Letter Report

# Analysis of Drawdown for Three Ground Water Projects in Roberts County, Texas, and Comparison to the 50-Percent Goal

by

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Prepared for

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SUMMARY

Three water-production projects have been proposed in and adjacent to Roberts County, Texas, and are in various stages of planning, permitting, construction, and implementation. The projects are referred to as the Amarillo, Mesa, and Canadian River Municipal Water Authority (CRMWA) projects. The total pumping from the Ogallala aquifer in these projects is anticipated to be more than 280,000 acre-feet/year. Additional permit applications for groundwater development in the Roberts County area are expected.

This study was performed at the request of the Panhandle Groundwater Conservation District to evaluate whether these projects, at an average pumping rate of 1 acre-foot/acre per year or at some lower average pumping rate, might meet District aquifer-management goals. These projects were evaluated in various combinations. Three scenarios treated each project by itself. Three more scenarios combined the three projects in pairs. A seventh scenario analyzed all three as simultaneous projects. An eighth scenario evaluated hypothetical production from the entire Roberts County area. The scenarios were evaluated using a groundwater flow model of the Ogallala aquifer developed for the Panhandle Regional Water Planning Group.

Results of the model predict that not all of the project area would meet the Panhandle Groundwater Conservation District's Management Plan goal of having at least half of the 1998 volume of water in the Ogallala aquifer remaining by 2050 (the "50-percent" goal) if pumping rates average of 1 acre-foot/acre per year. Multiple simultaneous projects also do not meet the 50-percent goal across of the area. On average, a pumping rate of 0.5 acre-foot/acre per year would allow about half the project areas to meet the aquifer management goal in 2050, but rates would have to be as low as 0.25 acre-foot/acre per year for the 50-percent goal to be met everywhere.

It remains possible that some allocation of pumping might be found that would allow a project to increase the amount of its area meeting the 50-percent goal. Also, additional geologic data might be developed that would result in revised predictions.

## INTRODUCTION

This report provides a preliminary analysis of changes in water level and saturated thickness in the Ogallala aquifer that would be associated with proposed and anticipated groundwater development projects in Roberts County and adjacent counties (table 1). Three projects are referred to as the Amarillo, Mesa, and Canadian River Municipal Water Authority (CRMWA) projects (figure 1). This report includes results for (1) each project run by itself, (2) projects operated simultaneously in pairs at rates and schedules given in table 1, (3) all three projects operating simultaneously as in table 1 and at various levels of reduced pumping, and (4) the three projects combined with other hypothetical pumping from the entire Roberts County area, at the rates and schedules given in table 1 and at various levels of reduced pumping.

Results of each project scenario were compared to a regional baseline level of future groundwater pumping without these projects. The Panhandle Groundwater Conservation District's Management Plan has the goal of having at least 50 percent of the 1998 estimated saturated thickness remaining in the Ogallala aquifer in 2050. This goal also has been adopted by the Panhandle Regional Water Planning Group. The focus of this study's analysis is on the feasibility of meeting that goal given the presently available description of these projects.

## METHODS AND APPROACH

This study was conducted between October and December, 2000, at the request of the Panhandle Groundwater Conservation District (the District).

To predict the drawdown of water levels in the Ogallala aquifer owing to these projects, the Bureau of Economic Geology (BEG) used a groundwater flow model developed for the Panhandle Regional Water Planning Group, described in Dutton and others (2000b). That model used MODFLOW (Harbaugh and McDonald, 1996) to interpret groundwater flow with specified pumping rates, hydrologic properties, and boundary conditions. The model had been calibrated for the period of 1950 to 1998, and baseline predictions for water levels in the 18 counties of the Panhandle Regional Water Planning Area were made for the period of 2000 to 2050, assuming future levels of groundwater demand. The model includes more than 27,000 1-mile × 1-mile model cells. Many assumptions are involved in the development and calibration of the Region A groundwater model (Dutton and others, 2000b). Hydraulic conductivity was mapped and assigned to the model on the basis of geologic maps of the amount of sand and gravel in the aquifer (Seni, 1980). Model calibration error was about 75 ft. Comparison of model results between project and baseline simulations, however, may cancel out some model error. Preliminary simulations also had been run using an earlier version of the model (Dutton and others, 2000a), in which transmissivity was assigned using geostatistical mapping techniques and held constant as water levels declined.

The model underestimated 1998 water levels in much of the Roberts County area (Dutton and others, 2000b). Model predictions, therefore, probably underestimate the amount of water remaing in 2050 although predictions of amount of drawdown might be more accurate. Model predictions may be considered conservative for this area, as more water may remain in 2050 than predicted.

One of the District's stipulations for the analysis is that there is to be no pumping allowed within ½-mile of property boundaries. The District provided digital ArcView files of the tracts of land included in the projects and the amount of pumping to be initially assigned to each tract. BEG used a CAD program to define the ½-mile setback from boundaries and used ArcView to assign the 1 square mile model cells. The Amarillo and Mesa projects consist of a number of tracts of land. The approach was taken to allow the ½-mile setback rule to be relaxed where contiguous properties lay within one project. Several parcels have extensions that are only 1 mile in width. It may be possible to locate wells along the center line of the extensions and thus honor the ½-mile setback rule. This report's analysis was simplified, however, by omitting these areas from the simulations.

Actual locations and future rates of pumping of water wells might differ from those simulated in this study. It was not within the scope of this study to target particular locations for placing water wells. Actual well locations and pumping rates need to be determined from detailed site considerations that are beyond the scope of this study. Pumping was assigned to each model cell representing the Amarillo and Mesa tracts not excluded by the ½-mile setback rule. Pumping was assigned to 99 cells for the Amarillo tracts and 354 cells for the Mesa tracts. Well locations have been selected and some of the 23 planned wells already have been installed for the CRMWA project. Of the 75 model cells representing the CRMWA tract, 16 contain wells and 7 of those cells include 2 wells per section as allowed by the District's permit. As part of the simulations, model cells represented additional hypothetical wells in the remainder of the CRMWA tract (discussed below).

Additional large-scale groundwater projects are expected in the entire Roberts County area. To represent these projects, another 370,000 acre-feet/year of pumping was assigned to 578 model cells and included in simulations with the Amarillo, Mesa, and CRMWA projects (figure 1).

Initial simulations assumed that 100 percent of the project rate was pumped in the first year of the project and this rate continued for later years. Thus, for example, the Mesa project went from 0 acre-feet/year in 2004 to 170,000 acre-feet/year in 2005 and CRMWA went from 0 acre-feet/year in 2000 to 40,000 acre-feet/year in 2001. An additional simulation was run for the CRMWA well field, in which pumping was 30,000 acre-feet/year for 2001 to 2010, increased by 500 acre-feet/year to 2030, and was 40,000 acre-feet/year from 2040 to 2050. This latter simulation had been included in a previous analysis for the Panhandle Water Planning Group (Dutton and others, 2000a, b). In addition, the CRMWA tract was simulated as having pumping assigned to each of its 75 model cells.

It is important to note that a uniform pumping rate of 1 acre-foot per year per acre applied to all model cells in a tract results in increased drawdown near the center of each project. This is mainly owing to the overlapping of areas of influence of wells. Where the areas of influence of two or more wells overlap, the drawdowns are added together. With a spatially uniform allocation of pumping among cells, the center of the tract has the greatest overlap of areas of influence and the greatest cumulative drawdown. Project pumping rates were allocated away from the center to decrease this effect.

Finally, pumping rates for the three combined projects and for the whole Roberts County scenario were successively reduced from 100 to 25 percent of total (table 4), the same for each project. This was to explore the degree to which water levels in model cells would meet the 50-percent goal at reduced pumping levels. The 100 and 70 percent pumping rates, for example, correspond to 1 and 0.7 acre-foot/acre per year, respectively.

Results of each of project simulations were compared to the baseline projection for 2050. Subtracting predicted water levels of the 2050 baseline simulation from those of the 2050 CRMWA simulation, for example, gives the amount of drawdown in water levels that would be attributed to the CRMWA well field alone. Dividing the saturated thickness projected for a given project in 2050 by the 1998 saturated thickness gives a saturated-thickness ratio. The goal of the Panhandle Ground Water Conservation District is that by 2050 at least half of the 1998 saturated thickness of the aquifer stills remains.

## RESULTS

### Water in Storage

Table 2 lists the amount of water estimated to be in storage in the Ogallala aquifer beneath the three project areas as of 1998. The numbers were derived from (1) saturated thickness of each model cell, (2) specific yield as mapped by Knowles and others (1984), (3) estimated recharge and return flow for the period from 1999 to 2050, and (4) project area within each model cell. Given the 50-percent rule, half of the 1998 volume of 80.5 million acre-feet of water in storage in the entire Roberts County area (figure 1), or 40.25 million acre-feet, should remain by 2050. In addition, as much as 5.7 million acre-feet may be expected to reach the water table from natural recharge and return flow from irrigation. So, perhaps 46 million acre-feet of water might be defined as 'available' for production between 1999 and 2050 given the District's 50-percent goal. At specified pumping rates (table 1), the 'available' water would last for approximately 21 to 23 years. If projects were able to meet the 50-percent goal, it would be by drawing water from beneath adjacent areas. For the 50-percent goal to be met solely by draining water from beneath individual projects, pumping rates would have to be as low as approximately 0.41 to 0.45 acre-feet/acre per year.

### Analysis of Separate Projects

The first step in the analysis was to test whether each project meets the Panhandle Ground Water Conservation District's goal of having 50 percent of the 1998 volume remaining in 2050. For the Amarillo and Mesa projects, an initial allocation of pumping at 1 acre-foot/acre per year was assigned to the model cells, then the resulting saturated-thickness ratio (the ratio of 2050 saturated thickness with project to the 1998 saturated thickness) was compared to the 50-percent goal. Pumping rates per model cell then were increased or decreased as needed to (1) have all model cells in the project tract meet the 50-percent goal and (2) keep the total pumping rate at the assigned level (table 1). These allocations were made using the August 2000 groundwater flow model (Dutton and others, 2000a).

Table 3 summarizes allocated pumping rates used for the projects. Rates ranged from 0.003 to 7.34 acre-feet/year per acre, not counting model cells to which no pumping was assigned. The average rate is close to 1 acre-foot per year per acre.

Table 4 shows the percent of each project area that is simulated as meeting the District's 50-percent goal. From 34 to 72 percent of the Amarillo and Mesa projects, respectively, are simulated as meeting the 50-percent goal by 2050 at average pumping rates of 1 acre-foot/acre per year. Figures 2 and 3 show the cumulative amount of drawdown predicted for these projects through 2050. The allocation of pumping among model cells in the tracts is not unique. Some other configuration or allocation of pumping might be found to meet the 50-percent goal.

Figures 4 and 5 show predicted drawdown by 2050 for the CRMWA tract. Drawdown was found to exceed the 50-percent drawdown limit in about 30 percent of the project area with pumping allocated only to the 16 model cells representing the 23 wells of the planned well field (figure 4). The model also predicts that some of the well field would go dry by 2050. No cells are predicted to go dry when pumping is distributed to 75 model cells (figure 5), but only about 44 percent of the area would meet the 50-percent goal. As previously stated, this is not a unique solution and it is possible that some other allocation might be found with which the goal could be met.

## Analysis of Simultaneous Projects

The scope of work included modeling all three projects (Amarillo, Mesa, and CRMWA) operating simultaneously and with other hypothetical pumping from the Roberts County area (figure 1). For these analyses, the allocated pumping rates that met the 50-percent goal for each of the specified projects were combined and additional simulations were made.

Combining projects results in the addition of their respective areas of drawdown. The overlap of the areas of drawdown predicted for the individual projects results in an increase in the percent of area of each project area that would exceed the 50-percent limit (table 4). From 4 to 29 percent of the individual project areas might meet the 50-percent goal given the various pairs of simultaneous projects. With all three projects operating simultaneously, less than 11 percent of the project areas meet the 50-percent goal at 1 acre-foot/acre per year. At

0.5 acre-foot/acre per year, about 46 percent of the three projects' area is simulated as meeting the 50-percent goal (table 4).

If uniform pumping of groundwater were to occur across all of the Roberts County area, rates would have to drop to less than 0.25 acre-foot/acre per year for the 50-percent goal to be met (table 4). This is less than the 0.45 acre-foot/acre per year rate predicted from the water budget approach (table 2), but is likely a more accurate prediction as it is based on the dynamics of groundwater movement in the area.

## REFERENCES

Dutton, A. R., Reedy, R. C., and Mace, R. E., 2000a, Predicted saturated thickness in the Ogallala aquifer in the Panhandle Water Planning Area—Numerical simulations of 2000 through 2050 withdrawal projections: Topical Report prepared for the Region A Panhandle Water Planning Group, Panhandle Regional Planning Commission under Contract number UTA99-0230, August 2000.

Dutton, A. R., Reedy, R. C., and Mace, R. E., 2000b, Saturated Thickness in the Ogallala Aquifer in the Panhandle Water Planning Area—Simulation of 2000 through 2050 Withdrawal Projections: Topical Report prepared for the Region A Panhandle Water Planning Group, Panhandle Regional Planning Commission under Contract number UTA99-0230, December 2000.

Harbaugh, A. W., and McDonald, M. G., 1996, User's documentation for MODFLOW-96, an update to the U.S. Geological Survey modular finite-difference groundwater flow model: U.S. Geological Survey Open-File Report 96-485.

Knowles, Tommy, Nordstrom, Phillip, and Klemt, W. B., 1984, Evaluating the groundwater resources of the High Plains of Texas: Austin, Texas, Department of Water Resources Report 288, volumes 1 to 3.

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Table 1. Operating schedules and projected pumping for Roberts County area water projects

| Project name used in this report | Project period | Approximate volume (acre-feet/year) |
| --- | --- | --- |
| Amarillo | 2025-2050 | 71,197 |
| Mesa (including QUIXX) | 2005-2050 | 170,000 |
| Canadian River Municipal Water Authority (CRMWA) | 2001-2050 | 40,000 |
| Roberts County "Other" | 2001-2050 | 369,920 |

Table 2. Estimated average availability of water in the Ogallala aquifer in PGWD area including three projects

| Location | Average 1998 saturated thickness[1] (ft) | Total 1998 water volume[2] (1000 acre feet) | 1998-2050 Recharge + Return Flow (1000 acre feet) | Available water to meet 2050 goal[3] (1000 acre feet) | Pumping rate to meet 2050 goal[4] (acre-feet/acre per year) | Years of supply at 1 acre-foot/acre per year[5] |
|---|---|---|---|---|---|---|
| Amarillo Field | 240 | 2,827 | 102 | 1,516 | 0.43 | 22 |
| Mesa Field | 233 | 7,686 | 267 | 4,110 | 0.44 | 23 |
| CRMWA Field | 250 | 1,715 | 64 | 921 | 0.41 | 21 |
| Roberts Co. | 255 | 28,647 | 1,101 | 15,425 | 0.45 | 23 |

[1] Average 1998 saturated thickness ranges from 2 to 556 ft

[2] Calculated by summing the product of average 1998 saturated thickness, specific yield, and tract area for all model cells

[3] Calculated by dividing "total 1998 water volume" by two to represent the 50-percent goal, and adding recharge and return flow

[4] Calculated by dividing "Available water" by 52 years and 640 acres/section. Assumes no inflow to the project area from outside its boundaries. Goal rate ranges from 0.03 to 0.86 acre-feet/yr per acre

[5] Calculated by dividing "Available water" by pumping rate from table 1 based on 1 acre-foot/yr per acre. Assumes no inflow to the project area from outside its boundaries

Table 3. Range in assumed pumping rates

Rate (acre-feet/year per acre)

| | Amarillo | Mesa | CRMWA |
|---|---|---|---|
| Minimum | 0.08 | 0 | 0.003 |
| Maximum | 2.04 | 7.34 | 1.710 |
| Average | 1.12 | 1.01 | 0.714 |

Percent of model cells

| Rate (acre-feet/year per acre) | Amarillo | Mesa | CRMWA |
|---|---|---|---|
| 0 to 0.5 | 15% | 37% | 27% |
| 0.5 to 1 | 34% | 29% | 43% |
| 1 to 2 | 47% | 19% | 28% |
| 2 to 5 | 3% | 13% | 3% |
| 5 to 10 | 0% | 2% | 0% |

Table 4. Percent of model cells meeting the 50-percent goal

| | Combined simulation | Project area | Percent of 1 acre-foot/acre per year pumping rate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100 | 75 | 50 | 40 | 35 | 30 | 25 |
| 1 | Amarillo alone | Amarillo | 72 | nm | nm | nm | nm | nm | nm |
| 2 | Mesa alone | Mesa | 34 | nm | nm | nm | nm | nm | nm |
| 3 | CRMWA alone | 16 model cells | 71 | nm | nm | nm | nm | nm | nm |
| 4 | CRMWA alone | All cells | 44 | nm | nm | nm | nm | nm | nm |
| 5 | CRMWA & Mesa | Mesa | 20 | nm | nm | nm | nm | nm | nm |
| 5 | CRMWA & Mesa | CRMWA | 4 | nm | nm | nm | nm | nm | nm |
| 6 | Amarillo & Mesa | Amarillo | 31 | nm | nm | nm | nm | nm | nm |
| 6 | Amarillo & Mesa | Mesa | 22 | nm | nm | nm | nm | nm | nm |
| 7 | Amarillo & CRMWA | Amarillo | 29 | nm | nm | nm | nm | nm | nm |
| 7 | Amarillo & CRMWA | CRMWA | 16 | nm | nm | nm | nm | nm | nm |
| 8 | Amarillo, Mesa, & CRMWA | Amarillo | 9 | nm | 46 | nm | 100 | nm | nm |
| 8 | Amarillo, Mesa, & CRMWA | Mesa | 16 | nm | 51 | nm | 100 | nm | nm |
| 8 | Amarillo, Mesa, & CRMWA | CRMWA | 0 | nm | 31 | nm | 100 | nm | nm |
| 8 | Amarillo, Mesa, & CRMWA | All cells | 11 | nm | 46 | nm | 100 | nm | nm |
| 9 | Roberts | Amarillo | 0 | 0 | 55 | 76 | 88 | 94 | 99 |
| 9 | Roberts | Mesa | 5 | 17 | 52 | 75 | 86 | 94 | 97 |
| 9 | Roberts | CRMWA | 0 | 0 | 28 | 63 | 73 | 84 | 93 |
| 9 | Roberts | All cells | 6 | 15 | 56 | 78 | 87 | 94 | 98 |

nm – not modeled

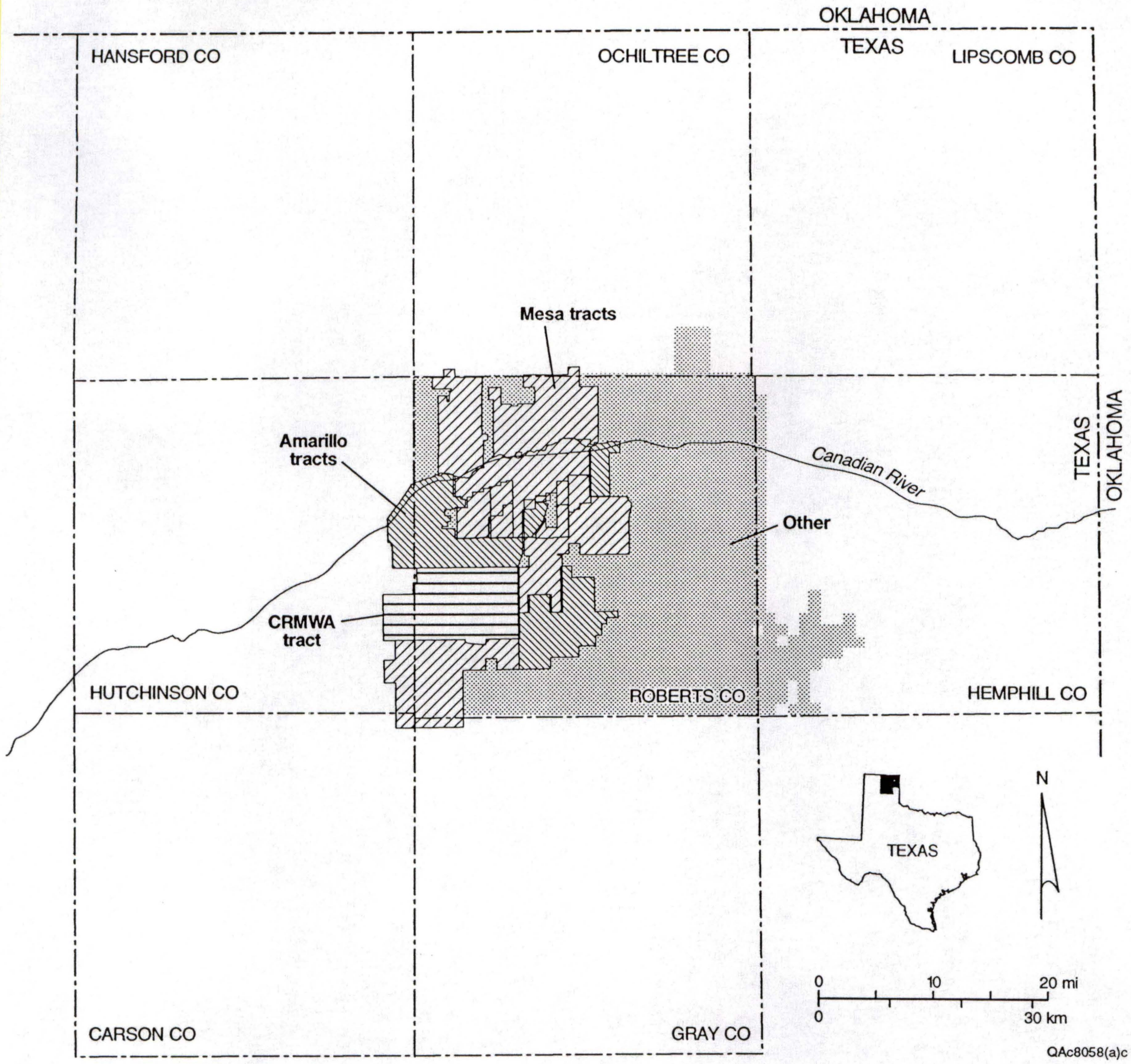


Figure 1. Location of study area in and around Roberts County, Texas. A groundwater model was used to evaluate water levels and pumping rates for three projects (Amarillo, CRMWA, and Mesa), operating separately as well as simultaneously. Other possible groundwater development was studied by simulating pumping from additional Roberts County and adjacent areas.

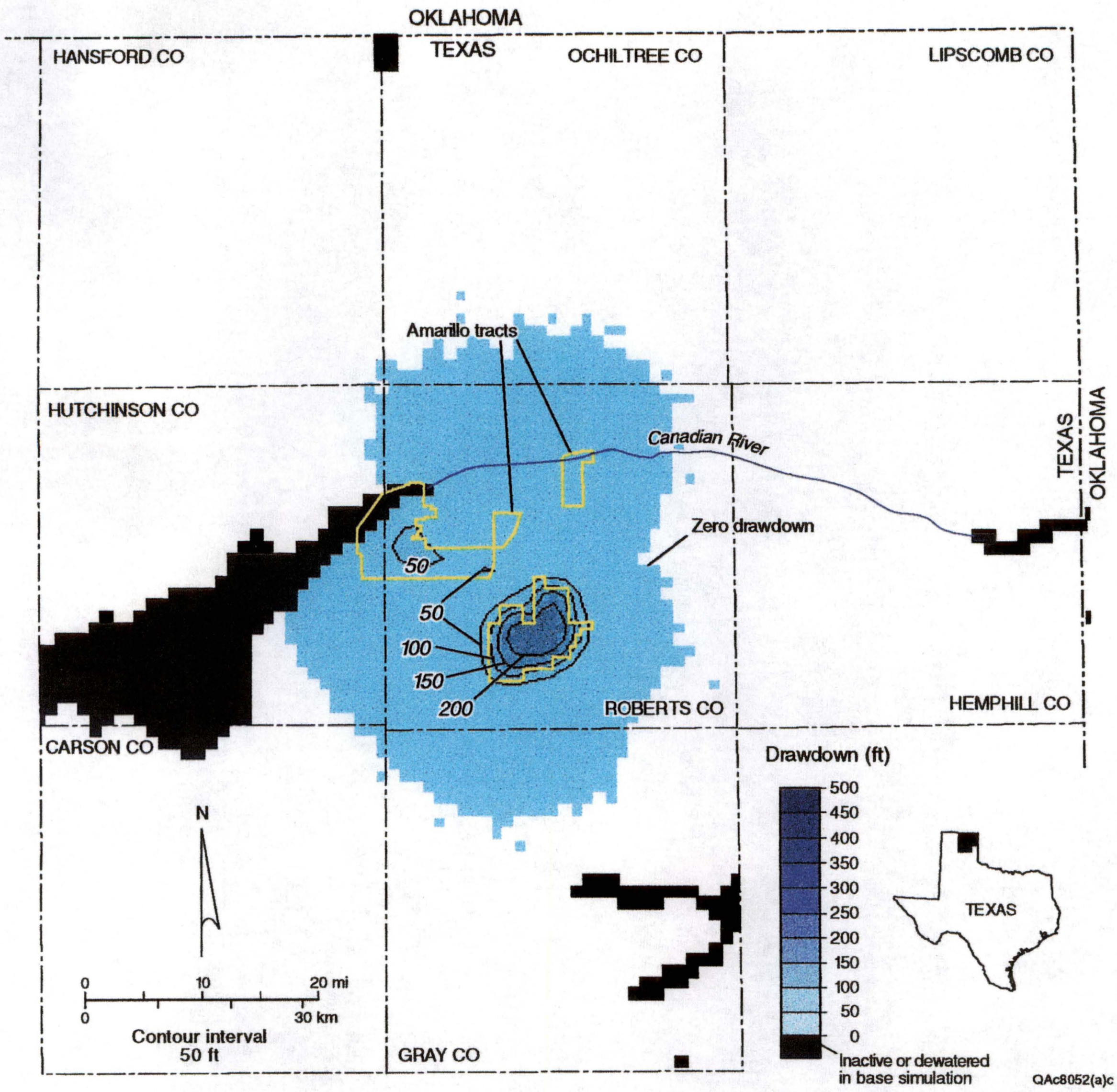


Figure 2. Drawdown of water levels in the Ogallala aquifer in 2050 in the vicinity of Roberts County, Texas, owing to the "Amarillo" groundwater project. Drawdown determined from the difference between water levels simulated with versus without the project. Pumping was assigned to each 1-mi$^2$ model cell in the project area. Average pumping rate was approximately 1 acre-foot/acre per year; rates were lower toward the center and higher away from the center. Other allocations and pumping rates would yield different amounts of drawdown.

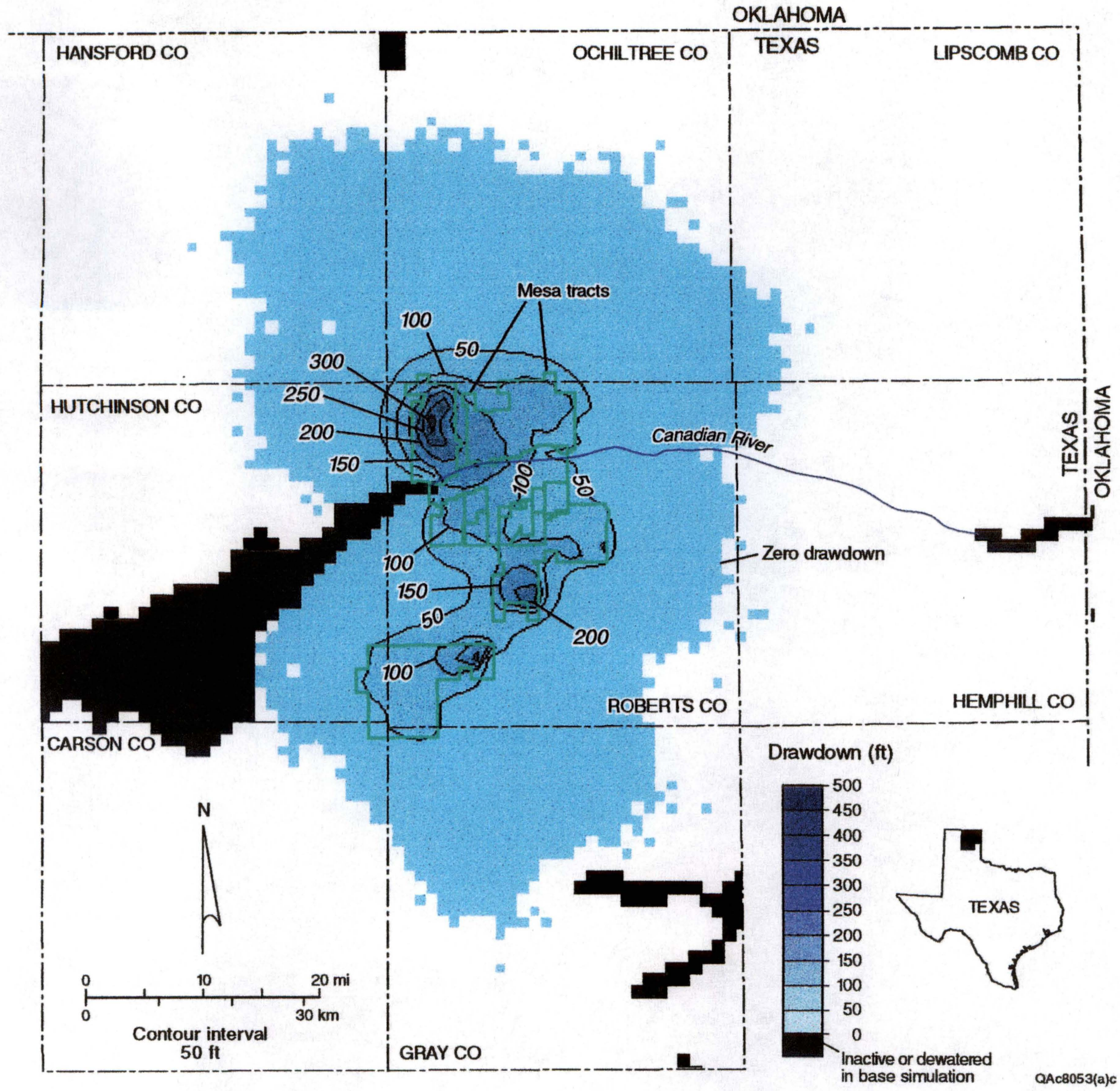


Figure 3. Drawdown of water levels in the Ogallala aquifer in 2050 in the vicinity of Roberts County, Texas, owing to the "Mesa" groundwater project. Drawdown determined from the difference between water levels simulated with versus without the project. Pumping was assigned to each 1-mi$^2$ model cell in the project area. Average pumping rate was approximately 1 acre-foot/acre per year; rates were lower toward the center of the project and higher away from the center. Other allocations and pumping rates would yield different amounts of drawdown.

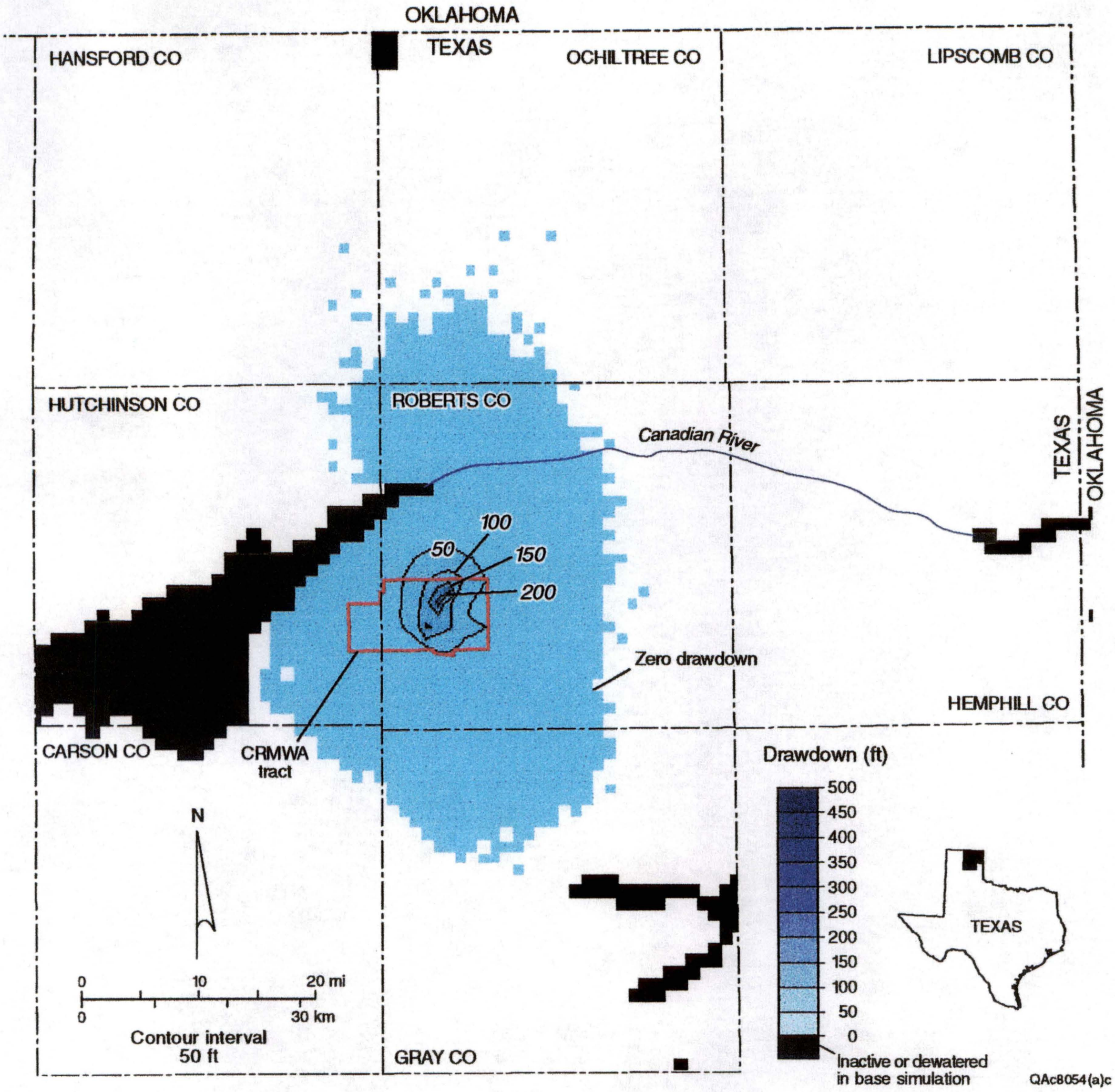


Figure 4. Drawdown of water levels in the Ogallala aquifer in 2050 in the vicinity of Roberts County, Texas, owing to the "CRMWA" groundwater project assumed to initially pump 30,000 acre-feet per year. Drawdown determined from the difference between water levels simulated with versus without the project. Pumping was assigned to 16 model cells, representing 23 wells, with 7 model cells have 2 wells.

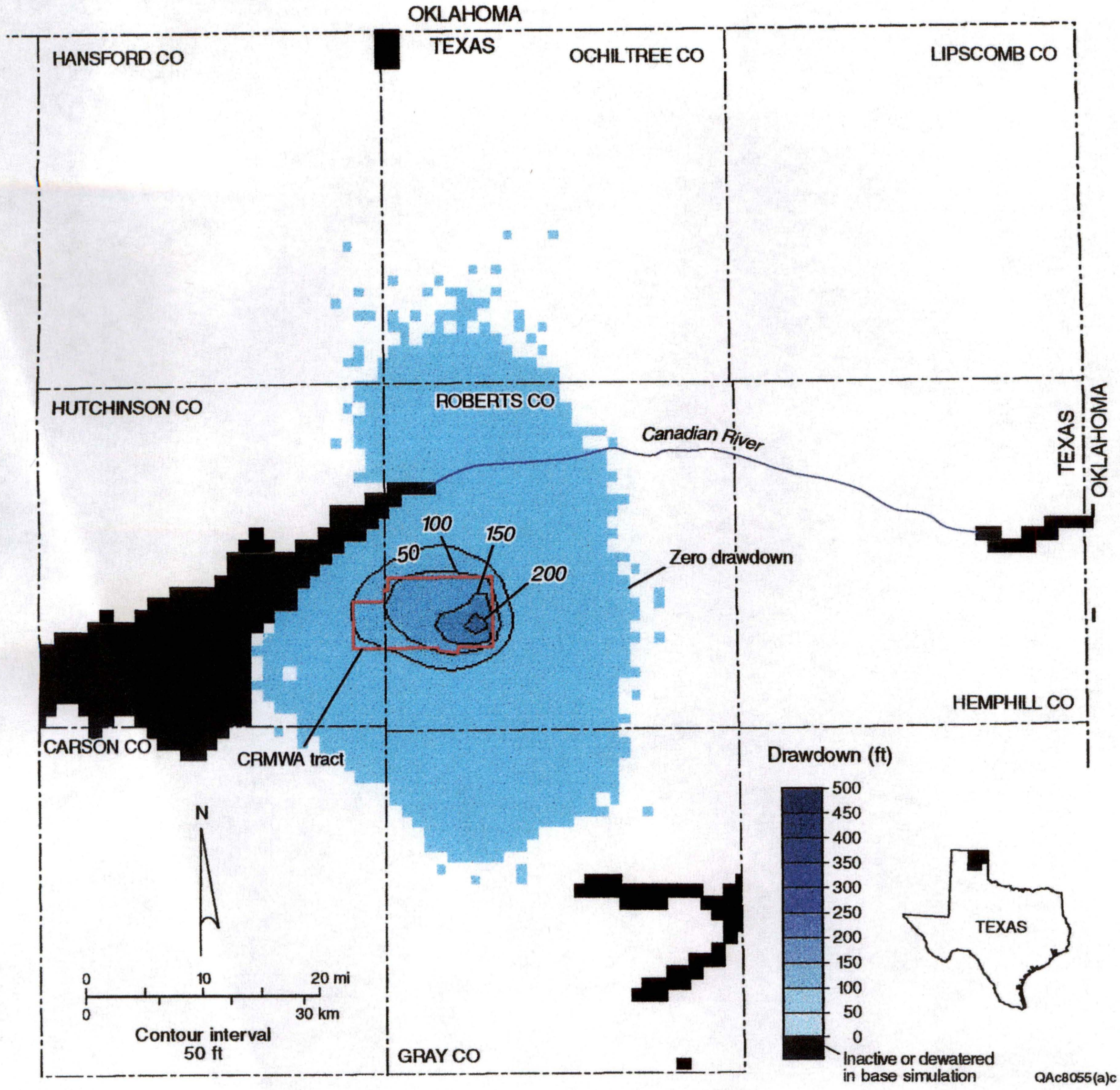


Figure 5. Drawdown of water levels in the Ogallala aquifer in 2050 in the vicinity of Roberts County, Texas, owing to the "CRMWA" groundwater project with pumping reallocated throughout the tract. Drawdown determined from the difference between water levels simulated with versus without the project. Pumping was assigned to each 1-mi$^2$ model cell in the project area. Average pumping rate by 2050 was approximately 1 acre-foot/acre per year; rates were lower toward the center and higher away from the center. Other allocations and pumping rates would yield different amounts of drawdown.