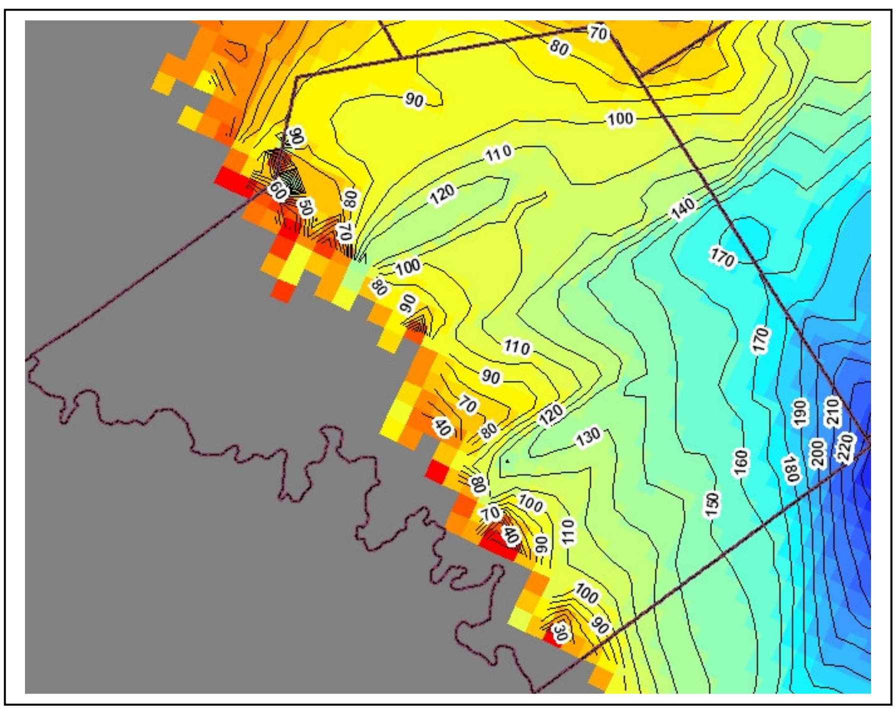
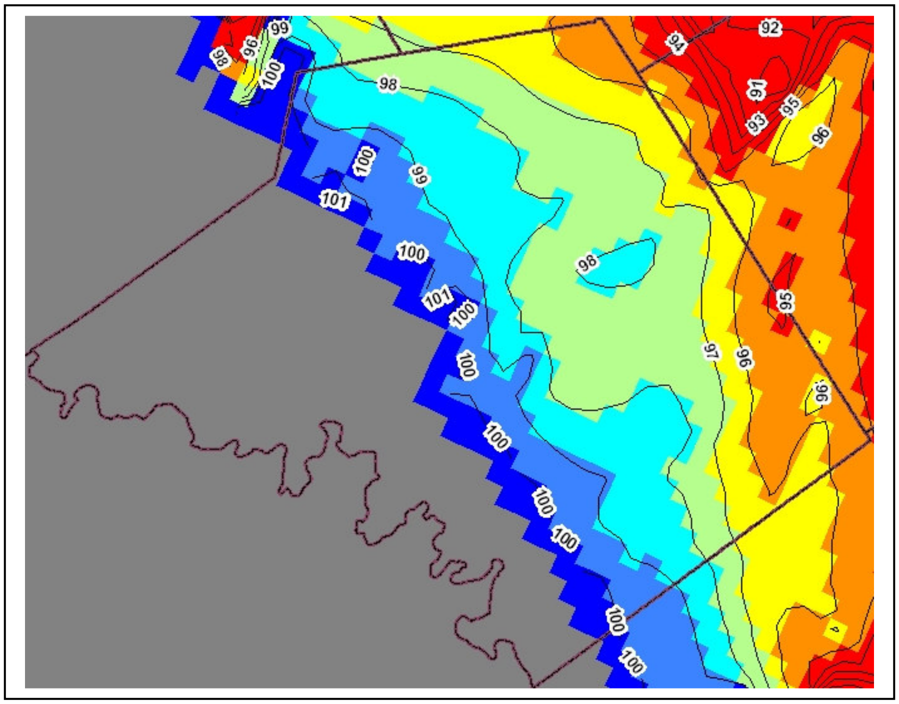
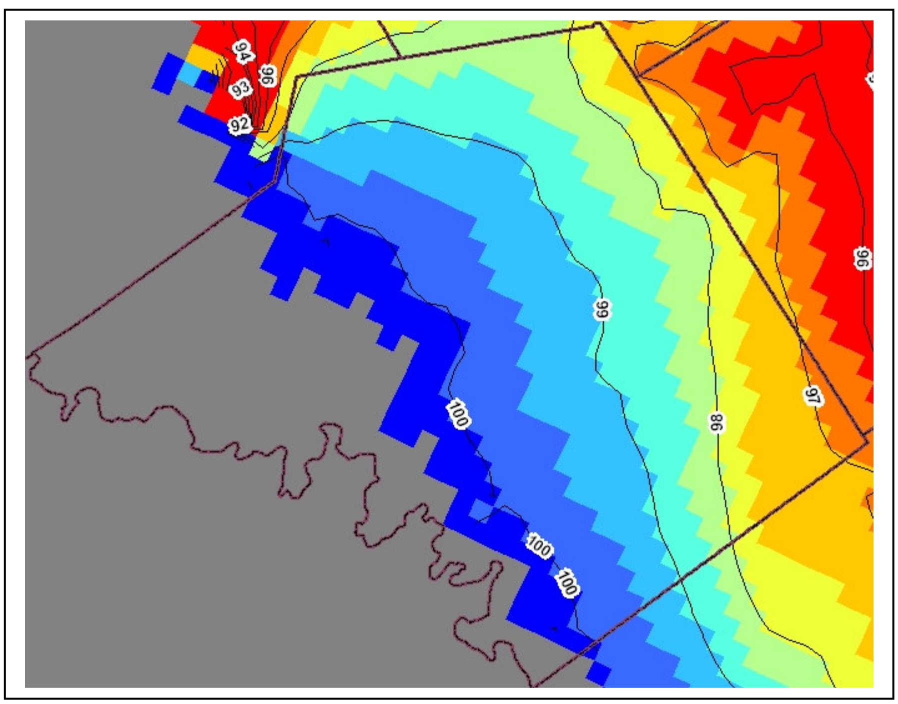


Hosston

Figure 5. Modeled saturated thicknesses (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage. Inactive (no-flow) areas are gray. Contour interval is 10 feet. Color shading is based on model cells and so is not smooth.

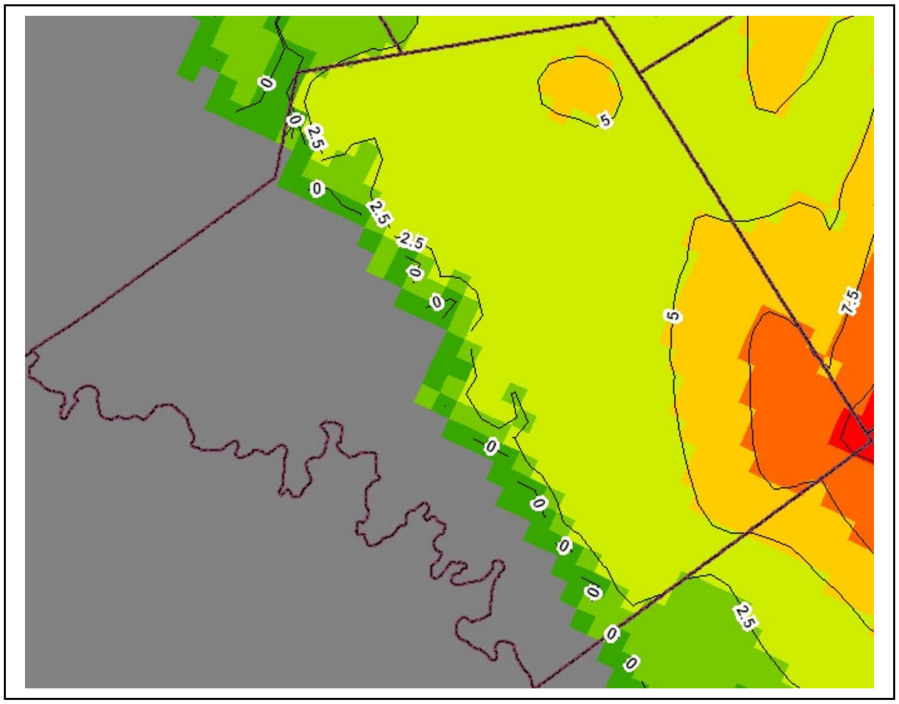


Hensell

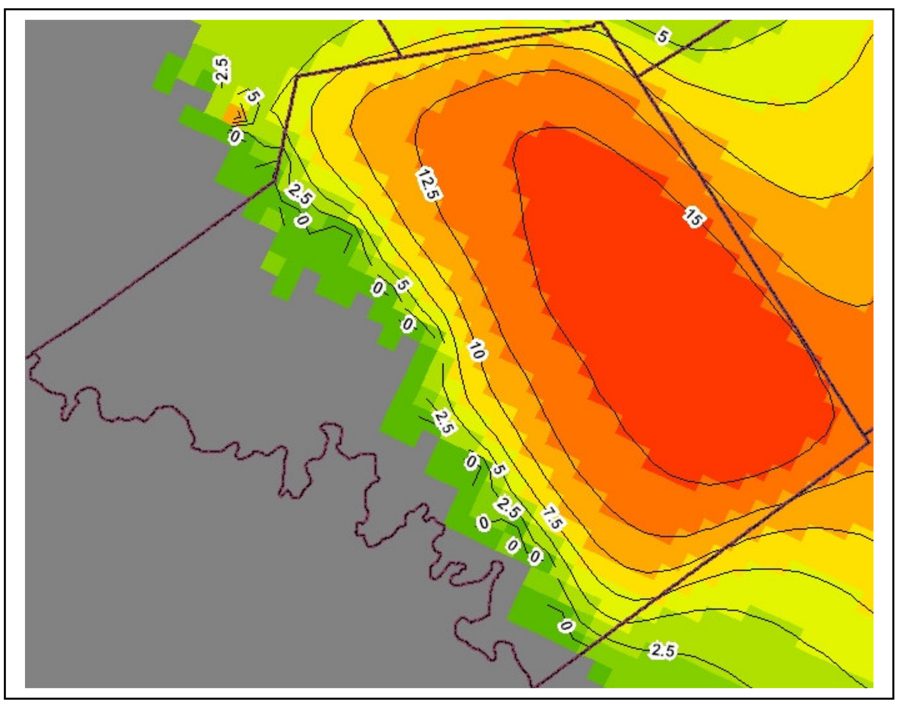


Hosston

Figure 6. Modeled percent of original (2000) saturated thickness remaining in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage. Inactive (no-flow) areas are gray. Contour interval is one percent. Color shading is based on model cells and so is not smooth.

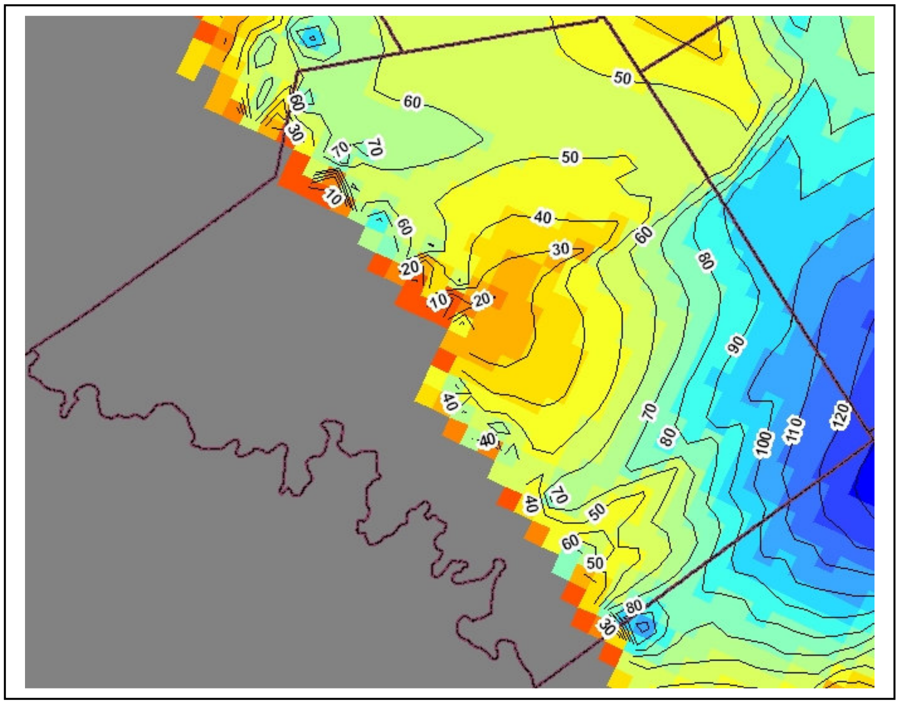


Hensell



Hosston

Figure 7. Modeled drawdowns (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 15 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 2.5 feet. Color shading is based on model cells and so is not smooth. Negative drawdown areas represent areas of water-level recovery.



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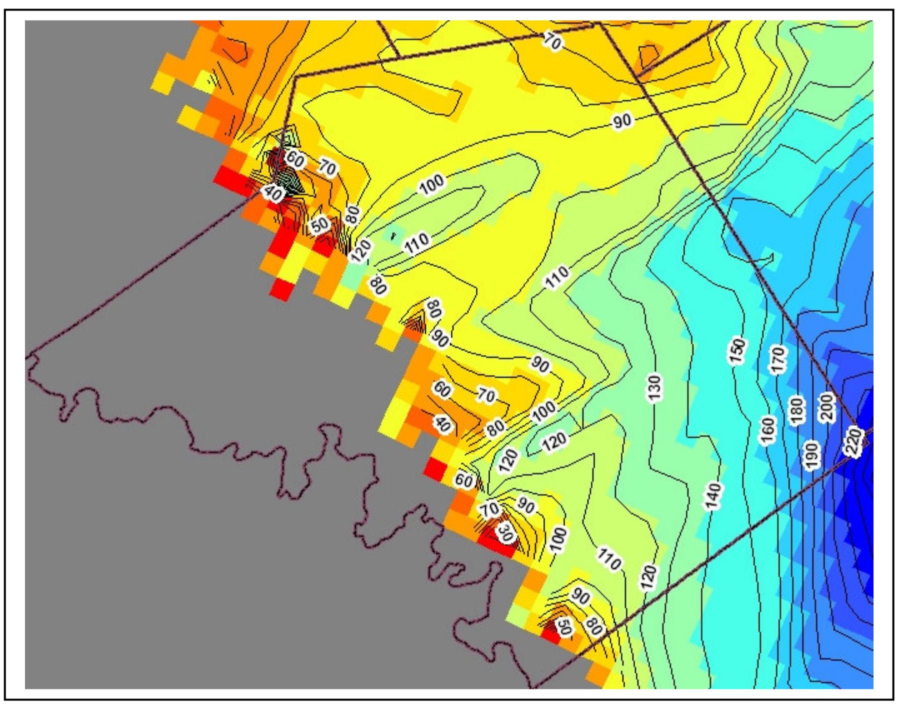
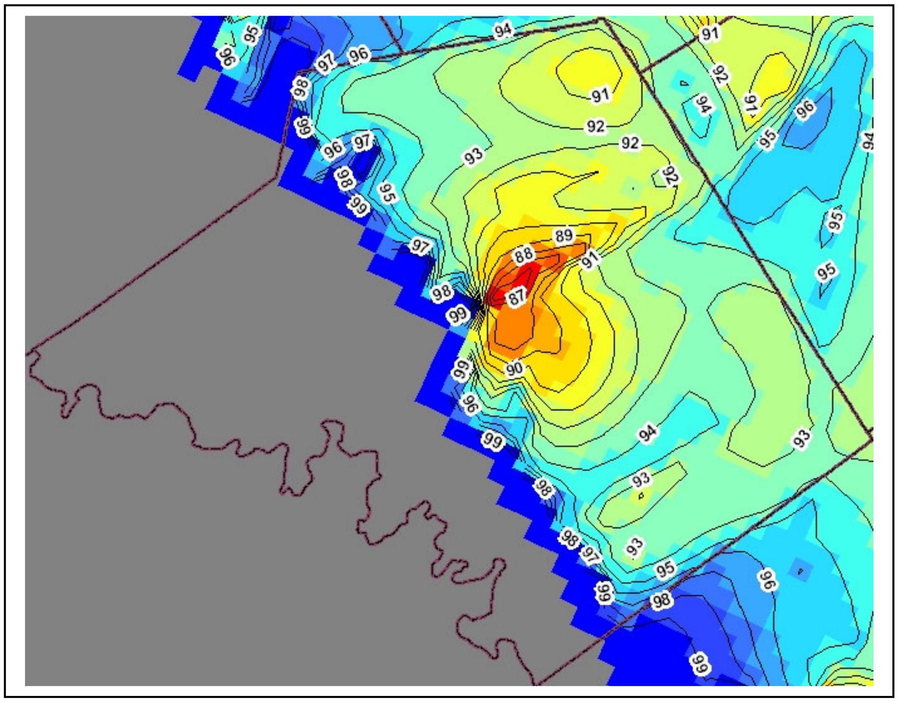


Hosston

Figure 8. Modeled saturated thicknesses (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 15 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 10 feet. Color shading is based on model cells and so is not smooth.



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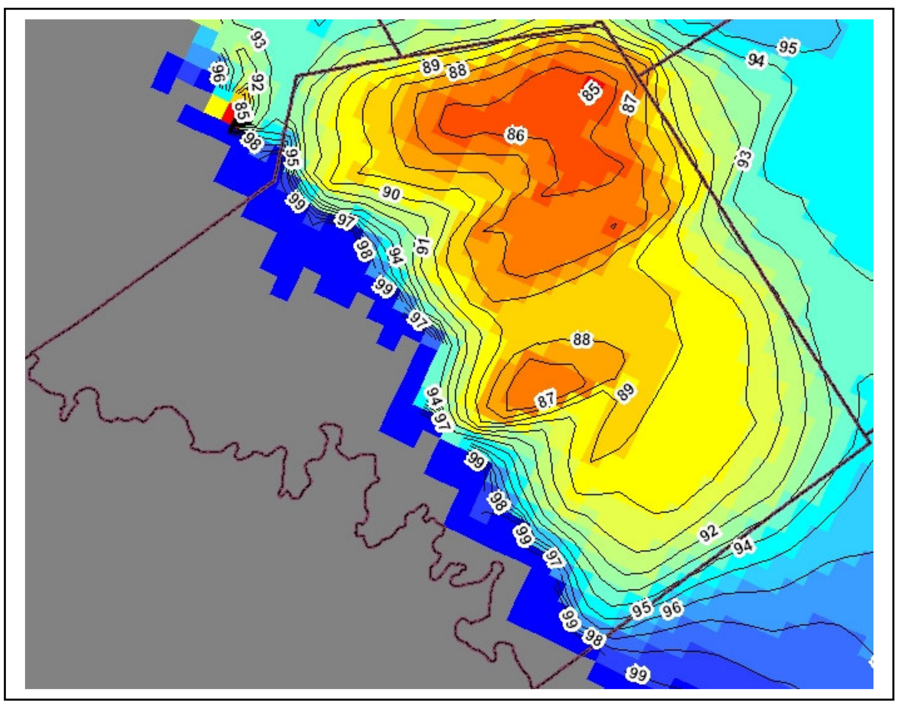
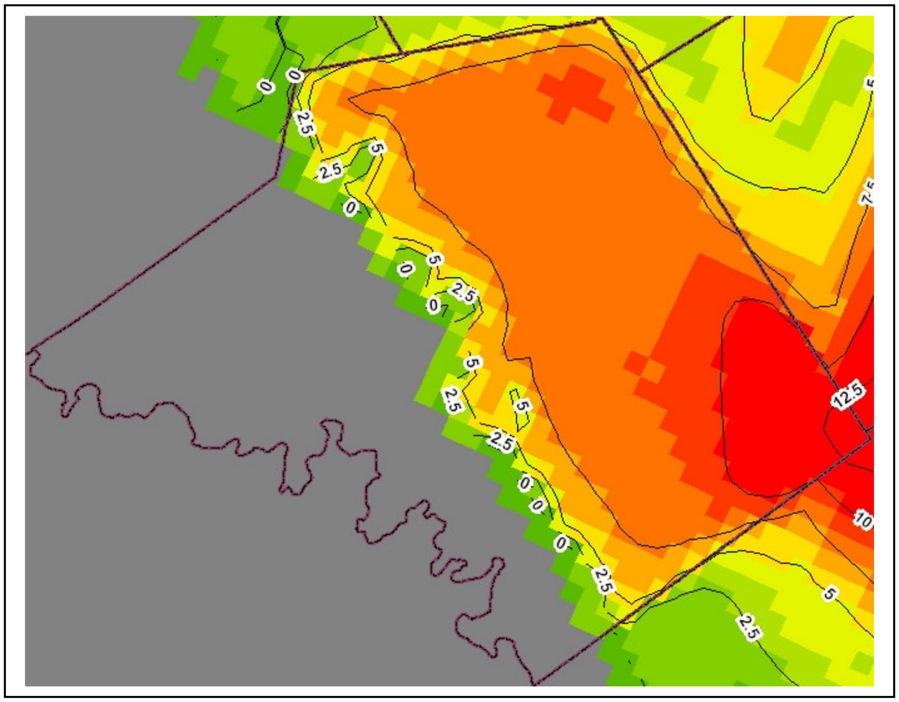


Hosston

Figure 9. Modeled percent of original (2000) saturated thickness remaining in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 15 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is one percent. Color shading is based on model cells and so is not smooth.



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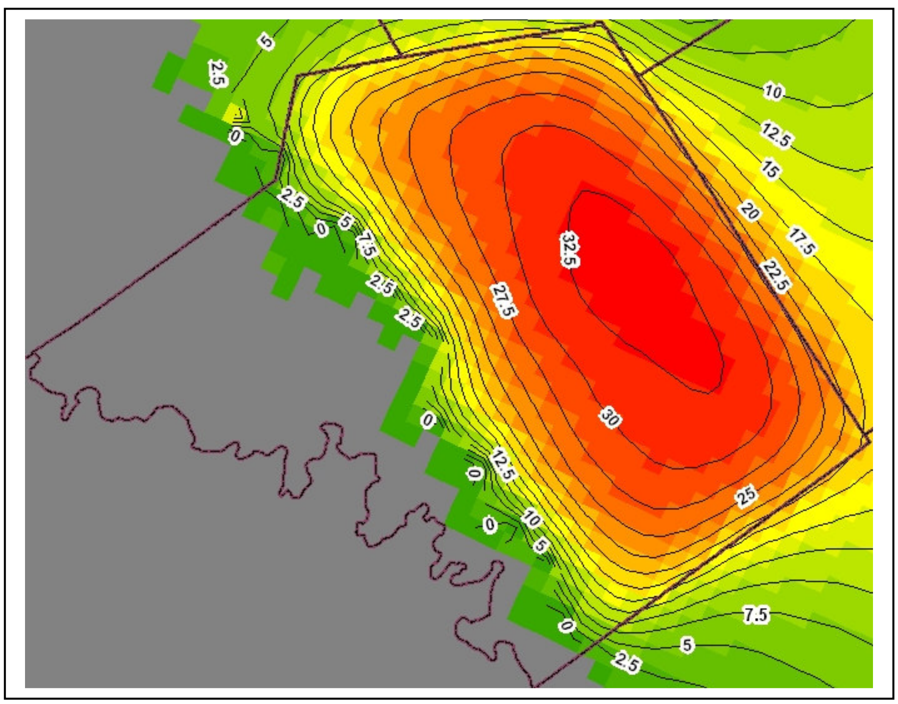
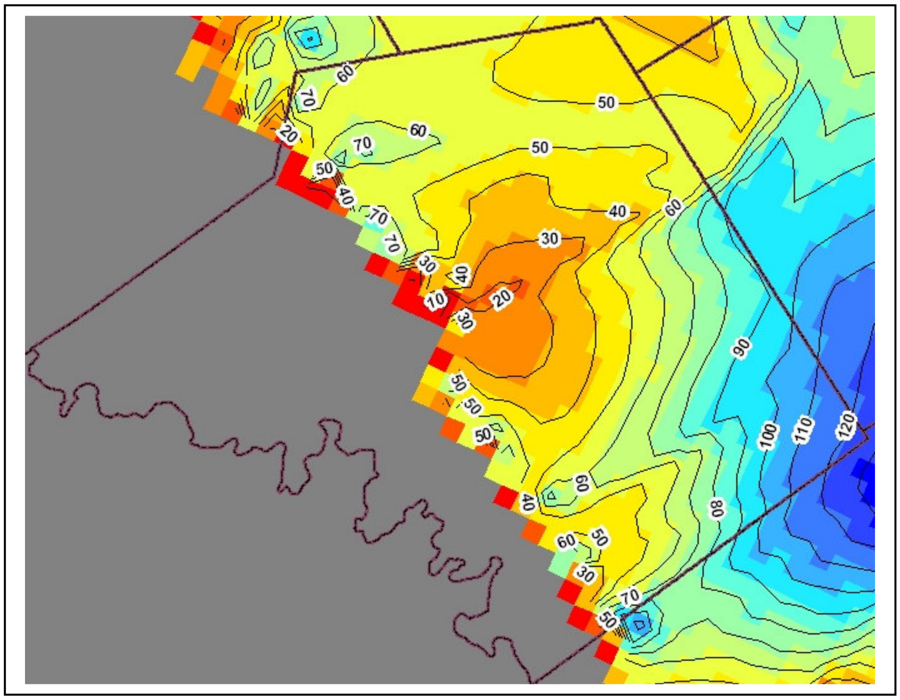


Hosston

Figure 10. Modeled drawdowns (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 30 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 2.5 feet. Color shading is based on model cells and so is not smooth. Negative drawdown areas represent areas of water level recovery.



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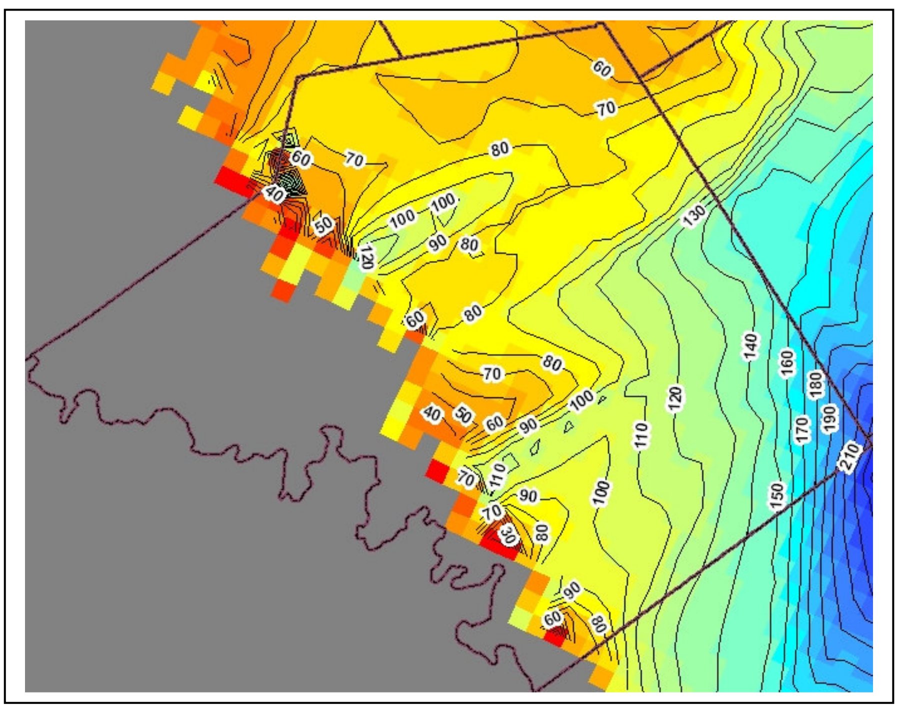
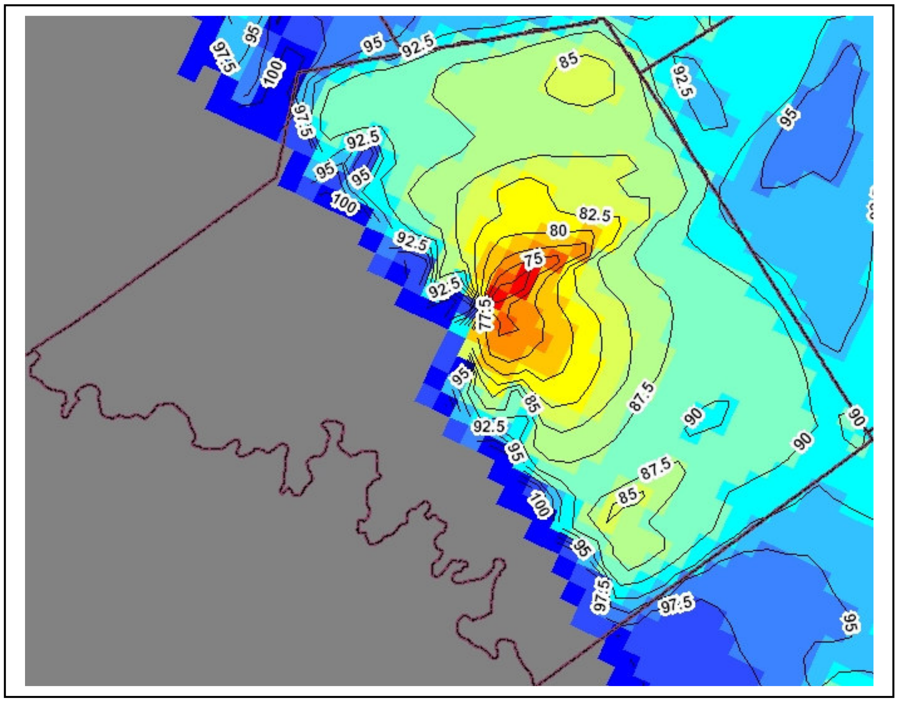


Hosston

Figure 11. Modeled saturated thicknesses (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 30 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 10 feet. Color shading is based on model cells and so is not smooth.



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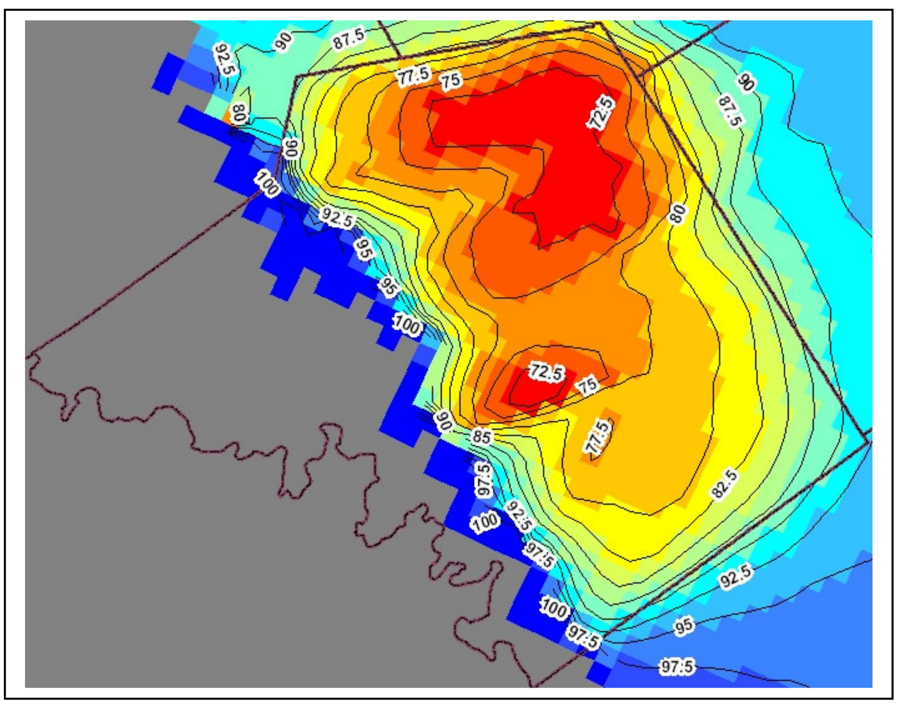
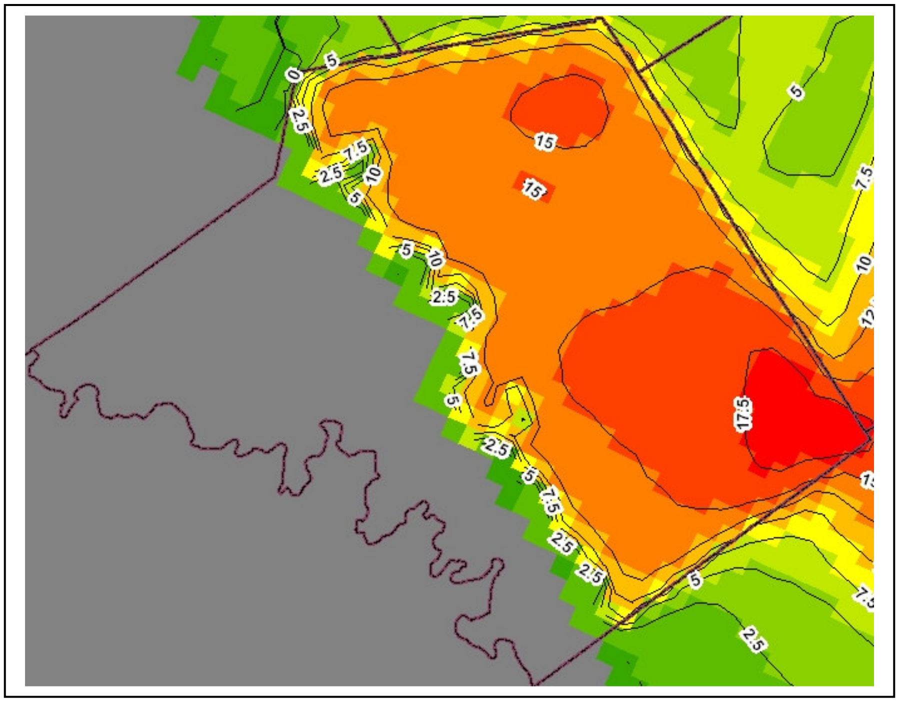


Hosston

Figure 12. Modeled percent of original (2000) saturated thickness remaining in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 30 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 2.5 percent. Color shading is based on model cells and so is not smooth.



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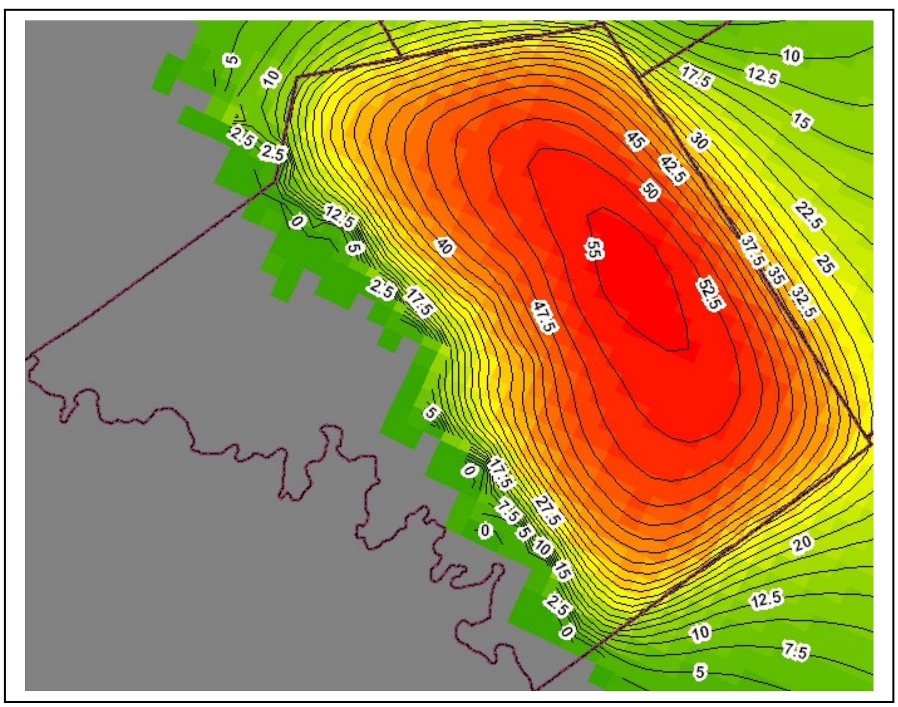
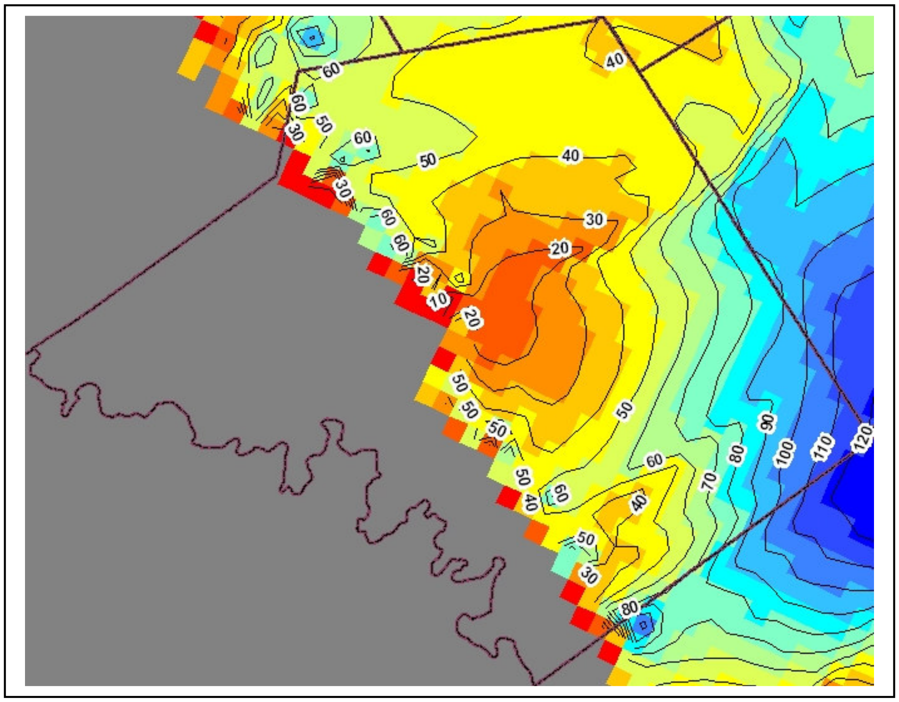


Hosston

Figure 13. Modeled drawdowns (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 50 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 2.5 feet. Color shading is based on model cells and so is not smooth. Negative drawdown areas represent areas of water level recovery.



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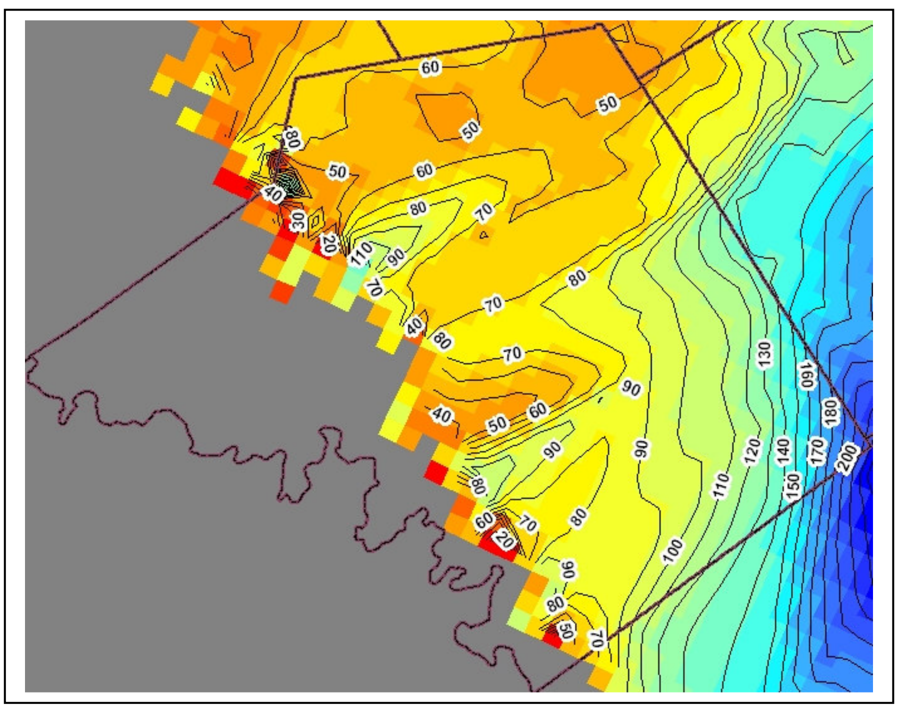
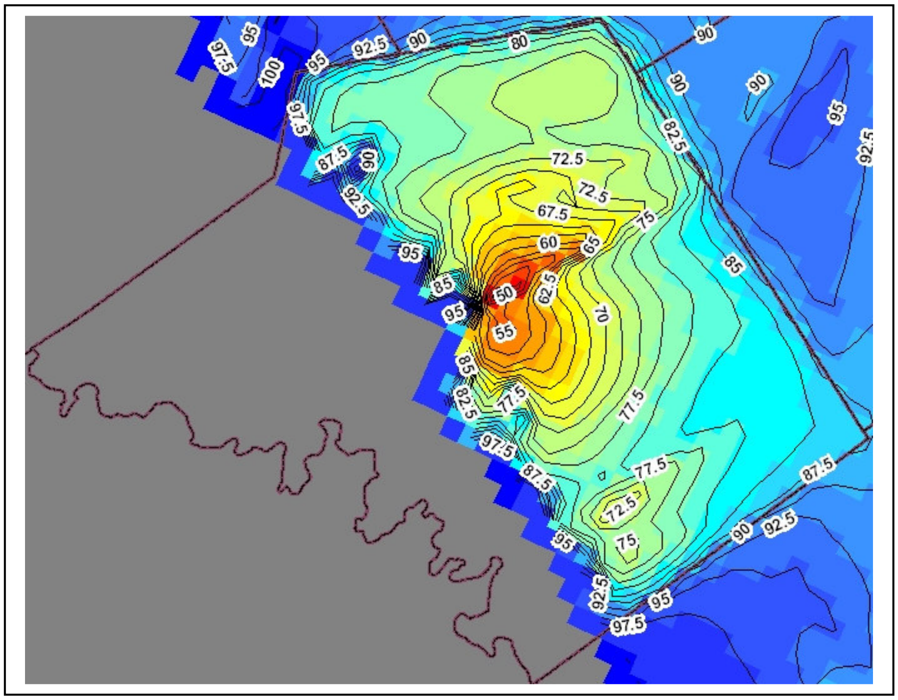


Hosston

Figure 14. Modeled saturated thicknesses (in feet) in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 50 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 10 feet. Color shading is based on model cells and so is not smooth.



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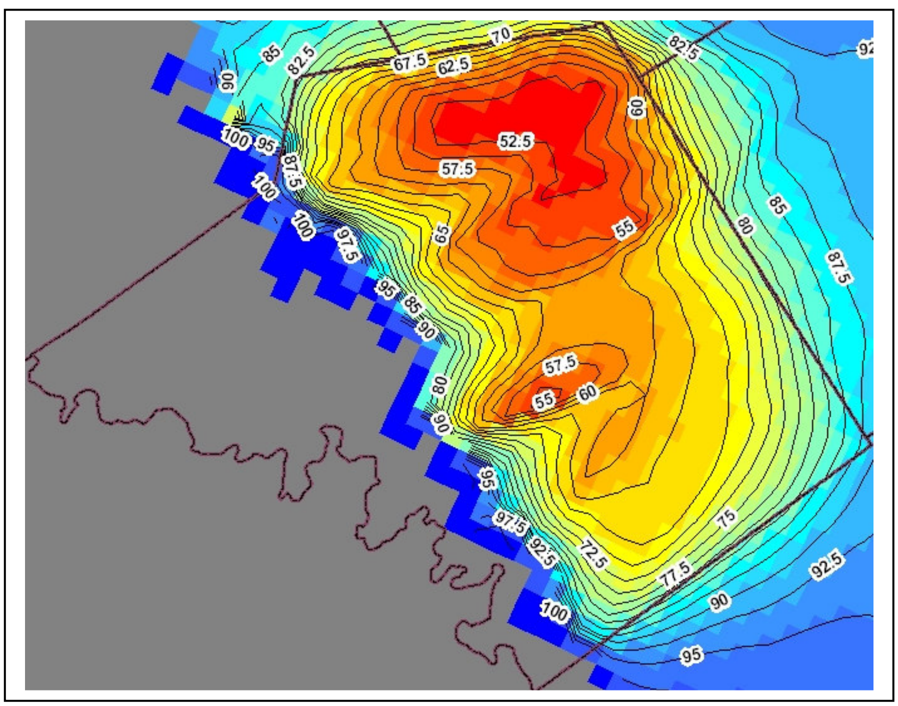

Hosston

Figure 15. Modeled percent of original (2000) saturated thickness remaining in 2050 in Mills County for Layer 5 (Hensell) and Layer 7 (Hosston) using existing predictive pumpage plus additional pumpage to reach a maximum of 50 percent loss of saturated thickness. Inactive (no-flow) areas are gray. Contour interval is 2.5 percent. Color shading is based on model cells and so is not smooth.