GAM Run 05-27

by Andrew C. A. Donnelly, P.G. and Roberto Anaya, P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 936-2415
October 27, 2005

REQUESTOR:

Mr. Art Dohmann on behalf of the Goliad County Groundwater Conservation District.

DESCRIPTION OF REQUEST:

Mr. Dohmann requested that two simulations using the central part of the Gulf Coast aquifer Groundwater Availability Model (GAM) be done, one using average recharge and the second using drought-of-record recharge. Mr. Dohmann requested we use 2005 pumping estimates he provided for Goliad County as the basis for pumpage projections used during the two 61-year predictive simulations and that we use the version of the GAM for the central part of the Gulf Coast aquifer that assumes the wells in the Evangeline aquifer fully penetrate the entire depth of the aquifer (see GAM run 05-04).

Mr. Dohmann requested that we provide recharge quantity and water budgets for Goliad County for both average recharge conditions and drought recharge conditions. We have also provided water-level maps for 2000, 2005, 2010, 2020, 2030, 2040, 2050, and 2060 for each of the model simulations.

METHODS:

To determine the water levels in Goliad County for selected years in the predictive period (2000 through 2060), we used a version of the GAM for the central part of the Gulf Coast aquifer that assumes the wells simulated in the Evangeline aquifer fully penetrate the entire depth of the Evangeline aquifer (see GAM run 05-04). We ran the model for the period 2000 through 2060 using average and then drought-of-record recharge conditions. We adjusted a predictive pumpage dataset that had spatially distributed pumpage based on data from the 2002 State Water Plan to match the pumpage estimates provided by Mr. Dohmann for Goliad County in 2005. We distributed the pumpage values to well locations supplied by Mr. Dohmann for all water use categories except for the Rural Domestic category, a portion of the Livestock category, and the oil and gas operations within the Mining category. Rural Domestic was distributed to previously established model cells and layers using a population density technique. Large capacity Livestock groundwater users were assigned to specific well locations and aquifers provided by Mr. Dohmann. The remaining Livestock pumpage volumes were distributed to previously established model cells and layers using a land-use technique. No information on the locations of oil and gas operations was available, so the pumpage for Mining was distributed uniformly across the county in rural areas. For Goliad County, we then applied the same ratios used to adjust 2005 to all the remaining years of the predictive period. For the model area outside of Goliad County, we used pumpage estimates based on an analysis that compared the 2002 State Water plan demands to the Board approved demands for the 2006 regional water plans.

PARAMETERS AND ASSUMPTIONS:

- See Waterstone and Parsons (2003) and Chowdhury and others (2004) for assumptions and limitations of the original GAM.

- See GAM run 05-04 (http://www.twdb.state.tx.us/gam/GAMruns/GR05-04.pdf) and the central part of the Gulf Coast aquifer GAM report (http://www.twdb.state.tx.us/gam/glfc_c/glfc_c_TWDB_SummaryReport.pdf) for a description of the original GAM, adjustments made to the original GAM, and limitations associated with this alternative model. This version of the GAM assumes that pumping in the Evangeline aquifer occurs throughout the entire section of the Evangeline aquifer. The root mean squared error (a measure of the difference between simulated and actual water levels during model calibration) in 1999 for the entire central part of the Gulf Coast aquifer for the alternative model is 51 feet (GAM Run 05-04).

- We used a 30-year average (1961 to 1990) to calculate average recharge for the simulation. Drought-of-record recharge conditions represent the 1950s drought, from 1951 to 1956. To create the drought-of-record recharge, the average recharge values were multiplied by factors (Table 1) to obtain drought estimates (for example, to create the recharge for 1956, the average recharge values for all areas in the model were multiplied by a factor of 0.526).

Table 1. Drought-of-record recharge factors.

Year	Recharge Factor
1951	0.795
1952	0.759
1953	0.839
1954	0.557
1955	0.707
1956	0.526

- The GAM uses drains to simulate wetlands that occur throughout the Gulf Coast region. In the model, groundwater discharges only when water levels rise above specified drain elevations.

- The four layers included in the model represent the Chicot aquifer, Evangeline aquifer, Burkeville confining unit, and the Jasper aquifer.

- The pumping scenario used in this model does not include the Lower Guadalupe Water Supply Project (LGWSP).

- The pumpage in the surrounding counties are estimates and assumes that the pumpage categories, spatial locations, and vertical assignments per aquifer layer as were assigned from the 2002 State Water Plan data are reasonable. Using 4,304 acre-feet of pumpage in 2005 as the target year in Goliad County, pumpage was reduced to 87 percent of this value in 2000 (3,745 acre-feet) and gradually increased up to 155 percent in 2060 (6,714 acre-feet).

RESULTS:

We graphed the average recharge simulated water levels for each of the four model layers in Goliad County for the years 2000, 2005, 2010, 2020, 2030, 2040, 2050, and 2060 (Figures 1 through 4). Water levels in the Chicot aquifer appear to rise and recover slightly from 2000 to 2005 in southeast Goliad County and then stabilize for the remainder of the simulation through 2060. Water levels in the Evangeline aquifer appear to decline slightly between 2000 and 2020 in the northern portion of Goliad County. Water levels in most of the rest of the county appear to remain fairly stable throughout the simulation, except for a slight decline between 2000 and 2005 in the southeastern portion of the county. Water levels in the Burkeville confining unit decline gradually from 2000 to 2060 throughout Goliad County and then begin to form two small cones of depression in northwest Goliad County. Water levels in the Jasper aquifer rise and recover from 2000 to about 2030 throughout Goliad County and then stabilize for the remainder of the simulation through 2060. Generally, the 60-year simulation shows minimal effects upon water levels in Goliad County under average recharge conditions. This assumes the trend and annual volume of pumpage simulated in Goliad County and the surrounding counties is reasonable.

Simulated water levels for each of the four model layers in Goliad County using drought-of-record recharge are shown for 2060 in Figure 5. Results for the drought-of-record simulation for 2000 to 2050 are identical to the results using average recharge conditions because we applied the drought-of-record recharge conditions only to the last six years of the drought simulation. Therefore, these figures are not repeated in this report. Water levels in 2060 in all model layers show a decrease in and near the outcrop areas when compared to average recharge conditions. The differences in water levels between average and drought recharge simulations decrease in the downdip areas. In Goliad County, drawdown in the Chicot aquifer is less than five feet over the six-year drought period. Drawdown in the Evangeline aquifer over this drought period is generally less than three feet throughout most of the county. The differences between the average and drought-of-record simulations in the Burkeville confining unit and the Jasper aquifer are negligible because most or all of the county falls within the far downdip portions of these aquifers/layers.

Water budgets for the last year (2060) of each simulation for the average recharge and drought-of-record model runs for Goliad County are presented in Tables 2 and 3, respectively. These tables show the annual flow, in acre-feet, of water into (Inflow) and out of (Outflow) each aquifer in the GAM for the central part of the Gulf Coast aquifer in Goliad County. The components of the budgets shown in Tables 2 and 3 include:

- Lakes and Reservoirs—This is water that flows into an aquifer from a surface lake or reservoir. In Goliad County this is only seen in the Chicot aquifer because the only lakes or reservoirs included in the model are present where the Chicot aquifer is the uppermost aquifer in the model. Lakes and Reservoirs are modeled in the GAM for the central part of the Gulf Coast aquifer using the MODFLOW River package.

- Wetlands—This is water that drains from an aquifer if water levels are above the elevation of the wetlands. This component is commonly associated with spring discharge from an aquifer and is always shown as "Outflow", or discharge, from an aquifer. Wetlands are modeled in the GAM for the central part of the Gulf Coast aquifer using the MODFLOW Drain package.

- Wells—This is water produced from wells in each aquifer. In the GAM for the central part of the Gulf Coast aquifer, this component is always shown as "Outflow" from an aquifer, because all wells included in the GAM produce (rather than inject) water. Wells are modeled in the GAM for the central part of the Gulf Coast aquifer using the MODFLOW Well package.

- Rivers and Streams—This is water that flows between streams and rivers and an aquifer. The direction and amount of flow depends on the water level in the stream or river and the aquifer. In areas where water levels in the stream or river are above the water level in the aquifer, water flows into the aquifer and is shown as "Inflow" in the budget. In areas where water levels in the aquifer are above the water level in the stream or river, water flows out of the aquifer and into the stream and is shown as "Outflow" in the budget. Rivers and streams are modeled in the GAM for the central part of the Gulf Coast aquifer using the MODFLOW Stream package.

- Recharge—This component simulates areally distributed recharge due to precipitation falling on outcrop areas of aquifers. Recharge is always shown as "Inflow" into an aquifer. This component does not include runoff from precipitation events that may recharge an aquifer within streams and rivers, which is included in the model in separate packages, as described above. Recharge is modeled in the GAM for the central part of the Gulf Coast aquifer using the MODFLOW Recharge package.

- Evapotranspiration—This is water that flows out of an aquifer due to direct evaporation and plant transpiration. This component of the budget will always be shown as "Outflow". Evapotranspiration is modeled in the GAM for the central part of the Gulf Coast aquifer using the MODFLOW Evapotranspiration (EVT) package.

- Storage—This is water stored in the aquifer. Storage that is included in "Inflow" is water that is removed from storage (that is, water levels decline). Water in storage that is included in "Outflow" is water that is added back into storage (that is, water levels increase). This component of the budget is often seen as water both going into and out of the aquifer because this is a county-wide budget, and water levels will decline in some areas (water is being removed from storage) and rising in others (water is being added to storage).

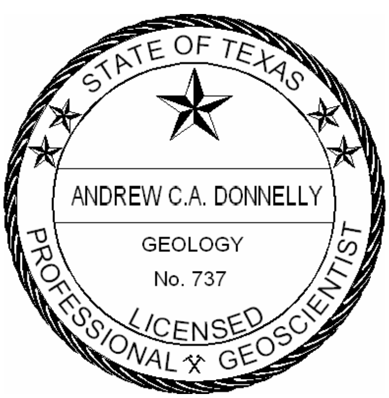
- Flow between aquifers—This describes the vertical flow, or leakage, between two aquifers. This flow is controlled by the water levels in each aquifer and aquifer properties of each aquifer that define the amount of leakage that can occur. "Inflow" to an aquifer from an overlying or underlying aquifer will always equal the "Outflow" from the other aquifer.

It is important to note that sub-regional water budgets for individual counties, such as Goliad County, are not exact. This is due to the one-mile spacing of the model grid, and because cells are assigned to a single county. The water budgets for an individual cell containing a county boundary are assigned to either one county or the other and therefore very minor variations in the county-wide budgets may be observed.

REFERENCES:

Chowdhury, A. H., Wade, S., Mace, R. E., and Ridgeway, C., 2004, Groundwater availability model of the Central Gulf Coast aquifer system: Numerical simulations through 1999: Texas Water Development Board, final report, 108 p.

Waterstone Environmental Hydrology and Engineering, Inc., and Parsons Engineering Science, Inc., 2003, Groundwater availability of the central Gulf Coast aquifer: numerical simulations to 2050 central Gulf Coast, Texas: Contract report prepared for the Texas Water Development Board, 156 p.



The seal appearing on this document was authorized by Andrew C.A. Donnelly, P.G. 737 on November 1, 2005.

Table 2. Summary of water budgets for Goliad County in 2060 using average recharge conditions. Flows reported in acre-feet per year.

Chicot Aquifer	Inflow	Outflow	**Jasper Aquifer**	Inflow	Outflow
Lakes and Reservoirs*	1,491	0	Lakes and Reservoirs*	0	0
Wetlands**	0	12	Wetlands**	0	0
Well	0	1,049	Well	0	0
Rivers and Streams***	2,721	8,266	Rivers and Streams***	0	0
Recharge	10,612	0	Recharge	0	0
Evapotranspiration	0	1,200	Evapotranspiration	0	0
Storage	38	0	Storage	56	7
Flow between Evangeline Aquifer	791	1,659	Flow between Burkeville Confining Unit	215	413
Evangeline Aquifer	Inflow	Outflow	**Burkeville Confining Unit**	Inflow	Outflow
Lakes and Reservoirs*	0	0	Lakes and Reservoirs*	0	0
Wetlands**	0	1	Wetlands**	0	0
Well	0	5,556	Well	0	109
Rivers and Streams***	22,987	15,603	Rivers and Streams***	0	0
Recharge	7,468	0	Recharge	0	0
Evapotranspiration	0	104	Evapotranspiration	0	0
Storage	96	0	Storage	106	1
Flow between Chicot Aquifer	1,659	791	Flow between Evangeline Aquifer	245	442
Flow between Burkeville Confining Unit	442	245	Flow between Jasper Aquifer	413	215

*Lakes and reservoirs were modeled using the MODFLOW river package

**Wetlands were modeled using the MODFLOW drain package

***Rivers and streams were modeled using the MODFLOW stream package

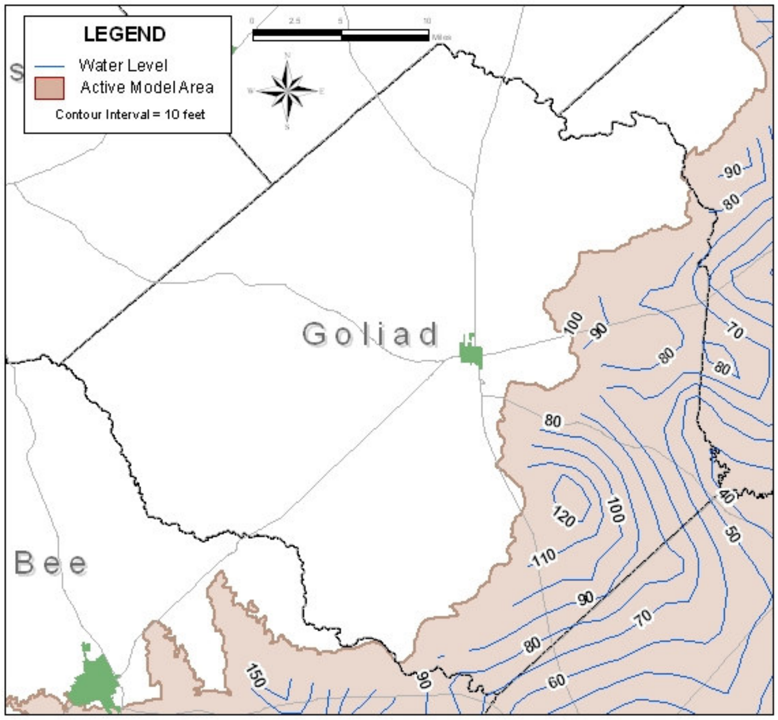
Table 3. Summary of water budgets for Goliad County in 2060 using drought-of-record recharge. Flows reported in acre-feet per year.

Chicot Aquifer	Inflow	Outflow	Jasper Aquifer	Inflow	Outflow
Lakes and Reservoirs*	1,543	0	Lakes and Reservoirs*	0	0
Wetlands**	0	8	Wetlands**	0	0
Well	0	1,049	Well	0	0
Rivers and Streams***	3,238	6,705	Rivers and Streams***	0	0
Recharge	5,582	0	Recharge	0	0
Evapotranspiration	0	1,058	Evapotranspiration	0	0
Storage	2,247	0	Storage	69	6
Flow between Evangeline Aquifer	799	1,353	Flow between Burkeville Confining Unit	206	417
Evangeline Aquifer	**Inflow**	**Outflow**	**Burkeville Confining Unit**	**Inflow**	**Outflow**
Lakes and Reservoirs*	0	0	Lakes and Reservoirs*	0	0
Wetlands**	0	1	Wetlands**	0	0
Well	0	5,556	Well	0	109
Rivers and Streams***	23,558	13,835	Rivers and Streams***	0	0
Recharge	3,928	0	Recharge	0	0
Evapotranspiration	0	92	Evapotranspiration	0	0
Storage	1,343	0	Storage	197	0
Flow between Chicot Aquifer	1,353	799	Flow between Evangeline Aquifer	204	505
Flow between Burkeville Confining Unit	505	204	Flow between Jasper Aquifer	417	206

*Lakes and reservoirs were modeled using the MODFLOW river package

**Wetlands were modeled using the MODFLOW drain package

***Rivers and streams were modeled using the MODFLOW stream package



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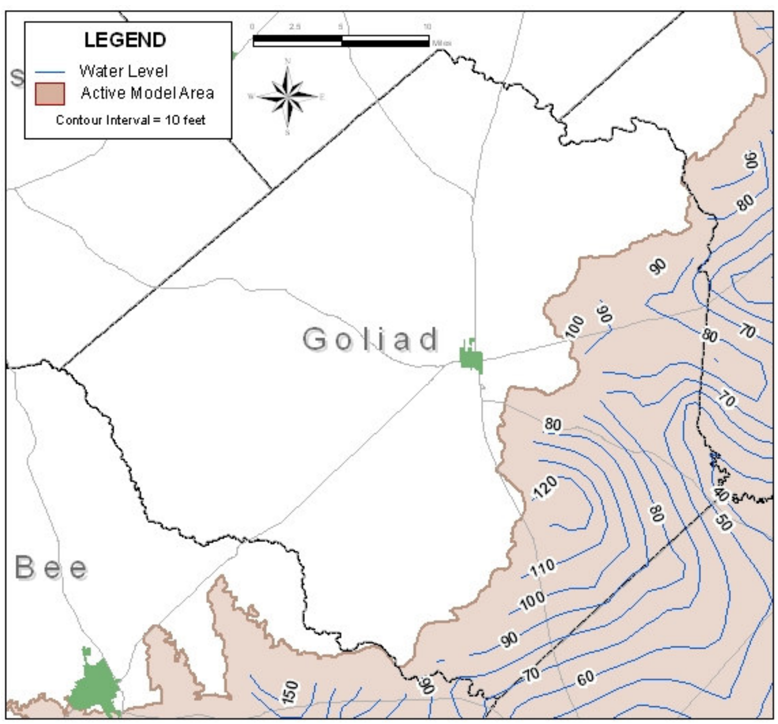
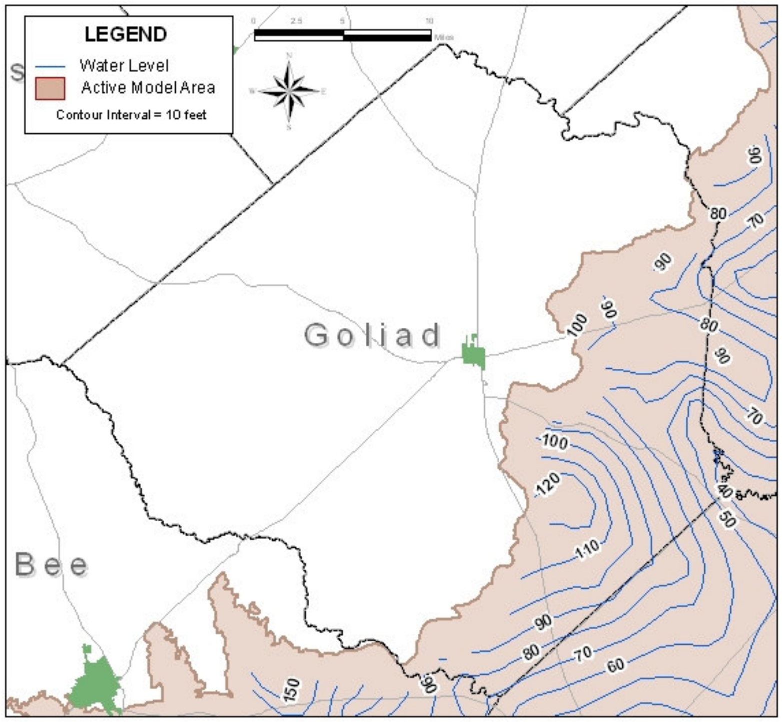


2005

Figure 1. Projected water levels in the Chicot aquifer for the years 2000, 2005, 2010, 2020, 2030, 2040, 2050, and 2060 under average recharge conditions.



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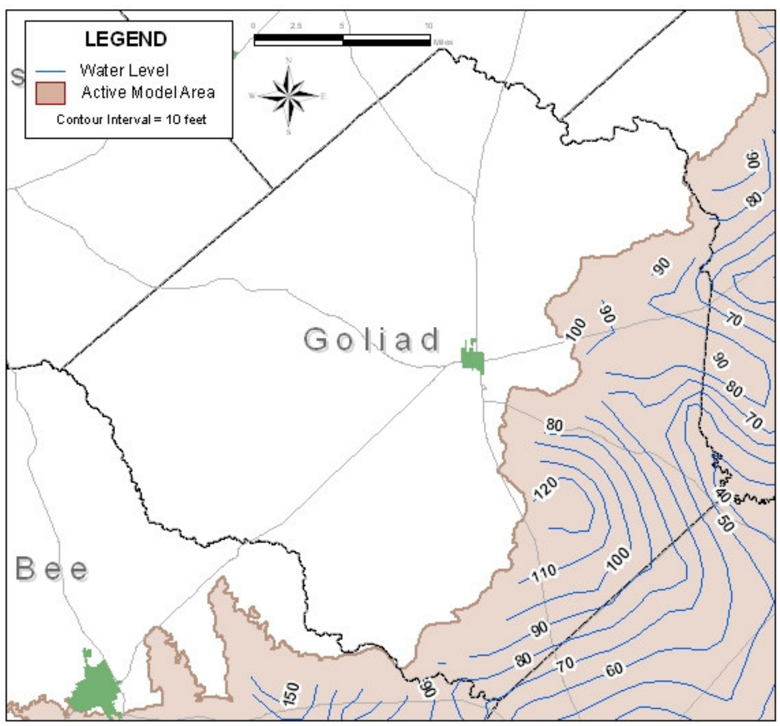

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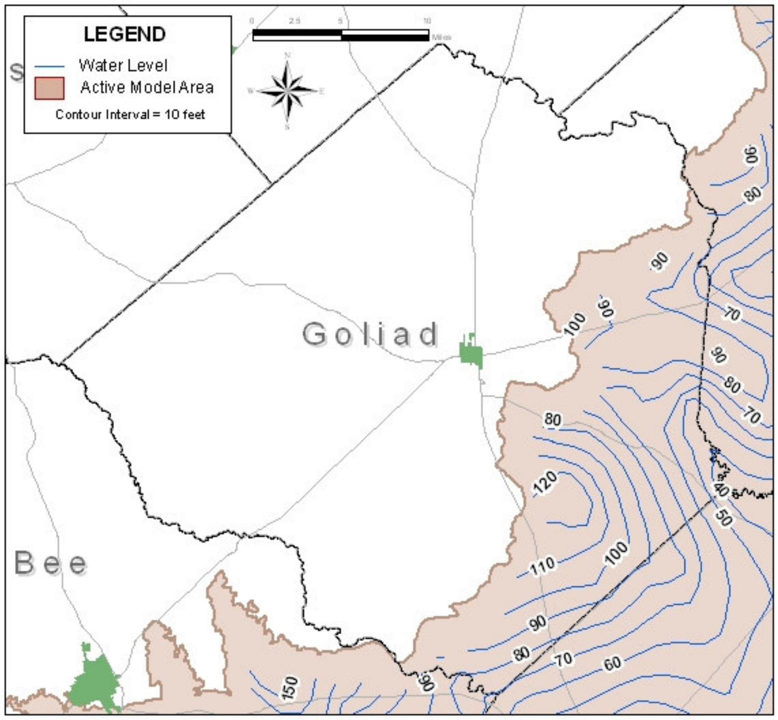

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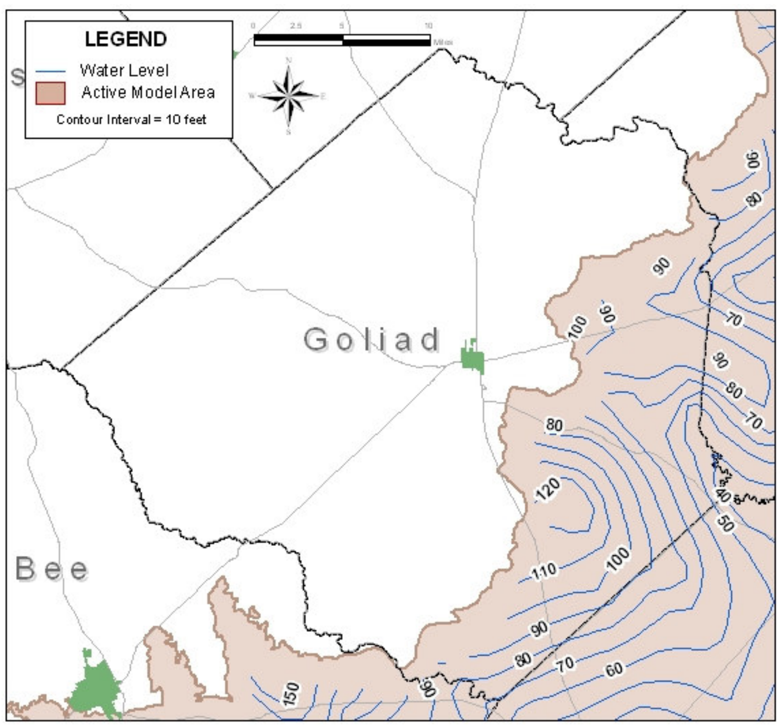

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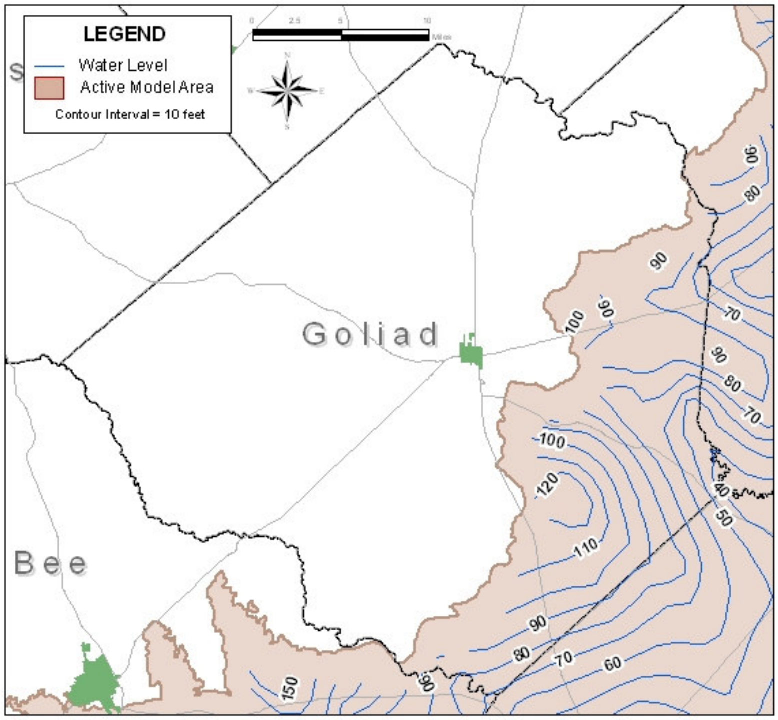

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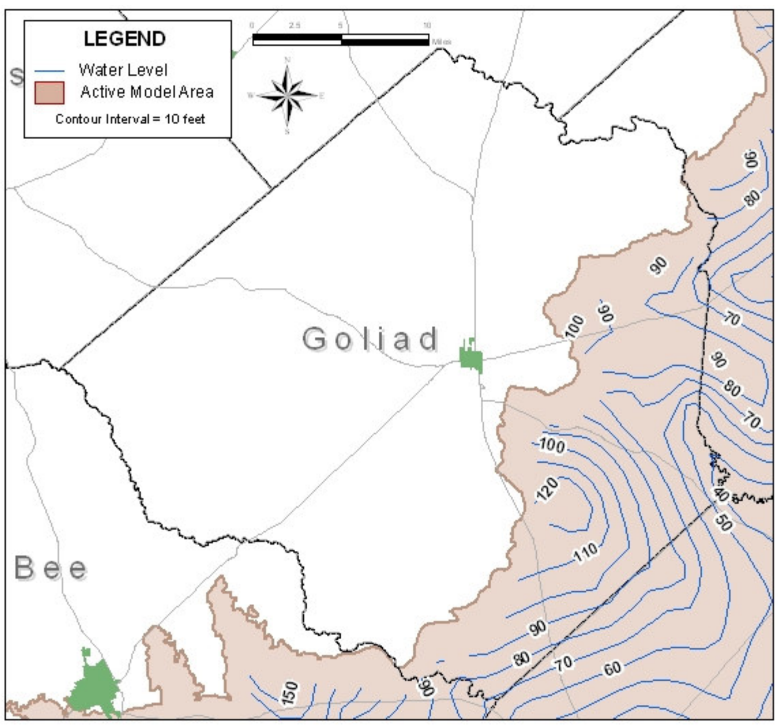

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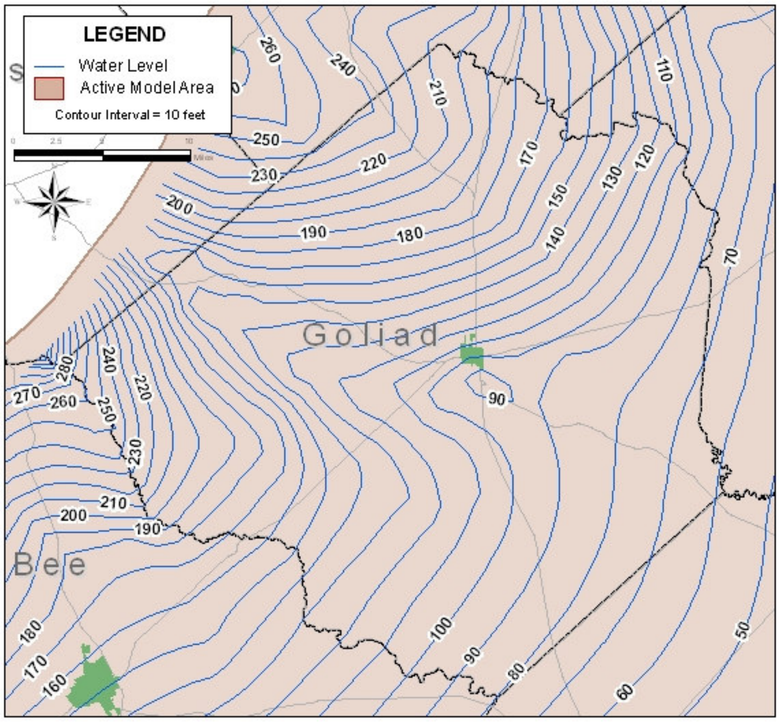

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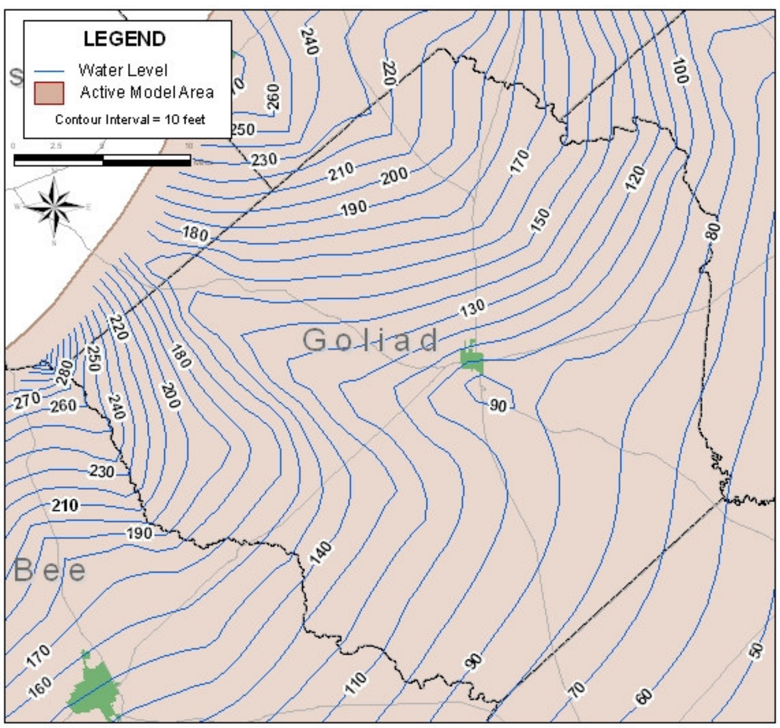

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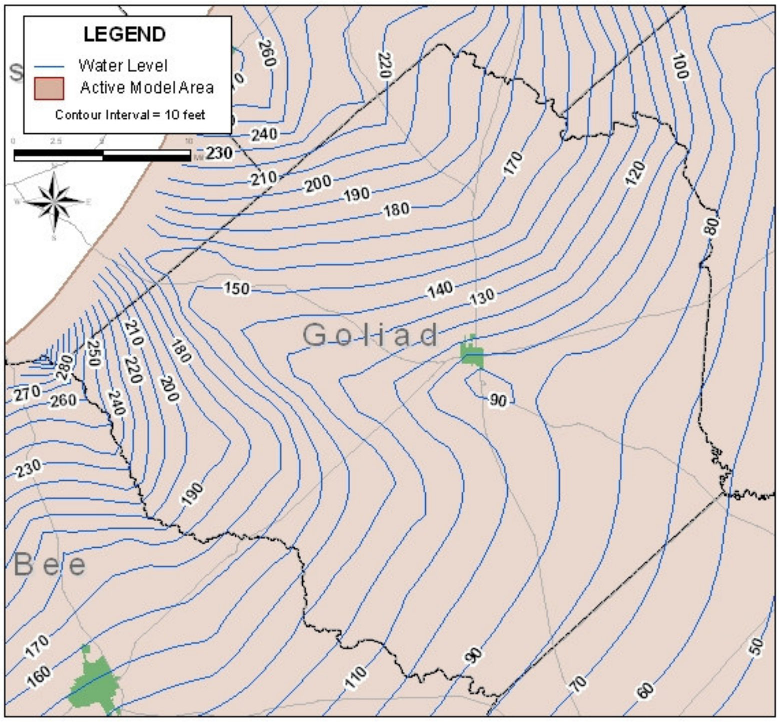
Figure 2. Projected water levels in the Evangeline aquifer for the years 2000, 2005, 2010, 2020, 2030, 2040, 2050, and 2060 under average recharge conditions.



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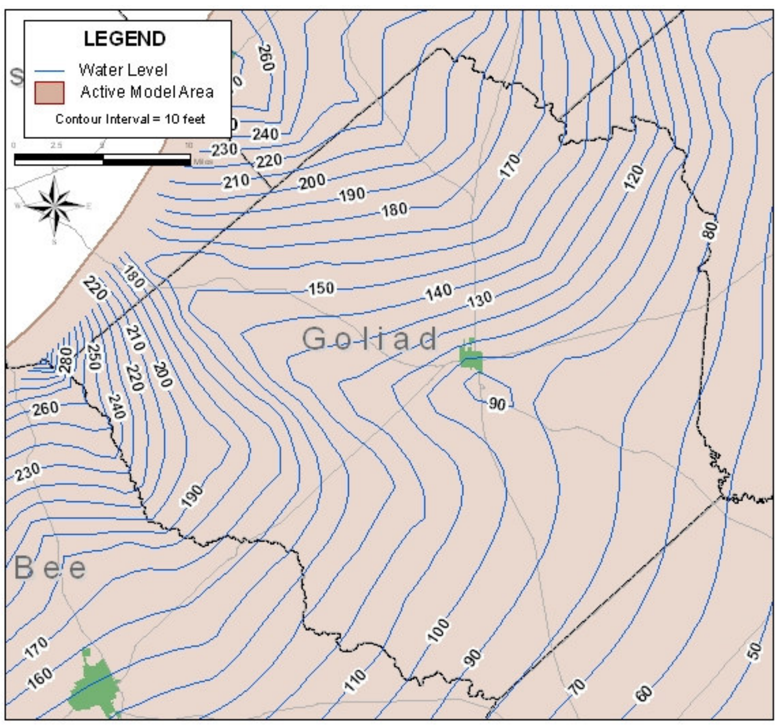

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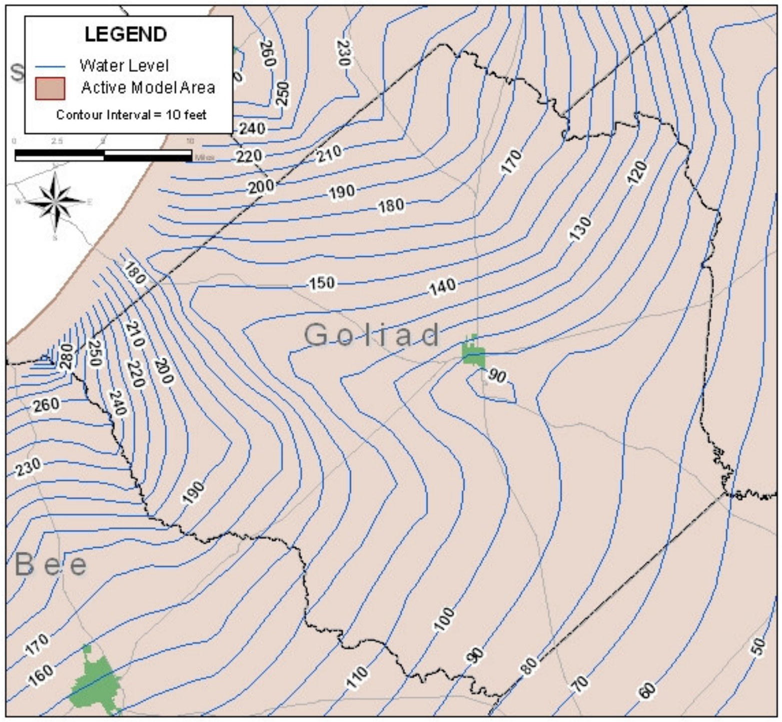

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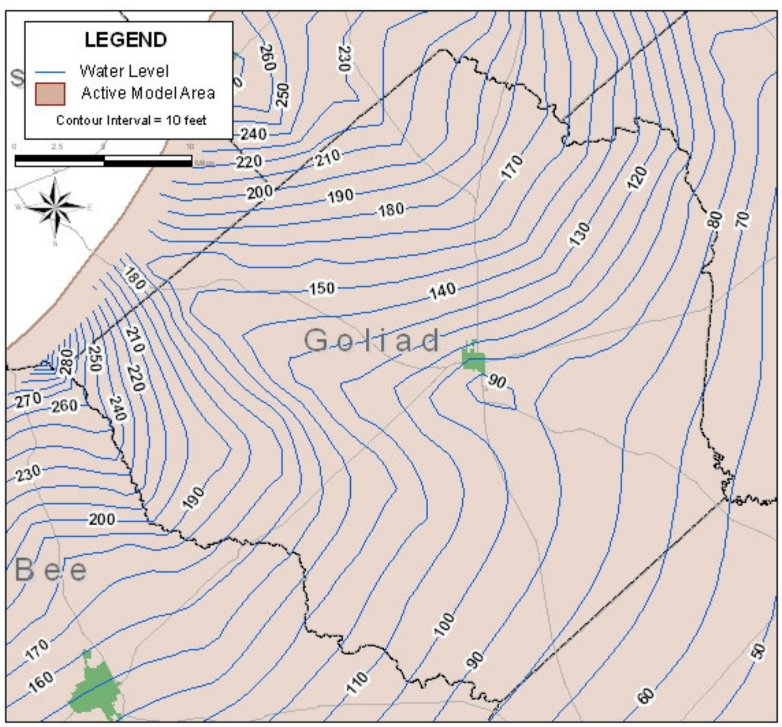

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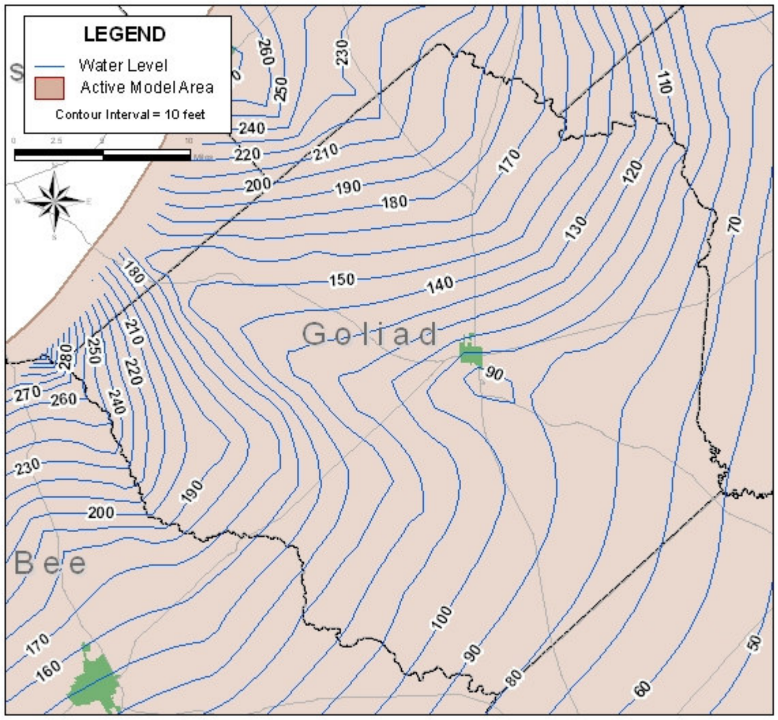

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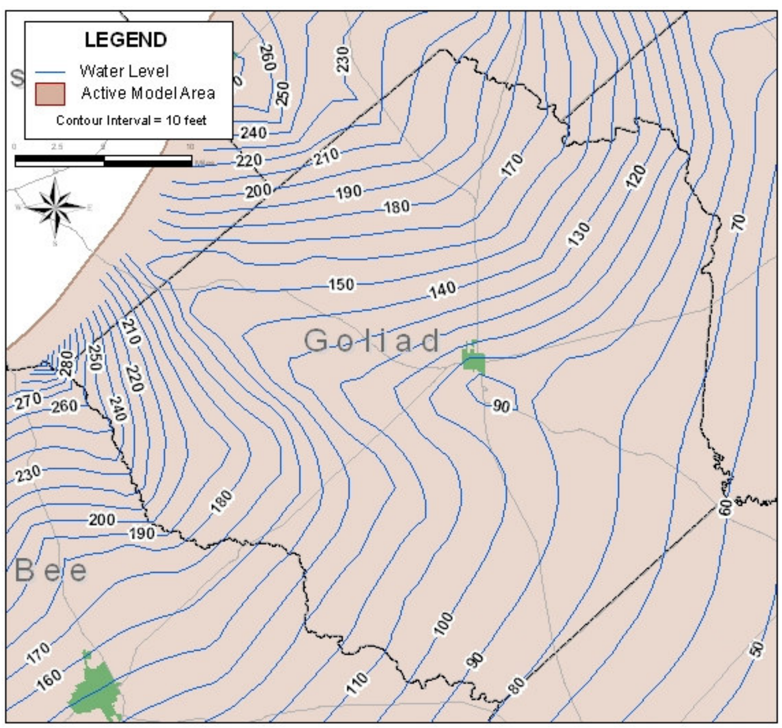

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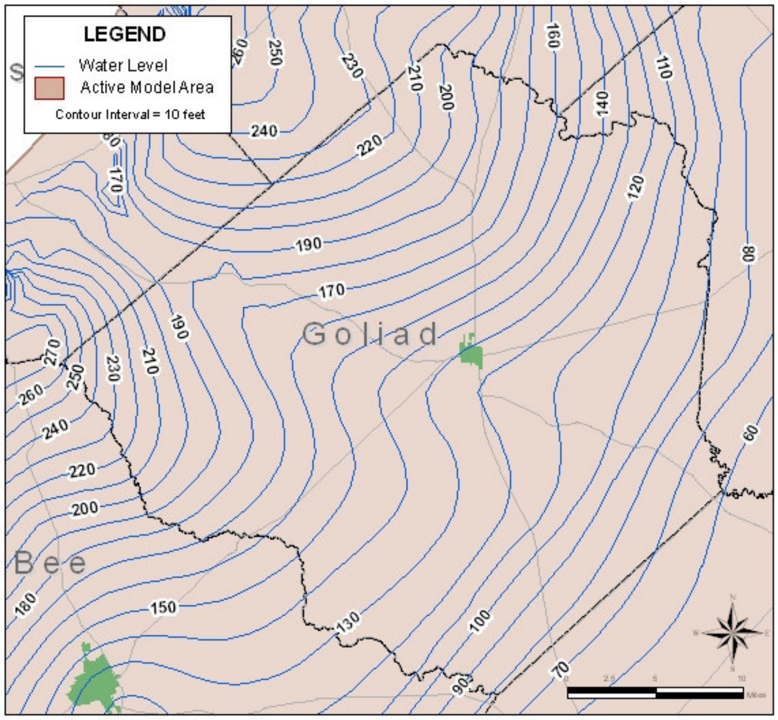

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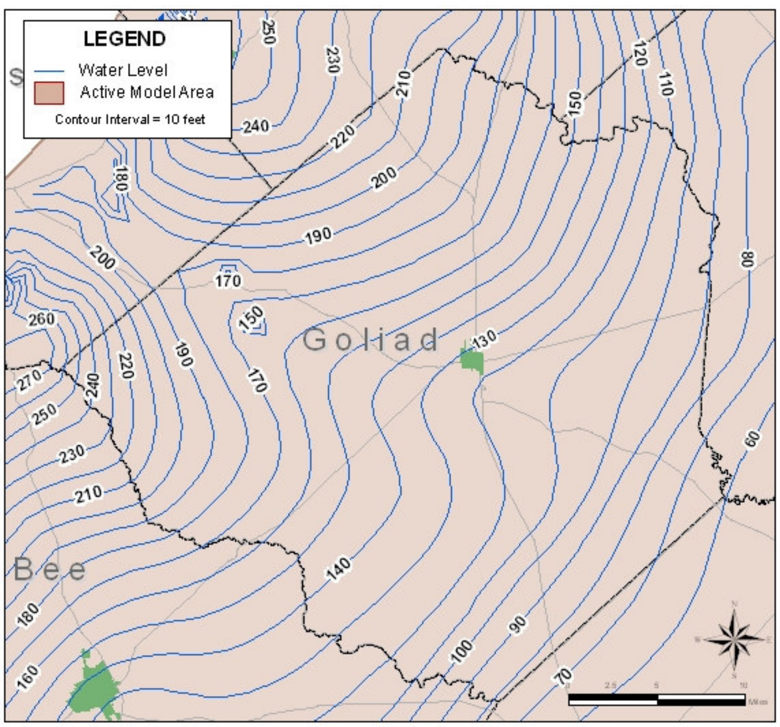
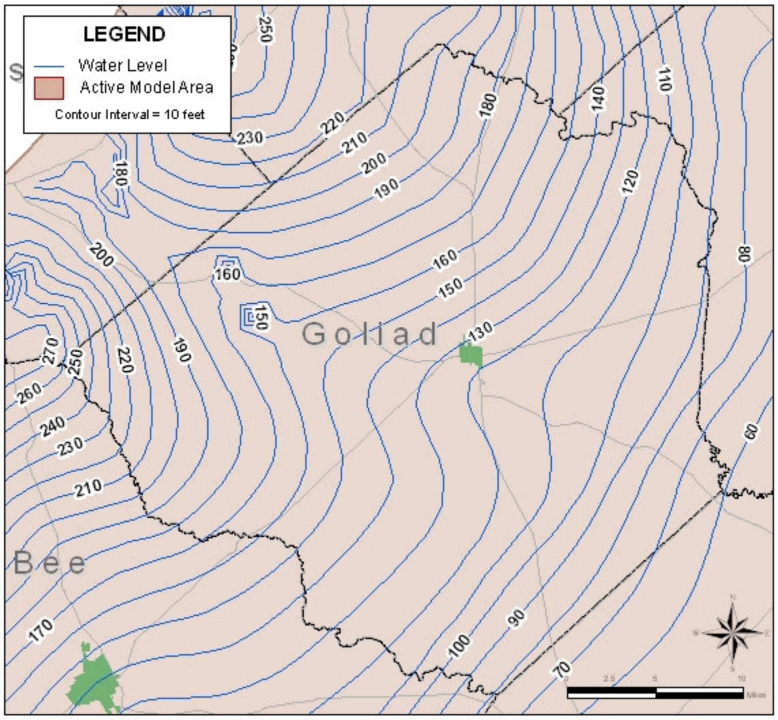


2005

Figure 3. Projected water levels in the Burkeville confining unit for the years 2000, 2005, 2010, 2020, 2030, 2040, 2050, and 2060 under average recharge conditions.



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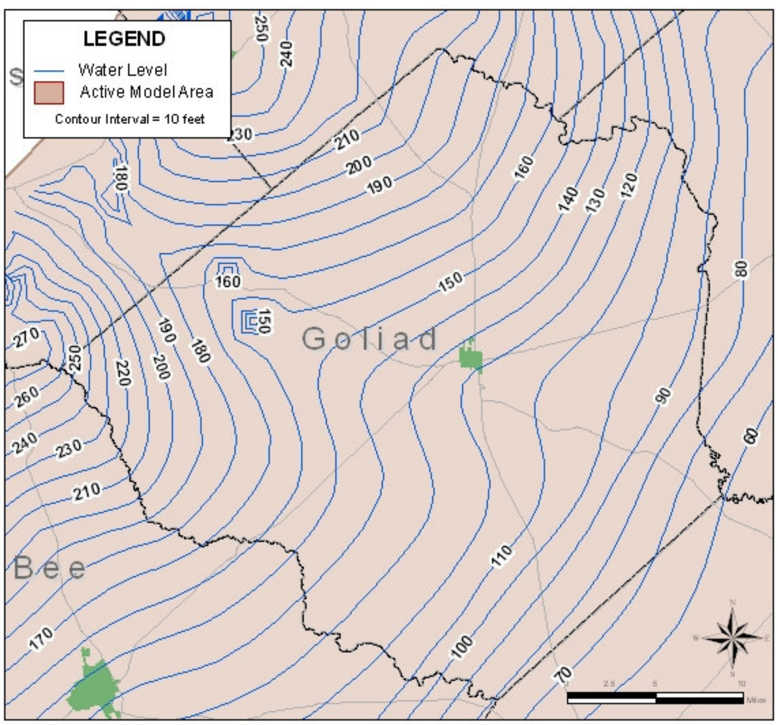

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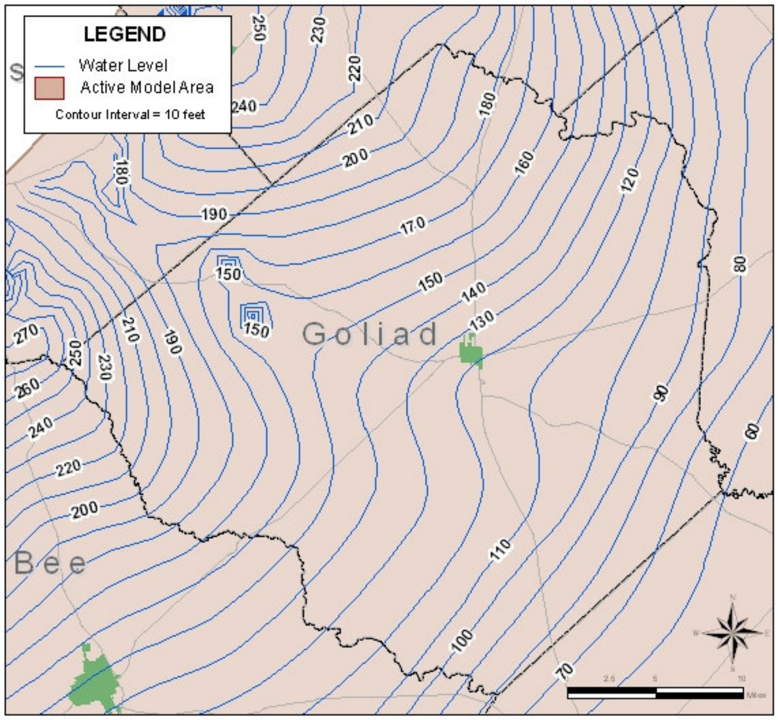

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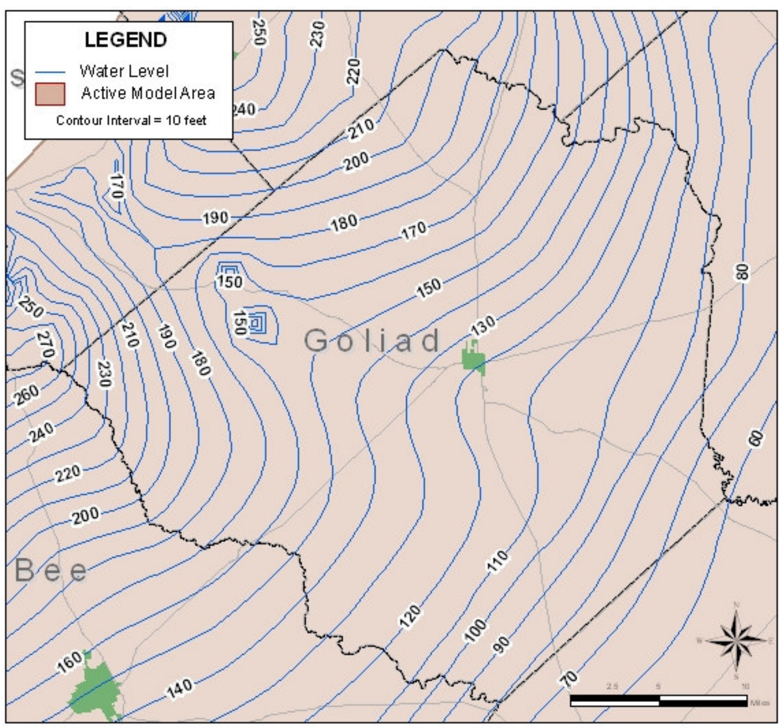

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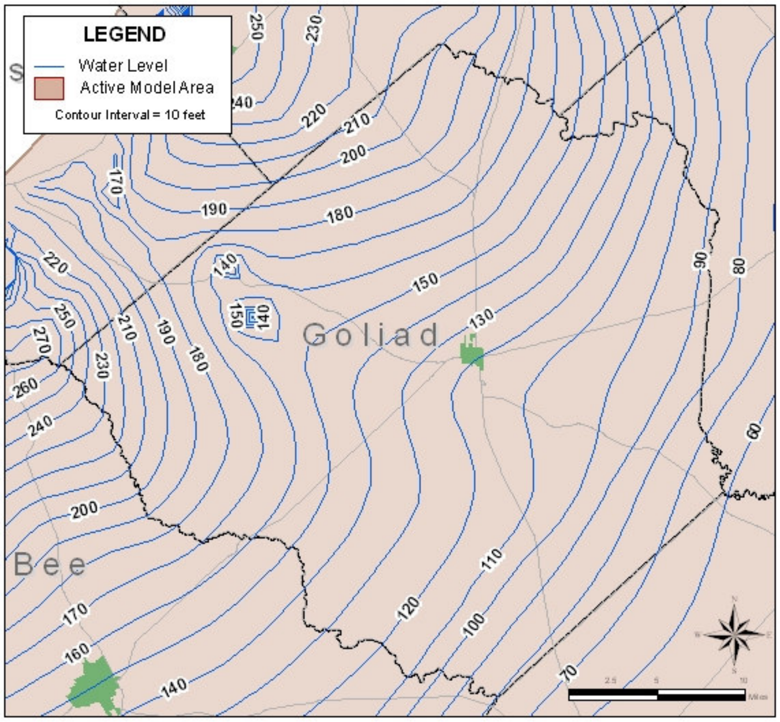

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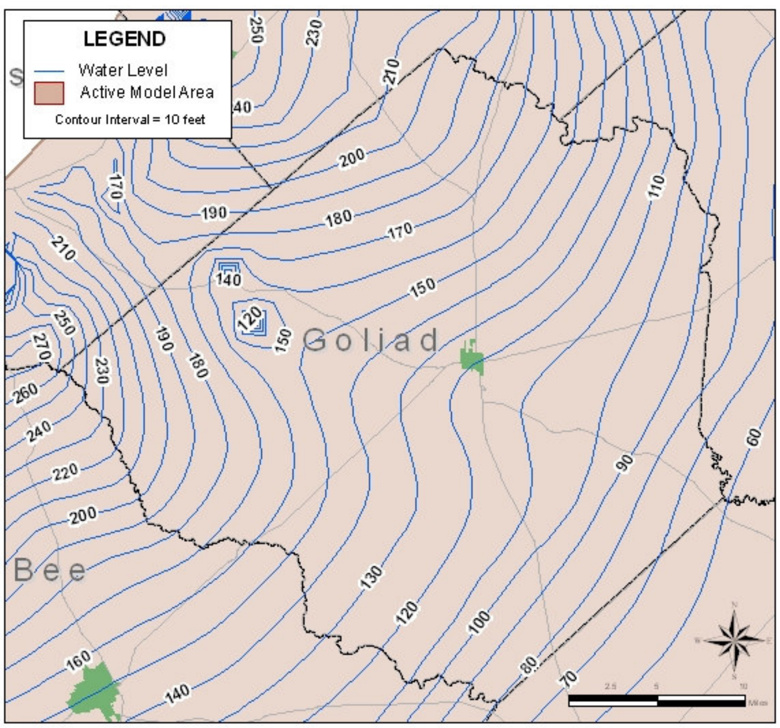

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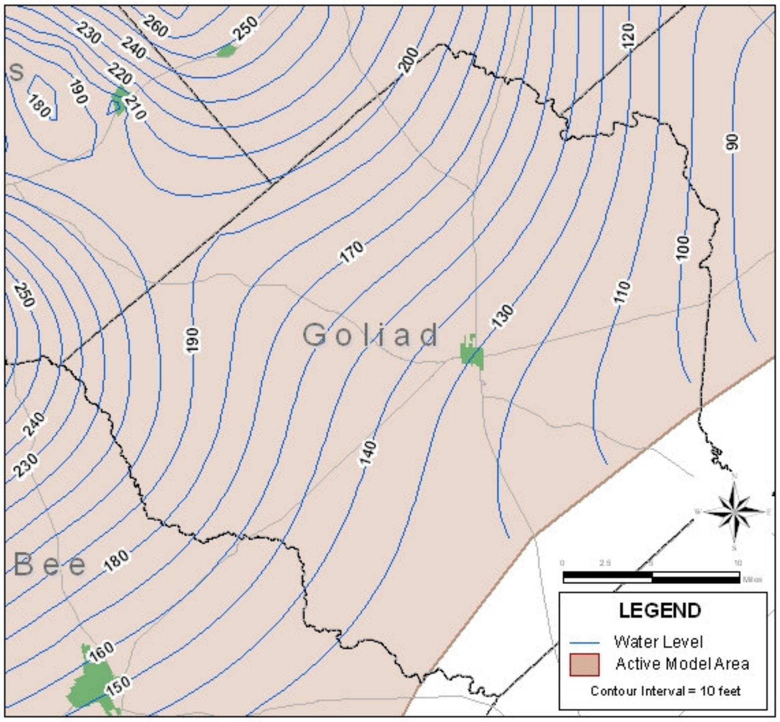

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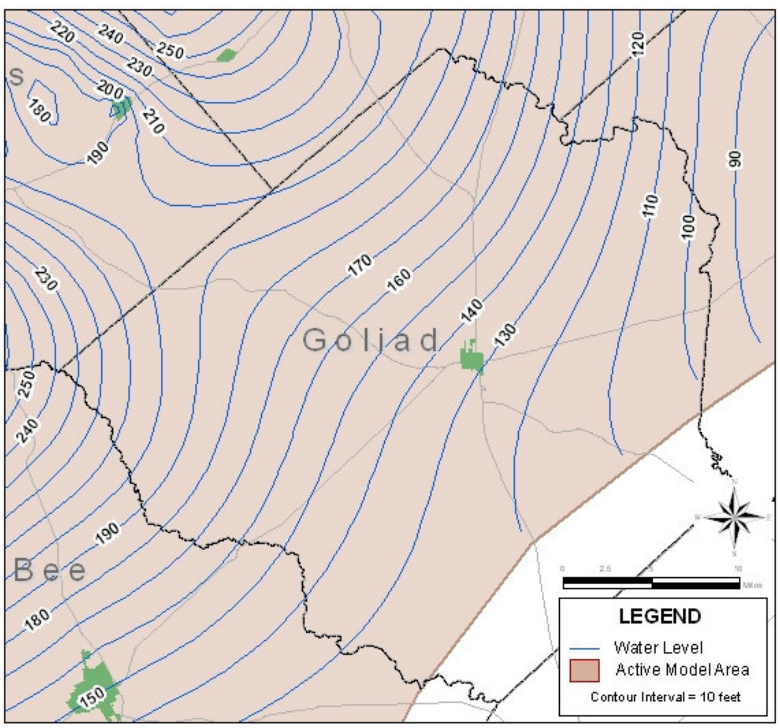
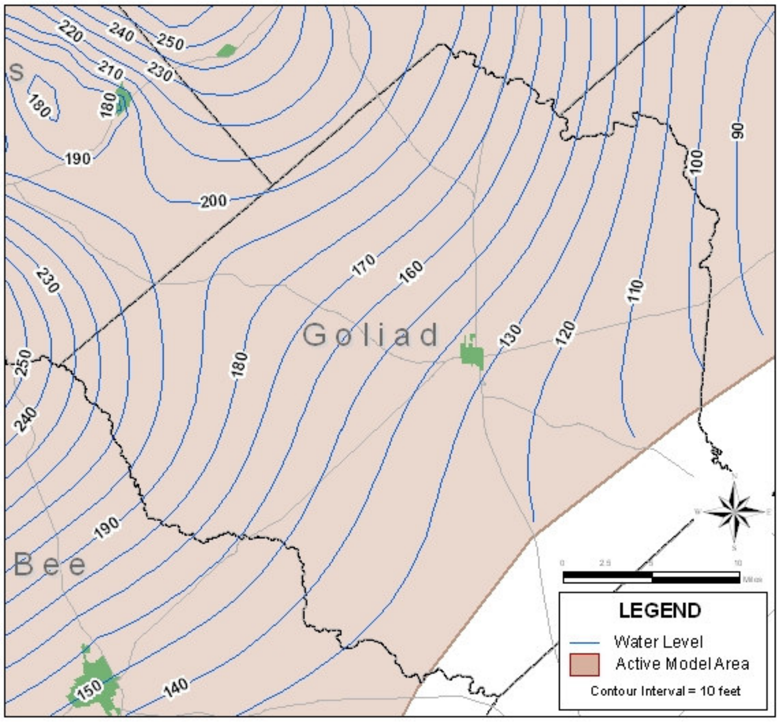


2005

Figure 4. Projected water levels in the Jasper aquifer for the years 2000, 2005, 2010, 2020, 2030, 2040, 2050, and 2060 under average recharge conditions.



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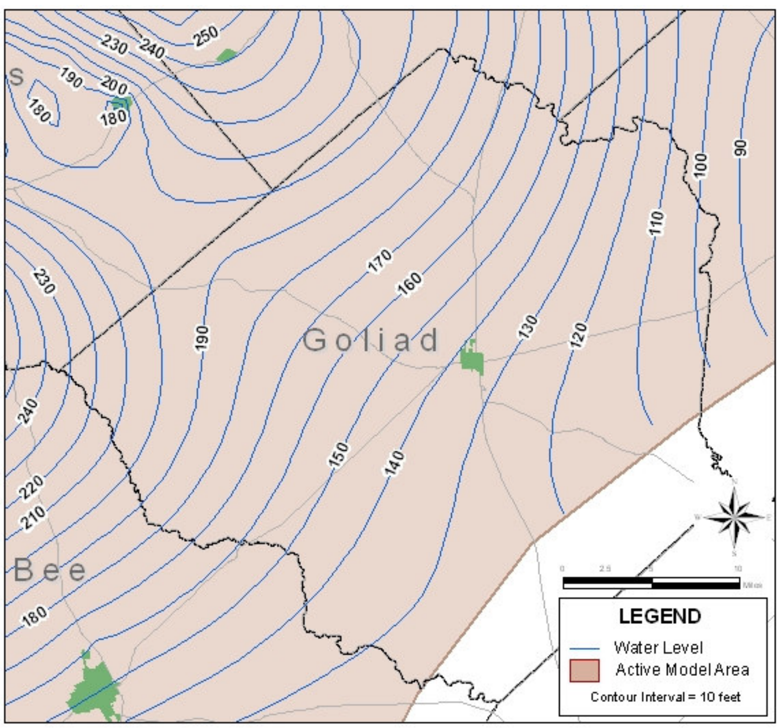

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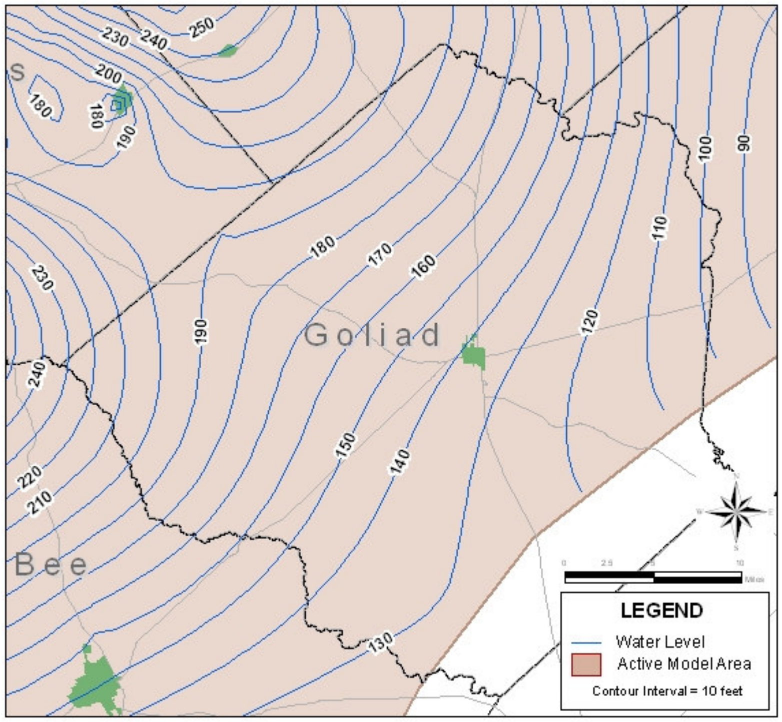

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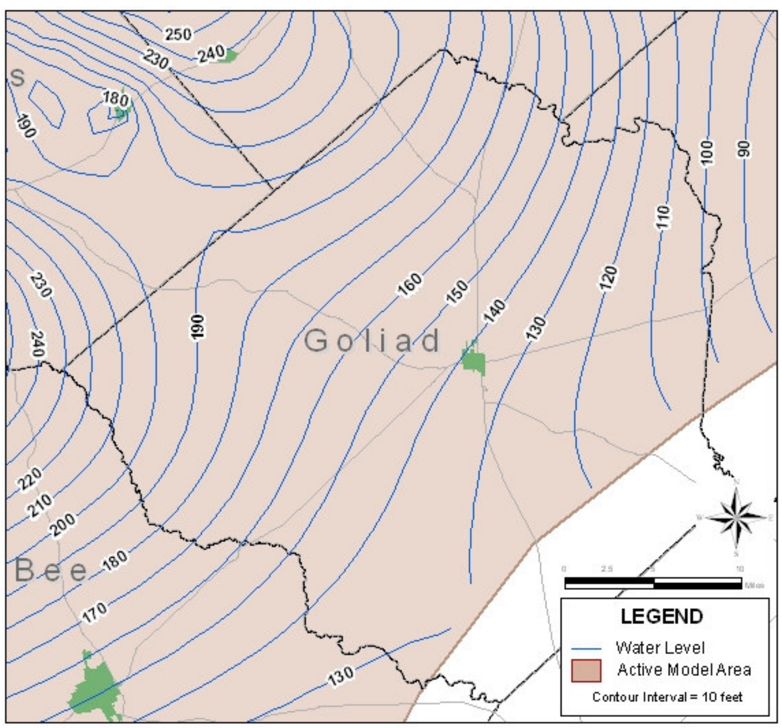

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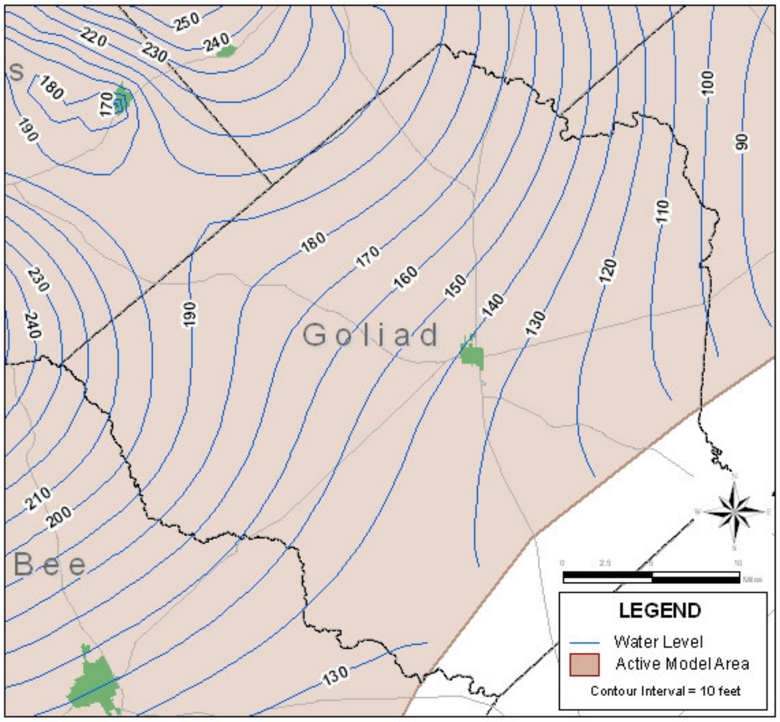

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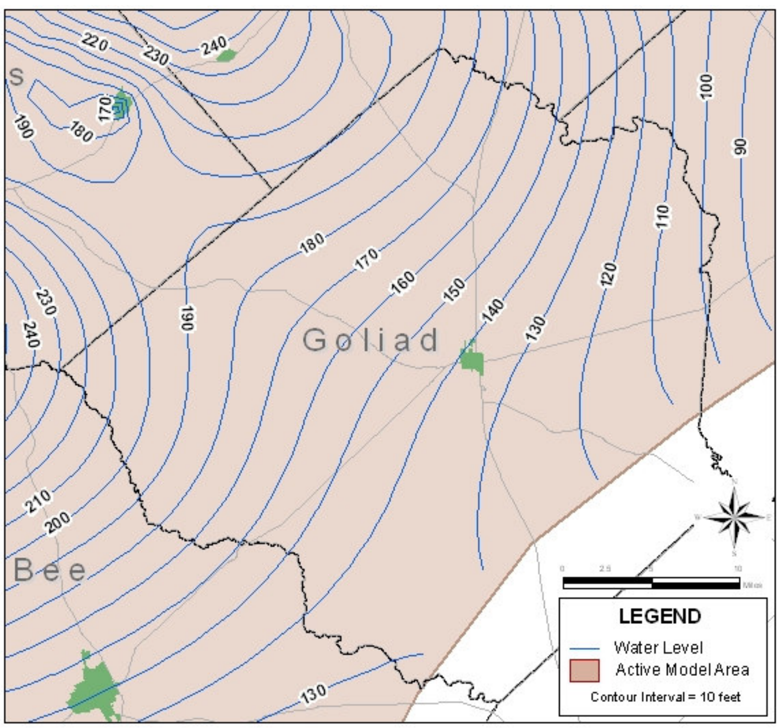

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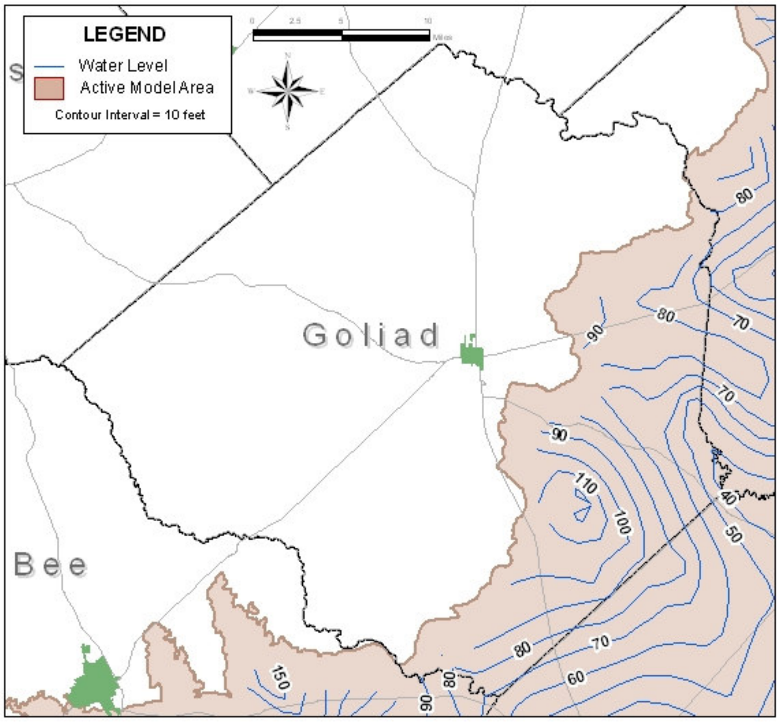
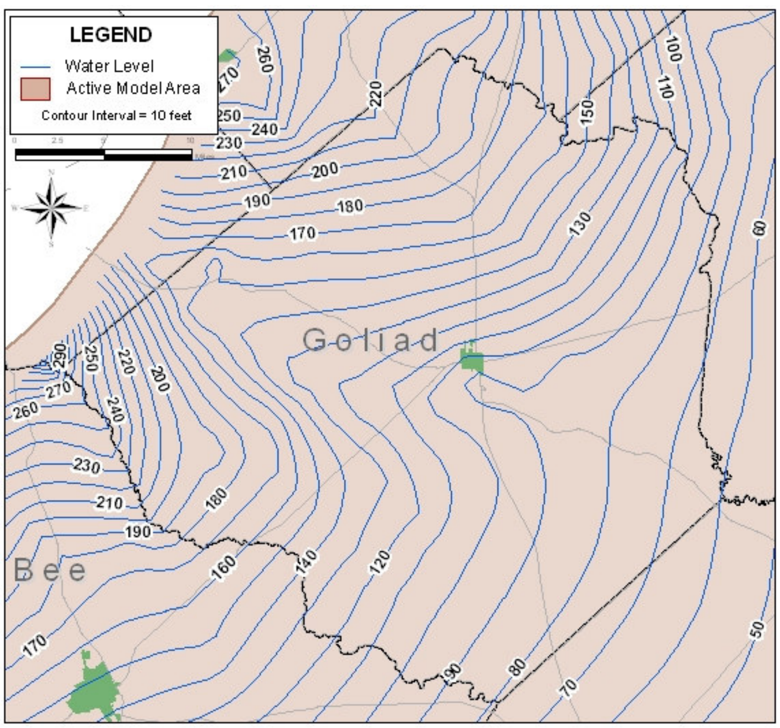
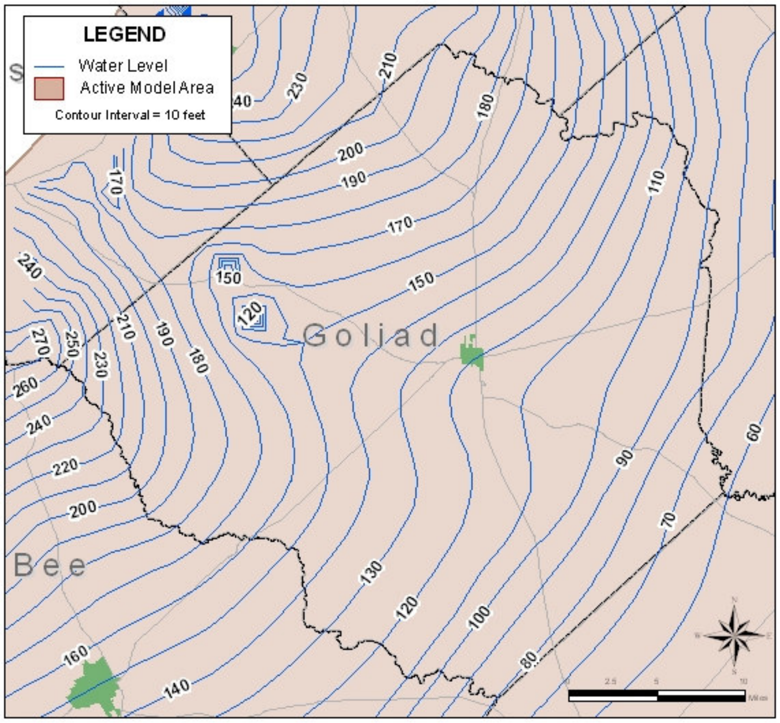


Chicot

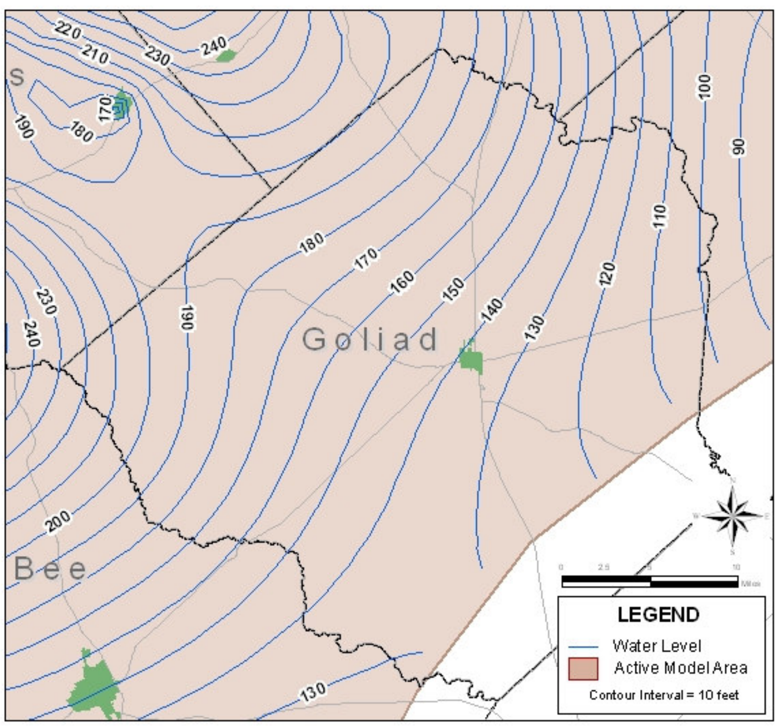


Evangeline

Figure 5. Projected water levels in the Chicot aquifer, Evangeline aquifer, Burkeville confining unit, and the Jasper aquifer for the year 2060 under drought of record conditions.



Burkeville Confining Unit



Jasper Aquifer

Figure 5. (Continued)