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SECOND DRAFT

LEA COUNTY
DEEP AQUIFER STUDY

by

Annie M. McCoy

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JOHN SHOMAKER & ASSOCIATES, INC.
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Lea County Water Users Association
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OBJECTIVES

The objectives of this report were to assess the potential of the aquifers that are present below the Ogallala aquifer throughout Lea County, including the Santa Rosa aquifer, Rustler Formation, Capitan aquifer, and San Andres aquifer, to provide ground-water supplies for Lea County, and particularly for eastern Lea County, where water demands for public supply, irrigated agriculture, and livestock are high and are projected to increase. Potential locations for exploratory wells in the deeper aquifers were ranked based on estimated well yields, water quality, the depth that wells would need to be completed, estimated proximity to fractures (for Santa Rosa aquifer and San Andres aquifer in particular), distance from high water demand areas of eastern Lea County (particularly the LCUWB), and the amount of data available for the aquifer at a location.

This report is not intended to provide an economic analysis of the water supply in terms of potential treatment costs and distribution costs for various water users in the County.

HYDROGEOLOGY OF POTENTIAL AQUIFERS IN LEA COUNTY

In this section, the reported hydrogeology of the aquifers that are present beneath the Ogallala aquifer, and present in areas of Lea County where the Ogallala aquifer is absent, is described from shallowest to deepest (youngest to oldest).

Cretaceous-Age Tucumcari Formation

The Cretaceous-age Tucumcari Formation is composed of shale with minor limestone and sandstone beds, and is present as small isolated blocks about 3 miles east of Eunice and in the far northeastern part of Lea County at depths of 150 to 200 feet (Nicholson and Clebsch, 1961). The maximum reported thickness of the Tucumcari Formation is 35 feet. In northeastern Lea County, some thickness of the Tucumcari Formation extends above the water table (Ash, 1961). Basal sandstone beds provide limited amounts of water. Ash (1961) reported a potentiometric surface elevation of 14 feet above land surface for one well completed in the Tucumcari Formation, indicating that water was freely flowing out of the well. Since that time, water has ceased to flow out of wells completed in the Tucumcari Formation in northeastern Lea County, probably due to widespread drilling of uncased seismic shot-holes for oil and gas exploration, which appears to have created a hydraulic connection with the overlying Ogallala aquifer (Leedshill-Herkenhoff, Inc. et al., 2000). Shale is the rock-type that dominates the Tucumcari Formation, and because shale does not typically have high permeability, it will probably not provide a substantial water supply except in areas where fractures have increased permeability.

Triassic-Age Santa Rosa Aquifer

The Santa Rosa aquifer, also known as the Dockum aquifer, occurs in the lower part of the interbedded sandstones and shales that make up the Triassic-age Dockum Group. The top of the Dockum Group is present at depths of 25 to 200 feet (Table 2).

The Upper Dockum Group consists of the Chinle Formation, which ranges in thickness from zero to 400 feet thick in the southern half of Lea County (and is typically less than 100 feet south of Township 21) and from 400 to 1,200 feet thick in the northern half of Lea County (Dutton and Simpkins, 1986). The Chinle Formation is dominated by shale, and will probably not provide a substantial water supply.

The Lower Dockum Group is 0 to 1,200 feet thick in the southern half of Lea County and 600 to 1,200 feet thick in the northern half of Lea County. The Lower Dockum Group consists of, from shallow to deep, the Cooper Canyon Formation, the Trujillo Sandstone, the Tecovas Formation, and the Santa Rosa Sandstone, which is the principal water-bearing unit and is referred to as the Santa Rosa aquifer in this report (Cazeau, 1962; Bradley and Kalaswad, 2001). The Santa Rosa aquifer is typically 250 to 500 feet thick. Ground water generally flows southeastward in the Santa Rosa aquifer, and the aquifer is recharged in part by upward leakage from the underlying Permian-age sediments (Lehman et al., 1992; Bradley and Kalaswad, 2001). Downward leakage into the Santa Rosa aquifer from the overlying Ogallala aquifer occurs in some areas as a result of hydraulic-head differences (Dutton and Simpkins, 1986). Data in the area east of Eunice indicates that it is unlikely that downward leakage through the lower Dockum into the Santa Rosa is occurring (Cook-Joyce, Inc. & Intera, Inc., August 2004, Cook-Joyce, Inc., November 2003).

Table 2. Summary of potential deep aquifer ground-water sources for Lea County

aquifer	geologic age	typical depth to top of aquifer, ft bgl	typical thickness, ft	estimated yields, gpm	total dissolved solids, mg/L	rank of potential
Tucumcari Formation	Cretaceous	150 to 200 in small area east of Eunice, and northeastern Lea County	0 to 35	na	na	5
Santa Rosa aquifer	Triassic	500 to 1,100	200 - 250 ~~250 to 500~~ (2,400 max)	6 to 100	635 to 2,500	3
Rustler Formation	Upper Permian	700 - 1,350 ~~580 to 1,240~~	80 to 140 (360 max)	10 to 100	10,347 to 325,800	4
Capitan aquifer	Permian	2,800 to 4,600	900 to 1,400 (2,200 max)	50 to 1,300	7,000 to 173,448	1 (highest potential)
San Andres aquifer	Permian	3,000 to 5,000	700 to 2,000	220[c]	9,556 to about 100,000	2
Delaware Basin aquifer	Permian	3,700 to 6,000	2,000 to 3,500	5 to 20	chloride 120,000 to 180,000[b]	6

ft bgl feet below ground level gpm gallons per minute
mg/L milligrams per liter na data not available

[b] For comparison, chloride concentration is about one-half of total dissolved solids concentration in the Capitan aquifer (Wallace, 1993)

[c] This is an average current production rate (oral communication, Warren, 2002), but based on pump settings and water levels during pumping, wells completed in the San Andres are capable of pumping at higher rates.

The Santa Rosa aquifer was tapped by the City of Jal's municipal wells until 1983, when the wells were abandoned due to low yield. The wells reportedly pumped dry after only 3 hours of pumping at an unspecified rate (Seifts, oral communication, 2002). These wells were also reported to have high chloride concentrations. Wells near Township 21 South, Range 36 East, near Oil Center, reportedly pump water from the Dockum aquifer, but contamination associated with nearby oil wells has been noted (Richey et al., 1985). The contamination could be related to seepage from brine pits or poorly-completed oil wells (Leedshill-Herkenhoff, Inc. et al., 2000).

Transmissivity calculated for a well completed in the Santa Rosa aquifer in Kermit, Texas, was 4,600 feet squared per day (ft^2/d) (Bradley and Kalaswad, 2001). Yields of wells completed in the Santa Rosa aquifer in Lea County reportedly range from 6 to 100 gallons per minute (gpm), and yields of wells completed in the Santa Rosa aquifer in Andrews and Gaines County, Texas, range from 5 to 251 gpm, and average about 86 gpm (Fig. 3; Nicholson and Clebsch, 1961; Texas Water Development Board). Well yields of up to 500 gpm have been reported for irrigation wells in isolated locations in Texas (Knowles et al., 1984).

Water quality ranges from fair to poor in the Santa Rosa aquifer, with total dissolved solids (TDS) concentrations estimated to range from about 635 to 1,950 milligrams per liter (mg/L) in Lea County (Richey et al., 1985), and 1,500 to 12,000 mg/L in Andrews and Gaines Counties, Texas (Fig. 4; Texas Water Development Board). TDS concentrations in the Santa Rosa aquifer are typically between 1,000 and 2,000 mg/L south of Township 21 South, and are typically between 2,000 and 5,000 mg/L north of Township 21 South (Dutton and Simpkins, 1986).

Upper Permian-Age Rustler Formation

Beneath the Triassic-age rocks, and above the evaporites and limestone of the Permian-age Salado and Castile Formations, is the Upper Permian-age Rustler Formation (Fig. 2). The Rustler Formation consists of interbedded limestone, dolomite, sand, and shale, and typically ranges from 80 to 140 feet thick in Lea County (Table 2; Richey et al., 1985; Hiss, 1975). The maximum thickness of the Rustler Formation is about 360 feet in Lea County, and the depth to the top of the Rustler Formation is typically 370 to 550 feet in the southern half of Lea County (Richey et al., 1985). The Culebra Limestone is an important water-bearing section of the

Rustler Formation near the Waste Isolation Pilot Plant in Eddy County (Richey, 1989). Yields of wells completed in the Rustler Formation reportedly range from 10 to 100 gpm (Richey et al., 1985). Water quality is poor because the Rustler Formation is in contact with the evaporites of the Salado and Castile Formations, which extend several thousand feet beneath the base of the Rustler Formation. TDS concentrations range from 10,347 to 325,800 mg/L in the Rustler Formation (Leedshill-Herkenhoff, Inc. et al., 2000).

Permian-Age Capitan Aquifer

The Capitan aquifer occurs in the dolomite and limestone of the Capitan reef complex, including the Capitan Limestone, parts of the Goat Seep Limestone, most of the Carlsbad facies of the Artesia Group, and carbonate banks in the upper part of the San Andres Limestone, which formed around the Delaware Basin when it was a shallow sea in the Permian period (Hiss, 1975; Muehlberger and Dickerson, 1989). The Capitan aquifer arcs across southern Lea County and is ~~marked~~ by ~~the rainbow of colors that represent~~ a steep gradient in the Earth's gravitational field on the isostatic gravity map of New Mexico (Fig. 5; Kucks et al., 2001). The Capitan aquifer is characterized by high porosity and permeability, and extensive solution caverns, solution channels, and sinkholes (Hiss, 1980). The Capitan aquifer is typically 900 to 1,250 feet thick, with a maximum thickness of about 2,200 feet (Table 2; Fig. 2; Leedshill-Herkenhoff, Inc. et al., 2000). The Capitan aquifer is thinnest where submarine canyons filled with sandstones, siltstones, and limestones, incised into the reef in the Permian period (Fig. 6, Fig. 7). The top of the Capitan aquifer is typically present at depths between 3,000 and 4,600 feet in Lea County.

Transmissivities in wells completed in the Capitan aquifer range from 5,400 to 25,000 ft^2/d, and well yields reportedly range from 50 to 1,300 gpm (Richey et al., 1985). Highest transmissivities appear to be measured in wells that are completed in the poorly-bedded limestone and wackestone of the Capitan and Goat Seep Limestones along the extreme southwestern edge of the Capitan aquifer (Hiss, 1975). Hathaway (1985) modeled a relatively low transmissivity of 864 ft^2/d for the Laguna submarine canyon (Fig. 6, Fig. 7) near the border between Eddy County and Lea County, suggesting that, in general, the submarine canyons have much lower transmissivities than the Capitan aquifer.

In the Capitan aquifer, ground water generally flows in a southeastward direction along the reef toward Texas (Fig. 5). Ground-water flow direction in the aquifer was influenced by the incision of the Pecos River into the Permian beds to the west in Eddy County, and by oil and ground-water development in the Delaware Basin. Some ground water flows in a northeastward direction from the Permian-age Delaware Basin aquifer into the Capitan aquifer (Fig. 5; Hiss, 1980; Leedshill-Herkenhoff, Inc. et al., 2000). The submarine canyons incised in the Capitan reef have lower transmissivities than the reef and therefore function as significant barriers to horizontal movement of water through the Capitan (Hiss, 1975; Wallace, 1993). The units that underlie the Capitan aquifer are typically 2 or 3 times less permeable than the Capitan aquifer, and have poor hydraulic connectivity with the aquifer. However, on the northeast side of the Capitan aquifer near Eunice, the adjacent and underlying San Andres aquifer has relatively high hydraulic conductivities that are equivalent to those of the Capitan aquifer (Wallace, 1993).

The Capitan aquifer's water is of poor quality, due to proximity to the evaporite deposits of the Delaware Basin and the Salado and Castile Formations. TDS concentrations typically range from 7,000 to 173,448 mg/L (Wallace, 1993; Brown, 1997; Leedshill-Herkenhoff, Inc. et al., 2000). The highest TDS and chloride concentrations occur in western Lea County near the border with Eddy County (Fig. 8).

Wallace (1993) determined that the zone of lowest chloride concentrations (below 5,000 mg/L) within the Capitan aquifer in Lea County is located in Townships 21 and 22 South, Range 35 East, based on observations of Hiss' data (1975). However, JSAI observed Hiss' data (1975) and found that the zone of lowest chloride concentrations is not confined to Townships 21 and 22 South, Range 35 East, but extend from Range 34 East south to the border between Lea County and Winkler County, Texas.

Some water-supply wells completed in the Capitan aquifer also produce oil, which originates in parts of the Artesia Group, which is adjacent to the Capitan aquifer along its northern and eastern margins (Fig. 2).

Permian-Age San Andres Aquifer

North and east of the Capitan aquifer in Lea County, the Permian-age marine shelf rocks include the Artesia Group and the underlying San Andres Limestone, referred to in this report as the San Andres aquifer. Wells drilled in the San Andres aquifer show highly variable yields, suggesting that permeability depends on the presence of fractures, solution caverns, and solution channels (Nielson and Sharp, 1985; Mayer and Sharp, 1998). The San Andres aquifer is an important water-bearing unit, while the Artesia Group (including the Tansill, Yates, Seven Rivers, Queen, and Grayburg Formations) is an important oil-bearing unit. Average transmissivities of wells drilled into cavernous zones in the San Andres aquifer are 21,341 ft^2/d and 33,437 ft^2/d (Scalapino, 1950). Porosity and permeability are high in the San Andres aquifer adjacent to the Capitan aquifer between Jal and Eunice (Fig. 9). In this area, the San Andres aquifer is thought to have good hydraulic connectivity with the Capitan aquifer (Hiss, 1975). The San Andres aquifer is typically 700 to 2,000 feet thick and the top of the aquifer is present at depths of 3,500 to 5,000 feet (Table 2).

In places, the San Andres aquifer produces highly saline water, with chloride concentrations exceeding 100,000 mg/L. However, chloride concentrations below 5,000 mg/L can be found in the area of high porosity and permeability described above. Some wells that produce water from the San Andres aquifer also produce oil and gas.

Permian-Age Delaware Basin Aquifer

South and west of the Capitan aquifer in Lea County, the Delaware Basin aquifer (Fig. 2) is composed of the Brushy Canyon, Cherry Canyon, and Bell Canyon Formations of the Delaware Mountain Group. These formations are mainly composed of sandstone, siltstone, and evaporite deposits. The Delaware Basin aquifer reportedly has lower permeability, lower yields (5 to 20 gpm), and produces water of poorer quality than the Capitan aquifer (Hiss, 1980; Uliana, 2001). Chloride concentrations in the Delaware Basin aquifer range from 120,000 to 180,000 mg/L in Lea County (Hiss, 1975).

STRUCTURES AFFECTING DEEPER AQUIFERS

Structures such as faults in the deeper aquifers are typically surrounded by zones of fractures that enhance the porosity and permeability of an aquifer. Enhanced permeability usually increases the potential of an aquifer to yield greater quantities of water to wells. JSAI has interpreted a number of faults and a structural 'high' from maps that show contoured elevations of the top of the Permian-age Capitan aquifer and Yates Formation (part of the Artesia Group of the Permian-age marine shelf), Upper Permian-age Rustler Formation, and the base of the Tertiary-age Ogallala Formation (Fig. 10, Fig. 11). The interpreted faults (structures) may extend upwards into the Triassic-age Santa Rosa aquifer. Data in Andrews County, Texas near the New Mexico state line indicates that faulting in this area has not increased the permeability of the Triassic-age Dockum Group rocks above the Santa Rosa because the fault joints in the upper portion of the Dockum Group in this area are clay filled (Cook-Joyce, Inc. & Intera, Inc., August 2004, Cook-Joyce, Inc., November 2003). Whether or not faulting in this area has increased the permeability of the Santa Rosa is unknown.

One fault interpreted from maps of the top of the Yates Formation and Rustler Formation extends from the western edge of Lea County to Range 35 East, about eighteen miles west of Hobbs, where this east-southeast trending system dissipates at a northwest-trending fault interpreted from maps of the top of the Ordovician-age Ellenburger Formation (compiled from aeromagnetic and gravity data by Shell Oil). A number of other northwest- and northeast-trending fractures or faults in areas around Lovington, Hobbs, and Eunice, were interpreted from the map of the top of the Ordovician-age Ellenburger Formation. These faults loosely bind the northwest, northeast, and east edges of a structural high that is present on the top of the Yates Formation and Rustler Formation (Fig. 10, Fig. 11). One northwest-trending fault interpreted from the top of the Ellenburger Formation appears to bisect, or offset, the structural high in Township 19 South, Range 37 and 38 East. The structural high coincides with a positive anomaly on the residual gravity map of Lea County (Fig. 10).