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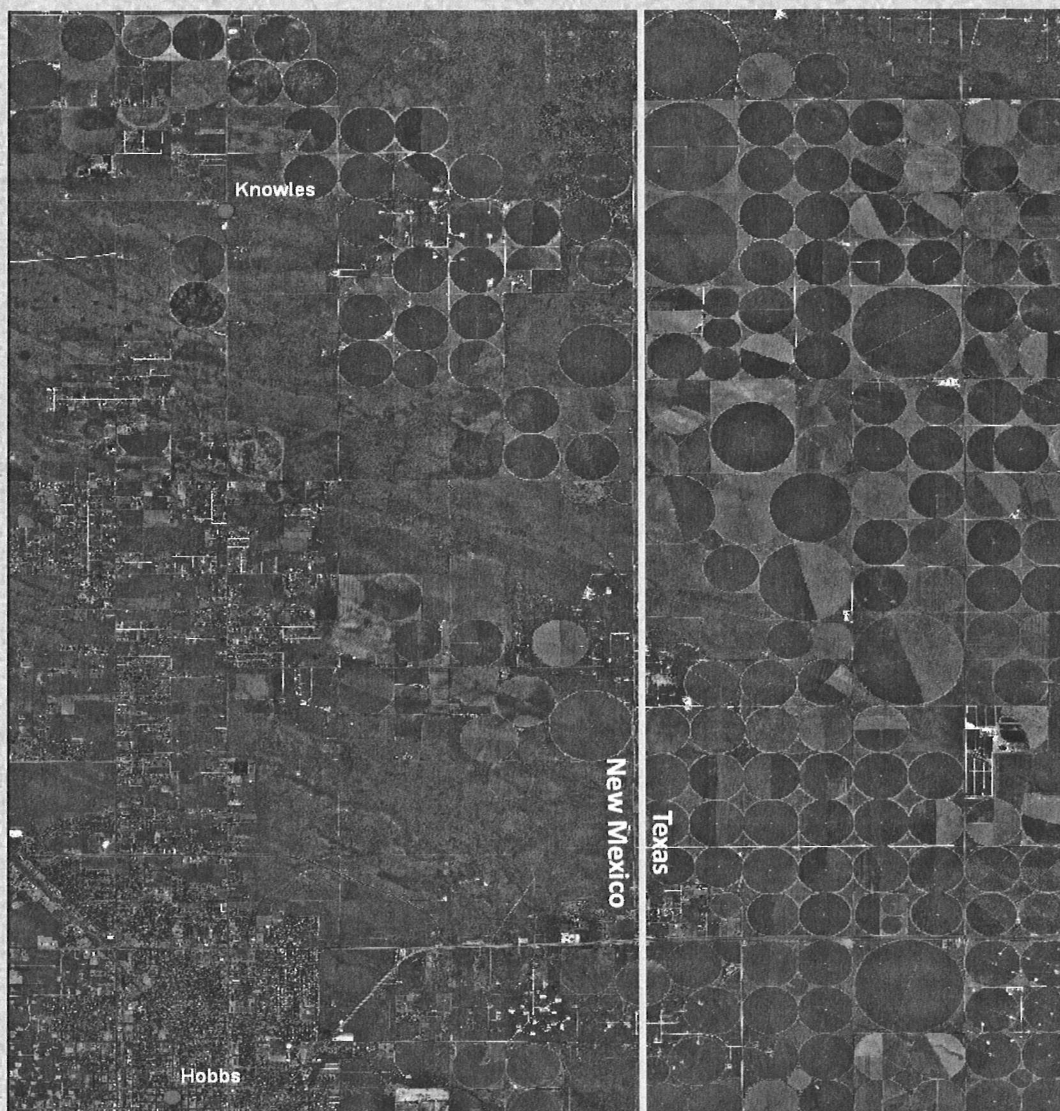
40-YEAR WATER DEVELOPMENT PLAN
LEA COUNTY, NEW MEXICO



prepared by

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EXECUTIVE SUMMARY

Lea County is experiencing significant economic development as a result of an influx of high technology companies moving into the County, the ongoing development of natural resources, and the development of renewable energy. As a result Lea County will need to supply water to select companies to ensure reliable supplies and to ensure that the companies implement best available practices in order to conserve water. Lea County will also need to provide water to homes and businesses in unincorporated areas that have and are projected to experience significant growth. This will require the County to complete groundwater supply wells and related infrastructure to deliver the water.

The estimated quantity of water that the County will need by the end of the 40-year planning period is 9,514 ac-ft/yr. Wells will be completed in the Ogallala aquifer at select locations identified in the 1999 permit applications filed by the Lea County Water Users Association. The Lea County Water Users Association will assign the required permit applications to the County. The quantity of water that will be put to beneficial use is significantly less than the 51,797 ac-ft/yr that was applied for by the Lea County Water Users Association. The permit applications for the remaining quantity of water will be withdrawn upon New Mexico Office of the State Engineer acceptance of this plan.

Ample quantities of relatively high quality water exist for the proposed development period. The County will require all companies using the subject water to submit water conservation plans and to implement best available technologies in order to reduce water use. Water will not be piped to areas outside of Lea County.

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APPENDIX

(follows text)

Appendix. Description of geologic units found on Figure 3.

DISCLAIMER

This report was prepared for the exclusive use of Lea County. Any other use of this report may be inappropriate. All work has been performed in accordance with generally accepted practices. No warranty is expressed or implied.

The results are based on reviews of selected published and unpublished information, and personal communication with individuals familiar with the study area. Unless contradicted by conflicting data obtained independently during the conduct of the work, all information was accepted at face value. The information obtained during interviews and from files, publications, and databases is sometimes inaccurate or incomplete. The information and conclusions in this report are subject to the accuracy, completeness, and availability of such data.

40-YEAR WATER DEVELOPMENT PLAN
LEA COUNTY, NEW MEXICO

1.0 INTRODUCTION

Lea County is experiencing significant economic development as a result of an influx of high technology companies moving into the County, the ongoing development of natural resources, and the development of renewable energy. As a result, Lea County will need to supply water to select companies, and homes and businesses in unincorporated areas to ensure safe and reliable supplies, and to ensure that the companies implement best available practices in order to conserve water.

In 1999, applications were filed by the Lea County Water Users Association (LCWUA) to appropriate 51,797 acre-feet/year (ac-ft/yr) of water, which was essentially all unappropriated water in the Lea County Underground Water Basin (UWB), in order to meet the projected demands for the County. The only areas where applications were not made to appropriate remaining water were those where the saturated thickness was estimated to be too small to allow viable well yields for uses other than those permitted under NMSA 72-12-1 (domestic and livestock). A portion of the applications to appropriate water have been assigned to Lea County. The remaining applications will be withdrawn upon promulgation of New Mexico Office of the State Engineer (NMOSE) guidelines for the Lea County UWB.

1.1 Purpose

The purpose of this water development plan is to allow the County to hold the subject water rights unused according to New Mexico Statute 72-1-9, until such time that the rights can be put to beneficial use. Lea County will need to hold water rights unused during at least the 40-year planning period. Water will be put to beneficial use at projects currently under construction, select future projects, and home and businesses in unincorporated areas. The projects will help bring continued economic development to Lea County. During the planning period, the County will also be completing the infrastructure for developing and distributing water supplies. Water will not be piped or otherwise diverted to areas outside of Lea County.

2.0 WATER RIGHTS SUMMARY

2.1 Summary of Basin Water-Rights Administration

The Lea County UWB was declared by the NMOSE in 1931 and closed to further appropriation in 1948. The basin was extended in 1952, and Orders re-opening parts of the basin to further development were issued in 1952 and again in 1953. In 1953, the NMOSE developed specific administrative criteria for managing groundwater appropriations within the Lea County UWB, and the Ogallala aquifer was the focus of the administrative criteria. Water rights within the basin were administered using a block system consisting of 36 sections within a given township and range. The Lea County UWB is a mined basin, wherein groundwater is removed at rates that exceed recharge to the aquifer. Administration of the basin was intended to allow use of groundwater to a specified amount of de-watering during a 40-year planning period.

Proposed guidelines for the basin have recently been developed by the NMOSE. The LCWUA has been actively involved in the development of these guidelines. The guidelines are currently in a draft form and the NMOSE held public meetings in May 2009 to introduce the guidelines to the public and solicit public input.

The proposed guidelines will be based on a block system consisting of 1-square-mile blocks that correspond to model cells in a groundwater-flow model (Musharrafieh and Chudnoff, 1999). Key aspects of the guidelines include the following: 1) water rights can be moved from one block to another throughout the basin, 2) an administrative groundwater-flow model will be used to identify areas where the saturated thickness of the aquifer will be less than 55 ft at 2045, and these areas will be designated as critical management areas (CMAs), 3) the administrative groundwater-flow model will be used to determine regional drawdowns resulting from an application, 4) applications to move water rights cannot create more drawdown than 0.025 ft/yr on a CMA, or 0.20 ft/yr on a non-CMA, and 5) local area impacts from proposed water-rights applications will also be performed and will include evaluation of impacts to the saturated thickness and reductions in water columns of existing wells.

2.2 Permits Filed by LCWUA

On August 5, 1999, the LCWUA filed 138 permit applications to appropriate 51,797 ac-ft/yr of water rights from the Lea County UWB. The LCWUA was also assigned permit applications to appropriate 5,990 ac-ft/yr of water from 12 wells located about 18 miles west of Lovington. The permit applications assigned to LCWUA were originally applied for by IMC Kalium. The applications were to appropriate essentially all unappropriated water remaining in the basin. Applications were not made to appropriate available water rights in areas where the saturated thickness was estimated to be too small to yield sufficient quantities of water to wells other than those for limited uses, or domestic and livestock purposes.

2.3 Place and Purpose of Use

Water uses for Lea County, per the applications to appropriate water, include municipal, industrial, irrigation, agricultural, petroleum, recovery or refining, mineral extraction, refining, power generation, or any other need as defined in the 40-year water plan.

The place of use will be within Lea County. No water associated with the County water rights will be allowed to be exported from the County. Economic development projects and proposed areas where water will be put to beneficial use are provided on Figure 1 and Table 1. Projects and locations may be modified from time to time as necessary during the planning period.

The County does not currently have plans to import water from other providers, nor to export water to other utilities. It is possible that the County may provide water to users that also obtain water from other providers.

No return-flow credit for the subject water rights is currently contemplated. In the event that return flow is contemplated, a return-flow plan will be submitted to the NMOSE for review and approval in accordance with applicable State regulations.

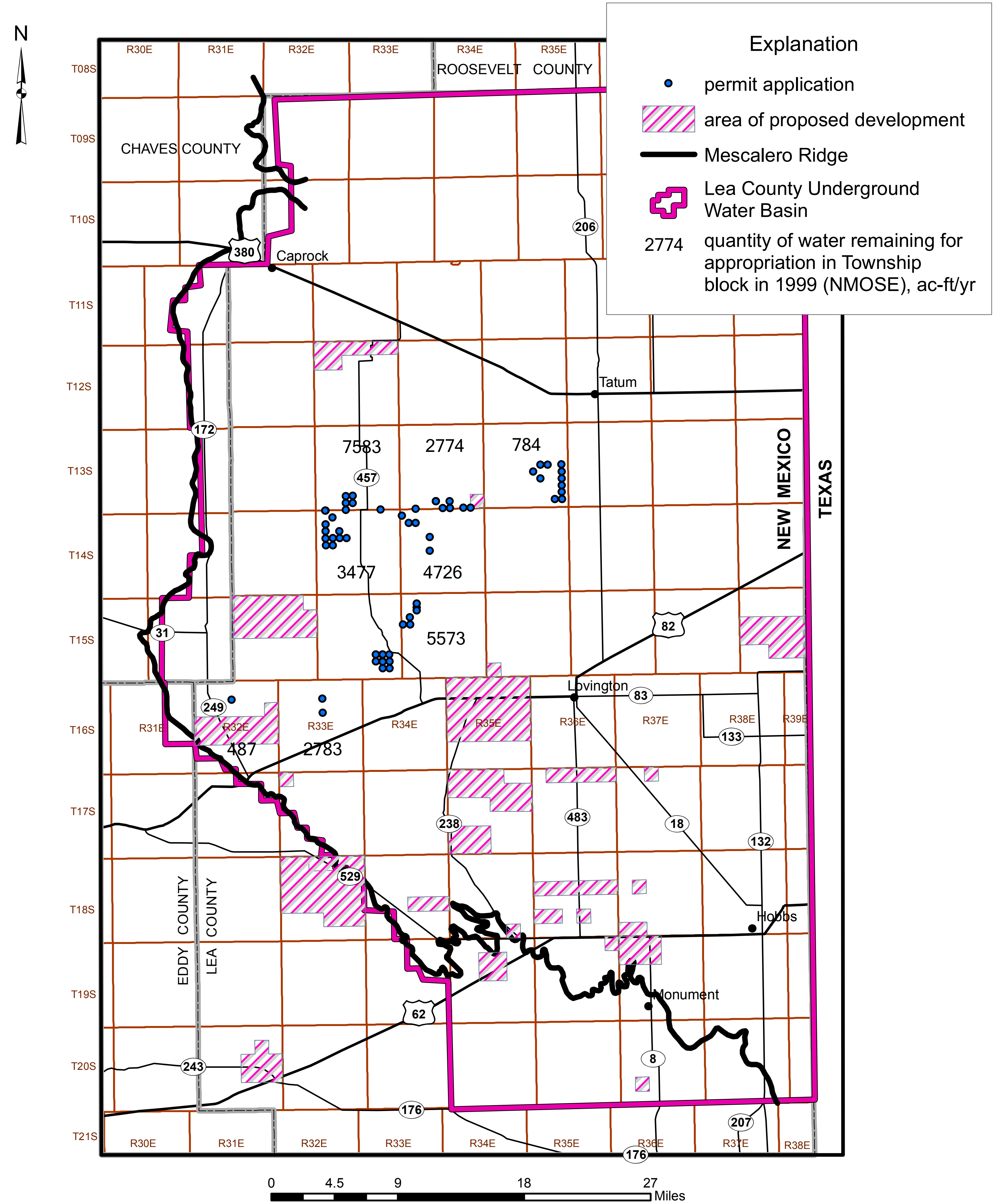

Figure 1. Map showing Lea County Underground Water Basin, permit application locations, quantity of water remaining in Township block, and areas of proposed development where water will be put to beneficial use, Lea County, New Mexico.

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Table 1. Summary of economic development projects, project type, location, and square footage of facilities, Lea County, New Mexico

project name	project type	location	square footage of facilities
International Isotopes	uranium enrichment/ fluorine extraction	T18S, R36E, Sec 27	30,000
Alternative Nuclear Generation	energy	T18S, R37E, Sec 31 and 32	45,000
NEF/LES Expansion	utility	T19S R36E, Sec 1	100,000
Jal Potash	mining	T25S, R38E, Sec 16-21, 28-33; T25S, R37E, Sec 13-17, 20-29, 32-36	50,000
Lea Nuclear	utility	T16S, R35E, Sec 1-24; T18S, R33E, Sec 1-27	250,000
Unincorporated Growth	well expansion	T17S, R36E, Sec 1-5; T28S, R36E, Sec 13-28; T15S, R38E, Sec 13-18; T19S, R37E, Sec 4-9	N/A
Zia Poly Pipe	plastics manufacturing	T18S, R36E, Sec29 and 30	36,000
De-conversion	nuclear	T20S, R32E, Sec 11, 13-15, 22-24	250,000
Solar Energy	alternative energy	T11S, R35E, Sec 27; T16S, R33E, Sec 15: T16S, R34E, Sec 27; T18S, R33E, Sec 1-4; T18S, R35E, Sec 15	unknown
Used Fuel Management	nuclear	T18S, R34E, Sec 22-24	60,000
Light Water Reactor Fuel Reprocessing	nuclear	T17S, R35E, Sec 3-15; T17S, R35E, Sec 28-33; T16S, R32E, Sec 12-24; T15S, R32E, Sec 2-18	200,000
LEACO Turbine	utility	T15S, R36E, Sec 6	unknown
Fast Reactor Fuel Reprocessing & Fuel Fabrication	nuclear	T12S, R33E, Sec 1-8	200,000
Nuclear Medicine Facility	nuclear/medicine	T18S R35E, Sec 35	25,000
Nuclear Storage Facility	nuclear	T19S, R35E, Sec 9-10, 15-16	200,000
Alternative Fuel Engine Manufacturing	alternative energy/manufacturing	T20S, R37E, Sec 29	125,000
Alternative Energy Generation (algae)	alternative energy	T17S, R33E, Sec 6	unknown
Alternative Energy Facility (biomass)	alternative energy	T13S, R34E, Sec 36	50,000
Solar Manufacturing Plant	alternative energy/manufacturing	T17S, R37E, Sec 4	250,000
Fluorine Extraction	nuclear	not yet determined	2,500
Hi-Tech Manufacturing Plant	manufacturing	T18S, R37E, Sec 17	120,000
Container Manufacturing	nuclear/manufacturing	not yet determined	115,000
Halfway Warehouse	warehouse	T15S, R35E, Sec 31	60,000
Research Incubator	nuclear/research	not yet determined	15,000
Alternative Battery Manufacturing	alternative energy	not yet determined	135,000

Source: Economic Development Corporation of Lea County, personal communication, April 2009.

3.0 WATER DEMAND

The Economic Development Corporation of Lea County (EDCLC) works with the County to bring new businesses to the County. EDCLC has provided a summary of projects that are currently being constructed and proposed projects with a high likelihood of being constructed in the near future, and estimated annual water demands.

Water demand in the unincorporated areas is projected to be one of the largest water demands. The University of New Mexico Bureau of Business and Economic Research (BBER) reports that much of the population growth in Lea County has been occurring outside of municipal boundaries since 2003 (BBER, 2007). BBER (2007) estimates that in a medium growth scenario, the Lea County population of 55,000 people in 2000 will increase to 73,500 people by 2030. The BBER (2007) projects that the unincorporated area near Hobbs will have a higher growth rate than the remaining portion of the County. Population projections were not provided for other unincorporated areas in the County, but rather for various large tracts that include municipalities.

JSAI used BBER (2007) and U.S. Census data (2000) to calculate population projection estimates for the unincorporated areas surrounding Eunice, Jal, and Tatum. BBER (2007) estimates that the population in the unincorporated area near Hobbs will be 11,694 people by 2030. The projected growth is predicated in part on the regions ability to provide infrastructure to accommodate the population growth. Lea County plans to provide the water distribution infrastructure for unincorporated areas near Hobbs and other selected unincorporated areas in the County. Table 2 summarizes population projections for the unincorporated areas outside of Eunice, Jal, Tatum, and Hobbs.

Table 2. U.S. Census tract number, total population, approximate percentage of population in study area outside municipality, and population projections for unincorporated areas outside of Eunice, Jal, Tatum, and Hobbs, Lea County, New Mexico

U.S. Census tract number	study area	U.S. Census total population for 2000	approximate percentage of population in study area outside municipality	population projections as of July 1 for area outside municipality				
				2010	2015	2020	2025	2030
8	Eunice area	2,896	21.3	670	708	742	772	803
9	Jal area	2,118	26.5	610	645	676	704	733
11	Tatum area*	3,976	82.7	3,597	3,801	3,974	4,130	4,291
N/A	Unincorporated Hobbs	N/A	N/A	9,313	9,966	10,553	11,112	11,694
total								**17,521**

Sources: BBER, 2007; U.S. Census Bureau, 2000.
* U.S. Census tract 11 also includes the unincorporated area around Lovington.

The Lea County average water usage for 1995 was 290 gallons per capita per day (gpcd) (Leedshill-Herkenhoff, Inc. et al., 2000). Based on 2004 water production information, the gpcd usage for the City of Hobbs was 285 gpcd (Tim Woomer, City of Hobbs Utilities Director, personal communication, June 2009). When compared to other New Mexico municipalities with similar climate, this usage is high. While the Lea County subdivision regulations do not require developers to install low-flow toilets and fixtures, the County encourages low water use landscaping techniques applying the principles of xeriscaping (Lea County Subdivision Regulations, Article 16, Section 16.3). The County will also require industry to comply with the water-conservation measures outlined below in section 5.0 WATER CONSERVATION MEASURES. Due to the water conservation measures, the gpcd for unincorporated areas that will be supplied by the County is expected to be approximately 200 gpcd.

Assuming a water use for the unincorporated areas around Hobbs, Eunice, Jal, and Tatum of 200 gpcd the water demand would be about 3,900 ac-ft/yr. Water demand at the Jal Potash is estimated to be 2,060 ac-ft/yr. However, the County will not provide water to Jal Potash, and Jal Potash will have to purchase water rights for its operations. Table 3 summarizes projects that are currently being constructed and proposed projects with a high likelihood of being constructed in the near future, and estimated annual water demands.

Table 3. Summary of estimated annual water demand for economic development facilities, estimated number of employees, estimated water demand for employees, and total water demand, Lea County, New Mexico

project name	estimated water demand for facility, ac-ft/yr	estimated number of employees	estimated water demand for employees,* ac-ft/yr	estimated total demand, ac-ft/yr
International Isotopes	175	150	5.3	180.3
Alternative Nuclear Generation	275	125	8.3	283.3
NEF/LES Expansion	350	200	10.5	360.5
Jal Potash	2,000	500	60	2,060**
Lea Nuclear	300		9	309
Unincorporated Growth	3,900	0	0	3,900
Zia Poly Pipe	125	6,000	3.8	128.8
De-conversion	375	15	11.3	386.3
Solar Energy	125	75	3.8	128.8
Used Fuel Management	350	3,000	10.5	360.5
Light Water Reactor Fuel Reprocessing	325	3,000	9.8	334.8
LEACO Turbine	375	20	11.3	386.3
Fast Reactor Fuel Reprocessing & Fuel Fabrication	325	40	9.8	334.8
Nuclear Medicine Facility	120	175	3.6	123.6
Nuclear Storage Facility	275	120	8.3	283.3
Alternative Fuel Engine Manufacturing	150	100	4.5	154.5
Alternative Energy Generation (algae)	375	40	11.3	386.3
Alternative Energy Facility (biomass)	375	300	11.3	386.3
Solar Manufacturing Plant	150	20	4.5	154.5
Fluorine Extraction	75	200	2.3	77.3
Hi-Tech Manufacturing Plant	175	80	5.3	180.3
Container Manufacturing	275	10	8.3	283.3
Halfway Warehouse	60	40	1.8	61.8
Research Incubator	70	100	2.1	72.1
Alternative battery Manufacturing	250	100	7.5	257.5
totals	**9,350**	**13,910**	**163.5**	**9,513.5**

Source: Economic Development Corporation of Lea County, personal communication, April 2009.

* Employee water use estimated from Vickers (2001) and Longworth et al. (2008).

** Jal Potash water demand is not included in the total water demand, since the County will not be supplying Jal Potash with water. Jal Potash will be purchasing water-rights from existing water-right owners.

4.0 PERMIT APPLICATIONS TO APPROPRIATE GROUNDWATER TO BE RETAINED BY LEA COUNTY

Lea County will retain selected permit applications to appropriate groundwater within the basin. The retained quantity and points of diversion will be significantly less than originally applied for by the LWCUA. The County will retain all proposed points of diversions within the selected township blocks per the applications filed in 1999, but the quantity that will be put to beneficial use will be reduced as shown in Table 4. Permit application locations to be kept to provide water for the 40-year planning period, quantity of water that was available for appropriation within the subject township blocks, and areas of economic development are shown on Figure 1.

Table 4. Locations where Lea County will retain permit applications to appropriate groundwater, originally applied for quantity, and quantity of water to be appropriated for the 40-year planning period

township, range	originally applied for consumptive use,[1] ac-ft/yr	required 40-year consumptive use, ac-ft/yr
T13S, R33E	7,583	1,200
T13S, R34E	2,744	1,200
T13S, R35E	784	1,200
T14S, R33E	3,477	1,700
T14S, R34E	4,726	1,230
T15S, R33E	5,590	1,700
T15S, R34E	5,573	1,250
T16S, R32E	487	50
T16S, R33E	2,783	50
totals	**34,173**	**9,580**

[1] for subject township blocks
ac-ft/yr - acre-feet per year

5.0 WATER CONSERVATION MEASURES

As indicated above, the majority of economic development planned for the County is related to high technology industries. The County will be the primary water provider for these industries. The County will require the industries to implement best available technologies for conserving water. Proposed water-conservation techniques and methods will be reviewed by the County prior to the County committing to providing water. Due to the nature and variability of these industries, it is not possible to develop a water conservation standard for each facility at this time. However, the County will require companies to comply with the requirements below.

- Outside landscaping will be limited to xeriscape methods, unless irrigation water is provided by reclaimed water or water harvested from roofs, parking lots, or other hard surfaces.
- Low-flow toilets and fixtures will be required.
- Industries must submit water conservation plans that include the following:
  - Evaluation of water demand and comparisons of best available technologies for proposed facility that document the proposed methods and equipment that provides water savings for the proposed operation.
  - Water reuse plan.
  - Evaluate potential for wastewater reuse (gray and black water).
  - Schedule of future water savings as new equipment or methodologies may become available.
  - Documentation that heating and cooling systems will be water efficient.
- Industries using cooling towers must provide for water treatment that will allow recycling of water, rather than single cycle (pass) use.
- Mining and milling operations must recycle water and provide a water use and recycling plan.
- Recycling plan.

The Lea County Subdivision Regulations do not require developers to install low-flow toilets and fixtures. However, the County encourages developers to implement low water use landscaping techniques applying the principles of xeriscaping (Lea County Subdivision Regulations, Article 16, Section 16.3). Lea County Subdivision Regulations could be amended to require additional water conservation measures for proposed subdivisions in order to reduce the amount of water diverted and consumptively used, limit runoff, and increase groundwater recharge in the County. Benefit-cost analysis should be performed on potential additional conservation measures, based on costs of implementation to developers and builders, and water conservation benefits (AWWA, 2006). Potential additional conservation measures include, but are not limited to, the following:

- reduce high water-use vegetation in residential landscaping
- require water-efficient landscape design, such as use of amended soils and mulch in planted areas, and prohibit laying of non-permeable plastic material in residential yards for weed control
- require rainwater harvesting
- require swimming pools to be covered with low-permeable covers
- require high-efficiency toilets
- require high-efficiency faucets and shower heads
- prohibit evaporative coolers with continuous bleed-off lines
- develop impact fee schedule that encourages incorporation of additional water conservation designs in new subdivisions

5.1 Reduce High Water-Use Vegetation in Residential Landscaping

Reducing high water-use vegetation in residential landscaping may involve limiting the area of sprinkler-irrigated turf grass to a fixed square footage, a percentage of the total lot area, or the building envelope of residences in new subdivisions for new homes in the unincorporated areas that will be connected to the Lea County water system. The planting of particularly high water-use turf grasses, such as Kentucky Bluegrass, could be restricted. Table 5 presents examples on how these restrictions could reduce the water used by a residence.

Table 5. Examples of water conservation associated with reductions in high water-use vegetation in residential landscaping

conservation measure	irrigated area, ft^2	"before" water use, ac-ft/yr	"after" water use, ac-ft/yr	savings, ac-ft/yr
reduce area of turf grass, assumed to be Bermuda Grass[a]	1,500 reduced to 1,000	0.16	0.11	0.05
replace Kentucky Bluegrass with Bermuda Grass[a]	1,500	0.23	0.16	0.07
replace Kentucky Bluegrass with Buffalo Grass[a]	1,500	0.23	0.10	0.13

[a] based on landscape irrigation water requirements for Hobbs in Lea County (Wilson, 1996)
ac-ft/yr - acre-feet per year
gpcd - gallons per capita per day

5.2 Require Water-Efficient Landscape Design

The County could require water-efficient residential landscape design for new subdivisions and new homes, including amendments to sandy soils to decrease permeability and retain more moisture, and using mulch in planted areas to reduce evaporation. The County could prohibit laying of non-permeable plastic material, which increases runoff and limits potential groundwater recharge, in residential yards for weed control.

5.3 Require Rainwater Harvesting

The County could require harvesting of rainwater runoff from the total roof area, or a percentage of the roof area, of residences in new subdivisions. Harvested rainwater would then be used for residential landscape irrigation. Gutters and downspouts direct roof water to a holding area, storage barrel, or cistern, and then water is gravity-fed or pumped to the planted area. Downspouts can also be extended so they drain directly into planted areas. Channels, pipes, and berms can convey and collect harvested rainwater at plants and trees. Sidewalks, patios, terraces, or driveways can be constructed with a 2-percent slope toward planted areas. Rainwater harvesting can also reduce flooding and erosion. Table 6 demonstrates a potential water savings of 0.05 ac-ft/yr through rainwater harvesting for a residence with a 2,000 ft^2 roof area in Lea County.

Table 6. Example of water conservation associated with rainwater harvesting at a residence in Lea County

conservation measure	roof area, ft^2	average annual precipitation,[a] ft	savings,[b] ac-ft/yr/house
rainwater harvesting	2,000	1.2	0.05

[a] average annual precipitation for period of record for all National Oceanic and Atmospheric Administration climatic recording stations in Lea County
[b] assuming runoff coefficient of 0.9 to 0.95, since some roofing materials (e.g., asphalt, tar, and gravel) do not shed all rainfall
ft^2 square feet
ac-ft/yr acre-feet per year

5.4 Require Swimming Pools to be Covered with Low-Permeable Covers

The County could require that outdoor swimming pools and spas at residences in new subdivisions be covered with low-permeable covers 50 percent of the time during the swimming season, and throughout the winter. Table 7 presents an example of water conservation associated with the use of low-permeable swimming pool covers.

Table 7. Example of water conservation associated with use of low-permeable swimming pool covers in Lea County

conservation measure	swimming pool area, ft^2	"before" cover, water lost to evaporation, [b] ac-ft/yr	"after" cover, water lost to evaporation, [b] ac-ft/yr	savings, ac-ft/yr
cover pool with low-permeable cover 50 percent of the time during swimming season[a]	600	0.07	0.04	0.03

[a] swimming season assumed to be May-October
[b] average annual pan evaporation of 62.1 inches at Hobbs weather station using modified Blaney-Criddle method of computing potential evaporation (Zhan and Shelp, 2009)
ac-ft/yr - acre-feet per year

5.5 Require High-Efficiency Toilets

Low-flow toilets, which use 1.6 gallons per flush, are required for all new residential construction under the National Plumbing Efficiency Standards. The County could require high-efficiency toilets, defined by the EPA as using 1.2 gallons or less per flush. Table 8 presents an example of water conservation associated with high-efficiency toilets.

Table 8. Example of water conservation associated with high-efficiency toilets

conservation measure	assumptions	"before" high-efficiency toilets, ac-ft/yr/household	"after" high-efficiency toilets, ac-ft/yr/household	savings, ac-ft/yr/household
high-efficiency toilets	6 flush per capita day,[a] 2.73 per capita multiplier[b]	0.03	0.02	0.01

[a] Wilson (1996)
[b] U.S. Census 2000: county population in households/number of households
ac-ft/yr - acre-feet per year
gpcd - gallons per capita per day

5.6 Restrictions on Evaporative Coolers

The County could prohibit evaporative coolers with continuous bleed-off lines, which siphon off water to avoid mineral build-up, for residential construction in new subdivisions.

5.7 Develop Impact Fee Schedule

The County could develop an impact fee schedule that encourages incorporation of additional water conservation designs, above and beyond those required by the County, in new subdivisions. Impact fees could be reduced for new subdivisions with designs that incorporate advanced rainwater harvesting systems or graywater reuse systems.

5.8 Precipitation and Temperature Data

Lea County climate is characterized by semi-arid to arid conditions with low annual precipitation, low humidity, and high average annual temperature. Climatological data for Lea County were compiled from eight National Oceanic and Atmospheric Administration (NOAA) weather stations in the study area. Data for all stations, from the beginning of the period of record for each station were retrieved from the Western Regional Climate Center (WRCC) digital database. Station locations, elevations, and available parameters are shown in Table 9.

Table 9. Summary of NOAA climatic data recording stations in Lea County

station name	coop ID	elevation, ft amsl	latitude	longitude	parameters recorded
Crossroads #2	292207	4,150	33º31′	103º21′	precipitation, snowfall T_{max}, T_{min},
Hobbs	294026	3,620	32º42′	10º08′	precipitation, snowfall T_{max}, T_{min},
Jal	294346	3,060	32º06′	103º12′	precipitation, snowfall T_{max}, T_{min},
Lovington 2 WNW	295204	3,900	32º58′	103º23′	precipitation, snowfall T_{max}, T_{min},
Maljamar 4 SE	295370	4,000	32º49′	103º42′	precipitation, snowfall T_{max}, T_{min},
Ochoa	296281	3,460	32º11′	103º26′	precipitation, snowfall T_{max}, T_{min},
Pearl	296659	3,800	32º39′	103º23′	precipitation, snowfall T_{max}, T_{min},
Tatum	298713	4,100	33º16′	103º19′	precipitation, snowfall T_{max}, T_{min},

Source: Western Regional Climate Center on-line database, accessed April 2009.
NOAA - National Oceanic and Atmospheric Administration
T_{max} - maximum temperature
T_{min} - minimum temperature
ft amsl - feet above mean sea level

Mean annual precipitation ranges from 16.1 inches per year at Tatum to 12.5 inches per year at Jal. The greater part of the precipitation is in the form of heavy showers of limited duration and areal extent. Regional rainfalls longer than 24 hours in duration are relatively rare, averaging one to four times a year. The Hobbs and Tatum areas have been more prone than much of Lea County to receive long-duration, heavy storms (Leedshill-Herkenhoff, Inc. et al., 2000). Highest precipitation rates occur between May and October. Snowfall in the area is typically light. Table 10 shows the average annual maximum and minimum temperatures, and precipitation for the period of record for each station.

Table 10. Summary of annual maximum and minimum temperature averages for NOAA climatic recording stations in Lea County

station name	coop ID	average annual T_{max}, ºF	average annual T_{min}, ºF	average annual precipitation, inches	period of record
Crossroads #2	292207	73.7	42.5	15.7	7/1/1929 – 5/31/2001
Hobbs	294026	76.3	47.4	16.0	1/1/1914 – 12/30/2005
Jal	294346	79.5	48.3	12.5	4/1/1919 – 12/31/2005
Lovington 2 WNW	295204	76.1	43.7	14.9	1/1/1919 – 2/28/1967
Maljamar 4 SE	295370	76.4	44.7	14.7	10/1/1942 – 10/31/2000
Ochoa	296281	77.5	47.3	11.3	1/1/1948 – 12/31/2005
Pearl	296659	75.3	45.4	13.8	5/1/1915 – 7/31/1996
Tatum	298713	74.7	42.1	16.1	6/1/1919 – 12/31/2005

Source: Western Regional Climate Center on-line database, accessed April 2009.
NOAA - National Oceanic and Atmospheric Administration
T_{max} - maximum temperature
T_{min} - minimum temperature
ºF - degrees Fahrenheit

Average annual precipitation and average annual maximum and minimum temperatures were compared with the respective station elevation, as shown on Figure 2. In general, average annual precipitation increases as elevation increases, and average annual temperatures decrease as elevation increases.

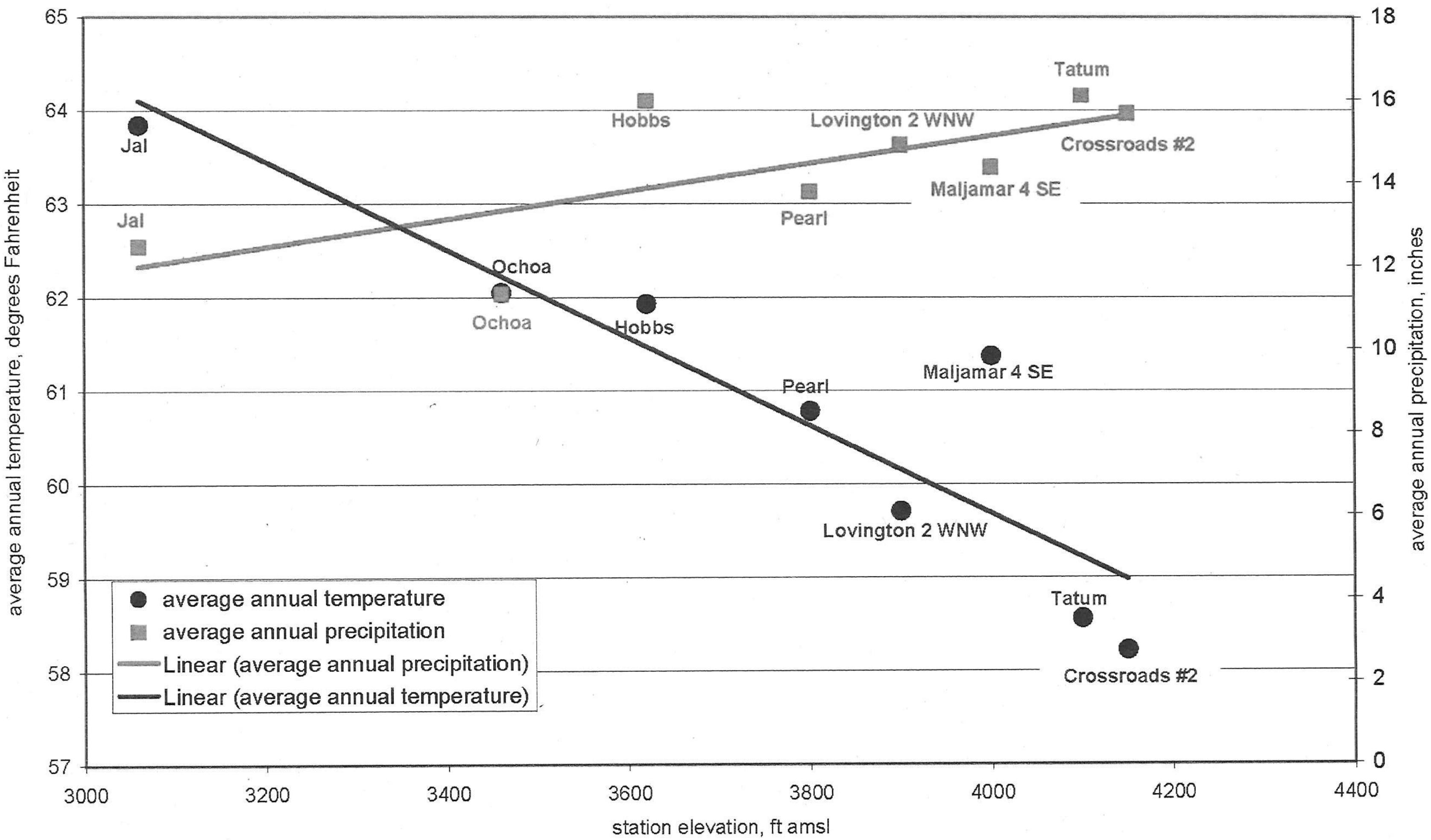


Figure 2. Graph showing average annual temperature and average annual precipitation versus elevation for period of record, Lea County, New Mexico.

6.0 GENERAL HYDROGEOLOGY

The Ogallala aquifer is the primary aquifer in Lea County for municipal, industrial, commercial, agricultural, and domestic uses, and, therefore, will be the primary aquifer discussed in this plan. The Triassic-age Dockum Group and Cretaceous-age rocks also provide limited supplies of water, but well yields from these rocks are generally low, except in areas where fracturing has increased aquifer permeability. Water from deeper Permian-age aquifer systems is primarily used for purposes related to the production of oil and gas resources. General hydrogeologic descriptions of Triassic- and Cretaceous-age rocks are provided below, and more detailed information can be found in *Lea County Regional Water Plan* (Leedshill-Herkenhoff, Inc. et al., 2000). A map showing the general geology of the area is provided as Figure 3, and geologic cross-sections are provided as Figures 4 and 5.

6.1 Tertiary-Age Ogallala Formation

The Ogallala aquifer is the main source of water in the Lea County UWB, and in adjoining west Texas where it is the primary source for irrigation and other uses. The Tertiary-age Ogallala Formation consists of interbedded layers of fine- to medium-grained sand and gravel, overlain by an upper caliche layer. The total thickness of the Ogallala ranges from zero to about 350 ft thick. The thickness of the formation varies (Nye, 1930) as a result of irregularities, formed by erosional channels, in the surface of the underlying Triassic-age Dockum Group sediments (red beds). The channels generally trend to the southeast (Ash, 1963).

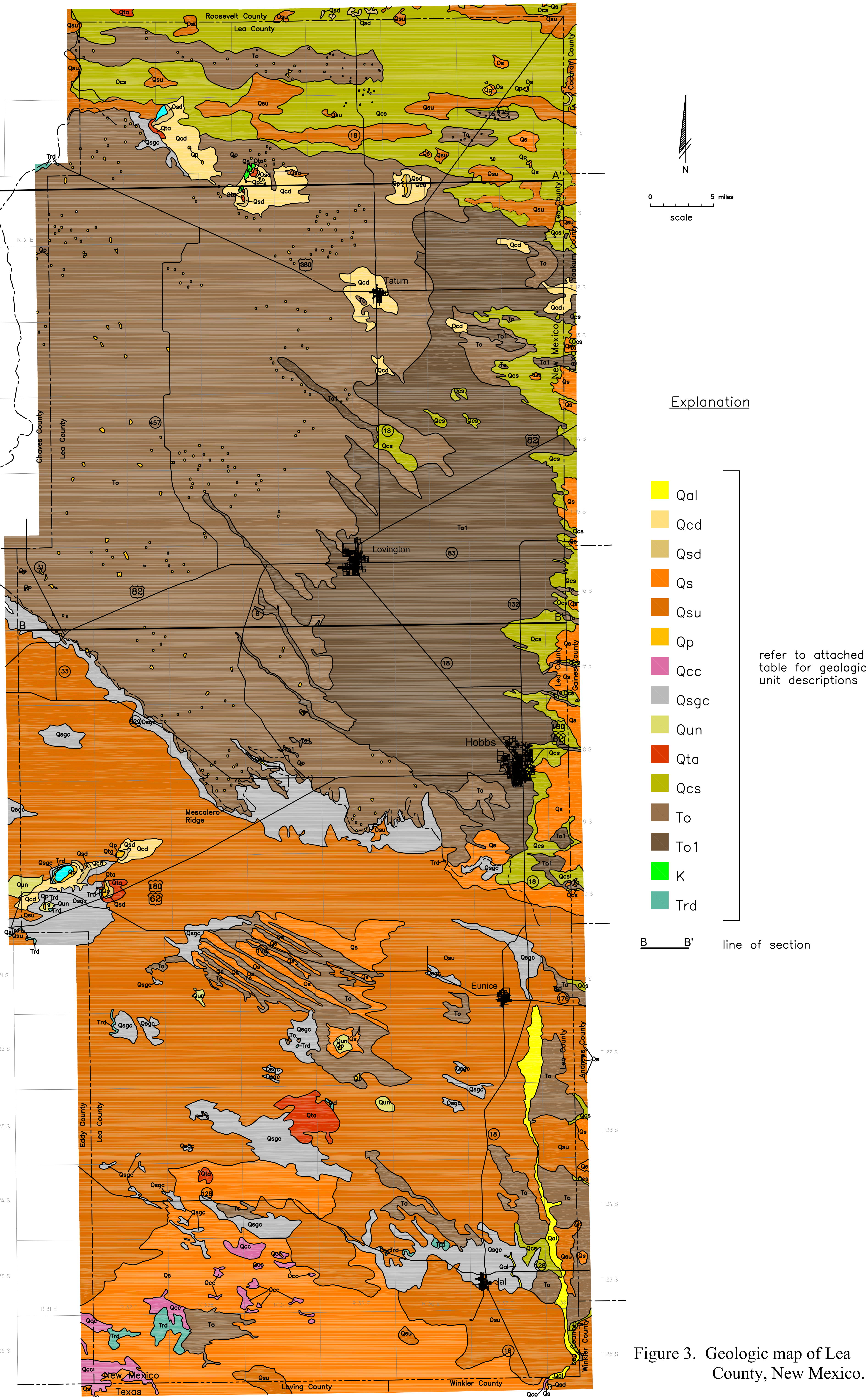


Figure 3. Geologic map of Lea County, New Mexico.

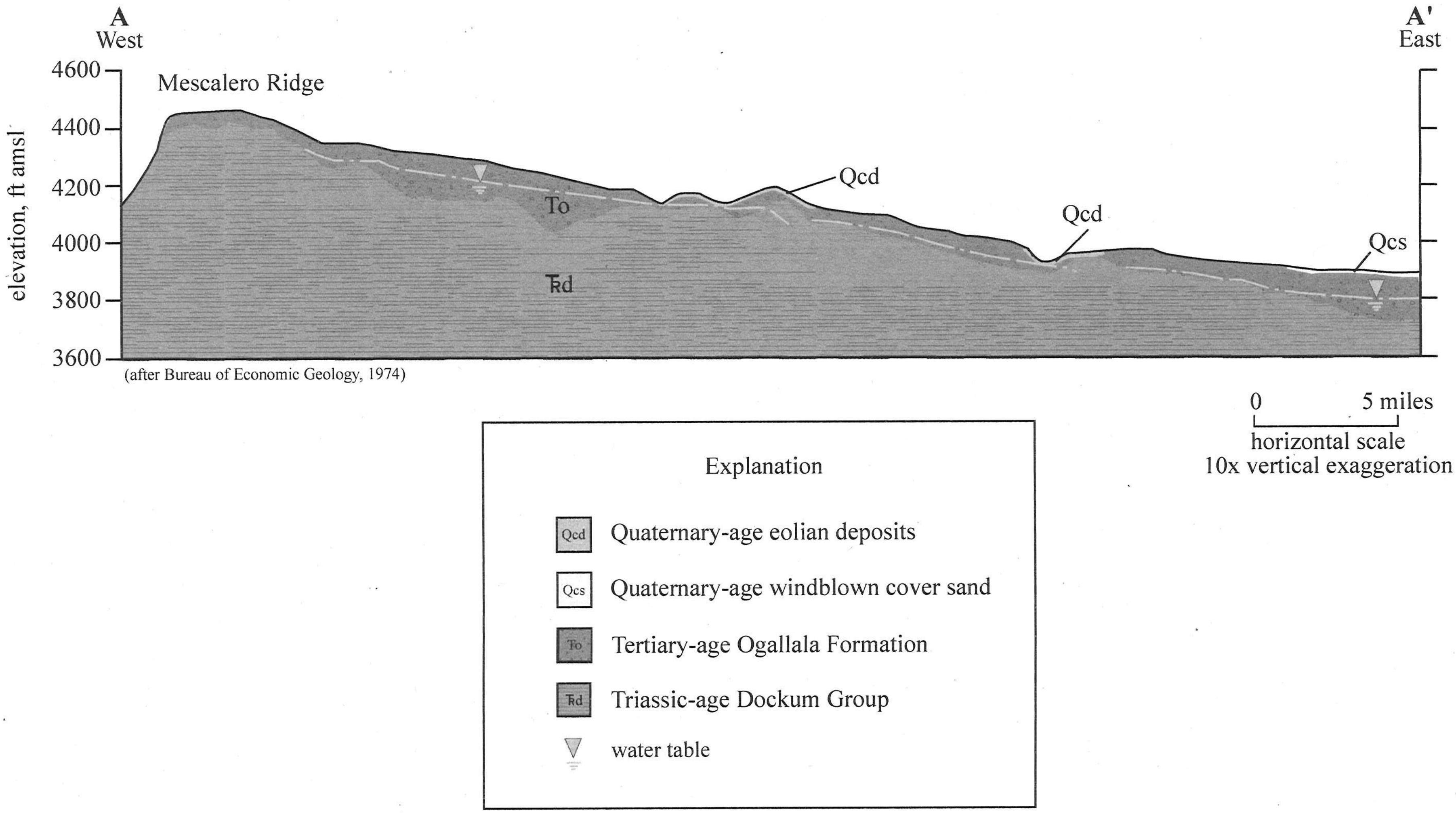


Figure 4. Geologic cross-section A-A', Lea County, New Mexico. See Figure 3 for line of section.

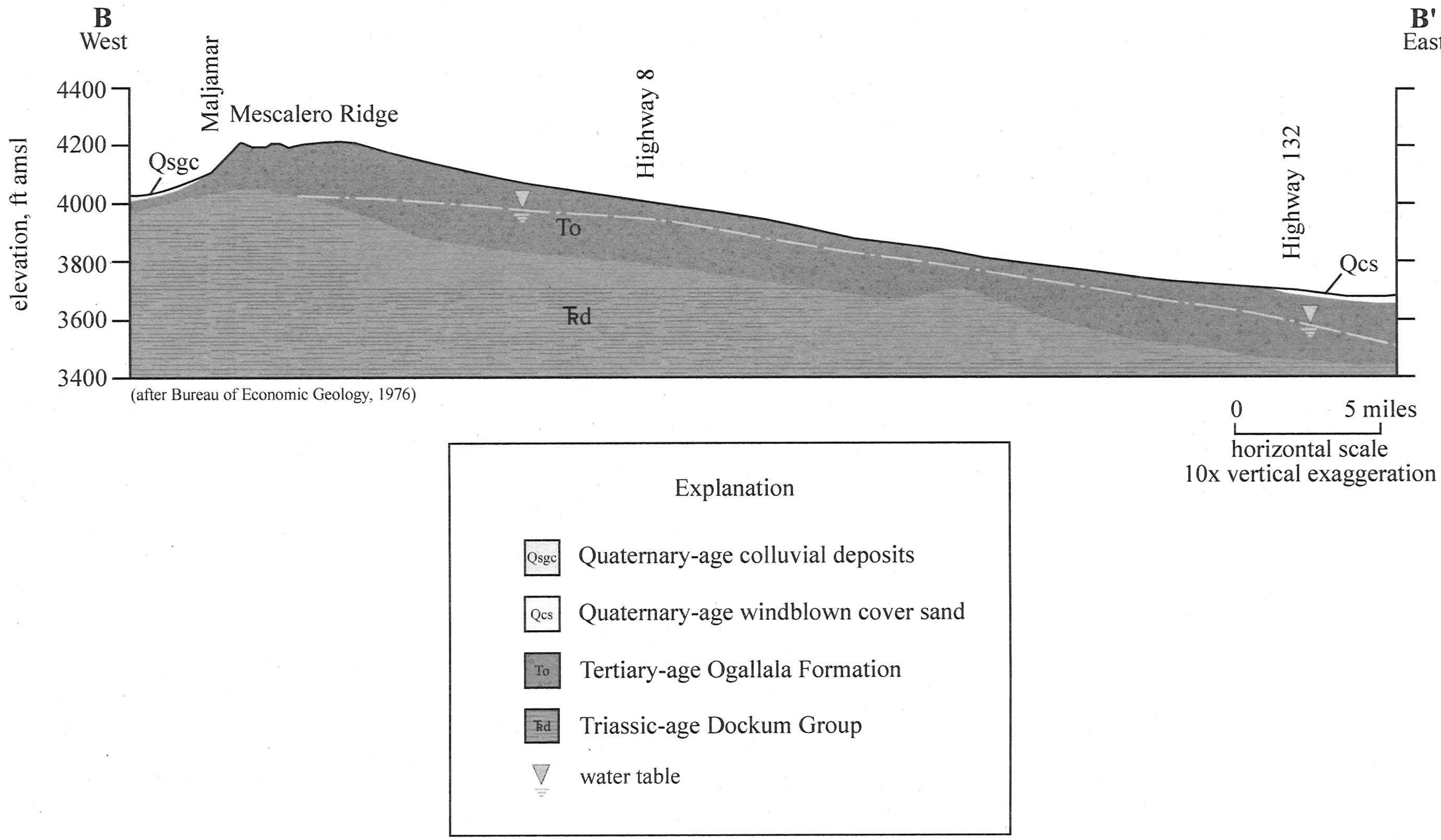


Figure 5. Geologic cross-section B-B', emphasizing the thickness of the Ogallala aquifer, Lea County, New Mexico. See Figure 3 for line of section.

The upper caliche portion of the formation ranges from about 10 to 60 ft thick and varies from poorly to well cemented. This caliche layer forms the promontories and cliff units of Mescalero Ridge, which is known locally as the "caprock." Outside of the primary portion of the basin, the aquifer only provides limited amounts of water to wells because the saturated thickness is fairly small or non-existent.

The Ogallala has been eroded from areas west of Mescalero Ridge in northern and central Lea County, and in parts of southern Lea County. Where the Ogallala is absent, underlying Triassic- or Cretaceous-age rocks are exposed or lie directly below alluvial cover. Cretaceous- and Triassic-age rocks underlying the Ogallala form a relatively impermeable barrier that restricts downward movement of groundwater.

6.2 Cretaceous-Age Rocks

The Cretaceous-age Tucumcari Formation exists in a limited area in northeastern Lea County. It is typically overlain by a variable thickness of the Ogallala Formation. The Tucumcari Formation was deposited in southern Lea County, but was subsequently almost entirely removed by erosion (Nicholson and Clebsch, 1961). The Tucumcari is approximately 150 ft thick in northeastern-most Lea County, and thins to the southwest. As mapped by Ash (1963), as much as one-third of the area of known Lea County Tucumcari Formation occurrence included some extent of the unit above the water table. The formation generally consists of fossiliferous dark gray siltstone and thin beds of brown sandy limestone, and gray limestone and sandstone.

Basal sandstone beds provide limited amounts of water from within the Tucumcari Formation. Several well completions into Cretaceous beds in northern Lea County are reported. Prior to the 1940s, some beds contained sufficient hydrostatic head to provide flow at land surface. Ash (1963) reported one well with a potentiometric surface elevation of 14 ft above land surface. Widespread drilling of uncased seismic shot-holes is considered the reason Cretaceous-zone water wells ceased flowing at land surface by the 1940s. Manmade hydraulic connections to the overlying Ogallala Formation could provided the path for excess head in the Tucumcari Formation to dissipate into the unconfined Ogallala aquifer.

The fine-grained character of most of the thickness of the Tucumcari Formation in Lea County will likely impede development of substantial amounts of water from this unit without the occurrence of secondary permeability features (i.e., fractures, limestone solutioning, etc.).

McAda's (1984) model of the Lea County UWB indicates that groundwater flow could occur between the Cretaceous-age rocks and the Ogallala aquifer. In the area near Ranger Lake, the Ogallala gains water from the Cretaceous-age units to the west and northwest. Cretaceous-age units also crop out on the west side of Ranger Lake, which may directly supply the lake with recharge, giving the Ogallala a net positive flow.

6.2.1 Dockum Group

The Triassic-age rocks in the study area are generally referred to as the Dockum Group (Ash, 1963), which includes the basal Santa Rosa Sandstone and the overlying Chinle Formation. Locally, these rocks are referred to as the red beds. Stratigraphic work by Lucas and Anderson (1993) refers to the basal Triassic-age rocks in the study area as the Santa Rosa Formation and the overlying Triassic-age rocks as the San Pedro Arroyo Formation, both of the Chinle Group.

The Dockum Group beds dip, or tilt, to the east or southeast (Ash, 1963). The thickness of the Dockum Group may range from 700 to 800 ft beneath Mescalero Ridge to more than 1,400 ft beneath the majority of Lea County UWB.

The Dockum Group is generally clay rich and acts a low permeable barrier to vertical groundwater flow. Occasionally, thin sandstone beds can be saturated, but production from the beds is very low. The Santa Rosa Sandstone is a specific, largely sandstone and conglomerate sequence within the Lower Dockum Group that is reported to be about 85 ft thick. Wells completed in the Santa Rosa Sandstone in Lea County reportedly produce from about 6 gallons per minute (gpm) up to 100 gpm (Nicholson and Clebsch, 1961).

7.0 HYDROGEOLOGY OF THE OGALLALA AQUIFER

7.1 Depth to Water and Saturated Thickness of the Ogallala

Depth to water ranges from about 20 to 30 ft in the northern and southeastern portions of the basin to about 200 to 250 ft in the west-central portion of the basin near Mescalero Ridge (Fig. 6; USGS, 2009). Saturated thickness of the aquifer ranges from only a few feet to a few tens of feet along the northeast portion of the basin and along portions of the Mescalero Ridge. Saturated thicknesses of 180 to 200 ft exist in selected areas in west-central and east-central portions of the Basin (Fig. 7; Tillery, 2008).

7.2 Well Yields

Well yields are variable and depend on the hydraulic properties of the aquifer, saturated thickness, and well completion. Irrigation well yields range from about 200 to nearly 2,000 gpm. As the saturated thickness declines, well yields will decline.

7.3 Groundwater Elevation and Flow Direction

The Ogallala is unconfined, and therefore flows in response to gravity, the inclination of Ogallala beds, and the slope of the top of the underlying confining stratum (red beds). The Ogallala Formation, deposited to the east of the southern ancestral Rocky Mountains, has retained an eastward slope typical to such a depositional environment. The direction of groundwater flow is southeast with a gradient of about 16 ft/mile in the northwestern portion of the basin and about 20 ft/mile in the central and eastern portions of the basin (Fig. 7).

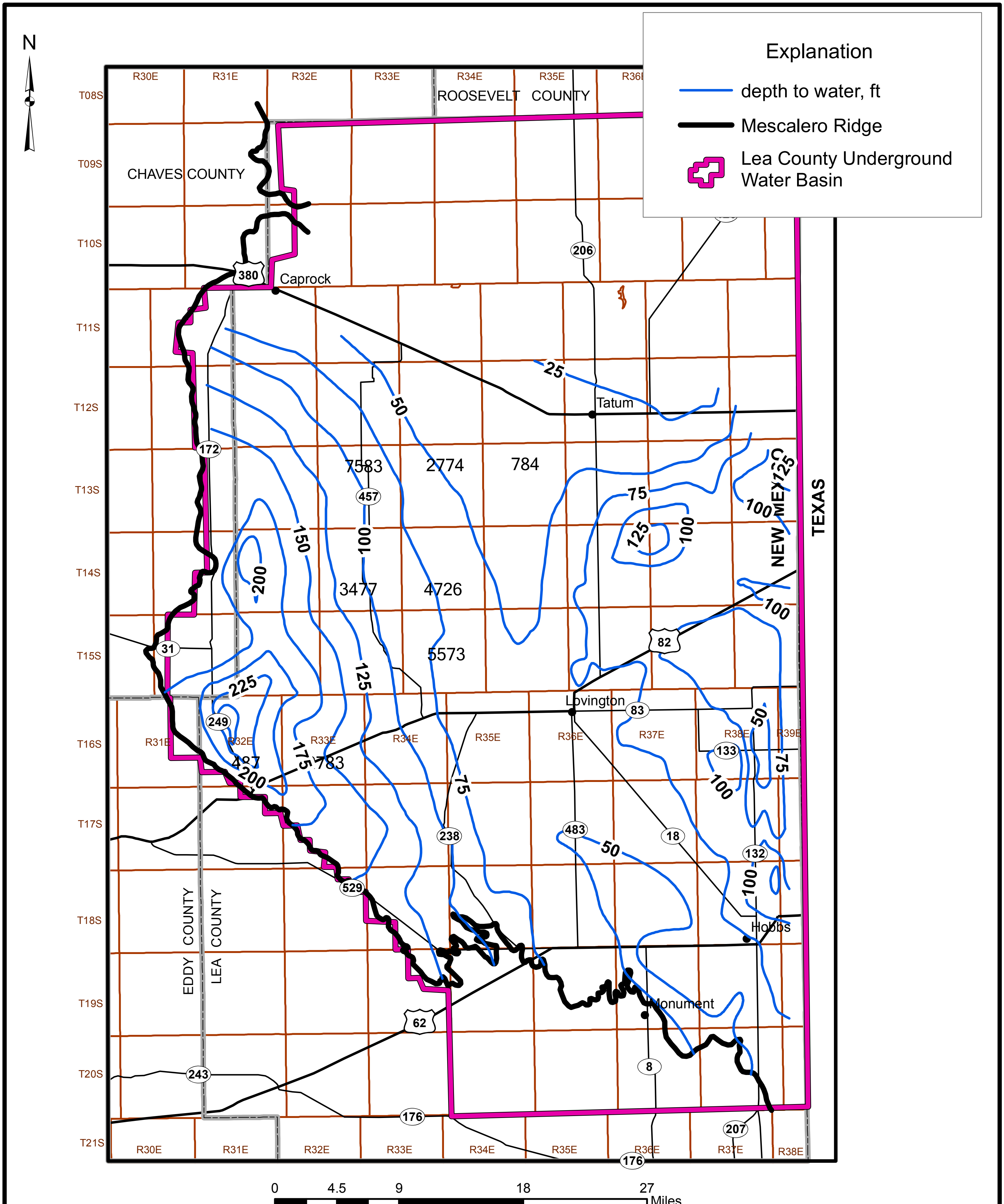
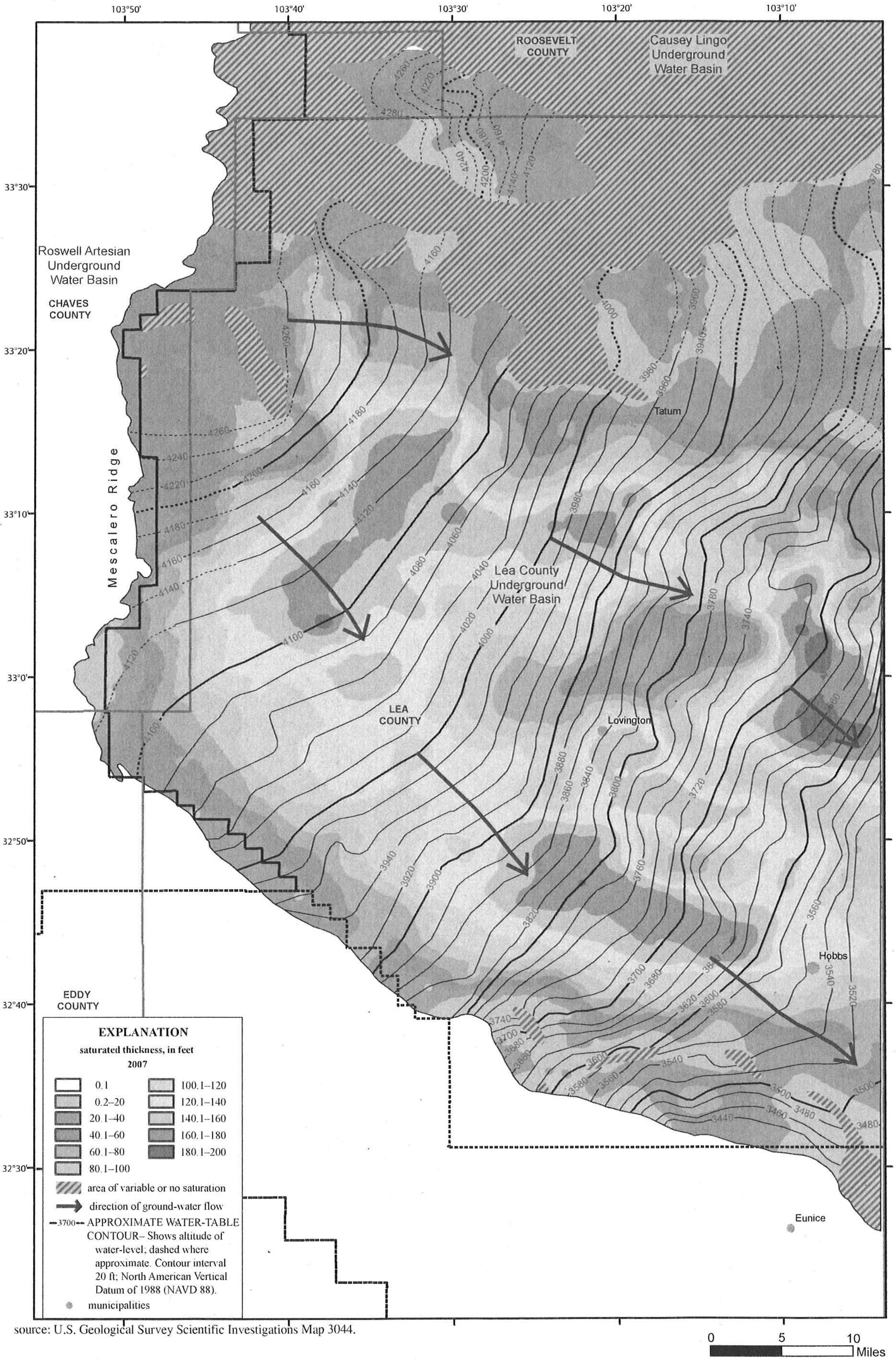


Figure 6. Map showing depth to water based on data from 2001 to 2008 in the Ogallala aquifer in the Lea County Underground Water Basin.



source: U.S. Geological Survey Scientific Investigations Map 3044.

Figure 7. Map showing water-table contours, saturated thickness, and direction of groundwater-flow, based on 2004 to 2007 groundwater-level data measurements of the Ogallala aquifer in Lea County Underground Water Basin.

8.0 GROUNDWATER WITHDRAWALS IN LEA COUNTY

Groundwater withdrawals for irrigation, m unicipal, domestic, industrial, and livestock uses result in the greatest amount of discharge from the aquifer.

Table 11. Groundwater withdrawals by category in Lea County for 2005

category	NMOSE groundwater withdrawals, 2005[1], ac-ft/yr
commercial (self-supplied)	3,264
domestic (self-supplied)	1,419
industrial (self-supplied)	6,088
irrigated agriculture (self-supplied)	135,371
livestock (self-supplied)	3,670
mining (self-supplied)	18,365
power (self-supplied)	4,415
public water supply	13,360
total	185,952

1 Longworth et al., 2008
ac-ft/yr - acre-feet per year

9.0 EVAPORATION, RECHARGE, AND NATURAL DISCHARGE

Evaporation from surface water is low due to the interaction with the limited number of lakes in the area, and general lack of a high water table. Estimates of evaporation from the zone of saturation can generally occur to depths ranging from 25 to 50 feet below ground level (ft bgl; Finch and Shomaker, 2006; JSAI, 2006). In 1952, that condition was found to occur around the perennial lakes, along Mescalero Ridge, and south of Mescalero Ridge, from Range 35 to 38 East (Ash, 1963). Most transpiration by native vegetation occurs near the perennial lakes, and springs and seeps, where the local water table is less than 20 ft bgl. Hale, Reiland, and Beverage (1965) calculated average annual evaporation from shallow reservoirs to be approximately 72 inches locally.

Recharge occurs through direct infiltration of areal precipitation, ephemeral stream channels, arroyos, and through concentration in the abundance of playa lakes. All recharge is subject to variations in amount and distribution of precipitation, soil type, and the hydraulic properties of underlying sediments or rocks. Drainage to playa lakes captures 80 to 90 percent of the rainfall. Estimates of recharge from precipitation range from 0.25 to 0.5 inches per year (Theis, 1934; McAda, 1984). The average annual recharge to the Ogallala aquifer in the Lea County UWB is estimated to range from 29,000 to 58,000 ac-ft/yr (Leedshill-Herkenhoff, Inc. et al., 2000).

In Lea County, the greatest amount of recharge from precipitation occurs in areas where dune sand covers bedrock highs, in channels of ephemeral drainages, and in areas well-covered by playa lakes. Generally, areal recharge throughout the basin does not occur unless precipitation events are of long duration or frequent occurrence, allowing deep percolation.

The greatest amount of natural discharge from the Ogallala is through subsurface flow across the Texas–New Mexico state line. The discharge across the state line was estimated to be about 49,000 ac-ft/yr during the period from 1995 to 1998 (Leedshill-Herkenhoff, Inc. et al., 2000). Ash (1963) noted some spring and seep discharge along the contact between Tertiary- and Triassic-age sediments in Townships 11 and 12 South, Range 31 East. Other springs are known to discharge into the few lakes of northern Lea County. Ranger and North Lakes are known to receive the majority of this discharge.

9.1 Hydraulic Properties of the Ogallala

The hydraulic conductivity reported for various portions of the Ogallala aquifer in the Lea County UWB has been evaluated by a number of different authors using different techniques. The techniques include aquifer tests and laboratory analysis (Theis, 1934), and model calibration (McAda, 1984; Musharrafieh and Chudnoff, 1999). Reported values range from 3 to 262 ft/day. Reported values from groundwater-flow models indicate areas with higher hydraulic conductivity near the central portion of the basin between Tatum and Lovington eastward to the Texas border, and near Hobbs eastward to the Texas border.

Specific yield varies throughout the basin and reported values range from 0.10 to 0.35. The specific yield for an unconfined aquifer is the volume of water that will drain from an aquifer per unit surface area of aquifer per unit decline of water. The value is expressed in percent. Musharrafieh and Chudnoff (1999) provide a thorough summary of hydraulic conductivity and specific yield data reported for the Ogallala aquifer in the Lea County UWB and other nearby areas.

Several groundwater in storage estimates have been made for the Ogallala aquifer portion of Lea County UWB (Ash, 1963; McAda, 1984, Leedshill-Herkenhoff, Inc. et al., 2000). The estimates assume specific yield values ranging from 0.20 to 0.35. Estimated groundwater in storage ranged from 31,100,100 to 49,000,000 ac-ft with recoverable groundwater in storage ranging from 14,000,000 to 21,600,000 ac-ft.

9.2 Historic Water Level Declines

Groundwater development for agriculture in the Lea County UWB was fairly limited from 1937 to 1939, averaging about 1,900 ac-ft/yr. Groundwater development increased significantly from 1940 to 1950, when 3,200 ac-ft/yr were pumped, compared to 95,000 ac-ft/yr in 1950. Pumping for irrigation varied from 1951 to 1960, and ranged from 105,000 ac-ft/yr in 1960 to 170,000 ac-ft/yr in 1955 (Ash, 1963).

Water-level declines of up to 8 ft occurred from 1940 to 1950 in the area from McDonald to Prairieview, and at Lovington, Humble City, and Hobbs (Ash, 1963). Declines in the Ogallala aquifer increased significantly from 1950 to 1968 as groundwater development increased. Measurable declines were noted throughout almost the entire Lea County UWB.

From 1968 to 1981, water-level declines of up to 25 ft occurred along the eastern boundary of the Lea County UWB. Groundwater declines exceeding 10 ft occurred along the eastern UWB boundary from the southern portion of Township 13 South to the southern portion of Township 18 South. Another decline of more than 10 ft was present in Township 17 South along the boundary of Ranges 32 and 33 East. No declines are shown to have occurred north of Tatum. Groundwater levels rose almost 10 ft near the southeast part of Lovington, and near the corner of Townships 12 and 13 South, Ranges 37 and 38 East (Leedshill-Herkenhoff, Inc. et al., 2000).

From 1981 to 1998, groundwater declines exceeding 25 ft occurred along the eastern border of the Lea County UWB in Townships 15, 16, and 17 South. Groundwater declines exceeding 10 ft occurred along the eastern UWB boundary from the southern portion of Township 13 South to the southern portion of Township 18 South. Another decline of more than 20 ft was present in Township 17 South along the boundary of Ranges 33 and 34 East. No declines are shown to have occurred north of Tatum. In general, groundwater levels rose throughout most of the northern portion of the basin. The most significant increases occurred in the southeast portion of Township 14 South, Range 32 East, where water levels rose more than 20 ft, and north of the Lea County UWB near the northwest quarter of Township 11 South, Range 36 East where water levels rose almost 36 ft.

Dugan and Cox (1994) report that decline rates from 1980 to 1993 could have been greater, except the annual precipitation from 1981 to 1992 was more than 6 inches above normal. The above-average annual precipitation could likewise be responsible for the water-level rises experienced throughout much of the northern portion of the basin during the same time period.

Pumping in Texas along the Texas-New Mexico border is in large part responsible for the most dramatic water-level declines in the basin. Continued pumping at the rates responsible for the more than 50-ft water-level declines along the border will continue to increase the hydraulic gradient in the area.

10.0 SURFACE WATER

There is no true integrated drainage system off the High Plains within Lea County. The land surface slopes to the east-southeast at 10 to 20 ft/mile, and localized interconnection of some of the playas occurs via shallow drainages, most notably in the eastern portion of the County's High Plains. The shallow drainages intermittently flow as a result of runoff associated with heavy rainfall during the summer. Water may also be present infrequently in small lakes and playas after relatively large summer precipitation events. Small, manmade earthen structures have also been constructed to collect surface runoff and are primarily used for livestock purposes. Ephemeral spring flows may provide limited water supplies to livestock and wildlife, and have been historically reported in areas along the base of Mescalero Ridge.

11.0 WATER PLAN ALTERNATIVES

11.1 Development of Deep Aquifers

While the Ogallala is the primary aquifer in Lea County, there also exist deep aquifers at depths greater than 2,500 ft bgl per Sections 72-12-25 through 72-12-28 NMSA 1978. This statue allows groundwater in aquifers, the top of which is located at a depth exceeding 2,500 ft below ground surface, and that have a total dissolved solids (TDS) concentration exceeding 1,000 milligrams per liter (mg/L), to be developed for uses other than domestic or municipal without the need for water rights or NMOSE review. House Bill 19, passed in the 2009 New Mexico State Legislative session, gives the State Engineer jurisdiction over the deep water for domestic and municipal uses in accordance with Sections 72-12-25 through 72-12-28 NMSA 1978. All appropriations of water from non-potable deep aquifers are restricted to oil and gas exploration and production, prospecting, mining, road construction, agriculture, electricity generation, industrial process, or geothermal use.

As indicated above, the majority of economic development planned for the County is related to high technology industries which could potentially require water of relatively high quality. If need be, the County could appropriate deep aquifer water for use, after water treatment, these waters can be used for industries with lower water-quality sensitivities. Water in the deep aquifer system is reported to have TDS concentrations ranging from 7,000 to more than 100,000 mg/L (McCoy and Peery, 2004), and would require treatment prior to use. To appropriate deep aquifer water, the County could drill its own deep wells, or possibly take over existing oil and gas exploratory wells that did not produce oil or gas.

11.2 Purchase Existing Water Rights

In the event the County needs additional water rights in the future, the County could purchase existing water rights and transfer them to selected well fields. The proposed new guidelines for the basin should make it easier to transfer water rights throughout the basin, except areas in, or immediately adjacent to, critical management areas (CMAs). Existing wells with water rights owned by others could also be purchased and incorporated into the distribution system.

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APPENDIX

Description of geologic units found on Figure 3

Geologic Descriptions

AGE	SYMBOL	NAME	DESCRIPTION
Quaternary			
	Qal	Alluvium	Floodplain and pediment deposits; includes low terrace deposits along streams, and bedrock locally in stream channels; pediment deposits of sandy silt locally modified by sheetwash action.
	Qcd	Eolian deposits	Sand, calcareous, mainly dark brown to grayish brown; derived from lacustrine, fluviatile, and eolian deposits; commonly rests on lacustrine deposits (Tahoka Formation) and eolian sand; includes some alluvium; mostly confined to New Mexico
	Qsd	Windblown sand	Sand and silt in sheets, Qs, locally includes cover sand; dunes and dune ridges, Qsd; and sand sheets, dunes, and dune ridges undivided,
	Qsu	Windblown sand	Sand and silt in sheets, Qs, locally includes cover sand; dunes and dune ridges, Qsd; and sand sheets, dunes, and dune ridges undivided,
	Qs	Windblown sand	Sand and silt in sheets, Qs, locally includes cover sand; dunes and dune ridges, Qsd; and sand sheets, dunes, and dune ridges undivided,
	Qp	Playa and pond deposits	Playa deposits, Qp, clay and silt, sandy, light gray, in shallow depressions, usually covered by thin deposit of Recent sediment (Wisconsinan)
	Qcc	Caliche	Caliche stripped of covering materials mapped separately; thickness up to 10 feet
	Qsgc	Colluvial deposits	Sand, silt, and gravel deposited by slopewash, and talus for Ogallala, red to gray; in part calichified, caliche 1 to 20 feet thick; may include weathered Gatuna Formation locally; rests mainly on Triassic and Permian rocks.
	Qun	Pond deposits	Gastropod-bearing sandy silt and silty clay, gray to light gray, deposited in ponds and shallow swales, locally may include upper part of Tahoka deposits.
	Qta	Tahoka Formation	Locally contains Vigo Park and Rich Lake Dolomites in uppermost clay zones, not separately mapped. Locustrine clay, silt, sand, and gravel, coarser toward margins of deposits, locally calcareous, selenitic. Clay and silt, sandy, indistinctly bedded to massive, weakly coherent, various shades of light gray and bluish gray. Sand, fine- to coarse-grained quartz, indistinctly bedded to massive, friable, gray, grades to gravel at margins of deposits. Molluscan and vertebrate fossils. Thickness 25 feet, feathers out laterally (Wisconsinan)
	Qcs	Windblown cover sand	Sand, fine- to medium-grained quartz, silty, calcareous, locally clayey, caliche nodules, massive, grayish red; distinct soil profile; thickness 25 feet, feathers out locally (mostly Illinoian, may included younger deposits)

Geologic Descriptions

AGE	SYMBOL	NAME	DESCRIPTION
Tertiary			
	To	Ogallala Formation	Sand, silt, clay, gravel, and caliche. Sand, fine- to coarse-grained quartz, silty in part, cemented locally by calcite and by silica, locally crossbedded, various shades of gray and red. Minor silt and clay with caliche nodules, massive, white, gray, olive green, maroon. Gravel, not everywhere present, composed of pebbles and cobbles of quartz, quartzite, minor chert, igneous rock, metamorphic rock, limestone, and abraded Gryphaea in intraformational channel deposits and in basal conglomerate. Caliche, sandy, pisolitic, forms caprock, may include some caliche of Pleistocene age. Where stippled pattern shown, overlain sporadically by 14 to 30 inches of brownish gray to brown to reddish brown, calcareous sand and silt of pre-Illinoian age; on San Juan Mesa, includes sandy loess. Pre-Illinoian sand and silt west of stippled pattern not separately mapped, confined mainly to northwest-southeast trending swales and irregular topographic lows. Thickness up to 350 feet.
	To1	Ogallala Formation	Overlain sporadically by 14 to 30 inches of brownish gray to brown to reddish brown, calcareous sand and silt of pre-Illinoian age
Cretaceous			
	K	Cretaceous undivided	Limestone and shale; limestone, mostly fine grained, argillaceous, thin to thick bedded and massive, in part nodular, grayish yellow, light gray; shale, calcareous, thinly laminated, dusky yellow, yellowish gray, light olive-gray, dark gray; marine megafossils abundant in some beds; outcrop thickness of 53 feet measured at northwestern margin of McKenzie Lake.
Triassic			
	Trd	Dockum Group	Shale, sandstone, siltstone, limestone, and gravel; mostly shale, thin bedded, micaceous, variegated; dips eastward; thickness up to 2000
Permian			
		Rustler Formation	Anhydrite and rock salt with subordinate dolomite, sandstone, claystone, and polyhalite; thickness 90to 450 feet
		Salado Formation	Rock salt with subordinate anhydrite, polyhalite, potassium ores, sandstone, and magnesite; thickness ranges from approximately 800 to 1,200 feet
		Castile Formation	Anhydrite and rock salt with subordinate limestone, thickness ranges to 2,100 feet in Lea County
		San Andres limestone	Artesia Group, limestone, sandstone, siltstone, shale, dolomite, and anhydrite; thickness averages approximately 1,500 feet
		Capitan Reef Complex	Consists of Goat Seep limestone and Capitan limestone, which occupy the Delaware Basin. Lithology consists of variations of carbonate beds including reef deposits; thickness ranges to in excess of 2,250 feet

Geologic Descriptions

AGE	SYMBOL	NAME	DESCRIPTION
Permian			
	Delaware	Mountain	Consists of a thick sequence of sandstones and siltstones interbedded with thin calcareous mudstones; thickness ranges from 2,000 to 4,000 feet
		Permian Leonardian	Series is composed of three distinctive facies: 1) basinal section composed of shale, siltstone, sandstone, and dark limestone; 2) reef and shelf-margin carbonates; 3) shelf section composed of carbonates, evaporites, and redbeds; thickness 2,000 to 3,500 feet