Chapter 7

The Dockum Aquifer in the Edwards Plateau

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Introduction

The Upper Triassic Dockum Group extends over approximately 96,000 square miles in parts of Colorado, Kansas, Oklahoma, New Mexico, and Texas. In Texas, sands of the Dockum Group constitute the Dockum aquifer, which is recognized by the Texas Water Development Board (TWDB) as a minor aquifer and produces small to moderate quantities of fresh to saline water (Ashworth and Hopkins, 1995). As delineated by Ashworth and Hopkins (1995), the Dockum aquifer includes an area containing groundwater with less than 5,000 mg/l total dissolved solids (Figure 7-1). However, for the purposes of this study, we also include other areas of the aquifer that have total dissolved solids concentrations greater than 5,000 mg/l. In this study, the term "Dockum aquifer" is used loosely for all water-bearing strata of the Dockum Group regardless of their total dissolved solids (TDS) content.

Locally, the Dockum aquifer can be an important source of groundwater for irrigation, public supply, oil-field activity, livestock, and manufacturing. However, deep pumping depths, poor water quality, low yields, and declining water levels have discouraged its more widespread use. Nevertheless, the aquifer may become an important secondary source in the future, especially in areas where demand from the overlying Ogallala and Edwards-Trinity (Plateau) aquifers is high. It could also be considered for desalination in the future.

The purpose of this article is to present a summary of the characteristics of the Dockum aquifer in areas underlain by the Edwards-Trinity formation. Much of the information presented in the article was obtained from previous literature and from TWDB records and represents a summary our recent TWDB report of the Dockum aquifer (Bradley and Kalaswad, 2003).

Physiography and Climate

The area overlying the Dockum aquifer in the study area is generally flat with a gentle slope toward the southeast. Drainage north and east of the Pecos River typically is closed,

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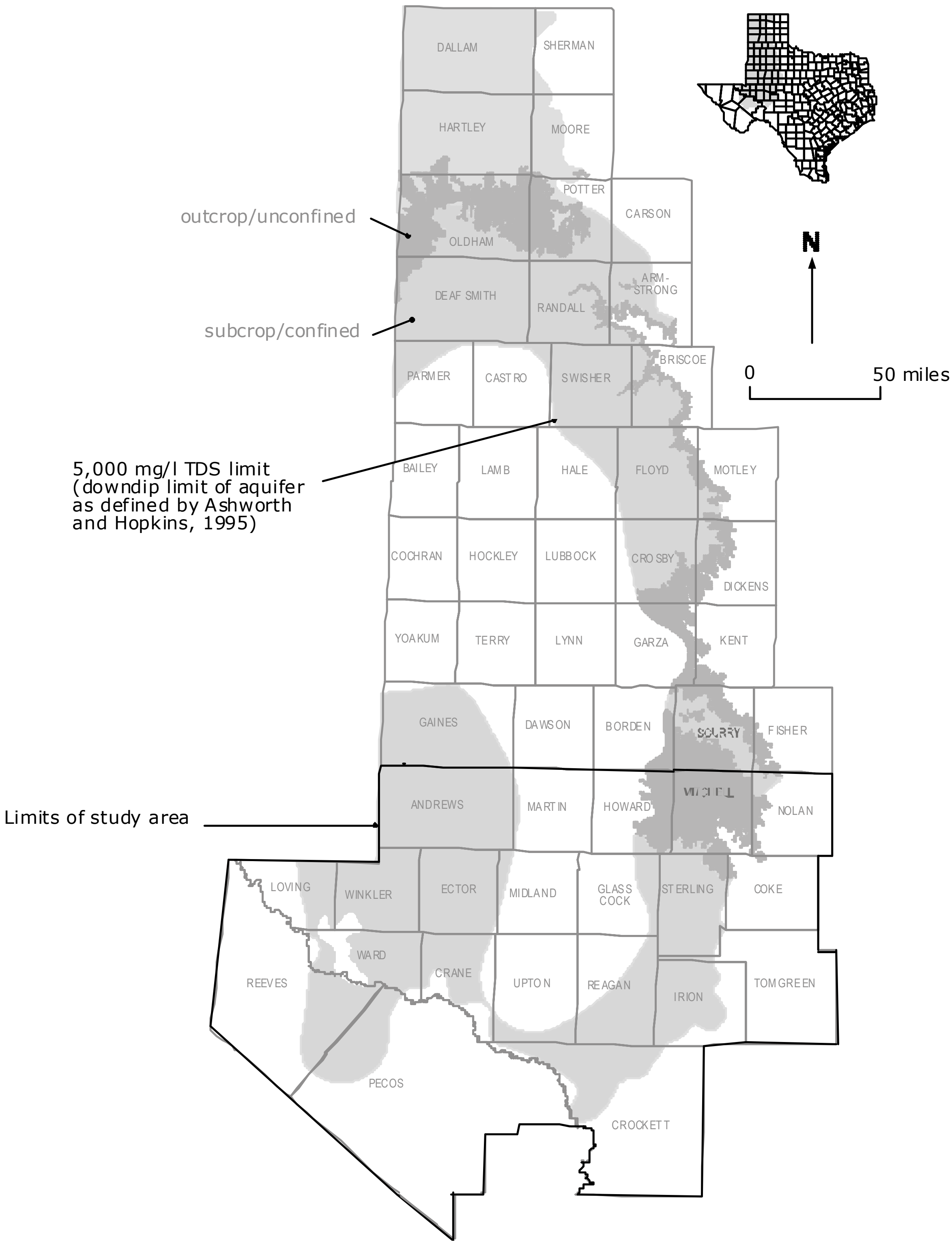

Figure 7-1: Areal extent of the Dockum aquifer and the study area.

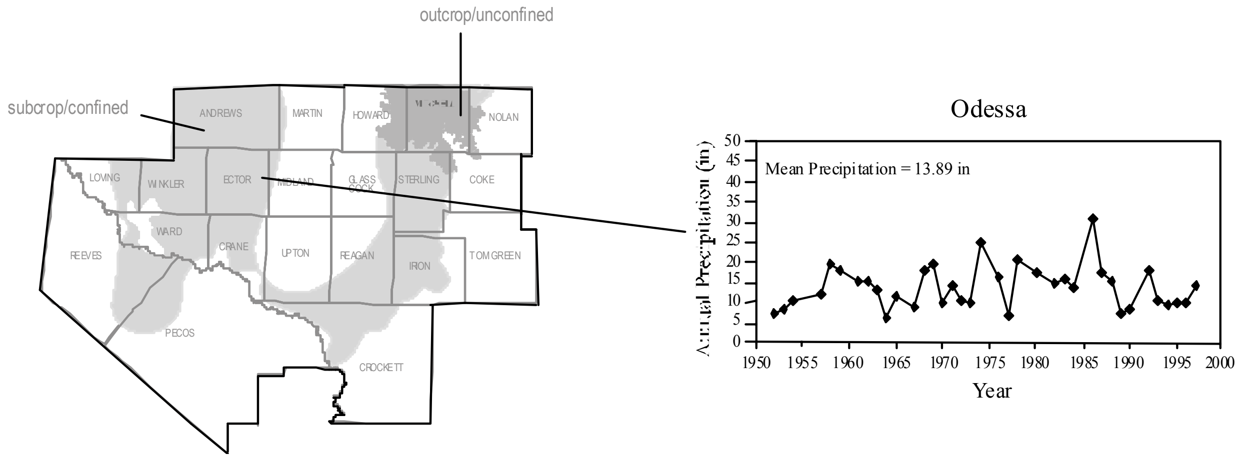

Figure 7-2: Historical annual precipitation recorded at Odessa, Ector County.

with runoff collecting in swales, sinks, and playas (Ashworth, 1990). The climate of the region is semiarid, with hot summers and mild winters (Larkin and Bomar, 1983). Mean annual precipitation in the study area is approximately 14 inches (Figure 7-2), and lake surface evaporation is about 80 inches/yr (Larkin and Bomar, 1983).

Geologic Setting

The approximately 2,000-ft thick Triassic sediments of the Dockum Group that form the Dockum aquifer consist of a series of alternating sandstones and shales (Cazeau, 1962). Individual sandstone units are light to dark or greenish-gray, buff, and red, and range in thickness from a few feet to about 50 ft. The red and maroon sandy shale units that separate the sandstones range in thickness from about 50 to 100 ft.

The formations within the Dockum Group (in ascending stratigraphic order) are the Santa Rosa Formation, the Tecovas Formation, the Trujillo Formation, and the Cooper Canyon Formation. Locally the term *Santa Rosa* has been applied to the lower sandstone zones in the Dockum Group that may include all units of the Dockum Group except the upper mudstone.

The basal formation, called the Santa Rosa Formation, rests unconformably on Upper Permian red beds and can be up to 130-ft thick (Lehman and others, 1992; Lehman, 1994a, b; Riggs and others, 1996). The Santa Rosa Formation is overlain by variegated mudstones and siltstones of the Tecovas Formation (Gould, 1907), which in turn is disconformably overlain by the 250-ft thick Trujillo Formation composed of massive, crossbedded sandstones and conglomerates (Lehman, 1994a, b). The Cooper Canyon Formation consists of reddish-brown to orange mudstone with some siltstone, sandstone, and conglomerate (Lehman and others, 1992).

The Dockum Group is generally considered to represent sediments deposited in fluvial, deltaic, and lacustrine environments within a closed continental basin (McGowen and others, 1977, 1979; Granata 1981). The basin apparently received sediments from all directions, although in the study area the source areas were primarily to the south and southwest (Granata, 1981).

The beds of the Dockum Group are essentially horizontal, with very gentle dips toward the center of the main basin, whose axis trends approximately north-south. The dip varies considerably from location to location but is approximately 30 ft/mi (Rayner, 1963). In the study area, the primary structural features are the Central Basin Platform in the east and the Delaware Basin in the west (Granata, 1981).

The top of the Dockum Group is relatively flat and reflects the final filling of the Dockum Basin and the effects of postdepositional erosion. The opening of the Gulf of Mexico in the Cenozoic Period tilted the entire region toward the southeast.

Hydrogeology

Recoverable groundwater in the Dockum aquifer is contained within the many sandstone and conglomerate beds that are present throughout the sedimentary sequence. The coarse-grained deposits form the more porous and permeable water-bearing units, whereas the fine-grained sediments form impermeable aquitards (Dutton and Simpkins, 1986). The coarse-grained deposits, which are developed in the lower and middle sections, are the most prolific parts of the aquifer and are referred to as the Best Sandstone (Figures 7-3 and 7-4). Locally, any water-bearing sandstone within the Dockum Group is typically referred to as the Santa Rosa aquifer. In the Pecos River Valley, the Dockum aquifer is commonly known as the Allurosa aquifer (White, 1971).

In the study area, the Dockum aquifer overlies Permian-age beds and in turn is overlain by Cretaceous strata, the Ogallala Formation, and the Cenozoic Pecos Alluvium. The aquifer typically is under confined or partially confined conditions where Dockum Group sandstones are in contact with the Cenozoic Pecos Alluvium aquifer.

Water Levels and Groundwater Flow

Potentiometric maps drawn from water levels measured by the TWDB between 1981 and 1996 indicate that groundwater flow in the Dockum aquifer in the study area is generally to the east and southeast (Figure 7-5). Hydrographs of wells located in the study area show a variety of water-level fluctuations (Figure 7-6). In Loving, Ector, and Reeves counties, the water table appears to have declined markedly, whereas in Ward and Winkler counties it has remained relatively stable or has declined only slightly. The most significant water-level decline (almost 85 ft) was recorded in well 28-39-401 in Ector County. This decline was presumably the result of pumping in a nearby municipal water-supply well.

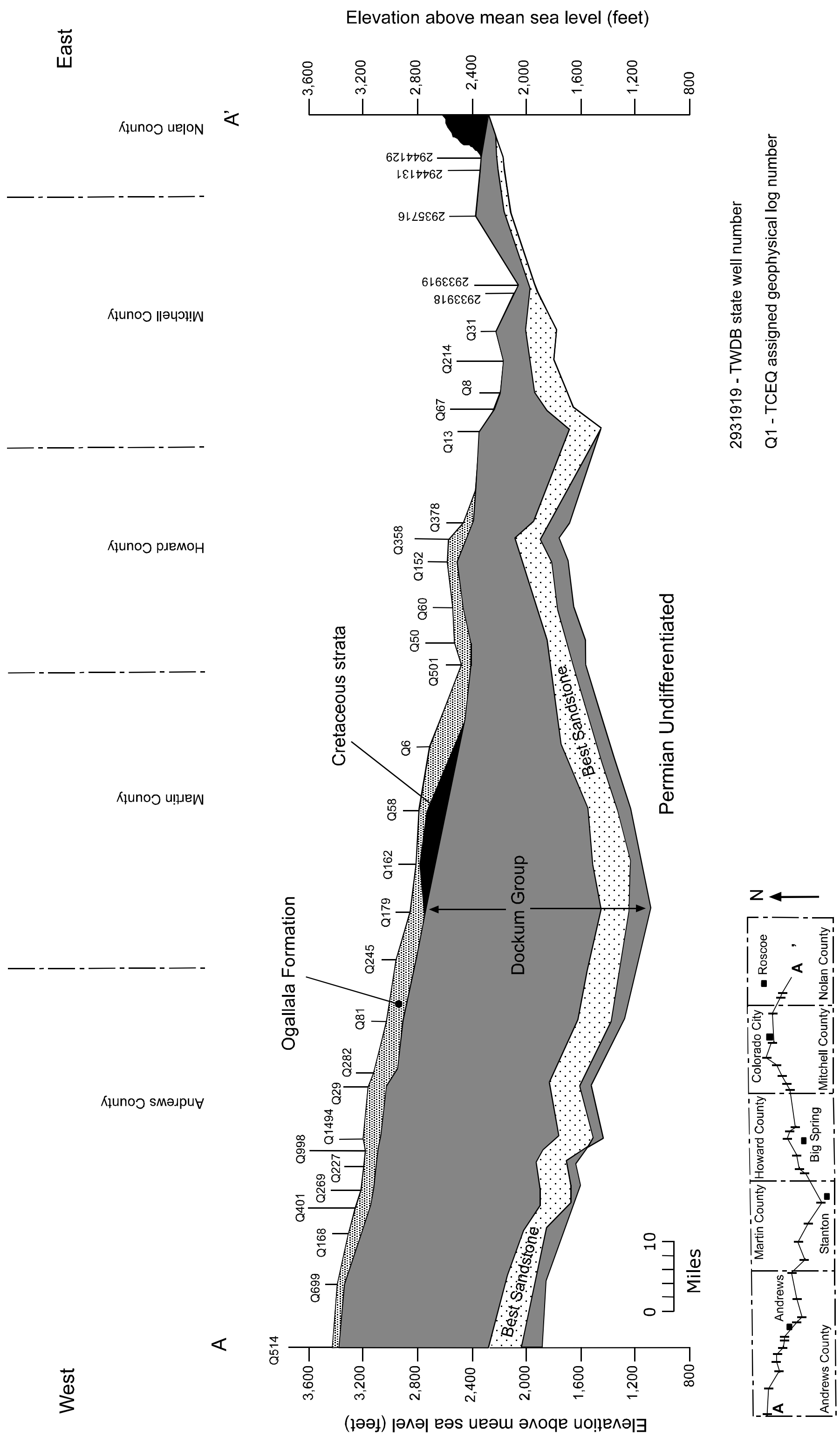

Figure 7-3: Geologic cross-section from A-A'.

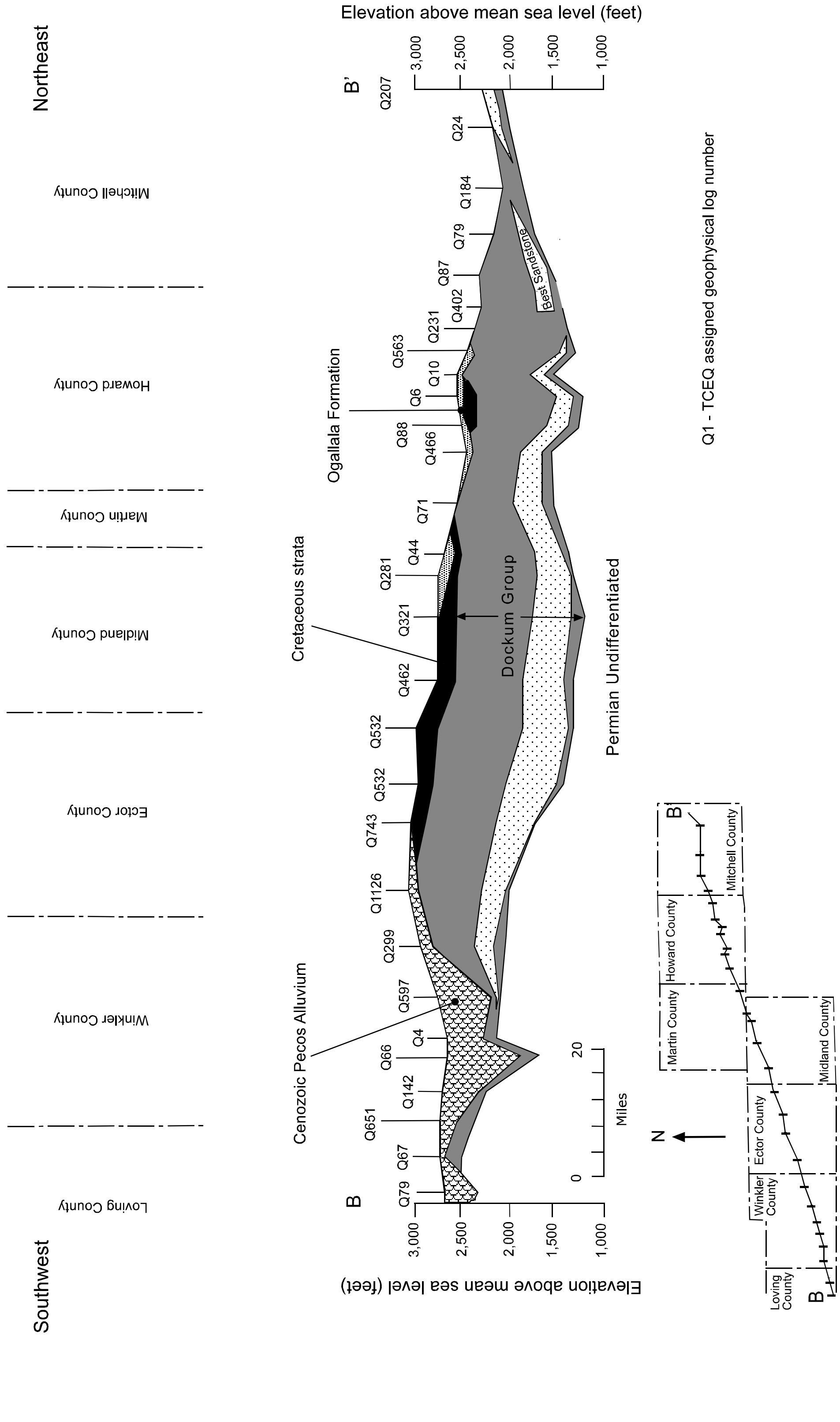

Figure 7-4: Geologic cross-section from B-B'.

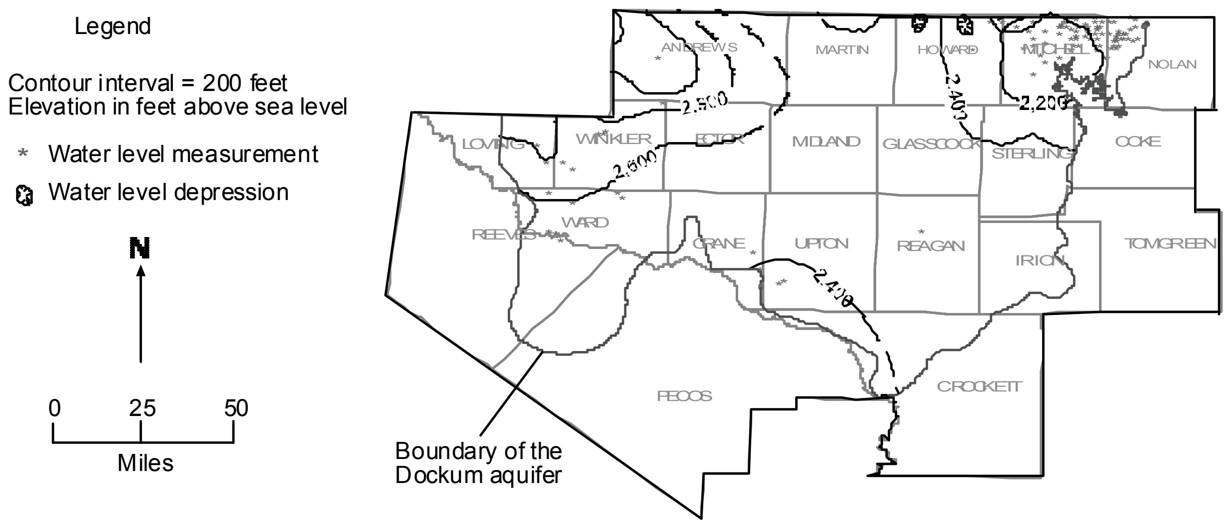

Figure 7-5: Approximate water-level elevations in the Dockum aquifer, 1981 through 1996.

Recharge

The Dockum aquifer is recharged by precipitation over areas where Dockum Group sediments are exposed at the land surface. Groundwater in the confined portions of the aquifer most likely originated as precipitation that fell on outcrops in eastern New Mexico in the Pleistocene. This recharge ceased when the Pecos and Canadian River valleys were incised during the late Pleistocene between the present-day Dockum aquifer in Texas and the paleo-recharge areas to the west (Dutton and Simpkins, 1986).

The Dockum aquifer is also recharged by upward leakage from the underlying Permian aquifer (Bassett and others, 1981; Bentley, 1981; Wirojanagud and others, 1984; Orr and others, 1985). Downward leakage into the Dockum aquifer occurs from the overlying Ogallala Formation, Cretaceous strata, and Cenozoic Pecos Alluvium as a result of hydraulic-head differences between the aquifers (Dutton and Simpkins, 1986; Nativ and Gutierrez, 1988).

In parts of Crockett, Irion, Reagan, Sterling, Tom Green, and Upton counties, the Santa Rosa Sandstone is in hydrologic contact with the overlying Edwards-Trinity (Plateau) aquifer (Walker, 1979; Ashworth and Christian, 1989). Groundwater samples obtained from wells completed in the Dockum aquifer in Sterling County are dominated by calcium bicarbonate-type (Ca-HCO_3) water that is characteristic of groundwater in the Edwards-Trinity (Plateau) aquifer. The presence of $CaHCO_3$ in Dockum groundwater suggests that there is some groundwater movement from the limestone-dominated Edwards-Trinity (Plateau) aquifer into the Dockum aquifer.

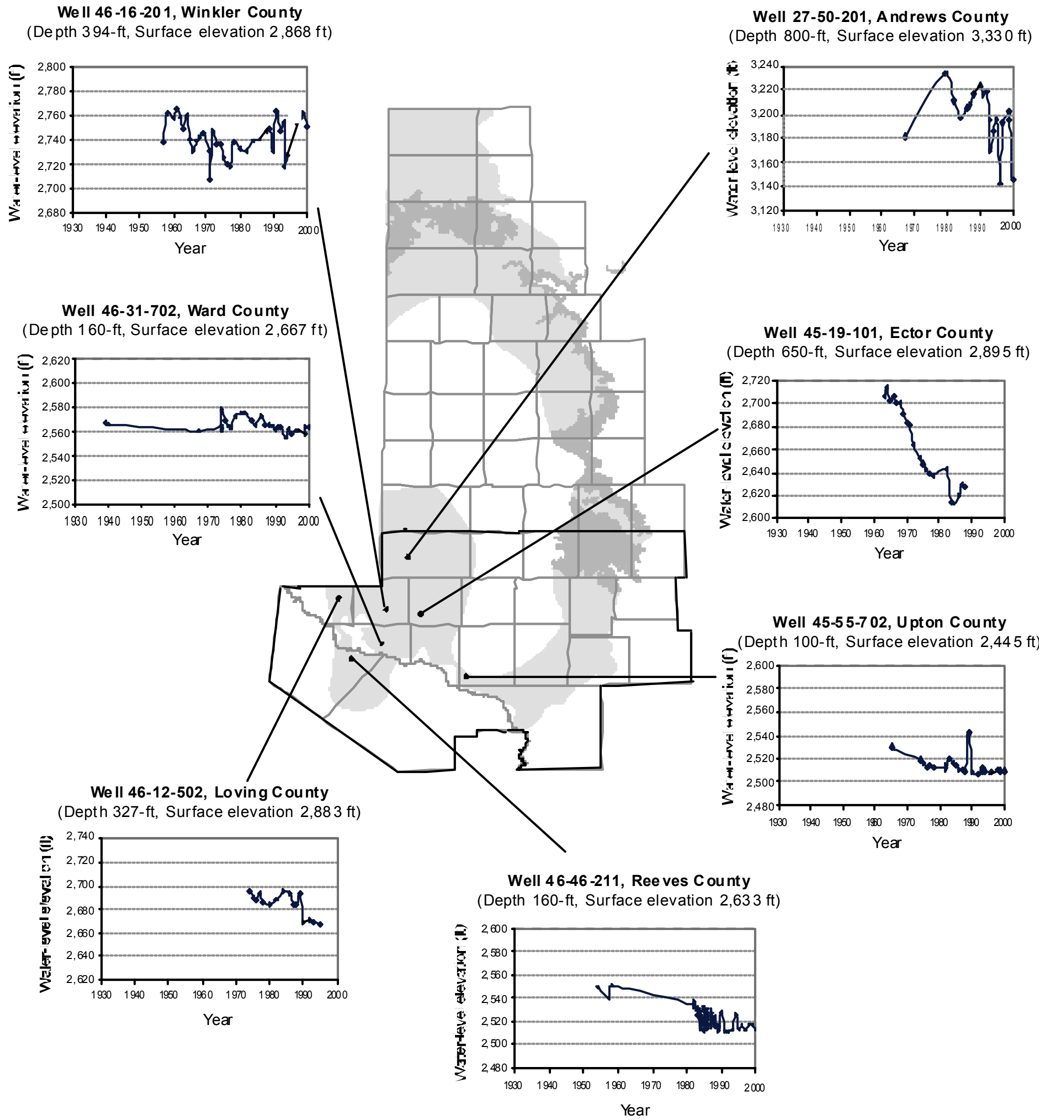

Figure 7-6: Selected hydrographs from the study area.

Aquifer Properties

The hydraulic properties of the Dockum aquifer vary considerably from location to location. Mean well yields measured by the TWDB in the study area ranged from approximately 6 gallons per minute (gpm) in Howard County to 418 gpm in Winkler County. Similarly, mean specific capacities ranged from 0.3 gallons per minute per foot (gpm/ft) in Upton County to 25 gpm/ft in Reeves County. The highest specific capacity within a county ranged from 0.3 gpm/ft in Upton County to 37 gpm/ft in Reeves County.

Transmissivity ranged from a low of about 48 feet squared per day (ft^2/d) in Upton County to a high of 4,600 ft^2/d in Winkler County. The high transmissivity in Winkler County was recorded during an aquifer test conducted on City of Kermit wells by the TWDB in 1957. These wells are completed in the Santa Rosa Sandstone described by Garza and Wesselman (1959) as a massive sandstone unit of limited areal extent. The storage coefficient was approximately 2.5×10^{-4}, which suggests that the aquifer in the test area is confined to partially confined.

Groundwater Quality

Groundwater in the Dockum aquifer generally is of poor quality. Over most of the study area it is characterized by decreasing quality with depth, mixed types of water, high concentrations of total dissolved solids (TDS) and other constituents that exceed secondary drinking water standards, and high sodium levels that may be damaging to irrigated land.

The chemical quality of water in the Dockum aquifer ranges from fresh (TDS of less than 1,000 mg/l) in outcrop areas around the fringes of the aquifer to brine (TDS greater than 10,000 mg/l) in the confined parts of the aquifer (Figure 7-7). TDS concentrations in the study area range from a mean value of 282 mg/l in Sterling County to 11,338 mg/l in Glasscock County. Groundwater in the Dockum aquifer is also typically hard with hardness ranging from less than 25 mg/l in Swisher County to more than 3,600 mg/l in Reagan County.

Groundwater samples collected in 1995 and 1996 from an area near the Edwards-Trinity (Plateau) aquifer did not show a unique chemical signature (Figure 7-8a). Where overlain by the Cenozoic Pecos Alluvium aquifer, groundwater in the Dockum aquifer is characterized by Ca-SO_4-mixed-anion-type waters (Figure 7-8b). Groundwater samples collected from Ector County had gross alpha particle concentrations of 6 to 23 picocuries per liter (piC/L). The MCL established by the Texas Commission on Environmental Quality for gross alpha particle activity limit is 15 piC/L. Groundwater samples from Crane, Irion, Mitchell, and Sterling counties had maximum radium-226 and radium-228 concentrations exceeding 5 piC/L. The occurrence of uranium in the Dockum Group has been known for years (McGowen and others, 1977) and is the source of the high concentrations of radium-226 and radium-228 detected in the groundwater samples.

Sodium in groundwater is a constituent that has neither an MCL nor a secondary standard but is still a concern where the water is used for irrigation purposes. Sodium adsorption ratios higher than 18 (which typically result in excess sodium in the soils) were detected in groundwater samples from Andrews, Ector, Glasscock, Howard, Martin, and Reagan counties. Samples from Andrews, Ector, Howard, and Martin counties also had residual sodium carbonate (RSC) values greater than 2.5 meq/L, suggesting that the water in these areas is not suitable for irrigation. The tendency of irrigation water to cause a high buildup of salts in the soil is called the salinity hazard of the water. The area with a salinity hazard is shown in Figure 7-9.

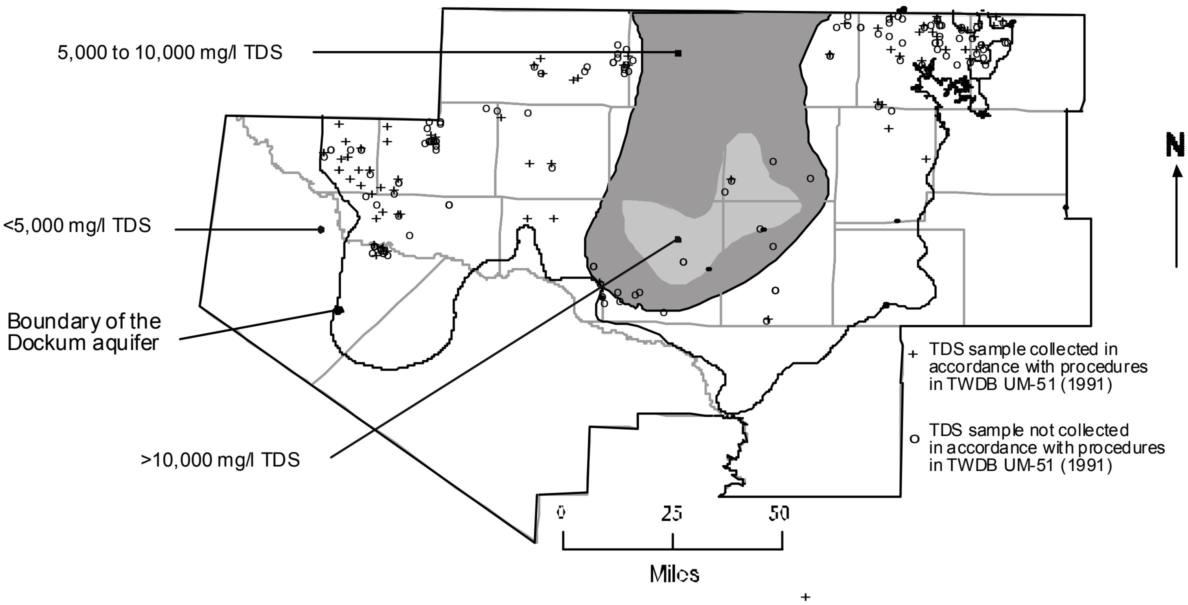

Figure 7-7: Distribution of total dissolved solids (TDS) in the study area, 1981 through 1996.

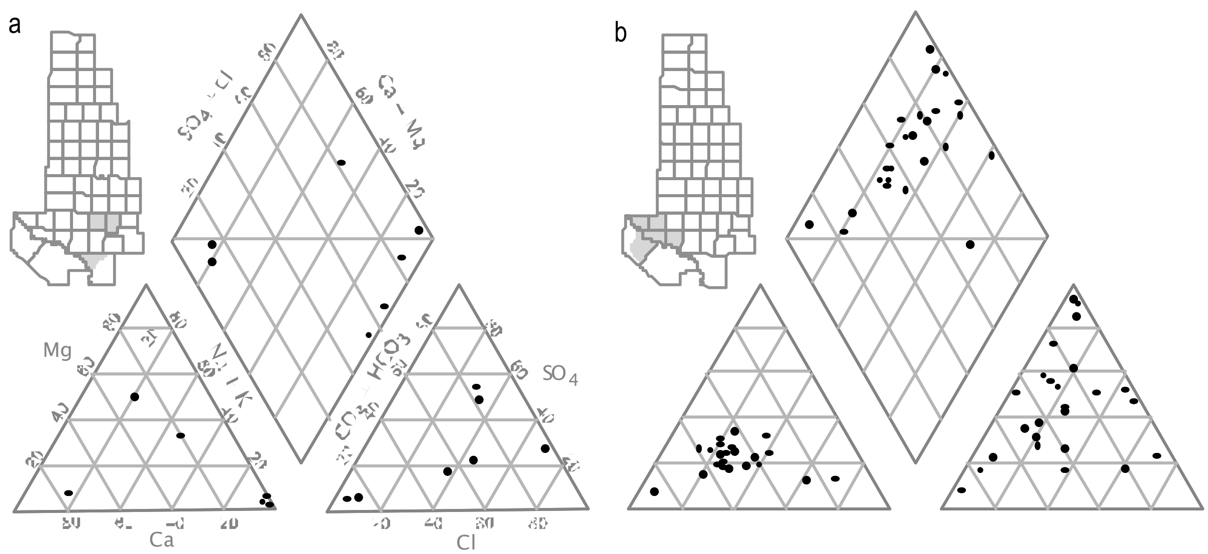

Figure 7-8: Trilinear diagrams for areas overlying the Edwards Plateau region (a) and the Pecos River valley (b).

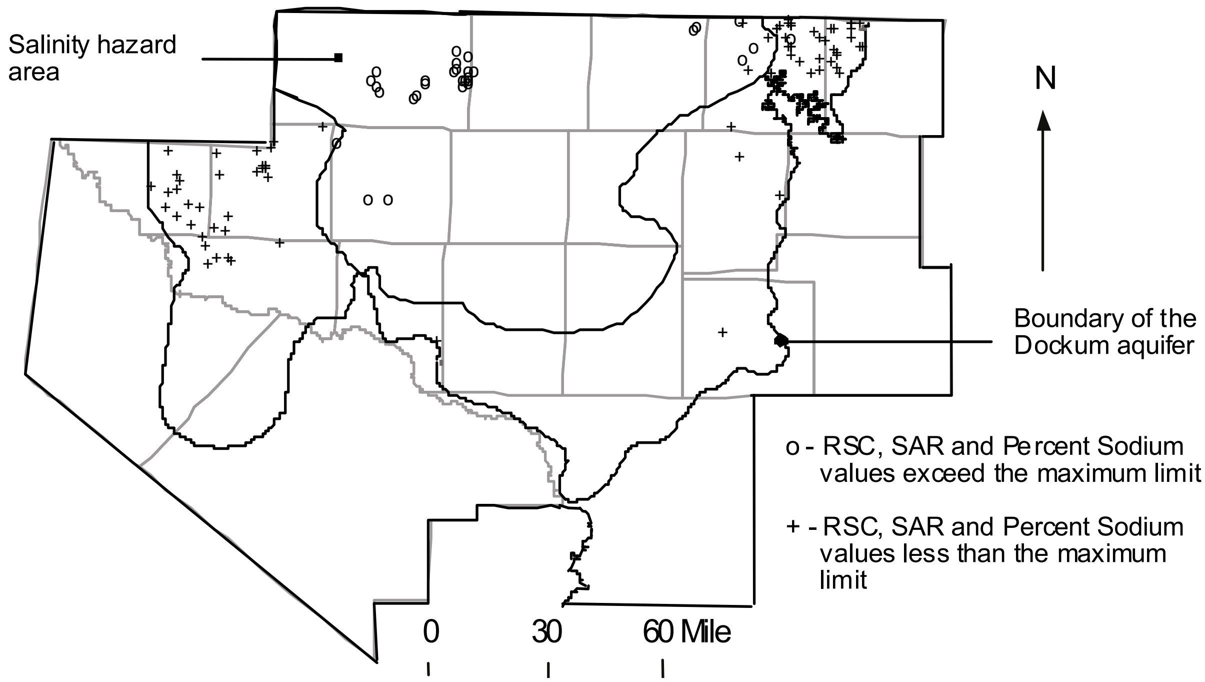

Figure 7-9: Salinity hazard for areas overlying the Dockum aquifer.

Discharge

Discharge of groundwater from the Dockum aquifer occurs at pumping wells, small springs that contribute to stream base flow in the outcrop, evapotranspiration, and cross-formational flow. The greatest amount of discharge occurs from the pumping of wells installed in the aquifer. Irrigation and public supply use is limited to areas of the Dockum aquifer where the water quality is acceptable, depth to water is shallow, and a sufficient thickness of sandstone exists to make the aquifer productive. Municipal users of Dockum aquifer water include the cities of Barstow, Kermit, and Pecos. The Colorado River Municipal Water District also uses water from the Dockum aquifer.

Springs occur in areas where the Dockum sediments intersect the water table. Brune (1981) described springs issuing from the Dockum aquifer along the Pecos River Valley. Many of these springs are now dry or have lower flows than they did in the past.

Estimate of Groundwater Volume in the Dockum Aquifer

Estimating the volume of water from the Dockum aquifer is difficult. Interbedded mudstones, sandstones, and other rock types; confined to partly confined conditions; and the very low recharge rates combine to make the aquifer a complex hydrologic system. We estimated the amount of water of different TDS concentrations in the aquifer on a county-by-county basis using the procedure and assumptions outlined below.

For the purpose of representing the saturated volume of the aquifer, we selected the “Best Sandstone” unit (Figures 7-3 and 7-4) because it is the most productive and widely used portion of the aquifer. To estimate the volume of water of different TDS concentrations (<5,000 mg/l, 5,000 to 10,000 mg/l, and >10,000 mg/l) within the Dockum aquifer, we used the TDS map (Figure 7-7) to measure aquifer areas within a county and multiplied these areas by the average thickness of the Best Sandstone unit (125 feet). We determined the average thickness of the Best Sandstone unit from available geologic cross-sections. For specific yield of the Best Sandstone unit, we chose a value of 0.065, which is a weighted average derived by adding the minimum specific yields of fine-grained sandstone and silt (0.1 and 0.03, respectively; Johnson, 1967, as cited in Fetter, 1980) in a sandstone unit that is composed of 35 percent sand and 65 percent silt. The aquifer parameters used here are generalized and can be improved by using site-specific aquifer properties where available to produce more accurate volume estimates.

A total of approximately 66 million acre-feet of water is present in the Dockum aquifer in the study area (Table 7-1). The total volume of water with TDS less than 5,000 mg/l is approximately 46 million acre-feet, and the total volume of water with TDS between 5,000 and 10,000 mg/l is about 15 million acre-feet. In parts of the aquifer where the water has very high TDS (>10,000 mg/l), we estimate the volume of water at approximately 5 million acre-feet. The largest volume of water (>6 million acre-feet) of all TDS concentrations is present in Andrews County.

It must be reiterated that not all of the water estimated here is available for withdrawal. Aquifer properties determined during this study clearly suggest that well yields and transmissivities are low over much of the aquifer and that the aquifer is generally not productive. Furthermore, the chemical quality of water in the aquifer precludes its use for many purposes. Because the confined parts of the aquifer receive little recharge, water withdrawn from these areas will essentially mine or deplete the aquifer.

Conclusions

Although not widely used at present, the Upper Triassic Dockum aquifer in the study area could become an important source of groundwater in the future, especially in areas where there is high demand from the overlying Edwards-Trinity (Plateau) aquifer.

Recoverable groundwater in the Dockum aquifer occurs within the many sandstone and conglomerate beds that are present throughout the 2,000-foot-thick sedimentary sequence, but mainly in the lower sections of the sequence (Best Sandstone unit). The hydrogeologic properties of the aquifer vary widely. Mean well yields range from 6 gpm in Howard County to 418 gpm in Winkler County, and mean specific capacities range from 0.3 gpm/ft (Upton County) to 25 gpm/ft (Reeves County). Transmissivity values range from about 48 ft^2/day in Upton County to 4,600 ft^2/day in Winkler County

Table 7-1: Volumetric estimate of groundwater in the Dockum aquifer.

County	Volumetric Estimate of Water (acre-feet)			
	<5,000 mg/l TDS	5,000 to 10,000 mg/l TDS	>10,000 mg/l TDS	Total
Andrews	6,544,360	0	0	6,544,360
Coke	126,706	0	0	126,706
Crane	2,283,863	431,64	0	2,715,503
Crockett	3,332,178	0	0	3,332,178
Ector	3,928,360	0	0	3,928,360
Glasscock	684,520	2,062,280	1,181,560	3,928,360
Howard	1,303,313	2,633,767	0	3,937,080
Irion	2,902,030	0	0	2,902,030
Loving	1,228,164	0	0	1,228,164
Martin	297,992	3,691,408	0	3,989,400
Midland	353,160	3,562,120	8,720	3,924,000
Mitchell	3,552,889	0	0	3,552,889
Nolan	569,920	0	0	569,920
Pecos	2,563,278	0	0	2,563,278
Reagan	2,995,320	941,760	1,185,920	5,123,000
Reeves	2,344,140	0	0	2,344,140
Sterling	3,955,862	0	0	3,955,862
Tom Green	234,466	0	0	234,466
Upton	802,240	1,639,360	2,973,520	5,415,120
Ward	2,685,426	0	0	2,685,426
Winkler	3,515,897	0	0	3,515,897
TOTAL	**46,204,084**	**14,962,335**	**5,349,720**	**66,516,139**

Note: The estimate of water in the aquifer is an estimate of storage and not of water that can be recovered.

Where exposed at the land surface, the Dockum aquifer is recharged by precipitation. The confined portions of the Dockum aquifer are recharged by upward leakage from the underlying Permian rocks and downward leakage from the overlying Ogallala, Edwards-Trinity (Plateau), and Cenozoic Pecos Alluvium aquifers. Discharge from the aquifer occurs from pumping wells and small springs and through evapotranspiration and cross-formational flow.

Regional groundwater flow maps suggest that flow is generally to the east and southeast. Hydrographs of wells installed in the aquifer show that water levels in the study area have fluctuated variably over time in different parts of the aquifer. For example, water levels declined by more than 80 feet in some wells and rose in others over the past 20 to 30 years.

Groundwater in the Dockum aquifer is generally of poor quality. Water quality ranges from fresh in the outcrop areas, in the northeast, to brine in the confined parts of the aquifer. Water quality also tends to deteriorate with depth, and TDS concentrations can exceed 60,000 mg/l in the deepest parts of the aquifer. Dockum aquifer water in the study area is also typically hard with hardness ranging from about 200 mg/l to more than 3,600 mg/l. Dockum groundwater from near the Edwards-Trinity (Plateau) aquifer is not characterized by a specific suite of chemical constituents but, where overlain by the Cenozoic Pecos Alluvium aquifer, contains Ca^{+2}, Mg^{+2}, SO_4^{2-} and Cl^- rich water.

Radium-226 and radium-228 were detected at concentrations greater than 5 pCi/l in samples collected from Crane, Irion, Mitchell, and Sterling counties. The source of the radionuclides in the groundwater is uranium that has long been known to be present in the Dockum sediments.

A large area overlying the Dockum aquifer in the study area is susceptible to salinity problems originating from the high concentrations of sodium present in Dockum groundwater. This type of water is most prevalent in the confined portions of the aquifer, and salinity is less of a concern along the outcrop areas.

Estimating the total amount of usable groundwater in the Dockum aquifer is difficult because of the interbedded nature of the geologic units, the confined to partially confined conditions of the aquifer, and low recharge rates. We estimate that the total amount of water in the Dockum aquifer in Texas is approximately 66 million acre-feet. Of this amount, approximately 46 million acre-feet contain TDS of less than 5,000 mg/l. However, not all of this water is readily available for withdrawal. In fact, the measured aquifer parameters suggest that the aquifer cannot provide large quantities of water. The confined parts of the aquifer receive little recharge, and any water withdrawn from these areas will essentially mine the aquifer.

The Dockum aquifer in the study area is only locally important where sufficient sandstone thickness and acceptable water quality are present. High TDS concentrations and salinity limit its use for many purposes.

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