PRELIMINARY ASSESSMENT

Ector Drum
Odessa, Ector County, Texas
TXD064215759

REGION 6

Prepared in cooperation with the U.S. Environmental Protection Agency

May 2015

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2604 N. Marco Avenue
Odessa, Ector County, Texas
TXD064215759

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1 INTRODUCTION

The Texas Commission on Environmental Quality (TCEQ) was tasked by the United States Environmental Protection Agency (EPA) Region 6 to conduct a Preliminary Assessment (PA) at the Ector Drum site in Odessa, Ector County, Texas. The specific goals for the PA are:

- Determine the potential threat to public health or the environment posed by the site;
- Determine the potential for a release of hazardous constituents into the environment; and
- Determine the potential for placement of the site on the National Priorities List (Ref. 1).

Completion of the PA was consistent with EPA guidance for performing preliminary assessments under CERCLA and included reviewing existing site information, collecting receptor information within the range of site influence, determining regional geology, groundwater, surface water, determining surrounding population characteristics, and conducting on- and off-site reconnaissance. This document includes a discussion of background site information (Section 2), a discussion of migration/exposure pathways and potential receptors (Section 3), and a list of pertinent references (Section 4) (References 1, 2, and 3).

2 SITE INFORMATION

2.1 SITE LOCATION

Site Name:	Ector Drum
CERCLIS ID No.:	TXD064215759
Location:	Odessa, Ector County, Texas, 79762
Latitude:	31.886022°
Longitude:	-102.294535°
Legal Description:	T-2-S, Block 3, Lot 14
Congressional District:	11

2.2 SITE DESCRIPTION

The site is a former drum recycler located at 2604 North Marco Avenue in Odessa, Ector County, Texas, approximately 230 feet southeast of the Odessa city limits (Figure 1). The current site is comprised of approximately 4.5 acres; however, the facility operated on the west side of North Marco Avenue as well on 2.75 additional acres from at least 1996 until 2011 (Ref. 11, pp. 1-7; Ref. 13, pp. 1-2). The company operated from 1988 to 2011, and is currently inactive (Ref. 4, p. 2; Ref. 8, pp. 1-8).

The main structures on the site include an office, a processing area, a drum unloading area, and a warehouse/storage structure (Figure 2). All site structures are in varying states of disrepair, thus drums, sacks of chemicals, and old equipment are exposed to the elements. A secondary containment area with two above ground storage tanks held waste water with an oily sheen at the last site visit in March 2015 (Figure 2; Ref. 7, p. 8). There is an onsite water well immediately east of the above ground storage tanks. The site also contains several large tractor trailers in the processing area, warehouse/storage area, and drum unloading area (Figure 2; Ref. 7, p. 3, 8). There is a plugged oil/gas well immediately adjacent to the drum/tote storage area in the northern portion of the property (Figure 2).

Properties immediately surrounding the site are dedicated primarily to commercial use. Businesses to the north of the site include a sign manufacturer, an oilfield service company, and a hauling company. An industrial yard and building border the site to the east (Figure 2). There is a funeral home and cemetery approximately 0.15 miles to the west (Figure 1). An older residential area borders the cemetery further west, approximately 0.25 mile from the site, and newer residences have been constructed within 0.5 mile of the site to the north and northwest. The site lies approximately 0.75 mile north of the former Permian Chemical Company State Superfund site that was deleted in 2002. The chemicals of concern for the former Superfund site included chromium and lead (Ref. 5, p. 8).

2.3 OWNERSHIP HISTORY

Ector Drum, Inc. was originally incorporated on June 22, 1988, and filed with the Secretary of State on June 24, 1988 (Ref. 8, pp. 1, 7). At the time of incorporation, the directors were listed as Thomas L. Salmon, Randy Beard, and Norman Smith (Ref. 8, p. 6). An assumed name certificate was filed with the Secretary of State on August 21, 1989 for Ector Drum, Inc. to conduct business under the name "Lone Star Drum Company." This certificate was signed by Norman Smith, President (Ref. 9, p. 1). On November 7, 2005, another assumed name certificate was filed for Ector Drum, Inc., to continue using the assumed name "Lone Star Drum Company," but this time was signed by Randy Beard, President (Ref. 10, p.1).

According to the Ector County Appraisal District, the front office strip of land was owned by Thomas Salmon prior to being sold to Randy Beard and his wife in 2012 (Ref. 11, p. 2). Of the three other parcels on the site currently owned by Ector Drum, Inc, two were purchased from Greenes Energy Group LLC in 1988 and 1997, respectively (Ref. 11, p. 3, 5). The parcel located at 2502 N. Marco Avenue that was purchased from Greenes Energy Group LLC in 1988 included one machine shop built in 1950 and an office and two machine shops built in 1954 (Ref. 11, p. 3). The Ector County CAD lists 2604 N. Marco Avenue as owned by Ector Drum, Inc (Ref. 11, p. 1).

Additionally, the presence of blue drums visible in historic images indicates that the site operated across North Marco Avenue as well for an indeterminate period prior to 1996 until site operations ceased. This property is located at 2525 North Marco Avenue, and was owned by Thomas Salmon until it was sold to Energy Coil & Rigging, LLC in 2012 (Figure 2; Ref. 11, p. 7). This property has since been mostly paved over and no longer contains drums.

2.4 OPERATIONS AND WASTE CHARACTERISTICS

The site was in operation from approximately 1988 through 2011 (Ref. 14, p. 1; Ref. 15, p. 2). The site conducted drum recycling operations with drums that were received "RCRA Empty," as defined in 40 CRF 261.7, from oilfield industrial sources that included primarily crude oil treatment fluids, corrosive chemicals, and lubrication oils. Drums were washed with a mild caustic solution, triple-rinsed, dried, air pressure tested, and painted for eventual resale. The caustic rinsing solution was recycled until it became spent. The waste stream was then pH adjusted and stored in a 200-gallon above ground tank to await off-site disposal. The majority of the waste streams generated were Class I and II wastes. Shredded plastic pails were taken to Charter Waste Management Landfill, Odessa for disposal. Small amounts of paint gun cleaning solvent was routinely generated, but was used for paint thinning prior to other application of paint. Metal drums that were received in poor condition were triple-rinsed, crushed, and taken to Commercial Metals in Odessa for reclamation. (Ref. 15, p. 2)

The site had both air and industrial and hazardous waste permits. The air permit (#91327) was issued on November 25, 2009 for a paint booth following an odor complaint investigation (Ref. 16, p. 1; Ref. 17, pp. 1-2). The industrial and hazardous waste EPA ID is TXD064215759, and the Industrial and Hazardous Waste Solid Waste Registration is #31752 (Ref. 18, p. 1).

2.5 PREVIOUS INVESTIGATIONS

There are several previous investigations of the site. There was one waste complaint for the facility on an unknown date that did not note any violations, but investigators suggested that Lone Star improve their housekeeping practices (Ref. 15, p. 2). On August 10, 2009, an odor complaint was filed with the TCEQ. The investigation that followed resulted in a Notice of Violation (NOV) for conducting outdoor spray painting without proper authorization. Following this NOV, the site obtained an air permit (Ref. 17, p. 2).

On April 5, 2011 a complaint was filed alleging waste water spillage around the loading dock area, and accumulating waste water in containers in two tractor trailers and assorted drums and totes in the lot behind the office building. During the investigation, it appeared that the facility was no longer operating. The investigator called Mr. Beard, who informed him that he laid off all of his employees on March 30, 2011; however, Mr. Beard was still arranging for disposal of on-site waste (Ref. 15, p. 2).

On July 25, 2014, the TCEQ received a complaint alleging that contaminated storm water was discharging from the site. Following the investigation, enforcement action was pursued due to excess amounts of waste left on site. Due to the threat that the existing site conditions posed, the TCEQ Critical Infrastructure Division was contacted, and SWS Environmental Services (SWS) was mobilized to assess site conditions (Ref. 4, p. 2). On October 8, 2014, SWS obtained samples from the on-site groundwater well, including a groundwater sample and a sample from the 1.8 feet of Phase Separated Hydrocarbons (PSH) floating on top (Ref. 19, p. 3). Samples of the PSH were analyzed for concentrations of total metals (EPA Method 6010), volatile and semi-volatile organic compounds (EPA Method 8260 and 8270), and TPH (TX methods 1005 and 1006) (Ref. 19, p. 3). Resulting lab analyses detected concentrations of arsenic (2.46 mg/L), chromium (33.1 mg/L), copper (5.0 mg/L), and lead (3.34 mg/L) exceeding their respective groundwater MCL values (Ref. 43, pp. 1-8). Nickel (2.92 mg/L), zinc (274 mg/L), and TPH (533,000 mg/L) were detected at concentrations significantly above background levels (Ref. 19, p. 3). Analysis of the water phase sample detected concentrations of chromium (0.298 mg/L), zinc (7.41 mg/L), mercury (0.00211 mg/L), and benzene (2.90 J mg/L) (Ref. 19, p. 3). Additionally, analyses for hydrocarbon speciation resulted in exceedances of Aliphatic C10-12 and C21-35, and Aromatic C12-16, C16-21, C21-36 for state levels (Ref. 19, p. 3).

On October 13, 2014, SWS conducted a 500-foot visual survey at the site. A walking and driving survey was also conducted within at least 0.25 miles of the site. Based on the interviews with the well owners/users, it was concluded that most of the wells are not used for drinking water purposes (Ref. 19, p. 4). On October 28, 2014, SWS Environmental submitted a Drinking Water Survey Report and Water Well Inventory to TCEQ (Ref. 19, Ref. 20).

On April 6, 2015, a Superfund Site Discovery and Assessment Program (SSDAP) State Screening groundwater sampling event was conducted (Reference 21). Ten wells were sampled immediately surrounding the site. Sample results are not yet available for inclusion in this assessment.

2.6 SITE VISIT

TCEQ Superfund personnel performed a site visit on March 5, 2014. The berm constructed of bags of concrete surrounding the on-site well appeared to be intact and functional. Animal tracks on an overturned barrel and a smashed beer can were documented in the drum unloading area (Ref. 7, p. 1). Investigators observed sacks of caustic soda (sodium hydroxide) and sodium nitrite on wooden pallets, metal totes, and numerous 4.3 gallon metal drums labeled “toluene,” “xylene,” and “isopropyl alcohol” (Ref. 7, p. 7). A black and orange liquid and an oily sheen in the secondary containment structure of the above ground storage tanks were also observed during the site visit (Ref. 7, pp. 5, 8).

2.7 SOURCES

Potential sources associated with the site include various chemicals within totes, drums, above ground storage tanks, chemical products, and waste piles. Contaminated soil resulting from ongoing leaks on site is also a potential source.

2.7.1 Source 1: Drums and Totes

The site contains many 55-gallon plastic and metal drums. Some plastic drums appear to possibly be bulging. Many of these drums are partially filled with unknown substances. Additionally, some are without lids and contain unknown substances that are also exposed to the elements and pose a threat of contamination to surface water runoff (Ref. 7, pp. 1, 2, 5-8). There are also numerous 360 gallon tote-containers, some of which still contain unknown liquids (Ref. 7, p. 4).

2.7.2 Source 2: Above Ground Storage Tanks

The site contains waste storage tanks (Fac. 001 and 002) that hold 200 bbl and 160 bbl, respectively (Figure 2; Ref. 14, p. 8). At the time of the most recent site visit, drums were floating in a mixture of unknown chemicals in the secondary containment area surrounding these tanks. An oily sheen was noted on the liquid adjacent to one of the drums (Ref. 7, pp. 2, 5).

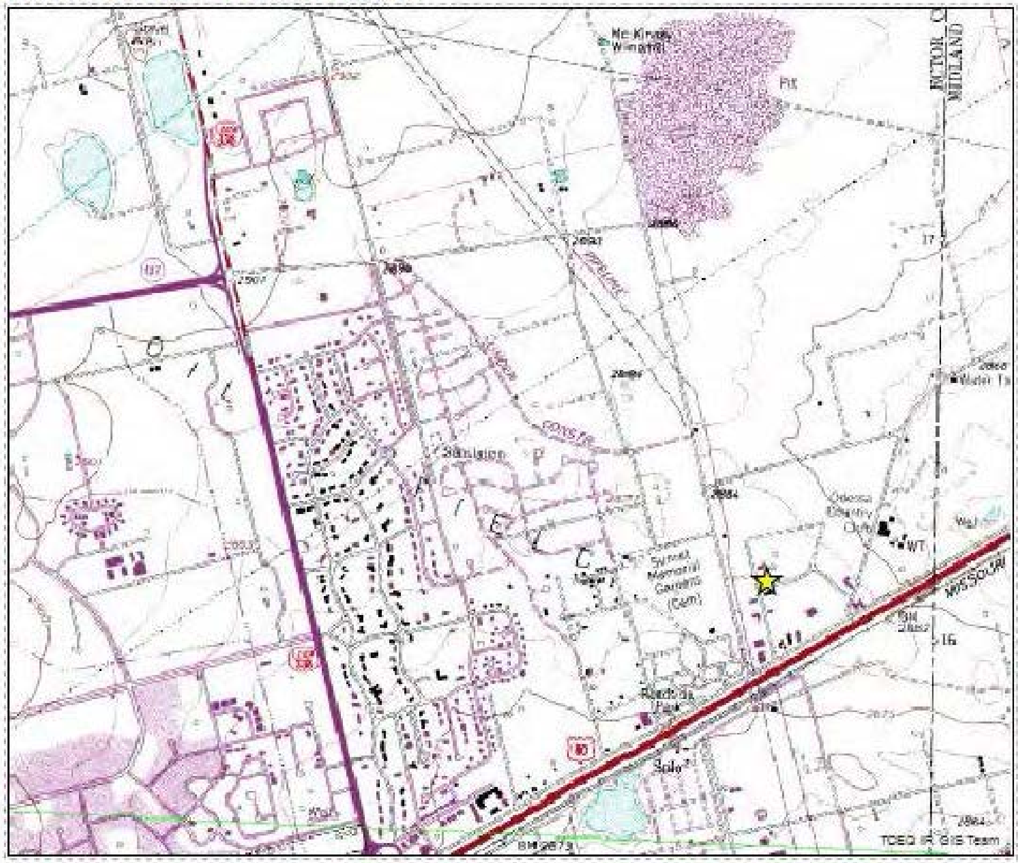
2.7.3 Source 3: Chemical Products

There are two partially full pallets of sacks of chemicals including caustic soda (sodium hydroxide) and sodium nitrite in the area between the drum unloading area and the processing area (Ref. 7, p. 7). It has previously been noted that chemicals that were used onsite at the time of operations appear to still be in the facility (Ref. 4, p. 2).

2.7.4 Source 4: Stained/Discolored Soil

Another source at the site is the stained and discolored soil and areas of pooled contamination on the ground surface (Ref. 22, p. 1). The ground is stained at various locations including in the drum unloading area (Ref. 7, p. 6). Additionally, a pool of an oily brown liquid observed under the loading rack during a previous investigation was once again observed at this location during the March 2004 site visit (Ref. 4, p. 2; Ref. 7, p. 3).

Figure 1. Site Location Map

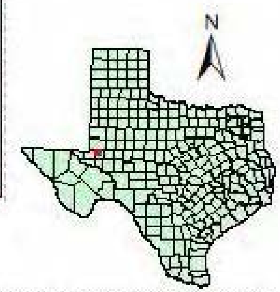


0 0.15 0.3 0.6 0.9 1.2
Miles

Ector Drum
Ector County, Texas
TXD064215759

Explanation

☆ Ector Drum Site Location



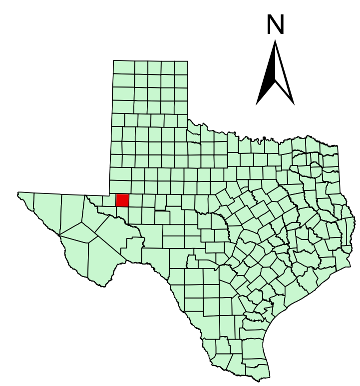
The base data used for this map is from NAIP Imagery, UTM Zone 14, WGS 1984. Projection: Web Mercator Auxiliary Sphere. This map was generated by the Remediation Division of the Texas Commission on Environmental Quality and is for informational purposes and is not suitable for legal, engineering, or survey purposes. This map does not represent an on-the-ground survey conducted by or under the supervision of a registered professional land surveyor. In cases where property boundaries are shown, it only represents the approximate relative location. No claims are made to the accuracy or completeness of the data or to its suitability for a particular use. For more information concerning this map, contact the Remediation Division at 800-633-9363. Map created on May 14, 2015.

Figure 2. Site Features Map

Ector Drum
Ector County, Texas
TXD064215759

Explanation

- Plugged Oil/Gas Well
- Water Well
- Site boundary



0 65 130 260 390 520 Feet

The base data used for this map is from NAIP imagery, UTM Zone 14, WGS 1984. Projection: Web Mercator Auxiliary Sphere. This map was generated by the Remediation Division of the Texas Commission on Environmental Quality and is for informational purposes and is not suitable for legal, engineering, or survey purposes. This map does not represent an on-the-ground survey conducted by or under the supervision of a registered professional land surveyor. In cases where property boundaries are shown, it only represents their approximate relative location. No claims are made to the accuracy or completeness of the data or to its suitability for a particular use. For more information concerning this map, contact the Remediation Division at 800-633-9363. Map created on May 14, 2015.

MIGRATION/EXPOSURE PATHWAYS

The following sections describe migration/exposure pathways and potential receptors within the site's range of influence.

2.8 GROUNDWATER MIGRATION PATHWAY

The target distance limit (TDL) for the groundwater migration pathway is a 4-mile radius that extends from the sources at the site. Figure 3 depicts the groundwater 4-mile TDL.

2.8.1 Geologic Setting

The site is located just west of the Ector County-Midland County line placing it in the southernmost portion of the High Plains subregion of Texas and the northwestern portion of the Edwards Plateau (Figure 1; Ref. 23, p. 1; Ref. 24, pp. 2, 3*)*. The mean precipitation in this area is approximately 13.89 inches (Ref. 25, p. 15).

The stratigraphy of the site beginning from the surface is presented in Table 2-1. The formations include Quaternary Alluvium, Ogallala Formation, parts of the Washita, Fredericksburg, and Trinity Group, and the Dockum Group (Ref. 26, p. 13; Ref. 27, p. 3; Ref. 28, p. 10).

The shallowest of the deposits that are present at the site are Quaternary Alluvium. These deposits are characterized as caliche, sand, gravel, and clay with a thickness of 0-125 feet (Ref. 28, p. 10). The sediments forming these deposits were partially derived from erosion along Concho Bluff (Ref. 28, p. 14).

Below the alluvium, the Ogallala Formation is present in some areas near the site. The Ogallala Formation is comprised of tan, yellow, reddish-brown silt, clay, sand and gravel that are coarser at the base of the formation (Ref. 26, p. 13). At the top of the formation, caliche caprock and calcic ancient soils occur in the fine-grained sediments (Ref. 26, p.

13). In Ector County, the Ogallala Formation is not more than approximately 60 feet thick, and generally lies above the water table (Ref. 28, p. 14). At some localities, the Ogallala Formation is below the water table, but water quantities from wells are small (Ref. 28, p. 14).

Underlying the Ogallala Formation is the Washita Group. At the site, only part of the Lower Washita Group, the Duck Creek Formation, is present (Ref. 29, p. 2). The Duck Creek Formation is composed of yellow-brown shale that is interbedded with thin lenses of clay-rich limestone and fine-grained sandstone (Ref. 26, p. 24). Locally, the Duck Creek Formation can exceed 50 feet in thickness (Ref. 26, p. 24).

The Fredericksburg Group underlies the Washita Group. The Kiamichi, Edwards, Comanche Peak, and Walnut Formations comprise the Fredericksburg Group (Ref. 29, p. 2). The Kiamichi Formation is comprised of yellow-brown to dark blue-gray shale that is thinly interbedded with gray, clay-rich limestone and yellow, fine-grained sandstone (Ref. 26, p. 24). Where the Kiamichi Formation is completely preserved, it is at least 110 feet thick (Ref. 26, p. 24). Underlying the Kiamichi formation are the light gray to yellow, thick-bedded "Rudist" limestones of the Edwards Formation (Ref. 26, pp. 23). Localized honeycombed-textured solution cavities are present within the Edwards Formation (Ref. 26, pp. 17-18). The Comanche Peak Formation underlies the Edwards Formation and consists of light gray to yellowish brown, irregularly bedded clay-rich limestone with thin beds of light gray shale (Ref. 25, p. 14). The Comanche Peak Formation can be up to 85 feet thick (Ref. 26, p. 24). The lowermost formation of the Fredericksburg Group is the Walnut Formation, which consists of light gray, calcareous shale, fine- to medium-grained sandstone, and light gray clay-rich limestone (Ref. 26, p. 24). It grades abruptly upward into thicker, massive, light gray, clay-rich limestone and interbedded marls of the Comanche Peak Formation (Ref. 26, p. 24). The Walnut Formation exceeds 30 feet in thickness in the southeastern parts of the Southern High Plains (Ref. 26, p. 24).

The Trinity Group is represented at the site by the Antlers Formation (Table 2-1; Ref. 29, p. 2). The Antlers Formation consists of white to purple unconsolidated to moderately well cemented, fine to coarse-grained quartz sandstone with well-rounded, frosted grains (Ref. 26, pp. 17). The thickness of the formation ranges from less than 1 foot to greater than 60 feet thick (Ref. 26, pp. 17). Thickness varies because the sediments were deposited on an uneven erosional surface (Ref. 30, p. 15). The formation dips to the southeast at an average rate of 10 feet per mile (Ref. 30, p. 15).

The Trinity group is underlain by the Dockum Group (Ref. 29, p. 2). The Dockum Group is comprised of the Chinle, Santa Rosa, and Tecovas Formations (Ref. 29, p. 2). The Chinle Formation consists of red to maroon and purple shale with lenticular beds of fine-grained red and gray sandstone and siltstone (Ref. 30, p. 15). This formation is usually not water-bearing (Ref. 30, p. 15). The top of this formation is the uneven erosional surface on which the Trinity Group was deposited (Ref. 30, p. 15). The Santa Rosa Formation is the primary water-bearing zone of the Dockum Group, with up to 700 feet of sand and conglomerate interbedded with silt and shale (Ref. 31, p. 33). In the Southern portion of the High Plains, the aquifer is used for oil field water-flooding operations (Ref. 31, p. 33). The Santa Rosa Formation is brownish red to greenish gray fine- to coarse-grained sandstone interbedded with shale (Ref. 30, p. 11). The Tecovas Formation is comprised of mudstones and siltstone with localized sandy mudstone with interbedded fine to medium-grained sandstones (Ref. 25, pp. 14, 28).

Table 2-1. Site Stratigraphy

System	Series	Group	Formation	Approximate Thickness (ft)	Hydrologic Unit
Quaternary	Pleistocene to Recent		Alluvium, eolian, and lacustrine deposit	0-125	Cenozoic Pecos Alluvium
Tertiary	Late Miocene to Pilocene		Ogallala	0-60	Ogallala
Cretaceous	Comanche	Washita	Duck Creek	0-75	Edwards-Trinity (Plateau)
		Fredericksburg	Kiamichi		
			Edwards		
			Comanche Peak		
			Walnut		
		Trinity	Antlers	0-125	
Triassic		Dockum	Chinle	700-1600	Confining Unit
			Santa Rosa		Dockum
			Tecovas		

(Ref. 26, p. 13; Ref. 27, p. 2; Ref. 28, p. 10; Ref. 29, p. 2)

2.8.2 Aquifer System

The water-bearing formations at the site include the Ogallala, the Edwards-Trinity (Plateau), and the Dockum. The Ogallala is thin in the area of the site, but may yield small quantities of water to wells (Ref. 28, p. 14). The Antler's Sand of the Edwards-Trinity (Plateau) aquifer is the most important water-producing unit in Ector and Midland Counties (Ref. 32, p. 59). The Dockum, while water-bearing, typically contains high amounts of naturally-occurring radioactive material (NORM) and high chlorides, and is thus used for oil field water-flooding operations in this area rather than as a drinking water source (Ref. 24, p. 4; Ref. 31, p. 33).

The Ogallala Aquifer is comprised of rocks of the Ogallala Formation. In the northern part of the high plains region, the saturated thickness of the formation is much greater than in the southern part (Ref. 31, p. 12). The site is located in the southern part of the high plains where the Ogallala overlaps Cretaceous rocks and is much thinner (Ref. 31, p. 12). The thickness in this location is not more than 60 feet (Ref. 28, p. 14). Average yield for wells in the Ogallala aquifer is approximately 500 gallons per minute (gpm) (Ref. 31, p. 12). Recharge to the aquifer occurs through the infiltration of precipitation and upward leakage from underlying formations, with total recharge rates averaging less than 0.5 inches per year (Ref. 31, p. 12; Ref. 26, p. 26).

The Edwards-Trinity (Plateau) aquifer, specifically the Antlers Formation, is the main aquifer at the site (Ref. 32, p. 59). In the Edwards Plateau region, the Edwards-Trinity (Plateau) aquifer includes all of the Fredericksburg and Trinity strata in addition to all of the Washita rocks (Table 2-1; Ref. 32, p. 57). The maximum hydraulic head in the Edwards-Trinity aquifer is in northwestern Ector County at approximately 3100 feet above sea level; the elevation at the site is between 2880 and 2885 feet above sea level (Figure 1; Ref. 32, p. 60). The groundwater in the Antlers Formation generally flows to the east-southeast along regional structural dip (Ref. 26, pp. 26, 32). Cementation within the formation has the ability to locally influence the flow pattern (Ref. 26, p. 32). Groundwater flow through the Antlers Formation is also influenced by eroded channel courses cut into the underlying Dockum Formation, which funnel water in an east-southeasterly direction (Ref. 26, p. 32).Wells in this aquifer have yields of less than 50 gpm to more than 1000 gpm (Ref. 26, p. 27).

The Antlers Formation portion of the Edwards-Trinity (Plateau) aquifer is usually confined with the red beds of the Dockum Group below and the clay or marl beds in the Walnut and Comanche Peak Formations above (Ref. 26, p. 32). Typically, the Antlers Formation is approximately 200-350 feet below ground surface (bgs) in this region; however, at the site it is between 100-130 feet bgs based on well logs (Ref. 26, p. 32; Ref. 20, pp. 7-8). The difference in thickness is due to the thinning of the Ogallala Formation in the area (Ref. 29, p. 3). The Antlers Formation is recharged through inflow from the overlying Ogallala Formation and infiltration of precipitation (Ref. 26, p. 36).

2.8.3 Drinking Water Receptors

The onsite water well is located just north of the drum unloading area and immediately adjacent to the above ground storage tanks (Figure 2). During the SWS sampling, approximately 1.8 feet of PSH was measured in the wellbore at 27.45 feet bgs (Ref. 19, p. 2). SWS personnel inferred that the PSH ran into the well casing through an electric conduit as a result of surface water runoff that contained releases of oil from drums at the site (Ref. 19, p. 2).

The site is located in a commercial area with neighborhoods in close proximity. The drinking water survey report indicated the presence of 73 wells (domestic, irrigation, industrial, and public water supply) within 0.5 miles of the site (Ref. 19, p. 2). The door to door survey conducted by SWS found 50 wells within 0.25 miles of the site (Ref. 19, p. 2). The survey also indicated that well owners/users were not using the well water for drinking purposes, but rather for sinks (hand washing), toilets, and irrigation (Ref. 19, p. 4). Three facilities (Schoppa's Material Handling, Permian Anchors, and New Life Church) had ice machines connected to the water supplied from their wells (Ref. 19, p. 4).

City water is available to 18 of the 35 facilities surveyed, but only a few have connected to the service (Ref. 19, pp. 3-4). Those that have connected include the new housing developments north of the site, the City of Odessa Country Club, and a few businesses on North Marco Avenue and US Business 20 (Ref. 19, p. 3). New Life Church is in the process of connecting to city water, and will then only use their water wells for irrigation purposes (Ref. 19, p. 4).

The only PWS well within 2 miles of the site is at the New Life Church which formerly was part of the Odessa Country Club; however, these wells are listed as inactive PWS wells in the TWDB record (Ref. 20, p. 81). No monitoring wells have been installed at this site (Ref. 19, pp. 1-13; Ref. 20, pp. 1-166). As of 2014, Ector County had an estimated population of 153,904 with 152 people per square mile (Ref. 33, p. 1).

2.9 SURFACE WATER MIGRATION PATHWAY

The surface water migration pathway TDL begins at the probable point of entry (PPE) of surface water runoff from the site to a surface water body and extends downstream for 15 miles. Figure 4 depicts the surface water 15-mile TDL.

2.9.1 Overland Route

The site and surrounding area is generally quite flat (Figure 1). There are no storm drains or curbs immediately adjacent to the site (Ref. 39, p. 1). The nearest surface water bodies include a wetland and fresh water pond approximately 0.6 miles to the southwest, several small ponds approximately 0.5 miles to the east-northeast, a small freshwater pond at University of Texas Permian Basin Park approximately 1.7 miles to the northwest, several wet lands approximately 0.6 to 08 miles to the east and southeast, and an intermittent stream, Monahans Draw, approximately 5 miles to the south (Figures 3 and 4; Ref. 38, p. 1).

The most probable point of entry to the wetland and fresh water pond to the southwest of the site is at the northern edge of the topographic depression immediately adjacent to the railroad tracks (Figures 1 and 4). This point of entry would require substantial flooding as the railroad tracks are built up slightly and act as a berm, and consequent divide, between runoff from the site and the wetland (Figure 1). Less consequential flooding would likely continue southwesterly along business 20 to a canal, which would then funnel runoff to the southeast through wetlands and Monahans Draw (Figure 4).

It is also possible that the overland route could be to the northeast of the site (Figure 1). Runoff along this route likely settles into ponds or depressions within one mile east of the site; however, with significant rainfall it is possible that the surface water could flow over the railroad tracks to the southeast to Monahans Draw (Figure 4).

The site is not located within a Federal Emergency Management Agency (FEMA) designated 100-year floodplain (Ref. 34, p. 1). The 2 year, 24 hour rainfall average for the site is approximately 2.75 inches (Ref. 35, p. 1).

Soil at the site is composed of fine sandy loam of the Faskin group, a well-drained soil composed of loamy eolian deposits from the Blackwater Draw Formation of Pleistocene age (Ref. 40, p. 2). This soil group averages more than 80 inches in depth, with a 0 to 3 percent slope (Ref. 40, p. 2).

2.9.2 Drinking Water Receptors

There are no surface drinking water intakes located within the 15-mile TDL. The nearest surface water intake (PWS#S0680002D) lies approximately 5.7 miles west of the site on Monahans Draw; however, it is located up-gradient of the 15-mile TDL (Ref. 41, pp. 1-2).

The number of intakes per surface water body is unknown. The average persons per household for Ector county is 2.8 (Ref. 33, p. 1).

2.9.3 Human Food Chain Receptors

Due to the arid climate and minimal surface water in the area, there are no known human food chain receptors.

2.9.4 Environmental Receptors

There are seven freshwater emergent wetlands and one freshwater forested/shrub wetland within the TDL (Ref. 38, p. 1). The largest freshwater emergent wetland is 11.89 acres and is located approximately 0.6 mile to the southwest of the site (Ref. 38, p. 1). The other freshwater emergent wetlands range from 2 to 8.60 acres, and are mostly to the east of the site (Ref. 38, p. 1). The freshwater forested/shrub wetland is 1.51 acres and is 0.69 mile from the site (Ref. 38, p. 1).

Threatened or endangered species potentially located within the 15-mile TDL include: Bald Eagle (*Haliaeetus leucocephalus*), Ferruginous Hawk (*Buteo regalis*), Peregrine Falcon (*Falco peregrinus*), American Peregrine Falcon (*Falco peregrinus anatum*), Arctic Peregrine Falcon (*Falco peregrinus tundrius*), Prairie Falcon (*Falco mexicanus*), Snowy Plover (*Charadrius alexandrines),* Western Snowy Plover (*Charadrius alexandrinus nivosus*), Mountain Plover (*Charadrius montanus*), Western Burrowing Owl (*Athene cunicularia hypugaea*), Sprague's Pipit (*Anthus spragueii***),** Baird's Sparrow (*Ammodramus bairdii*), Pale Townsend's big-eared bat (*Corynorhinus townsendii pallescens*), Black-tailed prairie dog (*Cynomys ludovicianus),* Gray Wolf (*Canis lupus*), Swift fox (*Vulpes velox*), Black-footed ferret (*Mustela nigripes*), Spot-tailed earless lizard (*Holbrookia lacerate*), Texas horned lizard (*Phrynosoma cornutum*), Havard's machaeranthera (*Xanthisma viscidum*) (Ref. 37, pp. 1-3).

2.10 SOIL EXPOSURE PATHWAY

The soil exposure pathway is evaluated based on the threat to resident and nearby populations from hazardous substances present within two feet of the surface.

2.10.1 Site Setting and Sources

There are no areas of observed contamination within 200 feet of a workplace, residence, school, or day care. While there is a fence surrounding the site, there is a large enough gap at a gate off of East Market Street which allows easy access to the site (Ref. 39, p. 2). The gate is held together with a locked chain. There is also a gate in between buildings off of North Marco Avenue which is held together with a locked chain, yet another large gap allows site access (Ref. 6, p. 3; Ref. 7, p. 6).

2.10.2 Receptors

There are no workers, residents, infants, or children located within 200 feet of an area of suspected contamination. Additionally, there are no school or day-care facilities, terrestrial sensitive environments, or land resources located within 200 feet of an area of suspected contamination. The migration route to groundwater is suspected to be through the on-site well (Ref. 19, p. 2).

2.11 AIR MIGRATION PATHWAY

The air migration pathway TDL is a 4-mile radius that extends from sources at the site (Figure 3).

2.11.1 Air Pathway Receptors

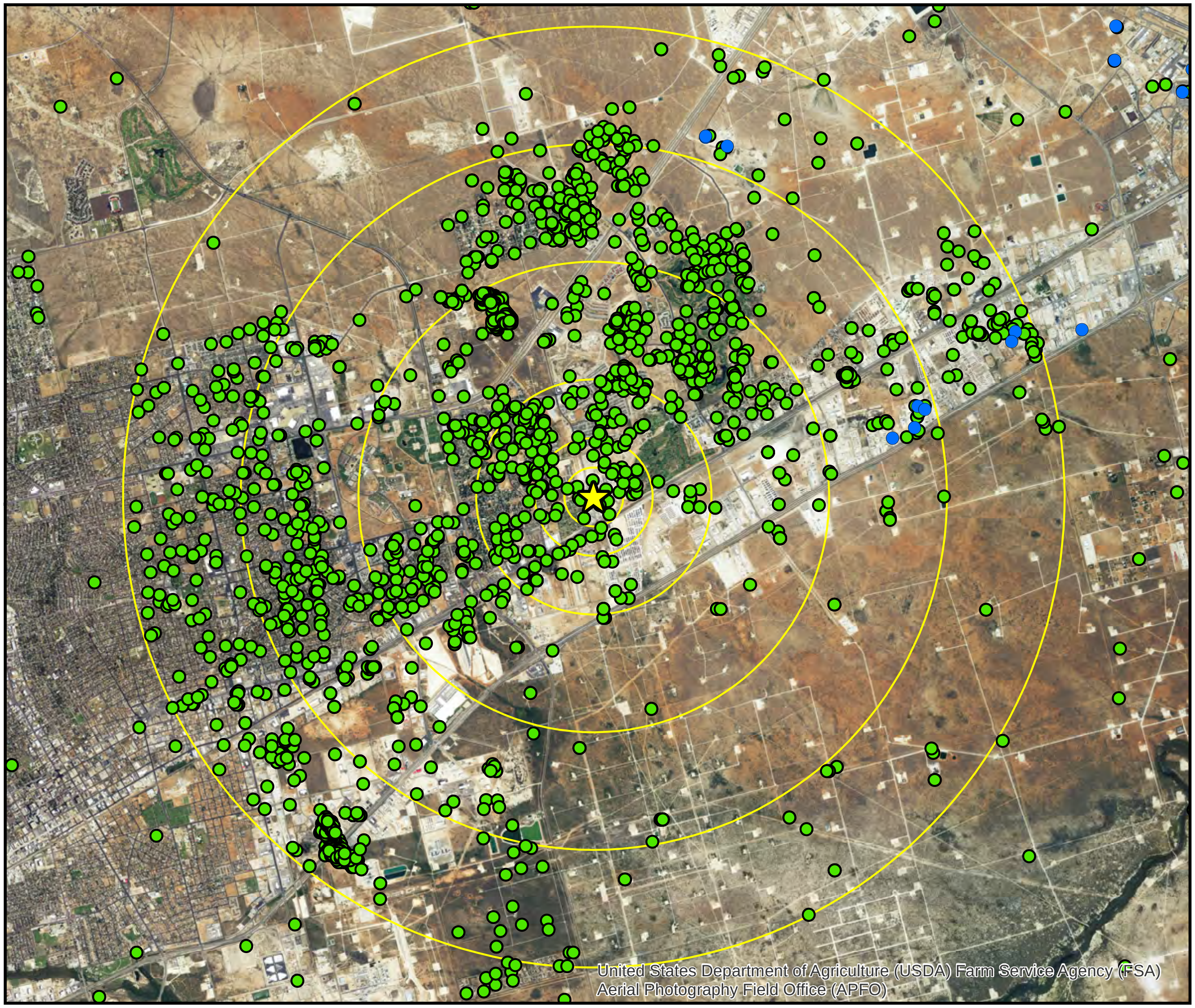
On August 10, 2009, an odor complaint was filed with the TCEQ (Ref. 17, p. 1). The complaint specified that when the complainant drove past the area on the way home, they noticed a strong odor. Additionally, at their house later in the day with increased temperature, they noticed odors (Ref. 17, p. 1). The investigation did not confirm an odor, but noted an unpermitted paint area, and Ector Drum was issued a notice of violation (Ref. 17, p. 1).

The nearest residence is approximately 0.2 mile from the site. There are 7 residences within 0.25 mile of the site and over 230 residences within 0.5 mile of the site.

2.11.2 Environmental Receptors

The site is approximately 0.25 miles from the Odessa Country Club golf course. There are no commercial agriculture, silviculture, or sensitive environments within 0.5 mile of potential sources at the site.

Figure 3. 4-Mile Radius Target Distance Limit Map

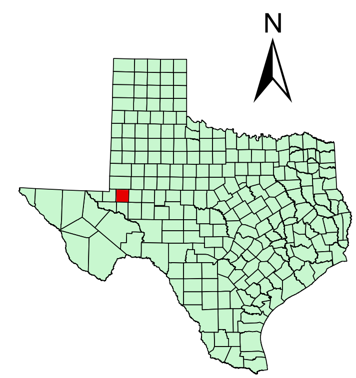


Ector Drum
Ector County, Texas
TXD064215759

Explanation

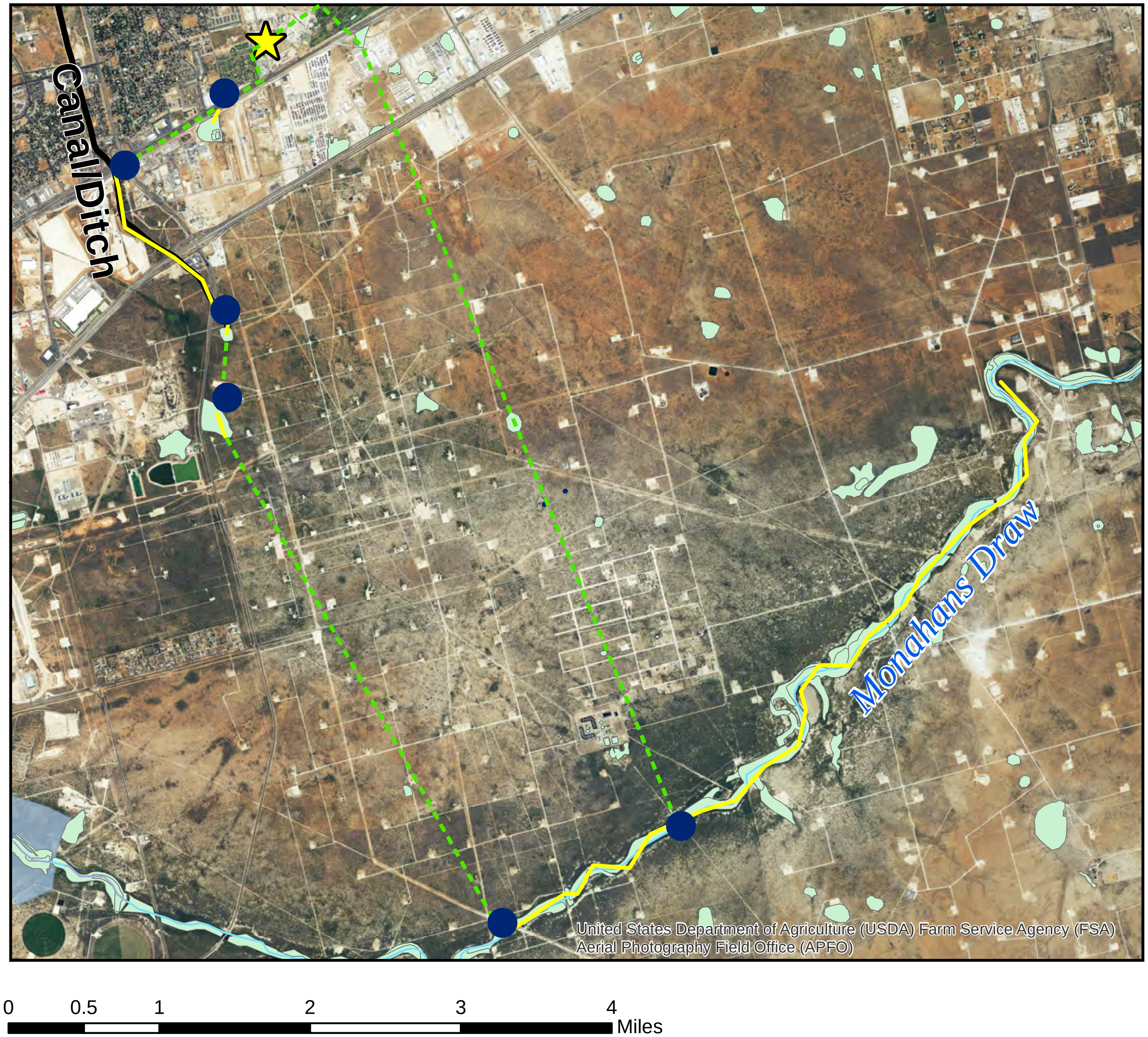
- Ector Drum Site
- TWDB Water Well Location
- PWS Location
- 4-mile TDL Outline

0 0.5 1 2 3 4 Miles



The base data used for this map is from NAIP imagery, UTM Zone 14, WGS 1984. Projection: Web Mercator Auxiliary Sphere. This map was generated by the Remediation Division of the Texas Commission on Environmental Quality and is for informational purposes and is not suitable for legal, engineering, or survey purposes. This map does not represent an on-the-ground survey conducted by or under the supervision of a registered professional land surveyor. In cases where property boundaries are shown, it only represents their approximate relative location. No claims are made to the accuracy or completeness of the data or to its suitability for a particular use. For more information concerning this map, contact the Remediation Division at 800-633-9363. Map created on May 14, 2015.

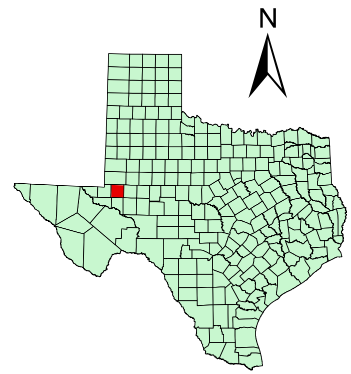
Figure 4. 15-mileTarget Distance Limit Map



Ector Drum
Ector County, Texas
TXD064215759

Explanation

- Ector Drum Site
- Overland Route
- Surface Water Route
- PPE
- NWI Wetland



The base data used for this map is from NAIP imagery, UTM Zone 14, WGS 1984. Projection: Web Mercator Auxiliary Sphere. This map was generated by the Remediation Division of the Texas Commission on Environmental Quality and is for informational purposes and is not suitable for legal, engineering, or survey purposes. This map does not represent an on-the-ground survey conducted by or under the supervision of a registered professional land surveyor. In cases where property boundaries are shown, it only represents their approximate relative location. No claims are made to the accuracy or completeness of the data or to its suitability for a particular use. For more information concerning this map, contact the Remediation Division at 800-633-9363. Map created on May 14, 2015.

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Part II

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40 CFR Part 300
Hazard Ranking System; Final Rule

000198

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EPA

Hazard Ranking System Guidance Manual

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Guidance for Performing Preliminary Assessments Under CERCLA

000202

Reference 4

Texas Commission on Environmental Quality
Investigation Report

Customer: Ector Drum, Inc.
Customer Number: CN600294458

Regulated Entity Name: ECTOR DRUM
Regulated Entity Number: RN100584291

Investigation # 1186740

Incident Numbers 200089

Investigator: TRENT MARTIN

Site Classification CONDITIONALLY EXEMPT SMALL QUANTITY GENERATOR

Conducted: 07/25/2014 -- 07/25/2014

NAIC Code: 423840
SIC Code: 5085

Program(s): INDUSTRIAL AND HAZARDOUS WASTE

Investigation Type: Compliance Investigation

Location: 2604 N Marco Ave, Odessa, TX

Additional ID(s):

Address: 2604 N MARCO AVE,
ODESSA, TX , 79762

Local Unit: REGION 07 - MIDLAND
Activity Type(s): IHWCMPL - Complaint investigation

Principal(s):

Role	Name
RESPONDENT	ECTOR DRUM INC

Contact(s):

Role	Title	Name	Phone
Regulated Entity Contact	ENVIRONMENTAL MANAGER	MR RANDY BEARD	(432) 556-3939

Other Staff Member(s):

Role	Name
Supervisor	WILLIAM EDMISTON
QA Reviewer	RALPH JOHNSON
Investigator	RALPH JOHNSON
Office System Administratic	

Associated Check List

Checklist Name	Unit Name
IHW COMPLAINT	Ector Drum

Investigation Comments:

INTRODUCTION
On July 25, 2014, Environmental Investigators Ralph Johnson and Trent Martin with the Texas Commission on Environmental Quality (TCEQ) Region 7 - Midland office, conducted a complaint investigation at Ector Drum, Inc. for the potential discharge of contaminated storm water coming from the site. In accordance with TCEQ

policy, the investigation was conducted unannounced. The site is located on 2604 N Marco Ave Odessa, Texas.

BACKGROUND

On June 23, 2014, the TCEQ Region 7 Office, received information alleging that the alleged site had potential discharge of contaminated storm water coming from the site. The Region 7 office was requested to conduct an on-site investigation to investigate the complaint. The complaint incident, #200089 was assigned to Investigator Trent Martin for investigation.

GENERAL FACILITY AND PROCESS INFORMATION

The site is located at 2604 N. Marco Ave. in Odessa, Texas and is operated by Ector Drum owner Mr. Randy Beard. The facility is a drum reconditioning business that is no longer in operation. The tract of land is in an industrial area but has residential areas close to the facility.

SUMMARY OF ON SITE INVESTIGATION

On July 25, 2014, Mr. Martin along with Senior Investigator Mr. Ralph Johnson arrived at the alleged source located 2604 N Marco Ave in Odessa, Texas and proceeded to look into the facility. The investigators were joined by Mr. Ricky George, Ector County Environmental Police. Going around the facility, it was noted that there were numerous openings throughout the fence line. Mr. Martin, Mr. Johnson, and Mr. George entered the facility through one of the broken fence panels and walked through the facility.

Upon entering the operating area it was discovered that there were many 350 gallon tote-containers and 55 gallons drums that were noted to be full of unknown chemical. Also, the ground surface at various locations showed evidence of chemical contamination most likely from long-term drum storage. Underneath the loading rack nearby observed a 20'X10'X4"pool of an oily brown liquid.

The facility waste storage tanks (Fac.001 and 002) are 200 bbl. tank and a 160 bbl. tank respectively. The concrete secondary containment vault was full of a mixture of water and unknown chemical. The freeboard was estimated to be approximately six to eight inches.

The investigators continued to walk the entire property and discovered many more 350 gallon tote-containers and 55 gallons drums as well as a good amount of contamination on the ground. Other chemicals that were also used on-site at time of operations were discovered to still be in the facility. At the back ends of the facility, many 55 gallon drums were sealed and were found to be fool of unknown chemicals.

Upon completion of the walk through of the facility, it was noticed that many of the original equipment that was at the facility was no longer there, but now housed many of the totes and drums for the facility.

SUMMARY OF EXIT INTERVIEW CONFERENCE

Due to the excess amounts of waste that was left on-site, an enforcement action will be pursued citing 30 TAC 335.4 for the large amount of waste stored on-site that may contribute to the discharge of industrial waste from the site during rainfall events and endanger public health and the environment. Mr. Beards was notified by phone about the Enforcement Action.

ADDITIONAL INFORMATION

Due to the threat posed by the existing site conditions, Critical Infrastructure Division was contacted about the location. State contractor, SWS Environmental was subsequently notified for their response to assess site conditions. Upon reaching an agreement, SWS will secure the site, conduct random sampling of the drums and totes, overpack leaking containers, and remove wastes accumulated in the secondary containament structure.

CONCLUSION

The investigation on July 25, 2014, determined that the site was in violation of 30 TAC 335.4 for the large amount of waste that was discovered at the site that could cause the discharge of industrial waste in the area and endanger public health and welfare. Based on the findings of this investigation, a Notice of Enforcement will be sent to Mr. Randy Beard.

NOE Date: 8/21/2014

OUTSTANDING ALLEGED VIOLATION(S)
ASSOCIATED TO A NOTICE OF ENFORCEMENT

Track Number: 545847 **Compliance Due Date: 02/16/2014**

Violation Start Date: Unknown

30 TAC Chapter 335.4

Alleged Violation:

Investigation: 1186740 Comment Date: 08/18/2014

Failure of the company to dispose of the excessive amount of industrial waste that was collected and stored on-site, that could be discharged into the surrounding areas, cause a nuisance for the surrounding area, and cause the endangerment to the public health and welfare.

Recommended Corrective Action: Remove all waste that was left on site. Begin the remediation process of removing all contaminated land and correcting the damages.

Signed ______________________________ **Date** ____________

Environmental Investigator

Signed ______________________________ **Date** ____________

Supervisor

Attachments: (in order of final report submittal)

___Enforcement Action Request (EAR)

___Letter to Facility (specify type) : __________

Investigation Report

___Sample Analysis Results

___Manifests

___Notice of Registration

___Maps, Plans, Sketches

___Photographs

___Correspondence from the facility

___Other (specify) :

____

____

Reference 5

The following is an Adobe Acrobat reproduction of the official

Community Relations Plan

for

Permian Chemical Company

No graphic illustrations are included with this electronic version, but are available with the printed versions as part of the Permian Chemical Company site repository records

at

Ector County Library
321 West 5th Street
Odessa, Texas

and/or

TNRCC Records Management Center
Austin, Texas

Scroll Down to View

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
Protecting Texas by Reducing and Preventing Pollution

Community Relations Plan
for the

PERMIAN CHEMICAL COMPANY PROPOSED STATE SUPERFUND SITE

Ector County, Texas
April 2002

Texas Natural Resource Conservation Commission
Remediation Division
12100 Park 35 Circle
Building D
Austin, Texas 78753
1-800-633-9363

www.tnrcc.state.tx.us/permitting/remed/superfund/index.html

COMMUNITY RELATIONS PLAN

for

PERMIAN CHEMICAL COMPANY PROPOSED STATE SUPERFUND SITE

April 2002

Inquiries relating to the Permian Chemical Company Proposed State Superfund Site should be directed to:

Ms. Janie Montemayor
Community Relations Coordinator
Remediation Division
Texas Natural Resource Conservation Commission

Physical Address: 12100 Park 35 Circle
Building D, MC-225
Austin, TX 78753

Mailing Address: MC-225
P.O. Box 13087
Austin, TX 78711-3087

Telephone: 1-800-633-9363
or
512-239-3844

E-Mail: jmontema@tnrcc.state.tx.us

Table of Contents

Appendices

I. *Texas Register* public notice regarding proposal of the Permian Chemical Company site to the state Superfund registry. Published July 16, 1993.

II. *Odessa American* public notice regarding proposal of the Permian Chemical Company site to the state Superfund registry. Published July 21, 1993.

III. *Texas Register* public notice of proposal non-residential land use for the Permian Chemical Company Proposed Superfund site. Published July 23, 1999.

IV. *Texas Register* public Notice of Intent to Take No Further Action at the Permian Chemical Company State Superfund Site and to Delete the Site from the State Registry. Published January 18, 2002.

V. Site Location Map

VI. Site Map

Community Relations Plan
for
Permian Chemical Company Proposed State Superfund Site
Odessa, Ector County, Texas
March 2002

Overview of Community Relations Plan

This community relations plan (CRP) identifies issues of community concern regarding Permian Chemical Company State Proposed Superfund site, in Odessa, Ector County, Texas. It also outlines the anticipated community relations activities to be conducted during each phase at the Permian Chemical Company site.

The Permian Chemical Company Community Relations Plan has been prepared to aid the Texas Natural Resource Conservation Commission (TNRCC) in developing a community relations program tailored to the needs of the community affected by the Permian Chemical Company site. The TNRCC will conduct community relations activities to ensure that the local public has input to decisions and access to information about Superfund activities at the Permian Chemical Company site.

This information in this plan is based primarily on the Resource Conservation Recovery Act (RCRA) 3012 Preliminary Assessment, the Hazard Ranking System (HRS) package, and the Pre-Statement of Work for the site.

Site Profile

Site Location and Description

Latitude 31°52' 21" North and Longitude 102° 17' 58" West.

The Permian Chemical Company (PCC) site is located on 30 acres of ground at 325 Pronto Ave., Odessa, Ector County, Texas on the east side of Pronto Road. Pronto Road is located approximately 0.9 mile east of Loop 338 between Texas Highway 80 and I-20 E. The site is situated on calcareous, sandy soils of the Ogallala Formation of the southern High Plains at an elevation of 2870 feet above mean sea level.

Site Background and History

(Note: The state agencies referred to in this history as the Texas Water Quality Board (TWQB), Texas Department of Water Resources (TDWR), Texas Water Commission (TWC) and the Texas Air Control

Board (TACB) are now known as the Texas Natural Resource Conservation Commission (TNRCC). The new agency, TNRCC, became effective September 1, 1993, as mandated under State Senate Bill 2 of the 73rd regular Legislative Session).

The PCC operated a chemical manufacturing plant from 1981 to 1987. The plant produced hydrochloric (HCI) acid and potassium sulfate from a reaction of sulfuric acid and potassium chloride. The production process employed at the plant generated corrosive wastewater streams which were hazardous because of low pH. An on-site neutralization ditch had been designated a hazardous waste treatment unit because it was lined with crushed limestone to enable neutralization of the acidic wastewater which flowed through it. The south pond had been designated as a hazardous waste impoundment because hazardous acidic waste water reached the pond during periods of high flow through the neutralization ditch. This pond had an estimated capacity of 300,000 gallons at an average depth of six inches. The south pond was identified as the source of contamination for the uppermost and second aquifers beneath the facility site because water levels and chemical analyses from monitor wells obtained during the Groundwater Quality Assessment submitted on September 25, 1985, indicated that the pond was recharging the ground water beneath the site. Spills and dumps may be additional sources of contamination.

The North Pond located along the northern border of PCC was a lined surface impoundment with an approximate capacity of 375,000 gallons. This pond had been in operation since mid-1980 and was used for the storage/evaporation of off-specification hydrochloric acid (HCl) and minor amounts of machinery and automotive oils. Although originally believed to be non-hazardous, a May 23, 1985, analysis of the impoundment waste water revealed toxic levels of chromium and lead with elevated levels of barium, cadmium, mercury, and silver. The lining is deteriorated and the North Pond may have been a source of contamination as indicated by chemical analysis during the September 25, 1985, Groundwater Quality Assessment.

A September 29, 1986, letter from PCC to the Texas Water Commission stated that PCC purchased waste oils from a company called Recon. This oil was used in a diluted form to spray as a dust control for the potassium sulfate according to a PCC letter to the TWC dated July 7, 1986. The process included blending one gallon of waste oil with one ton of potassium sulfate to create the dust control mixture.

The PCC was identified by the TWC as a generator/transporter/transporter storage and disposal facility. Based upon the December 30, 1986, Notice of Registration, the facility had been permitted by the TWC for a waste stream that included dilute HCl, HCl, absorbent salt washwater, cooling tower waste water, miscellaneous plant wastes, general miscellaneous plant refuse, ion exchange effluent, and neutralized acid. A portion of all the wastes was reported to be disposed of onsite. The dilute HCl was reported to be sold for recovery, and the miscellaneous plant waste, the general miscellaneous plant refuse, and the neutralized acid were reported to be disposed of offsite as well as onsite. The company was required to maintain records for storage, processing and/or disposal of the dilute HCl, the HCl, the absorbent salt washwater, and the ion exchange effluent.

In December 1993, Kaiser Aluminum transported 7,050,000 pounds (3525 tons) of potassium sulfate to its Baton Rouge, Louisiana, plant to be used as a potassium source in soil amendments.

In October 1994, TNRCC initiated plans for a Remedial Investigation/Feasibility Study (RI/FS) at the site. The first phase of the RI was conducted in October and November 1995, and included sampling and analysis of soils, sediment, surface water and groundwater for chemical constituents of concern including heavy metals, volatile organic compounds, petroleum hydrocarbons, inorganic salts, and dissolved solids.

Additional investigations were conducted in May through July 1996, during which additional monitoring wells were installed and sampled for analysis. At that time, a dormant pipeline, not associated with the site but associated with oilfield activities on the property adjacent to the site, was observed to have leaks. Subsequent analyses of soils and groundwater showed that these oilfield pipeline activities resulted in a release of petroleum hydrocarbons along the eastern side of the site.

Due to the deteriorated condition of process structures at the PCC site, demolition of unstable structures in the former process area was begun in September 1996, to allow soil sampling to be safely performed. The demolition was completed in November 1996.

Additional groundwater sampling was conducted in January 1997 to confirm results previously obtained from groundwater samples.

The Phase I RI Report was completed August 1997. The report confirmed that several volatile organic compounds and inorganic salts were present in the groundwater underlying the site. The volatile organic compounds present in groundwater that may have been attributed to site operations are a group of four compounds collectively referred to as the trihalomethanes (chloroform, bromoform, dibromochloromethane, and dichlorobromomethane). These compounds can form as a result of the reaction of chlorine with natural organic material. This mechanism of trihalomethane formation has been documented to occur in public water supply systems that use chlorine for disinfection purposes.

Investigation of the soils across the site showed that some soils contain high levels of inorganic salts, and some metals, including lead, chromium, and mercury are also present. The concentrations of metals are below health-based action levels.

A second phase of the RI was initiated in June 1999 and included the installation of additional monitoring wells to determine if the high levels of inorganic salts are attributable to the site, and sampling and analysis of soils in the former process area to evaluate whether soils in this area are contaminated. After completion of the RI, the potential risk the site poses to human health and the environment was assessed. Based on the results of this assessment it was determined that levels of contaminants did not pose an unacceptable risk to human health or the environment. The site was deed recorded for industrial use only in January 2002.

Site Chronology

1977	Dorchem, Inc. commenced operation, manufacturing hydrochloric acid for industrial use and potassium sulfate as fertilizer.
Aug. 1981	PCC bought facility and continued to produce hydrochloric acid and potassium sulfate.
Nov. 1981	60,000 gallons of hydrochloric acid spilled in central part of the site. Neutralized with sodium hydroxide.
Sept. 1983	TDWR sample analyses of facility discharge water in South Pond reveals a pH range from 1.0 to 6.5.
March 1984	North Pond water sample analyses reveal pH of 1.5.
May 1985	Elevated levels of chromium (15 ppm) and lead (31 ppm) found in water samples from North Pond.
Aug. 1985	PCC signs TDWR agreement to eliminate solid waste discharge and remedy groundwater.
Oct. 1985	PCC submits Solid Waste Closure Plan for North Pond, South Pond, South Dump, Potassium Storage Pile Area, and Neutralization Ditch.
March 1987	TWC Order for PCC to submit remedial action alternatives for groundwater and soil remediation.
Aug. 1987	PCC shut down operations.
Nov. 1987	PCC filed for bankruptcy.
Aug. 1988	Dames and Moore under contract to the PCC, completed investigation which showed elevated levels of dissolved solids in the groundwater.
Nov.1990	Site referred to TWC Hazardous and Solid Waste Division for consideration in Superfund.
Aug. 1992	Site scored 10.12 on Hazard Ranking System.

July 16, 1993	A legal notice was published in the *Texas Register*, (18 TexReg 4709) and on July 21, 1993, *in the Odessa American*, proposing the site to the state Superfund registry, and announcing a public meeting would be held on August 19, 1993, at the Odessa City Council Chambers to receive comments on the proposal of the site to the state Superfund registry.
Aug. 1993	Emergency response team acted to limit dangers that contaminants may have posed to public health and safety or the environment by removing potassium sulfate from the site, constructing a site perimeter fence to limit unauthorized access, and posting signs warning of contamination.
Dec. 1993	Kaiser Aluminum removed 3,525 tons of potassium sulfate from site.
Oct. 1994	TNRCC issued a work order to determine the nature and extent of contamination (RI/FS).
Sept. 15, 1995	An informal presentation was provided to the City Manager of the history and investigation data concerning the PCC site.
Sept. 28, 1995	Public meeting was conducted to discuss an upcoming Remedial Investigation at the PCC site, which had been proposed as a state Superfund site. The meeting was held at Odessa City Hall.
Oct. 1995	Began RI.
Nov. 1996	A removal action was conducted to contain acidic process fluids. Solid by product materials were collected and drummed. Unstable process structures at the site were dismantled and stockpiled in an interim storage area to eliminate potential hazards.
Aug. 28, 1997	RI Phase I completed.
June 22, 1999	RI Phase II, consisting of determination of the extent of the groundwater plume, underway.
July 23, 1999	Legal notices were published in the *Texas Register*, (24 TexReg 5798) and the *Odessa American*, proposing non-residential land use specifications for remediation of the site contamination. The land use designation may be considered in an remedial action proposed for the site. A public meeting, to receive citizens comments, was to be held August 30, 1999, at the Ector County Courthouse, Commissioner Court Room.

Aug. 30, 1999	A public meeting was held at the Ector County Courthouse, Commissioner Court Room to present to the community a proposed non-residential land use for the site, and receive citizen comments. Determination of land use may impact any remedial action proposed for the site.
Oct 19, 1999	Land Use Determination letters on the PCC site were mailed to state and city officials.
May 5, 2000	TNRCC approved the Phase II RI report.
June 26, 2000	The baseline risk assessment report was completed. The results of the risk assessment concluded that, with the exception of onsite low-PH materials, the site does not pose unacceptable excessive risk to human health or the environment. Although, the groundwater had low levels of contamination, it was determined in the risk assessment that they were below health based levels and the site did not pose unacceptable excess risk to human health or the environment.
July 1, 2000	TNRCC issued a work order for performance of a comprehensive waste inventory and waste characterization of all onsite wastes, including remaining process facilities' waste and investigation-derived waste. This study was to be used to support waste removal activities at the site.
May 31, 2001	TNRCC received the waste removal action work plan. The plan outlined disposition of investigation-derived waste and some remaining Class I wastes. Based on investigation technical reports, TNRCC concluded that the groundwater and soil at the site did not pose an unacceptable risk to human health or the environment. No further remedial action was warranted at the site. Conditions at the site met commercial/industrial cleanup criteria established by 30 Texas Administrative Code, Chapter 350 (Texas Risk Reduction Program).
Dec. 23, 2001	TNRCC approved the waste removal action report which related that all investigation-derived waste, hazardous waste and Class I wastes had been removed from the site and sent to an authorized waste disposal facility.
January 18, 2002	Legal notices were published in the *Texas Register*, (27 TexReg 511-512), and the *Odessa American*, proposing to delete the site from the state Superfund registry in accordance with 30 TAC §335.344, and receive public comment on the determination that the site no longer presents an imminent and substantial endangerment to public health and safety or the environment. A public meeting was scheduled for 7:00 pm., Tuesday, February 26, 2002 at the Ector County Library, Rotary Room, 2nd Floor, 321 West Fifth Street. No further remedial action planned.

<u>Community Profile</u>

Population & History of Odessa

The City of Odessa is located in West Texas between Dallas/Fort Worth and El Paso on Interstate 20. Odessa and its neighboring cities are located in what is known as the Permian Basin, which is 250 miles wide and 300 miles long. The basin was formed during the Permian Period, the final portion of the Paleozoic Era (approximately 280 million years ago). At the time, the basin was an ocean filled with marine life and plants. As the ocean dried up, the decaying plants and animals eventually helped form the gigantic pools of oil and gas that are still being taken from the basin.

Oil was discovered in the area in 1926. Odessa is still considerate one of the major oil field technology centers throughout the modern world.

The PCC site is located in Odessa, Ector County, Texas on the east side of Pronto Road. The population of Odessa in 2000 was 100,920 with ethnicity for the city as follows:

White	74.2%
Black or African American	5.4%
American Indian & Alaska Native	0.8%
Asian	0.7%
Native Hawaiian and Other Islander	0.0%
Hispanic or Latino (of any race)	40.8%
White persons, not of Hispanic /Latino origin	59.2%

<u>History of Community Involvement</u>

The TWC held a public meeting to propose listing of the PCC Site on the State Superfund Registry. The meeting was held at 7 p.m. on Thursday, August 19, 1993, at the Odessa City Hall, Council Chambers. The meeting notice was published in the legal section of the *Odessa American* on July 21, 1993, and in the *Texas Registry* on July 16, 1993. There were 5 citizens in attendance.

The TNRCC staff met with City Manager Jerry McGuire and gave an informal presentation of the history and investigative data concerning the site on Tuesday, September 15, 1995, at 9:30 a.m., in the Odessa City Hall Chambers.

On Thursday, September 28, 1995, at 7:00 p.m. a public meeting was held at the City Council Chambers. The purpose of the meeting was to provide information regarding the site investigation. There were 10 citizens in attendance.

The key community concerns at this time are the schedule of activities at the site and the impact the site has had on the groundwater.

Specific Objectives of the Community Relations Program

Maintain open communications between the TNRCC, Ector County officials, City of Odessa officials, and state officials, and concerned citizens.

Continue to expand the mailing list to include additional agencies, organizations, and residents that are interested in the project.

Provide a community relations contact from whom interested parties can receive information on site activities, project status, and study results.

Provide citizens, involved agencies, elected officials, civic leaders, and the media with accurate, timely information concerning site related activities by issuing fact sheets, press releases, and community meetings.

Brief field teams on community relations issues before performing on-site investigations.

Respond to telephone inquiries and written correspondence in a timely manner.

Provide all information, especially technical findings, in language that is understandable to the general public and in a form useful to interested citizens and elected officials through the preparation of fact sheets and news releases when major findings are made available during project phases.

Monitor community concerns and information requirements as the project progresses.

Modify the Community Relations Plan to address changes in community needs and to maintain accuracy during different project phases.

Community Relations Techniques & Tools

Project Mailing List - To provide the means through which press release, project status reports and other significant communications can be distributed to concerned groups and individuals.

Public Consultations - To conduct informal meetings (if needed) with residents. To provide an opportunity for affected residents to express any concerns and to make inquires to insure effective two-way communication.

Program Document Repositories - To maintain an easily accessible repository through which the public may review project outputs. The public will be informed periodically of the availability of project documents and the location of the repository.

Superfund Internet: Progress of activities at the PCC site is regularly posted to the TNRCC Superfund web site at: www.tnrcc.state.tx.us/permitting/remed/superfund/index.html

Elected Officials

State

The Honorable Teel Bivins
Texas State Senator
P O Box 12058
Austin TX 78711
(512) 463-0131

District address:
P.O. Box 9155
Amarillo, TX 79105

The Honorable Robert Duncan
Texas State Senate
P O Box 12062
Austin, TX 78711
(512) 463-0128

District address:
1330 East 8th
Ste 322
Odessa, TX 79761
(806) 762-1122

The Honorable Bob Turner
Texas House of Representative
P O Box 2910
Austin, TX 78711
(512) 463-0546

District address:
P O Box 879
Coleman, TX 76834
(915) 625-3596

Ector County

The Honorable Jerry Caddel
Ector County Judge
300 North Grant
Room 227
Odessa, TX 79761
(915) 335-3030

City

The Honorable Larry Melton
Mayor
City of Odessa
P O Box 4398
Odessa, TX 79760-4398
(915) 335-3200

The Honorable Richard Morton
City Manager
City of Odessa
P O Box 4398
Odessa, TX 79760-4398
(915) 337-7381

The Honorable Bill Cleaver
Council Member
City of Odessa
P O Box 4398
Odessa, TX 79760-4398
(915) 3377381

The Honorable Jim Morris
Council Member
City of Odessa
P O Box 4398
Odessa TX 79760-4398

(915) 337-7381

The Honorable Royce Bodiford
Council Member
City of Odessa
P O Box 4398
Odessa TX 79760-4398
(915) 337-7381

The Honorable Brandon Tate
Council Member
City of Odessa
P O Box 4398
Odessa TX 79760-4398
(915) 337-7381

The Honorable Berta Calzada
Council Member
City of Odessa
P O Box 4398
Odessa TX 79760-4398
(915) 337-7381

Area Media

Odessa American
P O Box 2952
Odessa TX 79760-2952
(915) 334-8641

Key Project Personnel

Mrs. Carol Boucher, Project Manager
TNRCC Remediation Division

Physical Address:	12100 Park 35 Circle Building D, Room 200-15 MC-143 Austin, TX 78753
Mailing Address:	P O Box 13087 MC-143 Austin, TX 78711-3087
Telephone:	1-800-633-9363 or (512) 239-2501
E-Mail:	cboucher@tnrcc.state.tx.us

Ms. Janie Montemayor
Community Relations Coordinator
Remediation Division

Physical Address:	12100 Park 35 Circle Building D, Room 256N MC-225 Austin, TX 78753
Mailing Address:	P O Box 13087 MC-225 Austin, TX 78711-3087
Telephone:	1-800-633-9363 or (512) 239-3844
E-Mail:	jmontema@tnrcc.state.tx.us

Program Document Repositories

Texas Natural Resource Conservation Commission
Records Management Center

Physical Address:	12100 Park 35 Circle Mail Code 199 Bldg. E, First Floor Austin, TX 78753
Mailing Address:	P O Box 13087, Mail Code 199 Austin, TX 78711-3087
Telephone:	1-800-633-9363 or (512) 239-2920

Ector County Library
Doris Baker
321 West 5th Street
Odessa TX 79761
Telephone: (915) 333-9633

Appendices

I. Texas Register publication of the State Superfund Registry

27 Tex Reg 512 January 18, 2002 Texas Register
IN ADDITION January 18, 2002 27 TexReg 511
26 TexReg 3660 May 18, 2001 Texas Register
IN ADDITION May 18, 2001 26 TexReg 3661
26 TexReg 9658 November 23, 2001 Texas Register
IN ADDITION November 23, 2001 26 TexReg 9659
IN ADDITION November 23, 2001 26 TexReg 9657
25 TexReg 4946 May 26, 2000 Texas Register
25 TexReg 4944 May 26, 2000 Texas Register
IN ADDITION May 26, 2000 25 TexReg 4945
25 TexReg 11756 November 24, 2000 Texas Register
IN ADDITION November 24, 2000 25 TexReg 11757
IN ADDITION June 4, 1999 24 TexReg 4303
24 TexReg 4304 June 4, 1999 Texas Register
IN ADDITION June 4, 1999 24 TexReg 4305
24 TexReg 10608 November 26, 1999 Texas Register
IN ADDITION November 26, 1999 24 TexReg 10609
23 TexReg 5524 May 22, 1998 Texas Register
IN ADDITION May 22, 1998 23 TexReg 5523
22 TexReg 3632 April 18, 1997 Texas Register
IN ADDITION April 18, 1997 22 TexReg 3631
21 TexReg 3274 April 12, 1996 Texas Register
IN ADDITION April12, 1996 21 TexReg 3273
20 TexReg 2484 March 31,1995 Texas Register
IN ADDITION March 31,1995 20 TexReg 2485
19 TexReg 546 January 25, 1994 Texas Register
IN ADDITION January 25, 1994 19 TexReg 545
IN ADDITION July 16,1993 18 TexReg 4709
24 TexReg 5798 July 23,1999 Texas Register

Reference 6

Ector Drum Site Visit
Date: 3/5/15
Weather: ~29°F slightly cloudy/partly sunny, some ice, light wind
Safety Meeting: 08:30-08:45a.m. Stephen Ellis, Katie Delbecq, and Kristen Kochelek present from TCEQ.
Stop 1: Drove by Ector Drum facility entering from the north. Cars/Trucks parked out front of facility. Wooden Picket & chained linked fence around property
Stop 2: Memorial Gardens - verified presence of WW-9 - pressure guage zero'd, hooked up to electrical supply. Used for irrigation looks off for the winter.
- Walked back behind on dirt road. Looks like former storage yard not completely paved over. Some dirt w/ drums & gravel still exist.
Central Garden - Large holding/Storage tanks - "Water Provided by Sunset" sign Granite slabs in the fenced enclosure. - *Need to call to verify use of well or prescence of this well.
Stop 3: Immediately Adjacent to Gardens off Newell Rd & Brown Ave on Right side Well, busted pipe. Homes immediately adjacent looks like owner Maybe Julio Nuñez.

Stop 4: Vista Crest - newer development. Visible
water meters present
→ 1 Vista Crest - "Water Well In Use"
→ Left a door hanger, talked with
woman, she will talk with her
husband - has a self-addressed
envelop + my business card.
→ Do not drink, only irrigation
well in front of house, brick
enclosure.
Stop 5: Grace Avenue - well in back of
property (picture) (Grace + Dania)
corner (look up owner) - No one
answered door.
Water wells in the area - a lot on city water now
"Cemetary sucked us dry"
Mellody Gilbert - 432-366-2280
Lots of great Info. The house above,
the people are not there much - got a
divorce, daughter may own - he goes
Son drilled a well recently just needs power
Asked 130' ~127' drilled to
* Signed Access Agreement
Be sure to call and talk w/ them
if we sample + get results.
Landon Gilbert 2606 Grace Ave want to
hook up to house

·Darin Wallum signed Access Agreement Runs carpet cleaning business. Said water next door was peeling the paint off of the house - why they were repainting 6618 Dania Dr

→ House in between a 2-story house on corner on Dania & the 2-story house owner's Rental on the other corner. 3 dogs on property ~~on~~ NE Rental property. According to Mellody, both of those properties either had or have a well.

Stop 6: Ector Drum Site - walked through Drum unloading area & looked at well in Well house. Documented specific chemicals listed on drums & other containers. Frac tank has been removed from site. Beer can & Animal ~~t~~racks noted on an empty (?) overturned drum in the Drum Unloading area. Walked perimeter (fenced).

11:14 A.M

END OF DAY TRAVEL TO AIRPORT

Reference 7

Photographic Documentation Log
Ector Drum PA Site Visit
Date: 3/5/15

Photo 1: Overturned drum with animal tracks. Facing west inside processing area. Photographer: Katie Delbecq

Photo 2: Stacked drums and containers inside processing area. Facing northwest. Photographer: Katie Delbecq

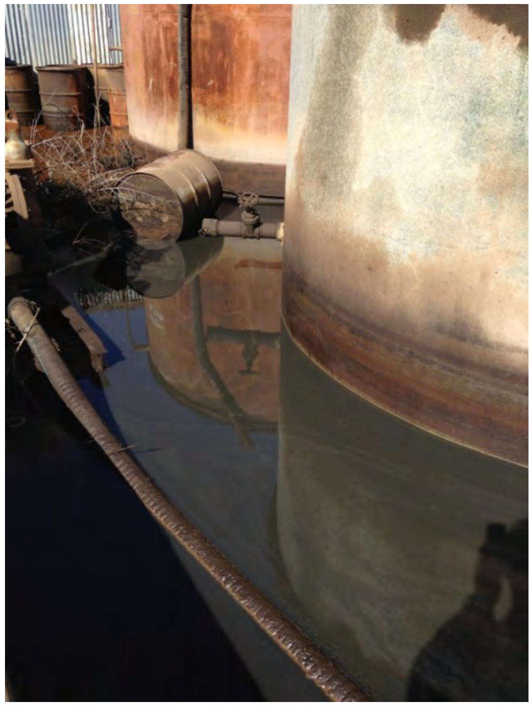

Photo 3: Oily residue on water in secondary containment structure of storage tanks. Facing northwest.
Photographer: Katie Delbecq

Photo 4: Piles of drums stored out on the site, some containing unknown liquid. Facing northwest.
Photographer: Katie Delbecq

Photo 5: Frozen liquid underneath loading dock on ground surface. Facing southeast. Photographer: Katie Delbecq

Photo 6: Tractor-trailers left onsite in front of the loading dock. Facing west. Photographer: Katie Delbecq

Photo 7: Stacked totes containing unknown liquid with drums surrounding. Facing southeast. Photographer: Katie Delbecq

Photo 8: More stacked totes contain unknown liquids in the brush onsite. Facing east. Photographer: Katie Delbecq

Photo 9: Plastic and metal drums in a liquid in the secondary containment structure of the onsite waste storage tanks. Liquid is orange with black substance originating from the metal drums. Facing northeast. Photographer: Stephen Ellis

Photo 10: Debris and drums in the liquid in the secondary containment of the onsite waste storage tanks. The liquid again is orange with a black substance appearing to originate from an overturned drum. Facing southeast. Photographer: Stephen Ellis

Photo 11: Inside of the drum unloading area and the processing area showing stained soil and overturned buckets along with the condition of the structure. Facing west-northwest. Photographer: Kristen Kochelek

Photo 12: Inside the drum unloading area, closer to the processing area showing stacked totes, possible bulging drum, stained soil, and condition of the structures. Facing west-northwest. Photographer: Kristen Kochelek

Photo 13: Pallet with full bags of sodium nitrite. Facing west. Photographer: Kristen Kochelek

Photo 14: Pallet with full sacks of caustic soda (sodium hydroxide) on it left inside the processing area. Facing south. Photographer: Kristen Kochelek

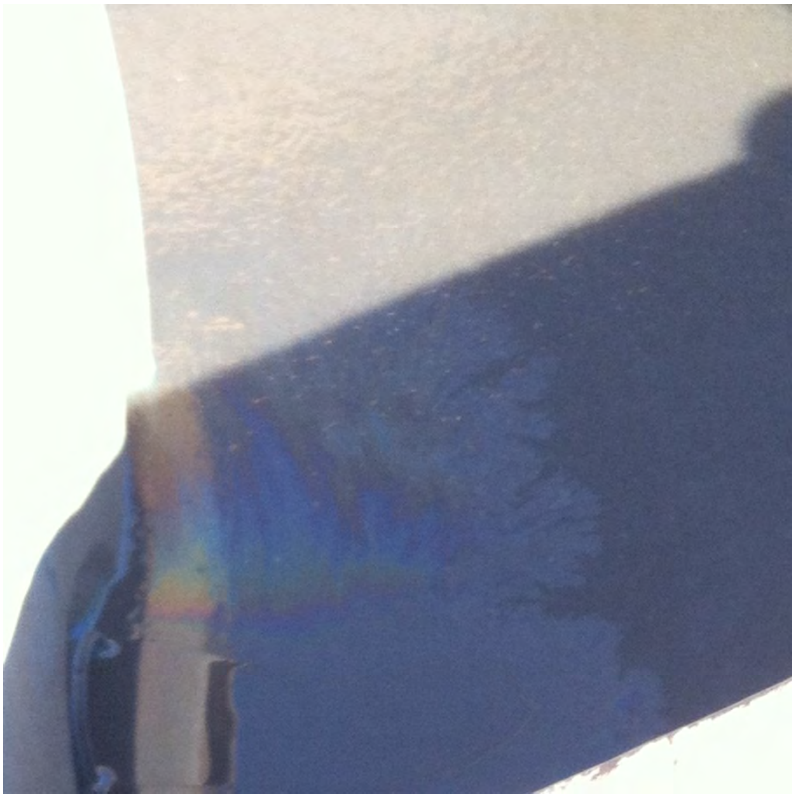

Photo 15: Oily sheen on the liquid in the secondary containment structure of the onsite waste storage tanks. Photographer: Kristen Kochelek

Photo 16: Drums, tractor-trailer, pooled water, and the condition of the structures near the loading dock. Facing west-northwest. Photographer: Kristen Kochelek

Reference 8

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FILED
In the Office of the
Secretary of State of Texas

JUN 24 1988

Corporations Section

ARTICLES OF INCORPORATION

OF

ECTOR DRUM, INC.

The undersigned natural person of the age of eighteen (18) years or more, acting as Incorporator of a corporation (hereinafter referred to as the "Corporation") under the Texas Business Corporation Act (hereinafter referred to as the "Act"), adopts the following Articles of Incorporation for the Corporation:

ARTICLE ONE

Name

The name of the Corporation is: ECTOR DRUM, INC.

ARTICLE TWO

Duration

The period of the duration of the Corporation is perpetual.

ARTICLE THREE

Purpose and Powers

Section 1. Purpose. The purpose for which the Corporation is organized is:

> To transact any or all lawful business for which corporations may be incorporated under the Texas Business Corporation Act.

Section 2. Statutory Powers. Subject to any limitations or restrictions imposed by the Act or other law, or by these Articles of Incorporation, and solely in furtherance of, but not in addition to, the purpose set forth in Section 1 of this Article, the Corporation shall have and may exercise all of the powers specified in the Act or in any other applicable law of Texas.

Section 3. Additional Powers. Subject to any limitations or restrictions imposed by the Act, by other law, or by these Articles of Incorporation, and solely in furtherance of, but not in addition to, the purpose set forth in Section 1 of this Article, the purpose enumerated in Section 1 of this Article shall be construed as creating powers (as well as declaring purposes) as fully as if the text of the clause in Section 1 of this Article was repeated in this Section.

Section 4. Direction of Purpose and Exercise of Powers by Directors. Subject to any limitations or restrictions imposed by the Act, by other law, or by these Articles of Incorporation, the Board of Directors is hereby authorized to direct, by resolution duly adopted, the purpose set forth in Section 1 of this Article and to exercise all the powers of the Corporation, without previous authorization or subsequent approval by the shareholders; and all parties dealing with the Corporation shall have the right to rely on any action taken by the Corporation pursuant to such action by the Board of Directors.

Section 5. Limiting Clause. Nothing in this Article is to be construed as authorizing the Corporation to transact any business in the State of Texas expressly prohibited by any law of Texas, or to engage in any activity in Texas which cannot lawfully be engaged in without first obtaining a license under the laws of Texas and such a license cannot be granted to a corporation.

ARTICLE FOUR

Capital Stock

The aggregate number of shares which the Corporation shall have authority to issue is One Hundred Thousand (100,000) shares of common stock each with a par value of One Dollar ($1.00). Common shares and the holders thereof shall not have cumulative voting rights, and no shareholder shall have any pre-emptive rights to subscribe for or acquire any treasury shares or any additional shares of any class of the Corporation if such shares shall be hereby or hereafter authorized or issued.

ARTICLE FIVE

Initial Consideration for Issuance of Shares

The Corporation will not commence business until it has received for the issuance of its shares consideration of the value of One Thousand Dollars ($1,000.00), consisting of money, labor done or property actually received.

ARTICLE SIX

Initial Registered Office and Agent

Section 1. Registered Office. The address of the initial registered office of the Corporation is 2502 Marco Street, Odessa, Texas 79763.

Section 2. Registered Agent. The name of the initial registered agent of the Corporation, at such address, is RANDY BEARD.

ARTICLE SEVEN

Contracts with Other Corporations

No contract or other transaction between the Corporation and any other corporation and no other act of the Corporation with relation to any other corporation shall, in the absence of fraud, in any way be invalidated or otherwise affected by the fact that any one or more of the directors of the Corporation are pecuniarily or otherwise interested in, or are directors or officers of, such other corporation. Any director of the Corporation may vote upon any contract or other transaction between the Corporation and any subsidiary or affiliated corporation without regard to the fact that he is also a director of such subsidiary or affiliated corporation. Any director of the Corporation individually, or any firm or association of which any director may be a member, may be a party to, or may be pecuniarily or otherwise interested in, any contract or transaction of the Corporation, provided that the fact that he individually or as a member of such firm or association is such a party or so interested shall be disclosed or shall have been known to the Board of Directors or a majority of such members thereof as shall be present at any meeting of the Board of Directors at which action upon any such contract or transaction shall be taken; and in any case described in this paragraph, any such director may be counted in determining the existence of a quorum at any meeting of the Board of Directors which shall authorize any such contract or transaction and may vote thereat to authorize any such contract or transaction.

ARTICLE EIGHT

Indemnification of Officers and Directors

Section 1. Indemnification of Officers and Directors. The Corporation shall have the power to adopt By-Laws providing for the indemnification to the fullest extent to which it is empowered to do so by the Texas Business Corporation Act or any other applicable laws as may from time to time be in effect, of any person who was, is or is threatened to be made a party to any threatened, pending or completed action, suit or proceeding, whether civil, criminal, administrative or investigative, by reason of the fact that he is or was a director or officer of the Corporation, or is or was serving at the request of the Corporation as a director, officer, partner, venturer, proprietary, trustee, employee, agent or similar functionary of another foreign or domestic corporation, partnership, joint venture, trust or other enterprise, against all expenses (including attorneys' fees), judgments, fines and amounts paid in settlement actually and reasonably incurred by him in connection with such action, suit or proceeding.

Section 2. Power to Purchase Insurance. The Corporation shall have the power to purchase and maintain insurance on behalf of any person who is or was a director, officer, employee or agent of the Corporation, or is or was serving at the request of the Corporation as a director, officer, employee or agent of another corporation, partnership, joint venture, trust or other enterprise against any liability asserted against him and incurred by him in any such capacity, or arising out of his status as such, whether or not the Corporation would have the power to indemnify him against such liability under the provision of this Article.

ARTICLE NINE

Data Respecting Directors

Section 1. Board of Directors. The number of directors shall from time to time be fixed by the By-Laws of the Corporation. The number of directors constituting the initial Board of Directors is three (3) who need not be residents of the State of Texas or shareholders of the Corporation.

Section 2. Names and Addresses. The names and addresses of the persons who are elected to serve as directors until the first annual meeting of the shareholders, or until their successors shall have been elected and qualify, are:

Name	Address
THOMAS L. SALMON	119 Santa Rita Odessa, Texas 79763
RANDY BEARD	204 Sunset Lane Odessa, Texas 79763
NORMAN SMITH	804 Larchmont Drive Odessa, Texas 79764

Section 3. Increase or Decrease of Directors. The number of directors of the Corporation may be increased or decreased from time to time by amendment to the By-Laws; but no decrease shall have the effect of shortening the term of any incumbent director. In the absence of a By-law fixing the number of directors, the number shall be three (3).

ARTICLE TEN

Data Respecting Incorporators

The name and address of the Incorporator of the Corporation is:

Name	Address
JIMMIE B. TODD	Suite 409, MBank Plaza 3800 East 42nd Street Odessa, Texas 79762-5982

IN WITNESS WHEREOF, the undersigned has hereunto set his hand this the 22nd day of June, 1988.

INCORPORATOR:

Jimmie B. Todd
JIMMIE B. TODD

THE STATE OF TEXAS §
§
COUNTY OF ECTOR §

I, the undersigned, a Notary Public, do hereby certify that on the 22nd day of June, 1988, personally appeared JIMMIE B. TODD, who, being by me first duly sworn, declared that he is the person who signed the foregoing document as Incorporator, and that the statements therein contained are true.

Veda V. Jones
NOTARY PUBLIC IN AND FOR
THE STATE OF TEXAS

(SEAL)

NOTARY PUBLIC STATE OF TEXAS
Veda V. Jones
Notary Public, State of Texas
My Commission Expires 11-30-88

Reference 9

3 7 1 1 1 5 0 0 6 2 7

FILED
In the Office of the
Secretary of State of Texas

AUG 21 1989

Clerk III Z
Corporations Section

ASSUMED NAME CERTIFICATE

THE STATE OF TEXAS §
§ KNOW ALL MEN BY THESE PRESENTS:
COUNTY OF ECTOR §

THAT ECTOR DRUM, INC., the undersigned, for the purpose of complying with Chapter 36, Title 4, Business and Commerce Code of the State of Texas, do hereby certify to the following facts:

1. LONE STAR DRUM COMPANY is the assumed name under which the business or professional service is or is to be conducted or rendered.

2. Registrant: A corporation.

3. Name and Address:

ECTOR DRUM, INC.
2502 Marco Street
Odessa, Texas 79763

Said Corporation was duly incorporated under the laws of the State of Texas and its registered or similar office address there is 2502 Marco Street, Odessa, Texas 79763.

County or counties within the State of Texas where the business or professional services are being or are to be conducted or rendered under said assumed name:

Ector and Midland Counties.

4. The Corporation is a business corporation.

5. The period, not to exceed ten (10) years, during which the assumed name will be used is from the 15th day of August, 1989, until the 14th day of August, 1999.

IN TESTIMONY WHEREOF, I have hereunto set my hand, this the 16th day of August, 1989.

ECTOR DRUM, INC.

BY: Norman Smith
Norman Smith
President

0 0 1 1 1 5 0 0 6 2 3

THE STATE OF TEXAS §
§
COUNTY OF ECTOR §

This instrument was acknowledged before me this 16th day of August, 1989 by Norman Smith.

OFFICIAL SEAL
EDITH HILLIARD
NOTARY PUBLIC
STATE OF TEXAS
My Comm Expires February 1, 1992

Edith Hilliard
Notary Public State of TX

Reference 10

FILED
In the Office of the
Secretary of State of Texas

NOV 07 2005

Corporations Section

THE STATE OF TEXAS §
§ ASSUMED NAME CERTIFICATE
COUNTY OF ECTOR § (OF A TEXAS CORPORATION)

Pursuant to the provisions of Chapter 36, Assumed Business or Professional Name Act, Title 4, Business and Commerce Code, V.T.C.A., this is to certify that **ECTOR DRUM, INC.**, a Texas Corporation, Charter No. 01081096;

(1) conducts business under the assumed name of **LONE STAR DRUM COMPANY**;

(2) its name as stated in its Articles of Incorporation is **ECTOR DRUM, INC.**;

(3) is incorporated under the laws of the State of Texas and the address of its registered office is 2525 North Marco Avenue, Odessa, Texas 79762;

(4) will use such assumed name for a period of ten (10) years;

(5) is a business corporation;

(6) has its registered office at 2525 North Marco Avenue, Odessa, Texas 79762, and its registered agent at such address is **RANDY BEARD**;

(7) has its principal office at 2525 North Marco Avenue, Odessa, Texas 79762;

(8) conducts business under its assumed name in the following Texas Counties: Ector.

EXECUTED this 4th day of November, 2005.

ECTOR DRUM, INC.

By: [signature]
Randy Beard, President

THE STATE OF TEXAS §
§
COUNTY OF ECTOR §

This instrument was acknowledged before me on the 4th day of November, 2005, by RANDY BEARD, as President of ECTOR DRUM, INC., a Texas Corporation, on behalf of said corporation.

(SEAL) VEDA V. JONES
Notary Public, State of Texas
My Commission Expires 11-30-2008

[signature]
NOTARY PUBLIC IN AND FOR
THE STATE OF TEXAS

G:\WDOX\CLIENTS\607\88381\ANCERT\00009156.F00

Reference 11

Ector County Appraisal District

1301 E 8th Street
Odessa, Texas 79761-4703
Phone:432-332-6834
Fax:432-332-1726

Last Update-Appraisal Info: April 1, 2015
Last Update-Unpaid Tax Amounts: April 1, 2015
Payments made after this date are not reflected in UNPAID TAX AMOUNTS.

Account Number: 99200.01565.00000

Parcel Number: P200001565

Owner's Information

ECTOR DRUM INC
DBA ECTOR DRUM INC
PO BOX 1888
ODESSA, TX 79760-1888

Property Location

2604 N MARCO AVE

Property Legal Description

BUSINESS PERSONAL PROPERTY
INV-FURN&FIXTURES-MACH&EQUIP-SUPP-VEH

Undivided Interest Percent

1.000000

DEED & EXEMPTION INFORMATION

Name	Year	Date	Vol / Pg	Inst.#	Exemptions
ECTOR DRUM INC	2015		/		None

PROPERTY VALUES

	2015	2014	2013	2012	2011
TOTAL MARKET VALUE	$153,622	$153,622	$139,656	$122,505	$122,505
APPRAISED VALUE	$153,622	$153,622	$139,656	$122,505	$122,505

JURISDICTION VALUES & TAX RATES

	2015 Value Tax Rate Tax Amt	2014 Value Tax Rate	2013 Value Tax Rate	2012 Value Tax Rate	2011 Value Tax Rate
ECTOR COUNTY	$153,622 0.002973 $456.72	$153,622 0.002973	$139,656 0.002973	$122,505 0.003183	$122,505 0.003564
ECTOR COUNTY I S D	$153,622 0.011610 $1,783.55	$153,622 0.011610	$139,656 0.011610	$122,505 0.011195	$122,505 0.011320
ECTOR CO HOSPITAL DIST	$153,622 0.000510 $78.35	$153,622 0.000510	$139,656 0.000456	$122,505 0.000498	$122,505 0.000521
ODESSA COLLEGE	$153,622 0.001766 $271.30	$153,622 0.001766	$139,656 0.001741	$122,505 0.001872	$122,505 0.001948
TOTAL ESTIMATED TAX AMOUNT	$2,589.91				

ORIGINAL TAX AMOUNTS

Year	TAX	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2014	$2,589.89	$1,783.55	$271.30	$456.71	$78.33	$0.00	$0.00	$0.00	$0.00	$0.00

UNPAID TAX AMOUNTS

Year	Balance	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2014	$2,848.88	$1,961.91	$298.43	$502.38	$86.16	$0.00	$0.00	$0.00	$0.00	$0.00

Pen/Int: $313.38 Atty Fee: $0.00 Total Due: $3,162.26

Year	Balance	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2013	$2,577.88	$1,783.55	$267.50	$456.71	$70.12	$0.00	$0.00	$0.00	$0.00	$0.00

Pen/Int: $696.03 Atty Fee: $654.78 Total Due: $3,928.69

Total due for all years: $7,090.95

Ector County Appraisal District

1301 E 8th Street
Odessa, Texas 79761-4703
Phone:432-332-6834
Fax:432-332-1726

Last Update-Appraisal Info: May 4, 2015
Last Update-Unpaid Tax Amounts: May 1, 2015
Payments made after this date are not reflected in UNPAID TAX AMOUNTS.

Account Number: 18100.00472.01000

Parcel Number: R100064365

Owner's Information
BEARD CARL RANDLE & SANDRA KAY
204 SUNSET LN
ODESSA, TX 79763-2946

Property Location
2606 N MARCO AVE

Property Legal Description
MARCO INDUSTRIAL SITES
BLOCK 3
.62 ACRE OUT OF W PART OF LOT 14

Land Size
0.6198

Undivided Interest Percent
1.000000

DEED & EXEMPTION INFORMATION

Name	Year	Date	Vol / Pg	Inst.#	Exemptions
BEARD CARL RANDLE & SANDRA KAY	2015	2/8/2012	/	2012-00001774	None
SALMON THOMAS L SR	2011				None

IMPROVEMENT INFORMATION

Description	Year	SQFT	Value
O34M - OFFICE	1979	1080	$26,508
WA2M - WAREHOUSE	1979	3750	$63,156

PROPERTY VALUES

	2015	2014	2013	2012	2011
TOTAL IMPROVEMENT VALUE	$89,664	$89,404	$79,822	$50,554	$47,259
LAND MARKET VALUE	$9,180	$9,180	$9,180	$9,180	$9,180
PRODUCTIVITY VALUE	$0	$0	$0	$0	$0
TOTAL MARKET VALUE	$98,844	$98,584	$89,002	$59,734	$56,439
10% HOMESTEAD CAP LOSS	$0	$0	$0	$0	$0
APPRAISED VALUE	$98,844	$98,584	$89,002	$59,734	$56,439

JURISDICTION VALUES & TAX RATES

	2015 Value Tax Rate Tax Amt	2014 Value Tax Rate	2013 Value Tax Rate	2012 Value Tax Rate	2011 Value Tax Rate
ECTOR COUNTY	$98,844 0.002973 $293.86	$98,584 0.002973	$89,002 0.002973	$59,734 0.003183	$56,439 0.003564
ECTOR COUNTY I S D	$98,844 0.011610 $1,147.58	$98,584 0.011610	$89,002 0.011610	$59,734 0.011195	$56,439 0.011320
ECTOR CO HOSPITAL DIST	$98,844 0.000510 $50.41	$98,584 0.000510	$89,002 0.000456	$59,734 0.000498	$56,439 0.000521
ODESSA COLLEGE	$98,844 0.001766 $174.56	$98,584 0.001766	$89,002 0.001741	$59,734 0.001872	$56,439 0.001948
TOTAL ESTIMATED TAX AMOUNT	$1,666.41				

ORIGINAL TAX AMOUNTS

Year	TAX	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2014	$1,662.01	$1,144.56	$174.10	$293.09	$50.26	$0.00	$0.00	$0.00	$0.00	$0.00

Ector County Appraisal District

1301 E 8th Street
Odessa, Texas 79761-4703
Phone:432-332-6834
Fax:432-332-1726

Last Update-Appraisal Info: May 4, 2015
Last Update-Unpaid Tax Amounts: May 1, 2015
Payments made after this date are not reflected in UNPAID TAX AMOUNTS.

Account Number: 18100.00472.00000

Parcel Number: R100064364

Owner's Information
ECTOR DRUM INC
PO BOX 1888
ODESSA, TX 79760-1888

Property Legal Description
MARCO INDUSTRIAL SITES
BLOCK 3
LOT 14 LESS .62 ACRES IN W PART

Property Location
2502 N MARCO AVE

Land Size
1.4921

Undivided Interest Percent
1.000000

DEED & EXEMPTION INFORMATION

Name	Year	Date	Vol / Pg	Inst.#	Exemptions
ECTOR DRUM INC	2015	8/1/1988	1014 / 449		None
GREENES ENERGY GROUP LLC	2014	8/1/1988	1014	449	None

IMPROVEMENT INFORMATION

Description	Year	SQFT	Value
O34M - OFFICE	1954	1500	$28,320
SB3M - MACH SHOP	1954	2400	$38,592
SB3M - MACH SHOP	1950	1232	$19,810
SB3M - MACH SHOP	1954	4248	$68,308

PROPERTY VALUES

	2015	2014	2013	2012	2011
TOTAL IMPROVEMENT VALUE	$155,030	$143,552	$139,351	$85,894	$80,290
LAND MARKET VALUE	$22,099	$22,099	$22,099	$22,099	$22,099
PRODUCTIVITY VALUE	$0	$0	$0	$0	$0
TOTAL MARKET VALUE	$177,129	$165,651	$161,450	$107,993	$102,389
10% HOMESTEAD CAP LOSS	$0	$0	$0	$0	$0
APPRAISED VALUE	$177,129	$165,651	$161,450	$107,993	$102,389

JURISDICTION VALUES & TAX RATES

	2015 Value Tax Rate Tax Amt	2014 Value Tax Rate	2013 Value Tax Rate	2012 Value Tax Rate	2011 Value Tax Rate
ECTOR COUNTY	$177,129 0.002973 $526.60	$165,651 0.002973	$161,450 0.002973	$107,993 0.003183	$102,389 0.003564
ECTOR COUNTY I S D	$177,129 0.011610 $2,056.47	$165,651 0.011610	$161,450 0.011610	$107,993 0.011195	$102,389 0.011320
ECTOR CO HOSPITAL DIST	$177,129 0.000510 $90.34	$165,651 0.000510	$161,450 0.000456	$107,993 0.000498	$102,389 0.000521
ODESSA COLLEGE	$177,129 0.001766 $312.81	$165,651 0.001766	$161,450 0.001741	$107,993 0.001872	$102,389 0.001948
TOTAL ESTIMATED TAX AMOUNT	$2,986.22				

ORIGINAL TAX AMOUNTS

Year	TAX	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2014	$2,792.68	$1,923.21	$292.54	$492.47	$84.46	$0.00	$0.00	$0.00	$0.00	$0.00

UNPAID TAX AMOUNTS

Year	Balance	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED

2014	$2,792.68*	$1,923.21	$292.54	$492.47	$84.46	$0.00	$0.00	$0.00	$0.00	$0.00
			Pen/Int:	$363.05		Atty Fee:	$0.00		Total Due:	$3,155.73

Year	Balance	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2013	$2,709.23*	$1,874.43	$281.13	$479.98	$73.69	$0.00	$0.00	$0.00	$0.00	$0.00
			Pen/Int:	$758.58		Atty Fee:	$693.56		Total Due:	$4,161.38

Total due for all years: $7,317.11

* Status: SUIT FILED / Cause: CC2-11,369-T

Ector County Appraisal District

1301 E 8th Street
Odessa, Texas 79761-4703
Phone:432-332-6834
Fax:432-332-1726

Last Update-Appraisal Info: May 4, 2015
Last Update-Unpaid Tax Amounts: May 1, 2015
Payments made after this date are not reflected in UNPAID TAX AMOUNTS.

Account Number: 18100.00490.00000

Parcel Number: R100030121

Owner's Information
ECTOR DRUM INC
DBA LONE STAR DRUM CO
PO BOX 1888
ODESSA, TX 79760-1888

Property Location
N MARCO AVE

Property Legal Description
MARCO INDUSTRIAL SITES
BLOCK 3
DRILL SITE

Land Size
1.0330

Undivided Interest Percent
1.000000

DEED & EXEMPTION INFORMATION

Name	Year	Date	Vol / Pg	Inst.#	Exemptions
ECTOR DRUM INC	2015	12/1/1997	1368 / 480		None
GREENES ENERGY GROUP LLC	2014	12/1/1997	1368	480	None

IMPROVEMENT INFORMATION

Description	Year	SQFT	Value
LAND ONLY	0	0	$0

PROPERTY VALUES

	2015	2014	2013	2012	2011
TOTAL IMPROVEMENT VALUE	$0	$0	$0	$0	$0
LAND MARKET VALUE	$103	$103	$103	$103	$103
PRODUCTIVITY VALUE	$0	$0	$0	$0	$0
TOTAL MARKET VALUE	$103	$103	$103	$103	$103
10% HOMESTEAD CAP LOSS	$0	$0	$0	$0	$0
APPRAISED VALUE	$103	$103	$103	$103	$103

JURISDICTION VALUES & TAX RATES

	2015 Value / Tax Rate / Tax Amt	2014 Value / Tax Rate	2013 Value / Tax Rate	2012 Value / Tax Rate	2011 Value / Tax Rate
ECTOR COUNTY	$103 0.002973 $0.31	$103 0.002973	$103 0.002973	$103 0.003183	$103 0.003564
ECTOR COUNTY I S D	$103 0.011610 $1.20	$103 0.011610	$103 0.011610	$103 0.011195	$103 0.011320
ECTOR CO HOSPITAL DIST	$103 0.000510 $0.05	$103 0.000510	$103 0.000456	$103 0.000498	$103 0.000521
ODESSA COLLEGE	$103 0.001766 $0.18	$103 0.001766	$103 0.001741	$103 0.001872	$103 0.001948
TOTAL ESTIMATED TAX AMOUNT	$1.74				

ORIGINAL TAX AMOUNTS

Year	TAX	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2014	$1.74	$1.20	$0.18	$0.31	$0.05	$0.00	$0.00	$0.00	$0.00	$0.00

UNPAID TAX AMOUNTS

Year	Balance	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2014	$1.74*	$1.20	$0.18	$0.31	$0.05	$0.00	$0.00	$0.00	$0.00	$0.00

Pen/Int: $0.23 Atty Fee: $0.00 Total Due: $1.97

Year	Balance	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2013	$1.74*	$1.20	$0.18	$0.31	$0.05	$0.00	$0.00	$0.00	$0.00	$0.00
			Pen/Int:	$0.49		Atty Fee:	$0.45		Total Due:	$2.67

Total due for all years: $4.64

* Status: SUIT FILED / Cause: CC2-11,369-T

Ector County Appraisal District

1301 E 8th Street
Odessa, Texas 79761-4703
Phone:432-332-6834
Fax:432-332-1726

Last Update-Appraisal Info: May 4, 2015
Last Update-Unpaid Tax Amounts: May 1, 2015
Payments made after this date are not reflected in UNPAID TAX AMOUNTS.

Account Number: 18100.00520.00000

Parcel Number: R100064357

Owner's Information
ENERGY COIL & RIGGING LLC
3750 KERMIT HWY
ODESSA, TX 79764-6433

Property Legal Description
MARCO INDUSTRIAL SITES
BLOCK 4
LOTS 2-3 & 8

Property Location
2525 N MARCO AVE

Land Size
2.7548

Undivided Interest Percent
1.000000

DEED & EXEMPTION INFORMATION

Name	Year	Date	Vol / Pg	Inst.#	Exemptions
ENERGY COIL & RIGGING LLC	2015	1/20/2012	/	2012-00000831	None
SALMON THOMAS L SR	2011				None

IMPROVEMENT INFORMATION

Description	Year	SQFT	Value
O33M - OFFICE	1982	1200	$49,383
WB1M - WAREHOUSE	1982	6000	$162,630
WB1M - WAREHOUSE	2014	6750	$239,066
WB1M - WAREHOUSE	2014	2800	$99,168

PROPERTY VALUES

	2015	2014	2013	2012	2011
TOTAL IMPROVEMENT VALUE	$550,247	$196,299	$175,248	$116,602	$108,970
LAND MARKET VALUE	$40,800	$40,800	$40,800	$40,800	$40,800
PRODUCTIVITY VALUE	$0	$0	$0	$0	$0
TOTAL MARKET VALUE	$591,047	$237,099	$216,048	$157,402	$149,770
10% HOMESTEAD CAP LOSS	$0	$0	$0	$0	$0
APPRAISED VALUE	$591,047	$237,099	$216,048	$157,402	$149,770

JURISDICTION VALUES & TAX RATES

	2015 Value Tax Rate Tax Amt	2014 Value Tax Rate	2013 Value Tax Rate	2012 Value Tax Rate	2011 Value Tax Rate
ECTOR COUNTY	$591,047 0.002973 $1,757.18	$237,099 0.002973	$216,048 0.002973	$157,402 0.003183	$149,770 0.003564
ECTOR COUNTY I S D	$591,047 0.011610 $6,862.06	$237,099 0.011610	$216,048 0.011610	$157,402 0.011195	$149,770 0.011320
ECTOR CO HOSPITAL DIST	$591,047 0.000510 $301.43	$237,099 0.000510	$216,048 0.000456	$157,402 0.000498	$149,770 0.000521
ODESSA COLLEGE	$591,047 0.001766 $1,043.79	$237,099 0.001766	$216,048 0.001741	$157,402 0.001872	$149,770 0.001948
TOTAL ESTIMATED TAX AMOUNT	$9,964.46				

ORIGINAL TAX AMOUNTS

Year	TAX	ISD	OC	COU	HOS	ODE	ECUD	GOL	FMLR	CED
2014	$3,997.22	$2,752.72	$418.72	$704.89	$120.89	$0.00	$0.00	$0.00	$0.00	$0.00

Reference 12

Instructions for Acce × | BUSINESS ORGANIZ ×

https://direct.sos.state.tx.us/corp_inquiry/corp_inquiry-entity.asp?:Sfiling_number=108109600&:Nsession_id=31416168&:Ndocument_number=599899490002&pgcurrent=

Apps | CATS | OAS: Operating... | Correspondenc... | Interstate Tech... | TRRP Protective... | TRRP Guidance ... | Superfund Staff... | www.epa.gov/s... | TCEQ Central R... | »

Texas Secretary of State

Carlos H. Cascos

UCC | Business Organizations | Trademarks | Notary | Account | Help/Fees | Briefcase | Logout

BUSINESS ORGANIZATIONS INQUIRY - VIEW ENTITY

Filing Number:	108109600	**Entity Type:**	Domestic For-Profit Corporation
Original Date of Filing:	June 24, 1988	**Entity Status:**	Forfeited existence
Formation Date:	N/A		
Tax ID:	17514519390	**FEIN:**	
Duration:	Perpetual		

Name: ECTOR DRUM, INC.
Address: PO BOX 1888
ODESSA, TX 79760 USA

REGISTERED AGENT | FILING HISTORY | NAMES | MANAGEMENT | ASSUMED NAMES | ASSOCIATED ENTITIES

Name	Address	Inactive Date
Randy Beard	2525 North Marco Ave. Odessa, TX 79762 USA	

Order | Return to Search

Reference 13

Alcove St
Dustin Dr
Anice St
Amber Dr
Billy Hext Rd
E Commerce St
E Market St
N Marco Ave
N Prospect Ave
Club Dr
W Hwy 80 E
© 2015 Google
672 ft
Imagery Date: 6/16/2011
Google earth


Billy Hext Rd
E Commerce St
Ector Drum
E Market St
N Marco Ave
N Prospect Ave
Club Dr
Image U.S. Geological Survey
© 2015 Google
479 ft
Imagery Date: 1/7/1996
lat 31.886135° lon -102.293823° elev 2884 ft
Eye alt 4954 ft
Google earth

Reference 14

Date: 05/05/2015

*** Texas Commission on Environmental Quality ***
Notice of Registration
Industrial and Hazardous Waste

31752 LONE STAR DRUM

Solid Waste Registration #: 31752
EPA ID:TXD064215759
CN: CN600294458
RN: RN100584291

Company Name: ECTOR DRUM, INC.
Site Name: LONE STAR DRUM
Site Location: 2604 N MARCO AVE, ODESSA, TX
Region: 7
County: 135 ECTOR
Land Type: PRIVATE
Initial Registration Date: 07/28/1980
Last Amendment Date: 06/05/2013
Last Update Date: 08/13/2013

Primary Contact: BEARD, RANDY
Title: ENVIRONMENTAL MANAGER
Mailing Address: PO BOX 1888
ODESSA, TX, 79760-1888
Phone:915-366-8352

Registration Status: INACTIVE
HW Permit:
IW Permit:
MW Permit:

Registration Type: GENERATOR,TRANSPORTER

Generator Type: Industrial

Hazardous Waste Generation Type: CONDITIONALLY EXEMPT SMALL QUANTITY GENERATOR

Receiver Type: null

Transporter Business Type: null

Transport Waste Class: 0

Universal Waste Activity:

Large Quantity Handler of Universal Waste (you accumulate 5,000 kg or more):

Destination Facility for Universal Waste:

NAICS Code: 423840 Industrial Supplies Merchant Wholesalers

Tax ID: 17514519390

31752 LONE STAR DRUM

Owner Information

Name: ECTOR DRUM INC,
Phone: 915-366-8352
Address: PO BOX 1888
ODESSA, TX, 79760-1888

Operator Information

Name: ECTOR DRUM INC,
Phone: 915-366-8352
Address: PO BOX 1888
ODESSA, TX, 79760-1888

Billing Contact: ECTOR DRUM INC,
Billing Address: PO BOX 1888
ODESSA, TX, 79760-1888

Title:
Phone: - -

Other Contact: BEARD, RANDY
Mailing Address: PO BOX 1888
ODESSA, TX, 79760-1888

Role: STEERS CONTACT
Phone:915-366-8352

As of 06/05/2013 - The next unassigned sequence number for WASTES is 0010.

The next unassigned sequence number for UNITS is 006.

**** WASTE INFORMATION ****

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason

****** Active Wastes ******

31752 LONE STAR DRUM

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason

** No Longer Generated Wastes **

00011101	1	Inactive	8/13/13	N	No	6/5/13	

Waste Description: Spent caustic washwater/Drum reconditioner/6-10-91
Date of Generation: 7/22/94
Texas Form Code: 110 - Caustic aqueous waste
EPA Form Code:
EPA Hazardous Waste Numbers: None
Current Management Units: None
Origin Codes: 1 - Generated on-site from a product process or service activity
NAICS Code:
New Chemical Substance: N

00022031	1	Inactive	8/13/13	N	No	6/5/13	

Waste Description: Solvents/Spent paint thinning and paint gun cleaning
Date of Generation: 7/22/94
Texas Form Code: 203 - Non-halogenated solvent
EPA Form Code:
EPA Hazardous Waste Numbers: None
Current Management Units: None
Origin Codes: 1 - Generated on-site from a product process or service activity
NAICS Code:
New Chemical Substance: N

00032061	1	Inactive		N	No	6/5/13	

Waste Description: Waste oil/Drainings from trucks and equipment

31752 LONE STAR DRUM

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason

** No Longer Generated Wastes **

Date of Generation: 7/22/94

Texas Form Code: 206 - Waste oil

EPA Form Code:

EPA Hazardous Waste Numbers: None

Current Management Units: OFF-SITE

Origin Codes: 1 - Generated on-site from a product process or service activity

NAICS Code:

New Chemical Substance: N

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason
00042051	1	Inactive	8/13/13	N	No	6/5/13	

Waste Description: Chemicals and waste oils (drainings, flushing, and washings) drum reconditioning, 9/88

Date of Generation: 7/22/94

Texas Form Code: 205 - Oil-water emulsion or mixture

EPA Form Code:

EPA Hazardous Waste Numbers: None

Current Management Units: OFF-SITE

Origin Codes: 1 - Generated on-site from a product process or service activity

NAICS Code:

New Chemical Substance: N

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason
00053081	1	Inactive		N	No	6/5/13	

Waste Description: Metal scrap/Drum reconditioning, cleaning & testing, 6/91

Date of Generation: 7/22/94

Texas Form Code: 308 - Empty or crushed metal drums or conainers

31752 LONE STAR DRUM

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason

** No Longer Generated Wastes **

EPA Form Code:
EPA Hazardous Waste Numbers: None
Current Management Units: OFF-SITE
Origin Codes: 1 - Generated on-site from a product process or service activity
NAICS Code:
New Chemical Substance: N

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason
00063892	2	Inactive	8/13/13	N	Yes	6/5/13	

Waste Description: Paint dust/Steel dust/From shot blasting operation on empty 55 gal. drums/6/91
Date of Generation: 7/22/94
Texas Form Code: 389 - Nonhazardous sandblasting waste
EPA Form Code:
EPA Hazardous Waste Numbers: None
Current Management Units: OFF-SITE
Origin Codes: 1 - Generated on-site from a product process or service activity
NAICS Code:
New Chemical Substance: N

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason
00079012	2	Inactive		N	Yes	6/5/13	

Waste Description: Plant refuse, general & misc.
Date of Generation: 7/22/94
Texas Form Code: 901 - Plant production refuse
EPA Form Code:
EPA Hazardous Waste Numbers: None

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason

** No Longer Generated Wastes **

Current Management Units: OFF-SITE
Origin Codes: 1 - Generated on-site from a product process or service activity
NAICS Code:
New Chemical Substance: N

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason
00084032	2	Inactive	8/13/13	N	Yes	6/5/13	

Waste Description: Paint waste, solid/Cleaning drum painting equipment/6/91
Date of Generation: 7/22/94
Texas Form Code: 403 - Solids resins or polymerized organics
EPA Form Code:
EPA Hazardous Waste Numbers: None
Current Management Units: OFF-SITE
Origin Codes: 1 - Generated on-site from a product process or service activity
NAICS Code:
New Chemical Substance: N

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason
0009205H	H	Inactive	8/13/13	N	No	6/5/13	

Waste Description: Chemical and waste oil from drum reconditioning. Drainage, flushings and washings. First generated 03/01.
Date of Generation: 1/10/00
Texas Form Code: 205 - Oil-water emulsion or mixture
EPA Form Code: Oil-water emulsion or mixture
EPA Hazardous Waste Numbers: D002
Current Management Units: OFF-SITE

31752 LONE STAR DRUM

Texas Waste Code	Waste Class	Status	Waste Status Code Change Date	Mixed Radioactive	TCEQ Audit Complete	Waste Update Date	Inactive Reason

** No Longer Generated Wastes **

Origin Codes: 1 - Generated on-site from a product process or service activity

Source Codes: G02 - Stripping and acid or caustic cleaning

NAICS Code: 423830 Industrial Machinery and Equipment Merchant Wholesalers

New Chemical Substance: N

31752 LONE STAR DRUM

**** UNITS AT THIS SITE MANAGING WASTE ****

WMU Sequence Number	Unit Capacity	Capacity UOM	Unit Status	Date of Unit Regis	Class of Waste from Offsite	UIC Permit Number	Unit Number on Permit	Unit Update Date	Deed Record Date

** 'Active', 'Closure Pending' & 'Closure Request' Units **

WMU Sequence Number	Unit Capacity	Capacity UOM	Unit Status	Date of Unit Regis	Class of Waste from Offsite	UIC Permit Number	Unit Number on Permit	Unit Update Date	Deed Record Date
001			ACTIVE	6/1/80					

Unit Type: Tank
Unit Regulatory Status:
Unit Description: Cap: 200 BBL"TANK STORAGE OF WASTE NUMBERS 001 AND 002"
Billing Class:
System Type Cd:
Unit Notes: Usage: Storage
Wastes Currently Managed in Unit: None
Wastes Previously Managed in Unit: 00032061 00042051

WMU Sequence Number	Unit Capacity	Capacity UOM	Unit Status	Date of Unit Regis	Class of Waste from Offsite	UIC Permit Number	Unit Number on Permit	Unit Update Date	Deed Record Date
002			ACTIVE	6/1/80					

Unit Type: Tank
Unit Regulatory Status:
Unit Description: Cap: 160 BBL
Billing Class:
System Type Cd:
Unit Notes: Usage: Processing
Wastes Currently Managed in Unit: None
Wastes Previously Managed in Unit: 00011101

WMU Sequence Number	Unit Capacity	Capacity UOM	Unit Status	Date of Unit Regis	Class of Waste from Offsite	UIC Permit Number	Unit Number on Permit	Unit Update Date	Deed Record Date
004			ACTIVE	7/22/94				9/14/11	

WMU Sequence Number	Unit Capacity	Capacity UOM	Unit Status	Date of Unit Regis	Class of Waste from Offsite	UIC Permit Number	Unit Number on Permit	Unit Update Date	Deed Record Date

** 'Active', 'Closure Pending' & 'Closure Request' Units **

Unit Type: Container Storage Area

Unit Regulatory Status: 05 Non-Hazardous Regulated

Unit Description: Drum and container storage area, East yard & drum crusher.

Billing Class:

System Type Cd: 141 Storage

Wastes Currently Managed in Unit: None

Wastes Previously Managed in Unit: 00053081

005			ACTIVE	7/22/94				9/14/11	

Unit Type: Containment Building

Unit Regulatory Status: 05 Non-Hazardous Regulated

Unit Description: Overhead dust collecting building, South side of Main Plant.

Billing Class:

System Type Cd: 141 Storage

Wastes Currently Managed in Unit: None

Wastes Previously Managed in Unit: 00063892 00084032

31752 LONE STAR DRUM

WMU Sequence Number	Unit Capacity	Capacity UOM	Unit Status	Date of Unit Regis	Class of Waste from Offsite	UIC Permit Number	Unit Number on Permit	Unit Update Date	Deed Record Date
** 'Inactive', 'Closed', 'Post Closure Care', 'Never Built' & 'Not Required' Units **									
003			INACTIVE	6/10/91					

Unit Type: Tank (Sub-surface)

Unit Regulatory Status:

Unit Description: Cap: 5 BBL

Billing Class:

System Type Cd:

Unit Notes: Usage: Storage

Wastes Currently Managed in Unit: None

Wastes Previously Managed in Unit: None

WMU Sequence Number	Unit Capacity	Capacity UOM	Unit Status	Date of Unit Regis	Class of Waste from Offsite	UIC Permit Number	Unit Number on Permit	Unit Update Date	Deed Record Date
** 'Not Yet Built' & 'Under Construction' Units **									

Reference 15

NA

Texas Commission on Environmental Quality
Investigation Report

The TCEQ is committed to accessibility. If you need assistance in accessing this document, please contact oce@tceq.texas.gov

Customer: Ector Drum, Inc.
Customer Number: CN600294458

Regulated Entity Name: ECTOR DRUM
Regulated Entity Number: RN100584291

Investigation # 912172

Incident Numbers 152318

Investigator: CHRISTINE HAMMIT

Site Classification CONDITIONALLY EXEMPT SMALL QUANTITY GENERATOR

Conducted: 04/05/2011 -- 04/05/2011

NAIC Code: 423840
SIC Code: 5085

Program(s): INDUSTRIAL AND HAZARDOUS WASTE

Investigation Type: Compliance Investigation

Location: 2604 N Marco Ave, Odessa, TX

Additional ID(s): TXD064215759
31752

Address: 2604 N MARCO AVE,
ODESSA, TX , 79762

Local Unit: REGION 07 - MIDLAND
Activity Type(s): IHWCMPL - Complaint investigation

Principal(s):

Role	Name
RESPONDENT	ECTOR DRUM INC

Contact(s):

Role	Title	Name	Phone	
Notified	ENVIRONMENTAL MANAGER	MR RANDY BEARD	Cell Home Work	(432) 556-3939 (432) 337-0786 (432) 366-8352
Participated in Investigation	ENVIRONMENTAL MANAGER	MR RANDY BEARD	Work	(432) 366-8352
Regulated Entity Contact	ENVIRONMENTAL MANAGER	MR RANDY BEARD		

Other Staff Member(s):

Role	Name
Supervisor	JARED BASURTO
Supervisor	WILLIAM EDMISTON

Associated Check List

Checklist Name	Unit Name
IHW COMPLAINT	LoneStar2011

Investigation Comments:

INTRODUCTION
On April 5, 2011 at 2:30PM, Christine Hammit, Environmental Investigator with the Region 7 TCEQ office attempted to conduct a complaint investigation of the subject facilities. Lone Star Drum is located at 2525 N. Marco Avenue in Odessa, Ector County. The area surrounding the facility has traditional been mainly industrial and pasture. Several housing developments have been completed in the recent years adjacent to this industrial zoning.

The complaint stated there was waste water spillage around the loading dock area. The owner was also accumulating waste water in containers in two tractor trailers and assorted drums and totes in the lot behind the office building. According to the complaint this has been going on for a couple of years.

The facility was not operating, there were no cars in any of the parking areas and all the doors were locked. It appeared to be closed. The investigator elected to call the owner, Randy Beard, whose cell phone number was located on the door for emergencies. Mr. Beard, answered the telephone and when questioned stated he had laid off all the employees on Wednesday, March 30, 2011 and was in the process of closing the facility. According to Mr. Beard, they just didn't have enough business to keep operating in the red. Lone Star was closing its doors after 29 years of operation. He was still going in and working on properly disposing of the wastes left on site.

GENERAL FACILITY AND WASTE PROCESS INFORMATION
Lone Star conducted drum recycling operations at their Marco Ave. Location. Drums received were "RCRA empty" and come from oilfield industrial sources consisting primarily of crude oil treatment, corrosive chemicals and lubrication oils.

The reconditioning process began with drums receiving a mild caustic solution for washing and triple rinsing. Containers were dried, air pressure tested and painted for eventual resale. The caustic solution used in rinsing was recycled until caustic properties become spent. The waste stream was then pH adjusted prior to storage in Fac. (001), a 200 gallon above ground tank. The waste water was then transported off-site for disposal.

The majority of waste streams generated were Class I and II wastes. Plant refuse including shredded plastic pails was taken to Charter Waste Management Landfill, Odessa for disposal. Small amounts of paint gun cleaning solvent was routinely generated, however they mixed it with new paint for thinning prior to application, since only one color paint was used. Metal drums in generally poor condition were triple rinsed, crushed, and taken to Commercial Metals, Odessa for reclamation.

BACKGROUND
There was one previous waste complaint for this facility. No waste violations were noted. However, it was suggested that Lone Star improve their housekeeping. Rainwater/waste water from operations was noted on the concrete floor of the facility and also being stored in the secondary containment for their product tanks. (This facility is very old and the roof has several holes in it; and the area has been experiencing some rainfall over the previous week.) Mr. Beard stated they usually clean the place up on Saturdays, it was suggested that instead they should

initiate daily housekeeping.

ADDITIONAL INFORMATION
Mr. Beard is working on disposal of the wastes remaining at the facility.

No Violations Associated to this Investigation

Signed ______________________ **Date** ____________
Environmental Investigator

Signed ______________________ **Date** ____________
Supervisor

Attachments: (in order of final report submittal)

___Enforcement Action Request (EAR)
___Letter to Facility (specify type) : __________
Investigation Report
___Sample Analysis Results
___Manifests
___Notice of Registration
___Maps, Plans, Sketches
___Photographs
___Correspondence from the facility
___Other (specify) :
____
____

Reference 16

Reference 17

Complaint Status

Complaint Tracking #: 128341
Complaint Received Date: 08/10/2009
Number Complaining: 1

Status:	CLOSED
Status Date:	08/19/2009
Nature:	ODOR
Frequency:	INTERMITTENT
Duration:	
Media:	AIR
Program:	AIR QUALITY - HIGH LEVEL
Priority:	Within 30 Calendar Days
Effect:	ENVIRONMENTAL
Receiving Water Body:	
Regulated Entity:	ECTOR DRUM
County:	ECTOR

Description:

Complainant alleges strong odor later in the day as the temperature rises.

Comment:

Ms. Broeder and Ms. Christine Hammit, Industrial Hazardous Waste Investigators, arrived at Lone Star Drum Company at approximately 1000 hours on August 18, 2009. The RE is located in an industrial area of Ector County that is close to a residential development. Upon arrival, Ms. Broeder conducted an odor survey of the property; no odors were detected in front of the business. The investigators then went inside the facility and were informed the owner, Mr. Randy Beard, was on an errand. The employee contacted Mr. Beard by phone. Ms. Hammit spoke with Mr. Beard on the phone and he stated he would be back in approximately 15 minutes.

When Mr. Beard arrived he was informed that an odor complaint had been lodged against the facility and he took the investigators on a tour of the facility. In the drum storage yard, a slight pesticide odor was detected. From the drum storage yard, the investigators toured the drum cleaning and refurbishing facility located directly across Marco Ave. Inside the facility a slight styrene type odor was detected.

Following the tour, Ms. Hammit informed Mr. Beard the facility had poor housekeeping and suggested cleaning up any spills and standing water immediately instead of waiting until Saturday when general housekeeping duties were performed. Ms. Broeder informed Mr. Beard that she was unable to detect any odors while alongside Marco Ave., but an additional odor survey still had to be conducted in the vicinity of the complainant.

At approximately 1045 hours the investigators departed Lone Star Drum and proceeded to the complainant's residence. Again no odors were detected in the vicinity of the complainant's residence, despite the area being downwind of Lone Star Drum. The temperature was 85 degrees Fahrenheit with winds out of the south at approximately 12 miles per hour (Attachment 1).

On August 19, 2009, Ms. Broeder contacted Mr. Beard by phone to discuss the painting operation at the facility. Ms. Broeder asked Mr. Beard approximately how many gallons of paint are used on a yearly basis. Mr. Beard did not have the information readily available and called Ms. Broeder back around 0945 hours. Mr. Beard stated he used approximately 2,900 gallons of paint a year and painted approximately 250 drums a day for an average of six hours a day. Mr. Beard said the painting area is not enclosed and that he did not have a permit for outdoor surface coating and no air related authorizations were found in Central Registry. Ms. Broeder informed Mr. Beard due the amount of painting done he would need to obtain the proper authorization and a Notice of Violation (NOV) will be issued for conducting outdoor spray painting without proper authorization. This is an alleged violation of Title 30 Texas Administrative Code Chapter 116 § 116.10(a)(4).

Action Taken:

Complaint was received in the R7 office, entered and assigned to an investigator. The complaint was originally entered and assigned as a waste complaint. Upon further investigation, by both sections, a potential air issue was discovered. Therefore, this complaint was noted as multimedia.

Complaints #127916 and #128341.

View Investigation Details

Return to Top

New Search

Complaint Status

Complaint Tracking #: 127916
Complaint Received Date: 08/10/2009
Number Complaining: 1

Status: CLOSED
Status Date: 09/04/2009

Nature: ODOR
Frequency: INTERMITTENT
Duration:
Media: WASTE
Program: INDUSTRIAL AND HAZARDOUS WASTE
Priority: Within 30 Calendar Days
Effect: ENVIRONMENTAL

Receiving Water Body:

Regulated Entity: ECTOR DRUM
County: ECTOR

Description:

Complainant alleges Lone Star Drum has drums stacked along the fence line. Complainant alleges that when travels home past the area, notices a strong odor. Complainant alleges notices odors at house usually later in the day as the tempreature increases. Complainant alleges concerned that the chemicals that cause the odor may have health effects.

Comment:

ADDITIONAL INFORMATION

While the air investigation did not confirm an odor, it was noted that the facility had a paint area. Mr. Beard was contacted for details on their painting operations. Based on the amount of paint used per year and the number of hours of painting per day, Lone Star is required to have a permit. A notice of violation was sent to Lone Star informing them a permit was required. Please see Investigation No. 766543 for complete details. The complainant was informed of the results of the investigation through the air portion of the complaint.

Action Taken:

Complaint received in the R7 office, entered and assigned to an investigator. Investigators visited the site on August 18, 2009.

View Investigation Details

Return to Top

Reference 18

Central Registry

Detail of: **Industrial and Hazardous Waste Solid Waste Registration 31752**

For: ECTOR DRUM (RN100584291)
2604 N MARCO AVE, ODESSA

Solid Waste Registration Status: INACTIVE

Held by: ECTOR DRUM INC (CN600294458)
OWNER OPERATOR View Compliance History

Mailing Address: PO BOX 1888 ODESSA, TX 79760-1888

BACK TO: **Facility Information**

IHW Waste

Texas Waste Code	Waste Description
00011101	Spent caustic washwater/Drum reconditioner/6-10-91
00022031	Solvents/Spent paint thinning and paint gun cleaning
00032061	Waste oil/Drainings from trucks and equipment
00042051	Chemicals and waste oils (drainings, flushing, and washings) drum reconditioning, 9/88
00053081	Metal scrap/Drum reconditioning, cleaning & testing, 6/91
00063892	Paint dust/Steel dust/From shot blasting operation on empty 55 gal. drums/6/91
00079012	Plant refuse, general & misc.
00084032	Paint waste, solid/Cleaning drum painting equipment/6/91
0009205H	Chemical and waste oil from drum reconditioning. Drainage, flushings and washings. First generated 03/01.

Reference 19

DRINKING WATER SURVEY REPORT
AND
WATER WELL INVENTORY

Lonestar Drum Facility

2604 North Marco Avenue
Odessa (Ector County), Texas 79762

October 28, 2014

Prepared for:

Texas Commission on Environmental Quality
Petroleum Storage Tank Division
State Lead Remediation Section
P.O. Box 13087, MC-136
Austin, Texas 78711-3087

Prepared by:
SWS Environment
9204 Hwy 287 NW
Fort Worth, Texas 76131

SWS Project No. RW2-410-1411

SWS
ENVIRONMENTAL SERVICES

9204 Hwy 287 NW
Fort Worth, TX 76131
Phone: 817.847.1333
Fax: 817.306.8086
www.swsenvironmental.com

October 28, 2014

MC-137
Omar Valdez
EMERGENCY RESPONSE COORDINATOR
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
P.O. BOX 13087
AUSTIN, TEXAS 78711-3087

RE: Drinking Water Survey, Former Lonestar Drum Facility, 2604 North Marco Avenue, (Ector County) Texas, SWS Job # RW2-410-1411

Dear Mr. Valdez:

On October 8, 2014, SWS received a request from the Texas Commission on Environmental Quality ("TCEQ") to conduct a Drinking Water Survey in accordance with Texas Water Code Section 26.408 covering a 0.5-mile radius around the Former Lonestar Drum Facility located at 2604 North Marco Avenue in Odessa, Ector County, Texas (See Attachment 1-Figures 1 and 2). This work was conducted under SWS's TCEQ Regional Umbrella Emergency Response contract and was authorized under a Work Order issued by the TCEQ Emergency Response Program coordinator (Mr. Anthony Buck). The work order was authorized following the discovery by SWS on October 8, 2014 during sampling of the onsite well of approximately 1.8 ft. of Phase Separated Hydrocarbons (PSH) in the wellbore. Based on observations made during the field activities,, the oil apparently ran into the well casing through an electric conduit as a result of surface water runoff impacted by releases of oil from drums at the site.-SWS personnel used bags of concrete to build a berm around the well to prevent additional impacts from future rainfall events. Following the discovery of the PSH, SWS contacted and notified TCEQ representatives of the impact to this well. The TCEQ Central Office TCEQ coordinator immediately authorized SWS to conduct a water well survey and SWS ordered a 0.5-mile radius water well records search from Banks Environmental Data ("Banks") out of Austin, Texas. The Banks report is included as Attachment 3 of this report. Banks' report was received on October 13, 2014 and SWS personnel mobilized to the site on October 13, 2014 to conduct the 500-foot visual survey and a 0.25-mile radius door to door walking water well survey. The results of these surveys are shown in Attachments 1, 2 and 3 of this report. **The results of the Banks survey indicated that 73 water wells (domestic, irrigation, industrial and public water supply) were identified by Banks Environmental Data in use within 0.5 miles of the site. (See Figure 2.0 and Banks Report – Attachment 3.0). The door to door survey conducted by SWS revealed a total of 50 wells within a 0.25 radius of the site (See Table 1 and Figure 2).**

Groundwater Contamination

On October 8, 2014 SWS mobilized to the site to collect a water sample from the onsite water well. Prior to sampling the well, an interface probe was used to gauge the well for the presence

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of Phase Separated Hydrocarbons (PSH). Approximately 1.8 feet of oil was measured in the well bore at a depth of 27.45 feet below ground surface. SWS personnel collected a sample of the non-aqueous and aqueous phase liquids and submitted the samples to Xenco Laboratories of Dallas, Texas. The samples were analyzed for concentrations of total metals (EPA Method 6010), volatile and semi-volatile organic compounds (EPA Method 8260 and 8270) and TPH (TX Methods 1005 and 1006).

An evaluation of the laboratory analytical results for the oil phase indicated concentrations of arsenic (2.46 mg/L),chromium (33.1 mg/L), copper (5.00 mg/L), lead (3.34mg/L), nickel (2.92 mg/L), and zinc (274 mg/L) all exceeded the TRRP Tier I Residential Groundwater Protective Concentration Levels (PCLs). For the water phase, concentrations of mercury (0.00211 mg/L), chromium (0.298 mg/L), and zinc (7.41 mg/L) exceeded the TRRP Tier I Residential Groundwater Protective Concentration Levels (PCLs) of 0.002 mg/L), 0.10 mg/L and 7.3 mg/L respectively. It should be noted however, that because of the nature of the matrix, the detection limits for all of the other *non-detected* priority pollutant metals (except for silver) are **above** the TRRP Tier I Residential Groundwater Protective Concentration Levels (PCLs). Similarly, no VOCs or SVOCs were detected but the detection limits were so elevated due to the dilution the samples were required to be ran at (1000 x). A benzene concentration (2.90 mg/L) was reported at a concentration below the quantitation limit (J Flagged) but above the laboratory detection limit at 1.00 mg/L. This concentration, although estimated, is substantially above the TRRP Tier I Residential Groundwater PCL of 0.005 mg/L established for this compound. The Texas 1005 TPH results indicated elevated total petroleum hydrocarbons (TPH) for the oil phase at 533,000 mg/kg and for the water phase (274 mg/L). The speciation of the TPH by TX Method 1006 indicated aliphatic hydrocarbons in the C6-C8 carbon range below the laboratory detection limits, C8-C10 (0.300 mg/L), C10-C12 (210 mg/L). C12-16 (4.61 mg/L), C16-C21 (15.3 mg/L) and C21-C35 (264 mg/L) exceeding the TRRP Tier I Residential Groundwater PCLs for the C12-C16 fraction established at 2.4 mg/L and for the C21-C-C35 fraction established at 39 mg/L. For the aromatic hydrocarbons, the laboratory reported C-7-C12 below the laboratory detection limits, C12-C16 (0.390 mg/L), C16-C21 (4.73 mg/L) and C21-C36 (17.3 mg/L). A comparison with the TRRP Tier I Residential Groundwater PCLs indicated the C12-C16, C16-C21 and C21-C36 carbon ranges exceed the criteria of 0.98 mg/L, 0.73 mg/L and 0.73 mg/L respectively. A copy of the signed laboratory report and completed chain of custody document is included as attachment 4.0 of this report.

Public Water Supply Availability

Following the site inspection, SWS personnel contacted personnel with the City of Odessa Water Administration Office (Mr. Agapita Bernal, Ph. No 432-335-3210) to verify the public water supply availability for the area. Eighteen of the thirty-five facilities surveyed have City water availability based on conversation with Mr. Bernal although only a few have connected to this service. These include the new housing developments located northwest, north, and northeast of the subject property and the City of Odessa Country Club as well as a few of the businesses located on North Marco and on US Business 20. The New Life Church located at 7184 Club Drive is currently in the process of converting over to City water and will use their wells for

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irrigation purposes only. The City of Odessa obtains water from surface water reservoirs including, O.H. Ivie, Lake Spence, and Thomas and some water wells provide water for use by residents within the City limits.

During the field inspection, conducted as part of this survey, attempts were made to locate city water meters at all surveyed locations as a further indication of the use of the public water supply within a 0.25 radius of the subject site. City water meters were observed at only a few locations. The survey area is made up primarily of residential and mixed commercial properties. A residential area is located northwest north and northeast of the subject site and all the residences are provided with water from the City of Odessa.

The survey area has recently been added as part of the Groundwater Conservation District with Mr. Tom Kerr as the director (Ph. 432-335-4634).

0.5-Mile Water Well Records Search

The Banks 0.5-mile Water Well Report™ (Attachment 3) indicated 73 water wells (domestic, irrigation, industrial and public water supply) were identified in use within 0.5 miles of the site. The Banks report identified four (4) public water supply wells operated by New Life Church located at 7184 Club Drive. The field survey however indicated that only two wells are located at this site. The facility was once part of the City of Odessa Country Club and the water wells supply the onsite pool. Bottled water for drinking water is provided although the ice maker is currently connected to the water wells onsite. According to Mr. Tim Halstead (Pastor) the Church is in the process of converting entirely to City water and a newly installed City water meter was observed at the site during the field survey. The water wells owned by Permian Homes are being used only for irrigation purposes according to Mr. Scott Cook (Permian Homes Superintendent). All the new homes are provided City water and water meters were observed at all the residences inspected during the field survey. Communication with the manager of the Odessa Country Club indicated that all the wells depicted in Banks Report (7 wells) are utilized solely for irrigation purposes and the Club House is provided water by the City of Odessa Public water supply. Similarly, based on communication with the funeral director (Mr. Mel Wideman) the wells identified by Banks at Sunset Memorial Gardens located at 6801 East Business 20, are used for irrigation purposes and City water is provided for domestic use.

500-Foot Visual Survey and 0.25-Mile Walking Water Well Survey

A visual walking door-to-door water well survey was performed within at least 500 ft. of the release site in all directions. A walking and driving survey was conducted within at least 0.25 miles of the release site and the door to door survey results are summarized in Table 1.0. The results of the field survey and water well inventory revealed the presence of fifty (50) water wells within 0.25 mile radius of the subject site. Based on interviews with the well owners/users most of the wells are not used for drinking water purposes but are mainly used to provide water for washing hands at sinks and for water for toilets and irrigation purposes. Three facilities however had ice machines connected to the water supplied from their onsite wells including

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Schoppa's Material Handling located at 2627 North Marco Ave., Permian Anchors located at 6927 East Business 20, and New Life Church located at 7184 Club Drive. The usage of water from wells at six (6) facilities was not documented as no one was available to interview. These facilities include: 1) H.K. Electric located at 2701 North Marco Avenue, 2) Mr. Bobby Moore-6938 East Commerce Street, 3) B- Mac Corporation, 6955 East Commerce Street, 4) Adam Doyle-6958 East Commerce Street, 5) PRB Machine -6968 East Commerce Street and 6) APP Auto Pax/Cardinal Industries Inc. located at 6977 East Commerce Street.

We appreciate the opportunity to assist you with this project and to provide you with this information. If you have any questions, please call me at 817 829-9135.

Sincerely,

Damon Waresback, P.G.
Senior Geologist

Attachments: Figure 1.0 Site Vicinity Map, Figure 2.0 Aerial Photograph, Table 1.0 Survey Data, Banks 0.5-Mile Radius Water Well Report, Access Agreements, Analytical Data

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ATTACHMENT 1

Vicinity Map - Figure 1

Water Well Location Map - Figure 2

Odessa, Texas, United States

SWS ENVIRONMENTAL SERVICES
9204 Hwy 287 NW
Fort Worth, Texas 76131

Date: 10/28/2014

Figure 1.0
Site Vicinity Map
Lonestar Drum Facility
2604 North Marco Avenue
Odessa (Ector County), TX 79762

N

SWS ENVIRONMENTAL SERVICES 9204 NW Hwy 287 Fort Worth, TX 76131	Date: 10/14/14 Project No. RW2-410-1411	Figure 3.0 0.25-Mile Radius Aerial Map 2604 N. Marco Ave. Odessa, Texas 79762	N

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ATTACHMENT 2

Table 1 – Survey Data

Table 1
Properties Surveyed Within 0.25 Mile of
2604 N. Marco Ave.
Odessa, Texas 79762

SWS Figure 1.0 Map ID No.	Banks Env. Well No.	State Well ID No.	Distance from known extent of groundwater impact contamination (feet)	Physical Address of Well Latitude Longitude (Decimal Degrees)	Well No.	Total Depth (feet)	Screened Interval (feet)	Sealed Interval (feet)	Private Drinking Water Well? (Yes or No)	Affected or Potentially Affected? (Yes or No)	Property Name, Current Mailing Address	Well Users Name, Current Mailing Address
1	Not Identified	NA	Subject Site	31.88548 Lat. -102.29437 Long.	1 well	UNK	UNK	UNK	Well formerly used as PW, well at store not in use	Yes -1.5 ft. PSH	Former Lonestar Drum Recycling	Ronny Beard
2	Not Identified	NA	293' and 764'	31.88548 Lat. -102.29349 Long./ 31.887923 Lat. -102.295131 Long	2 Wells-1 at each location	UNK	UNK	UNK	Wells used for toilets/washing hands	Not at present time*	Guardian Wellhead Protection, 2584 North Marco and 6907 E. Commerce, Odessa 79762	C/O Lance Bolds- Attorney 11757 Katy Freeway, Houston Texas 77079
3	3 & 4	45-06-8NN WIID3137	350' and 334'	31.885157 Lat. -102.293884 Long./ 31.884999 Lat. -102.29361 Long.	2 Wells Adjacent	110' 120'	80-110' 60-120'	0-20' 0-60'	Stephenson well used for toilets	UNK	Former Foster Storage	*Randy Stephenson 2564 North Marco Ave., Odessa, TX 79762
4	Not Identified	NA	NA	NA	NA	NA	NA	NA	City Water	NA	Woody Gregory	2414 North Marco Ave., Odessa, TX 79762
5	Not Identified	45-0-08 2 others not idenitified	443', 875'm 834'	31.884842 Lat. -102.293566 Long./ 31.883519 Lat. -102.293838 Long./ 31.883667 Lat. -102.293662 Long.	3 Wells have City Water	112' UNK UNK	71-112 UNK UNK	UNK UNK UNK	No, used for irrigation	UNK	Scott Thane Ditching Service LTD 6901 E. Business 20 Odessa, TX 79768	*Scott Thane P.O. Box 13888, Odessa, TX 79762
6	Not Identified	NA	813'	31.883796 N Lat -102.293515 W Long.	1 well	UNK	UNK	UNK	Yes, use well for ice maker	UNK	Permian Anchors 6927 E. Business 20 Odessa, TX 79762	*Sylvia Herriage 6927 E. Business 20 Odessa, TX 79762
7	Not Identified	NA	797'	31.883923 Lat. -102.293182 Long.	1 well	UNK	UNK	UNK	Well used for toilets ect.	UNK	Satellite Distributors 6931 E. Business 20 Odessa, TX 79762	Satellite Distributors 6931 E. Business 20 Odessa, TX 79762
8	Banks 7 & 13 Misplotted	NA	628'	31.884645 Lat. -102.293072 Long.	1 well for irrigation	UNK	UNK	UNK	City Water	UNK	Graham Brothers Entertainment 6999 E. Business 20 Odessa, TX 79762	Graham Brothers Entertainment 6999 E. Business 20 Odessa, TX 79762
9	8 Misplotted	NA	1035', 1268', 831'	31.885861 Lat. -102.291020 Long./ 31.887549 Lat. -102.290801 Long./ 31.886282 Lat. -102.291723 Long.	3 wells	UNK UNK UNK	UNK UNK UNK	UNK UNK UNK	Bottled drinking water/toilets, ect.	UNK	Rama Fabricators P.O. Box 7346 Odessa, Texas 79760-7346	*Ronny Rains/Rama Fabricators P.O. Box 7346 Odessa, Texas 79760-7346
9	Not Identified	NA	597'	31.88432 N Lat. -102.294994 Long.	1 well	UNK	UNK	UNK	Bottled water/irrigation, toilets	UNK	Rama Fabricators P.O. Box 7346 Odessa, Texas 79760-7346	*Ronny Rains/Rama Fabricators P.O. Box 7346 Odessa, Texas 79760-7346

Table 1
Properties Surveyed Within 0.25 Mile of
2604 N. Marco Ave.
Odessa, Texas 79762

SWS Figure 1.0 Map ID No.	Banks Env. Well No.	State Well ID No.	Distance from known extent of groundwater impact contamination (feet)	Physical Address of Well Latitude Longitude (Decimal Degrees)	Well No.	Total Depth (feet)	Screened Interval (feet)	Sealed Interval (feet)	Private Drinking Water Well? (Yes or No)	Affected or Potentially Affected? (Yes or No)	Property Name, Current Mailing Address	Well Users Name, Current Mailing Address
9	Not Identified	NA	361'	31.886961 Lat. -102.294991 Long.	1 well	UNK	UNK	UNK	Bottled water/irrigation, toilets	UNK	Rama Fabricators P.O. Box 7346 Odessa, Texas 79760-7346	*Ronny Rains/Rama Fabricators P.O. Box 7346 Odessa, Texas 79760-7346
10	27, 31, 34, 39, 42	See Banks Report	1641', 1774'	31.886872 Lat. -102.289180 Long./ 31.887266 Lat. -102.288849 Long	2 wells identified	See Banks Report	See Banks Report	See Banks Report	Yes, ice maker, pool	UNK	New Life Church 7184 Club Drive Odessa, TX 79762	*Tim Halstead, Pastor 7184 Club Drive Odessa, TX 79762
11	7, 15, 17, 22, 23, 28, 31	See Banks Report	Various	See Banks Report	7+	See Banks Report	See Banks Report	See Banks Report	No-Club house on City Water	UNK	Odessa Country Club No. 1 Fairway Drive Odessa, TX 79765	Ryan George, Club Manager No. 1 Fairway Drive Odessa, TX 79765
12	18, 19, 24, 25, 26, 46, 56	See Banks Report	Various	See Banks Report	8+	See Banks Report	See Banks Report	See Banks Report	City Water wells for irrigation	UNK	Permian Homes LLC 13020 Hwy 191 Odessa, TX 79707	David Cook, President 13020 Hwy 191 Odessa, TX 79707
13	9, 12, 13, 16, 21, 29, 40	See Banks Report	Various	See Banks Report	7+	See Banks Report	See Banks Report	See Banks Report	City Water wells for irrigation	UNK	Sunset Memorial Gardens 6801 E. Business 20 Odessa, TX 79762	Mel Wideman, Funeral Director 6801 E. Business 20 Odessa, TX 79762
14	14	45-06-8NN	1058'	31.883124 Lat. -102.294799 Long.	1 well	113'	50-113'	48-50'	Water used for toilets, sinks	UNK	Ewing Golf & Irrigation 6895 E. Business Hwy 20 Odessa, TX 79762	Tyler Mayes, Manager 6895 E. Business Hwy 20 Odessa, TX 79762
15	Not Identified	NA	1028'	31.883213 Lat. -102.294822 Long.	1 well	UNK	UNK	UNK	Water used for toilets, sinks	UNK	Midland-Odessa Auto Auction 2521 N. Marco Ave. Odessa, TX 79762	Kye Johnson, Owner 2521 N. Marco Ave. Odessa, TX 79762
16	1 idenitified, 6	45-06-8	558' 524'	31.884912 Lat. -102.295492 Long./ 31.884727 Lat. -102.295362 Long.	2 wells	107' UNK	50-107' UNK	0-15' UNK	Water used for irrigation, toilets, sinks	UNK	*Tommy and Brianne Hudson 2565 N. Marco Ave. Odessa, TX 79762	*Tommy and Brianne Hudson 2565 N. Marco Ave. Odessa, TX 79762
17	2	45-06-8NN	336'	31.886031 Lat. -102.295236 Long.	1 well	110'	Not on log	0-30'	well used for toilets, sinks	UNK	Energy Coil & Riggin 2925 N. Marco Ave. Midland, Texas 79762	Energy Coil & Riggin 2925 N. Marco Ave. Midland, Texas 79762
18	Not Identified	NA	451' 485'	31.886259 Lat. -102.295967 Long./ 31.886888 Lat. -102.295957 Long.	2 wells	UNK UNK	UNK UNK	UNK UNK	Well used for RO ice maker	UNK	Shoppas Material Handling 2627 N. Marco Ave. Odessa, TX 79762	Leroy Bird, Manager 2627 N. Marco Ave. Odessa, TX 79762
19	Not Identified	NA	318'	31.886678 Lat. -102.294949 Long.	1 well	UNK	UNK	UNK	Water used in toilets, sinks	UNK	Vital Signs 2628 N. Marco Ave. Odessa, TX 79762	*Chris Byrne, Owner 2628 N. Marco Ave. Odessa, TX 79762

Table 1
Properties Surveyed Within 0.25 Mile of
2604 N. Marco Ave.
Odessa, Texas 79762

SWS Figure 1.0 Map ID No.	Banks Env. Well No.	State Well ID No.	Distance from known extent of groundwater impact contamination (feet)	Physical Address of Well Latitude Longitude (Decimal Degrees)	Well No.	Total Depth (feet)	Screened Interval (feet)	Sealed Interval (feet)	Private Drinking Water Well? (Yes or No)	Affected or Potentially Affected? (Yes or No)	Property Name, Current Mailing Address	Well Users Name, Current Mailing Address
20	5	45-14-1	418'	31.887095 Lat. -102.29460 Long.	1 well	92'	70-80'	0-59'	Water used in toilets, sinks	UNK	Sabre Energy Services 264 N. Marco Ave. Odessa, TX 79762	David Collyer, Manager 264 N. Marco Ave. Odessa, TX 79762
21	Not Identified	NA	784'	31.887685 Lat. -102.295881 Long.	1 well	UNK	UNK	UNK	UNK, no one available	UNK	H K Electric 2701 N. Marco Ave. Odessa, TX 79762	H K Electric 2701 N. Marco Ave. Odessa, TX 79762
22	Not Identified	NA	293' and 764'	31.88548 Lat. -102.29349 Long./ 31.887923 Lat. -102.295131 Long	2 Wells-1 at each location	UNK	UNK	UNK	Well used for toilets/washing hands	Not at present time*	Guardian Wellhead Protection, 2584 North Marco and 6907 E. Commerce, Odessa 79762	C/O Lance Bolds- Attorney 11757 Katy Freeway, Houston Texas 77079
23	10 10	WIID 13903 2	759'	31.888055 Lat. -102.294721 Long.	1 well	117'	67-117'	50-67' 0-10'	Well used for toilets, sinks	UNK	Davis Lynch/Forum Energy Technologies 6919 East Commerce Odessa, TX 79762	*Kashie Kazanii 6919 East Commerce Odessa, TX 79762
24	Not Identified	NA	768'	31.888052 Lat. -102.294712 Long.	1 well	UNK	UNK	UNK	Well used for toilets, sinks	UNK	Iron Horse Tods LLC 6923 East Commerce Odessa, TX 79762	Michelle Ozuna, Manager 6923 East Commerce Odessa, TX 79762
25	Not Identified	NA	812'	31.888185 Lat. -102.294082 Long.	1 well	UNK	UNK	UNK	well used for toilets, sinks	UNK	Secorp Industries 6937 East Commerce Odessa, TX 79762	Chris Barber 6937 East Commerce Odessa, TX 79762
26	Not Identified	NA	456'	31.887104 Lat. -102.293753 Long.	1 well	UNK	UNK	UNK	UNK	UNK	Bobby Moore 6938 East Commerce Odessa, TX 79762	Bobby Moore 6938 East Commerce Odessa, TX 79762
27	Not Identified	NA	937'	31.888234 Lat. -102.292937 Long.	1 well	UNK	UNK	UNK	well used for toilets, sinks	UNK	County Line Adult Superstore 6947 E. Commerce Odessa, TX 79762	Nick Menke, Manager 6947 E. Commerce Odessa, TX 79762
28	Not Identified	NA	527'	31.887176 Lat. -102.293390 Long.	1 well	UNK	UNK	UNK	Well used for toilets, sinks	UNK	CTI 6926 East Commerce Odessa, TX 79762	Jim Cameron, Owner 6926 East Commerce Odessa, TX 79762
29	Not Identified	NA	570'	31.887050 Lat. -102.293037 Long.	1 well	UNK	UNK	UNK	well used for toilets, sinks	UNK	Ricky New 6948 East Commerce Odessa, TX 79762	Ricky New 6948 East Commerce Odessa, TX 79762
30	Not Identified	NA	873'	31.888205 Lat. -102.293358 Long.	1 well	UNK	UNK	UNK	UNK	UNK	B-Mac Corp. 6955 East Commerce Odessa, TX 79762	B-Mac Corp. 6955 East Commerce Odessa, TX 79762

Table 1
Properties Surveyed Within 0.25 Mile of
2604 N. Marco Ave.
Odessa, Texas 79762

SWS Figure 1.0 Map ID No.	Banks Env. Well No.	State Well ID No.	Distance from known extent of groundwater impact contamination (feet)	Physical Address of Well Latitude Longitude (Decimal Degrees)	Well No.	Total Depth (feet)	Screened Interval (feet)	Sealed Interval (feet)	Private Drinking Water Well? (Yes or No)	Affected or Potentially Affected? (Yes or No)	Property Name, Current Mailing Address	Well Users Name, Current Mailing Address
31	8	WIID35975	576'	31.886944 Lat. -102.292777 Long.	1 well	120'	10-120'	0-20'	UNK	UNK	Adam Doyle 6958 East Commerce Odessa, TX 79762	Adam Doyle 6958 East Commerce Odessa, TX 79762
32	Not Identified	NA	926'	31.888235 Lat. -102.293017 Long.	1 well	UNK	UNK	UNK	Well used for toilets, sinks	UNK	Systech 6965 East Commerce Odessa, TX 79762	*Larry Thorton 6965 East Commerce Odessa, TX 79762
33	Not Identified	NA	1132'	31.888617 Lat. -102.292449 Long.	1 well	UNK	UNK	UNK	well used for toilets, sinks	UNK	Pro Inspection Inc. 6975 East Commerce Odessa, TX 79762	David Nance, Owner 6975 East Commerce Odessa, TX 79762
34	Not Identified	NA	655'	31.886938 Lat. -102.292568 Long.	1 well	UNK	UNK	UNK	Unknown use	UNK	PRB Machine 6968 East Commerce Odessa, TX 79762	PRB Machine 6968 East Commerce Odessa, TX 79762
35	Not Identified	NA	1238'	31.888695 Lat. -102.291982 Long.	1 well	UNK	UNK	UNK	Unknown use	UNK	APP Auto Pax/ Cardinal Industries Inc. 6977 East Commerce Odessa, TX 79762	APP Auto Pax/ Cardinal Industries Inc. 6977 East Commerce Odessa, TX 79762

Reference 20

Prepared for:

SWS ENVIRONMENTAL SERVICES-FORT WORTH
PO BOX 18619
Panama City Beach, FL 32417

BANKS
ENVIRONMENTAL DATA
A DIVISION OF THE BANKS GROUP

Water Well Report

Lone Star Drum Facility

2604 N. Marco Ave

Odessa, TX

PO #: FW3-408-1470

ES-112845

Friday, October 10, 2014

Table of Contents Lone Star Drum Facility

Banks Environmental Data, Inc. - 1601 Rio Grande, Ste. 500 - Austin, TX 78701 - 800.531.5255 P - 512.478.1433 F
www.banksenvdata.com

Geographic Summary *Lone Star Drum Facility*

Location
TX

Coordinates	
Longitude & Latitude in Degrees Minutes Seconds	-102° 17' 40", 31° 53' 9"
Longitude & Latitude in Decimal Degrees	-102.294372°, 31.88596°
X and Y in UTM	755919.18, 3530988.64 (Zone 13)

Elevation
Target Property lies 2883.07 feet above sea level.

Zip Codes Searched

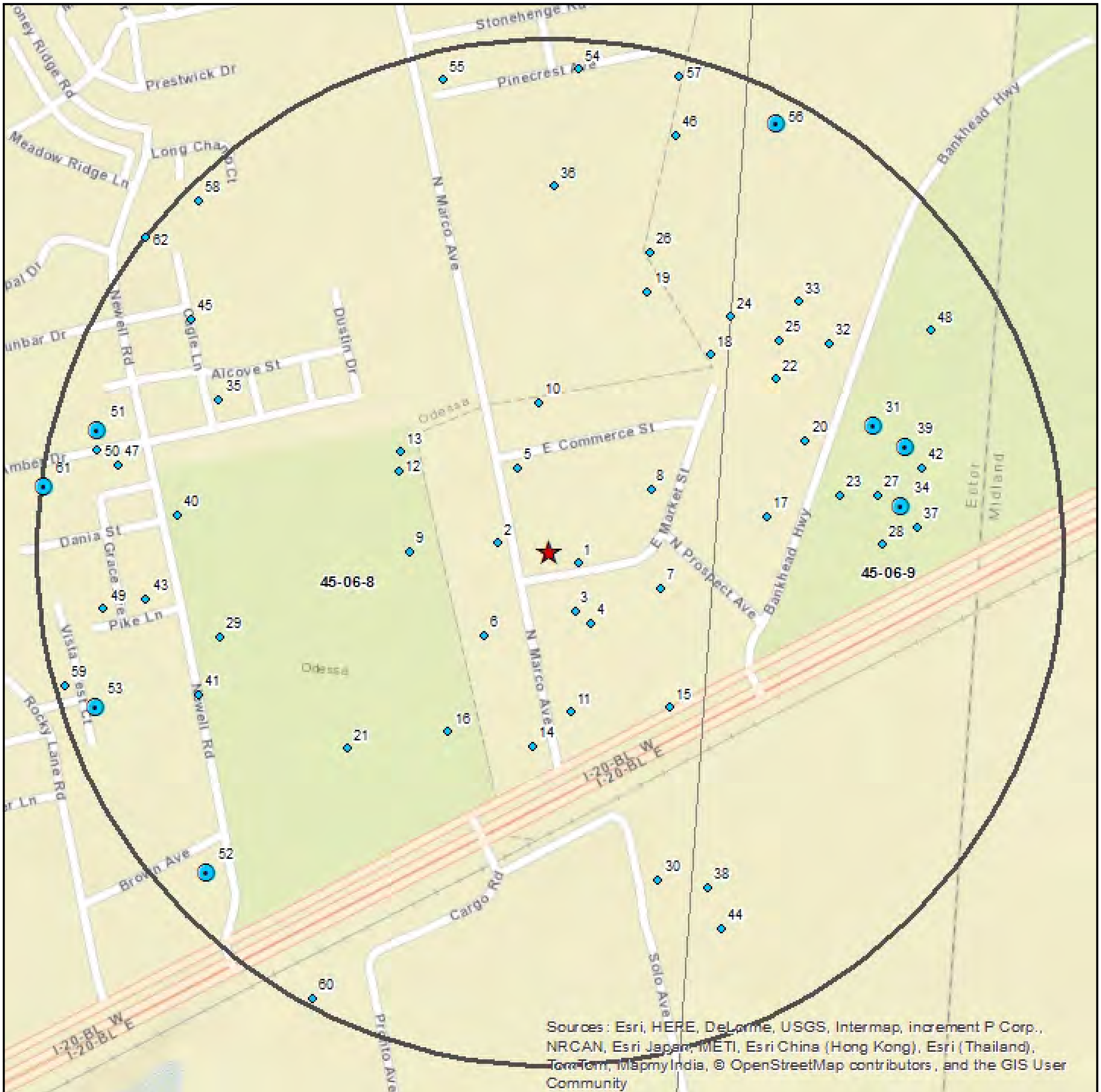
Search Distance	Zip Codes (historical zip codes included)
Target Property	79762
0.5 miles	79762, 79765

Topos Searched

Search Distance	Topo Name
Target Property	Odessa NE (1982)
0.5 miles	Odessa NE (1982)

Summary Map - 0.5 Mile Radius

BANKS ENVIRONMENTAL DATA
A DIVISION OF THE BANKS GROUP



Lone Star Drum Facility

Well

Well Cluster

Target Property

Search Buffer

Texas Quad Index

0' 500' 1000'

1 : 9,000

1 inch = 0.142 miles
1 inch = 750 feet
1 centimeter = 0.090 kilometers
1 centimeter = 90 meters

N

Lambert Conformal Conic Projection
1983 North American Datum
First Standard Parallel: 33 0' 00" North
Second Standard Parallel: 45 0' 00" North
Central Meridian: 96 0' 00" West
Latitude of Origin: 39 0' 00" North

Topographic Overlay Map - 0.5 Mile Radius

BANKS ENVIRONMENTAL DATA
A DIVISION OF THE BANKS GROUP

Lone Star Drum Facility

Well
Well Cluster
Target Property
Search Buffer

Target Property Quad Name(s)
Odessa NE (1982)

0' 500' 1000'

1 : 9,000

1 inch = 0.142 miles
1 inch = 750 feet

N

Lambert Conformal Conic Projection
1983 North American Datum
First Standard Parallel: 33 0' 00" North
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www.banksenvdata.com

Current Imagery Overlay Map - 0.5 Mile Radius

BANKS ENVIRONMENTAL DATA
A DIVISION OF THE BANKS GROUP

Lone Star Drum Facility

Well

Well Cluster

Target Property

Search Buffer

0' 500' 1000'

N

1 : 9,000

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Lambert Conformal Conic Projection
1983 North American Datum
First Standard Parallel: 33 0' 00" North
Second Standard Parallel: 45 0' 00" North
Central Meridian: 96 0' 00" West
Latitude of Origin: 39 0' 00" North

Water Well Details *Lone Star Drum Facility*

Map ID	Source ID	Dataset	Owner of Well	Type of Well	Depth Drilled	Completion Date	Longitude	Latitude	Elevation	Driller's Logs
1	WIID294351	TX TWDB WIID	Jamie Poldrack	Domestic	120	6/30/2012	-102.293888	31.885833	2883 ft ()	View
2	45-06-8NN	TX TCEQ HIST	Berry Hill Drilling & Supply	Domestic	110	05/03/1976	-102.295236	31.886031	2883 ft (+)	View
3	45-06-8NN	TX TCEQ HIST	Ch. Foster	Domestic	110	03/12/1982	-102.293884	31.885157	2883 ft ()	View
4	WIID311374	TX TWDB WIID	Randy Stephenson	Domestic	120	1/11/2013	-102.29361	31.884999	2883 ft ()	View
5	45-14-1	TX TCEQ HIST	Petroplex Savings	Industrial	92	10/03/1988	-102.294985	31.887108	2883 ft (+)	View
6	45-06-8	TX TCEQ HIST	Briaane Hudson	Domestic	107	05/03/1995	-102.295352	31.884727	2882 ft (-1)	View
7	45-06-812	TX TWDB GW	Odessa Country Club	Domestic	115	01/01/1946	-102.292499	31.885555	2883 ft ()	View
8	WIID359750	TX TWDB WIID	Adam Doyal	Domestic	120	4/12/2014	-102.292777	31.886944	2882 ft (-1)	View
9	45-06-805	TX TWDB GW	Sunset Memorial Gardens #2 well	Irrigation	116	01/01/1961	-102.296666	31.885833	2883 ft ()	View
10	WIID139032	TX TWDB WIID	Bob Simpkins	Domestic	117	4/8/2008	-102.294721	31.888055	2883 ft ()	View
11	45-06-8	TX TCEQ HIST	Watson Packers	Domestic	112	07/09/1987	-102.293829	31.883726	2882 ft (-1)	View
12	45-06-802	TX TWDB GW	Sunset Memorial Gardens	Irrigation	116	01/01/1963	-102.296944	31.886944	2883 ft (+)	View
13	45-06-809	TX TWDB GW	Sunset Memorial Gardens, Inc. Well #14	Irrigation	120	n/a	-102.296944	31.887221	2883 ft ()	View
14	45-06-8NN	TX TCEQ HIST	American Fence	Domestic	113	n/a	-102.294437	31.883206	2882 ft (-1)	View
15	45-06-813	TX TWDB GW	Odessa Country Club	Irrigation	115	01/01/1946	-102.292221	31.883888	2882 ft (-1)	View
16	45-06-808	TX TWDB GW	Sunset Memorial Gardens	Unused	102	n/a	-102.295833	31.883333	2881 ft (-2)	View
17	45-06-911	TX TWDB GW	Odessa Country Club	Irrigation	115	01/01/1938	-102.290833	31.886666	2880 ft (-3)	View
18	WIID347507	TX TWDB WIID	Permian Home	Domestic	120	10/18/2013	-102.291944	31.888888	2877 ft (-7)	View
19	WIID347506	TX TWDB WIID	Permian Home	Domestic	115	10/18/2013	-102.293055	31.889721	2877 ft (-6)	View
20	WIID238794	TX TWDB WIID	Interstate Treating	Domestic	114	2/1/2007	-102.290277	31.887777	2876 ft (-7)	View
21	45-06-9	TX TCEQ HIST	Sunset Memorial Gardens	Industrial	99	03/31/1988	-102.297485	31.882999	2880 ft (-3)	View
22	45-06-910	TX TWDB GW	Odessa Country Club	Domestic	115	01/01/1938	-102.290833	31.88861	2876 ft (-7)	View
23	45-14-2	TX TCEQ HIST	Odessa Country Club	Irrigation	114	05/27/1997	-102.289662	31.887042	2876 ft (-7)	View
24	WIID347505	TX TWDB WIID	Permian Home	Domestic	115	10/17/2013	-102.291666	31.889444	2875 ft (-8)	View
25	WIID347504	TX TWDB WIID	Permian Home	Domestic	115	10/17/2013	-102.290833	31.889166	2875 ft (-8)	View
26	WIID347788	TX TWDB WIID	Permian Homes	Domestic	115	10/18/2013	-102.293055	31.890277	2876 ft (-7)	View
27	G0680072A	TX TCEQ PWS	NEW LIFE CHURCH	Public Supply	130	n/a	-102.289032	31.887068	2874 ft (-9)	View
28	45-06-905	TX TWDB GW	Odessa Country Club	Irrigation	135	n/a	-102.288888	31.886388	2876 ft (-7)	View
29	45-06-804	TX TWDB GW	Sunset Memorial Gardens	Irrigation	116	01/01/1955	-102.299721	31.884444	2882 ft (-1)	View
30	45-06-9	TX TCEQ HIST	Michael McCulloch	Industrial	113	01/07/2002	-102.292206	31.881444	2878 ft (-5)	View
31	45-06-904	TX TWDB GW	Odessa Country Club	Irrigation	135	n/a	-102.289166	31.888055	2872 ft (-11)	View
31	G0680072D	TX TCEQ PWS	NEW LIFE CHURCH	Public Supply	114	05/27/1997	-102.289032	31.887902	2872 ft (-11)	View
32	WIID355654	TX TWDB WIID	Extreme Exteriors	Irrigation	115	1/28/2014	-102.289999	31.889166	2873 ft (-10)	View
33	WIID304978	TX TWDB WIID	Louis B. Sweeden	Domestic	130	10/12/2012	-102.290555	31.889721	2874 ft (-9)	View
34	45-06-912	TX TWDB GW	New Life Church Well #1	Unused	130	n/a	-102.28861	31.886944	2873 ft (-10)	View
34	G0680072B	TX TCEQ PWS	NEW LIFE CHURCH	Public Supply	130	n/a	-102.28875	31.886792	2874 ft (-9)	View
35	WIID301179	TX TWDB WIID	Gene Kirby	Domestic	120	8/20/2012	-102.3	31.887777	2881 ft (-2)	View
36	WIID115965	TX TWDB WIID	Angle Development	Domestic	110	5/25/2007	-102.294721	31.89111	2878 ft (-5)	View
37	45-06-913	TX TWDB GW	New Life Church Well #2	Unused	130	n/a	-102.288333	31.886666	2874 ft (-10)	View
38	WIID141952	TX TWDB WIID	Pradon Construction	Domestic	110	4/16/2008	-102.291388	31.881388	2877 ft (-6)	View
39	45-06-915	TX TWDB GW	New Life Church Well #4	Unused	114	05/27/1997	-102.28861	31.887777	2871 ft (-12)	View
39	G0680072C	TX TCEQ PWS	NEW LIFE CHURCH	Public Supply	112	08/21/1989	-102.28875	31.887625	2872 ft (-11)	View
40	45-06-803	TX TWDB GW	Sunset Memorial Gardens	Irrigation	116	01/01/1968	-102.300555	31.88611	2883 ft (+)	View

Water Well Details *Lone Star Drum Facility*

BANKS ENVIRONMENTAL DATA A DIVISION OF THE BANKS GROUP

Map ID	Source ID	Dataset	Owner of Well	Type of Well	Depth Drilled	Completion Date	Longitude	Latitude	Elevation	Driller's Logs
41	WIID318031	TX TWDB WIID	Bill Satler	Irrigation	85	3/22/2013	-102.3	31.88361	2881 ft (-2)	View
42	45-06-914	TX TWDB GW	New Life Church Well #3	Plugged or Destroyed	112	08/21/1989	-102.288333	31.887499	2870 ft (-13)	View
43	45-06-8	TX TCEQ HIST	Lenora Pike	Domestic	110	08/26/1986	-102.300976	31.884909	2883 ft ()	View
44	WIID142005	TX TWDB WIID	Pradon Construction	Domestic	110	4/16/2008	-102.29111	31.880832	2876 ft (-7)	View
45	WIID262160	TX TWDB WIID	Jimmy Sanders	Domestic	110	8/13/2011	-102.300555	31.888888	2881 ft (-2)	View
46	WIID347787	TX TWDB WIID	Permian Homes	Domestic	115	10/18/2013	-102.292777	31.891944	2876 ft (-7)	View
47	45-06-8	TX TCEQ HIST	Lewie Montgomery	Domestic	114	09/29/1975	-102.301596	31.886762	2884 ft (+)	View
48	45-06-906	TX TWDB GW	Odessa Country Club	Irrigation	135	n/a	-102.288333	31.889444	2870 ft (-13)	View
49	45-06-8NN	TX TCEQ HIST	Jean Pike	Domestic	115	09/30/1978	-102.301666	31.884726	2883 ft ()	View
50	WIID294305	TX TWDB WIID	Rhonda Krogh	Domestic	110	6/21/2012	-102.301944	31.886944	2884 ft (+1)	View
51	WIID296304	TX TWDB WIID	CLAY MCFADDEN	Irrigation	90	8/10/2012	-102.301944	31.887221	2884 ft (+1)	View
51	WIID296698	TX TWDB WIID	Rick Gibson	Domestic	115	7/13/2012	-102.302222	31.887221	2884 ft (+1)	View
52	45-06-8	TX TCEQ HIST	Julio Nunez Jr.	Domestic	108	09/05/1997	-102.299653	31.881104	2877 ft (-6)	View
52	45-06-8	TX TCEQ HIST	Julio Nunez, Jr.	Domestic	102	09/05/1997	-102.299514	31.881155	2877 ft (-6)	View
53	WIID274586	TX TWDB WIID	Roger Clayton	Domestic	105	11/14/2011	-102.301666	31.883333	2882 ft (-1)	View
53	WIID274591	TX TWDB WIID	Roger Stone	Domestic	110	11/14/2011	-102.301666	31.883333	2882 ft (-1)	View
54	WIID294352	TX TWDB WIID	Bobby Cox Properties	Domestic	120	6/30/2012	-102.294444	31.892777	2879 ft (-4)	View
55	WIID291297	TX TWDB WIID	Bobby Cox	Domestic	120	5/9/2012	-102.296666	31.892499	2882 ft (-1)	View
56	WIID347789	TX TWDB WIID	Permian Homes	Domestic	115	10/22/2013	-102.29111	31.892221	2874 ft (-10)	View
56	WIID347790	TX TWDB WIID	Permian Homes	Domestic	115	10/22/2013	-102.29111	31.892221	2874 ft (-10)	View
57	45-06-806	TX TWDB GW	Odessa Country Club	Irrigation	135	n/a	-102.292777	31.892777	2876 ft (-7)	View
58	WIID58154	TX TWDB WIID	Darrel Farris	Domestic	111	4/29/2005	-102.300555	31.890555	2884 ft (+1)	View
59	WIID286184	TX TWDB WIID	CORY BIZZELL	Irrigation	70	4/17/2012	-102.302222	31.88361	2882 ft (-1)	View
60	WIID315334	TX TWDB WIID	David Johnston	Irrigation	110	3/15/2013	-102.297777	31.879443	2876 ft (-7)	View
61	WIID294304	TX TWDB WIID	Greg Hand	Domestic	110	6/21/2012	-102.302777	31.886388	2884 ft (+1)	View
61	WIID302974	TX TWDB WIID	DOUG MILLICAN	Irrigation	104	10/24/2012	-102.302777	31.886388	2884 ft (+1)	View
61	WIID302977	TX TWDB WIID	JUAN VILLAREAL	Irrigation	104	10/24/2012	-102.302777	31.886388	2884 ft (+1)	View
62	WIID299888	TX TWDB WIID	Mark Bickers	Domestic	117	8/29/2012	-102.301388	31.889999	2885 ft (+2)	View

Well Summary

Water Well Dataset	# of Wells
TX TCEQ HIST	14
TX TCEQ PWS	4
TX TWDB GW	18
TX TWDB WIID	35
Total Count	**71**

STATE OF TEXAS WELL REPORT for Tracking #294351

Owner:	**Jamie Poldrack**	Owner Well #:	**No Data**
Address:	**7016 Stonehenge Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**7016 Stonehenge Odessa , TX**	Latitude:	**31° 53' 09" N**
Well County:	**Ector**	Longitude:	**102° 17' 38" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **6/30/2012** Completed: **6/30/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 120 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **40 ft to 120 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 40 ft with 12 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **8 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **10 GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling** **4223 W. 16th St.** **Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the

well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#294351**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 Top Soil
2-18 Caliche
18-40 Wet Sand
40-60 Water Sand
60-80 False Red Bed
80-118 Water Sand
118-120 Red Bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0-40
5 New PVC Slotted 40-60
5 New PVC 60-80
5 New PVC Slotted 80-120

2

RECEIVED
SEP 1 1978
DEPT. OF WATER RESOURCES

Send original copy by certified mail to the Texas Water Development Board P. O. Box 13087 Austin, Texas 78711

State of Texas

WATER WELL REPORT

For TWDB use only
Well No. 45-06-8NN
Located on map Yes
Received: 78

1) OWNER:
Person having well drilled Berry Hill Drlg Supply (Name) Address Box 6203 (Street or RFD) Odessa (City) Texas (State)

Landowner Abbott Bldg. Co. (Name) Address Box 6249 (Street or RFD) Midland (City) Tex (State)

2) LOCATION OF WELL:
County Ector, 7 miles in East (N.E., S.W., etc.) direction from P.O. Odessa (Town)

Locate by sketch map showing landmarks, roads, creeks, hiway number, etc.*

North

(Use reverse side if necessary)

or Give legal location with distances and directions from adjacent sections or survey lines.

Labor ______ League ______
Block ______ Survey ______
Abstract No. ______
(NW¼ NE¼ SW¼ SE¼) of Section ______

3) TYPE OF WORK (Check):
New Well ✓ Deepening
Reconditioning Plugging

4) PROPOSED USE (Check):
Domestic ✓ Industrial Municipal
Irrigation Test Well Other

5) TYPE OF WELL (Check):
Rotary ✓ Driven Dug
Cable Jetted Bored

6) WELL LOG:
Diameter of hole 8 in. Depth drilled 110 ft. Depth of completed well 110 ft. Date drilled May 3-78

All measurements made from ______ ft. above ground level.

From (ft.)	To (ft.)	Description and color of formation material
0	20	Caliche
20	40	Lime
40	60	Lime & Shale Brown
60	80	Shale & Sand
80	110	Sand & Yellow Clay
110	112	Red Bed.

(Use reverse side if necessary)

9) Casing:
Type: Old New ✓ Steel Plastic ✓ Other
Cemented from 0 ft. to 30 ft.

Diameter (inches)	Setting From (ft.)	Setting To (ft.)	Gage
5"	0	110	

10) SCREEN:
Type ______
Perforated Slotted

Diameter (inches)	Setting From (ft.)	Setting To (ft.)	Slot Size

7) COMPLETION (Check):
Straight wall Gravel packed ✓ Other
Under reamed Open Hole

8) WATER LEVEL:
Static level 87' ft. below land surface Date May 3 78
Artesian pressure ______ lbs. per square inch Date ______
Depth to pump bowls, cylinder, jet, etc., ______ ft. below land surface.

11) WELL TESTS:
Was a pump test made? Yes No ✓ If yes, by whom?
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.
Bailer test ______ gpm with ______ ft. drawdown after ______ hrs.
Artesian flow ______ gpm
Temperature of water ______

12) WATER QUALITY:
Was a chemical analysis made? Yes No ✓
Did any strata contain undesirable water? Yes No ✓
Type of water? Fresh depth of strata 30'

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief.

NAME William McDonald (Type or Print) Water Well Drillers Registration No. 1073

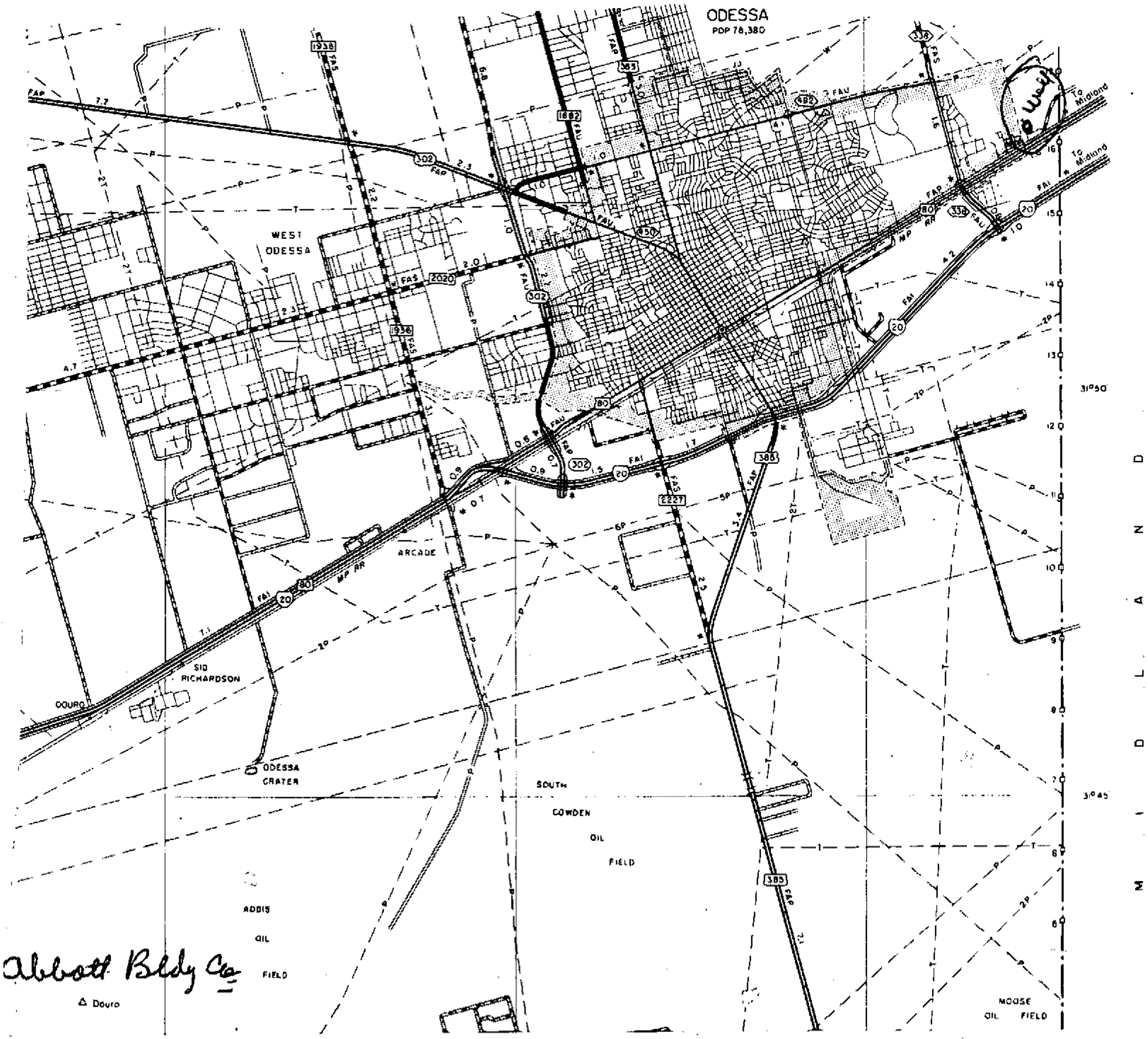
ADDRESS 1311 E. 42nd St. (Street or RFD) Odessa (City) Texas (State)

(Signed) Bill McDonald (Water Well Driller) McDonald Drlg. Co. of Odessa, Inc. (Company Name)

Please attach electric log, chemical analysis, and other pertinent information, if available.

*Additional instructions on reverse side.

TWDB-WD-8


ODESSA
POP 78,380
WEST ODESSA
ARCADE
SID RICHARDSON
DOURO
ODESSA CRATER
SOUTH COWDEN OIL FIELD
ADDIS OIL FIELD
MOOSE OIL FIELD
To Midland
MIDLAND
31°50'
31°45'
Abbott Bldg Co.
Douro

Dup

Send original copy by certified mail to the Texas Department of Water Resources P. O. Box 13087 Austin, Texas 78711

State of Texas
WATER WELL REPORT

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

For TDWR use only
Well No. 45-06-8NN
Located on map yes
Received: C. F. S.

1) OWNER Ch. Foster (Name) Address 39 88 Lake Side Dr. Odessa Tx (Street or RFD) (City) (State) (Zip)

2) LOCATION OF WELL: County Ector 7 miles in E (N.E., S.W., etc.) direction from Odessa (Town)
Foster Storage on Marco Ave.

Driller must complete the legal description to the right with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

☐ Legal description:
Section No. ______ Block No. ______ Township ______
Abstract No. ______ Survey Name ______
Distance and direction from two intersecting section or survey lines ______

☐ See attached map.

3) TYPE OF WORK (Check): ☑ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☑ Domestic ☐ Industrial ☐ Public Supply ☐ Irrigation ☐ Test Well ☐ Other ______

5) DRILLING METHOD (Check): ☐ Mud Rotary ☐ Air Hammer ☐ Driven ☐ Bored ☑ Air Rotary ☐ Cable Tool ☐ Jetted ☐ Other ______

6) WELL LOG:

Date drilled Mar 12-82

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
	Surface	

7) BOREHOLE COMPLETION:
☐ Open Hole ☐ Straight Wall ☐ Underreamed
☑ Gravel Packed ☐ Other ______
If Gravel Packed give interval . . . from 80 ft. to 110 ft.

From (ft.)	To (ft.)	Description and color of formation material
0	20	Caliche & Lime
20	40	Lime
40	60	Sandy Shale
60	80	Sand w/ Lime
80	100	Sand & Clay
100	109	Sand
109	110	Red Bed.

App 15 Gal per Min.

RECEIVED
AUG 30 1982
DEPT. OF WATER RESOURCES

(Use reverse side if necessary)

8) CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mgf., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casing Screen
5"		plastic	0	110	

CEMENTING DATA
Cemented from 80-70 ft. to 20-0 ft.
Method used Sack Cement.
Cemented by ______ (Company or Individual)

9) WATER LEVEL:
Static level 90 ft. below land surface Date Mar. 12-82
Artesian flow ______ gpm. Date ______

10) PACKERS: Type Depth

11) TYPE PUMP:
☐ Turbine ☐ Jet ☑ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

12) WELL TESTS:
☐ Type Test: ☐ Pump ☐ Bailer ☐ Jetted ☑ Estimated
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

13) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable water? ☐ Yes ☐ No
If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? Fresh Depth of strata ______
Was a chemical analysis made? ☐ Yes ☑ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief.

NAME William McDonald (Type or Print) Water Well Drillers Registration No. 1073

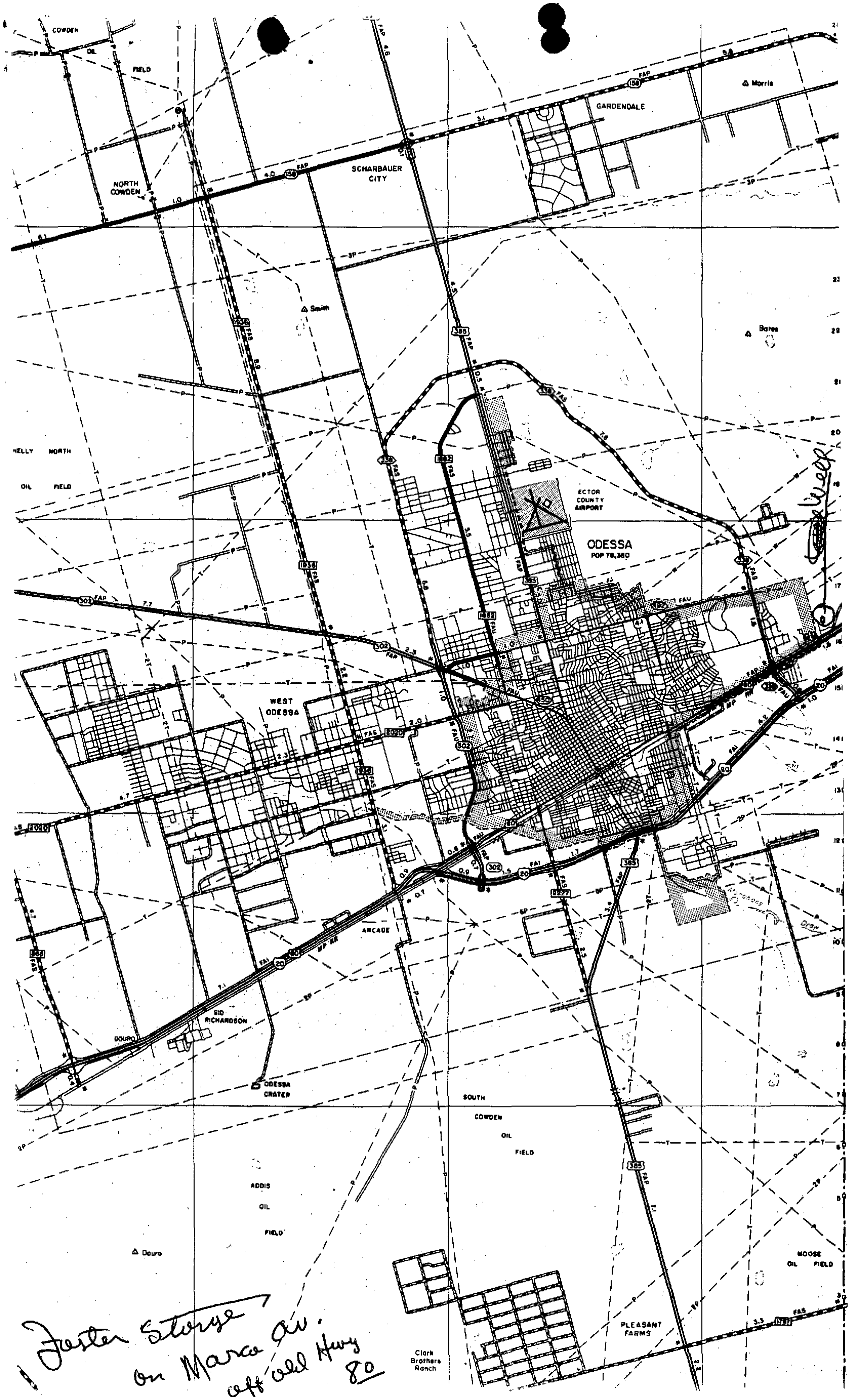
ADDRESS 1311 E 42nd (Street or RFD) Odessa (City) Tex (State) (Zip)

(Signed) Bill McDonald (Water Well Driller) McDonald Drlg of Odessa Inc. (Company Name)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TDWR-0392 (Rev. 1-12-79)

DEPARTMENT OF WATER RESOURCES COPY



Foster Storage on Marco av. off old Hwy 80

STATE OF TEXAS WELL REPORT for Tracking #311374

Owner:	**Randy Stephenson**	Owner Well #:	**No Data**
Address:	**2564 N. Marco** **Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**2564 N. Marco** **Odessa , TX**	Latitude:	**31° 53' 06" N**
Well County:	**Ector**	Longitude:	**102° 17' 37" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **1/11/2013** Completed: **1/11/2013**
Diameter of Hole:	Diameter: **8.5 in From Surface To 120 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **60 ft to 120 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 60 ft with 18 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **No Data** Method of Verification: **measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **20+ GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling** **4223 W. 16th St.** **Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the

well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#311374**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-10 top soil
10-30 caliche
30-60 sandstone
60-118 water sand
118-120 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 new PVC 0-60
5 new PVC Slotted 60-120

Please use black ink.
Send original copy by certified mail to the Texas Water Commission
P.O. Box 13087
Austin, Texas 78711

State of Texas
WATER WELL REPORT

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

Texas Water Well Drillers Board
P. O. Box 13087
Austin, Texas 78711

1) OWNER Petroplex Savings (Name) Address 5808 Commerce (Street or RFD) Odessa (City) Texas (State) 79762 (Zip)

2) LOCATION OF WELL:
County Ector ______ miles in ______ (N.E., S.W., etc.) direction from ______ (Town)

☐ Legal description:
Section No. ______ Block No. ______ Township ______
Abstract No. ______ Survey Name ______
Distance and direction from two intersecting section or survey lines ______

Driller must complete the legal description to the right with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

■ See attached map ⑦ 00 45-06-7

3) TYPE OF WORK (Check): ☒ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☐ Domestic ☒ Industrial ☐ Monitor ☐ Public Supply ☐ Irrigation ☐ Test Well ☐ Injection ☐ Other ______

5) DRILLING METHOD (Check): ☐ Driven ☐ Mud Rotary ☐ Air Hammer ☐ Jetted ☐ Bored ☒ Air Rotary ☐ Cable Tool ☐ Other ______

6) WELL LOG:
Date Drilling:
Started Oct 3 19 88
Completed Oct 3 19 88

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
	Surface	
7 7/8	same	

7) BOREHOLE COMPLETION:
☐ Open Hole ☐ Straight Wall ☐ Underreamed
☒ Gravel Packed ☐ Other ______
If Gravel Packed give interval . . . from 59 ft. to 80 ft.

From (ft.)	To (ft.)	Description and color of formation material
0-1		Caliche Rocks
1-12		Sand
12-45		Limestone
45-50		Sand & Gravel
50-69		SandStone
69-79		Clay
79-90		Sand
90-92		Red Bed

(Use reverse side if necessary)

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8) CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mgf., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casing Screen
5	New	Plain Plastic	0	70	1/8
		Perforated	70	80	

9) CEMENTING DATA [Rule 319.44(b)]
Cemented from 0 ft. to 59 ft. No. of Sacks Used ______
______ ft. to ______ ft. No. of Sacks Used ______
Method used Pressure
Cemented by Bernard Brockman

10) SURFACE COMPLETION
☒ Specified Surface Slab Installed [Rule 319.44(c)]
☐ Pitless Adapter Used [Rule 319.44(d)]
☐ Approved Alternative Procedure Used [Rule 319.71]

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) WELL TESTS:
Type Test: ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable water? ☐ Yes ☒ No
If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 12 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Hickerson Drilling & Pump (Type or Print) Water Well Driller's License No. 02497W

ADDRESS 3806 W. University (Street or RFD) Odessa (City) TExas (State) 79763 (Zip)

(Signed) Bernard Brockman (Licensed Water Well Driller) (Signed) ______ (Registered Driller Trainee)

For TWC use only Well No. 45-14-1
Located on map ______

Please attach electric log, chemical analysis, and other pertinent information, if available.

WWD-012 (Rev.01-28-87) TEXAS WATER COMMISSION COPY

Send original copy by certified mail to: TNRCC, P.O. Box 13087, Austin, TX 78711-3087 — *Please use black ink.*

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas
WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, TX 78711-3087
512-239-0530

1) OWNER Briaanc Hudson (Name) ADDRESS P.O. Box 12211 ~~Marco 2565~~ Odessa Tex (Street or RFD) (City) (State) (Zip)

2) ADDRESS OF WELL: County Ector 2565 Marco Odessa Tex (Street, RFD or other) (City) (State) (Zip) GRID # 45-06-8

3) TYPE OF WORK (Check): ☑ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☐ Monitor ☐ Environmental Soil Boring ☑ Domestic ☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5) 45-06-8 N↑

6) WELL LOG:
Date Drilling:
Started 5-3 19 95
Completed 5-3 19 95

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
8	Surface	107

7) DRILLING METHOD (Check): ☐ Driven ☑ Air Rotary ☐ Mud Rotary ☐ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☐ Other ______

From (ft.)	To (ft.)	Description and color of formation material
0	1	top soil
1	14	caliche
14	46	Hard Rock
46	52	Clay
52	105	water Sand
105	106	Clay
106	107	Red Bed

00950001

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall ☐ Underreamed ☑ Gravel Packed ☐ Other ______
If Gravel Packed give interval ... from 50 ft. to 107 ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
5	n	Plastic	0	107	1/4

9) CEMENTING DATA [Rule 338.44(1)]
Cemented from 0 ft. to 15 ft. No. of sacks used 7
______ ft. to ______ ft. No. of sacks used ______
Method used slurry pour
Cemented by PC
Distance to septic system field lines or other concentrated contamination ______ ft.
Method of verification of above distance ______

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

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10) SURFACE COMPLETION
☐ Specified Surface Slab Installed [Rule 338.44(2)(A)]
☑ Specified Steel Sleeve Installed [Rule 338.44(3)(A)]
☐ Pitless Adapter Used [Rule 338.44(3)(b)]
☐ Approved Alternative Procedure Used [Rule 338.71]

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: 50 gpm with ______ ft. drawdown after ______ hrs.

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☑ No If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☑ No

12) PACKERS: Type Depth

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Wheeler Drilling CO. (Type or print) WELL DRILLER'S LICENSE NO. 1540 WP

ADDRESS 4223 W. 16th (Street or RFD) Odessa (City) Tx. (State) 79763 (Zip)

(Signed) [signature] (Licensed Well Driller) (Signed) Filomeno Chávez (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 11-01-94) TNRCC COPY

4813500950

Texas Water Development Board
Well Schedule

State Well Number 45 06 812 Previous Well Number F-114 County ECTOR 135

River Basin COLORADO 14 Zone 1 Latitude 31 53 08 Longitude 102 17 33 Coordinates Accuracy 3

Owner's well No. ______ Location: ____ 1/4, ____ 1/4, Section 21 Block 41 Survey T.2S

Owner ODESSA COUNTRY CLUB Driller C HAMMET

Address ______ Tenant/Oper. ______

Date Drilled 1946 Depth 115 Source of Depth A Altitude 2884 Source of Alt. Data M

Aquifer ANTLERS 218ALRS Aquifer ID 13 Well Type W User ______

Well Construction Const Method ______ Casing Material ______

Completion Method ______ Screen Material ______

Lift Data Pump Mfr. ______ Type of Lift TURBINE T Pump Depth Setting (ft) ______ ft.

Motor Mfg ______ Power ELECT E H.P. ______

Yield Flow Rate ______ Pump Rate ______ GPM Meas Rept Est (Circle how rate was determined) Date of Test ______

Performance Test Length of test ______ hr Production Rate ______ GPM Meas Rept Est (Circle how rate was determined) Date of Test ______

Static Level ______ ft. Pumping Level ______ ft. Amount of Drawdown ______ ft. Specific Capacity ______ GPM/ft.

Water Use Primary DOMESTIC H Secondary IRRIGAT I Tertiary ______

Water Quality (Remarks: ______

Other Data Available Water Level M Water Quality N Logs ______ Other Data ______

Water Levels

Date 12 13 1947 Meas. 46.90 Remarks ____ M.P. + - ____

Date ______ Meas. ______ Remarks ____

Date ______ Meas. ______ Remarks ____

Recorded by ______ Date Record Collected or Information Updated 1947 Reporting Agency 02

Casing or Blank Pipe (C) / Well Screen or Slotted Zone (S) / Open Hole (O) — Cemented from ____ to ____	Diam. (in.)	Interval of C,S, or O. From	To
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

Remarks

1 WELL F-114 IN B5210
2
3
4
5
6

218ALRS
Aquifer

45-06 812
Well Number

Form at: V:/HEMon/Share/forms/WellSchedule

STATE OF TEXAS WELL REPORT for Tracking #359750

Owner:	**Adam Doyal**	Owner Well #:	**No Data**
Address:	**6958 E. Commerce Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**6958 E. Commerce Odessa , TX**	Latitude:	**31° 53' 13" N**
Well County:	**Ector**	Longitude:	**102° 17' 34" W**
Elevation:	**No Data**	GPS Brand Used:	**Tom Tom**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **4/12/2014** Completed: **4/12/2014**
Diameter of Hole:	Diameter: **7.875 in From Surface To 120 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **120 ft to 10 ft** Gravel Pack Size: **Pea Size**
Annular Seal Data:	1st Interval: **From 20 ft to 15 ft with 2 (#sacks and material)** 2nd Interval: **From 10 ft to 0 ft with 5 (#sacks and material)** 3rd Interval: **No Data** Method Used: **Mixer** Cemented By: **Driller** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **30 ft. below land surface on 4/12/2014** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**Submersible** Depth to pump bowl: **(No Data) ft**
Well Tests:	**Estimated** Yield: **60 GPM with 20 ft drawdown after 1 hour**
Water Quality:	Type of Water: **Fresh** Depth of Strata: **90 ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Marks Water Well P.O. Box 295 Odessa , TX 79760**
Driller License Number:	**4550**
Licensed Well Driller Signature:	**Bryan Mehlhoff**
Registered Driller Apprentice Signature:	**Bryan Mehlhoff**
Apprentice Registration Number:	**59300**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#359750**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL	CASING, BLANK PIPE & WELL SCREEN DATA
From (ft) To (ft) Description	Dia. New/Used Type Setting From/To
0-35 cleachy 35-37 clay & yellow 37-40 cleachy & water 40-55 white sand 55-60 yellow sand 60-65 false red 65-90 yellow 90-115 white sand 115-120 blue shell 120 red bed	**5" new slotted 120-100 0.35** **5" new plastic 100-0**

804

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt   Field No. D   State Well No. JH 45-06 805

Owner's Well No. South-East   County Ector

1. Location: NE 1/4, NE 1/4 Sec. 20, Block 41 Survey T & P RR Co T-2-S   805

2. Owner: Sunset Memorial Gardens Address: Odessa, Tx.

Tenant: Address:

Driller: Mr. Browning Address:

3. Elevation of LSD @ Well is 2883 ft. above msl, determined by Topo

4. Drilled: 1960-61; Dug, Cable Tool, Rotary,

5. Depth: Rept. 110-116 ft. Meas. NMT ft. 9-4-70

6. Completion: Open Hole, Straight Well, Underreamed, Gravel Packed

7. Pump: Mfgr. Reda Type Subm

No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.

Column Diam. ____ in., Length Tailpipe ____ ft.

8. Motor: Fuel Electric Make & Model ____ HP. 1

9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est.

10. Performance Test: Date ____ Length of Test ____ Made by ____

Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.

Production ____ gpm Specific Capacity ____ gpm/ft.

CASING & BLANK PIPE

Cemented From ____ ft. to ____ ft.

Diam. (in.)	Type	Setting, ft. from	to
6	Steel	0	TD

11. Water Level: NMT ft. rept./meas. 9-4-1970 above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

12. Use: Dom., Stock, Public Supply, Ind., (Irr), Waterflooding, Observation, Not Used,

13. Quality: (Remarks on taste, odor, color, etc.)

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

WELL SCREEN

Screen Openings ____

Diam. (in.)	Type	Setting, ft. from	to
	Unknown		

14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log, Formation Samples, Pumping Test,

15. Record by: D. Corley Date 9-4-1970

Source of Data Mr. Hoback & Obs.

16. Remarks: Well Pumping

TWDBE-GW-49

(Sketch)

2003FY TWDB Water Quality Field Data Sheet

Newly Inventoried Well: N

State Well Number: 45-06-805
County: Ector
County Code: 135
Aquifer Code: 218ALRS
Aquifer Id: 13

Name: SunSet Memorial
Address: 6901 E. Hwy 80
Odessa, TX 79762
Phone Number: 915-362-2331
Attention: DAVID Barrientos
Well Name or #: 2, Former #3

Sample ID Number: 924
Date: 3-20-03
Sampler(s): C. Muller

CIRCLE EACH SAMPLE FRACTION COLLECTED:				
(1)	(2)	(3)	(4)	5
500ml (filtered)	500ml (filtered)	250ml (filtered)	40 ml (unfiltered)	
Anions / Total Alk.	**Cations**	**Nitrate**	**Atrazine**	
Ice	Nitric (HNO3)	Ice + H2SO4	Ice and in dark	

Proper preservation requires adding enough of the correct acid to each sample fraction to bring the pH below 2.0.

Calibration Verification Readings		
pH	7 =	7.06
	4 or 10 =	10.04
SLP =	7.38 =	
Conductivity	500 =	500
	1000 =	1006
	2000 =	1980
	5000 =	4960

Time In: 9:15
Time Out: 10:20

W. L. depth from LSD (ft.):
W.L. remark:
M.P. =

Pumping Since: POA
Sampling Point: FAW

Well Use: I
Lift: S
Power: E

FIELD G.P.S. readings
Latitude: 31° 53' 11.0"
Longitude: 102° 17' 47.8"

Casing Type:
Casing Size: "

Sample Time: 9:45
Filter pressure: hand pump (line)

Field Alkalinity Titration:

7.08	Start pH
4.48	End pH
50.0	**mL Sample Size**
	mL Acid added for Phenol (> 8.3)
13.95	mL Acid added for Total (8.3 - 4.5)

Items below calculated from: mL acid added x 20 = Alkalinity

Phenol Alkalinity (82244): mg/L
Total Alkalinity (39086): 279 mg/L

Items Below Calculated Later From Results:
Dissolved Solids (mg/L): 1644
Hardness (as CaCO3): 826
Balanced: ✓

Water Quality Stabilization Parameters Table (at least 3 readings at five minute intervals)

Time:	9:30	9:35	9:40	9:45			
pH:	6.81	6.84	6.87	6.87			
Celsius Temp. (00010)	20.4	20.4	20.3	20.3			
Conductivity (uS/cm):	2720	2710	2730	2730			

Notes: Cemetery Industrial Storage Tank

Data Entered By Sampler Into Database: (yes) / no

v:\HENon\Grndwat\WaterQuality\WQFieldDataSheet2002.xls

LCRA Environmental Laboratory Services

Date: *10-Apr-03*

CLIENT: Texas Water Development Board **Client Sample ID:** 45-06-805

Lab Order: 0303282 **File No:** 23986

Project: TWDB FY03 **Collection Date:** 3/20/03 9:45:00 AM

Lab ID: 0303282-10 **Matrix:** GROUNDWATER

Analyses	Storet	Result	PQL	Qual	Units	DF	BatchID	Date Analyzed
ICP METALS DISSOLVED			**E200.7**					Analyst: **MLP**
Calcium		255	0.20		mg/L	1.02	R18983D	4/1/03 12:24:55 AM
Magnesium		45.7	0.20		mg/L	1.02	R18983D	4/1/03 12:24:55 AM
Potassium		7.46	0.20		mg/L	1.02	R18983D	4/1/03 12:24:55 AM
Sodium		244	0.70		mg/L	1.02	R18983D	4/1/03 12:24:55 AM
ICP METALS DISSOLVED			**E200.7**					Analyst: **MLP**
Boron		783	50		µg/L	1.02	R18985D	4/1/03 12:24:55 AM
Iron		ND	50		µg/L	1.02	R18985D	4/1/03 12:24:55 AM
Strontium		2240	20		µg/L	1.02	R18985D	4/1/03 12:24:55 AM
ICPMS DISSOLVED METALS			**E200.8**					Analyst: **SW**
Aluminum		ND	4.00		µg/L	1	R18943A	3/28/03
Antimony		ND	1.00		µg/L	1	R18943A	3/28/03
Arsenic		4.68	2.00		µg/L	1	R18943A	3/28/03
Barium		47.0	1.00		µg/L	1	R18943A	3/28/03
Beryllium		ND	1.00		µg/L	1	R18943A	3/28/03
Cadmium		ND	1.00		µg/L	1	R18943A	3/28/03
Chromium		3.73	1.00		µg/L	1	R18943A	3/28/03
Cobalt		ND	1.00		µg/L	1	R18943A	3/28/03
Copper		3.64	1.00		µg/L	1	R18943A	3/28/03
Lead		ND	1.00		µg/L	1	R18943A	3/28/03
Lithium		74.1	2.00		µg/L	1	R18943A	3/28/03
Manganese		ND	1.00		µg/L	1	R18943A	3/28/03
Molybdenum		1.55	1.00		µg/L	1	R18943A	3/28/03
Nickel		5.58	1.00		µg/L	1	R18943A	3/28/03
Selenium		11.5	4.00		µg/L	1	R18943A	3/28/03
Thallium		ND	1.00		µg/L	1	R18943A	3/28/03
Vanadium		23.3	1.00		µg/L	1	R18943A	3/28/03
Zinc		18.3	4.00		µg/L	1	R18943A	3/28/03
CATION/ANION BALANCES			**CALCULATION**					Analyst: **AMJ**
Cation/Anion Balance		Balanced			Date	1	R19127	4/10/03
ANIONS BY ION CHROMATOGRAPHY, DISSOLVE			**E300**					Analyst: **WR**
Bromide Dissolved		1.67	0.40		mg/L	20	R19006B	4/1/03 8:59:05 PM
Chloride Dissolved		543	20.0		mg/L	20	R19006B	4/1/03 8:59:05 PM

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quanititation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

LCRA Environmental Laboratory Services

Date: *10-Apr-03*

CLIENT: Texas Water Development Board
Client Sample ID: 45-06-805
Lab Order: 0303282 **File No:** 23986
Collection Date: 3/20/03 9:45:00 AM
Project: TWDB FY03
Matrix: GROUNDWATER
Lab ID: 0303282-10

Analyses	Storet	Result	PQL	Qual	Units	DF	BatchID	Date Analyzed
ANIONS BY ION CHROMATOGRAPHY, DISSOLVE E300								Analyst: **WR**
Fluoride Dissolved		0.72	0.20		mg/L	20	R19006B	4/1/03 8:59:05 PM
Sulfate Dissolved		316	20.0		mg/L	20	R19006B	4/1/03 8:59:05 PM
ALKALINITY			**M2320 B**					Analyst: **CMM**
Alkalinity, Phenolphthalein		ND	0		mg/L CaCO	1	R18879	3/25/03
Alkalinity, Total (As CaCO3)		265	2		mg/L CaCO	1	R18879	3/25/03
NITRATE AND NITRITE			**E353.2**					Analyst: **WM**
Nitrogen, Nitrate & Nitrite		5.52	0.40		mg/L	20	R18888D	3/24/03
SILICA			**E370.1**					Analyst: **WM**
Silica, Dissolved (as SiO2)		47.4	0.50		mg/L	1	R18955B	3/28/03

Qualifiers:
ND - Not Detected at the Reporting Limit
J - Analyte detected below quanititation limits
B - Analyte detected in the associated Method Blank
* - Value exceeds Maximum Contaminant Level
S - Spike Recovery outside accepted recovery limits
R - RPD outside accepted recovery limits
E - Value above quantitation range

Client: TEXAS WATER DEVELOPMENT BOARD
Recvd : 03/07/25
Job# : 1778
Final : 03/09/11

Purchase Order: 03-0483-0475
Contact: Radu Bogici, 512/463-6543
1700 N Congress Ave, P.O. Box 13231
Austin, TX 78711-3231, (F)-9893

Ector Co.

Cust	LABEL INFO		JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
TEXAS-	PIEDRAS		1778.01	030131	1000	275	0.82*	0.09
TEXAS-	312	46-01-701	1778.02	030318	1000	275	4.85	0.16
TEXAS-	315	46-45-601	1778.03	030319	1000	275	0.22 r	0.09
TEXAS-	323	46-26-701	1778.04	030320	1000	275	0.02	0.09
TEXAS-	925	45-14-103	1778.05	030320	1000	275	2.37	0.10
~~TEXAS-~~	~~141~~	~~55-26-505~~	1778.06	030320	1000	275	0.75*	0.09
TEXAS-	924	45-06-805	1778.07	030320	1000	275	1.91	0.09
TEXAS-	143	55-46-205	1778.08	030324	1000	275	1.31	0.10
TEXAS-	927	45-21-901	1778.09	030325	1000	275	0.08	0.09
TEXAS-	725	42-61-902	1778.10	030325	1000	275	1.63	0.09
TEXAS-	930	44-17-409	1778.11	030326	1000	276	0.03	0.09
TEXAS-	148	55-12-101	1778.12	030327	1000	275	0.87 r	0.09
TEXAS-	1151	53-63-401	1778.13	030402	1000	275	0.09	0.09
TEXAS-	22	52-07-502	1778.14	030402	1000	225	0.76 r	0.09
TEXAS-	1154	54-34-203	1778.15	030403	1000	254	1.46*	0.09
TEXAS-	935	44-09-502	1778.16	030408	1000	275	0.33*	0.09
TEXAS-	155	55-06-509	1778.17	030408	1000	275	2.13	0.09
TEXAS-	941	44-18-921	1778.18	030409	1000	275	0.10	0.09
TEXAS-	41	53-13-203	1778.19	030409	1000	275	0.14	0.09
TEXAS-	160	43-34-105	1778.20	030410	1000	275	3.56	0.12
TEXAS-	735	56-11-906	1778.21	030415	1000	275	0.48*	0.09
TEXAS-	739	42-57-611	1778.22	030417	1000	275	0.14	0.09
TEXAS-	947	44-50-109	1778.23	030422	1000	275	0.52*	0.09
TEXAS-	165	43-34-703	1778.24	030423	1000	275	0.12	0.09
TEXAS-	954	44-42-209	1778.25	030424	1000	275	6.68	0.22
TEXAS-	170	44-52-105	1778.26	030424	1000	271	0.03	0.09
TEXAS-	1167	53-54-801	1778.27	030501	1000	275	0.49 r	0.09
TEXAS-	180	44-61-303	1778.28	030506	1000	275	1.92	0.09
TEXAS-	185	44-29-803	1778.29	030508	1000	275	0.01	0.09
TEXAS-	956	44-57-304	1778.30	030513	1000	275	0.06	0.09
TEXAS-	1176	70-11-502	1778.31	030514	1000	275	0.55 r	0.09
TEXAS-	960	28-62-404	1778.32	030515	1000	275	0.10	0.09
TEXAS-	1180	55-55-904	1778.33	030515	1000	275	2.31	0.09
TEXAS-	191	~~45-51-703~~ 44-51-703	1778.34	030516	1000	276	2.73*	0.09
TEXAS-	741	56-27-907	1778.35	030519	1000	275	0.15*	0.09
TEXAS-	324	52-37-202	1778.36	030520	1000	275	1.69*	0.09
TEXAS-	743	55-48-303	1778.37	030520	1000	275	0.94 r	0.09
TEXAS-	328	73-42-905	1778.38	030521	1000	264	0.73*	0.09
TEXAS-	329	73-42-902	1778.39	030521	1000	275	2.47	0.12
TEXAS-	330	73-43-401	1778.40	030521	1000	275	0.01	0.09
TEXAS-	745	55-24-601	1778.41	030521	1000	275	0.27 r	0.09
TEXAS-	962	44-11-808	1778.42	030527	1000	275	0.46 r	0.09
TEXAS-	970	44-19-212	1778.43	030529	1000	275	0.10	0.09
TEXAS-	1186	70-45-505	1778.44	030529	1000	275	2.03	0.10
TEXAS-	196	44-37-404	1778.45	030603	1000	275	0.54 r	0.09
TEXAS-	201	44-27-806	1778.46	030604	1000	275	0.05	0.09
TEXAS-	1197	69-11-302	1778.47	030612	1000	275	2.35	0.09
TEXAS-	971	45-16-208	1778.48	030617	1000	275	0.06	0.09
TEXAS-	976	45-24-102	1778.49	030618	1000	221	1.54	0.09

-continued-

STATE OF TEXAS WELL REPORT for Tracking #139032

Owner:	**Bob Simpkins**	Owner Well #:	**#1**
Address:	**28 Brittany Ln.** **Odessa , TX 79761**	Grid #:	**45-06-8**
Well Location:	**6919 Commerce** **Odessa , TX**	Latitude:	**31° 53' 17" N**
Well County:	**Ector**	Longitude:	**102° 17' 41" W**
Elevation:	**2874 ft.**	GPS Brand Used:	**Garmin**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **4/7/2008** Completed: **4/8/2008**
Diameter of Hole:	Diameter: **8.75 in From Surface To 117 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **117 ft to 67 ft** Gravel Pack Size: **8/16**
Annular Seal Data:	1st Interval: **From 67 ft to 50 ft with 6 Hole Plug (#sacks and material)** 2nd Interval: **From 0 ft to 10 ft with 4 Cement (#sacks and material)** 3rd Interval: **No Data** Method Used: **Poured** Cemented By: **WTWWS** Distance to Septic Field or other Concentrated Contamination: **N/A ft** Distance to Property Line: **N/A ft** Method of Verification: **N/A** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **Fresh** Depth of Strata: **N/A ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**West Texas Water Well Service** **3410 Mankins** **Odessa , TX 79764**
Driller License Number:	**1704**
Licensed Well Driller Signature:	**Robert E Collis**
Registered Driller Apprentice Signature:	**Wayne Roland**
Apprentice Registration Number:	**57588**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the

contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking #**139032**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 5 Top Soil
5 13 Caliche
13 16 Tan Sandstone
16 26 Tan Sand
26 37 Brown Sandstone w/small gravel
37 38 Yellow Sandstone
38 50 Yellow Sand
50 53 Brown Clay w/small gravel
53 65 Brown Sandstone w/small gravel
65 70 Red Shale
70 75 Yellow Sandstone w/med. gravel
75 77 Yellow Sandstone w/some Red Shale
77 85 Yellow Sandstone w/some Gray Clay
85 90 Yellow Sandstone w/some Brown Sand
90 95 Tan Sand
95 100 Tan Sandstone
100 105 Yellow Sandstone w/Gray Clay & Red Shale
105 107 Gray Clay w/med. gravel
107 114 Yellow Clay w/heavy gravel
114 117 Red Clay w/heavy gravel

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New Screen 117 - 77 .035
5 New Plastic 77 - 0

Please use black ink.
Send original copy by certified mail to the
Texas Water Commission
P.O. Box 13087
Austin, Texas 78711

State of Texas
WATER WELL REPORT

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

Texas Water Well Drillers Board
P. O. Box 13087
Austin, Texas 78711

1) OWNER Watson Packers (Name) Address 2430 Marco (Street or RFD) Odessa (City) (State) (Zip)

2) LOCATION OF WELL:
County Ector ____ miles in ____ (N.E., S.W., etc.) direction from Odessa (Town)

☐ Legal description:

Driller must complete the legal description to the right with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

Section No. ____ Block No. ____ Township ____
Abstract No. ____ Survey Name ____
Distance and direction from two intersecting section or survey lines ____

☒ See attached map. on 45-04-3

3) TYPE OF WORK (Check): X☒ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): X☒ Domestic ☐ Industrial ☐ Monitor ☐ Public Supply ☐ Irrigation ☐ Test Well ☐ Injection ☐ Other ____

5) DRILLING METHOD (Check): ☐ Driven ☐ Mud Rotary ☐ Air Hammer ☐ Jetted ☐ Bored X☒ Air Rotary ☐ Cable Tool ☐ Other ____

6) WELL LOG:
Date Drilling:
Started July 9 19 87
Completed ____ 19 ____

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	

7) BOREHOLE COMPLETION:
☐ Open Hole ☐ Straight Wall ☐ Underreamed
X☒ Gravel Packed ☐ Other ____
If Gravel Packed give interval . . . from 71 ft. to 112 ft.

From (ft.)	To (ft.)	Description and color of formation material
0	1	Top Soil Rocky
1	35	Caliche
35	46	Limestone
46	59	Yellow Sand
59	65	Sand & Gravel
65	71	Shale
71	82	Sand & Gravel
82	109	Sand & Gravel
109	110	Shale
110	112	Red Bed

RECEIVED
JAN 21 1988
TEXAS WATER COMMISSION

(Use reverse side if necessary)

8) CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casing Screen
5	N	Plastic Plain	0	92	1/8
		Perf.	92	112	

9) CEMENTING DATA [Rule 319.44(b)]
Cemented from 0 ft. to 10 ft. No. of Sacks Used 4
____ ft. to ____ ft. No. of Sacks Used ____
Method used Poured Slurry
Cemented by Bernard Brorhm

10) SURFACE COMPLETION
☒ Specified Surface Slab Installed [Rule 319.44(c)]
☐ Pitless Adapter Used [Rule 319.44(d)]
☐ Approved Alternative Procedure Used [Rule 319.71]

11) WATER LEVEL:
Static level ____ ft. below land surface Date ____
Artesian flow ____ gpm. Date ____

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ____
Depth to pump bowls, cylinder, jet, etc., ____ ft.

14) WELL TESTS:
Type Test: ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: ____ gpm with ____ ft. drawdown after ____ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable water? ☐ Yes ☒ No
If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ____ Depth of strata ____
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 12 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Hickerson Drlg & Pump (Type or Print) Water Well Driller's License No. 02497W

ADDRESS 3806 West University (Street or RFD) Odessa (City) Texas (State) 79764 (Zip)

(Signed) Bernard Brorhm (Licensed Water Well Driller) (Signed) ____ (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

For TWC use only
Well No. 45-06-8
Located on map ____

WWD-012 (Rev.01-28-87) TEXAS WATER COMMISSION COPY

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt   Field No. A   State Well No. JA 45-06-802
Owner's Well No. NORTH-EAST   County Ector

802

1. Location: NE 1/4, NE 1/4 Sec. 20, Block 41 Survey T & P RR Co. T-2-S
2. Owner: Sunset Memorial Gardens Address: Odessa, TX
   Tenant: Address:
   Driller: Mr. Browning Address:
3. Elevation of LSD @ well is 2882 ft. above msl, determined by Topo
4. Drilled: 1963; Dug, Cable Tool, Rotary,
5. Depth: Rept. 110-116 ft. Meas. NMT ft. 9-4-70
6. Completion: Open Hole, Straight Wall, Underreamed, Gravel Packed
7. Pump: Mfgr. Peerless Type Turbine
   No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.
   Column Diam. ____ in., Length Tailpipe ____ ft.
8. Motor: Fuel Electric Make & Model ____ HP. 3
9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est.
10. Performance Test: Date ____ Length of Test ____ Made by ____
    Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.
    Production ____ gpm Specific Capacity ____ gpm/ft.

CASING & BLANK PIPE

Cemented From ____ ft. to ____ ft.

Diam. (in.)	Type	Setting, ft. from	to
6	Steel	0	TD

11. Water Level: NMT ft. rept./meas. 9-4-1970 above/below ____ which is ____ ft. above/below surface.
    ____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.
    ____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.
    ____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.
12. Use: Dom., Stock, Public Supply, Ind., (Irr), Waterflooding, Observation, Not Used,
13. Quality: (Remarks on taste, odor, color, etc.)
    Temp. 78 °F, Date sampled for analysis 9-4-70 Laboratory SHD
    Temp. ____ °F, Date sampled for analysis ____ Laboratory ____
    Temp. ____ °F, Date sampled for analysis ____ Laboratory ____
14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log,
    Formation Samples, Pumping Test,
15. Record by: D. Corley Date 9-4-1970
    Source of Data Mr. Hoback & obs.
16. Remarks: Well pumping
    SPC 78°F @ 650 mmhos

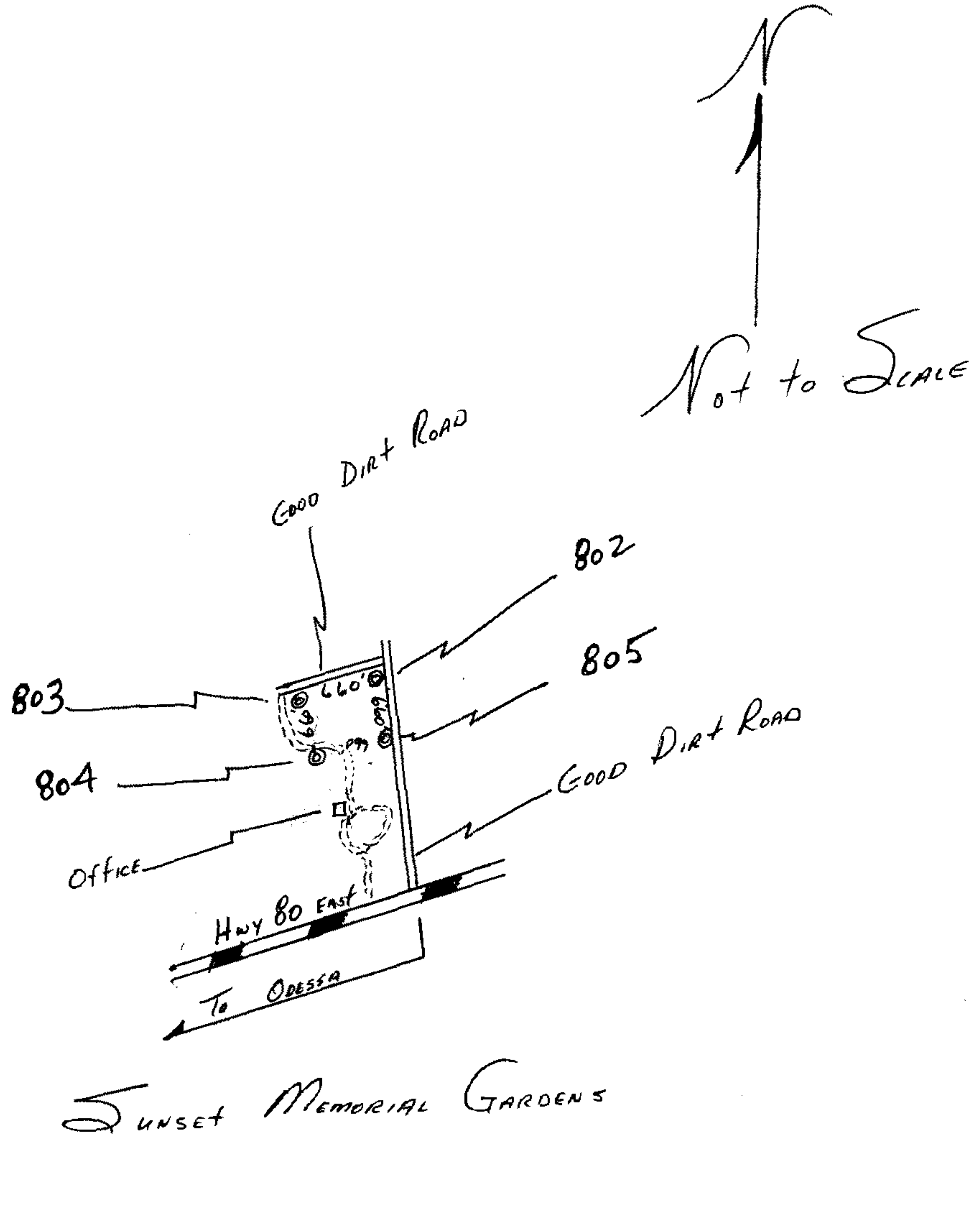
WELL SCREEN

Screen Openings ____

Diam. (in.)	Type	Setting, ft. from	to
	UNKNOWN		

TWDBE-GW-49

(Sketch)


Not to Scale
Good Dirt Road
802
805
803
660'
660
660
804
Good Dirt Road
Office
Hwy 80 East
To Odessa
Sunset Memorial Gardens

TWDBE-GW ONLY

Program No. ____

Proj. No. ____

CHEMICAL WATER ANALYSIS REPORT

Typewrite (Black ribbon) or Print Plainly
(soft pencil or black ink)
Do not use ball point pen

Texas State Department of Health Laboratories
1100 West 49th Street
Austin 5, Texas

Send report to:

Ground Water Division
Texas Water Development Board
P. O. Box 12386
Austin, Texas 78711

County: ECTOR
State Well No.: JN 45-06-802
Well No.: NORTH-EAST
Date Collected: 9-4-70
By: D. CORLEY

Location: NE 1/4, NE 1/4, SEC 20, BLK 41, T1 PRR Co. T-2-S

Source (type of well): TURBINE Owner: SUNSET MEMORIAL GARDENS

Date Drilled: 1963 Depth: 110-116 ft. WBF: K+

Producing intervals: — Water level: — ft.

Sampled after pumping: SEVERAL hrs. Yield: — GPM meas./est. Temperature: 78 °F °C

Point of collection: FAUCET AT WELL Appearance: CLEAR (clear - turbid - colored)

Use: IRR Remarks: COPY to: MR. HOBACK % OWNER
ODESSA, TEXAS

FOR LABORATORY USE ONLY

CHEMICAL ANALYSIS

KEY PUNCHED

Laboratory No. 473651 W Date Received: OCT 21 1970 Date Reported: NOV - 3 1970

	MG/L	ME/L		MG/L	ME/L
Silica	29		Carbonate		0
Calcium	80	4.01	Bicarbonate	237 (117)	3.88
Magnesium	11	0.92	Sulfate	64	1.34
Sodium	44	1.90	Chloride	53	1.50
Total		6.83	Fluoride	1.4	
☐ Potassium			Nitrate	5	
☐ Manganese		%Na	pH	7.2	Total 6.72
☐ Boron		SAR	1/Dissolved Solids (sum)		404
☐ Total Iron		RSC	Phenolphthalein Alkalinity as CaCO3		0
☐ ____ (other)			Total Alkalinity as CaCO3	(3.88)	194
			Total Hardness as CaCO3	(4.93)	247

Specific Conductance (micromhos/cm3): 645

Diluted Conductance (micromhos/cm3): 5 x 145
725

"☐" items will be analyzed if checked. Analyst ____

Total Iron requires separate sample. Checked by ____

1/ The bicarbonate reported in this analysis is converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure is used in the computation of this sum.

TWDBE-GW-50

Texas Water Development Board
Well Schedule

State Well No. 45 06 809 Previous Well No. ______ County Ector 135

River Basin ______ 14 Zone 1 Lat. 31 53 11 Long. 102 17 47 Accuracy of Coord. 1

Owner's Well No. 14 Location ___ 1/4, ___ 1/4, Section ___, Block ___, Survey ___

Owner: Sunset Memorial Gardens, Inc.

Driller: ______

Address: 6801 East Hwy. 80 Odessa Tx. 79762-9809 Tenant/Oper. (915) 362-2331

Date Drilled ______ Depth 120 Source of Depth Datum M Altitude 2884 Source of Alt. Datum M

Aquifer ______ 218ALRS Well Type W User 832790

Aquifer ID 13

Well Construction Const. Method ______ Casing Material PVC P

Completion ______ Screen Material ______

Casing or Blank Pipe (C)
Well Screen or Slotted Zone (S)
Open Hole (O)
Cemented from ___ to ___

	Diam. (in.)	Setting (feet) From	To
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

(20 max)

Lift Data Pump Mfr. ______ Type Subm S Setting ______

Motor Mfr. ______ Power Elec. E Horsepower ______

Yield Flow ___ GPM Pump ___ GPM Meas.,Rept.,Est. ___ Date ___

Performance Test Date ___ Length of Test ___ Production ___ GPM

Static Level ___ ft. Pumping Level ___ ft. Drawdown ___ ft. Sp.Cap. ___ GPM/ft.

Water Use Primary Irr. I Secondary ___ Tertiary ___

Quality (Remarks) ______

Other Data Available Water Level N Water Quality Y Logs ______ Other Data ______

Water Levels
Date ______ Meas. ______
Date ______ Meas. ______
Date ______ Meas. ______

Recorded By D.R. Jones Date Record Collected or Updated 03 09 1999 Reporting Agency 01

Remarks
1 Owners well #14.
2
3
4
5
6

Aquifer Antlers
Well No. 45-06 809

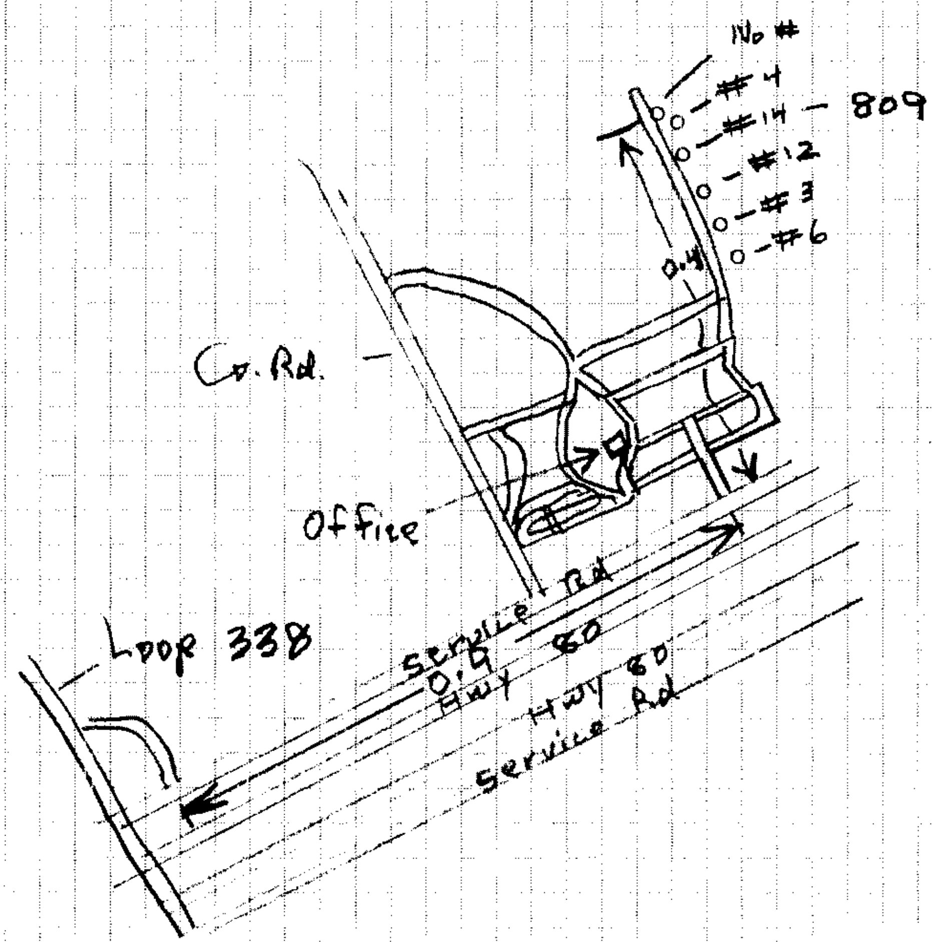
97-0402-/7-97
Recurrent

Texas Water Development Board

By D. R. Jones Date ______ Division ______

Chkd. ______ Date ______ Well Number 45-06-809

County Ector



96-0502

45-06-809
Well Number

TEXAS WATER DEVELOPMENT BOARD
WELL SCHEDULE

State Well Number - 45 06 809   Previous Well Number -   County - Ector 135
River Basin - Colorado River - 14   Zone - 1   Latitude - 31 53 11   Longitude - 102 17 47   Source of Coords - 1

Owners Well No. ______ Location ______ 1/4, ______ 1/4, Section ______, Block ______, Survey ______

Owner - Sunset Memorial
Gardens, Inc. Well #14   Driller -

Address ______   Tenant/Oper. ______
Date Drilled - / /   Depth - 120 ft.   Source of Depth - M   Altitude - 2,884 ft.   Source of Alt. - M
Aquifer - 218ALRS ANTLERS SAND   Well Type - W   User - 832790

WELL CONSTRUCTION   Const. Method - ______   Casing Material - ______
Completion - ______   Screen Material - ______

| Casing or Blank Pipe (C)
| Well Screen or Slotted Zone (
| Open Hole (O)
| Cemented from ____ to ____

	Diam. (in.)	Setting(feet) From	To
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			

LIFT DATA - Pump Mfr. ______ Type - SUBMERSIBLE PUMP   No. Stages ____

Bowls Diam. - ______ in.   Setting - ______ ft.   Column Diam. - ______ in.

Motor Mfr. - ______ Fuel or Power - ELECTRIC MOTOR   Horsepower -

YIELD Flow- ______ GPM   Pump- ______ GPM   Meas.,Rept.,Est- ______   Date- ______

PERFORMANCE TEST Date- ______ Length of Test- ______ Production- ______ GPM

Static Level- ____ ft.   Pumping Level- ____ ft.   Drawdown- ____ ft.   Sp.Cap.- ____ GPM/ft

QUALITY (Remarks- ______

WATER USE Primary- IRRIGATION   Secondary- ______   Tertiary- ______

OTHER DATA AVAILAIBLE   Water Levels- N   Quality- Y   Logs-   Other Data-

WATER LEVELS   Date- / /   Measurement-
Date- / /   Measurement-

Recorded By ______   Date Record Collected or Updated- 03/09/1999

Reporting Agency - TEXAS WATER DEVELOPMENT BOARD
REMARKS -
Owners well #14.

Aquifer - 218ALRS
Well No. - 45 06 809

Water Quality Field Data

SWN: 45-06-8 09
County: Ector
Aquifer(s): 218 ALBS

Name: Sunset Memorial Gardens
Address: 6801 East Hwy 80
Odessa, Tx 79762
owner's well # 14

Sample No. 423
Date: 03/09/99
By: D. R. Jones

	Bottle 1	Bottle 2	Bottle 3	Bottle 4	Bottle 5	Bottle 6	Bottle 7	Total SUB-Samples 3
	500 ml Anions	1 liter Cations	250 ml Nitrate	1 liter Radioactivity				
		2 ml HNO_3 (Nitric)	0.5 ml H_2SO_4 (Sulfuric)	2 ml HNO_3 (Nitric)				All filtered unless otherwise stipulated

Water Level — LSD Remark —
Temperature (00010) 20.4 c
Specific Conductance (00094) 1654 umhos/cm
pH (00400) 6.72
Eh (00090) +174.0 mv.
Phenol ALK (82244) 0 mg/l
Total ALK (39086) 221.0 mg/l
Carbonate (00452) 0 meq/l 0 mg/l
Bicarbonate (00453) 4.42 meq/l 269.70 mg/l
Total Cations(+) Balanced
Total Anions (-)
Total Hardness (00900) 500
Dissolved Solids 965

Time in Pump on @ 9:13
Time out 10:12 Sample time 9:50
Weather Sunny, Cool well use Irr.
Outside Temp 13.0 °C
Sampling point Faucet at well

Starting pH 6.84
11.05 ml. of 0.02N to
50 ml. of Sample
Ending pH 4.50

Time:	9:29	9:34	9:39	9:41			ml.	pH	ml.	pH	ml.	pH
pH:	6.49	6.65	6.72				1.0	6.70	11.0	4.57		
Temp:	20.3	20.4	20.4				2.0	6.58	11.05	4.50		
Eh:			+174.0				3.0	6.47				
Cond.	1650	1656	1654				4.0	6.36				
other notes:							5.0	6.25				
							6.0	6.14				
							7.0	6.02				
							8.0	5.87				
							9.0	5.68				
							10.0	5.39				

Environmental Laboratory Services
The Solution Lab

FINAL ANALYSIS REPORT

LAB ID: 9905589 SAMPLE DESCRIPTION: Groundwater
COMPANY: TX Water Dev. Board SAMPLE DATE: 03/09/99
ACCT NO: SAMPLE TIME: 0950
REQUISITION No.: R10368 DATE RECEIVED: 03/12/99
LOCATION ID: 45-06-809 REPORT DATE: 04/08/99

PARAMETER	RESULTS	UNITS	STORET #	PQL in WATER	DATE ANALYZED
Bromide	0.93	mg/L	71870	0.02	03/16/99
Chloride	281.0	mg/L	00941	1.5	03/16/99
Fluoride	0.70	mg/L	00950	0.01	03/16/99
Nit.,Nitrate/Nitrite	4.280	mg/L	00630	0.020	03/31/99
Nitrogen, Kjeldahl	0.511	mg/L	00623	0.040	03/16/99
Nitrogen, ammonia	<0.050	mg/L	00608	0.050	03/15/99
Phosphorus, Total	0.080	mg/L	00665	0.040	03/16/99
Silica	39.57	mg/L	00955	0.50	03/15/99
Sulfate	153.00	mg/L	00946	1.50	03/16/99
Alkalinity, Total	219	mg/L	00410	1	03/16/99
Alkalinity, Phenol.	0	mg/L	00415	0	03/16/99
Boron, Dissolved	385.00	ug/L	01020	50.00	03/17/99
Cobalt, Diss. ICPMS	<1.0	ug/L	01035	1.0	03/15/99
Iron, Dissolved	<50.00	ug/L	01046	50.00	03/17/99
Lithium, Diss. ICPMS	55.6	ug/L	01130	2.0	03/15/99
Molybdenum Dis ICPMS	2.8	ug/L	01060	1.0	03/15/99
Potassium, Dissolved	5.62	mg/L	00935	0.20	03/17/99
Strontium, Dissolved	1400.00	ug/L	01080	20.00	03/17/99
Vanadium, Diss ICPMS	32.7	ug/L	01085	1.0	03/15/99
Aluminum, Dis. ICPMS	<4.0	ug/L	01106	4.0	03/15/99
Arsenic, Diss. ICPMS	4.5	ug/L	01000	2.0	03/15/99
Barium, Diss. ICPMS	60.6	ug/L	01005	1.0	03/15/99
Cadmium, Diss. ICPMS	<1.0	ug/L	01025	1.0	03/15/99
Calcium, Dissolved	158.00	mg/L	00915	0.20	03/22/99
Chromium, Diss ICPMS	23.5	ug/L	01030	1.0	03/15/99
Copper, Diss. ICPMS	7.1	ug/L	01040	2.0	03/15/99
Lead, Diss. ICPMS	<1.0	ug/L	01049	1.0	03/15/99
Magnesium, Dissolved	25.90	mg/L	00925	0.20	03/17/99
Manganese, Dis ICPMS	14.3	ug/L	01056	1.0	03/15/99
Nickel, Diss. ICPMS	17.1	ug/L	01065	1.0	03/15/99
Selenium, Dis. ICPMS	10.0	ug/L	01145	4.0	03/15/99
Sodium, Dissolved	147.00	mg/L	00930	0.20	03/22/99
Antimony, Dis. ICPMS	<1.0	ug/L	01095	1.0	03/15/99
Beryllium, Dis ICPMS	<1.0	ug/L	01010	1.0	03/15/99
Thallium, Diss ICPMS	<1.0	ug/L	01057	1.0	03/15/99
Zinc, Diss. ICPMS	26.8	ug/L	01090	2.0	03/15/99

Lower Colorado River Authority • P. O. Box 220 • Austin, Texas 78767
3505 Montopolis Drive • Austin, Texas 78744 • (512) 356-6022 • (800) 776-5272 • (512) 356-6021 FAX

WQ FY07 TRNT/PECS

TWDB Water Quality Field Data Sheet

Newly Inventoried Well ______

SWN: 45-06-809
County: ECTOR
County Code: 135
Aquifer Code: 218ALRS
Aquifer Id: 13

Name: SUNSET MEMORIAL GARDEN
Address: 6801 E HWY 80
ODESSA 79762
Attention: LORENZO RODRIGUEZ
Well Name or #: 14

ID Number: 692
Date: 3-29-07
Sampler(s): MB

1	2	3	4	5	6	7	8	9	10
~~40 ml unfiltered Nitrate~~	250 ml filtered Cation (HNO3)	500 ml filtered Anions/T. Alk. ICE	500 ml filtered Nitrate ICE + (H2SO4)						

All acidified samples pH <2.0. (*) If natural pH<7, then add NaOH until pH is >7. If natural pH is ≥7, no NaOH required.

Calibration Verification Readings

pH 7 = 7.02
4 or 10 = 4.01
SLP = 100.4
Conductivity 500 = 534
1000 = 1042
2000 = 2030
5000 = 5000

Time In: 1440
Time Out: 1525
Water Level: 21.35
W.L. remark: ______
M.P. = +.50
Pumping time: 1445
Sampling Point: FAW
Well Use: I
Lift: S
Power: E

70
48.15
21.85

FIELD G.P.S. readings
Latitude: 31°53'13.7"
Longitude: 102°17'48.8"
Casing Type: PVC
Casing Size: 6"
Sample Time: 1515
Filter pressure: hand pump / line / spring (line circled)

Field Alkalinity Titration:
7.01 Start pH 4.46 End pH
______ mL Sample Size
______ mL Acid Phenol (> 8.3)
13.20 mL Acid Total (to pH 4.5)
mL acid added x 20 = Alkalinity

Phenol Alkalinity (82244): ______ mg/L
Total Alkalinity (39086): 264 mg/L

Items Below Calculated Later From Results:
Dissolved Solids (mg/L): 1138
Hardness (as CaCO3): 613
Balanced: B

Water Quality Stabilization Parameters Table (At least 3 readings @ 5 min. intervals)

Time	1455	1500	1505	1510	1515				
pH	6.95	6.95	6.94	6.94	6.94				
Celsius Temp.	21.3	21.6	21.6	21.6	21.6				
Conductivity	1791	1794	1797	1800	1800				

Notes:
3hp pump
Well closest to transformer pole
PICTURE

Data Entered By Sampler into Database yes / no

ENERGY LABORATORIES, INC. • 2393 Salt Creek Highway (82601) • P.O. Box 3258 • Casper, WY 82602
Toll Free 888.235.0515 • 307.235.0515 • Fax 307.234.1639 • casper@energylab.com • www.energylab.com

LABORATORY ANALYTICAL REPORT

Client:	Texas Water Development Board	**Report Date:**	04/16/07
Project:	TWDB	**Collection Date:**	03/29/07 15:15
Lab ID:	C07031427-006	**DateReceived:**	03/31/07
Client Sample ID:	4506809 (692)	**Matrix:**	Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
MAJOR IONS							
Alkalinity, Phenolphthalein as CaCO3	ND	mg/L		1		A2320 B	04/03/07 07:47 / jaj
Alkalinity, Total as CaCO3	258	mg/L		1		A2320 B	04/03/07 07:47 / jaj
Bromide	1.98	mg/L		0.50		E300.0	04/10/07 03:56 / bt
Calcium	185	mg/L		0.5		E200.7	04/03/07 18:06 / ts
Chloride	354	mg/L		1		A4500-Cl B	04/02/07 14:45 / jl
Fluoride	1.4	mg/L		0.1		A4500-F C	04/03/07 10:26 / jaj
Magnesium	36.1	mg/L		0.5		E200.7	04/03/07 18:06 / ts
Nitrogen, Nitrate+Nitrite as N	4.0	mg/L	D	0.2		E353.2	04/02/07 12:43 / jal
Potassium	8.2	mg/L		0.5		E200.7	04/03/07 18:06 / ts
Silica	33.8	mg/L		0.1		E200.7	04/03/07 18:06 / ts
Sodium	162	mg/L		0.5		E200.7	04/03/07 18:06 / ts
Sulfate	183	mg/L	D	3		A4500-SO4 E	04/02/07 16:04 / ljl
METALS - DISSOLVED							
Aluminum	ND	ug/L		1		E200.8	04/04/07 19:50 / aln
Antimony	ND	ug/L		1		E200.8	04/04/07 02:29 / sml
Arsenic	6	ug/L		1		E200.8	04/04/07 02:29 / sml
Barium	61	ug/L		1		E200.8	04/04/07 02:29 / sml
Beryllium	ND	ug/L		1		E200.8	04/04/07 02:29 / sml
Boron	369	ug/L		100		E200.7	04/03/07 18:06 / ts
Cadmium	ND	ug/L		1		E200.8	04/04/07 02:29 / sml
Chromium	4	ug/L		1		E200.8	04/04/07 02:29 / sml
Cobalt	ND	ug/L		1		E200.8	04/04/07 02:29 / sml
Copper	2	ug/L		1		E200.8	04/04/07 02:29 / sml
Iron	35	ug/L		30		E200.7	04/03/07 18:06 / ts
Lead	ND	ug/L		1		E200.8	04/04/07 02:29 / sml
Lithium	77	ug/L		1		E200.8	04/05/07 15:20 / sml
Manganese	164	ug/L		1		E200.8	04/04/07 02:29 / sml
Molybdenum	3	ug/L		1		E200.8	04/04/07 02:29 / sml
Selenium	5	ug/L		1		E200.8	04/04/07 02:29 / sml
Strontium	1600	ug/L		1		E200.8	04/04/07 02:29 / sml
Thallium	ND	ug/L		1		E200.8	04/04/07 02:29 / sml
Vanadium	28	ug/L		1		E200.8	04/04/07 02:29 / sml
Zinc	14	ug/L	D	2		E200.8	04/04/07 02:29 / sml
DATA QUALITY							
A/C Balance (± 5)	0.452	%				Calculation	04/06/07 10:21 / bws
Anions	19.3	meq/L				Calculation	04/06/07 10:21 / bws
Cations	19.5	meq/L				Calculation	04/06/07 10:21 / bws

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

WQ FY09

TWDB Water Quality Field Data Sheet

Newly Inventoried Well: No

SWN: 45-06-809
County: Ector
County Code: 135
Aquifer Code: 218ALRS
Aquifer Id: 13

Name: Sunset Memorial Garden
Address: 6801 E Hwy 80
Odessa, TX 79762
Attention:
Well Name or #:

ID Number: 1108
Date: 10/13/2010
Sampler(s): H. Rein

1	(2)	(3)	(4)	(5)	(6)	7	8	9	10
~~40 ml unfiltered~~	250 ml filtered	250 ml filtered	250 ml filtered	1L filtered	2L filtered				
~~Atrazine~~	**Cation**	**Anions/T. Alk.**	**Nitrate**	**UNAT**	**Radium**				
				Gross Alpha	**(226/228)**				
ICE	HNO3 by lab	ICE	ICE + H2SO4	HNO3 by lab	HNO3 by lab				

All acidified samples pH <2.0. (C14/C13 samples only: If natural pH<7, then add NaOH until pH is >7. If natural pH is ≥7, no NaOH required.)

Calibration Verification Readings		
pH	7 =	**7.08**
	4 or 10 =	**10.04**
SLP =	90.4	
Conductivity	500 =	**526**
	1000 =	**997**
	2000 =	**1974**
	5000 =	**4850**

Time In: 15:10
Time Out: 16:00

Water Level:
W.L. remark: 41
M.P. =

Pumping time: POA
Sampling Point: FAW

Well Use: I
Lift: S
Power: E
Casing Type:

FIELD G.P.S. readings
Latitude: 31 ° 53 ' 13.8 "
Longitude: 102 ° 17 ' 48.8 "
Casing Size: "

Field Alkalinity Titration:

7.06	Start pH	4.49	End pH
50.0	**mL Sample Size**		
	mL Acid added for Phenol (> 8.3)		
14.10	mL Acid added for Total (to pH 4.5)		

Items below calculated from: mL acid added x 20 = Alkalinity

Phenol Alkalinity (82244): mg/L
Total Alkalinity (39086): 282.0 mg/L
Colorimeter DO (00300) 7.1 mg/L

Sample Time: 15:30
Filter pressure: hand pump (line) spring

Field data entered by sampler into GWDB: 10/18/10 (yes) no
Balanced:

Water Quality Stabilization Parameters Table (At least 3 readings @ 5 min. intervals)

Time	15:12	15:17	15:22	15:27				
pH	6.85	6.85	6.86	6.87				
Celsius Temp.	22.6	22.5	22.5	22.5				
Conductivity	2341	1800	1678	1656				

Notes:
All wells are pumped thru same line, only one faucet, so sample is mixture of all wells.
Wells are all in same aquifer, same detph and all within a few feet of each other.
Faucet is at well #1 31 53' 07.4"N 102 17' 46.5" W

LCRA Environmental Laboratory Services

Date: *09-Nov-10*

CLIENT:	Texas Water Development Board	**Client Sample ID:**	45-06-809
Lab Order:	1010504	**Collection Date:**	10/13/2010 3:30:00 PM
Project:	TWDB FY2010	**Matrix:**	GROUNDWATER
Lab ID:	1010504-009	**Tag No:**	1108

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS, DISSOLVED		**E200.7**			**(E200.7)**	Analyst: **MV**
Calcium	238	0.20		mg/L	1	10/22/2010 1:22:09 PM
Magnesium	52.1	0.20		mg/L	1	10/22/2010 1:22:09 PM
Potassium	7.13	0.20		mg/L	1	10/22/2010 1:22:09 PM
Sodium	256	0.51		mg/L	1	10/22/2010 1:22:09 PM
ICP METALS, DISSOLVED		**E200.7**			**(E200.7)**	Analyst: **MV**
Boron	455	51		µg/L	1	10/22/2010 1:22:09 PM
Iron	< 51	51		µg/L	1	10/22/2010 1:22:09 PM
Strontium	2400	20		µg/L	1	10/22/2010 1:22:09 PM
ICPMS METALS, DISSOLVED		**E200.8**				Analyst: **SW**
Aluminum	< 4.1	4.1		µg/L	1	10/22/2010 4:39:41 PM
Antimony	< 1.0	1.0		µg/L	1	10/22/2010 12:28:33 PM
Arsenic	5.2	2.0		µg/L	1	10/22/2010 12:28:33 PM
Barium	62.5	1.0		µg/L	1	10/22/2010 12:28:33 PM
Beryllium	< 1.0	1.0		µg/L	1	10/22/2010 4:39:41 PM
Cadmium	< 1.0	1.0		µg/L	1	10/22/2010 12:28:33 PM
Chromium	3.9	1.0		µg/L	1	10/22/2010 4:39:41 PM
Cobalt	10.3	1.0		µg/L	1	10/22/2010 12:28:33 PM
Copper	4.4	1.0		µg/L	1	10/22/2010 12:28:33 PM
Lead	< 1.0	1.0		µg/L	1	10/22/2010 12:28:33 PM
Lithium	69.3	2.0	A	µg/L	1	10/22/2010 4:39:41 PM
Manganese	567	5.1		µg/L	5	10/22/2010 2:05:29 PM
Molybdenum	2.5	1.0		µg/L	1	10/22/2010 12:28:33 PM
Selenium	< 4.1	4.1		µg/L	1	10/22/2010 12:28:33 PM
Silver	< 1.0	1.0		µg/L	1	10/22/2010 12:28:33 PM
Thallium	< 1.0	1.0		µg/L	1	10/22/2010 12:28:33 PM
Uranium	11.6	1.0	A	µg/L	1	10/22/2010 4:39:41 PM
Vanadium	19.6	1.0		µg/L	1	10/22/2010 4:39:41 PM
Zinc	9.6	4.1		µg/L	1	10/22/2010 4:39:41 PM
MERCURY, TOTAL		**SW7470A**				Analyst: **AE**
Mercury	< 0.200	0.200		µg/L	1	10/21/2010 11:12:00 AM
DISSOLVED ANIONS BY ION CHROMATOGRAPH		**E300.0**				Analyst: **WR**
Bromide Dissolved	1.84	0.20		mg/L	10	10/26/2010 7:09:00 AM
Chloride Dissolved	549	10.0		mg/L	10	10/26/2010 7:09:00 AM
Fluoride Dissolved	1.28	0.10		mg/L	10	10/26/2010 7:09:00 AM
Sulfate Dissolved	336	10.0		mg/L	10	10/26/2010 7:09:00 AM
ALKALINITY		**SM2320 B**				Analyst: **JB**
Alkalinity, Phenolphthalein	< 2	2	A	mg/L CaCO3	1	10/26/2010

Qualifiers:

A Not Available for Accreditation
E Value Above Quantitation Range
N Not Accredited
X Value Exceeds Maximum Contaminant Level (MCL)

B Analyte Detected in Method Blank
H Holding Time Exceeded
S Spike Recovery Outside Recovery Limits

PQL: Practical Quantitation Limit

Values Below PQL Considered Estimated

LCRA Environmental Laboratory Services

Date: *09-Nov-10*

CLIENT:	Texas Water Development Board	**Client Sample ID:**	45-06-809
Lab Order:	1010504	**Collection Date:**	10/13/2010 3:30:00 PM
Project:	TWDB FY2010	**Matrix:**	GROUNDWATER
Lab ID:	1010504-009	**Tag No:**	1108

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ALKALINITY		**SM2320 B**				Analyst: **JB**
Alkalinity, Total (As CaCO3)	294	2		mg/L CaCO3	1	10/26/2010
CATION/ANION BALANCE		**CALCULATION**				Analyst: **AMJ**
Cation/Anion Balance	1.83	5.0	A	%	1	11/9/2010
NITRATE AND NITRITE		**SM4500-NO3-H**				Analyst: **KK**
Nitrogen, Nitrate & Nitrite	7.00	0.100		mg/L	5	11/8/2010
DISSOLVED PHOSPHATE AS P IN WATER		**E365.4**				Analyst: **CM**
Phosphorus, Dissolved (As P)	< 0.020	0.020		mg/L	1	10/21/2010
SILICA		**SM4500-SIO2-C**				Analyst: **KK**
Silica, Dissolved (as SiO2)	43.4	2.50		mg/L	5	10/18/2010 3:00:00 PM

Qualifiers:

A Not Available for Accreditation
E Value Above Quantitation Range
N Not Accredited
X Value Exceeds Maximum Contaminant Level (MCL)
B Analyte Detected in Method Blank
H Holding Time Exceeded
S Spike Recovery Outside Recovery Limits

PQL: Practical Quantitation Limit

Values Below PQL Considered Estimated

LCRA Environmental Laboratory Services

Date: *30-Nov-10*

CLIENT:	Texas Water Development Board	**Client Sample ID:**	45-06-809
Lab Order:	1010505	**Collection Date:**	10/13/2010 3:30:00 PM
Project:	TWDB FY2010	**Matrix:**	GROUNDWATER
Lab ID:	1010505-009	**Tag No:**	1108

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
RADIUM 226		**SM7500-RA B**				Analyst: **SUB**
Radium 226	0.6 ± 0.14	0.1		pCi/L	1	11/23/2010 10:00:18 PM
RADIUM 228		**SM7500-RA D**				Analyst: **SUB**
Radium 228	1.4 ± 0.6	1.0		pCi/L	1	11/17/2010 11:15:25 AM
GROSS ALPHA, GROSS BETA		**E900**				Analyst: **SUB**
Gross Alpha Particle Activity	< 12.6 ± 7.5	12.6		pCi/L	1	11/20/2010 11:00:43 AM

Qualifiers:

A Not Available for Accreditation
E Value Above Quantitation Range
N Not Accredited
X Value Exceeds Maximum Contaminant Level (MCL)

B Analyte Detected in Method Blank
H Holding Time Exceeded
S Spike Recovery Outside Recovery Limits

PQL: Practical Quantitation Limit

Values Below PQL Considered Estimated

LABORATORY ANALYTICAL REPORT

Client:	LCRA Environmental Laboratory Services	**Report Date:**	11/29/10
Project:	Not Indicated	**Collection Date:**	10/13/10 15:30
Lab ID:	C10100907-017	**DateReceived:**	10/22/10
Client Sample ID:	1010505-009A	**Matrix:**	Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES - DISSOLVED							
Gross Alpha	0.7	pCi/L	U			E900.0	11/20/10 11:00 / ep
Gross Alpha precision (±)	7.5	pCi/L				E900.0	11/20/10 11:00 / ep
Gross Alpha MDC	12.6	pCi/L				E900.0	11/20/10 11:00 / ep

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

LABORATORY ANALYTICAL REPORT

Client: LCRA Environmental Laboratory Services
Project: Not Indicated
Lab ID: C10100907-018
Client Sample ID: 1010505-009B

Report Date: 11/29/10
Collection Date: 10/13/10 15:30
DateReceived: 10/22/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES - DISSOLVED							
Radium 226	0.55	pCi/L				E903.0	11/23/10 22:00 / trs
Radium 226 precision (±)	0.14	pCi/L				E903.0	11/23/10 22:00 / trs
Radium 226 MDC	0.11	pCi/L				E903.0	11/23/10 22:00 / trs
Radium 228	1.4	pCi/L				RA-05	11/17/10 11:15 / plj
Radium 228 precision (±)	0.6	pCi/L				RA-05	11/17/10 11:15 / plj
Radium 228 MDC	1	pCi/L				RA-05	11/17/10 11:15 / plj

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

Send original copy by certified mail to the
Texas Department of Water Resources
P. O. Box 13087
Austin, Texas 78711

State of Texas
WATER WELL REPORT

For TDWR use only
Well No. 45-06-8NN
Located on map Yes
Received: [illegible]

1) OWNER American Fence (Name) Address Rd 1 Box 339-C (Street or RFD) Odessa (City) Texas (State) (Zip)

2) LOCATION OF WELL:
County Ector, ______ miles in ______ (N.E., S.W., etc.) direction from ______ (Town)

Driller must complete the legal description to the right with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

☐ Legal description:
Section No. ______ Block No. ______ Township ______
Abstract No. ______ Survey Name ______
Distance and direction from two intersecting section or survey lines ______

☑ See attached map.

3) TYPE OF WORK (Check): ☑ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☑ Domestic ☐ Industrial ☐ Public Supply ☐ Irrigation ☐ Test Well ☐ Other ______

5) DRILLING METHOD (Check): ☐ Mud Rotary ☐ Air Hammer ☐ Driven ☐ Bored ☐ Air Rotary ☑ Cable Tool ☐ Jetted ☐ Other ______

6) WELL LOG:
Date drilled 3-6-78

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
8	Surface	

7) BOREHOLE COMPLETION:
☐ Open Hole ☐ Straight Wall ☐ Underreamed
☑ Gravel Packed ☐ Other ______
If Gravel Packed give interval . . . from 50 ft. to 113 ft.

From (ft.)	To (ft.)	Description and color of formation material
0	3	Soil
3	30	Calichie
30	45	Yellow Rock
45	75	False Red Bed
75	100	Brown Sand
100	110	Red Sand
110	113	Blue Shale & Red Bed

(Use reverse side if necessary)

8) CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mgf., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casing Screen
5	N	Plastic	0	113	

CEMENTING DATA
Cemented from 48 ft. to 50 ft.
Method used Dry Cement
Cemented by Hickerson Co. (Company or Individual)

9) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

10) PACKERS: Type Depth

11) TYPE PUMP:
☐ Turbin ☐ Jet ☑ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

12) WELL TESTS:
☐ Type Test: ☐ Pump ☑ Bailer ☐ Jetted ☐ Estimated
Yield: 20 gpm with ______ ft. drawdown after ______ hrs.

13) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable water? ☐ Yes ☑ No
If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? Fresh Depth of strata ______
Was a chemical analysis made? ☑ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief.

NAME R. N. Hickerson (Type or Print) Water Well Drillers Registration No. 1786

ADDRESS 3806 W. University (Street or RFD) Odessa (City) Texas (State) 79763 (Zip)

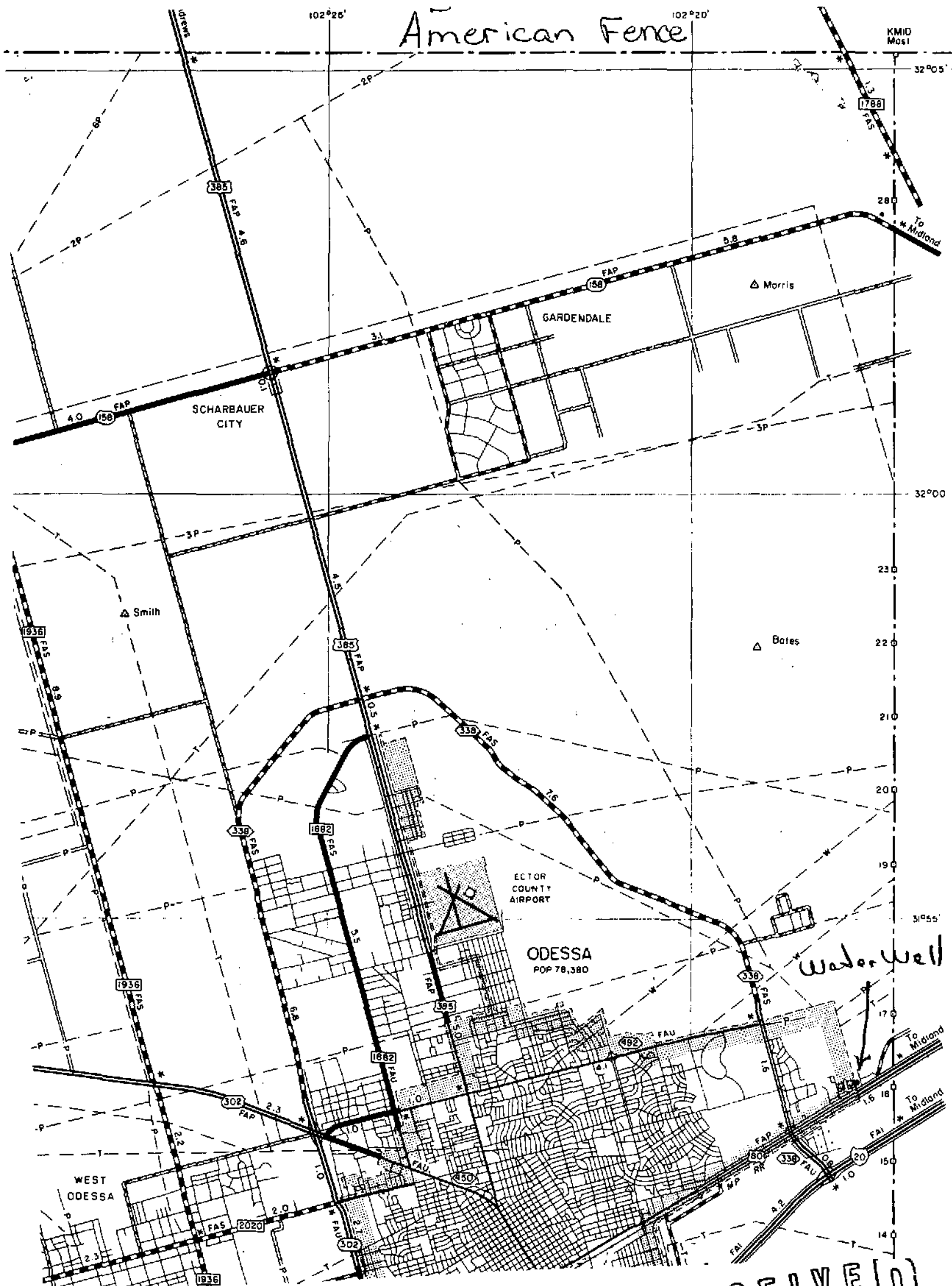
(Signed) R N Hickerson (Water Well Driller) Hickerson Drilling & Pump (Company Name)

Please attach electric log, chemical analysis, and other pertinent information, if available.

*Additional instructions on reverse side.

TDWR-0392

2) LOCATION OF WELL:



nay be

sections,
be indicated.

the

COUNTY

Texas Water Development Board
Well Schedule

State Well Number 45 06 813 Previous Well Number F-115 County ECTOR 135

River Basin COLORADO 14 Zone 1 Latitude 315302 Longitude 102 17 32 Coordinates Accuracy 3

Owner's well No. ______ Location: ______ 1/4, ______ 1/4, Section 21 Block 41 Survey T, 2S

Owner ODESSA COUNTRY CLUB Driller HINES WATER WELL CO.

Address ______ Tenant/Oper. ______

Date Drilled 1946 Depth 115 Source of Depth A Altitude 2882 Source of Alt. Data M

Aquifer ANTLERS 218ALRS Aquifer ID 13 Well Type W User ______

Well Construction Const Method ______ Casing Material ______
Completion Method ______ Screen Material ______

Casing or Blank Pipe (C) Well Screen or Slotted Zone (S) Open Hole (O) Cemented from ___ to ___			
	Diam. (in.)	Interval of C,S, or O. From	To
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

Lift Data Pump Mfr. ______ Type of Lift TURBINE T Pump Depth Setting (ft) ______ ft.
Motor Mfg ______ Power ELECT E H.P. ______

Yield Flow Rate ______ Pump Rate ______ GPM Circle how rate was determined Meas Rept Est Date of Test ______

Performance Test Length of test ______ hr Production Rate ______ GPM Circle how rate was determined Meas Rept Est Date of Test ______

Static Level ______ ft. Pumping Level ______ ft. Amount of Drawdown ______ ft. Specific Capacity ______ GPM/ft.

Water Use Primary IRR I Secondary ______ Tertiary ______

Water Quality (Remarks: ______

Other Data Available Water Level M Water Quality N Logs ______ Other Data ______

Water Levels
Date 12 13 1947 Meas. 47.10 Remarks ______ M.P. +/- ______
Date ______ Meas. ______ Remarks ______
Date ______ Meas. ______ Remarks ______

Recorded by ______ Date Record Collected or Information Updated 1947 Reporting Agency D2

Remarks
1 WELL F-115 IN B5210
2
3
4
5
6

218ALRS
Aquifer

45-06-813
Well Number

Form at: V:/HEMon/Share/forms/WellSchedule

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer TRINITY SS   Field No. ________   State Well No. 45-06-808

Owner's Well No. ________   County ECTOR

1. Location: ___ 1/4, ___ 1/4 Sec. ___, Block ___ Survey ___

2. Owner: SUNSET MEMORIAL GARDENS Address:

Tenant: ________ Address: ________

Driller: ________ Address: ________

3. Elevation of ________ is ____ ft. above msl, determined by ________

4. Drilled: 19 old; Dug, Cable Tool, Rotary,

5. Depth: Rept. ____ ft. Meas. 101.5 ft.

6. Completion: Open Hole, Straight Wall, Underreamed, Gravel Packed Surf Casing

7. Pump: Mfgr. ________ Type NONE

No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.

Column Diam. ____ in., Length Tailpipe ____ ft.

8. Motor: Fuel ____ Make & Model ____ HP. ____

9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est. ____

10. Performance Test: Date ____ Length of Test ____ Made by ____

Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.

E-LINE Production ____ gpm Specific Capacity ____ gpm/ft.

11. Water Level: 62.45 ft. rept. meas. 4-16 1974 above below Top of CASING which is 0 ft. above below surface.

____ ft. rept. meas. ____ 19 ____ above below ____ which is ____ ft. above below surface.

____ ft. rept. meas. ____ 19 ____ above below ____ which is ____ ft. above below surface.

____ ft. rept. meas. ____ 19 ____ above below ____ which is ____ ft. above below surface.

12. Use: Dom., Stock, Public Supply, Ind., Irr., Waterflooding, Observation, Not Used

13. Quality: (Remarks on taste, odor, color, etc.) ________

Temp. ___ °F, Date sampled for analysis ________ Laboratory ________

Temp. ___ °F, Date sampled for analysis ________ Laboratory ________

Temp. ___ °F, Date sampled for analysis ________ Laboratory ________

14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log,

Formation Samples, Pumping Test, ________

15. Record by: John Derton Date 4-16 1974

Source of Data OBSERVATION

16. Remarks: SQUARE CEMENT SLAB AROUND WELL

WELLS IN USE AT SUNSET MEMORIAL GARDENS

ARE SAID to be pumping most of the TIME.

CASING & BLANK PIPE

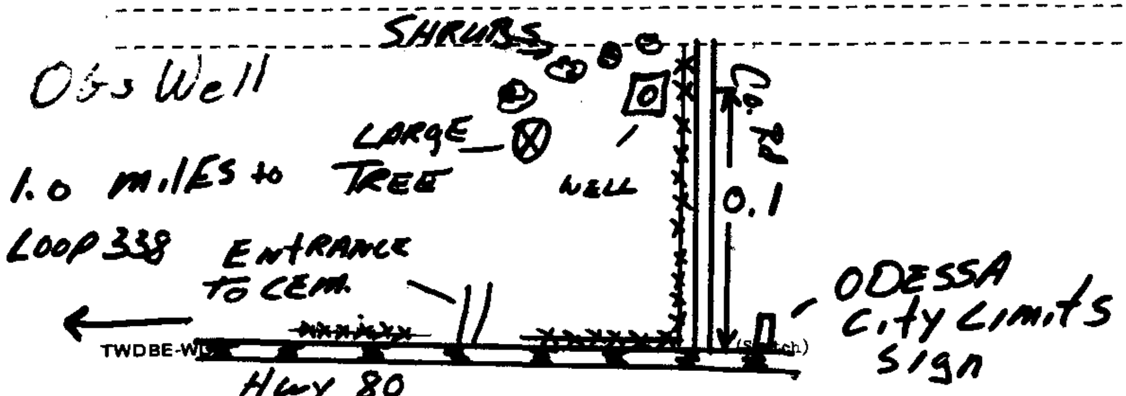
Cemented From ____ ft. to ____ ft.

Diam. (in.)	Type	Setting, ft. from	to
5 1/8	STEEL	0	5

WELL SCREEN

Screen Openings ____

Diam. (in.)	Type	Setting, ft. from	to



TWDBE-W

Texas Water Development Board
Well Schedule

State Well Number 45 06 911 Previous Well Number F 113 County ECTOR 135

River Basin COLORADO 14 Zone 1 Latitude 31 53 12 Longitude 102 17 27 Coordinates Accuracy 3

Owner's well No. ______ Location: ______ 1/4, ______ 1/4, Section 21 Block 41 Survey T.2S

Owner ODESSA COUNTRY CLUB Driller HINES WATER WELL CO.

Address ______ Tenant/Oper. ______

Date Drilled 1938 Depth 115 Source of Depth A Altitude 2879 Source of Alt. Data M

Aquifer ANTLERS 218ALRS Aquifer ID 13 Well Type W User ______

Well Construction Const Method ______ Casing Material ______
Completion Method ______ Screen Material ______

Lift Data Pump Mfr. ______ Type of Lift TURBINE T Pump Depth Setting (ft) ______ ft.
Motor Mfg ______ Power ELECT E H.P. ______

Yield Flow Rate ______ Pump Rate ______ GPM (Circle how rate was determined) Meas Rept Est Date of Test ______

Performance Test Length of test ______ hr Production Rate ______ GPM (Circle how rate was determined) Meas Rept Est Date of Test ______
Static Level ______ ft. Pumping Level ______ ft. Amount of Drawdown ______ ft. Specific Capacity ______ GPM/ft.

Water Use Primary IRRIGAT I Secondary ______ Tertiary ______

Water Quality (Remarks: ______

Other Data Available Water Level M Water Quality N Logs ______ Other Data ______

Water Levels
Date 12 13 1947 Meas. 37.20 Remarks ______ M.P. +/- ______
Date ______ Meas. ______ Remarks ______
Date ______ Meas. ______ Remarks ______

Recorded by ______ Date Record Collected or Information Updated 1947 Reporting Agency D2

Casing or Blank Pipe (C), Well Screen or Slotted Zone (S), Open Hole (O); Cemented from ___ to ___	Diam. (in.)	Interval of C,S, or O. From	To
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

Remarks
1 WELL F-113 IN B5210
2
3
4
5
6

218ALRS
Aquifer

45-06-911
Well Number

Form at: V:/HEMon/Share/forms/WellSchedule

STATE OF TEXAS WELL REPORT for Tracking #347507

Owner:	**Permian Home**	Owner Well #:	**No Data**
Address:	**P.O.box 12025 Odessa , TX 79768**	Grid #:	**45-06-8**
Well Location:	**No Data**	Latitude:	**31° 53' 20" N**
Well County:	**Ector**	Longitude:	**102° 17' 31" W**
Elevation:	**No Data**	GPS Brand Used:	**garmin**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/18/2013** Completed: **10/18/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 120 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 120 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **water** Cemented By: **Abe Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**MONTE MOORE DRILLING 1313 N.HWY.137 LAMESA , TX 79331**
Driller License Number:	**58699**
Licensed Well Driller Signature:	**Abraham Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a

written request to do so from the owner.

Please include the report's Tracking number (Tracking #**347507**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-58 sandy clay
58 -75 red clay
75 -115 sandy clay
115-120 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6 new plastic blank 0-80
screen 80-120 .035 gauge

STATE OF TEXAS WELL REPORT for Tracking #347506

Owner:	**Permian Home**	Owner Well #:	**No Data**
Address:	**P.O.box 12025** **Odessa , TX 79768**	Grid #:	**45-06-8**
Well Location:	**No Data**	Latitude:	**31° 53' 23" N**
Well County:	**Ector**	Longitude:	**102° 17' 35" W**
Elevation:	**No Data**	GPS Brand Used:	**garmin**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/18/2013** Completed: **10/18/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **water** Cemented By: **Abe Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**MONTE MOORE DRILLING** **1313 N.HWY.137** **LAMESA , TX 79331**
Driller License Number:	**58699**
Licensed Well Driller Signature:	**Abraham Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a

written request to do so from the owner.

Please include the report's Tracking number (Tracking #**347506**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-58 sandy clay
58 -75 red clay
75 -110 sandy clay
110-115 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6 new plastic blank 0-75
screen 75-115 .035 gauge

STATE OF TEXAS WELL REPORT for Tracking #238794

Owner:	**Interstate Treating**	Owner Well #:	**No Data**
Address:	**P. O. Box 1386** **Odessa , TX**	Grid #:	**45-06-9**
Well Location:	**741 Club Drive** **Odessa , TX**	Latitude:	**31° 53' 16" N**
Well County:	**Ector**	Longitude:	**102° 17' 25" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **2/1/2007** Completed: **2/1/2007**
Diameter of Hole:	Diameter: **8.5 in From Surface To 114 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **94 ft to 114 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 15 ft with 5 Cement (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **100+ ft** Distance to Property Line: **150 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **30 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling Company** **4223 W. 16th Street** **Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ron R. Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**$dfs**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the

well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#238794**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 Top Soil
2-30 Caliche
30-60 Dry Sand
60-73 Wet Sand
73-87 False Red Bed
87-94 Wet Sand
94-113 Water Sand
113-114 Red Bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0 94
5 New PVC Slotted 94 114

68

Please use black ink.
Send original copy by certified mail to the Texas Water Commission
P.O. Box 13087
Austin, Texas 78711

State of Texas
WATER WELL REPORT

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

Texas Water Well Drillers Board
P. O. Box 13087
Austin, Texas 78711

1) OWNER Sunset Memorial Gardens (Name) Address East Hwy 80 (Street or RFD) Odessa (City) Texas (State) (Zip)

2) LOCATION OF WELL:
County Ector ______ miles in ______ (N.E., S.W., etc.) direction from ______ (Town)

Driller must complete the legal description to the right with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

☐ Legal description:
Section No. ______ Block No. ______ Township ______
Abstract No. ______ Survey Name ______
Distance and direction from two intersecting section or survey lines ______

☞ See attached map. /

3) TYPE OF WORK (Check): [X] New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☐ Domestic [X] Industrial ☐ Monitor ☐ Public Supply ☐ Irrigation ☐ Test Well ☐ Injection ☐ Other ______

5) DRILLING METHOD (Check): ☐ Driven ☐ Mud Rotary ☐ Air Hammer ☐ Jetted ☐ Bored [X] Air Rotary ☐ Cable Tool ☐ Other ______

6) WELL LOG:
Date Drilling:
Started March 31 1988
Completed ______ 19___

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	

7) BOREHOLE COMPLETION:
☐ Open Hole ☐ Straight Wall ☐ Underreamed
[X] Gravel Packed ☐ Other ______
If Gravel Packed give interval . . . from 40 ft. to 99 ft.

From (ft.)	To (ft.)	Description and color of formation material
0	11	Top Soil
11	16	Clay
16	40	Limestone
40	63	Sand & Gravel
63	65	Limestone
65	95	Sand & Gravel
95	99	Red BEd

(Use reverse side if necessary)

RECEIVED
JUL 22 1988
TEXAS WATER COMMISSION

8) CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mgf., if commercial	Setting (ft.) From	To	Gage Casing Screen
5		Perf	59	99	1/8
		Plain	0	59	

9) CEMENTING DATA [Rule 319.44(b)]
Cemented from 0 ft. to 10 ft. No. of Sacks Used 3
______ ft. to ______ ft. No. of Sacks Used ______
Method used Poured Slurry
Cemented by Bernard Brockman

10) SURFACE COMPLETION
[X] Specified Surface Slab Installed [Rule 319.44(c)]
☐ Pitless Adapter Used [Rule 319.44(d)]
☐ Approved Alternative Procedure Used [Rule 319.71]

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) WELL TESTS:
Type Test: ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable water? ☐ Yes ☐ No
If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 12 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Hickerson Drlg & Pump (Type or Print) Water Well Driller's License No. 02497W

ADDRESS 3806 West University (Street or RFD) Odessa (City) Texas (State) 79764 (Zip)

(Signed) Bernard Brockman (Licensed Water Well Driller) (Signed) ______ (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

For TWC use only
Well No. 45-06-9
Located on map ______

WWD-012 (Rev.01-28-87) TEXAS WATER COMMISSION COPY

A N D R E W S C O U N T Y
C R A N E C O U N T Y
U P T O N C O U N T Y
GOLDSMITH
GARDENDALE
NORTH COWDEN
ODESSA
WEST ODESSA
PENWELL
PLEASANT FARMS
A
B
Sunset Memo
NOTICE
KEY TO SUPPLEMENTARY SHEETS

Texas Water Development Board
Well Schedule

State Well Number 45 06 910 Previous Well Number F112 County ECTOR 135

River Basin COLORADO 14 Zone 1 Latitude 315319 Longitude 1021727 Coordinates Accuracy 3

Owner's well No. ______ Location: ______ 1/4, ______ 1/4, Section 21 Block 41 Survey T&2S

Owner ODESSA COUNTRY CLUB Driller HINES WATER WELL CO.

Address ______ Tenant/Oper. ______

Date Drilled 1938 Depth 115 Source of Depth A Altitude 2875 Source of Alt. Data M

Aquifer ANTLERS 218ALRS Aquifer ID 13 Well Type W User ______

Well Construction Const Method ______ Casing Material ______

Completion Method ______ Screen Material ______

Lift Data Pump Mfr. ______ Type of Lift TURBINE T Pump Depth Setting (ft) ______ ft.

Motor Mfg ______ Power ELECT E H.P. ______

Yield Flow Rate ______ Pump Rate ______ GPM Meas Rept Est (Circle how rate was determined) Date of Test ______

Performance Test Length of test ______ hr Production Rate ______ GPM Meas Rept Est (Circle how rate was determined) Date of Test ______

Static Level ______ ft. Pumping Level ______ ft. Amount of Drawdown ______ ft. Specific Capacity ______ GPM/ft.

Water Use Primary ADMESTIC H Secondary ______ Tertiary ______

Water Quality (Remarks: ______

Other Data Available Water Level N Water Quality N Logs ______ Other Data ______

Water Levels

Date ______ Meas. ______ Remarks ______ M.P. +/- ______

Date ______ Meas. ______ Remarks ______

Date ______ Meas. ______ Remarks ______

Recorded by ______ Date Record Collected or Information Updated 1948 Reporting Agency D2

Casing or Blank Pipe (C)
Well Screen or Slotted Zone (S)
Open Hole (O)
Cemented from ______ to ______

	Diam. (in.)	Interval of C, S, or O. From	To
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

Remarks
1 WELL F-112 IN B5210
2
3
4
5
6

218ALRS
Aquifer

45-06-910
Well Number

Form at: V:/HEMon/Share/forms/WellSchedule

Send original copy by certified return receipt requested n TNRCC, MC 177, P.O. Box 13087, Austin, TX 78711-308

ATTENTION OWNER: *Confidentiality Privilege Notice on on reverse side of Well Owner's copy (pink)*

State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
MC 177
P.O. Box 13087
Austin, TX 78711-3087
512-239-0530

1) OWNER Odessa Country Club (Name) ADDRESS 7184 Club Dr. (Street or RFD) Odessa (City) TX (State) 79762 (Zip)

2) ADDRESS OF WELL: County Ector Bankhead Rd. (Street, RFD or other) Odessa (City) TX (State) (Zip) GRID # 2/5-14-2

3) TYPE OF WORK (Check): [X] New Well [ ] Deepening [ ] Reconditioning [ ] Plugging

4) PROPOSED USE (Check): [ ] Monitor [ ] Environmental Soil Boring [ ] Domestic [ ] Industrial [X] Irrigation [ ] Injection [ ] Public Supply [ ] De-watering [ ] Testwell
If Public Supply well, were plans submitted to the TNRCC? [ ] Yes [ ] No

5) N

6) WELL LOG:
Date Drilling:
Started 5-27 19 97
Completed 5-27 19 97

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
	Surface	
8 1/2		

7) DRILLING METHOD (Check): [ ] Driven [X] Air Rotary [ ] Mud Rotary [ ] Bored [ ] Air Hammer [ ] Cable Tool [ ] Jetted [ ] Other ______

From (ft.)	To (ft.)	Description and color of formation material
0	4	Sand
4	8	Caliche
8	12	Limestone
12	20	Caliche Rocks
20	25	Shale
25	50	Pack Sand
50	55	Red Shale
55	75	Sand & gravel
75	80	Shale
80	112	Sand & gravel
112	113	Shale
113	114	Red Bed

(Use reverse side of Well Owner's copy, if necessary)

8) Borehole Completion (Check): [ ] Open Hole [ ] Straight Wall [ ] Underreamed [X] Gravel Packed [ ] Other ______
If Gravel Packed give interval ... from 80 ft. to 114 ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
5	N	Plain Plastic	0	94	
5	N	Perf	94	114	1/8

9) CEMENTING DATA [Rule 338.44(1)]
Cemented from 0 ft. to 20 ft. No. of sacks used 2
______ ft. to ______ ft. No. of sacks used ______
Method used Poured Slurry
Cemented by WTWWS
Distance to septic system field lines or other concentrated contamination ______ ft.
Method of verification of above distance None

13) TYPE PUMP: [ ] Turbine [ ] Jet [ ] Submersible [ ] Cylinder [ ] Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

10) SURFACE COMPLETION
[ ] Specified Surface Slab Installed [Rule 338.44(2)(A)]
[X] Specified Steel Sleeve Installed [Rule 338.44(3)(A)]
[ ] Pitless Adapter Used [Rule 338.44(3)(b)]
[ ] Approved Alternative Procedure Used [Rule 338.71]

14) WELL TESTS:
Type test: [ ] Pump [ ] Bailer [ ] Jetted [ ] Estimated
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

RECEIVED
JUL 08 1997
TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
[ ] Yes [X] No If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? [ ] Yes [ ] No

12) PACKERS: Type Depth

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME West Texas Water Well Service (Type or print) WELL DRILLER'S LICENSE NO. 2497W

ADDRESS 3432 W. University (Street or RFD) Odessa (City) TX (State) 79764 (Zip)

(Signed) Bernard Brahm (Licensed Well Driller) (Signed) ______ (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 05-21-96) *White - TNRCC* *Yellow - DRILLER* *Pink - WELL OWNER*

STATE OF TEXAS WELL REPORT for Tracking #347505

Owner:	**Permian Home**	Owner Well #:	**No Data**
Address:	**P.O.box 12025 Odessa , TX 79768**	Grid #:	**45-06-8**
Well Location:	**No Data**	Latitude:	**31° 53' 22" N**
Well County:	**Ector**	Longitude:	**102° 17' 30" W**
Elevation:	**No Data**	GPS Brand Used:	**garmin**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/17/2013** Completed: **10/17/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **water** Cemented By: **Abe Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**MONTE MOORE DRILLING 1313 N.HWY.137 LAMESA , TX 79331**
Driller License Number:	**58699**
Licensed Well Driller Signature:	**Abraham Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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written request to do so from the owner.

Please include the report's Tracking number (Tracking #**347505**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-58 sandy clay
58 -75 red clay
75 -110 sandy clay
110-115 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6 new plastic blank 0-75
screen 75-115 .035 gauge

STATE OF TEXAS WELL REPORT for Tracking #347504

Owner:	**Permian Home**	Owner Well #:	**No Data**
Address:	**P.O.box 12025** **Odessa , TX 79768**	Grid #:	**45-06-9**
Well Location:	**No Data**	Latitude:	**31° 53' 21" N**
Well County:	**Ector**	Longitude:	**102° 17' 27" W**
Elevation:	**No Data**	GPS Brand Used:	**garmin**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/17/2013** Completed: **10/17/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **water** Cemented By: **Abe Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**MONTE MOORE DRILLING** **1313 N.HWY.137** **LAMESA , TX 79331**
Driller License Number:	**58699**
Licensed Well Driller Signature:	**Abraham Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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written request to do so from the owner.

Please include the report's Tracking number (Tracking #**347504**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-58 sandy clay
58 -75 red clay
75 -110 sandy clay
110-115 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6 new plastic blank 0-75
screen 75-115 .035 gauge

STATE OF TEXAS WELL REPORT for Tracking #347788

Owner:	**Permian Homes**	Owner Well #:	**No Data**
Address:	**P.O. BOX.12025** **Odessa , TX 79768**	Grid #:	**45-06-8**
Well Location:	**No Data**	Latitude:	**31° 53' 25" N**
Well County:	**Ector**	Longitude:	**102° 17' 35" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/18/2013** Completed: **10/18/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Water** Cemented By: **Peter Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Monte Moore Drilling** **1313 N Hwy 137** **Lamesa , TX 79331**
Driller License Number:	**58700**
Licensed Well Driller Signature:	**Peter Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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written request to do so from the owner.

Please include the report's Tracking number (Tracking #**347788**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-55 sandy clay
55-75 red clay
75-111 sandy clay
111-115 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" New Plastic 0-75 blank
75-115 Slotted .035

10/10/2014 Texas Commission on Environmental Quality
10:10:58 DWW Water System Summary Sheet

PWS ID	PWS Name	Central Registry RN
TX0680072	NEW LIFE CHURCH	RN101210565

Organization/Customer *	Central Registry CN
NEW LIFE CHURCH OF CHRIST	

*Regulatory mail will be addressed to this organization/person

All Water System Contacts

Type	Contact	Communication	
		Phone Type	**Value**
AC - Administrative Contact	HALSTEAD, TIM 1021 SAWDUST RD SPRING, TX 77380	BUS - Business	432-272-5556
		MOB - Mobile	432-230-9311
OW - Owner	NEW LIFE CHURCH OF CHRIST 2817 JBS PKWY STE E3 ODESSA, TX 79762-8160		

Operator Grade	Number

Water Operator Licenses

No Licensing Data for this PWS

Owner Type	Owner Type Options: COUNTY, DISTRICT, FEDERAL GOVERNMENT, INVESTOR OWNED, MUNICIPALITY, NATIVE AMERICAN, PRIVATE, STATE GOVERNMENT, WATER SUPPLY CORPORATION
Private	

System Type	System Type Options: COMMUNITY, TRANSIENT/NON-COMMUNITY, NON-PUBLIC, NON-TRANSIENT/NON-COMMUNITY
NP - NON-PUBLIC	

Population Type	Population Served	# of Connect	# I/C w/other PWS
NonResidential	300	1	0

Total Product (MGD)	Average Daily Consump.	Max Daily Demand (MGD)	Total Storage (MG)	Elev. Storage (MG)	Service Pump Cap.	Max.Purchase Cap. (MGD/GPM)	Pressure Tank Cap. (MG)

Activity Status	Deactivation Date	Reason
I - INACTIVE	09/11/2006	

Last Survey Date	Surveyor	Survey Type	Region	County
02/15/2006	LINDSEY, D BUCKNER	Sanitary Survey	ODESSA	ECTOR
01/29/2003	CYNTHIA, D WILLIAMS	Sanitary Survey	ODESSA	ECTOR
No Site Visit Data				

(Treatment Plant)							
Entry Point	EP Name/Source Summation (Activity Status)	Plant Name (Activity Status)	Plant Num	Chemical Mon Type	Chem Sample Point	Distribution Mon Type	Dist Sample Point
EP001	TRT-TAP / No Source Listed(I)	PLANT(I)	TP3256		NO		NO

Train:	Unnamed

(Treatments)				
Disinfection Zone	Treatment Sequence	Objective	Process	Treatment
null	null	D	423	HYPOCHLORINATION, PRE

(Active Sources)

(Inactive/Offline Sources)			
SourceNumber	Name	Status	Depth
G0680072C	3 - 600' SE OF CLUB HOUSE	P	112
G0680072A	1 - STORAGE	O	130
G0680072D	4 - 300' E OF CLUB HOUSE	O	114
G0680072B	2 - 300' S OF STORAGE	O	130

Code Explanations
Monitoring Type Codes: (GW) GROUNDWATER , (GUP) GROUNDWATER UNDER THE INFLUENCE - PURCHASED , (SWP) SURFACE WATER - PURCHASED , (GU) GROUNDWATER UNDER THE INFLUENCE OF SURFACE WATER , (N) NO SOURCES , (SW) SURFACE WATER
Activity Status Codes: (A) ACTIVE , (D) DELETED/DISSOLVED , (I) INACTIVE , (P) PROPOSED ,
Operational Status Codes: (E) EMERGENCY , (I) INTERIM/PEAK (O) OTHER , (P) PERMANENT , (S) SEASONAL
Source Types: (G) GROUND WATER , (S) SURFACE WATER , (U) GROUND WATER UNDER THE INFLUENCE

- End of Report -

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt   Field No. D   State Well No. JH 45-06-905
Owner's Well No. ____   County Ector

1. Location: SE 1/4 NW 1/4 Sec. 21, Block 41 Survey T&PRR Co. T-2-S

2. Owner: Odessa Country Club   Address: Box 346, Odessa, TX.
Tenant: do   Address:
Driller: unknown   Address:

3. Elevation of LSD @ well is 2874 ft. above msl, determined by Topo

4. Drilled: unknown 19__; Dug, (Cable Tool) Rotary,

5. Depth: Rept. 130-135 ft. Meas. NMT ft. 9-9-70

6. Completion: Open Hole, Straight Well, Underreamed, Gravel Packed

7. Pump: Mfgr. Reda   Type Subm
No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.
Column Diam. ____ in., Length Tailpipe ____ ft.

8. Motor: Fuel Electric Make & Model ____ HP. 1 1/2

9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est.

10. Performance Test: Date ____ Length of Test ____ Made by ____
Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.
Production ____ gpm Specific Capacity ____ gpm/ft.

CASING & BLANK PIPE

Cemented From ____ ft. to ____ ft.

Diam. (in.)	Type	Setting, ft. from	to
8 5/8	Steel Surf Csg only		

11. Water Level: NMT ft. rept./meas. 9-9-1970 above/below ____ which is ____ ft. above/below surface.
____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.
____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.
____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

12. Use: Dom., Stock, Public Supply, Ind., (Irr.) Waterflooding, Observation, Not Used,

13. Quality: (Remarks on taste, odor, color, etc.)
Temp. ___ °F, Date sampled for analysis ____ Laboratory ____
Temp. ___ °F, Date sampled for analysis ____ Laboratory ____
Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log,
Formation Samples, Pumping Test,

15. Record by: D. Corley   Date 9-9-1970
Source of Data Horace Taylor & obs.

16. Remarks: Well is S-SE of Club Hse About 200 Ft. Well pumping. [illegible]

WELL SCREEN

Screen Openings ____

Diam. (in.)	Type	Setting, ft. from	to
	unknown		

TWDBE-GW-49   (Sketch)

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt   Field No. C   State Well No. JM 45-06-804

Owner's Well No. South-West   County Ector

200 ft. From Oil Well

1. Location: NE 1/4, NE 1/4 Sec. 20, Block 41 Survey T&PRR Co. T-2-S

2. Owner: Sunset Memorial Gardens Address: Odessa, Tx

Tenant: Address:

Driller: unknown Address:

3. Elevation of LSD @ well is 2882 ft. above msl, determined by Topo

4. Drilled: 19 54-55, Dug, Cable Tool, Rotary,

5. Depth: Rept. 110-116 ft. Meas. NMT ft. 9-4-70

6. Completion: Open Hole, Straight Wall, Underreamed, Gravel Packed

7. Pump: Mfgr. Reda Type Subm

No. Stages, Bowls Diam. in., Setting ft.

Column Diam. in., Length Tailpipe ft.

8. Motor: Fuel Electric Make & Model HP. 3/4

9. Yield: Flow gpm, Pump gpm, Meas., Rept., Est.

10. Performance Test: Date Length of Test Made by

Static Level ft. Pumping Level ft. Drawdown ft.

Production gpm Specific Capacity gpm/ft.

CASING & BLANK PIPE

Cemented From ft. to ft.

Diam. (in.)	Type	Setting, ft. from	to
6	steel	0	70

11. Water Level: NMT ft. rept./meas. 9-4-1970 above/below which is ft. above/below surface.

ft. rept./meas. 19 above/below which is ft. above/below surface.

ft. rept./meas. 19 above/below which is ft. above/below surface.

ft. rept./meas. 19 above/below which is ft. above/below surface.

12. Use: Dom., Stock, Public Supply, Ind., (Irr), Waterflooding, Observation, Not Used,

13. Quality: (Remarks on taste, odor, color, etc.)

Temp. 77 °F, Date sampled for analysis 9-4-70 Laboratory SHD

Temp. °F, Date sampled for analysis Laboratory

Temp. °F, Date sampled for analysis Laboratory

14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log, Formation Samples, Pumping Test,

15. Record by: D. Corley Date 9-4-1970

Source of Data Mr. Hoback & obs.

16. Remarks: Well Pumping

SPC 77°F @ 1250 mmhos

WELL SCREEN

Screen Openings

Diam. (in.)	Type	Setting, ft. from	to
	unknown		

(Sketch)

88
804

TWDBE-GW-49

Texas Water Development Board

Chemical Water Analysis Report

GWR- MB - 1993 - 988
(Anions)

TWDB Use Only
Work No. 320-11220
IAC No.

Send Reply To:
Ground Water Unit
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711

Attention: PHIL NORDSTROM

State Well Number: 45-06-804

County: ECTOR

Date & Time: 5-17-93 @ 1050

Owner: SUNSET MEMORIAL GARDENS

☑ Send Copy To Owner

Address: 6801 E. HWY 80 ODESSA 79762

Sampled After Pumping: 1/2 Hours

Date Drilled: 1955 Depth: 116

Yield: ____ GPM ☐ Measured ☐ Estimated

Collection Point: FAUCET @ WELLHEAD pH 7.04

Use: IRRIGATION Temperature: 20.5 °C

By: BIRI

Specific Conductance: 4810

Requested Chemical Analysis

Laboratory No.: [redacted] Date Received: MAY 21 1993 Date Reported: JUN 07 1993

THD-Sample No. EB3 1100 Date Received 05/21/93 Date Reported 06/04/93

		MEQ/L	MG/L
Silica	(00955)		51
Sulfate	(00946)	16.90	811
Chloride	(00941)	31.25	1108
Fluoride	(00950)	0.07	1.40
P.Akalinity	(00415)	0.00	0
T.Akalinity	(00410)	4.82	241

** Convert mg/l Boron to µg/l for data entry.*

890091-C
July 1991

Water Quality Sampling Run

SWN: 45-06-804
County: ECTOR
Aquifer(s): 218ALRS

Name: SUNSET MEMORIAL GARDENS
Address: 6801 E. HWY 80
ODESSA 79762

Sample No. 988
Date: 5-17-93
By: BIRI

	Bottle 1	Bottle 2	Bottle 3	Bottle 4	Bottle 5	Bottle 6	Bottle 7	Total SUB-Samples
	1 liter Anions	1 liter Cations	1 liter Radioactivity	500 ml Nitrate	1 Qt.(glass) (TOC)Organics			
Preserve with:		2 ml HNO_3 (Nitric)	2 ml HNO_3 (Nitric)	1 ml H_2SO_4 (Sulfuric)				All filtered unless otherwise stipulated. All on ice.

Water Level UTM LSD Remark

Temperature (00010) 20.5 c

Specific Conductance (00094) 4810 umhos/cm

pH (00400) 7.04

Eh (00090) +85.5 mv.

Phenol ALK (82244) 0 mg/l

Total ALK (39086) 239.6 mg/l

Carbonate (00452) meq/l 0 mg/l

Bicarbonate (00453) meq/l 292.3 mg/l

Total Cations(+)

Total Anions (-)

Total Hardness (46570) 1320

Dissolved Solids(70301) 3310

Time in: 1000
Time out: 1125
Weather 10 MPH WIND
Outside Temp: 80°F
Sampling point: @ FAUCET @ WELLHEAD

Starting pH 7.14
11.98 ml. of 0.02N to
50 ml. of Sample
Ending pH 4.50

Time:	1025	1031	1037	1043	1049	
pH:	7.01	7.03	7.04	7.03	7.04	
Temp:	20.8	20.8	20.6	20.5	20.5	
Eh:						
Cond.	4870	4930	4910	4850	4810	

ml.	pH	ml.	pH	ml.	pH
0	7.14	10.00	5.59		
1.00	6.96	10.50	5.49		
2.00	6.83	11.00	5.31		
3.00	6.70	11.25	5.20		
4.00	6.56	11.50	5.02		
5.00	6.40	11.70	4.77		
6.05	6.25	11.80	4.69		
7.00	6.08	11.90	4.58		
8.00	5.94	12.05	4.43		
9.00	5.77				

31°53'03"
102°17'55"

other notes: SUBM - ELECT

Well is between Rita Fuentes & Leon Marsh

owners well #2

Texas Water Development Board

Chemical Water Analysis Report

HM- MB .1993.988

HM = Heavy Trace and Alkaline-Earth Metals

TWDB Use Only

Work No. 320-11220

IAC No.

Send Reply To:
Ground Water Unit
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711

Attention: PHIL NORDSTROM

State Well Number: 45-06-804

County: ECTOR

Date & Time: 5-17-93 @ 1050

Owner: SUNSET MEMORIAL GARDENS

☑ Send Copy To Owner

Address:

Sampled After Pumping: ______ Hours

Date Drilled: ______ Depth: ______

Yield: ______ GPM ☐ Measured ☐ Estimated

Collection Point: ______ pH ______

Use: ______ Temperature: ______ °C

By: GIRI

Specific Conductance:

Requested Chemical Analysis

Laboratory No. [redacted]

Date Received: MAY 21 1993

Date Reported: AUG. 3 1993

		me/l	mg/l			me/l	mg/l
Calcium	(00915)		400	Sodium	(00930)		634
Magnesium	(00925)		77	Potassium	(00935)		15

		µg/l			µg/l
	(01106)		Manganese	(01056)	<0.5
Arsenic	(01000)	8.8		(71890)	
Barium	(01005)	33.6		(01062)	
	(01025)			(01145)	
	(01030)			(01075)	
Copper	(01040)	2.2	Strontium*	(01080)	4400
Iron	(01046)	9.6		(01085)	
Lead	(01049)	<5	Zinc	(01090)	5.5

* Do not analyze unless it is checked.
Note: Crossout those elements not to be analyzed.

890091-E

Texas Water Development Board

Chemical Water Analysis Report

GWN- MB - 1993-988

(Nitrogen Cycle)

TWDB Use Only	
Work No.	320-11220
IAC No.	

Send Reply To:
Ground Water Unit
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711

Attention: PHIL NORDSTROM

State Well Number: 45-06-804

County: ECTOR

Date & Time: 5-17-93 @ 1050

Owner: SUNSET MEMORIAL GARDENS

☑ Send Copy To Owner

Address:

Sampled After Pumping: ______ Hours

Date Drilled: ______ Depth: ______

Yield: ______ GPM ☐ Measured ☐ Estimated

Collection Point: ______ pH ______

Use: ______ Temperature: ______ °C

By: BIRI

Specific Conductance:

Requested Chemical Analysis

Laboratory No.: [redacted]

Date Received: MAY 21 1993

Date Reported: JUN 07 1993

mg/l

THD-Sample No. EB3 1079 Date Received 05/21/93 Date Reported 06/04/93

00623-	0.7	TKN as N mg/L
00608-	0.03	Ammonia as N mg/L
00613-	< 0.01	Nitrite as N mg/L
59.81 00618-	13.51	Nitrate as N mg/L

*Note: To convert NO_3-N to NO_3, multiply by 4.427.

890091-D

Texas Water Development Board

Chemical Water Analysis Report

RAD - MB . 1993 . 988

RAD = Radioactivity Sample

TWDB Use Only
Work No. 320-11220
IAC No.

Send Reply To:
Ground Water Unit
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711

Attention: PHIL NORDSTROM

State Well Number: 45-06-804

County: ECTOR

Date & Time: 5-17-93 @ 1050

Owner: SUNSET MEMORIAL GARDENS

☑ Send Copy To Owner

Address:

Sampled After Pumping: ______ Hours

Date Drilled: ______ Depth: ______

Yield: ______ GPM ☐ Measured ☐ Estimated

Collection Point: ______ pH ______

Use: ______ Temperature: ______ °C

By: BIRI

Specific Conductance:

Requested Chemical Analysis

Laboratory No.: [redacted]

Date Received: MAY 21 1993

Date Reported: JUL 23 1993

Alpha	(01503)	20±3	pCi/l
Beta	(03503)	49±6	pCi/l
	(09503)		pCi/l
	(81366)		pCi/l
	(11500)		pCi/l
	(26403)		pCi/l
	(22703)		pCi/l

* Do not analyze unless it is checked *yes*.

890091-F

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(soft pencil or black ink)
Do not use ball point pen

Texas Department of Health Laboratories
1100 West 49th Street
Austin, Texas 78756

TDWR ONLY

Program No. ______ Lab No. 01
Work No. 6040-410

CHEMICAL WATER ANALYSIS REPORT

RECEIVED JAN 31 '80 GW-TDWR

Send report to:

Data Collection and Evaluation Section
Texas Department of Water Resources
P.O. Box 13087
Austin, Texas 78711

County: 068 ECTOR
State Well No.: 45-06-804
Well No. ______
Date Collected: 07-11-79

Location: SOUTH-WEST, 200FT FROM OIL WELL NE 1/4, NE 1/4 SEC 20 BLK 41 T&P R.R. T-2-S
Sample No. ______ By C. CORNELIS

Source (type of well): SUBM Owner: SUNSET MEMORIAL GARDENS

Date Drilled: 1954-55 Depth: 115 ft. WBF: KCT

Producing intervals ______ Water level: 80 ft. Sample depth ______ ft.

Sampled after pumping: ON ARRIVAL hrs. Yield ______ GPM meas. est. Temperature: 071 °F ______ °C

Point of collection: TAP AT WELL Appearance: ☑ clear ☐ turbid ☐ colored ☐ other

Use: IRR. Remarks: MAIL: RT. 1, BOX 352 ODESSA, TEXAS 79763

(FOR LABORATORY USE ONLY)

CHEMICAL ANALYSIS

Laboratory No. C9 12514 Date Received JUL 17 1979 Date Reported AUG 24 '79

	MG/L	ME/L
Silica	36	
Calcium	111	5.53
Magnesium	14	1.17
Sodium	85	3.70
Total		10.40
☐ Potassium	4.0	.11
³☐ Manganese	.	
☐ Boron	.	
³☐ Total Iron	.	
☐ (other) ______ MG/L		

10.51

%Na ______
SAR ______
RSC ______

	MG/L	ME/L
Carbonate	0	.0
¹Bicarbonate (114)	232	3.81
Sulfate	120	2.50
Chloride	146	4.11
Fluoride	1.0	.0
Nitrate	19.8	0.32
pH	7.3	
Total		10.74
¹Dissolved Solids (residue at 180°C)		624
Phenolphthalein Alkalinity as $CaCO_3$		0
Total Alkalinity as $CaCO_3$ (3.81)		191
Total Hardness as $CaCO_3$ (6.70)		335

Specific Conductance (micromhos/cm³): 935
Diluted Conductance (micromhos/cm³): 8 x 148 = 1184

"☐" items will be analyzed if checked.

²Nitrogen Cycle

Ammonia - N	.
Nitrite - N	.
Nitrate - N	.
Organic Nitrogen	.

[1] The bicarbonate reported in this analysis can be converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure used in the computation of dissolved solids.
[2] Nitrogen cycle requires separate sample.
[3] Total Iron and Manganese require separate sample.

Analyst ______ Checked By ______

TDWR-0148 (Rev.7-78)

TWDBE-GW ONLY

Program No. ____

Proj. No. ____

CHEMICAL WATER ANALYSIS REPORT

Typewrite (Black ribbon) or Print Plainly
(soft pencil or black ink)
Do not use ball point pen

Texas State Department of Health Laboratories
1100 West 49th Street
Austin 5, Texas

Send report to:

Ground Water Division
Texas Water Development Board
P. O. Box 12386
Austin, Texas 78711

County: ECTOR

State Well No. JH 45-06-B804

Well No. Southwest

Date Collected: 9-4-70

By: D. CORLEY

Location: NE/4, NE/4, Sec 20, Blk 41, T&PRRCo. T-2-S

Source (type of well): SUBM Owner: Sunset Memorial Gardens

Date Drilled: 1954-55 Depth: 110-116 ft. WBF: K+

Producing intervals: — Water level: — ft.

Sampled after pumping: Several hrs. Yield: — GPM meas. est. Temperature: 77 °F °C

Point of collection: Faucet @ Well Appearance: Clear (clear - turbid - colored)

Use: IRR Remarks: Copy to: MR. HOBACK c/o Owner ODESSA, TEXAS.

FOR LABORATORY USE ONLY

KEY PUNCHED

CHEMICAL ANALYSIS

Laboratory No. 173652 Date Received: OCT 21 1970 Date Reported: NOV - 3 1970

	MG/L	ME/L		MG/L	ME/L
Silica	35		Carbonate		0
Calcium	149	7.43	Bicarbonate (117)	237	3.88
Magnesium	18	1.51	Sulfate	217	4.52
Sodium	94	4.09	Chloride	162	4.55
Total		13.03	Fluoride	1.4	
☐ Potassium			Nitrate	11	0.18
☐ Manganese		%Na	pH 7.4	Total	13.13
☑ Boron	0.6	SAR	1/Dissolved Solids (sum)	800	
☐ Total Iron		RSC	Phenolphthalein Alkalinity as $CaCO_3$	0	
☐ ____ (other)			Total Alkalinity as $CaCO_3$	(3.88)	194
			Total Hardness as $CaCO_3$	(8.94)	447

Specific Conductance (micromhos/cm3) 1200

Diluted Conductance (micromhos/cm3) 10 x 149

"☐" items will be analyzed if checked. 1490

Analyst ____

Total Iron requires separate sample.

Checked by ____

1/ The bicarbonate reported in this analysis is converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure is used in the computation of this sum.

TWDBE-GW-50

Typewrite (Black ribbon) or Print Plainly
(soft pencil or black ink)
Do not use ball point pen

Texas State Department of Health Laboratories
1100 West 49th Street
Austin, Texas 78756

TWDBE-GW ONLY
Program No. 6026
Proj. No.

CHEMICAL WATER ANALYSIS REPORT

Send report to:

Ground Water Data and Protection Division
Texas Water Development Board
P.O. Box 13087
Austin, Texas 78711

County JH ECTOR
State Well No. 45-06-804
Well No.
Date Collected 09-11-74
By C. CORNELIS

Location NE1/4 NE1/4 SEC 20 BLK 41 T&P RR Co TWP 2-S
Source (type of well) SUBM Owner SUNSET MEMORIAL GARDENS % JAMES SIMPSON BOX 12 ODESSA, TX
Date Drilled 1954-55 Depth 115 ft. WBF TRINITY
Producing intervals Water level 79 ft.
Sampled after pumping hrs. Yield GPM meas. est. Temperature 070 °F °C
Point of collection FAUCET AT WELL Appearance ☑ clear ☐ turbid ☐ colored ☐ other
Use IRR. Remarks

(FOR LABORATORY USE ONLY)

CHEMICAL ANALYSIS

Laboratory No. 276953 Date Received SEP 27 1974 Date Reported DEC - 5 1974

Constituent	MG/L	ME/L
Silica	33	
Calcium	100	5.00
Magnesium	7	0.56
Sodium	61	2.65
Total		8.21
☐ Potassium	.	
☐ Manganese	.	
☐ Boron	.	
3/☐ Total Iron	.	

%Na
SAR
RSC

☐ (other) MG/L

Constituent	MG/L	ME/L
Carbonate	0	.
Bicarbonate (114)	232	3.80
Sulfate	82	1.71
Chloride	92	2.59
Fluoride	1.5	.
Nitrate	18.0	0.29
pH	7.6	
Total		8.39

1/ Dissolved Solids (sum in MG/L)	510
Phenolphthalein Alkalinity as CaCO3	0
Total Alkalinity as CaCO3 (3.80)	190
Total Hardness as CaCO3 (5.56)	278

2/ Nitrogen Cycle

Ammonia - N	.
Nitrite - N	.
Nitrate - N	.
Organic Nitrogen	.

Specific Conductance (micromhos/cm3) 795

Diluted Conductance (micromhos/cm3) 7 x 130
910

"☐" items will be analyzed if checked.

1/ The bicarbonate reported in this analysis is converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure is used in the computation of this sum.
2/ Nitrogen cycle requires separate sample.
3/ Total Iron requires separate sample.

TWDBE-WD-1 (Rev. 1-25-72)

Analyst Checked By

Typewrite (Black ribbon) or Print Plainly
(soft pencil or black ink)
Do not use ball point pen

Texas Department of Health Laboratories
1100 West 49th Street
Austin, Texas 78756

TDWR ONLY
Organization No. 410 Lab No. 01
Work No. 6040

CHEMICAL WATER ANALYSIS REPORT

County 068 ECTOR
State Well No. 45-06-804
Well No.
Date Collected 6-27-85

Send report to:

Data Collection and Evaluation Section
Texas Department of Water Resources
P.O. Box 13087
Austin, Texas 78711

Owner Sunset Memorial Gardens Send copy to owner Sample No. By J.D. Jones
Address Rt 1 Box 352 Odessa Tx Well Location
Date Drilled 54-55 Depth 115 ft. WBF Trinity group (180) Source (type of well) Sub-m
Producing intervals Water level ft. Sample depth ft.
Sampled after pumping 5 min hrs. Yield GPM meas./est. Temperature 070 °F °C
Point of collection hose on faucet next to well Appearance ☐ clear ☐ turbid ☐ colored ☐ other
Use Irr. Remarks

(FOR LABORATORY USE ONLY)

Laboratory N[redacted]

CHEMICAL ANALYSIS

KEY PUNCHED

Date Received JUL 01 '85

Date Reported JUL 23 '85

WATER ANALYSIS

State Well No:45-06-804 Date:071785 Sample No:EW5-2829

	MG/L	ME/L		MG/L	ME/L
Silica:00955:	57		Carbonate:00445:	0	0
Calcium:00910:	152	7.60	Bicarbonate:00440:	224	3.68
Magnesium:00920:	33	2.74	Sulfate:00945:	376	7.83
Sodium:00929:	96	4.17	Chloride:00940:	106	2.99
Potassium:00937:	5	.13	Fluoride:00951:	2.2	.12
T.Cations		14.64	Nitrate:71850:	20.02	.32
Manganese:01055:		%Na	T. Anions		14.94
			pH:00403:	8.1	
Boron:01022:		SAR			
			180 deg TDS:70300:	984	
Total Iron:01045:		RSC	P. Alk.:00415:	0	
ther			T. Alk.:00410:	184	
(Specific Cond.:00095:		1150	T. Hardness:00900:	517	

luted Conductance (micromhos/cm3)
11 x155 =1705
items will be analyzed if checked.

Ammonia-N:00610:
Nitrite-N:00615:
Nitrate-N:00620:
OrganicNitrogen:00605:

3-0811 (Rev. 10-26-83)

WQ FY 2011

TWDB Water Quality Field Data Sheet

Newly Inventoried Well: N

SWN: 45-06-804
County: Ector
County Code: 135
Aquifer Code: 218AIRS
Aquifer Id: 13

Name: Sunset Memorial Gardens
Address: 6801 E Hwy 80
Odessa, Tx 79762

Attention: Bill Valley
Well Name or #:

ID Number: 1556
Date: 7/7/2011
Sampler(s): WS.

1	2	3	4	5	6	7	8	9	10	11
40 mL unfiltered	500 ml filtered	500 ml filtered	250 ml filtered	~~1L filtered~~	2L filtered					
Atrazine	**Cation**	**Anions/T. Alk.**	**Nitrate**	**Gross Alpha**	**Radium** (226/228)					
ICE	~~HNO3 by lab~~	ICE	ICE + H2SO4	HNO3 by lab	HNO3 by lab					

All acidified samples pH <2.0. (C14/C13 samples only: If natural pH<7, then add NaOH until pH is >7. If natural pH is ≥7, no NaOH required.)

Calibration Verification Readings

pH	7 =	7.00
	4 or 10 =	9.94
SLP = 97.		
Conductivity	500 =	537
	1000 =	1007
	2000 =	2040
	5000 =	5000

Time In: 9:45
Time Out:

Water Level:
W.L. remark:
M.P. =

Pumping time: PDA
Sampling Point: FAW

Well Use: I

FIELD G.P.S. readings

Lift: Sub
Latitude: checked
Power: E
Longitude: out

Casing Type:
Casing Size:

Sample Time: 10:10
Filter pressure: hand pump / line / spring

Field Alk. Titration (0.0200 N) H2SO4

6.85 Start pH 4.44 End pH
50 **mL Sample Size**
mL Acid Phenol (> 8.3)
15.7 mL Acid Total (to pH 4.5)
mL acid added x 20 = Alkalinity

30
14
314

Phenol Alkalinity (82244): mg/L
Total Alkalinity (39086): 314 mg/L
Colorimeter DO (00300): mg/L

Field Data entered into GWDB: yes / no
Balanced:

Water Quality Stabilization Parameters Table (At least 3 readings @ 5 min. intervals)

Time	9:55	10:00	10:05						
pH	6.73	6.72	6.72						
Celsius Temp.	21.1	21.0	21.0						
Conductivity	4420	4470	4470						

Notes:

CLIENT:	Texas Water Development Board	**Client Sample ID:**	45-06-804
Lab Order:	1107238	**Collection Date:**	7/7/2011 10:10:00 AM
Project:	TWDB Suite	**Matrix:**	GROUNDWATER
Lab ID:	1107238-012	**Tag No:**	1556

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS, DISSOLVED			**E200.7**			Analyst: **MV**
Calcium	374	0.20		mg/L	1	7/21/2011 11:53:52 AM
Magnesium	139	0.20		mg/L	1	7/21/2011 11:53:52 AM
Potassium	11.1	0.20		mg/L	1	7/21/2011 11:53:52 AM
Sodium	622	5.00		mg/L	10	7/21/2011 2:19:34 PM
ICP METALS, DISSOLVED			**E200.7**			Analyst: **MV**
Boron	1180	50		µg/L	1	7/21/2011 11:53:52 AM
Iron	< 50	50		µg/L	1	7/21/2011 11:53:52 AM
Strontium	7010	200		µg/L	10	7/21/2011 2:19:34 PM
ICPMS METALS, DISSOLVED			**E200.8**			Analyst: **SW**
Aluminum	< 4.0	4.0		µg/L	1	7/20/2011 12:10:17 AM
Antimony	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Arsenic	7.9	2.0		µg/L	1	7/20/2011 12:10:17 AM
Barium	29.7	1.0		µg/L	1	7/20/2011 12:10:17 AM
Beryllium	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Cadmium	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Chromium	4.1	1.0		µg/L	1	7/20/2011 12:10:17 AM
Cobalt	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Copper	3.1	1.0		µg/L	1	7/20/2011 12:10:17 AM
Lead	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Lithium	247	2.0	A	µg/L	1	7/20/2011 12:10:17 AM
Manganese	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Molybdenum	3.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Selenium	12.9	4.0		µg/L	1	7/20/2011 12:10:17 AM
Silver	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Thallium	< 1.0	1.0		µg/L	1	7/20/2011 12:10:17 AM
Uranium	21.9	1.0	A	µg/L	1	7/20/2011 12:10:17 AM
Vanadium	30.6	1.0		µg/L	1	7/20/2011 12:10:17 AM
Zinc	11.8	4.0		µg/L	1	7/20/2011 12:10:17 AM
MERCURY, TOTAL			**SW7470A**			Analyst: **AE**
Mercury	< 0.200	0.200		µg/L	1	7/14/2011 2:32:00 PM
DISSOLVED ANIONS BY ION CHROMATOGRAPH			**E300.0**			Analyst: **JB**
Bromide Dissolved	4.03	0.50		mg/L	25	7/12/2011 9:04:00 AM
Chloride Dissolved	1330	25.0		mg/L	25	7/12/2011 9:04:00 AM
Fluoride Dissolved	2.28	0.25		mg/L	25	7/12/2011 9:04:00 AM
Sulfate Dissolved	768	25.0		mg/L	25	7/12/2011 9:04:00 AM
ALKALINITY			**SM2320 B**			Analyst: **KH**
Alkalinity, Phenolphthalein	< 2	2	A	mg/L CaCO3	1	7/12/2011

Qualifiers:

A Not Available for Accreditation
E Value Above Quantitation Range
N Not Accredited
X Value Exceeds Maximum Contaminant Level (MCL)

B Analyte Detected in Method Blank
H Holding Time Exceeded
S Spike Recovery Outside Recovery Limits

PQL: Practical Quantitation Limit

Values Below PQL Considered Estimated

LCRA Environmental Laboratory Services

Date: *02-Aug-11*

CLIENT:	Texas Water Development Board	**Client Sample ID:**	45-06-804
Lab Order:	1107238	**Collection Date:**	7/7/2011 10:10:00 AM
Project:	TWDB Suite	**Matrix:**	GROUNDWATER
Lab ID:	1107238-012	**Tag No:**	1556

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ALKALINITY		**SM2320 B**				Analyst: **KH**
Alkalinity, Total (As CaCO3)	292	2		mg/L CaCO3	1	7/12/2011
CATION/ANION BALANCE		**CALCULATION**				Analyst: **AMJ**
Cation/Anion Balance	1.69	5.0	A	%	1	8/2/2011
NITRATE AND NITRITE		**SM4500-NO3-H**				Analyst: **KH**
Nitrogen, Nitrate & Nitrite	13.6	0.200		mg/L	10	7/28/2011
DISSOLVED PHOSPHATE AS P IN WATER		**E365.4**				Analyst: **CM**
Phosphorus, Dissolved (As P)	< 0.020	0.020		mg/L	1	7/15/2011
SILICA		**SM4500-SIO2-C**				Analyst: **KH**
Silica, Dissolved (as SiO2)	55.6	2.50		mg/L	5	7/12/2011

Qualifiers:

A Not Available for Accreditation
E Value Above Quantitation Range
N Not Accredited
X Value Exceeds Maximum Contaminant Level (MCL)

B Analyte Detected in Method Blank
H Holding Time Exceeded
S Spike Recovery Outside Recovery Limits

PQL: Practical Quantitation Limit

Values Below PQL Considered Estimated

CLIENT:	Texas Water Development Board	**Client Sample ID:**	45-06-804
Lab Order:	1107239	**Collection Date:**	7/7/2011 10:10:00 AM
Project:	TWDB Suite	**Matrix:**	GROUNDWATER
Lab ID:	1107239-012	**Tag No:**	1556

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
RADIUM 226		**SM7500-RA B**				Analyst: **SUB**
Radium 226	0.4 ± 0.14	0.2		pCi/L	1	8/13/2011 8:26:45 PM
RADIUM 226		**SM7500-RA D**				Analyst: **SUB**
Radium 228	< 1.3 ± 0.8	1.3		pCi/L	1	8/8/2011 5:53:17 PM
GROSS ALPHA, GROSS BETA		**E900**				Analyst: **SUB**
Gross Alpha Particle Activity	52.0 ± 22.9	33.3	X	pCi/L	1	8/18/2011 8:06:02 AM

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client:	LCRA Environmental Laboratory Services	**Report Date:**	08/26/11
Project:	Not Indicated	**Collection Date:**	07/07/11 10:10
Lab ID:	C11070591-023	**DateReceived:**	07/18/11
Client Sample ID:	1107239-012A	**Matrix:**	Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES - DISSOLVED							
Gross Alpha	52.0	pCi/L				E900.0	08/18/11 08:06 / ep
Gross Alpha precision (±)	22.9	pCi/L				E900.0	08/18/11 08:06 / ep
Gross Alpha MDC	33.3	pCi/L				E900.0	08/18/11 08:06 / ep

45·06·804

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: LCRA Environmental Laboratory Services
Project: Not Indicated
Lab ID: C11070591-024
Client Sample ID: 1107239-012B

Report Date: 08/26/11
Collection Date: 07/07/11 10:10
DateReceived: 07/18/11
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES - DISSOLVED							
Radium 226	0.35	pCi/L				E903.0	08/13/11 20:26 / trs
Radium 226 precision (±)	0.14	pCi/L				E903.0	08/13/11 20:26 / trs
Radium 226 MDC	0.15	pCi/L				E903.0	08/13/11 20:26 / trs
Radium 228	0.8	pCi/L	U			RA-05	08/08/11 17:53 / js
Radium 228 precision (±)	0.8	pCi/L				RA-05	08/08/11 17:53 / js
Radium 228 MDC	1.3	pCi/L				RA-05	08/08/11 17:53 / js

45·06·804

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

Attention Owner:
Confidentiality Privilege Notice on reverse side of owner's copy.

Texas Department of License and Regulation

Water Well Driller/Pump Installer Program
P.O. Box 12157 Austin, Texas 78711 (512)463-7880 FAX (512)463-8616
Toll free (800)803-9202
Email address: water.well@license.state.tx.us

This form must be completed and filed with the department and owner within 60 days upon completion of the well.

WELL REPORT

A. WELL IDENTIFICATION AND LOCATION DATA

1) OWNER

Name	Address	City	State	Zip
MICHAEL McCULLOCH	601 N. GRANDVIEW	ODESSA	TX	79761

2) WELL LOCATION

County	Physical Address	City	State	Zip
MIDLAND	131 SOLO AVE.	ODESSA	TX	

3) Type of Work ☒ New Well ☐ Reconditioning ☐ Replacement ☐ Deepening

Lat. Long. Grid # 45-06-9

4) Proposed Use (check) ☐ Monitor ☐ Environmental Soil Boring ☐ Domestic ☒ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell ☐ Rig Supply If Public Supply well, were plans submitted? ☐ Yes ☐ No

5) N↑

6) Drilling Date
Started 1 / 7 / 02
Completed 1 / 7 / 02

Diameter of Hole

Dia.(in)	From (ft)	To (ft)
8 1/2	0	113

7) Drilling Method (check) ☐ Driven ☒ Air Rotary ☐ Mud Rotary ☐ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☐ Other

From (ft)	To (ft)	Description and color of formation material
0	2	SAND
2	5	CALICHE
5	55	LIMESTONE
55	75	TAN SHALE
75	95	SAND
95	112	SAND & GRAVEL
112	113	RED BED

(Use reverse side of Well Owner's copy, If necessary)

8) Borehole Completion ☐ Open Hole ☐ Straight Wall ☐ Under-reamed ☒ Gravel Packed ☐ Other
If Gravel Packed give the interval from 50 ft. to 113 ft.

Casing, Blank Pipe, and Well Screen Data

Dia. (in.)	New Or Used	Steel, Plastic, etc. Perf., Slotted, etc Screen Mfg., if commercial	Setting (ft) From	To	Gage Casing Screen
5	NEW	PLAIN PVC	0	83	
5	NEW	PERF. PVC	83	113	1/8

9) Cementing Data
Cementing from 0 ft. to 15 ft. # of sacks used 2
HOLE PLUG 15 ft. to 50 ft. # of sacks used 10
Method Used POURED SLURRY
Cementing By WEST TEXAS WATER WELL SERVICE
Distance to septic system field or other concentrated contamination ft.
Method of verification of above distance NONE

RECEIVED
TDLR MAIL ROOM SH
FEB 11 2002
RECEIPT # AMOUNT

10) Surface Completion
☐ Specified Surface Slab Installed
☒ Specified Surface Sleeve Installed
☐ Pitless Adapter Used
☐ Approved Alternative Procedure Used

11) Water Level
Static level ft. below Date / /
Artesian Flow gpm. Date / /

12) Packers Type Depth

13) Plugged ☐ Well plugged within 48 hours
Casing left in well: Cement/Bentonite placed in well:

From (ft)	To (ft)	From (ft)	To (ft)	Sacks used

14) Type Pump
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder ☐ Other
Depth to pump bowls, cylinder, jet etc., ft.

15) Water Test
Typetest ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: gpm with ft. drawdown after hrs.

16) Water Quality
Did you knowingly penetrate a strata which contain undesirable constituents.
☐ YES ☐ NO If yes, did you submit a REPORT OF UNDESIRABLE WATER
Type of water Depth of Strata
Was a chemical analysis made ☐ Yes ☐ No

Company or individual's Name (type or print) WEST TEXAS WATER WELL SERVICE Lic. No. 2497W

Address 3432 W. UNIVERSITY BLVD. City ODESSA State TX Zip 79764

Signature Bernard Brookr 2/1/02 Signature / /
Licensed Driller/Pump Installer Date Apprentice Date

TDLR FORM 6001WWD *White - TDLR* *Yellow - Owner* *Pink - Driller/Pump Installer*

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt   Field No. C   State Well No. JH 45 06 904

Owner's Well No. ____   County Ector

1. Location: NE 1/4, NW 1/4 Sec. 21, Block 41 Survey T&PRR Co. T-2-S

2. Owner: ODESSA Country Club   Address: Box 396, ODESSA, Tex.

Tenant: do   Address:

Driller: UNKNOWN   Address:

3. Elevation of LSD @ WELL is 2871 ft. above msl, determined by Topo

4. Drilled: UNKNOWN 19__; Dug, (Cable Tool), Rotary,

5. Depth: Rept. 130-135 ft. Meas. NMT ft. 9-9-70

6. Completion: Open Hole, Straight Wall, Underreamed, Gravel Packed

7. Pump: Mfgr. ~~Smith~~ Pomona   Type TURBINE

No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.

Column Diam. ____ in., Length Tailpipe ____ ft.

8. Motor: Fuel ELECTRIC Make & Model ____ HP. 5

9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est.

10. Performance Test: Date ____ Length of Test ____ Made by ____

Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.

Production ____ gpm Specific Capacity ____ gpm/ft.

11. Water Level: NMT ft. rept./meas. 9-9-1970 above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

12. Use: Dom., Stock, Public Supply, Ind., (Irr.), Waterflooding, Observation, Not Used, ALSO PUBLIC SUPPLY

13. Quality: (Remarks on taste, odor, color, etc.)

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log, Formation Samples, Pumping Test,

15. Record by: D. CORLEY   Date 9-9-1970

Source of Data HORACE TAYLOR & OBS

16. Remarks: WELL IS S-SE of Country Club About 100 Ft. It sets on East side of LARGE GATHERING TANK FOR CLUB USE.

CASING & BLANK PIPE

Cemented From ____ ft. to ____ ft.

Diam. (in.)	Type	Setting, ft. from	Setting, ft. to
8 5/8	STEEL	0	TD

WELL SCREEN

Screen Openings ____

Diam. (in.)	Type	Setting, ft. from	Setting, ft. to
	UNKNOWN		

TWDBE-GW-49

(Sketch)

10/10/2014 Texas Commission on Environmental Quality
10:10:27 DWW Water System Summary Sheet

PWS ID	PWS Name	Central Registry RN
TX0680072	NEW LIFE CHURCH	RN101210565

Organization/Customer *	Central Registry CN
NEW LIFE CHURCH OF CHRIST	

*Regulatory mail will be addressed to this organization/person

All Water System Contacts

Type	Contact	Communication	
		Phone Type	**Value**
AC - Administrative Contact	HALSTEAD, TIM 1021 SAWDUST RD SPRING, TX 77380	BUS - Business	432-272-5556
		MOB - Mobile	432-230-9311
OW - Owner	NEW LIFE CHURCH OF CHRIST 2817 JBS PKWY STE E3 ODESSA, TX 79762-8160		

Operator Grade	Number

Water Operator Licenses
No Licensing Data for this PWS

Owner Type	Owner Type Options: COUNTY, DISTRICT, FEDERAL GOVERNMENT, INVESTOR OWNED, MUNICIPALITY, NATIVE AMERICAN, PRIVATE, STATE GOVERNMENT, WATER SUPPLY CORPORATION
Private	

System Type	System Type Options: COMMUNITY, TRANSIENT/NON-COMMUNITY, NON-PUBLIC, NON-TRANSIENT/NON-COMMUNITY
NP - NON-PUBLIC	

Population Type	Population Served	# of Connect	# I/C w/other PWS
NonResidential	300	1	0

Total Product (MGD)	Average Daily Consump.	Max Daily Demand (MGD)	Total Storage (MG)	Elev. Storage (MG)	Service Pump Cap.	Max.Purchase Cap. (MGD/GPM)	Pressure Tank Cap. (MG)

Activity Status	Deactivation Date	Reason
I - INACTIVE	09/11/2006	

Last Survey Date	Surveyor	Survey Type	Region	County
02/15/2006	LINDSEY, D BUCKNER	Sanitary Survey	ODESSA	ECTOR
01/29/2003	CYNTHIA, D WILLIAMS	Sanitary Survey	ODESSA	ECTOR
No Site Visit Data				

(Treatment Plant)							
Entry Point	EP Name/Source Summation (Activity Status)	Plant Name (Activity Status)	Plant Num	Chemical Mon Type	Chem Sample Point	Distribution Mon Type	Dist Sample Point
EP001	TRT-TAP / No Source Listed(I)	PLANT(I)	TP3256		NO		NO

Train:	Unnamed

(Treatments)				
Disinfection Zone	Treatment Sequence	Objective	Process	Treatment
null	null	D	423	HYPOCHLORINATION, PRE

(Active Sources)

(Inactive/Offline Sources)			
SourceNumber	Name	Status	Depth
G0680072C	3 - 600' SE OF CLUB HOUSE	P	112
G0680072A	1 - STORAGE	O	130
G0680072D	4 - 300' E OF CLUB HOUSE	O	114
G0680072B	2 - 300' S OF STORAGE	O	130

Code Explanations
Monitoring Type Codes: (GW) GROUNDWATER , (GUP) GROUNDWATER UNDER THE INFLUENCE - PURCHASED , (SWP) SURFACE WATER - PURCHASED , (GU) GROUNDWATER UNDER THE INFLUENCE OF SURFACE WATER , (N) NO SOURCES , (SW) SURFACE WATER
Activity Status Codes: (A) ACTIVE , (D) DELETED/DISSOLVED , (I) INACTIVE , (P) PROPOSED ,
Operational Status Codes: (E) EMERGENCY , (I) INTERIM/PEAK (O) OTHER , (P) PERMANENT , (S) SEASONAL
Source Types: (G) GROUND WATER , (S) SURFACE WATER , (U) GROUND WATER UNDER THE INFLUENCE

- End of Report -

STATE OF TEXAS WELL REPORT for Tracking #355654

Owner:	**Extreme Exteriors**	Owner Well #:	**No Data**
Address:	**1800 Industrial blud Abilene , TX 79602**	Grid #:	**45-06-9**
Well Location:	**No Data**	Latitude:	**31° 53' 21" N**
Well County:	**Ector**	Longitude:	**102° 17' 24" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Irrigation**

Drilling Date:	Started: **1/28/2014** Completed: **1/28/2014**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Water** Cemented By: **Peter Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Monte Moone Drilling 1313 N Hwy 137 Lamesa , TX 79331**
Driller License Number:	**58700**
Licensed Well Driller Signature:	**Peter Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a

written request to do so from the owner.

Please include the report's Tracking number (Tracking #**355654**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-55 sandy clay
55-75 Red clay
75-111 sandy clay
111-115 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" New Plastic 0-75 Blank 75-115 Slotted .035

STATE OF TEXAS WELL REPORT for Tracking #304978

Owner:	**Louis B. Sweeden**	Owner Well #:	**No Data**
Address:	**7004 Robbie Rd. Odessa , TX**	Grid #:	**45-06-9**
Well Location:	**7004 Robbie Rd. Odessa , TX**	Latitude:	**31° 53' 23" N**
Well County:	**Ector**	Longitude:	**102° 17' 26" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/12/2012** Completed: **10/12/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 130 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **60 ft to 130 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 60 ft with 18 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **8 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **15 GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling 4223 W. 16th St. Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#304978**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-3 top soil
3-18 caliche
18-40 dry sand
40-50 wet sand
50-60 false red bed
60-70 water sand
70-90 false red bed
90-124 water sand
124-130 red bed
70-129 water sand
129-130 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 new PVC 0-60
5 new PVC slotted 60-130

TWDB Groundwater Database Query Result

REPORTED WATER WELL DATA ON STATE WELL NUMBER = 4506912

Query for another State Well Number: Submit

| Water Quality | Infrequent Constituent | Water Level | 5 Day Water Level | Well Casing | Remarks | Scanned Images |

*For a complete explanation, click here to read the TWDB Groundwater Data System Data Dictionary.

Field	Value	*Explanation
STATE WELL NUMBER	4506912	
COUNTY CODE	135	Ector County, Texas
BASIN	14	Colorado River Basin
PREVIOUS WELL NUMBER		
LATITUDE	315313	DMS (in decimal degrees: 31.886944)
LAT DEC	31.886944	
LONGITUDE	1021719	DMS (in decimal degrees: -102.288611)
LONG DEC	-102.28861	
OWNER 1	New Life Church	
OWNER 2	Well #1	
DRILLER 1		
DRILLER 2		
SOURCE OF COORDINATES	0	
AQUIFER CODE	218ALRS	Antlers Sand
AQUIFER ID1	13	Edwards-Trinity Plateau Aquifer
AQUIFER ID2		
AQUIFER ID3		
ELEVATION	2877	feet
ELEVATION MEASUREMENT METHOD	D	Digital Elevation Model -DEM

ALPHA CODE		
DATE DRILLED		
WELL TYPE	W	Withdrawal of Water
WELL DEPTH	130	feet
SOURCE OF DEPTH	A	Another Government Agency
TYPE OF LIFT	U	Unknown
TYPE OF POWER		
HORSEPOWER		
PRIMARY WATER USE	U	Unused
SECONDARY WATER USE		
TERTIARY WATER USE		
WATER LEVEL AVAILABLE	N	
WATER QUALITY AVAILABLE	N	
WELL LOGS AVAILABLE		
OTHER DATA AVAILABLE		
DATE COLLECTED OR UPDATED	03292012	
REPORTING AGENCY	03	TWC/TNRCC/TCEQ
WELL SCHEDULE IN FILE		
CONTRUCTION METHOD		
COMPLETION		
CASING MATERIAL		
SCREEN MATERIAL		
GMA	7	
RWPA	F	
DISTRICTID		

Groundwater Database Disclaimer

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10/10/2014 Texas Commission on Environmental Quality
10:10:37 DWW Water System Summary Sheet

PWS ID	PWS Name	Central Registry RN
TX0680072	NEW LIFE CHURCH	RN101210565

Organization/Customer *	Central Registry CN
NEW LIFE CHURCH OF CHRIST	

*Regulatory mail will be addressed to this organization/person

All Water System Contacts

Type	Contact	Communication	
		Phone Type	**Value**
AC - Administrative Contact	HALSTEAD, TIM 1021 SAWDUST RD SPRING, TX 77380	BUS - Business	432-272-5556
		MOB - Mobile	432-230-9311
OW - Owner	NEW LIFE CHURCH OF CHRIST 2817 JBS PKWY STE E3 ODESSA, TX 79762-8160		

Operator Grade	Number

Water Operator Licenses
No Licensing Data for this PWS

Owner Type	Owner Type Options: COUNTY, DISTRICT, FEDERAL GOVERNMENT, INVESTOR OWNED, MUNICIPALITY, NATIVE AMERICAN, PRIVATE, STATE GOVERNMENT, WATER SUPPLY CORPORATION
Private	

System Type	System Type Options: COMMUNITY, TRANSIENT/NON-COMMUNITY, NON-PUBLIC, NON-TRANSIENT/NON-COMMUNITY
NP - NON-PUBLIC	

Population Type	Population Served	# of Connect	# I/C w/other PWS
NonResidential	300	1	0

Total Product (MGD)	Average Daily Consump.	Max Daily Demand (MGD)	Total Storage (MG)	Elev. Storage (MG)	Service Pump Cap.	Max.Purchase Cap. (MGD/GPM)	Pressure Tank Cap. (MG)

Activity Status	Deactivation Date	Reason
I - INACTIVE	09/11/2006	

Last Survey Date	Surveyor	Survey Type	Region	County
02/15/2006	LINDSEY, D BUCKNER	Sanitary Survey	ODESSA	ECTOR
01/29/2003	CYNTHIA, D WILLIAMS	Sanitary Survey	ODESSA	ECTOR
No Site Visit Data				

(Treatment Plant)							
Entry Point	EP Name/Source Summation (Activity Status)	Plant Name (Activity Status)	Plant Num	Chemical Mon Type	Chem Sample Point	Distribution Mon Type	Dist Sample Point
EP001	TRT-TAP / No Source Listed(I)	PLANT(I)	TP3256		NO		NO

Train:	Unnamed

(Treatments)				
Disinfection Zone	Treatment Sequence	Objective	Process	Treatment
null	null	D	423	HYPOCHLORINATION, PRE

(Active Sources)

(Inactive/Offline Sources)			
SourceNumber	Name	Status	Depth
G0680072C	3 - 600' SE OF CLUB HOUSE	P	112
G0680072A	1 - STORAGE	O	130
G0680072D	4 - 300' E OF CLUB HOUSE	O	114
G0680072B	2 - 300' S OF STORAGE	O	130

Code Explanations
Monitoring Type Codes: (GW) GROUNDWATER , (GUP) GROUNDWATER UNDER THE INFLUENCE - PURCHASED , (SWP) SURFACE WATER - PURCHASED , (GU) GROUNDWATER UNDER THE INFLUENCE OF SURFACE WATER , (N) NO SOURCES , (SW) SURFACE WATER
Activity Status Codes: (A) ACTIVE , (D) DELETED/DISSOLVED , (I) INACTIVE , (P) PROPOSED ,
Operational Status Codes: (E) EMERGENCY , (I) INTERIM/PEAK (O) OTHER , (P) PERMANENT , (S) SEASONAL
Source Types: (G) GROUND WATER , (S) SURFACE WATER , (U) GROUND WATER UNDER THE INFLUENCE

- End of Report -

STATE OF TEXAS WELL REPORT for Tracking #301179

Owner:	**Gene Kirby**	Owner Well #:	**No Data**
Address:	**#11 Long Champ Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**#11 Long Champ Odessa , TX**	Latitude:	**31° 53' 16" N**
Well County:	**Ector**	Longitude:	**102° 18' 00" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **8/20/2012** Completed: **8/20/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 120 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **70 ft to 120 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 70 ft with 21 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **6 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **18 GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling 4223 W. 16th St. Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#301179**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-3 top soil
3-18 caliche
18-50 dry sand
50-70 wet sand
70-118 water sand
118-120 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0-80
5 New PVC Slotted 80-120

STATE OF TEXAS WELL REPORT for Tracking #115965

Owner:	**Angle Development**	Owner Well #:	**No Data**
Address:	**2628 Marco** **Odessa , TX 79762**	Grid #:	**45-06-8**
Well Location:	**2628 Marco** **Odessa , TX 79762**	Latitude:	**31° 53' 28" N**
Well County:	**Ector**	Longitude:	**102° 17' 41" W**
Elevation:	**No Data**	GPS Brand Used:	**Megallan 315-320**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **5/24/2007** Completed: **5/25/2007**
Diameter of Hole:	Diameter: **8 in From Surface To 110 ft**
Drilling Method:	**Cable Tool**
Borehole Completion:	Gravel Packed From: **110 ft to 35 ft** Gravel Pack Size: **Pea size**
Annular Seal Data:	1st Interval: **From 35 ft to 0 ft with 23 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **mixer** Cemented By: **driller** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **no septic** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **35 ft. below land surface on 5/25/2007** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**Submersible** Depth to pump bowl: **(No Data) ft**
Well Tests:	**Bailer** Yield: **80 GPM with 5 ft drawdown after 1 hour**

Water Quality:	Type of Water: **Fresh** Depth of Strata: **70 ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Marks Water Well** **P O Box 295** **Odessa , TX 79760**
Driller License Number:	**4550**
Licensed Well Driller Signature:	**Mark A Mehlhoff**
Registered Driller Apprentice Signature:	**James Schlauch**
Apprentice Registration Number:	**wwdapp00001288**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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Please include the report's Tracking number (Tracking #**115965**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-3 top soil
3-25 brown sand
25-40 hard lime stone
40-110 tan sand and gravel
110 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5" New Slotted 110-90 035
5" New Plastic 90-0

TWDB Groundwater Database Query Result

REPORTED WATER WELL DATA ON STATE WELL NUMBER = 4506913

Query for another State Well Number: Submit

| Water Quality | Infrequent Constituent | Water Level | 5 Day Water Level | Well Casing | Remarks | Scanned Images |

*For a complete explanation, click here to read the TWDB Groundwater Data System Data Dictionary.

Field	Value	*Explanation
STATE WELL NUMBER	4506913	
COUNTY CODE	135	Ector County, Texas
BASIN	14	Colorado River Basin
PREVIOUS WELL NUMBER		
LATITUDE	315312	DMS (in decimal degrees: 31.886667)
LAT DEC	31.886666	
LONGITUDE	1021718	DMS (in decimal degrees: -102.288333)
LONG DEC	-102.288333	
OWNER 1	New Life Church	
OWNER 2	Well #2	
DRILLER 1		
DRILLER 2		
SOURCE OF COORDINATES	0	
AQUIFER CODE	218ALRS	Antlers Sand
AQUIFER ID1	13	Edwards-Trinity Plateau Aquifer
AQUIFER ID2		
AQUIFER ID3		
ELEVATION	2877	feet
ELEVATION MEASUREMENT METHOD	D	Digital Elevation Model -DEM

ALPHA CODE		
DATE DRILLED		
WELL TYPE	W	Withdrawal of Water
WELL DEPTH	130	feet
SOURCE OF DEPTH	A	Another Government Agency
TYPE OF LIFT	U	Unknown
TYPE OF POWER		
HORSEPOWER		
PRIMARY WATER USE	U	Unused
SECONDARY WATER USE		
TERTIARY WATER USE		
WATER LEVEL AVAILABLE	N	
WATER QUALITY AVAILABLE	N	
WELL LOGS AVAILABLE		
OTHER DATA AVAILABLE		
DATE COLLECTED OR UPDATED	03292012	
REPORTING AGENCY	03	TWC/TNRCC/TCEQ
WELL SCHEDULE IN FILE		
CONTRUCTION METHOD		
COMPLETION		
CASING MATERIAL		
SCREEN MATERIAL		
GMA	7	
RWPA	F	
DISTRICTID		

Groundwater Database Disclaimer

The Groundwater Database (GWDB) of the Texas Water Development Board (TWDB) contains information about more than 123,500 water well, spring, and oil/gas test sites in Texas including associated water level and water quality data. Because data collection methods and data maintenance have varied and evolved over the years, the information in the GWDB has a range of accuracy that the user needs to be aware of. See Explanation of Groundwater Data for information on the sources of information and level of accurracy in the document.

STATE OF TEXAS WELL REPORT for Tracking #141952

Owner:	**Pradon Construction**	Owner Well #:	**No Data**
Address:	**2100 W 83rd Odessa , TX**	Grid #:	**45-06-9**
Well Location:	**Solo Rd. off ECR 20 Odessa , TX**	Latitude:	**31° 52' 53" N**
Well County:	**Ector**	Longitude:	**102° 17' 29" W**
Elevation:	**No Data**	GPS Brand Used:	**Not Given**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **4/16/2008** Completed: **4/16/2008**
Diameter of Hole:	Diameter: **8.5 in From Surface To 110 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **90 ft to 110 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 90 ft with 27 Cement (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **15+ ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **30 GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling Company 4223 W 16th St. Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronald R. Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**^EO**

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Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-1 topsoil
1-30 dry sand
30-90 wet sand
90-106 water sand
106-109 gray clay
109-110 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5" N PVC 0'-90'
5" N PVC Slotted 90'-110'

TWDB Groundwater Database Query Result

REPORTED WATER WELL DATA ON STATE WELL NUMBER = 4506915

Query for another State Well Number: Submit

| Water Quality | Infrequent Constituent | Water Level | 5 Day Water Level | Well Casing | Remarks | Scanned Images |

*For a complete explanation, click here to read the TWDB Groundwater Data System Data Dictionary.

Field	Value	*Explanation
STATE WELL NUMBER	4506915	
COUNTY CODE	135	Ector County, Texas
BASIN	14	Colorado River Basin
PREVIOUS WELL NUMBER		
LATITUDE	315316	DMS (in decimal degrees: 31.887778)
LAT DEC	31.887777	
LONGITUDE	1021719	DMS (in decimal degrees: -102.288611)
LONG DEC	-102.28861	
OWNER 1	New Life Church	
OWNER 2	Well #4	
DRILLER 1		
DRILLER 2		
SOURCE OF COORDINATES	0	
AQUIFER CODE	218ALRS	Antlers Sand
AQUIFER ID1	13	Edwards-Trinity Plateau Aquifer
AQUIFER ID2		
AQUIFER ID3		
ELEVATION	2874	feet
ELEVATION MEASUREMENT METHOD	D	Digital Elevation Model -DEM

ALPHA CODE		
DATE DRILLED	05271997	
WELL TYPE	W	Withdrawal of Water
WELL DEPTH	114	feet
SOURCE OF DEPTH	A	Another Government Agency
TYPE OF LIFT	U	Unknown
TYPE OF POWER		
HORSEPOWER		
PRIMARY WATER USE	U	Unused
SECONDARY WATER USE		
TERTIARY WATER USE		
WATER LEVEL AVAILABLE	N	
WATER QUALITY AVAILABLE	N	
WELL LOGS AVAILABLE		
OTHER DATA AVAILABLE		
DATE COLLECTED OR UPDATED	03292012	
REPORTING AGENCY	03	TWC/TNRCC/TCEQ
WELL SCHEDULE IN FILE		
CONTRUCTION METHOD		
COMPLETION		
CASING MATERIAL		
SCREEN MATERIAL		
GMA	7	
RWPA	F	
DISTRICTID		

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10/10/2014 Texas Commission on Environmental Quality
10:10:49 DWW Water System Summary Sheet

PWS ID	PWS Name	Central Registry RN
TX0680072	NEW LIFE CHURCH	RN101210565

Organization/Customer *	Central Registry CN
NEW LIFE CHURCH OF CHRIST	

*Regulatory mail will be addressed to this organization/person

All Water System Contacts

Type	Contact	Communication	
		Phone Type	**Value**
AC - Administrative Contact	HALSTEAD, TIM 1021 SAWDUST RD SPRING, TX 77380	BUS - Business	432-272-5556
		MOB - Mobile	432-230-9311
OW - Owner	NEW LIFE CHURCH OF CHRIST 2817 JBS PKWY STE E3 ODESSA, TX 79762-8160		

Operator Grade	Number

Water Operator Licenses
No Licensing Data for this PWS

Owner Type	Owner Type Options: COUNTY, DISTRICT, FEDERAL GOVERNMENT, INVESTOR OWNED, MUNICIPALITY, NATIVE AMERICAN, PRIVATE, STATE GOVERNMENT, WATER SUPPLY CORPORATION
Private	

System Type	System Type Options: COMMUNITY, TRANSIENT/NON-COMMUNITY, NON-PUBLIC, NON-TRANSIENT/NON-COMMUNITY
NP - NON-PUBLIC	

Population Type	Population Served	# of Connect	# I/C w/other PWS
NonResidential	300	1	0

Total Product (MGD)	Average Daily Consump.	Max Daily Demand (MGD)	Total Storage (MG)	Elev. Storage (MG)	Service Pump Cap.	Max.Purchase Cap. (MGD/GPM)	Pressure Tank Cap. (MG)

Activity Status	Deactivation Date	Reason
I - INACTIVE	09/11/2006	

Last Survey Date	Surveyor	Survey Type	Region	County
02/15/2006	LINDSEY, D BUCKNER	Sanitary Survey	ODESSA	ECTOR
01/29/2003	CYNTHIA, D WILLIAMS	Sanitary Survey	ODESSA	ECTOR
No Site Visit Data				

(Treatment Plant)							
Entry Point	EP Name/Source Summation (Activity Status)	Plant Name (Activity Status)	Plant Num	Chemical Mon Type	Chem Sample Point	Distribution Mon Type	Dist Sample Point
EP001	TRT-TAP / No Source Listed(I)	PLANT(I)	TP3256		NO		NO

Train:	Unnamed

(Treatments)				
Disinfection Zone	Treatment Sequence	Objective	Process	Treatment
null	null	D	423	HYPOCHLORINATION, PRE

(Active Sources)

(Inactive/Offline Sources)			
SourceNumber	Name	Status	Depth
G0680072C	3 - 600' SE OF CLUB HOUSE	P	112
G0680072A	1 - STORAGE	O	130
G0680072D	4 - 300' E OF CLUB HOUSE	O	114
G0680072B	2 - 300' S OF STORAGE	O	130

Code Explanations
Monitoring Type Codes: (GW) GROUNDWATER , (GUP) GROUNDWATER UNDER THE INFLUENCE - PURCHASED , (SWP) SURFACE WATER - PURCHASED , (GU) GROUNDWATER UNDER THE INFLUENCE OF SURFACE WATER , (N) NO SOURCES , (SW) SURFACE WATER
Activity Status Codes: (A) ACTIVE , (D) DELETED/DISSOLVED , (I) INACTIVE , (P) PROPOSED ,
Operational Status Codes: (E) EMERGENCY , (I) INTERIM/PEAK (O) OTHER , (P) PERMANENT , (S) SEASONAL
Source Types: (G) GROUND WATER , (S) SURFACE WATER , (U) GROUND WATER UNDER THE INFLUENCE

- End of Report -

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt Field No. B State Well No. JH 45-06-803

Owner's Well No. North-West County Ector

1. Location: NE 1/4, NE 1/4 Sec. 20, Block 41 Survey T&PRR Co. T-2-S

2. Owner: Sunset Memorial Gardens Address: Odessa, TX.

Tenant: Address:

Driller: Dixon Pump & Drilling Co. Address: 2309 W-2nd Odessa, TX.

3. Elevation of LSD @ Well is 2883 ft. above msl, determined by Topo

4. Drilled: 1968; Dug, Cable Tool, Rotary,

5. Depth: Rept. 110-116 ft. Meas. NMT ft. 9-4-70

6. Completion: Open Hole, Straight Wall, Underreamed, Gravel Packed

7. Pump: Mfgr. Reda Type Subm

No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.

Column Diam. ____ in., Length Tailpipe ____ ft.

8. Motor: Fuel Electric Make & Model ____ HP. 3/4

9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est.

10. Performance Test: Date ____ Length of Test ____ Made by ____

Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.

Production ____ gpm Specific Capacity ____ gpm/ft.

CASING & BLANK PIPE

Cemented From ____ ft. to ____ ft.

Diam. (in.)	Type	Setting, ft. from	to
6	Steel	0	TD

11. Water Level: NMT ft. rept./meas. 9-4-1970 above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

12. Use: Dom., Stock, Public Supply, Ind., (Irr), Waterflooding, Observation, Not Used,

13. Quality: (Remarks on taste, odor, color, etc.)

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

WELL SCREEN

Screen Openings ____

Diam. (in.)	Type	Setting, ft. from	to
	Unknown		

14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log, Formation Samples, Pumping Test,

15. Record by: D. Corley Date 9-4-1970

Source of Data Mr. Hoback & Obs.

16. Remarks: Well Pumping

TWDBE-GW-49 (Sketch)

Send original copy by certified mail to the Texas Water Development Board P. O. Box 12386 Austin, Texas 78711

State of Texas

WATER WELL REPORT

For TWDB use only Well No. 6-83 Located on map Received: Form GW 8 Form GW 9

GW 7

1) OWNER:
Person having well drilled Sunset Memorial Gardens, Inc. (Name) Address (Street or RFD) Odessa, Texas (City) (State)

Landowner Sunset Memorial Gardens, Inc. (Name) Address Odessa, Texas (Street or RFD) (City) (State)

2) LOCATION OF WELL:
County Ector Labor League Abstract No.

NW¼ NE¼ SW¼ SE¼ of Section Block No. Survey
(Circle as many as are known)

miles in (NE, SW, etc.) direction from (Town).

NORTH

Intersection hiway 80 and hiway 385 - East on hiway 80 4 miles - north 1/2 mile

Sketch map of well location with distances from adjacent section or survey lines, and to landmarks, roads, and creeks.

3) TYPE OF WORK (Check):
New Well ☒ Deepening ☐
Reconditioning ☐ Plugging ☐

4) PROPOSED USE (Check):
Domestic ☐ Industrial ☒ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

5) TYPE OF WELL (Check):
Rotary ☐ Driven ☐ Dug ☐
Cable ☒ Jetted ☐ Bored ☐

6) WELL LOG:
Diameter of hole 10 in. Depth drilled 109 ft. Depth of completed well 109 ft. Date drilled 3/19/68

All measurements made from 0 ft. above ground level.

From (ft.)	To (ft.)	Description and color of formation material	From (ft.)	To (ft.)	Description and color of formation material
0	5	Top soil			
5	20	Caliche			
20	30	Rock			
30	60	Sand			
60	70	Hard Sand			
70	80	White water sand			
80	107	Sand & Gravel			
107	109	Red Bed			(Use reverse side if necessary)

7) COMPLETION (Check):
Straight wall ☐ Gravel packed ☐ Other ☐
Under reamed ☐ Open hole ☐

8) WATER LEVEL:
Static level ft. below land surface Date
Artesian pressure lbs. per square inch Date

9) CASING:
Type: old ☐ New ☒ Steel ☒ Plastic ☐ Other ☐
Cemented from ft. to ft.

Diameter (inches)	Setting From (ft.)	Setting To (ft.)	Gage
6	1' Above grd.	109	.188

10) SCREEN:
Type
Perforated ☒ Slotted ☐

Diameter (inches)	Setting From (ft.)	Setting To (ft.)	Slot size
6	79	109	.090"

11) WELL TESTS:
Was a pump test made? ☒ Yes ☐ No If yes by whom? Dixon Pump & Drilling Company
Yield: 30 gpm with 20 ft. drawdown after 3½ hrs
Bailer test gpm with ft. drawdown after hrs
Artesian flow gpm Date
Temperature of water
Was a chemical analysis made? ☐ Yes ☐ No
Did any strata contain undesirable water? ☐ Yes ☐ No
Type of water? depth of strata

12) PUMP DATA:
Manufacturer's Name
Type H.P.
Designed pumping rate gpm ☐ gph ☐
Type power unit
Depth to bowls, cylinder, jet, etc., ft. below land surface.

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief.

NAME R.G. Dixon Water Well Drillers Registration No. 18

Address 2309 West 2nd St. Odessa Texas

45-06-803

STATE OF TEXAS WELL REPORT for Tracking #318031

Owner:	**Bill Satler**	Owner Well #:	**0**
Address:	**6347 Mecca** **Odessa , TX 79764**	Grid #:	**45-06-8**
Well Location:	**6347 Mecca Country Club North Lot 20 Blk 18** **Odessa , TX 79764**	Latitude:	**31° 53' 01" N**
Well County:	**Ector**	Longitude:	**102° 18' 00" W**
Elevation:	**2936 ft.**	GPS Brand Used:	**Garmin Nuvi**
Type of Work:	**New Well**	Proposed Use:	**Irrigation**

Drilling Date:	Started: **3/22/2013** Completed: **3/22/2013**
Diameter of Hole:	Diameter: **8 in From Surface To 85 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **59 ft to 83 ft** Gravel Pack Size: **3/8**
Annular Seal Data:	1st Interval: **From 0 ft to 50 ft with 12 bags cement (#sacks and material)** 2nd Interval: **From 0 ft to 50 ft with 3 bags Bentite (#sacks and material)** 3rd Interval: **From 50 ft to 58 ft with (No Data) (#sacks and material)** Method Used: **Tremie Pipe Pressure Grout** Cemented By: **Tom Shelton** Distance to Septic Field or other Concentrated Contamination: **100+ ft** Distance to Property Line: **10 ft** Method of Verification: **measuring tape** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **41 ft. below land surface on 3/22/2013** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **(No Data) GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **60 ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**DT Boring** **6200 N County RD West** **Odessa , TX 79764**
Driller License Number:	**59339**
Licensed Well Driller Signature:	**Tom Shelton**
Registered Driller Apprentice Signature:	**Jess Shelton**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the

well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#318031**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
Sand 0' to 8' Brown
Cleche 8' to 36' Grey
Sand 36' to 59' Grey
Sand 59' to 83' Yellow
Red Bed 83' to 85' Red

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5" New Plastic Jetstream 0' to 65' solid
5" New Plastic Jestream 65' to 85' .020

TWDB Groundwater Database Query Result

REPORTED WATER WELL DATA ON STATE WELL NUMBER = 4506914

Query for another State Well Number: Submit

| Water Quality | Infrequent Constituent | Water Level | 5 Day Water Level | Well Casing | Remarks | Scanned Images |

*For a complete explanation, click here to read the TWDB Groundwater Data System Data Dictionary.

Field	Value	*Explanation
STATE WELL NUMBER	4506914	
COUNTY CODE	135	Ector County, Texas
BASIN	14	Colorado River Basin
PREVIOUS WELL NUMBER		
LATITUDE	315315	DMS (in decimal degrees: 31.887500)
LAT DEC	31.887499	
LONGITUDE	1021718	DMS (in decimal degrees: -102.288333)
LONG DEC	-102.288333	
OWNER 1	New Life Church	
OWNER 2	Well #3	
DRILLER 1		
DRILLER 2		
SOURCE OF COORDINATES	0	
AQUIFER CODE	218ALRS	Antlers Sand
AQUIFER ID1	13	Edwards-Trinity Plateau Aquifer
AQUIFER ID2		
AQUIFER ID3		
ELEVATION	2874	feet
ELEVATION MEASUREMENT METHOD	D	Digital Elevation Model -DEM

ALPHA CODE		
DATE DRILLED	08211989	
WELL TYPE	W	Withdrawal of Water
WELL DEPTH	112	feet
SOURCE OF DEPTH	A	Another Government Agency
TYPE OF LIFT	N	None
TYPE OF POWER		
HORSEPOWER		
PRIMARY WATER USE	G	Plugged or Destroyed
SECONDARY WATER USE		
TERTIARY WATER USE		
WATER LEVEL AVAILABLE	N	
WATER QUALITY AVAILABLE	N	
WELL LOGS AVAILABLE		
OTHER DATA AVAILABLE		
DATE COLLECTED OR UPDATED	03292012	
REPORTING AGENCY	03	TWC/TNRCC/TCEQ
WELL SCHEDULE IN FILE		
CONTRUCTION METHOD		
COMPLETION		
CASING MATERIAL		
SCREEN MATERIAL		
GMA	7	
RWPA	F	
DISTRICTID		

Groundwater Database Disclaimer

The Groundwater Database (GWDB) of the Texas Water Development Board (TWDB) contains information about more than 123,500 water well, spring, and oil/gas test sites in Texas including associated water level and water quality data. Because data collection methods and data maintenance have varied and evolved over the years, the information in the GWDB has a range of accuracy that the user needs to be aware of. See Explanation of Groundwater Data for information on the sources of information and level of accurracy in the document.

Please use black ink. Send original copy by certified mail to the Texas Water Commission P.O. Box 13087 Austin, Texas 78711

State of Texas
WATER WELL REPORT

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

Texas Water Well Drillers Board
P. O. Box 13087
Austin, Texas 78711

1) OWNER Lenora Pike (Name) Address Pike Road (Street or RFD) Odessa (City) Tx (State) (Zip)

2) LOCATION OF WELL: County Ector ______ miles in ______ (N.E., S.W., etc.) direction from ______ (Town)

Driller must complete the legal description to the right with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

☐ Legal description:
Section No. ______ Block No. ______ Township ______
Abstract No. ______ Survey Name ______
Distance and direction from two intersecting section or survey lines ______

☑ See attached map. 8#0N 45-13-9

3) TYPE OF WORK (Check): ☑ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☑ Domestic ☐ Industrial ☐ Monitor ☐ Public Supply ☐ Irrigation ☐ Test Well ☐ Injection ☐ Other ______

5) DRILLING METHOD (Check): ☐ Driven ☐ Mud Rotary ☐ Air Hammer ☐ Jetted ☐ Bored ☑ Air Rotary ☐ Cable Tool ☐ Other ______

6) WELL LOG:

Date Drilling: Started Aug 26 1986 Completed Aug 26 1986

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
	Surface	
7 7/8"	0'	110'

From (ft.)	To (ft.)	Description and color of formation material
0'	5'	Topsoil
5'	11'	Caliche
11'	25'	Limestone
25'	60'	Packsand and gravel
60'	75'	Clay
75'	90'	Packsand
90'	108'	Sand gravel
108'	110'	Red Bed

(Use reverse side if necessary)

7) BOREHOLE COMPLETION: ☐ Open Hole ☐ Straight Wall ☐ Underreamed ☑ Gravel Packed ☐ Other ______
If Gravel Packed give interval . . . from 70' ft. to 110 ft.

8) CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mgf., if commercial	Setting (ft.) From	To	Gage Casing Screen
5"	N	Plastic	0'	90'	
5"	N	Plastic	90'	110'	1/8"

9) CEMENTING DATA [Rule 319.44(b)]
Cemented from 0' ft. to 10' ft. No. of Sacks Used ______
Bentonite Pellets 65' ft. to 70' ft. No. of Sacks Used ______
Method used Poured Slurry
Cemented by Bernard Brockman

10) SURFACE COMPLETION
☑ Specified Surface Slab Installed [Rule 319.44(c)]
☐ Pitless Adapter Used [Rule 319.44(d)]
☐ Approved Alternative Procedure Used [Rule 319.71]

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) WELL TESTS:
Type Test: ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable water? ☐ Yes ☑ No
If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☑ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 12 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Hickerson Drilling (Type or Print) Water Well Driller's License No. 02497W

ADDRESS 3806 W University (Street or RFD) Odessa (City) Tx (State) 79764 (Zip)

(Signed) Bernard J Brockman (Licensed Water Well Driller) (Signed) ______ (Registered Driller Trainee)

For TWC use only Well No. 45-06-8 Located on map ______

Please attach electric log, chemical analysis, and other pertinent information, if available.

STATE OF TEXAS WELL REPORT for Tracking #142005

Owner:	**Pradon Construction**	Owner Well #:	**No Data**
Address:	**2100 W. 83rd** **Odessa , TX**	Grid #:	**45-06-9**
Well Location:	**Solo Rd. off I-20** **Odessa , TX**	Latitude:	**31° 52' 51" N**
Well County:	**Ector**	Longitude:	**102° 17' 28" W**
Elevation:	**No Data**	GPS Brand Used:	**Not Given**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **4/16/2008** Completed: **4/16/2008**
Diameter of Hole:	Diameter: **8.5 in From Surface To 110 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **90 ft to 110 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 90 ft with 27 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **25 x 17 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **30 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling Company** **4223 West 16th St.** **Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronald R. Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**^EO**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#142005**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-1 topsoil
1-30 dry sand
30-90 wet sand
90-109 water sand
109-110 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5" N PVC 0'-90'
5" N PVC Slotted 90'-110'

STATE OF TEXAS WELL REPORT for Tracking #262160

Owner:	**Jimmy Sanders**	Owner Well #:	**1**
Address:	**2911 Cagle** **Odessa , TX 79762**	Grid #:	**45-06-8**
Well Location:	**2911 cagle** **Odessa , TX 79762**	Latitude:	**31° 53' 20" N**
Well County:	**Ector**	Longitude:	**102° 18' 02" W**
Elevation:	**No Data**	GPS Brand Used:	**Tom Tom**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **8/13/2011** Completed: **8/13/2011**
Diameter of Hole:	Diameter: **7.875 in From Surface To 110 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **110 ft to 20 ft** Gravel Pack Size: **Pea**
Annular Seal Data:	1st Interval: **From 20 ft to 15 ft with 2 (#sacks and material)** 2nd Interval: **From 10 ft to 0 ft with 5 (#sacks and material)** 3rd Interval: **No Data** Method Used: **Mixer** Cemented By: **Driller** Distance to Septic Field or other Concentrated Contamination: **No septic ft** Distance to Property Line: **15 ft** Method of Verification: **Tape** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **20 ft. below land surface on 8/13/2011** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**Submersible** Depth to pump bowl: **(No Data) ft**
Well Tests:	**Estimated** Yield: **100 GPM with 20 ft drawdown after 1 hour**

Water Quality:	Type of Water: **Fresh** Depth of Strata: **90 ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Marks Water Well** **P. O. Box 295** **Odessa , TX 79760**
Driller License Number:	**4550**
Licensed Well Driller Signature:	**Mark A Mehlhoff**
Registered Driller Apprentice Signature:	**Bryan Mehlhoff**
Apprentice Registration Number:	**57317**
Comments:	**No Data**

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Please include the report's Tracking number (Tracking **#262160**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-5 top soil
5-25 cleatchy
25-70 yellow sand
70-90 brown sand
90-105 white sand
105-108 yellow sand
108-110 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5" New PVC screen 110-90 .035
5" New PVC casing 90-0

STATE OF TEXAS WELL REPORT for Tracking #347787

Owner:	**Permian Homes**	Owner Well #:	**No Data**
Address:	**P.O. BOX.12025** **Odessa , TX 79768**	Grid #:	**45-06-8**
Well Location:	**No Data**	Latitude:	**31° 53' 31" N**
Well County:	**Ector**	Longitude:	**102° 17' 34" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/18/2013** Completed: **10/18/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Water** Cemented By: **Peter Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Monte Moore Drilling** **1313 N Hwy 137** **Lamesa , TX 79331**
Driller License Number:	**58700**
Licensed Well Driller Signature:	**Peter Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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written request to do so from the owner.

Please include the report's Tracking number (Tracking #**347787**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-55 sandy clay
55-75 red clay
75-111 sandy clay
111-115 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" New Plastic 0-75 blank
75-115 Slotted .035

Dupe

Send original copy by certified mail to the Texas Water Development Board
P. O. Box 13087
Austin, Texas 78711

State of Texas

WATER WELL REPORT

For TWDB use only
Well No. 45-06-8?
Located on map yes
Received: 76?

1) OWNER:
Person having well drilled LEWIE MONTGOMERY (Name) Address 2110 DEERING (Street or RFD) ODESSA (City) TEXAS (State)

Landowner SAME AS ABOVE (Name) Address (Street or RFD) (City) (State)

2) LOCATION OF WELL:
County ECTOR, 5 miles in EAST (N.E., S.W., etc.) direction from ODESSA TEXAS (Town)

Locate by sketch map showing landmarks, roads, creeks, hiway number, etc.*

O COUNTRY CLUB ESTATES

CITY LIMITS

North ↑

(Use reverse side if necessary)

or

Give legal location with distances and directions from adjacent sections or survey lines.

Labor ______ League ______

Block 10 LOT 2 Survey ______

Abstract No. ______

(NW¼ NE¼ SW¼ SE¼) of Section ______

3) TYPE OF WORK (Check): **(New Well)** Deepening Reconditioning Plugging

4) PROPOSED USE (Check): **(Domestic)** Industrial Municipal Irrigation Test Well Other

5) TYPE OF WELL (Check): Rotary Driven Dug **(Cable)** Jetted Bored

6) WELL LOG:
Diameter of hole 8 in. Depth drilled 114 ft. Depth of completed well 114 ft. Date drilled 9-29-75

All measurements made from 0 ft. above ground level.

From (ft.)	To (ft.)	Description and color of formation material
0	20	SOIL REDISH
20	40	CALICHE ROCK WHITE
40	60	ROCK SHALE GRAY
60	80	DRY WATER SAND WHITE
80	100	WATER SAND BROWN
100	114	WATER SAND RED BED

(Use reverse side if necessary)

9) Casing:
Type: Old **(New)** Steel **(Plastic)** Other
Cemented from 85 ft. to 65 ft.

Diameter (inches)	Setting From (ft.)	To (ft.)	Gage
5"	114	1' ABOVE GROUND LEVEL	100 WALL

10) SCREEN:
Type ______
(Perforated) Slotted BORED 1/4

Diameter (inches)	Setting From (ft.)	To (ft.)	Slot Size
5"	114	94	

7) COMPLETION (Check): **(Straight wall)** **(Gravel packed)** Other Under reamed Open Hole

8) WATER LEVEL:
Static level 80 ft. below land surface Date 9-30-75

Artesian pressure ______ lbs. per square inch Date ______

Depth to pump bowls, cylinder, jet, etc., 112 ft. below land surface.

11) WELL TESTS:
Was a pump test made? **(Yes)** No If yes, by whom? E.L. HEARD

Yield: 12 gpm with 30 ft. drawdown after 4 hrs.

Bailer test ______ gpm with ______ ft. drawdown after ______ hrs.

Artesian flow ______ gpm

Temperature of water COOL

12) WATER QUALITY:
Was a chemical analysis made? Yes **(No)**

Did any strata contain undesirable water? Yes **(No)**

Type of water? FRESH-SWEET depth of strata 15'

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief.

NAME ERVIN L. HEARD (Type or Print) Water Well Drillers Registration No. 330

ADDRESS 1400 E. 42ND (Street or RFD) ODESSA (City) TEXAS (State)

(Signed) E. L. Heard (Water Well Driller) E.L. HEARD DRILLING CO 2510 W. 42ND (Company Name)

Please attach electric log, chemical analysis, and other pertinent information, if available.

*Additional instructions on reverse side.

TWDBE-WD-8

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt   Field No. E   State Well No. JH 45-06-906

Owner's Well No. WELL BY #1 TEE   County Ector

1. Location: NE 1/4, NW 1/4 Sec. 21, Block 41, Survey T&PRR Co. T-2-S

2. Owner: ODESSA Country CLUB   Address: Box 396, ODESSA, TX.

Tenant: do   Address:

Driller: UNKNOWN   Address:

3. Elevation of LSD @ WELL is 2870 ft. above msl, determined by Topo

4. Drilled: UNKNOWN 19__; Dug, (Cable Tool), Rotary,

5. Depth: Rept. 130-135 ft. Meas. NMT ft. 9-9-70

6. Completion: Open Hole, Straight Wall, Underreamed, Gravel Packed

7. Pump: Mfgr. REDA   Type Sub.m

No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.

Column Diam. ____ in., Length Tailpipe ____ ft.

8. Motor: Fuel ELECTRIC Make & Model ____ HP. 1 1/2

9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est.

10. Performance Test: Date ____ Length of Test ____ Made by ____

Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.

Production ____ gpm Specific Capacity ____ gpm/ft.

CASING & BLANK PIPE

Cemented From ____ ft. to ____ ft.

Diam. (in.)	Type	Setting, ft. from	to
8 5/8	Steel	0	TD

11. Water Level: NMT ft. rept./meas. 9-9-1970 above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

____ ft. rept./meas. ____ 19__ above/below ____ which is ____ ft. above/below surface.

12. Use: Dom., Stock, Public Supply, Ind., (Irr), Waterflooding, Observation, Not Used, ALSO PUBLIC SUPPLY

13. Quality: (Remarks on taste, odor, color, etc.)

Temp. 77 °F, Date sampled for analysis 9-9-70 Laboratory SHD

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

Temp. ___ °F, Date sampled for analysis ____ Laboratory ____

14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log, Formation Samples, Pumping Test,

15. Record by: D. CORLEY   Date 9-9-1970

Source of Data HORACE TAYLOR & OBS.

16. Remarks: WELL IS N-NE of COUNTRY CLUB ABOUT 200± Ft. PUMPING, SAMPLED SPC 77°F @ 1000 mmhos

WELL SCREEN

Screen Openings ____

Diam. (in.)	Type	Setting, ft. from	to
	UNKNOWN		

TWDBE-GW-49

(Sketch)

TWDBE-GW ONLY

Program No.

Proj. No.

CHEMICAL WATER ANALYSIS REPORT

Typewrite (Black ribbon) or Print Plainly
(soft pencil or black ink)
Do not use ball point pen

Texas State Department of Health Laboratories
1100 West 49th Street
Austin 5, Texas

Send report to:

Ground Water Division
Texas Water Development Board
P. O. Box 12386
Austin, Texas 78711

County Ector

State Well No. 45-06-906

Well No. By #1 TBO

Date Collected 9-9-70

By D. Corley

Location NE 1/4, NW 1/4, Sec 21, Blk 41, T&PRRCo. T-2-S

Source (type of well) Subm Owner Odessa Country Club, Box 546, Odessa Tx.

Date Drilled — Depth 130-135 ft. WBF Kt

Producing intervals — Water level — ft.

Sampled after pumping several hrs. Yield — GPM meas. est. Temperature 77 °F °C

Point of collection Discharge @ Gathering Tank Appearance Clear
clear - turbid - colored

Use Irr Remarks Copy to: Horace Taylor c/o Owner

FOR LABORATORY USE ONLY

CHEMICAL ANALYSIS

KEY PUNCHED

Laboratory No. 173641 Date Received OCT 21 1970 Date Reported NOV - 3 1970

	MG/L	ME/L		MG/L	ME/L
Silica	27		Carbonate		0
Calcium	104	5.20	Bicarbonate (123)	250	4.10
Magnesium	17	1.43	Sulfate	91	1.90
Sodium	74	3.20	Chloride	130	3.66
Total		9.83	Fluoride	1.2	
☐ Potassium			Nitrate	14	0.23
☐ Manganese		%Na	pH 7.6	Total	9.89
☑ Boron	0.3	SAR	1/Dissolved Solids (sum)	580	
☐ Total Iron		RSC	Phenolphthalein Alkalinity as $CaCO_3$	0	
☐ ___ (other)			Total Alkalinity as $CaCO_3$	(4.10)	205
			Total Hardness as $CaCO_3$	(6.63)	332

Specific Conductance (micromhos/cm3) 925

Diluted Conductance (micromhos/cm3) 7 x 153
1071

"☐" items will be analyzed if checked.

Total Iron requires separate sample.

Analyst

Checked by

1/ The bicarbonate reported in this analysis is converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure is used in the computation of this sum.

TWDBE-GW-50

Dugd

Send original copy by certified mail to the Texas Water Development Board P. O. Box 13087 Austin, Texas 78711

State of Texas

WATER WELL REPORT

For TWDB use only
Well No. 45-06-8NN
Located on map YES
Received: 78

1) OWNER:
Person having well drilled JEAN PIKE (Name) Address 2522 GRACE (Street or RFD) ODESSA (City) TEXAS (State)

Landowner JEAN PIKE (Name) Address 2522 GRACE (Street or RFD) ODESSA (City) TEXAS (State)

2) LOCATION OF WELL:
County ECTOR, 4 miles in E (N.E., S.W., etc.) direction from ODESSA (Town)

Locate by sketch map showing landmarks, roads, creeks, hiway number, etc.*

OVER

North

(Use reverse side if necessary)

or Give legal location with distances and directions from adjacent sections or survey lines.

Labor ______ League ______
Block ______ Survey ______
Abstract No. ______
(NW¼ NE¼ SW¼ SE¼) of Section ______

3) TYPE OF WORK (Check): New Well ✓ Deepening Reconditioning Plugging

4) PROPOSED USE (Check): Domestic ✓ Industrial Municipal Irrigation Test Well Other

5) TYPE OF WELL (Check): Rotary Driven Dug Cable ✓ Jetted Bored

6) WELL LOG:
Diameter of hole 8 in. Depth drilled 115 ft. Depth of completed well 115 ft. Date drilled 9-30-78
All measurements made from 18" ft. above ground level.

From (ft.)	To (ft.)	Description and color of formation material
0	5	TOP SOIL
5	25	CALCHIE
25	35	HARD WHITE SAND STONE
35	67	HARD GRAY SAND
67	83	RED SHALE
83	105	GRAY SAND
105	112	HARD BROWN SAND
112	113	BLUE SHALE
113	115	RED BED

(Use reverse side if necessary)

9) Casing:
Type: Old New ✓ Steel Plastic ✓ Other
Cemented from 78 ft. to 83 ft.

Diameter (inches)	Setting From (ft.)	Setting To (ft.)	Gage
5	0	115	

10) SCREEN:
Type
Perforated ✓ Slotted

Diameter (inches)	Setting From (ft.)	Setting To (ft.)	Slot Size
5	95	115	5/32

7) COMPLETION (Check):
Straight wall Gravel packed ✓ Other
Under reamed Open Hole

8) WATER LEVEL:
Static level 68 ft. below land surface Date 9-30-78
Artesian pressure ______ lbs. per square inch Date ______
Depth to pump bowls, cylinder, jet, etc., ______ ft. below land surface.

11) WELL TESTS:
Was a pump test made? Yes No ✓ If yes, by whom?
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.
Bailer test 10 gpm with 47 ft. drawdown after 1/2 hrs.
Artesian flow ______ gpm
Temperature of water ______

12) WATER QUALITY:
Was a chemical analysis made? Yes ✓ No
Did any strata contain undesirable water? Yes No ✓
Type of water? FRESH depth of strata 47

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief.

NAME JAMES C HOLMAN (Type or Print) Water Well Drillers Registration No. 1753

ADDRESS RT 2 BOX 5117 (Street or RFD) ODESSA (City) TEXAS (State)

(Signed) James C. Holman (Water Well Driller) HOLMAN DRILLING (Company Name)

Please attach electric log, chemical analysis, and other pertinent information, if available.

*Additional instructions on reverse side.

TWDBE-WD-8

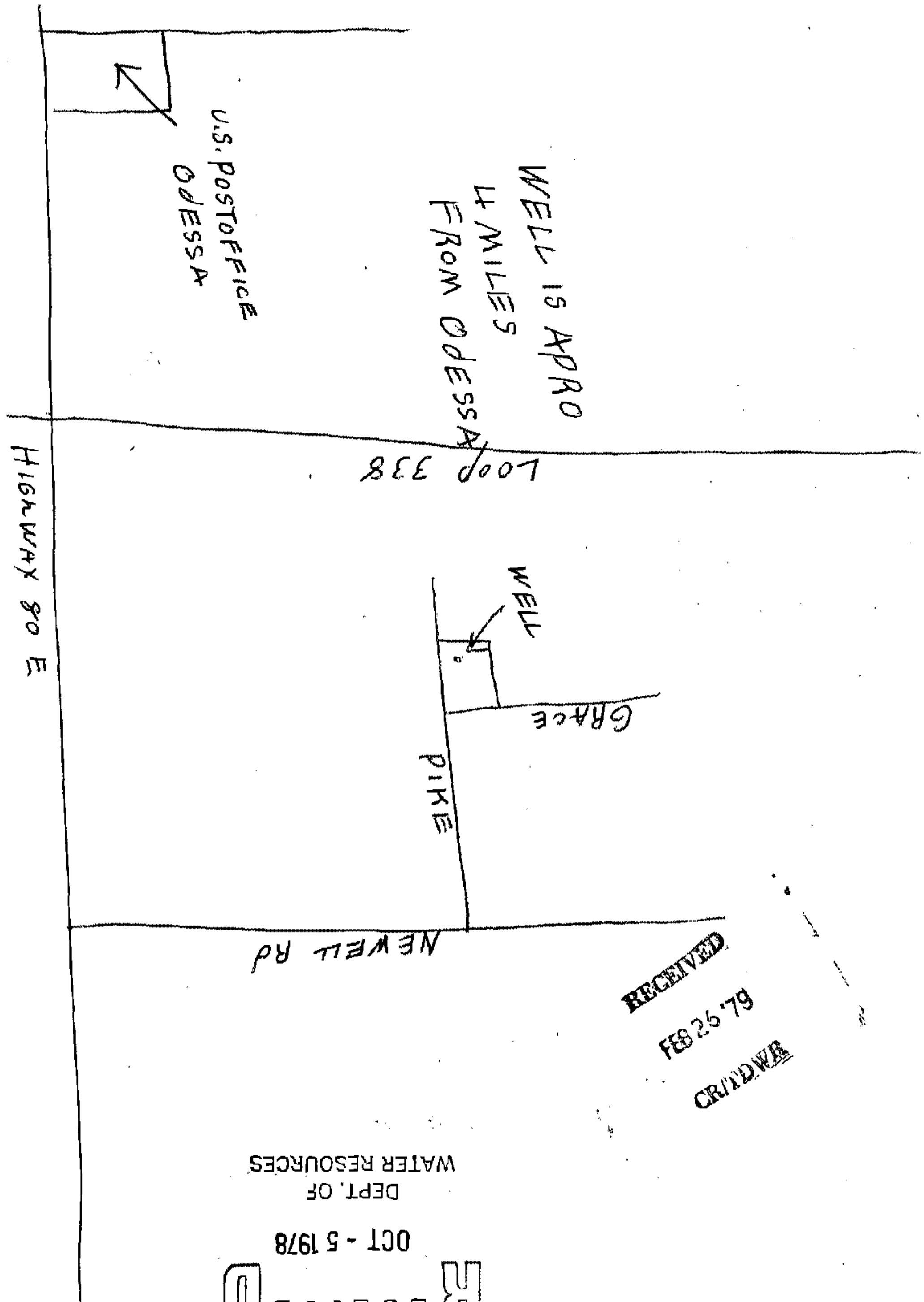
2) LOCATION OF WELL:

The sketch showing the well location must be as accurate as possible, showing landmarks, in sufficient detail so that the well may be plotted on a General Highway Map of the county in which the well is located.

Reference points from which distances are measured and directions given should be of a permanent nature (e.g. highway intersections, center of towns, river and creek bridges, railroad crossings). The distance and direction from the nearest town should always be indicated.

When giving a legal description include a sketch showing location of the well within the described area, e.g. survey abstract.

Information furnished in Section 2) of the TWDBE-GW-53 is very important. Unless the well can be accurately located on a map the value of the other data contained in the Report is greatly reduced.



STATE OF TEXAS WELL REPORT for Tracking #294305

Owner:	**Rhonda Krogh**	Owner Well #:	**No Data**
Address:	**6525 Opal** **Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**6525 Opal** **Odessa , TX**	Latitude:	**31° 53' 13" N**
Well County:	**Ector**	Longitude:	**102° 18' 07" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **6/21/2012** Completed: **6/21/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 110 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **60 ft to 110 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 60 ft with 18 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **15 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **20 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling** **4223 W. 16th St.** **Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the

well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#294305**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-3 Top Soil
3-18 Caliche
18-30 Dry Sand
30-40 Rock
40-60 Wet Sand
60-108 Water Sand
108-110 Red Bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0-70
5 New PVC Slotted 70-110

STATE OF TEXAS WELL REPORT for Tracking #296304

Owner:	**CLAY MCFADDEN**	Owner Well #:	**JN 3378**
Address:	**6551 AMBER DR** **ODESSA , TX 79762**	Grid #:	**45-06-8**
Well Location:	**6551 AMBER DR** **ODESSA , TX 79762**	Latitude:	**31° 53' 14" N**
Well County:	**Ector**	Longitude:	**102° 18' 07" W**
Elevation:	**No Data**	GPS Brand Used:	**GARMIN GPS III PLUS**
Type of Work:	**New Well**	Proposed Use:	**Irrigation**

Drilling Date:	Started: **8/10/2012** Completed: **8/10/2012**
Diameter of Hole:	Diameter: **8.75 in From Surface To 90 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **15 ft to 90 ft** Gravel Pack Size: **.02**
Annular Seal Data:	1st Interval: **From 0 ft to 55 ft with CEMENT (#sacks and material)** 2nd Interval: **From 55 ft to 60 ft with 1 BAG HOLE PLUG (#sacks and material)** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Alternative Procedure Used**

Water Level:	Static level: **48 ft. below land surface on 8/10/2012** Artesian flow: **25 GPM**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**DARRELL CRASS DRILLING COMPANY** **PO BOX 60031** **MIDLAND , TX 79711**
Driller License Number:	**2752**
Licensed Well Driller Signature:	**R DARRELL CRASS**
Registered Driller Apprentice Signature:	**TOM H SHELTON**
Apprentice Registration Number:	**59176**
Comments:	**14 - 18 NOT APPLICABLE**

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#296304**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 - 1 TOP SOIL
1 - 14 SAND
14 - 56 CALICHE
56 - 88 SAND
88 - 90 RED BED

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" NEW PVC PIPE BLANK 0 - 70
6" NEW PVC PIPE .020 SCREEN 70 - 90

STATE OF TEXAS WELL REPORT for Tracking #296698

Owner:	**Rick Gibson**	Owner Well #:	**No Data**
Address:	**#5 Cascade Ct. Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**#5 Cascade Ct. Odessa , TX**	Latitude:	**31° 53' 14" N**
Well County:	**Ector**	Longitude:	**102° 18' 08" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **7/13/2012** Completed: **7/13/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **75 ft to 115 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 75 ft with 23 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **5 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **20 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling 4223 W. 16th St. Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the

well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#296698**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-3 top soil
3-18 caliche
18-50 dry sand
50-60 wet sand
60-75 false red bed
75-114 water sand
114-115 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0-75
5 New PVC Slotted 75-115

Send original copy by certified return receipt requested mail to: TNRCC, MC 177, P.O. Box 13087, Austin, TX 78711-3087

ATTENTION OWNER: *Confidentiality Privilege Notice on on reverse side of Well Owner's copy (pink)*

State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
MC 177
P.O. Box 13087
Austin, TX 78711-3087
512-239-0530

1) OWNER Julio Nunez, Jr. (Name) ADDRESS 8312 Golder (Street or RFD) Odessa (City) TX (State) (Zip)

2) ADDRESS OF WELL: County Ector Brown St./University Acres (Street, RFD or other) Odessa (City) TY (State) (Zip) GRID # 45-06-8

3) TYPE OF WORK (Check): ☑ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☐ Monitor ☐ Environmental Soil Boring ☑ Domestic ☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5)

6) WELL LOG:
Date Drilling:
Started Sep 5 19 97
Completed Sep 5 19 97

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	108

7) DRILLING METHOD (Check): ☐ Driven ☑ Air Rotary ☐ Mud Rotary ☐ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☐ Other ______

From (ft.)	To (ft.)	Description and color of formation material
0	3	Top Soil
3	18	Caliche
18	70	Dry Sand & Rock
70	90	Wet Sand
90	95	Flase Red
75	105	Water Sand
105	108	Red Bed

(Use reverse side of Well Owner's copy, if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall ☐ Underreamed ☑ Gravel Packed ☐ Other ______
If Gravel Packed give interval ... from 70 ft. to 108 ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
5	N	PVC	0	108	160

9) CEMENTING DATA [Rule 338.44(1)]
Cemented from 0 ft. to 15 ft. No. of sacks used 7
______ ft. to ______ ft. No. of sacks used ______
Method used Pumped
Cemented by Row
Distance to septic system field lines or other concentrated contamination ______ ft.
Method of verification of above distance ______

10) SURFACE COMPLETION
☐ Specified Surface Slab Installed [Rule 338.44(2)(A)]
☐ Specified Steel Sleeve Installed [Rule 338.44(3)(A)]
☐ Pitless Adapter Used [Rule 338.44(3)(b)]
☐ Approved Alternative Procedure Used [Rule 338.71]

NOV 20 1997

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer ☐ Jetted ☑ Estimated
Yield: 5 gpm with ______ ft. drawdown after ______ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☑ No If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☑ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Wheeler Drilling (Type or print) WELL DRILLER'S LICENSE NO. 1540 WI

ADDRESS 4223 W. 16th (Street or RFD) Odessa (City) TY (State) 79763 (Zip)

(Signed) [signature] (Licensed Well Driller) (Signed) ______ (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 05-21-96) *White - TNRCC* *Yellow - DRILLER* *Pink - WELL OWNER*

Send original copy by certified return receipt requested mail to: TNRCC, MC 177, P.O. Box 13087, Austin, TX 78711-3087

ATTENTION OWNER: *Confidentiality Privilege Notice on on reverse side of Well Owner's copy (pink)*

State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
MC 177
P.O. Box 13087
Austin, TX 78711-3087
512-239-0530

1) OWNER Julio Nunez, Jr. (Name) ADDRESS 8312 Golder (Street or RFD) Odessa (City) TX (State) - (Zip)

2) ADDRESS OF WELL: County Ector Brown St/University Acres (Street, RFD or other) Odessa (City) TX (State) (Zip) GRID # 45-06-8 ?

3) TYPE OF WORK (Check): ☑ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☐ Monitor ☐ Environmental Soil Boring ☑ Domestic ☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☐ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5)

6) WELL LOG:
Date Drilling:
Started Sep 5 19 97
Completed Sep 5 19 97

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	102

7) DRILLING METHOD (Check): ☐ Driven ☑ Air Rotary ☐ Mud Rotary ☐ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☐ Other ______

From (ft.)	To (ft.)	Description and color of formation material
0	3	Top Soil
3	18	Caliche
18	70	Dry Sand & Rock
70	80	Wet Sand
80	90	Flase Red
90	109	Water Sand
109	102	Red Bed

(Use reverse side of Well Owner's copy, if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☐ Straight Wall ☐ Underreamed ☑ Gravel Packed ☐ Other ______
If Gravel Packed give interval ... from 90 ft. to 102 ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
5	N	PVC	0	102	160

9) CEMENTING DATA [Rule 338.44(1)]
Cemented from 0 ft. to 15 ft. No. of sacks used 7
______ ft. to ______ ft. No. of sacks used ______
Method used Pumped
Cemented by Row
Distance to septic system field lines or other concentrated contamination ______ ft.
Method of verification of above distance N/A

10) SURFACE COMPLETION
☐ Specified Surface Slab Installed [Rule 338.44(2)(A)]
☑ Specified Steel Sleeve Installed [Rule 338.44(3)(A)]
☐ Pitless Adapter Used [Rule 338.44(3)(b)]
☐ Approved Alternative Procedure Used [Rule 338.71]

FILED ... NOV 20 1997 ... SEQ # ... RECD

11) WATER LEVEL:
Static level ______ ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) WELL TESTS:
Type test: ☐ Pump ☐ Bailer (circled) ☐ Jetted ☐ Estimated
Yield: 5 gpm with ______ ft. drawdown after ______ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☑ No If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☑ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Wheeler Drilling (Type or print) WELL DRILLER'S LICENSE NO. 1540WI

ADDRESS 4223 W. 16th (Street or RFD) Odessa (City) TX (State) 79763 (Zip)

(Signed) [signature] (Licensed Well Driller) (Signed) ______ (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 05-21-96) *White - TNRCC* *Yellow - DRILLER* *Pink - WELL OWNER*

STATE OF TEXAS WELL REPORT for Tracking #274586

Owner:	**Roger Clayton**	Owner Well #:	**No Data**
Address:	**# 41 Sunnygrove Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**# 41 Sunnygrove Odessa , TX**	Latitude:	**31° 53' 00" N**
Well County:	**Ector**	Longitude:	**102° 18' 06" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **11/14/2011** Completed: **11/14/2011**
Diameter of Hole:	Diameter: **8.5 in From Surface To 105 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **65 ft to 105 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 65 ft with 20 cement (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **n/a ft** Distance to Property Line: **6 ft** Method of Verification: **measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **30 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling Co. 4223 W. 16th Street Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#274586**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 to 1 top soil
1 to 30 dry sand
30 to 65 wet sand
65 to 104 water sand
104 to 105 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 new pvc 0 to 65
5 new pvc slotted 65 to 105

STATE OF TEXAS WELL REPORT for Tracking #274591

Owner:	**Roger Stone**	Owner Well #:	**No Data**
Address:	**# 28 Vista Crest Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**# 28 Vista Crest Odessa , TX**	Latitude:	**31° 53' 00" N**
Well County:	**Ector**	Longitude:	**102° 18' 06" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **11/14/2011** Completed: **11/14/2011**
Diameter of Hole:	Diameter: **8.5 in From Surface To 110 ft**
Drilling Method:	**Air Hammer**
Borehole Completion:	Gravel Packed From: **80 ft to 110 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 80 ft with 24 cement (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **n/a ft** Distance to Property Line: **6 ft** Method of Verification: **measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **20 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling Co. 4223 W. 16th Street Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 to 1 top soil
1 to 35 dry sand & rock
35 to 60 wet sand
60 to 83 false red bed
83 to 108 water sand
108 to 110 red bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 new pvc 0 to 80
5 new pvc slotted 80 to 110

STATE OF TEXAS WELL REPORT for Tracking #294352

Owner:	**Bobby Cox Properties**	Owner Well #:	**No Data**
Address:	**PO Box 60423** **Midland , TX**	Grid #:	**45-06-8**
Well Location:	**7005 Pinecrest** **Odessa , TX**	Latitude:	**31° 53' 34" N**
Well County:	**Ector**	Longitude:	**102° 17' 40" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **6/30/2012** Completed: **6/30/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 120 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **80 ft to 120 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 80 ft with 24 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **6 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **10 GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling** **4223 W. 16th St.** **Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-3 Top Soil
3-18 Caliche
18-50 Dry Sand
50-70 Wet Sand
70-80 False Red Bed
80-115 Water Sand
115-120 Red Bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0-80
5 New PVC Slotted 80-120

STATE OF TEXAS WELL REPORT for Tracking #291297

Owner:	**Bobby Cox**	Owner Well #:	**No Data**
Address:	**6903 Pinecrest Ave Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**6903 Pinecrest Ave Odessa , TX**	Latitude:	**31° 53' 33" N**
Well County:	**Ector**	Longitude:	**102° 17' 48" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **5/9/2012** Completed: **5/9/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 120 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **50 ft to 120 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 50 ft with 15 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **8 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **15 GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling 4223 W. 16th St. Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-1 Top Soil
1-30 Rock & Caliche
30-40 Dry Sand
40-50 Wet Sand
50-60 Water Sand
60-85 False Red bed
85-90 Water Sand
90-100 False Red Bed
100-115 Water Sand
115-120 Red Bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0-50
5 New PVC Slotted 50-120

STATE OF TEXAS WELL REPORT for Tracking #347789

Owner:	**Permian Homes**	Owner Well #:	**No Data**
Address:	**P.O. BOX.12025** **Odessa , TX 79768**	Grid #:	**45-06-9**
Well Location:	**No Data**	Latitude:	**31° 53' 32" N**
Well County:	**Ector**	Longitude:	**102° 17' 28" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/22/2013** Completed: **10/22/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Water** Cemented By: **Peter Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Monte Moore Drilling** **1313 N Hwy 137** **Lamesa , TX 79331**
Driller License Number:	**58700**
Licensed Well Driller Signature:	**Peter Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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written request to do so from the owner.

Please include the report's Tracking number (Tracking #**347789**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL	CASING, BLANK PIPE & WELL SCREEN DATA
From (ft) To (ft) Description	Dia. New/Used Type Setting From/To
0-2 top soil	**6" New Plastic 0-75 blank**
2-25 caliche	**75-115 Slotted .035**
25-55 sandy clay	
55-75 red clay	
75-111 sandy clay	
111-115 red clay	

STATE OF TEXAS WELL REPORT for Tracking #347790

Owner:	**Permian Homes**	Owner Well #:	**No Data**
Address:	**P.O. BOX.12025** **Odessa , TX 79768**	Grid #:	**45-06-9**
Well Location:	**No Data**	Latitude:	**31° 53' 32" N**
Well County:	**Ector**	Longitude:	**102° 17' 28" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **10/22/2013** Completed: **10/22/2013**
Diameter of Hole:	Diameter: **10 in From Surface To 115 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 115 ft** Gravel Pack Size: **1/4**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 8 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Water** Cemented By: **Peter Neufeld** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Monte Moore Drilling** **1313 N Hwy 137** **Lamesa , TX 79331**
Driller License Number:	**58700**
Licensed Well Driller Signature:	**Peter Neufeld**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-2 top soil
2-25 caliche
25-55 sandy clay
55-75 red clay
75-111 sandy clay
111-115 red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" New Plastic 0-75 blank
75-115 Slotted .035

GW 1

TEXAS WATER DEVELOPMENT BOARD

WELL SCHEDULE

Aquifer Kt   Field No. A   State Well No. JH 45-06-806
Owner's Well No.   County Ector

1. Location: SE 1/4, SW 1/4 Sec. 16, Block 41, Survey T&PRR Co. T-2-S
2. Owner: Odessa Country Club   Address: Box 346, Odessa, TX.
   Tenant: do   Address:
   Driller: Unknown   Address:
3. Elevation of LSD @ well is 2875 ft. above msl, determined by Topo
4. Drilled: Unknown 19__; Dug, (Cable Tool), Rotary,
5. Depth: Rept. 130-135 ft. Meas. NMT ft. 9-9-70
6. Completion: Open Hole, Straight Wall, Underreamed, Gravel Packed
7. Pump: Mfgr. Reda   Type Subm
   No. Stages ____, Bowls Diam. ____ in., Setting ____ ft.
   Column Diam. ____ in., Length Tailpipe ____ ft.
8. Motor: Fuel Electric   Make & Model ____   HP. 1 1/2
9. Yield: Flow ____ gpm, Pump ____ gpm, Meas., Rept., Est.
10. Performance Test: Date ____ Length of Test ____ Made by ____
    Static Level ____ ft. Pumping Level ____ ft. Drawdown ____ ft.
    Production ____ gpm   Specific Capacity ____ gpm/ft.
11. Water Level: NMT ft. rept. meas. 9-9-1970 above below ____ which is ____ ft. above below surface.
    ____ ft. rept. meas. ____ 19__ above below ____ which is ____ ft. above below surface.
    ____ ft. rept. meas. ____ 19__ above below ____ which is ____ ft. above below surface.
    ____ ft. rept. meas. ____ 19__ above below ____ which is ____ ft. above below surface.
12. Use: Dom., Stock, Public Supply, Ind., (Irr), Waterflooding, Observation, Not Used,
13. Quality: (Remarks on taste, odor, color, etc.)
    Temp. 79 °F, Date sampled for analysis 9-9-70 Laboratory SHD
    Temp. ___ °F, Date sampled for analysis ____ Laboratory ____
    Temp. ___ °F, Date sampled for analysis ____ Laboratory ____
14. Other data available as circled: Driller's Log, Radioactivity Log, Electric Log,
    Formation Samples, Pumping Test,
15. Record by: D. Corley   Date 9-9-1970
    Source of Data Horace Taylor foss.
16. Remarks: Well is 20-30 yds W-NW of oil storage tanks & heater unit. UTM
    Well pumping, sampled
    SPC 79°F @ 990 mmhos

CASING & BLANK PIPE

Cemented From ____ ft. to ____ ft.

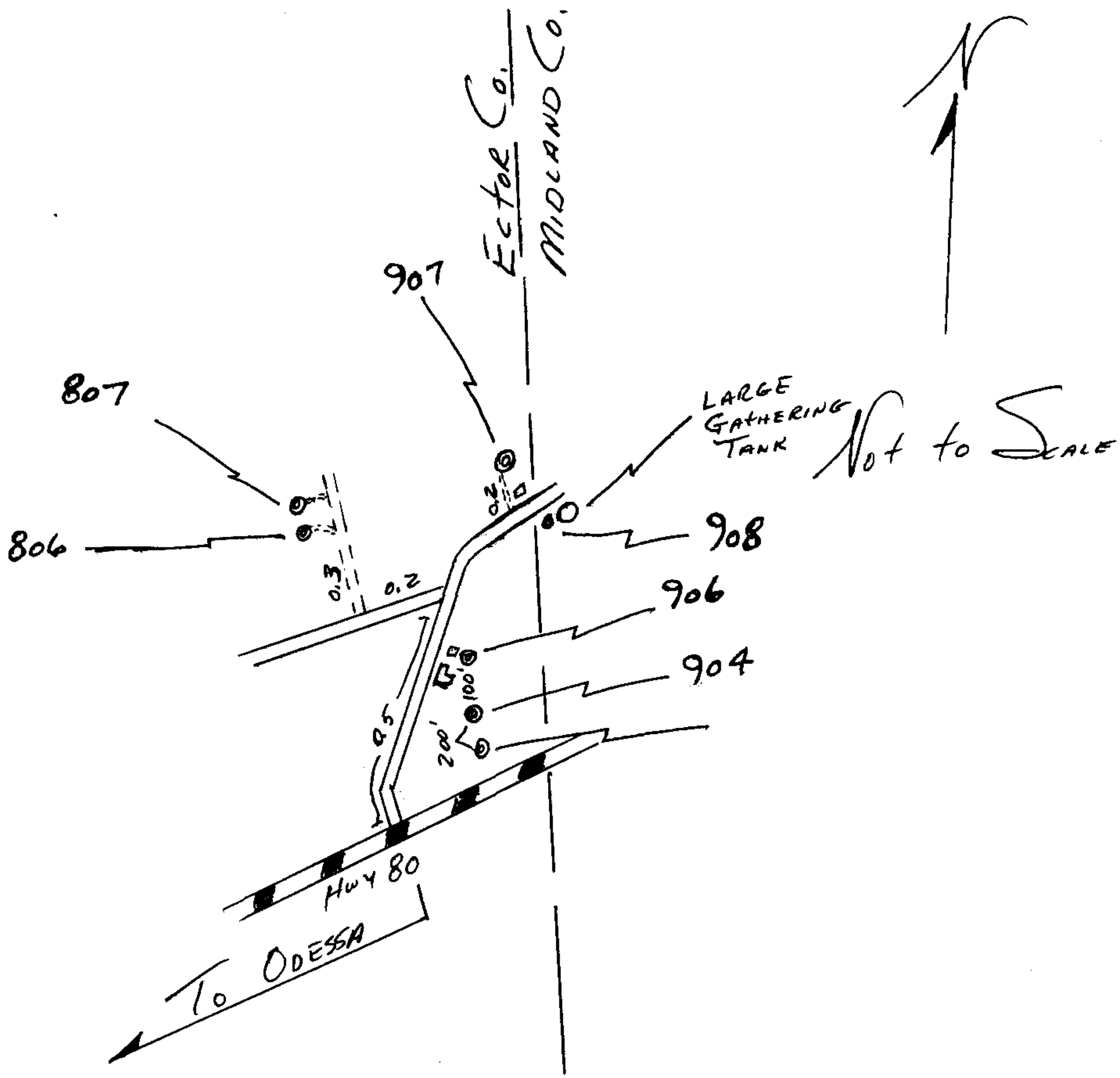
Diam. (in.)	Type	Setting, ft. from	to
8 5/8	Steel Surf. Csg only		

WELL SCREEN

Screen Openings

Diam. (in.)	Type	Setting, ft. from	to
	Unknown		

TWDBE-GW-49   (Sketch)


Ector Co.
Midland Co.
907
807
806
Large Gathering Tank
Not to Scale
908
906
904
0.2
0.3
0.2
0.5
100'
200'
Hwy 80
To Odessa

TWDBE-GW ONLY
Program No. 7424
Proj. No.

CHEMICAL WATER ANALYSIS REPORT

Typewrite (Black ribbon) or Print Plainly
(soft pencil or black ink)
Do not use ball point pen

Texas State Department of Health Laboratories
1100 West 49th Street
Austin 5, Texas

Send report to:

Ground Water Division
Texas Water Development Board
P. O. Box 12386
Austin, Texas 78711

County Ector
State Well No. 5H45-06-806
Tank Bat. Well No.
Date Collected 9-9-70
By D. Corley

Location SE/4, SW 1/4, Sec 16, Blk 41, T&PRRCo. T-2-S

Source (type of well) Subm Owner Odessa Country Club

Date Drilled — Depth 130-135 ft. WBF Kt

Producing intervals — Water level — ft.

Sampled after pumping Several hrs. Yield — GPM meas. est. Temperature 79 °F °C

Point of collection Faucet @ Well Appearance Clear
clear - turbid - colored

Use IRR Remarks

FOR LABORATORY USE ONLY

KEY PUNCHED

CHEMICAL ANALYSIS

Laboratory No. 173603 W Date Received OCT 21 1970 Date Reported NOV - 3 1970

	MG/L	ME/L		MG/L	ME/L
Silica	25		Carbonate		0
Calcium	89	4.45	Bicarbonate	114 231	3.78
Magnesium	15	1.21	Sulfate	71	1.47
Sodium	81	3.50	Chloride	133	3.76
Total		9.16	Fluoride	1.4	
☐ Potassium	4	.10	Nitrate	11	0.18
☐ Manganese		%Na 9.26	pH 7.4	Total	9.19
☑ Boron	0.3	SAR	1/ Dissolved Solids (sum)		540
☐ Total Iron		RSC	Phenolphthalein Alkalinity as $CaCO_3$		0
☐ ____ (other)			Total Alkalinity as $CaCO_3$	(3.78)	189
			Total Hardness as $CaCO_3$	(5.66)	283

Specific Conductance (micromhos/cm3) 894

Diluted Conductance (micromhos/cm3) 7 x 146

"☐" items will be analyzed if checked. 1022

Analyst

Total Iron requires separate sample.

Checked by

1/ The bicarbonate reported in this analysis is converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure is used in the computation of this sum.

TWDBE-GW-60

STATE OF TEXAS WELL REPORT for Tracking #58154

Owner:	**Darrel Farris**	Owner Well #:	**No Data**
Address:	**#17 Long Champ** **Odessa , TX 79762**	Grid #:	**45-06-8**
Well Location:	**#17 Long Champ** **Odessa , TX 79762**	Latitude:	**31° 53' 26" N**
Well County:	**Ector**	Longitude:	**102° 18' 02" W**
Elevation:	**No Data**	GPS Brand Used:	**Garmin**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **4/29/2005** Completed: **4/29/2005**
Diameter of Hole:	Diameter: **8.75 in From Surface To 111 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **111 ft to 40 ft** Gravel Pack Size: **3/8**
Annular Seal Data:	1st Interval: **From 40 ft to 2 ft with 8 Bentonite (#sacks and material)** 2nd Interval: **From 2 ft to 0 ft with 2 Cement (#sacks and material)** 3rd Interval: **No Data** Method Used: **Poured Slurry** Cemented By: **M. Tharp** Distance to Septic Field or other Concentrated Contamination: **N/A ft** Distance to Property Line: **N/A ft** Method of Verification: **N/A** Approved by Variance: **N/A**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**

Water Quality:	Type of Water: **Fresh** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**West Texas Water Well Service** **3410 Mankins** **Odessa , TX 79764**
Driller License Number:	**55070**
Licensed Well Driller Signature:	**Mike Tharp**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the

contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking #**58154**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 3 Top Soil
3 15 Limestone
15 16 Caliche
16 24 Limestone
24 29 Caliche/Limestone Mix
29 37 Cemented Sstone & Chert
37 69 Brown Sand/Limestone
69 71 Sandstone
71 75 Red Shale
75 83 Tan Sand/Gravel
83 107 Yellow Gravel & Sand
107 108 Yellow Clay
108 109 Blue/Gray Clay
109 111 Red Clay

CASING, BLANK PIPE & WELL SCREEN DATA

No Data

STATE OF TEXAS WELL REPORT for Tracking #286184

Owner:	**CORY BIZZELL**	Owner Well #:	**JN 3002**
Address:	**#1 VISTA CREST COURT MIDLAND , TX 79762**	Grid #:	**45-06-8**
Well Location:	**#1 VISTA CREST COURT ODESSA , TX 79762**	Latitude:	**31° 53' 01" N**
Well County:	**Ector**	Longitude:	**102° 18' 08" W**
Elevation:	**No Data**	GPS Brand Used:	**GARMIN GPS III PLUS**
Type of Work:	**New Well**	Proposed Use:	**Irrigation**

Drilling Date:	Started: **4/17/2012** Completed: **4/17/2012**
Diameter of Hole:	Diameter: **8.75 in From Surface To 70 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **47 ft to 70 ft** Gravel Pack Size: **.02**
Annular Seal Data:	1st Interval: **From 0 ft to 42 ft with 13 BAG CEMENT (#sacks and material)** 2nd Interval: **From 42 ft to 47 ft with 1 BAG HOLE PLUG (#sacks and material)** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Alternative Procedure Used**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**DARRELL CRASS DRILLING PO BOX 60031 MIDLAND , TX 79711**
Driller License Number:	**2752**
Licensed Well Driller Signature:	**R DARRELL CRASS**
Registered Driller Apprentice Signature:	**D L CRASS**
Apprentice Registration Number:	**58425**
Comments:	**13 - 18 NOT APPLICABLE**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 - 11 TOP SOIL & SAND
11 - 36 CLICHIE
36 - 51 LIMESTONE
51 - 68 SAND
68 - 70 RED BED

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" NEW PVC PIPE BLANK 0 - 50
6" NEW PVC PIPE SCREEN 50 - 70

STATE OF TEXAS WELL REPORT for Tracking #315334

Owner:	**David Johnston**	Owner Well #:	**#3**
Address:	**7001 N. County Road West** **Odessa , TX 79764**	Grid #:	**45-06-8**
Well Location:	**Midland , TX**	Latitude:	**31° 52' 46" N**
Well County:	**Midland**	Longitude:	**102° 17' 52" W**
Elevation:	**2813 ft.**	GPS Brand Used:	**Garmin**
Type of Work:	**New Well**	Proposed Use:	**Irrigation**

Drilling Date:	Started: **3/15/2013** Completed: **3/15/2013**
Diameter of Hole:	Diameter: **8.75 in From Surface To 110 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **20 ft to 110 ft** Gravel Pack Size: **Vealmore**
Annular Seal Data:	1st Interval: **From 15 ft to 20 ft with 4 Bentonite (#sacks and material)** 2nd Interval: **From 0 ft to 15 ft with 8 Cement (#sacks and material)** 3rd Interval: **No Data** Method Used: **Cement slurry** Cemented By: **WTWWS** Distance to Septic Field or other Concentrated Contamination: **N/A ft** Distance to Property Line: **N/A ft** Method of Verification: **N/A** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Jetted** Yield: **30 GPM with (No Data) ft drawdown after (No Data) hours**
Water Quality:	Type of Water: **N/A** Depth of Strata: **N/A ft.** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**West Texas Water Well Service** **3410 Mankins** **Odessa , TX 79764**
Driller License Number:	**2713**
Licensed Well Driller Signature:	**Russell Southerland**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking #**315334**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 1 Topsoil
1 10 Limestone
10 27 Caliche
27 30 Red clay
30 55 Yellow shale, sandstone
55 70 Red clay
70 95 Sand, sandstone (water)
95 110 Red clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC casing 2 - 90
5 New PVC screen 90 - 110 .035

STATE OF TEXAS WELL REPORT for Tracking #294304

Owner:	**Greg Hand**	Owner Well #:	**No Data**
Address:	**6500 Opal** **Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**6500 Opal** **Odessa , TX**	Latitude:	**31° 53' 11" N**
Well County:	**Ector**	Longitude:	**102° 18' 10" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **6/21/2012** Completed: **6/21/2012**
Diameter of Hole:	Diameter: **8.5 in From Surface To 110 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **70 ft to 110 ft** Gravel Pack Size:
Annular Seal Data:	1st Interval: **From 0 ft to 60 ft with 18 (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Pumped** Cemented By: **Jason** Distance to Septic Field or other Concentrated Contamination: **50+ ft** Distance to Property Line: **6 ft** Method of Verification: **Measured** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **20 GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Wheeler Drilling** **4223 W. 16th St.** **Odessa , TX 79763**
Driller License Number:	**1540**
Licensed Well Driller Signature:	**Ronnie Wheeler**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

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Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-3 Top Soil
3-18 Caliche
18-30 Dry Sand
30-40 Rock
40-60 Wet Sand
60-108 Water Sand
108-110 Red Bed

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
5 New PVC 0-70
5 New PVC Slotted 70-110

STATE OF TEXAS WELL REPORT for Tracking #302974

Owner:	**DOUG MILLICAN**	Owner Well #:	**JN 3537**
Address:	**6544 AMBER DR ODESSA , TX 79762**	Grid #:	**45-06-8**
Well Location:	**6544 AMBER DR ODESSA , TX 79762**	Latitude:	**31° 53' 11" N**
Well County:	**Ector**	Longitude:	**102° 18' 10" W**
Elevation:	**No Data**	GPS Brand Used:	**GARMIN GPS III PLUS**
Type of Work:	**New Well**	Proposed Use:	**Irrigation**

Drilling Date:	Started: **10/24/2012** Completed: **10/24/2012**
Diameter of Hole:	Diameter: **8.75 in From Surface To 104 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **57 ft to 104 ft** Gravel Pack Size: **.02**
Annular Seal Data:	1st Interval: **From 0 ft to 52 ft with CEMENT (#sacks and material)** 2nd Interval: **From 52 ft to 57 ft with 1 BAG HOLE PLUG (#sacks and material)** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Alternative Procedure Used**

Water Level:	Static level: **38 ft. below land surface on 10/24/2012** Artesian flow: **25 GPM**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**DARRELL CRASS DRILLING COMPANY PO BOX 60031 MIDLAND , TX 79711**
Driller License Number:	**2752**
Licensed Well Driller Signature:	**R DARRELL CRASS**
Registered Driller Apprentice Signature:	**TOM H SHELTON**
Apprentice Registration Number:	**59176**
Comments:	**14 - 18 NOT APPLICABLE**

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#302974**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0' - 2' BROWN TOP SOIL
2' - 16' GRAY SAND
16' - 56' GRAY CALICHE
56' - 68' GRAY SAND
68' - 102' YELLOW SAND
102' - 104' RED BED

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" NEW PVC PIPE BLANK 0' - 64'
6" NEW PVC PIPE .020 SCREEN 64' - 104'

STATE OF TEXAS WELL REPORT for Tracking #302977

Owner:	**JUAN VILLAREAL**	Owner Well #:	**JN 3536**
Address:	**6548 AMBER DR ODESSA , TX 79762**	Grid #:	**45-06-8**
Well Location:	**6548 AMBER DR ODESSA , TX 79762**	Latitude:	**31° 53' 11" N**
Well County:	**Ector**	Longitude:	**102° 18' 10" W**
Elevation:	**No Data**	GPS Brand Used:	**GARMIN GPS III PLUS**
Type of Work:	**New Well**	Proposed Use:	**Irrigation**

Drilling Date:	Started: **10/24/2012** Completed: **10/24/2012**
Diameter of Hole:	Diameter: **8.75 in From Surface To 104 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **58 ft to 104 ft** Gravel Pack Size: **.02**
Annular Seal Data:	1st Interval: **From 0 ft to 53 ft with CEMENT (#sacks and material)** 2nd Interval: **From 53 ft to 58 ft with 1 BAG HOLE PLUG (#sacks and material)** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Alternative Procedure Used**
Water Level:	Static level: **39 ft. below land surface on 10/24/2012** Artesian flow: **20 GPM**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**DARRELL CRASS DRILLING COMPANY PO BOX 60031 MIDLAND , TX 79711**
Driller License Number:	**2752**
Licensed Well Driller Signature:	**R DARRELL CRASS**
Registered Driller Apprentice Signature:	**TOM H SHELTON**
Apprentice Registration Number:	**59176**
Comments:	**14 - 18**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

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Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0' - 2' BROWN TOP SOIL
2' - 16' GRAY SAND
16' - 56' GRAY CALICHE
56' - 68' GRAY SAND
68' - 102' YELLOW SAND
102' - 104' RED BED

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
6" NEW PVC PIPE BLANK 0' - 64'
6" NEW PVC PIPE .020 SCREEN 64' - 104'

STATE OF TEXAS WELL REPORT for Tracking #299888

Owner:	**Mark Bickers**	Owner Well #:	**No Data**
Address:	**6605 Dunbar** **Odessa , TX**	Grid #:	**45-06-8**
Well Location:	**6605 Dunbar** **Odessa , TX**	Latitude:	**31° 53' 24" N**
Well County:	**Ector**	Longitude:	**102° 18' 05" W**
Elevation:	**2888 ft.**	GPS Brand Used:	**Garmin**
Type of Work:	**New Well**	Proposed Use:	**Domestic**

Drilling Date:	Started: **8/29/2012** Completed: **8/29/2012**
Diameter of Hole:	Diameter: **10 in From Surface To 10 ft** Diameter: **7.875 in From 10 ft To 117 ft**
Drilling Method:	**Air Rotary**
Borehole Completion:	Gravel Packed From: **10 ft to 117 ft** Gravel Pack Size: **Pea gravel**
Annular Seal Data:	1st Interval: **From 0 ft to 10 ft with 6 bags cement (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **Poured** Cemented By: **Driller** Distance to Septic Field or other Concentrated Contamination: **over 100 ft** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **25 ft. below land surface on 8/29/2012** Artesian flow: **No Data**
Packers:	**No Data**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**Estimated** Yield: **40+ GPM with (No Data) ft drawdown after (No Data) hours**

Water Quality:	Type of Water: **Groundwater** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Elite Drillers Corporation** **10418 Shire Country** **San Antonio , TX 78254**
Driller License Number:	**58820**
Licensed Well Driller Signature:	**Bryce J Wallace**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0 - 2 Topsoil.
2 - 24 Caliche.
24 - 55 Sand.
55 - 87 Sandstone and sand.
87 - 90 Grey clay.
90 - 110 Sand and sandstone.
110 - 117 Red clay.

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
4 1/2 New PVC SDR 17 +2 - 77
4 1/2 New PVC Factory Perf 77 - 117

Dataset Descriptions and Sources *Lone Star Drum Facility*

BANKS ENVIRONMENTAL DATA A DIVISION OF THE BANKS GROUP

Dataset	Source	Dataset Description	Update Schedule	Data Requested	Data Obtained	Data Updated	Source Updated
TX HGSD - Texas HGSD	Harris Galveston Subsidence District/Fort Bend Subsidence District	This dataset contains all groundwater well records compiled by Harris Galveston Subsidence District/Fort Bend Subsidence District.	Quarterly	06/23/2014	03/24/2014	04/06/2013	03/24/2014
TX TCEQ HIST - Texas TCEQ Historical	Texas Commission on Environmental Quality	This dataset contains all historical water well records searched from the TCEQ Public Water Well Viewer. Banks Environmental Data plots each well record based on location information found on the log.	As requested	N/A	N/A	N/A	N/A
TX TCEQ PWS - Texas TCEQ PWS	Texas Commission on Environmental Quality	This dataset contains a collection of records from Texas Water Districts, Public Drinking Water Systems and Water and Sewer Utilities who submit information to the TCEQ.	Quarterly	06/06/2014	06/13/2014	07/13/2014	06/06/2014
TX TWDB GW - Texas TWDB Groundwater Database	Texas Water Development Board	This dataset contains water well records contained within Texas Water Development Board Groundwater Database.	Quarterly	07/03/2014	07/03/2014	07/13/2014	07/01/2014
TX TWDB WIID - Texas TWDB Submitted Drillers' Logs	Texas Water Development Board	This dataset contains water well records from the Texas Water Development Board Submitted Driller's Reports Database.	Quarterly	07/03/2014	07/03/2014	07/13/2014	07/01/2014
WW USGS - USGS Water Wells	U.S. Geological Survey	This dataset contains groundwater well records from the U.S. Geological Survey.	Quarterly	06/30/2014	06/30/2014	07/13/2014	06/30/2014

Disclaimer *Lone Star Drum Facility*

The Banks Environmental Data Water Well Report was prepared from existing state water well databases and/or additional file data/records research conducted at the state agency and the U.S. Geological Survey. Banks Environmental Data has performed a thorough and diligent search of all groundwater well information provided and recorded. All mapped locations are based on information obtained from the source. Although Banks performs quality assurance and quality control on all research projects, we recognize that any inaccuracies of the records and mapped well locations could possibly be traced to the appropriate regulatory authority or the actual driller. It may be possible that some water well schedules and logs have never been submitted to the regulatory authority by the water driller and, thus, may explain the possible unaccountability of privately drilled wells. It is uncertain if the above listing provides 100% of the existing wells within the area of review. Therefore, Banks Environmental Data cannot fully guarantee the accuracy of the data or well location(s) of those maps and records maintained by the regulatory authorities.

Banks Environmental Data, Inc. - 1601 Rio Grande, Ste. 500 - Austin, TX 78701 - 800.531.5255 P - 512.478.1433 F
www.banksenvdata.com

Reference 21

Superfund Site Discovery and Assessment Program
Field Sampling Plan
for the

State Screening Phase

of the

Ector Drum Inc. Site

Odessa, Ector County, Texas

March 2015

Texas Commission on Environmental Quality
12100 Park 35 Circle, Bldg. D
Austin, Texas 78753

FSP Approval, Key Participants, and Distribution List						
Name	Responsibility	Organization	Phone Number Email Address	FSP Approval Signature	Approval Date	Control Copy #
Nancy Johnson	Project Manager	TCEQ Superfund Section	817-588-5862 nancy.johnson@tceq.texas.gov			1
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Valeri Salinas	CONTRACTOR Health & Safety Officer	CB&I Environmental & Infrastructure, Inc.	432-681-2802 valeri.salinas@cbi.com			
As noted by my signature above, I have reviewed the FSP for the project and the QAPP (QTRAK# 14-453) and I affirm I understand my responsibilities and my authority for implementing the FSP and QAPP on this project.						

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APPENDICES

1.0 PROJECT SUMMARY

1.1 Overview

The Texas Commission on Environmental Quality (TCEQ) Superfund Site Discovery and Assessment Program (SSDAP) is conducting sampling, data collection, and related activities at the site named below. This field sampling plan (FSP), along with the TCEQ *Quality Assurance Project Plan for the Superfund Programs* (QAPP) listed below, describe the planned activities for this phase of work. A separate health and safety plan (HASP) addressing the safety protocols has also been prepared.

Site Name:	Ector Drum Inc.
SSDAP Phase:	☐ Eligibility Sampling ☒ State Screening Sampling ☐ HRS Sampling ☐ Removal Assessment Sampling ☐ Removal Action Confirmation Sampling ☒ Drinking Water Evaluation Sampling
City, County:	Odessa, Ector
Superfund QAPP	QTRAK# 14-453, Rev. 11
The work described in this FSP will be conducted by:	
Contractor: Subcontactor:	CB&I Environmental & Infrastructure, Inc. DHL Analytical, Inc. and GEL Laboratories, LLC
Assessment, Investigation, and Remediation Services (AIRS) Contract	582-14-40666

This FSP describes the data quality objectives (DQOs) for the field event, the field activities and sampling methods to be used, and the activities for managing the collected data and supporting information. The contractors and subcontractors involved in the field event will read this FSP and the QAPP prior to initiating field activities and will comply with the specified procedures. The field team will have the FSP and QAPP on-site and readily available during the field event.

Appendix A contains the laboratory certification for the method and analytes to be used in the analysis of environmental matrices at the site. Appendix B lists the field standard operating procedures (SOPs) to be used for this project.

The Texas Risk Reduction Program rule (TRRP), codified in 30 Texas Administrative Code (TAC) Chapter 350 (30 TAC 350), establishes the regulatory requirements for this project. The State Superfund rules, found in 30 TAC 335 Subchapter K, establish the administrative requirements for this project. The Hazard Ranking System (HRS), in Title 40 of the Code of Federal Regulations (40CFR) Part 300, provides the principal mechanism to assess the relative threat to human health and/or the environment posed by the site and to evaluate eligibility of the site for the state or federal Superfund programs.

1.2 Document Control

The Contractor is responsible for controlled distribution of the FSP and is required to verify the current approved version of the FSP is being used and outdated material is removed from circulation and archived. The QAPP Element A.3 specifies the Contractor responsibilities for controlled distribution of this FSP.

1.3 SSDAP Phase

The SSDAP evaluates, screens, and ranks sites for eligibility to the State Superfund Program and conducts imminent threat assessments. For the site to be eligible for the State Superfund Program, a hazardous substance, as defined in the Texas Health and Safety Code §361.003(11) and the 40 CFR 302.4, must be documented as present and attributable to the site. This sampling event is for the project phase(s) specified below. The project objectives for the phase are presented in Table 1 (Project Objectives).

1.3.1 ☐ Eligibility Sampling Phase

The purpose of this sampling event is to determine if the Site is eligible for evaluation and scoring under the SSDAP by documenting a release if hazardous substances to the environment.

1.3.2 ☒ State Screening Sampling Phase

The purpose of this sampling event is to screen or prioritize this eligible site by documenting impacts to receptors in the critical pathways of exposure (indicated in Section 2.3) to facilitate HRS scoring (40 CFR Part 300 Hazard Ranking System; Final Rule).

1.3.3 ☐ Hazard Ranking System Sampling Phase

The purpose of this sampling event is to collect data to generate a qualifying HRS score. If the HRS score is 5.0 or greater, a State HRS Document may be prepared, and the site may be proposed for listing on the State Superfund Registry.

1.3.4 ☐ Removal Assessment Sampling Phase

The purpose of this sampling event is to document the extent of a release or potential threat of release of a hazardous substance where immediate action is warranted to protect human health and the environment.

1.3.5 ☐ Removal Action Confirmation Sampling Event

The purpose of this sampling event is to determine the effectiveness of removal action activities. Confirmation samples will be collected to document the removal action objectives have been met.

1.3.6 ☒ Drinking Water Evaluation Sampling Event

The purpose of this sampling event is to assess impacts of hazardous substances to drinking water sources within the target distance limit. Groundwater wells or other drinking water sources will be sampled to determine the concentrations of hazardous substances present.

1.4 References

1.4.1 Guidance

The following guidance documents were used during the preparation of this FSP:

- Texas Risk Reduction Program Protective Concentration Levels for Residential Groundwater Ingestion, Class 1 and 2, November 2014
- Environmental Protection Agency (EPA) Superfund Chemical Data Matrix (SCDM) values, January 2015

1.4.2 Site-Specific Documents and Secondary Data Sources

Site-specific documents and secondary data sources used to prepare this FSP are:

- Texas Commission on Environmental Quality Investigation Reports #912172 and #1186740;

- Ector County Appraisal District, http://www.ectorcad.org/;
- United States Department of Agriculture Soil Conservation Service Soil Survey of Ector and Crane Counties, Texas, August 1978;
- Banks Environmental Data Water Well Report, Lone Star Drum [Ector Drum] Facility, October 10, 2014;
- SWS Environmental Services Drinking Water Survey Report and Water Well Inventory, Lonestar Drum [Ector Drum] Facility; October 28, 2014; and
- U.S. Fish and Wildlife Service National Wetlands Inventory, http://www.fws.gov/wetlands/.

1.5 Project Team and Responsibilities

The roles and responsibilities of the project team are listed in Element A.4 of the QAPP. These individuals are responsible for project planning and communications and for implementing this FSP. Lines of communication and authority for the project team are shown in Figure 1 (Project Organization Chart).

Additional roles and responsibilities for this sampling event are conducted by the contractor health and safety officer, whose responsibilities are specifically listed in the separate project-specific health and safety plan.

1.6 Schedule

The schedule for the activities specified in this FSP is maintained by the TCEQ PM and the Contractor PM. The TCEQ PM and the Contractor PM are responsible for communicating the schedule to the project team.

Following the safety briefing and prior to initiating field activities each day, the TCEQ or Contractor PM will discuss the following regarding activities for that day:

- team roles, responsibilities, and assignments;
- sample locations and sampling procedures;
- decontamination procedures;
- any planned deviations from the FSP or QAPP;
- QA/QC activities;
- boundaries of the safe zone and location(s) where food and water can be consumed; and

- the schedule for the day.

2.0 COMPONENTS OF CONCEPTUAL SITE MODEL

The conceptual site model (CSM) is the basis for the approach, means, and methods selected for this FSP. The CSM takes into account current site conditions and potential human and environmental exposure through potential or actual contaminant release and probable migration to potential receptors. The key components of the CSM for this site at this time are the site setting, the site history and process knowledge, including previous sampling and analytical results, the pathways and associated targets within the HRS distance limit, and potential sources.

2.1 Site Setting

2.1.1 Site Location and Description

The Ector Drum, Inc. Site (site) is located at 2604 N. Marco Ave. in Odessa, Ector County, Texas and is approximately 230 feet southeast of the city limits (Figure 2). The site was operated by Ector Drum, Inc., a drum reconditioning business. Ector Drum, Inc. received drums that originated from oilfield industrial sources consisting primarily of crude oil treatment, corrosive chemicals and lubrication oils. The 1.33-acre tract of land is in an industrial area with residential areas close to the facility.

2.1.2 Site Features

The site consists of multiple buildings and a large storage yard. The storage yard contains numerous 55-gallon drums, 350-gallon totes and a few waste storage tanks, some of which appear to be empty and some of which contain uncharacterized wastes and chemicals (Figure 3). Some of the original processing equipment at the facility has been removed, and some buildings are now used to house totes and drums. The large number of containers at the site is alleged to have contributed to the discharge of industrial waste from the site during rainfall events and endanger public health and the environment. There are no current operations at the site.

2.1.3 Soils

The dominant soil composition in the general area is a fine sandy loam of the Faskin soil group. It has moderate infiltration rates and is well drained with moderate corrosion potential.

2.1.4 Geology and Hydrogeology

The understanding of the geology and hydrogeology relevant to the presence and migration of target chemicals of concern (COCs) through geologic media at and near the site is based on one drinking water survey containing data from the two wells comprising the site. The site is within the Texas High Plains physiographic region with the major hydrogeologic units containing potable water within the Ogallala Formation and Trinity Sand with the underlying "red beds" of the upper Chinle Formation acting as an aquitard. Groundwater at the site is approximately 60 feet below ground surface per the documents and references cited in Section 1.4.2. The soils associated with the site have moderate infiltration rates with well drained soils that have moderately coarse textures. Based on this information it is presumed that contaminants most likely can travel through the soil and groundwater in the area due to the fine sandy loam texture. In general, contaminant plumes move more quickly through sandy-gravely types of soils than silty-clayey types of soils.

2.1.4.1 Groundwater Use

Numerous domestic water supply wells are within the target distance limit, as detailed in the SWS Environmental Services Water Survey Report cited in Section 1.4.2. The wells are completed in the shallow Ogallala Formation and Antlers Formation with total depths ranging from 85 to 130 feet below ground surface (bgs). The depth to static water level in these wells ranges from 30 to 90 feet, depending on seasonal fluctuations. Domestic wells within proximity of the site are used for household use and irrigation.

2.1.5 Topography and Drainage

The site has a gentle slope to the south-southeast, and it appears surface water runoff flows overland south, possibly into a storm water drainage channel that runs along Business Interstate 20.

2.1.6 Surface Water and Sediment

The HRS target distance limit for the Site is a 4.0 mile radius. Approximately 0.5 miles to the east-northeast of the Site are three man-made bodies of water associated with the Odessa Country Club golf course. There is also a wetland approximately 0.5 miles east of the Site and is classified as a freshwater emergent wetland; currently the wetland area is dry. Another area classified as a freshwater emergent wetland is located approximately 0.7 miles southwest of the site. Water collects in these wetland areas when there are heavy rains.

2.2 Site History and Process Knowledge

- On June 23, 2014, the TCEQ Region 7 Office received information alleging that the site had potential discharge of contaminated storm water coming from the site property. The Region 7 office was requested to conduct an on-site inspection to investigate the complaint.
- On July 25, 2014, the TCEQ conducted a complaint investigation at Ector Drum, Inc., for the potential discharge of contaminated storm water from the site. Numerous storage containers with unknown chemicals were observed on-site. Numerous areas with ground staining and contamination were also noted. Due to the excess amounts of waste that was left on-site, it was noted that an enforcement action would be pursued.
- On October 8, 2014, SWS Environmental Services (SWS) conducted sampling activities at an on-site well. Samples were collected from the oil product above the water in the well and for the groundwater in the well.
- On October 13, 2014, SWS conducted a 500-foot visual survey at the site. A walking and driving survey was also conducted within at least 0.25 miles of the site. Based on the interviews with the well owners/users, it was concluded that most of the wells are not used for drinking water purposes.
- On October 28, 2014, SWS Environmental submitted a Drinking Water Survey Report and Water Well Inventory to TCEQ.

2.2.1 Release History and Contaminant Sources

TCEQ received information that the site had potential discharge of contaminated storm water migrating from the site. During the site investigation numerous drums, totes and storage tanks containing unknown chemicals were observed at the site. Underneath the loading rack a 20'x10'x4" pool of an unknown substance was also observed. The ground surface at various locations showed evidence of chemical contamination most likely from the long-term drum storage. The concrete secondary containment of two tanks on-site was full of a mixture of water and unknown chemical. Chemicals were also discovered in the buildings on-site. Due to the high number of waste storage containers on-site an estimation of the volume in unknown.

During a second site investigation, an onsite well contained 1.8 feet of Phase Separated Hydrocarbons that was measured in the wellbore. Based on observations made during the field activities, the oil apparently ran into the well casing through an electric conduit as a result of surface water runoff impacted by releases of oil from drums at the site.

It was determined that the large amount of waste stored on-site may contribute to the discharge of industrial waste from the site during rainfall events and endanger public health and the environment.

2.2.2 Previous Sampling and Analytical Results

On October 8, 2014, SWS mobilized to the site to collect water samples from the onsite water well. An evaluation of the laboratory analytical results for the oil phase indicated concentrations of arsenic (2.46 mg/kg), chromium (33.1 mg/kg), copper (5.00 mg/kg), lead (3.34 mg/kg), nickel (2.92 mg/kg), and zinc (274 mg/kg) were listed in the SWS report as all exceeding the TRRP Tier I Residential Groundwater Protective Concentration Levels (PCLs). They were reported in mg/kg, however, and do not exceed the TRRP Tier I Residential Soil PCLs. Table 3 (Summary of Historical Analytical Results) lists and describes the historical analytical results.

For the water phase, concentrations of chromium (1.49 mg/L), lead (0.281 mg/L), thallium (0.319 mg/L) and zinc (37.1 mg/L) exceeded the TRRP PCLs of 0.10 mg/L, 0.015 mg/L, 0.002 mg/L and 7.3 mg/L, respectively. No VOCs or SVOCs were detected, but the detection limits were highly elevated due to the dilution of the samples which were required to be analyzed at (1000x and 10x respectively). A benzene concentration (2.70 mg/L) was reported at a concentration below the quantitation limit (J Flagged) but above the laboratory detection limit at 1.00 mg/L. This concentration, although estimated, is substantially above the TRRP PCL of 0.005 mg/L for groundwater. The speciation of the TPH by TX Method 1006 indicated aliphatic hydrocarbons in the C6-C8 carbon range were below the laboratory detection limits, C8-C10 (0.300 mg/L), C10-C12 (2.10 mg/L), C12-C16 (4.61 mg/L), C16-C21 (15.3 mg/L) and C21-C35 (264 mg/L) exceeded the TRRP PCLs for the C12-C16 fraction established at 2.4 mg/L and for the C21-C35 fraction established at 39 mg/L. For the aromatic hydrocarbons, the laboratory reported C7-C12 below the laboratory detection limits, C12-C16 at 0.390 mg/L, C16-C21 at 4.73 mg/L and C21-C36 at 17.3 mg/L. A comparison with the TRRP PCL indicated the C16-C21 and C21-C36 carbon ranges exceed the criteria of 0.73 mg/L and 0.73 mg/L respectively (Table 3).

2.3 Pathways

Based on the CSM, the pathways selected for evaluation during this SSDAP phase are the critical pathways for HRS scoring and imminent threat evaluation.

The groundwater pathway is the only pathway that will be evaluated during this phase as it is the primary pathway for potential imminent threat, and it represents the critical pathway for the purpose of generating an HRS site score.

2.3.1 Groundwater Pathway

The results of the water well survey conducted revealed the presence of 50 water wells within a 0.25 mile radius of the subject site and approximately 70 water wells (domestic, irrigation, and industrial) were identified in use within a 0.5 mile radius of the site. Based on interviews with the well owners/users of the 0.25 mile radius, most of the wells are not used for drinking water purposes but are mainly used to provide water for washing hands at sinks, toilets and irrigation purposes. Three facilities, however, had ice machines connected to the water supplied from their onsite wells. The nearest well adjacent to the site is located approximately 300 feet south of the site. The nearest well that uses well water for drinking is located approximately 800 feet south of the site.

2.3.2 Soil Pathway

Soil staining and pools of unidentified liquids were observed on-site during the site investigation conducted by the TCEQ. Multiple areas of staining were observed and are most likely associated with the unknown liquids on-site which could leach into the groundwater via the soil and/or migrate offsite via sheet flow during rainfall.

2.3.3 Surface Water Pathway

The surface water pathway is not considered a viable pathway at this time and will not be evaluated during this phase.

2.3.4 Air Pathway

No suspected sources of potential qualifying air emissions are known at this time; therefore, the air pathway will not be evaluated during this phase.

2.4 Potential Sources

It was determined that the large amount of waste stored on-site may contribute to the discharge of industrial waste from the site during rainfall events and endanger public health and the environment.

3.0 ANALYTICAL REQUIREMENTS

3.1.1 Selection of Chemicals of Concern

The project team identified the chemicals of concern (COCs) for the site based on a review of site history, process knowledge, environmental fate and transport, and previous analytical results. The COCs are listed below and are indicated by an "X" in Table 4 (Analytes and COCs). The list of COCs may be amended based on additional analytical results and/or additional site information.

All the chemicals listed for each analytical method are listed as COCs at this time. Listed below are the methods chosen by the project team.

Due to the unknown chemicals on-site many methods have been selected for the site. The COCs for this site include volatile organic compounds (VOCs) (EPA 8260C), semi-volatile organic compounds (SVOCs) (EPA 8270D), metals (EPA 6020A), mercury (EPA 7470A), chloride (EPA 300.0) and Naturally Occurring Radioactive Material (NORM) analysis of Ra 226 (903.1) and Ra 228 (904.0).

3.1.2 Significance Above Background

The analytical data will be evaluated to determine if a COC or an analyte is present at concentrations *significantly above background*. To be documented as *significantly above background*, the COC or analyte concentration in one or more release samples must be equal to or greater than the sample quantitation limit (SQL) for that sample, and one of the following statements must be true:

- When the COC or analyte is detected above the SQL in one or more background sample, the COC or analyte concentration in a release sample is greater than three times the highest concentration in the background sample(s); or
- When the COC or analyte is not detected above the SQL in any background sample, the COC or analyte concentration in the release sample is greater than or equal to the highest background SQL for the COC or analyte.

3.1.3 Analytical Methods

The laboratory will use the EPA methods from the SW-846 manual, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, for sample analyses unless otherwise specified in this FSP. Requirements for these analytical methods are specified in the QAPP or in Section 6.0 of this FSP. Any site-specific exceptions, additions, or changes to the requirements of the QAPP are documented in Section 6.0 of this FSP. The analytical methods selected and the analytes and COCs for each method are detailed in Table 4 (Analytes and COCs). Table 5 (Analyses Summary) summarizes the analytical method(s) by which the samples will be analyzed.

Each of the selected analyses will be performed in accordance with the applicable published methods for extraction, cleanup, preparation, and determination. The laboratory will include all method-required and method-recommended quality control steps, including the QA/QC procedures specified in the laboratory quality assurance manual and the procedures specified in the QAPP. The QC acceptance criteria specified in the QAPP will be used unless otherwise specified in Section 6 of this FSP.

3.1.4 Selected Laboratories

Laboratories providing analytical services for this project are accredited through the Texas Laboratory Accreditation Program (TLAP) for the most current standards adopted by the National Environmental Laboratory Accreditation Program (NELAP) and the requirements in 30 TAC 25. These laboratories have documented SOPs in place and data on record which demonstrate the laboratory capabilities to generate data that meet the project objectives by the methods specified in this FSP. When requested by the TCEQ, the Contractor will make available any laboratory procedure or activity associated with the analysis of samples from this sampling event.

Table 7 (Preparatory and Analytical Methods by Laboratory) lists by laboratory the preparatory and analytical methods each laboratory will use to analyze samples. Appendix A contains an excerpt of the laboratory NELAP certificate. Each page of the excerpt contains the laboratory certification number. The excerpt includes the following pages from the certificate:

- Page 1 presents the NELAP Recognized Laboratory Accreditation certificate and certificate number (T104704211-14-13) for the DHL Analytical, Inc. laboratory;
- Page 4 presents the analyte chloride for 300.0 analysis in non-potable water;
- Page 6 through 7 presents the analytes for 6020 analysis in non-potable water;
- Page 35 through 36 of GEL Laboratories, LLC NELAP Recognized Laboratory Accreditation certificate and certificate number (T104704235-14-9) presents the analyte Radium-226 in non-potable water;
- Page 12 presents the analyte mercury for 7470 analysis in non-potable water;
- Page 13 through 15 presents the analytes for 8260 analysis in non-potable water;
- Page 15 through 21 presents the analytes for 8270 analysis in non-potable water.

3.1.5 Analytes

Table 4 (Analytes and COCs) presents the analytes selected for each analytical method and the analytes identified as COCs, marked with an “X,” for this site. The laboratory will report analytical results for all analytes and COCs listed in Table 4.

3.2 Level of Required Performance

The level of required performance (LORP) is the lowest quantified analyte or COC concentration required from the laboratory to achieve project objectives. The LORPs for this sampling event are derived from:

- the January 2015 Superfund Chemical Data Matrix (SCDM) hazardous substances benchmarks which may be used to evaluate the site in the Hazard Ranking System (HRS); and
- the November 2014 Texas Risk Reduction Program (TRRP) residential Tier 1 total-soil-combined protective concentration levels (PCLs) for a 30-acre source area and the Tier 1 residential Class 1 or 2 groundwater ingestion PCLs listed in the TRRP PCL tables. The PCLs may be used to determine if a removal or other action is warranted.

Table 4 (Analytes and COCs) lists the analytes, the COCs, the respective LORPs, the source of each LORP, and the laboratory method quantitation limits (MQLs). For each analyte and COC, the corresponding laboratory MQL should be less than or equal to the LORP. The default LORP is the lower of the SCDM benchmark or TRRP PCL for a specific analyte or COC. If no standard available method is capable of quantifying an analyte or COC below the default LORP, the MQL of method selected becomes the LORP. If the MQL is the LORP for an analyte, the Contractor, with concurrence from the TCEQ PM, will verify the MQL supports the project objectives and meets the sensitivity needs of the project for this sampling event. If the project team has identified the analyte as a COC and the MQL is the LORP, the TCEQ PM will review the project objectives and approve the use of the MQL or will direct the Contractor to select another method capable of achieving a lower MQL.

The laboratory MQLs listed in Table 4 for some COCs are greater than the LORP. The Contractor has reviewed the project objectives and the site-specific conditions and has concluded the analysis of the COCs by the specified method is advisable for the sampling event. The TCEQ PM concurs with this project decision.

3.3 Batching of Samples

The laboratories will batch as many TCEQ project samples together as possible. The Contractor will consult with the laboratory regarding the needs of the laboratory. The Contractor will follow the best procedures and order (for collecting, packaging, and delivering the samples to the laboratories) that allows the laboratories to batch as many TCEQ project samples together as possible. The number of batches is estimated in Table 5 (Analyses Summary).

3.4 Sample Shipment

Contractor will ship samples on the same day the samples are collected.

3.5 Analytical Reporting

Analytical results will be reported in milligrams per liter (mg/L) for water, milligrams per kilograms (mg/kg) for soil, and grams per cubic meter (g/m^3) for vapor or air. The laboratory will report the data following the specifications in the QAPP Element A.9 and Element A.7 (reporting of non-detected results) with one exception. Under SSDAP, the laboratory will report non-detected results as less than the value of the sample quantitation limit (SQL), not the sample detection limit (SDL) as specified in Element A.7 The SQL is the MQL adjusted for the sample-specific factors, such as dilution or percent solids.

3.6 Analytical Results Turnaround Time

The Contractor will report the preliminary analytical results to the TCEQ PM within the timeframes specified in the applicable Work Order and Contract. The Contractor will report the reviewed data and validated data to the TCEQ PM within the timeframes specified in the applicable Work Order and Contract.

3.7 Data Review, Validation, and Reporting

The laboratory will review the data as specified in QAPP Element D.2.1.1 and will submit the laboratory data package as specified in QAPP Element A.9.2.

The CONTRACTOR will

- Annotate qualified data on the analytical data sheets with appropriate data review qualifiers as listed in Table D.1.1-2 in the QAPP and associated qualifier codes and bias codes as listed in Table D.1.1-3 in the QAPP.
- Prepare the data review memoranda pursuant to the contract requirements.

4.0 SAMPLING STRATEGY

The pathways to be evaluated during this sampling event are described in Section 2.1.9.

The groundwater pathway is to be evaluated during the state screening sampling event. Water samples will be collected and analyzed for VOCs (Method 5030/ 8260C), SVOCs (Method 3510/8270D), metals (Method 3010/6020A), mercury (Method 7470A), chloride (Method 300.0) and NORM analysis of Ra 226 (Method 903.1) and Ra 228

(Method 904.0). Also the lab will report tentatively identified compounds for SVOCs (method 8270D). The sampling plan will include up to 30 domestic water well grab samples, 16 of which have been identified by the TCEQ prior to fieldwork (see Figure 6 for proposed sample locations). Water wells will be purged and water parameter measurements will be collected. After purging, groundwater samples will be collected from the domestic water wells from a location as close to the wellhead as possible. Well selection for sampling will be based on location in relation to the original site and upon receiving access. The state screening sampling event will be conducted to assess additional domestic wells potentially affected by the observed releases of the target COCs exceeding the PCL or MCL within the affected groundwater bearing unit. No wells are proposed to be installed in connection with the site at this time.

4.1 Sampling Summary

All samples will be collected in accordance with this FSP and the referenced SOPs. When possible, samples will be collected in order from the lowest to highest suspected COC concentration with the exception of surface water samples. No collection of surface water or sediment samples is planned for this sampling event. As applicable to the planned analyses, the order of sample collection at each sample location will be: VOCs, SVOCs, metals, cyanide, pesticides/PCBs, and other analyses.

Field sampling personnel will wear non-lubricated nitrile disposable gloves, or other suitable disposable gloves, during the sampling and the handling of samples and sampling equipment. The disposable gloves will be changed between each sample location. Prior to sampling activities, sampling equipment will be handled and decontaminated in accordance with Superfund SOP 1.5 (Decontamination).

4.1.1 Sample Plan for the Groundwater Pathway

The sampling plan will include up to 30 domestic water well grab samples from faucets or sampling ports. Water wells will be purged in accordance with SOP No. 7.9 (Purging a Drinking Water Well). During the purge, measurements will be collected in accordance with SOP No. 7.5 (Measurement of Field Parameters). After purging, groundwater samples will be collected in accordance with SOP 7.10 (Sampling a Drinking Water Well).

Quality control and quality assurance samples are to be collected along with the field water well samples during sampling activities. Duplicates will be collected at a frequency of 1 per every 10 project samples. MS/MSD samples will be collected at a frequency of 1 per every 20 project samples. Trip blanks will be collected 1 per each cooler containing aqueous VOC samples. Field blanks will be collected at a frequency of 1 per every 20 project samples at the area of suspected airborne contamination.

Sample locations will be determined in the field by TCEQ personnel. Access agreements will be obtained by CB&I and the TCEQ by correspondence or during field activities prior to sampling commencement. If additional wells are added in the field at the discretion of TCEQ, then GPS locations will be collected as needed per SOP 17.1 GPS Data Collection and Submission.

Sample results will be used to document observed releases to receptors in the groundwater pathway. Samples will also aid in delineation of the contaminant groundwater plume for evaluation and potential remediation purposes.

Table 6 (Sample Summary by Pathway) lists and describes the pathways.

4.2 Groundwater Sample Collection

For this sampling event, the field team will collect samples from:

- Domestic water wells.

4.2.1 Sample Collection from Wells With a Sealed Wellhead

The field team will use Superfund SOP 7.9 (Purging a Drinking Water Well) and Superfund SOP 7.10 (Sampling a Drinking Water Well) to collect groundwater from wells with a sealed wellhead such as residential, PWS, industrial, irrigation, or livestock wells. If the field team determines the well is in use, the field lead will document that information in the field logbook, and the TCEQ PM may elect to reduce the minimum purge time to five minutes.

4.2.2 Water Well Filtration Systems

If any residential wells have filtration systems, samples will be collected before the filtration system, if possible.

4.3 Quality Control Samples

The Contactor will collect QC samples in accordance with Superfund SOP 6.5 (QA/QC Samples). Table 5 (Analyses Summary) presents the pathway or source and the sample type, location and frequency for each QC sample. The QC samples the Contractor will collect, and the associated frequencies, are:

- An MS/MSD sample pair will be collected at a frequency of 1 per 20 project samples collected of each matrix.
- Field Blank (FB) samples will be collected at a frequency of 1 per 20 samples of each matrix when analyzing for VOCs or other suspected airborne COCs.
- Trip Blank (TB) samples will be collected at a frequency of 1 for each cooler containing aqueous VOC samples. The sample vials will be filled with ASTM Type II reagent grade water before sample containers are transported to the field. If the containers are coming from the laboratory, the laboratory prepared the trip blanks.
- Temperature Blank samples will be collected at a frequency of 1 per cooler.
- Field Duplicates (FD) samples will be collected at a frequency of 1 per 10 project samples.

4.4 Sample Handling

4.4.1 Sample Identification and Documentation

Samples will be identified and documented in accordance with Superfund SOP 6.6 (Sample Identification and Documentation).).

The sampling numbering system for this project phase is:

- GW- (for groundwater well);
- XX - (numbering system, beginning with 01).

4.4.2 Sample Containers, Preservation, and Holding Times

Sample containers, sample preservation requirements, sample volumes, and holding times are specified in Table B.2.2-1 of the QAPP.

4.4.3 Custody Procedures

Custody procedures will be conducted in accordance with Superfund SOP 6.4 (Sample Handling and Control).

5.0 ADDITIONAL ACTIVITIES

5.1 Initial Site Inspection

Prior to investigative activities the site will be inspected and photographed for indications of contamination and other important features, as described in Superfund SOP 1.1 (Initial Site Reconnaissance) .

5.2 Access Agreements

When possible, the TCEQ will obtain formal access agreements documenting landowner permission for the TCEQ and TCEQ contractors to investigate, sample, and remediate property. Access agreements will be secured with relevant landowners and/or tenants using Form TCEQ-10452. When the TCEQ or Contractor is unable to secure a written access agreement from a property owner, verbal agreement for access will be obtained whenever possible and documented in the field logbook. If the property is abandoned, or the owner cannot be determined or contacted, the TCEQ PM will determine further actions as directed by TCEQ management.

Access agreements have been secured by the TCEQ.

5.3 Site Clearing and Access to Sample Locations

In conjunction with the TCEQ PM, the Contractor is responsible for selecting the sample, monitor well, borehole, and other data collection locations in the field, based on the requirements of the FSP, the physical setting, and access. The Contractor is responsible for verifying the selected data collection locations are physically accessible to personnel and equipment in accordance with Superfund SOP 1.2 (Site Preparation and Control). The Contractor will discuss accessibility of sample locations with the TCEQ PM as necessary.

If accessibility issues arise due to unsafe conditions or obstructions on the properties that are to be sampled, the owner(s) of the property will be sought to remove any debris blocking access or anything that would create an unsafe condition.

5.4 Site Restoration

To the extent practical, the work site and sample locations will be restored to their original condition in accordance with Superfund SOP 1.3 (Site Restoration). Efforts will be made to minimize impacts to work sites and sample locations, particularly residential properties and properties in or near sensitive environments.

5.5 Decontamination

The Contractor will conduct decontamination processes in accordance with Superfund SOP No. 1.5 (Decontamination).

5.6 Investigation Derived Waste

The Contractor will handle and dispose of Investigation Derived Waste (IDW) in accordance with Superfund SOP 1.4 (Management of Investigation Derived Waste). Except when instructed otherwise by the TCEQ PM, the Contractor will dispose of IDW in the same fiscal year as it was generated.

5.7 Deviations in the Field from FSP, QAPP OR SOP

Deviations in the field from SOPs, the approved FSP, or the QAPP will be approved by the TCEQ PM and recorded with the associated rationale in the field logbook.

6.0 EXCEPTIONS, ADDITIONS, AND CHANGES TO THE FSP, QAPP, OR SOP

6.1 Exceptions, Additions, and Changes to the FSP Standard Language

The exceptions, additions, and changes to the standard language in this FSP for this project are:

- There are no exceptions, additions or changes to the standard language in this FSP for this project.

6.2 Exceptions, Additions, and Changes to the QAPP

The exceptions, additions, and changes to the QAPP planned for this project are:

- GEL Laboratories is National Environmental Laboratory Accreditation Conference (NELAC)-accredited under the Texas Laboratory Accreditation Program (TLAP) for Radium-226 by EPA Method 903.1 for Non-Potable Water. However, GEL Laboratories is not certified for Radium-228 by EPA Method 904.0 for Non-Potable Water. Since the TLAP does not currently offer accreditation for Radium-228 by Method 904.0 for this matrix, the Radium-228 data are exempt from accreditation under 30 TAC §25.6.

- The QAPP does not cover EPA Methods 903.0 and 904.1, so there are no MQL or QC Acceptance Criteria Tables for Radium-226 and 228. Therefore, GEL Labs will use their laboratory protocol and QC limits to perform the Radium methods.
- The QAPP does not cover EPA Method 300.0, so there are no MQL or QC Acceptance Criteria Tables for Chloride. Therefore, DHL Analytical will use their laboratory protocol and QC limits to perform the Chloride methods. Laboratory QC acceptance criteria for the LCS, MS/MSD by EPA Method 300.0 is 90-110% with RPD ≤ 20%. The actual laboratory MQL to be utilized for the project-defined compound is listed in Table 4. The laboratory MQL is less than the LORP for chloride in groundwater.
- No data validation will be performed, and a data usability summary report will not be prepared; only a data review memorandum will be prepared.

Element A.7

- Under the SSDAP program, the laboratory will report non-detected results as less than the value of the sample quantitation limit (SQL), not the sample detection limit (SDL). The SQL is the laboratory MQL adjusted for sample specific factors, such as dilution or percent moisture.

B.5.1 Definitive Analytical Methods

Table B.5.1.9-1 Method SW8260C MQLs for Volatile Organics

- Actual laboratory MQLs to be utilized for the project-defined compound list are listed in Table 4. The laboratory MQLs are below the LORPs for all volatile organic compounds except those listed in Table 4 as greater than the LORP. The MQL for those compounds then become the LORP.
- DHL Analytical is National Environmental Laboratory Accreditation Conference (NELAC)-accredited under the Texas Laboratory Accreditation Program (TLAP) for EPA SW-846 Method 8260 for all associated analytes listed in the QAPP except cyclohexane. DHL is not certified for cyclohexane. TLAP does not currently offer accreditation for cyclohexane by EPA SW-846 Method 8260. Cyclohexane data are exempt from accreditation under 30 TAC §25.6.

Table B.5.1.9-3 Method SW8260C Calibration and QC Procedures for Volatile Organics

- Calibration verification acceptance criteria for DHL Analytical by SW8260C limits recoveries of all analytes to within ±20% of the expected value. If more than 20% of the compounds included in the ICAL fail for this criteria, then corrective action must be taken prior to the analysis of samples.

- DHL Analytical allows for reporting with qualification if the calibration verification or LCS is biased high and samples are non-detects.

Table B.5.1.10-1 Method SW8270D MQLs for Semivolatile Organics

- Actual laboratory MQLs to be utilized for the project-defined compound list are listed in Table 4. The laboratory MQLs are below the LORPs for all semivolatile organic compounds except those listed in Table 4 as greater than the LORP. The MQL for those compounds then become the LORP.
- DHL Analytical is National Environmental Laboratory Accreditation Conference (NELAC)-accredited under the Texas Laboratory Accreditation Program (TLAP) for EPA SW-846 Method 8270 for all associated analytes listed in the QAPP except benzaldehyde. DHL is not certified for benzaldehyde. TLAP does not currently offer accreditation for benzaldehyde by EPA SW-846 Method 8270 compound. Benzaldehyde data are exempt from accreditation under 30 TAC §25.6.

Table B.5.1.10-3 Method SW8270D Calibration and QC Procedures for Semivolatile Organics

- Calibration verification acceptance criteria for DHL Analytical by SW8270D limits recoveries of all analytes to within ±20% of the expected value. If more than 20% of the compounds included in the ICAL fail for this criteria, then corrective action must be taken prior to the analysis of samples.
- DHL Analytical allows for reporting with qualification if the calibration verification or LCS is biased high and samples are non-detects.

Table B.5.1.16-1 Method SW6020A MQLs for Metals by ICP-Mass Spec

- Actual laboratory MQLs and LORP values for metals to be utilized for the project-defined compound list are listed in Table 4. The laboratory MQLs are below the LORPs for all metals in groundwater except arsenic, cobalt and thallium. The MQL for arsenic, cobalt and thallium then become the LORP.

Table B.5.1.16-3 Method SW6020A Calibration and QC Procedures for ICP-Mass Spec Metals

- Interference check solutions change acceptance criteria to read, "ICS-A – All non-spiked analytes shall be present at < MQL except zinc. ICS-AB recovery shall be within ±20% of true value except zinc. The zinc value in the ICS-AB shall be corrected for zinc present in the ICS-A and the recovery shall be within ±20% of true value.
- For assessing the results of the serial dilution test as noted in Table B.5.1.16-3 of the QAPP, DHL Analytical will use relative percent difference (RPD) instead of percent difference from the original determination. The ±10% QC acceptance criterion specified in the table will be used as the control limits.

Table B.5.1.19-1 Method SW7470A MQLs for Mercury

- The actual laboratory MQL to be utilized for mercury is listed in *Table 4*. The laboratory MQL is less than the LORP.

Table B.5.1.19-2 Method SW7470AQC Acceptance Criteria

- QC acceptance criteria for MS/MSD recoveries deviate from Table B.5.1.19-2. The laboratory QC acceptance criterion for the MS/MSD is 80-120% for the water matrix.

Table B.5.1.19-3 Method SW7470ACalibration and QC Procedures for Mercury

- For assessing the results of the serial dilution test, DHL Analytical will use relative percent difference (RPD) instead of percent difference from the original determination. The ±10% QC acceptance criterion will be used as the control limits. This is not a required QC Check.

Element B.5.3.2.7 Method Detection Limit, Method Quantitation Limit, and Sample Detection Limit

- MDLs are performed in accordance with NELAC requirements. Quarterly DCS analysis for MDL verification is performed in lieu of the annual MDL Study.
- The analytical tables in Element B.5.1 state one of the QC Checks entitled "MDL study" specify that a method detection limit (MDL) study be performed "Once per 12 month period". The following phrase will be added: "or perform detectability check standards (DCS) on a quarterly basis throughout the year to verify the MDL".
- In addition; the acceptance criteria in these tables will be changed from "Detection limits shall be ≤ ½ the MQLs in Table B5.1.x-1 to "Detection limits

shall be ≤ ½ the MQLs listed in Table B5.1.x-1 unless discussed in Section 6 of the project FSP. (Note: x corresponds to the TCEQ subsection. For example, the QC acceptance criteria for VOCs by EPA Method SW8260C are presented in TCEQ QAPP Table B.5.1.9-1 so x = 9 for VOCs.)

Element D.2.1.3 Process for Data Validation

- The data validation as specified in QAPP Element D.2.1.3 will not be performed.

Element D.2.1.2 Data Usability Review by the Independent Data Reviewer

- The data usability review as specified in QAPP Element D.2.1.2 will not be performed.

Element D.2.3.1. Data Usability Summary

The DUS as specified in QAPP Element D.2.3.1.will not be prepared.

6.3 *Exceptions, Additions, and Changes to* SOP

The exceptions, additions, and changes to an SOP planned for this project are:

- No deviations from Superfund SOPs are planned or anticipated.

TABLES

CHECKLIST 1: TABLE CHECKLIST

Table #	Title						
☒ Table 1	Project Objectives						
☐ Table 2	RESERVED						
☒ Table 3	Previous Analytical Results Tables	☒ Part A: VOCs	☒ Part B: SVOCs	☒ Part C: Metals	☐ Part D: Pesticides	☒ Part E: TPH	☐ Part F:
☒ Table 4	Analytes and Target COCs	Soil Res 30	Soil Res 0.5	Soil C/I 30	Soil C/I 0.5	Water Res	Water C/I
		☐ 6010C	☐ 6010C	☐ 6010C	☐ 6010C	☐ 6010C	☐ 6010C
		☐ 6020A	☐ 6020A	☐ 6020A	☐ 6020A	☒ 6020A	☐ 6020A
		☐ 7196A	☐ 7196A	☐ 7196A	☐ 7196A	☐ 7196A	☐ 7196A
		☐ 7471B	☐ 7471B	☐ 7471B	☐ 7471B	☒ 7470A	☐ 7470A
		☐ 8081B	☐ 8081B	☐ 8081B	☐ 8081B	☐ 8081B	☐ 8081B
		☐ 8082A	☐ 8082A	☐ 8082A	☐ 8082A	☐ 8082A	☐ 8082A
		☐ 8141B	☐ 8141B	☐ 8141B	☐ 8141B	☐ 8141B	☐ 8141B
		☐ 8151A	☐ 8151A	☐ 8151A	☐ 8151A	☐ 8151A	☐ 8151A
		☐ 8260C	☐ 8260C	☐ 8260C	☐ 8260C	☒ 8260C	☐ 8260C
		☐ 8270D	☐ 8270D	☐ 8270D	☐ 8270D	☒ 8270D	☐ 8270D
		☐ 8280B	☐ 8280B	☐ 8280B	☐ 8280B	☐ 8280B	☐ 8280B
		☐ 8290A	☐ 8290A	☐ 8290A	☐ 8290A	☐ 8290A	☐ 8290A
		☐ 9056A	☐ 9056A	☐ 9056A	☐ 9056A	☐ 9056A	☐ 9056A
		☐ 1005	☐ 1005	☐ 1005	☐ 1005	☐ 1005	☐ 1005
		☐	☐	☐	☐	☒300.00	☐
		☐	☐	☐	☐	☒903.1	☐
		☐	☐	☐	☐	☒904.0	☐
☒ Table 5	Analyses Summary						
☒ Table 6	Sample Summary						
☒ Table 7	Analytical and Preparatory Methods by Laboratory						

TABLE 1 PROJECT OBJECTVIES

CATEGORY	X	PROJECT OBJECTIVES
Visual Survey		Visually examine the site to determine the presence of source material, wastes, releases, or threatened releases to environmental media.
		Visually examine the site to determine topography, overland surface water drainage route, surface well casing, and other features which may affect the mobility and migration of COCs.
		Visually examine the site to evaluate the potential for releases from the site to affect receptors or targets.
Release Of Hazardous Substances		Determine if hazardous substances are present in environmental media or if a release of hazardous substances to environmental media has occurred.
Background Estimation		Estimate background concentrations for target COCs and analytes in soil.
		Estimate background concentrations for target COCs and analytes in groundwater.
		Estimate background concentrations for target COCs and analytes in surface water and/or sediment.
Soil		Determine if a release of COCs to surface soils has occurred or has the potential to occur.
		Estimate the volume of contaminated soil.
Groundwater		Determine if a release of COCs to groundwater has occurred or has the potential to occur.
	X	Determine if COCs are present in private drinking water wells or public supply wells.
Surface Water And Sediment		Determine if a release of COCs to surface water and/or sediment has occurred or has the potential to occur.
		Determine the actual or potential release of COCs to sensitive environments and other receptors along the surface water pathway.
		Determine if a release of COCs to drinking water intakes or other surface water and/or sediment receptors has occurred or has the potential to occur.
Source Materials Or Wastes		Determine if hazardous substances are present in source materials or wastes.
		Determine concentrations of COCs in source materials or wastes.
		Estimate the volume of source materials or wastes.
Attribution		Determine if a release is attributable to the site.
		Determine if a release is attributable to source area.
Removal Action		Determine if wastes, source materials, and/or highly contaminated environmental media qualify for a removal action under Chapter 361 of the Texas Health and Safety Code.
		Estimate the volume of contaminated media that may qualify for removal action.
		Determine if removal of wastes, source materials, and/or contaminated media was completed to action levels.
Disposal Options		Determine if wastes, source material, and/or environmental media meet the definition of hazardous waste defined in the Texas Health and Safety Code §361.003(11) and the 40 Code of Federal Regulations §302.4.
		Classify, characterize, and/or profile wastes, source materials, and/or contaminated environmental media to determine disposal options.
		Evaluate disposal options for Investigation Derived Wastes (IDW).
OTHER (Describe)		
Mark applicable Project Objectives in the 2nd column.		

Table 3
Summary of Historical Analytical Results

Ector Drum Inc.
2604 North Marco Ave.
Odessa, TX

Sample Name			Water Well - Oil Phase		
Sample Date				10/8/2014	
Metals	**Units**	**TRRP PCL**			
Antimony	mg/kg	**5.4E+00**	<	0.184	U
Arsenic	mg/kg	**5.0E+00**		2.46	
Beryllium	mg/kg	**1.8E+00**	<	0.0631	U
Cadmium	mg/kg	**1.5E+00**	<	<0.0728	U
Chromium	mg/kg	**2.4E+03**		33.1	
Copper	mg/kg	**1.0E+03**		5	
Lead	mg/kg	**3.0E+00**		3.34	
Nickel	mg/kg	**1.6E+02**		2.92	
Selenium	mg/kg	**2.3E+00**	<	0.16	U
Silver	mg/kg	**4.8E-01**	<	0.0631	U
Thallium	mg/kg	**1.7E+00**	<	0.165	U
Zinc	mg/kg	**2.4E+03**		274	
Mercury	mg/kg	**2.1E+00**		0.124	
VOCs	**Units**	**TRRP PCL**			
Benzene	mg/kg	**2.6E-02**	<	10.0	U
Bromobenzene	mg/kg	**2.3E+00**	<	10.0	U
Bromochloromethane	mg/kg	**NA**	<	10.0	U
Bromodichloromethane	mg/kg	**6.5E-02**	<	10.0	U
Bromoform	mg/kg	**6.3E-01**	<	10.0	U
Bromomethane	mg/kg	**1.3E-01**	<	10.0	U
tert-Butylbenzene	mg/kg	**1.0E+02**	<	10.0	U
Sec-Butylbenzene	mg/kg	**8.5E+01**	<	10.0	U
n-Butylbenzene	mg/kg	**1.5E+02**	<	10.0	U
Carbon Tetrachloride	mg/kg	**6.2E-02**	<	10.0	U
Chlorobenzene	mg/kg	**1.1E+00**	<	10.0	U
Chloroethane	mg/kg	**3.1E+01**	<	20.0	U
Chloroform	mg/kg	**1.0E+00**	<	10.0	U
Chloromethane	mg/kg	**4.1E-01**	<	20.0	U
2-Chlorotoluene	mg/kg	**9.1E+00**	<	10.0	U
4-Chlorotoluene	mg/kg	**1.1E+01**	<	10.0	U
p-Cymene (p-Isopropyltoluene)	mg/kg	**2.3E+02**	<	10.0	U
1,2-Dibromo-3-Chloropropane	mg/kg	**1.7E-03**	<	8.77	U
Dibromochloromethane	mg/kg	**4.9E-02**	<	10.0	U
1,2-Dibromoethane	mg/kg	**2.1E-04**	<	10.0	U
Dibromomethane	mg/kg	**NA**	<	10.0	U
1,2-Dichlorobenzene	mg/kg	**1.8E+01**	<	10.0	U
1,3-Dichlorobenzene	mg/kg	**6.7E+00**	<	10.0	U
1,4-Dichlorobenzene	mg/kg	**2.1E+00**	<	10.0	U
Dichlorodifluoromethane	mg/kg	**2.4E+02**	<	10.0	U

Table 3
Summary of Historical Analytical Results

1,2-Dichloroethane	mg/kg	**1.8E+01**	<	10.0	U
1,1-Dichloroethane	mg/kg	**1.4E-02**	<	10.0	U
trans-1,2-dichloroethene	mg/kg	**4.9E-01**	<	10.0	U
cis-1,2-Dichloroethene	mg/kg	**2.5E-01**	<	10.0	U
1,1-Dichloroethene	mg/kg	**5.0E-02**	<	10.0	U
2,2-Dichloropropane	mg/kg	**1.2E-01**	<	10.0	U
1,3-Dichloropropane	mg/kg	**6.4E-02**	<	10.0	U
1,2-Dichloropropane	mg/kg	**2.3E-02**	<	10.0	U
trans-1,3-dichloropropene	mg/kg	**3.6E-02**	<	10.0	U
1,1-Dichloropropene	mg/kg	**1.3E-01**	<	10.0	U
cis-1,3-Dichloropropene	mg/kg	**6.6E-03**	<	10.0	U
Ethylbenzene	mg/kg	**7.6E+00**	<	10.0	U
Hexachlorobutadiene	mg/kg	**3.3E+00**	<	10.0	U
isopropylbenzene	mg/kg	**3.5E+02**	<	10.0	U
Methylene Chloride	mg/kg	**1.3E-02**	<	60.0	U
MTBE	mg/kg	**6.2E-01**	<	10.0	U
Naphthalene	mg/kg	**3.1E+01**	<	20.0	U
n-Propylbenzene	mg/kg	**4.5E+01**	<	10.0	U
Styrene	mg/kg	**3.3E+00**	<	10.0	U
1,1,1,2-Tetrachloroethane	mg/kg	**1.4E+00**	<	10.0	U
1,1,2,2-Tetrachloroethane	mg/kg	**2.3E-02**	<	10.0	U
Tetrachloroethylene	mg/kg	**5.0E-02**	<	20.0	U
Toluene	mg/kg	**8.2E+00**	<	10.0	U
1,2,3-Trichlorobenzene	mg/kg	**2.6E+01**	<	10.0	U
1,2,4-Trichlorobenzene	mg/kg	**4.8E+00**	<	10.0	U
1,1,2-Trichloroethane	mg/kg	**2.0E-02**	<	10.0	U
1,1,1-Trichloroethane	mg/kg	**1.6E+00**	<	10.0	U
Trichloroethene	mg/kg	**3.4E-02**	<	10.0	U
Trichlorofluoromethane	mg/kg	**1.3E+02**	<	10.0	U
1,2,3-Trichloropropane	mg/kg	**5.3E-04**	<	1.8	U
1,2,4-Trimethylbenzene	mg/kg	**4.9E+01**		224	
1,3,5-Trimethylbenzene	mg/kg	**5.3E+01**	<	10.0	U
Vinyl Chloride	mg/kg	**2.2E-02**	<	4.0	U
o-Xylene	mg/kg	**7.1E+01**	<	10.0	U
m,p-Xylenes	mg/kg	**1.1E+02**	<	20.0	U
Total Xylenes	mg/kg	**1.2E+02**	<	10.0	U
SVOCs	**Units**	**TRRP PCL**			
Acenaphthene	mg/kg	**2.4E+02**	<	250	U
Acenaphthylene	mg/kg	**4.1E+02**	<	250	U
Aniline (Phenylamine, Aminobenzene)	mg/kg	**3.7E-01**	<	250	U
Anthracene	mg/kg	**6.9E+03**	<	250	U
Benzo(a)anthracene	mg/kg	**1.8E+01**	<	250	U
Benzo(a)pyrene	mg/kg	**7.6E+00**	<	250	U
Benzo(b)fluoranthene	mg/kg	**6.0E+01**	<	250	U
Benzo(g,h,i)perylene	mg/kg	**4.6E+04**	<	250	U
Benzo(k)fluoranthene	mg/kg	**6.2E+02**	<	250	U
Benzoic Acid	mg/kg	**1.9E+02**	<	750	U

Table 3
Summary of Historical Analytical Results

Benzyl Butyl Phthalate	mg/kg	**1.6E+03**	<	250	U
bis(2-chloroethoxy) methane	mg/kg	**1.2E-02**	<	250	U
bis(2-chloroethyl) ether	mg/kg	**2.1E-03**	<	250	U
bis(2-chloroisopropyl) ether	mg/kg	**1.9E-01**	<	250	U
bis(2-ethylhexyl) phthalate	mg/kg	**1.6E+02**	<	250	U
4-Bromophenyl-phenylether	mg/kg	**3.5E-01**	<	250	U
di-n-Butyl Phthalate	mg/kg	**NA**	<	250	U
4-chloro-3-methylphenol	mg/kg	**4.5E+00**	<	250	U
4-Chloroaniline	mg/kg	**2.1E-02**	<	250	U
2-Chloronaphthalene	mg/kg	**6.7E+02**	<	250	U
2-Chlorophenol	mg/kg	**1.6E+00**	<	250	U
4-Chlorophenyl Phenyl Ether	mg/kg	**3.2E-02**	<	250	U
Chrysene	mg/kg	**1.5E+03**	<	250	U
Dibenz(a,h)Anthracene	mg/kg	**9.5E+00**	<	250	U
Dibenzofuran	mg/kg	**3.3E+01**	<	250	U
1,2-Dichlorobenzene	mg/kg	**1.8E+01**	<	250	U
1,3-Dichlorobenzene	mg/kg	**6.7E+00**	<	250	U
1,4-Dichlorobenzene	mg/kg	**2.1E+00**	<	250	U
3,3-Dichlorobenzidine	mg/kg	**6.3E-02**	<	500	U
2,4-Dichlorophenol	mg/kg	**3.5E-01**	<	250	U
Diethyl Phthalate	mg/kg	**1.6E+02**	<	250	U
Dimethyl Phthalate	mg/kg	**6.2E+01**	<	250	U
2,4-Dimethylphenol	mg/kg	**3.2E+00**	<	250	U
4,6-dinitro-2-methyl phenol	mg/kg	**4.7E-03**	<	250	U
2,4-Dinitrophenol	mg/kg	**9.4E+00**	<	250	U
2,4-Dinitrotoluene	mg/kg	**5.3E-03**	<	250	U
2,6-Dinitrotoluene	mg/kg	**4.8E-03**	<	250	U
Fluoranthene	mg/kg	**1.9E+03**	<	250	U
Fluorene	mg/kg	**3.0E+02**	<	250	U
Hexachlorobenzene	mg/kg	**1.1E+00**	<	250	U
Hexachlorobutadiene	mg/kg	**3.3E+00**	<	250	U
Hexachlorocyclopentadiene	mg/kg	**1.9E+01**	<	250	U
Hexachloroethane	mg/kg	**1.3E+00**	<	250	U
Indeno(1,2,3-c,d)Pyrene	mg/kg	**1.7E+02**	<	250	U
Isophorone	mg/kg	**3.0E+00**	<	250	U
2-Methylnaphthalene	mg/kg	**1.7E+01**	<	250	U
2-methylphenol	mg/kg	**7.1E+00**	<	250	U
3&4-Methylphenol	mg/kg	**6.3E-01**	<	250	U
Naphthalene	mg/kg	**3.1E+01**	<	250	U
4-Nitroaniline	mg/kg	**1.1E-01**	<	250	U
3-Nitroaniline	mg/kg	**2.6E-02**	<	250	U
2-Nitroaniline	mg/kg	**2.2E-02**	<	250	U
Nitrobenzene	mg/kg	**3.5E-01**	<	250	U
2-Nitrophenol	mg/kg	**1.3E-01**	<	250	U
4-Nitrophenol	mg/kg	**1.0E-01**	<	500	U
N-Nitrosodi-n-Propylamine	mg/kg	**3.5E-04**	<	250	U
N-Nitrosodiphenylamine	mg/kg	**2.8E+00**	<	250	U

Table 3
Summary of Historical Analytical Results

di-n-Octyl Phthalate	mg/kg	**8.1E+05**	<	250	U
Pentachlorophenol	mg/kg	**1.8E-02**	<	500	U
Phenanthrene	mg/kg	**4.2E+02**	<	250	U
Phenol	mg/kg	**1.9E+01**	<	250	U
Pyrene	mg/kg	**1.1E+03**	<	250	U
Pyridine	mg/kg	**6.9E-02**	<	250	U
1,2,4-Trichlorobenzene	mg/kg	**4.8E+00**	<	250	U
2,4,6-Trichlorophenol	mg/kg	**1.7E-01**	<	250	U
2,4,5-Trichlorophenol	mg/kg	**3.4E+01**	<	250	U
TPH	**Units**	**TRRP PCL**			
C6-C12 Gasoline Range Hydrocarbons	mg/kg	**6.5E+01**	<	1490	UK
C12-C28 Diesel Range Hydrocarbons	mg/kg	**2.0E+01**		368000	K
C28-C35 Oil Range Hydrocarbons	mg/kg	**2.0E+01**		165000	K
Total TPH 1005	mg/kg	**NA**		533000	K
TPH - Aliphatics	**Units**	**TRRP PCL**			
C6 to C8 Aliphatic Hydrocarbons +	mg/kg	**4.2E+02**	<	6820	UK
C8 to C10 Aliphatic Hydrocarbons +	mg/kg	**3.6E+02**		1460	JK
C10 to C12 Aliphatic Hydrocarbons +	mg/kg	**2.5E+04**		3920	K
C12 to C16 Aliphatic Hydrocarbons +	mg/kg	**4.9E+05**		8720	K
C16 to C21 Aliphatic Hydrocarbons +	mg/kg	**1.0E+06**		31600	K
C21 to C35 Aliphatic Hydrocarbons +	mg/kg	**1.0E+06**		451000	K
TPH - Aromatics	**Units**	**TRRP PCL**			
C6 to C8 Aromatics Hydrocarbons +	mg/kg	**2.0E+01**	<	44.1	UK
C8 to C10 Aromatics Hydrocarbons +	mg/kg	**6.5E+01**		119	K
C10 to C12 Aromatics Hydrocarbons +	mg/kg	**1.0E+02**		144	K
C12 to C16 Aromatics Hydrocarbons +	mg/kg	**2.0E+02**		625	K
C16 to C21 Aromatics Hydrocarbons +	mg/kg	**4.7E+02**		4680	K
C21 to C35 Aromatics Hydrocarbons +	mg/kg	**3.7E+05**		26600	K

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Table 4 ANALYTES AND TARGET COCs (AQUEOUS)

Method 6020A Metals by ICP MS

Target COC? (X)	**Method 6020A Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Aluminum	7429-90-5	10	$^{GW}GW_{Ing}$	24	10	yes	0.030	yes
X	Antimony	7440-36-0	0.006	$^{GW}GW_{Ing}$	0.006	0.006	yes	0.0025	yes
X	Arsenic	7440-38-2	0.000044	SCDM	0.010	0.000044	yes	0.005	NO
X	Barium	7440-39-3	2.0	$^{GW}GW_{Ing}$	2.0	2.0	yes	0.010	yes
X	Beryllium	7440-41-7	0.004	$^{GW}GW_{Ing}$	0.004	0.004	yes	0.001	yes
X	Cadmium	7440-43-9	0.005	$^{GW}GW_{Ing}$	0.005	0.005	yes	0.001	yes
X	Chromium (total)	7440-47-3	0.04	$^{GW}GW_{Ing}$	0.1	0.04	yes	0.005	yes
X	Cobalt	7440-48-4	0.004	$^{GW}GW_{Ing}$	0.007	0.004	yes	0.005	NO
X	Copper	7440-50-8	1.3	$^{GW}GW_{Ing}$	1.3	0.6	yes	0.010	yes
X	Lead (inorganic)	7439-92-1	0.015	$^{GW}GW_{Ing}$	0.015	0.015	yes	0.001	yes
X	Manganese	7439-96-5	1.1	$^{GW}GW_{Ing}$	1.1	2.1	yes	0.010	yes
X	Nickel and compounds	7440-02-0	0.3	$^{GW}GW_{Ing}$	0.49	0.3	yes	0.010	yes
X	Selenium	7782-49-2	0.05	$^{GW}GW_{Ing}$	0.05	0.05	yes	0.005	yes
X	Silver	7440-22-4	0.07	$^{GW}GW_{Ing}$	0.12	0.07	yes	0.002	yes
X	Thallium and compounds (as thallium chloride)	7791-12-0	0.0001	$^{GW}GW_{Ing}$	0.002	0.0001	yes	0.0015	NO
X	Zinc	7440-66-6	4.0	$^{GW}GW_{Ing}$	7.3	4.0	yes	0.005	yes

COC = chemical of concern

Target COC = a chemical of concern associated with the site

CAS = Chemical Abstract Service Registry Number

LORP = Level of required performance as defined in TRRP (highlighted)

TRRP PCL = Texas Risk Reduction Program Protective Concentration Limit (June 29, 2012)

$^{GW}GW_{Ing}$ = TRRP PCL for groundwater ingestion

mg/L = milligrams per liter (ppm)

SCDM = Superfund Chemical Data Matrix (March 31, 2012)

NELAP = National Environmental Laboratory Accreditation Program

MQL = Method quantitation limit

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 7470A Mercury by Cold Vapor

Target COC? (X)	**Method 7470AC Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Mercury (pH = 4.9)	7439-97-6	0.002	$^{GW}GW_{Ing}$	0.002	0.002	yes	0.0002	yes

COC = chemical of concern

Target COC = a chemical of concern associated with the site

CAS = Chemical Abstract Service Registry Number

LORP = Level of required performance as defined in TRRP (highlighted)

TRRP PCL = Texas Risk Reduction Program Protective Concentration Limit (June 29, 2012)

$^{GW}GW_{Ing}$ = TRRP PCL for groundwater ingestion

mg/L = milligrams per liter (ppm)

SCDM = Superfund Chemical Data Matrix (March 31, 2012)

NELAP = National Environmental Laboratory Accreditation Program

MQL = Method quantitation limit

SSDAP

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)

Method 8260C Volatile Organic Compounds by GC/MS

Target COC? (X)	**Method 8260C Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Acetone (2-propanone)	67-64-1	1.0	SCDM	22	1.0	yes	0.015	yes
X	Benzene	71-43-2	0.0012	SCDM	0.005	0.0012	yes	0.001	yes
X	Bromobenzene	108-86-1	0.20	$^{GW}GW_{Ing}$	0.20	NA	yes	0.001	yes
X	Bromodichloromethane	75-27-4	0.0010	SCDM	0.015	0.0010	yes	0.001	NO
X	Bromoform	75-25-2	0.12	$^{GW}GW_{Ing}$	0.12	NA	yes	0.001	yes
X	Bromomethane	74-83-9	0.034	$^{GW}GW_{Ing}$	0.034	NA	yes	0.001	yes
X	Butylbenzene, n-	104-51-8	1.2	$^{GW}GW_{Ing}$	1.2	NA	yes	0.001	yes
X	Butylbenzene, sec-	135-98-8	0.98	$^{GW}GW_{Ing}$	0.98	NA	yes	0.001	yes
X	Butylbenzene, tert-	98-06-6	0.98	$^{GW}GW_{Ing}$	0.98	NA	yes	0.001	yes
X	Carbon disulfide	75-15-0	1.0	SCDM	2.4	1.0	yes	0.015	yes
X	Carbon tetrachloride	56-23-5	0.0009	SCDM	0.005	0.0009	yes	0.001	NO
X	Chlorobenzene	108-90-7	0.10	$^{GW}GW_{Ing}$	0.10	0.3	yes	0.001	yes
X	Chlorobromomethane (bromochloromethane)	74-97-5	0.98	$^{GW}GW_{Ing}$	0.98	NA	yes	0.001	yes
X	Chloroethane (ethyl chloride)	75-00-3	9.8	$^{GW}GW_{Ing}$	9.8	NA	yes	0.001	yes
X	Chloroform	67-66-3	0.0021	SCDM	0.24	0.0021	yes	0.001	yes
X	Chlorohexane, 1-	544-10-5	0.98	$^{GW}GW_{Ing}$	0.98	NA	yes	0.005	yes
X	Chloromethane (methyl chloride)	74-87-3	0.070	$^{GW}GW_{Ing}$	0.070	NA	yes	0.001	yes
X	Chlorotoluene, o- (2-chlorotoluene)	95-49-8	0.49	$^{GW}GW_{Ing}$	0.49	NA	yes	0.001	yes
X	Chlorotoluene, p- (4-chlorotoluene)	106-43-4	0.49	$^{GW}GW_{Ing}$	0.49	NA	yes	0.001	yes
X	Cumene (isopropylbenzene)	98-82-8	1.0	SCDM	2.4	1.0	yes	0.001	yes
X	Cyclohexane	110-82-7	120	$^{GW}GW_{Ing}$	120	NA	NO	0.015	yes
X	Cymene (isopropyltoluene)	99-87-6	2.4	$^{GW}GW_{Ing}$	2.4	NA	yes	0.001	yes
X	Dibromo-3-chloropropane, 1,2-	96-12-8	0.000020	SCDM	0.00020	0.00002	yes	0.010	NO
X	Dibromochloromethane (chlorodibromomethane)	124-48-1	0.011	$^{GW}GW_{Ing}$	0.011	NA	yes	0.001	yes

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 8260C Volatile Organic Compounds by GC/MS

Target COC? (X)	**Method 8260C Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Dichlorobenzene, 1,2-	95-50-1	0.60	$^{GW}GW_{Ing}$	0.60	NA	yes	0.001	yes
X	Dichlorobenzene, 1,3-	541-73-1	0.73	$^{GW}GW_{Ing}$	0.73	NA	yes	0.001	yes
X	Dichlorobenzene, 1,4-	106-46-7	0.012	SCDM	0.075	0.012	yes	0.001	yes
X	Dichlorodifluoromethane	75-71-8	4.9	$^{GW}GW_{Ing}$	4.9	NA	yes	0.001	yes
X	Dichloroethane, 1,1-	75-34-3	0.011	SCDM	4.9	0.011	yes	0.001	yes
X	Dichloroethane, 1,2-	107-06-2	0.00073	SCDM	0.005	0.00073	yes	0.001	NO
X	Dichloroethylene, 1,1-	75-35-4	0.007	$^{GW}GW_{Ing}$	0.007	0.007	yes	0.001	yes
X	Dichloroethylene, cis-1,2-	156-59-2	0.030	SCDM	0.070	0.03	yes	0.001	yes
X	Dichloroethylene, trans-1,2	156-60-5	0.10	$^{GW}GW_{Ing}$	0.10	0.3	yes	0.001	yes
X	Dichloropropane, 1,2-	78-87-5	0.0018	SCDM	0.005	0.0018	yes	0.001	yes
X	Dichloropropane, 1,3-	142-28-9	0.009	$^{GW}GW_{Ing}$	0.009	NA	yes	0.001	yes
X	Dichloropropane, 2,2-	594-20-7	0.013	$^{GW}GW_{Ing}$	0.013	NA	yes	0.001	yes
X	Dichloropropene, 1,1-	563-58-6	0.009	$^{GW}GW_{Ing}$	0.009	NA	yes	0.001	yes
X	Dichloropropene, cis 1,3-	10061-01-5	0.0017	$^{GW}GW_{Ing}$	0.0017	NA	yes	0.001	yes
X	Dichloropropene, trans 1,3-	10061-02-6	0.009	$^{GW}GW_{Ing}$	0.009	NA	yes	0.001	yes
X	Ethyl benzene	100-41-4	0.0061	SCDM	0.70	0.0061	yes	0.001	yes
X	Ethylene dibromide (dibromoethane, 1,2-)	106-93-4	0.000030	SCDM	0.00005	0.000030	yes	0.001	NO
X	Hexachlorobutadiene	87-68-3	0.00086	SCDM	0.012	0.00086	yes	0.003	NO
X	Hexanone, 2-	591-78-6	0.12	$^{GW}GW_{Ing}$	0.12	NA	yes	0.015	yes
X	Methyl acetate (acetic acid, methyl ester)	79-20-9	24	$^{GW}GW_{Ing}$	24	NA	yes	0.015	yes
X	Methyl cyclohexane	108-87-2	120	$^{GW}GW_{Ing}$	120	NA	yes	0.015	yes
X	Methyl ethyl ketone (2-butanone)	78-93-3	9.0	SCDM	15	9.0	yes	0.015	yes
X	Methyl isobutyl ketone (4-methyl-2-pentanone)	108-10-1	1.0	$^{GW}GW_{Ing}$	2.0	1.0	yes	0.015	yes

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 8260C Volatile Organic Compounds by GC/MS

Target COC? (X)	**Method 8260C Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Methylene bromide (dibromomethane)	74-95-3	0.12	$^{GW}GW_{Ing}$	0.12	NA	yes	0.001	yes
X	Methylene chloride (dichloromethane)	75-09-2	0.005	$^{GW}GW_{Ing}$	0.005	0.011	yes	0.0025	yes
X	MTBE (methyl tert-butyl ether)	1634-04-4	0.037	SCDM	0.24	0.037	yes	0.001	yes
X	Naphthalene	91-20-3	0.3	SCDM	0.49	0.3	yes	0.015	yes
X	Propylbenzene, n-	103-65-1	0.98	$^{GW}GW_{Ing}$	0.98	NA	yes	0.001	yes
X	Styrene	100-42-5	0.10	$^{GW}GW_{Ing}$	0.10	0.1	yes	0.001	yes
X	Tetrachloroethane, 1,1,1,2-	630-20-6	0.035	$^{GW}GW_{Ing}$	0.035	NA	yes	0.001	yes
X	Tetrachloroethane, 1,1,2,2-	79-34-5	0.0003	SCDM	0.0046	0.0003	yes	0.001	NO
X	Tetrachloroethylene (perchlorethylene)	127-18-4	0.0050	$^{GW}GW_{Ing}$	0.005	0.005	yes	0.002	yes
X	Toluene	108-88-3	1.0	$^{GW}GW_{Ing}$	1.0	1.0	yes	0.002	yes
X	Trichloro-1,2,2-trifluoroethane, 1,1,2-	76-13-1	730	$^{GW}GW_{Ing}$	730	NA	yes	0.015	yes
X	Trichlorobenzene, 1,2,3-	87-61-6	0.073	$^{GW}GW_{Ing}$	0.073	NA	yes	0.005	yes
X	Trichlorobenzene, 1,2,4-	120-82-1	0.0023	SCDM	0.070	0.0023	yes	0.005	NO
X	Trichloroethane, 1,1,1-	71-55-6	0.20	$^{GW}GW_{Ing}$	0.20	0.2	yes	0.001	yes
X	Trichloroethane, 1,1,2-	79-00-5	0.0011	SCDM	0.005	0.0011	yes	0.001	yes
X	Trichloroethylene (TCE)	79-01-6	0.001	SCDM	0.005	0.001	yes	0.002	NO
X	Trichlorofluoromethane	75-69-4	4.0	SCDM	7.3	4.0	yes	0.001	yes
X	Trichloropropane, 1,2,3-	96-18-4	0.00000071	SCDM	0.00003	0.00000071	yes	0.001	NO
	Trimethylbenzene, 1,2,4-	95-63-6	1.2	$^{GW}GW_{Ing}$	1.2	NA		0.001	yes
	Trimethylbenzene, 1,3,5-	108-67-8	1.2	$^{GW}GW_{Ing}$	1.2	NA		0.001	yes
X	Vinyl chloride	75-01-4	0.000017	SCDM	0.002	0.000017	yes	0.001	NO

MQL = Method quantitation limit

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 8270D Semivolatile Organic Compounds by GC/MS

Target COC? (X)	**Method 8270D Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Acenaphthene	83-32-9	0.90	SCDM	1.5	0.9	yes	0.0008	yes
X	Acenaphthylene	208-96-8	1.5	$^{GW}GW_{Ing}$	1.5	NA	yes	0.0008	yes
X	Acetophenone	98-86-2	2.4	$^{GW}GW_{Ing}$	2.4	NA	yes	0.0008	yes
X	Anthracene	120-12-7	4.0	SCDM	7.3	4.0	yes	0.0008	yes
X	Atrazine	1912-24-9	0.00029	SCDM	0.0030	0.00029	yes	0.0008	NO
X	Benz-a-anthracene	56-55-3	0.000029	SCDM	0.0013	0.00003	yes	0.0008	NO
X	Benzaldehyde	100-52-7	2.4	$^{GW}GW_{Ing}$	2.4	NA	NO	0.0008	yes
X	Benzo-a-pyrene	50-32-8	0.0000029	SCDM	0.00020	0.0000029	yes	0.0008	NO
X	Benzo-b-fluoranthene	205-99-2	0.0013	$^{GW}GW_{Ing}$	0.0013	NA	yes	0.0008	yes
X	Benzo-g,h,i-perylene	191-24-2	0.73	$^{GW}GW_{Ing}$	0.73	NA	yes	0.0008	yes
X	Benzoic acid	65-85-0	98	$^{GW}GW_{Ing}$	98	NA	yes	0.0060	yes
X	Benzo-k-fluoranthene	207-08-9	0.00029	SCDM	0.013	0.0003	yes	0.0008	NO
X	Benzyl alcohol	100-51-6	2.4	$^{GW}GW_{Ing}$	2.4	NA	yes	0.0020	yes
X	Biphenyl, 1,1-	92-52-4	1.2	$^{GW}GW_{Ing}$	1.2	NA	yes	0.0008	yes
X	Bis (2-chloroethoxy) methane	111-91-1	0.00083	$^{GW}GW_{Ing}$	0.00083	NA	yes	0.0008	yes
X	Bis (2-chloroethyl) ether	111-44-4	0.00083	$^{GW}GW_{Ing}$	0.00083	NA	yes	0.0008	yes
X	Bis (2-chloroisopropyl) ether	108-60-1	0.013	$^{GW}GW_{Ing}$	0.013	NA	yes	0.0008	yes
X	Bis (2-ethyl-hexyl) phthalate	117-81-7	0.0015	SCDM	0.006	0.0015	yes	0.0030	NO
X	Bromophenyl phenylether, 4-	101-55-3	0.000061	$^{GW}GW_{Ing}$	0.000061	NA	yes	0.0008	NO
X	Butyl benzyl phthalate	85-68-7	0.035	$^{GW}GW_{Ing}$	0.48	0.035	yes	0.0060	yes
X	Caprolactam	105-60-2	12	$^{GW}GW_{Ing}$	12	NA	yes	0.0008	yes
X	Carbazole	86-74-8	0.003	SCDM	0.046	0.003	yes	0.0008	yes
X	Chloro-3-methylphenol, 4-	59-50-7	0.12	$^{GW}GW_{Ing}$	0.12	NA	yes	0.0008	yes
X	Chloroaniline, p-	106-47-8	0.0046	$^{GW}GW_{Ing}$	0.0046	NA	yes	0.0020	yes
X	Chloronaphthalene, 2- (chloronaphthalene, beta)	91-58-7	2.0	$^{GW}GW_{Ing}$	2.0	NA	yes	0.0008	yes
X	Chlorophenol, 2-	95-57-8	0.12	$^{GW}GW_{Ing}$	0.12	NA	yes	0.0008	yes
X	Chlorophenyl phenylether, 4-	7005-72-3	0.000061	$^{GW}GW_{Ing}$	0.000061	NA	yes	0.0008	NO
X	Chrysene	218-01-9	0.003	SCDM	0.13	0.003	yes	0.0008	yes

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 8270D Semivolatile Organic Compounds by GC/MS

Target COC? (X)	**Method 8270D Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Cresol, o- (2-methylphenol)	95-48-7	1.2	$^{GW}GW_{Ing}$	1.2	NA	yes	0.0008	yes
X	Cresol, p- (4-methylphenol)	106-44-5	0.12	$^{GW}GW_{Ing}$	0.12	0.18	yes	0.0008	yes
X	Dibenz-a,h-anthracene	53-70-3	0.0000029	SCDM	0.00020	0.0000029	yes	0.0008	NO
X	Dibenzofuran	132-64-9	0.01	SCDM	0.098	0.01	yes	0.0008	yes
X	Dichlorobenzidine, 3,3-	91-94-1	0.0020	$^{GW}GW_{Ing}$	0.0020	NA	yes	0.0008	yes
X	Dichlorophenol, 2,4-	120-83-2	0.04	$^{GW}GW_{Ing}$	0.073	0.04	yes	0.0008	yes
X	Diethyl phthalate	84-66-2	1.0	$^{GW}GW_{Ing}$	20	1.0	yes	0.0060	yes
X	Dimethyl phenol, 2,4-	105-67-9	0.49	$^{GW}GW_{Ing}$	0.49	0.73	yes	0.0008	yes
X	Dimethylphthalate	131-11-3	20	$^{GW}GW_{Ing}$	20	NA	yes	0.0060	yes
X	Di-n-butyl phthalate	84-74-2	2.4	$^{GW}GW_{Ing}$	2.4	1.0	yes	0.0060	yes
X	Dinitro-2-methylphenol, 4,6- (dinitro-o-cresol, 4, 6-)	534-52-1	0.0024	$^{GW}GW_{Ing}$	0.0024	NA	yes	0.0020	yes
X	Dinitrophenol, 2,4-	51-28-5	0.049	$^{GW}GW_{Ing}$	0.049	NA	yes	0.0040	yes
X	Dinitrotoluene, 2,4-	121-14-2	0.0013	$^{GW}GW_{Ing}$	0.0013	NA	yes	0.0008	yes
X	Dinitrotoluene, 2,6-	606-20-2	0.0013	$^{GW}GW_{Ing}$	0.0013	NA	yes	0.0008	yes
X	Di-n-octyl phthalate	117-84-0	0.10	SCDM	0.98	0.10	yes	0.0060	yes
X	Fluoranthene	206-44-0	0.98	$^{GW}GW_{Ing}$	0.98	1.5	yes	0.0008	yes
X	Fluorene	86-73-7	0.6	SCDM	0.98	0.6	yes	0.0008	yes
X	Hexachlorobenzene	118-74-1	0.000042	SCDM	0.0010	0.000042	yes	0.0008	NO
X	Hexachlorobutadiene	87-68-3	0.00086	SCDM	0.012	0.00086	yes	0.0008	yes
X	Hexachlorocyclopentadiene (HCCPD)	77-47-4	0.050	$^{GW}GW_{Ing}$	0.050	NA	yes	0.0020	yes
X	Hexachloroethane	67-72-1	0.017	$^{GW}GW_{Ing}$	0.017	NA	yes	0.0008	yes
X	Indeno-1,2,3-cd-pyrene	193-39-5	0.000029	SCDM	0.0013	0.000029	yes	0.0008	NO
X	Isophorone	78-59-1	0.96	$^{GW}GW_{Ing}$	0.96	NA	yes	0.0008	yes
X	Methylnaphthalene, 2-	91-57-6	0.06	SCDM	0.098	0.06	yes	0.0008	yes
X	Naphthalene	91-20-3	0.3	SCDM	0.49	0.3	yes	0.0008	yes
X	Nitroaniline, 2-	88-74-4	0.007	$^{GW}GW_{Ing}$	0.007	NA	yes	0.0008	yes
X	Nitroaniline, 3-	99-09-2	0.007	$^{GW}GW_{Ing}$	0.007	NA	yes	0.0008	yes
X	Nitroaniline, 4-	100-01-6	0.046	$^{GW}GW_{Ing}$	0.046	NA	yes	0.0008	yes

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 8270D Semivolatile Organic Compounds by GC/MS

Target COC? (X)	**Method 8270D Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Nitrobenzene	98-95-3	0.03	SCDM	0.049	0.03	yes	0.0008	yes
X	Nitrophenol, 2-	88-75-5	0.049	$^{GW}GW_{Ing}$	0.049	NA	yes	0.0008	yes
X	Nitrophenol, 4-	100-02-7	0.049	$^{GW}GW_{Ing}$	0.049	NA	yes	0.0040	yes
X	Nitrosodi-n-propylamine, n-	621-64-7	0.00013	$^{GW}GW_{Ing}$	0.00013	NA	yes	0.0008	NO
X	Nitrosodiphenylamine	86-30-6	0.013	SCDM	0.19	0.013	yes	0.0008	yes
X	Pentachlorophenol	87-86-5	0.0001	SCDM	0.0010	0.0001	yes	0.0008	NO
X	Phenanthrene	85-01-8	0.73	$^{GW}GW_{Ing}$	0.73	NA	yes	0.0008	yes
X	Phenol	108-95-2	4.0	$^{GW}GW_{Ing}$	7.3	4.0	yes	0.0008	yes
X	Pyrene	129-00-0	0.4	SCDM	0.73	0.4	yes	0.0008	yes
X	Trichlorophenol, 2,4,5-	95-95-4	2.4	$^{GW}GW_{Ing}$	2.4	NA	yes	0.0008	yes
X	Trichlorophenol, 2,4,6-	88-06-2	0.0061	SCDM	0.024	0.0061	yes	0.0008	yes

COC = chemical of concern

Target COC = a chemical of concern associated with the site

CAS = Chemical Abstract Service Registry Number

LORP = Level of required performance as defined in TRRP (highlighted)

TRRP PCL = Texas Risk Reduction Program Protective Concentration Limit (June 29, 2012)

$^{GW}GW_{Ing}$ = TRRP PCL for groundwater ingestion

mg/L = milligrams per liter (ppm)

SCDM = Superfund Chemical Data Matrix (March 31, 2012)

NELAP = National Environmental Laboratory Accreditation Program

MQL = Method quantitation limit

SSDAP

Table 4 ANALYTES AND TARGET COCs (AQUEOUS)

Method 300.0 Chloride by GC/MS

Target COC? (X)	**Method 300.0 Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (mg/L)	Is Lab MQL <LORP? (Y/N)
			LORP (mg/L)	Source of LORP					
X	Chloride	16887-00-6	250	Secondary MCL[5] mg/L	NA	NA	yes	1.000	yes

COC = chemical of concern

Target COC = a chemical of concern associated with the site

CAS = Chemical Abstract Service Registry Number

LORP = Level of required performance as defined in TRRP (highlighted)

TRRP PCL = Texas Risk Reduction Program Protective Concentration Limit (June 29, 2012)

$^{GW}GW_{Ing}$ = TRRP PCL for groundwater ingestion

mg/L = milligrams per liter (ppm)

SCDM = Superfund Chemical Data Matrix (March 31, 2012)

NELAP = National Environmental Laboratory Accreditation Program

MQL = Method quantitation limit

SSDAP
Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 903.1 Radium 226

Target COC? (X)	**Method 903.1 Analyte in Water**	CAS	LORP		for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (pCi/L)	Is Lab MQL <LORP? (Y/N)
			LORP	Source of LORP					
X	Radium 226	13982-63-3	5.0 pCi/L	MCL	NA	NA	yes	1.000	yes

COC = chemical of concern

Target COC = a chemical of concern associated with the site

CAS = Chemical Abstract Service Registry Number

LORP = Level of required performance as defined in TRRP (highlighted)

TRRP PCL = Texas Risk Reduction Program Protective Concentration Limit (November 12, 2014)

$^{GW}GW_{Ing}$ = TRRP PCL for groundwater ingestion

pCi/L = Picocuries per liter (ppm)

SCDM = Superfund Chemical Data Matrix (March 31, 2012)

NELAP = National Environmental Laboratory Accreditation Program

MQL = Method quantitation limit

MCL = = Maximum Contaminant Level promulgated by National Primary Drinking Water Standards

SSDAP
Table 4 ANALYTES AND TARGET COCs (AQUEOUS)
Method 904.0 Radium 228

Target COC? (X)	**Method 904.0 Analyte in Water**	CAS	LORP		TRRP PCL for Residential Class 1, 2 Groundwater PCLs $^{GW}GW_{Ing}$ (mg/L)	SCDM Groundwater Exposure Pathway Benchmark (mg/L)	Is Lab NELAP accredited? (Y/N)	Lab MQL (pCi/L)	Is Lab MQL <LORP? (Y/N)
			LORP	Source of LORP					
X	Radium 228	15262-20-1	5.0 pCi/L	MCL	NA	NA	no	3.000	yes

COC = chemical of concern

Target COC = a chemical of concern associated with the site

CAS = Chemical Abstract Service Registry Number

LORP = Level of required performance as defined in TRRP (highlighted)

TRRP PCL = Texas Risk Reduction Program Protective Concentration Limit (November 12, 2014)

$^{GW}GW_{Ing}$ = TRRP PCL for groundwater ingestion

pCi/L = Picocuries per liter (ppm)

SCDM = Superfund Chemical Data Matrix (March 31, 2012)

NELAP = National Environmental Laboratory Accreditation Program

MQL = Method quantitation limit

MCL = = Maximum Contaminant Level promulgated by National Primary Drinking Water Standards

Table 5 Analysis Summary

Pathway	Samples by Medium	Analyses by Matrix						
Name / Description	Groundwater	6020A aqueous	7470A aqueous	8260C aqueous	8270D aqueous	300.0 aqueous	903.1 aqueous	904.0 aqueous
Groundwater	10	10	10	10	10	10	10	10
Field Sample & Analyses Subtotals	10	10	10	10	10	10	10	10
Matrix Spike (1 in 20/matrix)	1	1	1	1	1	1	1	1
Matrix Spike Dup (1 in 20/matrix)	1	1	1	1	1	1	1	1
Field Duplicates (specified in FSP)	1	1	1	1	1	1	1	1
Field Blanks (1 in 20/matrix for VOCs)				1				
Esitmate of trip blanks (1/cooler for VOCs)				1				
Estimate of Equipment Blanks				0				
Field & QC Sample & Analysis Totals	13	13	13	15	13	13	13	13
Estimated Batches for data usability review								
Estimate of number of batches to be validated								

Instructions

Populate the yellow-highlighted cells based on site-specfic plans.
The white cells contain either text or formulas and are locked.
Green-highlghted cells contain no information and are locked.
Locked cells can be opened with approval from TCEQ SSDAP program coordinator.
Estimate equipment rinsate blanks for non-dedicated equipment based on a frequency of 1 at the beginning of the first day and 1 at the end of each day for each
Delete columns and rows not used for this FSP.

TABLE 6 Sample Summary by Pathway

Pathway		Matrix (aqueous/ solid)	Sample Locations, Depths and Intervals	Sampling Plan Rationale
#	Name/Description			
1	Groundwater/ Private wells in the vicinity of the Site	Groundwater	Domestic Water Wells, locations to be determined	Test up to 10 domestic water wells to determine COC concentrations in sole-source drinking water.

Table 7
Ector Drum Inc. Site

	Laborabory Name	Analytical Method	Prep Method
1	DHL Analytical, Inc. Austin, TX		
	aqueous		
	metals by ICP-MS	6020A	3010A
	Mercury in liquid wastes	7470A	
	volatile organic compounds by GC/MS	8260C	5030C
	semivolatile organic compounds by GC/MS	8270D	3510C
	Chloride	300.0	

	Laborabory Name	Analytical Method	Prep Method
2	GEL Laboratories, LLC		
	aqueous		
	Radium 226	903.1	
	Radium 228	904.0	

FIGURES

CHECKLIST 2: FIGURES CHECKLIST

Figure #	Title	Information Presented
☒ Figure 1	Project Organization Chart	Project roles with lines of communication and authority
☒ Figure 2	Site Location Map(s)	Site Location Map
☒ Figure 3	Site Features Map(s)	Topography and Wetland Areas
☒ Figure 4	Not Used for this FSP	Not Used for this FSP
☒ Figure 5	Not Used for this FSP	Not Used for this FSP
☒ Figure 6	Proposed Sample Location Map(s)	Proposed Sample Locations

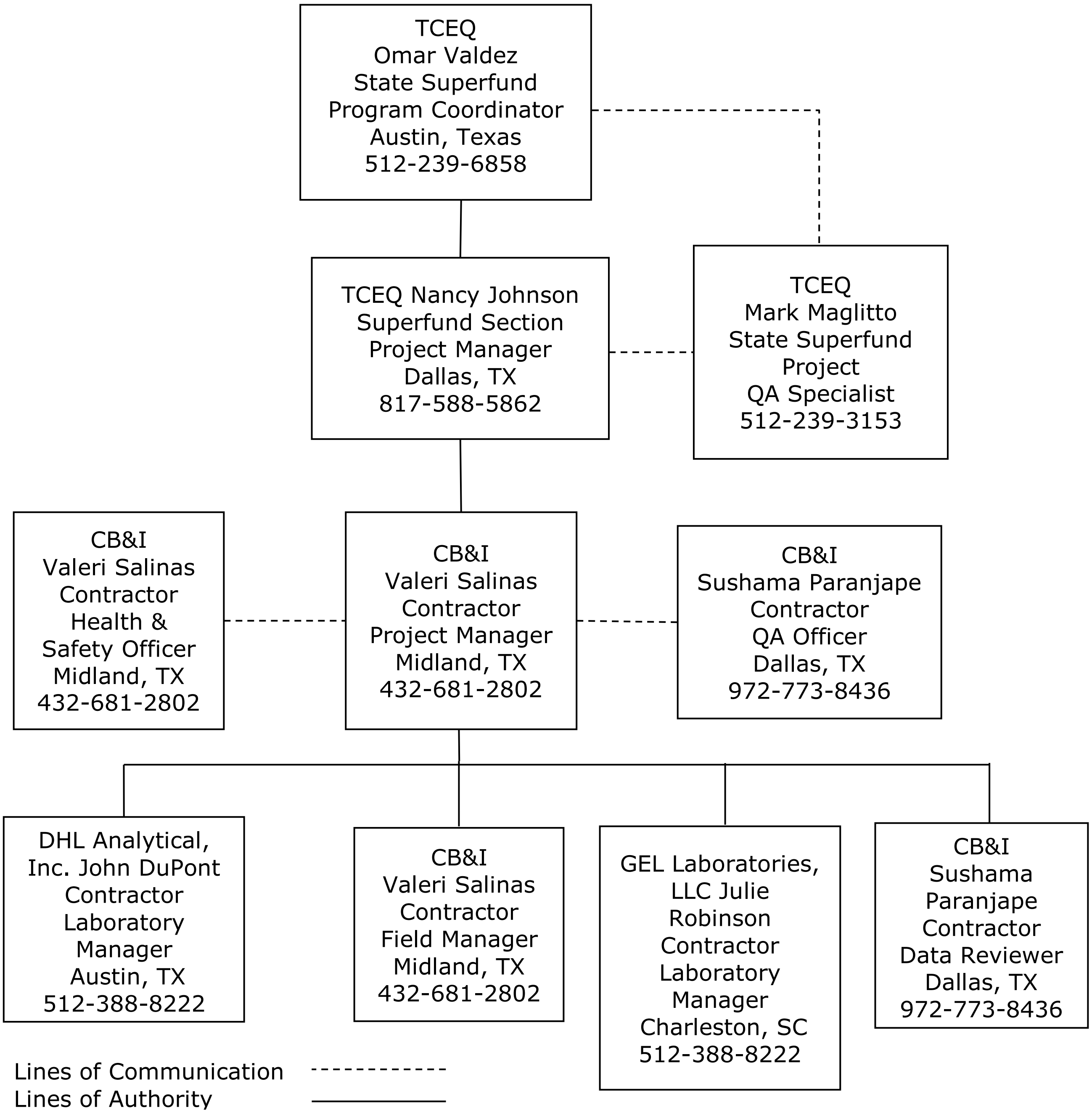


Figure 1 Project Organization Chart

Legend

Ector Drum Inc. Site

0.25 Mile Radius
(from center of site)

N

0 100 200 300 400 800
Feet

ECTOR DRUM INC.
2604 N. MARCO AVENUE
ODESSA, TEXAS

FSP

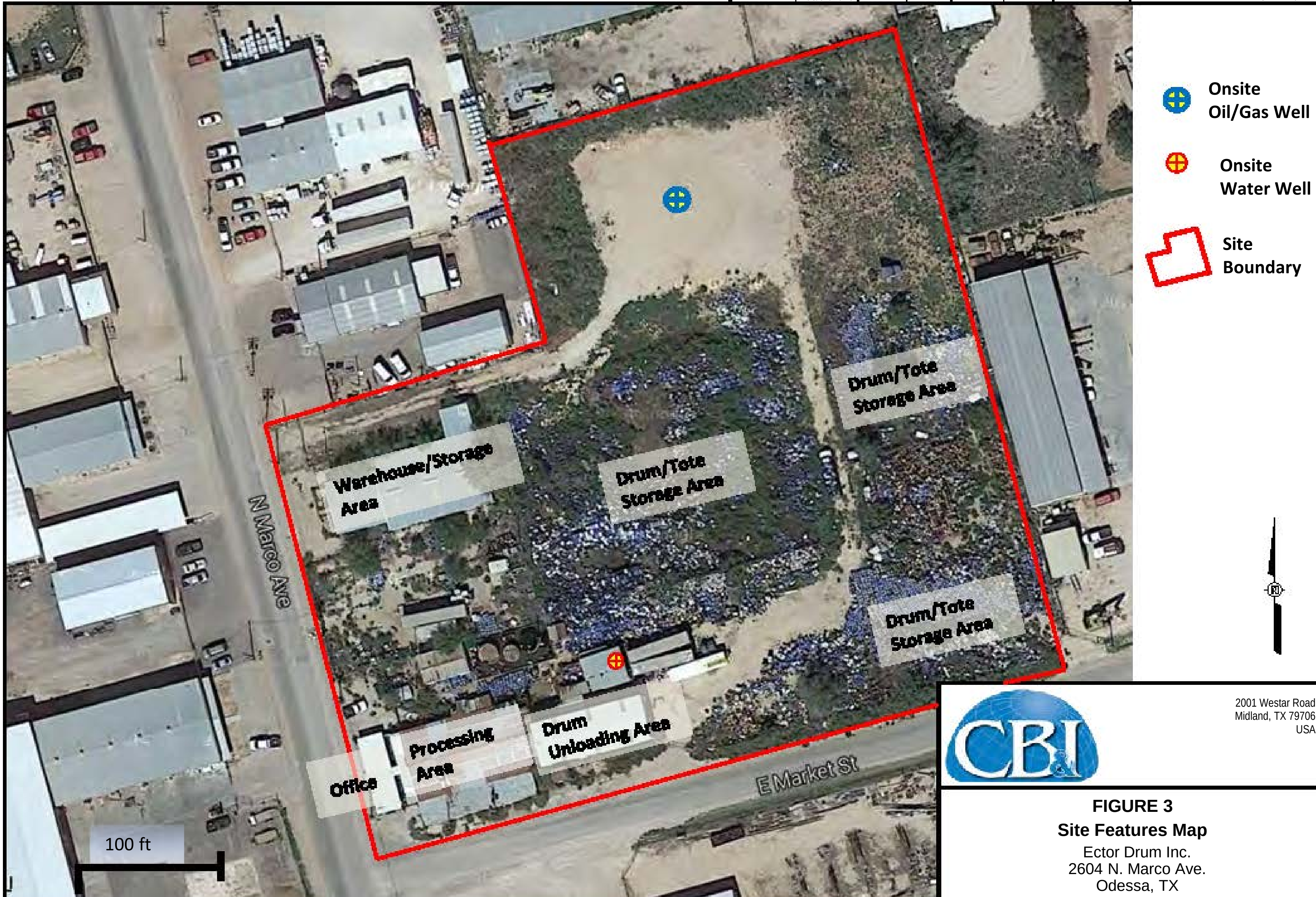
FIGURE NUMBER
2

SITE LOCATION MAP

2001 Westar Road
Midland, Texas 79706
www.CBI.com

G:\EctorDrum\GIS_Documents\Project_Maps\edi_153752_001_site_location.mxd; Analyst: ben.holt; Date: 3/2/2015 2:16:46 PM

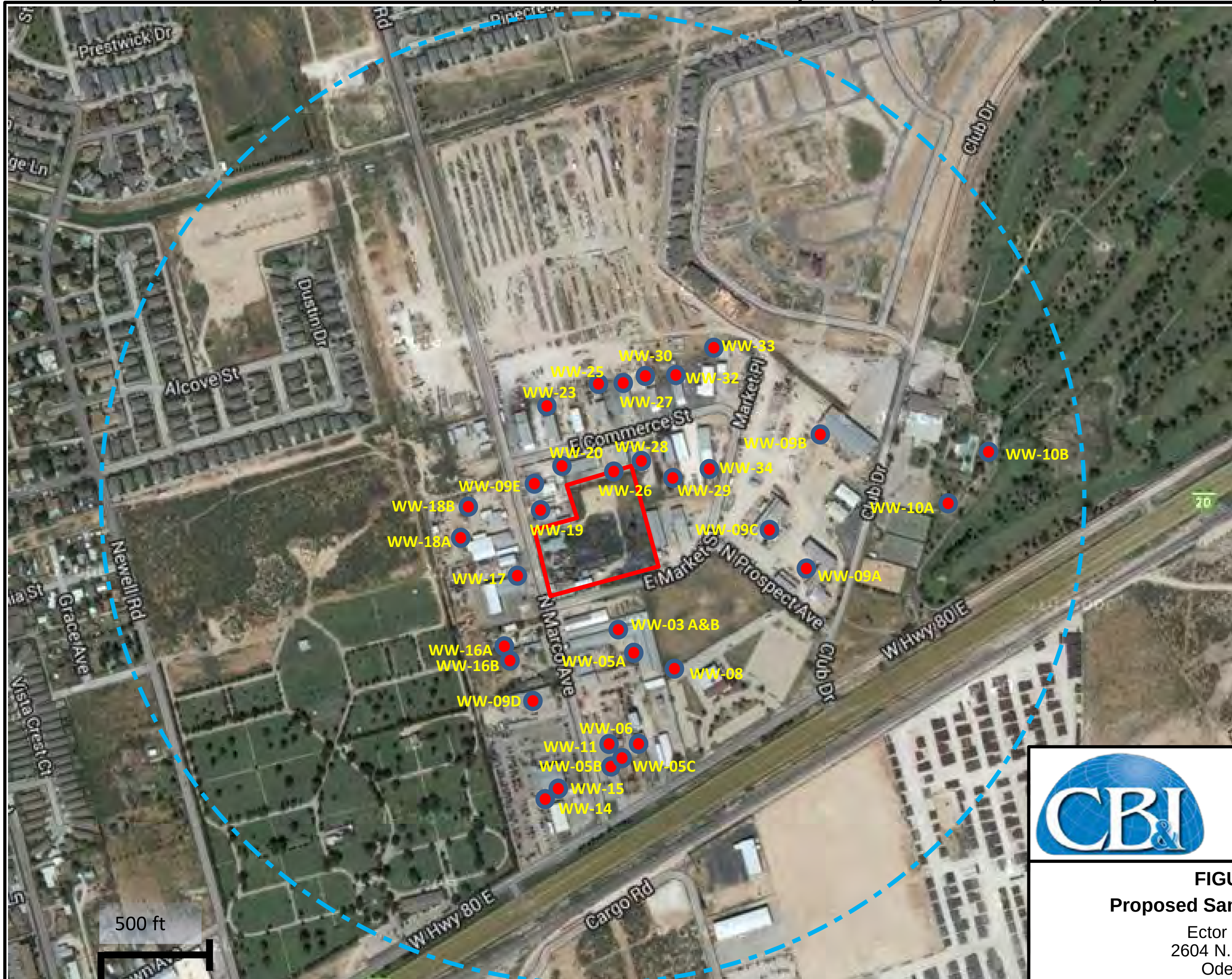
DRAWN BY						OFFICE	Imagery obtained from 2014 Google Map data
VS	03/02/2015					Midland, TX	



CB&I
2001 Westar Road
Midland, TX 79706
USA

FIGURE 3
Site Features Map
Ector Drum Inc.
2604 N. Marco Ave.
Odessa, TX

DRAWN BY					OFFICE	Imagery obtained from 2014 Google Map data
VS	03/23/2015				Midland, TX	



½ Mile Radius

Site Boundary

Proposed Sample Location

WW-12 Banks Water Well Search Map Number

CB&I

2001 Westar Road
Midland, TX 79706
USA

FIGURE 6
Proposed Sample Locations

Ector Drum Inc.
2604 N. Marco Ave.
Odessa, TX

APPENDICES

APPENDIX A: LABORATORY CERTIFICATIONS

Texas Commission on Environmental Quality

NELAP-Recognized Laboratory Accreditation is hereby awarded to

DHL Analytical, Inc.

2300 Double Creek Drive
Round Rock, TX 78664-3801

in accordance with Texas Water Code Chapter 5, Subchapter R, Title 30 Texas Administrative Code Chapter 25, and the National Environmental Laboratory Accreditation Program.

The laboratory's scope of accreditation includes the fields of accreditation that accompany this certificate. Continued accreditation depends upon successful ongoing participation in the program. The Texas Commission on Environmental Quality urges customers to verify the laboratory's current location(s) and accreditation status for particular methods and analyses (www.tceq.texas.gov/goto/lab). Accreditation does not imply that a product, process, system or person is approved by the Texas Commission on Environmental Quality.

Certificate Number: T104704211-14-13
Effective Date: 5/1/2014
Expiration Date: 4/30/2015

Executive Director Texas Commission on Environmental Quality

Texas Commission on Environmental Quality

NELAP - Recognized Laboratory Fields of Accreditation

Certificate:	T104704211-14-13
Expiration Date:	4/30/2015
Issue Date:	5/1/2014

DHL Analytical, Inc.

2300 Double Creek Drive
Round Rock, TX 78664-3801

These fields of accreditation supercede all previous fields. The Texas Commission on Environmental Quality urges customers to verify the laboratory's current accreditation status for particular methods and analyses.

Matrix: ***Non-Potable Water***

Barium	TX	1015	10014605
Beryllium	TX	1020	10014605
Boron	TX	1025	10014605
Cadmium	TX	1030	10014605
Calcium	TX	1035	10014605
Chromium	TX	1040	10014605
Cobalt	TX	1050	10014605
Copper	TX	1055	10014605
Iron	TX	1070	10014605
Lead	TX	1075	10014605
Magnesium	TX	1085	10014605
Manganese	TX	1090	10014605
Molybdenum	TX	1100	10014605
Nickel	TX	1105	10014605
Potassium	TX	1125	10014605
Selenium	TX	1140	10014605
Silver	TX	1150	10014605
Sodium	TX	1155	10014605
Strontium	TX	1160	10014605
Thallium	TX	1165	10014605
Tin	TX	1175	10014605
Titanium	TX	1180	10014605
Vanadium	TX	1185	10014605
Zinc	TX	1190	10014605

Method EPA 245.1

Analyte	AB	Analyte ID	Method ID
Mercury	TX	1095	10036609

Method EPA 300.0

Analyte	AB	Analyte ID	Method ID
Bromide	TX	1540	10053006
Chloride	TX	1575	10053006

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Matrix: ***Non-Potable Water***

m+p-xylene	TX	5240	10102202
Methyl tert-butyl ether (MTBE)	TX	5000	10102202
o-Xylene	TX	5250	10102202
Toluene	TX	5140	10102202
Xylene (total)	TX	5260	10102202

Method EPA 6020

Analyte	AB	Analyte ID	Method ID
Aluminum	TX	1000	10156204
Antimony	TX	1005	10156204
Arsenic	TX	1010	10156204
Barium	TX	1015	10156204
Beryllium	TX	1020	10156204
Boron	TX	1025	10156204
Cadmium	TX	1030	10156204
Calcium	TX	1035	10156204
Chromium	TX	1040	10156204
Cobalt	TX	1050	10156204
Copper	TX	1055	10156204
Iron	TX	1070	10156204
Lead	TX	1075	10156204
Lithium	TX	1080	10156204
Magnesium	TX	1085	10156204
Manganese	TX	1090	10156204
Molybdenum	TX	1100	10156204
Nickel	TX	1105	10156204
Potassium	TX	1125	10156204
Selenium	TX	1140	10156204
Silver	TX	1150	10156204
Sodium	TX	1155	10156204
Strontium	TX	1160	10156204

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Matrix: *Non-Potable Water*

Thallium	TX	1165	10156204
Tin	TX	1175	10156204
Titanium	TX	1180	10156204
Vanadium	TX	1185	10156204
Zinc	TX	1190	10156204

Method EPA 608

Analyte	AB	Analyte ID	Method ID
Aroclor-1016 (PCB-1016)	TX	8880	10103603
Aroclor-1221 (PCB-1221)	TX	8885	10103603
Aroclor-1232 (PCB-1232)	TX	8890	10103603
Aroclor-1242 (PCB-1242)	TX	8895	10103603
Aroclor-1248 (PCB-1248)	TX	8900	10103603
Aroclor-1254 (PCB-1254)	TX	8905	10103603
Aroclor-1260 (PCB-1260)	TX	8910	10103603

Method EPA 624

Analyte	AB	Analyte ID	Method ID
1,1,1-Trichloroethane	TX	5160	10107207
1,1,2,2-Tetrachloroethane	TX	5110	10107207
1,1,2-Trichloroethane	TX	5165	10107207
1,1-Dichloroethane	TX	4630	10107207
1,1-Dichloroethylene	TX	4640	10107207
1,2-Dibromoethane (EDB, Ethylene dibromide)	TX	4585	10107207
1,2-Dichlorobenzene	TX	4610	10107207
1,2-Dichloroethane (Ethylene dichloride)	TX	4635	10107207
1,2-Dichloropropane	TX	4655	10107207
1,3-Dichlorobenzene	TX	4615	10107207
1,4-Dichlorobenzene	TX	4620	10107207
2-Butanone (Methyl ethyl ketone, MEK)	TX	4410	10107207
2-Chloroethyl vinyl ether	TX	4500	10107207
Acetone (2-Propanone)	TX	4315	10107207
Acrolein (Propenal)	TX	4325	10107207

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Matrix: ***Non-Potable Water***

Pyridine	TX	5095	10107401
Toxaphene (Chlorinated camphene)	TX	8250	10107401

Method EPA 7196

Analyte	AB	Analyte ID	Method ID
Chromium (VI)	TX	1045	10162400

Method EPA 7470

Analyte	AB	Analyte ID	Method ID
Mercury	TX	1095	10165807

Method EPA 8015

Analyte	AB	Analyte ID	Method ID
Diesel range organics (DRO)	TX	9369	10173203
Ethylene glycol	TX	4785	10173203
Gasoline range organics (GRO)	TX	9408	10173203
Propylene Glycol	TX	6657	10173203

Method EPA 8021

Analyte	AB	Analyte ID	Method ID
Benzene	TX	4375	10174808
Ethylbenzene	TX	4765	10174808
m+p-xylene	TX	5240	10174808
Methyl tert-butyl ether (MTBE)	TX	5000	10174808
o-Xylene	TX	5250	10174808
Toluene	TX	5140	10174808
Xylene (total)	TX	5260	10174808

Method EPA 8082

Analyte	AB	Analyte ID	Method ID
Aroclor-1016 (PCB-1016)	TX	8880	10179007
Aroclor-1221 (PCB-1221)	TX	8885	10179007
Aroclor-1232 (PCB-1232)	TX	8890	10179007
Aroclor-1242 (PCB-1242)	TX	8895	10179007
Aroclor-1248 (PCB-1248)	TX	8900	10179007
Aroclor-1254 (PCB-1254)	TX	8905	10179007

Texas Commission on Environmental Quality

NELAP - Recognized Laboratory Fields of Accreditation

DHL Analytical, Inc.

2300 Double Creek Drive
Round Rock, TX 78664-3801

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Issue Date: 5/1/2014

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Matrix: ***Non-Potable Water***

Aroclor-1260 (PCB-1260)	TX	8910	10179007
PCBs (total)	TX	8870	10179007

Method EPA 8260

Analyte	AB	Analyte ID	Method ID
1,1,1,2-Tetrachloroethane	TX	5105	10184802
1,1,1-Trichloroethane	TX	5160	10184802
1,1,2,2-Tetrachloroethane	TX	5110	10184802
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	TX	5195	10184802
1,1,2-Trichloroethane	TX	5165	10184802
1,1-Dichloroethane	TX	4630	10184802
1,1-Dichloroethylene	TX	4640	10184802
1,1-Dichloropropene	TX	4670	10184802
1,2,3-Trichlorobenzene	TX	5150	10184802
1,2,3-Trichloropropane	TX	5180	10184802
1,2,4-Trichlorobenzene	TX	5155	10184802
1,2,4-Trimethylbenzene	TX	5210	10184802
1,2-Dibromo-3-chloropropane (DBCP)	TX	4570	10184802
1,2-Dibromoethane (EDB, Ethylene dibromide)	TX	4585	10184802
1,2-Dichlorobenzene	TX	4610	10184802
1,2-Dichloroethane (Ethylene dichloride)	TX	4635	10184802
1,2-Dichloropropane	TX	4655	10184802
1,3,5-Trimethylbenzene	TX	5215	10184802
1,3-Dichlorobenzene	TX	4615	10184802
1,3-Dichloropropane	TX	4660	10184802
1,4-Dichlorobenzene	TX	4620	10184802
1-Chlorohexane	TX	4510	10184802
2,2-Dichloropropane	TX	4665	10184802
2-Butanone (Methyl ethyl ketone, MEK)	TX	4410	10184802
2-Chloroethyl vinyl ether	TX	4500	10184802
2-Chlorotoluene	TX	4535	10184802

Texas Commission on Environmental Quality

NELAP - Recognized Laboratory Fields of Accreditation

Certificate:	**T104704211-14-13**
Expiration Date:	**4/30/2015**
Issue Date:	**5/1/2014**

DHL Analytical, Inc.

2300 Double Creek Drive
Round Rock, TX 78664-3801

These fields of accreditation supercede all previous fields. The Texas Commission on Environmental Quality urges customers to verify the laboratory's current accreditation status for particular methods and analyses.

Matrix: ***Non-Potable Water***

2-Hexanone (MBK)	TX	4860	10184802
4-Chlorotoluene	TX	4540	10184802
4-Isopropyltoluene (p-Cymene)	TX	4915	10184802
4-Methyl-2-pentanone (MIBK)	TX	4995	10184802
Acetone (2-Propanone)	TX	4315	10184802
Acrolein (Propenal)	TX	4325	10184802
Acrylonitrile	TX	4340	10184802
Benzene	TX	4375	10184802
Bromobenzene	TX	4385	10184802
Bromochloromethane	TX	4390	10184802
Bromodichloromethane	TX	4395	10184802
Bromoform	TX	4400	10184802
Carbon disulfide	TX	4450	10184802
Carbon tetrachloride	TX	4455	10184802
Chlorobenzene	TX	4475	10184802
Chlorodibromomethane	TX	4575	10184802
Chloroethane (Ethyl chloride)	TX	4485	10184802
Chloroform	TX	4505	10184802
cis-1,2-Dichloroethylene	TX	4645	10184802
cis-1,3-Dichloropropene	TX	4680	10184802
Dibromomethane (Methylene bromide)	TX	4595	10184802
Dichlorodifluoromethane (Freon-12)	TX	4625	10184802
Ethylbenzene	TX	4765	10184802
Ethyl-t-butylether (ETBE) (2-Ethoxy-2-methylpropane)	TX	4770	10184802
Hexachlorobutadiene	TX	4835	10184802
Iodomethane (Methyl iodide)	TX	4870	10184802
Isopropyl ether	TX	4905	10184802
Isopropylbenzene (Cumene)	TX	4900	10184802
m+p-xylene	TX	5240	10184802
Methyl acetate	TX	4940	10184802

DHL Analytical, Inc.	**Certificate:**	**T104704211-14-13**
2300 Double Creek Drive	**Expiration Date:**	**4/30/2015**
Round Rock, TX 78664-3801	**Issue Date:**	**5/1/2014**

These fields of accreditation supercede all previous fields. The Texas Commission on Environmental Quality urges customers to verify the laboratory's current accreditation status for particular methods and analyses.

Matrix: ***Non-Potable Water***

Analyte	AB	Analyte ID	Method ID
Methyl bromide (Bromomethane)	TX	4950	10184802
Methyl chloride (Chloromethane)	TX	4960	10184802
Methyl tert-butyl ether (MTBE)	TX	5000	10184802
Methylcyclohexane	TX	4965	10184802
Methylene chloride (Dichloromethane)	TX	4975	10184802
Naphthalene	TX	5005	10184802
n-Butylbenzene	TX	4435	10184802
n-Propylbenzene	TX	5090	10184802
o-Xylene	TX	5250	10184802
sec-Butylbenzene	TX	4440	10184802
Styrene	TX	5100	10184802
T-amylmethylether (TAME)	TX	4370	10184802
tert-Butyl alcohol	TX	4420	10184802
tert-Butylbenzene	TX	4445	10184802
Tetrachloroethylene (Perchloroethylene)	TX	5115	10184802
Toluene	TX	5140	10184802
Total trihalomethanes	TX	5205	10184802
trans-1,2-Dichloroethylene	TX	4700	10184802
trans-1,3-Dichloropropylene	TX	4685	10184802
trans-1,4-Dichloro-2-butene	TX	4605	10184802
Trichloroethene (Trichloroethylene)	TX	5170	10184802
Trichlorofluoromethane (Fluorotrichloromethane, Freon 11)	TX	5175	10184802
Vinyl acetate	TX	5225	10184802
Vinyl chloride	TX	5235	10184802
Xylene (total)	TX	5260	10184802

Method EPA 8270

Analyte	AB	Analyte ID	Method ID
1,2,4,5-Tetrachlorobenzene	TX	6715	10185805
1,2,4-Trichlorobenzene	TX	5155	10185805
1,2-Dichlorobenzene	TX	4610	10185805

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Matrix: *Non-Potable Water*

1,2-Diphenylhydrazine	TX	6220	10185805
1,3-Dichlorobenzene	TX	4615	10185805
1,4-Dichlorobenzene	TX	4620	10185805
1-Naphthylamine	TX	6425	10185805
2,3,4,6-Tetrachlorophenol	TX	6735	10185805
2,4,5-Trichlorophenol	TX	6835	10185805
2,4,6-Trichlorophenol	TX	6840	10185805
2,4-Dichlorophenol	TX	6000	10185805
2,4-Dimethylphenol	TX	6130	10185805
2,4-Dinitrophenol	TX	6175	10185805
2,4-Dinitrotoluene (2,4-DNT)	TX	6185	10185805
2,6-Dichlorophenol	TX	6005	10185805
2,6-Dinitrotoluene (2,6-DNT)	TX	6190	10185805
2-Chloronaphthalene	TX	5795	10185805
2-Chlorophenol	TX	5800	10185805
2-Methyl-4,6-dinitrophenol (4,6-Dinitro-2-methylphenol)	TX	6360	10185805
2-Methylnaphthalene	TX	6385	10185805
2-Methylphenol (o-Cresol)	TX	6400	10185805
2-Naphthylamine	TX	6430	10185805
2-Nitroaniline	TX	6460	10185805
2-Nitrophenol	TX	6490	10185805
2-Picoline (2-Methylpyridine)	TX	5050	10185805
3,3'-Dichlorobenzidine	TX	5945	10185805
3-Methylcholanthrene	TX	6355	10185805
3-Nitroaniline	TX	6465	10185805
4,4'-DDD	TX	7355	10185805
4,4'-DDE	TX	7360	10186002
4,4'-DDT	TX	7365	10185805
4-Aminobiphenyl	TX	5540	10185805
4-Bromophenyl phenyl ether (BDE-3)	TX	5660	10185805

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Matrix: *Non-Potable Water*

4-Chloro-3-methylphenol	TX	5700	10185805
4-Chloroaniline	TX	5745	10185805
4-Chlorophenyl phenylether	TX	5825	10185805
4-Dimethyl aminoazobenzene	TX	6105	10185805
4-Methylphenol (p-Cresol)	TX	6410	10185805
4-Nitroaniline	TX	6470	10185805
4-Nitrophenol	TX	6500	10185805
7,12-Dimethylbenz(a) anthracene	TX	6115	10185805
a-a-Dimethylphenethylamine	TX	6125	10185805
Acenaphthene	TX	5500	10185805
Acenaphthylene	TX	5505	10185805
Acetophenone	TX	5510	10185805
Aldrin	TX	7025	10186002
alpha-BHC (alpha-Hexachlorocyclohexane)	TX	7110	10186002
alpha-Chlordane	TX	7240	10185601
Aniline	TX	5545	10185805
Anthracene	TX	5555	10185805
Aroclor-1016 (PCB-1016)	TX	8880	10186002
Aroclor-1221 (PCB-1221)	TX	8885	10185203
Aroclor-1232 (PCB-1232)	TX	8890	10185407
Aroclor-1242 (PCB-1242)	TX	8895	10185203
Aroclor-1248 (PCB-1248)	TX	8900	10186002
Aroclor-1254 (PCB-1254)	TX	8905	10185601
Aroclor-1260 (PCB-1260)	TX	8910	10185203
Atrazine	TX	7065	10185805
Azinphos-methyl (Guthion)	TX	7075	10185805
Benzidine	TX	5595	10185805
Benzo(a)anthracene	TX	5575	10185805
Benzo(a)pyrene	TX	5580	10185805
Benzo(b)fluoranthene	TX	5585	10185805

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Issue Date: 5/1/2014

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Matrix: *Non-Potable Water*

Benzo(e)pyrene	TX	5605	10185805
Benzo(g,h,i)perylene	TX	5590	10185805
Benzo(k)fluoranthene	TX	5600	10185805
Benzoic acid	TX	5610	10185805
Benzyl alcohol	TX	5630	10185805
beta-BHC (beta-Hexachlorocyclohexane)	TX	7115	10185203
Biphenyl	TX	5640	10185805
bis(2-Chloroethoxy)methane	TX	5760	10185805
bis(2-Chloroethyl) ether	TX	5765	10185805
bis(2-Chloroisopropyl) ether	TX	5780	10185805
bis(2-Ethylhexyl) phthalate (DEHP)	TX	6255	10185805
Butyl benzyl phthalate	TX	5670	10185805
Caprolactam	TX	7180	10185805
Carbaryl (Sevin)	TX	7195	10185407
Carbazole	TX	5680	10185805
Carbophenothion	TX	7220	10185407
Chlordane (tech.)	TX	7250	10185203
Chlorfenvinphos	TX	7255	10185805
Chrysene	TX	5855	10185805
Coumaphos	TX	7315	10186002
Crotoxyphos	TX	7330	10185407
delta-BHC (delta-Hexachlorocyclohexane)	TX	7105	10185805
Demeton	TX	7390	10185407
Demeton-o	TX	7395	10185203
Demeton-s	TX	7385	10185601
Dibenz(a,h) anthracene	TX	5895	10185805
Dibenzofuran	TX	5905	10185805
Dichlorovos (DDVP, Dichlorvos)	TX	8610	10186002
Dicrotophos	TX	7465	10185407
Dieldrin	TX	7470	10186002

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Issue Date:	5/1/2014

DHL Analytical, Inc.

2300 Double Creek Drive
Round Rock, TX 78664-3801

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Matrix: *Non-Potable Water*

Diethyl phthalate	TX	6070	10185805
Dimethoate	TX	7475	10185805
Dimethyl phthalate	TX	6135	10185805
Di-n-butyl phthalate	TX	5925	10185805
Di-n-octyl phthalate	TX	6200	10185805
Dioxathion	TX	7495	10185203
Diphenylamine	TX	6205	10185805
Disulfoton	TX	8625	10185601
Endosulfan I	TX	7510	10185805
Endosulfan II	TX	7515	10185203
Endosulfan sulfate	TX	7520	10185601
Endrin	TX	7540	10185203
Endrin aldehyde	TX	7530	10185805
Endrin ketone	TX	7535	10186002
EPN (Phosphonothioic acid, phenyl-, O-ethyl O-(p-nitrophenyl) ester)	TX	7550	10186002
Ethion	TX	7565	10185805
Ethyl methanesulfonate	TX	6260	10185805
Famphur	TX	7580	10185407
Fensulfothion	TX	7600	10185203
Fenthion	TX	7605	10186002
Fluoranthene	TX	6265	10185805
Fluorene	TX	6270	10185805
gamma-BHC (Lindane, gamma-Hexachlorocyclohexane)	TX	7120	10185203
gamma-Chlordane	TX	7245	10185203
Heptachlor	TX	7685	10185601
Heptachlor epoxide	TX	7690	10185805
Hexachlorobenzene	TX	6275	10185805
Hexachlorobutadiene	TX	4835	10185805
Hexachlorocyclopentadiene	TX	6285	10185805
Hexachloroethane	TX	4840	10185805

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Issue Date:	**5/1/2014**

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Matrix: *Non-Potable Water*

Hexachlorophene	TX	6290	10185805
Indeno(1,2,3-cd) pyrene	TX	6315	10185805
Isodrin	TX	7725	10185407
Isophorone	TX	6320	10185805
Leptophos	TX	7755	10186002
Malathion	TX	7770	10186002
Methoxychlor	TX	7810	10185601
Methyl methanesulfonate	TX	6375	10185805
Methyl parathion (Parathion, methyl)	TX	7825	10185203
Mevinphos	TX	7850	10186002
Monocrotophos	TX	7880	10185203
Naled	TX	7905	10185203
Naphthalene	TX	5005	10185805
Nitrobenzene	TX	5015	10185805
n-Nitrosodiethylamine	TX	6525	10185805
n-Nitrosodimethylamine	TX	6530	10185805
n-Nitrosodi-n-butylamine	TX	5025	10185805
n-Nitrosodi-n-propylamine	TX	6545	10185805
n-Nitrosodiphenylamine	TX	6535	10185805
n-Nitrosopiperidine	TX	6560	10185805
Parathion, ethyl	TX	7955	10185805
Pentachlorobenzene	TX	6590	10185805
Pentachloronitrobenzene (PCNB)	TX	6600	10185805
Pentachlorophenol	TX	6605	10185805
Phenacetin	TX	6610	10185805
Phenanthrene	TX	6615	10185805
Phenol	TX	6625	10185805
Phorate	TX	7985	10186002
Phosmet (Imidan)	TX	8000	10186002
Phosphamidon	TX	8005	10185805

Certificate:	**T104704211-14-13**
Expiration Date:	**4/30/2015**
Issue Date:	**5/1/2014**

DHL Analytical, Inc.

2300 Double Creek Drive
Round Rock, TX 78664-3801

These fields of accreditation supercede all previous fields. The Texas Commission on Environmental Quality urges customers to verify the laboratory's current accreditation status for particular methods and analyses.

Matrix: *Non-Potable Water*

Pronamide (Kerb)	TX	6650	10185805
Pyrene	TX	6665	10185805
Pyridine	TX	5095	10185805
Quinoline	TX	6670	10185805
Sulfotepp	TX	8155	10186002
Terbufos	TX	8185	10185805
Tetrachlorvinphos (Stirophos, Gardona)	TX	8197	10186002
Tetraethyl pyrophosphate (TEPP)	TX	8210	10185407
Toxaphene (Chlorinated camphene)	TX	8250	10185203

Method EPA 8321

Analyte	AB	Analyte ID	Method ID
2,4,5-T	TX	8655	10188804
2,4-D	TX	8545	10188804
2,4-DB	TX	8560	10188804
Dalapon	TX	8555	10188804
Dicamba	TX	8595	10188804
Dichloroprop (Dichlorprop, Weedone)	TX	8605	10188804
Dinoseb (2-sec-butyl-4,6-dinitrophenol, DNBP)	TX	8620	10188804
MCPA	TX	7775	10188804
MCPP	TX	7780	10188804
Silvex (2,4,5-TP)	TX	8650	10188804

Method EPA 8330

Analyte	AB	Analyte ID	Method ID
1,3,5-Trinitrobenzene (1,3,5-TNB)	TX	6885	10189807
1,3-Dinitrobenzene (1,3-DNB)	TX	6160	10189807
2,4,6-Trinitrotoluene (2,4,6-TNT)	TX	9651	10189807
2,4-Dinitrotoluene (2,4-DNT)	TX	6185	10189807
2,6-Dinitrotoluene (2,6-DNT)	TX	6190	10189807
2-Amino-4,6-dinitrotoluene (2-am-dnt)	TX	9303	10189807
2-Nitrotoluene	TX	9507	10189807
3-Nitrotoluene	TX	9510	10189807

Certificate:	**T104704235-15-10**
Expiration Date:	**2/28/2016**
Issue Date:	**3/1/2015**

GEL Laboratories, LLC

2040 Savage Road
Charleston, SC 29407-4731

These fields of accreditation supercede all previous fields. The Texas Commission on Environmental Quality urges customers to verify the laboratory's current accreditation status for particular methods and analyses.

Matrix: ***Non-Potable Water***

Analyte	AB	Analyte ID	Method ID
RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine)	UT	9432	10189807

Method EPA 900.0

Analyte	AB	Analyte ID	Method ID
Gross-alpha	UT	2830	10112400
Gross-beta	UT	2840	10112400

Method EPA 9012

Analyte	AB	Analyte ID	Method ID
Amenable cyanide	UT	1510	10193201
Total cyanide	UT	1645	10193201

Method EPA 9020

Analyte	AB	Analyte ID	Method ID
Total organic halides (TOX)	UT	2045	10194000

Method EPA 903.1

Analyte	AB	Analyte ID	Method ID
Radium-226	UT	2965	10113403

Method EPA 9034

Analyte	AB	Analyte ID	Method ID
Sulfide	UT	2005	10196006

Method EPA 9040

Analyte	AB	Analyte ID	Method ID
pH	UT	1900	10196802

Method EPA 9041

Analyte	AB	Analyte ID	Method ID
pH	UT	1900	10197601

Method EPA 9050

Analyte	AB	Analyte ID	Method ID
Conductivity	UT	1610	10198604

Method EPA 9056

Analyte	AB	Analyte ID	Method ID
Bromide	UT	1540	10199209
Chloride	UT	1575	10199209

APPENDIX B: STANDARD OPERATING PROCEDURES

CHECKLIST 3: FIELD SOP CHECKLIST

	#	SOP Name
☒	1.1	Initial Site Reconnaissance
☒	1.2	Site Preparation and Control
☒	1.3	Site Restoration
☒	1.4	Investigative Derived Waste (IDW)
☒	1.5	Decontamination
☒	6.1	Documentation and Reporting
☒	6.3	VOC Samples
☒	6.4	Sample Handling and Control
☒	6.5	QC Samples
☒	6.6	Sample Identification and Documentation
☒	7.5	Measurement of Field Parameters
☒	7.8	Groundwater Sampling Using a Low-flow Techniques
☒	7.9	Purging a Drinking Water Well
☒	7.10	Sampling a Drinking Water Well
☒	17.1	GPS Data Collection and Submission

1.0 METHOD SUMMARY

This standard operating procedure (SOP) provides guidance for conducting an initial site reconnaissance. The purpose of this reconnaissance is to familiarize personnel with the site and to identify hazards which may affect field activities.

2.0 EQUIPMENT/APPARATUS/REAGENTS

2.1 Equipment List

- Health and Safety Plan
- Appropriate personal protective equipment (PPE)
- Any other equipment listed in the Health and Safety Plan

3.0 PROCEDURES

1. Identify property and/or facility owners.
2. Obtain property access (access agreements).
3. Identify property boundaries.
4. Identify any special requirements for the preparation of the site (e.g., heavy equipment required to clear trees).
5. Identify areas on the site which may require control (e.g., fencing).
6. Identify vehicle access routes.
7. An organic vapor analyzer (OVA) is typically used during this survey. These gross measurements may be used on a preliminary basis to (1) determine levels of personal protection, (2) establish site work zones, and (3) map candidate areas for more thorough qualitative and quantitative studies involving air sampling.
8. Identify locations for central decontamination area and exits for it, field office/laboratory, and emergency equipment (e.g., fire extinguishers and PPE).
9. Prior to investigative activities inspect and photograph the site for indications of contamination and other important features, including but not limited to:
    a. Presence and estimated area of source material, wastes, releases, or threatened releases;
    b. Topography, overland flow pathways, surface well casing, and other features which may affect the mobility and migration of COCs;
    c. Potential for releases from the site;
    d. Location, dimensions, and conditions of Areas of Concern;
    e. Condition of site security (e.g. fence, gates, locks, signage); and
    f. Other relevant site features.
10. Provide a description of each important site features in field log book entries.

4.0 CAUTIONS AND INTERFERENCES

Two people should perform the initial site reconnaissance staying together at all times. Also, all instrumentation should be intrinsically safe or enclosed in explosion-proof casing.

1.0 METHOD SUMMARY

This standard operating procedure (SOP) provides guidance for site preparation and control. It is intended to assist field personnel in preparing the site before conducting any work activities.

2.0 EQUIPMENT/APPARATUS/REAGENTS

2.1 Equipment List

- Appropriate personal protective equipment (PPE)
- Caution tape, orange cones and/or other visible means of delineating boundaries
- Heavy gauge plastic sheeting
- Collection systems for decontamination areas (e.g., sump pump)
- 55-gallon drums or other appropriate containers
- Sheets of plywood
- Hay bales
- 2 x 4 lumber
- Landscape timbers
- Tables or sawhorse benches
- Site Plan

3.0 PROCEDURES

1. Don appropriate PPE.
2. Identify and mark utility locations in accordance with SOP 2.4
3. Designate and mark the decontamination zone with caution tape, orange cones and/or other visible means. To control access of personnel and equipment to possible contaminants, the site will be divided into work zones. There is only one entrance and exit to the zones. Three categories of zones and one command post are utilized. For all operations except Level D, work zones will be designated as follows:
   a. Support Zone or Clean Zone -- Along with the command post, this is the outermost boundary of the site. Contamination of personnel and equipment in this area is unlikely.
   b. Contamination Reduction Zone -- This area serves as a corridor between the exclusion zone and the support zone and is the area where decontamination activities occur. All personnel and equipment passing through this corridor from the exclusion zone to the support zone must undergo appropriate decontamination.
   c. Exclusion Zone -- This is the area where actual operations are being conducted. Access to this area is limited to personnel and equipment being utilized at that particular time for the specific operation in progress. The risk of contamination in this area is high.
4. Create a central decontamination area for drilling rigs and other large equipment (see SOP 1.5). The decontamination area should be large enough to allow storage of cleaned equipment and materials prior to use, as well as drums of decontamination waste. The decontamination area shall be lined with heavy gauge plastic sheeting, and designed with a collection system to capture decontamination waters. Solid wastes shall be accumulated in 55-gallon drums or other appropriate containers and stored in a designated investigative derived waste (IDW) storage area (see SOP 1.4).
   a. A large equipment decontamination pad can be constructed by placing sheets of plywood on the ground and covering them with plastic sheeting. Walls for controlling over spray can be

created from hay bales or by constructing 2 x 4 frames covered with plastic sheeting. Landscape timbers can be used to create berms around the floor of the decontamination pad. A sump pump should be used to collect decontamination water and transfer the water to 55-gallon drums.

   b. A small equipment decontamination line can be created by placing plastic sheeting on the ground and using tables or sawhorse benches to hold wash basins.

   c. Decontamination lines are site specific since they are dependent upon the types of contamination and the type of work activity onsite. It is usually a location in a shaded area in which the wind can help to cool personnel.

5. Identify the locations of utilities, the field office/laboratory, IDW storage areas, exclusion zone, contamination reduction zone (including decontamination facilities), and the clean zone on a site plan.

4.0 CAUTIONS AND INTERFERENCES

This section is not applicable to this SOP.

1.0 METHOD SUMMARY

This standard operation procedure (SOP) describes the steps necessary for site restoration. Upon completion of field activities, the site should be repaired to its original condition when possible. All drums or waste containers should be staged in a designated staging area and all other waste should be removed. All borings should be backfilled.

2.0 EQUIPMENT/APPARATUS/REAGENTS

Varies depending on which of the following tasks are completed.

3.0 PROCEDURES

1. Minimize impacts to work sites and sampling locations, particularly those in or near sensitive environments, such as wetlands with the use of soil erosion fences or by diverting streams/brooks during work operations.
2. Fill boreholes and pits, re-vegetate or erect erosion fences as necessary, re-establish streams, brooks, etc, as applicable.
3. Remove all sampling, decontamination equipment, and other items introduced to the site upon completion of work.
4. Remove all drums, trash, and other waste upon completion of work at the site.
5. Transport decontamination and/or purge water and soil cuttings to the designated locations.

4.0 CAUTIONS AND INTERFERENCES

This section is not applicable to this SOP.

STANDARD OPERATING PROCEDURE NO. 1.4
INVESTIGATION-DERIVED WASTE

1.0 METHOD SUMMARY

This standard operating procedure (SOP) describes procedures for managing investigation-derived waste (IDW) generated during field activities. IDW should be classified and disposed of in accordance with applicable laws and regulations. **It is the goal of the Superfund Program to properly dispose of all IDW in the fiscal year in which it was generated.** IDW should be properly disposed based on waste classification results. IDW may include, but is not limited to:

- **Environmental media IDW** such as soil cuttings from drilling or hand augering, ground water obtained through well development or well purging, and excess sample material;
- **Personnel protective equipment** (PPE) such as disposable coveralls, gloves, booties, and respirator canisters;
- **Disposable equipment** such as plastic tarps and equipment covers, aluminum foil, PVC pipe, disposable bailers, rope, twine, plastic tubing, broken or unused sample containers, and tape;
- **Trash** such as boxes, packing and shipping materials, and paper;
- **Drilling mud** and **drilling water**; and
- **Purge and Decontamination waters**.

The IDW will be segregated at the Site according to matrix (solid or liquid) and how it was derived (drill cuttings, drilling fluid, decontamination fluids, or purged groundwater). Each container will be properly labeled with site identification, sampling point, matrix, target chemicals of concern, and other pertinent information for handling. Although most of these materials are non-hazardous, occasionally IDW which meets the definition of hazardous waste may be generated. To the extent possible, non-hazardous waste should be segregated from hazardous waste.

2.0 EQUIPMENT/APPARATUS/REAGENTS

2.1 Equipment List

- U.S. Department of Transportation (DOT)-approved containers (e.g., 55-gallon drums, roll-off bins)
- Wrenches for securing drum lids
- Labels and/or paint or pens capable of withstanding outdoor environments for a number of years
- Lumber (for staging area construction)
- Plastic sheeting (for staging area construction)
- Plywood (for staging area construction)
- 5-gallon buckets
- Manifests
- Container log

3.0 PROCEDURES

Segregate the IDW according to matrix (e.g., solid, liquid, sludge), origin, and likely disposal classification (non-hazardous versus hazardous). Classify IDW based on waste classification results.

If practical, reduce the volume of IDW by compaction. Regularly collect IDW, litter, and garbage to maintain the cleanliness and orderliness of the Site. All IDW should be properly containerized, labeled, staged, and disposed of.

3.1 Non-Hazardous IDW

GENERAL PROCEDURES

The following general procedures apply to non-hazardous IDW that must be containerized, sampled, and/or must remain on-site for a period of time.

1. Keep non-hazardous IDW segregated from IDW that may meet the definition of hazardous waste.
2. Keep obviously-contaminated IDW (e.g., oily soil cuttings) segregated from apparently non-contaminated IDW.
3. Place IDW in appropriate containers (e.g., U.S. DOT 55-gallon drums, roll-off bins, trash bags, etc.)
4. To the extent practical, containerize IDW from different locations separately to facilitate proper classification and disposal. Drill cuttings from different boreholes can be put in the same drums provided they originate from similar areas of the site (e.g., up-gradient, background borings, etc.).
5. Transport containers to the staging area in a manner to prevent spillage or evaporative loss.
6. Store containers in an appropriate staging area.
7. Label each container with site identification, date of accumulation, description and source of the materials, contact information, and other pertinent information.
8. Record the sample numbers which will be used to classify each container in the field logbook.
9. Collect classification samples (if appropriate) from the IDW.
10. Analyze samples for appropriate Target Chemicals of Concern (Target COCs).
11. Review classification sample results.
12. Classify the IDW for disposal.
13. Prepare transport documentation as needed.
14. Transport IDW to appropriate disposal facility.

15. If the IDW was generated at an active facility, consider obtaining permission from the operator of the facility to place non-hazardous IDW in facility dumpsters, if available.

16. On larger projects, waste hauling services may be obtained and a dumpster located at the site.

17. Include the completed log of IDW information and labeling and a rough sketch of the IDW locations with the identifiers of each container in the field logbook.

18. Maintain a log (Appendix A) of all containers, stating their identification number and contents.

19. Document disposal of IDW in a report or email to the TCEQ Project Manager (PM) (include waste manifests).

UN-CONTAMINATED ENVIRONMENTAL MEDIA IDW

If acceptable to the TCEQ PM, it may be possible to return uncontaminated environmental media to the site based on the analytical results of samples collected from associated environmental media. For example, it may be acceptable to characterize drill cuttings based on the borehole sample results from which the cuttings originated; or well purge-water may be characterized based on the groundwater sample results from the well from which the purge-water originated. For the purposes of this SOP, "uncontaminated" environmental media are soil or water which do not contain Target COCs at concentrations in excess of the TRRP Assessment Level. The following procedures should be used for uncontaminated environmental media as site conditions allow:

1. Containerize and store the environmental media IDW;

2. Associate samples with environmental media IDW;

3. In the field logbook, record associated environmental samples for each container;

4. Collect classification samples from representative containers;

5. Classify the IDW based on 1) analyses of associated environmental samples or 2) samples from environmental media IDW; and

6. After reviewing associated sample results and obtaining TCEQ PM Concurrence, deposit uncontaminated environmental media IDW at the site.

Soil IDW should be properly containerized in U.S. Department of Transportation (DOT)-approved containers (55-gallon drums or roll-off bins), labeled, and staged on-site pending.

TRASH, DISPOSABLE EQUIPMENT, AND PERSONNEL PROTECTIVE EQUIPMENT (PPE)

Non-investigative waste, such as litter and household garbage, should be collected on an as-needed basis to maintain the Site in a clean and orderly manner. This waste will be containerized and transported to the designated sanitary landfill or collection bin. The following procedures should be followed for disposal of trash, equipment, and PPE.

1. Non-hazardous IDW, such as litter, garbage, and non-contaminated PPE, should be collected, stored in appropriate containers, and properly disposed of.

2. Obviously uncontaminated IDW such as trash may be disposed of in accordance with applicable laws.

3. With the owner's permission, trash may be disposed of in available dumpsters, at appropriate landfills, or other public disposal locations.

4. Used PPE should be properly decontaminated, placed in plastic trash bags, and disposed of in accordance with applicable laws.

DRILLING MUD AND DRILLING WATER

The following procedures should be followed for disposal of drilling mud and drilling water.

1. Dispose of drill cuttings, purge or development water, and drilling mud in a permitted landfill or sanitary sewer.

2. Alternatively, obtain permission to place IDW in active facility treatment systems.

PURGE AND DECONTAMINTION WATERS

Purge and decontamination water will be properly containerized, labeled, and stored on site in 55 gallon drums. The following procedures should be followed for disposal of decontamination waters.

1. Collect waste classification samples from decontamination waters.

2. Classify IDW based on the analytical results.

3. With the concurrence of the TCEQ PM, pour uncontaminated decontamination water out on the site

4. Properly dispose of decontamination waters off-site.

3.2 HAZARDOUS IDW

A disposal subcontractor will dispose of any hazardous IDW as specified in applicable regulations.

1. To the extent possible, avoid generating IDW that may meet the definition of hazardous waste.
2. Keep non-hazardous IDW segregated from IDW that may meet the definition of hazardous waste.
3. Properly containerize and label IDW that is suspected to meet the definition of hazardous waste.
4. Store these materials in appropriate containers at a segregated staging area with a secondary containment structure.
5. Perform waste classification analyses requested by the potential disposal facility.
6. Review sample results to determine waste classification.
7. Manifest and transport hazardous waste to a permitted treatment or disposal facility in accordance with waste classification and applicable laws.
8. If required, file an Annual Waste Summary with the TCEQ Office of Waste by the applicable deadline.

4.0 CAUTIONS AND INTERFERENCES

Further guidance on IDW requirements for CERCLA sites may be found at:

http://www.epa.gov/superfund/policy/remedy/pdfs/RCRA_Biennial_Report_Requirements_for_CERCLA.pdf

APPENDIX A

DRUMMED MATERIAL WORKSHEET

Project Name	**Project Number**
Site Address	**Project Manager**

Drum No.	Boring No.	Date	Contents	Sample ID	Lab Results	Disposition

STANDARD OPERATING PROCEDURE NO. 1.5
DECONTAMINATION

1.0 METHOD SUMMARY

This standard operating procedure (SOP) provides a description of the methods used for preventing, minimizing, or limiting cross-contamination of samples due to inappropriate or inadequate equipment decontamination and to provide general guidelines for developing decontamination procedures for sampling equipment used during hazardous waste operations. This SOP does not address detailed personnel decontamination; however, all disposable Personal Protective Equipment (PPE) will be decontaminated such that it can be disposed of as Class 3 waste. Non-dedicated sampling equipment and tools will be decontaminated prior to use and between sample locations. Dedicated sampling equipment will be decontaminated prior to first use, unless certified free of contaminants by the manufacturer. The TCEQ Project Manager (PM) may modify the decontamination frequency, as appropriate.

Removing or neutralizing contaminants from equipment minimizes the likelihood of sample cross contamination, reduces or eliminates transfer of contaminants to clean areas, and prevents the mixing of incompatible substances. Gross contamination can be removed by physical decontamination procedures. These abrasive and non-abrasive methods include the use of brushes, air and wet blasting, and high and low pressure water cleaning.

2.0 EQUIPMENT/APPARATUS/REAGENTS

- non-phosphate detergent
- tap water
- distilled or deionized water
- long and short handled brushes
- bottle brushes
- drop cloth/plastic sheeting
- paper towels
- plastic or galvanized tubs or buckets
- pressurized sprayers
- aluminum foil
- re-sealable bags
- trash bags
- appropriate personal protective equipment (PPE)
- face shield (for hard hat)
- high pressure washer (if necessary)
- fuel for high pressure washer
- 55-gallon drums
- plywood
- sump pump
- landscape timbers, 4 x 4's, or 2 x 4's

3.0 PROCEDURES

3.1 Decontamination

Decontamination of drilling equipment, well construction materials, sampling equipment, tools, etc. shall be described in the project work plan or field sampling plan. All samples and equipment leaving the contaminated area of a site must be decontaminated to remove any contamination that may have adhered to equipment. This includes casing, drill bits, auger flights, the portions of drill rigs that stand above boreholes, sampling devices, and instruments, such as slugs and sounders. In addition, the contractor shall take care to prevent the sample from coming into contact with potentially contaminating substances, such as tape, oil, engine exhaust, corroded surfaces, and dirt.

The following procedures shall be used to decontaminate large pieces of equipment, such as casings, auger flights, pipe and rods, and those portions of the drill rig that may stand directly over a boring or well location or that come into contact with casing, auger flights, pipe, or rods:

1. Prepare the decontamination zone in accordance with SOP 1.2.
2. Don appropriate PPE.
3. Deposit the contaminated equipment on the plastic drop cloth/sheet or in a container inside the contaminant reduction zone (CRZ).
4. Place large pieces of equipment (e.g., auger flights) on sawhorses.
5. Use a high-pressure washer and a low-phosphate soap (e.g., Alconox) to remove encrusted material from grossly contaminated equipment. If necessary, use a brush to scrub the equipment until all visible dirt, grime, grease, oil, loose paint, rust flakes, etc., have been removed.
6. Rinse all equipment with potable water.
7. Store the equipment on sawhorses or wrapped in clean plastic sheeting.
8. Decontamination water should be collected and transferred to a 55-gallon drum at the end of the day or whenever significant quantities of water have accumulated. Drums of investigative derived waste (IDW) should be managed in accordance with SOP 1.4.

The following procedures shall be used to decontaminate small pieces of sampling equipment such as split spoons, bailers, trowels/spoons and bowls:

1. Prepare the decontamination zone in accordance with SOP 1.2.
2. Don appropriate PPE.
3. Scrub the equipment with a solution of potable water and low-phosphate soap (e.g., Alconox).
4. If organic constituents are contaminants of concern, rinse the equipment with a pesticide-grade solvent, typically acetone. If acetone is a constituent of concern, substitute methanol as the rinse agent.
5. Rinse the equipment with copious quantities of distilled or deionized water.
6. Allow the equipment to air dry on a clean surface or rack elevated at least two feet above ground.

Wrap the sampling device in aluminum foil or place in sealable plastic bags prior to reuse.

The following procedures shall be used to decontaminate equipment used in the sampling of media potentially contaminated with metals.

- rinse all equipment with potable water;
- clean equipment with a brush in a solution of laboratory grade detergent (Liquinox, Alconox, or equivalent);
- rinse with potable water;
- rinse with 10% nitric acid solution (trace metals grade);
- rinse with distilled or deionized water;

- rinse with reagent grade isopropanol if also analyzing for organic compounds;
- rinse with deionized water;
- Allow equipment to completely dry, then collect an equipment rinsate sample using ASTM Type II reagent grade water, seal the rinsate sample container with a custody seal, and place the sample in the shipment cooler;
- Place the equipment on clean plastic sheeting and allow to air dry; and
- If the equipment is not to be used immediately, place small equipment in plastic sealable bag and place a custody-seal across the sealed opening of the bag.

At the completion of the decontamination activities, all fluids and solid waste should be containerized and managed in accordance with SOP 1.4.

If a particular contaminant fraction is not present at the site, the ten (10) step decontamination procedure specified above may be modified for site specificity. For example, the solvent rinse may be eliminated if organics are not of concern at a site. Modifications to the standard procedure should be documented in the site specific work plan or subsequent report.

4.0 CAUTIONS AND INTERFERENCES

1. The use of distilled/deionized water commonly available from commercial vendors is typically acceptable for decontamination of sampling equipment.
2. The use of an untreated potable water supply is not an acceptable substitute for tap water. Tap water may be used from any municipal or industrial water treatment system.
3. If solvents are utilized in decontamination they raise health and safety, and waste disposal concerns.
4. Damage can be incurred by solvent washing of complex and sophisticated sampling equipment.

STANDARD OPERATING PROCEDURE NO. 6.1
DOCUMENTATION AND REPORTING

1.0 METHOD SUMMARY

This SOP provides requirements for documenting and reporting site activities. The objective of the documentation program is to accurately and completely describe all field activities, thereby demonstrating that all field activities are conducted in accordance with the project specific Field Sampling Plan or Field Work Plan and applicable Superfund Program Standard Operating Procedures (SOPs).

2.0 EQUIPMENT/APPARATUS/REAGENTS

Equipment typically required for documenting the progress of the project includes:

- Field logbook (bound, pre-paginated, all weather or water resistant)
- Field forms
- Camera
- Video recorder (if necessary)
- Permanent marking pens
- Ink pens (with permanent waterproof, black ink)

The field logbook shall contain the following information at a minimum:

- Location, date and time of each activity
- Weather conditions (changes)
- Activity being performed
- Identity of the person(s) performing the activity
- The numerical value and units of any field measurements
- The identity of, and the calibration results for, each field instrument being used
- All information required to demonstrate that the work is conducted in accordance with applicable Sampling Plans, Work Plans and SOPs
- visitors to the site
- deviations from planned activities.

Specific information which shall be included for each sample includes:

- Sample type and sampling method
- The identity of each sample and depth(s) from which it was collected
- The amount of each sample
- Sample description (e.g., color, odor, clarity)
- Identification of sampling devices
- Identification of conditions that might affect the representativeness of a sample (e.g., refueling operations, damaged well casings)
- All information required to demonstrate that the work is conducted in accordance with applicable Sampling Plans, Work Plans and SOPs

All information relating to installation and development of monitor wells, installation of temporary groundwater sampling points, well development, well purging, groundwater sample collection and all other sampling activities or field work shall be recorded in a field logbook or field form(s). When field forms are used the field logbook shall reference the data noted on field forms and the field forms shall be dated and signed by the author. The field logbook will be bound with consecutively numbered pages and will be suitable for submission as evidence in legal proceedings. Each entry in the field logbooks will be signed and dated by the author. All original data recorded in the field logbook and other field forms will be written using permanent, waterproof ink. Errors made in the field logbook will be corrected by the individual making the entry by crossing a single line through the error, entering the correct information, and dating and initialing the correction. The field logbooks and field forms will become part of the project file, and should be kept in the project file at all times when not in the possession of the field team.

Field corrective actions shall be documented in the field logbook and/or field forms. Field corrective action reports shall document the methods used when general field practices or procedures specified in the standard operating procedures were not followed. The field corrective action reports shall include the methods used to resolve a noncompliance.

3.0 PHOTOGRAPHS

General guidelines (all types of photos):

- If possible, use a camera that has a time and/or date stamp. Record the date and time each photo was taken on the photo or with the photo file (as applicable) and in the field logbook.
- Do not use special lenses (i.e., wide-angle lenses) as they can distort the image
- A brief, accurate description of what the photograph shows, including the name of the site and location shall be recorded in the field logbook.
- Include the name of the photographer, and witness, as applicable.

When photographs are taken the record of each frame exposed/recorded is kept in the bound field logbook along with the information above required for each photograph. The field investigator shall then enter the required information on the prints, slides or CD (if digital photos) using the photographic record from the bound field logbook, to identify each photograph.

<u>Conventional 35 mm Cameras</u>

- Obtain negatives in one continuous, uncut sheet and include with the pictures.
- Arrange photos in album format and include the above information for each photo and submit with the field logbook.

<u>Digital Cameras</u>

- Submit a CD-R of the downloaded picture files in JPEG format (include the above information for each photo) and submit with the field logbook.
- Digital camera recording mode (dependent on camera's pixel resolution quality and picture quality mode) shall be set to achieve a minimum pixel resolution of 1600 x 1200 or higher.

4.0 OTHER FIELD FORMS

Other types of records which may be used in the field include:

- Drum inventory forms
- Well development/purging records
- Boring logs
- Well construction diagrams (as-builts)

5.0 CAUTIONS AND INTERFERENCES

This section is not applicable to this SOP.

1.0 METHOD SUMMARY

The objective of this standard operating procedure (SOP) is to provide guidance for the sampling of volatile organic compounds (VOCs).

2.0 EQUIPMENT/APPARATUS/REAGENTS

Typical equipment required for groundwater and soil sampling includes:

- 40-mL glass vials with a PTFE-lined septum that can be hermetically sealed.
- 5-g samplers, or equivalent, and coring tool used as a transport device.
- Stir bar
- Bailer (stainless steel or disposable)
- Scoop or spatula
- 4-oz glass sample jars
- Portable balance - For field use, capable of weighing to 0.01 gram.

3.0 PROCEDURES

3.1 Water Sample Collection

The following procedures shall be followed for the collection of groundwater VOC samples. The sample volume shall be dictated in the Field Sampling Plan:

1. The 40-mL glass sample vials must be pre-cleaned and/or be certified free of VOCs.
2. Wells shall be purged in accordance with one of the following SOPs: SOP 7.2 (Monitor Well Purging with a Bailer), SOP 7.3 (Monitor Well Purging with a Pump), or SOP 7.3 (Monitor Well Micro Purging).
3. Label sample vials in accordance with SOP 6.5 (Sample Handling and Control).
4. Carefully fill a 40-mL vial with a slow, steady stream of water down the side of the vial to minimize aeration of the sample.
5. Fill the vial with water to the top so that a meniscus is formed. Allow any air bubbles to rise to the surface. Carefully and quickly screw the cap onto the container and finger tighten.
6. Invert the vial and tap it gently, looking for any air bubbles. If the sample contains air bubbles, discard the sample and repeat the sampling process with a new sampling container.
7. Refer to the site-specific field sampling plan for the site-specific sample volume. The typical sample volume for a regular water sample is three 40-mL vials. Six additional 40-mL vials are typically needed for the sample identified as the matrix spike/matrix spike duplicate (MS/MSD).
8. Preserve to a pH of 2 with HCl and cool to 4°C (±2°C) immediately after collection. DO NOT FREEZE water samples. Samples collected for determining concentrations of highly reactive VOCs, (e.g., vinyl chloride, styrene, 2-chlorovinylether, or acrylamide) will not be acid preserved and must be analyzed within seven days.
9. Package sample for shipment in accordance with SOP 6.5
10. During sample shipment, all conditions relating to the isolation/segregation of the samples from potential contaminants (gasoline/diesel engines or generators, highly contaminated samples, etc.) must be observed.

11. Decontaminate all non-disposable sampling equipment prior to moving to new sampling point and in accordance with SOP 1.5
12. Groundwater and surface water samples for VOC analysis that are not acid preserved will be cooled in the field for transport and storage and analyzed within seven days of collection.

3.2 Soil Sample Collection

This section is based on the TCEQ Guidance on SW846-5035 and provides guidance for the implementation of Method 5035. The intent of Method 5035 is to collect the sample causing the least amount of disturbance to the soil structure and to transfer and hermetically seal the sample in a sample container as quickly as possible.

The recommended method of sample collection for both low and high concentration soils is the closed-system field collection using hermetically sealed 40-mL vials or hermetically sealed intermediate sample containers. Refer to the site-specific field sampling plan for the sample mass and equipment needed. The typical sample equipment needed for a regular soil sample is three 40-mL vials with each to hold 5-grams of soil. Six 40-mL vials are typically needed for the sample identified as the matrix spike/matrix spike duplicate (MS/MSD).

Bulk sampling can be used for sample points where contamination is expected to be high or where the procedure requires a sample volume that exceeds the recommended 5 grams, such as TCLP determination, or where a sample using Method 5035 procedures cannot be collected. Method 5035 includes a procedure for preparing low concentration samples, i.e., soil samples that can reasonably be expected to contain concentrations of VOCs between 5 mg/kg and 200 mg/kg, and a second procedure for high concentration samples, i.e., soil samples that are expected to contain greater than 200 mg/kg of VOCs.

It is recommended that screening of samples, both in the field using an appropriate field instrument and in the laboratory using a gas chromatography screening method, be conducted prior to selecting the Method 5035 option. The appropriate analytical methodology shall be dictated in the Field Sampling Plan.

3.2.1 <u>Field procedures</u>

This recommended sample collection technique does not require preservative.

1. The 40-mL amber glass sample vials must be pre-cleaned and/or be certified free of VOCs.
2. Sample vials should be prepared in a fixed laboratory or other controlled environment. The tare weight of the sample vial including cap, septum, and label must be determined and recorded on the label prior to shipping the vials to the field for sample collection. Clean gloves should be worn when handling tared vials.
3. Exposure to air must be minimized by obtaining the sample directly from the source media using a coring device or a commercially designed sampling device and by transferring the sample as quickly as possible to a vial (or sealing the sample borer/hermetically sealed sample container immediately). The vial should be quickly wiped free of any particulate matter that would compromise the integrity of the vial seal. Fingers should be used to minimize exposure to air by forming a temporary seal between the vial and the sampling device. The coring/sampling device must be designed to fit tightly against the mouth of the vial or be small enough to be inserted into the vial. The vial must be hermetically sealed immediately after placing the sample in the vial.

4. The coring device can be used to collect multiple aliquots from the same sample point provided the integrity of the coring device is not compromised. If the coring device is designed and approved to be used as a temporary storage device for transport to the laboratory, the manufacturer's instructions should be followed. If a bulk sample is being collected because the concentrations in the soil are considered high, a 4-oz sample jar should be filled to capacity to minimize the head space in the sample container.
5. Refer to the site-specific field sampling plan for the site-specific sample mass needed. The typical sample size collected should be three aliquots, approximately 5 grams (10 grams for TPH analysis by TCEQ 1005 and 1006) each. Typically, six aliquots are collected at each sample point for matrix spike/matrix spike duplicate (MS/MSD) sampling. The coring device should be calibrated to the required sample size and designed to minimize the disturbance of the sample during collection. Several calibrated coring devices are available commercially. When practical, use a portable balance to weigh the sealed vial containing the sample to ensure that 5.0 ± 0.5 grams of sample were added. For non-cohesive soils and waste (e.g., dry sand, fly ash, etc.), highly cohesive materials (e.g., concrete, rock, etc), and soils that have high compressive and shear strength, the sample should be quickly transferred into a 4-oz jar using a scoop or spatula. Enough sample should be collected such that the head space in the jar is minimized.
6. A bulk sample with no preservative should be collected to use for screening purposes in the laboratory, but not for quantitative analysis. After the sample is screened in the laboratory, the sample can be used to determine the percent moisture, to run the MS/MSD, to check reactivity with sodium bisulfate, and/or to determine the appropriate extraction solvent, as necessary.
7. For the samples with high concentrations of VOCs, the sample is extracted with methanol and the extract is used for dilutions and/or re-analysis. Therefore, only two aliquots are recommended, one aliquot for analysis and one aliquot for re-analysis, if necessary. If the VOC concentration is unknown, collect three aliquots.
8. Sample containers remain unopened from the time of collection until analysis.
9. The use of a balance in the field is required to check the tare weight when field preservation with methanol is being conducted. For other sample collection procedures, balances are used to verify that an adequate volume (weight) of soil is collected, because the initial soil sample size will affect the quantitation limit that can be achieved on the sample.
10. All samples must be properly packaged (SOP 6.4) and chilled to 4°C (±2°C) immediately upon collection.
11. During sample shipment, all conditions relating to the isolation/segregation of the samples from potential contaminants (gasoline/diesel engines or generators, highly contaminated samples, etc.) must be observed.
12. Decontaminate all non-disposable sampling equipment prior to moving to another well and/or at the end of the day.

3.2.2 <u>Quality Control</u>

The laboratory quality control measures specified throughout Method 5035 must be followed. Field quality control measures should include a trip blank in every sample shuttle that contains samples for volatile analysis regardless of the sample collection technique.

4.0 CAUTIONS AND INTERFERENCES

4.1 Groundwater Sample Collection

Make sure that there are no air bubbles in the sample bottle. Be careful not to agitate the sample. The sample bottle should be quickly sealed, chilled to 4°C (±2°C), and shipped to the laboratory.

4.2 Soil Sample Collection

The recommended method of sample collection for both low and high concentration soils is to collect the sample using a coring device and to quickly extrude the sample core into a tared 40-mL vial that does not contain preservative but does contain the stir bar, if applicable. The threads of the vial are inspected and wiped clean, and the vial is quickly sealed and chilled, held at 4°C (±2°C), and shipped to the laboratory. The laboratory should analyze the sample within 48 hours from the time of collection. Alternatively, the laboratory can preserve the sample within the 48 hour time frame to extend the holding time to 14 days. The manual addition of any water, surrogates, and/or internal standards, and all additions of preservatives should be made using a 22-gauge or thinner needle through the septum seal. This collection procedure does not require the use of preservatives in the field or balances in the field. An alternative method is the collection of the sample using an approved coring device that serves as an intermediate hermetically sealed sample container. This type of sampling device should be used according to the manufacturer's instructions.

STANDARD OPERATING PROCEDURE NO. 6.4
SAMPLE HANDLING AND CONTROL

1.0 METHOD SUMMARY

This SOP presents procedures for maintaining control of environmental samples following collection through shipment to the analytical laboratory. In addition, this SOP describes standard chain-of-custody protocols which should be followed to document the possession of samples from the time of collection until the laboratory report is submitted.

2.0 EQUIPMENT/APPARATUS/REAGENTS

Equipment needed for use in this SOP includes:

- Pre-cleaned sample containers
- Preservatives (if not in containers)
- Sturdy cooler, in good repair
- Fiberglass strapping tape
- Duct tape
- Clear tape
- Bubble wrap or other packing material
- Ziploc-type bags
- Trash bags
- Ice
- Shipping labels
- Pens, markers, etc.

3.0 PROCEDURES

3.1 Sample Packaging

Environmental samples should be packed prior to shipment using the following procedures:

1. Allow sufficient headspace (approximately 10 percent of the volume of the container) in all bottles (except volatile organic analysis (VOA) vials with a septum seal) to compensate for any pressure and temperature changes which may occur during shipment.
2. Ensure that the lids on all bottles are tight.
3. Select a sturdy cooler in good repair. Secure and tape the drain plug with fiberglass strapping tape or duct tape. Line the cooler with a heavy duty plastic garbage bag.
4. Place glass sample bottles into bubble wrap bags or wrap a layer of bubble wrap around glass containers. Many laboratories provide bubble wrap bags for sample shipment. Place two to three VOA vials in a single bag.
5. Place the bottles in the cooler with larger bottles on the bottom inside the garbage bag. Insert polyethylene bottles between glass bottles for cushion. Put VOA vials (in bubble wrap bags) on their side on top of the larger sample containers.
6. Ensure that a trip blank has been included as appropriate for VOA samples and that a temperature blank (if supplied) is included as outlined in SOP No. 6.3, and SOP No. 6.5.
7. Place ice that has been Adouble bagged@ on top of and/or between the samples. Fill remaining void space in the cooler with bubble wrap. Ensure that a sufficient quantity of ice has been placed into the cooler to maintain VOC samples at 4°C. In summer months, it may be necessary to fill as much as 50 percent of the cooler volume with ice to properly cool warm samples.
8. Securely fasten the top of the garbage bag with tape.

9. Place the Chain-of-Custody record into a Ziploc-type bag and tape the bag to the inside of the cooler lid.

10. Close the cooler and securely tape (preferably with fiberglass strapping tape) the top of the cooler shut. Chain-of-custody seals (preferably two) should be affixed to the cooler with clear tape so that the cooler can not be opened without breaking the seals.

11. Place the shipping label in a sealed pouch on the lid of the cooler for shipment. A label containing the name and address of the shipper and the destination should be placed on the outside of each additional cooler included in the shipment.

3.2 Sample Shipping

Samples collected in the field shall be transported to the laboratory or field testing site as expeditiously as possible (within 24 hours of sampling) to avoid hold time exceedances and to ensure that samples remain properly preserved. Samples for VOC analysis must be maintained at a temperature of 4^{o}C.

In general environmental samples include drinking water, most ground water and ambient surface water, soil, sediment, treated municipal and industrial wastewater effluent, biological specimens, or any samples not expected to be contaminated with high levels of hazardous materials. Samples collected from process wastewater streams, drums, bulk storage tanks, soil, sediment, or water samples from areas suspected of being highly contaminated may require shipment as dangerous goods. Regulations for packing marking, labeling, and shipping of dangerous goods by air transport are promulgated by the International Air Transport Authority (IATA), which is equivalent to United Nations International Civil Aviation Organization (UN/ICAO). It is the responsibility of the shipper to ensure that shipments are made in accordance with all applicable laws, including contents and labeling.

3.3 Sample Chain-of-Custody

Procedures to ensure the custody and integrity of the samples should begin at the time of sampling and continue through transport, sample receipt, preparation, analysis and storage, data generation and reporting, and sample disposal. Records concerning the custody and condition of the samples are maintained in field laboratory records.

The contractor shall maintain chain-of-custody records for all field and field QC samples. A sample is defined as being within a person's custody if any of the following conditions exist:

- It is in their possession,
- It is in their view,
- It was in their possession and they secured it in a locked area, or
- It is in a designated secured area.

All sample containers shall be sealed in a manner that shall prevent or provide detection of tampering if it occurs. In no case shall tape be used to seal sample containers. Samples shall not be packaged with activated carbon unless prior approval is obtained from TCEQ.

The following minimum information concerning the sample shall be documented on the TCEQ chain-of-custody form (Attachment 1):

- Unique sample identification
- Date and time of sample collection
- Source of sample (including name, location, and sample type)

- Designation of matrix spike/matrix spike duplicate (MS/MSD)
- Preservative used
- Analyses required
- Number of sample containers
- Pertinent field data (pH, temperature, elevated headspace results or contaminant concentrations)
- Serial numbers of custody seals and transportation cases (if used)
- Name(s) of person(s) collecting the samples
- Custody transfer signatures and dates and times of sample transfer from the field to transporters and to the laboratory or laboratories
- Transporter tracking number (if applicable) or courier receipts

4.0 CAUTIONS AND INTERFERENCES

This section is not applicable to this SOP.

CHAIN OF CUSTODY RECORD

Page _____ of _____

Project Name				Project No.					Analytical Parameters										Remarks
Project Location				Project Manager															
Sampler(s)																			
Sample		Type		Sample Identification	Matrix	Containers													
Date	Time	Comp.	Grab			No.	Type												Remarks

Signatures	Date	Time	Shipping Details	Special Instructions
Relinquished by:			Method of Shipment	
Received by:			Airbill No.	
Relinquished by:			Lab Address	

Received for Laboratory by:				

STANDARD OPERATING PROCEDURE NO. 6.5
QUALITY CONTROL SAMPLES

1.0 METHOD SUMMARY

Quality control (QC) samples are collected to determine if sample bottle preparation, shipment, handling, and storage procedures result in contamination or other effects on environmental samples. QC samples include:

- Equipment Blanks.
- Trip Blanks.
- Field Blanks.
- Temperature Blanks.
- Field Duplicate Samples.
- Field Split Samples.
- Matrix Spike/Matrix Spike Duplicates (MS/MSD).

2.0 EQUIPMENT/APPARATUS/REAGENTS

The following equipment is used for collection of QC samples:

- Pre-cleaned sample containers (with preservatives, if required)
- ASTM Type II reagent grade water
- Stainless steel sampling bowl
- Stainless steel sampling spoon
- Other equipment as prescribed for collecting samples

3.0 PROCEDURES

3.1 EQUIPMENT BLANKS

Equipment blanks are used to assess the effectiveness of equipment decontamination procedures. An equipment blank (also known as a rinsate blank) is a sample of ASTM Type II reagent grade water poured into, over, or pumped through the sampling device; collected in a sample container; and transported to the laboratory for analysis. These blanks are collected immediately after the equipment has been decontaminated and are analyzed for all laboratory analyses requested for the environmental samples collected with that equipment.

FREQUENCY

Equipment blanks are not collected from disposable or dedicated (e.g., a monitoring well bailer dedicated to a single well) equipment. They are collected at a frequency of one blank per equipment type, per environmental media, per day.

PROCEDURE

Equipment blanks should be collected using the following procedures:

1. Properly decontaminate the sampling device [see SOP 1.5 (Decontamination)].
2. Select the proper sample containers and an appropriate quantity of ASTM Type II reagent grade water.
3. Complete the sample labels with the appropriate information.
4. Slowly pour the ASTM Type II reagent grade water through or over the sampling device until the sample bottle is filled to the appropriate level.
5. Securely tighten the cap on the bottle.
6. Prepare the bottle for shipment in accordance with SOP 6.4 (Sampling Handling and Control).

DATA EVALUATION

Contamination detected in the equipment blank may indicate that contamination was introduced by the sampling equipment. If the same analytes are found in the field samples, these analytes may represent contamination originating from the sampling equipment.

3.2 TRIP BLANKS

Samples can be contaminated by diffusion of volatile organic compounds (VOCs) through the septum seal into the sample during storage, shipping, and handling. Contamination may also be present in the bottles used to contain the sample or in the reagent grade water.

Trip blanks are used to assess the potential introduction of VOC contaminants to the sample during sample handling, transportation, and storage. They consist of a VOC sample vial filled in the laboratory with ASTM Type II reagent grade water, transported to the sampling site, handled like an environmental sample, and returned to the laboratory for analysis. The trip blank is shipped and stored with VOC water samples and should not be opened in the field.

FREQUENCY

Trip blanks are prepared only when VOC samples are collected and are analyzed only for VOC analytes. One trip blank should be included in each sample cooler containing samples for VOC analysis.

PROCEDURE

The procedures for submitting a trip blank are:

1. Prepare the coolers for shipment to the laboratory. If possible, pack all samples for VOC analysis in one cooler so that only one trip blank is required.
2. Identify the trip blank on the chain-of-custody record. If the project will continue for several days, be sure to number trip blanks sequentially so that multiple trip blanks with the same identification number are not submitted to the laboratory.

DATA EVALUATION

Contamination detected in the trip blank may indicate that contamination was present in the sample bottles or was introduced during sample handling. If the same analytes are found in the field samples, these analytes may represent contamination introduced during sample handling, transportation, or storage.

3.3 FIELD BLANKS

Field blanks are used to assess the potential introduction of contaminants from field sources (e.g., gasoline motors in operation) to the samples during sample collection. A field blank consists of ASTM Type II reagent grade water poured into a VOC sample vial at the sampling site (in the same vicinity as the associated samples). Field blanks must be collected downwind of possible VOC sources. The field blank is handled like an environmental sample and transported to the laboratory for analysis.

FREQUENCY

Field blanks are prepared only when VOC samples are collected and are analyzed only for VOC analytes. They are collected at a frequency of one blank per 20 VOC samples for each matrix.

PROCEDURE

The procedures for collecting field blanks are:

1. Select the proper sample containers (VOC vials) and an appropriate quantity of ASTM Type II reagent grade water.
2. Complete the sample labels with the appropriate information.
3. Pour the ASTM Type II reagent grade water into the vial just to overflowing so that there is a meniscus at the top of the vials.
4. Securely tighten the lid on the sample vials.
5. Prepare the sample for shipment in accordance with SOP 6.4 (Sampling Handling and Control).

DATA EVALUATION

Contamination detected in the field blank may indicate that VOC contamination was introduced from field sources. If the same analytes are found in the field samples, these analytes may represent contamination introduced during sample collection, transportation, or storage.

3.4 TEMPERATURE BLANKS

Temperature blanks are prepared by the analytical laboratory and included in the shipment of sample coolers and containers. They are used to determine the temperature of the environmental samples upon receipt by the laboratory.

FREQUENCY

A temperature blank will be included with each cooler sent to the laboratory with environmental samples.

PROCEDURE

Temperature blanks are typically prepared by the analytical laboratory and included in the shipment of sample coolers and containers. The temperature of temperature blank samples is measured by the laboratory upon receipt of environmental samples.

DATA EVALUATION

Excessive temperature in the blank may indicate the potential for analyte loss or degradation prior to sample analysis.

3.5 FIELD DUPLICATE SAMPLES

Field duplicate samples are collected simultaneously or in immediate succession, using identical recovery techniques, and treated in an identical manner during storage, transportation, and analysis. Locations for field duplicate samples should be designated prior to field work but should be adjusted in the field based on field observations. They are shipped "blind" to the laboratory (the nomenclature used to identify the duplicate sample does not reveal to the laboratory that the sample is part of a field duplicate pair).

3.6 FIELD SPLIT SAMPLES

Field split samples are collected by retrieving double sample volume from the environmental matrix from one location, fully homogenizing the complete volume, and from that homogenized volume collecting two separate aliquots. Each aliquot is given a unique sample number. Field split samples are intended to evaluate laboratory precision if sent "blind" to the same laboratory. Field split samples are intended to evaluate inter-laboratory precision if the samples are sent to separate laboratories and each laboratory performs the same analysis using the same standard operating procedure(s) for the preparation and analysis of the sample.

FREQUENCY

The frequency of collection of field duplicates is specified in the FSP.

PROCEDURE

The procedures for collecting field duplicates are:

1. Select the proper sample containers for collecting two samples.
2. Complete the sample labels with the appropriate information.

3. Specify the locations designated for the collection of field duplicate samples. (If possible, collect field duplicate samples in areas known to be contaminated to assess the laboratory's ability to measure contamination).
4. Collect the sample as required.
    a. Groundwater Samples
        i. Collect the sample in accordance with the appropriate sampling SOP.
        ii. Fill the first sample bottle half full with the pump or bailer then fill the second sample bottle half full. Fill the remainder of each sample bottle beginning with the first bottle. If a bailer is used, attempt to fill equal quantities from each bailer load into both bottles.
    b. Soil Samples
        i. Collect double the required volume of soil for a normal sample in accordance with the appropriate sampling SOP.
        ii. Place the soil in a stainless steel bowl and mix the sample with a stainless steel spoon. Do not mix samples for VOC analysis as the mixing process may cause a release of VOCs.
        iii. Arrange the soil into quarters within the sample bowl and set aside two of the quarters.
        iv. Mix the sample again.
        v. Fill the appropriate sample jars using the material from the bowl, placing equal portions of soil in the each bottle.
5. Securely tighten the caps on the sample bottles.
6. Prepare the sample for shipment in accordance with SOP 6.5 (Sampling Handling and Control).

DATA EVALUATION

Field duplicate sample results may be used to assess total precision, which includes the inherent spatial variability of contaminants in the field, the sample collection process, any mixing process employed, and the laboratory extraction and analysis process. The two largest components of variability (imprecision) are the inherent spatial variability of contaminants in the field and the mixing process. These two components of variability cannot be assessed separately from the other components of variability through the collection of low numbers of field duplicate samples. There are no corrective actions for the failure to achieve duplicate goals.

Field duplicate sample collection and analyses result in two equally valid analytical results (hence the term "duplicate"). Neither the "original" sample nor the "duplicate" sample is more valid than the other. Therefore, both sample results should be considered in environmental projects. As listed below, several options are available depending on the situation and the goal of the project:

1. Use both sample results;
2. Use the mean of the two sample results; or

3. Use the maximum of the two sample results.

3.6 MATRIX SPIKE/MATRIX SPIKE DUPLICATE (MS/MSD)

A matrix spike is a measured, known amount of target analyte which is added to a sample prior to extraction and analysis in order to determine the effects the sample matrix (e.g., soil, waste, or water) has on the recovery of contaminants.

Frequently the sample to be used for spiking is split into three aliquots, two of which are spiked with known concentrations of contaminants. Many laboratories can prepare the MS/MSD samples from the submitted sample volume, while others may require additional (e.g. triplicate) volume. The two spiked aliquots are known as the matrix spike (MS) and the matrix spike duplicate (MSD) sample.

The MS and MSD are spiked at a level less than or equal to the midpoint of the calibration curve for each analyte identified in the FSP. When the contaminants are not identified in the FSP, the MS/MSD are spiked with a subset of the analytes included in the laboratory's initial calibration standard mixture(s) that are representative of the range and characteristics of the calibrated analytes. All three aliquots are analyzed.

The choice of which sample to select for the MS/MSD analysis is important. If left up to the laboratory, a relatively contaminant-free sample, which is likely to provide good matrix spike recoveries, may be selected. This practice circumvents the primary purpose of the MS/MSD analysis, which is to assess matrix effects that may be associated with samples from a site. Therefore, the sample to be used for the MS/MSD should be designated by the field team from likely contaminated areas; however, source areas or sample locations with known high concentrations should not be selected for the MS/MSD analysis. Only TCEQ project samples should be used for the MS/MSD on Superfund projects.

FREQUENCY

One MS/MSD sample will be designated for every 20 environmental samples per environmental medium.

PROCEDURE

The following procedures apply to MS/MSDs:

1. Contact the laboratory to confirm the necessary volume for MS/MSD samples.
2. Plan which field locations will be appropriate to collect MS/MSD samples.
3. Collect the required volume for the designated sample(s).
4. Identify the MS/MSD and associated parent sample on the chain of custody.
5. Ship the sample with other environmental samples.
6. Confirm that the TCEQ samples were analyzed as the MS/MSD at the required frequency.

DATA EVALUATION

Percent recoveries are calculated for each of the spiked analytes to give an indication of how the matrix is affecting the reported concentrations (i.e. the direction and magnitude of any potential bias to the reported sample results). The relative percent difference (%RSD) between the MS and the MSD is calculated to assess the analytical precision of the laboratory. TCEQ does not use the MS/MSD to control the analytical process.

4.0 CAUTIONS AND INTERFERENCES

The types of QC samples and frequency for collection are outlined in the project Quality Assurance Project Plan (QAPP). It is important to identify the sample frequency in the Field Sampling Plan (FSP). QC samples should be selected to match the sampling program (i.e., it is not necessary to collect trip blanks for sites where only samples for metals analysis are being collected).

1.0 METHOD SUMMARY

This standard operating procedure (SOP) provides guidance for sample identification and documentation. The purpose of these procedures is to insure that samples are properly labeled and handled.

2.0 EQUIPMENT/APPARATUS/REAGENTS

2.1 Equipment List

- Field logbook;
- Sample labels;
- Indelible pens;
- Digital camera;
- Shipping labels and manifests;
- Chain-of-custody (C-O-C) labels and
- C-O-C documentation records.

3.0 PROCEDURES

FIELD LOGBOOK ENTRIES

All sample locations will be visually inspected, described in the field logbook, and photographed. Information regarding sample collection and all measurements and calculations performed relating to the sample location will be entered into the field logbook in accordance with Superfund SOP 6.1 (Field Activity Documentation and Reporting). At a minimum, the following information will be recorded in the field logbook in indelible ink:

- date and time of sample collection;
- environmental matrix and sample type (e.g., soil composite or groundwater grab);
- sample collection method;
- sample preservation method;
- name of the person who collected the sample;
- sample identification number
- depth and interval sampled (e.g., a three inch soil interval was collected from the three to six inches deep);
- field measurements made on the sample during collection, e.g., photoionization readings using a photoionization detector (PID);
- when low-flow technology used, the flow rate (e.g., mL/min) as the sample was collected;
- GPS file number or latitude and longitude coordinates;
- photograph number, date and time with a description of the purpose of the photograph (e.g., "This photo documents the sample collected at location X of material released to soil from the corroded and leaking drums in the drum storage area observed and documented in photos 2 & 3.");
- name of photographer and direction of the photograph (e.g., NNW, SE…);
- relevant observations such as soil color, obvious staining, and weather conditions; and
- deviations from the Superfund Quality Assurance Project Plan, Field Sampling Plan, or Superfund SOPs.

Sample Identification

A unique sample identification numbering system should be used. Samples shall be uniquely identified, labeled, and documented in the field at the time of collection. Samples should be identified with standard sample labels which are affixed to the sample containers. The following information shall be included on the sample label at the time of collection using permanent ink:

- Project number
- Field identification or sample station number
- Date and time of sample collection
- Designation of the sample as a grab or composite
- Whether the sample is preserved or unpreserved
- The types of analyses to be performed
- Any relevant comments (such as readily detectable or identifiable odor, color, or known hazardous properties)
- Signature or initials of the sampler(s)

DOCUMENTATION OF WELL DATA

Well data will be recorded for each sampled drinking water well, monitor well, or other groundwater sampling point. This information includes, but is not limited to:

- well name or number;
- address;
- owner and/or tenant;
- condition of the well, pump, filter system etc;
- total depth of well (when possible);
- water and non-aqueous phase liquid levels (when possible);
- “totalizer” readings;
- purge volumes and times;
- field parameters;
- date; and
- sampling information.

PHOTOGRAPHIC DOCUMENTATION

All sample locations will be photographed. Sample location photographs will include a sign showing date sampled and sample location number and an available landmark, such as a fencepost, tree, or other feature. The field logbook will include a table cross-referencing sample locations and photograph numbers. The photographic log will also identify and describe any salient features in the photographs.

SAMPLE BOTTLE LABELING

Sample bottles may be temporarily labeled prior to or immediately after sample collection. Sample bottles will be permanently labeled as soon as practical after collection. Sample labels will include:

- field sample ID,
- project name and number,
- sampling date and time,
- name of the sample collector,
- method of sample preservation, and
- laboratory analyses required.

FIELD SAMPLE IDs

Logical and organized sample identification number conventions will be used. Previously established sample identification number conventions for the site will be followed unless requested otherwise by the TCEQ PM. An example sample numbering system is detailed below:

- identify **source or waste material samples** using the prefix "XX" followed by a sequential number.
- identify **soil samples** using the prefix "SO" followed by a sequential number.
- identify **sediment samples** using the prefix "SE" followed by a sequential number.
- identify **surface water samples** using the prefix "SW" followed by a sequential number.
- identify **monitor well samples** using the prefix "MWxx" where "xx" refers to the monitor well number) followed by a date sequence number (e.g. 110809 for August 9th, 2011).
- identify **drinking water well samples** using the prefix "DWxx" where "xx" refers to the well number or other identifying label) followed by a date sequence number.
- identify **other groundwater samples** using the prefix "GW" followed by a date sequence number.
- identify **field duplicate samples** with a selected number. Include collection times as a random increment of time after the collection time of the first duplicate sample. The identification of duplicate samples should not include any information the laboratory could use to identify the samples as duplicates. Record duplicate pair samples along with the actual time of collection in the field logbook.
- identify **field blanks** and **equipment rinsate blanks** either as groundwater ("GW") or surface water ("SW") samples followed by a selected number. The actual identification of these samples should be recorded in the field logbook and should be associated with the prefix "GW" or "SW" according to the actual sample and time of collection.
- identify **trip blanks** using the prefix "TB" followed by a sequential number.

CHAIN-OF-CUSTODY (C-O-C) DOCUMENTATION

All sample shipments will be accompanied by the C-O-C record which identifies the contents of the shipment. The original C-O-C record plus copies will accompany the shipment with one copy retained in the project file. Another copy will be returned to the project team with the analytical results.

The samples will be relinquished to representatives of the carrier service (e.g., Federal Express, United Parcel Service) or be delivered directly to the laboratory by the CONTRACTOR. When the samples are relinquished to the carrier service, a notation to that effect will be made on the C-O-C record.

When samples are delivered directly to the laboratory, the C-O-C record will be signed by the receiving laboratory personnel.

Preformatted C-O-C records will be used as the primary documentation mechanism to ensure that information pertaining to each sample is recorded. In addition, field notebooks containing a sample log will be maintained for all samples collected. Copies of the C-O-C records and the field logs will be retained in the project file.

4.0 CAUTIONS AND INTERFERENCES

The C-O-C should be verified against the documentation in the logbook, field data sheets, and FSP to ensure that the sample identification information and requested analyses and turn-around times are correct. Any edits to the C-O-C, sample bottle labels, logbooks, or field data sheets should be made by a single strike through the incorrect information and the initials of the sampler or person having custody of the samples.

STANDARD OPERATING PROCEDURE NO. 7.5
MEASUREMENT OF FIELD PARAMETERS

1.0 METHOD SUMMARY

Field parameters are collected during surface water or groundwater sampling events to identify physical/chemical characteristics of the sample that are representative of field conditions as they exist at the time of sample collection. They are also used to indicate when stagnant water has been removed from the well so that sampling may begin. Numerous instruments are commercially available for measuring field parameters. The setup and use of all instruments should follow a basic format to imply consistency of use. Regardless of the brand of meter used, all meters should be properly maintained and operated in accordance with the manufacturer=s instructions and calibrations should be checked prior to use.

2.0 EQUIPMENT/APPARATUS/REAGENTS

The following is a typical equipment list used for measuring field parameters:

2.1 Equipment List

- Logbook
- Field data sheets
- Decontamination solutions
- Tap water
- Field parameter instruments (pH meter, thermometer, conductivity meter, turbidimeter, DO meter)
- Calibration standards
- Tap water
- Non-phosphate soap (Note: Alconox is not considered a non-phosphate soap; rather a low-phosphate soap)
- Glass bulb thermometer

3.0 PROCEDURES

3.1 Temperature

Temperature is a measure of hotness or coldness on a defined scale as measured using a thermometer. Typical types of thermometers include**:**

- Digital (thermo-couple) thermistor
- Glass bulb mercury filled
- Bi-metal strip/dial indicator

No matter which type of thermometer is used, it should be calibrated prior to use, if possible. Digital thermometers should be calibrated prior to use by comparison with a mercury bulb thermometer and should agree within ∀ 0.5 ^{o}C.

The procedures for measuring temperature are as follows:

1. Clean the probe end with analyte-free water and immerse into sample.
2. Swirl the thermometer in the sample.
3. Allow the thermometer to equilibrate with the sample.
4. Suspend the thermometer away from the sides and bottom to observe the reading.
5. Record the reading in the field log book or on the appropriate sampling log sheet. Units of temperature are degrees Celsius (^{o}C) and should be recorded to the nearest tenth (0.1).

Conversion Formulas:

$^{o}F = (1.8\ ^{o}C) + 32^{o}$ or $^{o}C = 0.56\ (^{o}F - 32^{o})$

3.2 pH

Hydrogen ion concentration (pH) is used to express both acidity and alkalinity on a scale which ranges from 0 to 14 with 7 representing neutrality.

The procedures for measuring pH in the field are as follows:

1. Calibrate the instrument in accordance with the manufacturer=s specifications.
2. Collect a sample. Measure the temperature prior to measuring the pH.
3. Immerse the probe in the sample, keeping it away from the sides and bottom of the sample container. Allow ample time for the probe to equilibrate with the sample.
4. While suspending the probe away from the sides and bottom of the sample container, record the pH. Units of pH are standard units and should be recorded in tenths (0.1).
5. Rinse the probe with analyte-free water and store it in an analyte-free water filled container until the next sample is ready.
6. Perform a post calibration at the end of the day and record all findings.

3.3 Conductivity

Conductivity is defined as the quality or power of conducting or transmitting. The procedures for measuring conductivity in the field are as follows:

1. Calibrate the instrument in accordance with the manufacturer=s specifications.
2. Collect the sample and check and record its temperature.
3. Correct the conductivity instruments temperature adjustment to the temperature of the sample (if required).
4. Immerse the probe in the sample keeping it away from the sides and bottom of the container. It is important that the entire portion of the probe be wetted by the sample. This will be evident when some of the sample water is seen coming out of the small weep hole.
5. Record the result in the field log book or field sampling sheet. Units of conductivity are micro ohms per centimeter (µohms/cm) at 25°C. Results should be reported to the nearest 10 units for readings below 1,000 Φohms/cm and to the nearest 100 units for readings above 1,000 Φohms/cm.
6. Rinse probe.

3.4 Dissolved Oxygen

Dissolved oxygen (DO) should be measured in-situ or Adown hole@ whenever possible. If in-situ measurements are not possible, precautions should be taken to minimize the time the sample is exposed to ambient air. Dissolved oxygen readings should not exceed the saturation limit of oxygen in water (8 to 10 mg/l). If readings greater than 10mg/l are observed, the meter is probably not functioning correctly. The procedures for collecting a DO sample are as follows:

1. Inspect the membrane of the DO meter for air bubbles and/or holes. If air bubbles or holes exist, replace the membrane.
2. Calibrate the DO meter in accordance with the manufacturer=s specifications.

3. Measure the temperature of the sample and adjust the temperature setting of the DO meter, if so equipped.

4. Record the reading in the field log book or field sampling sheet. Dissolved oxygen is measured in units of mg/l. Results should be reported to the nearest tenth of a unit (0.1).

3.5 Turbidity

Turbidity is measured using a nephelometer/turbidimeter. The procedures for measuring turbidity are as follows:

1. Rinse the sample cell with analyte-free water.

2. Follow the manufacturer=s specifications for collecting a turbidity measurement.

3. Record the reading in the field log book or field sampling sheet. The units of turbidity are nephelometric turbidity units or NTUs. Units should be recorded to the nearest whole unit.

4.0 CAUTIONS AND INTERFERENCES

Refer to owner=s manual for instructions on proper calibration methods of all field parameter measuring equipment.

STANDARD OPERATING PROCEDURE NO. 7.8
GROUNDWATER SAMPLING USING A LOW-FLOW TECHNIQUES

1.0 METHOD SUMMARY

Most hazardous waste site investigations utilize some form of a groundwater sampling or monitoring program to fully characterize the nature and extent of groundwater contamination. In order to obtain a representative groundwater sample for chemical analysis it is important to remove stagnant water in the borehole or pump tubing before collection of the sample. This may be achieved using a variety of instruments including pumps and bailers. Once purging is completed and the correct laboratory-cleaned sample containers have been prepared, sampling may proceed. Sampling may be conducted with any of the above instruments, and need not be the same as the device used for purging. During sampling, a field data sheet should be completed, a chain of custody form prepared, and all pertinent data recorded in the site logbook. This SOP describes the procedures for sampling a monitoring well using low-flow techniques. Low-flow methods are typically used in conjunction with micropurging (See SOP 7.4).

2.0 EQUIPMENT/APPARATUS/REAGENTS

The following is a typical equipment list used for sampling groundwater monitoring wells using a pump.

- Field data sheets and sample jar labels
- Chain-of-custody forms/Custody seals
- Sample containers
- Knife or scissors
- 5-gallon buckets
- Plastic sheeting
- Shipping containers
- Packing materials
- Ziploc-type plastic bags
- Field parameter instruments (pH meter, thermometer, conductivity meter, turbidimeter, DO meter)
- Calibration standards
- Non-phosphate soap (Note: Alconox is not considered a non-phosphate soap; rather a low-phosphate soap)
- Generator, if using pump
- Air compressor for bladder pumps
- Pump
- Gasoline for generator
- Discharge tubing for pump
- Control box (if necessary)
- Appropriate pump fittings (e.g., hose clamps, barbed fittings, etc.)
- Appropriate PPE

3.0 PROCEDURES

This section outlines the procedures for collecting representative groundwater samples using the following steps: Each step in the procedure is covered in a separate SOP. The reference SOP is in parenthesis.

Low-flow sampling procedures should be used whenever pumps are used for groundwater sampling. These procedures should be used in conjunction with micropurging techniques.

1. Prepare for sampling using: SOP 6.1 (Documentation), 6.3 (Collection of VOCs), 6.4 (Sample Handling and Control), and 6.5 (Collection of QC Samples).
2. Water level/sediment measurements will be taken in accordance with SOP 7.1 (Water Level Measurement)

3. Measurement of field parameters will be done in accordance with SOP 7.5 (Measurements of Monitoring Well Field Parameters).
4. Purging will be done in accordance with SOP 7.4 (Micro Purging).
5. Allow well to recharge after purging to 90% of the static water level.
6. Disconnect flow-through cells.
7. Assemble and label the appropriate bottles.
8. Set the pump height so that the intake is near the center of the screened interval.
9. Adjust the flow rate of the pump to minimize aeration and bubble formation. A flow rate of <0.5 L/min is typically appropriate. The pump discharge should produce a thin, continuous stream of water when filling the sample container.
10. Begin using the pump to fill the appropriate container. Samples should be collected in the following order:
    - Volatile organic compounds (VOCs)
    - Semi-volatile organic compounds (SVOCs); including polyaromatic hydrocarbons (PAHs)
    - Inorganic constituents (metals)
    - Mercury
    - Cyanide
    - Total organic carbon (TOC)
    - Total organic halogen (TOX)
    - Samples requiring field filtration
    - Samples for field parameter measurement
    - Samples for nutrient anion determinations
11. Filter and preserve samples as required by sampling plan.
12. Cap the sample container tightly and place pre-labeled sample container in a pre-chilled cooler.
13. Replace the well cap.
14. Log all samples in the site logbook and on the chain-of-custody form and label all samples in accordance with SOP 6.1 (Documentation).
15. Package samples and complete necessary paperwork in accordance with SOP 6.4 (Sample Handling and Control).
16. Transport sample to decontamination zone for preparation for transport to analytical laboratory.

4.0 CAUTIONS AND INTERFERENCES

Before sampling, monitoring wells shall be allowed to stabilize for a minimum period of 24 hours after development.

The primary goal in performing groundwater sampling is to obtain a representative sample of the groundwater body. Analysis can be compromised by field personnel in two primary ways: (1) taking an unrepresentative sample, or (2) by incorrect handling of the sample. There are numerous ways of introducing foreign contaminants into a sample, and these must be avoided by following strict sampling procedures and utilizing trained field personnel. While laboratory methods have become extremely sensitive, well controlled and quality assured, they cannot compensate for a poorly collected sample. The collection of a sample should be as sensitive, highly developed and quality assured as the analytical procedures.

Sample withdrawal methods require the use of pumps, compressed air, bailers, and samplers. Ideally, sample withdrawal equipment should be completely inert, economical to manufacture, easily cleaned, sterilized, reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for sample collection. Wells should be sampled as soon as possible after purging (certainly no more than 24 hours) and should be sampled in order from least contaminated to most contaminated or from upgradient to downgradient if chemistry is unknown. Water levels shall be allowed to recover to 90% of the static water level before sampling. All non-dedicated equipment shall be decontaminated in accordance with SOP 1.5 (Decontamination) prior to use or upon completion of the sampling activities.

TCEQ

STANDARD OPERATING PROCEDURE NO. 7.9
PURGING A DRINKING WATER WELL

Alan Batcheller, Director
Remediation Division

12/18/07
Date

1.0 METHOD SUMMARY

This standard operating procedure (SOP) is applicable to drinking water wells with a sealed wellhead. Purging is the process of removing water from the well bore which may not be representative of aquifer conditions. Purging a well is performed immediately prior to sampling, causing the replacement of water in the well bore with groundwater from the adjacent formation. This procedure allows for the collection of a representative sample(s) from the water bearing unit(s).

Drinking water wells typically have a sealed wellhead which prevents the use of a water level indicator. Without knowing the total depth of the well, the volume of water in the well cannot be calculated. However, if water level data and well construction records are available, the volume of water in the well bore can be used to estimate a purge volume in accordance with SOP 7.3 (Purging a Monitoring Well with a Pump). To ensure that an adequate volume of water is removed from the well to allow for the collection of a representative sample, the well is generally purged until consistent readings of field parameters are obtained. During purging, a field data sheet shall be completed, and pertinent information and observations shall be entered into the site logbook. Once purging is completed and field parameter values have stabilized, sampling may proceed.

1.1 ASSOCIATED SOPS

SOP 1.4 (Management of Investigative Derived Waste)
SOP 7.3 (Purging a Monitor Well with a Pump)
SOP 7.5 (Measurement of Field Parameters)
SOP 7.10 (Sampling a Drinking Water Well)

2.0 EQUIPMENT/APPARATUS/REAGENTS

The following is a list of equipment typically used for purging a drinking water well.

- Site logbook
- Field data sheets
- Calculator

- Flow-Through Cell (and probes)
- Flow-Through Cell Apparatus (discharge tubing or hose, hose clamps, "Y" adaptor(s))
- Field parameter instruments: pH meter, thermometer, conductivity meter, turbidimeter, DO meter (Individual meters optional/Used in lieu of Flow-Through Cell and probes)
- Calibration standards
- 5-gallon buckets
- Drums
- Marking pen for labeling drums
- Wrench for opening/sealing drums
- Garden hose, minimum length 25 feet
- Appropriate PPE
- Camera (Optional)

3.0 PROCEDURES

1. Identify applicable components of the drinking water system between the wellhead and the point to be sampled. Observe the location(s) of exterior faucets, piping, pressure tank(s), water softener, filtration system, or multiple wells that may be connected/plumbed. Record in the site logbook a sketch of the system from the wellhead to the point the system enters the structure. If one or more points inside the structure are to be purged and sampled, extend the sketch to the point(s) sampled.

2. Locate the tap or faucet which is at, or nearest, to the wellhead (i.e., optimally prior to a water softener and/or filtration system) for purging and subsequent sample collection.

3. Record in the site logbook the location of the tap or faucet to be used for purging and sampling.

4. Calibrate the field parameter instruments in accordance with SOP 7.5 (Measurement of Field Parameters), or in accordance with manufacturer's specifications.

5. If the purge water is to be discharged onto the ground directly from the tap or faucet, determine if the purging will cause water to pool near the wellhead. If unsafe working conditions or damage to property could be caused by the purge water, attach one end of a garden hose to the faucet. Then, position the other end of the hose so that the purge water will safely drain away from the work area.

6. If the purge water is to be discharged into a 5-gallon bucket or drum, attach one end of the garden hose to the faucet. Then, position the other end of the hose so that the purge water will flow into the bucket or drum.

7. Open the tap or faucet so that the water flows at a high rate. Record the time that the purging begins in the field data sheet and the site logbook.

8. After the water has flowed for at least 15 minutes (or when the calculated purge volume has been achieved), collect measurements of pH, conductivity and temperature. Measurements of dissolved oxygen (DO), turbidity, oxidation reduction potential (ORP), or other parameters may be collected based on the approved site Field Sampling Plan or site-specific criteria. Collect all measurements in accordance with SOP 7.5 (Measurement of Field Parameters). Record the measurement collection time in the field data sheet and the site logbook.

9. While the water continues to flow, record field parameter measurements at intervals of no less than 5 minutes. Continue this procedure until three (3) consecutive measurements are consistent within the following specific tolerance limits:

pH	+/-0.5	(required)
conductivity	+/-10%	(required)
temperature	+/-0.5°C	(required)
dissolved oxygen	+/- 0.3 mg/L	
turbidity	+/-10% (> 10NTU)	
ORP	+/-10mV	

If field parameters have not stabilized after 3 successive readings (or, when the calculated well volume has been achieved), continue taking measurements at 3 minute intervals up to a maximum of 5 successive readings. If, after 5 successive readings, the parameters have not stabilized, an entry shall be made in the field logbook indicating that sampling will be conducted even though the field parameters are outside the specified tolerance limits.

10. Reduce the flow of water to disconnect the hose prior to sampling. Do not shut off the flow while disconnecting the hose.

11. Collect samples as described in SOP 7.10 (Sampling a Drinking Water Well) or in accordance with the approved site Field Sampling Plan.

12. ~~Shut off the water.~~

13. If purge waters have been collected for disposal, store and dispose of the purge waters in accordance with SOP 1.4 (Management of Investigative Derived Waste).

4.0 CAUTIONS AND INTERFERENCES

The primary goal in performing groundwater sampling is to obtain a representative sample of the water bearing unit. Samples collected for analysis can be compromised in the field by: (1) taking an unrepresentative sample, (2) handling the sample incorrectly, and/or (3) introducing foreign contaminants into the sample. Sample integrity can be optimized by following appropriate sampling protocol(s) and utilizing trained field personnel.

This purging procedure is intended for wells with a sealed wellhead. Do not open sealed wellheads.

TCEQ

STANDARD OPERATING PROCEDURE NO. 7.10
SAMPLING A DRINKING WATER WELL

Alan Batcheller, Director
Remediation Division

12/13/07
Date

1.0 METHOD SUMMARY

The objective of this standard operating procedure (SOP) is to provide guidance for the sampling of a drinking water well. Drinking water wells are sampled to determine the potential risk to human health and/or characterize the nature and extent of groundwater contamination. Drinking water wells typically have a sealed wellhead which prevents sampling directly at the wellhead. To collect a representative sample from the water well, use the tap or faucet located at, or nearest, to the wellhead. Using the tap or faucet, purge the well in accordance with SOP 7.9 (Purging a Drinking Water Well). Once the well is purged, collect the groundwater sample using a clean sample container which is appropriate for the intended analysis. During the sampling event, complete a field data sheet, and enter pertinent information and observations into the site logbook.

1.1 ASSOCIATED SOPS

SOP 6.1 (Field Activity Documentation and Reporting)
SOP 6.3 (Collection of VOC Samples)
SOP 6.4 (Sample Handling and Control)
SOP 6.5 (Collection of QA/QC Samples)
SOP 7.7 (Groundwater Sampling Using a Pump)
SOP 7.9 (Purging a Drinking Water Well)

2.0 EQUIPMENT/APPARATUS/REAGENTS

The following is a list of equipment typically used for sampling a drinking water well.

- Site logbook
- Field data sheet
- Chain of custody forms
- Custody seals
- Sample containers/ cooler
- Sample preservatives (if sample aliquots are not pre-preserved)
- Sample container labels
- Shipping containers

- Ice
- Ziploc-type plastic bags
- Packing material
- Appropriate PPE
- Disposable gloves
- Camera (optional)

3.0 PROCEDURES

1. Refer to SOPs 6.1 (Field Activity Documentation and Reporting), 6.3 (Collection of VOC Samples), 6.4 (Sample Handling and Control), 6.5 (Collection of QA/QC Samples), the approved site Field Sampling Plan, and the project Quality Assurance Project Plan (QAPP).

2. Purge the well in accordance with SOP 7.9 (Purging a Drinking Water Well).

3. Label the appropriate sample aliquots in accordance with SOP 6.4 (Sample Handling and Control).

4. Reduce the flow of water to prevent the formation of air bubbles in the sample container during sample collection.

5. Sample aliquots should be collected in the following order (as applicable):

    - Volatile organic compounds (VOCs)
    - Semivolatile organic compounds (SVOCs); including polyaromatic hydrocarbons (PAHs)
    - Inorganic constituents (metals)
    - Inorganic constituents (water quality parameters; cations/anions)
    - Mercury
    - Cyanide
    - Total organic carbon (TOC)
    - Samples requiring field filtration
    - Samples for field parameter measurement
    - Samples for nutrient anion determinations

6. Filter (if applicable) and preserve samples in accordance with the approved site Field Sampling Plan. Do not preserve samples if the sample containers were preserved by the laboratory.

7. Fill the appropriate sample aliquots. For VOC samples, the sample aliquots should be filled to the top of the container so a meniscus is formed (SOP 6.3 Collection of VOC Samples). Avoid contact between the sample container and the faucet.

8. Carefully and quickly screw the cap onto the sample container and finger tighten.

9. Collect the appropriate QA/QC samples in accordance with SOP 6.5 (Collection of QA/QC Samples), or as required by the approved site Field Sampling Plan.

10. Complete the sample label information in accordance with SOP 6.4 (Sample Handling and Control) and place the labeled sample aliquots in a pre-chilled cooler.

11. Shut off the water.

12. Document the sample collection in accordance with SOP 6.1 (Field Activity Documentation and Reporting).

13. Complete the chain-of-custody form in accordance with SOP 6.4 (Sample Handling and Control).

14. Package all samples and paperwork in a shipping container in accordance with SOP 6.4 (Sample Handling and Control).

15. Transport or ship the sample container(s) to the analytical laboratory.

16. Restore the site following the applicable portions of SOP 1.3 (Site Restoration).

4.0 CAUTIONS AND INTERFERENCES

The primary goal in performing groundwater sampling is to obtain a representative sample of the water bearing unit. Samples collected for analysis can be compromised in the field by: (1) taking an unrepresentative sample, (2) handling the sample incorrectly, and/or (3) introducing foreign contaminants into the sample. Sample integrity can be optimized by following appropriate sampling protocol(s) and utilizing trained field personnel.

Wells should be sampled as soon as possible after purging and should be sampled in order from least contaminated to most contaminated or from upgradient to downgradient if the chemistry is unknown.

1.0 METHOD SUMMARY

TCEQ requires the use of Global Positional System (GPS) in conjunction with other technologies to collect and maintain positional data that provides physical and environmental site information about plume and contaminate changes over time. Also GPS technologies are used to provide the boundaries of buildings, real property, waste areas, locations of wells and other relevant site features.

2.0 GPS CERTIFICATION

To ensure that TCEQ receives reliable and accurate positional data, TCEQ OPP 8.12 requires that the GPS data collector must be certified. The TCEQ staff may obtain GPS certification by attending a training course presented by either an internal GPS trainer or by a manufacturer-certified GPS trainer. Non-TCEQ staff may obtain GPS certification from a manufacturer-certified GPS trainer. All GPS data collectors must verify that the certification instruction they have received meets the minimum elements listed in Table 1 - GPS Certified Training Minimum Elements in the Third Party GPS Training Certification section of this SOP.

3.0 EQUIPMENT/APPARATUS

- A DGPS (Differential Global Positioning System) receiver can be either a stand alone unit, or a GPS module with Differential GPS antenna and relevant satellite subscription, plugged into a portable computer. The_DGPS receiver must:
- Have six channel parallel reception or better.
- Have sub-meter horizontal accuracy.
- Employ these processing parameters:

    - Position acquisition rate - 1/second or better
    - Position mode - 3D (uses 4 satellites)
    - Maximum PDOP - 6(or less)
    - Minimum Elevation - User-Selectable (record elevation accuracy)

- Have the ability to perform real-time differential correction (no post processing).
- Receive correction data from a recognized, reliable source, and which is appropriate for real-time correction in the geographic area in which the GPS measurements will be made.
- Output correction data in RTCM-SC104 (Radio Technical Commission of Maritime Service - Special Committee Paper No.104) format via an RS-232 cable_or other compatible connection which matches the DGPS receiver.
- Have ability to store at least 180 position measurements.
- Have ability to transfer almanac and position data to a personal computer via a serial port or USB connection.
- Include software to perform mission planning, differential correction, point data averaging, and conversion to common formats (Grid or ArcView).
- Have a water and shock resistant case.
- Include portable power source(s) which will last a full working day.

- All weather proof Field Log Book.
- A laser rangefinder (optional)

4.0 GPS DATA COLLECTION AND ACCURACY

Horizontal Accuracy - All horizontal positions collected using certified GPS units shall maintain sub-meter accuracy. In order to meet sub-meter accuracy, latitude and longitude coordinates should be carried out to at least 6 places for decimal degree and at least 2 place for decimal seconds.

DGPS - Differential Global Positioning System (DGPS) receiver which corrects the atmospheric effects. DGPS are used for realtime GPS mapping and tracking without the need for post-processing.

PDOP - Positional Dilution of Precision. A measure of the quality of a GPS measurement taken from a given set of four satellites at a given time. If the satellites are not widely distributed from the user=s location, the PDOP value will be higher, and the quality of the measurement will be diminished. PDOP values greater than 6 are not acceptable.

Datum - A mathematical model used by cartographers to define the shape of the earth in a specific area. Always use North America Datum of 1983 (NAD 83).

Differential Correction - A process applied to raw GPS data that removes certain types of errors; primarily, the error introduced by Selective Availability. This process requires correction data from a reference GPS receiver operating from a precisely known location. Correction data must be obtained from a recognized, reliable source (such as the reference network maintained by the Texas Department of Transportation) or Racal LandStar, and certain Trimble units, provide a satellite delivered GPS correction service, which provide 24 hour accurate and reliable real time precise positioning on land and in the air. For full coverage in Texas, the differential signal is transmitted to the user by high-power geostationary satellites. The GPS and differential signal are both received by the GPS via a single antenna.

A single position reading obtained through appropriate use of real-time correction must have sub-meter accuracy.

Collection Methods - GPS data may be collected using one of three methods:

- Superimposed - The superimposed method involves standing on top of or next to the subject for which you are collecting GPS locational data. Collect 60-100 readings.
- Centroid - The centroid method is used when the superimposed method cannot be used (e.g. well inside a locked fence or structure). Take points equal distance from the desired point by starting and stopping the GPS and by averaging these points. The unit will average the point for each reading and then all the points as one point which will be the center of all the readings. Collect a minimum of 30 readings per point prior to averaging.

- Offset - The offset method is used when the superimposed method cannot be used and only when accurate offset measurements can be made (e.g. Using a laser rangefinder, tape measure, etc.) The potential error associated with the offset measurement must be added to the potential error associated with the GPS measurement. A note in the GPS logging software and the field log book of bearing and distance from the offset location can be used but location must be corrected before it is entered into a table or shape file.
- Points - The point is used for well and sample locations, gates, sub-meter objects, etc.
- Line - The line is used for trail, road, stream, berm, etc.
- Polygon - The polygon is used for buildings, site boundary, waste area, ponds or piles, etc. If it is hard to walk the entire perimeter, readings can be taken at each corner of the polygon by starting and stopping the GPS at the corners and within the same Station. The program will add the line in between the points of the Station to create a polygon.

5.0 DATA SUBMITTALS

Correction Status - All GPS data submitted must have a field indicating each record=s differential correction status. There are only two selections available:

- Differential Correction - Indicates that the record has been differentially corrected.
- Uncorrected - Indicates that the record has not been differentially corrected.

Offset - The offset points must be noted in the field log book and actual points calculated before entering the station into the final database or shape file.

Events - Each event must be in separate data table or shape file.

Data Sets - Each data set must be in separate file or layer (e.g All wells, buildings, site boundaries, sample results/event, site features, roads, trails, utilities, etc. must be in separate layers/tables). Arc View files - All data must be in Decimal Degrees, NAD 83 exported to Arc View 3.2 as a shape files with the relevant metadata, a hard copy of the Arc View tables must accompany the electronic version for TCEQ submittal.

Field Log Book - Site name location and details of field activity must be noted in the field log book, including the name and coordinates of each station and bearing and distance details describing any station off-sets.

Minimum Attributes - All GPS data submitted to TCEQ should conform to the data attributes defined in Table 1.

Table 1
GPS Data Attributes

Attribute	Data Type	Field Length	Description
Latitude	Number	Double	Decimal Degree to a minimum of six decimal places
Longitude	Number	Double	Decimal Degree to a minimum of six decimal places
Site Name	Text	50	Superfund Site Name
Station Name	Text	50	Monitoring well number or Sample name
Station Reference / Comments	Text	50	Station Location Relative to Facility
Station Type	Text	10	Point, Line or Polygon
Collector Name	Text	50	Last Name, First Initial
GPS Certificate Number	Text	8	TCEQ GPS Certificate Number
Collection Method	Text	15	Superimposed, Centroid, Offset
Datum	Text	5	Horizontal Datum (NAD27, NAD83 or WGS84)
Max PDOP	Number	Single	Maximum PDOP value in effect during data collection (not > 6)
Receiver Type	Text	50	GPS model name & accuracy
Correction Status*	Text	50	Tells whether or not GPS data was differentially corrected
GPS Date	Date	N/A	Date GPS data was collected
GPS Time	Text	8	Time GPS data was collected
Total Positions Collected	Number	Integer	Number of positions collected/corrected

* Data that is not differentially corrected will be rejected.

Data Format - GPS data submitted to TCEQ should be in electronic format (dBASE IV, .dbf file format is preferred). The following is an example of how the data table should be structured. The data may be submitted via email, on diskette, or CD.

Table 2
Third Party GPS Data
Example Data Table

Latitude	Longitude	Site Name	Station Name	Station Reference/ Comments	Collector Name	TCEQ GPS Certificate Number	Datum	Collection Method	Max PDOP	Receiver Type	Correction Status	GPS Date	GPS Time	Total Positions
11.111000	99.999000	Pioneer	MW-21	NW Corner	Terry, D	95081107	NAD83	Superimposed	4.4	Trimble XRS DGPS	Differential Correction	5/22/00	10:10 AM	61
11.111100	99.999100	Pioneer	MW-22	Center of the facility	Terry, D	95081107	NAD83	Centroid	5.2	Trimble XRS DGPS	Differential Correction	5/22/00	10:25 AM	108
11.111200	99.999200	Pioneer	MW-23	S of entrance	Terry, D.	95081107	NAD83	Superimposed	3.5	Trimble XRS DGPS	Differential Correction	5/22/00	1:38 PM	66
11.111200	99.999200	Pioneer	site location	South Entrance of facility	Terry, D.	95081107	NAD83	Superimposed	3.5	Trimble XRS DGPS	Differential Correction	5/22/00	3:38 PM	60

Third Party GPS Training Certification
Minimum Qualifications
Texas Natural Resource Conservation Commission

TCEQ OPP 8.12 requires all GPS training courses to include both lecture/classroom discussion and hands-on exercises. Table 1 contains the minimum elements that must be included in any TCEQ-recognized GPS certification training course

<table>
<tr><th colspan="2">Table 1
GPS Certification Training
Minimum Elements</th></tr>
<tr><th>Minimum lecture and/or demonstration elements</th><th>Minimum hands-on exercises, to be successfully completed by each student</th></tr>
<tr><td>Q Background of the Global Positioning System.
Q GPS accuracy issues.
Q Relevant Agency operating policies.
Q Operation of GPS equipment, including basic troubleshooting.
Q Data collection procedures.
Q Differential correction, both real time processing and post processing.
Q Coordinate averaging for point locations.
Q Data output in formats appropriate for import to GIS or tabular databases.</td><td>Q Pre-planning, including data quality objectives, equipment and materials needed, logistics of field data collection, and prediction of GPS data collection conditions.
Q Navigation to a given coordinate.
Q Storing and transferring raw positional data.
Q Differential correction of raw data through post processing.
Q Averaging corrected point data and outputting to a GIS file.</td></tr>
<tr><td colspan="2">Class exercises shall also include computer plotting of point data to allow students to better understand GPS accuracy issues and the effects of differential correction and point data averaging</td></tr>
<tr><td colspan="2">Note:
All certified GPS users recognized by TCEQ must be recertified every 2 years;
$ Sales or user demonstrations do NOT constitute GPS training;
$ GPS training courses should last a minimum of six to eight hours;
$ The TCEQ GPS operating policy is available online at:
http://www.tceq.state.tx.us/gis/gisplcy.html</td></tr>
</table>

Individuals obtaining or with current GPS certification training must verify that the instruction they have received meets the minimum elements listed in Table 1. Therefore, fill out the attached form, along with copies of GPS training certificates, and return them to:

David P. Terry
TCEQ GPS Coordinator (MCC-155)
SWAP Team
Texas Commission on Environmental Quality
P.O. Box 13087
Austin, Texas 78711-3087
(512) 239 4755
Email: dterry@tceq.state.tx.us

GPS Certification Verification Form
Texas Commission on Environmental Quality

Contact Information				
GPS Training Coordinator Information			**Training Provider Information**	
Name			Organization Providing GPS Training	
Organization			Instructor	
Mailing Address			Course Name	
City	State	ZIP	Course Date	Course Hours
Email Address			GPS System (e.g. Trimble, Magellan, etc.)	Manufacture Yes 9 No 9

The following individual(s) have received GPS certification training that complies with TCEQ OPP 8.12 minimum training elements:

Name	Title

I hereby state that the information provided is true, accurate, and complete to the best of my abilities

Signature of GPS Training Coordinator or GPS Trainer	Title	Date
Printed Name	Telephone Number	Extension

Reference 22

TCEQ Interoffice Memorandum

To: Monica Harris, P.G.
Manager, Superfund Section, Remediation Division

From: Trent Martin, Field Investigator, Midland Region office

Date: September 17, 2014

Subject: **Referral to Superfund: Ector Drum**
2604 N Marco Ave Odessa, TX 79762
RN100584291; TCEQ ID No. 31752; EPA ID No. TXD064215759

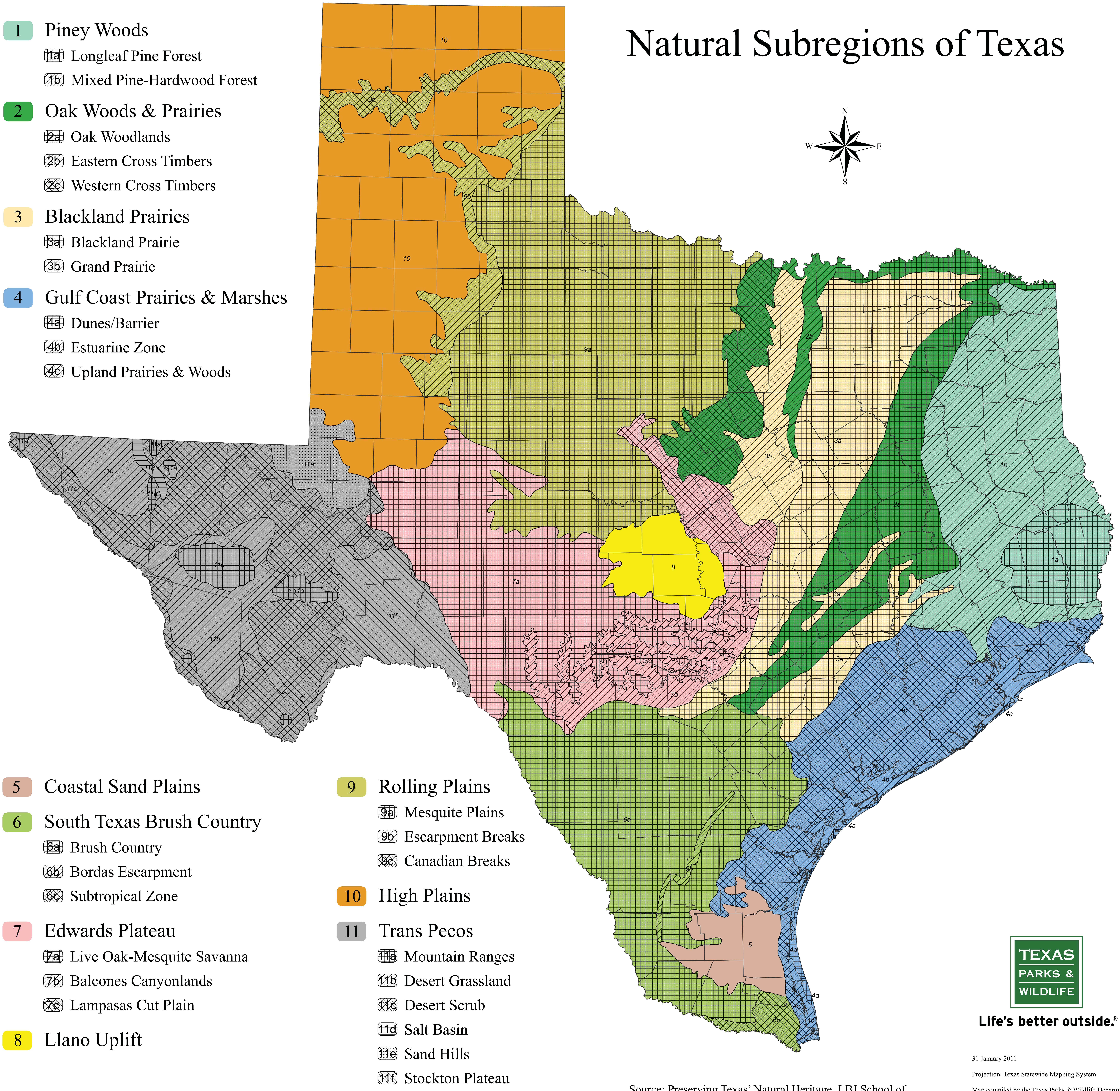
On July 25, 2014, Investigators Ralph Johnson and Trent Martin traveled to Ector Drum for a complaint investigation alleging the potential for run-off of chemicals impacting the surrounding areas. It was discovered that the site has been abandoned for approximately two years and noted numerous 350 gallon Tote-containers and 55 gallon drums that appeared to contain hydrocarbon based oil well treating chemical and waste lube oil stored on-site. Some of them were open and leaking onto the ground. The ground at the facility was also impacted with these chemicals with large patches of stained soil and some areas with standing liquid and the site's water well that is on site shows signs that oily wastes may have gotten into it (see attached photos). From this investigation an Enforcement Action Request was prepared and has been submitted to the Enforcement Division.

Due to the amount of impacted area and the concerns that the City of Odessa, TX had concerning the site, SWS Environmental was contracted thru the Critical infrastructure Division to conduct a limited emergency removal. SWS Environmental was on site from August 26 to August 28. When SWS Environmental finished they had recovered approximately 20,000 gallons of oily wastes from a secondary containment structure for waste storage tanks, all open drums, and any pooled liquid on the ground.

The site is still a concern due to the potential impact it can have to the surrounding area, with fires being a concern. At this time, EPA has shown interest in taking the remediation project.

Reference 23

Natural Subregions of Texas



Source: Preserving Texas' Natural Heritage. LBJ School of Public Affairs Policy Research Project Report 31, 1978

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31 January 2011

Projection: Texas Statewide Mapping System

Map compiled by the Texas Parks & Wildlife Department GIS Lab. No claims are made to the accuracy of the data or to the suitability of the data to a particular use.

Reference 24

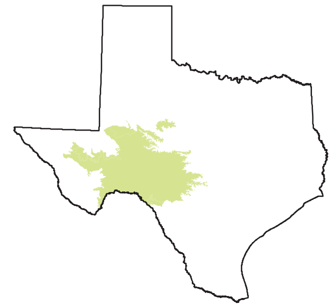
Aquifers of Texas

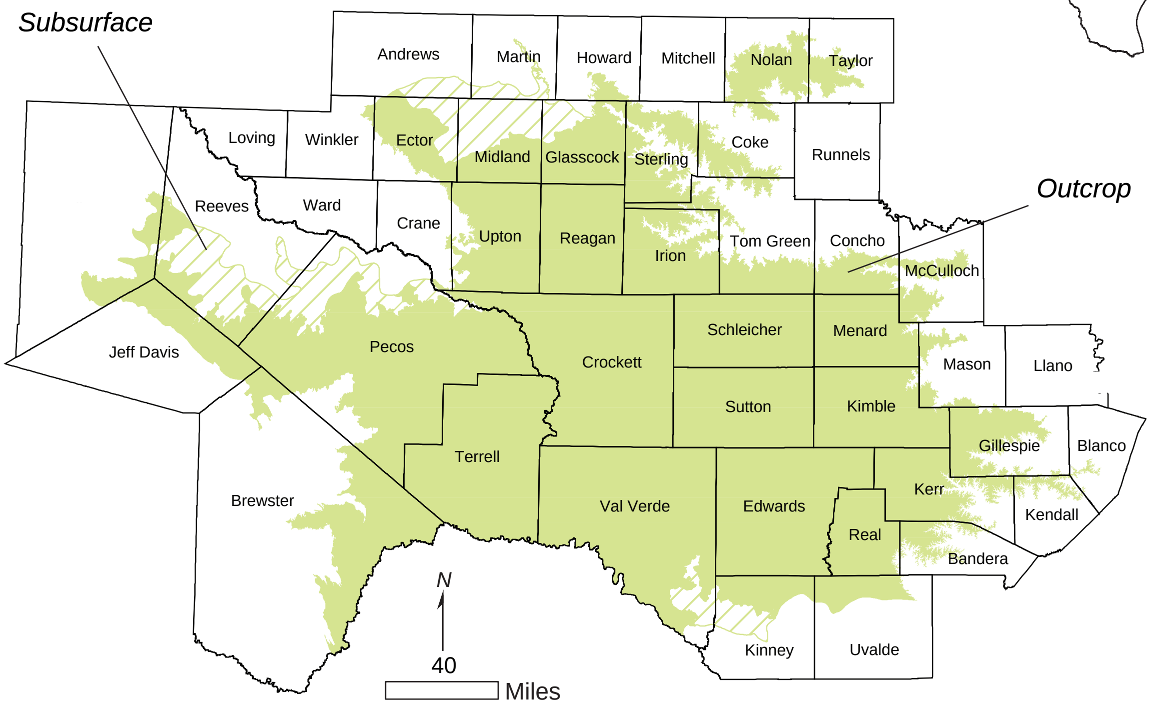
by Peter G. George, Ph.D., P.G. • Robert E. Mace, Ph.D., P.G. •
Rima Petrossian, P.G.

Report 380
July 2011

Texas Water Development Board
www.twdb.texas.gov

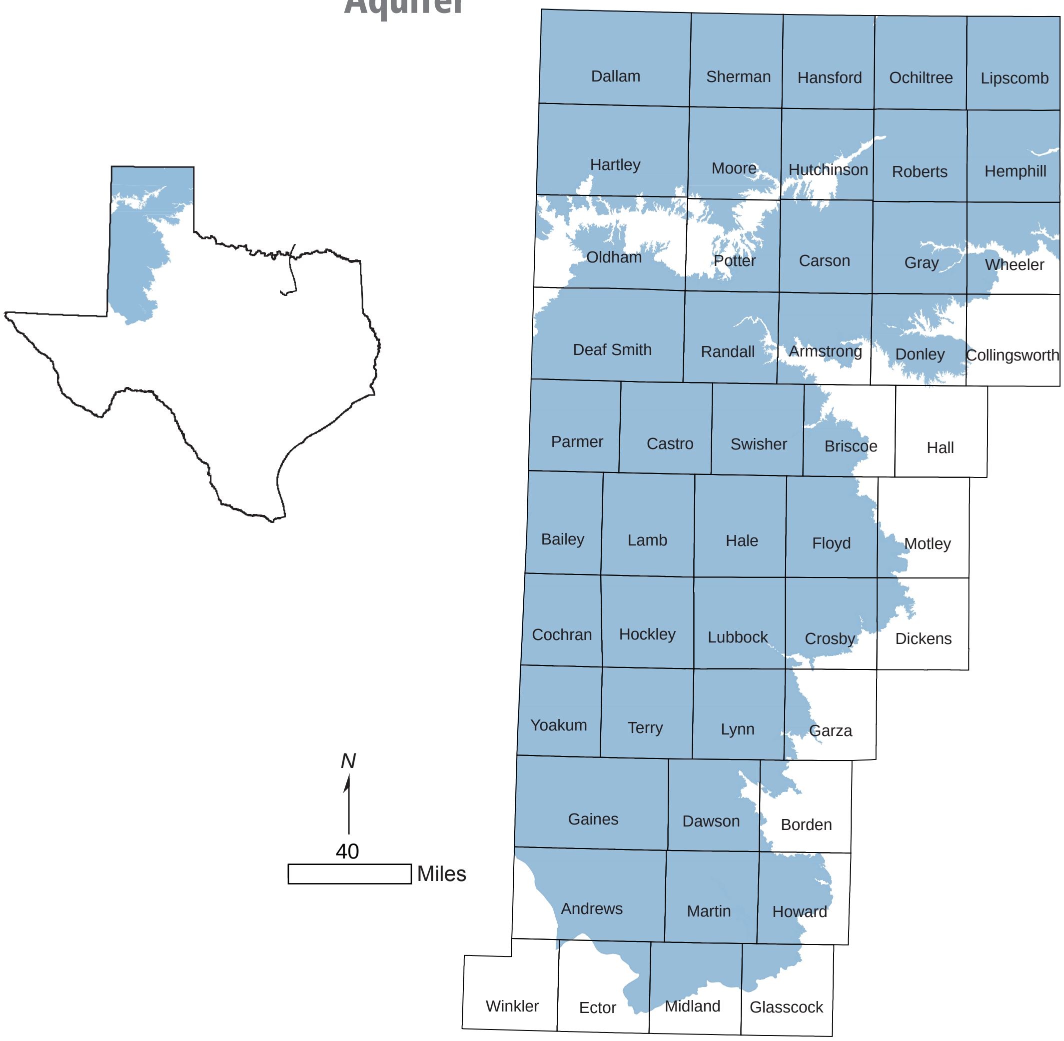
Edwards-Trinity (Plateau)
Aquifer





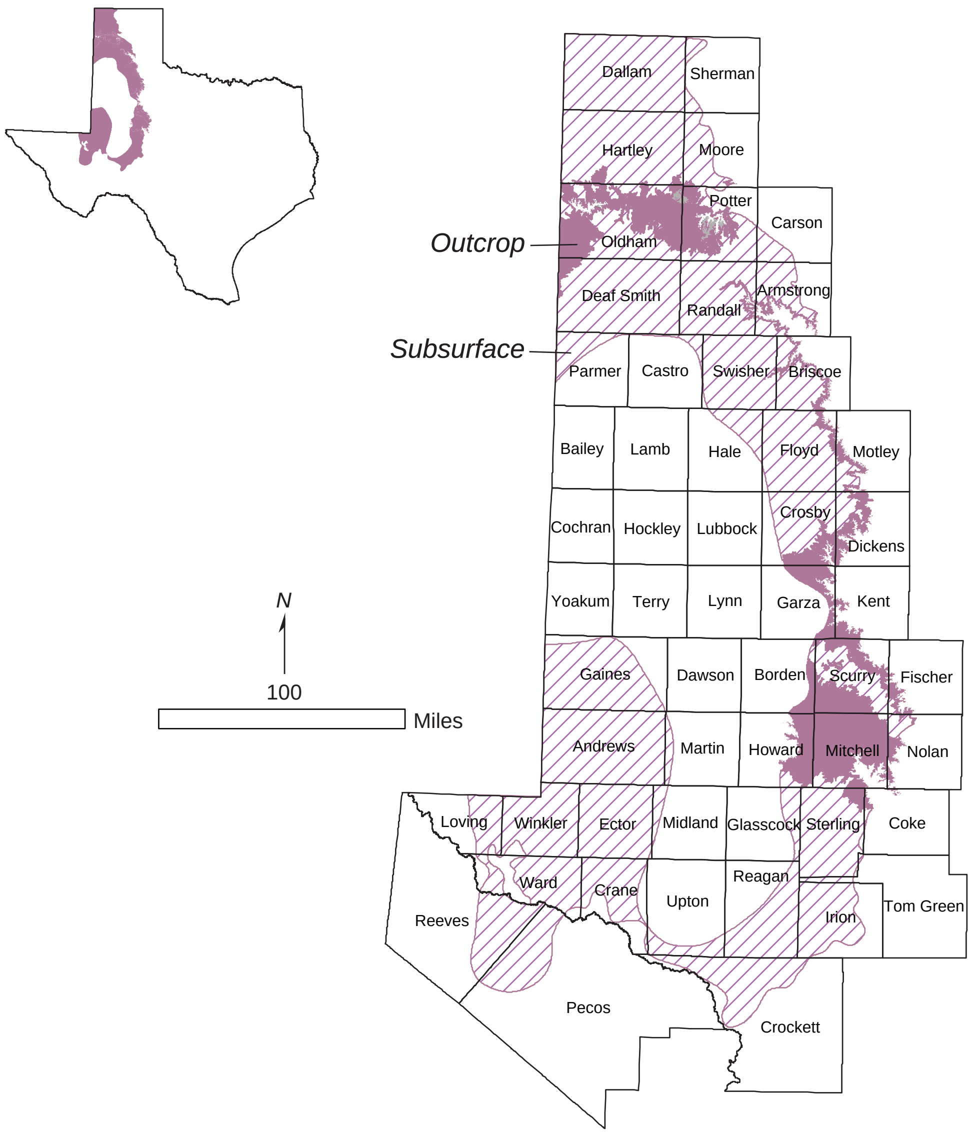
The Edwards-Trinity (Plateau) Aquifer is a major aquifer extending across much of the southwestern part of the state. The water-bearing units are composed predominantly of limestone and dolomite of the Edwards Group and sands of the Trinity Group. Although maximum saturated thickness of the aquifer is greater than 800 feet, freshwater saturated thickness averages 433 feet. Water quality ranges from fresh to slightly saline, with total dissolved solids ranging from 100 to 3,000 milligrams per liter, and water is characterized as hard within the Edwards Group. Water typically increases in salinity to the west within the Trinity Group. Elevated levels of fluoride in excess of primary drinking water standards occur within Glasscock and Irion counties. Springs occur along the northern, eastern, and southern margins of the aquifer primarily near the bases of the Edwards and Trinity groups where exposed at the surface. San Felipe Springs is the largest exposed spring along the southern margin. Of groundwater pumped from this aquifer, more than two-thirds is used for irrigation, with the remainder used for municipal and livestock supplies. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. The regional water planning groups, in their 2006 Regional Water Plans, recommended water management strategies that use the Edwards Trinity (Plateau) Aquifer, including the construction of a well field in Kerr County and public supply wells in Real County.

Ogallala
Aquifer



The Ogallala Aquifer is the largest aquifer in the United States and is a major aquifer of Texas underlying much of the High Plains region. The aquifer consists of sand, gravel, clay, and silt and has a maximum thickness of 800 feet. Freshwater saturated thickness averages 95 feet. Water to the north of the Canadian River is generally fresh, with total dissolved solids typically less than 400 milligrams per liter; however, water quality diminishes to the south, where large areas contain total dissolved solids in excess of 1,000 milligrams per liter. High levels of naturally occurring arsenic, radionuclides, and fluoride in excess of the primary drinking water standards are also present. The Ogallala Aquifer provides significantly more water for users than any other aquifer in the state. The availability of this water is critical to the economy of the region, as approximately 95 percent of groundwater pumped is used for irrigated agriculture. Throughout much of the aquifer, groundwater withdrawals exceed the amount of recharge, and water levels have declined fairly consistently through time. Although water level declines in excess of 300 feet have occurred in several areas over the last 50 to 60 years, the rate of decline has slowed, and water levels have risen in a few areas. The regional water planning groups for the Panhandle and Llano Estacado regions, in their 2006 Regional Water Plans, recommended numerous water management strategies using the Ogallala Aquifer, including drilling new wells, developing well fields, overdrafting, and reallocating supplies.

Dockum
Aquifer



The Dockum Aquifer

is a minor aquifer found in the northwest part of the state. It is defined stratigraphically by the Dockum Group and includes, from oldest to youngest, the Santa Rosa Formation, the Tecovas Formation, the Trujillo Sandstone, and the Cooper Canyon Formation. The Dockum Group consists of gravel, sandstone, siltstone, mudstone, shale, and conglomerate. Groundwater located in the sandstone and conglomerate units is recoverable, the highest yields coming from the coarsest grained deposits located at the middle and base of the group. Typically, the water-bearing sandstones are locally referred to as the Santa Rosa Aquifer. The water quality in the aquifer is generally poor—with freshwater in outcrop areas in the east and brine in the western subsurface portions of the aquifer—and the water is very hard. Naturally occurring radioactivity from uranium present within the aquifer has resulted in gross alpha radiation in excess of the state's primary drinking water standard. Radium-226 and -228 also occur in amounts above acceptable standards. Groundwater from the aquifer is used for

Reference 25

Texas Water Development Board

Report 359

The Groundwater Resources of the Dockum Aquifer in Texas

by
Robert G. Bradley, P.G., and
Sanjeev Kalaswad, Ph.D., P.G.

December 2003

Geoscientist Seal

The contents of this report (including figures and tables) document the work of the Following Licensed Texas Geoscientists:

Robert Bradley, P.G. No. 707

Robert Bradley prepared the original illustrations, data assimilation, and draft reports, all of which were subsequently modified and updated by Sanjeev Kalaswad.

The seal appearing on this document was authorized on May 19, 2009 by

Robert Bradley

Sanjeev Kalaswad, P.G. No. 478

Sanjeev Kalaswad wrote the report, prepared the illustrations including the geological cross-sections and chemical plots, and helped develop the groundwater estimates in the aquifer.

The seal appearing on this document was authorized on May 19, 2009 by

Sanjeev Kalaswad

Report 359 - The Groundwater Resources of the Dockum Aquifer in Texas, 2003

Texas Water Development Board

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Austin, Texas 78711-3231

December 2003
Report 359
(Printed on recycled paper)

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Appendix I

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Appendix III

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1.0 Executive Summary

The Dockum aquifer is a minor aquifer that underlies much of the Ogallala Formation in the Texas Panhandle and West Texas. Recoverable groundwater in the Dockum aquifer occurs within the many Upper Triassic sandstone and conglomerate beds that host the aquifer. The hydrogeologic properties of the aquifer vary widely. For example, well yields range from 0.5 to 2,500 gpm and transmissivity from 48 to 4,600 square feet per day. Generally, however, well yields and transmissivities are fairly low throughout much of the aquifer.

Precipitation recharges the aquifer where it is exposed at the land surface around the eastern and southern edges of the aquifer. The confined portions of the aquifer receive some recharge by leakage from overlying and underlying geologic units. We estimate that annual recharge to the aquifer is approximately 31,000 acre-feet. Discharge from the aquifer occurs from pumping wells, small springs, evapotranspiration and cross-formational flow.

Regional groundwater flow in the aquifer is generally to the east. Historical hydrographs of wells show that water levels in the northern and southern parts of the aquifer have declined in some areas and risen in others over the past 20 to 30 years. In the central part of the aquifer, water levels have generally risen over the same time period.

Groundwater in the Dockum aquifer is generally of poor quality. Water quality ranges from fresh in the outcrop areas to brine in the confined parts of the aquifer. It also tends to deteriorate with depth, and total dissolved solids (TDS) concentrations can exceed 60,000 mg/l in the deepest parts of the aquifer. Water in the Dockum aquifer is also typically hard with a mean hardness of about 470 mg/l. Radionuclides naturally derived from uranium minerals in the host rocks occur at concentrations above 5 pCi/l in widespread areas of the aquifer. Most counties in the study area also had at least one groundwater sample that contained sulfate or chloride at concentrations greater than the secondary standard of 250 mg/l. In contrast, fluoride concentrations were higher than the secondary standard in only a few samples collected from five counties. Much of the land overlying the Dockum aquifer is susceptible to salinity problems originating from the high concentrations of sodium in the groundwater. This problem is most prevalent over the confined areas of the aquifer and is less of a concern over the outcrops.

We estimate that the total amount of water in the entire Dockum aquifer in the study area is approximately 185 million acre-feet. Of this amount, approximately 109 million acre-feet contains TDS of less than 5,000 mg/l, about 27 million acre-feet between 5,000 and 10,000 mg/l, and 49 million acre-feet greater than 10,000 mg/l. However, not all of the water in the Dockum is readily available for withdrawal. In fact, measured aquifer parameters suggest that the aquifer can provide only small quantities of water. Furthermore, because the confined part of the aquifer (where water with the highest TDS concentrations is present) receives little recharge, any significant withdrawal of water from these areas will essentially mine or deplete the aquifer.

2.0 Introduction

The Upper Triassic Dockum Group extends over approximately 96,000 square miles in parts of Colorado, Kansas, Oklahoma, New Mexico and Texas (Figure 2-1). In Texas, sands of the Dockum Group produce small to moderate quantities of fresh to saline water and constitute the Dockum aquifer which is classified as a minor aquifer (Ashworth and Hopkins, 1995). As delineated by Ashworth and Hopkins (1995), the Dockum aquifer includes an area of the aquifer containing groundwater with less than 5,000 mg/l total dissolved solids (Figure 2-2). However, for the purposes of this report, we also include other areas of the aquifer that have total dissolved solids concentrations greater than 5,000 mg/l. In this report, the term "Dockum aquifer" is used loosely for all water-bearing strata of the Dockum Group regardless of their dissolved solids 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.

To date, only a few investigations have been conducted on the Dockum aquifer in Texas. One of the first regional studies was conducted by Gould (1907) in west Texas. Later, Galloway (1955) investigated Triassic artesian wells near Hereford, Texas, to evaluate the feasibility of obtaining water from similar types of wells in eastern New Mexico. Other studies of a local nature were conducted by Fink (1963) and Rayner (1965). Several county-level studies on the Dockum aquifer have also been conducted (see, for example, Garza and Wesselman, 1959; Ogilbee and others, 1962; Shamburger, 1967; White, 1971; Duffin, 1984; and Ashworth, 1986).

The aim of this study was to evaluate the groundwater resources of the Dockum aquifer (Figure 2-2). Specific goals of the investigation were to compile and evaluate existing geologic and hydrologic information on the area, determine the quality of groundwater in the Dockum aquifer, and estimate the approximate amount of groundwater in the aquifer. Much of the information presented in this report was obtained from previous literature and Texas Water Development Board (TWDB) records. We collected groundwater samples in 1995 and 1996 from all of the counties in the study area to assess the chemical quality of water in the aquifer.

3.0 Study Area

The study area (Figure 2-2) encompasses the total areal extent of the Dockum Group in Texas (approximately 42,000 square miles). The outcrop area of the Dockum Group is approximately 5,500 square miles, and extends as a north-south-trending belt paralleling the eastern escarpment of the Llano Estacado. The belt is narrow between Armstrong and Dickens counties in the north but broadens south of Dickens County to include most of Scurry and Mitchell counties.

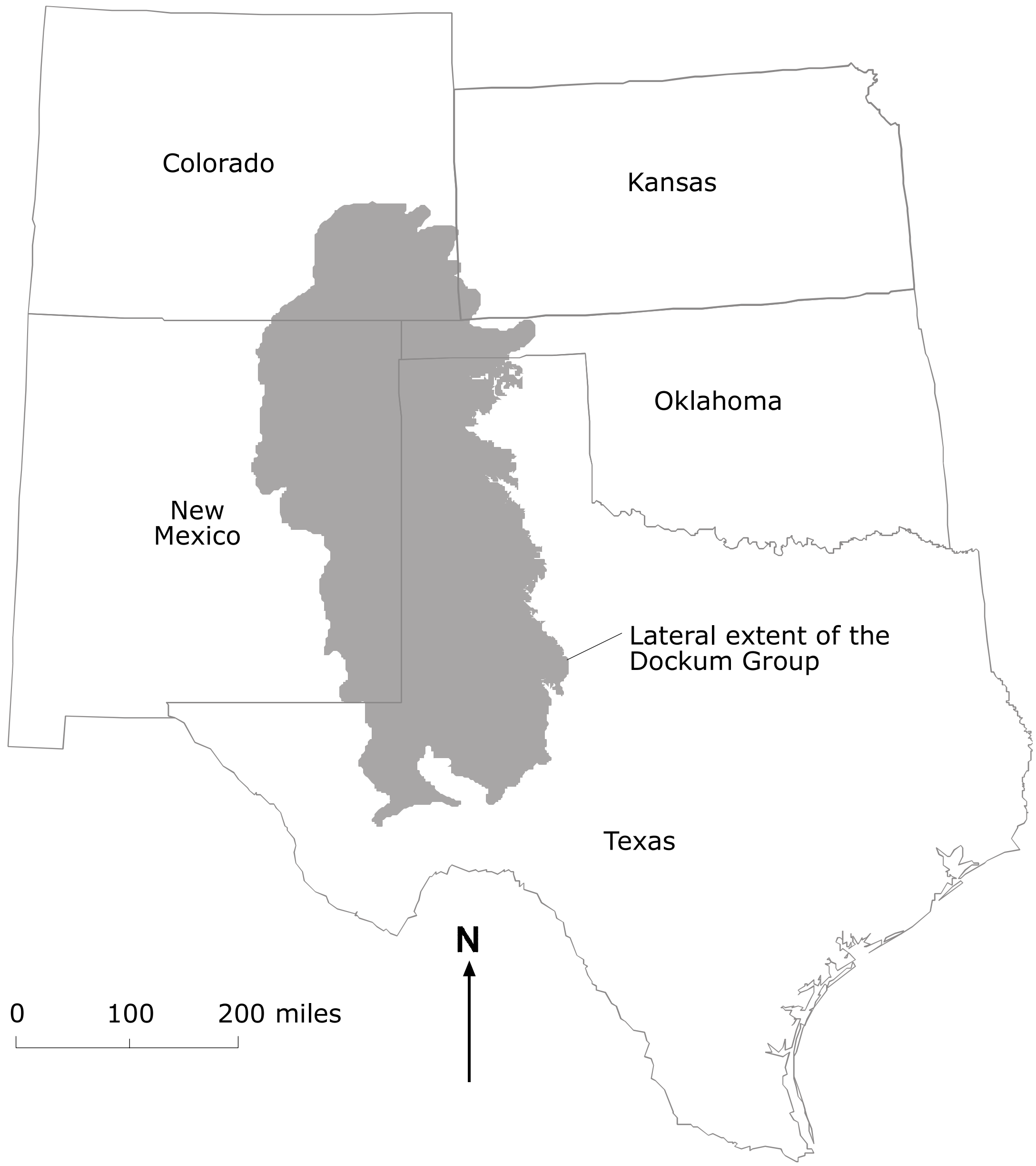

Figure 2-1. Lateral extent of the Dockum Group in southwestern United States (modified from McKee and others, 1959; Bureau of Economic Geology, 1967, 1968, 1969, 1974, and 1983; McGowen and others, 1977).

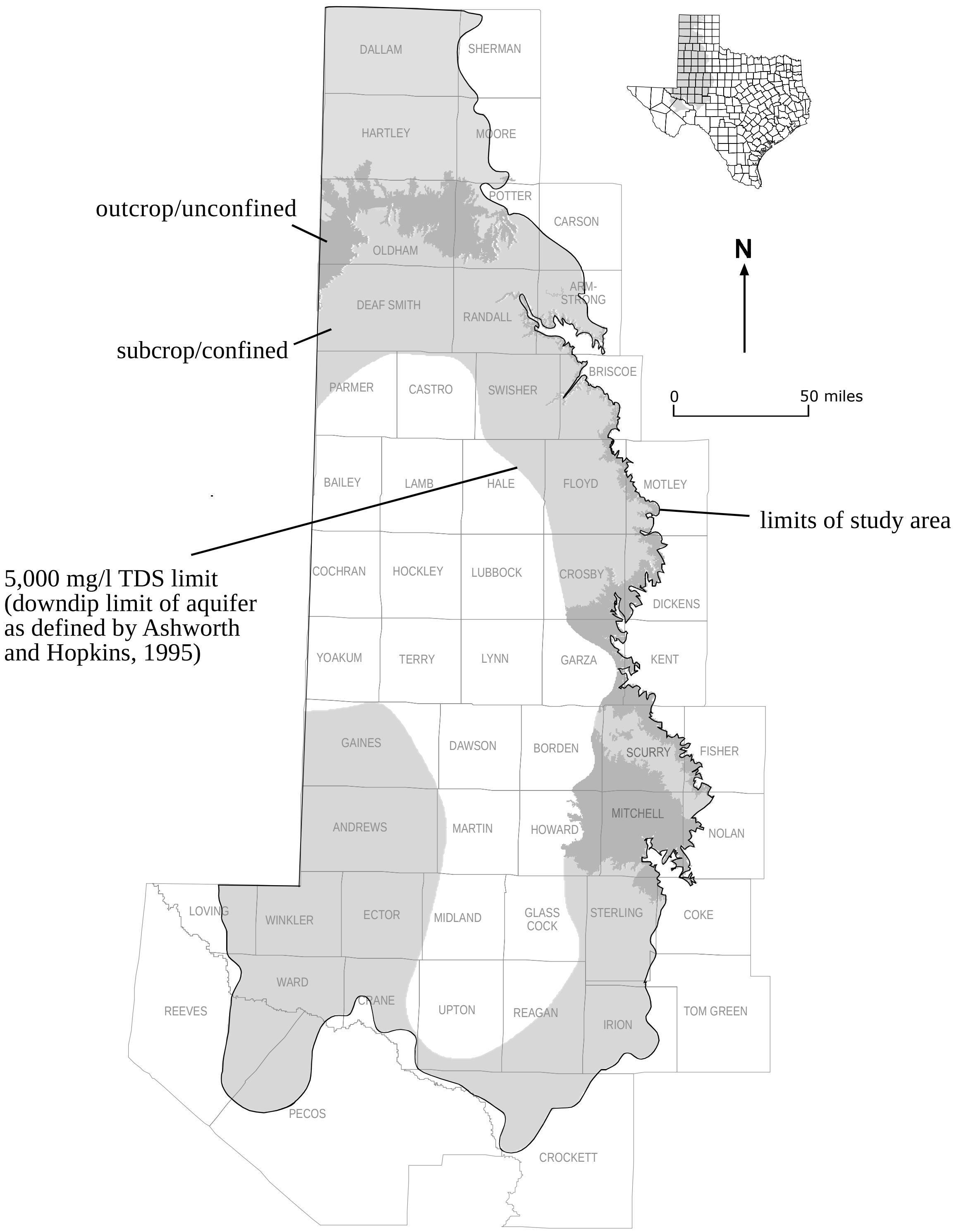

Figure 2-2. Areal extent of the study area and the Dockum aquifer in Texas.

Within the study area, the Dockum aquifer is exposed along the Canadian River in the north, along the east edge of the Caprock Escarpment in the east, and in parts of Borden, Fisher, Garza, Howard, Kent, Mitchell, Nolan, and Scurry counties in the south. Other small exposures are found in Coke, Crane, Ector, Loving, Martin, Sterling, and Ward counties. Covered outliers of the Dockum aquifer are present in Hansford, Hutchinson, and Ochiltree counties.

The Dockum aquifer in the study area overlies Permian-age units and is in turn overlain by Jurassic rocks in the northwest corner of the Texas Panhandle, by Cretaceous sediments in the southern High Plains and Edwards Plateau, and by the Ogallala Formation in the northern High Plains (Table 3-1). In the southwest part of the study area, the aquifer is overlain by the Cenozoic Pecos Alluvium.

3.1 Physiography

Much of the study area lies within the High Plains section of the Great Plains physiographic province which extends from the Pecos River in the south to the latitude of the Great Bear Lake in Canada (Thornbury, 1965). The High Plains section in Texas is a vast, monotonous flat surface underlain primarily by Tertiary sediments. The eastern edge of the section is marked by a pronounced escarpment called the Caprock Escarpment.

Smaller parts of the study area in the south lie within the Pecos Valley and the Edwards Plateau sections of the Great Plains physiographic province. The Pecos Valley section, which lies southwest of the High Plains section, consists of a broad north-south-trending topographic depression underlain by highly soluble Cretaceous rocks. To its east lies the Edwards Plateau section, characterized by low relief (except along major stream channels) in the west and higher relief in the east. The Edwards Plateau is underlain by carbonate rocks of Cretaceous age. A small part of the study area east of the Caprock Escarpment falls within the Osage section of the Central Lowlands province and is underlain by mainly Pennsylvanian or Permian rocks.

Five major river basins drain the study area, including the basins of the Canadian and Red rivers, which drain eastward, and the basins of the Brazos, Colorado, and Pecos rivers, which drain toward the southeast. A significant part of the Dockum Group outcrop is drained by the Canadian and Colorado rivers and their tributaries.

3.2 Climate

The climate over much of the northern and central parts of the study area is of a continental steppe type and is characterized by large variations in daily temperatures, relatively low humidity, and infrequent rainfall events (Larkin and Bomar, 1983). Average annual precipitation in these areas ranges from about 21 inches in the eastern parts of the study area to about 17 inches in the western parts (Figure 3-1). Historically, mean annual precipitation has ranged from 13.89 inches in the southern part of the study area (Figure 3-1c) to 22.23 inches in the central part (Figure 3-1b). Three-fourths of the precipitation in these areas typically occurs between early spring and early fall. May and September are usually the rainiest months. Snowfall is an important source of precipitation in the winter. Temperatures often exceed 100° F in the summer and drop below freezing in the winter.

Table 3-1. Geologic Formations in the Texas Panhandle and West Texas and Their Water-Bearing Characteristics (modified from Knowles and others, 1984; Lehman, 1994a and 1994b).

System	Series	Group	Formation	Physical Characteristics	Water-bearing Characteristics
Quaternary			Cenozoic Pecos Alluvium	Unconsolidated to partially consolidated sand, silt, gravel, clay, and caliche.	Yields small to large amounts of fresh to slightly saline water.
Tertiary	Late Miocene to Pliocene		Ogallala	Tan, yellow, and reddish-brown, silty to coarse-grained sand alternating with yellow to red silty clay and variable sized gravel.	Yields moderate to large amounts of water to well.
Cretaceous		Washita		Massive, fine to coarse grained, white, gray, or yellowish gray limestone and thick, dark greenish gray, gray, or yellow marl.	Yields small to large amounts of water to wells and springs.
		Fredericksburg	Kiamichi	Thinly laminated, sometimes sandy, gray to yellowish-brown shale with beds of thin, gray argillaceous limestone, and, thin, yellow limestone.	Yields small amounts of water locally to wells.
			Edwards	Light-gray to yellowish-gray, thick bedded to massive, fine- to coarse-grained limestone.	Yields small to large amounts of water to wells and springs.
			Comanche Peak	Light gray to yellowish-brown, irregularly bedded, argillaceous limestone, thin beds light-gray shale.	Yields small to large amounts of water to wells.
			Walnut	Light-gray to yellowish-brown, fine to medium-grained, sandstone, thin bedded, gray to grayish-yellow, calcareous shale; and light gray to grayish-yellow, argillaceous limestone.	Not known to yield water to wells.
		Trinity	Antlers	White, gray, yellowish-brown to purple, fine to medium-grained, loosely cemented sandstone and conglomerate, with beds of siltstone and clay.	Yields small to moderate amounts of water to wells.
Jurassic			Morrison	Variegated shale, sandstone, siltstone, and limestone.	Yields small amounts of fresh to slightly saline water.
			Exeter	Light-colored sandstone.	Yields small amounts of fresh to slightly saline water.
Triassic		Dockum	Cooper Canyon	Reddish-brown to orange siltstone and mudstone with lenses of sandstone, and conglomerate.	Yields small to large quantities of fresh to brine water to wells and springs.
			Trujillo	Gray, brown, greenish-gray, fine to coarse-grained sandstone and sandy conglomerate with thin gray and red shale interbeds.	
			Tecovas	Variegated, sometimes sandy mudstone with interbedded fine to medium-grained sandstones.	
			Santa Rosa	Red to reddish-brown sandstone and conglomerate.	
Permian	Ochoa		Dewey Lake	Red siltstone and shale.	Not known to yield water to wells.
			Rustler	Dolomite, anhydrite, sandstone, conglomerate, and variegated shale.	Yields small to large amounts of slightly to moderately saline water.
	Guadalupe	Undifferent-iated		Sandstone, shale, gypsum, anhydrite, dolomite, and selenite.	Yields small to large amounts of fresh to moderately saline water.

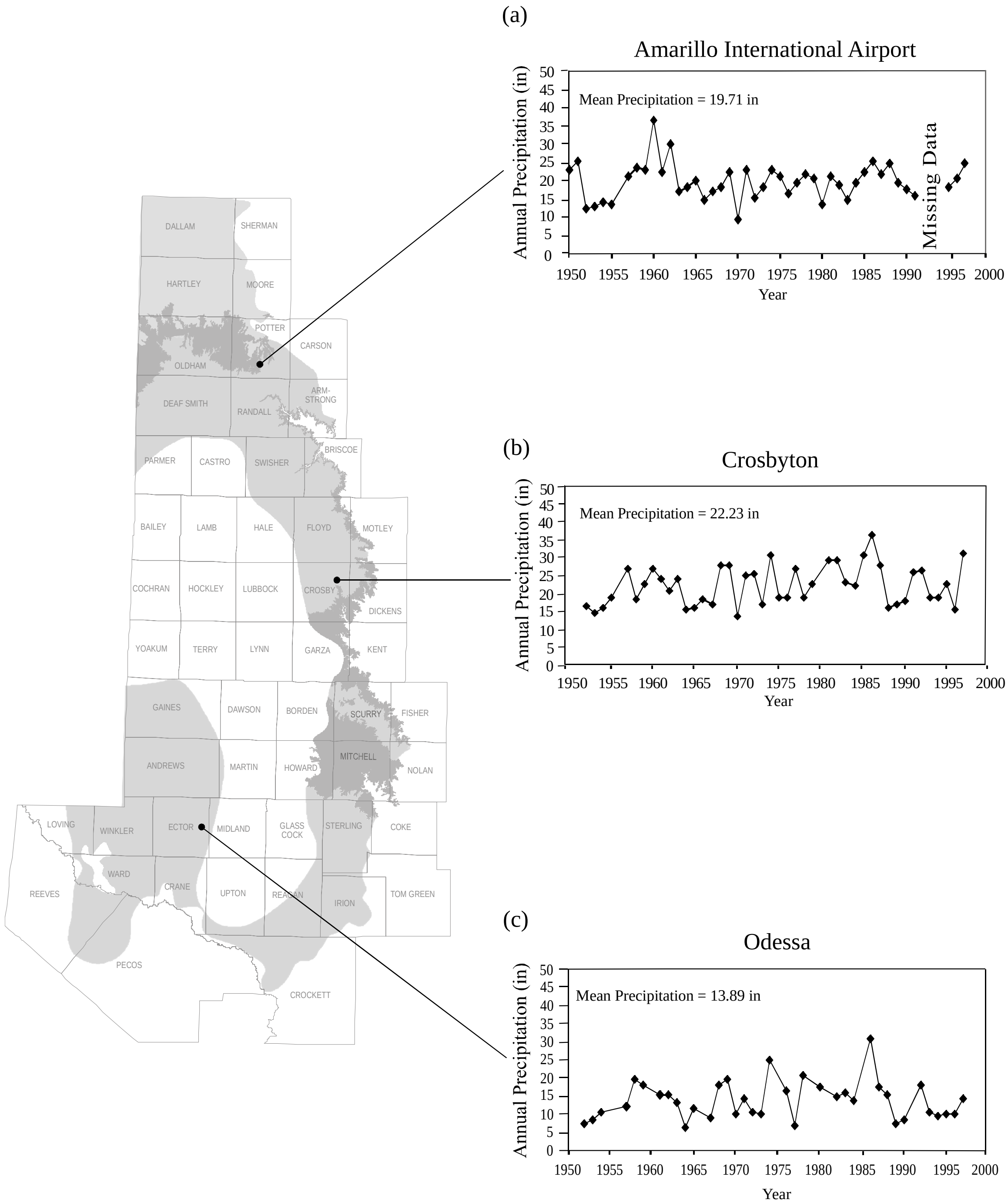

Figure 3-1. Historical annual precipitation recorded at (a) Amarillo International Airport, (b) Crosbyton, and (c) Odessa.

Evaporation in the northern and central parts of the study area is greatest in the summer months. The average annual evaporation potential for an open surface water body in Lubbock County is approximately three-and-half times the average annual precipitation (Knowles and others, 1984).

The southern part of the study area (Trans-Pecos) is semi-arid and is characterized by a wide range of temperatures, low rainfall, and high evaporation rates (Ashworth, 1990). Temperatures typically range from below freezing in winter to over 100° F during the summer. Average annual precipitation in the southern part of the study area ranges from 9 inches in the west to about 14 inches in the east with much of it occurring in April and October. Historical annual precipitation at the Odessa rain gage station has ranged from 6.2 inches to 30.8 inches (Figure 3-1c).

4.0 Geology

The 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 feet. They are often lens-shaped, partly conglomeratic, poorly sorted, friable, and micaceous. The red and maroon sandy shale units that separate the sandstones range in thickness from about 50 to 100 feet.

Recoverable groundwater in the Dockum aquifer is present within the many sandstone and conglomerate beds that occur throughout the sedimentary sequence. The coarse-grained deposits form the more porous and permeable water-bearing units of the Dockum Group, whereas the fine-grained sediments form impermeable aquitards in the group (Fallin, 1989). The more prolific parts of the aquifer are consequently developed in the lower and middle sections where the coarse-grained sediments predominate (Best Sandstone in Figure 4-1 through 4-10). 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 usually known as the Allurosa aquifer (White, 1971).

The geologic setting of the Dockum Group, as well as information on aquifer properties, water levels, chemical quality of water in the aquifer, and recharge to and discharge from the aquifer are presented below.

4.1. Stratigraphy

Recent investigations of the Dockum Group have largely focused on stratigraphic nomenclature, and a fair amount of controversy has arisen over its rank as a group or formation (for an in-depth

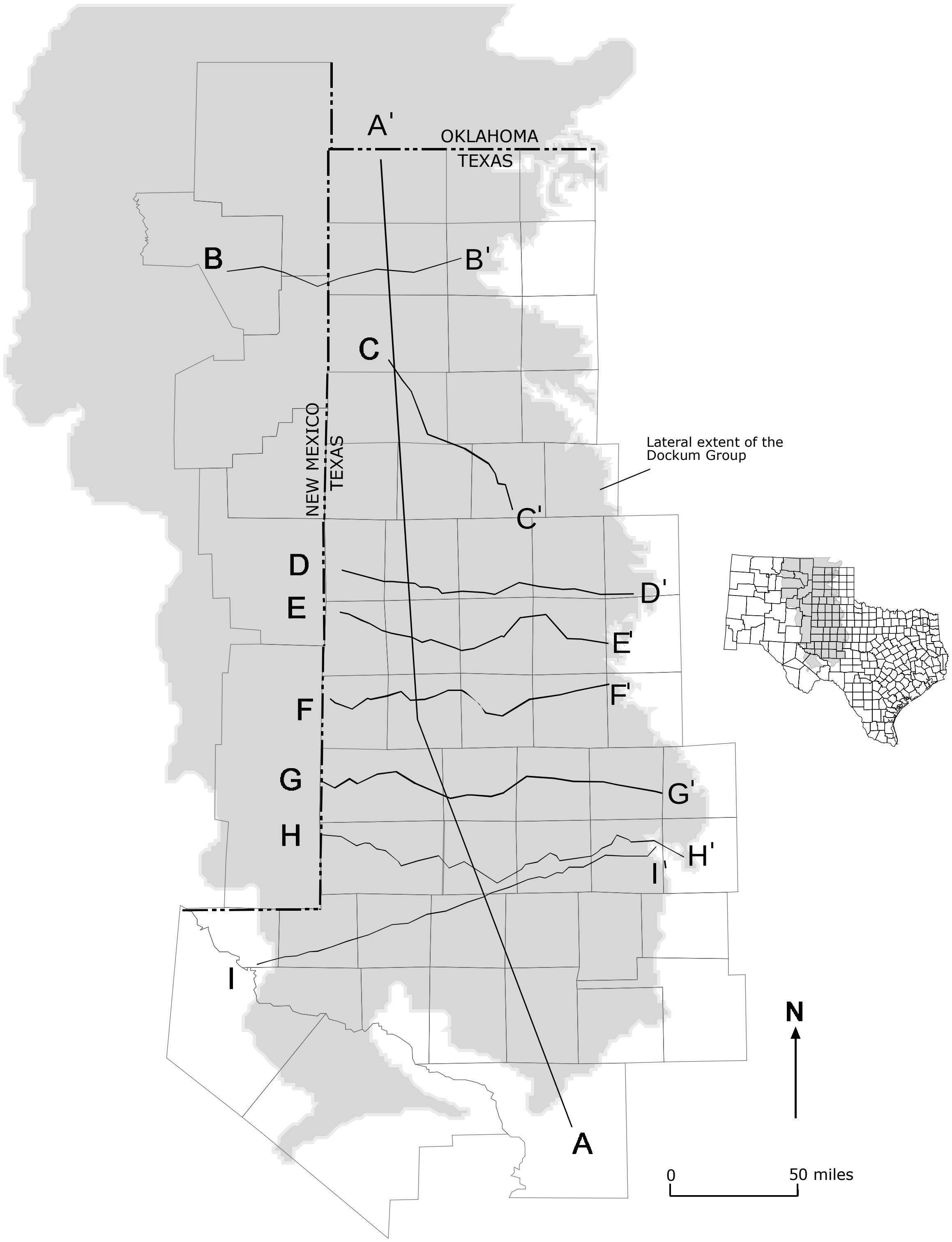

Figure 4-1. Index map of geologic cross-sections.

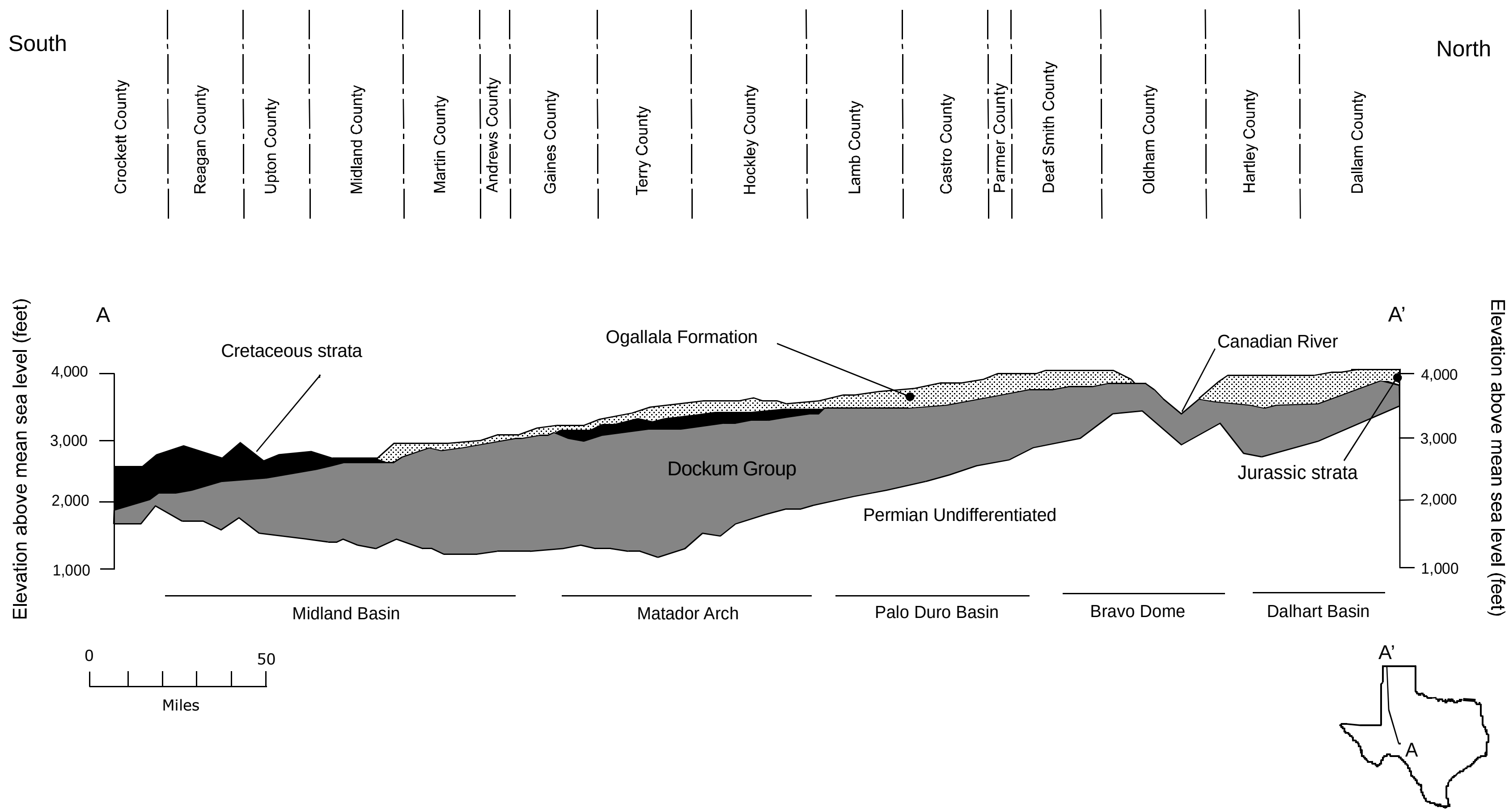

Figure 4-2 Geologic cross-section A-A'.

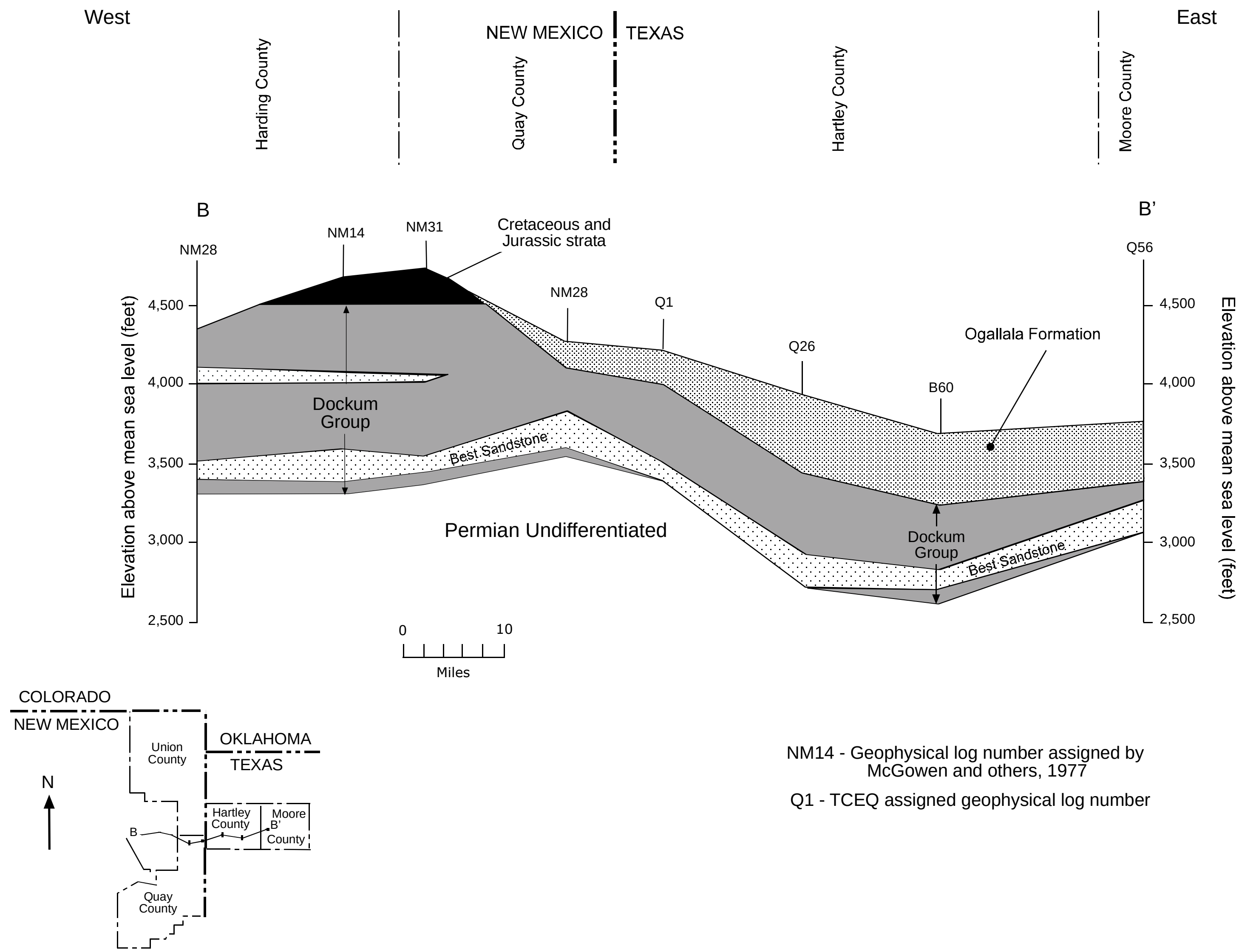

Figure 4-3. Geologic cross-section B-B'.

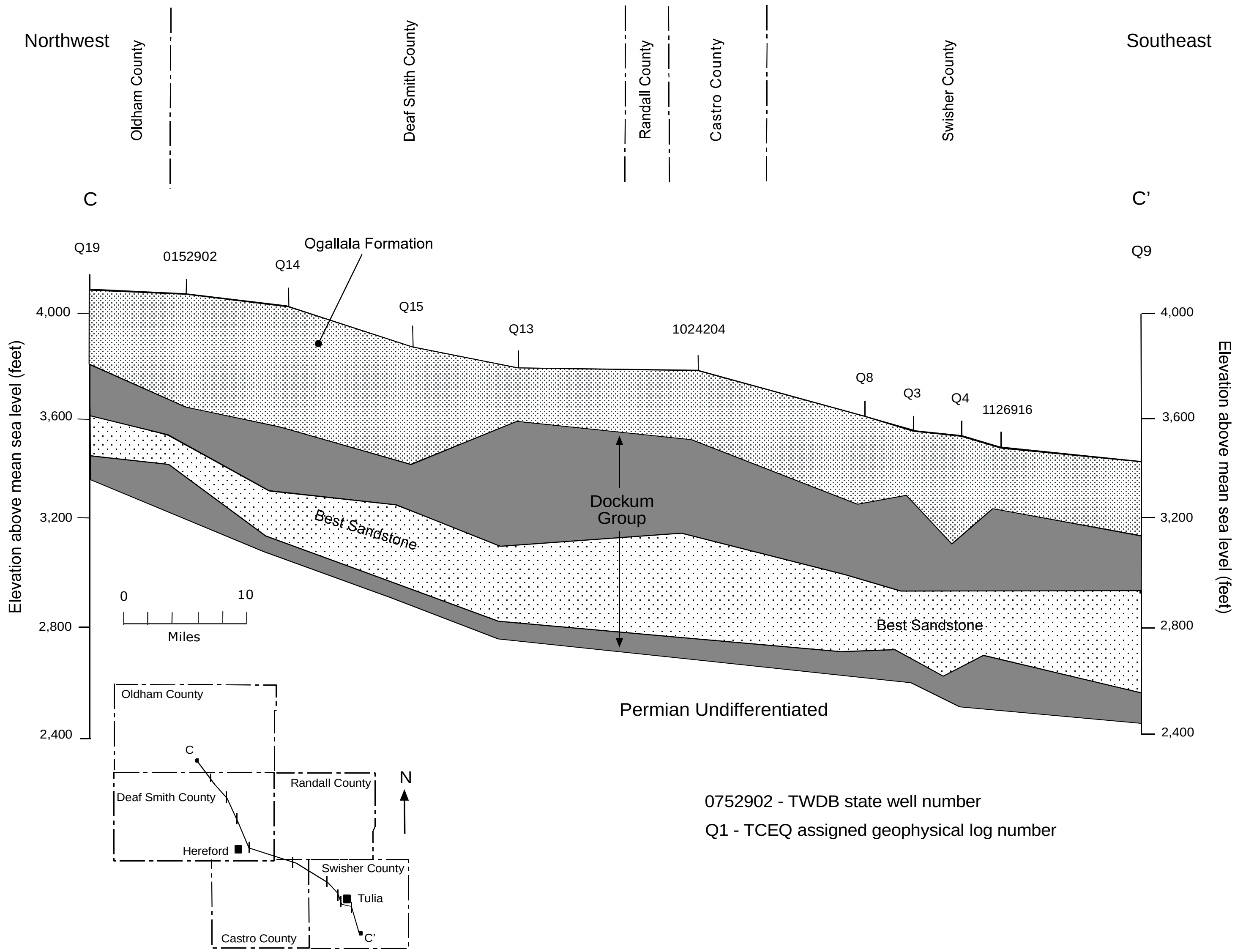

Figure 4-4. Geologic cross-section C-C'.

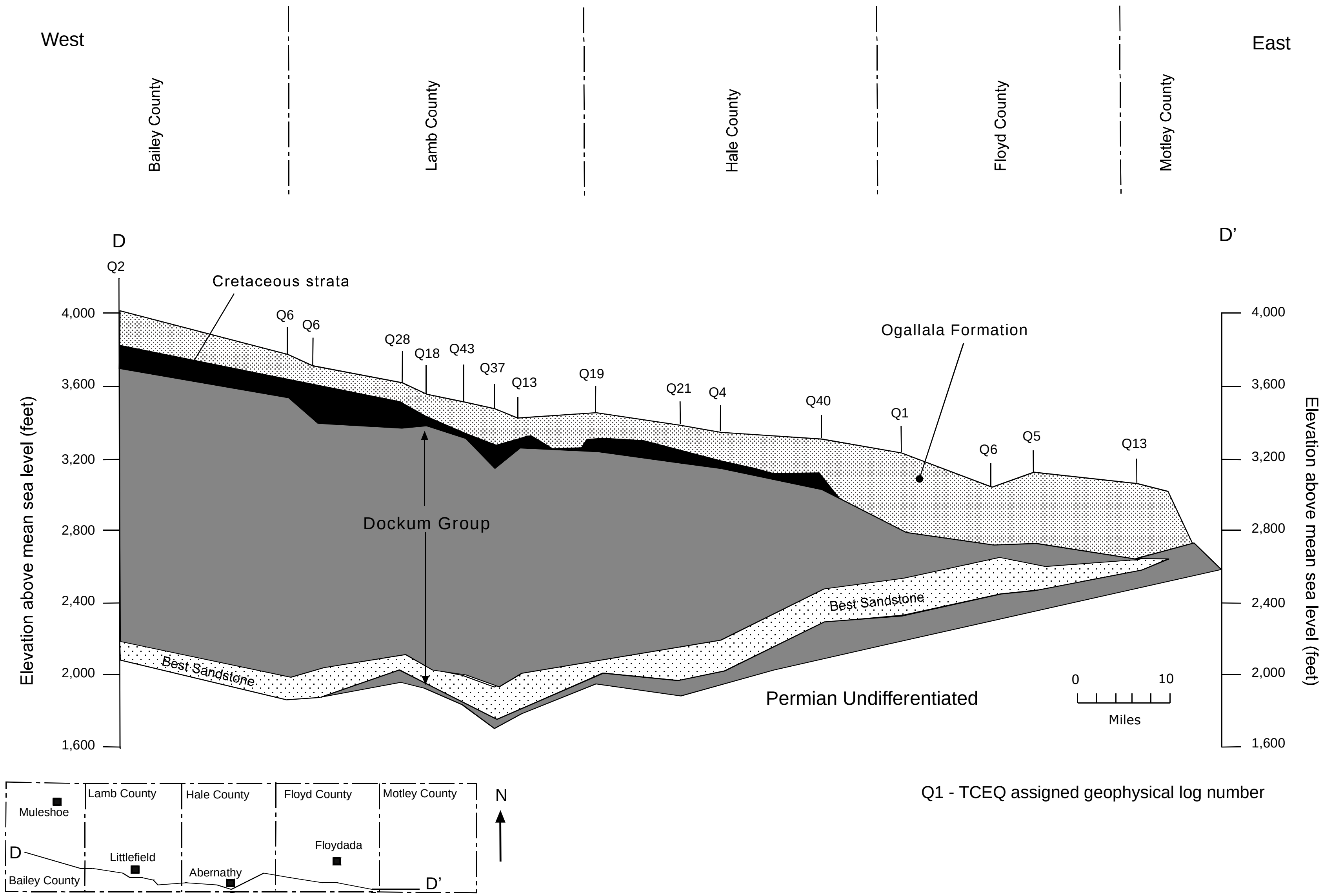

Figure 4-5 Geologic cross-section D-D'.

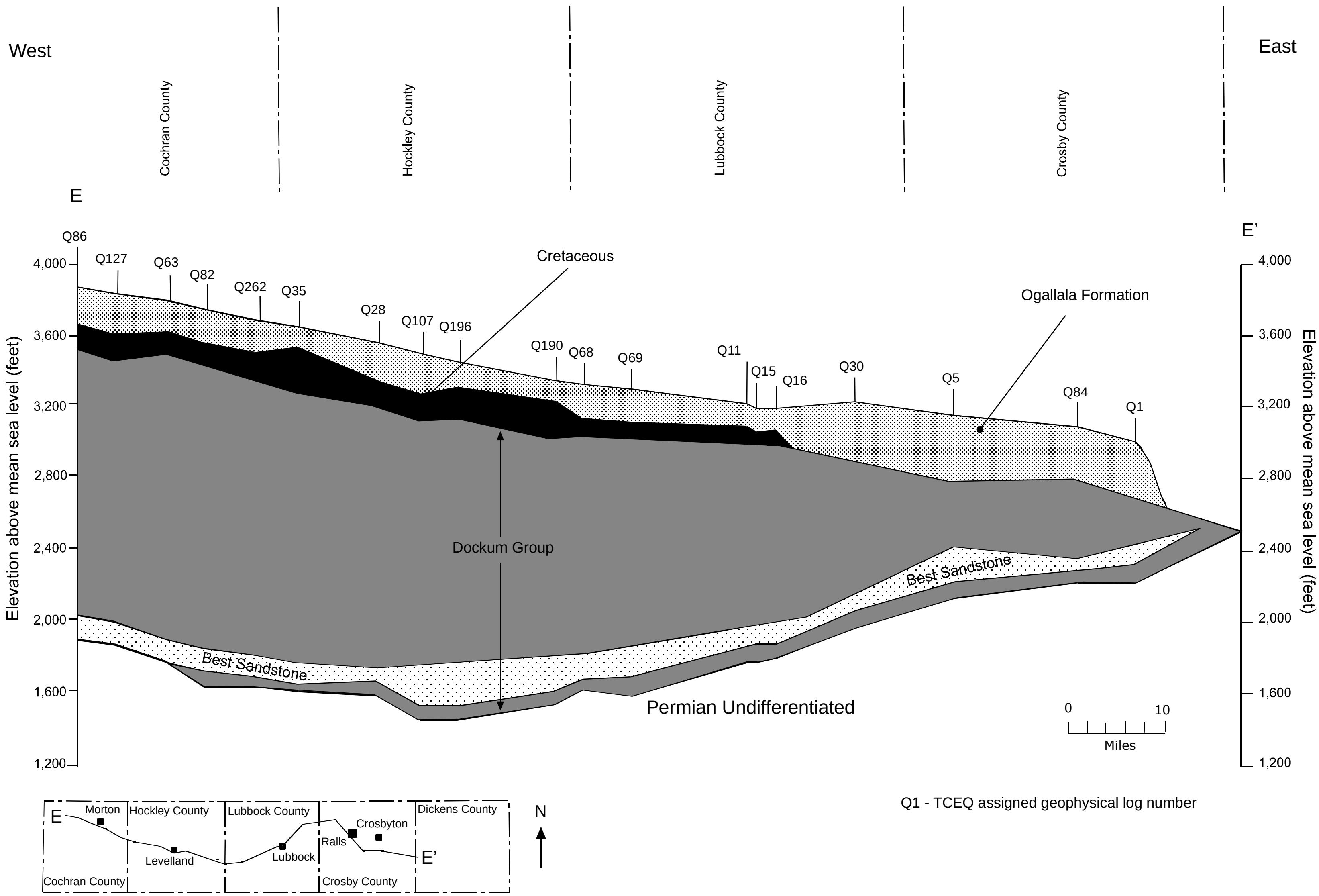

Figure 4-6 Geologic cross-section E-E'.

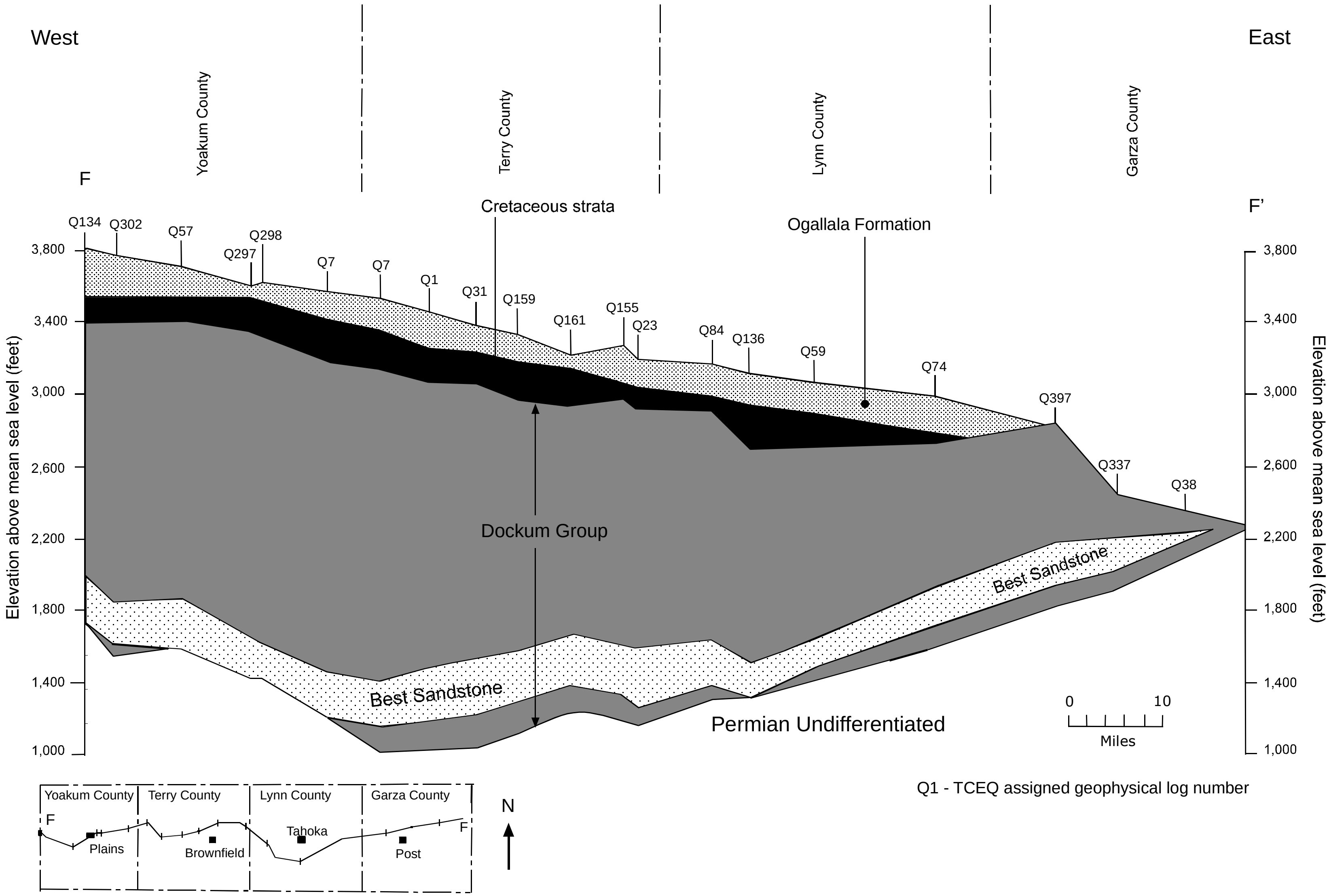

Figure 4-7. Geologic cross-section F-F'.

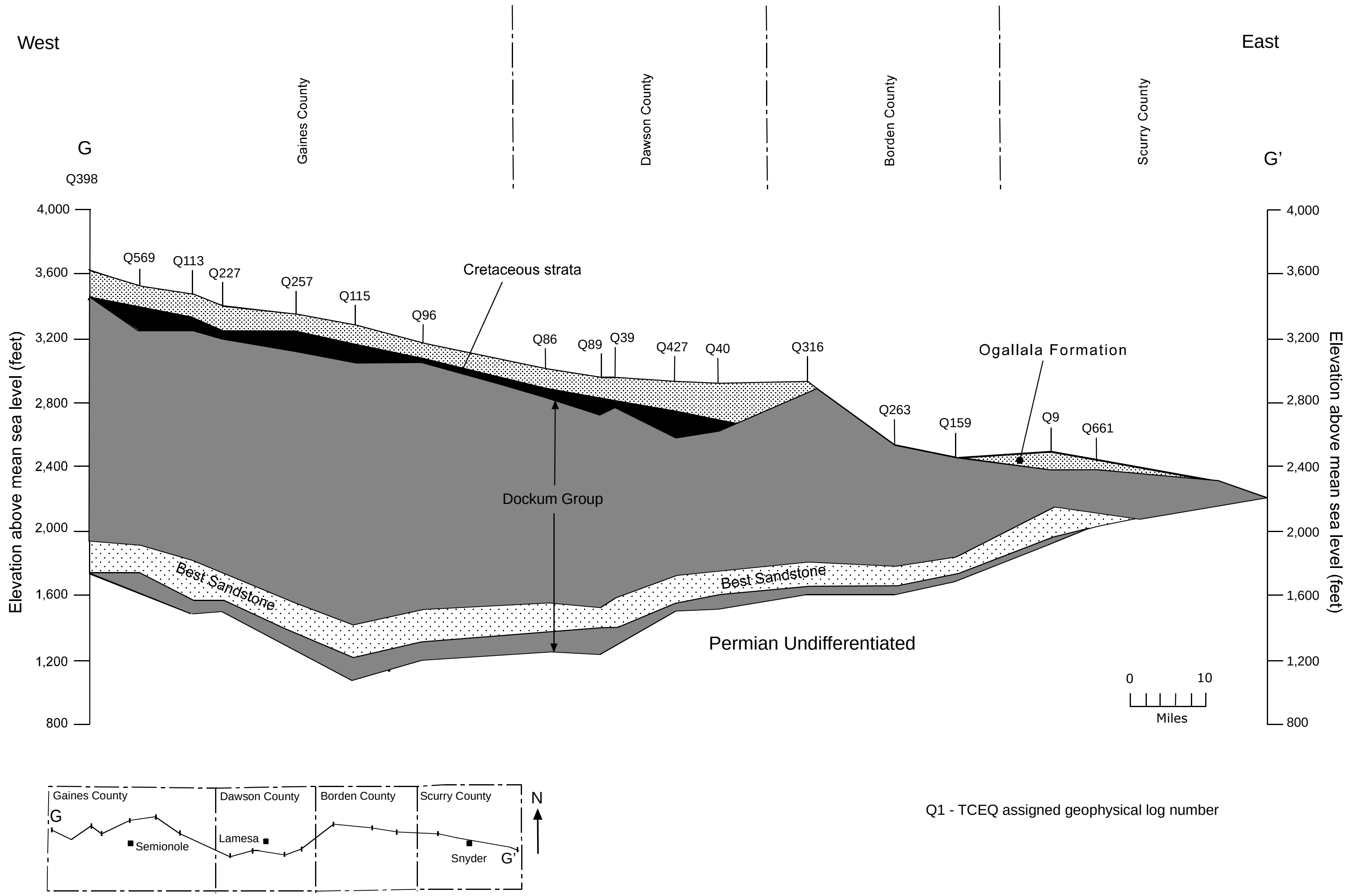

Figure 4-8. Geologic cross-section G-G'.

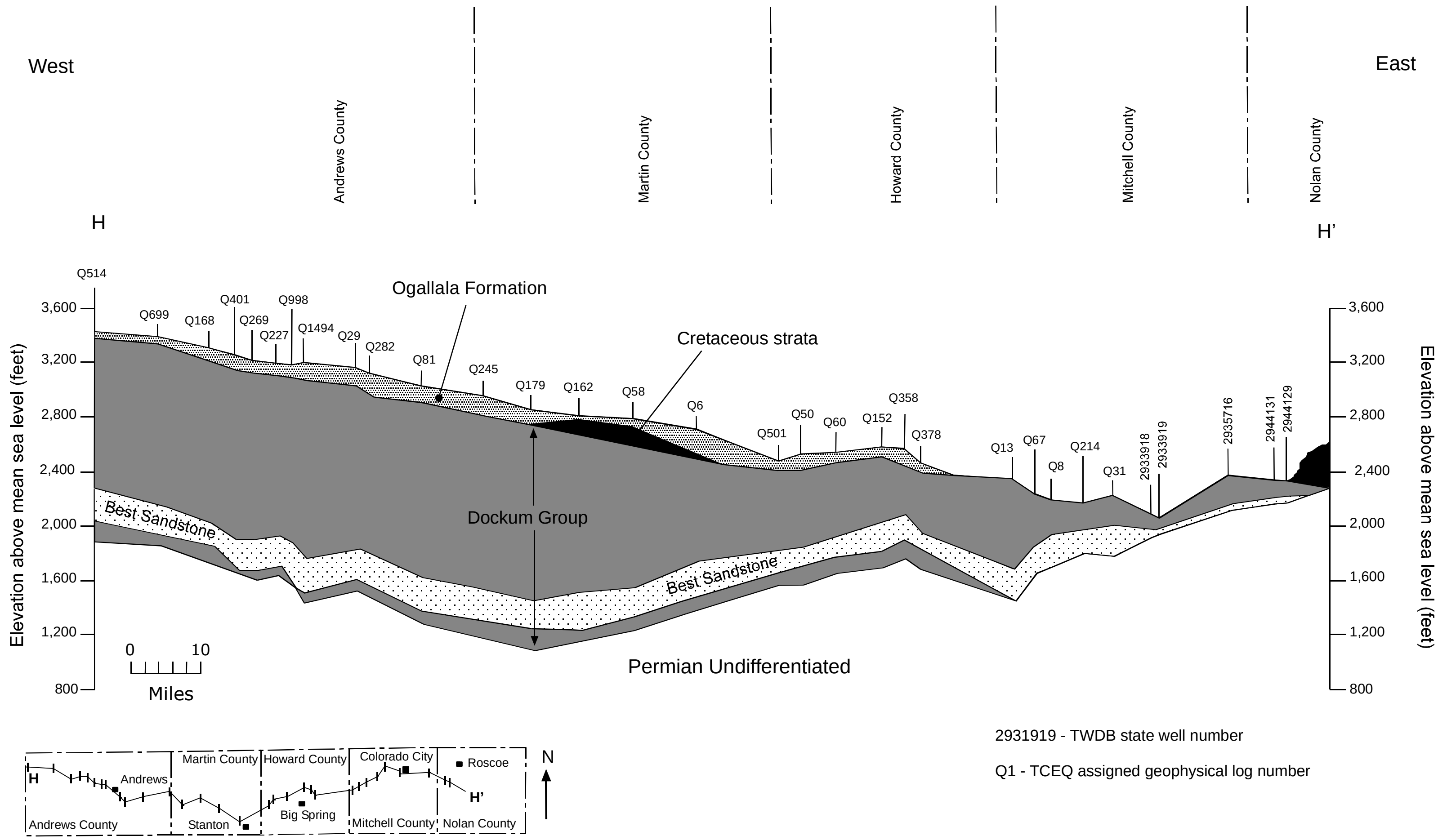

Figure 4-9. Geologic cross-section H-H'.

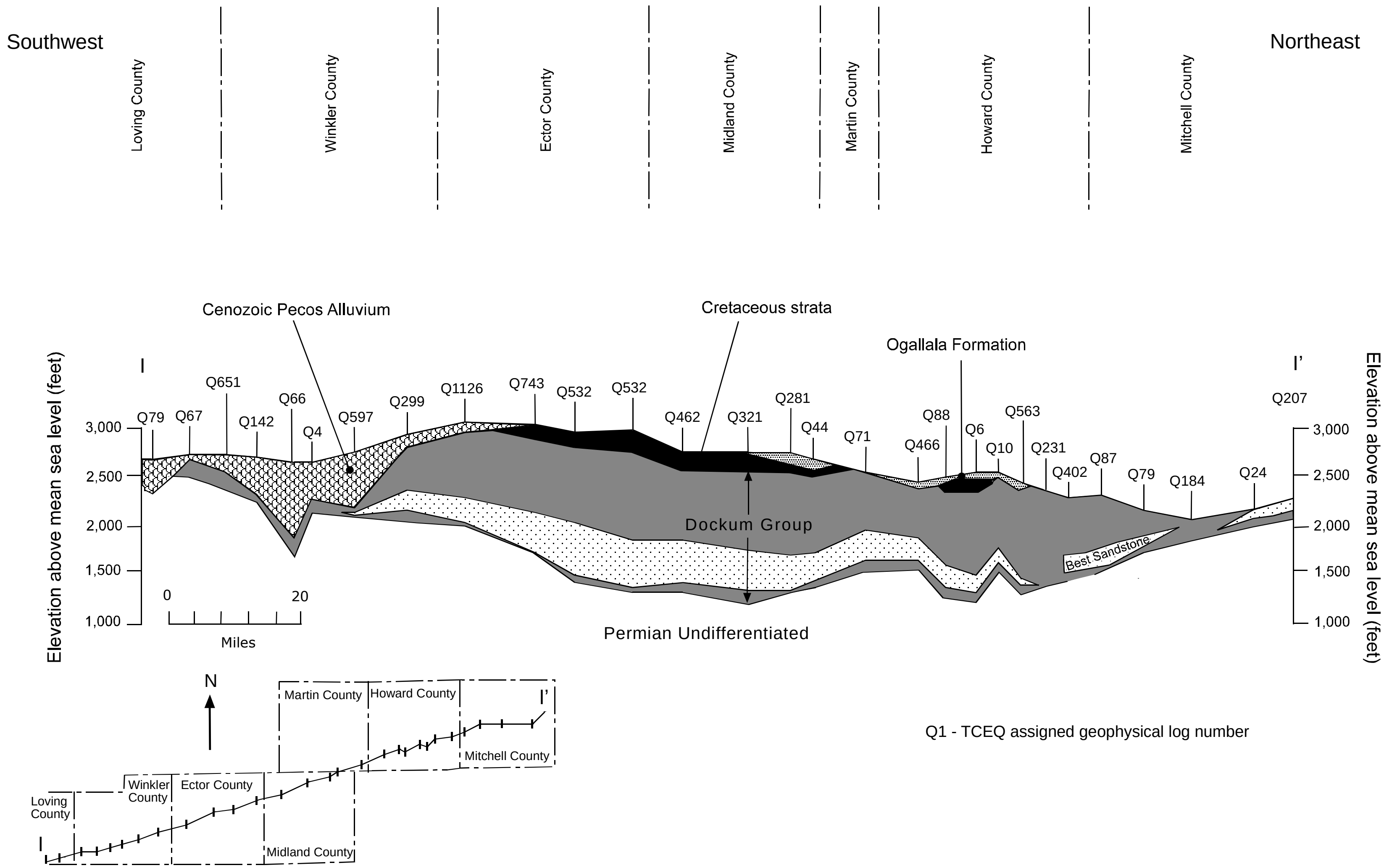

Figure 4-10. Geologic cross-section I-I’.

Table 4-1. Development of Upper Triassic Stratigraphic Nomenclature in Texas (modified from Lucas and Anderson, 1995; McGowen, and others, 1977, 1979).

<table>
<tr><th colspan="2">Cummins (1890)</th><th colspan="2">Gould (1907)</th><th colspan="2">Adams (1929)</th><th>Adkins (1932)</th><th colspan="2">Reeside and others (1957)</th><th colspan="2">McGowen and others (1977, 1979)</th><th colspan="3">Lucas and Anderson (1992, 1993, 1994, 1995)</th><th colspan="2">Lehman (1994a, 1994b)</th></tr>
<tr><td colspan="2">Not Recognized</td><td rowspan="5">Dockum Group</td><td rowspan="2">Trujillo Formation</td><td rowspan="5">Dockum Series</td><td>Chinle Formation</td><td>Chinle Formation</td><td>Not Described</td><td>Chinle Formation</td><td rowspan="5">Dockum Group</td><td rowspan="2">Upper</td><td rowspan="5">Chinle Group</td><td rowspan="5">Dockum Formation</td><td>Bull Canyon Member</td><td rowspan="5">Dockum Group</td><td>Cooper Canyon Formation</td></tr>
<tr><td rowspan="4"></td><td>Sandstone</td><td rowspan="4">Santa Rosa Sandstone</td><td>Trujillo Formation</td><td>Trujillo Formation</td><td>Santa Rosa Formation</td><td>Trujillo Member</td><td>Trujillo Sandstone</td></tr>
<tr><td rowspan="2">Red Clay</td><td rowspan="3">Tecovas Formation</td><td rowspan="2">Tecovas Formation</td><td rowspan="2">Tecovas Formation</td><td rowspan="2">Tecovas Formation</td><td rowspan="3">Lower</td><td>Tecovas Member</td><td rowspan="2">Tecovas Formation</td></tr>
<tr><td>Colorado City Member</td></tr>
<tr><td>Conglomerate</td><td>Camp Springs Conglomerate</td><td>Camp Springs Conglomerate</td><td>Camp Springs Conglomerate</td><td>Camp Springs Member</td><td>Santa Rosa Formation</td></tr>
</table>

discussion, see Lucas and Anderson, 1992, 1993, 1994; Lehman, 1994a, 1994b). Table 4-1 is a summary of the development of the stratigraphic nomenclature of the Dockum Group. Because our study is focused on groundwater resources, we have avoided the stratigraphic controversy and have retained the well established and widely accepted nomenclature of Dockum Group suggested by Lehman (1994a, 1994b) to describe the Triassic-age rocks.

Rocks of the Dockum Group are the only Triassic-age sediments exposed at the land surface in Texas. The formations within the Dockum Group (in ascending stratigraphic order) are: Santa Rosa Formation, Tecovas Formation, Trujillo Sandstone, and Cooper Canyon Formation (Lehman 1994a and 1994b in Table 4-1). 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. Traditionally, the base of the Dockum Group has been identified as a mudstone that is difficult to distinguish from older Permian sediments (McGowen and others, 1977, 1979; Granata, 1981). However, some older studies and more recent investigations describe the base of the Dockum Group as an extensive sandstone or conglomerate bed. The basal unit, called the Santa Rosa Formation, rests unconformably on Upper Permian red beds and can be as much as 130 feet thick (Lehman and others, 1992; Lehman, 1994a, 1994b; 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-foot-thick Trujillo Formation composed of massive crossbedded sandstones and conglomerates (Lehman, 1994a, 1994b). The Trujillo Formation, exposed in some of the outcrop areas, has been mapped along the Canadian River (Bureau of Economic Geology, 1969, 1983).

Gould (1907) recognized an additional mudstone unit above the Trujillo Formation. The upper beds of this unit consist of reddish-brown to orange mudstone, along with some siltstone, sandstone and conglomerate and are now known as the Cooper Canyon Formation (Lehman and others, 1992). Previously, these beds were referred to as the Chinle Formation or the Chinle Equivalent (Table 4-1).

The subsurface mapping of individual beds within the Dockum Group has not been entirely successful. The apparent discontinuity of many beds in the subsurface has precluded an accurate correlation of outcrop units or the mapping of their exact subsurface extent (McGowen and others, 1977; Granata, 1981). Geologic cross-sections (Figure 4-1 through 4-10) illustrate the general stratigraphy of the Dockum Group in the study area. Appendix A contains a list of wells with geophysical logs that we used to construct the cross-sections. The approximate elevations of the base and top of the Dockum Group are shown in figure 4-11 and 4-12, respectively.

4.2 Depositional Environment

McGowen and others (1977, 1979) and Granata (1981) described the Dockum Group as a 2,000-foot-thick sequence of sediments that accumulated in fluvial, deltaic, and lacustrine environments within a closed continental basin. On the basis of paleocurrent analysis, Lucas and Anderson (1992) concluded that sediments of the Dockum Group were mainly fluvial in origin and that the siltstones and mudstones were deposited on floodplains, interfluves, and in small

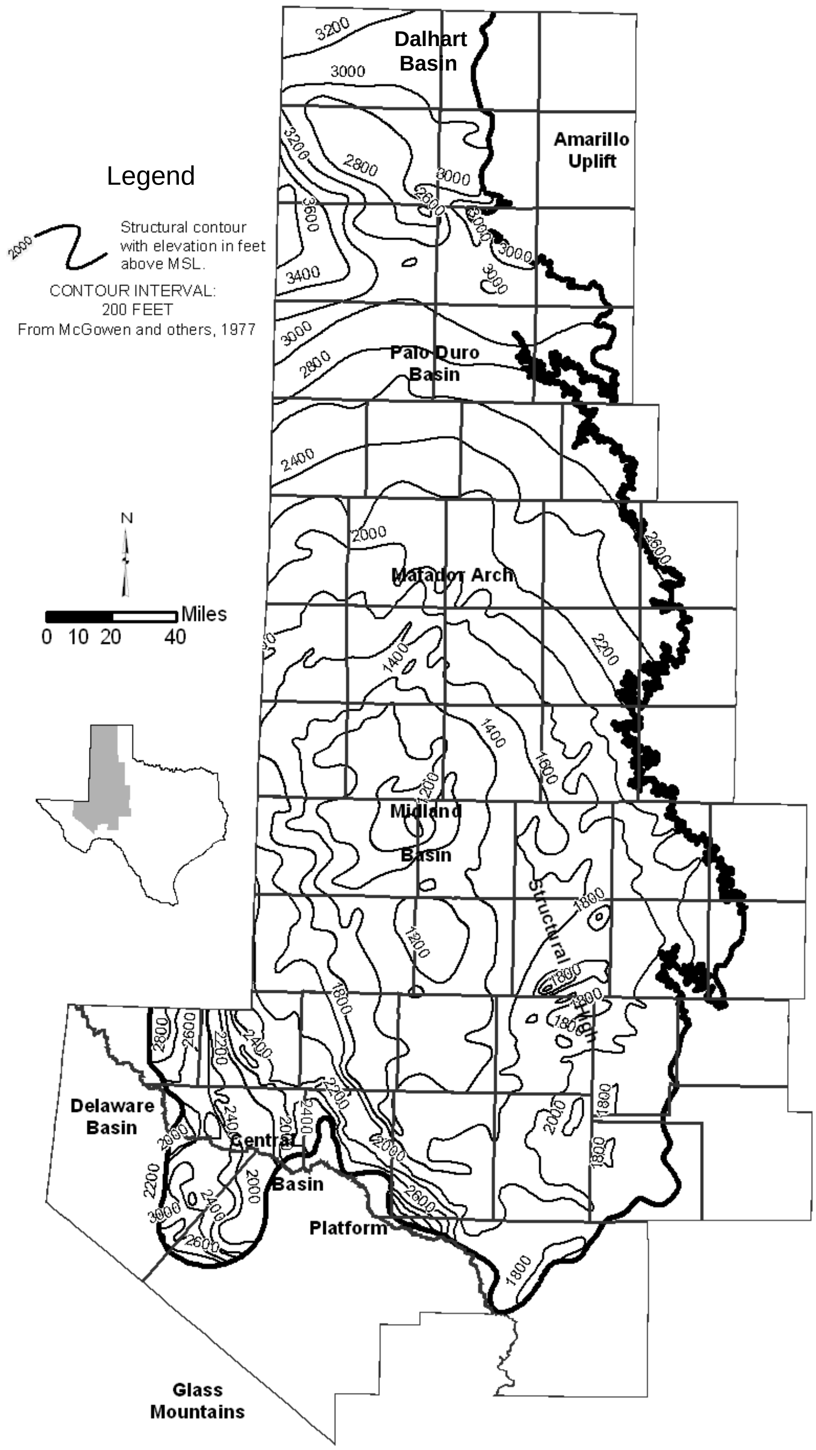

Figure 4-11. Approximate elevation of the bottom of the Dockum Group.

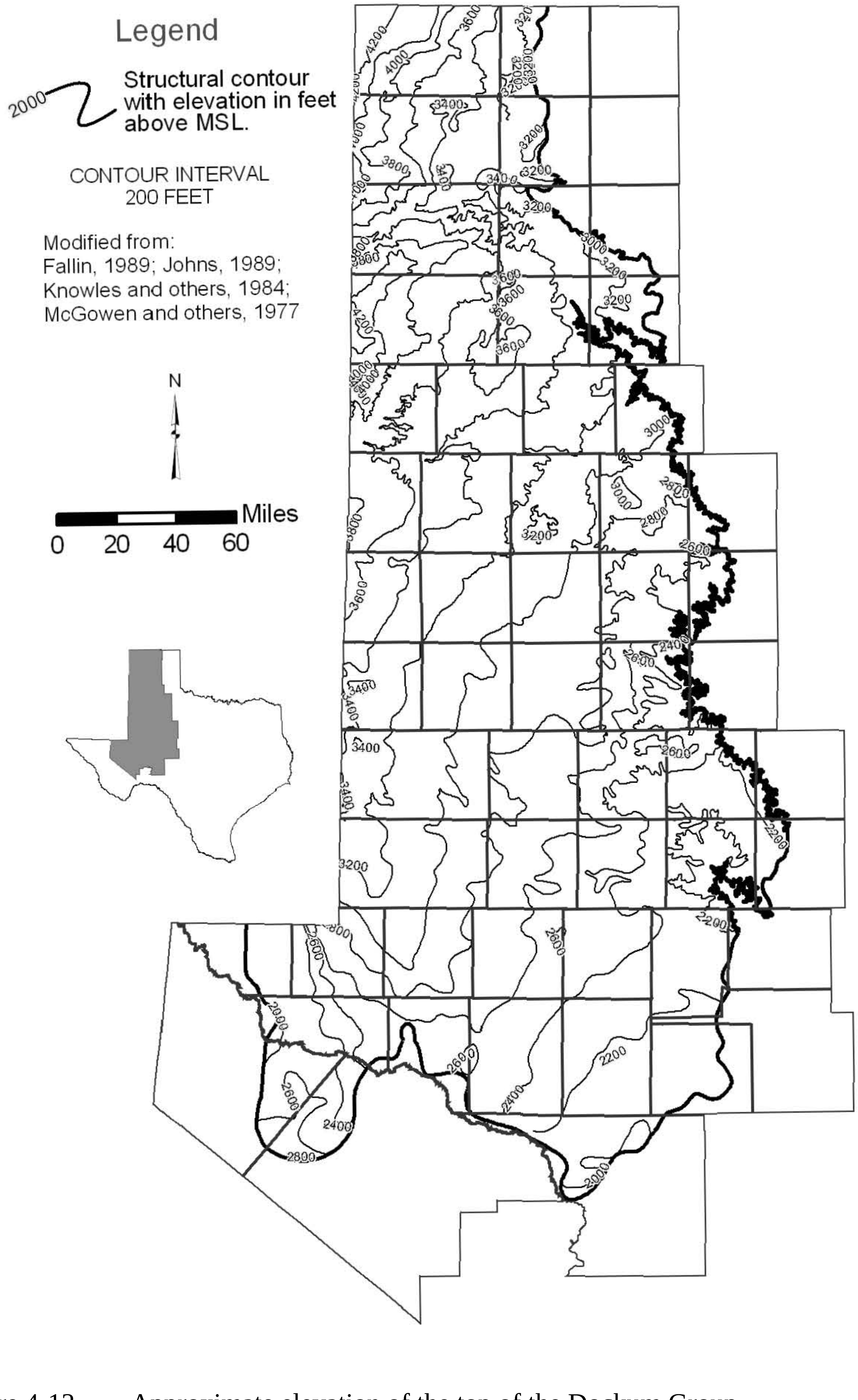

Figure 4-12. Approximate elevation of the top of the Dockum Group.

isolated ponds. The basin received sediments from all directions from the erosion of Paleozoic sedimentary source rocks exposed around the edges of the basin. Meandering, low-gradient streams traversed lowlands to the east and west, and higher gradient streams were present at the north and south ends of the basin.

On the basis of an analysis of detrital zircon grains in northwest Texas, Riggs and others (1996) suggested that early deposition of the Dockum Group (Santa Rosa Formation) was accomplished by a river system that flowed from Texas to Nevada during the Late Triassic.

4.3 Structure

The beds of the Dockum Group are essentially horizontal, with gentle dips toward the center of the structural basin whose axis trends approximately north-south. The dip varies considerably from location to location but is approximately 30 feet per mile (Rayner, 1965). Deposition of the Dockum Group sediments in the Triassic represents the final filling of a number of small adjoining, intracratonic basins that were active mainly in the Paleozoic (Granata, 1981). In Texas, these basins include the Midland basin in the south, the Palo Duro basin in the central region, and the Dalhart basin in the north (Figure 4-11, Fallin, 1989). The basins are separated by structural highs such as the Amarillo Uplift between the Dalhart and Palo Duro basins and the Matador Arch between the Palo Duro and Midland basins (Figure 4-11). The Central Basin Platform present at the southwest end of the Midland Basin separated the Midland Basin from the Delaware Basin to the west. The entire area over which the Dockum Group sediments were deposited has been referred to as the Dockum Basin (Granata, 1981).

The top of the Dockum Group is relatively flat (Figure 4-11) and reflects the final filling of the Dockum Basin and the effects of post-depositional erosion. The opening of the Gulf of Mexico in the Cenozoic tilted the entire region toward the southeast.

5.0 Water Levels and Regional Groundwater Flow

We used water-level information available in the TWDB database and from the USGS New Mexico district to construct an average water-level elevation map for the study area during the 1981 through 1996 time period (Figure 5-1). Water-level information from New Mexico was used primarily to constrain water-level contours in the Texas part of the Dockum aquifer. Groundwater flow in the Dockum aquifer is generally to the east and southeast (Figure 5-1). In Hartley and Oldham counties, groundwater flows locally toward the Canadian River. In Mitchell County, groundwater flows toward the Colorado River. Hydraulic gradients range from about 8 feet per mile in the central part of the aquifer to 37 feet per mile along the Canadian River. A relatively steep gradient of about 14 feet per mile is present in Cochran, Yoakum, and Gaines counties. The rate of groundwater flow ranges from about 0.002 feet per day in Terry County to 0.05 feet per day in Deaf Smith County. We determined these flow rates from hydraulic conductivities derived from aquifer tests, an assumed average aquifer porosity, and regional hydraulic gradients shown on water-level maps.

We also used the water-level information to construct hydrographs for 20 wells in the study area (Figure 5-2, 5-3, and 5-4). For convenience in discussing the hydrographs, we divided the study

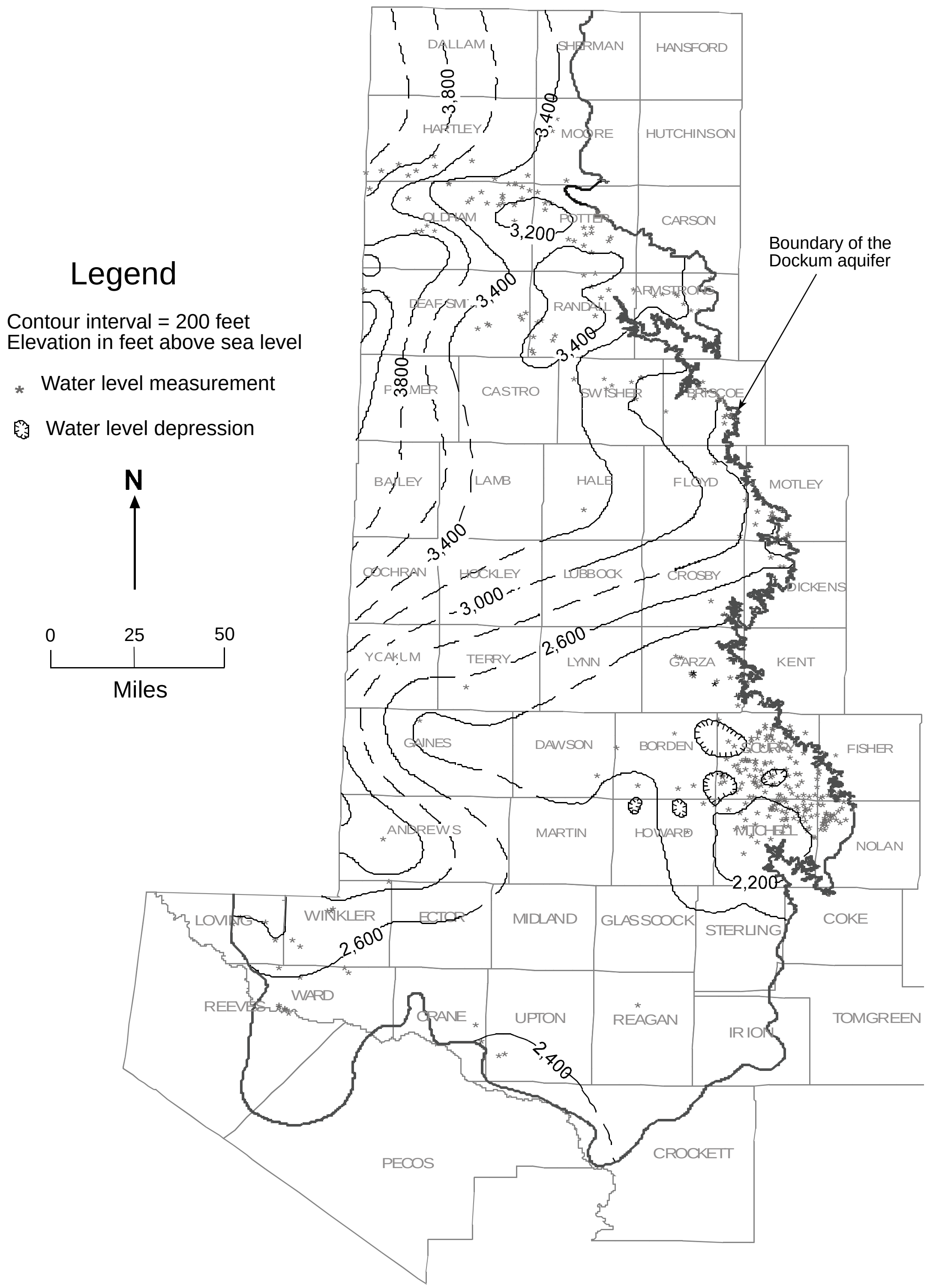

Figure 5-1. Approximate water level elevations in the Dockum aquifer, 1981 through 1996.

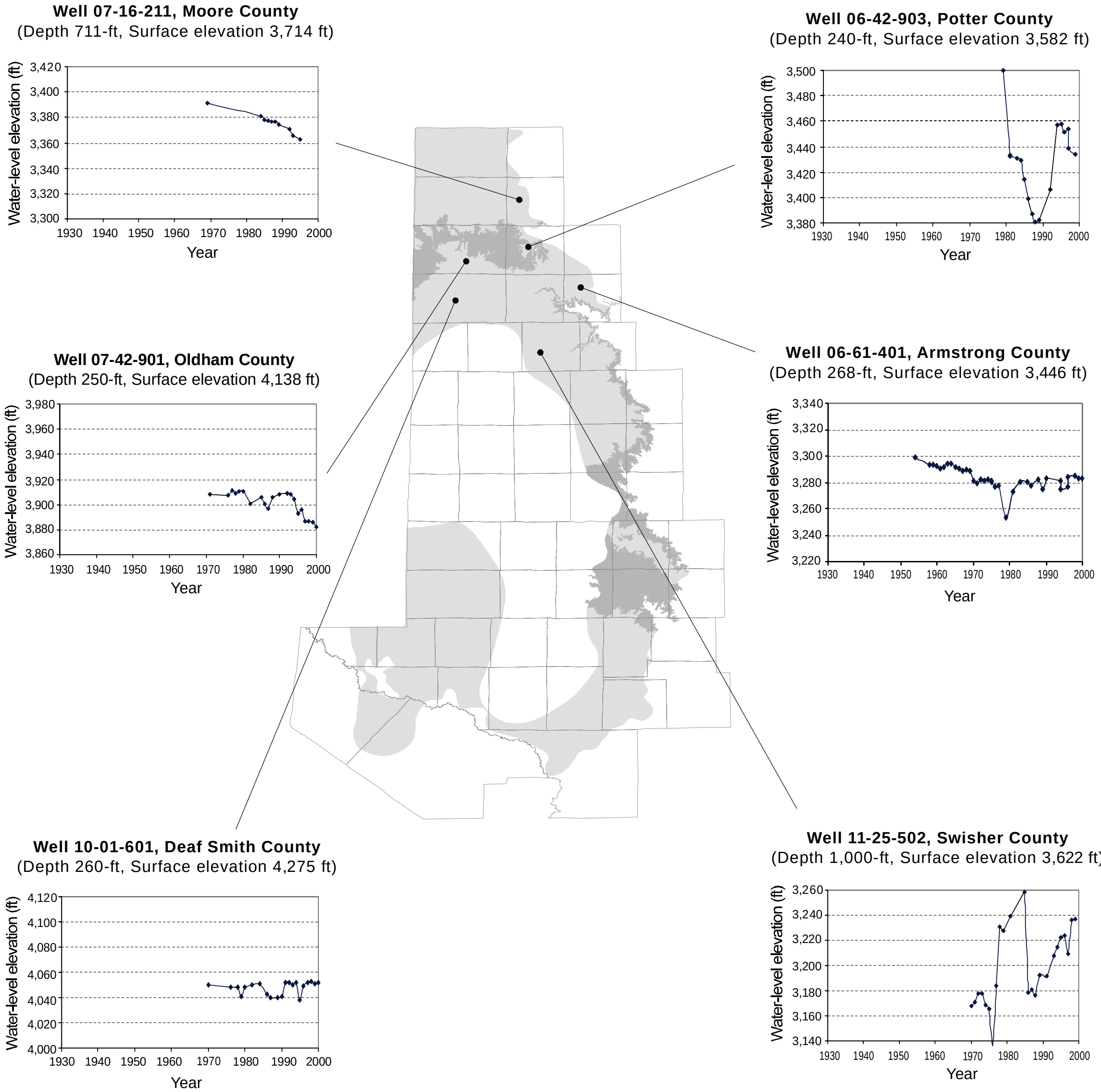

Figure 5-2. Selected hydrographs from the northern part of the study area.

area into three areas: a northern area (Figure 5-2), a central area (Figure 5-3), and a southern area (Figure 5-4).

Overall, the hydrographs show that water levels in many parts of the aquifer have fluctuated over time. The fluctuations were not uniform everywhere. For example, in the northern part of the study area, water levels in Moore, Potter, and Armstrong counties generally declined from 1981 through 1996. The largest recorded decline (110 feet) was in well 06-42-903 in Potter County (Figure 5-2). In other areas, the water level remained relatively stable (Deaf Smith County),

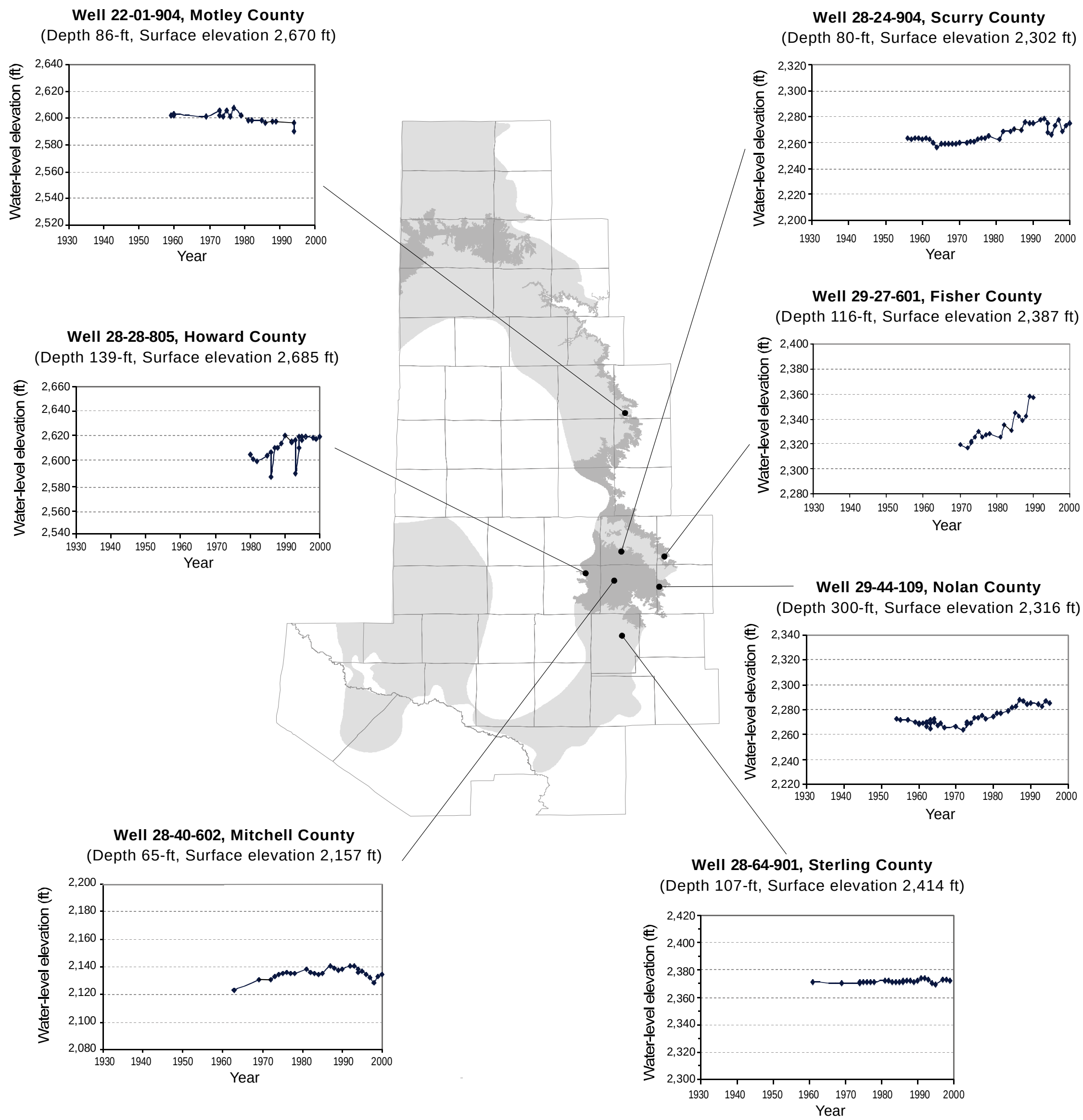

Figure 5-3. Selected hydrographs from the central part of the study area.

declined slightly (Oldham County), or even rose (Swisher County).In the central part of the study area (Howard, Mitchell, Scurry, Nolan, Fisher, and Sterling counties) the hydrographs generally show an increase in water levels over much of the area (Figure 5-3). The largest increase (almost 45 feet) was recorded in well 29-27-601 in Fisher County (Figure 5-3). This well and others that had a rise in water level are located on or near the outcrop of the Dockum aquifer and reflect increased recharge, reduced pumpage, or both. The Sterling County hydrograph (well 28-64-901) is flat, suggesting that the aquifer was not being used much or that it was receiving recharge from the overlying Cretaceous aquifer. The drought of the late 1950s is clearly evident in the Nolan County hydrograph (Figure 5-3), which shows a fall in water level in the late 1960’s and early 1970’s presumably in response to increased pumpage from irrigation wells or decreased recharge

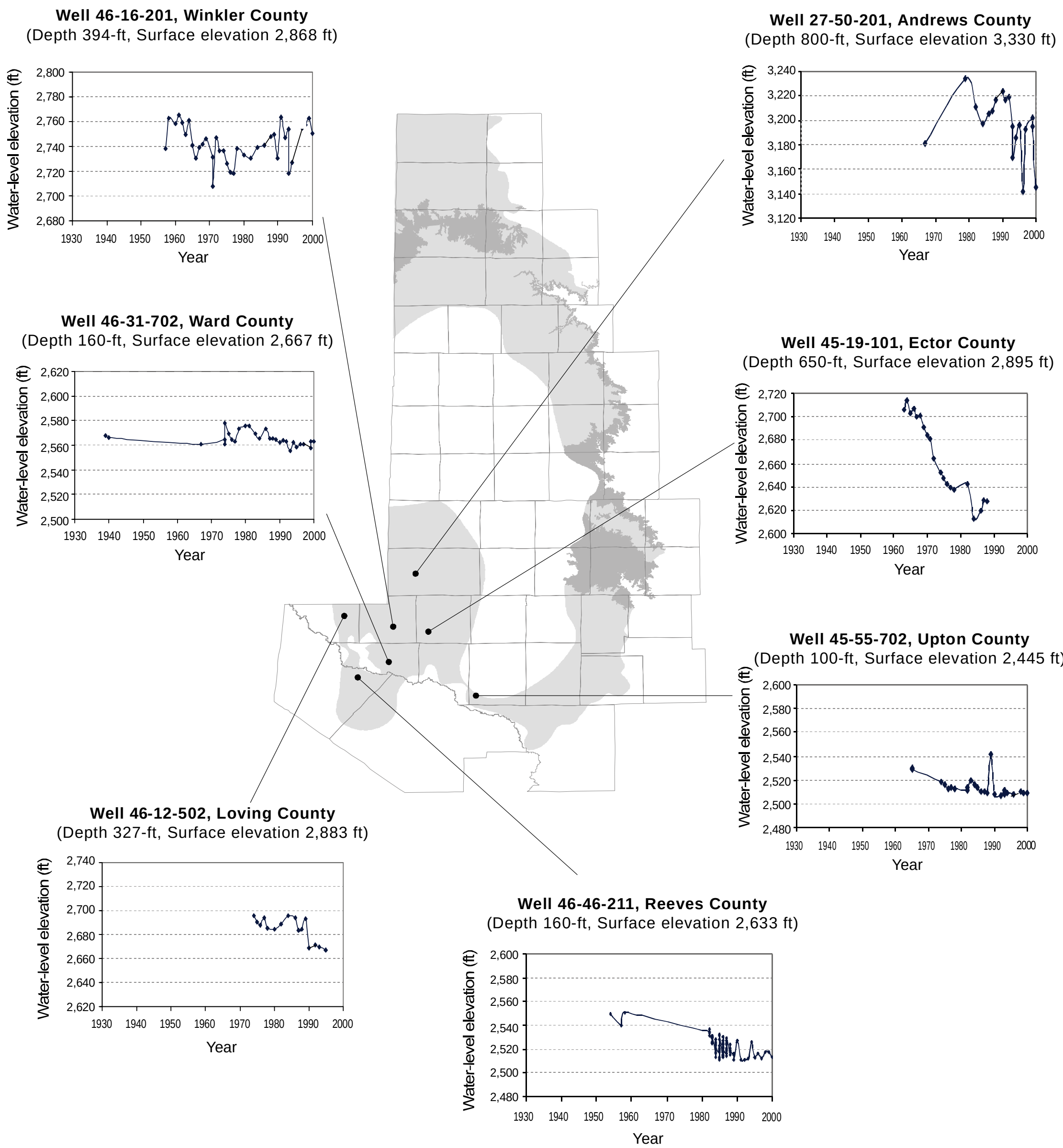

Figure 5-4. Selected hydrographs from the southern part of the study area.

to the aquifer. Hydrographs of wells in the south part of the study area (Andrews, Ector, Upton, Loving, Reeves, Ward, and Winkler counties) show a variety of water-level fluctuations (Figure 5-4). Hydrographs of wells in Loving, Ector, and Reeves counties show a distinct decline in the water table, whereas that from Ward County shows relatively stable water levels or only small declines. The most significant water-level decline (almost 85 feet) occurred in well 28-39-401 in Ector County (Figure 5-4). This decline was most likely the result of pumping from a nearby municipal water-supply well.

Where overlain by younger formations, the Dockum aquifer is typically under confined conditions. Within the Dockum Group itself, mudstone units (especially the thick upper sequence within the center of the aquifer basin) also act as confining beds. The aquifer is partially confined in areas where the Dockum Group sediments are exposed at the surface. The aquifer is also partially confined in parts of the Pecos River valley (Loving, Reeves, Ward and Winkler counties) where Dockum Group sandstones are in contact with the Cenozoic Pecos Alluvium. Where exposed at land surface, the Dockum aquifer is typically under unconfined conditions.

5.1 Recharge

The Dockum aquifer is recharged by precipitation over areas where Dockum Group sediments are exposed at the land surface (Figure 2-2). Shamburger (1967) suggested that substantial recharge also occurred along stream channels and tributaries of several creeks, such as Champion Creek and the South Fork Champion Creek in Nolan County, where the basal conglomerate and sandstone units are exposed (Lucas and Anderson, 1993). Shamburger (1967) reported that one well in Nolan County was capable of producing 15 to 20 percent more water after sustained heavy runoff into the South Fork Champion Creek.

Groundwater in the confined parts of the Dockum aquifer in Texas most likely originated as precipitation that fell on outcrops in eastern New Mexico. This recharge ceased when the Pecos River and Canadian River valleys were incised during the Pleistocene between the present-day Dockum aquifer in Texas and the paleo-recharge areas to the west (Dutton and Simpkins, 1986; Figure 5-5).

Soils on the outcrop of the Dockum aquifer have a major effect on recharge to the aquifer. Soils that have formed on the outcrop of the Dockum Group sediments belong to hydrologic groups B, C, and D (soils that are classified on the basis of their water intake at the end of long-duration storms). A vast majority of the soils are included in Group B, which is characterized by moderate infiltration rates when saturated. Some soils on the outcrop belong to Group C which is characterized by slow infiltration rates when saturated. The Group D soils, which have the second-largest areal extent on the outcrop, are typically heavy clay soils exhibiting a high shrink-swell potential and a very slow infiltration rate when saturated. Areas that have Group B soils near subsurface sandstone units provide the greatest recharge potential to the aquifer.

The Dockum aquifer is also recharged by upward leakage from the underlying Permian rocks, although in the Palo Duro Basin the water movement is downward because the hydraulic head in the Dockum aquifer is almost 1,800 feet higher than it is in the underlying Permian brine 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 rocks, 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 ($Ca\text{-}HCO_3$)

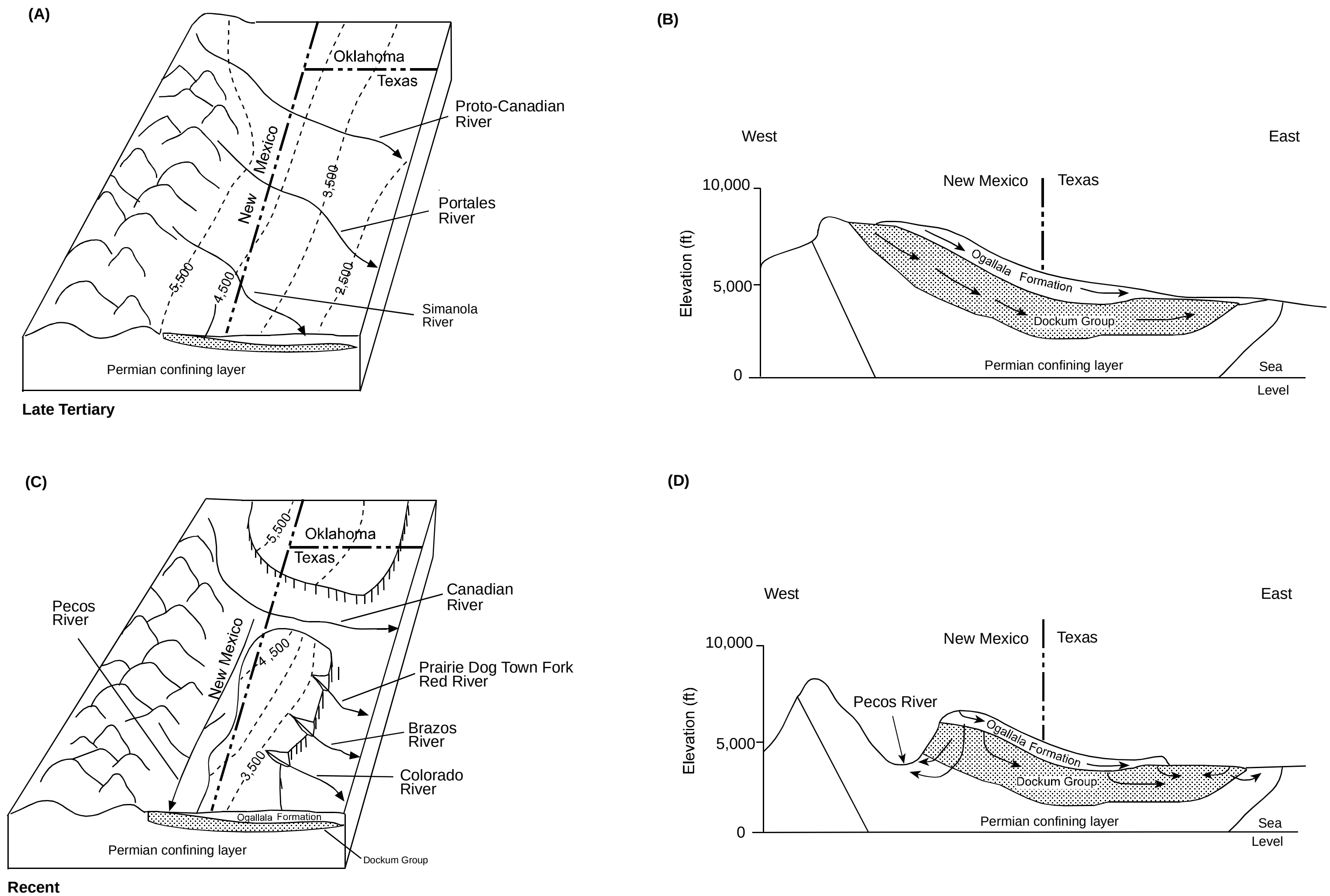

Figure 5-5. Hypothetical regional flow paths of groundwater in the Dockum aquifer. Before hydrologic divides developed, groundwater flowed from an area in eastern New Mexico downdip into the confined portions of the aquifer in Texas (A and B). After divides formed by incision of rivers (C and D), groundwater flow into Texas from New Mexico was essentially cut off(modified from Gustavson and Finley, 1985; Dutton and Simpkins, 1986). Contours are in feet above mean sea level.

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.

A combination of groundwater divides and thick, relatively impermeable mudstones (Cooper Canyon Formation) above the sandstone layers in the center of the basin prevents the aquifer from receiving direct recharge from surface precipitation. We estimate that the annual recharge to the entire aquifer is approximately 31,000 acre-feet. This estimate was derived for outcrops and other areas in contact with overlying aquifers.

5.2 Aquifer Properties

The properties of an aquifer are typically described using terms such as well yield, specific capacity, transmissivity, hydraulic conductivity and storativity (Driscoll, 1986). Well yield is defined as the volume of water discharged per unit time from a well either by pumping or from free flow. It is typically measured in gallons per minute (gpm). Specific capacity is the well yield per unit drawdown in the water level when the well is pumped. The specific capacity of a well, expressed as gallons of water per minute per foot of drawdown, can be a good indicator of the water-producing ability of an aquifer. Aquifers with high specific capacities are generally productive aquifers whereas those that have low specific capacities are not as productive.

Transmissivity is a term that describes the ease with which water can move through an aquifer. Transmissivity specifically describes the volume of water that will move through a vertical strip of the aquifer one unit wide, under a unit hydraulic gradient, for a unit time. Storativity (or storage coefficient) represents the volume of water released from or taken into storage per unit of aquifer storage area per unit change in head. The storativity of an unconfined aquifer corresponds to its specific yield which is the fraction of water that can be drained by gravity for a unit volume of aquifer. In confined aquifers, storativity is the result of compression of the aquifer and expansion of the confined water when pressure is reduced during pumping.

Table 5-1 is a compilation of Dockum aquifer properties from various sources including the TWDB Well Information/Ground Water Data database and published literature. Mean well yields by county ranged from 6 gpm in Howard County to 770 gpm in Moore County with individual yields ranging from 0.5 gpm in Mitchell County to 2,500 gpm in Winkler County (Table 5-1, Figure 5-6, and Appendix III).

Specific capacity tests performed on 86 wells completed in the Dockum aquifer indicate that mean specific capacities by county ranged from 0.14 gallons per minute per foot (gpm/ft) in Garza County to 25 gpm/ft in Reeves County (Table 5-2). The mean specific capacity from all tests was 3.84 gpm/ft. The highest specific capacity within a county ranged from 0.19 gpm/ft in Garza County to 37 gpm/ft in Reeves County (Table 5-2).

We also performed 21 pumping tests in nine counties to determine aquifer properties including transmissivity which was calculated using standard techniques (i.e., Theis, 1935; Cooper and Jacob, 1946). Transmissivity ranged from about 48 square feet per day (ft^2/d) in Upton County to 4,600 ft^2/d in Winkler County (Table 5-1). The mean transmissivity from all tests was

Table 5-1. Summary of Dockum aquifer properties.

County	TWDB Well No.	Test Date	Screened Interval(s) (feet bgs)	Yield (gpm)	Transmissivity (gpd/ft)	Transmissivity (ft^2/d)	Storage Coefficient	Type of Test	Source of Data
Deaf Smith	10-13-503	12/01/1966	683-944	1,400	14,800	1,978	--	D	1
		12/04/1966			10,700	1,430		R	1
	10-14-202	01/16/1959	600-776	788	22,000	2,941	1.0×10^{-4}	M	2,4
Mitchell	29-34-709	03/1963	--	--	7,900	1,056	4.5×10^{-5}	D	8
		11/05/1963			7,000	936	5.5×10^{-5}	D	8
	29-34-714	03/1963	--	75	4,400	588	--	D	8
		11/05/1963		66	4,700	628		D	8
	29-34-716	03/1963	--	--	7,700	1,029	6.5×10^{-5}	D	8
		03/1963			6,100	815	9.6×10^{-5}	R	8
		11/05/1963			6,500	869	4.4×10^{-5}	D	8
	29-35-437[A]	11/21/1963	120-195 205-273	170	11,270	1,506	1.3×10^{-4}	D	6,8
	29-35-712	01/09/1964	--	--	5,856	783	4.4×10^{-4}	D	7,9
		01/10/1964			7,760	1,037	4.4×10^{-4}	R	7,9
	29-35-713	01/09/1964	--	245	3,680	492	--	D	8
	29-43-403	--	--	70	12,300	1,644	1.2×10^{-4}		6,8
Motley	22-01-201	10/26/1968	200-282 287-300	321	11,700	1,564	--	R	7,8
Potter	06-42-601	07/25/1958	140-170	--	480	64	--	R	8
Scurry	28-31-301	07/22/1970	440-450 500-510 520-530 545-555	608	8,000	1,069	--	D	8
		07/23/1970			5,900	789		R	8

NOTES: * = Open hole

- Well numbers used in previous reports and subsequently renumbered: **A**. 29-35-106, **B**. D-291, **C**. D-293, **E**. D-299, **F**. D-279.
- Types of tests: **D** = Drawdown, **M** = Average Value, **R** = Recovery, **SD** = Step Drawdown.
- Sources of data: **1**. Dutton and Simpkins, 1986; **2**. Fink, 1963; **3**. Garza and Wesselman, 1959; **4**. Rayner, 1963; **5**. Robotham et al., 1985; **6**. Shamburger, 1967; **7**. Smith, 1973; **8**. TWDB Central Records; **9**. White, 1968.

gpm = gallons per minute
bgs = below ground surface
gpd/ft = gallons per day per foot

Table 5-1. Summary of Dockum aquifer properties (continued).

County	TWDB Well No.	Test Date	Screened Interval (s) (feet bgs)	Yield (gpm)	Transmissivity (gpd/ft)	Transmissivity (ft^2/d)	Storage Coefficient	Type of Test	Source of Data
Swisher	11-26-611	07/24/1967	620-820	2,000	15,600	2,085	--	D	1
		07/24/1967			28,800	3,850		SD	
Terry	27-05-204	02/19/1985	1833-1853	74.9	1,533	205	--	D	5
		02/19/1985	1873-1893 1903-1993		1,081			R	
	27-05-205	02/26/1985	1733-1793	72.2	866	116	--	D	5
		02/26/1985	1813-1833 1853-1903		1,199			R	
Upton	45-46-603	03/08/1966	428-490	36	360	48	--	D	9
Winkler	46-16-104[B]	04/27/1957	--	305	25,000	3,342	--	R	3
		07/26/1957		--	24,000	3,208		D	
		07/27/1957		--	24,000	3,208		R	
	46-16-130[C]	07/26/1957	--	--	25,000	3,342	2.9×10^{-4}	D	3
		07/27/1957			24,000	3,208	2.5×10^{-4}	R	
	46-16-201[D]	07/26/1957	265-364*	1,875	37,000	4,646	--	R	3
	46-16-101[E]	08/18/1957	230-405*	1,200	12,000	1,604	--	R	3
	46-16-120[F]	08/17/1957	274-700*	--	13,000	1,738	2.5×10^{-4}	D	3
		08/18/1957			13,000	1,738	2.4×10^{-4}	R	

NOTES: * = Open hole

- Well numbers used in previous reports and subsequently renumbered: **A**. 29-35-106, **B**. D-291, **C**. D-293, **E**. D-299, **F**. D-279.
- Types of tests: **D** = Drawdown, **M** = Average Value, **R** = Recovery, **SD** = Step Drawdown.
- Sources of data: **1**. Dutton and Simpkins, 1986; **2**. Fink, 1963; **3**. Garza and Wesselman, 1959; **4**. Rayner, 1963; **5**. Robotham et al., 1985; **6**. Shamburger, 1967; **7**. Smith, 1973; **8**. TWDB Central Records; **9**. White, 1968.

gpm = gallons per minute
bgs = below ground surface
gpd/ft = gallons per day per foot

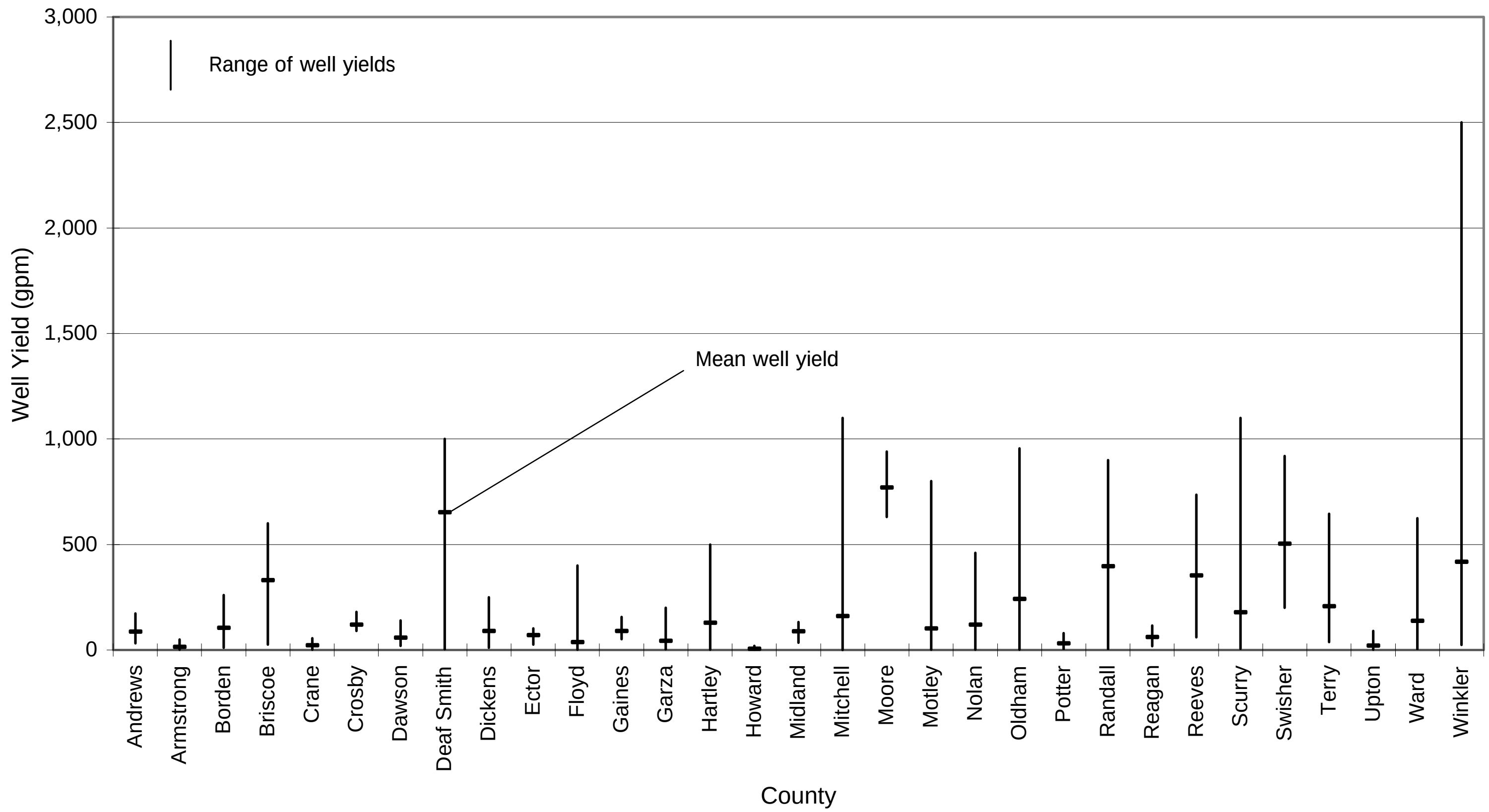

Figure 5-6. Range of well yields in the Dockum aquifer by county.

Table 5-2. Summary of Specific Capacities of Wells in the Dockum Aquifer (from TWDB Reports).

County	Specific Capacity (gpm/ft) Maximum	Minimum	Mean	Number of Records
Andrews	0.76	0.76	0.76	1
Armstrong	2.8	0.60	1.7	2
Borden	2.6	0.203	0.82	7
Crosby	2.3	1.8	2.0	2
Deaf Smith	12.4	0.02	8	3
Dickens	7.0	1.3	4.2	4
Gaines	0.579	0.442	0.511	2
Garza	0.19	0.055	0.14	3
Martin	0.42	0.42	0.42	1
Mitchell	3.6	0.30	1.2	14
Moore	11	7.7	9.5	2
Motley	8.2	1.8	5.5	3
Nolan	2.0	0.38	1.0	6
Oldham	3.5	0.3	2	7
Potter	0.78	0.78	0.78	1
Randall	9.00	4.32	6.66	2
Reeves	37	13	25	2
Scurry	6.1	0.33	2.8	18
Swisher	1.93	1.93	1.93	1
Upton	0.307	0.307	0.307	1
Winkler	17.1	.13	5.3	4

NOTE: gpm/ft = gallons per minute per foot

approximately 1,500 ft^2/d. The Winkler County pumping test was performed on the City of Kermit's municipal wells, which are completed in the Santa Rosa Formation that was described by Garza and Wesselman (1959) as a massive sandstone unit of limited areal extent. Storativity values ranged from 4.4×10^{-5} in Mitchell County to 2.9×10^{-4} in Winkler County (Table 5-1). The mean storativity from all aquifer tests conducted in the study area was 1.9×10^{-4}. The low storativities suggest that the Dockum aquifer is confined to partly confined in the test areas. The above parameters suggest that the aquifer may not be able to provide large quantities of water.

5.3 Chemical Quality

Groundwater in the Dockum aquifer is generally 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 that are present around the fringes of the aquifer to brine (TDS greater than 10,000 mg/l) in the confined parts of the aquifer (Figure 5-7). TDS concentrations also tend to increase with depth and range from 5,000 mg/l to more than 60,000 mg/l (Figure 5-8 and Appendix IV) in the deepest parts of the aquifer. 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 (Figure 5-9 and Appendix VII). The mean hardness value for the entire study area is approximately 470 mg/l.

In the northern and northeastern counties of the study area, the groundwater is composed of mixed cations and HCO_3^- type water (Figure 5-10a and 5-10b). In the central part of the study area (Andrews, Dawson, Gaines, Hockley, and Terry counties), the groundwater is dominated by $Na^+ + K^+$ and $Cl^- + SO_4^{2+}$ (Figure 5-10). The eastern outcrop area consists of $Ca^{2+} + Mg^{2+}$ and mixed-anion-type water (Figure 5-10d). The seven groundwater samples that we collected from an area near the Edwards-Trinity (Plateau) aquifer in 1995 and 1996 do not show a characteristic signature (Figure 5-10e). Where overlain by the Cenozoic Pecos Alluvium, groundwater in the Dockum aquifer is characterized by $Ca^{2+} + Mg^{2+}$ and $SO_4^{2-} + Cl^-$ rich waters (Figure 5-10f). A more detailed listing of the major cations and anions detected in the groundwater samples is available in Appendices V and VI, respectively.

One of the primary contaminants of concern in the study area is nitrate. The maximum contaminant level (MCL) for nitrate (measured as nitrogen) is 10 mg/l. Groundwater samples obtained from the study area between 1981 and 1996 indicate that nitrate concentrations were higher than their MCL in counties where the Dockum aquifer is either exposed at the surface or is in hydrologic communication with an overlying aquifer such as the Cenozoic Pecos Alluvium or the Edwards-Trinity (Plateau) aquifer. In these areas, the likely sources of nitrate are livestock waste, agricultural fertilizers, and old cesspools.

The radiological constituents for which we tested groundwater samples included gross alpha, gross beta, radium-226, and radium-228 (Table 5-3). The MCL established by the EPA for gross-alpha particle activity limit is 15 picoCuries per liter (piC/l). The MCL for combined radium-226 and radium-228 is 5 piC/l. Some areas of the Dockum aquifer contained radium-226 and radium-228 in concentrations greater than 5 piC/l (Table 5-4). The occurrence of uranium minerals in the Dockum Group has been recognized for years (McGowen and others, 1977) and is the source of the high concentrations of radium-226 and radium-228 detected in groundwater samples. Radium-226 and radium-228 are daughter products of the various uranium decay series.

Other constituents that we tested for in the groundwater samples included antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, and thallium. The concentrations of arsenic, barium, chromium, and nickel were below their respective MCLs in all of the samples that were analyzed. However, the detection limit for some of the analyses was higher than the MCL. Therefore, it is possible that some elements could have been present at concentrations above their MCLs but were not detected because of the elevated detection limits. The concentrations of antimony, beryllium, cadmium, lead, mercury, selenium, and thallium exceeded their respective MCLs in several counties (Table 5-4).

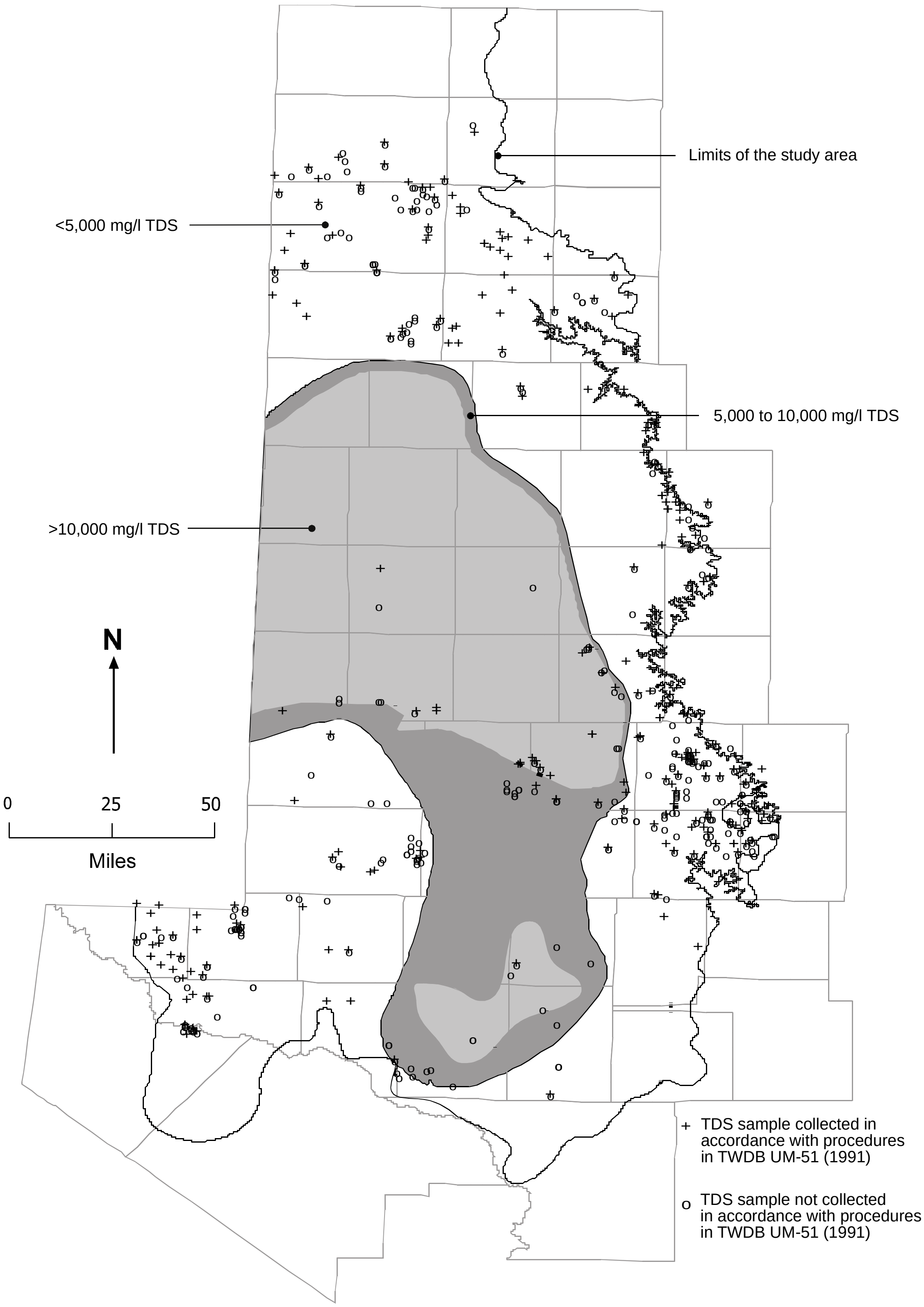

Figure 5-7. Distribution of total dissolved solids (TDS) in the Dockum aquifer, 1981 through 1996 (TWDB, 1997)

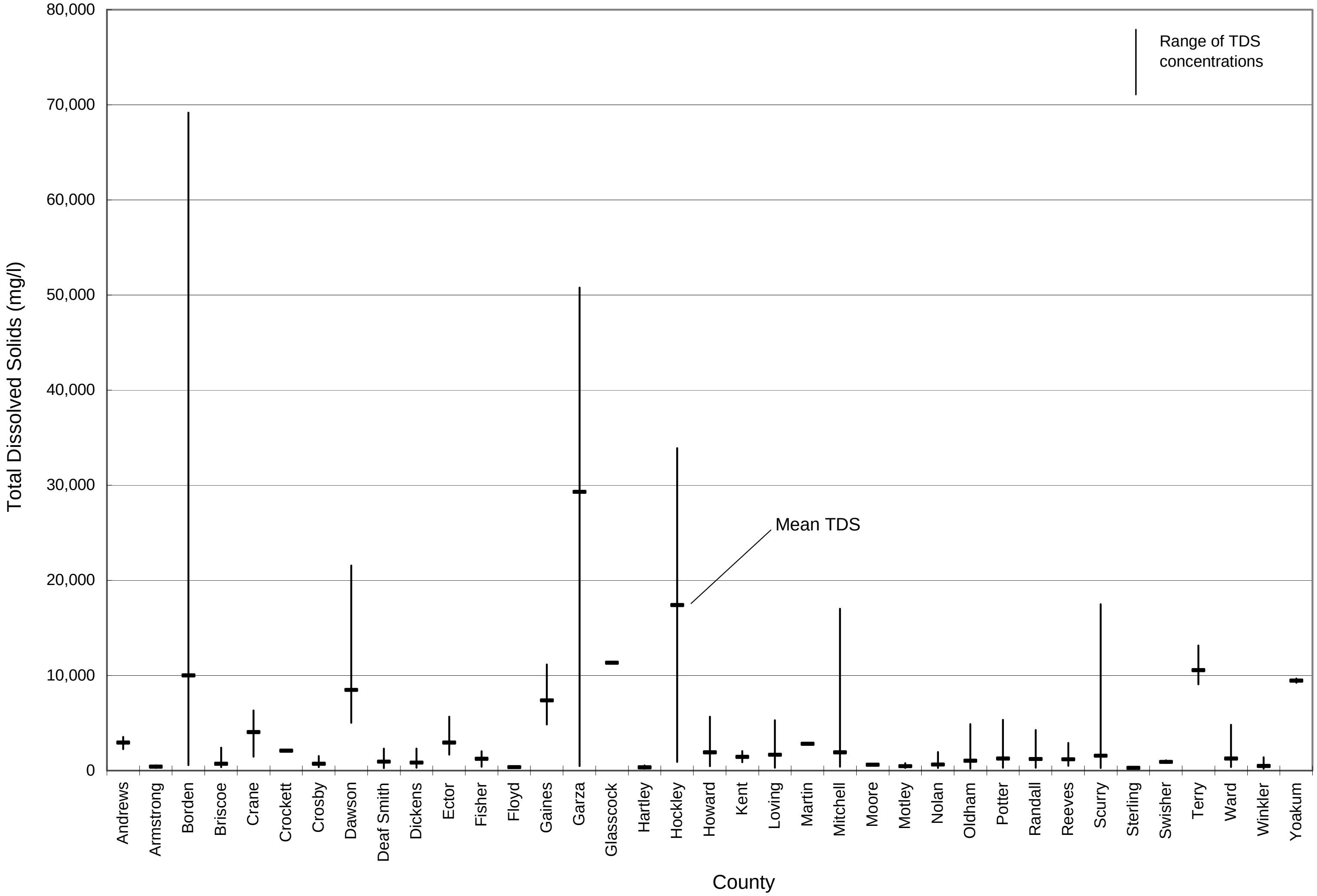

Figure 5-8. Concentrations of total dissolved solids (TDS) detected in the Dockum aquifer water samples 1981 through 1996.

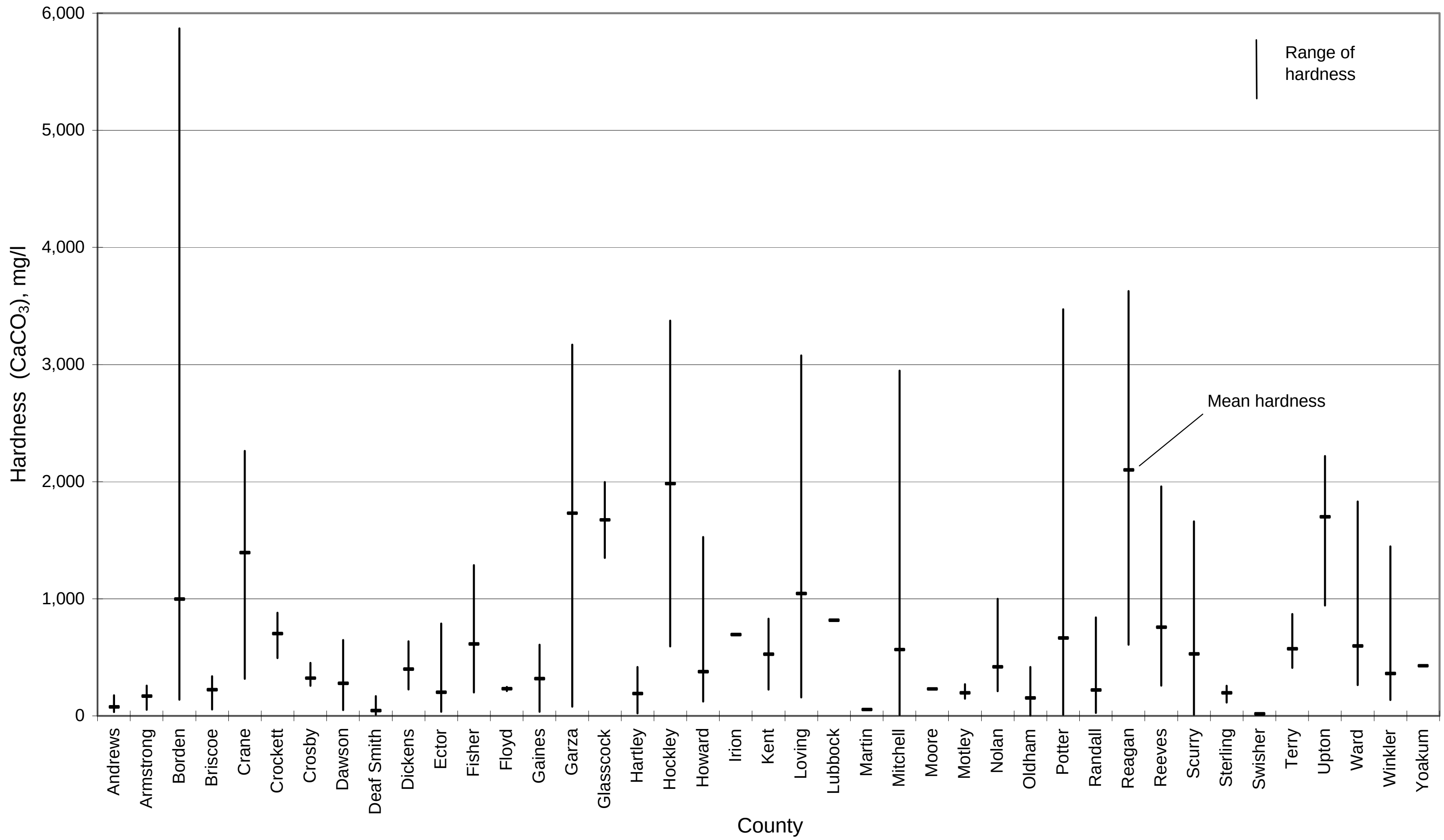

Figure 5-9. Range of hardness in groundwater samples obtained from the Dockum aquifer, 1981through1996.

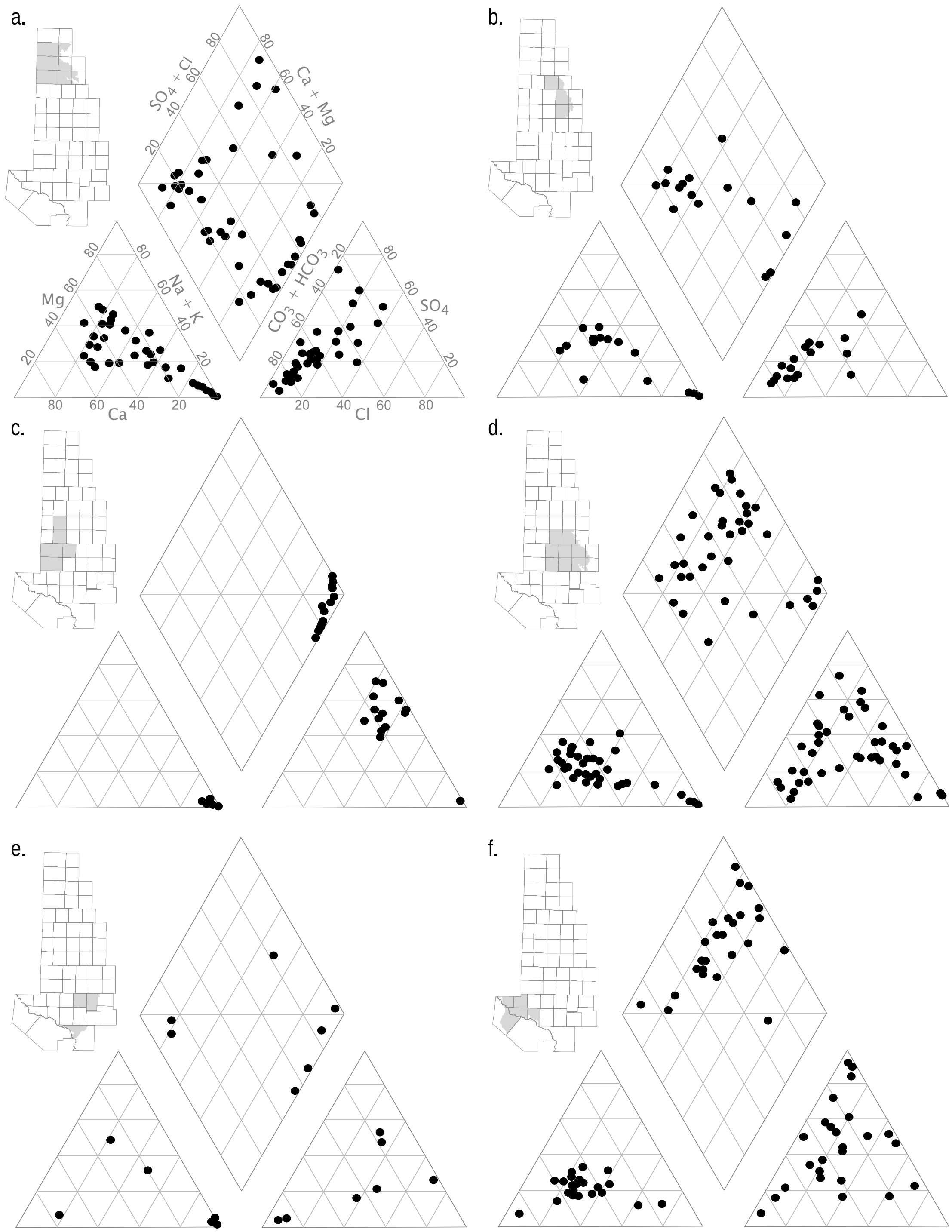

Figure 5-10. Trilinear diagrams for the northern (a, b) and central (c, d) parts of the study area, and for areas overlying the Edwards Plateau region (e) and Pecos River valley (f).

Table 5-3. Gross Alpha, Gross Beta, and Radium Isotope concentrations detected in groundwater samples obtained from the Dockum aquifer, 1981 through 1996.

County	Gross Alpha pCi/l		Gross Beta pCi/l		Radium-226 pCi/l		Radium-228 pCi/l	
	No. of samples	**Range**	**No. of samples**	**Range**	**No. of samples**	**Range**	**No. of samples**	**Range**
Andrews	9	<3 - 19	9	<4 - 16	9	0.2 - 6.1	9	<0.1 - 7
Armstrong	7	<2 - 24	7	1 - 13	7	0.5 - 0.6	7	1 - 6
Borden	9	3 - <72	9	4.5 - 60	9	<0.2 - 3.1	9	<1 - 25
Briscoe	9	5.5 - 21	9	<3 -13	9	0.2 - 3.1	9	<1 - 4
Crane	3	9 - <13	3	<7 - <11	3	<0.6 - 6.8	3	1 - 5
Crockett	3	7 - 19	3	10 - 16	3	1.4 - 4.9	3	2 - 4
Crosby	2	9.1 - 12	2	9 - 9.3	2	<0.6 - 6.6	2	1 - 13
Dawson	5	7.3 - 29	5	<4 - 36	5	1.1 - 3.9	5	1.5 - 19
Deaf Smith	12	<5 - 519	13	<3 - 183	13	<0.2 - 1.4	13	<1 - 4
Dickens	9	<2 - 28	10	4.7 - 12	10	0.2 - 0.6	10	<1 - 8
Ector	3	<6 - 23	3	<4 - 11	1	<0.6	1	3
Fisher	5	3.3 - 20	5	<4 - 18	2	0.2 - 0.9	2	<1
Floyd	7	<3 - 7.2	7	5 - 10	7	<0.2 - 0.5	7	<1 - 1.6
Gaines	3	<13 - 81	3	<9 - 21	3	<0.6 - [illegible]	3	<2 - <3
Garza	9	2.9 - 244	9	<4 - 193	9	1.4 - 59	9	<1 - 47
Glasscock	1	90	1	40	1	<0.6	1	3
Hartley	5	2 - 11	5	<3 - 8	5	<0.6	5	<1 - 5
Hockley	1	<197	1	<57	1	17.6	1	52
Howard	10	3 - 30	10	<3 - [illegible]	10	<0.6 - 3.4	10	<1 - 5
Irion	2	<4 - 20	2	<4 - 31	2	2 - 2.4	2	3.2 - 11
Kent	4	3.5 -35	4	<4 - 23	4	<0.6 - 3.5	4	1.8 - 3
Loving	3	3 - 7	3	<3 - 5.4	3	0.3 - 0.7	3	1.1 - <2
Mitchell	23	<2.2 - 50	23	<4 - 64	22	<0.2 - 8.4	22	<1 - 3.3
Motley	10	<2 - 25	10	4 - 15	10	0.4 - 2.7	10	<1 - 3
Nolan	16	<2 - 27	16	<4 - 34	6	0.3 - 3	6	<1
Oldham	17	4 - 42	17	<3 - <30	17	<0.2 - [illegible]	17	<1 - 6
Potter	12	<4 -47	12	<3 - <12	12	<0.2 - 3.2	12	<1 - 4
Randall	4	10 - 42	4	7 - 30	3	<0.6 - 2	3	<3 - 5
Reagan	2	10 - 29	2	21 - 43	2	0.7 - 4	2	<1 - 8.2
Reeves	5	4.8 - 13	5	<5 - 13	3	<0.2	3	<1
Scurry	28	3.6 - 43	28	<4 - 30	27	<0.2 - 7.3	27	<1 - 3.6
Sterling	5	2.4 - 4.5	4	<4	4	0.4 - 8	3	<1 - 3
Swisher	3	<2 - <3	3	<3 - 10	3	<0.6	3	<2 - 5
Terry	1	<33	1	<23	1	4.6	1	9
Upton	2	14 - 25	2	24 - 28	2	0.2 - 3.3	2	<1 - 4.5
Ward	8	<2 - 13	8	4 - 13	6	<0.2	6	<1 - 1.5
Winkler	6	4 - 5.6	7	0.6 - 10	4	<0.2 -	5	<0.1 - 2

NOTE: pCi/l = pico Curies per liter

Table 5-4. Elements detected at concentrations above their maximum contaminant levels (MCLs) in groundwater samples collected from the Dockum aquifer, 1981 through 1996.

	Concentration in micrograms per liter (mg/l)						
	Antimony	**Beryllium**	**Cadmium**	**Lead**	**Mercury**	**Selenium**	**Thallium**
County	**0.006**	**0.004**	**0.005**	**0.0015**	**0.002**	**0.05**	**0.002**
Andrews	---	---	---	---	---	0.0588	---
Borden	---	---	<0.01	<0.05	---	0.0822	<0.005
Crane	---	---	---	<0.05	0.0113	0.0565	<0.004
Crosby	---	---	<0.01	---	---	---	---
Dawson	<0.01	<0.005	<0.01	<0.05	---	0.0992	<0.01
Deaf Smith	---	---	---	---	0.0028	---	---
Dickens	---	---	<0.01	<0.05	---	---	---
Fisher	---	---	<0.01	<0.05	---	0.0507	---
Gaines	---	---	---	---	---	0.1121	<0.005
Garza	<0.05	<12.5	0.025	<0.05	---	0.093.7	<0.05
Glasscock	<0.01	<0.005	---	---	---	0.2406	<0.01
Hockley	<0.05	---	0.025	<0.05	---	---	<0.05
Howard	---	---	<0.01	<0.05	---	0.0833	---
Kent	---	---	<0.01	<0.05	---	---	---
Loving	---	---	<0.01	<0.05	---	0.050	---
Mitchell	---	---	<0.01	<0.05	---	0.1031	---
Nolan	---	---	<0.01	<0.05	---	---	---
Potter	---	---	<0.01	<0.05	---	---	---
Randall	---	---	---	<0.05	---	0.0647	---
Reeves	---	---	<0.01	<0.05	---	---	---
Scurry	---	---	<0.01	<0.05	---	---	---
Sterling	---	---	<0.01	<0.05	---	---	---
Terry	<0.01	<0.005	<0.005	---	---	0.1136	<0.01
Winkler	---	---	<0.01	<0.05	---	---	---
Yoakum	---	---	---	---	---	4.9	---

NOTES: The concentrations listed above are the highest concentrations detected in samples collected in each county. Only detected concentrations higher than the MCLs are listed in the table. The detection limit for some samples was greater than the MCL, and these results are also included in the table. Other elements that were analyzed but were not detected above their MCLs are arsenic, barium, chromium, and nickel. The MCL for lead is the action level as outlined in TAC 290.120. If a county is not listed above, then all constituents tested for in the groundwater samples obtained from that county were below their MCLs.

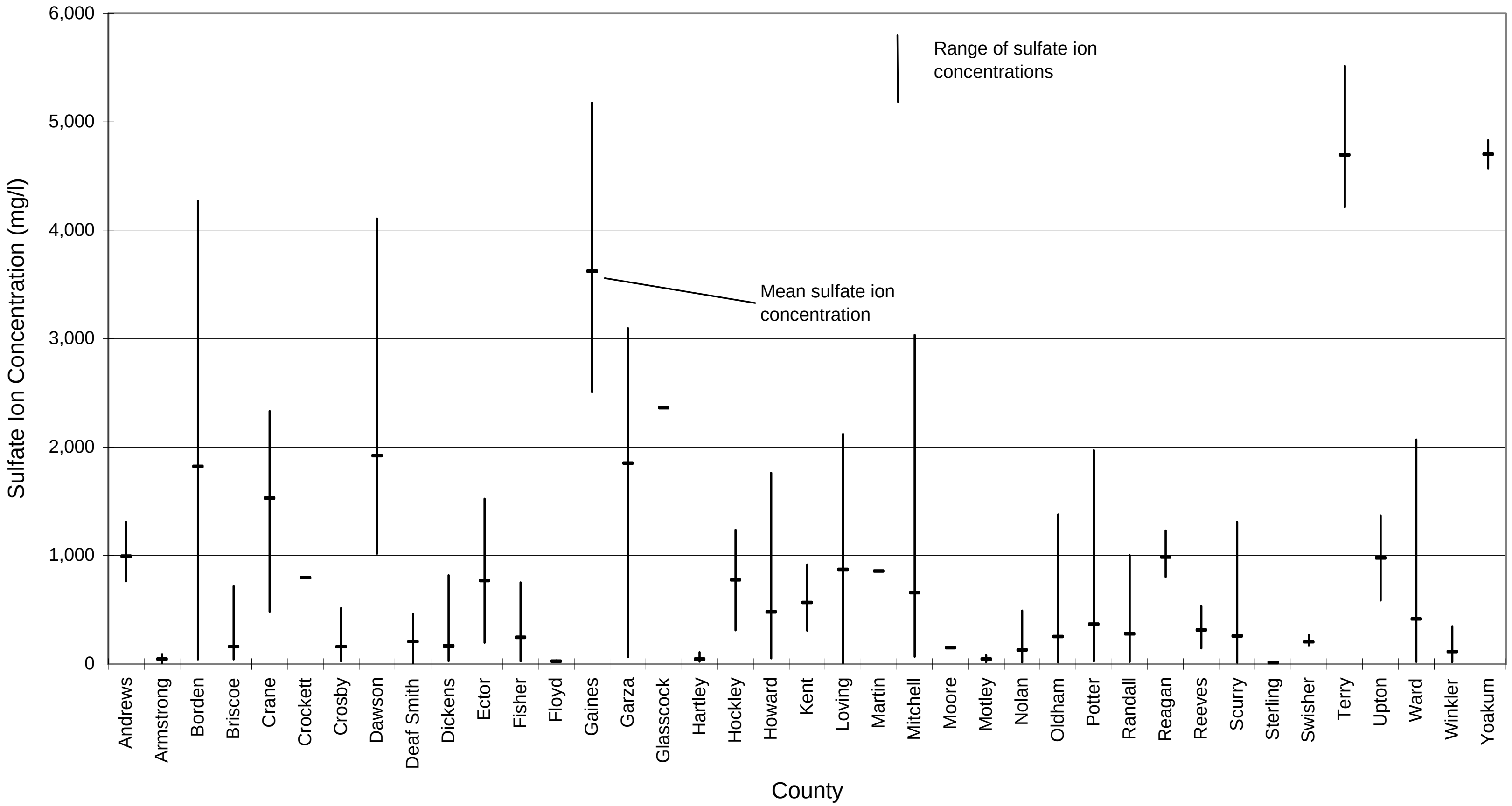

Figure 5-11. Range of sulfate ion concentrations in groundwater samples obtained from the Dockum aquifer, 1981through 1996.

We also analyzed the groundwater samples collected from the study area for TDS, fluoride, chloride, and sulfate. Groundwater in most counties contained TDS at concentrations higher than the secondary standard of 1,000 mg/l (Figure 5-8). TDS concentrations were below the secondary standard in samples collected from Armstrong, Floyd, Hartley, Moore, Motley, and Sterling counties. Most counties had at least one groundwater sample that contained sulfate (Figure 5-11) or chloride at concentrations higher than the secondary standard of 250 mg/l. These two constituents were the dominant anions over much of the study area.

Fluoride concentrations were higher than the secondary standard of 4.0 mg/l in only a few samples that were obtained from Briscoe, Dawson, Deaf Smith, Ector, and Scurry counties (Appendix V). The fluoride in the groundwater is derived from the fluorite grains that occur as heavy minerals in the Dockum sediments.

Sodium in groundwater is a constituent that has neither an MCL nor a secondary standard but that is still a concern where the water is used for irrigation purposes. If sodium exceeds 60 percent of the total cations in water, the water may be unsuitable for irrigation. To determine the hazard of sodium in groundwater, we calculated sodium adsorption ratio (*SAR*), residual sodium carbonate (*RSC*) and percent-sodium. In many counties the percent-sodium values were above 60 percent (Figure 5-12).

The potential effect of sodium on irrigated land can also be determined by *SAR* proposed in 1954 by the United States Salinity Laboratory (USSL, 1954). This indicator is calculated from

$$SAR = \frac{Na}{\frac{\sqrt{Ca + Mg}}{2}},$$

where sodium, calcium, and magnesium concentrations are expressed in milliequivalents per liter (meq/l). *SAR* values lower than 10 suggest that sodium does not pose a threat to the irrigated land, whereas values higher than 18 typically result in excess sodium in the soils. In the central part of the Dockum aquifer, the *SAR* values of groundwater samples were generally higher than 18 (Figure 5-13).

Another indicator of sodium hazard is *RSC*. As calcium and magnesium precipitate out of the groundwater in the unsaturated zone and onto soils, the relative proportion of sodium in irrigation water increases. *RSC* is calculated by

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

or

$$RSC = 0.02 \times (\text{total alkalinity} - \text{hardness})$$

where carbonate, bicarbonate, calcium, and magnesium concentrations are expressed in meq/l. Water with *RSC* values greater than 2.5 meq/l is not suitable for irrigation (Figure 5-14).

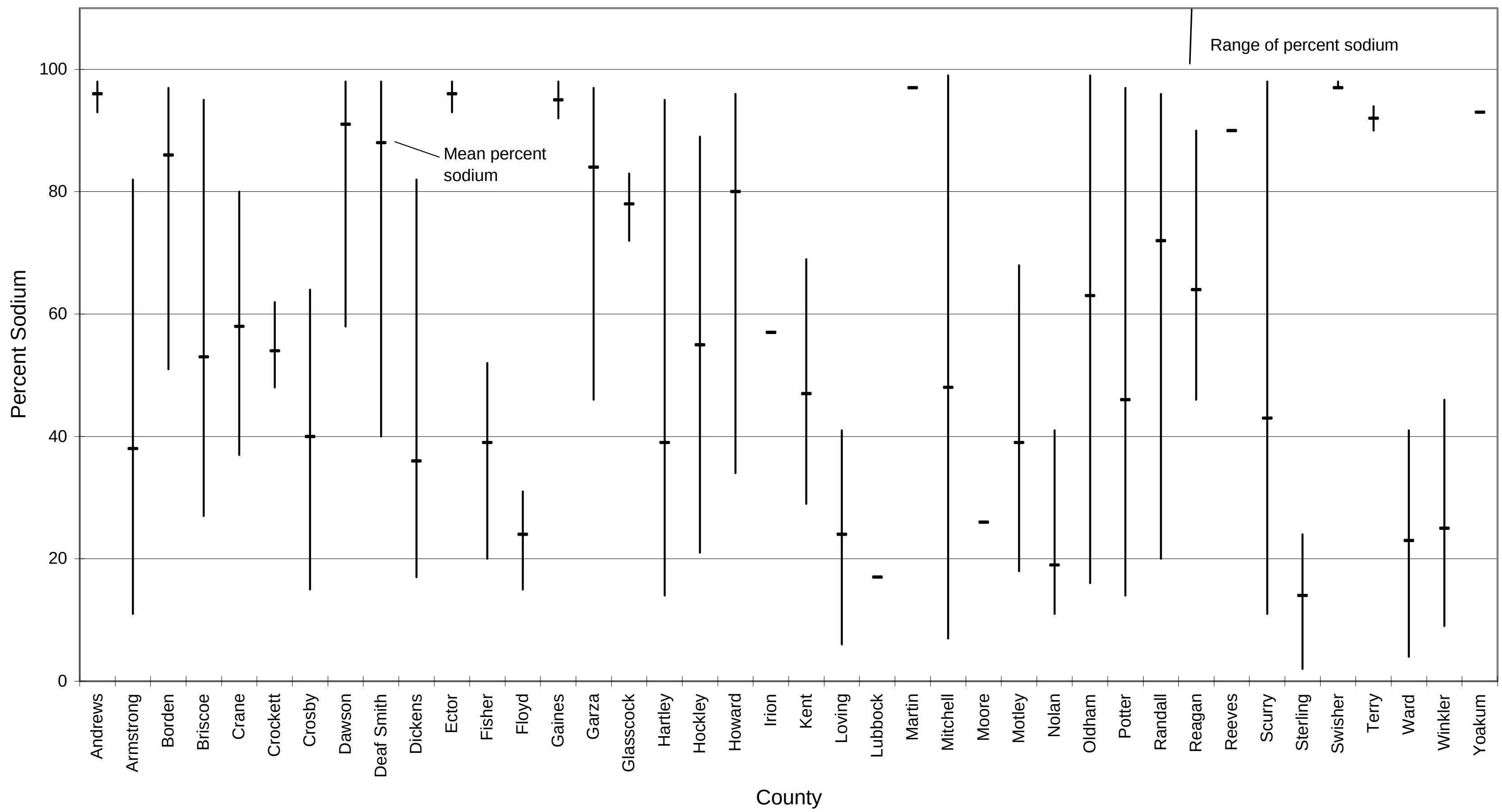

Figure 5-12. Percent sodium in groundwater samples obtained from the Dockum aquifer, 1981 through 1996.

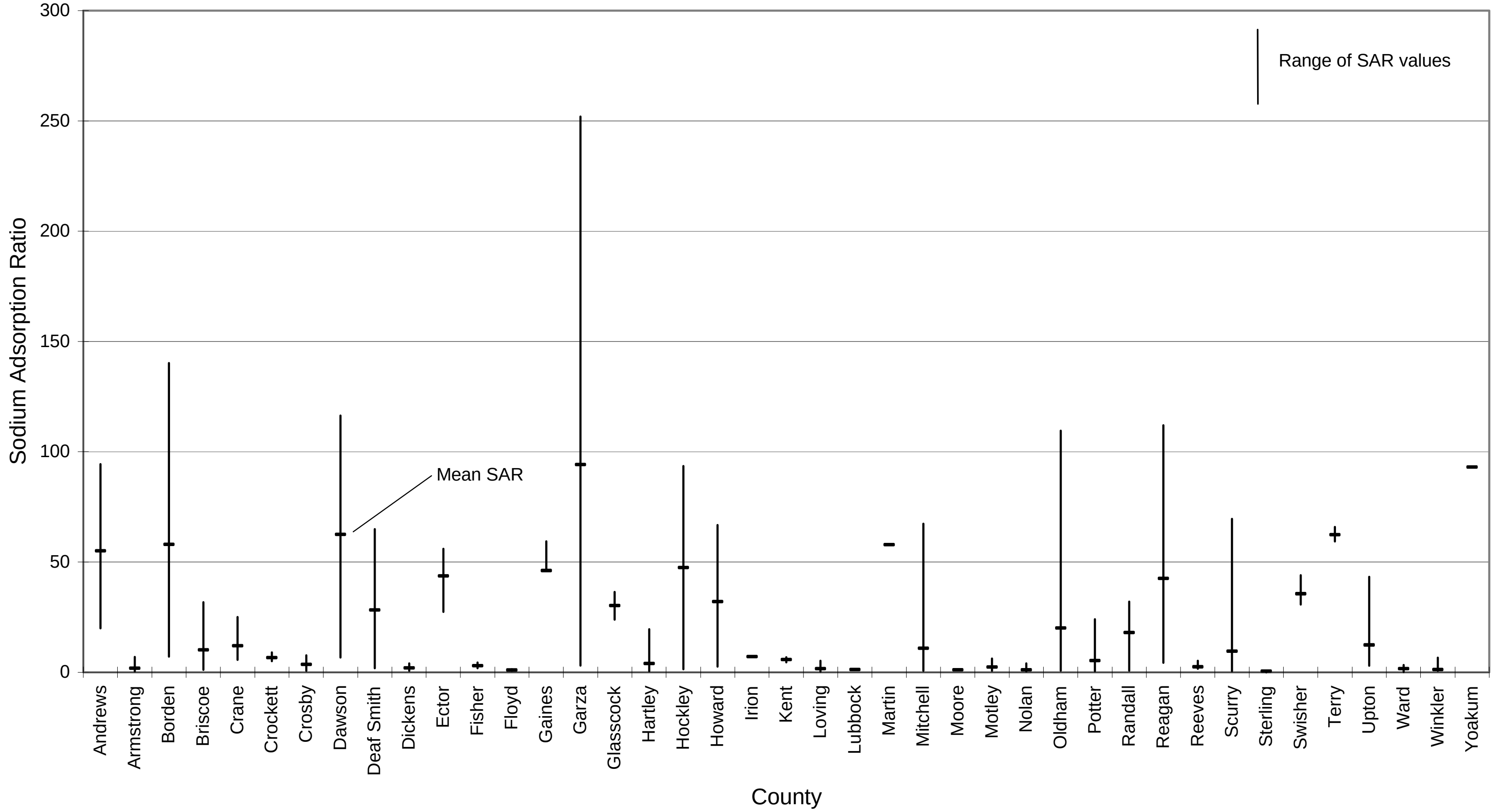

Figure 5-13. Range of Sodium Adsorption Ratio (SAR) values in groundwater samples from the Dockum aquifer, 1981 through 1996.

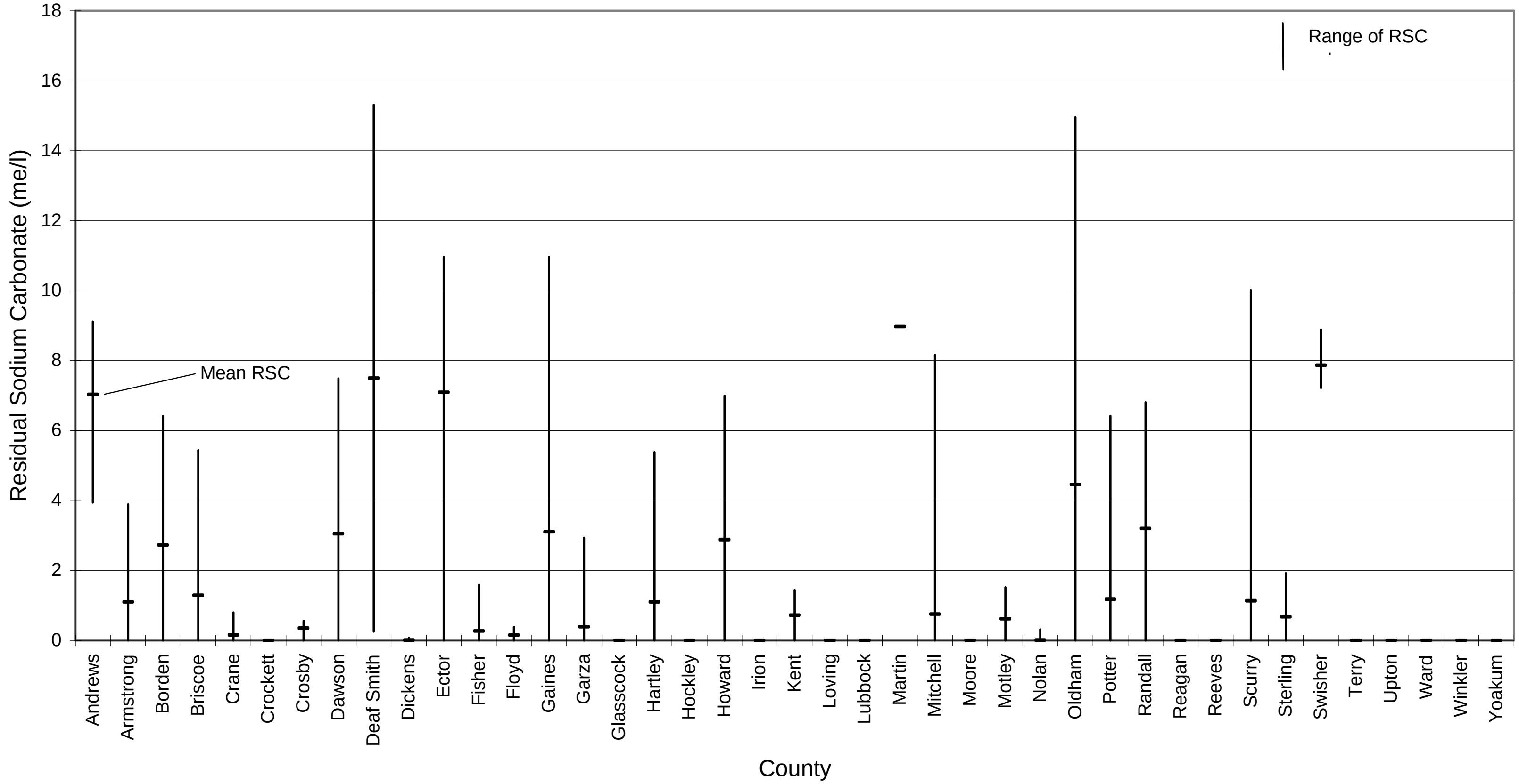

Figure 5-14. Residual Sodium Carbonate (RSC) values in groundwater samples obtained from the Dockum aquifer, 1981 through 1996.

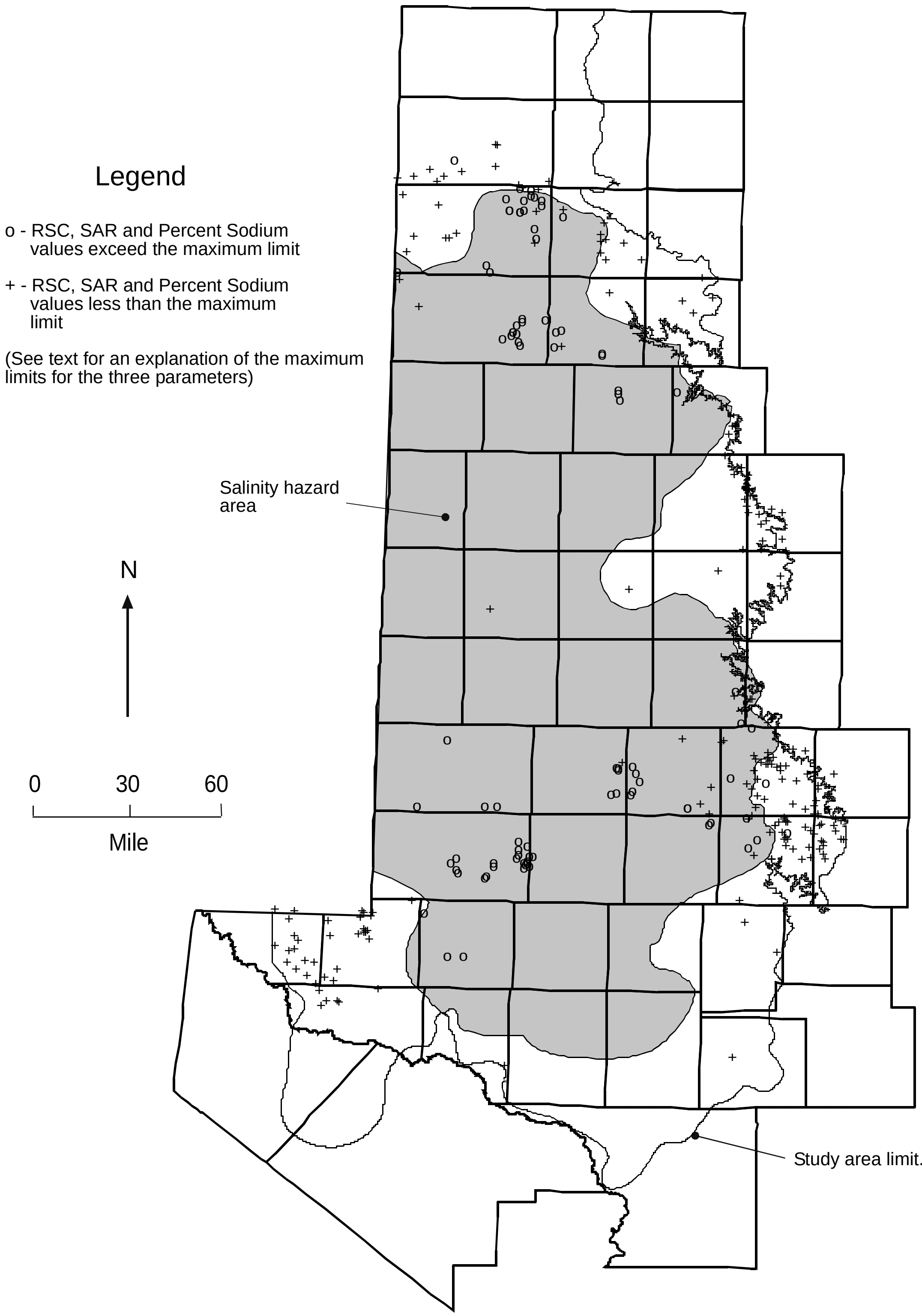

Figure 5-15. Salinity hazard for areas overlying the Dockum aquifer.

Except for parts of the study area that overlie the aquifer where the Dockum sediments outcrop, much of the study area is susceptible to salinity hazard (Figure 5-15). More detailed information about percent sodium, *SAR*, and *RSC* values that were calculated for the study area is presented in Appendix VII.

Only three groundwater samples from the study area had boron concentrations of more than 3 mg/l (Appendix VII). The highest concentration (55.5 mg/l) was detected in a sample from a deep well in Yoakum County that is probably influenced by brine from underlying Permian rocks. Boron, an element that is essential for healthy plant growth, can be toxic to crops at high concentrations. The maximum range of boron concentration that crops can typically tolerate is between 0.67 and 3 mg/l (Scofield, 1936).

5.4 Discharge

Discharge of groundwater from the Dockum aquifer occurs due to pumping, small springs that contribute to stream baseflow in the outcrop (Brune, 1981), evapotranspiration, and cross-formational flow. Most current discharge occurs from the pumping of wells installed in the aquifer.

In the central part of the basin, wells are typically completed in the basal sandstone-dominated zone. However, many wells in the High Plains are completed in both the Dockum and in the overlying Ogallala aquifer. Such dual completion wells can be found in Armstrong, Briscoe, Carson, Crosby, Dallam, Deaf Smith, Floyd, Garza, Hale, Hartley, Hutchinson, Lamb, Moore, Oldham, Potter, Randall, Sherman, and Swisher counties. The primary reason for completing wells in both the Dockum and Ogallala aquifers is to increase well yield. Wells completed in the Edwards-Trinity (Plateau) and Dockum aquifers are present in Bailey, Ector, Hale, Irion, Reagan, Sterling, and Upton counties and in the Cretaceous outlier in Nolan County. In outcrop areas along the Canadian River (primarily in Oldham and Potter counties), wells are completed in both the Dockum and older Permian aquifers.

Irrigation and public-supply uses are limited to areas of the Dockum aquifer in which the water quality is acceptable (TDS generally less than 1,000 mg/l), depth to water is shallow, and a sufficient thickness of sandstone exists to make the aquifer productive. Past and present municipal users of Dockum aquifer water include the cities of Barstow, Canyon, Colorado City, Dickens, Happy, Hereford, Hermleigh, Kermit, Loraine, Pecos, and Snyder. The Colorado River Municipal Water Authority also uses water from this aquifer.

Figure 5-16 illustrates historical water use from the Dockum aquifer between 1994 and 2000. The estimated total pumpage increased from 40,035 acre-feet in 1994 to 50,682 acre-feet in 2000. Irrigation accounted for 58 percent of total water use in 1994 and 66 percent in 2000. While irrigation use increased during the 1994 to 2000 time period, municipal, manufacturing, mining, and livestock water use remained relatively constant (Figure 5-16).

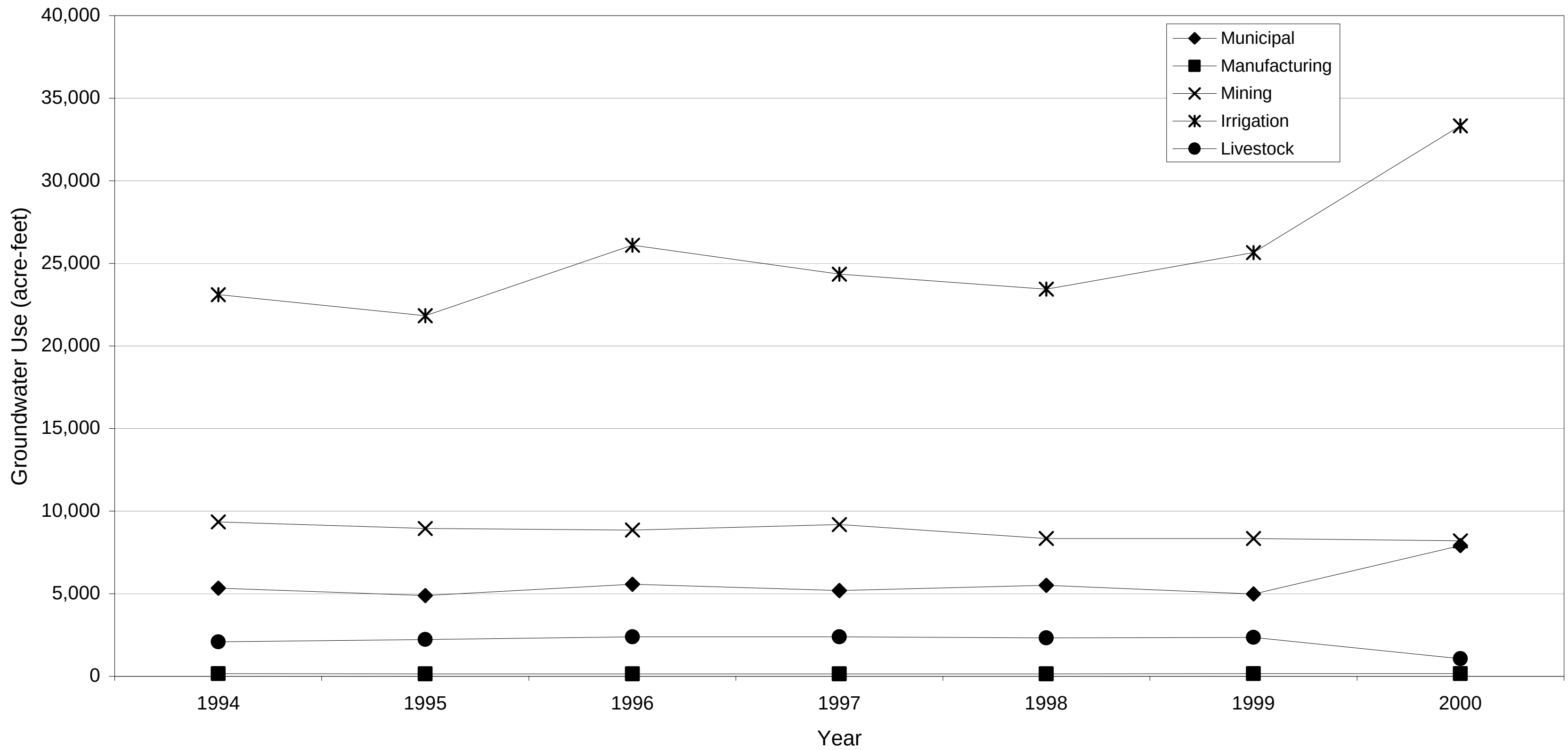

Figure 5-16. Historical water use from the Dockum aquifer, 1994 through 2000.

6.0 Estimate of Groundwater in the Dockum Aquifer

The amount of water in an aquifer that is available for withdrawal can generally be determined by multiplying the saturated volume of the aquifer by its specific yield (the fraction of water that will drain from a saturated porous medium under the influence of gravity). However, estimating this volume for 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 chemical quality (TDS) 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 (Figure 4-2 to 4-10) 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 5-7) to measure aquifer areas within a county (Appendix VIII) 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 (Figure 4-2 to 4-10). 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 185 million acre-feet of water is present in the Dockum aquifer in Texas (Table 5-5). The total volume of water with TDS less than 5,000 mg/l is approximately 109 million acre-feet and that with TDS between 5,000 and 10,000 mg/l is about 27 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 49 million acre-feet.

The largest volume of water (>6 million acre-feet) of all TDS concentrations is present in Andrews, Dallam, Deaf Smith, Gaines, Hartley and Oldham counties. With the exception of Hartley County, these same counties also have the largest volume of water with TDS concentrations less than 5,000 mg/l. Bailey, Cochran, Hockley, Lamb, Lubbock, Lynn, and Terry counties contain the largest volume of water (>3,000 acre-feet) with TDS concentrations greater than 10,000 mg/l.

It must be reiterated that not all of the water estimated here is available for withdrawal. Aquifer properties determined during this study (Chapter 5.2) clearly suggest that well yields and transmissivities are low over much of the aquifer, and 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.

Table 5-5 Estimated volume of water in the Dockum aquifer

	Volume of Water (acre-feet)			
County	**<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
Armstrong	1,948,573	0	0	1,948,573
Bailey	0	0	3,605,720	3,605,720
Borden	440,360	1,146,680	2,332,600	3,919,640
Briscoe	2,012,801	0	0	2,012,801
Carson	566,664	0	0	566,664
Castro	294,089	1,395,200	2,225,991	3,915,280
Cochran	0	0	3,379,000	3,379,000
Coke	126,706	0	0	126,706
Crane	2,283,863	431,640	0	2,715,503
Crockett	3,332,178	0	0	3,332,178
Crosby	688,819	2,442,990	792,192	3,924,001
Dallam	6,561,800	0	0	6,561,800
Dawson	0	2,881,960	1,050,760	3,932,720
Deaf Smith	6,526,920	0	0	6,526,920
Dickens	1,159,849	0	0	1,159,849
Ector	3,928,360	0	0	3,928,360
Fisher	308,048	0	0	308,048
Floyd	4,122,680	202,440	0	4,325,120
Gaines	5,025,677	1,353,003	170,040	6,548,720
Garza	892,506	514,480	2,498,280	3,905,266
Glasscock	684,520	2,062,280	1,181,560	3,928,360
Hale	1,124,880	553,720	2,703,200	4,381,800
Hartley	6,374,320	0	0	6,374,320
Hockley	0	0	3,958,880	3,958,880
Howard	1,303,313	2,633,767	0	3,937,080
Irion	2,902,030	0	0	2,902,030
Kent	306,120	0	0	306,120
Lamb	0	0	4,429,760	4,429,760
Loving	1,228,164	0	0	1,228,164
Lubbock	0	0	3,924,000	3,924,000
Lynn	0	0	3,889,120	3,889,120
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
Moore	1,588,314	0	0	1,588,314
Motley	669,553	0	0	669,553
Nolan	569,920	0	0	569,920
Oldham	6,544,360	0	0	6,544,360
Parmer	1,020,240	845,840	1,979,440	3,845,520
Pecos	2,563,278	0	0	2,563,278
Potter	3,051,550	0	0	3,051,550
Randall	3,974,774	0	0	3,974,774
Reagan	2,995,320	941,760	1,185,920	5,123,000
Reeves	2,344,140	0	0	2,344,140
Scurry	3,466,602	0	0	3,466,602
Sherman	413,212	0	0	413,212
Sterling	3,955,862	0	0	3,955,862
Swisher	3,883,622	40,378	0	3,924,000
Terry	0	361,880	3,518,520	3,880,400
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
Yoakum	0	741,200	2,746,800	3,488,000
TOTAL	**109,170,417**	**27,442,106**	**48,554,023**	**185,166,546**

7.0 Summary and Conclusions

Although not widely used at present, the Upper Triassic Dockum aquifer in the Texas Panhandle and West Texas could become an important source of groundwater in the future, especially in areas where there is high demand from the Ogallala and Edwards-Trinity (Plateau) aquifers. This report documents a comprehensive regional hydrogeologic study of the Dockum 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. Well yields range from 0.5 gpm in Mitchell County to 2,500 gpm in Winkler County, and specific capacities from 0.19 gpm/ft (Garza County) to 37 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 while storage coefficients range from 4.4×10^{-5} in Mitchell County to 2.9×10^{-4} in Winkler County.

Where exposed at the land surface, the Dockum aquifer is recharged by precipitation, and the confined portions by upward leakage from the underlying Permian rocks and downward leakage from the overlying Ogallala, Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium aquifers. We estimate that annual recharge to the aquifer is approximately 31,000 acre-feet. 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. Hydrographs of wells installed in the aquifer show that water levels have fluctuated variably over time in different parts of the aquifer. For example, in the northern and southern parts of the aquifer, water levels have both declined (by more than 80 feet) in some wells and risen in others over the past 20 to 30 years, while in the central part of the aquifer, they have generally risen over the same time period.

Groundwater in the Dockum aquifer is generally of poor quality. Water quality ranges from fresh in the outcrop areas, in the east, to brine in the confined western part of the aquifer. It 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 is also typically hard with a mean hardness of about 470 mg/l. A mixed-cation and HCO_3^- type water characterizes groundwater in the northern and northeastern counties of the study area whereas in the counties in the central area the groundwater typically contains Na^+, K^+, Cl^- and SO_4^{2-} in the west and Ca^{2+}, Mg^{2+} and mixed-anions in the east. 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 widespread areas of the aquifer. The source of the radionuclides in the groundwater is uranium that has long been known to be present in the Dockum sediments. Most counties in the study area also had at least one groundwater sample that contained sulfate or chloride at concentrations greater than the secondary standard of 250 mg/l. In contrast, fluoride concentrations were higher than the secondary standard in only a few samples collected from Briscoe, Dawson, Deaf Smith, Ector, and Scurry counties.

Much of the area overlying the Dockum aquifer 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. High boron concentrations did not appear to be widespread, and only three samples contained boron at concentrations greater than 3 mg/l.

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 available in the entire Dockum aquifer in Texas is approximately 185 million acre-feet. Of this amount, approximately 109 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.

8.0 Acknowledgements

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Appendix I

List of wells with geophysical well logs used for the cross-sections in this report.

County	Q Number	Operator	Lease & Well Number	Date Drilled
Andrews	29	Honolulu Oil Corp.	Parker D-6	1957
	81	Anderson -Prichard Oil Corp.	Faskin J #1	1951
	168	Mid-Cont. Petr. Corp.	Un. 8 #8	1948
	227	Stanolind O & G Co.	Un B-EH #1	1948
	245	The Texas Co.	J.E. Mabee A #1 Tract 3	1948
	269	Gulf Oil Corp.	Tex. QQ#2	1948
	282	James G. Brown & Assoc.	Eastman #1	1962
	401	Ashmun & Hilliard	Un. #1-15A	1960
	514	Great Western Drilling Co.	Scratch Royalty #1	1958
	699	Stanolind O & G Co.	Chesley #1	1951
	998	Midwest Oil Corp.	J. L. Bennett #3	1954
	1494	Mobil Oil Co.	Elizabeth Armstrong #17	1962
Bailey	2	Phillips Petroleum Co.	Stephens A #1	1951
	6	Shell Oil Co.	Nichols #1	1951
Borden	159	Shell Oil Co.	Miller #1-A	1957
	263	Shell Oil Co.	W.T. Long #1	1951
	316	Southland Royalty Co.	J. Dorward #1	1956
Cochran	63	J.D. Baker	M.E. Hancock No. 1	11/10/1956
	82	Amerada Petr. Corp.	Elma Slaughter No. 1	07/30/1958
	86	Geochemical Surveys	F.O. Masten "I" No. 1	06/15/1960
	127	Shell Oil Co.	Tanner-Enochs No. 1	01/16/1960
	262	Pan American Pet. Corp.	H.H. Kern "A" No. 1	06/10/1967
Crosby	1	Cities Service Oil Co.	Jones "C" No. 1	1957
	5	Humble Oil & Ref. Co	R.N. Irvin #1	1953
	84	Safari Drilling Co.	Jordan #1	1973
Dawson	39	Amerada Petr. Corp.	Dunlop Est. #1	1961
	40	The Texas Co.	Anna R. Nowell #1	1958
	86	Blackwood & Nichols Co.	Richards #1	1955
	89	The Texas Co.	B.E. Miller #1	1957
	427	Texas Crude	Berry #39	
Deaf Smith	13	Hereford Salt Inc.	No. 1 Sharp	
	14	Stone and Webster Engineering Corp.	No. 1 J. Friemel	
	15	Stone and Webster Engineering Corp.	No. 1 Detten	
Floyd	1	Poff-Brinsmere	Krause #1	1952
	5	Standard Oil Co. of Texas	Minnie Adams #1	1952
	6	Standard of Texas	L.M. Daniels #1	1948
	13	Kern Co. Land Co.	W.J. Ross #1	1966
Gaines	96	McDaniel & Beecher	Radford Groc. Co. #1	1947
	113	Mobil Oil Co.	H&J #2	1959
	115	Kelley Bell	Cornett #1	1957
	227	Sinclair O&G Co.	P.W. DuBose #2	1952
	257	Luling Oil & Gas Co. et.al.	Folk #1	1958
	398	Blackwood Nichols	Granberry 1-7	1953
Garza	38	R.L. Turley	C.A. Bird #1-A	1954
	337	Alamo Corp.	Neff #1	1952
	397	D.J. Stone Oil & Gas Operations	Post Est. #5-1	1966

List of wells with geophysical well logs used for the cross-sections in this report.

County	Q Number	Operator	Lease & Well Number	Date Drilled
Hale	4	Chambers & Kennedy	Hix #1	1961
	19	Sinclair O & G Co.	J.N. Teauge #1	1964
	21	Western Drilling. Co.	E.M. Jones #1	1954
	40	Plymouth Oil Co.	Daly & Hulburt	1958
Hockley	28	Stanolind Oil And Gas Co.	W.J. Powell No. 1	08/19/1946
	35	T&P Coal and Oil Co.	Bailey No. 1	07/28/1947
	107	Feldmont Oil Corp.	C.M. Phillips No. 1	10/22/1957
	190	G.P. Livermore Inc.	Wells-Hassell No. 1	02/04/1951
	196	Pierce and Dehlinger	Humphries No. 1	10/20/1973
Howard	50	Glen H. McCarthy & S& W Drlg. Co.	Doyle Vaughn #1	1953
	60	Tidwell & Cowder	J.F. Selers #1	1955
	152	SunRay Oil Corp.	R. Harper #1	1951
	358	Gulf Oil Corp.	Maedelle Roley #1	1960
	378	Amerada Petroleum Corp.	G.G. White #1	1969
	501	R.S. Anderson	Mullie Anderson #1	1955
Lamb	6	Cities Service Oil Co.	Stanley #1	1960
	13	Midwest Oil Co.	Duane Moser #1	1957
	18	Amerada Petroleum Corp.	Mary Hagler #1	1957
	28	L.C. Hewett	Cunningham #1	1957
	37	Big Spring Exploration. Co.	Sybert #1	1960
	43	Sharples Oil Corp.	Sharples #1	1954
Lubbock	11	Leland Fikes	J.W. Lemon #2	1956
	15	James G. Brown & Assoc.	Charles Lundell Est. #2	1956
	16	Leland Fikes	Ida S. Collins B#1	1957
	30	Amerada Pet. Corp.	Stribling #1	1948
	68	Continental Oil Co.	E.A. Marquis #1	1955
	69	MFC Corp.	J. Clark #1	1950
Lynn	59	Barnsdall Oil Co.	B. Williams #1	1949
	74	Dalton H. Cobb & Kern Co. Land Co.	Camp & Norman #1	1961
	94	McAlester Fuel	Edwards #1	1949
	136	Apache Corp.	Franklin #1	1969
Martin	6	G.M. McGarr & G.T. Trusler	Billington #1	1959
	58	Sinclair Oil & Gas Co.	-Dickenson #1	1951
	162	Cities Service Oil Co.	Orson #1	1953
	179	Leland Davidson	Guy Mabee #1	1965
Mitchell	8	Standard Oil Co. of Texas	Z.F. Morrison #1	1955
	13	Standard Oil Co.of Texas	Foster #3B	1957
	31	Kay Kimbell et. al.	T.L. Holman #1	1956
	67	R.S. Anderson	Mobil #1	1962
	214	Blue Danube Oil Co.	May #1	1955
Oldham	19	Pan American Petroleum Co.	No. 1 D. Whaley	
Scurry	9	Sun Oil Co.	Randals # B-4	1956
	661	Chevron Oil Co.	Sacroc Unit #176-5	1975
Swisher	3	Frankfort Oil Co.	No. 1 Bradford	
	4	H.L. Hunt Oil Co.	No. 1 Bivins	
	8	Frankfort Oil Co.	No. 1 Culton	
Terry	1	Coroco Drilling Co.	Atlas Life #1	1952
	7	Great Western Drilling Co.	Brit Clare "C" #1	1960
	23	Champlin Ref. Co.	Linsley #1	1950

List of wells with geophysical well logs used for the cross-sections in this report.

County	Q Number	Operator	Lease & Well Number	Date Drilled
Terry	131	Bert Field	Beckham #1	1955
	155	Seaboard Oil Co.	Hinson #1	
	159	Shell Oil Co.	Loyce Floyd #1	1957
	161	Gulf Oil Corp.	T.L. Lowe #1	1951
Yoakum	7	Honolulu Oil Corp.	Cobb #2	1950
	57	Honolulu Oil Corp.	Davis #2	1954
	134	Amerada Pet. Corp.	Weems #1	1952
	297	The Texas Co.	Fitzgerald #1	1953
	298	Texaco Inc.	Fitzgerald #1	1973
	302	Sinclair Oil & Gas Co.	R.N. McGinty #1	1952

Appendix II

Details of well yields in the Dockum aquifer.

County	Well Yield (gpm)			Number of Records
	Mean	Maximum	Minimum	
Andrews	87	173	32	35
Armstrong	15	0	1	17
Borden	105	260	10	16
Briscoe	331	600	25	4
Crane	23	55	1	6
Crosby	120	180	90	3
Dawson	59	140	19	16
Deaf Smith	653	1,000	3	17
Dickens	90	250	10	10
Ector	70	103	26	4
Floyd	38	400	2	12
Gaines	91	157	50.8	3
Garza	43	200	3	24
Hartley	130	500	1	4
Howard	6	20	1	4
Midland	89	133	35	3
Mitchell	161	1,100	0.5	358
Moore	770	940	630	3
Motley	102	800	2	44
Nolan	120	460	2	187
Oldham	242	955	1.5	24
Potter	32	80	5	16
Randall	397	900	5	26
Swisher	504	920	200	5
Reagan	61	116	17.5	3
Reeves	353	736	60	20
Scurry	179	1,100	6	108
Terry	207	645	37	4
Upton	21	90.5	1.2	21
Ward	139	625	5	7
Winkler	418	2,500	24	17

Appendix III

Details of specific capacity tests in the Dockum aquifer.

County	TWDB Well Number	Discharge (gpm)	Drawdown (feet)	Duration of Test (hours)	Specific Capacity (gpm/ft.)
Andrews	2755403	152	200	24	0.76
Armstrong	0662203	12	20	3	0.60
	0663402	34	12	8	2.8
Borden	2806601	150	280	6	0.535
	2819601	130	639	4.5	0.203
	2819602	125	254	6	0.492
	2827301	125	248	6	0.504
	2827302	125	160	6	0.781
	2830601	160	244	6	0.655
	2930602	260	100	8	2.6
Crosby	2339501	90	40	40	2.3
	2339502	90	50	12	1.8
Deaf Smith	0750702	5	240	5	0.02
	0752902	900	79	6.75	11
	1014443	556	44.8	48	12.4
Dickens	2210829	250	40	2	6.3
	2210830	175	25	2	7.0
	2210831	100	75	6	1.3
	2218103	75	35	3	2.1
Gaines	2706501	50.8	115	3	0.442
	2706502	157	271	2	0.579
Garza	2345801	62	332	7	0.19
	2354701	40	223	3	0.18
	2362614	18	325	24	0.055
Martin	2755202	83	200	24	0.42
Mitchell	2840718	250	401	1	0.623
	2840808	60	100	1	0.60
	2926907	86	60	6	1.4
	2934434	71	192	1	0.37
	2934523	75	250	24	0.30
	2934524	180	145	2	1.24
	2934926	100	138	3	0.725
	2935211	175	103	2	1.70
	2935721	350	240	4	1.46
	2942211	207	100	1	2.07
	2942212	250	70	4	3.6
	2942213	80	120	2	0.67

Details of specific capacity tests in the Dockum aquifer.

County	TWDB Well Number	Discharge (gpm)	Drawdown (feet)	Duration of Test (hours)	Specific Capacity (gpm/ft.)
Mitchell (cont.)	2942214	100	112	2	0.893
	2942215	60	112	2	0.54
Moore	0716506	740	96	18	7.7
	0716507	630	56	17	11
Motley	2201201	800	125	6	6.40
	2210915	450	55	24	8.2
	2936524	150	83	1	1.8
Nolan	2936525	75	80	3	0.94
	2936824	75	200	3	0.38
	2944211	91.3	110	2	0.830
	2944505	130	113	24	1.15
	2944707	60	30	1	2.0
	2944708	100	115	3	0.87
Oldham	0730401	880	272	24	3.24
	0738202	20	74	24	0.27
	0738401	150	90	69	1.7
	0738402	180	132	48	1.36
	0738403	175	50	3	3.5
	0738404	40	70	3	0.57
	0738501	5	20	24	0.3
Potter	0642601	50	64	52	0.78
Randall	1101205	760	176	12	4.32
	1101606	900	100	3	9.00
Reeves	4646217	400	30	12	13
	4646602	736	20	213	37
Scurry	2815603	40	40	4	1.0
	2823902	475	203	168	2.34
	2824401	350	188	24	1.86
	2824403	400	78	7	5.1
	2824706	521	123	6	4.24
	2824707	400	75	6	5.3
	2824801	400	66	6	6.1
	2824802	400	100	6	4.00
	2824803	360	110	7	3.23
	2909905	60	180	4	0.33
	2917207	350	170	24	2.06
	2917403	254	89	24	2.9
	2917703	326	58	24	5.6
	2918603	130	40	12	3.3

Details of specific capacity tests in the Dockum aquifer.

County	TWDB Well Number	Discharge (gpm)	Drawdown (feet)	Duration of Test (hours)	Specific Capacity (gpm/ft.)
Scurry	2918702	85	142	3	0.60
	2919401	140	209	3	0.670
	2925401	150	220	24	0.682
	2925602	30	70	1	0.43
Swisher	1126612	600	311	24	1.93
Upton	4546603	36.4	118.4	3	0.307
Winkler	4608516	40	320	48	0.13
	4616213	1,800	105	24	17.1
	4616703	150	44	21	3.4
	4616705	86	187	24	0.46

Appendix IV

Total dissolved solids in groundwater samples from the Dockum aquifer, 1981 through 1996.

County	Total Dissolved Solids (mg/l)			Number of Samples
	Mean	Maximum	Minimum	
Andrews	2,939	3,540	2,252	25
Armstrong	390	551	280	11
Borden	10,000	69,170	588	14
Briscoe	700	2,397	360	11
Crane	4,040	6,316	1,443	3
Crockett	2,082	2,082	2,082	1
Crosby	712	1,528	351	4
Dawson	8,474	21,547	5,018	7
Deaf Smith	926	2,307	263	32
Dickens	824	2,302	303	16
Ector	2,932	5,665	1,688	4
Fisher	1,230	2,038	393	5
Floyd	345	389	307	9
Gaines	7,370	11,159	4,847	3
Garza	29,300	50,784	471	16
Glasscock	11,338	11,338	11,338	1
Hartley	323	553	212	7
Hockley	17,400	33,920	905	2
Howard	1,900	5,658	454	13
Kent	1,420	2,043	885	5
Loving	1,650	5,291	290	20
Martin	2,805	2,805	2,805	1
Mitchell	1,900	17,007	405	52
Moore	593	593	593	1
Motley	460	776	278	14
Nolan	632	1,951	273	28
Oldham	1,030	4,887	209	40
Potter	1,243	5,348	305	14
Randall	1,210	4,262	305	8
Reeves	1,180	2,911	513	5
Scurry	1,560	17,496	286	55
Sterling	282	361	249	5
Swisher	897	1,066	805	6
Terry	10,540	13,164	9,084	3
Ward	1,250	4,819	371	13
Winkler	473	1,408	206	22
Yoakum	9,454	9,675	9,232	2

NOTES: Reliable samples could not be obtained from Carson, Castro, Coke, Dallam, Hale, Irion, Midland, Parmer, Pecos, Reagan, Sherman, Tom Green and Upton counties.

Appendix V

Major cations detected in groundwater samples collected from the Dockum aquifer, 1981 through 1996.

County	Sodium (mg/l)			Potassium (mg/l)			Calcium (mg/l)			Magnesium (mg/l)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
Andrews	1,070	1,754.97	778.9	6	11	3	16	23.62	9	9	30	3
Armstrong	124	124	12.36	6	7	3.02	39	57	10.59	28	39	6.39
Borden	3,430	24,696	178	13	59	2.3	210	1,601	32.22	71	456	10
Briscoe	200	1,023	40	7	10	1.86	50	77	11.08	27	37.33	6.93
Crane	790	1,374	393.5	19	26.4	14.09	336	500.2	65.36	152	278.9	36.88
Crockett	400	562.8	253.8	13	16.09	10.25	117	133.7	86.29	100	132.1	67.45
Crosby	140	374	21	9	9.63	8.6	51	70	40	41	67	27
Dawson	2,920	7,476	1,770	26	101	11	109	397	34	49	186	14
Deaf Smith	330	909	16.33	4	9.1	1.78	14	67.83	2	8	48.37	0.77
Dickens	120	334	21	6	8.3	3.12	118	211	52	35	144	15
Ector	1,000	1,767	680.9	7	8.86	6.34	40	120	7.29	35	119	4.56
Fisher	160	316	67	7	11.37	3.5	185	416.44	43	49	103	21
Floyd	40	50	21	6	8.5	4.18	50	68.12	36	24	35	15
Gaines	2,250	3,294	1,559	8	10.77	5.59	79	145.6	40.55	29	53.35	15.38
Garza	10,650	19,216	127	36	69	2.9	448	798	20	165	287	10
Glasscock	4,015	4,015	4,015	36	35.5	35.5	63	63.04	63.04	96	95.71	95.71
Hartley	60	207.2	14.9	4	5.31	1.83	29	43.66	4.23	20	29.37	2.58
Hockley	6,240	12,397	73	19	25.29	12	496	907.6	85	176	258.7	93
Howard	610	1,949	84	6	10	1	49	140	31	21	63	10
Irion	423.8	423.8	423.8	12.02	12.02	12.02	131.6	131.6	131.6	87.28	87.28	87.28
Kent	240	299	181	5	6	3.62	146	297.7	44	69	114.6	22
Loving	140	499	7.9	5	12	0.4	257	830	41	83	245	8.1
Martin	991	991	991	7	7	7	14	14	14	5	5	5
Mitchell	410	5,779	26	6	30	1.44	140	615	9	79	565	4
Moore	127	127	127	10	9.7	9.7	52	52.3	52.3	23	22.7	22.7
Motley	90	217	20	6	8.1	3.3	51	81	33	17	26.07	7
Nolan	60	263.12	14	5	13.59	1	114	309.5	50	30	112	2

Major Cations Detected in Groundwater Samples Collected from the Dockum Aquifer, 1981 through 1996.

County	Sodium (mg/l)			Potassium (mg/l)			Calcium (mg/l)			Magnesium (mg/l)		
	Mean	**Maximum**	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**Minimum**
Oldham	320	1,781	19	4	10	1	34	101	1.8	17	45	0.12
Potter	220	952	16.99	6	18.86	1	114	566	2.4	65	525.2	1.26
Randall	370	1,240	20.1	5	16	1.32	36	158	3.31	26	106	2.01
Reeves	160	463	66.7	6	11.9	3.8	176	398	73	45	117	18.6
Scurry	380	6,132	18	6	15	1.42	124	416	1.7	41	150.16	0.57
Sterling	20	29.2	6.1	1	1.85	1	61	75.39	37.04	14	37.26	3.7
Swisher	340	396.5	303.1	2	2.91	2	4	5	3.58	2	2.26	1
Terry	3,350	4,006	2,965	14	14.39	14.39	144	231	97	51	70.24	41
Ward	130	381	6.1	4	7	2.14	210	940	62	56	230	5.9
Winkler	40	110.4	15	4	9.87	1.59	90	356	41	16	39	6.03
Yoakum	3,090	3,140	3,035	16	22.6	9	113	122	103	47	52	42

Appendix VI

Major Anion Concentrations Detected in Samples from the Dockum Aquifer, 1981 through 1996.

County	Chloride (mg/l)			Sulfate (mg/l)			Bicarbonate (mg/l)			Carbonate (mg/l)			Number of Samples
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	
Andrews	572	302	868	994	764	1,309	512	378.31	596.75	6	0	16.8	25
Armstrong	28	13	45	46	9	91	293	248.95	423.46	1	0	7.2	11
Borden	4,177	34	38,022	1,821	44	4,273	428	113.49	578.44	1	0	8.4	14
Briscoe	99	20	387	159	44	723.2	337	257.49	436.88	0	0	0	11
Crane	1,060	224	1,849	1,528	483.1	2,333	233	123.25	433.22	0	0	0	3
Crockett	421	421	421	797	796.8	796.8	353	323.39	380.75	0	0	0	3
Crosby	70	17	170	160	26	516	398	303.87	567	2	0	8	4
Dawson	3,196	1,313	11,962	1,921	1,019	4,107	436	324.61	507.66	25	0	163.2	7
Deaf Smith	106	3	508	206	9	460.8	474	198.92	999.46	9	0	37.2	32
Dickens	160	20	410	167	27.9	819	324	229.43	390.51	0	0	0	16
Ector	795	339	1,900	769	196	1,525	549	380.75	706.58	1	0	2.4	4
Fisher	333	33	826	245	26	752	314	216	402.71	0	0	0	5
Floyd	22	16	41	25	19	34	282	253.83	313.63	0	0	3.6	9
Gaines	1,196	510	2,284	3,622	2,512	5,177	361	322.17	389.29	0	0	0	3
Garza	16,010	80	28,000	1,853	63	3,095	227	124	383.19	1	0	8	16
Glasscock	4,575	4,575	4,575	2,362	2,362	2,362	349	349.02	349.02	0	0	0	1
Hartley	19	14	40	46	23	107.5	224	84.2	336.82	6	0	30	7
Hockley	9,584	169	18,999	775	311	1,239	165	87.86	241.63	0	0	0	2
Howard	503	49	1,593	480	54	1,764	351	223	602.85	1	0	8	13
Irion	-	-	-	-	-	-	315	314.85	314.85	0	0	0	1
Loving	149	10	1,608	873	10	2,120	203	54.92	550.38	0	0	0	20
Martin	612	612	612	857	857	857	600	600.41	600.41	7	7.2	7.2	1
Mitchell	411	25	7,774	657	69	3,035	324	200.14	545.49	0	0	7.2	52
Moore	16	15.6	15.6	149	149.3	149.3	391	390.51	390.51	0	0	0	1

Major Anion Concentrations Detected in Samples from the Dockum Aquifer, 1981 through 1996.

County	Chloride (mg/l)			Sulfate (mg/l)			Bicarbonate (mg/l)			Carbonate (mg/l)			Number of Samples
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	
Motley	78	13	226	45	18	80.5	282	220.88	336.82	0	0	1.2	14
Nolan	108	17	479	128	15	494	276	202.58	385.63	0	0	0	28
Oldham	161	4	1,498	252	14.1	1,381	421	80.54	1,036.07	8	0	39.6	40
Potter	276	16	1,879	367	24.2	1,971	283	201.36	374.65	3	0	38.4	14
Randall	311	9	1,664	277	20.9	1,004	314	125.7	449.09	1	0	1.2	8
Reagan	474	221	914	986	804	1,230	274	211.12	338.04	0	0	0	3
Reeves	333	55	1,250	314	143	538	187	156.2	211.12	0	0	0	5
Scurry	547	14	9,339	259	13	1,312	306	186.71	621.16	1	0	28.8	55
Sterling	13	7	18	12	11	14	272	231.87	385.63	0	0	0	5
Swisher	89	65	116	205	172.5	269.8	487	456.41	558.92	6	1.2	12	6
Terry	2,101	1,546	3,177	4,694	4,212	5,514	362	275.8	407.6	0	0	0	3
Upton	440	216	663	978	586	1370	232	178.17	286.78	0	0	0	2
Ward	286	9	2,145	415	20	2,069	198	53.7	303.87	0	0	0	13
Winkler	90	6	465	113	18	350	157	100.07	256.27	0	0	0	22
Yoakum	1,260	1,232	1,288	4,700	4,570	4,830	374	348	399	0	0	0	2

Appendix VII

Percent Sodium, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Boron, and Hardness Values in Groundwater Samples from the Dockum Aquifer, 1981 through 1996.

County	Percent Sodium				SAR				RSC (me/l)				Boron (mg/l)				Hardness (as CaCO3) mg/l			
	No. of Samples	Mean	Max	Min	No. of Samples	Mean	Max	Min	No. of Samples	Mean	Max	Min	No. of Samples	Mean	Max	Min	No. of Samples	Mean	Max	Min
Andrews	23	96	98	93	23	55.07	94.38	19.87	23	7.03	9.12	3.94	9	1.064	1.316	0.9102	23	76.13	175	34
Armstrong	6	38	82	11	6	1.8	7	0.36	7	1.1	3.89	0	6	0.237	0.511	0.1107	7	170	260	53
Borden	10	86	97	51	10	57.9	140.21	7.04	10	2.72	6.41	0	9	1.245	1.83	0.2683	11	998.36	5870	138
Briscoe	7	53	95	27	7	10.12	31.73	1.14	7	1.29	5.44	0	5	0.819	2.184	0.2333	7	224.14	338	56
Crane	5	58	80	37	5	12	25.07	5.63	5	0.16	0.8	0	3	0.664	1.177	0.1284	5	1394.4	2263	317
Crockett	3	54	62	48	2	6.55	9.04	4.97	3	0	0	0	3	1.286	1.374	1.177	3	704	881	495
Crosby	3	40	64	15	3	3.51	7.67	0.57	3	0.35	0.56	0	2	0.3419	0.3838	0.3	3	322.67	452	256
Dawson	9	91	98	58	9	62.5	116.41	6.74	9	3.05	7.49	0	4	1.109	1.657	0.58	9	278.1	649	50
Deaf Smith	19	88	98	40	19	28.2	64.89	1.8	20	7.5	15.32	0.25	10	1.041	3.193	0.0746	20	46.7	170	10
Dickens	8	36	82	17	7	1.92	4.03	0.61	7	0.01	0.08	0	9	0.306	0.59	0.0806	7	399.86	638	226
Ector	4	96	98	93	5	43.66	56.01	27.36	5	7.09	10.96	0	3	1.14	1.433	0.7428	5	203	789	36
Fisher	6	39	52	20	6	2.94	4.44	1.87	6	0.27	1.59	0	6	0.408	0.63	0.1937	6	614.67	1288	199
Floyd	6	24	31	15	6	1.02	1.35	0.6	6	0.15	0.39	0	3	0.1992	0.2458	0.1529	6	232.17	249	213
Gaines	4	95	98	92	4	46.07	59.36	52.88	5	3.1	10.96	0	3	1.717	1.926	1.583	5	318.2	609	35
Garza	14	84	97	46	14	94.1	252.01	3.08	15	0.39	2.94	0	9	2.028	2.94	0.35	15	1731	3171	78
Glasscock	2	78	83	72	2	30.16	36.44	23.88	2	0	0	0	1	1.531	1.531	1.531	2	1673.5	1998	1349
Hartley	5	39	95	14	5	3.89	19.59	0.46	5	1.1	5.38	0	5	0.428	1.669	0.0869	6	192	418	21
Hockley	2	55	89	21	2	47.4	93.47	1.3	2	0	0	0	1	1.539	1.539	1.539	2	1984.5	3375	594
Howard	9	80	96	34	9	32	66.69	2.61	9	2.88	7	0	10	1.25413	2.17	0.3893	9	377.22	1526	123
Irion	1	57	57	57	1	7.03	7	7	1	0	0	0	1	0.6261	0.6261	0.6261	1	694	694	694
Kent	3	47	69	29	2	5.7	6.88	4.51	2	0.72	1.44	0	4	0.556	0.78	0.1549	2	526.5	830	223
Loving	12	24	41	6	12	1.65	5.25	0.22	14	0	0	0	3	0.292	0.527	0.1361	14	1045.9	3078	159
Lubbock	1	17	17	17	17	1.25	1.25	1.25	1	0	0	0	0	0	0	0	1	818	818	818
Martin	1	97	97	97	1	57.86	57.86	57.86	1	8.97	8.97	8.97	0	0	0	0	1	55	55	55
Mitchell	41	48	99	7	41	10.9	67.41	0.65	41	0.75	8.16	0	31	0.486	2.1	0.05	41	566.7	2949	9
Moore	1	26	26	26	1	1.12	1.1	1.1	1	0	0	0	1	0.57	0.57	0.57	1	230	230	230

County	Percent Sodium				SAR				RSC (me/l)				Boron (mg/l)				Hardness (as CaCO3) mg/l			
Motley	10	39	68	18	10	2.3	6.26	0.62	10	0.62	1.52	0	10	0.27	0.45	0.0987	10	196.8	271	148
Nolan	23	19	41	11	23	1.1	4.01	0.4	23	0.01	0.32	0	18	0.438	0.75	0.0911	23	418.83	999	210
Oldham	33	63	99	16	34	20	109.54	0.68	34	4.46	14.96	0	10	0.66	2.712	0.0618	35	154	418	4
Potter	13	46	97	14	13	5.2	24.12	0.5	13	1.18	6.42	0	7	0.35	0.6695	0.1512	14	664.6	3472	11
Randall	6	72	96	20	6	18	31.99	0.72	6	3.2	6.81	0	5	1.84	3.361	0.176	6	222.3	842	27
Reagan	3	64	90	46	3	42.6	111.93	4.31	3	0	0	0	0	0	0	0	3	2100	3628	608
Reeves	1	90	90	90	13	2.5	5.25	1.55	13	0	0	0	1	0.2277	0.2277	0.2277	13	758	1960	260
Scurry	45	43	98	11	45	9.57	69.61	0.5	46	1.13	10.01	0	30	0.45	2.04	0.0814	46	528.8	1662	11
Sterling	5	14	24	2	5	0.51	0.89	0.05	5	0.67	1.92	0	6	0.119	0.15	0.055	5	196.8	257	115
Swisher	5	97	98	97	5	35.56	44	30.69	5	7.87	8.89	7.22	3	0.89	1.037	0.7587	5	17.6	20	15
Terry	3	92	94	90	3	62.3	65.92	59.24	3	0	0	0	1	1.675	1.675	1.675	3	572.33	871	410
Upton	0	0	0	0	7	12.4	43.26	2.94	7	0	0	0	0	0	0	0	7	1700	2218	943
Ward	10	23	41	4	10	1.6	3.25	0.15	10	0	0	0	6	0.268	0.4032	0.1541	10	598	1831	263
Winkler	17	25	46	9	17	1.2	6.61	0.61	20	0	0	0	7	0.227	0.3789	0.0609	20	361.6	1448	136
Yoakum	1	93	93	93	1	63.68	63.68	63.68	1	0	0	0	1	55.5	55.5	55.5	1	429	429	429

Appendix VIII

Areas in each County underlain by the Dockum Aquifer with Different TDS Consentrations.

	Area of Aquifer (Acres)			
County	**<5,000 mg/l TDS**	**5,000 to 10,000 mg/l TDS**	**>10,000 mg/l TDS**	**Total**
Andrews	960,640	0	0	960,640
Armstrong	286,029	0	0	286,029
Bailey	0	0	529,280	529,280
Borden	64,640	168,320	342,400	575,360
Briscoe	295,457	0	0	295,457
Carson	83,180	0	0	83,180
Castro	43,169	204,800	326,751	574,720
Cochran	0	0	496,000	496,000
Coke	18,599	0	0	18,599
Crane	335,246	63,360	0	398,606
Crockett	489,127	0	0	489,127
Crosby	101,111	358,604	116,285	576,000
Dallam	963,200	0	0	963,200
Dawson	0	423,040	154,240	577,280
Deaf Smith	958,080	0	0	958,080
Dickens	170,253	0	0	170,253
Ector	576,640	0	0	576,640
Fisher	45,218	0	0	45,218
Floyd	605,164	29,716	0	634,880
Gaines	737,714	198,606	24,960	961,280
Garza	131,010	75,520	366,720	573,250
Glasscock	100,480	302,720	173,440	576,640
Hale	165,120	81,280	396,800	643,200
Hartley	935,680	0	0	935,680
Hockley	0	0	581,120	581,120
Howard	191,312	386,608	0	577,920
Irion	425,986	0	0	425,986
Kent	44,935	0	0	44,935
Lamb	0	0	650,240	650,240
Loving	180,281	0	0	180,281
Lubbock	0	0	576,000	576,000
Lynn	0	0	570,880	570,880
Martin	43,742	541,858	0	585,600
Midland	51,840	522,880	1,280	576,000
Mitchell	521,525	0	0	521,525
Moore	233,147	0	0	233,147
Motley	98,283	0	0	98,283
Nolan	83,658	0	0	83,658
Oldham	960,640	0	0	960,640
Parmer	149,760	124,160	290,560	564,480
Pecos	376,261	0	0	376,261
Potter	447,934	0	0	447,934
Randall	583,453	0	0	583,453
Reagan	439,680	138,240	174,080	752,000
Reeves	344,094	0	0	344,094
Scurry	508,859	0	0	508,859
Sherman	60,655	0	0	60,655
Sterling	580,677	0	0	580,677
Swisher	570,073	5,927		576,000
Terry	0	53,120	516,480	569,600
Tom Green	34,417	0	0	34,417
Upton	117,760	240,640	436,480	794,880
Ward	394,191	0	0	394,191
Winkler	516,095	0	0	516,095
Yoakum	0	108,800	403,200	512,000
	16,025,015	**4,028,199**	**7,127,196**	**27,180,410**

NOTES: TDS-total dissolved solids.

Reference 26

Texas Water Development Board

Report No. 314

Hydrogeology of Lower Cretaceous Strata Under the Southern High Plains of Texas and New Mexico

by
J. A. Tony Fallin

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M. Reginald Arnold II, Executive Administrator

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ABSTRACT

Lower Cretaceous strata underlie approximately 10,000 square miles of the Southern High Plains of Texas and New Mexico. The strata lie below the regional water table in most places, and are included in the greater High Plains aquifer system, one of the major sources of ground water used for irrigation purposes in the United States.

A typical Lower Cretaceous section under the Southern High Plains includes a relatively thin (zero to 60 feet) sand and sandstone deposit overlain by marls, clays, and associated marine limestones of varying (zero to 200 feet) thickness. Stratigraphically and in ascending order, the deposits correlate with the Antlers, Walnut, Comanche Peak, Edwards, Kiamichi, and Duck Creek Formations of west-central Texas. The strata are covered largely by sand, silt, clay, and gravel deposits that make up the Ogallala Formation (Tertiary), a major water-bearing unit in the High Plains aquifer system. Shale, siltstone, and sandstone of Late Triassic age underlie the Lower Cretaceous deposits.

There are two distinct ground-water aquifers in Lower Cretaceous strata under the Southern High Plains. One occurs in the Antlers Formation, a basal sand and sandstone deposit. The sandstone aquifer: (1) underlies approximately 9,000 square miles of the Southern High Plains; (2) occurs generally 200 to 350 feet below ground surface; (3) comprises an irregular sheet deposit that pinches and swells in thickness while thinning regionally to the northwest; and (4) is confined largely by bounding shale and marl beds. Ground water in the Antlers is almost always under artesian pressure, and numerous wells have flowed at ground surface when completed in it.

A second Lower Cretaceous aquifer under the Southern High Plains is formed by jointed limestones of the Comanche Peak and Edwards Formations. The carbonate aquifer: (1) underlies approximately 8,000 square miles of southern and eastern parts of the Southern High Plains; (2) occurs generally between 20 and 250 feet below ground surface; (3) is in deposits that combine to form a thin, arcuate wedge that tapers to the northwest; and (4) is largely unconfined along its eastern edge. Ground water in the limestone occurs primarily in joints, solution cavities, and along bedding planes, and water-table conditions prevail throughout unconfined parts of the system.

Ground-water movement through both of the Lower Cretaceous aquifers under the Southern High Plains is generally to the east-southeast in conformance with hydraulic head distribution and regional structure. Flow rates are estimated to vary from a few feet per year in lower sandstones to more than a hundred feet per day sometimes where solution cavities and joint systems are well developed in limestone intervals along the Southern High Plains escarpment.

Recharge to the Lower Cretaceous aquifers occurs directly from the bounding Ogallala Formation along northern and western parts of

the subcrop area, and by downward percolation from overlying ground-water units at other locations. Discharge is to well heads in Texas and New Mexico; to streams, springs, and seeps along the Southern High Plains escarpment in Texas; and to surrounding formations.

Ground water in the Lower Cretaceous aquifers is generally fresh (less than 1,000 mg/l dissolved solids) to slightly saline (1,000 to 3,000 mg/l dissolved solids) in character, and usually has either a mixed-cation-bicarbonate, calcium-bicarbonate, or sodium-bicarbonate hydrochemical signature. However, water quality decreases in areas where saline lakes and the gypsiferous Tahoka and Double Lakes Formations (Pleistocene) overlie them, becoming moderately saline (3,000 to 10,000 mg/l dissolved solids) in character and exhibiting either a sodium-sulfate or a sodium-chloride hydrochemical signature.

Yields from wells completed in Lower Cretaceous aquifers under the Southern High Plains generally range between 50 and 200 gallons per minute, although production of more than 1,000 gallons per minute has been reported from isolated localities. The higher yield wells are completed in thick, channel-fill sandstone sections of the Antlers Formation in the Causey-Lingo area, New Mexico, and in the Antlers, Comanche Peak, and Edwards Formations in Hale and Lubbock Counties, Texas. Wells dually completed in both Ogallala and Lower Cretaceous strata are also common over southern and eastern parts of the Southern High Plains.

It is estimated that Lower Cretaceous aquifers under the Southern High Plains contain approximately 13 million acre-feet of ground water when full. Annual production from both aquifers is estimated to have exceeded 15 thousand acre-feet in recent years, with the ground water being used primarily for crop irrigation.

Areas where Lower Cretaceous aquifers indicate potential for further development include parts of Cochran, Hockley, and Terry Counties, Texas, and Lea County, New Mexico, where the basal Antlers Formation is particularly thick in erosion channels cut into underlying Triassic strata. Expanded development of the Comanche Peak-Edwards limestone aquifers also appears feasible in east-central Lubbock and northeastern Lynn Counties, Texas.

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INTRODUCTION

Purpose and Scope

The primary purpose of this report is to describe the hydrogeology of Lower Cretaceous strata under the Southern High Plains. The Lower Cretaceous strata are incorporated in the High Plains aquifer system that provides essentially all of the ground water used for crop irrigation purposes on the Southern High Plains.

Significantly, clay and marl intervals in the Lower Cretaceous section under the Southern High Plains form regional aquicludes in the High Plains aquifer system. The aquicludes separate individual ground-water flow zones in the Lower Cretaceous section, forming boundaries between aquifers that have unique hydraulic characteristics, and that are discussed individually under separate headings in this report.

The report pertains to all areas where Lower Cretaceous strata are know to exist under the Southern High Plains (Figure 1), including parts of southeastern New Mexico as well as Texas. This allows for the presentation of New Mexico data that have a direct bearing on flow dynamics, ground-water chemistry, and other hydrologic properties of Lower Cretaceous aquifers in Texas. The report stems largely from field, lab, and office investigations made by the author and other individuals cited in the text.

Approximately 1,000 well logs from commercial and other drilling sources were analyzed to determine and map subsurface facies characteristics, regional thicknesses, and areal extent of Lower Cretaceous strata shown in the report. Well log information supplied from numerous oil, gas, and ground-water investigations made in the study area was obtained largely from office files located at the New Mexico State Engineer's Office in Roswell, New Mexico, and at the Texas Water Development Board (TWDB) in Austin, Texas. Regional cross-sections presented with the text were also constructed from select information recorded on drillers' logs filed with the New Mexico State Engineer's Office, the Texas Water Commission (TWC), and from descriptions of formation outcrops measured in the field. Water samples collected from wells tapping the Lower Cretaceous strata were analyzed at the Texas Department of Health Laboratories in Austin, Texas, for data used in the report.

As part of the High Plains aquifer system, discrete aquifer intervals in the Lower Cretaceous section under the Southern High Plains are developed locally as a source of fresh to slightly saline ground water. Accordingly, findings in this report have applications to projects addressing ground-water inventory, development, and management on the Southern High Plains.

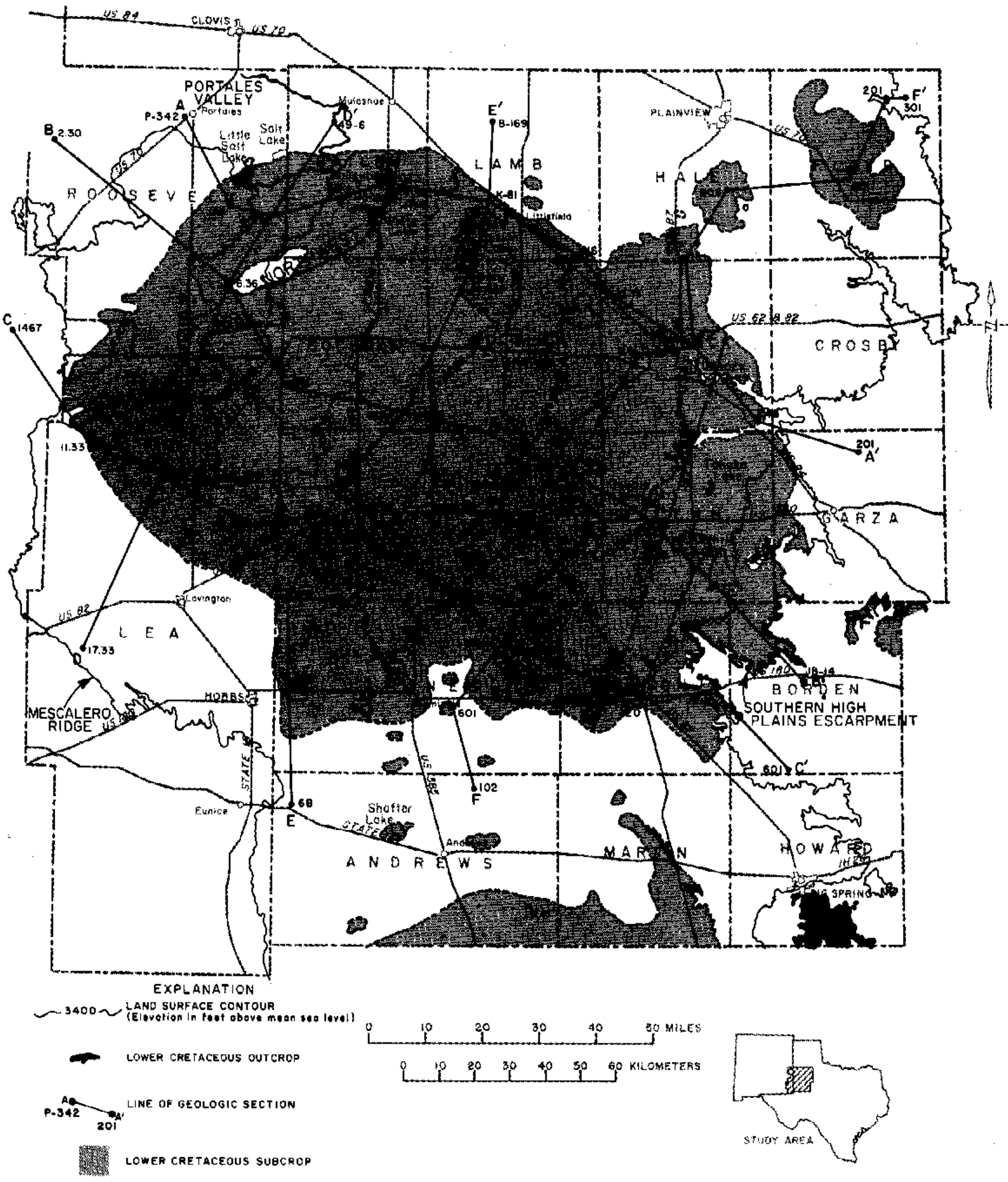

Figure 1

Study Area Location Map

Previous Investigations

Investigative studies describing the geology of Lower Cretaceous strata under the Southern High Plains are limited. Sellards and others (1932) briefly notes that Lower Cretaceous strata are present in the southern Texas Panhandle, with the Edwards Formation extending "...westward to the cap of the Llano Estacado." Brand (1950, 1953) also addresses Cretaceous outcrops on the Llano Estacado of Texas in a University of Texas Ph.D. dissertation and other publications.

Local and regional hydrogeologic surveys that offer short discussions of Lower Cretaceous strata in the study area include reports by Leggat (1952), Cronin and Wells (1960), Mount and others (1967), Knowles and others (1984), and others listed in the Selected References section of this report. Basic ground-water information for the Southern High Plains is also recorded in various State and Federal reports, including annual U.S. Geological Survey publications listing water levels and artesian pressures in the United States.

Location and General Features

Lower Cretaceous strata underlie approximately 10,000 square miles of the Southern High Plains, including areas under all or parts of Bailey, Borden, Cochran, Dawson, Gaines, Garza, Hale, Hockley, Lamb, Lubbock, Lynn, Terry, and Yoakum Counties, Texas, and of Lea and Roosevelt Counties, New Mexico. The strata are covered largely by the Ogallala Formation (Neogene) and other surficial deposits. However, limited outcrops of the Mesozoic rocks are exposed along the margins of isolated playa depressions, and along escarpments demarking eastern and western edges of the Southern High Plains physiographic province.

As an elevated plateau region, the Southern High Plains is characterized by flat, treeless terrain. Shallow playa depressions and sand dunes are also typical features in certain parts of the province. The plains slope imperceptibly to the southeast and are generally devoid of major drainage systems. Native vegetation in the region includes numerous dryland grasses and more localized growths of shinoak, sagebrush, mesquite, and yucca. Farm crops are cultivated over much of the Southern High Plains, primarily during late spring and summer months.

Economic Development

The Southern High Plains economy is based largely on agricultural development and the production of oil and gas. Large-scale irrigation farming began in the region during the 1930's and 1940's, primarily with the development of water-bearing formations within the High Plains aquifer. At about the same time, large oil and gas deposits were discovered in various Permian Basin reservoirs underlying the study area.

Today, the Southern High Plains is one of the most intensively cultivated areas in the North American mid-continent. Crops grown in the study area include cotton, grain sorghums, soybeans, wheat, barley, oats, corn, and assorted vegetables. Beef cattle are also raised in the region, often being penned and fattened in feedlots that have expanded over the province since the early 1960's.

Oil and gas development is extensive on the Southern High Plains. Collectively, oilfields in the study area contain more than 12 billion barrels of oil in place, making them the single largest oil play in the southern mid-continent area (Galloway, et. al., 1983). The oilfields are particularly well developed in southern parts of the study area where oil reservoirs are defined in carbonate rocks that were deposited on the northern shelf of a Permian-age basin. Many of the fields are in secondary phases of production and some of the world's largest enhanced oil recovery (EOR) projects utilizing injected water and carbon dioxide as hydrocarbon displacement agents are currently operating in the region.

Satellite industries supporting oil, gas, and agricultural development also contribute to the overall economy of the study area. The support industries usually have home or field offices located in local Southern High Plains cities such as Lubbock, Levelland, Brownfield, Plains, Lamesa, Denver City, and Seminole, Texas.

Climate

The Southern High Plains has a semiarid climate, with precipitation generally measuring between 14 and 20 inches a year. Precipitation is usually light during winter months, increasing in the late spring and early fall. Temperatures typically range from the low to mid-90's (degrees F) in the summer and from the low to mid-50's in the winter.

Weather patterns are sometimes extreme over the Southern High Plains. Temperatures can drop as much as 60 F over short periods of time when "blue northers" blow across the region, sometimes depositing light snows in the winter. Low humidity and strong southeasterly breezes commonly accompany higher summer temperatures, resulting in high surface evaporation rates and generating periodic dust storms across the Plains. Thunderstorms crossing the area during rainy periods occasionally produce hail and tornadoes, especially during late spring and summer months.

Acknowledgements

Numerous farmers, ranchers, and other land holders on the Southern High Plains permitted access to their properties and supplied ground-water information integrated in this report. Also, well drillers, pump companies, and municipal officials in the study area provided drillers' logs, pump test information, and municipal well data that were helpful in defining the subsurface character of Lower Cretaceous strata and their contained waters. Private ground-water consultants provided assistance in helping locate drillers' logs and other information used in the report, especially Sherman Galloway of Roswell, New Mexico.

State and Federal personnel who helped locate well log and quality of ground-water data, or who provided other useful information related to the geology and chemistry of ground water in the study area, included Steve Seni and Ronit Nativ of the Bureau of Economic Geology in Austin, Texas; Arthur Mason of the New Mexico State Engineer's Office in Roswell, New Mexico; and Don Hart of the U.S. Geological Survey Water Resource Division in Albuquerque, New Mexico. Also, earlier researchers who analyzed and published data related to the geology and hydrology of the Southern High Plains are to be credited, with special acknowledgements going to John Brand, Edward Leggat, and James Cronin.

The need for a more comprehensive regional geologic and hydrologic study of Lower Cretaceous strata under the Southern High Plains was brought to the author's attention by Phil Nordstrom of the TWDB. Tommy Knowles, Chief of the Board's Water Availability Data and Studies Section of the TWDB, was subsequently apprised of the need and provided administrative support for the investigation. Manuscript typing and drafting are credited to Yolanda Briones and Steve Gifford respectively of the Board.

Geology

Regional Setting

A variety of rock types and different sedimentary formations representing all major geologic eras underlie the Southern High Plains. The rocks include deeply buried and structurally complex Precambrian metamorphic and igneous assemblages that generally range from 0.8 to 1.7 million years in age, and occupy a failed rift system that first projected into the southern cratonic area of North America during Proterozoic time. The rocks fringe on the Greenville-Llano tectonic front to the south and are bound by older Canadian Shield provinces to the north.

Early and middle Paleozoic formations under the Southern High Plains are composed largely of shallow marine shelf carbonates that range from 3,000 to 6,000 feet thick. The strata have numerous regional and sub-regional unconformities, suggesting that extensive and frequent epeirogenic crustal movements affected depositional environments during early and middle Paleozoic time.

Late Paleozoic strata in the study area include marine carbonate and evaporite sequences of Permian age that measure over 8,000 feet thick in places. The strata accumulated in and around a shallow structural depression or basin that developed over older Precambrian rift zones in northwest Texas during the Permian.

Mesozoic strata under the Southern High Plains include Late Triassic redbed sequences composed primarily of lacustrine mudstones, and fluvial-deltaic sandstones and shales (Table 1). The continental redbeds are up to 2,000 feet thick in places, and are unconformably overlain by the erosional outliers of Lower Cretaceous marine rocks that are described in more detail in following sections of this report.

Strata capping Mesozoic and older rock units under the Southern High Plains include the Ogallala Formation and younger surficial deposits. The Ogallala Formation is a near-surface deposit of sand, silt, clay, and gravel that accumulated in fluvial, eolian, and alluvial fan depositional environments during Neogene time. Localized fluvial, eolian, and lacustrine deposits forming the Tahoka, Double Lakes, and Blackwater Draw Formations, as well as modern day stream alluvium and dune sand, cover the Ogallala Formation at most locations.

Tectonic History

The tectonic history of the Southern High Plains is varied and complex. During early and middle Paleozoic time, epicontinental seas periodically transgressed over the region in response to epeirogenic downwarping along what is now North America's southern cratonic boundary. Sediments deposited or precipitated in the marine environments included constructional shallow marine carbonates and lesser amounts of clean sandstone and shale (Fallin, 1985; Nicholas and Rozendal, 1975).

Table 1. - *Physical and Water-Bearing Characteristics of Cenozoic and Mesozoic Strata Under the Southern High Plains.*

System	Series	Group	Formation	Approximate maximum thickness (feet)	Physical character of rocks	Water-bearing characteristics*	
Quaternary	Pleistocene to Recent		Alluvium, eolian and lacustrine deposits	60	Windblown sand and silt, stream alluvium, and silt and clay playa lake deposits.	Yields small amounts of water to wells.	
Tertiary	Late Miocene to Pliocene		Ogallala	600	Composite accumulation of tan, yellow, and reddish-brown silt, clay, sand and gravel that is generally coarser-grained near the base of the formation. Caliche caprock and calcic paleosols occur in fine-grained deposits near the top of the formation.	Yields moderate to large amounts of water to wells. The principal aquifer in the study area with yields of some wells in excess of 1,000 gal/min.	
Cretaceous	Comanche	Washita	Duck Creek	50	Yellow, sandy shale and thin gray to yellowish-brown, argillaceous limestone beds.	Yields small amounts of water locally to wells.	
		Fredericksburg	Kiamichi	110	Thinly laminated, sometimes sandy, gray to yellowish-brown shale with interbeds of thin, gray, argillaceous limestone and thin, yellow sandstone.	Yields small amounts of water locally to wells.	
			Edwards Limestone	35	Light-gray to yellowish-gray, thick bedded to massive, fine to coarse-grained limestone.	Yields moderate to large amounts of water locally to wells from fractures and solution cavities.	Yields small amounts of water to wells.
			Comanche Peak Limestone	85	Light-gray to yellowish-brown, irregularly bedded, argillaceous limestone and thin interbeds of light-gray shale.		Yields small amounts of water to wells.
			Walnut	30	Light-gray to yellowish-brown, fine- to medium-grained, argillaceous sandstone; thin bedded, gray to grayish-yellow, calcareous shale; and light-gray to grayish-yellow, argillaceous limestone.	Not known to yield water to wells.	
		Trinity	Antlers	60	White, gray, yellowish-brown to purple, fine- to coarse-grained, argillaceous, loosely cemented sand, sandstone, and conglomerate with interbeds of siltstone and clay.	Yields small to moderate amounts of water to wells in the study area.	
Triassic	Upper	Dockum	Undivided	2,000	Upper unit, varicolored siltstone, claystone, conglomerate, fine-grained sandstone, and limestone. Lower unit, varicolored, fine to medium-grained sandstone with some claystone and interbedded shale.	Yields small to moderate amounts of water to wells. Water quality variable with stratigraphic position and depth.	

* Yields of wells: small = <50 GPM, moderate = 50-500 GPM, large = >500 GPM.

The convergence and collision of North and South America in the late Paleozoic Era subsequently displaced open marine seas along the southern edge of the North American craton, first into interior sag basins and other depressions bordering the Ouachita tectonic belt, then away from the region entirely. Cut off from open ocean currents, inland seas overlying the Permian Basin in the Southern High Plains region ultimately evaporated, leaving behind large deposits of halite, potash salts, and anhydrite.

In the early Mesozoic Era, fresh water lake basins developed over the mid-continent region, leading to the accumulation of lacustrine and fluvial-deltaic deposits that make up the Dockum Group (Late Triassic). Major source areas contributing sediments to the lake basins included the Ouachita tectonic belt to the south and east, a structural remnant from the collision of North and South America (Granata, 1981).

The separation of North and South America and consequent opening of the Gulf of Mexico followed, with crustal subsidence around the edge of the Gulf tilting and draining mid-continent lake basins to the southeast during the Jurassic Period. At about the same time, compressional orogenic events in western North America, e.g., the Nevadan orogeny, downwarped the entire mid-continent region, permitting oscillating seas to transgress over the study area in the Early Cretaceous Period and to deposit the Lower Cretaceous strata that are the subject of this report.

Laramide uplift and other tectonic events associated with Tertiary doming along the Rio Grande rift system to the west subsequently elevated the Southern High Plains above sea level again, tilting the region to the southeast at the same time. Partial draining and erosion of Cretaceous and older formations accompanied the uplift, exposing the strata to direct fresh-water recharge in some places and depositing younger, fresh water-bearing sediments (i.e., the Ogallala Formation) on top of the units in others. Today, eroded outliers of Lower Cretaceous and younger strata continue to mantle older rock units under uplifted portions of the Southern High Plains.

Cretaceous System

Introduction

A typical Lower Cretaceous section under the Southern High Plains includes a basal sand and sandstone deposit overlain by marine marls, clays, and associated limestones. Deposited on eroded Late Triassic terrain and covered largely by Tertiary-age sediments, the Lower Cretaceous strata form buried mesas with more than 250 feet of subsurface relief at some locations. The buried mesas are erosional outliers of a system of rocks that are much more extensively preserved and exposed in the Edwards Plateau region of South-Central Texas.

The regional unconformities that bound Lower Cretaceous strata under the Southern High Plains are irregular surfaces crosscut with erosional channels at some locations (Figures 2 and 3). The channels trend east-southeast across the study area, with upper

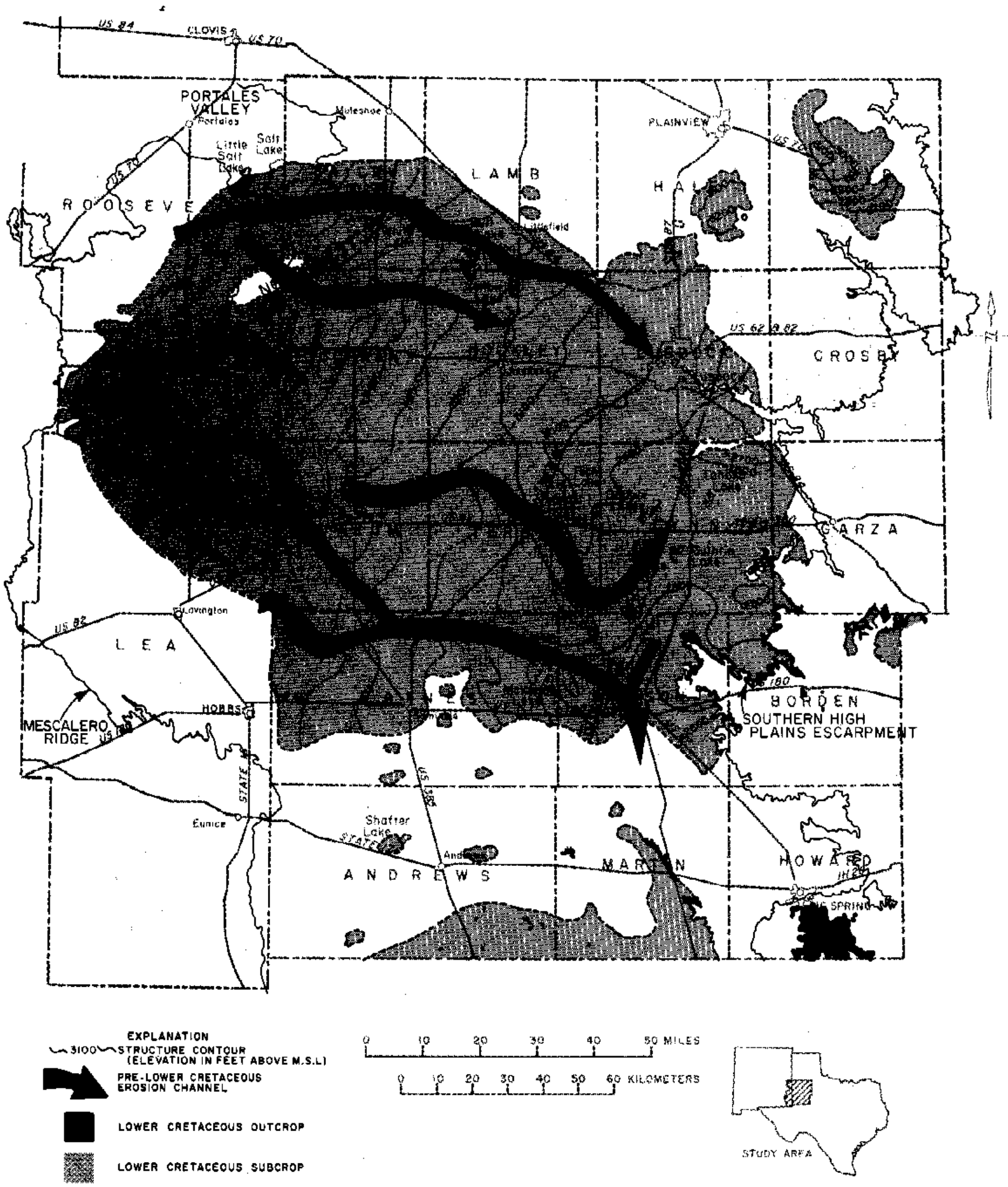

Figure 2

Structure Contour Map Showing the Altitude of the Base of Lower Cretaceous Strata Under the Southern High Plains

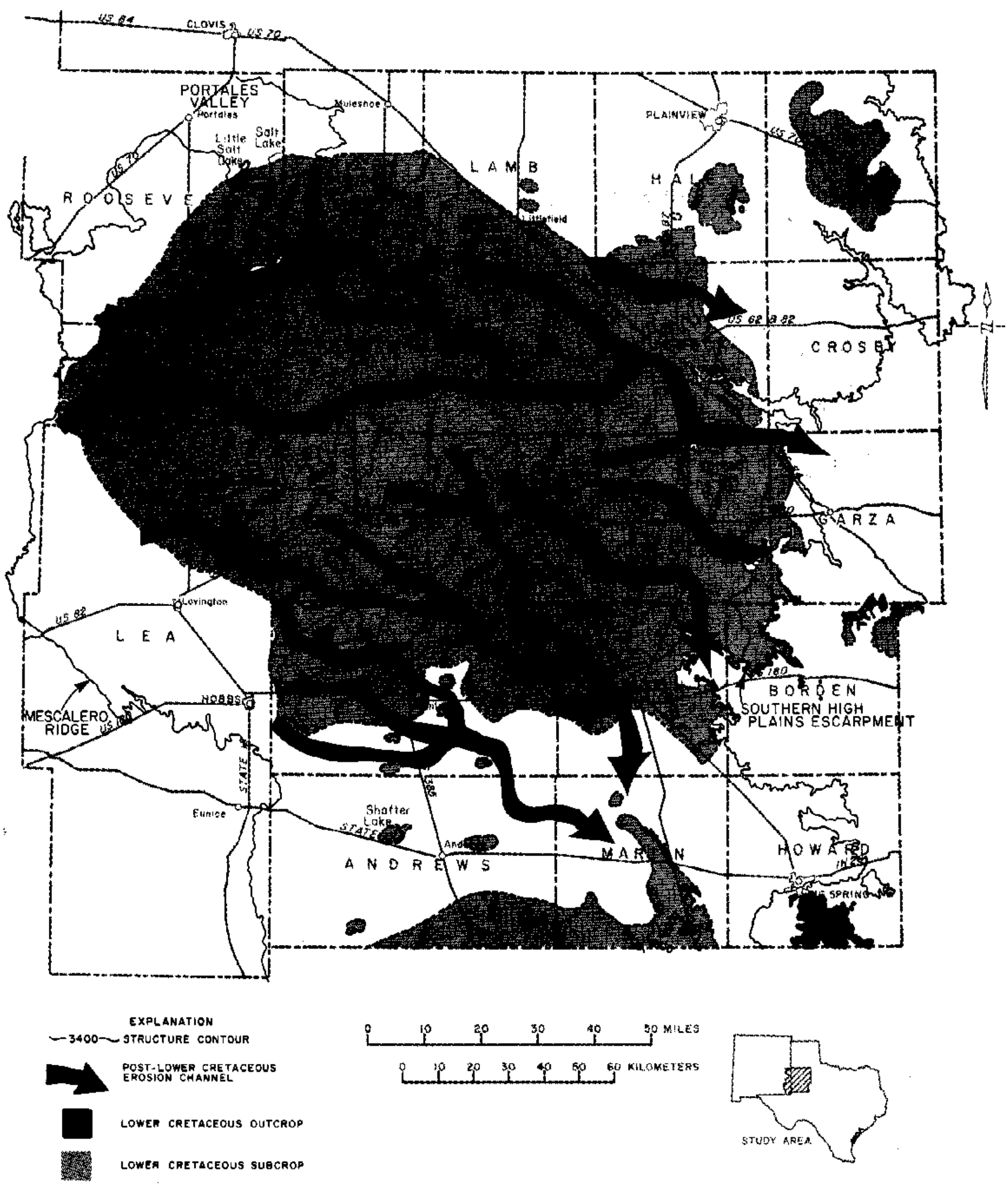

Figure 3

Structure Contour Map Showing the Altitude of the Top of Lower Cretaceous Strata Under the Southern High Plains

channel courses sometimes cutting entirely through the Lower Cretaceous section (e.g., Slaton Channel, southeast Lubbock County, Texas).

Strata immediately underlying the regional unconformities are discolored at many locations, reflecting the effects of subaerial weathering during hiatal periods that bounded Lower Cretaceous depositional events. Reddish-brown mudstones are commonly tinted blue-green one to two feet below the Late Triassic-Lower Cretaceous unconformity, and blue-gray limestones and clays in upper parts of the Lower Cretaceous section are often oxidized yellow to a depth of 10 or more feet immediately below the Ogallala Formation.

Stratigraphy

As many as six Lower Cretaceous formations have been described under the Southern High Plains. The formations define parts of the Trinity, Fredericksburg, and Washita Groups of the Gulf Coast Comanchean Series in North America. Biostratigraphic zonation of the sequence is based primarily upon the occurrence of ammonites and other marine fossils in the stratigraphic section (Brand, 1953).

Trinity Group

In the Southern High Plains region, the Trinity Group is represented by the Antlers Formation, a white to purple, unconsolidated to moderately well cemented, fine- to coarse-grained quartz sand and sandstone. In the study area, the Antlers Formation is interbedded locally with green clay and pink siltstone, and has scattered lenses of gravel that include well-rounded quartz pebbles and claystone clasts derived from underlying Late Triassic strata. Quartz grains in the Antlers Formation are typically well rounded and frosted in appearance, both characteristics associated with near-shore marine, beach and dune sand deposits.

As an irregular sheet deposit, the Antlers Formation pinches and swells in thickness while thinning regionally to the northwest (Figures 4 and 5). Measured sections of the unit range from less than one to more than 60 feet thick under the Southern High Plains. In eastern New Mexico and more northern parts of the study area in Texas, the Antlers Formation is locally absent, having been removed by post-depositional erosion at some locations.

Fredericksburg Group

The Fredericksburg Group under the Southern High Plains includes the Walnut, Comanche Peak, Edwards, and Kiamichi Formations. Also, part of the time transgressive Antlers Formation is probably of Fredericksburg age in northwestern parts of the study area.

Lithologically, the Walnut Formation is composed of light gray, calcareous shale, fine- to medium-grained sandstone, and light gray, argillaceous limestones. It grades abruptly upward into thicker, more massive, light gray, argillaceous limestones and interbedded marls of the Comanche Peak Formation.

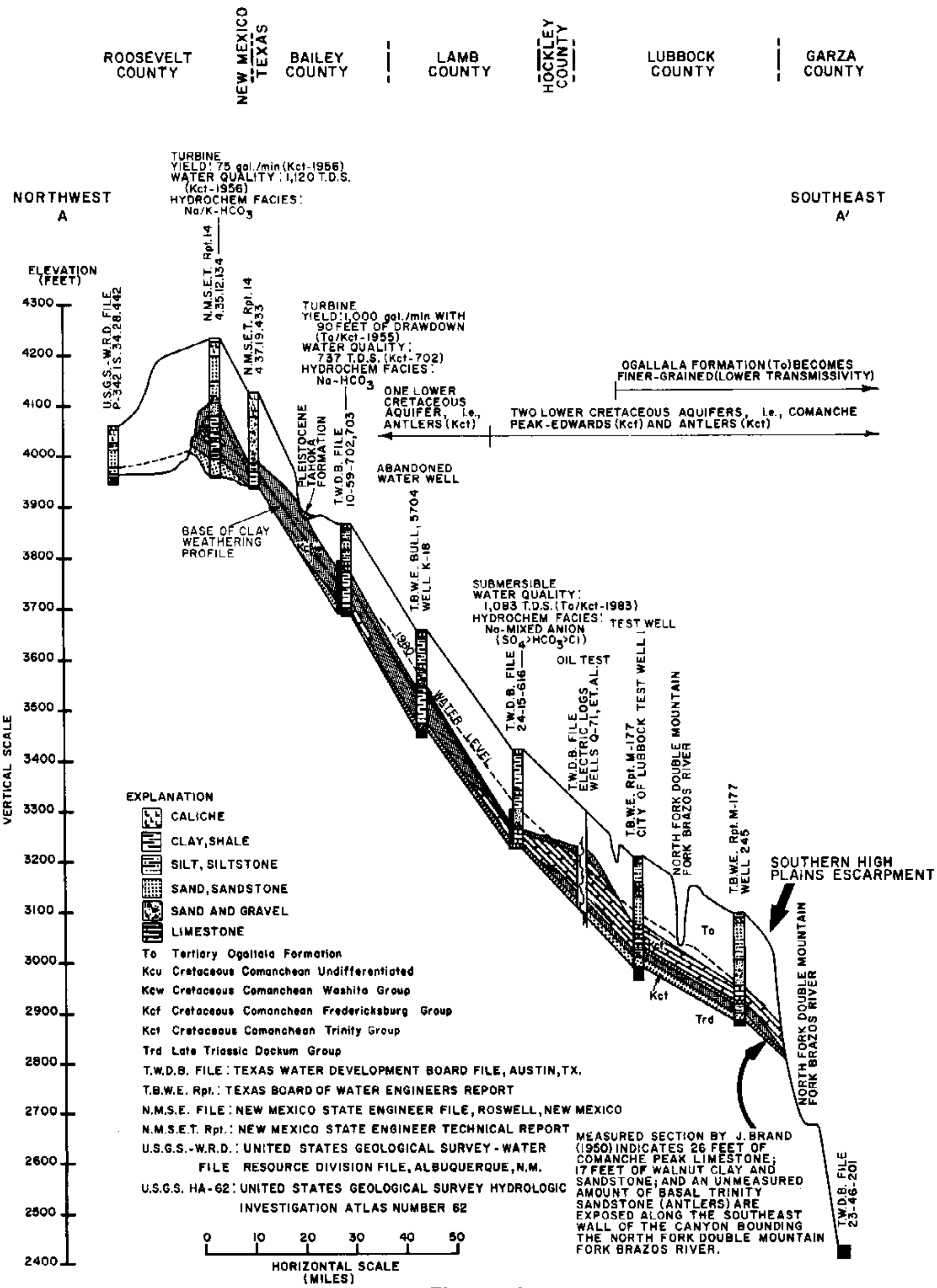

Figure 4

Geologic Section A - A'
Showing Dip Profile of Lower Cretaceous Strata Under the Southern High Plains

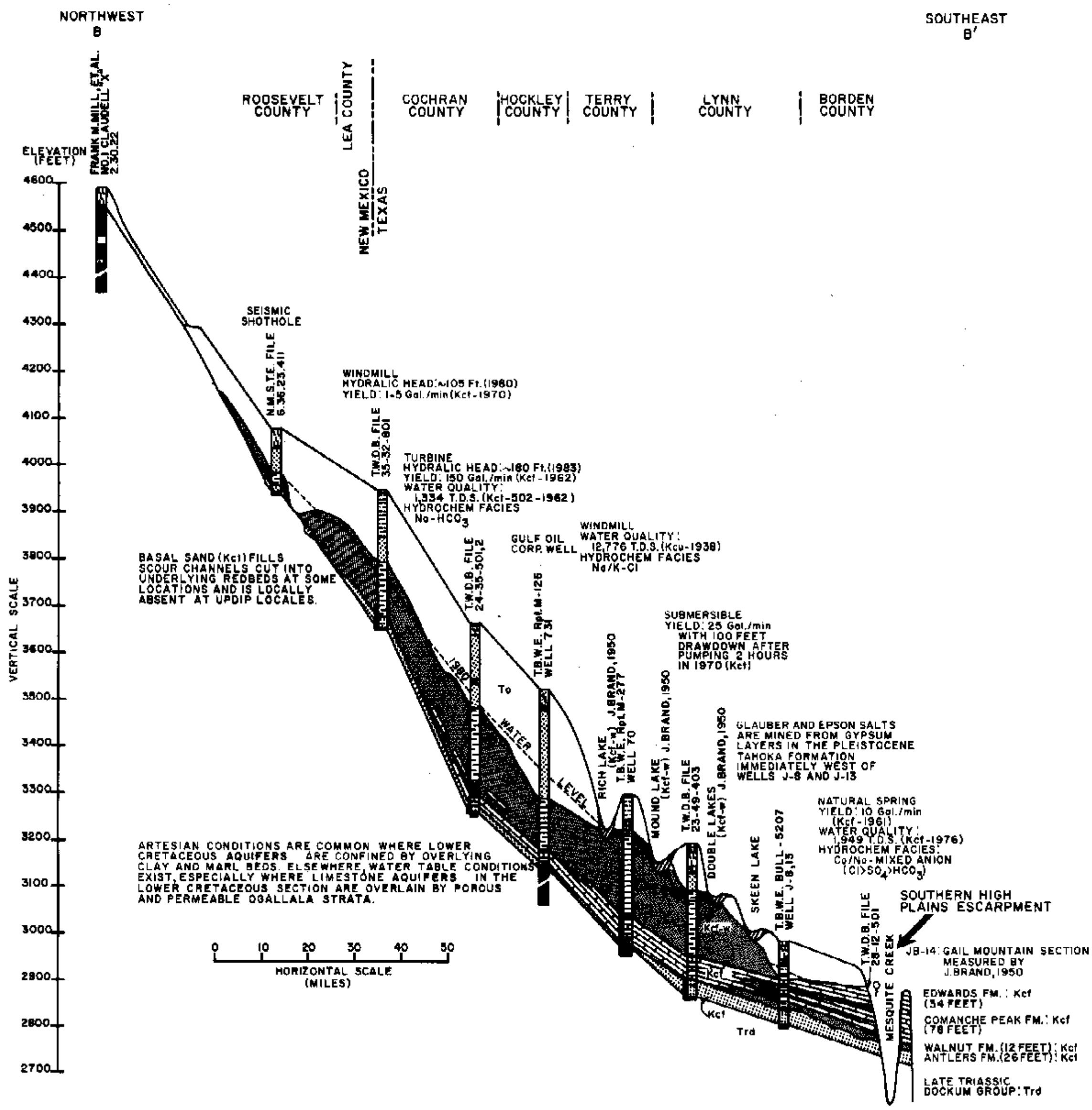

Figure 5

**Geologic Section B - B'
Showing Dip Profile of Lower Cretaceous Strata
Under the Southern High Plains**

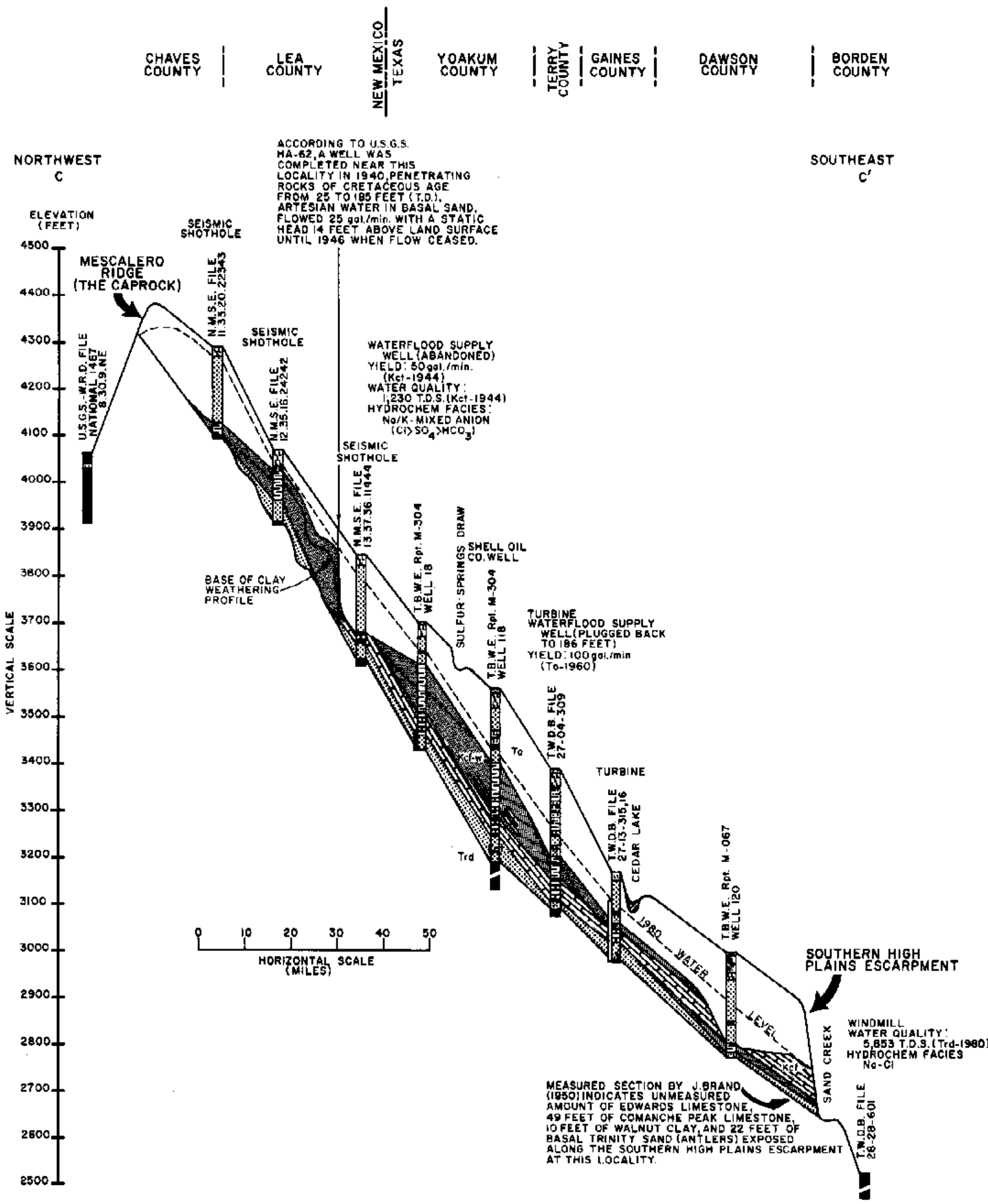

Figure 6

**Geologic Section C - C'
Showing Dip Profile of Lower Cretaceous Strata
Under the Southern High Plains**

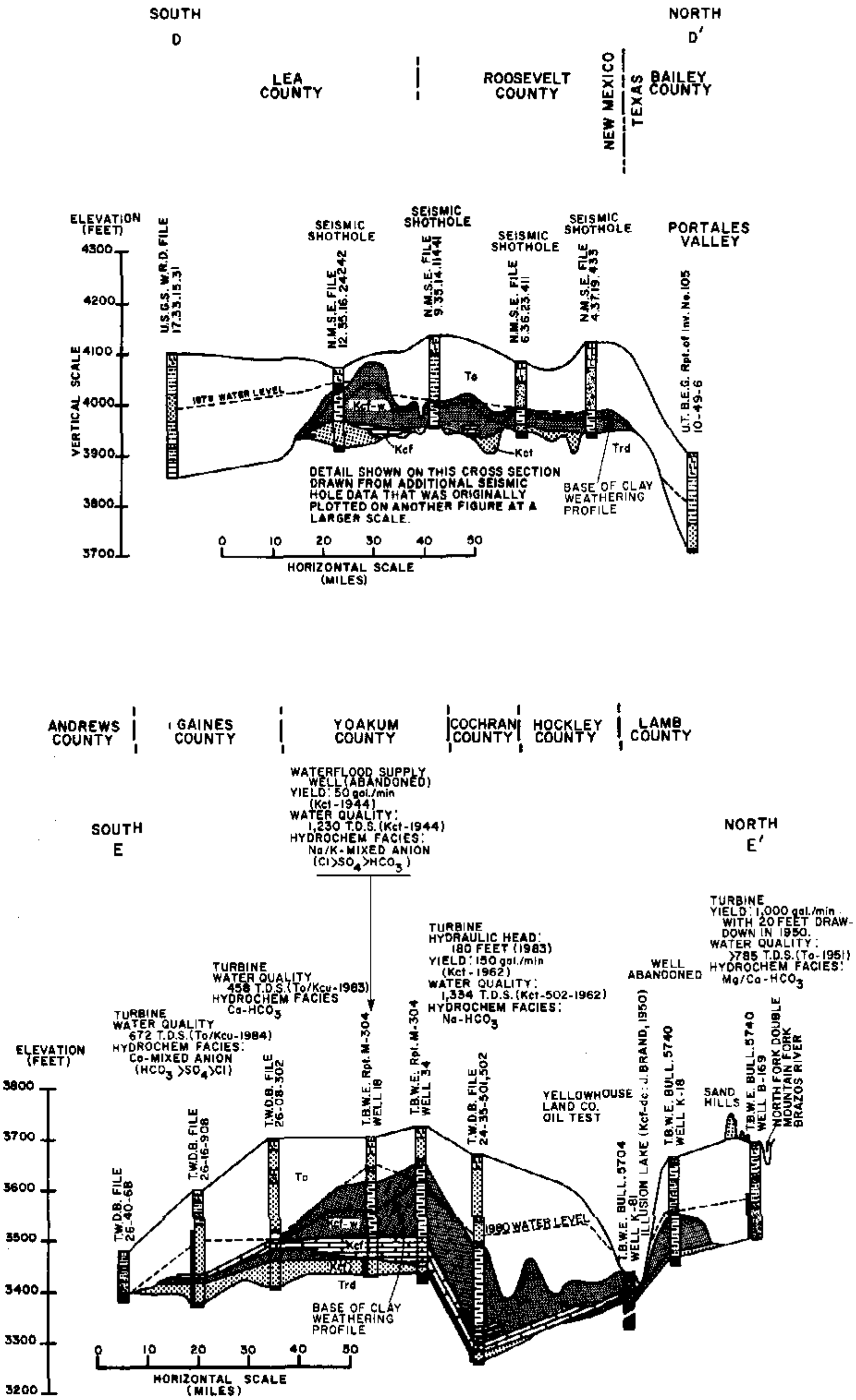

Figure 7

Geologic Sections D - D' and E - E' Showing Strike Profiles of Lower Cretaceous Strata Under the Southern High Plains

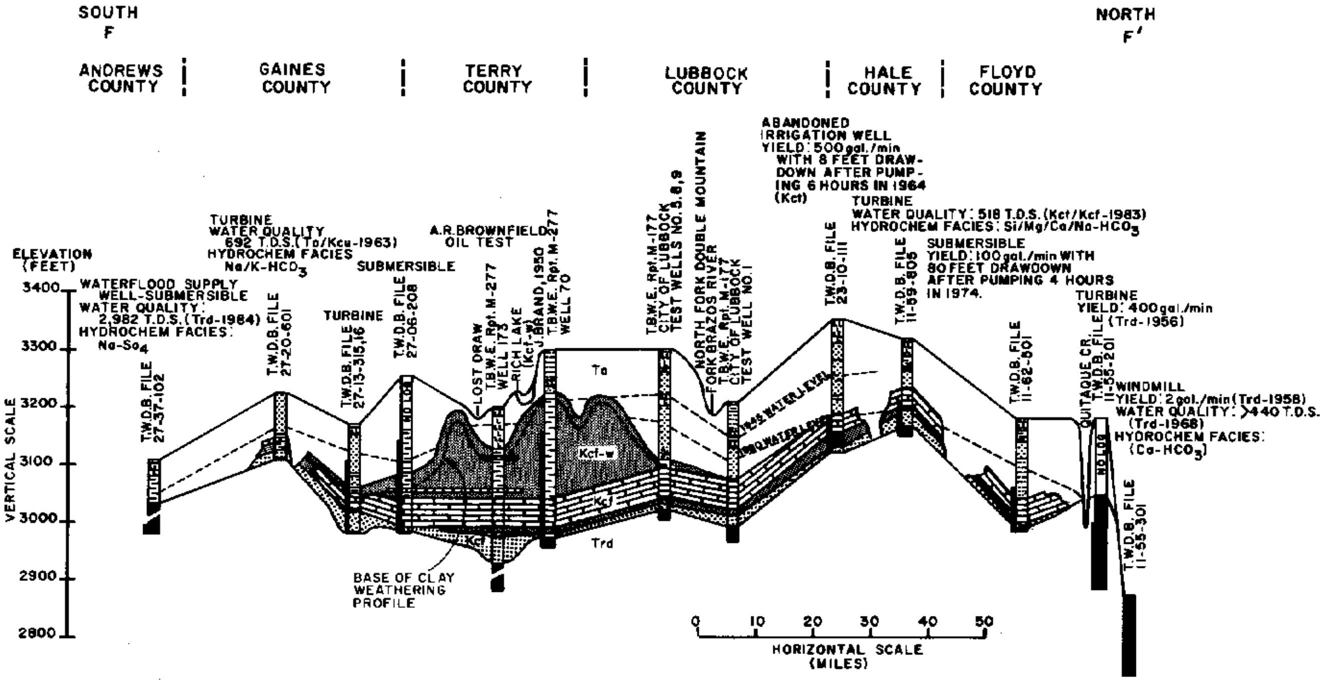

Figure 8

Geologic Section F - F'
Showing Strike Profile of Lower Cretaceous Strata
Under the Southern High Plains

Under southeastern parts of the Southern High Plains, the Walnut Formation exceeds 30 feet in thickness, while the Comanche Peak Formation is as much as 85 feet thick. However, like the underlying Antlers Formation, both the Walnut and Comanche Peak Formations thin appreciably to the northwest, disappearing entirely at some locations.

The Edwards Formation overlies the Comanche Peak Formation in the southeast part of the Southern High Plains. It is profiled in steeper parts of the High Plains escarpment, and is a light gray to yellow, thick-bedded "Rudist" limestone that is honeycombed locally with solution cavities.

The Edwards Formation measures as much as 35 feet thick along the High Plains escarpment. However, the formation pinches out abruptly to the northwest, signaling the edge of a platform reef complex that developed over much of the central Texas region during the Early Cretaceous Period.

The Kiamichi Formation is the uppermost stratigraphic unit of the Fredericksburg Group. It is composed primarily of yellow-brown to dark blue-gray shale, but also has thin interbeds of gray, argillaceous limestone and yellow, fine-grained sandstone.

Where completely preserved, the Kiamichi Formation is at least 110 feet thick under the Southern High Plains. However, part or all of the formation is missing in some parts of the study area due to post-depositional erosion.

Washita Group

The Washita Group overlies the Fredericksburg Group and is represented by the Duck Creek Formation under the Southern High Plains. The Duck Creek Formation is composed of yellow-brown shale interbedded with thin lenses of argillaceous limestone and fine-grained sandstone.

Data from isolated wells suggest that the Duck Creek Formation probably exceeds 50 feet in thickness under the Southern High Plains. However, like the underlying Kiamichi Formation, it has been thinned or completely removed by post-depositional erosion at many locations. Undifferentiated sections of the Duck Creek and Kiamichi Formations generally thicken to the north and northwest in marked contrast to other Lower Cretaceous stratigraphic intervals in the study area.

Depositional History

Facies analyses and other geologic criteria indicate that Lower Cretaceous strata in the study area accumulated as epicontinental seas moved over the region from the southeast. The basal Antlers Formation accumulated during Early to Middle Albian time (Figure 9) in near-shore marine, beach, and coastal sand dune environments, sometimes being reworked as seas transgressed, regressed, then transgressed over the study area again. During latter parts of the same depositional period, the Walnut and Comanche Peak

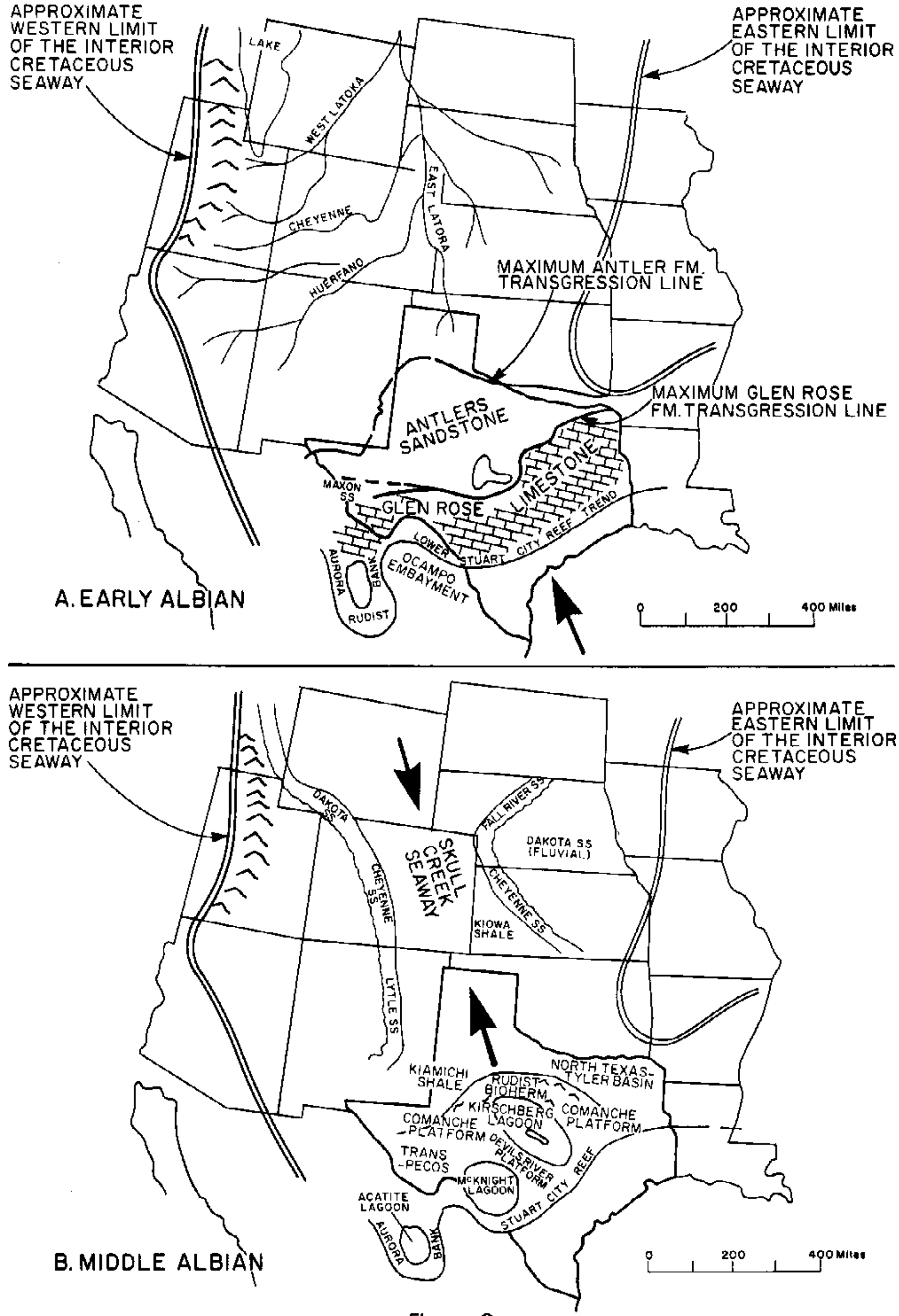

Figure 9

Early and Middle Albian Paleogeographic Maps of the Southern Mid-Continent Region of North America After West Texas Geological Society, 1981; (Mallory, 1972; Fisher and Rodda, 1969)

Formations accumulated offshore in shallow lagoon and carbonate platform environments. Then, as Mesozoic seas stabilized in early Middle Albian time, a more extensive platform and lagoonal complex developed over much of Central Texas. Rudist bioherms grew over and along the edges of the platform, ultimately defining the Edwards Formation that crops out along the southeastern High Plains escarpment and over the Edwards Plateau region of South-Central Texas.

Following Edwards deposition, the Southern High Plains was subaerially exposed in areas where major Edwards bioherms were developed. Then Middle Albian seas transgressed over the region again, eventually covering the entire mid-continent area of North America. The Kiamichi Formation and other lithostratigraphic equivalents (e.g., basal parts of the Tucumcari Shale in New Mexico) accumulated mostly in the expanded shallow marine sea before more stagnant lagoonal environments developed over the study area near the end of Fredericksburg time.

Renewed transgression subsequently opened the mid-continent seaway again, forming a shallow, open marine environment in which the Duck Creek Formation accumulated. Gulfward retreat of Upper Comanchean seas followed, bringing to an end all Lower Cretaceous deposition over the Southern High Plains.

Hydrology

Introduction

Essentially all Lower Cretaceous strata under the Southern High Plains occur below the regional water table, and are saturated with fresh to moderately saline ground water. Only in limited updip recharge areas of eastern New Mexico, and downdip drain areas along the Southern High Plains escarpment in Texas does the regional water table drop below the upper surface of the Lower Cretaceous subcrop.

The Lower Cretaceous strata are in hydraulic continuity with other water-bearing formations in the region, and are considered to be part of the High Plains aquifer. Basal sandstone beds in the Antlers Formation, and solution cavities, fractures, joints, and bedding planes in limestone portions of the Comanche Peak and Edwards Formations define ground-water aquifers in the Lower Cretaceous section. However, limestone and sandstone stringers in the Kiamichi and Duck Creek Formations also transmit limited amounts of ground water through the system at some locations.

Aquiclude intervals in the Lower Cretaceous section include thick clay and marl beds that form major parts of the Walnut, Kiamichi, and Duck Creek Formations. Yielding little, if any, ground water to wells and springs in the study area, the fine-grained strata serve to confine ground-water aquifers in the High Plains aquifer at some locations, while also diverting regional ground-water flow around and over much of the Lower Cretaceous subcrop.

Ground-water movement and drainage through the Lower Cretaceous strata is generally to the east-southeast in conformance with head distribution and structural dip (Figure 10). Intraformational facies changes, joint patterns, local cementation, and sinuosity of underlying scour channels, however, prompt local deviations in flow patterns.

Ground-water flow rates in the Lower Cretaceous strata are estimated to vary from a few feet per year in lower sandstone sections to more than 100 feet per day sometimes where solution cavities and joint systems are particularly well developed in limestone intervals. Discharge from these aquifers is to well heads in Texas and New Mexico; to streams, springs, and seeps along the Southern High Plains escarpment in Texas; and to surrounding formations. Recharge to the system occurs directly from bounding Ogallala deposits along northern and western parts of the subcrop area, and indirectly by downward percolation or infiltration from the overlying Ogallala at other locations (Figure 11). Precipitation is the principal source of recharge to the bounding and overlying Ogallala Formation, with ground-water renewal rates to the Ogallala generally averaging less than one half inch per year when semiarid climatic conditions prevail over the Southern High Plains.

Overall well yields from Lower Cretaceous strata under the Southern High Plains range from less than 50 to more than 1,000 gallons per minute. Highest yield rates have thus far come from isolated wells completed in the Antlers Formation in the Causey-Lingo area of Roosevelt County, New Mexico, and from wells completed in the Antlers, Comanche Peak, and Edwards Formations in Hale and Lubbock Counties, Texas. Wells dually completed in Ogallala and Lower Cretaceous rocks are common in many parts of the study area, particularly where the Comanche Peak and Edwards Formations are well developed in the Lower Cretaceous section.

The content of dissolved solids in ground water in Lower Cretaceous rocks is shown in Figure 12. The water is generally characterized by either a mixed-cation-bicarbonate (mixed-HCO_3) or sodium-bicarbonate (Na-HCO_3) hydrochemical signature (Figure 13). However, in areas overlain by saline lakes and the gypsiferous Tahoka and Double Lakes Formations (Pleistocene), either sodium-chloride (Na-Cl) or sodium-sulfate (Na-SO_4) hydrochemical facies usually prevail. Ground water in the Lower Cretaceous section is slightly basic, with pH values ranging between 7.5 and 8.5. The water is moderately to extremely hard, with equivalent concentrations of calcium carbonate typically ranging between 100 and 1,000 milligrams per liter.

As part of the High Plains aquifer, Lower Cretaceous strata have a pronounced effect on regional ground-water movement under the Southern High Plains. More specifically, the baffling effect of Lower Cretaceous clay and marl intervals, and the less extensive development of porous and permeable deposits (i.e., the Ogallala Formation) over the areas of Lower Cretaceous subcrop, serve to restrict regional ground-water flow in the aquifer system. As a consequence, well yields and water quality are somewhat diminished in the study area when compared to most other regions producing from the High Plains aquifer. Ponding of ground water in the Ogallala Formation behind buried Lower Cretaceous subcrop highs is also apparent, particularly in Lea County, New Mexico, where updip Ogallala deposits are buttressed against Lower Cretaceous clay and marl intervals (Figure 6), and in Cochran, Hockley, and Lubbock Counties, Texas, where regional water levels are measurably offset from adjoining areas to the north and south (Figures 7 and 8).

Regional Aquifer Characteristics

Antlers Formation

General Features

As a relatively thin, irregular sheet deposit that decreases in overall thickness to the northwest, the Antlers Formation is limited as an aquifer throughout much of the study area. Only in western and southern subcrop areas where thicker than usual sections

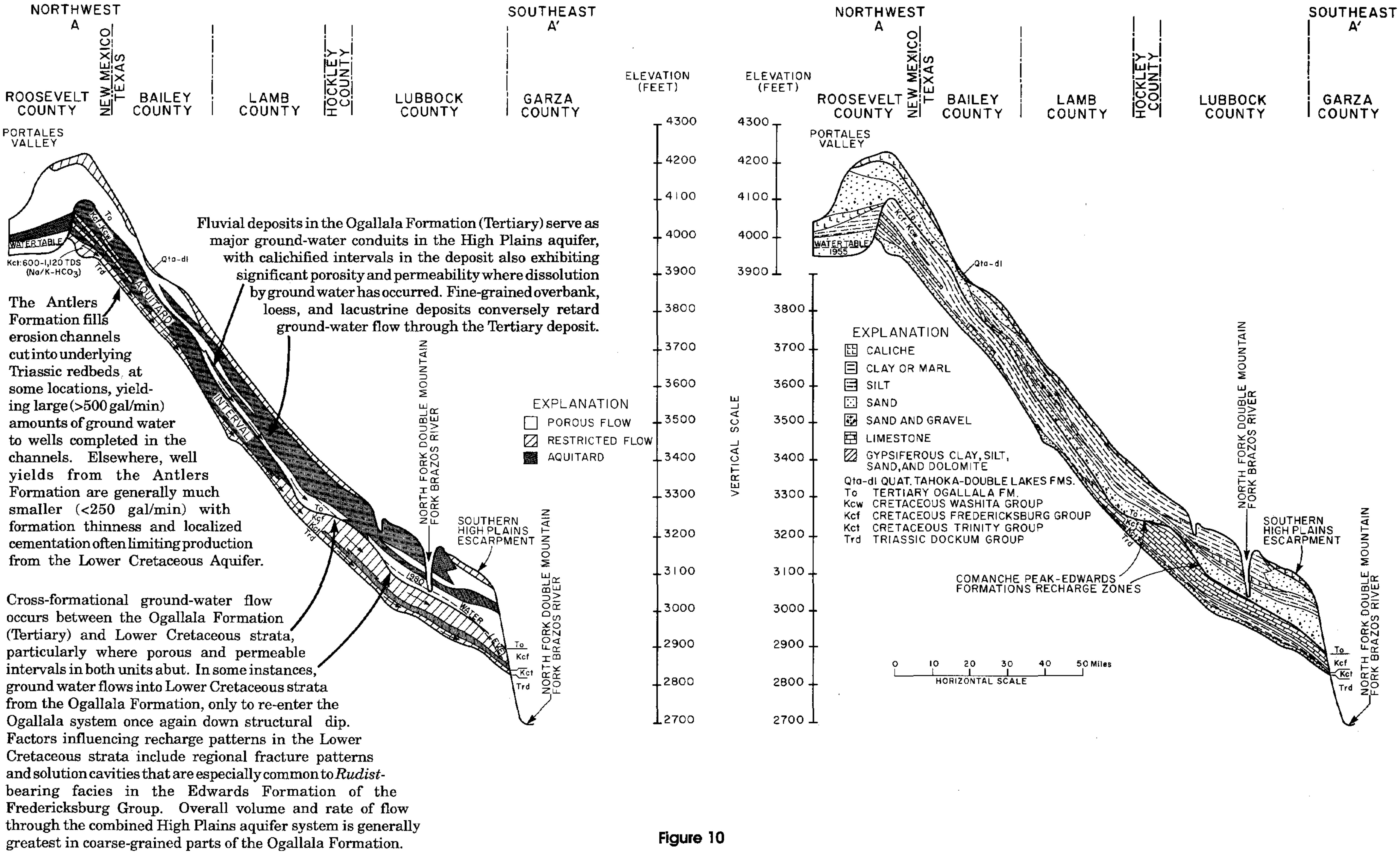

Figure 10

Facies Distribution and Ground-Water Flow Paths in the Southern High Plains Aquifer: Section A - A'

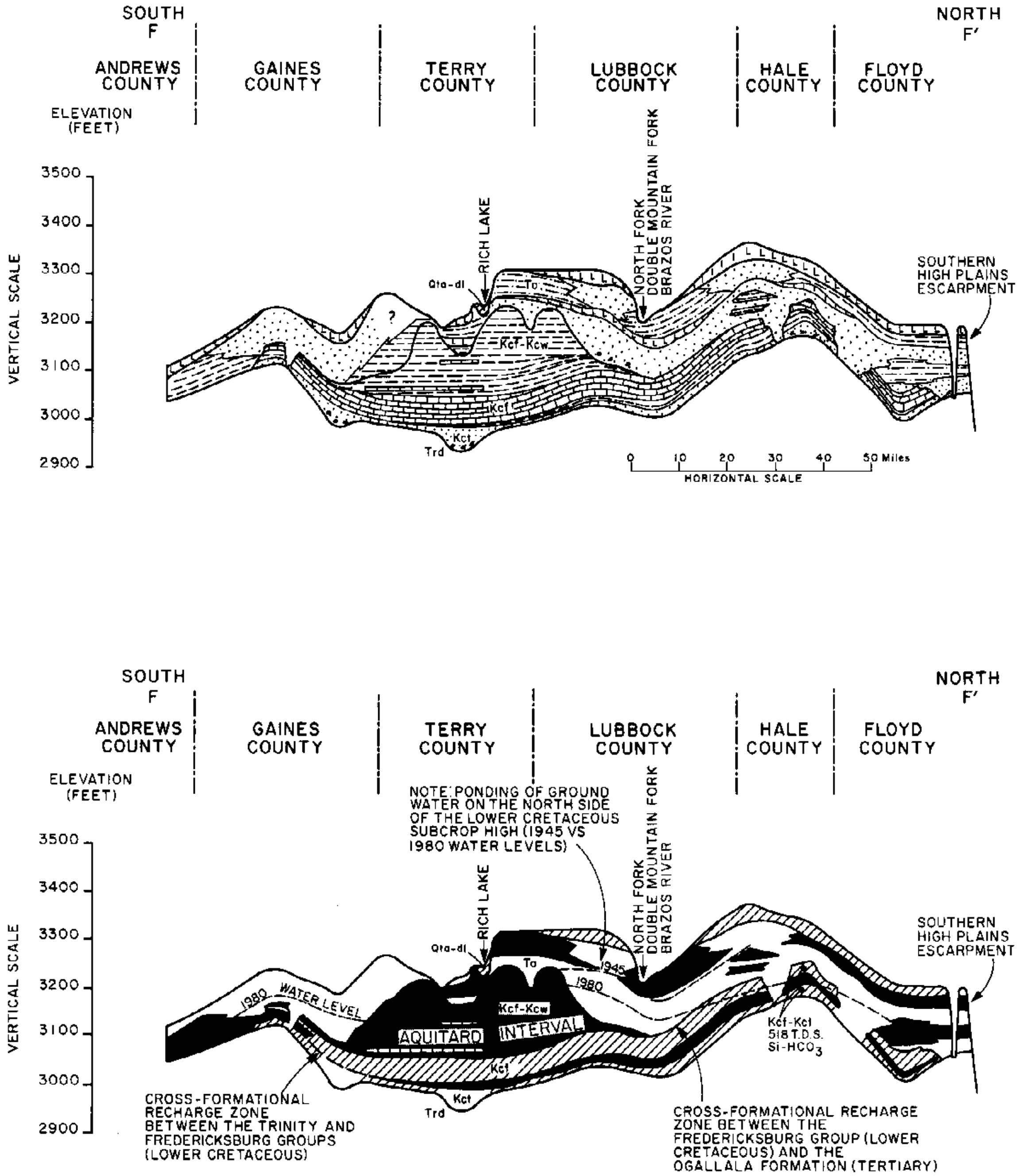

Figure 11

Facies Distribution and Ground-Water Flow Paths in the Southern High Plains Aquifer: Section F - F'
(See Figure 10 for Explanation of Symbols and Patterns)

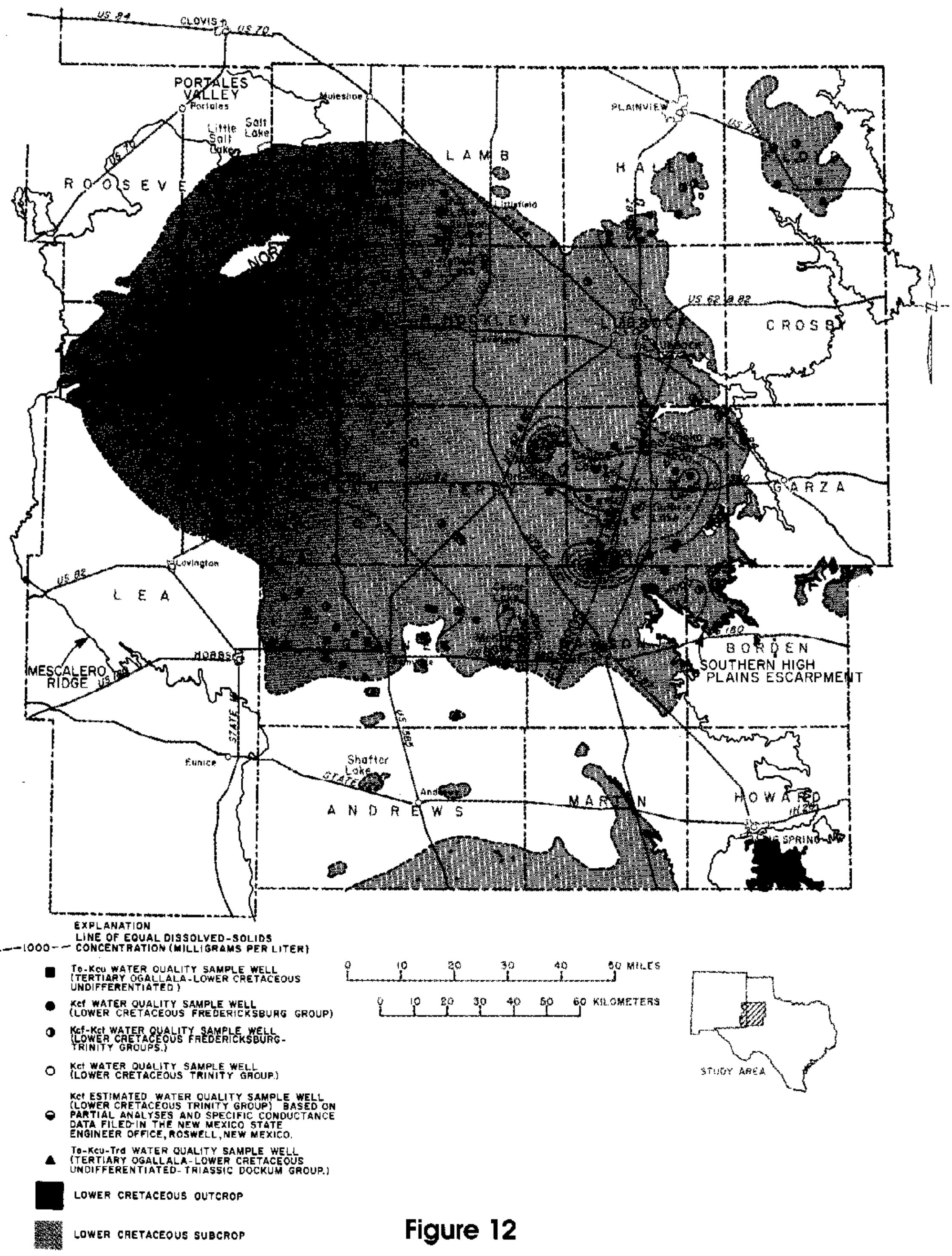

Figure 12

Water Quality Map of Lower Cretaceous Aquifers Under the Southern High Plains

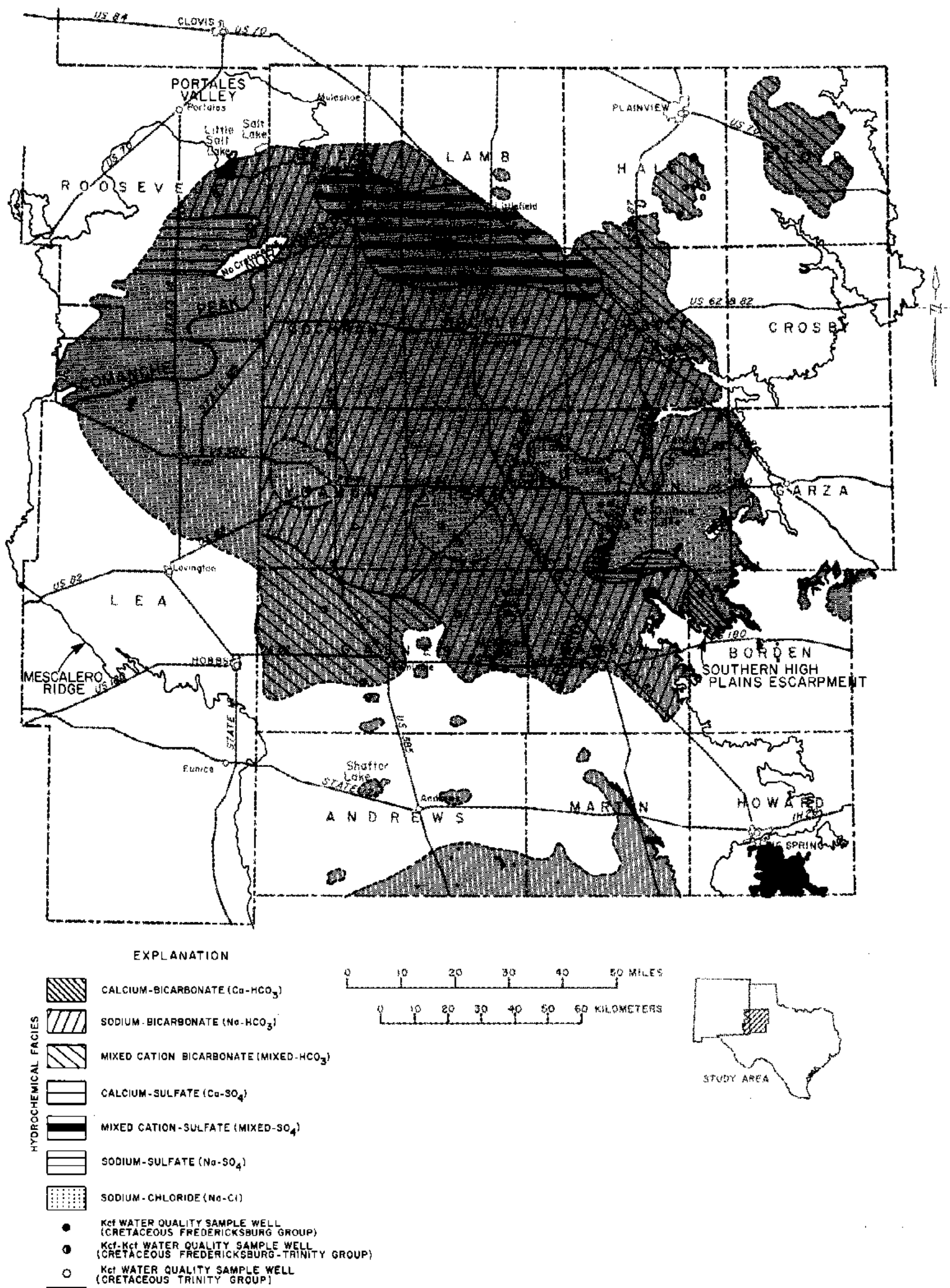

Figure 13

Generalized Hydrochemical Facies Map of Lower Cretaceous Aquifers Under the Southern High Plains

occur in erosion channels cut into the underlying Triassic section do wells generally produce more than 100 gallons per minute from the basal Lower Cretaceous aquifer.

Stratigraphically, the Antlers Formation is almost everywhere bound by underlying mudstone sequences in the Dockum Group, and by overlying clay or marl beds in the Walnut, Comanche Peak, and Kiamichi Formations. As a consequence, ground water in the formation is usually confined, and artesian pressures are common to the system. Exceptions occur in areas such as eastern New Mexico where numerous uncased seismic holes have been drilled into the Lower Cretaceous strata, allowing confined ground water to leak upward into the overlying Ogallala Formation while decreasing hydraulic pressures in the Antlers Formation below (Ash, 1963).

Regional ground-water flow through the Antlers Formation is generally to the east-southeast in conformance with regional structure dips. Calcite and more limited quartz cementation, however, influences flow patterns through certain parts of the formation, restricting and even preventing water movement at some locations. The cementation is only locally well developed, and loose sand also occurs within the stratigraphic unit. In fact, unconsolidated to only weakly cemented intervals in the basal Lower Cretaceous Formation measure more than 60 feet thick at some locations in southeast Roosevelt County, New Mexico, and in northwest Gaines County, Texas. Another factor that influences regional ground-water movement through the Antlers Formation is eroded channel courses cut into the underlying Late Triassic section. Funneling water in a sinuous east-southeasterly direction, deposits in the paleo-drainage courses are particularly well defined under parts of Lea and Roosevelt Counties, New Mexico, and under parts of Cochran, Dawson, Gaines, Lynn, and Terry Counties, Texas (Figure 2).

The Antlers Formation generally occurs 200 to 350 feet below land surface under the Southern High Plains, and wells tapping it are often dually completed in the overlying Ogallala Formation for additional yield. Actual production from wells completed solely in the Antlers Formation ranges from less than 50 to more than 1,000 gallons of water per minute in the study area, with highest yields thus far coming exclusively from wells completed in thicker-than-average sections filling erosion channels cut into the underlying Dockum Group in Roosevelt County, New Mexico.

Pump Test Data

Pump test data for wells completed in the Antlers Formation varies from location to location. The specific capacity of one well completed in the formation 10 miles south of Whiteface in Cochran County, Texas, was 1.63 gallons per minute per foot of drawdown after it was pumped for 27 hours at a rate of 150 gallons per minute in 1962 (Rayner, 1963). A cone of depression was calculated to extend several miles around the Cochran County well, and it was determined that the aquifer possesses very low recoverable artesian storage characteristics at the investigation site. Similarly, another well in Yoakum County, Texas, also indicated limited transmissivity values for the Antlers Formation, having a specific capacity of only 1.1 gallons per minute per foot of drawdown while pumping 65 gallons per minute over a period of time (Mount and others, 1967). Elsewhere, hydraulic conductivity in the formation is clearly better developed, since some wells in Roosevelt County, New Mexico, have produced as much as 1,200 gallons per minute from the Antlers for extended periods of time, then have recovered relatively quickly after pumping has ceased.

Water Quality and Chemistry

Limited analyses suggest that ground-water quality in the Antlers Formation generally ranges from fresh to slightly saline in character, and exhibits either a calcium-bicarbonate or sodium-bicarbonate hydrochemical signature. However, in areas overlain by saline lakes and where the near-surface gypsiferous Tahoka and Double Lakes Formations are present, water quality in the Antlers and in the High Plains aquifer as a whole, is diminished, with dissolved solids exceeding 6,000 mg/l in places, and either sodium-sulfate or sodium-chloride hydrochemical facies prevailing.

Regional Storage

Core, well log, and outcrop data indicate that the Antlers Formation under the Southern High Plains has an average stratigraphic thickness of 15 feet, an average porosity of 15 percent, and an areal extent of about 9,000 square miles, suggesting the formation contains approximately 12 million acre-feet of ground water. Approximately 90 percent of the aquifer underlies Texas, where the storage capacity below specific surface drainage basins is estimated as follows: Colorado River Basin, 7,348,320 acre-feet, and Brazos River Basin, 3,149,280 acre-feet. It is estimated that approximately 25 percent of all ground water stored in the Antlers Formation may be economically recoverable. Finite replenishment rates, overall formation thinness, and low coefficient of storage values will most assuredly limit any sustained, long-term production from the aquifer.

Comanche Peak and Edwards Formations

General Features

Limestone intervals in the Comanche Peak and Edwards Formations combine to form an effective aquifer system under the Southern High Plains, especially where the stratigraphic units are maximally developed along the southern and eastern edges of the study area in Borden, Dawson, Floyd, Hale, Gaines, Lubbock, and Lynn Counties, Texas. Filling solution cavities, fractures, joints, and bedding planes, ground water in the limestone formations generally flows in a southeasterly direction, sometimes issuing at springs and seeps along the eastern edge of the Southern High Plains escarpment.

Stratigraphically, the Comanche Peak-Edwards aquifer is usually underlain by the Walnut Formation, and overlain by either the Kiamichi or Ogallala Formations. Calcareous shales in the Comanche Peak and Walnut Formations generally form an effective aquiclude that separates the aquifer from artesian ground-water zones in the Antlers Formation below them. In eastern parts of the study area, sand and gravel beds in the Ogallala Formation commonly cover the limestone aquifer, making the system upwardly unconfined. The upward unconfinement permits ground water to occur under water-table conditions throughout most of the area where the aquifer is maximally developed under the Southern High Plains.

Producing intervals in the Comanche Peak-Edwards aquifer range from less than 10 to more than 60 feet thick in the study area, and wells are generally designed to accept water under open-hole or slotted-casing conditions from the entire water-yielding section upon completion. As to be expected, wells completed along zones of major fracture concentrations, or in cavernous parts of the section, yield substantially more water than wells completed in unfractured or uncavernous parts of the limestone aquifer (Figure 14). In the study area, surface lineament studies suggest that major fracture trends in the Comanche Peak-Edwards aquifer are oriented northwest-southeast, and to a lesser extent, northeast-southwest. The fracture trends are especially well developed in Bordon, Dawson, Hale, Hockley, Lubbock, and Terry Counties, Texas (Figure 14). For additional yield purposes, many wells completed in the limestones also draw water from producing intervals in the underlying Antlers Formation and overlying Ogallala Formation.

The Comanche Peak-Edwards aquifer usually occurs between 20 and 250 feet below the land surface along the eastern edge of the study area, with the shallowest parts of the system being located immediately adjacent to the Southern High Plains escarpment in Borden, Dawson, and Lynn Counties, Texas. Well yields from the reservoir range from less than 50 to more than 800 gallons per minute, with highest production having thus far come from well sites in Hale and Lubbock Counties, Texas.

Pump Test Data

Pump tests show that the specific capacity of the Comanche Peak-Edwards aquifer system varies from one locality to the next, reflecting the uneven distribution and development of cavity-prone **Rudist** facies, and other porous and permeable zones in the stratigraphic section over the study area. In Hale County, Texas, where individual well yields regularly exceed 250 gallons per minute, five separate pump tests have indicated the system's specific capacity to be 2.1, 35.3, 62.5, 22.7, and 5.9 gallons of per minute per foot of drawdown, respectively. Another pump test in Lamb County, Texas, showed a specific capacity of 2.2 gallons per minute per foot of drawdown for a well producing 65 gallons per minute from the aquifer. Also, a well completed solely in the Edwards Formation four miles east of O'Donnell on the Lynn-Dawson county line was drawn down only 0.69 foot when pumped at a rate of 810

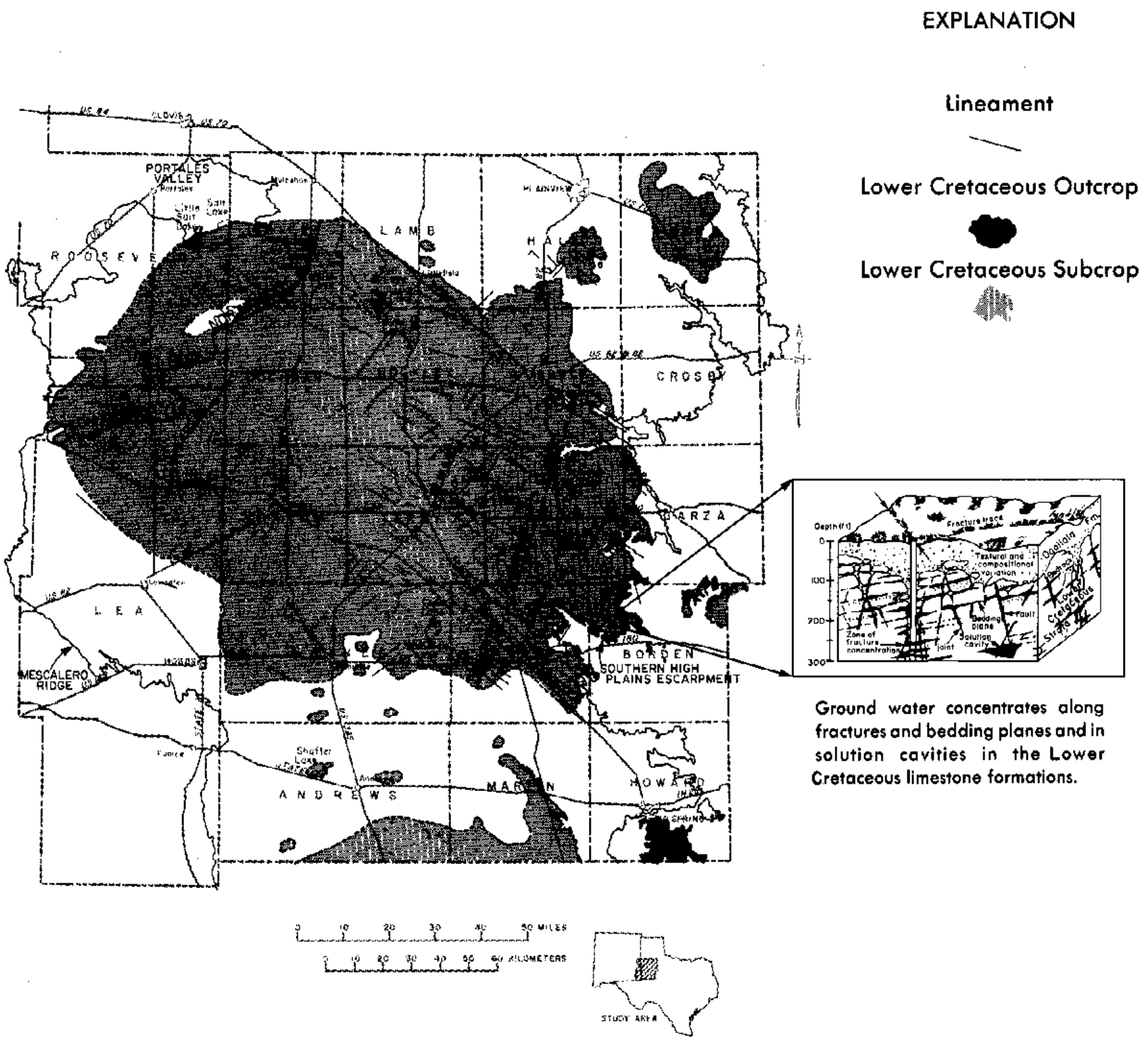

Figure 14
Study Area Surface Lineation Map, and
Block Diagram Inset Showing Ground-Water
Concentrations in Fractured Carbonate Terrain
(After Finley and Gustavson, 1981; Lattman and Parizek, 1964)

gallons per minute for an hour and twenty minutes in 1950, indicating the aquifer's local specific capacity to be 1,175 gallons per minute per foot of drawdown (Leggat, 1952). Significantly, the latter well is thought to have drawn much of its production from a cavity receiving water from the Ogallala Formation.

Water Quality and Chemistry

Ground water in the Comanche Peak-Edwards system is generally fresh to slightly saline and usually has either a mixed-cation-bicarbonate or sodium-bicarbonate hydrochemical signature. However, as in the underlying Antlers Formation, water quality in the Comanche Peak-Edwards system is diminished in areas overlain by saline lakes, and where the near-surface gypsiferous Tahoka and Double Lakes Formations are present. In northeast Gaines County, and most of Lynn County, Texas, where numerous saline lakes exist and the Tahoka and Double Lakes Formations are widespread, the amount of dissolved solids in ground water from the Comanche Peak-Edwards aquifer regularly exceeds 3,000 mg/l, with either sodium-sulfate or sodium-chloride hydrochemical facies prevailing.

Regional Storage

Core, well log, and outcrop data indicate that the Comanche Peak - Edwards system has an average saturated thickness of 20 feet and average porosity of 1.5 percent, suggesting that the aquifer stores approximately 1.5 million acre-feet of ground water in the 8,000 square mile area where it is maximally developed under the Southern High Plains. Essentially all of the effective storage underlies Texas, 95 percent (1,459,200 acre-feet) being located under the Brazos River Basin. Full aquifer storage capacity under the Colorado River Basin is estimated to be 76,800 acre-feet.

Kiamichi and Duck Creek Formations

In the south-central part of the Southern High Plains, where both the Antlers and Comanche Peak-Edwards systems are poorly developed, ground water is in places transmitted through thin limestone and sandstone beds in the Lower Cretaceous Kiamichi and Duck Creek Formations. The thin, discontinuous strata have limited yield and storage capacities, and are typically separated by thicker shale and clay intervals in the stratigraphic section. Accordingly, wells draw from multiple horizons when producing from the Kiamichi and Duck Creek Formations, with overall yield usually augmenting larger production from the overlying Ogallala Formation.

Regional Recharge and Discharge

The primary source of natural ground-water recharge to Lower Cretaceous strata under the Southern High Plains is inflow from the bounding and overlying Ogallala Formation (Figure 11). The Ogallala Formation, in turn, receives most of its water supply via infiltration of surface precipitation, and runoff that periodically fills playa lakes and other ephemeral drainage systems over the study area, a source of limited and often overdrawn supply in recent years.

Cross-formational recharge between Tertiary and Lower Cretaceous strata occurs most readily where saturated sand and gravel beds in the Ogallala Formation abut against, or overlie porous and permeable parts of the Antlers, Comanche Peak, and Edwards Formations. Saturated sand and gravel beds in the Ogallala Formation, in turn, occur most frequently in lower parts of the formation along paleovalley courses that were scoured into underlying strata in pre-Ogallala time.

Under the Southern High Plains, pre-Ogallala paleovalley courses are best developed immediately north of the Lower Cretaceous subcrop area, and to a lesser extent, over and around certain parts of the subcrop area itself. Acting as natural ground-water conduits in the High Plains aquifer, Ogallala deposits filling the paleovalley courses distribute ground water in an east-southeasterly direction to, around, and over the Lower Cretaceous subcrop (Figure 3). Subcrop exposures of the basal Lower Cretaceous Antlers Formation thus receive water directly from the Ogallala in Lea and Roosevelt Counties, New Mexico, and in Floyd, Gaines, Hale, and Lamb Counties, Texas, where the Antlers Formation is best developed. The Comanche Peak and Edwards Formations are recharged mostly along subcrop exposures in Dawson, Floyd, Hale, Lubbock, and Lynn Counties, Texas, with joints, fractures, and solution cavities providing infiltration routes through the section.

Tertiary and Lower Cretaceous ground-water aquifers under the Southern High Plains are also recharged directly and indirectly by surface water spreading basins and dual-purpose well systems. Surface water spreading basins are generally limited to areas where high-permeability sediments occur at or near the ground surface, or where major distributary channel trends are best developed in the Ogallala Formation.

Dual-purpose wells, i.e., wells designed for both subsurface injection and ground-water withdrawal purposes, provide an effective means of recharging the High Plains aquifer where low-permeability zones occur between the land surface and the regional water table. The wells are generally constructed in and around playa lake basins in order to take advantage of ponded rain water on a seasonal basis. Life spans of dual-purpose wells rarely exceed 10 years, with sediment clogging usually diminishing system effectiveness over time.

In use since the 1940's, there were as many as 200 dual-purpose recharge wells operating in and around the study area in the early 1970's, 28 being located in Borden County, Texas. Overall use of the dual-purpose well recharge system has declined in the study area since the 1970's, however, and only a few pump systems installed during the 1970's remain operative today.

Discharge from Lower Cretaceous aquifers in the study area is primarily to well heads in Texas and New Mexico, and to streams, springs, and seeps along the Southern High Plains escarpment in

Texas. Annual well pumpage from the Lower Cretaceous ground-water system is estimated to have exceeded 15,000 acre-feet in recent years, although exact figures are difficult to calculate since numerous wells over the Southern High Plains are dually completed in Lower Cretaceous and Ogallala sections, with the component yields from each being undetermined.

Springs and seeps draining from Lower Cretaceous strata in the Southern High Plains are particularly well developed in Borden County, Texas, along the Southern High Plains escarpment. There are also several springs and seeps along the North Fork Double Mountain Fork of the Brazos River that drain from Lower Cretaceous strata in Yellow House Canyon, Lubbock County, Texas. Yields from individual springs in the study area rarely exceed 10 gallons per minute, except when prolonged rainy periods over the plains rejuvenate local systems briefly.

Significantly, Lower Cretaceous strata also discharge some ground water into other, bounding formations. In Floyd County, Texas, the Lower Cretaceous subcrop is completely surrounded by saturated, coarse-grained Ogallala deposits. As ground water flows from the Ogallala deposits into porous updip intervals of the Lower Cretaceous section, it continues to move downdip, ultimately to flow back into the Ogallala system once again. Vertical leakage into the underlying Dockum Group also occurs at isolated locations, particularly in parts of Borden, Cochran, Dawson, Floyd, and Yoakum Counties, Texas, and in Lea and Roosevelt Counties, New Mexico, where coarse-grained fluvial-deltaic deposits occur in upper parts of the Late Triassic section.

Utilization and Development

Wells completed in the Lower Cretaceous section under the Southern High Plains supply water for a number of different surface uses. Of 250 located wells in the study area, 30 are listed as domestic or stock wells, 35 as industrial wells (used primarily to augment waterflood projects in West Texas oilfields, and to supply glauber and epsom salt mining operations), and 180 as irrigation wells. The communities of Seminole in Gaines County, Wellman in Terry County, Abernathy in Hale County, and O'Donnell in Lynn County, Texas, also draw part of their public water supply from wells completed in the Lower Cretaceous section, as do various residents and public schools in the Causey Lingo area of Roosevelt County, New Mexico.

Spread widely over the study area, wells drawing from Lower Cretaceous strata under the Southern High Plains are mostly concentrated in parts of Floyd, Gaines, Hale, and Lynn Counties, Texas, and in the Causey-Lingo area of Roosevelt County, New Mexico. Undeveloped areas showing potential for further development include parts of Bailey, Cochran, Gaines, and Yoakum Counties, Texas, and northern areas in Lea County, New Mexico, where the basal Lower Cretaceous Antlers Formation fills erosional channels cut into the underlying Dockum Group (Figure 15). Also, the

Comanche Peak-Edwards-Antlers aquifer system appears to have potential for further development in east-central Lubbock and northeast Lynn Counties, Texas, where fresh-water recharge occurs directly by downward percolation from the overlying Ogallala Formation and by lateral infiltration of Ogallala waters along the deeply eroded and buried Slaton channel course (Figure 15).

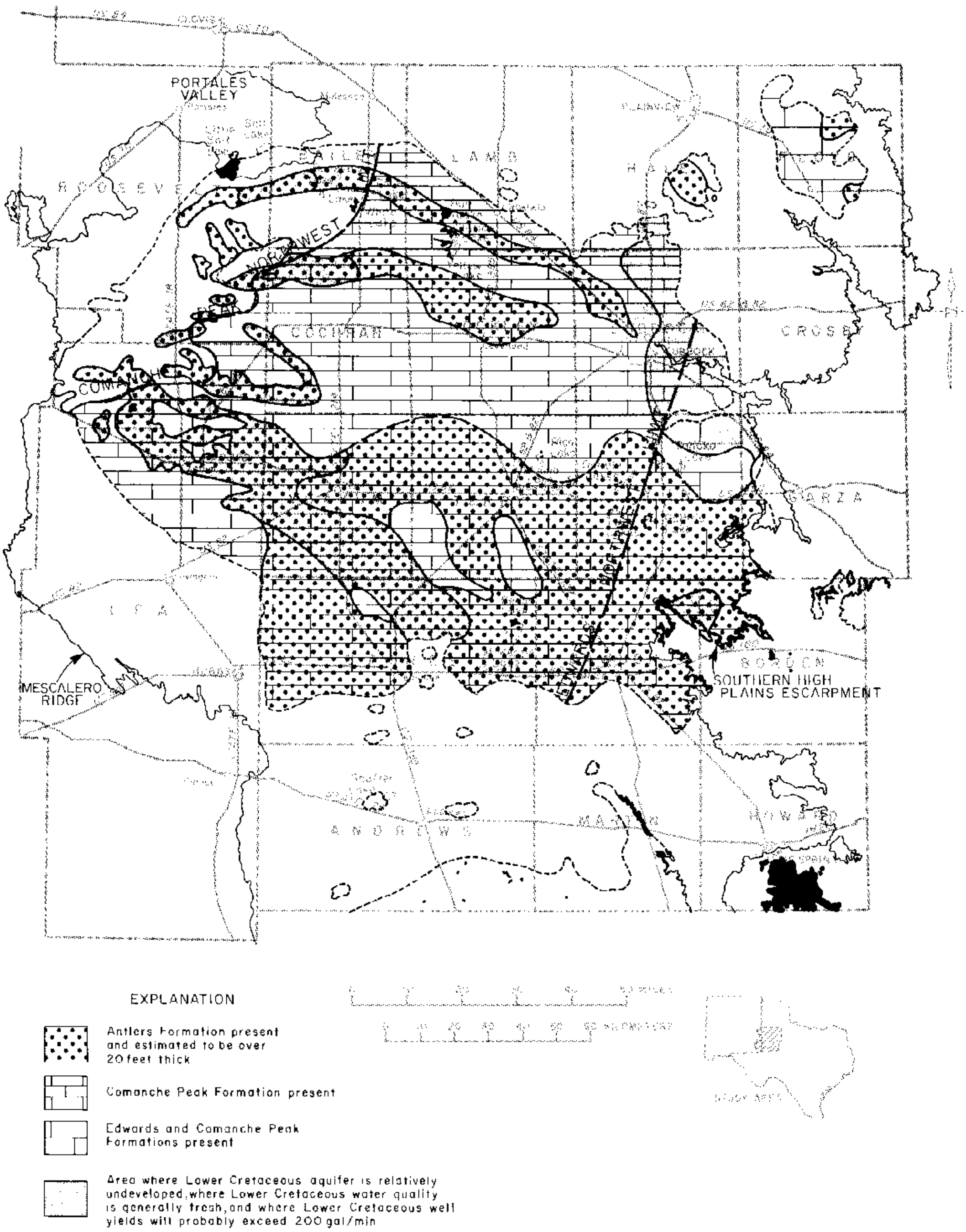

Figure 15

Map Showing the Areal Extent of Lower Cretaceous Aquifers Under the Southern High Plains, With Underdeveloped Areas Having Potential Fresh Ground-Water Reserves Highlighted

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Reference 27

TEXAS BOARD OF WATER ENGINEERS

BULLETIN 6107

A SUMMARY OF THE OCCURRENCE AND DEVELOPMENT OF GROUND WATER IN THE SOUTHERN HIGH PLAINS OF TEXAS

By

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United States Geological Survey

Prepared by the Geological Survey
United States Department of the Interior
in cooperation with
the Texas Board of Water Engineers

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September 1961

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to Paleozoic are present in the subsurface. The geologic history of the Southern High Plains pertinent to this report begins with the Permian, therefore, discussion of the older rocks in the subsurface is omitted. Table 1 briefly summarizes the geologic and water-bearing properties of the formations exposed in the area. Table 2 gives the estimated ages and duration of the geologic time units discussed.

Geologic History

At the beginning of Permian time, the present area of the Southern High Plains was almost entirely covered by the sea. Pre-Permian rocks already had been folded and subsequently had subsided to form basin-like areas which were at least partly separated by elevated land which had been uplifted along the major structural features of the area (Figure 3). According to Hoots (1925, page 119) subsidence in the basins probably continued throughout Permian time.

During Permian time the basins were filled with sediments, and the elevated lands also were covered by a thick series of sediments which underlies all of the Southern High Plains. The diversity in lithology of the Permian sediments indicates varying conditions of deposition. Rocks ranging from strictly marine to continental origin and various chemical precipitates, such as salt, anhydrite, and gypsum, were deposited. Marine sediments became less prevalent later in the Permian and the deposition of evaporites and non-marine sediments indicates an intermittent but progressive withdrawal of the sea, in general to the southwest. Uplift of the land probably accompanied or followed the withdrawal of the sea.

Erosion and deposition of continental sediments characterized the early part of the geologic history of the Mesozoic era in the Southern High Plains. During Early and Middle Triassic time, the area was subjected to erosion. In Late Triassic time, continental sediments, comprising the Dockum group, were deposited. Hoots (1925, pages 125-126) suggests that subsidence of the basin areas occurred during Triassic time.

The Southern High Plains area was apparently subjected to erosion throughout all or much of the Jurassic period. Non-marine sediments of this age, which are present in Quay County, New Mexico (Dobrovolny, Summerson, and Bates, 1946, sheet 2) a few miles west of the Texas-New Mexico state line, have not been found in the Southern High Plains of Texas. Their absence may possibly be due to nondeposition, but they may have been removed subsequently by erosion along with some of the Upper Triassic rocks prior to the deposition of the Lower Cretaceous strata.

In Early Cretaceous time the sea advanced from the southeast across the Southern High Plains and deposited sediments belonging to the Comanche series. Following the deposition of these sediments, the sea withdrew and thus ended the last marine transgression of this area. Extensive erosion during Late Cretaceous and Early Cenozoic time removed a part of the Triassic and Cretaceous rocks, the latter being entirely removed from a part of the area (Figure 4).

During Late Cretaceous time and at intervals throughout much of Cenozoic time, orogenic movement, uplift, and volcanic activity were taking place in the area to the west and northwest of the Southern High Plains in New Mexico and Colorado. These widespread and repeated orogenies resulted in the development of the Southern Rocky Mountains and the mountain ranges to the south of them in New Mexico and Texas. Baker (1915, page 22) has suggested that the southeast dip of the Mesozoic rocks of the Southern High Plains, which, according to King (1959, page 128),

Table 1.--Stratigraphic units and their water-bearing properties, Southern High Plains of Texas

System	Series	Formation or group	Thickness (feet)	Lithologic description	Water supply
Quaternary	Recent		0- 15	Chiefly windblown sand and silt.	Yields no water to wells. Sandy areas form excellent recharge facilities.
	Pleistocene		0- 144	Sand, clay, diatomaceous earth, volcanic ash, limestone.	Mostly above water table. Does not yield large supplies.
Tertiary	Pliocene	Ogallala formation	0- 500	Fine to coarse sand and gravel; clay, silt, and caliche.	Yields large supplies of water throughout the Southern High Plains.
Cretaceous	Comanche	Washita, Fredericksburg, and Trinity groups	0- 200+	Fine to coarse sandstone and conglomerate; limestone, blue and yellow shale or clay.	Locally important as source of small supplies of water; should not be considered as a major source of water for the Southern High Plains in general.
Triassic		Dockum group Tecovas formation Santa Rosa sandstone Chinle formation equivalent	150-1,800+	Varicolored shale and sandy shale, gray or brown cross-bedded sandstone and conglomerate.	Probably capable of yielding small to moderate supplies of water; most of the water is at least slightly saline.
Permiam			8,000±	Soft red sandstone, shale, and clay, beds of gypsum and dolomite.	Not known to yield water to wells; water is probably saline.

Reference 28

TEXAS BOARD OF WATER ENGINEERS

BULLETIN 5210

GROUND-WATER RESOURCES OF ECTOR COUNTY, TEXAS

By

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United States Geological Survey

Prepared cooperatively by the Geological Survey,
United States Department of the Interior

December 1952

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ILLUSTRATIONS

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GROUND-WATER RESOURCES OF ECTOR COUNTY, TEXAS

By

D. B. Knowles

ABSTRACT

The rock formations in Ector County that are of significance in relation to the occurrence of ground water include, from older to younger, those of the Permian system, the Dockum group of the Triassic system, the Trinity and Fredericksburg groups of the Cretaceous system, the Ogallala formation of the Tertiary system, and alluvium of the Quaternary system.

The Permian rocks generally contain only highly mineralized water. Sands and sandstones of Triassic age in general contain water of undesirable quality, although small quantities obtained from these rocks in the southwestern part of the county are used for domestic purposes. The sand of the Trinity group is the most important water-bearing formation in the county.

Water in the sand of the Trinity group occurs under water-table conditions in Ector County, and yields of wells are generally proportional to the thickness of the saturated sand. The saturated part of the sand is thin in the vicinity of Concho Bluff but thickens northeastward.

The City of Odessa operates two well fields containing a total of 72 wells that draw water from the sand of the Trinity group. The pumpage from these wells averaged 2,901,000 gallons a day in 1949. The wells are closely spaced, and, when heavily pumped, mutual interference among them results in considerable increase in the pumping lift and decrease in the yield.

The well field north of Odessa contains 66 wells. Near the center of the field the water level declined about 26 feet from September 1947 to December 1949. It is estimated that more than 14 percent of the saturated material in the well field was unwatered between the spring of 1944, when the first wells were drilled, and December 1949. The yields of some of the wells have decreased considerably.

It is believed that wells drilled in an area a few miles northeast of the Odessa well field might yield considerably more water than the present wells.

Most of the formations of the Fredericksburg group, and the Ogallala formation lie above the water table and, therefore, yield little or no water to wells. The Quaternary alluvium covers that part of the county southwest of Concho Bluff and lies directly on Triassic rocks. In the extreme northeastern part of Ector County and in northwestern Midland County, four irrigation wells that probably draw water from refilled channels of ancient Midland Draw have yields reported to range from 400 to 800 gallons a minute.

INTRODUCTION

LOCATION

Ector County is in the western part of the Midland Basin in west Texas near the southeast corner of New Mexico. It is bounded on the north by Andrews County, on the east by Midland County, on the south by Upton, Crane, and Ward Counties, and on the west by Winkler County. The intersection of longitude 102°30' and latitude 31°50' is near the middle of the county. The county has an area of 907 square miles. According to the United States Bureau of the Census, the population in 1950 was 42,102, of which 29,432 (70%) resided in Odessa, the county seat.

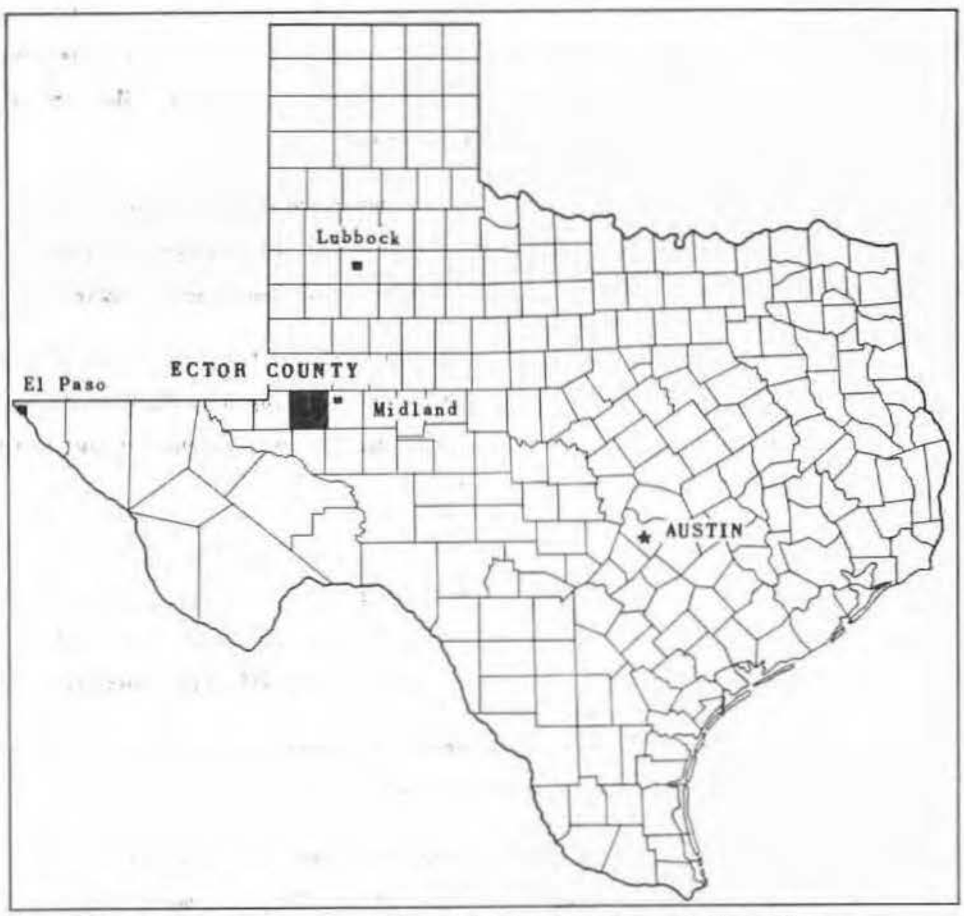

FIGURE 1.- Index map of Texas showing location of Ector County.

PREVIOUS INVESTIGATION

An inventory of water wells in Ector County was made in 1937 (Davis, 1937),[1] at which time the depths, diameters, depths to water, use of water, and other records were obtained. Samples of water were collected from many of the wells for chemical analysis.

PURPOSE AND SCOPE OF THIS INVESTIGATION

The investigation of the ground-water resources of Ector County was begun in the fall of 1947 as a part of the State-wide cooperative program by the Texas Board of Water Engineers and the United States Geological Survey. It was interrupted several times by work relating to other projects and was not completed until 1949. The purpose of the investigation was to obtain basic data relating to the quantity and quality of the ground water available in Ector County, with special reference to the availability of large supplies for municipal or other large-scale use.

The report includes a part of the records collected by Davis in 1937 and the data obtained during the present investigation. It includes records of 419 wells, drillers' logs of 188 wells, and chemical analyses of water from 171 wells. The locations of these wells are shown on plate 1. Logs and surface altitudes of several hundred seismograph shot holes and a few water wells were used to contour the surface of the redbeds of the Dockum group (pl. 2).

The work was done under the general direction of A. N. Sayre, chief of the Ground Water Branch, U. S. Geological Survey and under the supervision of W. L. Broadhurst, district geologist in charge of ground-water work in Texas.

AGRICULTURAL AND INDUSTRIAL DEVELOPMENT

Agriculture is limited primarily to the raising of cattle and sheep in Ector County. The U. S. Department of Agriculture reported that 13,304 cattle, 2,150 sheep, and small numbers of other livestock were raised in 1945. Only 1,410 acres of land, planted mostly in grain sorghum and truck crops, were tilled in 1944.

Ector County which produced 48,317,906 barrels of oil in 1949, ranked second in Texas oil production that year. The total produced in the county from 1926, when oil was discovered, through 1949 was 402,703,893 barrels. Other major industries include the production or manufacture of carbon black, gasoline, and oil-field supplies and equipment.

ACKNOWLEDGMENTS

The writer thanks the many persons who contributed information for this report. Representatives of oil companies furnished logs of the several hundred seismograph shot holes which were used in the preparation of plate 2. The City of Odessa determined altitudes of many water wells that were used in preparing figure 5 and assisted in other ways during the investigation. Special thanks are due A. L. Wright, municipal water superintendent, for his assistance and cordial cooperation during the investigation. The owners of private wells contributed much of the well information in this report.

1/ See list of references, page 2[illegible].

TOPOGRAPHY

Ector County lies at the southern end of the High Plains. The land surface is broken by a prominent westward-facing escarpment, known as Concho Bluff, which extends southeastward across the western part of the county. (See pl. 1.) Concho Bluff owes its prominence to the erosion-resistant caliche, limestone, and sandstone exposed along its face.

The eastern part of the county, which is on the Plains, is generally rolling. Many small depressions and some shallow draws are present. Midland Draw and Monahans Draw, which flow southeast are the most prominent drainageways but carry water only after heavy rains. Much of the storm runoff collects in the numerous depressions to form ponds, which range from 5 to 40 feet in depth, and from a few hundred feet up to about a mile in diameter.

An undulating alluvial plain lies west of Concho Bluff. It is broken by sand hills along the western county boundary, where dune topography is prevalent. Many small gullies head along Concho Bluff, but elsewhere in the area only a few shallow draws, which drain southwestward, are present. The loose material composing the plain absorbs most of the rain; therefore, it has not been extensively eroded by surface runoff.

PRECIPITATION

The average annual rainfall in Texas decreases from east to west. Ector County is in the semiarid part of the State. No precipitation station is maintained in the county, but the records from a U. S. Weather Bureau station at Midland, about 20 miles northeast of Odessa, show that the minimum yearly rainfall during the period of record was 5.52 inches in 1917 and the maximum was 29.34 inches in 1920. The average precipitation for 31 years of complete record during the period 1885-1950 was 16.35 inches. It is estimated that the average annual rainfall in Ector County is about 15 to 16 inches.

The available records of rainfall at Midland, compiled from reports of the U. S. Weather Bureau, are given in the following table.

Table 1.- Monthly precipitation, in inches, at Midland, Midland County, Tex., 1885-1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1885	-	-	-	-	-	-	-	-	-	-	0.01	0.15	-
1886	0.02	0.33	0.43	0.29	0.10	1.42	0.43	2.02	1.47	0.76	.00	.00	7.27
1887	T	T	T	1.10	-	1.51	1.07	1.21	.25	2.15	.00	.90	-
1888	.47	-	-	-	-	-	-	-	-	-	-	-	-
1891	-	-	-	.22	2.52	-	-	3.00	6.20	-	-	-	-
1894	-	-	-	-	2.25	.85	.60	.97	1.40	.32	.00	.30	-
1895	.70	1.40	.00	.00	4.90	2.89	3.58	1.69	2.45	.60	1.70	1.00	20.91
1896	2.05	2.10	.00	.00	1.04	-	-	-	-	-	-	-	-
1897	-	-	-	.00	4.55	1.71	2.28	2.86	1.14	.04	.00	-	-
1898	.00	-	-	1.20	-	-	-	2.60	-	-	-	-	-
1904	.22	T	.00	.56	2.65	3.95	.25	.50	2.95	.62	1.90	.05	13.65
1909	-	-	-	-	-	-	1.25	.18	.18	.49	1.48	.32	-
1910	.00	.00	.00	.00	.60	.83	.73	.28	3.35	1.20	.08	.06	7.13
1911	.70	2.90	.40	3.67	6.00	.50	3.15	.32	1.25	.10	.06	3.06	22.11
1912	1.00	1.31	.10	.29	7.34	.79	.70	1.07	1.20	.89	.85	.85	16.39
1913	T	.23	1.00	2.07	.27	3.81	1.27	1.32	4.68	2.60	4.49	2.67	24.41
1914	.24	.10	.30	.29	2.72	6.68	3.71	3.39	2.16	3.71	1.58	1.40	26.28
1915	.26	.47	.46	5.20	.55	.23	3.51	1.62	3.08	.10	.00	.83	16.31
1916	.03	.00	.27	2.85	.36	.83	3.65	.05	2.42	2.45	.45	.05	13.41
1917	.18	.00	.00	.83	.20	1.32	.45	1.79	.60	.00	.15	.00	5.52
1918	.57	.92	.15	.00	1.78	2.86	.10	1.42	1.35	1.84	1.03	.63	12.65
1919	.45	.00	3.58	.92	.85	2.12	.10	2.05	5.79	4.39	.65	.00	20.90
1920	2.68	.18	T	.08	3.13	1.63	3.56	13.03	.70	1.70	2.50	.15	29.34
1921	.00	1.80	.44	.20	1.12	1.92	.00	1.41	2.51	.49	.00	.00	9.89
1922	.56	.10	.62	9.77	1.90	1.44	.00	.50	.00	1.16	.85	.00	16.90
1923	.39	4.19	2.33	.97	.15	.72	1.95	1.23	.82	3.04	.69	1.19	17.67
1924	T	.75	.64	.97	2.89	.00	.51	2.71	.48	.83	.00	.20	9.98
1925	.45	.00	T	3.17	3.16	.62	2.06	3.54	2.12	1.87	.00	.00	16.99
1926	.87	.22	2.49	4.20	1.33	3.04	1.84	.67	1.43	5.13	.04	1.95	23.21
1927	.16	.64	.57	T	.36	1.63	2.15	.82	2.41	.61	.00	.52	9.87
1928	.00	.24	.34	2.82	4.87	2.75	1.35	3.50	.82	2.38	.42	.45	19.94
1929	.13	1.39	2.40	.04	1.99	.75	1.90	.15	4.78	3.04	.35	.00	16.92
1930	.85	.00	.11	1.29	1.13	5.95	.06	4.24	.51	1.59	1.87	.78	18.38
1931	.89	1.32	.78	3.52	.58	.67	2.01	1.14	.02	4.78	1.65	2.41	19.77
1932	.61	3.71	.16	3.29	5.48	2.31	.41	1.61	7.26	.97	.00	3.51	29.32
1933	T	.88	.00	T	.06	.33	.96	1.59	1.74	.29	.51	.22	6.58
1935	-	-	.22	.54	2.62	2.39	2.63	.07	3.26	1.79	.94	.26	-
1936	.10	T	.40	.90	3.21	1.00	6.18	.00	6.47	1.14	.51	.52	20.43
1937	.30	.06	1.08	.60	-	-	-	-	-	-	-	1.09	-
1938	1.14	1.34	.14	.06	-	-	-	-	-	-	-	-	-
1944	.20	1.20	.00	.20	1.38	1.60	2.22	2.96	2.19	1.08	1.86	.89	15.78
1945	1.33	.11	1.00	.00	T	.42	5.30	.00	.50	-	.00	.33	-
1946	.97	.00	.00	T	.12	1.49	.00	1.81	1.96	1.43	.00	.56	8.34
1947	.51	.00	1.60	.00	1.85	1.09	.95	.50	.91	1.78	.93	.62	10.74
1948	-	-	-	-	-	2.00	3.41	.27	.83	1.68	T	.20	-
1949	-	-	-	1.90	3.12	-	1.11	2.68	1.44	1.61	T	.73	-
1950	.57	.20	.03	.79	3.35	1.30	1.84	.69	-	-	.00	T	-
Avg.	.50	.76	.58	1.30	2.11	1.77	1.73	1.75	2.13	1.60	.67	.70	16.35
Years of complete record	39	37	38	42	39	38	40	42	40	38	41	41	31

T, trace.

GENERAL GEOLOGY

The geologic formations that crop out in Ector County range in age from Cretaceous to Recent. The following table lists the principal subdivisions, their chief composition, and their water-bearing properties. Those listed below the Cretaceous do not crop out but are penetrated by some wells.

Table 2.- Water-bearing formations in Ector County, Tex.

System	Subdivision	Character of rocks	Thickness (feet)	Water supply	Remarks
Quaternary	Pleistocene and Recent	Caliche, sand, gravel, and clay	0-125	Yields only small quantities of water to wells except in Midland and Monahans Draws where valley fill of possible Pleistocene age yields large quantities of water to a few wells	Lies directly on Triassic rocks southwest of Concho Bluff
Tertiary	Pliocene (Ogallala formation)	Caliche, sandy clay, and sand	0-60	Yields meager quantities of water to wells	In general lies above the water table
Cretaceous	Fredericksburg group	Clay, limestone, and shell aggregate	0-75	Yields meager quantities of water to wells	In general lies above the water table
	Trinity group	Clay, fine-to medium-grained sand, and gravel	0-125	Generally yields moderate quantities of water to wells, except near Concho Bluff	Principal source of water in Ector County
Triassic	Dockum group	Red shale interbedded with sandstone and conglomerate	700-1,600	Generally contains highly mineralized water. In places in southwestern Ector County it yields small quantities of potable water to wells	Commonly known as redbeds
Permian	Undifferentiated	Rock salt, anhydrite, red shale, sandstone, limestone, and conglomerate	5,000+	No wells draw from these rocks; water in them probably is highly mineralized	

GEOLOGIC STRUCTURE

Ector County lies in the southern part of the large structural Permian Basin or geosyncline that covers much of western Texas, eastern New Mexico, and parts of Oklahoma and Kansas. A south-trending structural "high," to which Cartwright (1930, p. 970) applied the name Central Basin Platform, lies in the southern part of the basin. This platform, which has a width of 30 to 35 miles and a length of at least 150 miles, divides the southern Permian Basin into two sub-basins, the Delaware Basin to the west and the Midland Basin to the east. Ector County lies in the extreme western part of the Midland Basin. The rocks of Cretaceous age and younger are nearly flat, but the older rocks show complex structural features at depth.

The ground-water reservoirs that contain usable water lie above the Permian rocks. Two geologic sections (fig. 2, A-A', and B-B') show the structure on the top of the Permian salt and the top of the Triassic rocks. These cross sections are from sample logs of oil tests furnished by oil companies; the drillers' logs of these oil tests are given in table 5.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PERMIAN SYSTEM

The rocks of the Permian system are not exposed in Ector County but have been encountered in drilling for oil. Oil is produced from several zones in the Permian rocks within the county. The total thickness of these rocks is more than 5,000 feet. The upper Permian rocks closely resemble the overlying Triassic rocks, and the contact between the two systems is not always distinguishable from drillers' logs. However, the deep maroon color characteristic of the Triassic shales is rare in the Permian.

No wells were found in the county that draw water from the Permian rocks, but on the basis of the water found in them in other counties, it is believed that the water contained in these rocks is highly mineralized.

TRIASSIC SYSTEM

DOCKUM GROUP

The Triassic system is represented by rocks of the Dockum group. According to the geologic map of Texas (U. S. Geol. Survey, 1937), rocks of the Dockum group are not exposed in Ector County, but they are generally encountered beneath the surface at depths of less than 200 feet. They lie unconformably upon the uneven and eroded surface of the Permian rocks and range in thickness from about 700 to 1,600 feet. The group consists chiefly of variegated shale interbedded with sandstone and conglomerate. The most persistent beds of sandstone and conglomerate occur near the base.

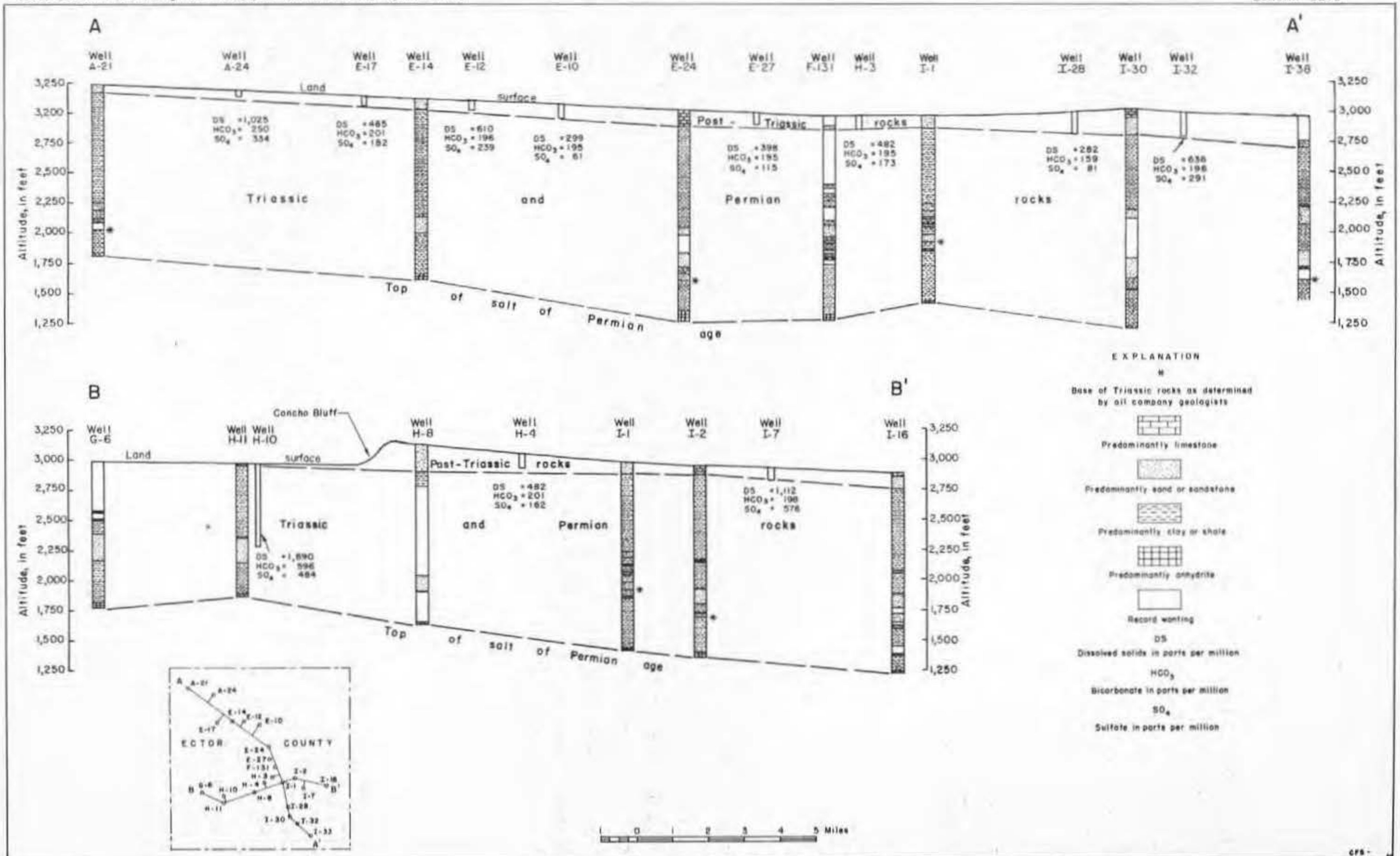

FIGURE 2.- Geologic sections in Ector County, Tex.

Study of the available data indicates that only small quantities of water are available from the Dockum group in the county and that the water is too highly mineralized for most uses. A few wells, which range in depth from 431 to 710 feet, obtain mineralized but usable water from these rocks in the southwestern part of the county.

CRETACEOUS SYSTEM

TRINITY GROUP

A sand and gravel was deposited on the eroded surface of older rocks as the sea advanced northward and northwestward across Texas in Cretaceous time. The sand has the appearance of a single stratigraphic unit, although it becomes progressively younger toward the northwest. Hill (1901) has discussed this subject at some length.

The Trinity group in Ector County lies unconformably on an eroded surface of Triassic rocks. It is exposed along the edge of Concho Bluff in the southwestern part of the county and in a narrow east-west belt a few miles north of Odessa. The exposed sediments along Concho Bluff average about 75 feet in thickness. They consist of a green clay, probably lying directly on the Triassic rocks, gray sand and gravel, and fine-grained yellow sand. In Ector County these deposits are the only representative of what is known farther east as the Trinity group and are probably equivalent to the Paluxy sand of that group. In some places the sand has the appearance of hard sandstone or quartzite and forms erosion-resistant ledges along Concho Bluff. The sand yields more water of acceptable quality than any other water-bearing formation in the county, but owing to the relatively thin saturated section and low permeability only moderate quantities of water are obtained from individual wells. The yields of individual wells range from a few gallons a minute near Concho Bluff to about 300 gallons a minute north and northeast of Odessa.

FREDERICKSBURG GROUP

The Fredericksburg group of central Texas has been divided into four formations which, in ascending order, are the Walnut clay, the Comanche Peak limestone, the Edwards limestone, and the Kiamichi formation. However, no effort will be made in this report to classify the rocks of the Fredericksburg group into formations, because they are not important sources of water.

The Fredericksburg group lies conformably on the Trinity group throughout the area east of Concho Bluff. The group, which consists mostly of yellow clay, white and yellow limestone, and shell aggregate is about 40 feet thick. The rocks are exposed in the north-central part of the county and along Concho Bluff, which owes much of its prominence to the hard, erosion-resistant limestone. Most of the rocks of the group lie above the water table; therefore, little ground water is to be found in them although the water that is present is of acceptable quality.

TERTIARY SYSTEM

OGALLALA FORMATION

The Tertiary system is represented in Ector County by remnants of the Ogallala formation which cover much of the county east of Concho Bluff. The Ogallala rests unconformably upon rocks of the Fredericksburg group and consists of caliche, sandy clay, and sand. It is probably not more than 60 feet thick throughout most of the county and in general lies above the water table. In local areas where the Ogallala lies below the water table, the water is of satisfactory quality, but the quantities that can be expected from wells are small.

QUATERNARY SYSTEM

The Quaternary rocks cover the older rocks in that part of the county southwest of Concho Bluff. They lie unconformably upon an eroded surface of Triassic rocks and form a rolling alluvial plain, except in the extreme western part of the county where sand hills are prevalent. The deposits consist mostly of sand, clay, and gravel which were derived partly from erosion along Concho Bluff, but the sand hills along the western county boundary probably migrated by wind action from the west.

The Quaternary sand and gravel generally contain only thin sections of saturated material and yield only small quantities of water to wells. Only a few wells in the county draw water from these rocks, and the analyses of samples from them show that the water is of poor quality.

In the northeastern part of the county, the valley fill in Midland Draw and Monahans Draw probably is of Pleistocene age and may be the source of relatively large quantities of water. For example, well C-32 was reported to yield about 500 gallons a minute in October 1948. Three other wells located in Midland County three-fourths of a mile to 4 miles east of well C-32, are reported to have yields ranging from 400 to 800 gallons a minute.

DEVELOPMENT OF WATER FROM WELLS

In many parts of western Texas, particularly in the High Plains, depressions in the surface of pre-Tertiary rocks have been filled with sand, thus locally providing thicker sands which yield proportionately greater quantities of water to wells. These depressions are in the form of buried stream channels or circular depressions known as sink holes. The more recent alluvium and windblown material have obscured the ancient topography so that the present relatively smooth surface presents little indication of the locations of the more favorable ground-water reservoirs.

Reference 29

Texas Water Development Board

Report 360

Aquifers of the Edwards Plateau

edited by
Robert E. Mace,
Edward S. Angle, and
William F. Mullican, III

February 2004

System	Series	Group	Formation	Description of Rocks	Hydrogeologic Units
Quaternary	Pleistocene to Recent		Alluvium, eolian and lacustrine deposits	Sand, clay, silt, caliche, and gravel.	Generally yields small amounts of water to wells; may yield large amounts of water along stream valleys of Edwards Plateau.
Tertiary	Late Miocene to Pliocene		Ogallala	Tan, yellow, and reddish brown silt, clay, sand, and gravel. Caliche layers common near the surface.	Yields moderate to large amounts of water to wells across Southern High Plains. Yields small to moderate amounts of water in Andrews, Martin, Howard, Ector, Midland and Glasscock Counties.
Cretaceous	Comanche	Washita	Duck Creek	Yellow, sandy shale and thin gray to yellowish brown argillaceous limestone beds.	Yields small amounts of water locally to wells.
		Fredericksburg	Kiamichi	Gray to yellowish brown shale with thin interbeds of gray argillaceous limestone and yellow sandstone.	Yields small amounts of water locally to wells.
			Edwards	Light gray to yellowish gray, thick to massive bedded, fine- to coarse-grained limestone.	Generally yields fairly small amounts of water to wells beneath Southern High Plains, but may yield large amounts of water locally due to fractures and solution cavities.
			Comanche Peak	Light gray to yellowish brown, irregularly bedded argillaceous limestone with thin interbeds of light gray shale.	
			Walnut	Light gray to yellowish brown argillaceous sandstone; thin-bedded gray shale; light gray to grayish yellow argillaceous limestone.	Not known to yield water to wells.
		Trinity	Antlers	White, gray, yellowish brown to purple, argillaceous, loosely cemented sand, sandstone, and conglomerate with interbeds of siltstone and clay.	Yields small to moderate amounts of water to wells. Primary aquifer of Cretaceous system within the study area.
Triassic		Dockum	Chinle	Red, maroon to purple shale. Thin, discontinuous beds of sand and silt.	May yield small amounts of water to wells. Commonly known as the “red beds” that form the base of the High Plains aquifer.
			Santa Rosa	Multi-colored fine- to coarse-grained micaceous sandstone with some claystone and shale interbeds.	Yields moderate amounts of water to wells.
			Tecovas	Red to red-brown shale with fine-grained micaceous sand.	Not known to yield water to wells.

Figure 5-2: Summary of geologic and hydrogeologic units (after Walker, 1979; Knowles and others, 1984; Fallin, 1989).

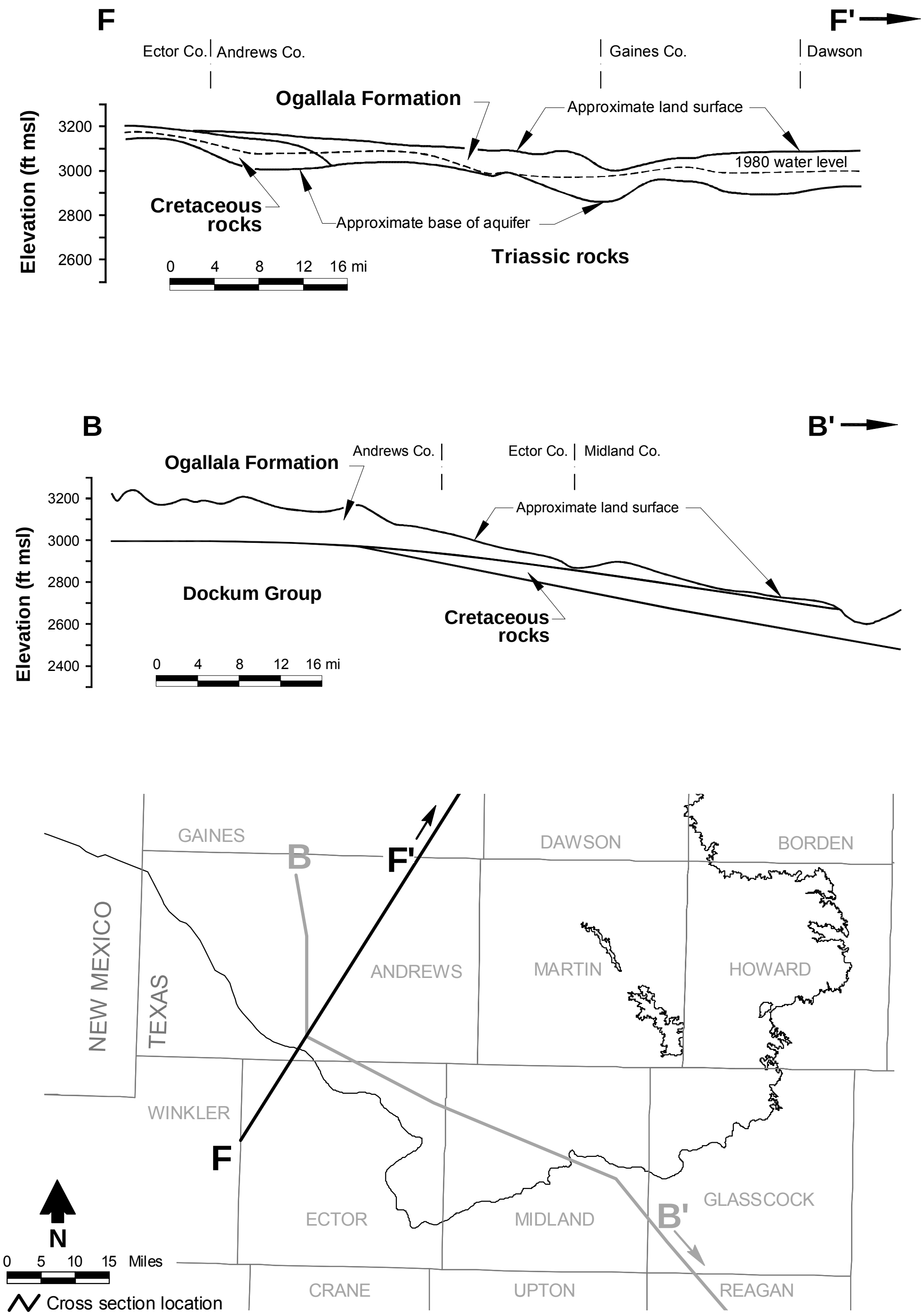

Figure 5-5: Portions of hydrogeologic cross sections (after Knowles and others, 1984; Barker and Ardis 1996).

Reference 30

Evaluation of Ground-Water Resources In Parts of Midland, Reagan, and Upton Counties, Texas

by
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and
Prescott C. Christian, Geologist

February 1989

Texas Water Development Board

M. Reginald Arnold II, Executive Administrator

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ABSTRACT

The evaluation of ground-water conditions in parts of Midland, Reagan, and Upton Counties is in response to the 1985 passage of House Bill 2 by the Sixty-ninth Texas Legislature, which called for the identification and study of areas in theState that are experiencing, or expected to experience within the next 20 years, critical underground water problems. The study area is located on the northern edge of the Edwards Plateau in west-central Texas and has a semi-arid climate that is characterized by low rainfall and high rate of evaporation. Agricultural and petroleum industries dominate the economy.

Water needs for the area are supplied almost entirely from the Edwards-Trinity (Plateau) aquifer which occurs in the Edwards Limestone and Antlers Sand formations of Lower Cretaceous age and, where hydrologically connected, in sandy units of the Dockum Group of Triassic age. Average recharge to the Edwards-Trinity (Plateau) aquifer is calculated to be 30,000 acre-feet per year and is derived principally from precipitation that falls within the study area. Water-level declines of over 100 feet have occurred in southern Glasscock and northern Reagan Counties since irrigation development was initiated in the late 1940's; however, water levels have changed very little over the past five years.

The chemical quality of the ground water over most of the study area does not meet Federal drinking water standards, although the water supplied to the cities of Big Lake and Rankin is acceptable. The quality of water is generally acceptable for irrigation use, but special management practices are needed to grow salt-tolerant crops in some areas. Dissolved solids generally range between 1,000 and 10,000 milligrams per liter, and calcium- and sodium-sulfate are the predominate hydrochemical facies, although, high concentrations of chloride also occur locally.

In 1985, the total pumpage of ground water within the study area was about 43,628 acre-feet, of which 96 percent was used for agriculture irrigation. This amount is projected to increase slightly by the year 2010. The average annual effective recharge to the aquifer is less than the present and projected water demand; therefore, with the projected level of pumpage, water in the aquifer will be drawn from storage. By the year 2010, approximately seven percent of the water held in storage in the aquifer will have been used, with approximately 7,004,000 acre-feet remaining. This quantity should be adequate to meet projected needs through the year 2010, although continued deterioration of the chemical quality could limit the use of some of this water.

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Purpose

In 1985, the Sixty-ninth Texas Legislature recognized that certain areas of the State were experiencing, or were expected to experience within the next 20 years, critical ground-water problems. House Bill 2 was enacted which, in part, directed the Texas Department of Water Resources to identify the critical ground-water areas, conduct studies in those areas, and submit its findings and recommendations on whether a ground-water conservation district should be established in the respective areas to address the ground-water problems (Subchapter C, Chapter 52, Texas Water Code).

This study in the area of Midland, Reagan, and Upton Counties was conducted to address the problems of overdraft and contamination with respect to the Edwards-Trinity (Plateau) aquifer, which is the primary aquifer in the area.

Location and Extent

The study area is located in parts of Midland, Reagan, and Upton Counties on the northern part of the Edwards Plateau in west-central Texas (Figure 1). Midland, most of Reagan, and the northeast half of Upton County lie within the Colorado River basin, while southwestern Upton County and extreme southwestern Reagan County are in the Rio Grande basin. Cities in the area include Big Lake in Reagan County and Rankin in Upton County. The study area generally falls within the boundary of an "underground water reservoir" delineated by the Texas Water Rights Commission in 1969. Major emphasis in the report is placed on southeast Midland County, northwest Reagan County, and northeast Upton County, a rural agricultural area. In order to more completely describe the aquifer, several of the maps in the report extend into Glasscock County; however, current and projected water use is reported only for the area of primary concern designated in Figure 1. Glasscock County is included in an underground water conservation district.

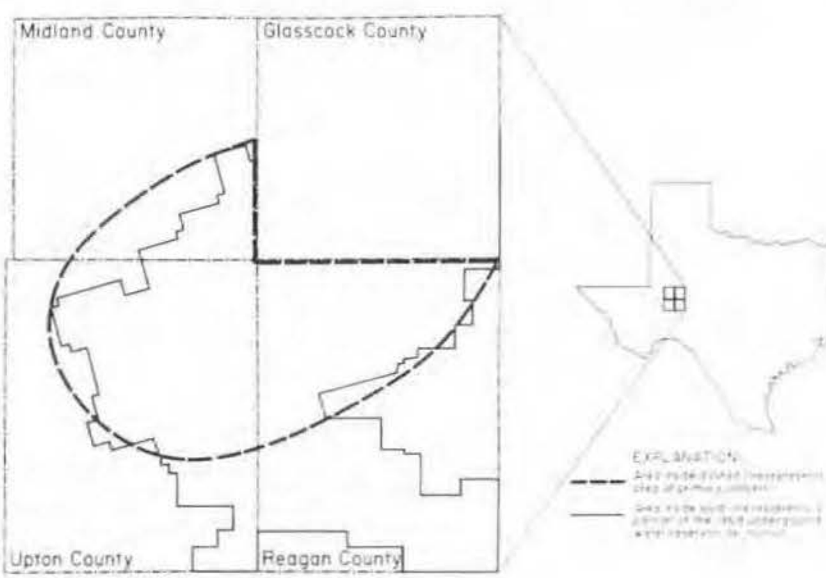


Figure 1
Location of Study Area

Geographic Setting

Topography and Drainage

The northern part of the study area is characterized topographically by a relatively broad, flat plateau. Further south, the plateau becomes more dissected, with wide valleys separating flat-topped ridges and mesas in many places.

The northern plateau area is underlain by limestone strata and covered by a veneer of caliche and silty clay loam. Numerous small depressions and isolated ephemeral streams occur on the surface. Southern uplands in the study area are underlain by resistive limestone beds that are capped by calichefied soils ,while the valleys between the ridges contain clayey alkaline soil.

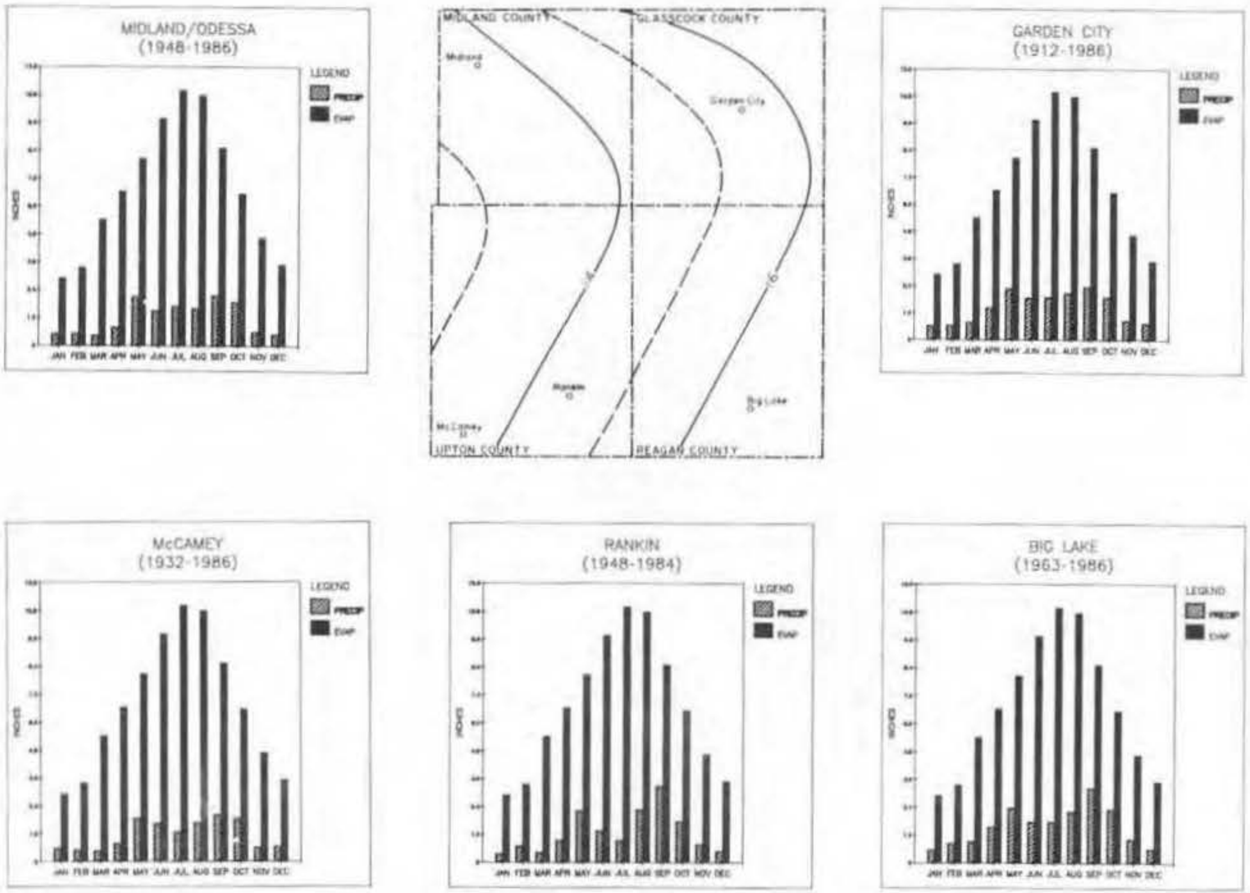
Interior drainage patterns are common in many parts of the study area. Precipitation that does not sink immediately into the ground or evaporate back into the atmosphere collects mostly in the numerous surface depressions, or playas, that are common to the plateau area. During heavy rainfall, runoff drains mostly northeastward through Johnson Draw and eastward through Lacy Creek in the northern part, and eastward through Centralia Draw in the central to southern area. Lacy Creek and Centralia Draw are tributaries to the North and Middle Concho Rivers, respectively. Drainage from the uplands in the southern extremity of the study area is to the south and southwest along Five Mile Creek and other tributaries of the Pecos River.

Climate

The semi-arid climate in the region, as recorded by the National Weather Service, is characterized by low rainfall, high rate of evaporation, and wide temperature ranges. Temperatures sometimes drop below freezing when cold fronts pass through the region during winter months, while rising to break 100° F periodically during the summer. Minimum temperatures in the region average 28° F in January, in comparison to maximum temperatures in July that average 95° F.

The average annual precipitation ranges from 13 to 16 inches, increasing in an eastward direction across the study area (Figure 2). Most of the precipitation in this area falls during thunderstorms between May and October when prevailing south-southeasterly winds bring moist air into the region from the Gulf of Mexico. As a result, large differences in rainfall occur over the area from year to year and within relatively small geographic areas.

Average annual gross lake evaporation is approximately 81 inches, an amount more than five times the average annual precipitation in the same region (Figure 2). Evaporation rates are highest in summer months at the same time that soil moisture demand by plants is at its highest.



EXPLANATION

Average Annual Precipitation (1951-1980) in inches

Isohyets adapted from Larkin and Bomar, 1983

Precipitation Graphs from National Weather Service Data

Figure 2

Average Annual Precipitation,and Average Monthly Precipitation vs. Gross Lake Evaporation for Period of Record at Selected Stations

Economy

The economy of the region is based primarily on the production of oil and gas, raising of cattle and sheep, and irrigated farm production, all of which are heavily dependent on ground water.

Oil was discovered in the Santa Rita Well No. 1 on University Land in Reagan County in 1923. Additional discoveries were made in Reagan and Upton Counties in 1925 which brought about a sharp increase in population. A second oil boom that began in the late 1940's and included development of the Spraberry Trend in Glasscock and Reagan Counties substantially revitalized the economy of the area. Total crude production as of January 1, 1987 for Glasscock, Reagan, and Upton Counties was 1.2 billion barrels (Railroad Commission of Texas, 1986). The industry suffered a major depression in 1982 as world oil prices dropped.

Agriculture, including ranching and farming, is also a major industry in the region, generating a total annual income of approximately 12.8 million dollars in Reagan and Upton Counties in 1985 (Texas Department of Agriculture and U.S. Department of Agriculture, 1985). Development of irrigated farming in the area began in the late 1940's and is heavily dependent on the quantity and quality of available ground water.

Previous and Current Investigations

Several ground-water investigations have been published by the Texas Water Development Board and its predecessor agencies that address the geohydrology of the study area (Figure 3). The most exten-

Midland County	**Glasscock County**
TBWE Misc. Pub. 187 TBWE Bulletin 5906 TBWE Bulletin 6107 TWDB Report 51 TDWR Report 235 TDWR Report 288 TDWR Report 294	TBWE Misc. Pub. 094 TBWE Bulletin 5903 TBWE Bulletin 6107 TWDB Report 51 TWDB Report 143 TDWR Report 235 TDWR Report 288 TDWR LP 203 TDWR Report 294
Upton County	**Reagan County**
TBWE Bulletin 5903 TWC Bulletin 6502 TWDB Report 51 TWDB Report 078 TDWR Report 235 TDWR Report 294	TBWE Bulletin 5903 TWC Bulletin 6502 TWDB Report 51 TWDB Report 145 TDWR Report 235 TDWR Report 294

Figure 3 **State Reports, by County, that Address Ground - Water Resources.**

TBWE: Texas Board of Water Engineers
TDWR: Texas Department of Water Resouces
TWC: Texas Water Commission
TWDB: Texas Water Development Board

sive investigation (Walker, 1979) made by the state included the four county area in a regional study of the entire Edwards-Trinity (Plateau) aquifer. In addition, a few local water-availability studies have been conducted by private consulting firms at the request of water-supply organizations. Publications containing information relating to the geology and hydrology of the aquifer in the study area are listed in the selected references at the end of this report.

Geologic mapping in the study area is best presented on the Big Spring, Hobbs, Pecos, and San Angelo Geologic Atlas Sheets published by the University of Texas, Bureau of Economic Geology . The base map for this report was adapted from these sheets. A number of publications by the Bureau describe both Cretaceous and Triassic sediments in the area.

The Texas Water Development Board has maintained a water-level and chemical quality monitoring network within the study area since the mid 1960's. The network consists of 102 water-level observation wells measured annually and 1,218 chemical analyses of water samples taken from 931 wells. Monitoring of the aquifer is also being done in nearby Glasscock County by the Glasscock County Underground Water Conservation District.

A regional investigation of the Edwards-Trinity (Plateau) aquifer was initiated by the U.S. Geological Survey in 1985 and is scheduled to be completed in 1991. The Edwards-Trinity "regional aquifer system analysis" (RASA) project is intended to define the hydrogeologic framework and to describe the geochemistry and ground-water flow of the aquifer system in order to provide a better understanding of its long-term water-yielding potential.

Acknowledgements

The authors wish to thank numerous individuals for their cooperation in providing information on the aquifer in their area. More specifically, appreciation is extended to city, county, and water supply district officials who furnished information concerning their municipal water-supply systems, and to the many property owners who allowed access to their wells to measure water levels and sample for chemical quality. Mr. Mark Hoelsher, previous manager of the Glasscock County Underground Water Conservation District, provided vital information pertaining to aquifer conditions within Glasscock County.

Additionally, special thanks are given to a group of individuals who served on an advisory committee that was formed by the Board to provide a medium through which those most affected by the conditions of the Edwards-Trinity (Plateau) aquifer in the study area could contribute to the study. The committee consisted of a small number of concerned and knowledgeable citizens who represent public supply, irrigation, and industrial users of the ground water in the study area.

Geohydrology

Geology as Related to Ground Water

Regional Structure

The most prominent geologic structures under the study area are the Central Basin Platform, a structural high in the southwestern corner of Upton County, and the Midland Basin, a structural depression underlying the rest of the study area. Both features are subdivisions of the more extensive Permian Basin (Figure 4). As shown in section X-X', the Triassic and Permian strata, which underlie Cretaceous strata, are relatively thin and flat-lying on the Central Basin Platform, thicken and dip sharply basinward along the flanks of the platform, and are thickest in the Midland Basin. In contrast, the Cretaceous strata dip gently toward the southeast and do not appreciably reflect the underlying platform-basin structure.

Local structural features include subsurface depressions apparently caused by solution of Permian evaporites and collapse of overlying sediments. These depressions were later filled with collapse debris and subsequent sediments. Similar solution features also occur in the Cretaceous limestone which often produce conduits to the surface through which water or other fluids can rapidly be conveyed into the Edwards-Trinity (Plateau) aquifer.

Stratigraphy

Geologic units in the study area that contain ground water range in age from Early Paleozoic to Quaternary. Permian and older aquifers produce very saline to brine quality water, while Triassic, Cretaceous, and more recent aquifers contain moderately saline to fresh water. Surface exposures of geologic units in the study area are illustrated in Figure 5, and the thickness, lithology, and water-bearing characteristics of these units are summarized in Table 1.

Paleozoic Era

Early and middle Paleozoic age formations in the study area are composed largely of shallow marine shelf carbonates that range from 3,000 to 6,000 feet thick. Late Paleozoic strata include marine carbonate and evaporite sequences of Permian age that measure over 8,000 feet thick in places. These strata accumulated in and around the Permian basin, a shallow structural depression that developed in West Texas during the Permian.

Triassic System

The Dockum Group unconformably overlies strata of Permian age and dips northwestward toward the center of the Midland Basin. Three subdivisions of the Dockum are identified within the study area. The lower unit consists of 100 to 200 feet of red shale and siltstone and is difficult to discern from the underlying Dewey Lake Redbeds.

A middle, sandy unit, commonly referred to as the Santa Rosa Sandstone, consists of brownish red to greenish gray, fine- to coarse-grained, micaceous sandstone interbedded with variegated shale and is the primary water-bearing zone in the Dockum. Downhole geophysical log

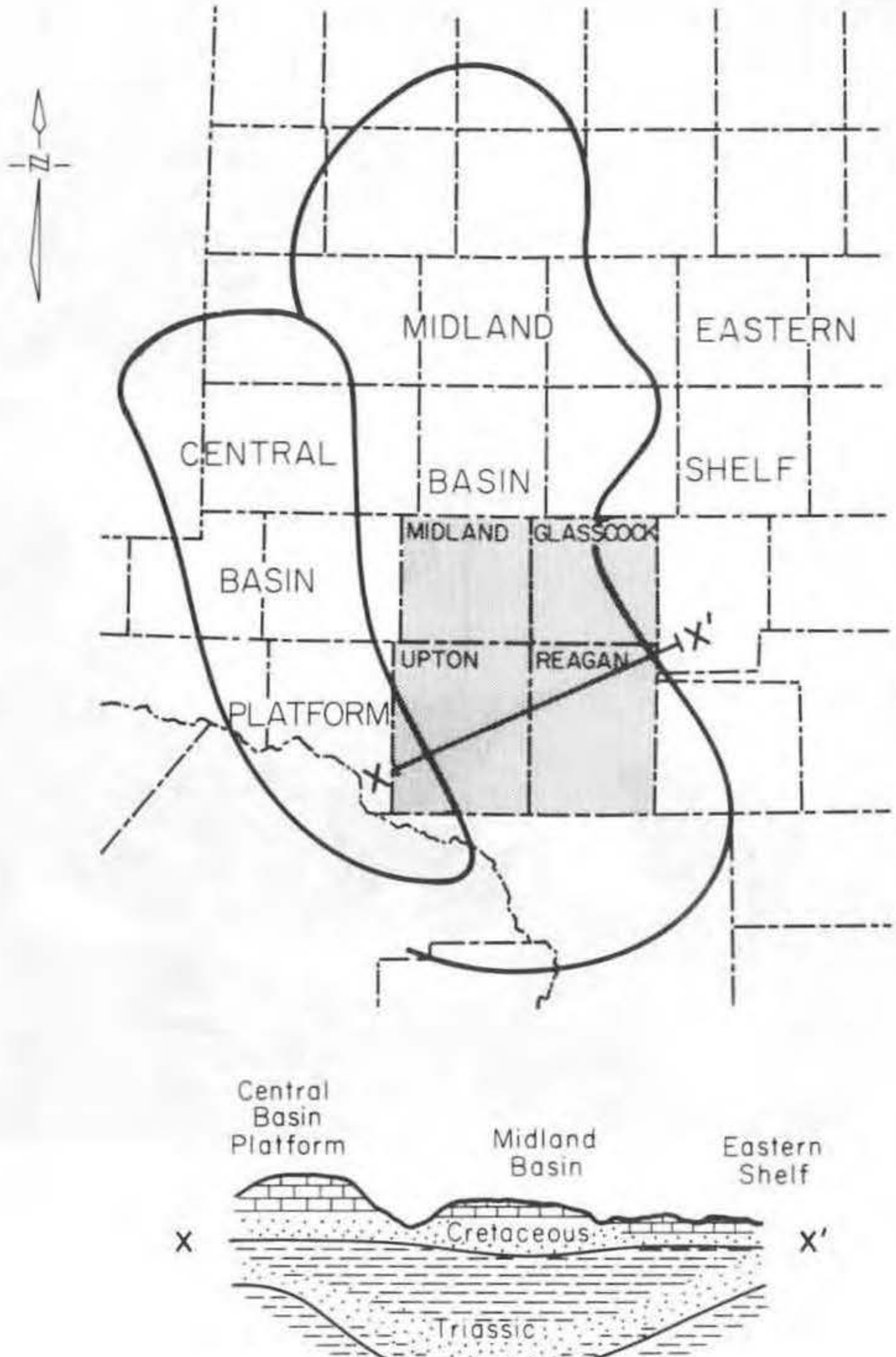


Figure 4
Regional Structure

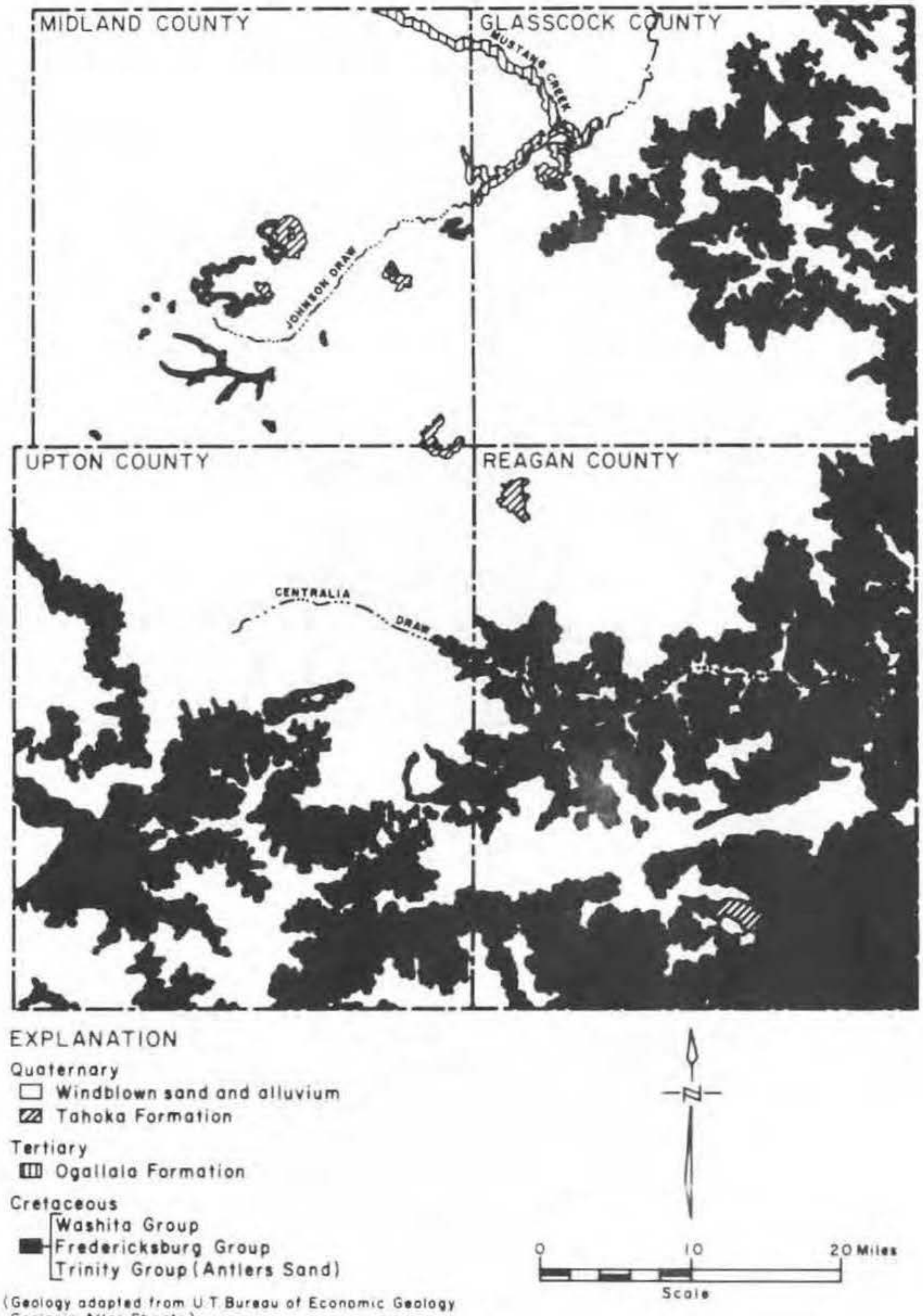


Figure 5
Generalized Geologic Map

Table 1. Geologic Units and Their Water-Bearing Characteristics

Era	System	Group	Stratigraphic Unit	Approximate Maximum Thickness	Character of Rocks	Water-Bearing Characteristics*
Cenozoic	Quaternary		Playa Deposits	--	Clay and silt.	Not known to yield water to wells.
			Windblown Cover Sand	20	Grayish red to brown sand.	
			Alluvium	200	Clay, sand, gravel and caliche in floodplain and terrace deposits.	Yields small amounts of water to domestic and stock wells in stream valleys.
			Tahoka Formation	40	Gray clay, silt and sand in lake deposits.	Contains small amounts of saline water.
	Tertiary		Ogallala	--	Tan, yellow, and reddish brown silty sand mixed with clay, gravel, and caliche layers.	The Ogallala aquifer does not occur in the study area, but fresh water may flow laterally from it into the Trinity Group.
Mesozoic	Cretaceous	Washita	Buda Limestone	80	Clay, marl, and limestone.	Yields small to moderate amounts of water to wells mostly in the southern part of Upton and Reagan Counties.
		Fredericksburg	Edwards Limestone: Segovia Formation Fort Terrett Formation	170	Gray to brown limestone and dolomite.	
		Trinity	Antlers Sand	225	Buff to gray sand and sandstone with red shale layers.	Primary aquifer throughout the area. Yields small to moderate amounts of fresh to moderately saline water to wells.
	Triassic	Dockum		1,200	Upper part: red, maroon and purple shale with red and gray siltsone and sandstone lenses. Middle part: brownish red to greenish gray sandstone and shale. Lower part: red shale and siltstone.	Upper part yields small amounts of slightly to moderately saline water to some wells. Middle part yields small to moderate amounts of fresh to slightly saline water to wells in eastern Reagan and southwestern Upton Counties, and moderate to very saline water to wells in the remainder of the area. Lower part not known to yield water to wells.
Paleozoic	Permian			14,000	Marine carbonates and evaporites.	Yields very saline to brine water as a byproduct from oil wells.

* **Yields of wells:** **small** -- less than 50 gallons per minute; **moderate** -- 50 to 500 gallons per minute.
Chemical Quality of Water: **fresh** -- less than 1,000 milligrams per liter (mgl); **slightly saline** -- 1,000 to 3,000 mgl; **moderately saline** -- 3,000 to 10,000 mgl; **very saline** -- 10,000 to 35,000 mgl; **brine** -- more than 35,000 mgl.

characteristics, large sandstone volumes, and high sand/mud ratios indicate that this unit is a prograding fan-delta deposit within the study area (Granata, 1981). The unit is thickest along the eastern flank of the Central Basin Platform in southwestern Upton County (Figure 6, section A-A'). Figure 7 shows the base of the sand unit, which indicates a dip both northeastward away from the Platform and northwestward toward the center of the Midland Basin.

The upper unit of the Dockum consists of red to maroon and purple shale and lenticular beds of fine-grained, red and gray sandstone and siltstone. This unit is often referred to as the "redbed" by water well drillers and is nonwater-bearing, except for thin sandstone lenses. The top of the unit has been subjected to erosion, resulting in an angular unconformity with the overlying strata.

Cretaceous System

Cretaceous sands, shales, and limestones were deposited on an eroded land surface by the last great epicontinental sea advance over the North American mid-continent. The stratigraphy of the Cretaceous in the study area consists only of the Comanche Series, which is divisible into the Trinity, Fredericksburg, and Washita Groups.

A basal sand unit, that unconformably overlies Triassic rocks, is termed the Antlers Sand of the Trinity Group and consists of buff to gray, fine- to medium-grained, cross-bedded, quartz sand and sandstone interbedded with lesser amounts of red, gray, and purple shale (Walker, 1979). In some places, a fine gravel may occur at the base. The base of the formation is often difficult to determine due to the reworking of Triassic and Permian age red shales by the Early Cretaceous seas. Laterally extensive red shale layers occur within the formation over much of the study area and appear to have some confining effect on ground water below the layers. Thickness of the Antlers Sand varies because of the uneven eroded surface on which the sand was deposited and ranges from less than 75 to more than 225 feet (Figure 8). The formation dips southeasterly at an average rate of about ten feet per mile (Figure 9). This unit is the primary water-producing zone in the study area.

The Antlers Sand is overlain by the Fort Terrett and Segovia Formations (Edwards Limestone) of the Fredericksburg Group. The Fort Terrett Formation consists of a light gray to yellowish brown, argillaceous, nodular limestone in the lower part, grading upward into a light to dark gray limestone and brownish gray dolomite. The overlying Segovia Formation consists of light gray, cherty limestone and brownish gray dolomite, the uppermost beds of which include one or more thick limestone units that form the flat resistive layer capping many of the hills. This formation underlies the windblown cover sand that occurs over most of the farming belt on the upland-plateau area.

The Washita Group, represented primarily by the Buda Limestone, occurs in the southern part of Reagan County where it overlies the Segovia Formation. The formation consists of thin-bedded, hard, sparry limestone at the top and microcrystalline limestone at the bottom, separated by yellow, fossiliferous, nodular marl. In the southwestern part of Upton County, the Washita Group has not been differentiated and consists of calcareous clay, marl, and thin- to massive-bedded limestone that caps the highest hills, such as King Mountain.

Reference 31

Texas Water Development Board

Report 345

Aquifers of Texas

by
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and
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Texas Water Development Board

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INTRODUCTION

Water is one of the state's most precious natural resources and basic economic commodities. It interrelates with and affects almost every aspect of human and natural existence. The purpose of this report is to provide a general overview of this resource in Texas and the aquifers in which it resides.

Ground-water sources supplied 56 percent of the 13.5 million acre-feet of water used in the state in 1992. Figure 1 illustrates the level of ground-water pumpage by county in 1992. More than 75 percent of the 7.6 million acre-feet of ground-water pumpage was for irrigated agriculture, with municipal use accounting for almost 17 percent of the total pumpage (Fig. 2). Due to its widespread availability and relatively low cost, ground water accounts for about 69 percent of the total water used for irrigation and about 41 percent of the water used for municipal needs (Fig. 3).

The Texas Water Development Board (TWDB) has identified and characterized nine major and 20 minor aquifers in the state based on the quantity of water supplied by each. A major aquifer is generally defined as supplying large quantities of water in large areas of the state. Minor aquifers typically supply large quantities of water in small areas or relatively small quantities in large areas. The major and minor aquifers, as presently defined, underlie approximately 81 percent of the state. Lesser quantities of water may also be found in the remainder of the state.

The surface extent, or outcrop, of each aquifer is the area in which the host formations are exposed at the land surface. This area corresponds to the principal recharge zone for the aquifers. Ground water encountered within this area is normally under unconfined, water-table conditions and is most susceptible to contamination.

Some water-bearing formations dip below the surface and are covered by other formations. Aquifers with this characteristic are common, although not exclusive, east and south of Interstate Highway 35. Aquifers covered by less permeable formations, such as clay, are confined under artesian pressure. Delineations of the downdip boundaries of such aquifers as the Edwards (BFZ), Trinity, and Carrizo-Wilcox are based on chemical quality criteria.

Aquifer water quality is described in terms of dissolved-solids concentrations expressed in milligrams per liter (mg/l) and is classified as fresh (less than 1,000 mg/l), slightly saline (1,000 - 3,000 mg/l), moderately saline (3,000 - 10,000 mg/l), and very saline (10,000 - 35,000 mg/l). Aquifer downdip boundaries shown on the maps delineate extents of the aquifers that contain ground water with dissolved-solids concentrations that meet the needs of the aquifers' primary uses. The quality limit for most aquifers is 3,000 mg/l dissolved solids, which meets most agricultural and industrial needs. However, the limit for the Edwards (BFZ) is 1,000 mg/l for public water supply use. The limit for the Dockum and Rustler is 5,000 mg/l, and10,000 mg/l for the Blaine for specific irrigation and industrial uses. Some aquifers, such as the Hueco Bolson and Lipan, have depth limitations at which water of acceptable quality can be obtained.

The following descriptions provide general information pertaining to location, geology, quality, yield, common use, and specific problems of the aquifers throughout their Texas extents. Geologic ages of the aquifers are summarized in Table 1. The aquifers are organized in the order of their magnitude of annual withdrawals, with the aquifer experiencing the largest amount of pumpage listed first. A more thorough understanding of each aquifer may be gained by referring to the suggested reports following each aquifer description.

The characterization of the state's ground-water resources and the development of the maps depicting these aquifers have been accomplished by many staff members of the TWDB over many years. The aquifer maps and reports undergo continual revision to reflect the latest information available. Individual aquifer maps accompanying each description are shown at different scales, but are configured from the same map projection as the major and minor aquifer maps.

The authors gratefully acknowledge all who provided input into this report and specifically thank Phil Nordstrom, Richard Preston, and David Thorkildsen for their valuable contributions. Mark Hayes and Steve Gifford also gave significantly of their time and talents in producing the illustrations.

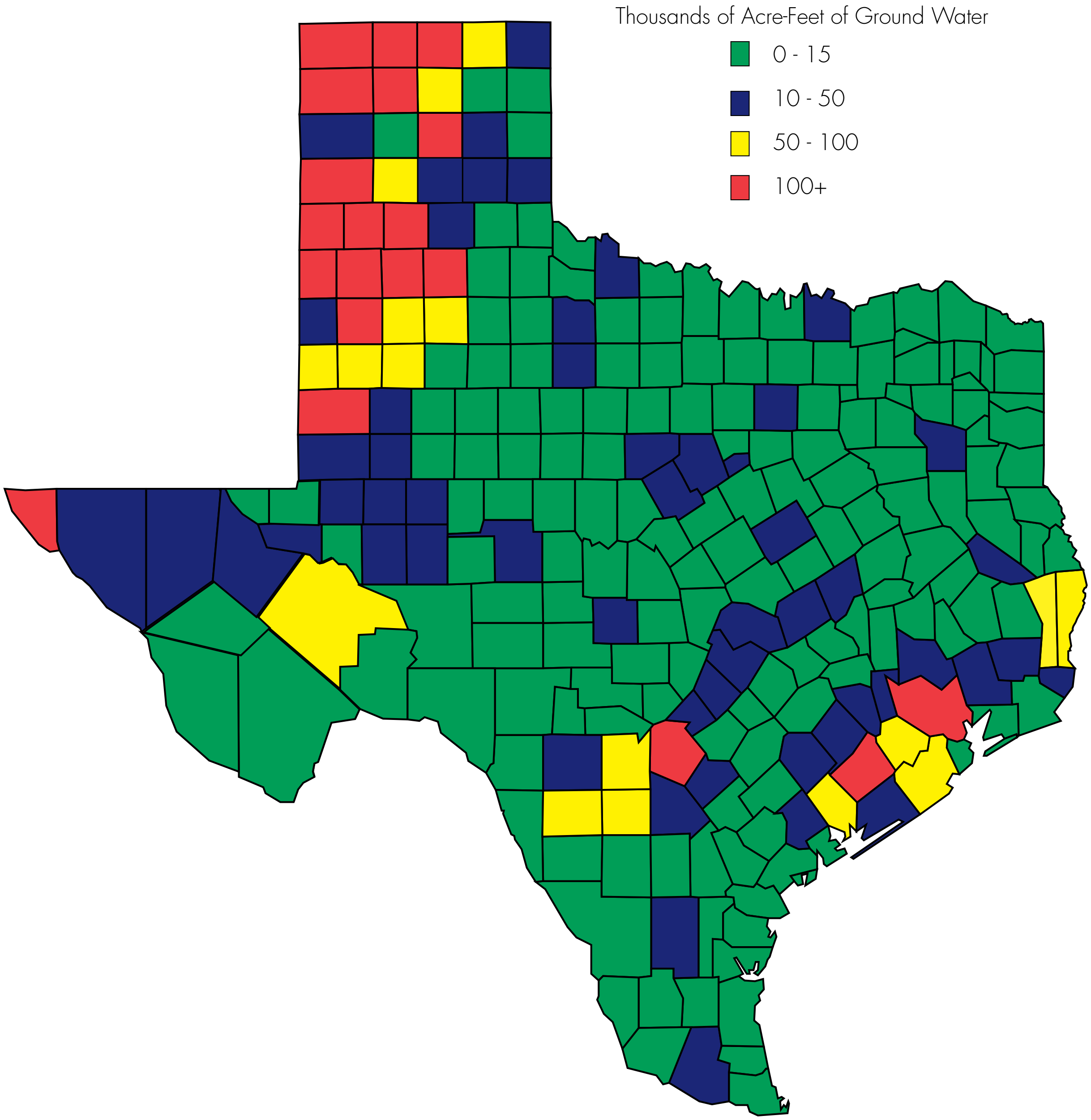


Figure 1. 1992 Ground-Water Pumpage

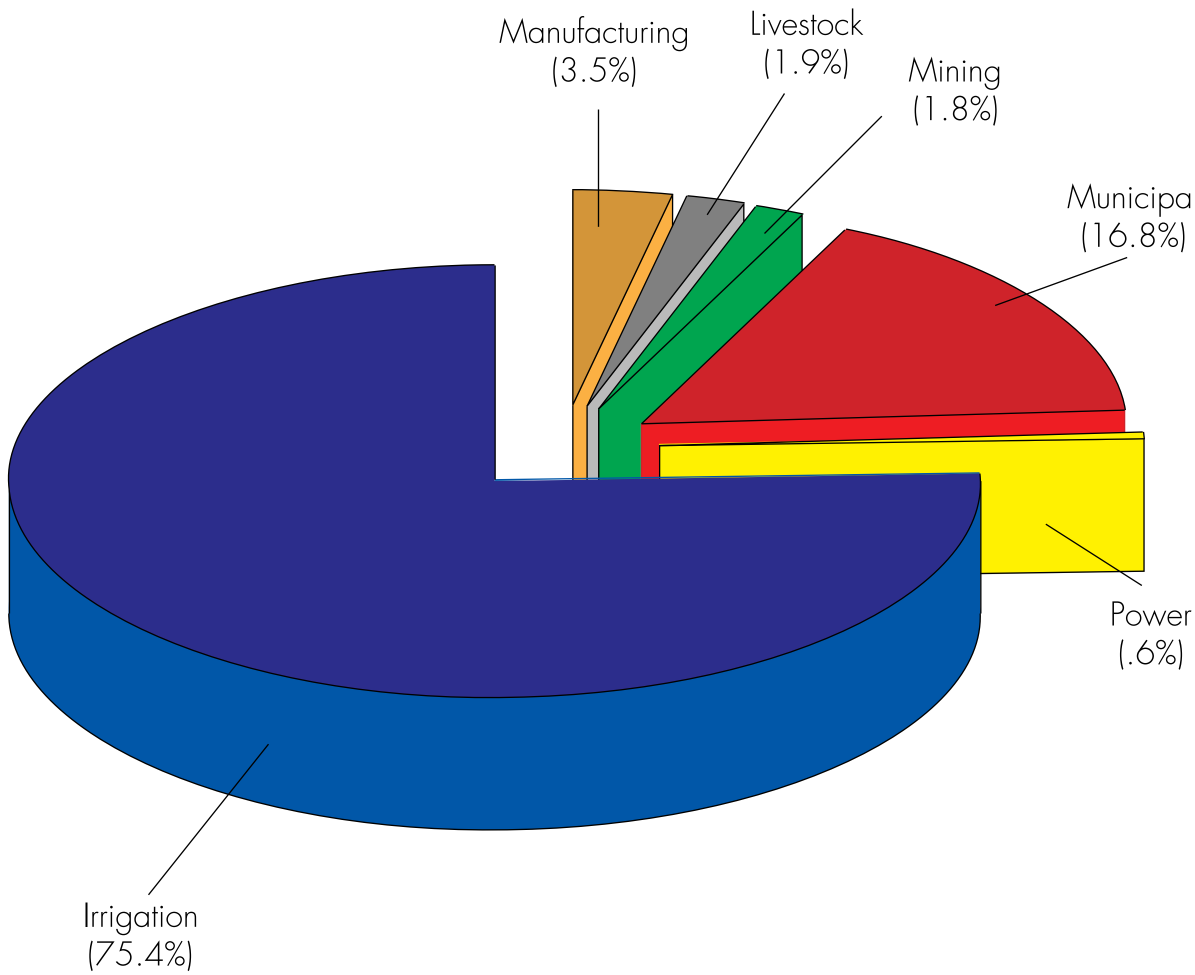


Figure 2. 1992 Ground-Water Use

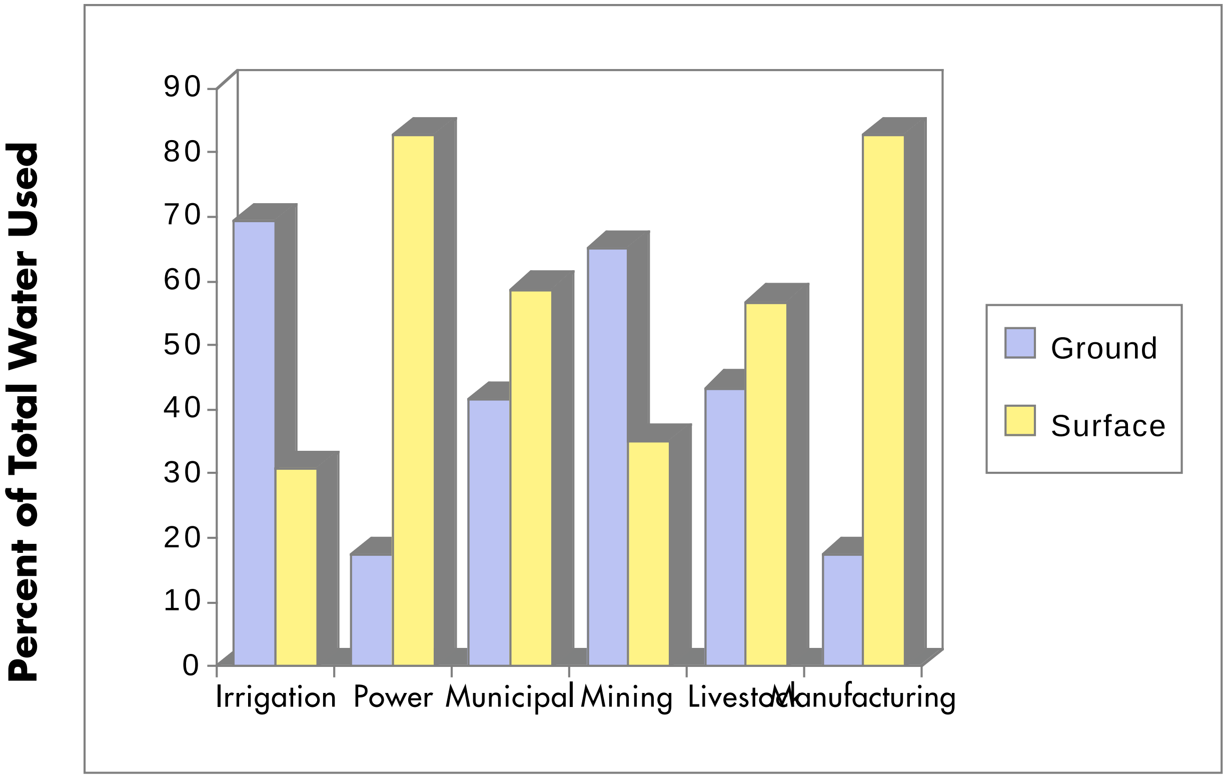


Figure 3. 1992 Water Use by Type

Table 1. Geologic Ages of Aquifers in Texas

Era	Period	Aquifer
Cenozoic	Quaternary	Cenozoic Pecos Alluvium Brazos River Alluvium West Texas Bolsons Seymour Lipan
	Tertiary	Gulf Coast Carrizo-Wilcox Hueco-Mesilla Bolson Ogallala Sparta Igneous Queen City
Mesozoic	Cretaceous	Woodbine Edwards-Trinity (Plateau) Edwards-Trinity (High Plains) Edwards (BFZ) Trinity Nacatoch Blossom Rita Blanca
	Jurassic	Rita Blanca
	Triassic	Dockum
Paleozoic	Permian	Blaine Bone Spring-Victorio Peak Capitan Reef Complex Rustler Lipan
	Pennsylvanian	Marble Falls Marathon
	Mississippian	Marathon
	Devonian	Marathon
	Silurian	Marathon
	Ordovician	Ellenburger-San Saba Marathon
	Cambrian	Ellenburger-San Saba Hickory
Precambrian		

GENERAL GROUND-WATER PRINCIPLES

Vast quantities of water percolate underground through geologic formations known as *aquifers*. The occurrence of water within the formations takes different forms. In sedimentary rocks, such as those composed of sand and gravel, water is contained in the spaces between grains. Some of the largest aquifers in Texas, including the Ogallala, Gulf Coast, and Carrizo-Wilcox, hold water in this fashion. Limestone formations, such as the Edwards, contain water in crevices and caverns caused in part by dissolution of the limestone by ground water. A third occurrence of ground water is within the cracks, fractures, and joints developed in harder formations such as granite and volcanic rock.

Two rock characteristics of fundamental importance related to the occurrence of ground water are *porosity,* which is the amount of open space contained in the rock, and *permeability,* the ability of the porous material to allow fluids to move through it. In sedimentary rocks consisting of sandstone, gravel, clay, and silt, the porosity is a function of the size, shape, sorting, and degree of cementation of the grains. In limestone and other harder rock, the porosity is a function of openings such as cracks, crevices, and caverns. Fine-grained sediments, such as clay and silt, usually have high porosity. However, due to the small size of the voids in these sediments, the permeability is low, and these formations do not readily yield or transmit water. For a geologic formation to be an aquifer, it must be porous, permeable, and yield water in sufficient quantities to provide a usable supply.

Recharge is the addition of water to an aquifer. This water may be absorbed from precipitation, streams, and lakes either directly into a formation or indirectly by way of leakage from another formation. Generally, only a small portion of the total precipitation seeps down through the soil cover to reach the water table. Among the factors that influence the amount of recharge to an aquifer are the amount and frequency of precipitation; the areal extent of the outcrop or intake area; the topography, type and amount of vegetation, and condition of soil cover in the outcrop area; and the ability of the aquifer to accept recharge and transmit it to areas of discharge.

Ground water is said to occur under either *water-table* or *artesian* conditions. Ground water in the outcrop of many aquifers is unconfined and under water-table conditions. Water under these conditions is under atmospheric pressure and will rise or fall in response to changes in the volume of water stored. In most places, the configuration of the water table approximates the topography of the land surface. In a well penetrating an unconfined aquifer, water will rise to the level of the water table.

Away from the outcrop, ground water in the aquifer may occur beneath a relatively impermeable bed. Here, water is under artesian, or confined, conditions, and the impermeable bed confines the water under a pressure greater than atmospheric. In a well penetrating an artesian aquifer, water will rise above the confining bed. If the pressure head is large enough to cause the water in the well to rise above the land surface, the well will flow.

Ground water moves from areas of recharge to areas of discharge, or from points of higher water level to points of lower water level. Under normal artesian conditions, movement of ground water usually is in the direction of the aquifer's regional dip. Under water-table conditions, the slope of the water table, and consequently the direction of ground-water movement, are usually closely related to the slope of the land surface. However, in the case of both artesian and water-table conditions, local anomalies develop in which some water moves toward pumpage areas. The rate of ground-water movement in an aquifer is normally very slow, or in the magnitude of a few feet to a few hundred feet per year.

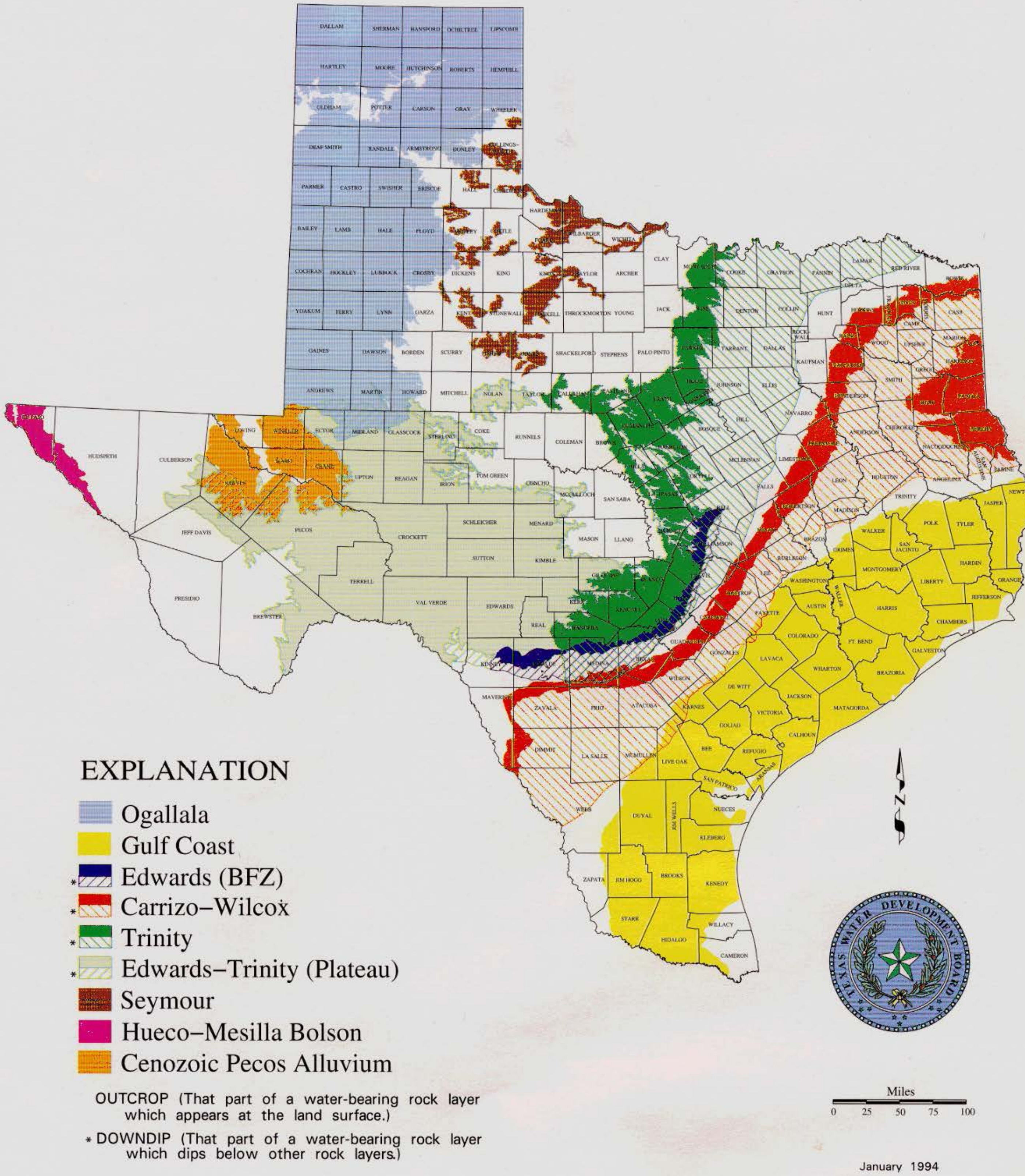
Discharge is the loss of water from an aquifer by either artificial or natural means. Artificial discharge takes place from flowing and pumped water wells, and from drainage ditches, gravel pits, or other excavations that intersect the water table. Natural discharge occurs as springs, evaporation, transpiration, and leakage between formations.

Changes in water levels indicate a change in the ground-water storage in an aquifer. These changes can be due to many causes, with some regionally significant and others confined to more local areas. In short, water-level fluctuations are caused by changes in recharge and discharge.

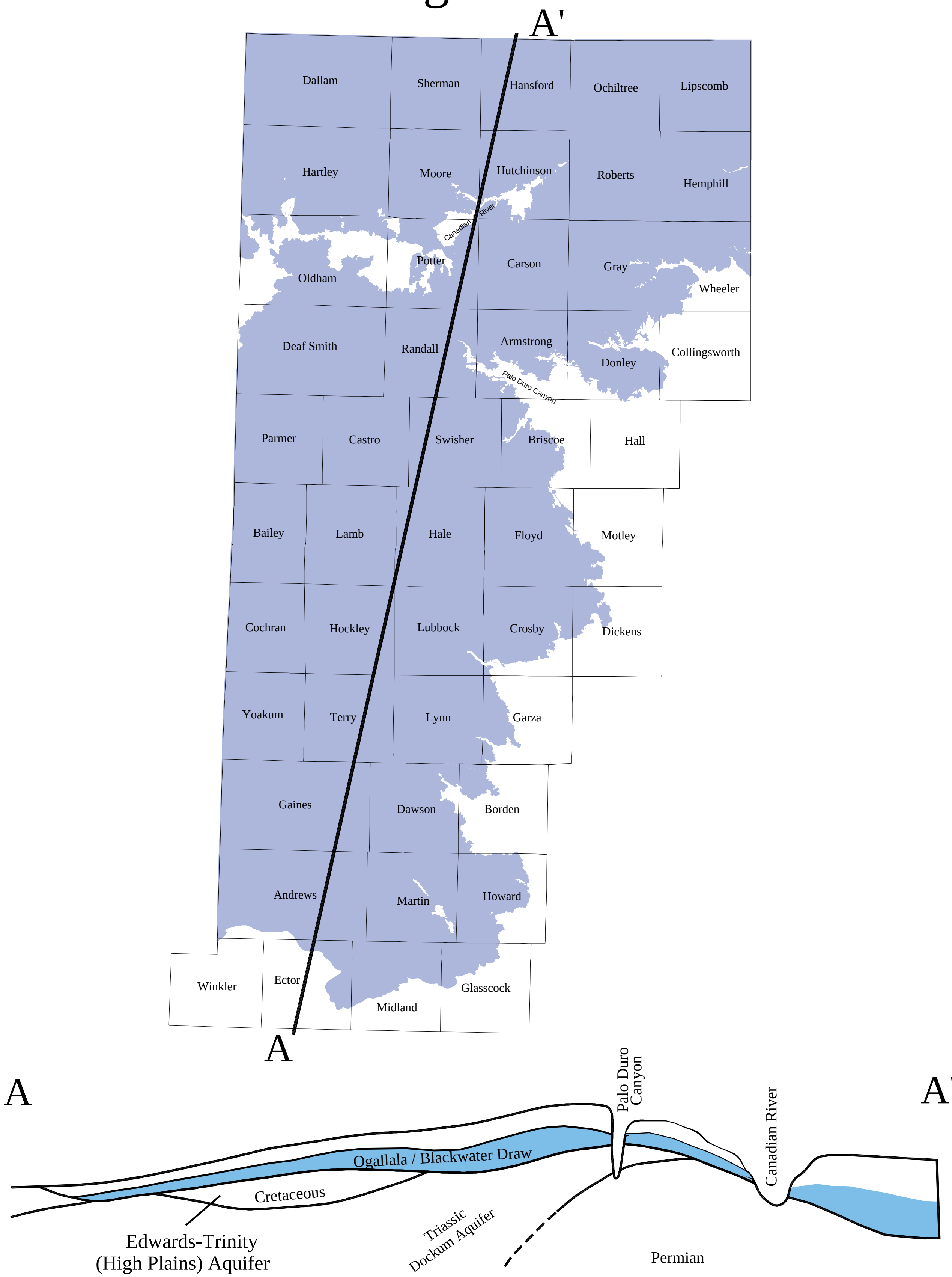
When recharge is reduced, as in the case of a drought, or when pumpage is greater than recharge, some of the water discharged from the aquifer must be withdrawn from storage, resulting in a decline of water levels. If water levels are lowered excessively, springs and shallow wells may go dry. However, when sufficient precipitation resumes or pumpage is reduced, the volume of water drained from storage may be replaced and water levels will rise accordingly. Changes in water levels in water-table aquifers are generally less pronounced than in artesian aquifers.

When a water well is pumped, water levels in the vicinity are drawn down in the shape of an inverted cone with its apex at the pumped well. The development of these *cones of depression* depends on the aquifer's ability to store and move water and on the rate of pumping. If the cone of one well overlaps the cone of another, additional lowering of water levels will occur as the wells compete for the same water.

MAJOR AQUIFERS OF TEXAS



Ogallala



A'
Dallam
Sherman
Hansford
Ochiltree
Lipscomb
Hartley
Moore
Hutchinson
Roberts
Hemphill
Canadian River
Oldham
Potter
Carson
Gray
Wheeler
Deaf Smith
Randall
Armstrong
Donley
Collingsworth
Palo Duro Canyon
Parmer
Castro
Swisher
Briscoe
Hall
Bailey
Lamb
Hale
Floyd
Motley
Cochran
Hockley
Lubbock
Crosby
Dickens
Yoakum
Terry
Lynn
Garza
Gaines
Dawson
Borden
Andrews
Martin
Howard
Winkler
Ector
Midland
Glasscock
A
A
A'
Palo Duro Canyon
Canadian River
Ogallala / Blackwater Draw
Cretaceous
Edwards-Trinity (High Plains) Aquifer
Triassic Dockum Aquifer
Permian

Ogallala Aquifer

The Ogallala aquifer, the major water-bearing unit in the High Plains of Texas, provides water to all or parts of 46 counties. Water-bearing areas of the Ogallala are laterally connected except where the Canadian River has eroded through the formation, thereby forming the boundary between two separate flow systems referred to as the Northern and Southern High Plains. Vertical hydrologic communication also occurs between the Ogallala and the underlying Cretaceous, Jurassic, and Triassic formations in many areas and between the overlying Quaternary Blackwater Draw Formation where present. Although many communities use the Ogallala aquifer as their sole source of drinking water, approximately 95 percent of the water is used for irrigation.

The Ogallala is composed primarily of sand, gravel, clay, and silt deposited during the Tertiary Period. Ground water, under water-table conditions, moves slowly through the Ogallala Formation in a southeastward direction toward the caprock edge or eastern escarpment of the High Plains. Saturated thickness of the aquifer is generally greater in the northern part of the region and thinner in the southern part where the formation overlaps Cretaceous rocks. The saturated thickness, greatest where sediments have filled previously eroded drainage channels, ranges up to approximately 600 feet. Coarse-grained sediments in these channels also have the greatest permeability and supply water to wells with yields of up to 2,000 gal/min. Average yield of Ogallala wells is approximately 500 gal/min.

The chemical quality of the water in the aquifer is generally fresh; however, both dissolved-solids and chloride concentrations increase from north to south. In the Northern High Plains, dissolved solids are usually less than 400 mg/l. Dissolved-solids concentrations typically exceed 400 mg/l in the Southern High Plains, where extensive areas with concentrations exceeding 1,000 mg/l are common, especially in the vicinity of alkali lakes. The chemical quality in the south is probably influenced by upward leakage and subsequent mixing of water from the underlying Cretaceous aquifers. Fluoride content is commonly high, and selenium concentrations locally are in excess of drinking water standards.

Recharge to the Ogallala occurs principally by infiltration of precipitation on the surface and, to a lesser extent, by upward leakage from underlying formations. Only about one inch of the precipitation actually reaches the water table annually because rainfall is minimal, the evaporation rate is high, and the infiltration rate is slow. The highest recharge infiltration rates occur in areas overlain by sandy soils and in playa-lake basins.

Since the expansion of irrigated agriculture in the mid-1940s, greater amounts of water have been pumped from the aquifer than have been recharged. As a result, some areas have experienced water-level declines in excess of 100 feet from predevelopment to 1990. Reduced pumpage in some areas of the High Plains has resulted in a reduction in the rate of water-level decline.

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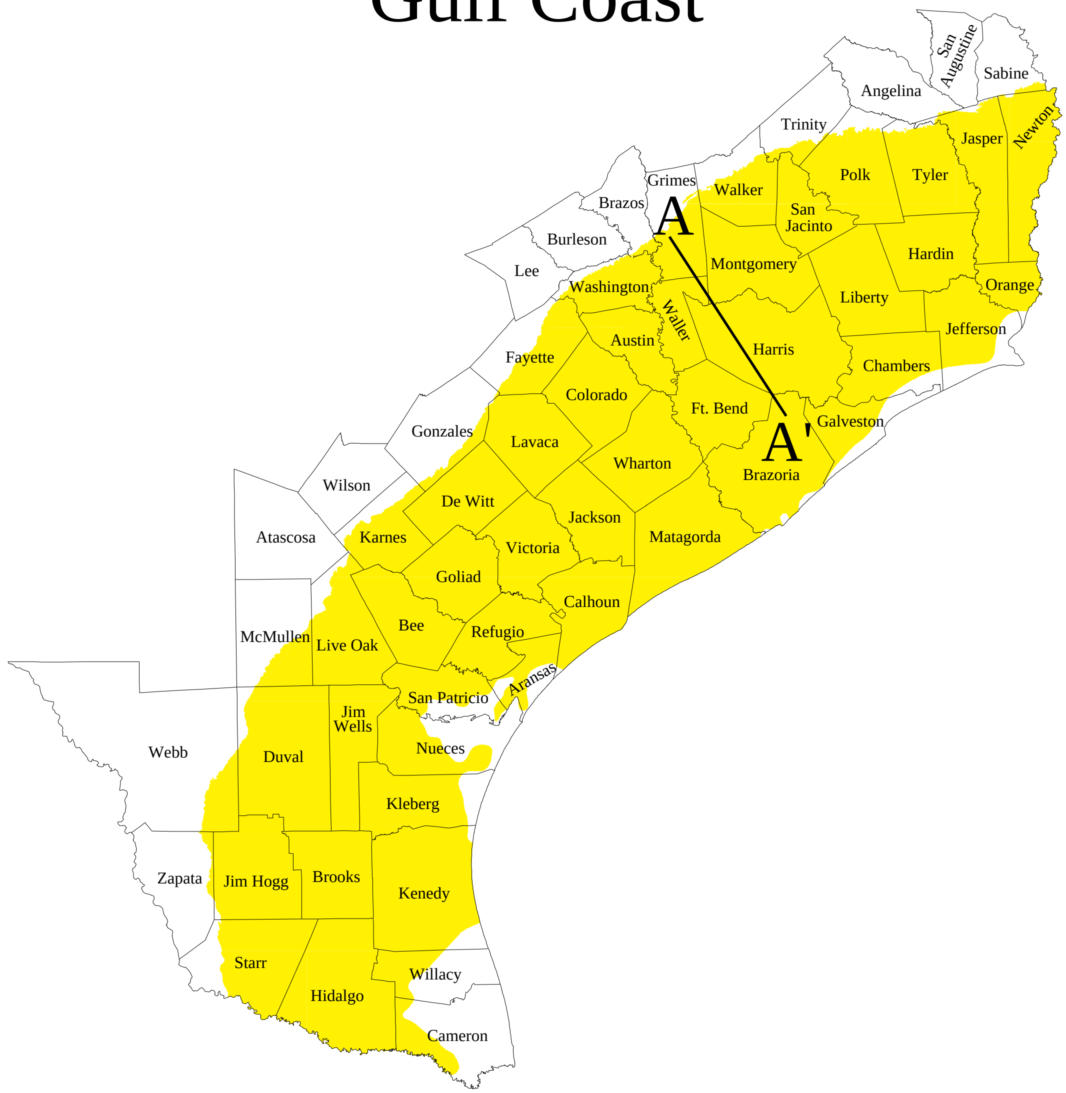
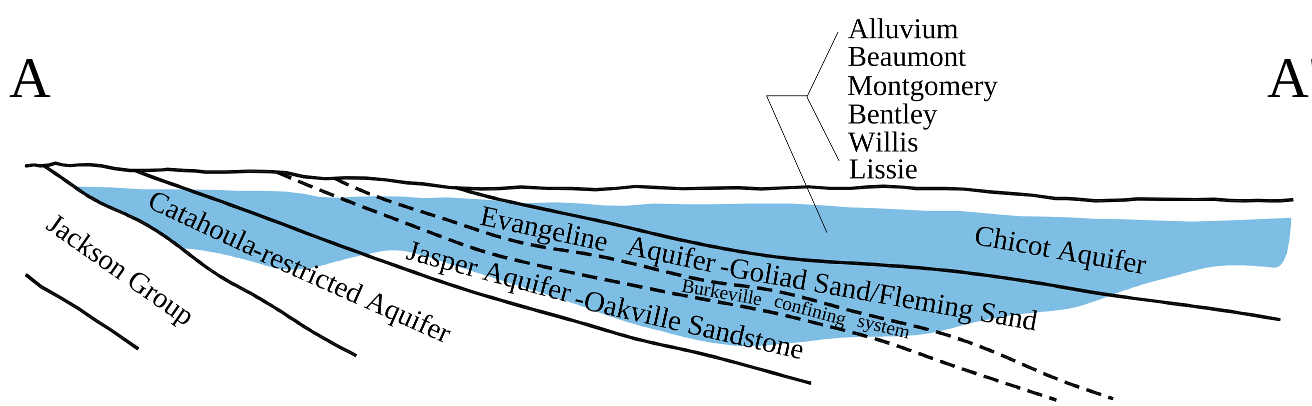
Gulf Coast





Modified from Baker, 1979

Gulf Coast Aquifer

The Gulf Coast aquifer forms a wide belt along the Gulf of Mexico from Florida to Mexico. In Texas, the aquifer provides water to all or parts of 54 counties and extends from the Rio Grande northeastward to the Louisiana-Texas border. Municipal and irrigation uses account for 90 percent of the total pumpage from the aquifer. The Greater Houston metropolitan area is the largest municipal user, where well yields average about 1,600 gal/min.

The aquifer consists of complex interbedded clays, silts, sands, and gravels of Cenozoic age, which are hydrologically connected to form a large, leaky artesian aquifer system. This system comprises four major components consisting of the following generally recognized water-producing formations. The deepest is the Catahoula, which contains ground water near the outcrop in relatively restricted sand layers. Above the Catahoula is the Jasper aquifer, primarily contained within the Oakville Sandstone. The Burkeville confining layer separates the Jasper from the overlying Evangeline aquifer, which is contained within the Fleming and Goliad sands. The Chicot aquifer, or upper component of the Gulf Coast aquifer system, consists of the Lissie, Willis, Bentley, Montgomery, and Beaumont formations, and overlying alluvial deposits. Not all formations are present throughout the system, and nomenclature often differs from one end of the system to the other. Maximum total sand thickness ranges from 700 feet in the south to 1,300 feet in the northern extent.

Water quality is generally good in the shallower portion of the aquifer. Ground water containing less than 500 mg/l dissolved solids is usually encountered to a maximum depth of 3,200 feet in the aquifer from the San Antonio River Basin northeastward to Louisiana. From the San Antonio River Basin southwestward to Mexico, quality deterioration is evident in the form of increased chloride concentration and saltwater encroachment along the coast. Little of this ground water is suitable for prolonged irrigation due to either high salinity or alkalinity, or both. In several areas at or near the coast, including Galveston Island and the central and southern parts of Orange County, heavy municipal or industrial pumpage had previously caused an updip migration, or saltwater intrusion, of poor-quality water into the aquifer. Recent reductions in pumpage here have resulted in a stabilization and, in some cases, even improvement of ground-water quality.

Years of heavy pumpage for municipal and manufacturing use in portions of the aquifer have resulted in areas of significant water-level decline. Declines of 200 feet to 300 feet have been measured in some areas of eastern and southeastern Harris and northern Galveston counties. Other areas of significant water-level declines include the Kingsville area in Kleberg County and portions of Jefferson, Orange, and Wharton counties. Some of these declines have resulted in compaction of dewatered clays and significant land surface subsidence. Subsidence is generally less than 0.5 foot over most of the Texas coast, but has been as much as nine feet in Harris and surrounding counties. As a result, structural damage and flooding have occurred in many low-lying areas along Galveston Bay in Baytown, Texas City, and Houston. Conversion to surface-water use in many of the problem areas has reversed the decline trend.

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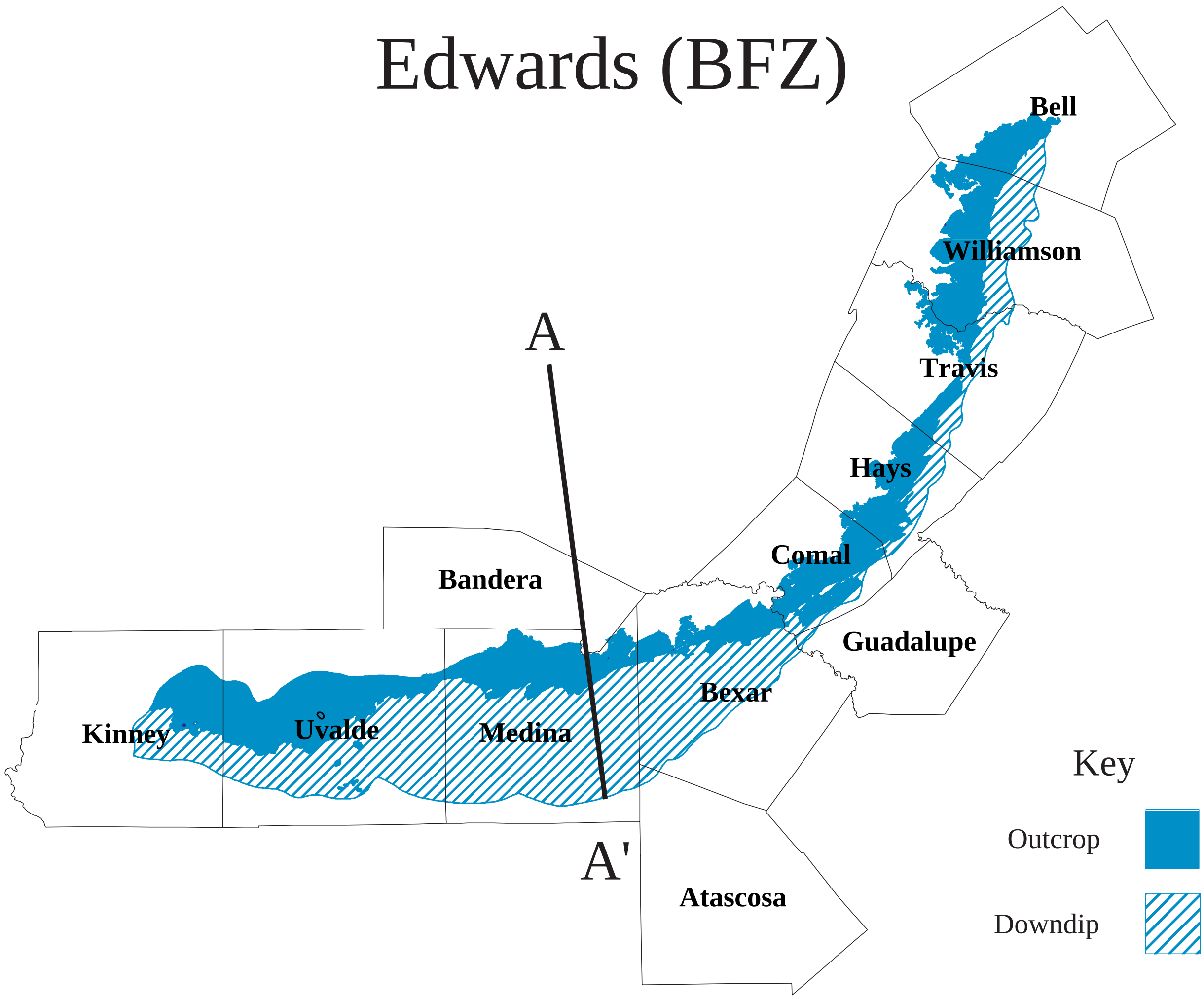
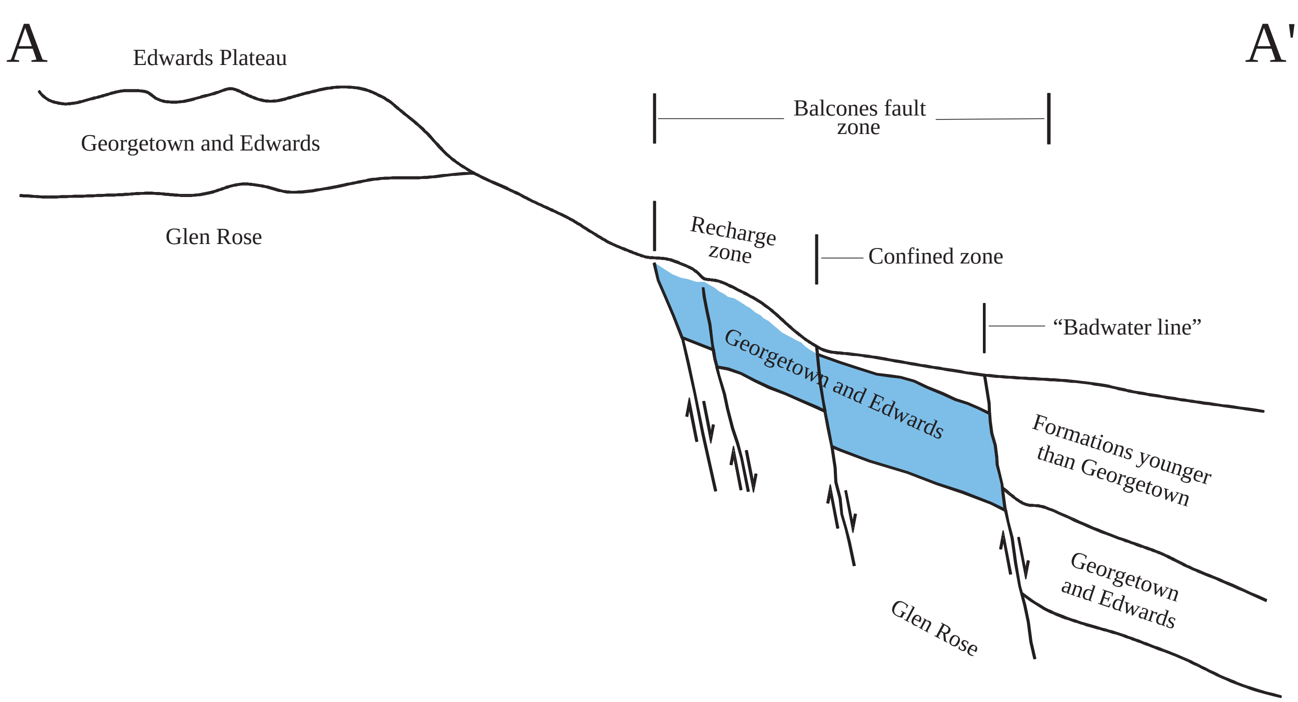
Edwards (BFZ)





Modified from Maclay and Small, 1986

Edwards (Balcones Fault Zone)

The Edwards (Balcones Fault Zone, or BFZ) aquifer covers approximately 4,350 square miles in parts of 11 counties. The aquifer forms a narrow belt extending from a ground-water divide in Kinney County through the San Antonio area northeastward to the Leon River in Bell County. A poorly defined ground-water divide near Kyle in Hays County hydrologically separates the aquifer into the San Antonio and Austin regions. The name Edwards (BFZ) distinguishes this aquifer from the Edwards-Trinity (Plateau) and the Edwards-Trinity (High Plains) aquifers.

Water from the aquifer is primarily used for municipal, irrigation, and recreational purposes; approximately 54 percent is used for municipal supply. San Antonio, which obtains its entire municipal water supply from the Edwards aquifer, is one of the largest cities in the world to rely solely on a single ground-water source. The aquifer feeds several well-known recreational springs and underlies some of the most environmentally sensitive areas in the state.

The aquifer, composed predominantly of limestone formed during the early Cretaceous Period, exists under water-table conditions in the outcrop and under artesian conditions where it is confined below the overlying Del Rio Clay. The Edwards aquifer consists of the Georgetown Limestone, formations of the Edwards Group (the primary water-bearing unit) and their equivalents, and the Comanche Peak Limestone where it exists. Thickness ranges from 200 feet to 600 feet.

Recharge to the aquifer occurs primarily by the downward percolation of surface water from streams draining off the Edwards Plateau to the north and west and by direct infiltration of precipitation on the outcrop. This recharge reaches the aquifer through crevices, faults, and sinkholes in the unsaturated zone. Unknown amounts of ground water enter the aquifer as lateral underflow from the Glen Rose Formation. Water in the aquifer generally moves from the recharge zone toward natural discharge points such as Comal, San Marcos, Barton, and Salado springs. Water is also discharged artificially from hundreds of pumping wells, particularly municipal supply wells in the San Antonio region and irrigation wells in the western extent.

In the updip portion, ground water moving through the aquifer system has dissolved large amounts of rock to create highly permeable solution zones and channels that facilitate rapid flow and relatively high storage capacity within the aquifer. Highly fractured strata in fault zones have also been preferentially dissolved to form conduits capable of transmitting large amounts of water. Due to its extensive honeycombed and cavernous character, the aquifer yields moderate to large quantities of water. Some wells yield in excess of 16,000 gal/min, and one well drilled in Bexar County flowed 24,000 gal/min from a 30-inch diameter well. The aquifer is significantly less permeable farther downdip where the concentration of dissolved solids in the water exceeds 1,000 mg/l.

The chemical quality of water in the aquifer is typically fresh, although hard, with dissolved-solids concentrations averaging less than 500 mg/l. The downdip interface between fresh and slightly saline water represents the extent of water containing less than 1,000 mg/l. Within a short distance downgradient of this "bad water line," the ground water becomes increasingly mineral-ized.

Due to its highly permeable nature in the fresh-water zone, the Edwards aquifer responds quickly to changes and extremes of stress placed on the system. This is indicated by rapid water-level fluctuations during relatively short periods of time. During times of adequate rainfall and recharge, the Edwards aquifer is able to supply sufficient amounts of water for all demands as well as sustain spring flows at many locations throughout its extent. However, under conditions of below-average rainfall or drought when discharge exceeds recharge, spring flows may be reduced to environmentally detrimental levels, and mandatory rationing may be established.

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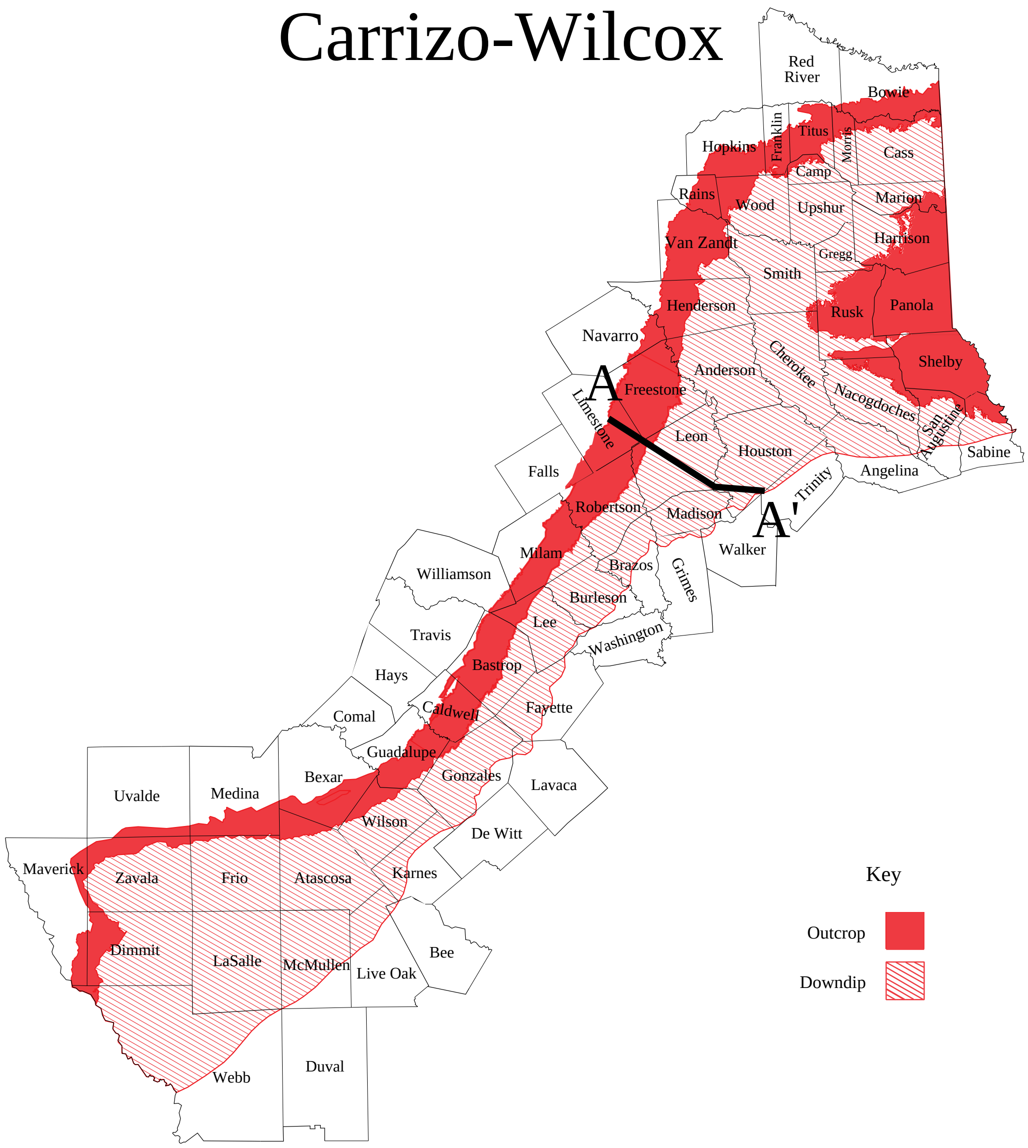
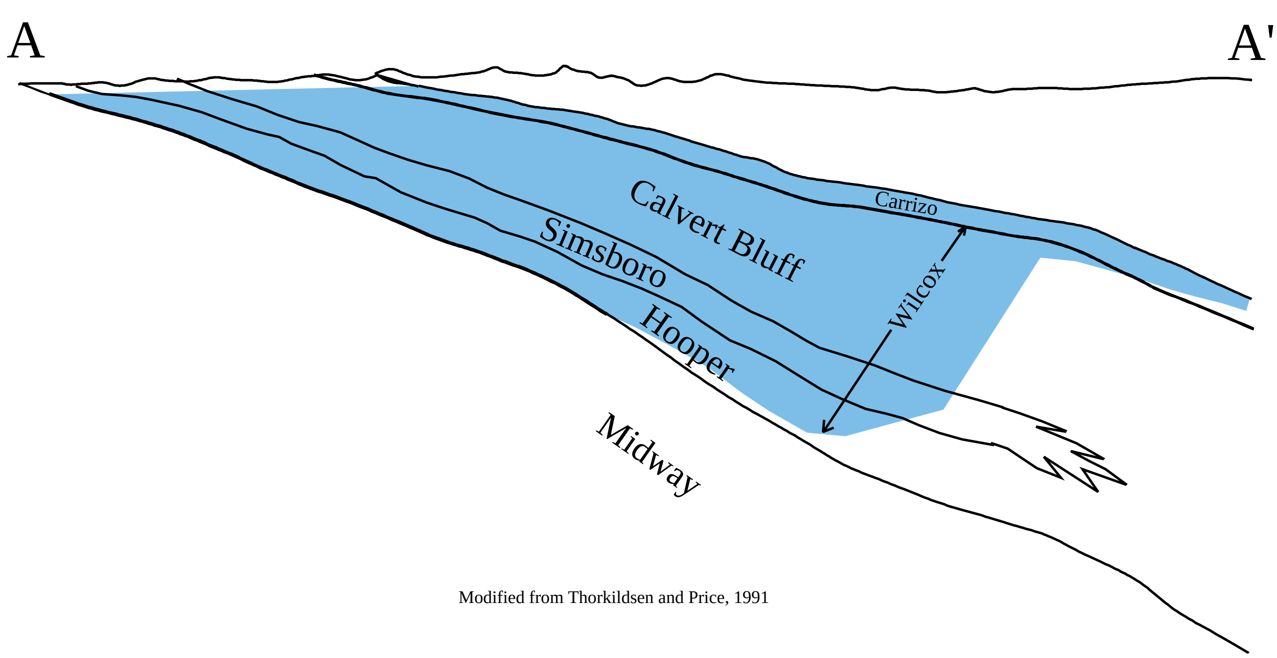
Carrizo-Wilcox





Modified from Thorkildsen and Price, 1991

Carrizo-Wilcox Aquifer

The Wilcox Group and the overlying Carrizo Formation of the Claiborne Group form a hydrologically connected system known as the Carrizo-Wilcox aquifer. This aquifer extends from the Rio Grande in South Texas northeastward into Arkansas and Louisiana, providing water to all or parts of 60 counties. The Carrizo Sand and Wilcox Group crop out along a narrow band that parallels the Gulf Coast and dips beneath the land surface toward the coast, except in the East Texas structural basin adjacent to the Sabine Uplift, where the formations form a trough.

Municipal and irrigation pumpage account for about 35 percent and 51 percent, respectively, of total pumpage. The largest metropolitan areas dependent on ground water from the Carrizo-Wilcox aquifer are Bryan-College Station, Lufkin-Nacogdoches, and Tyler. Irrigation is the predominant use in the Winter Garden region of South Texas.

The Carrizo-Wilcox aquifer is predominantly composed of sand locally interbedded with gravel, silt, clay, and lignite deposited during the Tertiary Period. South of the Trinity River and north of the Colorado River, the Wilcox Group is divided into three distinct formations: the Hooper, Simsboro, and Calvert Bluff. Of the three, the Simsboro typically contains the most massive water-bearing sands. This division cannot be made south of the Colorado River or north of the Trinity River due to the absence of the Simsboro as a distinct unit. Aquifer thickness in the downdip artesian portion ranges from less than 200 feet to more than 3,000 feet.

Well yields are commonly 500 gal/min, and some may reach 3,000 gal/min downdip where the aquifer is under artesian conditions. Some of the greatest yields (more than 1,000 gal/min) are produced from the Carrizo Sand in the southern, or Winter Garden, area of the aquifer. Yields of greater than 500 gal/min are also obtained from the Carrizo and Simsboro formations in the central region.

Regionally, water from the Carrizo-Wilcox aquifer is fresh to slightly saline. In the outcrop, the water is hard, yet usually low in dissolved solids. Downdip, the water is softer, has a higher temperature, and contains more dissolved solids. Hydrogen sulfide and methane may occur locally. Excessively corrosive water with a high iron content is common throughout much of the northeastern part of the aquifer. Localized contamination of the aquifer in the Winter Garden area is attributed to direct infiltration of oil field brines on the surface and to downward leakage of saline water to the overlying Bigford Formation.

Significant water-level declines have developed in the semiarid Winter Garden portion of the Carrizo aquifer, as the region is heavily dependent on ground water for irrigation. Since 1920, water levels have declined as much as 100 feet in much of the area and more than 250 feet in the Crystal City area of Zavala County. Significant water-level declines resulting from extensive municipal and industrial pumpage also have occurred in Northeast Texas. Tyler and the Lufkin-Nacogdoches area have experienced declines in excess of 400 feet, and in a few wells, as much as 500 feet since the 1940s. In this area, conversion to surface-water use is slowing the rate of water-level decline. The northeast outcrop area has been dewatered in the vicinity of lignite surface-mining operations, and the Simsboro Sand Formation of the Wilcox Group has been affected by water-level declines in parts of Robertson and Milam counties.

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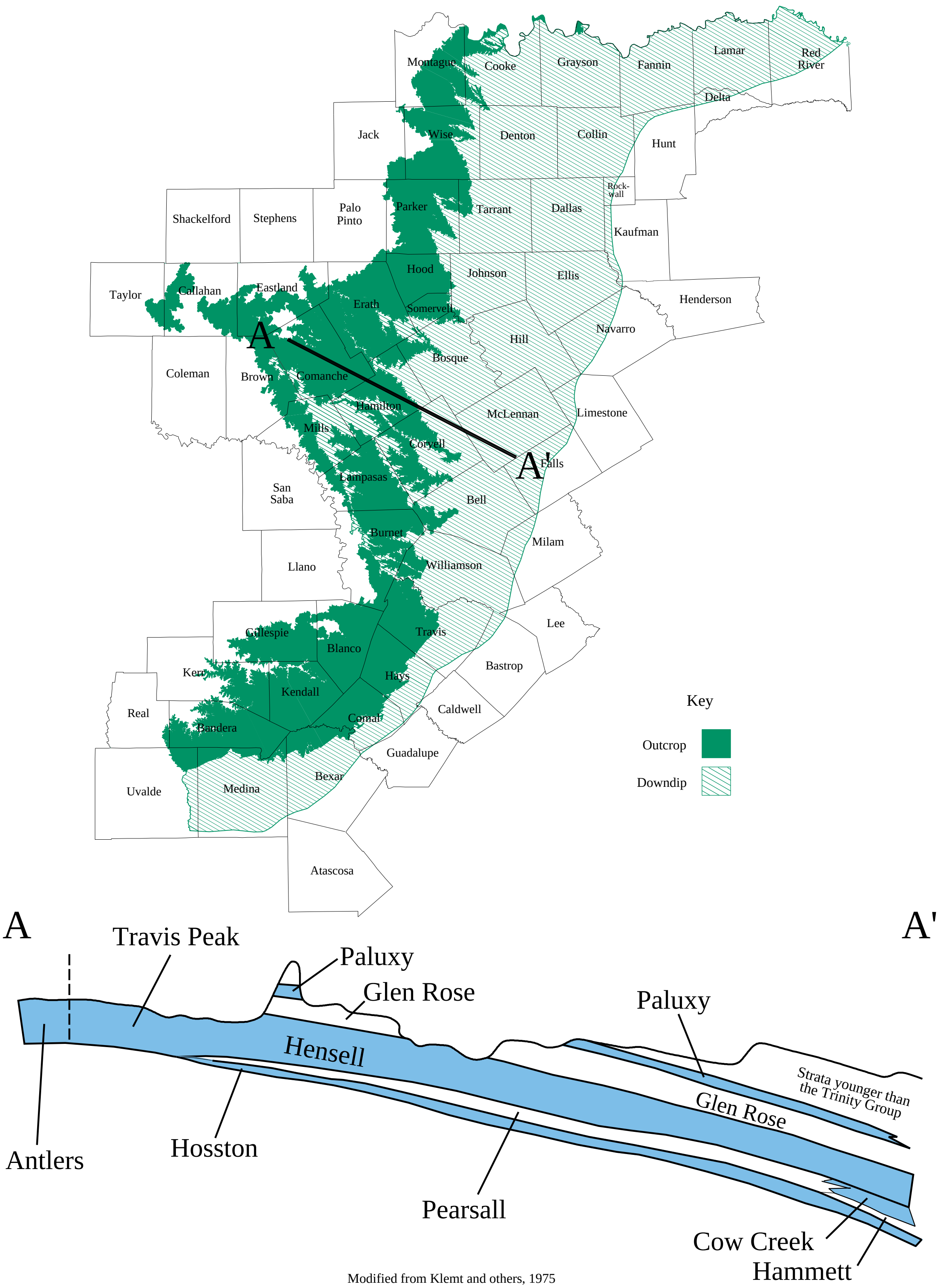
Trinity



Modified from Klemt and others, 1975

Trinity Aquifer

The Trinity aquifer consists of early Cretaceous age formations of the Trinity Group where they occur in a band extending through the central part of the state in all or parts of 55 counties, from the Red River in North Texas to the Hill Country of South-Central Texas. Trinity Group deposits also occur in the Panhandle and Edwards Plateau regions where they are included as part of the Edwards-Trinity (High Plains and Plateau) aquifers.

Formations comprising the Trinity Group are (from youngest to oldest) the Paluxy, Glen Rose, and Twin Mountains-Travis Peak. Updip, where the Glen Rose thins or is missing, the Paluxy and Twin Mountains coalesce to form the Antlers Formation. The Antlers consists of up to 900 feet of sand and gravel, with clay beds in the middle section. Water from the Antlers is mainly used for irrigation in the outcrop area of North and Central Texas.

Forming the upper unit of the Trinity Group, the Paluxy Formation consists of up to 400 feet of predominantly fine- to coarse-grained sand interbedded with clay and shale. The formation pinches out downdip and does not occur south of the Colorado River.

Underlying the Paluxy, the Glen Rose Formation forms a gulfward-thickening wedge of marine carbonates consisting primarily of limestone. South of the Colorado River, the Glen Rose is the upper unit of the Trinity Group and is divisible into an upper and lower member. In the north, the downdip portion of the aquifer becomes highly mineralized and is a source of contamination to wells that are drilled into the underlying Twin Mountains.

The basal unit of the Trinity Group consists of the Twin Mountains and Travis Peak formations, which are laterally separated by a facies change. To the north, the Twin Mountains Formation consists mainly of medium- to coarse-grained sands, silty clays, and conglomerates. The Twin Mountains is the most prolific of the Trinity aquifers in North-Central Texas; however, the quality of the water is generally not as good as that from the Paluxy or Antlers Formations. To the south, the Travis Peak Formation contains calcareous sands and silts, conglomerates, and limestones. The formation is subdivided into the following members in descending order: Hensell, Pearsall, Cow Creek, Hammett, Sligo, Hosston, and Sycamore.

Extensive development of the Trinity aquifer has occurred in the Fort Worth-Dallas region where water levels have historically dropped as much as 550 feet. Since the mid-1970s, many public supply wells have been abandoned in favor of a surface-water supply, and water levels have responded with slight rises. Water-level declines of as much as 100 feet are still occurring in Denton and Johnson counties. The Trinity aquifer is most extensively developed from the Hensell and Hosston members in the Waco area, where the water level has declined by as much as 400 feet.

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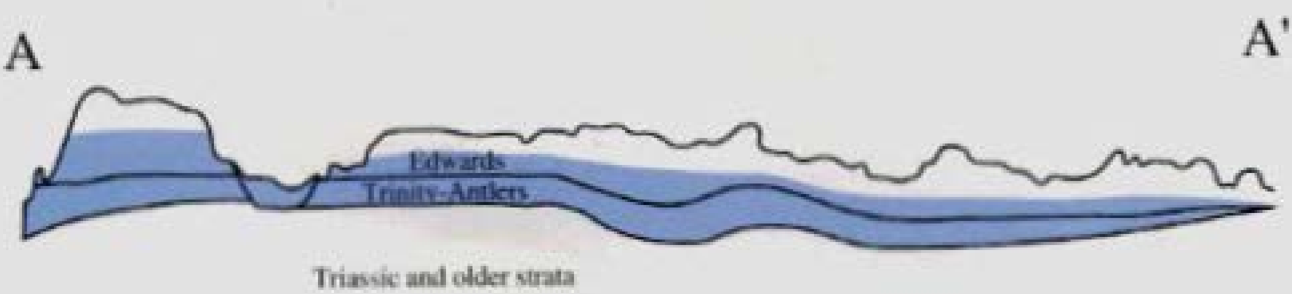
Edwards-Trinity (Plateau)



Modified from Walker, 1979

Edwards-Trinity (Plateau) Aquifer

The Edwards-Trinity (Plateau) aquifer underlies the Edwards Plateau east of the Pecos River and the Stockton Plateau west of the Pecos River, providing water to all or parts of 38 counties. The aquifer extends from the Hill Country of Central Texas to the Trans-Pecos region of West Texas. Irrigation accounts for 70 percent of the total pumpage, whereas municipal use accounts for 15 percent.

The aquifer consists of saturated sediments of lower Cretaceous age Trinity Group formations and overlying limestones and dolomites of the Comanche Peak, Edwards, and Georgetown formations. The Glen Rose Limestone is the primary unit of the Trinity in the southern part of the plateau and is replaced by the Antlers Sand north of the Glen Rose pinchout. The Maxon Sand is present in the western Stockton Plateau region. Maximum saturated thickness of the aquifer is greater than 800 feet.

The aquifer generally exists under water-table conditions; however, where the Trinity is fully saturated and a zone of low permeability occurs near the base of the overlying Edwards aquifer, artesian conditions may exist in the Trinity. Reported well yields commonly range from less than 50 gal/min, where saturated thickness is thin, to more than 1,000 gal/min, where large-capacity wells are completed in jointed and cavernous limestone.

Chemical quality of Edwards-Trinity (Plateau) water ranges from fresh to slightly saline. The water is typically hard and may vary widely in concentrations of dissolved solids made up mostly of calcium and bicarbonate. The salinity of the ground water tends to increase toward the west. Certain areas have unacceptable levels of fluoride.

There is little pumpage from the aquifer over most of its extent, and water levels have remained constant or have fluctuated only with seasonal precipitation. In some instances, water levels have declined as a result of increased pumpage. Although historical declines have occurred in the northwestern part of the aquifer in Reagan, Upton, Midland, and Glasscock counties as a result of irrigation, none of the areas has experienced declines greater than 20 feet since 1980.

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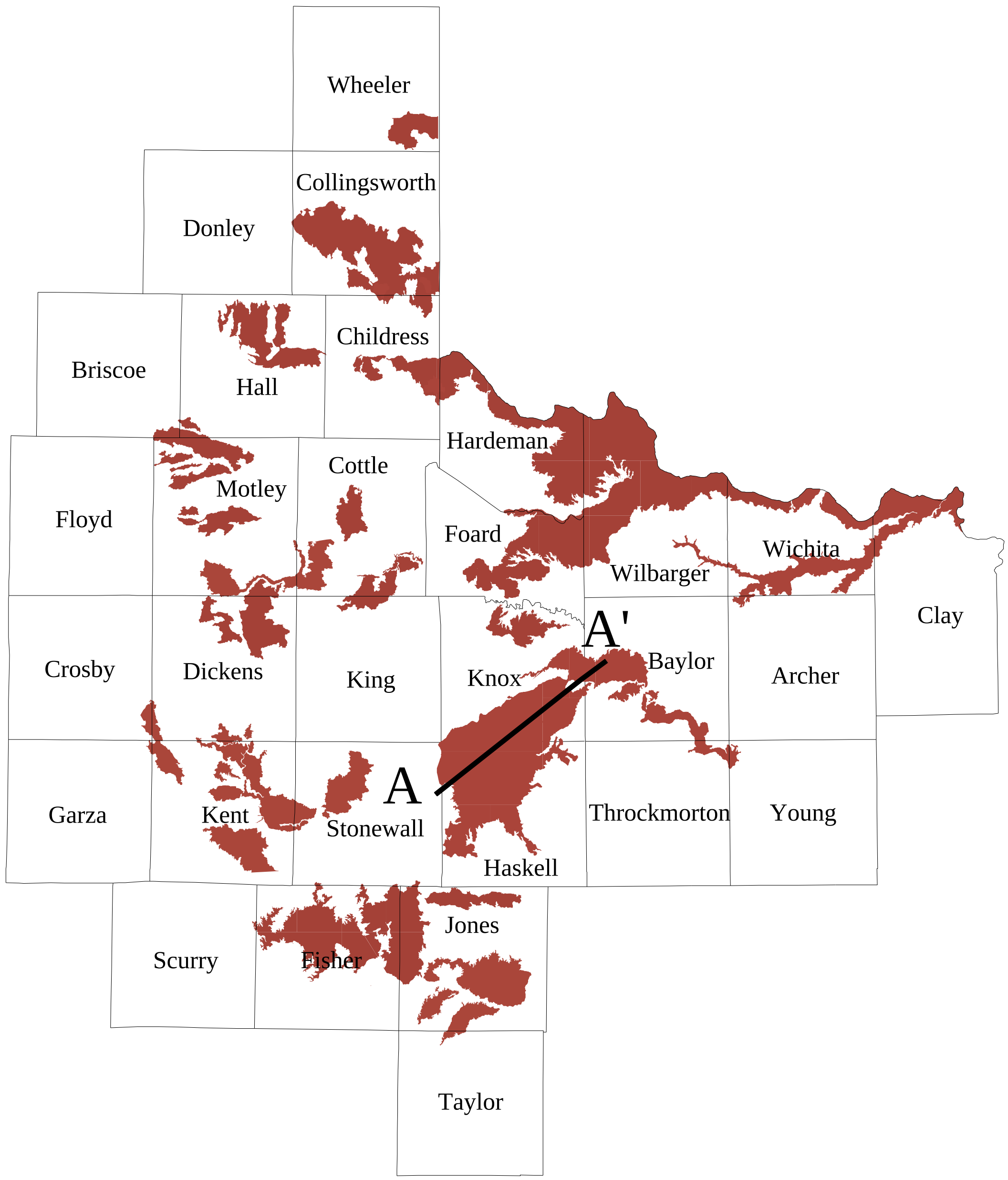
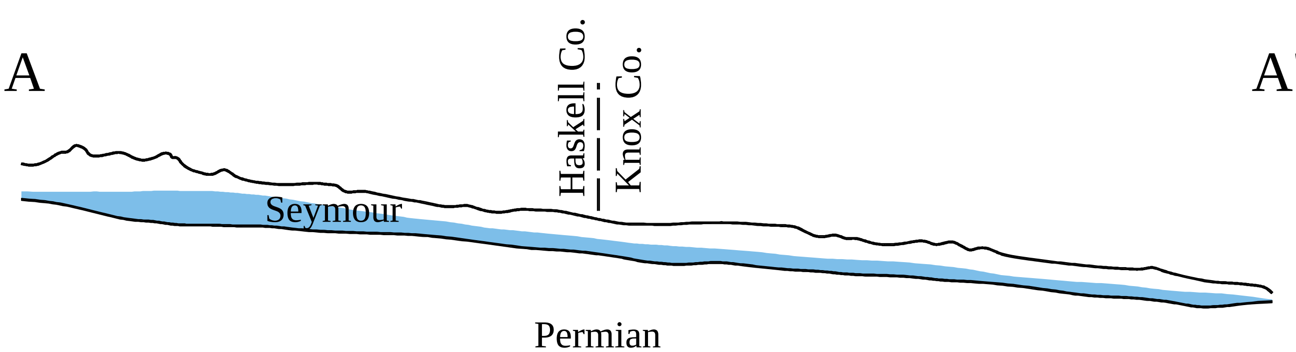
Seymour





Modified from R.W. Harden and Assoc., 1978

Seymour Aquifer

The Seymour Formation consists of isolated areas of alluvium found in parts of 23 north-central and Panhandle counties. Approximately 90 percent of the water pumped from the aquifer is used for irrigation. Municipal pumpage, primarily for the communities of Vernon, Burkburnett, and Electra, accounts for eight percent.

The Seymour aquifer consists of discontinuous beds of poorly sorted gravel, conglomerate, sand, and silty clay deposited during the Quaternary Period by eastward-flowing streams. Individual accumulations vary greatly in thickness, although most of the Seymour is less than 100 feet thick. In isolated northern parts of the aquifer, the formation may be as thick as 360 feet.

The aquifer exists under water-table conditions throughout much of its extent, but artesian conditions may occur where the water-bearing zone is overlain by clay. The lower, more permeable part of the aquifer produces the greatest amount of ground water. Yields of wells range from less than 100 gal/min to as much as 1,300 gal/min, depending on saturated thickness, and average about 300 gal/min. No significant water-level declines have occurred in the aquifer.

Water quality in these alluvial remnants generally ranges from fresh to slightly saline; however, higher salinity problems occur. The salinity has increased in many heavily pumped areas to the point where the water has become unsuitable for domestic and municipal uses. Natural salt pollution in the upper reaches of the Red and Brazos river basins precludes the full utilization of these water resources. Brine pollution from earlier oil field activities has resulted in localized contamination of fresh ground- and surface-water supplies. High nitrate concentrations in excess of drinking water standards in Seymour ground water are widespread.

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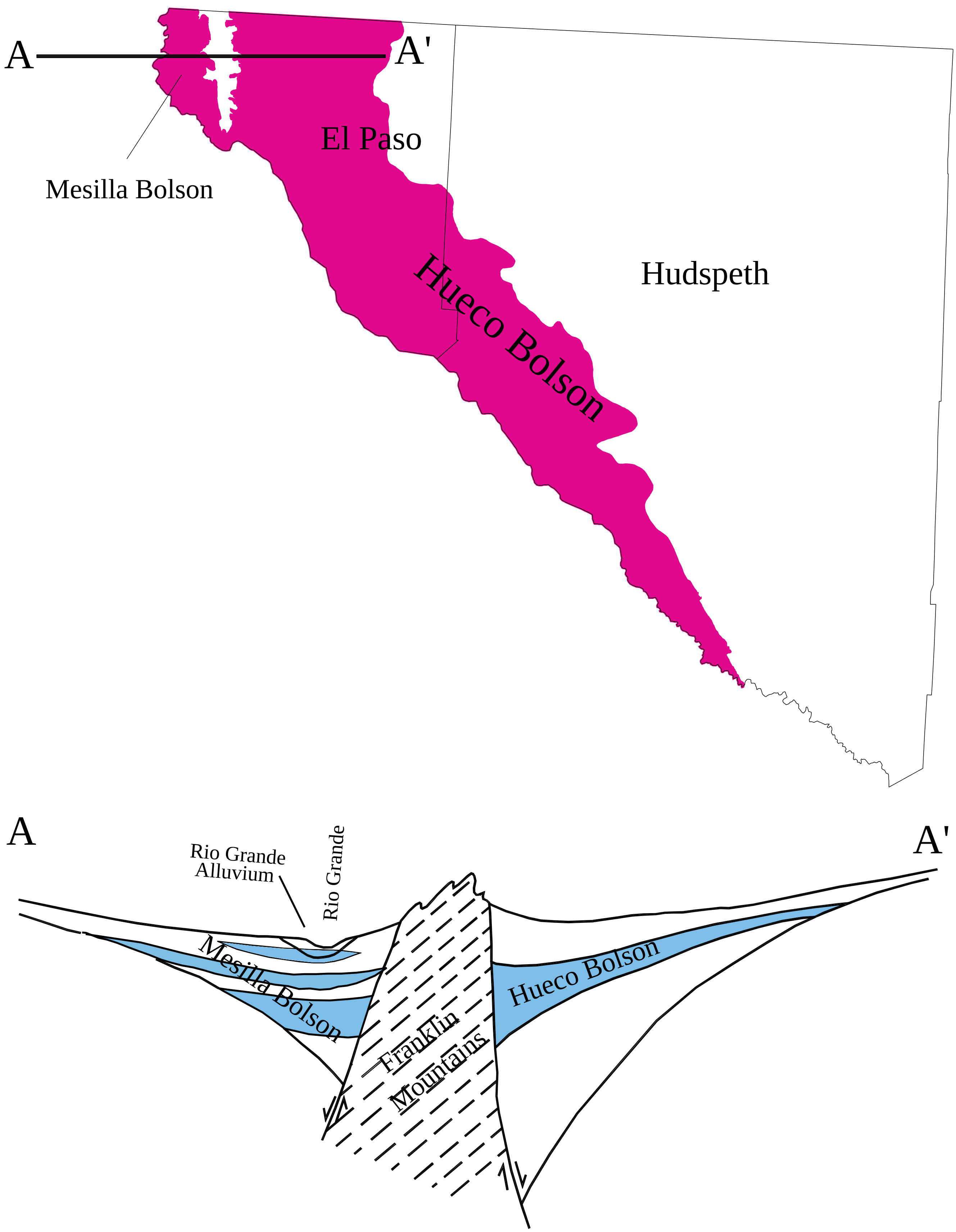
Hueco-Mesilla Bolson



Hueco-Mesilla Bolson Aquifers

The Hueco and Mesilla Bolson aquifers are located in El Paso and Hudspeth counties in the far western tip of Texas. The aquifers are composed of Tertiary and Quaternary basin-fill (bolson) deposits that extend northward into New Mexico and westward into Mexico. The Hueco Bolson, east of the Franklin Mountains, is the principal aquifer in the El Paso area; to the west is the Mesilla Bolson. Eighty-seven percent of the water pumped from the aquifers is used for municipal supply, primarily for the city of El Paso. Across the international border, water for Ciudad Juarez is supplied from the Hueco Bolson.

The Hueco Bolson, approximately 9,000 feet in total thickness, consists of silt, sand, and gravel in the upper part, and clay and silt in the lower part. Only the upper several hundred feet of the bolson contain fresh to slightly saline water. The majority of the Hueco water in Texas occurs in the El Paso metropolitan area; very little occurs in Hudspeth County.

The Mesilla Bolson consists of approximately 2,000 feet of clay, silt, sand, and gravel. Three water-bearing zones in the Mesilla (shallow, intermediate, and deep) have been identified based on water levels and quality. The shallow water-bearing zone includes the overlying Rio Grande Alluvium.

The chemical quality of the ground water in the Hueco Bolson differs according to its location and depth. Dissolved-solids concentrations in the upper, fresher part of the aquifer range from less than 500 mg/l to more than 1,500 mg/l and average about 640 mg/l. Quality of Hueco Bolson water in Mexico is slightly poorer.

Chemical quality of ground water in the Mesilla Bolson ranges from fresh to saline, with salinity generally increasing to the south along the valley. The water is commonly freshest in the deep zone of the aquifer and contains progressively higher concentrations of dissolved solids in the shallower zones. Increasing deterioration of quality of these aquifers is the result of large-scale ground-water withdrawals, which are depleting the aquifers of the freshest water.

Historical large-scale ground-water withdrawals, especially from municipal well fields in the downtown areas of El Paso and Ciudad Juarez, have caused major water-level declines. These declines, in turn, have significantly changed the direction of flow, rate of flow, and chemical quality of ground water in the aquifers. Declining water levels have also resulted in a minor amount of land-surface subsidence.

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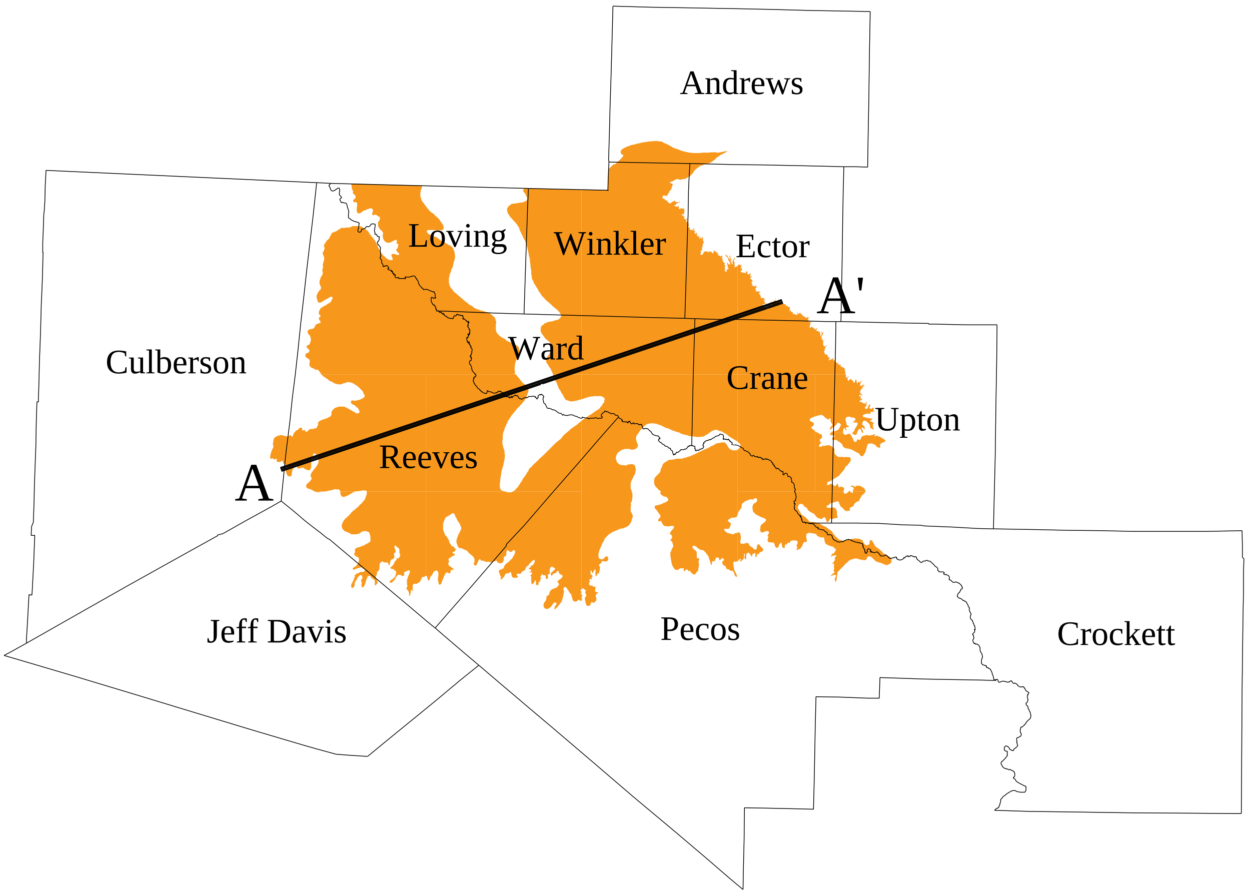
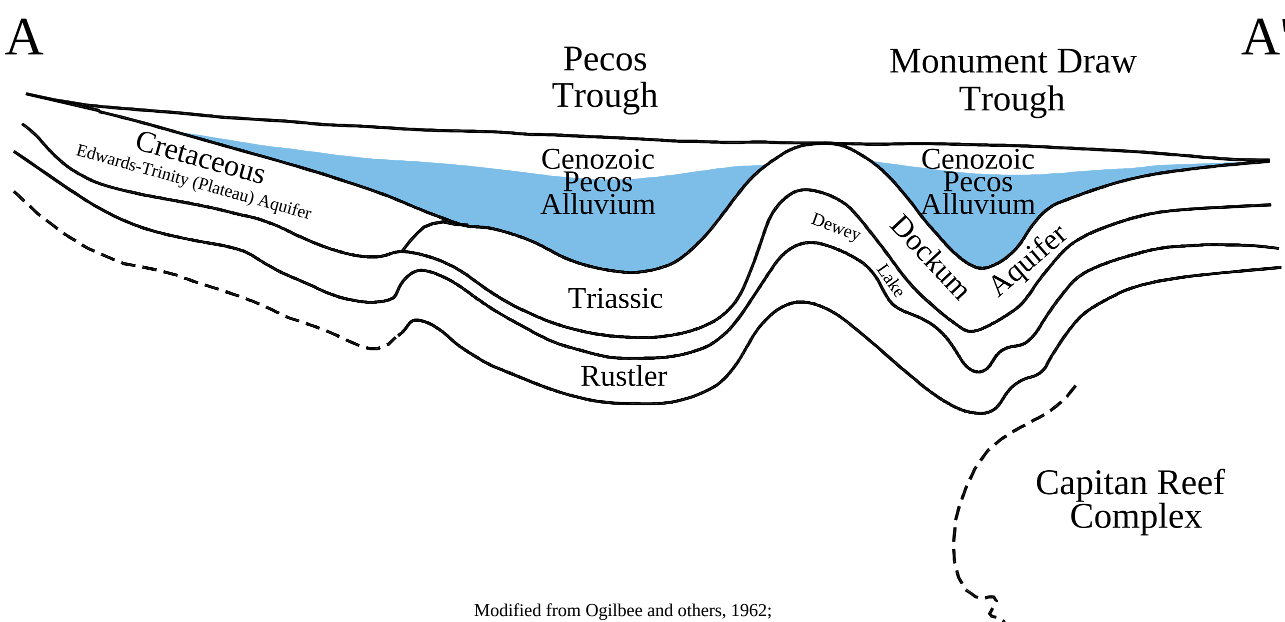
Cenozoic Pecos Alluvium





Modified from Ogilbee and others, 1962;
and Ashworth, 1990

Cenozoic Pecos Alluvium Aquifer

The Cenozoic Pecos Alluvium aquifer, located in the upper part of the Pecos River Valley of West Texas, provides water to parts of Andrews, Crane, Ector, Loving, Pecos, Reeves, Upton, Ward, and Winkler counties. The aquifer is the principal source of water for irrigation in Reeves and northwestern Pecos counties, and for industrial, power generation, and public supply uses elsewhere. A significant amount of water is exported to cities east of the area. Approximately 81 percent of the water pumped from the aquifer is used for irrigation.

The Cenozoic Pecos Alluvium of Quaternary age consists of up to 1,500 feet of alluvial fill and occupies two hydrologically separate basins: the Pecos Trough in the west and the Monument Draw Trough in the east. The aquifer is hydrologically connected to underlying water-bearing strata, including the Edwards-Trinity in Pecos and Reeves counties and the Triassic Dockum in Ward and Winkler counties.

Ground water in the Cenozoic Pecos Alluvium aquifer occurs under semiconfined or unconfined (water-table) conditions, although confining clay beds may create localized artesian conditions. Moderate to large yields can generally be expected from wells completed in this aquifer.

The chemical quality of water in the aquifer is highly variable, differing naturally with location and depth, and is generally better in the Monument Draw Trough. Water from the aquifer is typically hard and contains dissolved-solids concentrations ranging from less than 300 mg/l to more than 5,000 mg/l. Sulfate and chloride are the two predominant constituents. A natural deterioration of quality occurs with increasing depth of the water-bearing strata. Some quality deterioration has resulted from past petroleum industry activities in Loving, Ward, and Winkler counties, and from irrigation in Pecos, Reeves, and Ward counties.

Water-level declines in excess of 200 feet historically have occurred in south-central Reeves and northwest Pecos counties, but have moderated since the mid-1970s with the decrease in irrigation pumpage. Ground water that once rose to the surface and flowed into the Pecos River, now flows in the subsurface toward areas of heavy pumpage. As a consequence, baseflow to the Pecos River has declined. Elsewhere, only moderate water-level declines have occurred as a result of less intense pumpage for industrial and public supply uses in Ward and Winkler counties.

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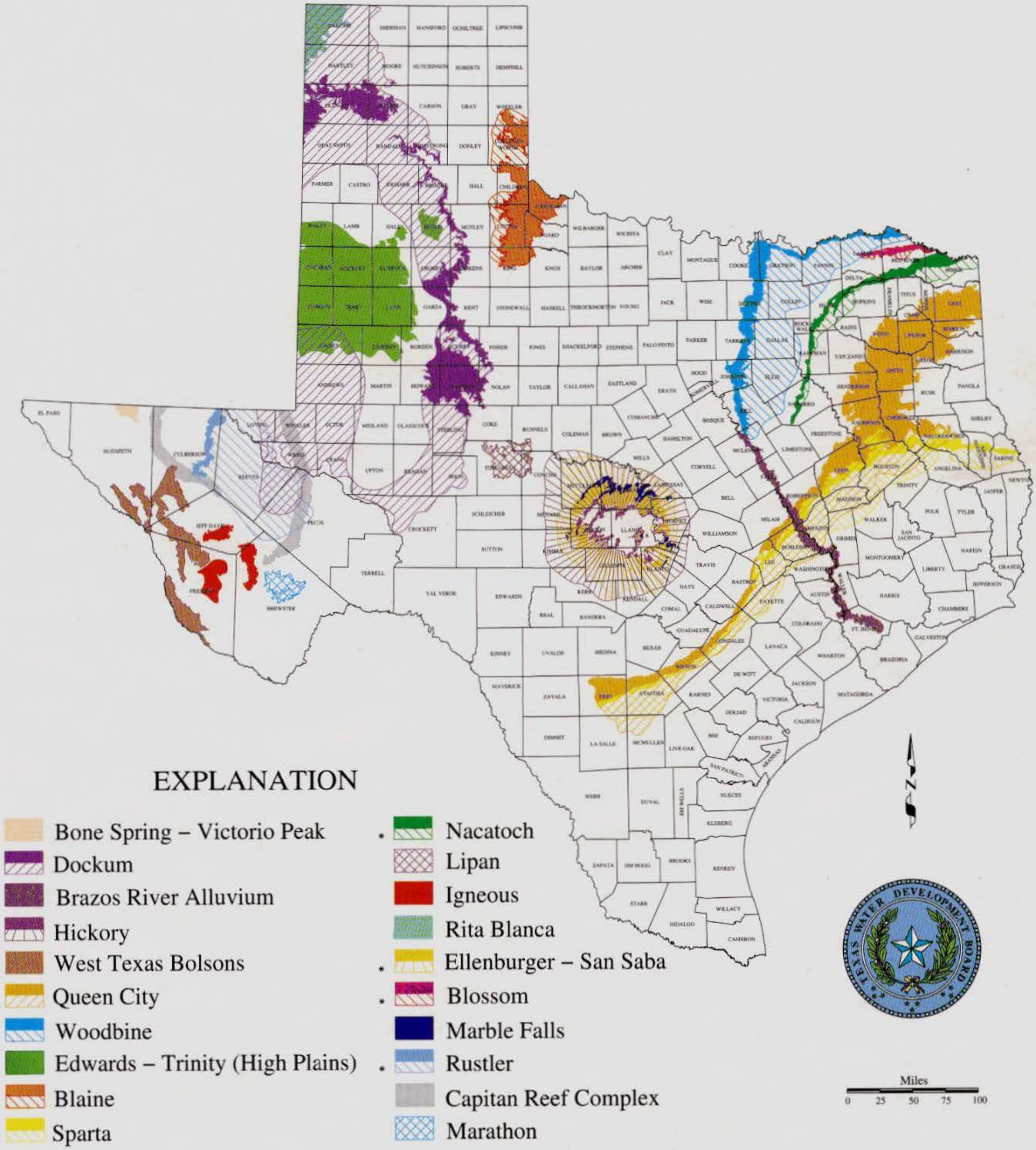
MINOR AQUIFERS OF TEXAS



OUTCROP (That part of a water-bearing rock layer which appears at the land surface.)
* DOWNDIP (That part of a water-bearing rock layer which dips below other rock layers.)

January 1994

Bone Spring - Victorio Peak

Bone Spring-Victorio Peak Aquifer

The Bone Spring-Victorio Peak aquifer occupies the eastern edge of the Diablo Plateau west of the Guadalupe Mountains in northeast Hudspeth County and extends northward into the Crow Flats area of New Mexico. The Bone Spring and Victorio Peak formations are composed of as much as 2,000 feet of early Permian age limestone beds and contain ground water in joints, fractures, and solution cavities. Permeability of the limestones is highly variable, and well yields differ widely from about 150 gal/min to more than 2,000 gal/min.

The aquifer is used almost exclusively for irrigation. Dell City is the only community that withdraws water from the aquifer for public supply. Water levels have declined in the aquifer since pre-irrigation times; however, the levels have remained relatively constant since the late 1970s.

Ground water withdrawn from the aquifer commonly contains between 2,000 mg/l and 6,000 mg/l dissolved solids, but is acceptable for irrigation because the high permeability of the soil alleviates soil salinity. Because the water does not meet drinking water standards, the community of Dell City must use a demineralization process. The quality of the ground water has deteriorated somewhat as salts, leached from surface soils by irrigation return flow, percolate downward to the aquifer.

References

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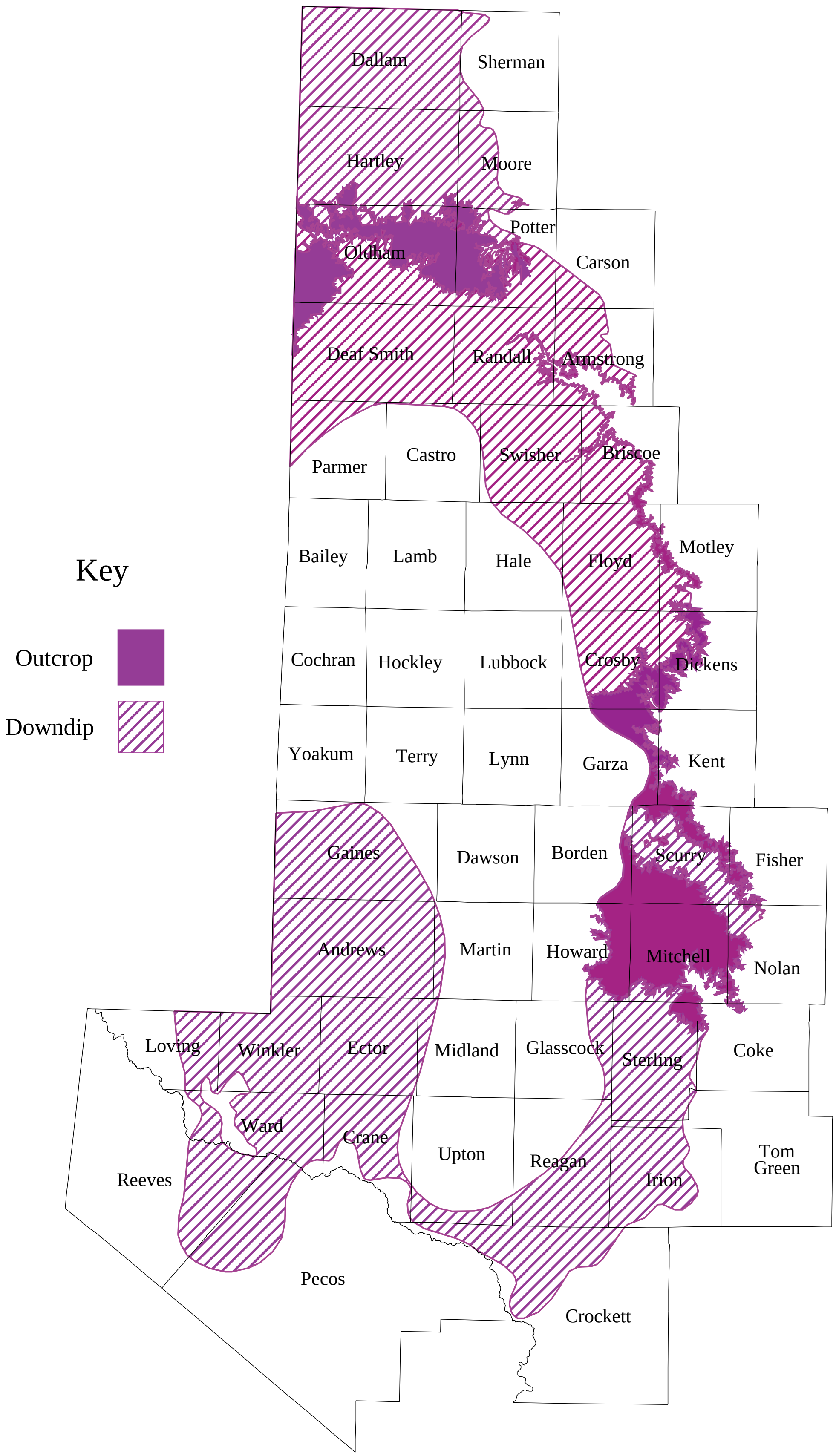
Dockum


Key
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Downdip
Dallam
Sherman
Hartley
Moore
Potter
Oldham
Carson
Deaf Smith
Randall
Armstrong
Parmer
Castro
Swisher
Briscoe
Bailey
Lamb
Hale
Floyd
Motley
Cochran
Hockley
Lubbock
Crosby
Dickens
Yoakum
Terry
Lynn
Garza
Kent
Gaines
Dawson
Borden
Scurry
Fisher
Andrews
Martin
Howard
Mitchell
Nolan
Loving
Winkler
Ector
Midland
Glasscock
Sterling
Coke
Ward
Crane
Upton
Reagan
Irion
Tom Green
Reeves
Pecos
Crockett

Dockum Aquifer

The Dockum Group of Triassic age underlies much of the Ogallala Formation of the High Plains area of Texas and New Mexico, the northern part of the Edwards Plateau, and the eastern part of the Cenozoic Pecos Alluvium. Where exposed east of the High Plains caprock and in the Canadian River Basin, the land surface takes on a reddish color. In the subsurface, the Dockum is commonly referred to as the "red bed." The primary water-bearing zone in the formation, the Santa Rosa, consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale.

Ground water from the Dockum aquifer is used for irrigation in the eastern outcrop area of Scurry and Mitchell counties, and for municipal water supply in the central part of the High Plains where marginally acceptable quality conditions prevail. Elsewhere, the aquifer is used extensively for oil field water-flooding operations, particularly in the southern part of the High Plains.

Concentrations of dissolved solids in the ground water range from less than 1,000 mg/l near the eastern outcrop to more than 20,000 mg/l in the deeper parts of the aquifer to the west. Relatively high sodium concentrations pose a salinity hazard for soils, thereby limiting regional long-term use of the water for irrigation. The extent of the aquifer as delineated includes the area in which the Dockum ground water contains less than 5,000 mg/l dissolved solids.

References

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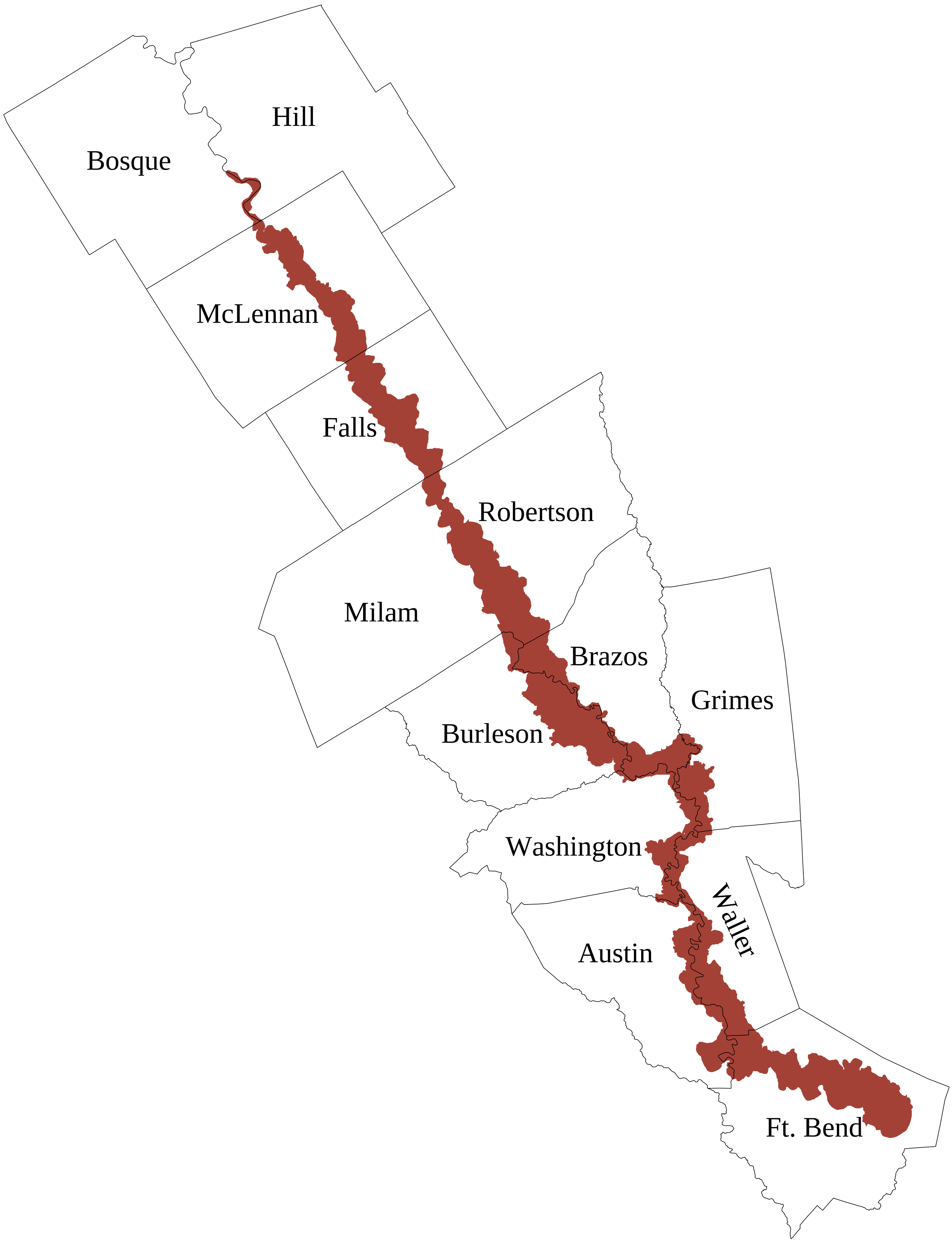
Brazos River Alluvium



Brazos River Alluvium Aquifer

Water-bearing alluvial sediments occur in floodplain and terrace deposits of the Brazos River of southeast Texas. The Brazos River Alluvium aquifer, up to seven miles wide, stretches for 350 miles along the sinuous course of the river between southern Hill and Bosque counties and eastern Fort Bend County. Irrigation accounts for almost all of the pumpage from the aquifer.

The Quaternary alluvial sediments consist of clay, silt, sand, and gravel, and generally are coarsest in the lower part of the accumulations. Saturated thickness of the alluvium is as much as 85 feet or more, with maximum thickness occurring in the central and southeastern parts of the aquifer. Some wells yield up to 1,000 gal/min, but the majority yield between 250 gal/min and 500 gal/min.

The chemical quality of the ground water varies widely. In many areas, concentrations of dissolved solids exceed 1,000 mg/l. Most of the Brazos River Valley irrigated with this ground water contains soils sufficiently permeable to alleviate any soil salinity problems. In some places, the water from the aquifer is fresh enough to meet drinking water standards.

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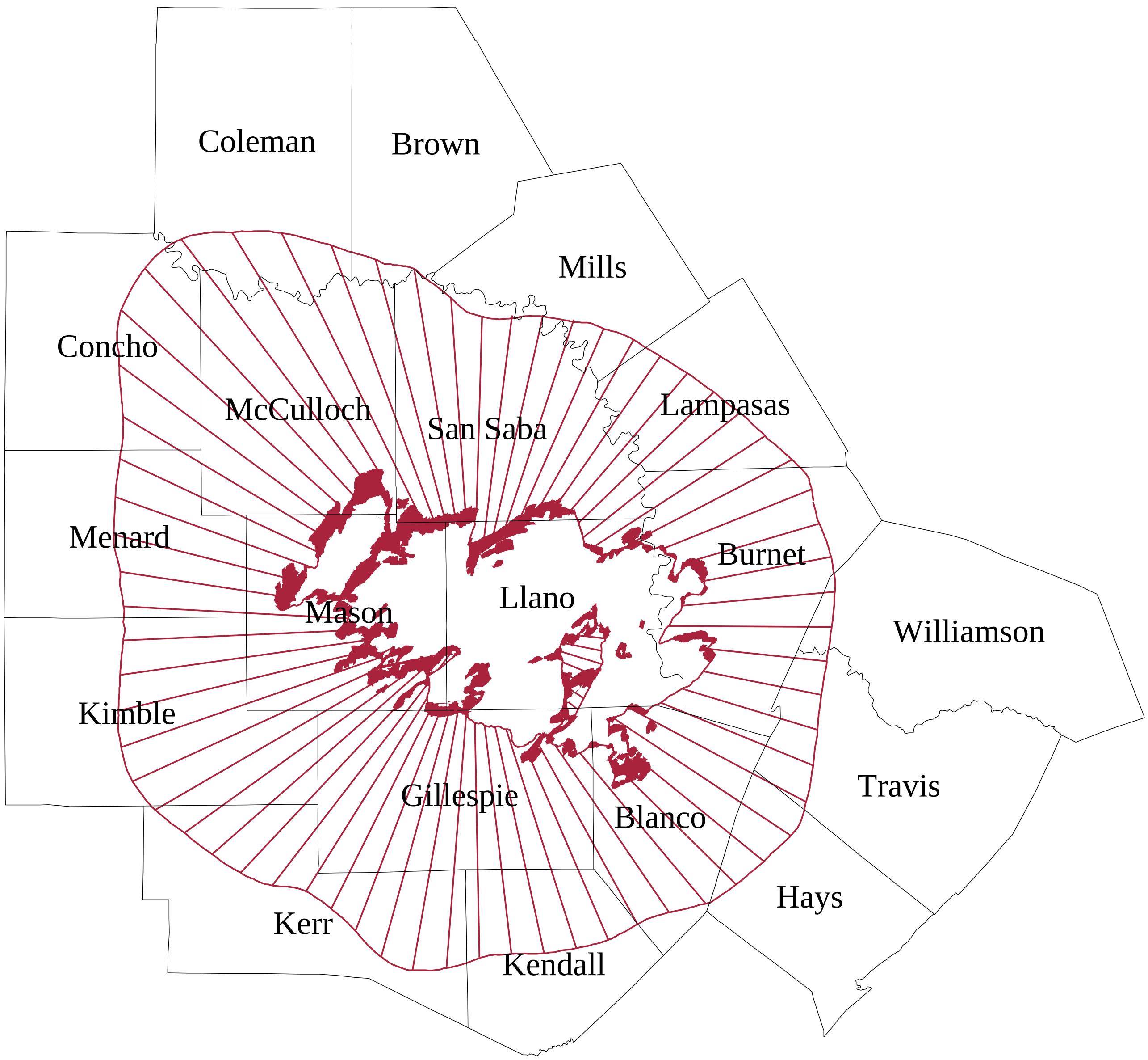
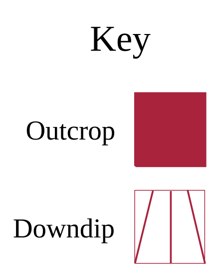
Hickory


Coleman
Brown
Mills
Concho
McCulloch
San Saba
Lampasas
Menard
Burnet
Llano
Mason
Williamson
Kimble
Travis
Gillespie
Blanco
Hays
Kerr
Kendall


Key
Outcrop
Downdip

Hickory Aquifer

The Hickory aquifer occurs in parts of 19 counties in the Llano Uplift region of Central Texas. Discontinuous outcrops of the Hickory Sandstone overlie and flank exposed Precambrian rocks that form the central core of the uplift. The downdip artesian portion of the aquifer encircles the uplift and extends to maximum depths approaching 4,500 feet. Most of the water pumped from the aquifer is used for irrigation. The largest capacity wells, however, have been completed for municipal water-supply purposes at Brady, Mason, and Fredericksburg.

The Hickory Sandstone Member of the Cambrian Riley Formation is composed of some of the oldest sedimentary rocks found in Texas. In most of the northern and western portions of the aquifer, the Hickory can be differentiated into lower, middle, and upper units, which reach a maximum thickness of 480 feet in southwestern McCulloch County. In the southern and eastern extents of the aquifer, the Hickory consists of only two units. Block faulting has compartmentalized the Hickory aquifer, thus restricting flow.

Ground water from the aquifer is generally fresh. However, locally, the aquifer produces water with excessive alpha particles and total radium concentrations in excess of drinking water standards. The water can also contain radon gas. The upper unit of the Hickory produces ground water containing concentrations of iron in excess of drinking water standards.

References

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West Texas Bolsons

West Texas Bolsons Aquifer

In the western part of the Trans-Pecos region of Texas, several deep basins filled with erosional material of Quaternary age, contain significant quantities of ground water. These filled basins, or bolsons, are the Red Light Draw, Eagle Flat, Green River Valley, Presidio-Redford, and Salt Basin. The Salt Basin can be subdivided into the Wild Horse, Michigan, Lobo, and Ryan flats. The upper part of the Salt Basin extending north of Wild Horse Flat contains ground water with dissolved solids well in excess of 3,000 mg/l and is, therefore, not included as part of the designated aquifer. These bolsons provide variable amounts of water mainly for irrigation and municipal water supplies in parts of Culberson, Hudspeth, Jeff Davis, and Presidio counties. The communities of Presidio, Sierra Blanca, Valentine, and Van Horn use these aquifers for municipal water supplies.

Bolson deposits in each of these basins differ according to the type of rock material that was eroded from the adjacent uplands and the manner in which this material was deposited. Sediments range from coarse-grained volcanics and limestones redeposited as alluvial fans to fine-grained silt and clay lake deposits. Yields of some wells exceed 3,000 gal/min, but most wells produce less than 1,000 gal/min. Water quality differs from basin to basin, ranging from fresh to slightly saline. Recharge is minimal in this region due to low annual rainfall and high evaporation rates.

References

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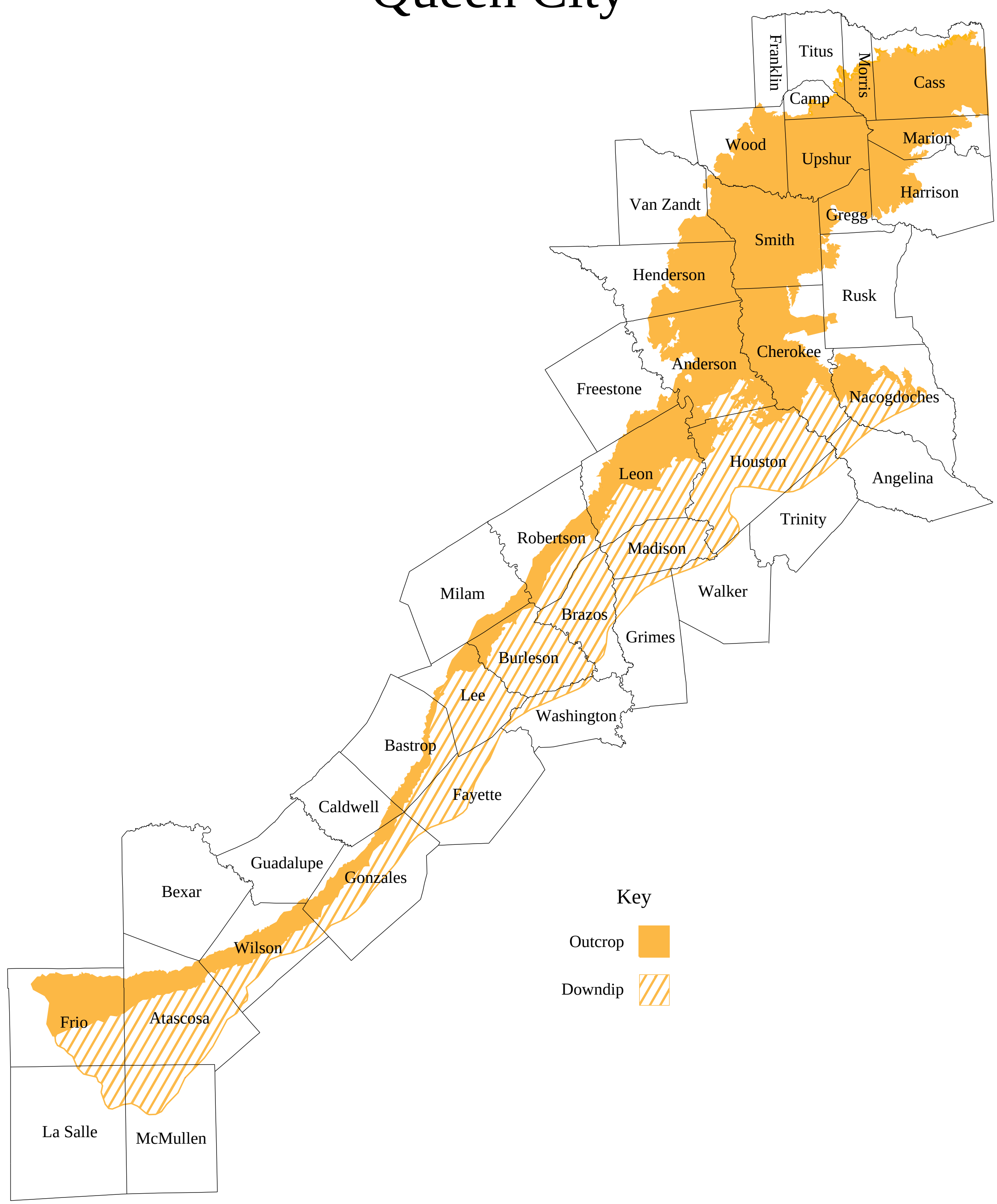
Queen City


Franklin
Titus
Morris
Cass
Camp
Wood
Upshur
Marion
Harrison
Van Zandt
Gregg
Smith
Henderson
Rusk
Cherokee
Anderson
Freestone
Nacogdoches
Houston
Leon
Angelina
Trinity
Robertson
Madison
Milam
Walker
Brazos
Grimes
Burleson
Lee
Washington
Bastrop
Fayette
Caldwell
Guadalupe
Gonzales
Bexar
Wilson
Frio
Atascosa
La Salle
McMullen
Key
Outcrop
Downdip

Queen City Aquifer

The Queen City aquifer extends across Texas from the Frio River in South Texas northeastward into Louisiana. The aquifer provides water for domestic and livestock purposes throughout most of its extent, significant amounts of water for municipal and industrial supplies in Northeast Texas, and water for irrigation in Wilson County. Yields of individual wells are commonly low, but a few exceed 400 gal/min.

Sand, loosely cemented sandstone, and interbedded clay units of the Queen City Formation of the Tertiary Claiborne Group make up the aquifer. These beds fill the East Texas structural basin adjacent to the Sabine Uplift and then dip gently to the south and southeast toward the Gulf Coast. Although total aquifer thickness is usually less than 500 feet, it can approach 700 feet in some areas of Northeast Texas.

Water of excellent quality is generally found within the outcrop and for a few miles downdip, but water quality deteriorates with depth in the downdip direction. In some areas, water of acceptable quality may occur at depths of approximately 2,000 feet. The water may be acidic in much of Northeast Texas and relatively high in iron concentrations in some locations.

References

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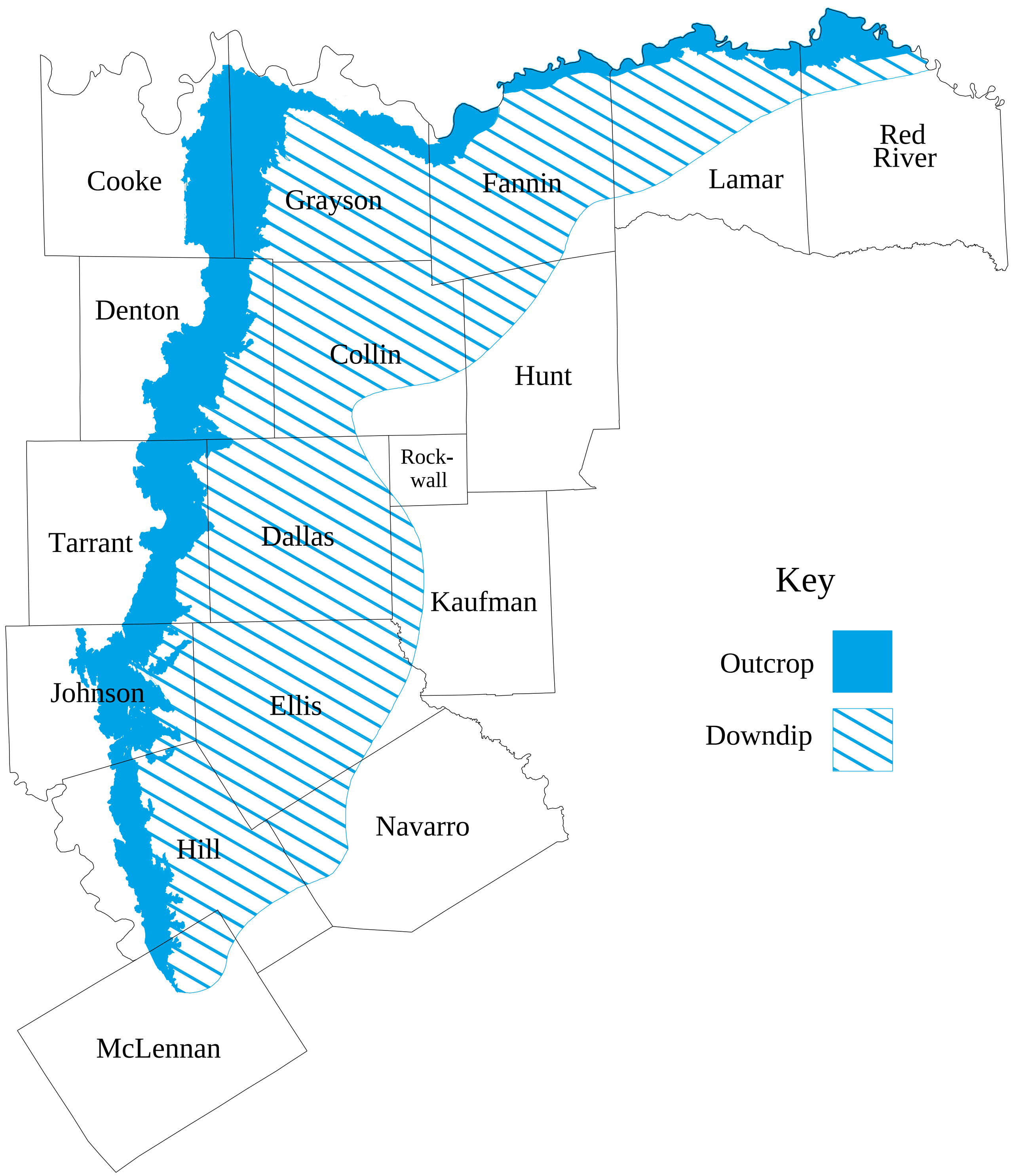
Woodbine



Cooke
Grayson
Fannin
Lamar
Red River
Denton
Collin
Hunt
Rock-wall
Tarrant
Dallas
Kaufman
Johnson
Ellis
Navarro
Hill
McLennan
Key
Outcrop
Downdip

Woodbine Aquifer

The Woodbine aquifer extends from McLennan County in North-Central Texas northward to Cooke County and eastward to Red River County, paralleling the Red River. Water produced from the aquifer furnishes municipal, industrial, domestic, livestock, and small irrigation supplies throughout its North Texas extent.

The Woodbine Formation of Cretaceous age is composed of water-bearing sandstone beds interbedded with shale and clay. The aquifer dips eastward into the subsurface where it reaches a maximum depth of 2,500 feet below land surface and a maximum thickness of approximately 700 feet. The Woodbine aquifer is divided into three water-bearing zones that differ considerably in productivity and quality. Only the lower two zones of the aquifer are developed to supply water for domestic and municipal uses. Heavy municipal and industrial pumpage has contributed to water-level declines in excess of 100 feet in the Sherman-Denison area of Grayson and surrounding counties.

Chemical quality deteriorates rapidly in well depths below 1,500 feet. In areas between the outcrop and this depth, quality is considered good overall as long as ground water from the upper Woodbine is sealed off. The upper Woodbine contains water of extremely poor quality in downdip locales and contains excessive iron concentrations along the outcrop.

References

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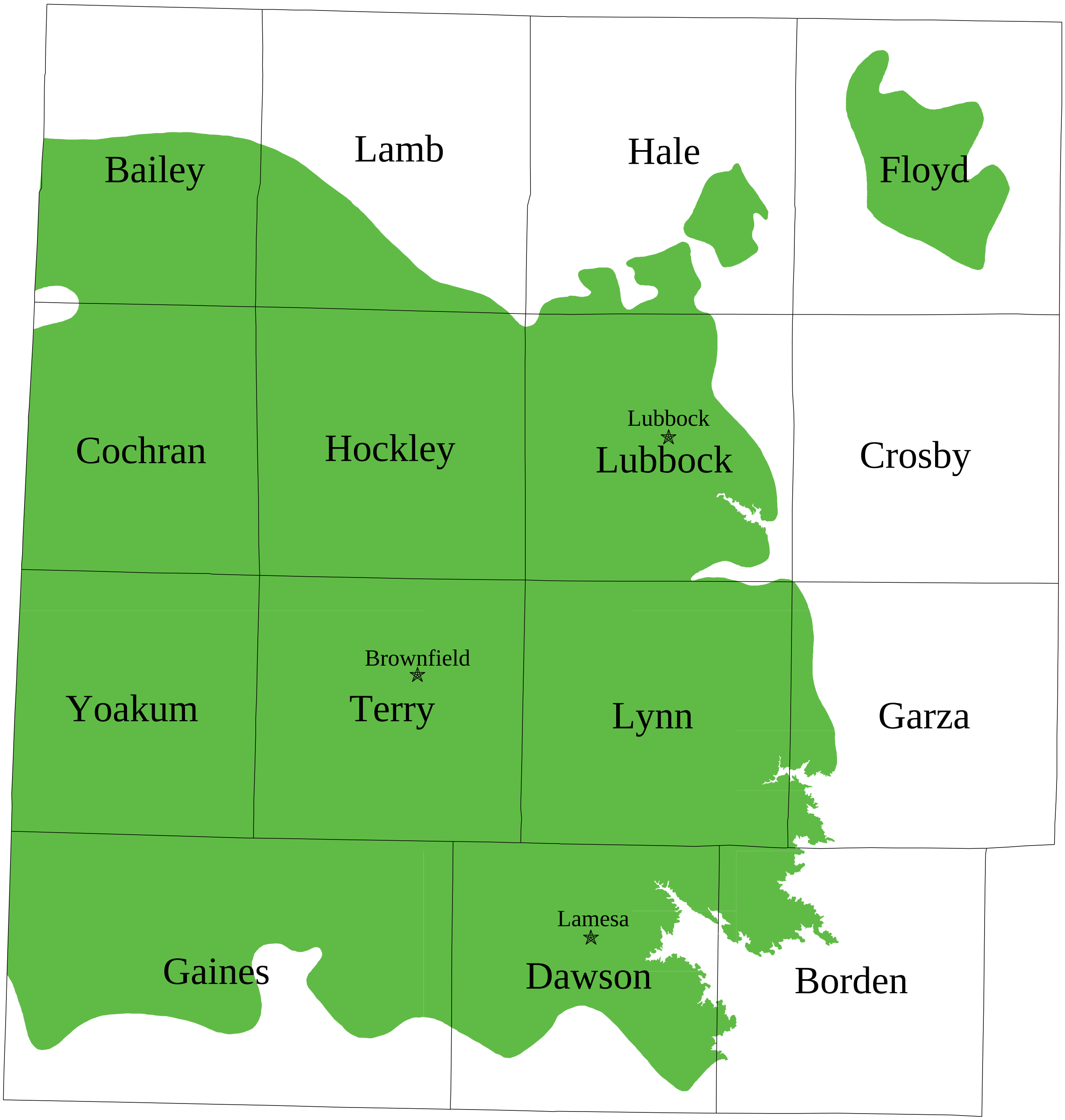
Edwards-Trinity (High Plains)



Edwards-Trinity (High Plains) Aquifer

The Edwards-Trinity (High Plains) aquifer includes Cretaceous age water-bearing formations of the Fredericksburg and Trinity Groups. These formations underlie the Ogallala Formation in the south-central part of the Texas High Plains and extend westward into New Mexico. The majority of the wells completed in the aquifer provide water for irrigation and yield 50 gal/min to 200 gal/min.

Two distinct ground-water zones occur in the aquifer. One occurs in the basal sand and sandstone deposits of the Antlers Formation (Trinity Group) and is usually under artesian pressure. The other water-bearing zone occurs primarily in joints, solution cavities, and bedding planes in limestones of the Comanche Peak and Edwards formations. In much of the area, this zone is hydrologically connected to the overlying Ogallala aquifer. Recharge to the aquifer occurs directly from the bounding Ogallala Formation along northern and western parts of the subcrop and by downward percolation from overlying units at other locations. Upward movement of ground water from the Triassic Dockum into the Edwards-Trinity is also believed to occur in Lynn County.

Ground-water movement is generally to the southeast. In many places, the ground-water potentiometric surface in the Edwards-Trinity aquifer is higher than in the Ogallala aquifer, resulting in the upward migration of water from the Edwards-Trinity. In these areas, the Edwards-Trinity has a significant impact on the water level and quality of the Ogallala. Wells drilled into the Edwards-Trinity are usually completed also in the overlying Ogallala. Water-level declines of up to 30 feet have occurred in such wells in western Gaines County.

Water in the aquifer is typically fresh to slightly saline and is generally poorer in quality than water in the overlying Ogallala aquifer. Water quality deteriorates in areas where these formations are overlain by saline lakes and the gypsiferous Tahoka and Double Lakes formations.

References

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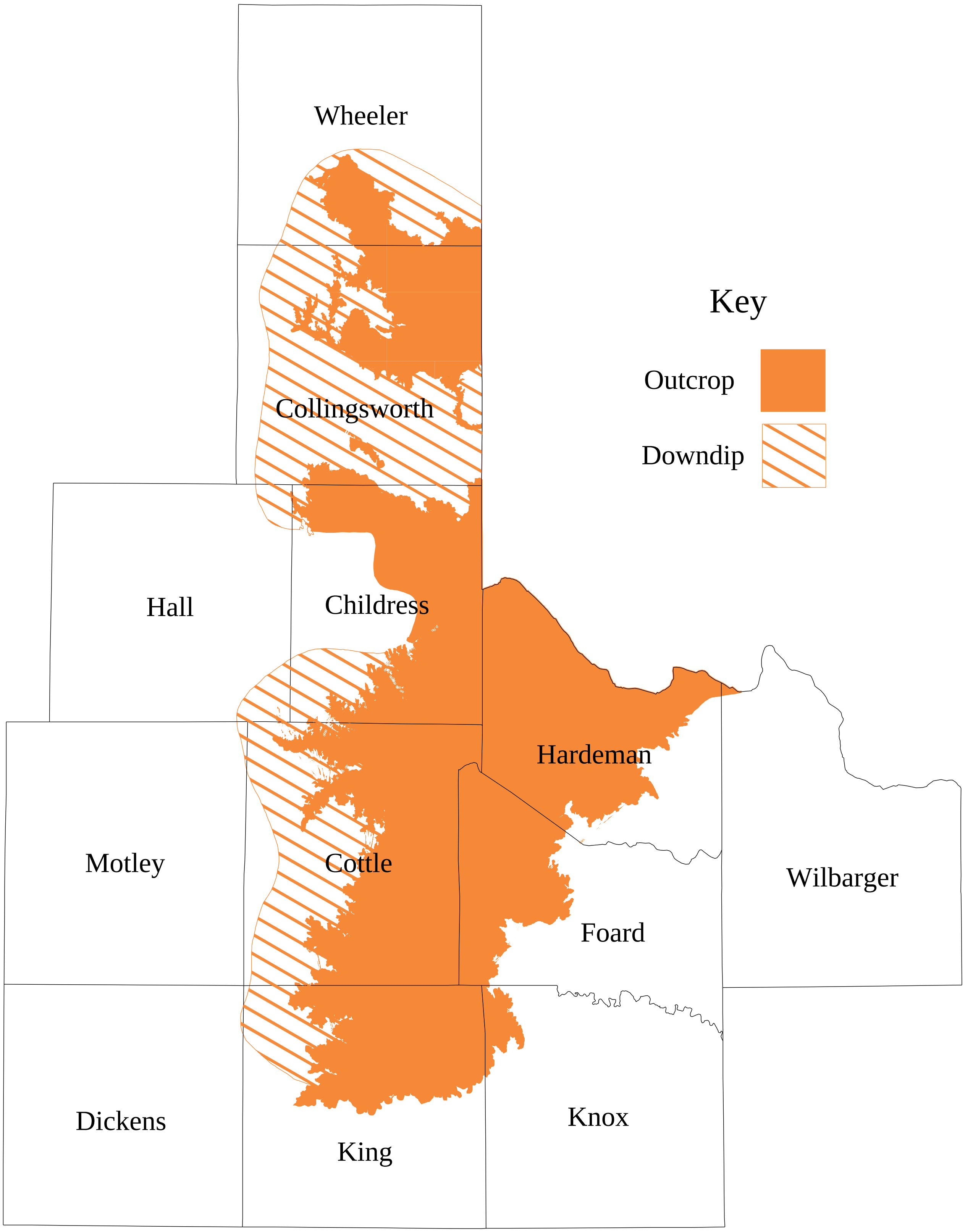
Blaine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Foard
Wilbarger
Dickens
King
Knox
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Outcrop
Downdip

Blaine Aquifer

The Blaine aquifer provides water in nine counties in West-Central Texas from Wheeler County to King County, extending eastward in the subsurface to adjacent counties. Although the formation is present farther south, the limited use of its water does not justify its inclusion as a minor aquifer in that area. Saturated thickness of the aquifer approaches 300 feet in its northern extent. The Blaine Formation, of Permian age, contains water primarily in numerous solution channels.

Water recharged to the aquifer moves along solution channels in the formation dissolving evaporite deposits of anhydrite and halite, which, in turn, contribute to its overall poor quality. Dissolved-solids concentrations in the Blaine increases with depth of the aquifer and in natural discharge areas along surface drainages. The extent of the aquifer, based on usage, includes water containing less than 10,000 mg/l dissolved solids.

The primary use of Blaine ground water is for irrigation of highly salt-tolerant crops. Well yields vary from a few gallons per minute to more than 1,500 gal/min. Seasonal water-level declines are limited to those areas dependent on ground water for irrigation.

References

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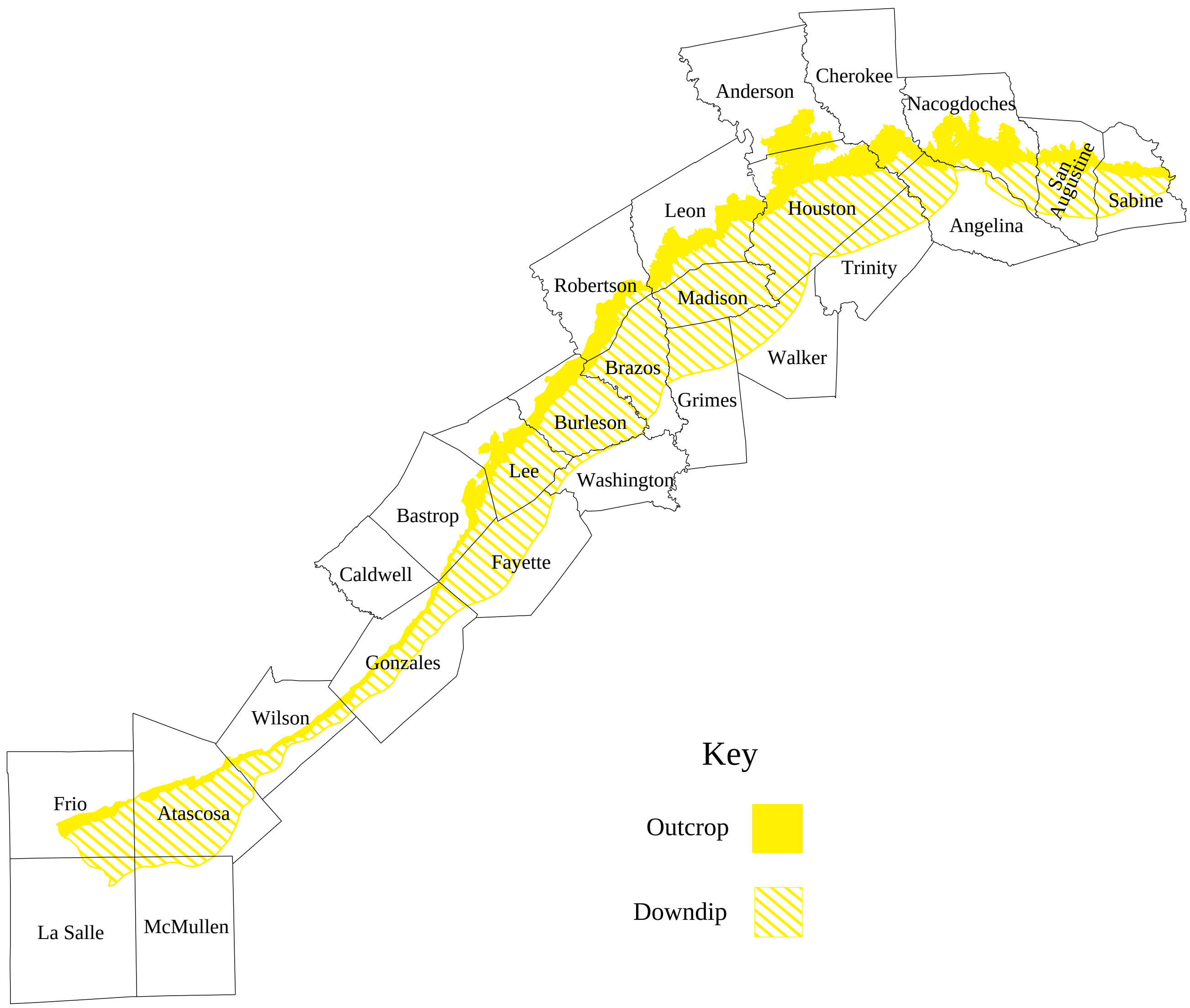
Sparta


Anderson
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Nacogdoches
San Augustine
Sabine
Leon
Houston
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Trinity
Robertson
Madison
Walker
Brazos
Grimes
Burleson
Lee
Washington
Bastrop
Caldwell
Fayette
Gonzales
Wilson
Frio
Atascosa
La Salle
McMullen
Key
Outcrop
Downdip

Sparta Aquifer

The Sparta aquifer extends in a narrow band from the Frio River in South Texas northeastward to the Louisiana border in Sabine County. The Sparta provides water for domestic and livestock supplies throughout its extent, and water for municipal, industrial, and irrigation purposes in much of the region. Yields of individual wells are generally less than 100 gal/min, although most high-capacity wells average 400 gal/min to 500 gal/min. A few wells produce as much as 1,200 gal/min.

The Sparta Formation, part of the Claiborne Group deposited during the Tertiary, consists of sand and interbedded clay with massive sand beds in the basal section. These beds dip gently to the south and southeast toward the Gulf Coast and reach a total thickness of up to 300 feet.

Water of excellent quality is commonly found within the outcrop and for a few miles downdip, but it deteriorates with depth in the downdip direction. Locally, water within the aquifer may contain iron concentrations in excess of drinking water standards.

References

Alexander, W.H., Jr., and White, D.E., 1966, Ground-water resources of Atascosa and Frio counties, Texas: TWDB Rept. 32, 211 p.

Anders, R.B., 1957, Ground-water geology of Wilson County, Texas: TBWE Bull. 5710, 66 p.

Baker, E.T., Jr., Follett, C.D., McAdoo, G.D., and Bonnet, C.W., 1974, Ground-water resources of Grimes County, Texas: TWDB Rept. 186, 34 p.

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Harris, H.B., 1965, Ground-water resources of La Salle and McMullen counties, Texas: TWC Bull. 6520, 96 p.

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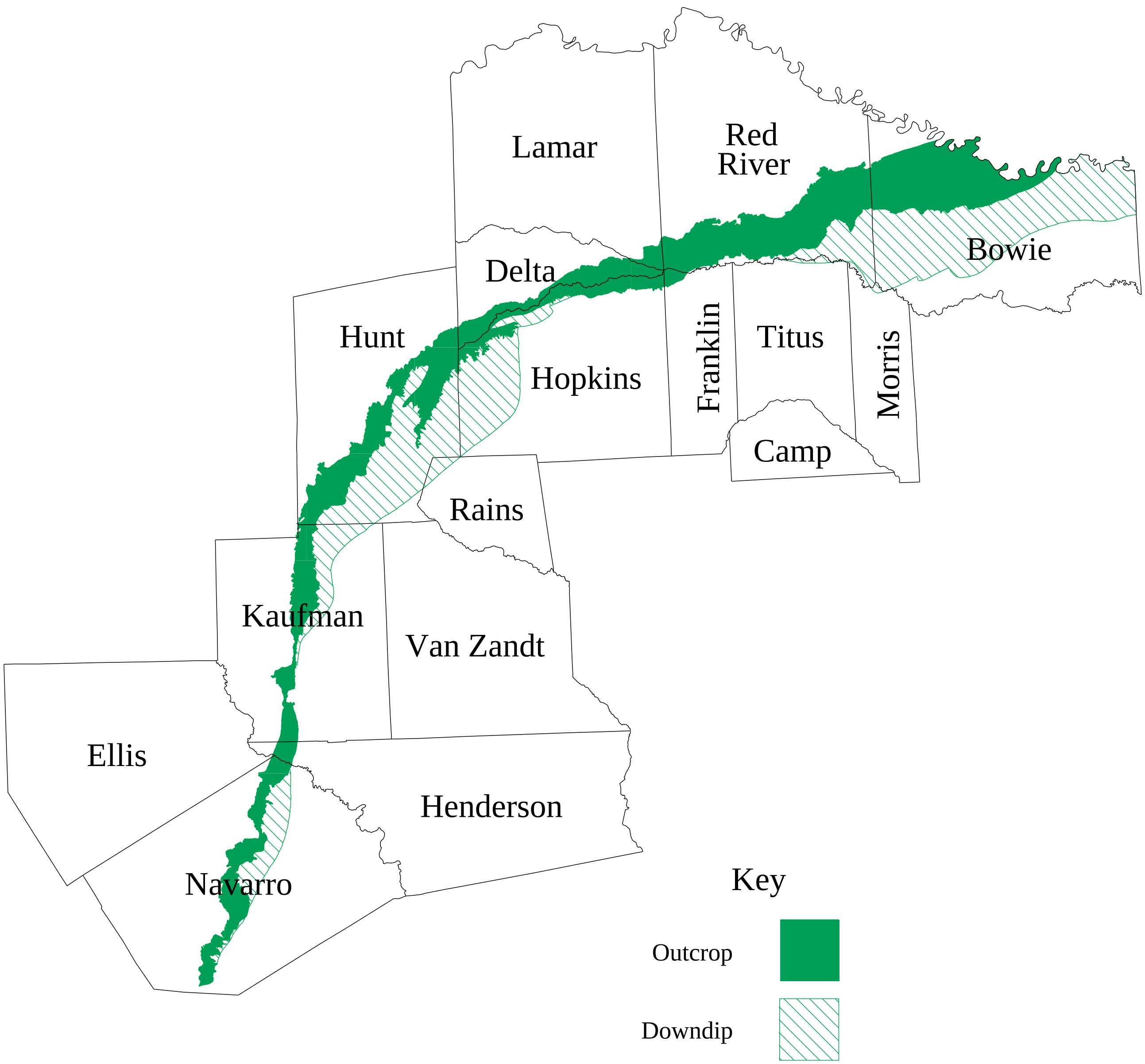
Nacatoch



Lamar
Red River
Delta
Hunt
Hopkins
Franklin
Titus
Morris
Bowie
Camp
Rains
Kaufman
Van Zandt
Ellis
Henderson
Navarro
Key
Outcrop
Downdip

Nacatoch Aquifer

The Nacatoch aquifer occurs in a narrow band in Northeast Texas and extends eastward into Arkansas and Louisiana. The Nacatoch Formation, composed of one to three sequences of sand beds separated by impermeable layers of mudstone or clay, was deposited in the East Texas Basin during the Cretaceous Period. A hydrologically connected mantle of alluvium up to 80 feet thick covers the Nacatoch along major drainageways. The south and east basinward dip of the formation is interrupted by the Mexia-Talco fault zone, which alters the normal flow direction and adversely affects the chemical quality of the ground water.

The quality of ground water in the aquifer is generally alkaline, high in sodium bicarbonate, soft, and increases in dissolved-solids concentrations in the downdip portion of the aquifer. The downdip limit of usable water (less than 3,000 mg/l), especially in the northern region, is controlled by the Mexia-Talco fault system. In areas where the Nacatoch occurs as multiple sand layers, the upper layer contains the best-quality water.

Water from the aquifer is extensively used for rural domestic and livestock purposes; however, the town of Commerce has historically pumped the greatest amount from the aquifer. Declining water levels that had developed around Commerce in Delta and Hunt counties have begun to stabilize as a result of conversion to surface water.

References

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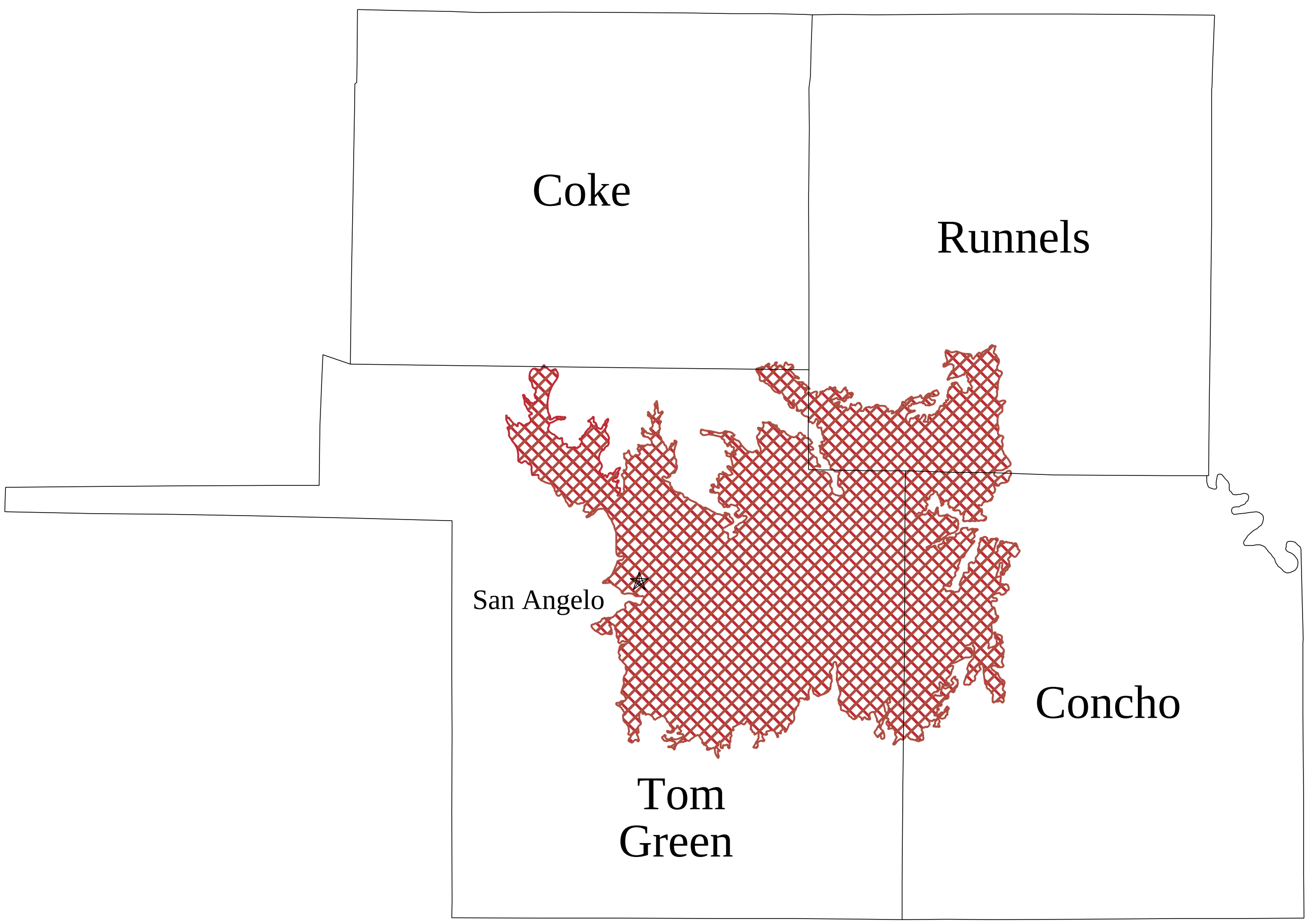
Lipan



Lipan Aquifer

The Lipan aquifer is located in the Lipan Flats area of eastern Tom Green, western Concho, and southern Runnels counties. The water is principally used for irrigation, with limited amounts used for rural domestic and livestock purposes.

The aquifer comprises up to 125 feet of saturated alluvial deposits of the Leona Formation of Quaternary age. Also included in the aquifer are the updip portions of the underlying Choza Formation and Bullwagon Dolomite of Permian age that are hydrologically continuous with the Leona and contain fresh to slightly saline water.

Ground water in the Lipan aquifer naturally discharges by seepage to the Concho River and by evapotranspiration in areas where the water table is at or near land surface. Well yields commonly range from 100 gal/min to more than 1,000 gal/min.

Ground water in the Leona Formation ranges from fresh to slightly saline and is very hard. Water in the underlying updip portions of the Choza and Bullwagon tends to be slightly saline. The chemical quality of ground water in the Lipan aquifer often does not meet drinking water standards; however, it is generally suitable for irrigation.

References

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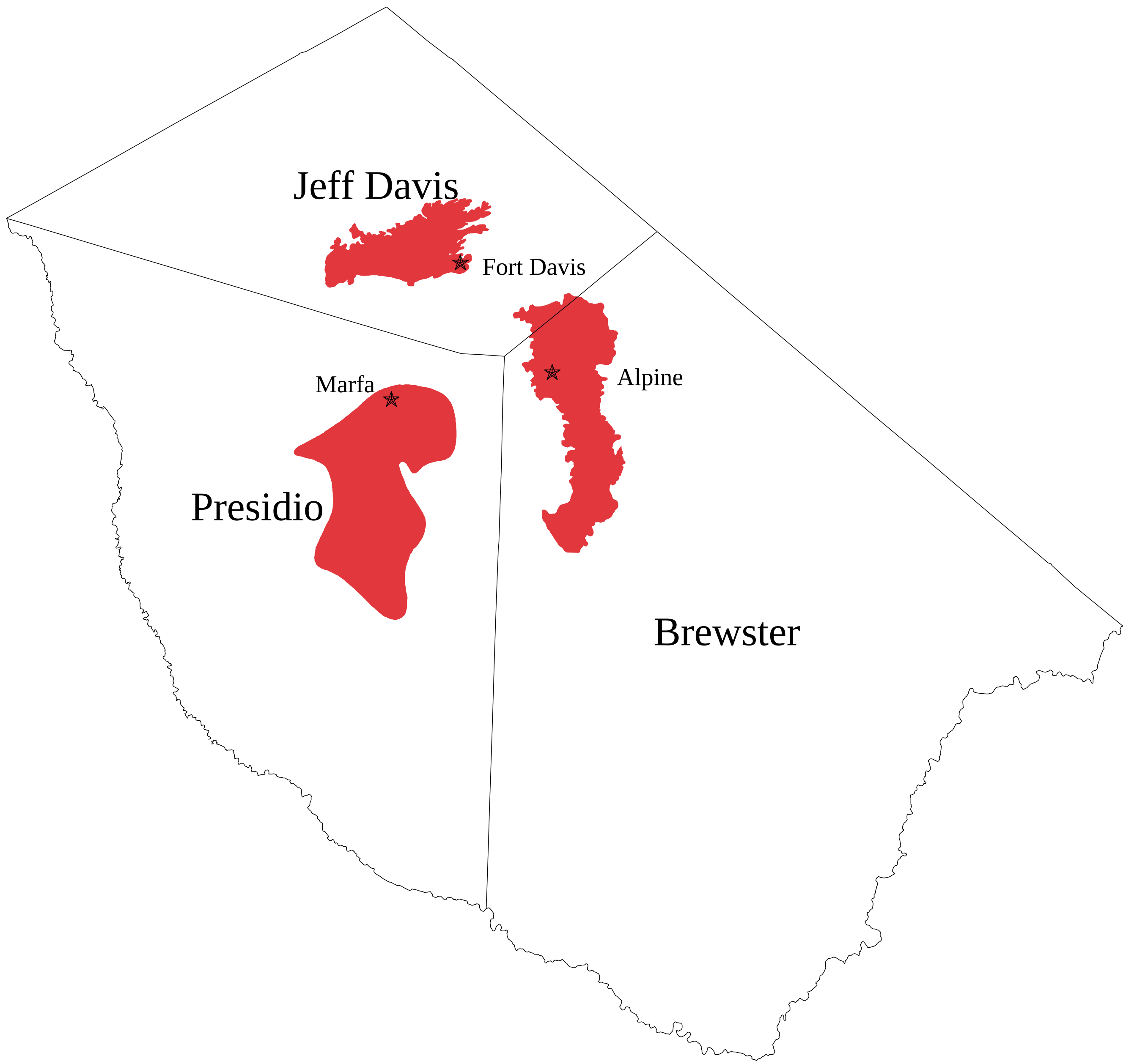
Igneous



Igneous Aquifer

The Igneous aquifer occurs in three separate areas in the arid Trans-Pecos region of West Texas within Brewster, Presidio, and Jeff Davis counties. Ground water occurs in fissures and fractures of lava flows, tuffs, and related intrusive and extrusive igneous rocks of Tertiary age. These rocks reach an average thickness of 900 feet to 1,000 feet. The cities of Alpine, Fort Davis, and Marfa use water for municipal supply from the aquifer.

The aquifer in the Alpine area includes the Cottonwood Springs Basalt, Sheep Canyon Basalt, Crossen Trachyte, and associated alluvium; of these, the principal water-bearing unit of the aquifer is the Crossen Trachyte. The aquifer in the Marfa area includes parts of the Petan Basalt and the Tascotal Formation. The Davis Mountains aquifer includes the Barrel Springs Formation and associated alluvium.

Well yields are moderate to large in the Marfa area, and small to moderate in the Alpine and Fort Davis areas. Yields of wells in the Igneous aquifer vary widely because the basalts have a wide range in permeability; lower permeabilities generally occur in the lower sections, and moderately high permeabilities occur in the faulted and fractured upper layers. Water quality is good for municipal and domestic uses. Elevated levels of silica and fluoride have been found in water from some wells, reflecting the igneous origin of the rock.

References

Davis, M.E., 1961, Ground-water reconnaissance of the Marfa area, Presidio County, Texas: TBWE Bull. 6110, 23 p.

Littleton, R.T., and Audsley, G.L., 1957, Ground-water geology of the Alpine area, Brewster, Jeff Davis, and Presidio counties, Texas: TBWE Bull. 5712, 37 p.

Rita Blanca

Rita Blanca Aquifer

The Rita Blanca aquifer underlies the Ogallala Formation in western Dallam and Hartley counties in the northwest corner of the Texas Panhandle and is a small part of a large aquifer that extends into Oklahoma, Colorado, and New Mexico. Irrigation accounts for most of the ground-water use from this aquifer, with Texline being the only community that uses the aquifer for municipal water supply.

Ground water occurs in coarse-grained Cretaceous age sands and gravels of the Lytle and Dakota formations. Ground water also occurs in the Exeter Sandstone and the Morrison Formation of Jurassic age. Highest yields of 600 gal/min to 800 gal/min are obtained from wells completed in the Lytle and Dakota sandstones.

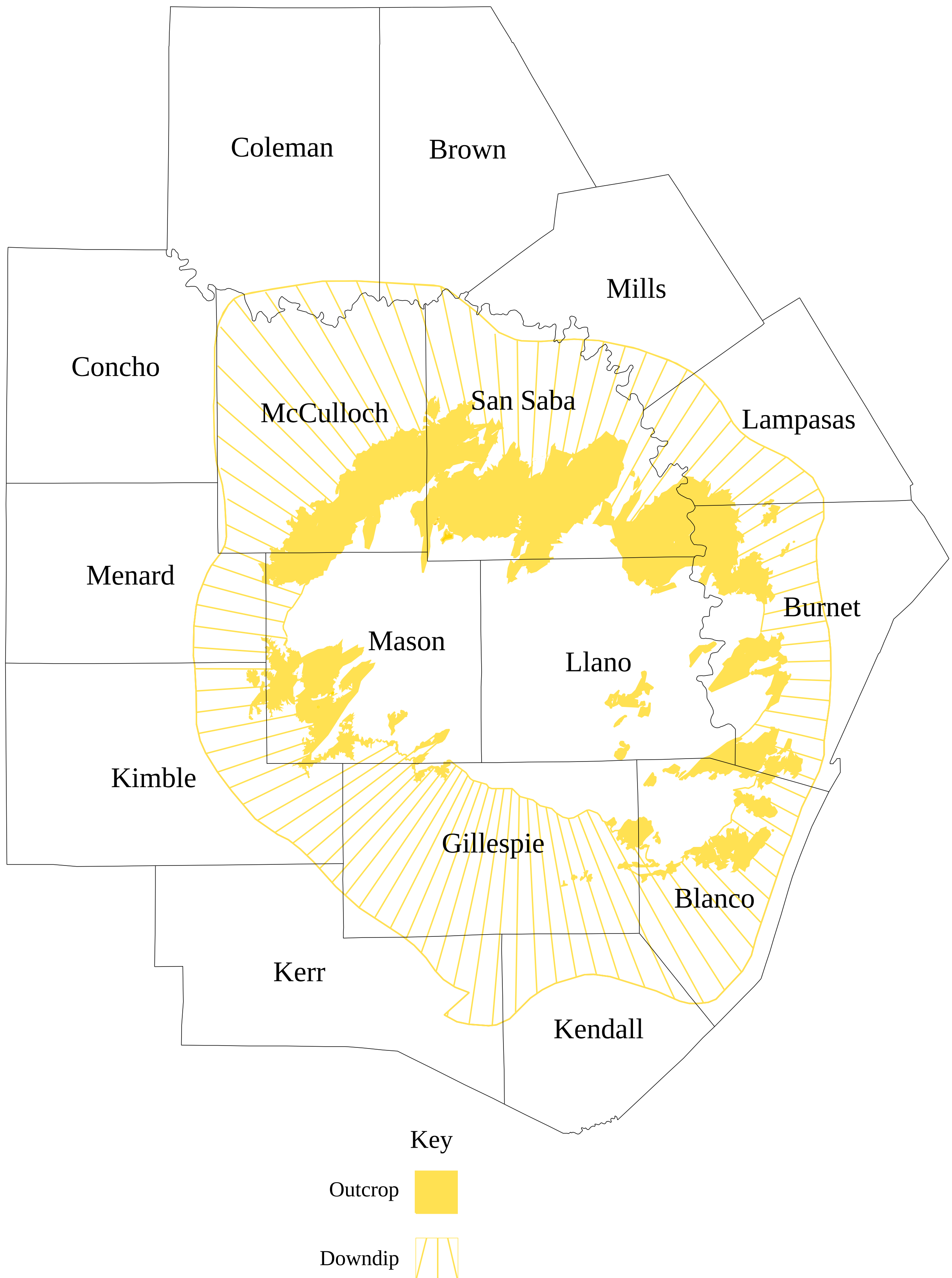
Water quality in the aquifer is usually fresh, but very hard. Some formations, however, produce water that is slightly saline, which is unsuitable for irrigating most crops grown in the region. Water-level declines have developed in excess of 50 feet in some irrigated areas. As a result, many springs in the northern part of Dallam County have disappeared that once contributed to the constant flow in creeks.

References

Christian, P., 1989, Evaluation of ground-water resources in Dallam County, Texas: TWDB Rept. 315, 27 p.

Knowles, T., Nordstrom, P., and Klemt, W.B., 1984, Evaluating the ground-water resources of the High Plains of Texas: TDWR Rept. 288, 4 vols.

Ellenburger-San Saba



Ellenburger-San Saba Aquifer

The Ellenburger-San Saba aquifer occurs in parts of 15 counties in the Llano Uplift area of Central Texas. Discontinuous outcrops of the aquifer encircle older rocks in the core of the uplift, and the remaining downdip portion extends to depths of approximately 3,000 feet below land surface. Regional block faulting has significantly compartmentalized the aquifer.

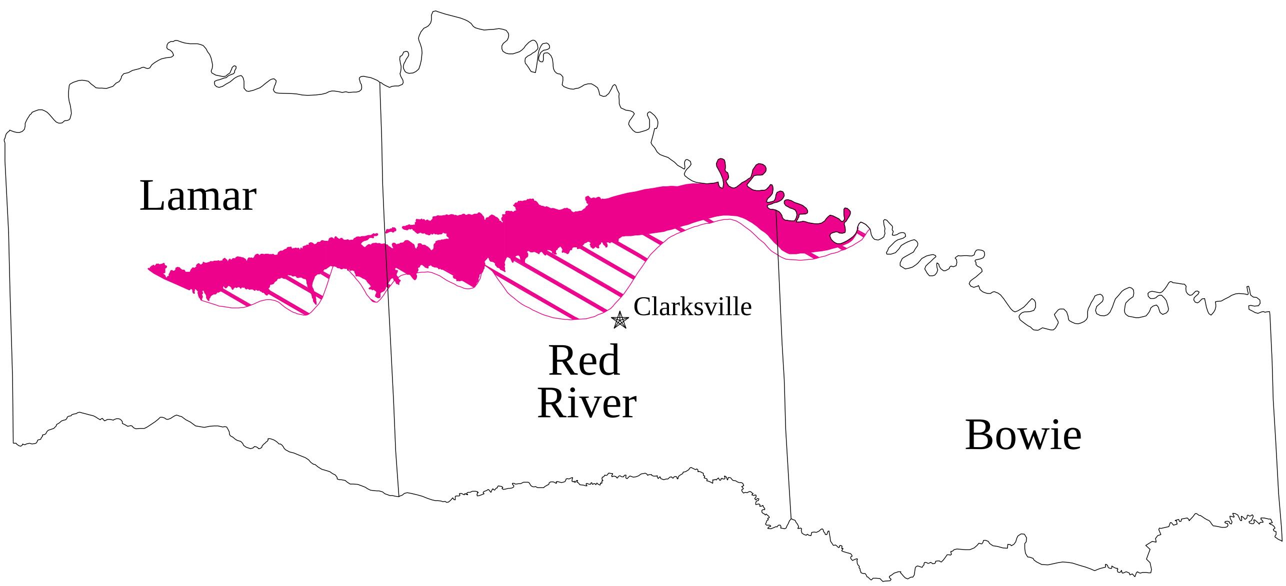
Three-fourths of the water pumped from the aquifer is used for municipal water supplies at Fredericksburg, Johnson City, Bertram, and Richland Springs. Also, a large portion of water flowing from San Saba Springs, which is the water supply for the city of San Saba, is believed to be from the Ellenburger-San Saba and Marble Falls aquifers.

The aquifer occurs in limestone and dolomite facies in the San Saba Member of the Wilberns Formation of late Cambrian age, and in the Honeycut, Gorman, and Tanyard formations of the Ellenburger Group of early Ordovician age. Water in the aquifer primarily occurs in solution cavities formed along faults and related fractures. The Ellenburger-San Saba aquifer in some areas may be hydrologically connected to the Marble Falls aquifer. Water produced from the aquifer is inherently hard and usually has less than 1,000 mg/l dissolved solids.

References

Bluntzer, R.L., 1992, Evaluation of the ground-water resources of the Paleozoic and Cretaceous aquifers in the Hill Country of Central Texas: TWDB Rept. 339, 139 p.

Blossom



Key

Outcrop

Downdip

Blossom Aquifer

The Blossom aquifer occupies a narrow east-west band in parts of Bowie, Red River, and Lamar counties in the northeast corner of Texas. The Blossom Sand Formation consists of alternating sequences of sand and clay deposited during the Cretaceous Period. In places, the formation attains a thickness of 400 feet, although no more than 29 percent of this thickness consists of water-bearing sand.

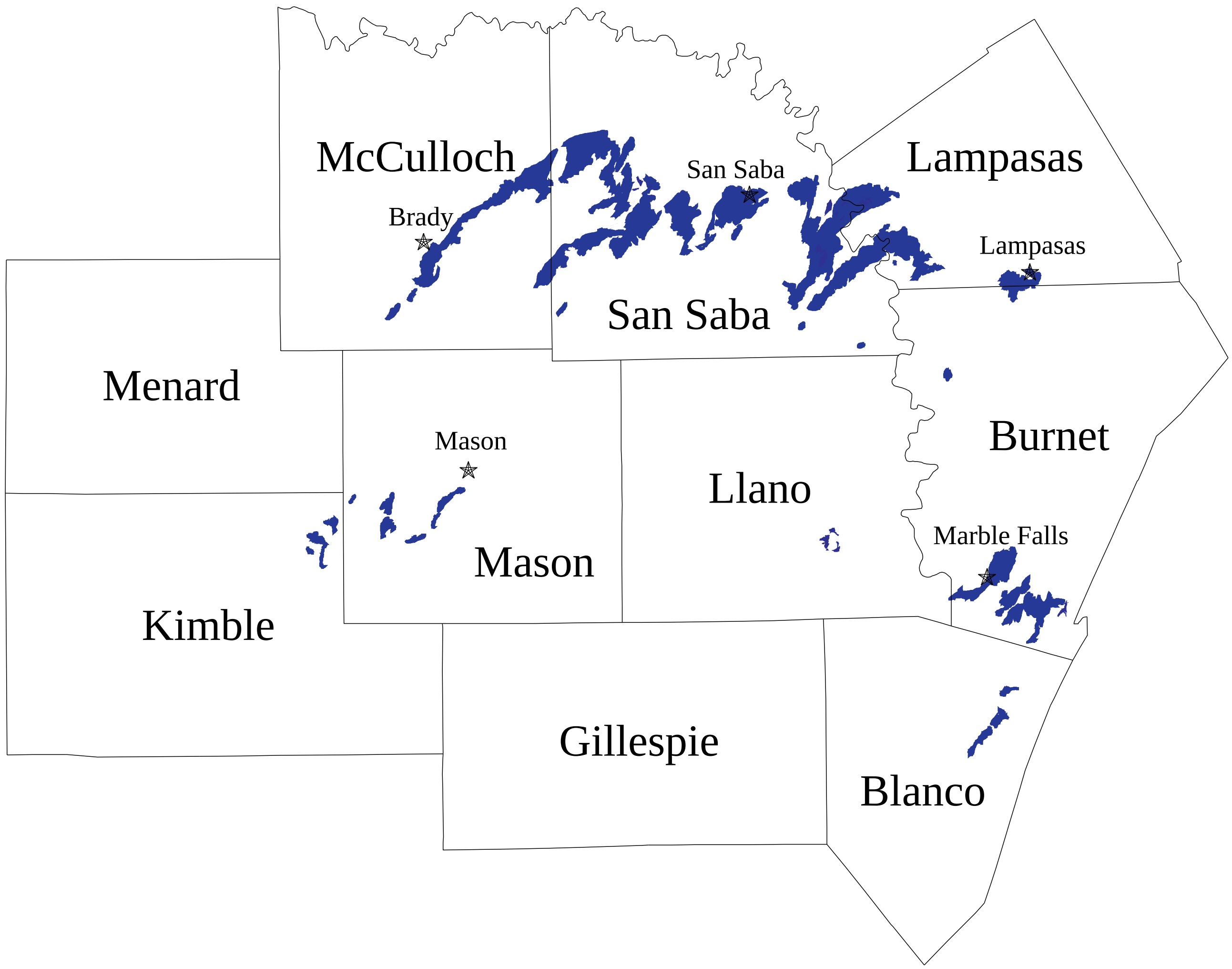
Ground water from the Blossom aquifer is generally soft, slightly alkaline, and, in some areas, high in sodium, bicarbonate, and iron. Water quality, although not acceptable for irrigation due to its high sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) values, is generally acceptable for most nonindustrial uses.

The Blossom aquifer yields water in small to moderate amounts over a limited area on and south of the outcrop, with the largest well yields of 650 gal/min occurring in Red River County. Production decreases in the western half of the aquifer, where yields of 35 gal/min to 85 gal/min are more typical. Historically, Clarksville and the Red River Water Supply Corporation in Red River County have pumped the greatest amounts from the aquifer, which resulted in a water-level deline; however, in recent years, the rate of decline has slowed or even stabilized in some wells as a result of more surface-water use in the area.

References

McLaurin, C., 1988, Occurrence, availability, and chemical quality of ground water in the Blossom Sand aquifer: TWDB Rept. 307, 32 p.

Marble Falls



Marble Falls Aquifer

The Marble Falls aquifer occurs in several separated outcrops, primarily along the northern and eastern flanks of the Llano Uplift. It provides water to parts of Blanco, Burnet, Lampasas, McCulloch, and San Saba counties, and to even smaller parts of Kimble, Llano, and Mason counties in Central Texas. San Saba and Rochelle are the two largest communities that withdraw water from the aquifer for public supply use. Wells have been reported to yield as much as 2,000 gal/min; however, most wells produce substantially less.

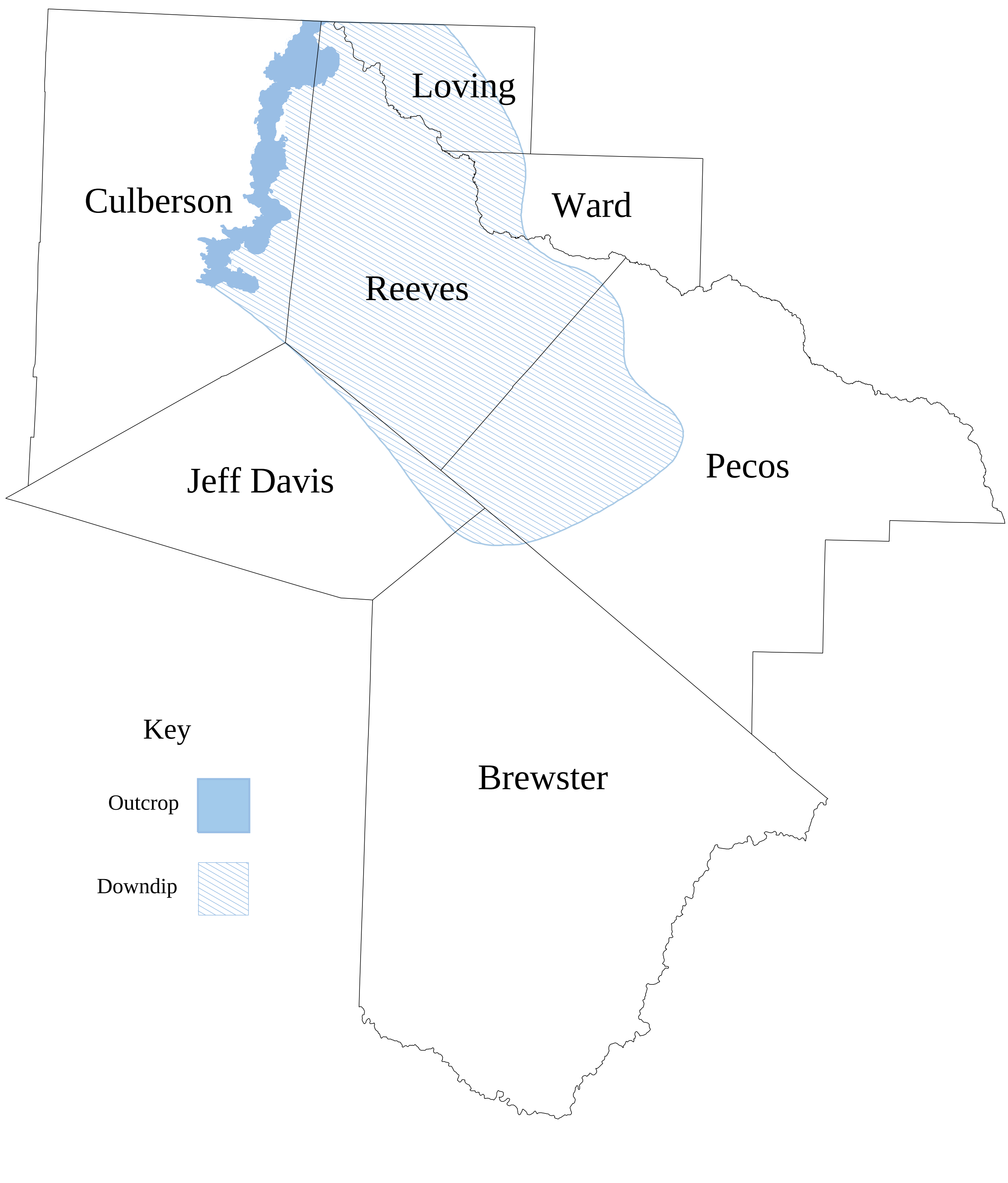
Ground water occurs in fractures, solution cavities, and channels in the limestone of the Marble Falls Formation of the Pennsylvanian Bend Group. Maximum thickness of the formation is 600 feet. Where underlying beds are thin or absent, the Marble Falls and Ellenburger-San Saba aquifers may be hydrologically connected. Numerous large springs issue from the aquifer and provide a significant part of the baseflow to the San Saba River in McCulloch and San Saba counties, and to the Colorado River in San Saba and Lampasas counties.

The quality of water produced from the aquifer is suitable for most purposes. The downdip artesian portion in most areas is not extensive and becomes significantly mineralized within relatively short distances from the outcrop recharge area.

References

Bluntzer, R.L., 1992, Evaluation of the ground-water resources of the Paleozoic and Cretaceous aquifers in the Hill Country of Central Texas: TWDB Rept. 339, 130 p.

Rustler


Loving
Culberson
Ward
Reeves
Jeff Davis
Pecos
Brewster
Key
Outcrop
Downdip

Rustler Aquifer

The Rustler Formation of Permian age crops out in eastern Culberson County in the Trans-Pecos region of Texas and extends eastward into the subsurface of the Delaware Basin. The aquifer is principally located in Loving, Pecos, Reeves, and Ward counties where it yields water for irrigation, livestock, and water-flooding operations in oil-producing areas. High dissolved-solids concentrations render the water unsuitable for human consumption.

Water occurs in highly permeable solution zones that have developed in dolomite, limestone, and gypsum beds of the Rustler Formation. The dissolved-solids concentrations of the water increase downgradient, eastward into the basin, with a shift from sulfate to chloride as the predominant anion.

References

Armstrong, C.A., and McMillion, L.G., 1961, Geology and ground-water resources of Pecos County, Texas: TBWE Bull. 6106, 2 vols.

Maley, V.C., and Huffington, R.M., 1953, Cenozoic fill and evaporite solution in the Delaware Basin, Texas and New Mexico: Geological Society of America Bull. Vol. 64, No. 5, pp. 539-546.

Rickey, S.F., Wells, J.G., and Stephens, K.T., 1985, Geohydrology of the Delaware Basin and vicinity, Texas and New Mexico: U.S. Geological Survey Water-Resources Inv. 84-4077, 99 p.

Capitan Reef Complex

Capitan Reef Complex Aquifer

The Capitan Reef formed along the margins of the Delaware Basin, an embayment covered by a shallow Permian sea. In Texas, two arcuate strips of the reef, 10 to 14 miles wide, are exposed in the Guadalupe, Apache, and Glass mountains; elsewhere, the reef is in the subsurface. The reef extends northward into New Mexico where it provides abundant fresh water to the city of Carlsbad.

Most of the ground water pumped from the aquifer in Texas is used for oil reservoir water-flooding operations in Ward and Winkler counties. A small amount is used for irrigation of salt-tolerant crops in Pecos and Culberson counties.

In Texas, the aquifer is composed of up to 2,360 feet of dolomite and limestone deposited as reef, fore-reef, and back-reef facies. Water-bearing formations include the Capitan Limestone, Goat Seep Limestone, and most of the Carlsbad facies of the Artesia Group—including the Grayburg, Queen, Seven Rivers, Yates, and Tansill formations.

The aquifer generally contains water of poor quality and yields small to large quantities of moderately saline to brine water. Water of the freshest quality is located on and near areas of recharge where the reef is exposed at the surface in the three mountain ranges.

References

Hiss, W.L., 1975, Stratigraphy and ground-water hydrology of the Capitan aquifer, Southeastern New Mexico and Western Texas: U.S. Geological Survey and New Mexico State Engineer Open-File Rept., 396 p.

Rickey, S.F., Wells, J.G., and Stephens, K.T., 1985, Geohydrology of the Delaware Basin and vicinity, Texas and New Mexico: U.S. Geological Survey Water-Resources Inv. 84-4077, 99 p.

Marathon

Marathon Aquifer

The Marathon aquifer occurs entirely within north-central Brewster County. Ground water is used primarily for municipal water supply by the city of Marathon and for domestic and livestock purposes. Water from the aquifer is typically of good quality but hard, with dissolved solids usually ranging from 500 mg/l to 1,000 mg/l.

The Marathon aquifer is contained within the Gaptank, Dimple, Tesnus, Caballos, Maraviallas, Fort Pena, and Marathon Limestone formations; of these, the Marathon Limestone Formation is the most productive unit. These Early Paleozoic (Pennsylvanian through Ordovician) formations occur in a region of complex folding and faulting within the Marathon Uplift.

Water in the Marathon aquifer occurs in numerous crevices, joints, and cavities, and extends to depths ranging from 350 feet to about 900 feet. The depth of most wells is less than 250 feet, and well yields range from less than 10 gal/min to more than 300 gal/min. Many of the shallow wells in the region actually produce water from alluvial deposits that cover portions of the rock formations.

References

DeCook, K.J., 1961, A reconnaissance of the ground-water resources of the Marathon area, Brewster County, Texas: TBWE Bull. 6111, 51 p.

Reference 32

HYDROGEOLOGIC FRAMEWORK OF THE EDWARDS-TRINITY AQUIFER SYSTEM, WEST-CENTRAL TEXAS

REGIONAL AQUIFER-SYSTEM ANALYSIS

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1421-B

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Hydrogeologic Framework of the Edwards-Trinity Aquifer System, West-Central Texas

By **RENÉ A. BARKER** *and* **ANN F. ARDIS**

REGIONAL AQUIFER-SYSTEM ANALYSIS—
EDWARDS-TRINITY AQUIFER SYSTEM

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Gordon P. Eaton, *Director*

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FOREWORD

THE REGIONAL AQUIFER-SYSTEM ANALYSIS PROGRAM

The Regional Aquifer-System Analysis (RASA) Program represents a systematic effort to study a number of the Nation's most important aquifer systems, which, in aggregate, underlie much of the country and which represent an important component of the Nation's total water supply. In general, the boundaries of these studies are identified by the hydrologic extent of each system and, accordingly, transcend the political subdivisions to which investigations have often arbitrarily been limited in the past. The broad objective for each study is to assemble geologic, hydrologic, and geochemical information; to analyze and develop an understanding of the system; and to develop predictive capabilities that will contribute to the effective management of the system. The use of computer simulation is an important element of the RASA studies to develop an understanding of the natural, undisturbed hydrologic system and the changes brought about in it by human activities and to provide a means of predicting the regional effects of future pumping or other stresses.

The final interpretive results of the RASA Program are presented in a series of U.S. Geological Survey Professional Papers that describe the geology, hydrology, and geochemistry of each regional aquifer system. Each study within the RASA Program is assigned a single Professional Paper number beginning with Professional Paper 1400.

Gordon P. Eaton
Director

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[Plates are in pocket]

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNIT

Multiply	By	To obtain
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
foot squared per day (ft^2/d)	0.0929	meter squared per day
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality unit:

mg/L, milligram per liter

HYDROGEOLOGIC FRAMEWORK OF THE EDWARDS-TRINITY AQUIFER SYSTEM, WEST-CENTRAL TEXAS

By René A. Barker and Ann F. Ardis

ABSTRACT

The Edwards-Trinity aquifer system underlies about 42,000 square miles of west-central Texas. Nearly flat-lying Comanche (mostly Lower Cretaceous) and Gulf (Upper Cretaceous) strata of the aquifer system thin northwestward atop generally massive pre-Cretaceous rocks that are comparatively impermeable and structurally complex. From predominately terrigenous clastic sediments in the east and terrestrial deposits in the west, the rocks of early Trinitian (Comanchean) age grade upward into supratidal and intertidal evaporitic and dolomitic rocks and shallow-marine, lagoonal, and basinal carbonate strata of late Trinitian, Fredericksburgian, and Washitan (Comanchean) age. A thick, downfaulted remnant of mostly open-shelf sediments of Eagle-fordian through Navarroan (Gulfian) age confines a small, southeastern part of the aquifer system.

While clastic deposition prevailed upon alluvial plains inland of a westward-advancing Cretaceous sea, offshore environments were dominated by the biogenic accumulation of calcium carbonate in warm, generally clear seawater. The Trinity strata were deposited as the sea encroached upon the Llano uplift, the most prominent feature on a rolling peneplain composed of folded and faulted pre-Cretaceous rocks. The Fredericksburg and Washita strata mostly formed above the Llano uplift, on a carbonate platform sheltered from storm waves and deep ocean currents by the Stuart City reef trend. Subsequently, the entire study area was blanketed with mostly argillaceous sediments of the Eagle Ford, Austin, Taylor, and Navarro Groups.

During late Oligocene through early Miocene time, large-scale normal faulting formed the Balcones fault zone, where the Cretaceous strata were displaced vertically, fractured intensively, and rotated differentially within a series of southwest-to-northeast trending fault blocks. Ground-water flow shifted toward the northeast in response to rejuvenated hydraulic gradients and high-angle barrier faults that blocked southeastward flow. Subsurface conduits lengthened in a southwest-to-northeast direction as evaporites and soluble calcareous constituents (other carbonate minerals and allochems) dissolved from the fractured strata and discharged to downgradient springs and streams. The springs originated in topographically low areas where confined ground water was diverted to the surface by barrier faults. Ground-water conduits enlarged through carbonate dissolution along flowpaths that converged toward the springs. The major springs persisted to control modern potentiometric levels and discharge patterns. Stream erosion eventually breached the overlying, low-permeability Gulf rocks and provided discharge areas for aquifers in the underlying, more permeable Comanche rocks.

The Balcones faulting triggered processes responsible for sizable contrasts between the hydraulic characteristics of Cretaceous strata in the Balcones fault zone and those elsewhere in the Edwards-Trinity aquifer system. By vertically displacing the terrain, the faulting increased hydraulic gradients, which enhanced the percolation of meteoric (precipitation-derived) water from land surface and increased the velocity of ground-water flow. A dynamic regime of shallow ground-water flow evolved that promoted dissolution and enhanced the transmissivity of the Edwards Group in the Balcones fault zone. Cementation, recrystallization, and replacement resulting from deep burial and comparatively sluggish ground-water movement combined to diminish the transmissivity of the underlying Trinity strata, as well as most Cretaceous strata in the Hill Country, Edwards Plateau, and Trans-Pecos.

The Cretaceous strata comprise a regional aquifer system of three aquifers and two confining units. The aquifers are the Edwards aquifer in the Balcones fault zone, the Trinity aquifer in the Hill Country and deeper parts of the Balcones fault zone, and the Edwards-Trinity aquifer in the Edwards Plateau and Trans-Pecos. The Navarro-Del Rio confining unit confines downdip parts of the Edwards aquifer in the Balcones fault zone. The Hammett confining unit, composed of the Hammett Shale, confines basal parts of the Trinity and Edwards-Trinity aquifers in most of the Hill Country and in a small southeastern part of the Edwards Plateau. The confining units mostly are composed of calcareous mudstone, siltstone, and shale deposited in low-energy terrigenous and open-shelf marine environments. The permeable strata mainly result from fractures and joint cavities, solution channels, and fabric-selective forms of porosity caused by the dissolution of evaporites and soluble calcareous constituents. Transmissivity in the Edwards-Trinity aquifer system ranges from less than 5,000 to more than 5,000,000 feet squared per day. Although transmissivity probably averages about 750,000 feet squared per day in the Edwards aquifer, it probably averages less than 10,000 feet squared per day elsewhere in the aquifer system. Outside the Balcones fault zone, where the hydraulic conductivity typically is small, transmissivity generally is greater than 5,000 feet squared per day where the saturated thickness of the aquifer exceeds 500 feet and generally is less than 5,000 feet squared per day where saturated thickness is less than 500 feet.

INTRODUCTION

The Edwards-Trinity aquifer system, underlying about 42,000 mi^2 of west-central Texas, was studied as a part of the Regional Aquifer-System Analysis (RASA) program of the U.S. Geological Survey. The U.S. Geological Survey began the RASA program during 1978 to improve the hydrogeologic information on the major aquifer systems in the Nation. The Edwards-Trinity RASA was one of 28 projects identified for study (Weeks and Sun, 1987). Key objectives of each RASA study were to (1) delineate the regional aquifers and regional confining units in the study area, (2) evaluate the effects of the geology on the ground-water-flow system, and (3) integrate the results of previous hydrogeologic investigations in the study area.

PURPOSE AND SCOPE

This report describes the hydrogeologic framework of the Edwards-Trinity aquifer system. The depositional, tectonic, diagenetic, and stratigraphic conditions of the rocks that compose the aquifer system are described under "Geologic Setting." The hydraulic characteristics, aquifers, and confining units are described under "Edwards-Trinity Aquifer System." A correlation chart (pl. 1) and seven hydrogeologic sections (pls. 2–8) illustrate the relations between the chronostratigraphic and lithostratigraphic units and the aquifers and confining units in the study area.

STUDY AREA AND AQUIFER-SYSTEM BOUNDARY

The RASA study area (fig. 1) extends in places beyond the Edwards-Trinity aquifer system to include contiguous terrain that is connected hydraulically to the aquifer system. The boundary of the aquifer system coincides in most places with the outer edge of Cretaceous rocks that are the principal source of ground water. Contiguous hydraulically connected rocks lie between the Edwards-Trinity aquifer system and the limits of regional ground-water flow.

The Edwards-Trinity aquifer system comprises three regional aquifers and two regional confining units (fig. 2). From east to west, the aquifers are the Edwards aquifer, Trinity aquifer, and Edwards-Trinity aquifer. The aquifers are laterally adjacent except in the southeastern part of the system, where a downfaulted part of the Trinity aquifer is overlain by the Edwards aquifer. The Navarro-Del Rio confining unit confines downdip parts of the Edwards aquifer, and the Hammett confining unit confines basal parts of the Trinity and Edwards-Trinity aquifers.

With the exception of the High Plains aquifer (defined by Weeks and others, 1988), the aquifer nomenclature used in this report was adopted from that recommended in the recently amended Texas Water Plan (Texas Water Development Board, 1990, p. 1–5 and 1–6).

The boundary of the Edwards-Trinity aquifer system between west-central Travis County and eastern Brewster County mostly is defined by geologic conditions. From west-central Travis County to north-central Glasscock County, the boundary coincides approximately with the updip limit of the Cretaceous rock outcrop (University of Texas, Bureau of Economic Geology, 1974b; 1975; 1976a, c; 1981a; Ashworth and Flores, 1991, fig. 1). This segment of the boundary is characterized in places by a low escarpment facing away from the aquifer system. From north-central Glasscock County to northwestern Ector County, the boundary coincides approximately with the updip limit of the Cretaceous rock subcrop. This segment is defined approximately because the basal Cretaceous sand at the base of the Edwards-Trinity aquifer (Mount and others, 1967, p. 45) is virtually indistinguishable from the Ogallala Formation, which forms the High Plains aquifer in that area (Weeks and others, 1988). From northwestern Ector County to Culberson County, the boundary is where Cretaceous rocks abut the Cenozoic Pecos alluvium of Cenozoic age (University of Texas, Bureau of Economic Geology, 1976b; Rees and Buckner, 1980, fig. 2). From Culberson County to the Rio Grande in Brewster County, the boundary traverses the eastern flanks of several mountain ranges where the Cretaceous rocks pinch out, are structurally detached, or mostly are impermeable (Rees and Buckner, 1980, fig. 2).

The boundary of the Edwards-Trinity aquifer system between eastern Brewster County and west-central Travis County mostly is defined by hydrologic conditions. Because potentiometric data indicate that the Rio Grande is a regional ground-water drain (Bush and others, 1993), the boundary of the aquifer system is assumed to coincide with the Rio Grande from eastern Brewster County to south-central Val Verde County. From the Rio Grande in south-central Val Verde County to the Colorado River in central Travis County, the aquifer system is bounded by a narrow transition zone between freshwater and saline water (fig. 2) that minimizes the downdip flow of freshwater from the Edwards aquifer. The aquifer system boundary coincides with the updip edge of the transition zone, which is defined by the 1,000-mg/L line of equal dissolved-solids concentration as modified from Maclay and others (1980, fig. 7). Although dissolved-solids data for the Trinity aquifer are too sparse to define lines of equal dissolved-solids concentration, the

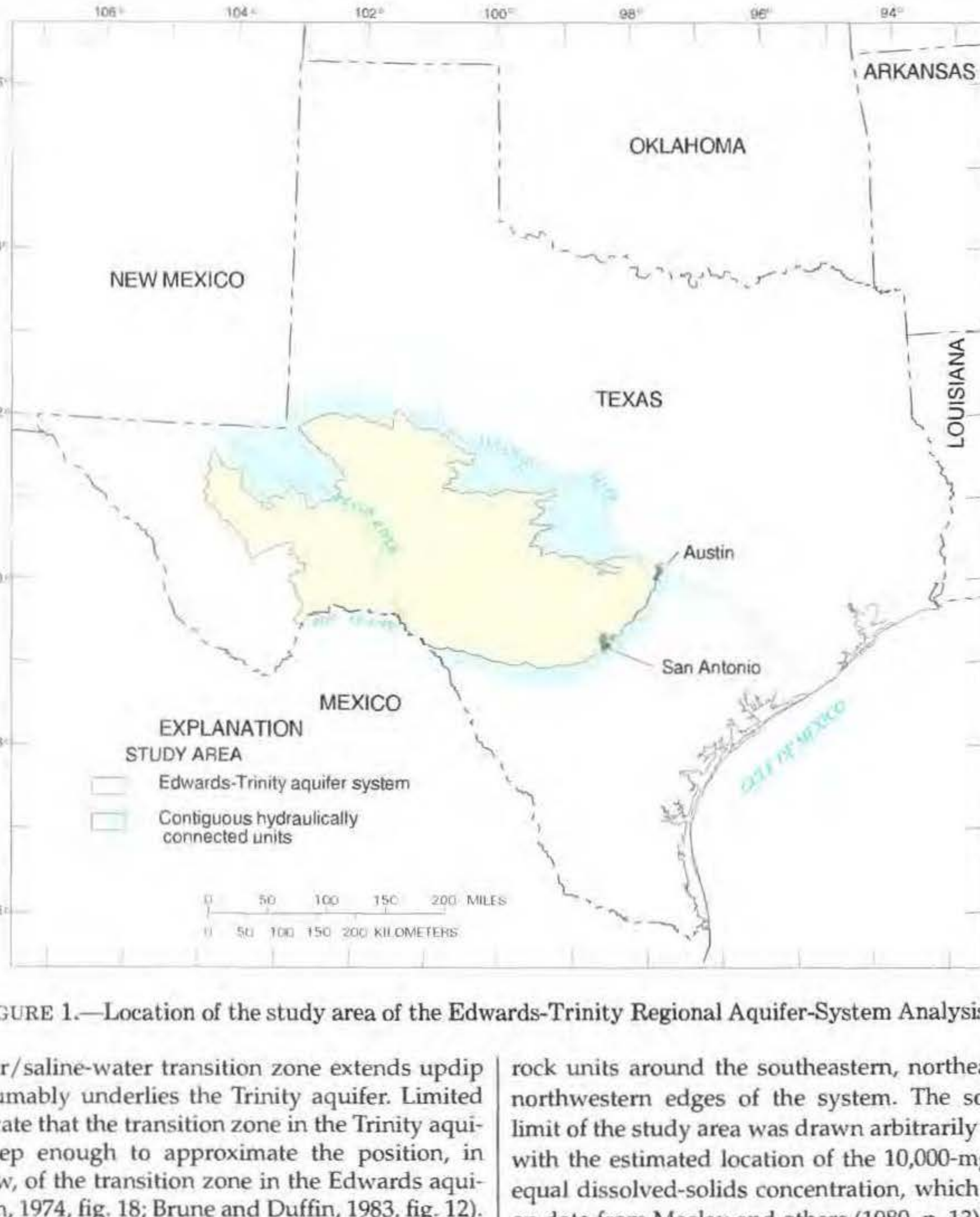


FIGURE 1.—Location of the study area of the Edwards-Trinity Regional Aquifer-System Analysis.

freshwater/saline-water transition zone extends updip and presumably underlies the Trinity aquifer. Limited data indicate that the transition zone in the Trinity aquifer is steep enough to approximate the position, in plane view, of the transition zone in the Edwards aquifer (Duffin, 1974, fig. 18; Brune and Duffin, 1983, fig. 12).

The Colorado River bounds the Edwards-Trinity aquifer system through west-central Travis County. Although Cretaceous rocks extend north of the river, potentiometric data (Baker and others, 1986, fig. 20) indicate that ground-water flow is truncated at this deeply entrenched, regional drain.

The study area (fig. 1) was extended beyond the boundary of the Edwards-Trinity aquifer system to account for the hydraulic connection with contiguous rock units around the southeastern, northeastern, and northwestern edges of the system. The southeastern limit of the study area was drawn arbitrarily to coincide with the estimated location of the 10,000-mg/L line of equal dissolved-solids concentration, which was based on data from Maclay and others (1980, p. 13). The study area is delimited on the northeast by the Colorado River, a regional discharge boundary (Kuniansky, 1990) for aquifers in the contiguous pre-Cretaceous rocks that underlie the river (Mount and others, 1967, pl. 4). The northwestern part of the study area includes much of the Cenozoic Pecos alluvium aquifer (Texas Water Development Board, 1990, fig. 1–1) and a small part of the High Plains aquifer (Weeks and others, 1988, fig. 1).

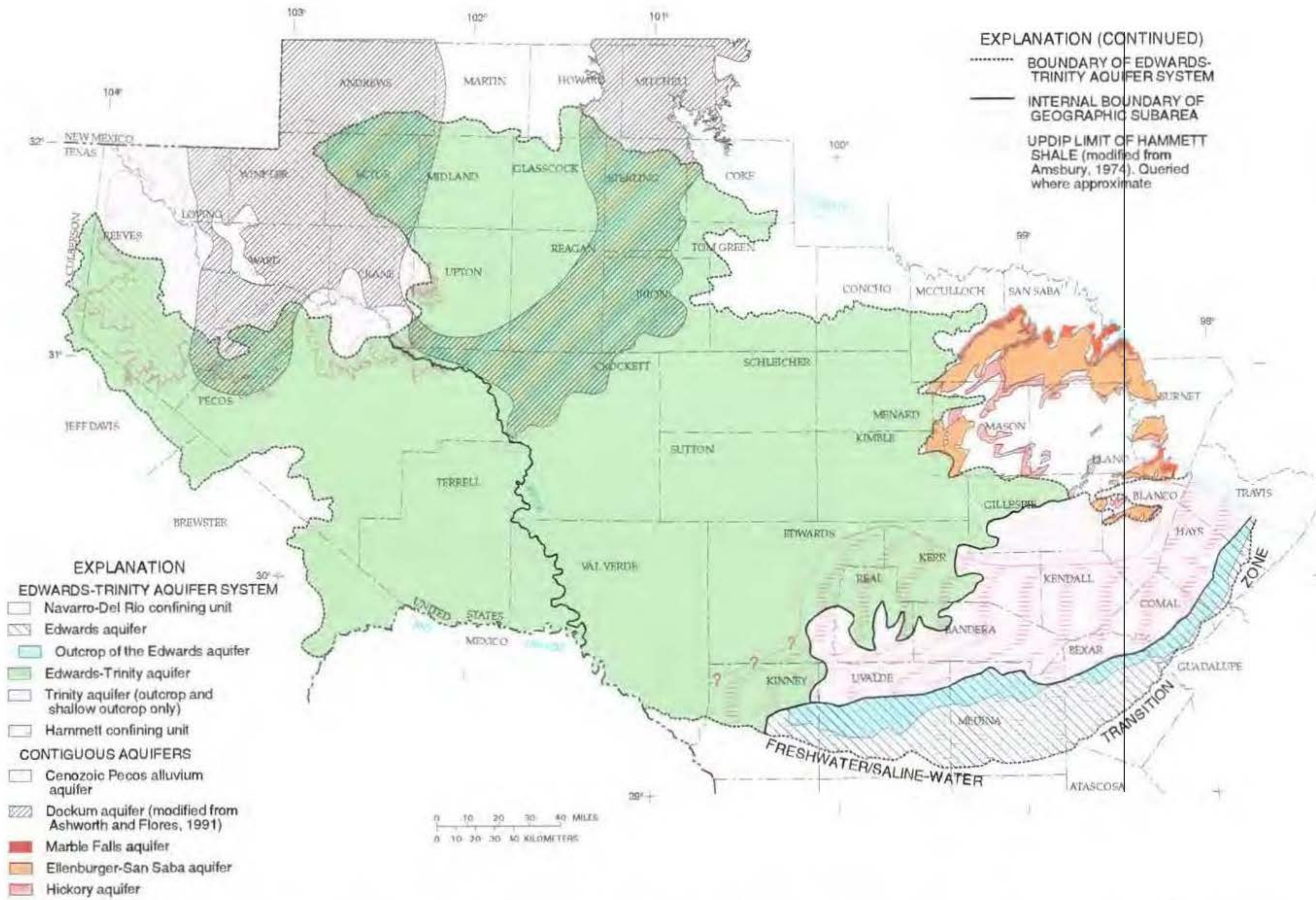


FIGURE 2.—Location of the aquifers and confining units in the Edwards-Trinity aquifer system and of contiguous major aquifers in west-central Texas.

The Edwards-Trinity aquifer system is overlain locally by the Del Rio Clay or Buda Limestone. Together, these relatively impermeable units comprise the lower 10 to 20 percent of the Navarro-Del Rio confining unit (fig. 2), which overlies the Edwards aquifer in the southeastern part of the study area. The base of the Edwards-Trinity aquifer system is formed of Paleozoic and Triassic rocks that mostly are impermeable (Barker and Ardis, 1992). Where adjacent Paleozoic and Triassic rocks are permeable, they form contiguous hydraulically connected units (fig. 1).

GEOGRAPHIC SETTING

The Edwards-Trinity aquifer system was divided into four geographic subareas (fig. 3), each of which is characterized by distinct physiographic, hydrologic, and geologic patterns. From largest to smallest, the subareas are the Edwards Plateau (24,000 mi^2); the Trans-Pecos (9,700 mi^2); the Hill Country (5,300 mi^2); and the Balcones fault zone south of the Colorado River (3,000 mi^2). (The Balcones fault zone south of the Colorado River is hereinafter referred to as Balcones fault zone.) The Edwards-Trinity aquifer extends throughout the Edwards Plateau and Trans-Pecos. The Trinity aquifer is the principal aquifer in the Hill Country, and the Edwards aquifer is the principal aquifer in the Balcones fault zone.

The Edwards Plateau (fig. 3) is a resistant carbonate-rock upland veneered with loose, thin soils atop nearly flat-lying limestone and dolostone. Caprock mesas, broad alluvial fans, and dry arroyos punctuate an otherwise nearly featureless plain. The topographic contours in figure 3 indicate a gradual northwest-to-southeast slope on the land surface, from altitudes of about 3,000 to 2,000 ft above sea level, and a steeper north-to-south gradient, from about 2,000 to 1,000 ft above sea level.

In contrast to interior parts of the Edwards Plateau, the eastern and southern margins of the Plateau are topographically rugged where high-velocity headwaters have cut narrow, steep-walled canyons into the carbonate terrain. Watercourses that are intermittent in the higher elevations of the Edwards Plateau evolve downstream into perennial streams, as their channels intersect the water table and gain base flow in the Hill Country (Kuniansky, 1989).

Most carbonate strata in the eastern part of the Edwards Plateau are Fredericksburg and Washita rocks that in the past were known collectively as "Edwards and associated limestones." Rose (1972) included these strata in the Edwards Group (pl. 1). The Edwards Group and its equivalents in the Trans-Pecos and western part of the Edwards Plateau are connected hydraulically to the underlying terrigenous clastic and carbonate sediments of Trinitian age. Thus, the name Edwards-Trinity aquifer was given to all Lower Cretaceous rocks in the Edwards Plateau and Trans-Pecos that, for the most part, are hydraulically continuous (Texas Water Development Board, 1990, fig. 1–1).

The Trans-Pecos lies west of the Pecos River (fig. 3). Southeast of Fort Stockton, in the Stockton Plateau (Fenneman, 1931, p. 47), the Trans-Pecos is an extension of the Edwards Plateau. Northwest of Fort Stockton, the Trans-Pecos occupies much of what Fenneman (1931, p. 48) called the Toyah basin, which is the southernmost part of the trough-like, alluvial-filled valley of the Pecos River. The Toyah basin is topographically flatter than the Stockton Plateau and is covered with alluvium that ranges in thickness from a few feet near the broad escarpment of the Stockton Plateau to several hundred feet near the northern limit of Cretaceous rocks. Thus, the Edwards-Trinity aquifer is exposed or only thinly covered in the southern part of the Trans-Pecos, and it is partly buried under a mantle of alluvial sediments of varying thickness in the northern part.

Land-surface altitudes in the Trans-Pecos decrease from nearly 5,000 ft in the foothills of mountains that bound the aquifer system on the west to about 1,100 ft near the confluence of the Pecos River and Rio Grande. The Pecos River and Rio Grande are the only perennial streams in the Trans-Pecos. Between the mountain front and the Pecos River, the land surface is characterized by intermittently flowing streams. From well-defined valleys in the western foothills, the intermittent streams descend onto gently sloping lowlands. The stream channels broaden into shallow arroyos as they leave the foothills and enter the alluvial-filled Toyah basin and nearly disappear as they approach the Pecos River (Armstrong and McMillion, 1961, p. 13–14). Valleys in the Stockton Plateau generally are defined most clearly where they cut through dense carbonate rock. Along the eastern and southern boundary of the Stockton Plateau, the Pecos River and Rio Grande flow through deep, narrow canyons with cliff-forming walls of massive limestone.

The streams originating along the southeastern margin of the Edwards Plateau and their downstream tributaries are largely responsible for the high topographic relief of the Hill Country (fig. 3). Headward erosion by southeast-flowing streams has stripped all but a few thin remnants of the Edwards Group and its stratigraphic equivalents from the Hill Country, exposing Trinity rocks at land surface; thus, "Trinity" was adopted for the name of the principal aquifer in the Hill Country (Texas Water Development Board, 1990, fig. 1–1). The Trinity aquifer is an extension of the lower part of the Edwards-Trinity aquifer of the Edwards

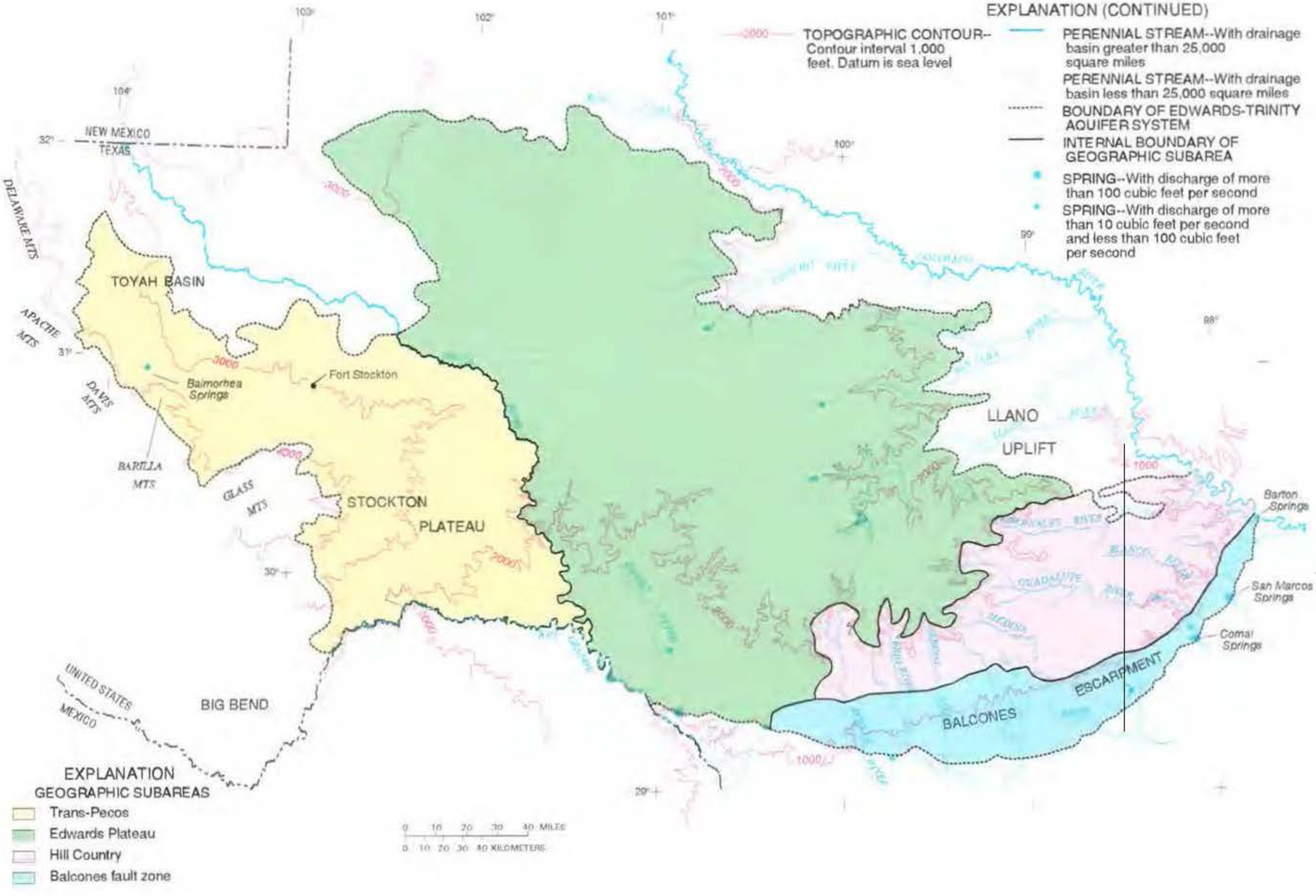


FIGURE 3.—Location of the geographic subareas of the Edwards-Trinity aquifer system and the major springs and perennial streams.

Plateau; the hydraulic properties of the two are similar, but the Edwards Group and its equivalents mostly are absent in the Hill Country. The boundary between the Edwards Plateau and the Hill Country was delineated from the outcrop configuration of the Trinity rocks (University of Texas, Bureau of Economic Geology, 1977; 1981a; 1983).

The major streams descend relatively steep gradients as they cut through the Hill Country. Many upgradient reaches are contained within deep, narrow canyons characterized by nearly vertical walls. Although most canyons broaden downstream into relatively flat-bottomed valleys, they typically retain nearly vertical walls. Attributing the widening of the steep-walled canyons to a condition known as "spring sapping," Fenneman (1931, p. 53) stated that the effect of spring discharge in the area was "*** to sap the strong rocks of the canyon walls which thereupon retreat and separate."

The Balcones fault zone, lying south and east of the Hill Country (fig. 3), is defined by an en echelon network of mostly down-to-the-southeast normal faults (fig. 4). The faults are most abundant across northern Medina, central Bexar, southern Comal, southern Hays, and central Travis Counties (Baker and others, 1986, fig. 2; Maclay and Small, 1986, fig. 3). These faults are the principal structural features of the study area, and they greatly influence the rate and direction of ground-water flow.

The gradual southeastward dip of the Cretaceous rocks in the Trans-Pecos, Edwards Plateau, and Hill Country is interrupted in the Balcones fault zone. Because of post-depositional subsidence and vertical displacement, the rocks in the Balcones fault zone dip more steeply than those elsewhere in the study area.

The Edwards Group, of Fredericksburgian and early Washitan ages, contains the most transmissive rocks in the study area and composes most of the Edwards aquifer in the Balcones fault zone. The rocks of Trinitian age, which are relatively impermeable and deeply buried in the fault zone, contribute little to the transmissivity of the fault zone.

The boundary between the Hill Country and the Balcones fault zone separates the area where the Trinity aquifer is the principal source of ground water from the area where the Edwards aquifer is the principal source. The boundary connects the updip edge of major faults that juxtapose rocks of Trinitian age on the west against the Edwards Group (or the stratigraphic equivalents of the Edwards Group) on the east. This delineation was based on fault locations mapped by the University of Texas, Bureau of Economic Geology (1974a; 1977; 1983), and was substantiated by potentiometric data (Kuniansky, 1990) and the relief on the base of the Edwards Group (G.E. Groschen, U.S. Geological Survey, written commun., 1988).

The boundary between the Edwards Plateau and the Balcones fault zone is somewhat arbitrary through east-central Kinney County (fig. 2). This segment of the boundary is intended to separate the area where the Edwards-Trinity aquifer is the principal aquifer from the area where the Edwards aquifer is the principal aquifer. This delineation was based on geophysical and transmissivity data.

The topography of the Balcones fault zone smooths gulfward from the Balcones escarpment, which approximately coincides with the 1,000-ft topographic contour (fig. 3). The Edwards aquifer crops out over much of the Balcones fault zone (figs. 2, 3). However, the downward displacement of the faulted strata and the steepening slope of the sediments above the Ouachita structural belt (figs. 5, 6) cause the Edwards aquifer to be hydraulically confined and progressively more deeply buried beneath the Navarro-Del Rio confining unit southeast of the outcrop area.

The broad stream valleys in downgradient parts of the Hill Country narrow where the streams enter the Balcones fault zone and flow onto the relatively permeable Edwards Group (Wermund and Woodruff, 1977, p. 342). The streams leak appreciable amounts of water to the Edwards aquifer as they flow over the intensively faulted outcrop area of the Edwards Group. Hydraulic heads in confined parts of the Edwards aquifer mostly are above land surface near the freshwater/saline-water transition zone, resulting in several large springs that discharge from downgradient parts of the freshwater-flow system. Comal and San Marcos Springs (fig. 3) discharge at rates that average more than 100 ft^3/s.

Precipitation over the Edwards-Trinity aquifer system averaged about 20 in/yr during 1951–80 (Riggio and others, 1987, fig. 11). During this time, precipitation averaged about 28 in/yr over the Balcones fault zone, about 30 in/yr over the Hill Country, about 19 in/yr over the Edwards Plateau, and about 13 in/yr over the Trans-Pecos. The distribution of perennial streams (fig. 3) attests that considerably more precipitation falls on the eastern part of the aquifer system than on the western part. The rising topography and increasing distance from the Gulf of Mexico (the principal source of moisture) cause the average annual precipitation to decrease from east to west (Carr, 1967, p. 2). Moisture-laden air from the Gulf cools and releases precipitation as the air masses progress inland. The rising, relatively rugged terrain north of the Balcones escarpment makes the orographic effect on precipitation especially evident over the Hill Country.

May and September generally are the months of greatest precipitation in the Balcones fault zone, Hill

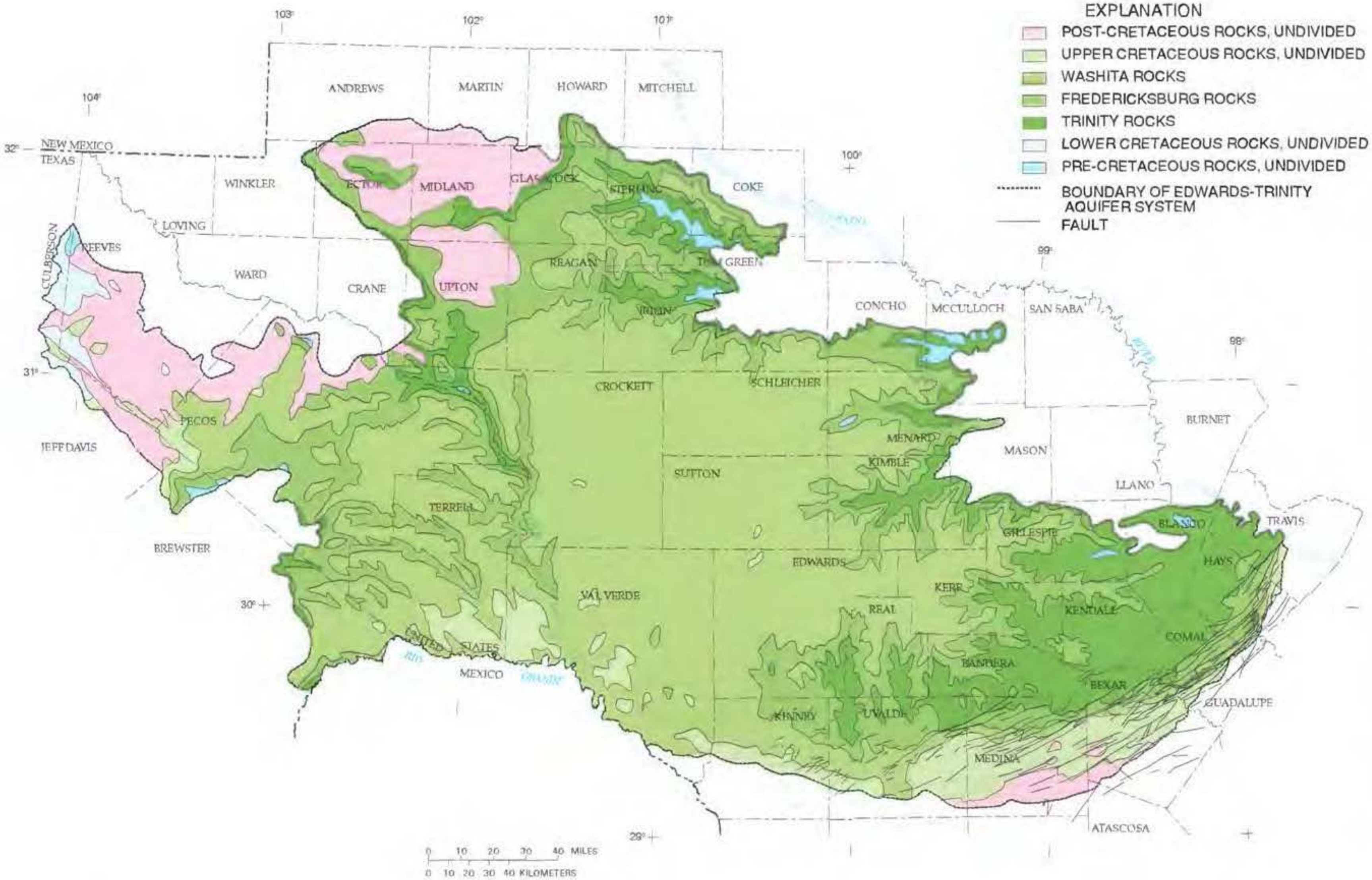


FIGURE 4.—Location of the outcrop and shallow subcrop of rocks in the area of the Edwards-Trinity aquifer system. (Modified from King and Biekman, 1974.)

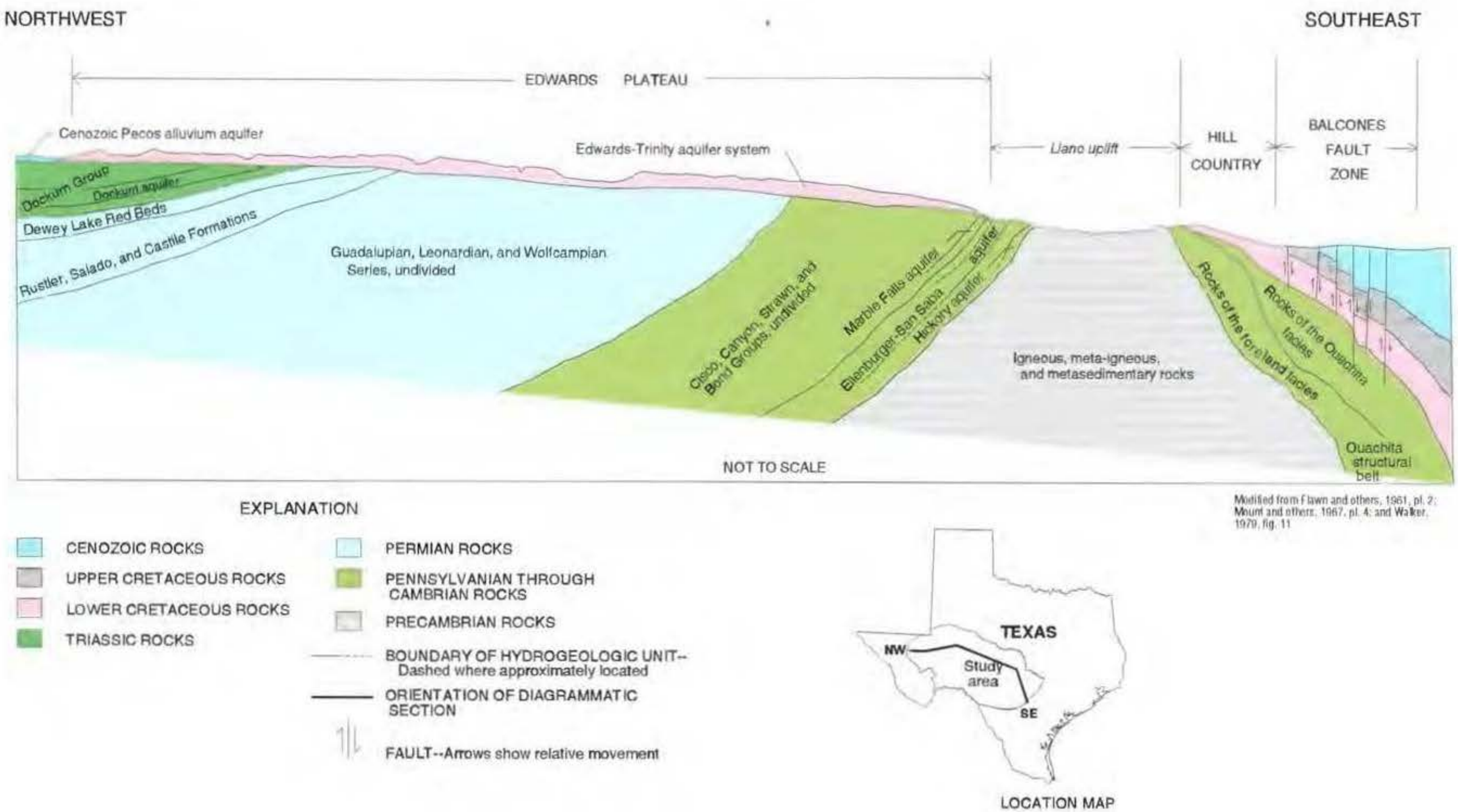


FIGURE 5.—Generalized relation between the Edwards-Trinity aquifer system and the pre-Cretaceous rocks and hydrogeologic units that form the base of the system.

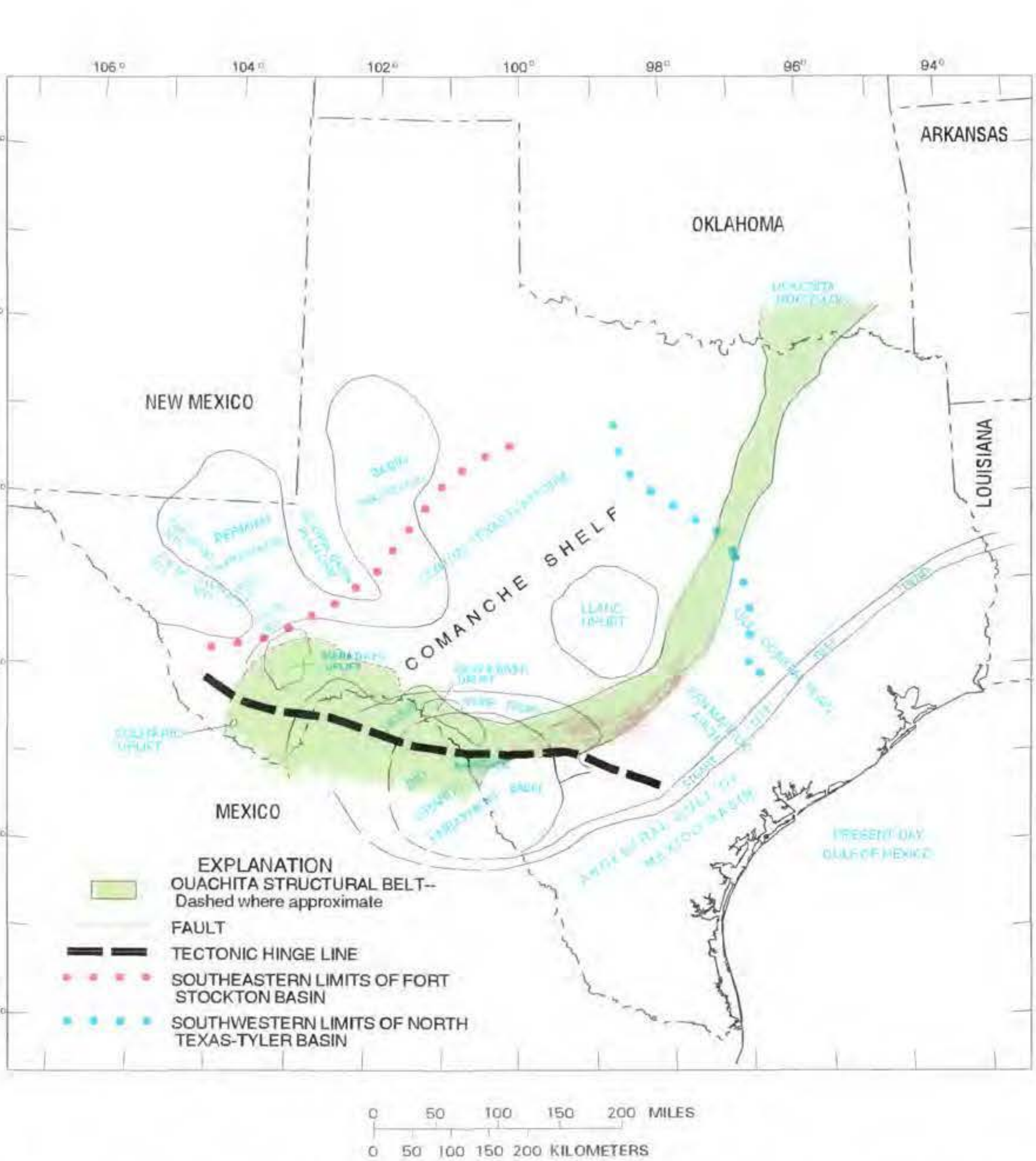


FIGURE 6.—Paleogeographic and structural features in west-central Texas and parts of adjacent States and northern Mexico.

Country, and Edwards Plateau. Precipitation in the Trans-Pecos is infrequent and typically limited to small areas, and primarily results from convective showers and thunderstorms in July, August, and September (Carr, 1967, p. 14; Linsley and others, 1975, p. 61).

PREVIOUS WORK AND ACKNOWLEDGMENTS

Previous reports on the hydrogeology of west-central Texas generally cover less area than the regional scale of the RASA project. Therefore, interpretations and descriptions in this report were synthesized from the published results of several agencies, companies, and institutions—in addition to the unpublished records of a few individuals. Chief contributors of the published data used in this report are the U.S. Geological Survey, the Bureau of Economic Geology of the University of Texas at Austin, and the former Texas Department of Water Resources (TDWR)—now separated into the Texas Water Development Board (TWDB) and the Texas Natural Resource Conservation Commission (TNRCC).

TABLE 1.—*Carbonate-rock classification systems adapted from Dunham (1962) and Folk (1962)*

<table>
<tr><th colspan="6">Carbonate-rock classification system from Dunham (1962)</th></tr>
<tr><th colspan="5">DEPOSITIONAL TEXTURE RECOGNIZABLE</th><th rowspan="5">DEPOSITIONAL TEXTURE NOT RECOGNIZABLE</th></tr>
<tr><td colspan="4">Original components not bound together during deposition</td><td rowspan="4">Original components were bound together during deposition...as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.</td></tr>
<tr><td colspan="3">Contains mud (particles of clay and fine silt size)</td><td rowspan="3">Lacks mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>Less than 10 percent grains</td><td>More than 10 percent grains</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td><td>Crystalline carbonate
(Subdivide according to classifications designed to bear on physical texture or diagensis.)</td></tr>
</table>

<table>
<tr><th colspan="9">Carbonate-rock classification system from Folk (1962)</th></tr>
<tr><th></th><th colspan="4">MORE THAN 2/3 LIME MUD MATRIX</th><th rowspan="2">SUB-EQUAL SPAR AND LIME MUD</th><th colspan="3">MORE THAN 2/3 SPAR CEMENT</th></tr>
<tr><td>Percent allochems</td><td>0–1 percent</td><td>1–10 percent</td><td>10–50 percent</td><td>More than 50 percent</td><td>Sorting poor</td><td>Sorting good</td><td>Rounded and abraded</td></tr>
<tr><td>Representa-tive rock terms</td><td>Micrite and dismicrite</td><td>Fossilif-erous micrite</td><td>Sparse biomicrite</td><td>Packed biomicrite</td><td>Poorly washed biosparite</td><td>Unsorted biosparite</td><td>Sorted biosparite</td><td>Rounded biosparite</td></tr>
<tr><td>1959 terminology</td><td>Micrite and dismicrite</td><td>Fossilif-erous micrite</td><td colspan="2">Biomicrite</td><td colspan="4">Biosparite</td></tr>
</table>

Publications of the American Association of Petroleum Geologists and the Geological Society of America and some unpublished dissertations and theses from the University of Texas (at Austin and at Arlington) also were useful. The carbonate-rock terminology used in this report (table 1) is based on classification procedures recommended by Dunham (1962) and Folk (1962).

Much of the geologic information on the western and southern parts of the study area was summarized for this report from unpublished data provided by Dr. C.I. "Ike" Smith, former Chairman of the Department of Geology at the University of Texas at Arlington. The authors are greatly indebted to Dr. Smith for his enthusiastically shared knowledge about the Cretaceous rocks of southwestern Texas and northern Mexico.

GEOLOGIC SETTING

DEPOSITIONAL, TECTONIC, AND DIAGENETIC CONDITIONS

The depositional, tectonic, and diagenetic conditions that characterize the rocks that form the Edwards-Trinity aquifer system are strikingly different from those of the underlying, comparatively impermeable pre-Cretaceous rocks. The typically medium- to thin-bedded Cretaceous strata of the aquifer system mostly dip southeastward atop generally massive, westward-dipping Paleozoic and Triassic units (fig. 5). The unconformity between the Cretaceous rocks of the aquifer system and the pre-Cretaceous complex (Barker and Ardis, 1992) marks a major shift in the geologic evolution of the study area. This hiatus in the rock record spans about 60 million years of crustal warping and erosion between the deposition of terrestrial red beds during Late Triassic time and the deposition of terrigenous clastic and shallow-marine carbonate sediments during Early Cretaceous time. The following discussion summarizes the geologic history of the pre-Cretaceous rocks upon which the Cretaceous seas encroached and reconstructs the depositional, tectonic, and diagenetic activity from the beginning of the Cretaceous Period to the present. The discussion is limited to processes affecting the hydrology of the Edwards-Trinity aquifer system.

PRE-CRETACEOUS HISTORY

The pre-Cretaceous geologic history of west-central Texas was dominated by (1) an elongated depositional trough called the Ouachita geosyncline, (2) land masses located south and east of the geosyncline that were the primary sources of clastic sediment, and (3) shallow inland seas over a stable continental foreland located north and west of the geosyncline. From southeastern Oklahoma, the Ouachita geosyncline extended around the southeastern and southern margins of the Llano and Devils River uplifts to the southeastern and eastern margins of the Marathon and Solitario uplifts (fig. 6). The Llano and Devils River uplifts were resistant promontories of Precambrian crystalline rock on the southern margin of ancestral North America. The geosyncline might have resulted from subduction associated with the ancestral (pre-Gulf of Mexico) positioning of the North American and Afro-South American continental plates (Walper and Miller, 1985). Presently, the Ouachita geosyncline is represented by the mostly buried Ouachita structural belt (Flawn and others, 1961).

While the coarsest Paleozoic deposits accumulated in the Ouachita geosyncline, comparatively fine-grained deposits of mostly organic and chemical origin formed in the foreland area (Sellards, 1935, p. 18). During the 400 million years preceding Late Cambrian sedimentation, uplift and erosion prevailed over deposition (Flawn, 1956). During the Late Cambrian through Mississippian time, about 5,000 ft of mostly carbonate strata formed in the foreland area atop an unevenly eroded surface of folded and faulted Precambrian rocks. Intermittent pulses of uplift and volcanic activity maintained prominent land areas along the cratonic margins of the geosyncline, which provided the subsiding trough with coarse, largely quartzose clastic sediments. Deposition rates quickened during the Pennsylvanian Period, and this faster rate of sedimentation continued through Early Permian time. More than 5,000 ft of marine sandstone, limestone, and shale accumulated in the foreland area during Pennsylvanian through Early Permian time. The geosynclinal deposits continued to subside rapidly through most of this time and reached depths of more than 20,000 ft before succumbing to orogeny.

The Ouachita orogeny climaxed between Late Pennsylvanian and Early Permian time, when the geosynclinal deposits were uplifted, thrust faulted, and intensively folded into a Late Paleozoic mountain range. The mountains extended from Mississippi, through the Ouachita Mountains of Arkansas and Oklahoma, to the Marathon and Solitario uplifts of Texas. Sediments in the Ouachita geosyncline underwent incipient to low-grade metamorphism, with strong shearing and hydrothermal effects, as the Paleozoic rocks were thrust northward (Flawn and others, 1961). The Llano and Devils River uplifts were resistant buttresses against which the Ouachita facies were thrust. Intervening rocks of the foreland facies were sheared and folded (Webster, 1980), which created petroleum traps and some of the most productive oil and gas reservoirs in the world. Interior parts of the Ouachita facies were altered to marble, phyllite, schist, slate, or related products of heat and pressure.

During the waning stages of the Ouachita orogeny, the Permian Basin (fig. 6) developed in west Texas beneath a broad, shallow sea. The sea became increasingly saline as the basin became more isolated from the open ocean about the middle of Late Permian time, a time of intense aridity (King, 1942, p. 711–763). Detrital influx to the Permian Basin eventually ceased and the predominate sediments became gypsum, anhydrite, halite, and potash. Following uplift and erosion toward the end of Late Permian time, the connection between the Permian Basin and open ocean improved and the highly saline water was gradually replaced by fresher seawater. Fine-grained clastic sediments (probably eroded from slightly higher areas to the south, west, and north) were deposited as a relatively thin red-bed unit above the older evaporitic strata. The sea withdrew from the Permian Basin as West Texas was uplifted at the close of the Paleozoic Era.

The withdrawal of the Permian sea was followed by long periods of nondeposition, crustal warping, and erosion during Early through Middle Triassic time. As uplift continued in the Llano area and erosion planed down the central basin platform (fig. 6), a closed continental basin formed over much of west-central Texas and eastern New Mexico. During Late Triassic time, Paleozoic rocks were eroded from the surrounding high ground and redeposited in low-lying fluvial, deltaic, and lacustrine environments as red beds of the Dockum Group (McGowen and others, 1979, p. 6).

West-central Texas was above sea level during most of the Jurassic Period. During this time, the landscape was tilted toward the southeast and eroded to a rolling peneplain. The Wichita Paleoplain, as it was named by Hill (1901), was characterized by broad river valleys and low ridges of resistant rocks. The ancestral Ouachita Mountains were deeply eroded across central Texas and the remnants subsided rapidly as the Gulf of Mexico began to open (Flawn, 1964, p. 271–274). The continental interior tilted southeastward across the subsiding Ouachita structure, causing a reversal in the direction of surface drainage. The reversal in drainage, which might have begun late in the Permian Period, was completed by the end of the Jurassic Period. Accordingly, the earlier pattern of northwestward drainage toward a closed continental basin was superseded by southeastward drainage toward a westward-advancing Cretaceous sea (Sellards, 1933, p. 24).

CRETACEOUS PERIOD

Rifting and subsidence in the ancestral Gulf of Mexico basin (fig. 6) continued into the Cretaceous Period (Wood and Walper, 1974). A broad continental shelf nearly encircled the basin, bridging the Yucatan Peninsula of Mexico and southern parts of Texas, Louisiana, Mississippi, Alabama, and Florida with the Bahama Islands (Bebout and Loucks, 1974, p. 2). The Cretaceous strata of the Edwards-Trinity aquifer system (pl. 1) formed atop, and landward of, this continental shelf. While alluvial plains inland of a westward-advancing Comanchean sea were dominated by clastic deposition, shallow offshore environments—characterized by warm, generally clear seawater—promoted the biogenic accumulation of calcium carbonate. Comparatively deep, open-shelf environments subsequently supported the widespread deposition of mostly calcareous Gulf strata.

Although during Trinitian time the Llano uplift was an imposing structural feature on an otherwise rolling peneplain composed of folded and faulted pre-Cretaceous rocks, its importance decreased throughout the remainder of the Cretaceous Period. By Fredericksburgian time, the uplift had been eroded to such a low altitude that it contributed little sediment. However, the Llano uplift (together with the San Marcos arch) remained high enough to keep depositional environments in the Maverick basin isolated from those in the north Texas-Tyler basin (fig. 6) through most of Washitan time. The Llano uplift subsequently was buried by more than 1,000 ft of Upper Cretaceous (mostly Gulfian) strata.

Comanchean Epoch: Trinitian Age

Subsidence in the ancestral Gulf of Mexico basin (fig. 6), coupled with eustatic rises in sea level, caused the Early Cretaceous sea to advance westward over an eroded, uneven surface of pre-Cretaceous rocks (fig. 7). Islands of Precambrian metamorphic and igneous rocks and Paleozoic sedimentary rocks stood high on the Llano uplift and shed clastic debris into the encroaching Trinitian sea (Stricklin and others, 1971, p. 7). The Trinity rock record indicates a cyclic pattern of shoreline advance and retreat, superimposed upon an overall pattern of marine transgression. The transgressions were interrupted occasionally by short-lived regressions, which left comparatively little sediment. The regressions probably were triggered by a lowering of sea level, decreasing rates of subsidence, increases in the supply of clastic sediment from rising inland source areas, or some combination of these conditions (McFarlan, 1977, p. 10). The lateral and vertical distributions of the Trinity rock units (pl. 1) are shown in figures 8 and 9, respectively.

The gradational nature of the Trinity rock record is indicated on the southern flank of the Llano uplift (fig. 8), where basal terrigenous deposits overlap pre-Cretaceous rocks (fig. 9, *H–H′*) and grade upward into carbonate sediments. From less than 150 ft thick near the Llano uplift, the Trinity rock sequence thickens downdip to more than 1,000 ft thick in the Balcones fault zone. The wedge-like Trinity rock units are diachronous (time-transgressive) toward the Llano uplift, which largely controlled the structural setting and depositional environments during Trinitian time.

The Trinity rocks in the study area were deposited during three major transgressive-regressive cycles of sedimentation. Stricklin and others (1971) regarded the rock record of each cycle as a "clastic-carbonate couplet" characterized by terrigenous clastic deposits on the bottom and marine carbonate sediments on top. Each couplet documents a major advance of the Early Cretaceous sea, terminated by an overall drop in sea level or a dynamic equilibrium between the land and sea. The couplets are separated by disconformities and generally onlap rocks of the previous cycle. From oldest to youngest, the couplets are composed of (1) the Sycamore Sand (Hosston Formation, downdip) and Sligo Formation; (2) the Hammett Shale (Pine Island Shale Member of the Pearsall Formation, downdip) and Cow Creek Limestone (Cow Creek Limestone Member, downdip); and (3) the Hensel Sand (Bexar Shale Member, downdip) and Glen Rose Limestone.

While aggrading streams deposited detrital sand and gravel of the Sycamore Sand on the southern flank of the Llano uplift (Inden, 1974), calcareous mud and silt of the Hosston Formation (Bebout and others, 1981) accumulated offshore in a transgressing sea. Dolomitic siltstone and rhythmically bedded mudstone of the Sligo Formation (Stricklin and others, 1971) were

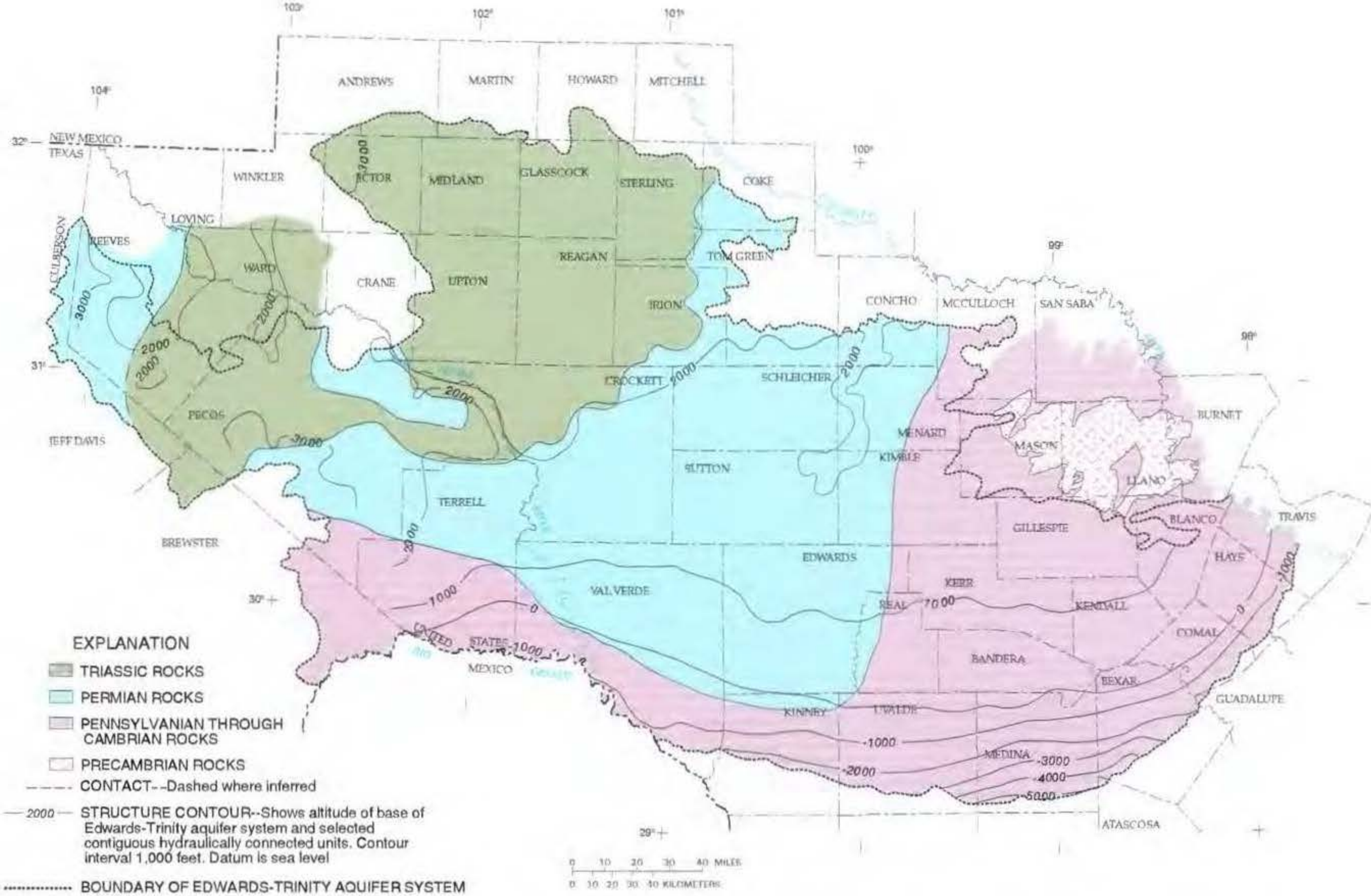


FIGURE 7.—Chronology and configuration of the rocks that form the base of the Edwards-Trinity aquifer system and selected contiguous hydraulically connected units. (Modified from Barker and Ardis, 1992.)

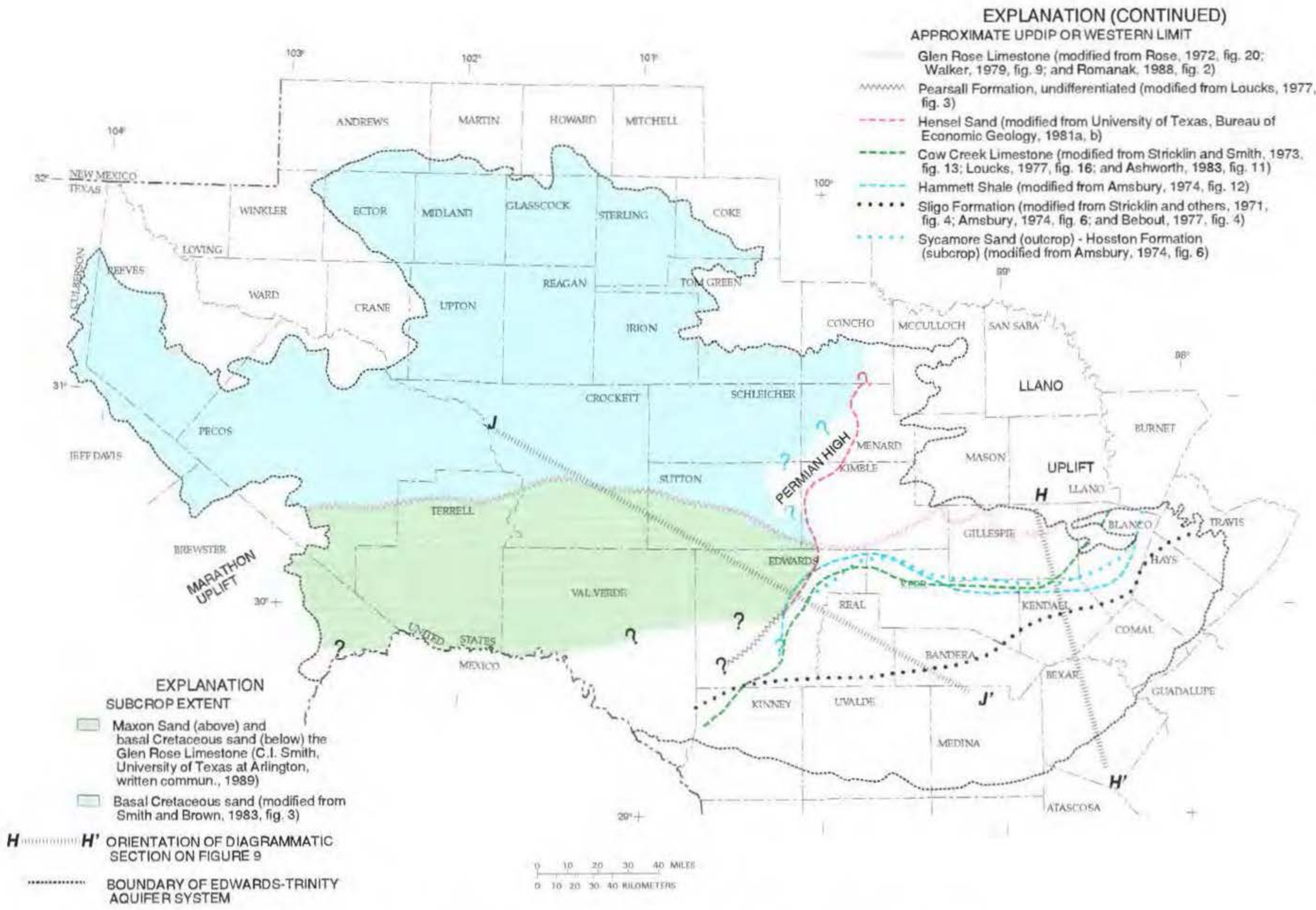
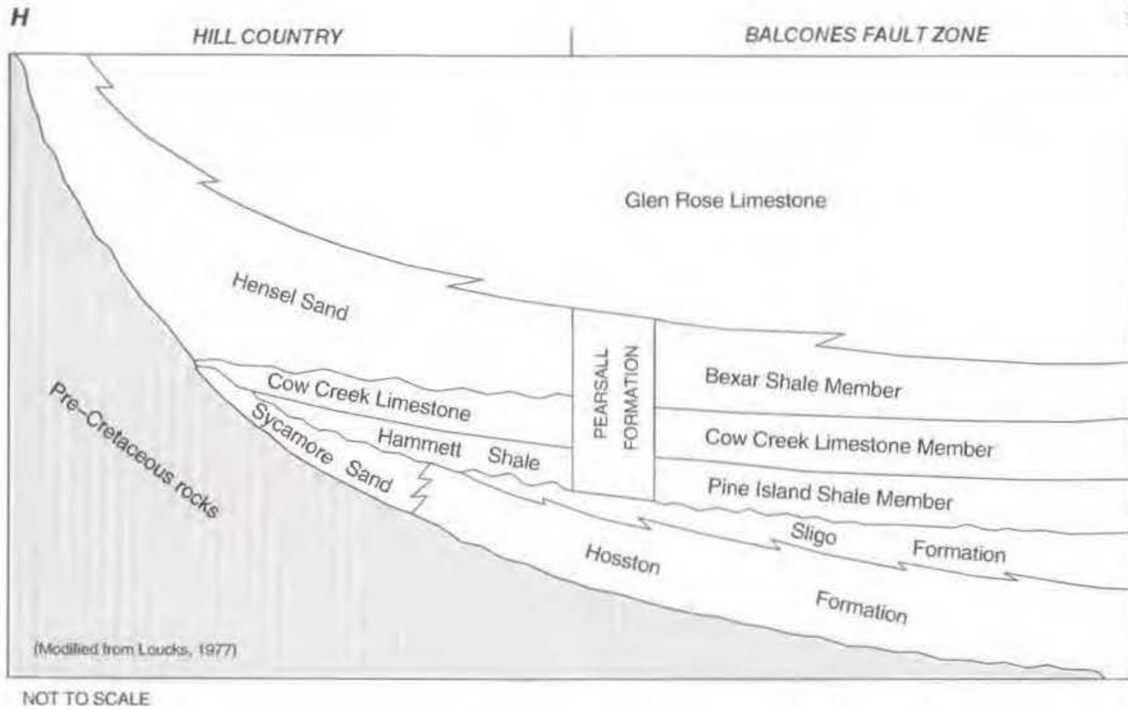


FIGURE 8.—Lateral distribution of Trinity rock units in west-central Texas.



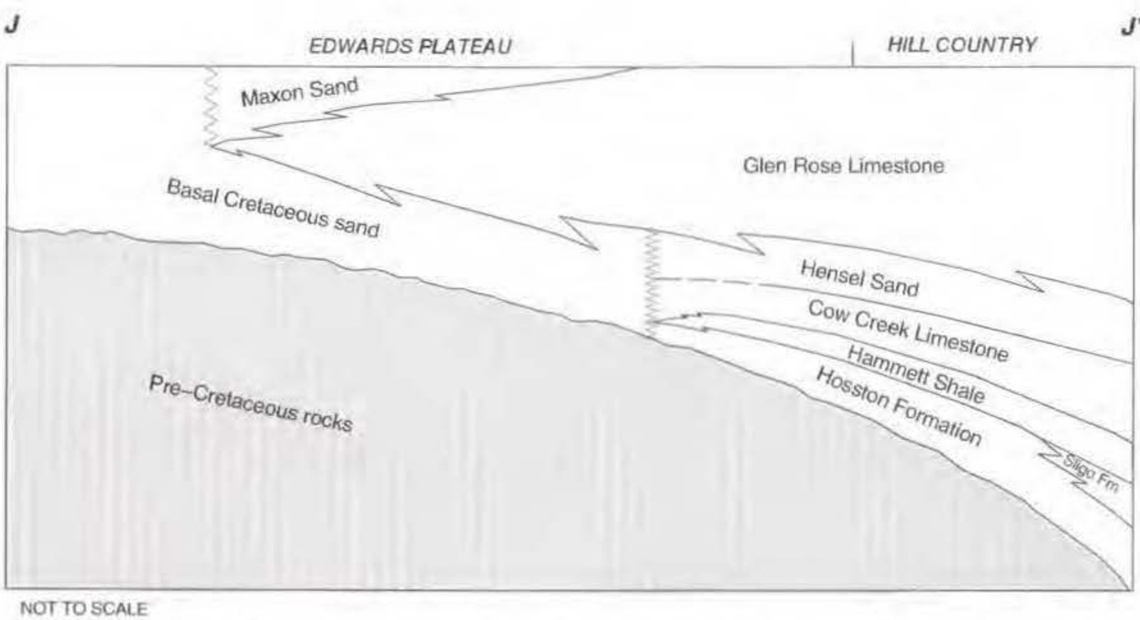


FIGURE 9.—Vertical distribution of Trinity rock units in west-central Texas and their relation to geographic subareas. (See fig. 8 for orientation of diagrams.)

deposited above the Hosston Formation in a mostly regressive lower Trinity sea whose shoreline approached but never reached the updip limit of Sycamore Sand (fig. 8).

Following a period of sea level lowering and subaerial exposure, the middle Trinity sea rapidly transgressed inland over deeply weathered and eroded surfaces of Sligo Limestone and Sycamore Sand and deposited the argillaceous Hammett Shale (Stricklin and others, 1971, p. 14). The Hammett Shale and its downdip equivalent, the Pine Island Shale Member of the Pearsall Formation, mostly were deposited in an unusually quiet body of seawater, such as a broad lagoon or open embayment, where water salinities ranged from normal marine to brackish (Amsbury, 1974, p. 22). Carbonate sedimentation dominated during deposition of the Hammett Shale, as the production of carbonate mud increased and the influx of clastic detritus decreased.

The Cow Creek Limestone formed as mostly high-energy, beach-dominated environments prograded seaward from the Llano uplift (Stricklin and Smith, 1973). Depositional conditions were controlled principally by a shelf profile that steepened prior to Cow Creek deposition and a regressive sea that persisted through the end of middle Trinitian time. Lower parts of the Cow Creek Limestone appear to have been deposited offshore under gradually shoaling conditions. Coquina in the upper parts are thought to have formed within a shoreline reentrant, where mollusk shells furnished by slackened longshore currents were sorted by waves refracted against the curved shoreline of the reentrant (Stricklin and Smith, 1973). High-gradient streams transported Precambrian igneous and metamorphic detritus and Paleozoic sedimentary rock fragments from the Llano uplift to the shoreline, where they mixed with the shell debris and extended the land area. As the reentrant filled and the shoreline stabilized, upper parts of the beach became subaerially exposed. An irregular topography and pockets of caliche developed atop parts of the Cow Creek Limestone, as unconsolidated sediments were redistributed by the wind and storm waves, and infiltrating meteoric water leached carbonate surfaces.

Further subsidence initiated the third and final major transgression of the Trinity sea. The Bexar Shale Member of the Pearsall Formation (Forgotson, 1957, p. 2,347) was deposited as a mixture of terrigenous clastic and marine carbonate sediments in the "fine-grained distal part" of a deltaic system that prograded seaward from the Llano uplift (Loucks, 1977, p. 106). The Hensel Sand formed in the updip part of this system, where alluvial fans on the flanks of the Llano uplift coalesced into a low-lying coastal plain. The coastal plain merged on the south and east with the shallow-marine environment of the Bexar Shale. The basal Cretaceous sand (Romanak, 1988) formed west of the Llano uplift (fig. 8), where typically it amassed as a sprawling, braided stream deposit atop an eroded surface of pre-Cretaceous rocks (fig. 9, *J–J′*).

As sandy red beds of the updip Hensel Sand formed in terrestrial settings around the Llano uplift, the Glen Rose Limestone accumulated to the southwest (above the basal Cretaceous sand) and south (above the Bexar Shale) in low-energy, shallow-marine environments. During early Glen Rose time, rudist reefs and biostromes flourished in pockets of well-circulated water of less-than-normal salinity (Perkins, 1974; Petta, 1977). The reef structures vanished as hypersaline conditions dominated late Glen Rose time in response to reduced water circulation and increased aridity (Stricklin and Amsbury, 1974). The upper member of the Glen Rose Limestone mostly formed in restricted environments dominated by broad tidal flats in the lee of an incipient Stuart City reef trend (fig. 6) that began to build along the shelf edge during middle to late Trinitian time.

The rate of regional subsidence during middle to late Trinitian time was greatest toward the south. As a result, the Glen Rose Limestone is more than three times as thick in southern Kinney County as in central Sutton County (pl. 6). Jager (1942, p. 384) attributed this southward thickening to the rapid sinking of the Rio Grande embayment (fig. 6). Trinity rocks in the study area were deposited over the northern flank of the Rio Grande embayment (Murray, 1961, p. 128).

The sea withdrew from the study area during late Trinitian time. As the shoreline receded toward the south and east, the carbonate-producing marine environments of the Glen Rose Limestone were replaced in the southwestern part of the study area by a fluvial-deltaic system that deposited the Maxon Sand (King, 1980, p. 21). While sandy and silty red beds of the Maxon Sand accumulated atop the Glen Rose Limestone between southern Pecos County and central Edwards County (fig. 8), the upper part of the Glen Rose Limestone mostly was exposed as a broad tidal mudflat east of Edwards County. The evaporites and thin beds of dolomitic and marly limestone that formed upon the mudflat were dominated by consolidation, cementation, and weathering (Lozo and Smith, 1964, p. 291). (Mud cracks, algal structures, ripple marks, dinosaur tracks, and clam borings characteristic of the depositional settings are preserved near the top of the Glen Rose Limestone.) The shoreline receded at the end of Trinitian time to a position parallel to and slightly north of the present-day Balcones fault zone.

Comanchean Epoch: Fredericksburgian and Washitan Ages

By early Fredericksburgian time, an offshore bioherm of rudists, corals, and calcareous sediment had grown to an almost continuous reef-island ridge along the seaward edge of the continental shelf in the ancestral Gulf of Mexico basin (Bebout and Loucks, 1974, p. 6). This shelf margin ridge, called the Stuart City reef trend (Winter, 1962), extended from northern Mexico across nearly 500 mi of southeastern Texas (fig. 6). The aggressive upward growth of the Stuart City reef trend during Fredericksburgian through most of Washitan time probably resulted from an abrupt rise in sea level that might have been triggered by an increase in the rate of sea-floor spreading (Bay, 1977, p. 17).

The Stuart City reef trend sheltered depositional environments in the study area from storm waves and deep ocean currents in the ancestral Gulf of Mexico. While water depths exceeded 1,000 ft in the basin, they ranged from a few feet to generally less than 100 ft on the carbonate platform upon which the rocks of the Edwards-Trinity aquifer system formed. While dark, argillaceous sediments characterized by planktonic foraminifera accumulated basinward in reducing environments, calcareous strata containing warm-water organisms formed in shallow-marine environments on the carbonate platform (Bebout and Loucks, 1974, p. 2–6). Evaporitic and dolomitic strata formed upon tidal flats, which occupied the higher elevations of the carbonate platform and frequently were subjected to subaerial exposure, oxidation, and erosion.

The Fredericksburg and lower Washita strata of west-central Texas were deposited landward of the Stuart City reef trend, largely on a part of the continental shelf known as the Comanche shelf (Rose, 1972). According to C.I. Smith (University of Texas at Arlington, written commun., 1989), depositional environments on the Comanche shelf were controlled by the (1) distribution and rates of subsidence and uplift, (2) influx of fine-grained terrigenous sediment, and (3) extent of water circulation, or degree of restriction relative to that of the open sea. The resulting lithofacies determine the stratigraphy and, together with the effects of post-depositional tectonics and carbonate diagenesis, the hydraulic characteristics of rocks that compose the Edwards-Trinity aquifer system.

Structural features of the Comanche shelf that most strongly affected Fredericksburg and Washita deposition are shown in figures 6 and 10. The lateral and vertical distributions of the resulting rock units are shown in figures 11 and 12, respectively.

The central Texas platform was an elongated mound on the Comanche shelf (figs. 6, 10) that extended from northwest of the Llano uplift to approximately the San Angelo area (fig. 11). The San Marcos arch, a somewhat narrower structural high, extended southeast from the Llano uplift to the Stuart City reef trend. By early Fredericksburgian time, the most prominent parts of the Llano uplift probably had been eroded to a few low-standing islands in the Cretaceous sea. However, because the Llano uplift bridged the central Texas platform and San Marcos arch, depositional environments in the study area generally were isolated from those of north Texas. The Maverick basin, which today straddles the boundary between Texas and Mexico, was a semicircular depression along the southern margin of the Comanche shelf. The Devils River trend, a narrow carbonate bank composed largely of rudists and reef debris, developed around the northern and western margins of the Maverick basin during middle Fredericksburgian through early Washitan time. The Devils River trend, together with the Stuart City reef trend, virtually surrounded the Maverick basin, which contributed to the uniqueness of the lithofacies that formed inside the basin. The Fort Stockton basin was a slowly subsiding marine embayment extending from northern Mexico across the northwestern part of the Comanche shelf.

During Fredericksburgian through early Washitan time, the central Texas platform (figs. 6, 10) was dominated by supratidal, intertidal, and restricted shallow-marine depositional environments (fig. 13). During periods of especially low sea level and extreme aridity, the crest of the central Texas platform became a broad, sabkha-type mudflat where evaporites, dolostone, and thin-bedded dolomitic limestone were deposited (Fisher and Rodda, 1966). Comparatively thick-bedded, rudist-bearing, bioclastic carbonate strata were deposited concurrently on the southwestern flank of the central Texas platform in mostly open shallow-marine to open-shelf environments. Here, the water typically was deeper and the circulation generally was less restricted than in the tidal flat environments that prevailed over the crest of the central Texas platform. Marly carbonate strata were deposited at this time in the Fort Stockton basin, an open-marine embayment of moderately deep, quiet water.

The eastern part of the Fort Terrett Formation and the Segovia Formation (Rose, 1972) formed near the crest of the central Texas platform mostly in supratidal to restricted shallow-marine environments. The western part of the Fort Terrett Formation and the Fort Lancaster Formation (Scott and Kidson, 1977) formed mostly in open shallow-marine to open-shelf environments transitional to those on the central Texas platform and in the Fort Stockton basin.

The Finlay Formation, a cliff-forming limestone with quartz sand in the lower part and rudists in the upper part (Reaser and Malott, 1985), formed in the Fort Stockton basin during Fredericksburgian time—when the basin primarily was a shallow, open lagoon. The Boracho Formation (Brand and Deford, 1958) was deposited later in a deeper, shelf-basin environment that received fine-grained terrigenous sediment from west of the study area (fig. 13). The fine-grained, siliciclastic nature of the Boracho Formation inhibited the precipitation of calcium carbonate and growth of rudists in the Fort Stockton basin during Washitan time (C.I. Smith, University of Texas at Arlington, oral commun., 1989).

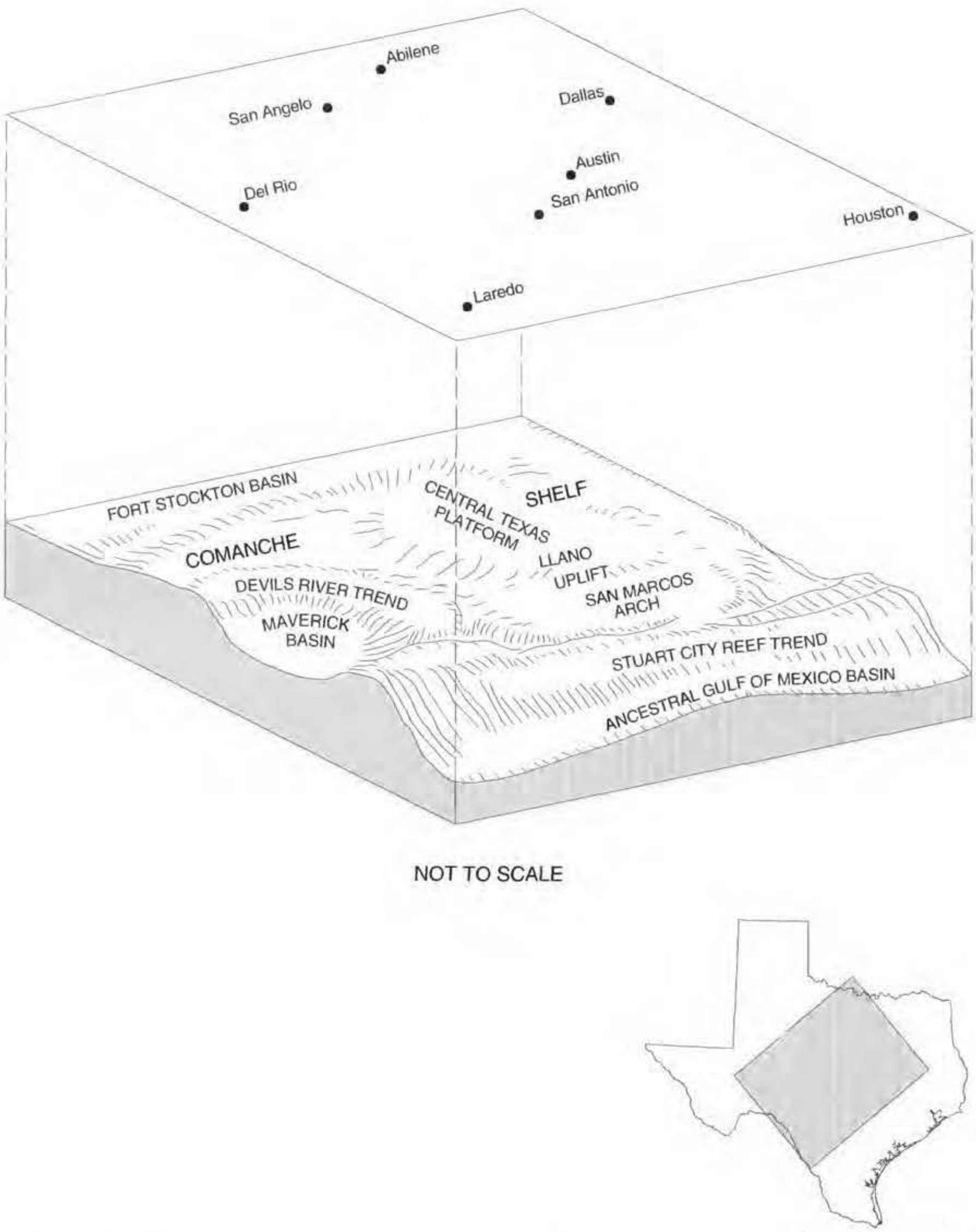


FIGURE 10.—Structural controls on the deposition of Fredericksburg and Washita strata of the Edwards-Trinity aquifer system. (Modified from Rose, 1972, fig. 2.)

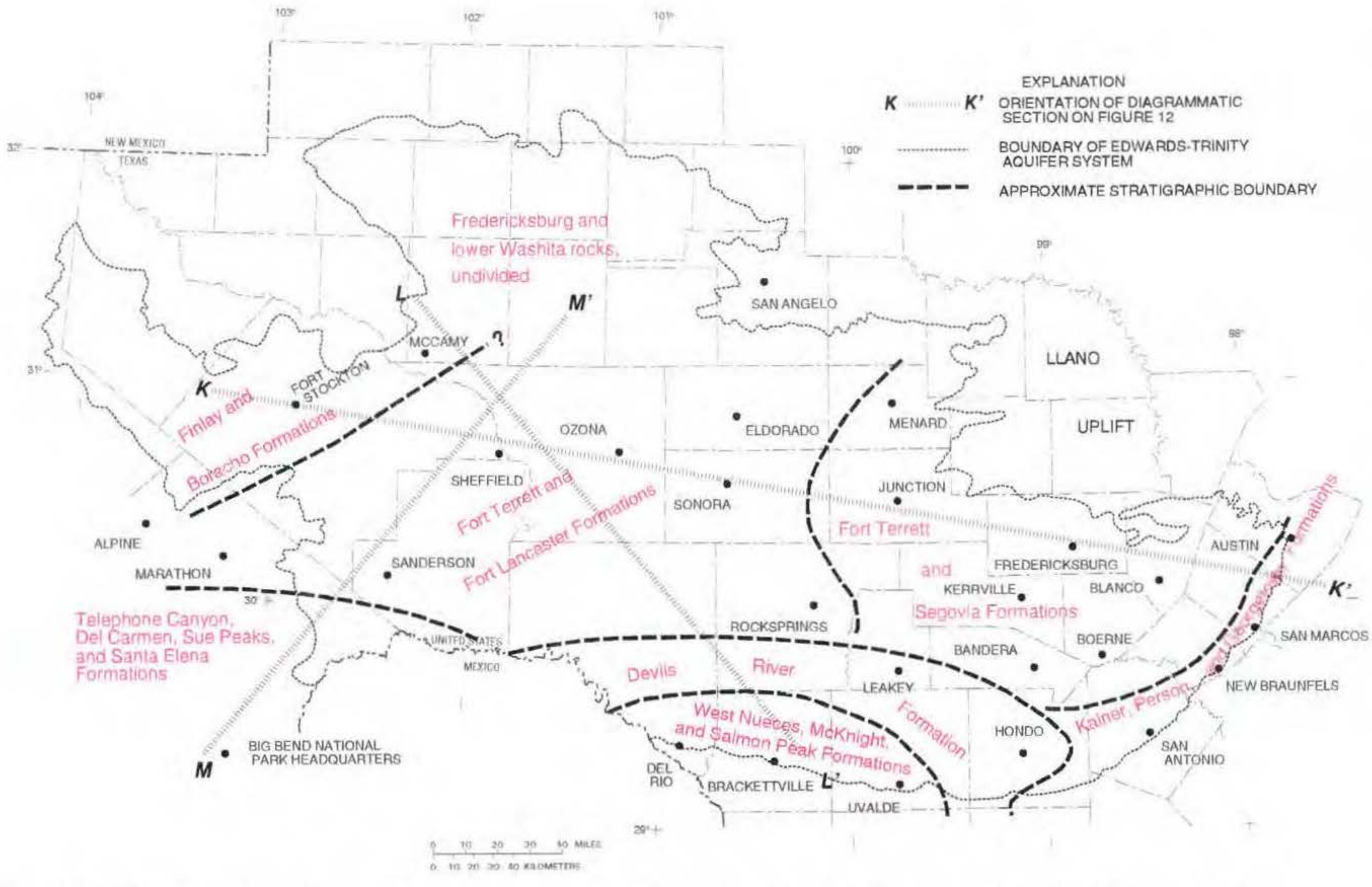


FIGURE 11.—Lateral distribution of Fredericksburg and lower Washita rock units in west-central Texas. (Modified from Smith and Brown, 1983.)

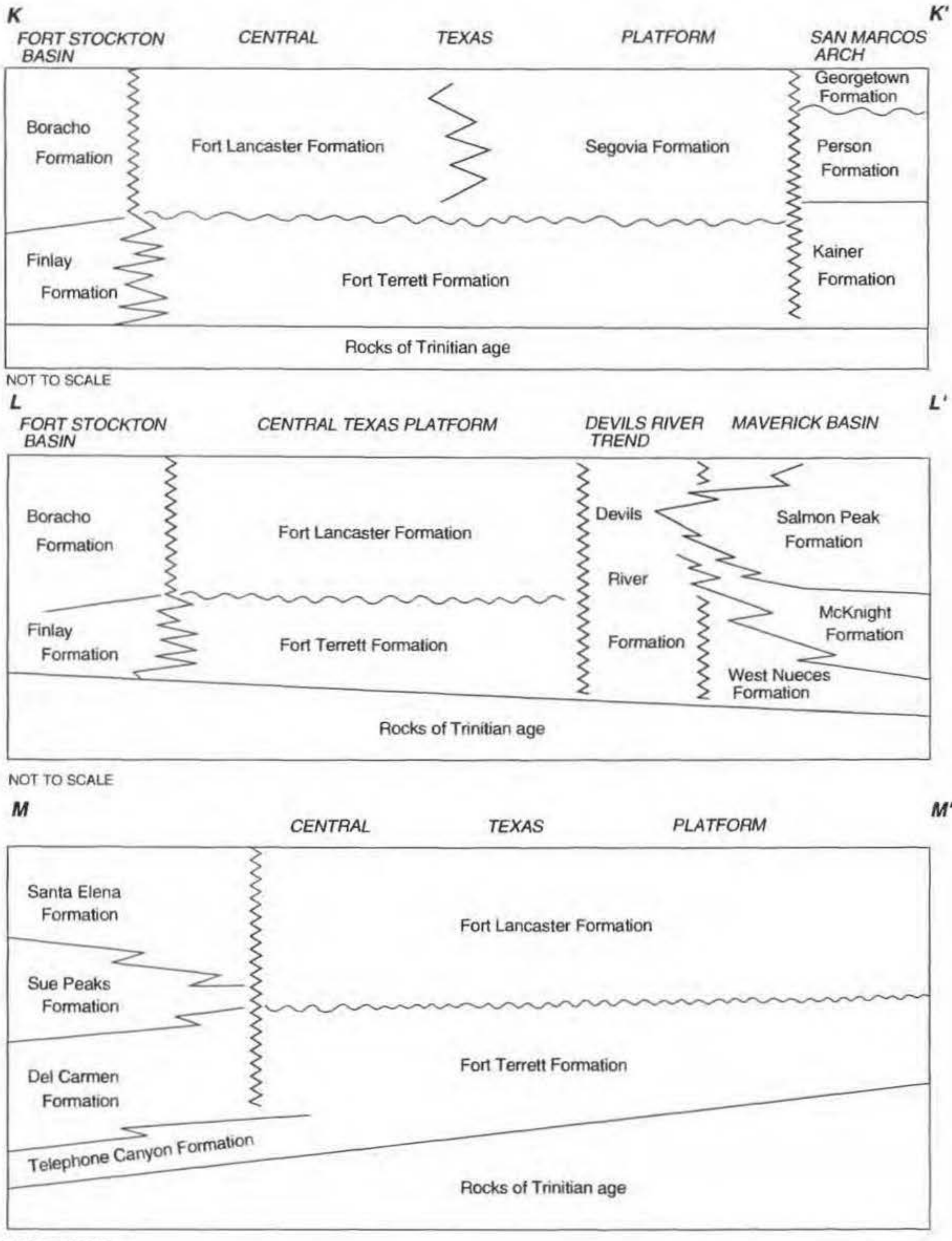


FIGURE 12.—Vertical distribution of Fredericksburg and lower Washita rock units in west-central Texas (modified from Smith and Brown, 1983), and their relation to depositional environments. (See fig. 11 for orientation of diagrams.)

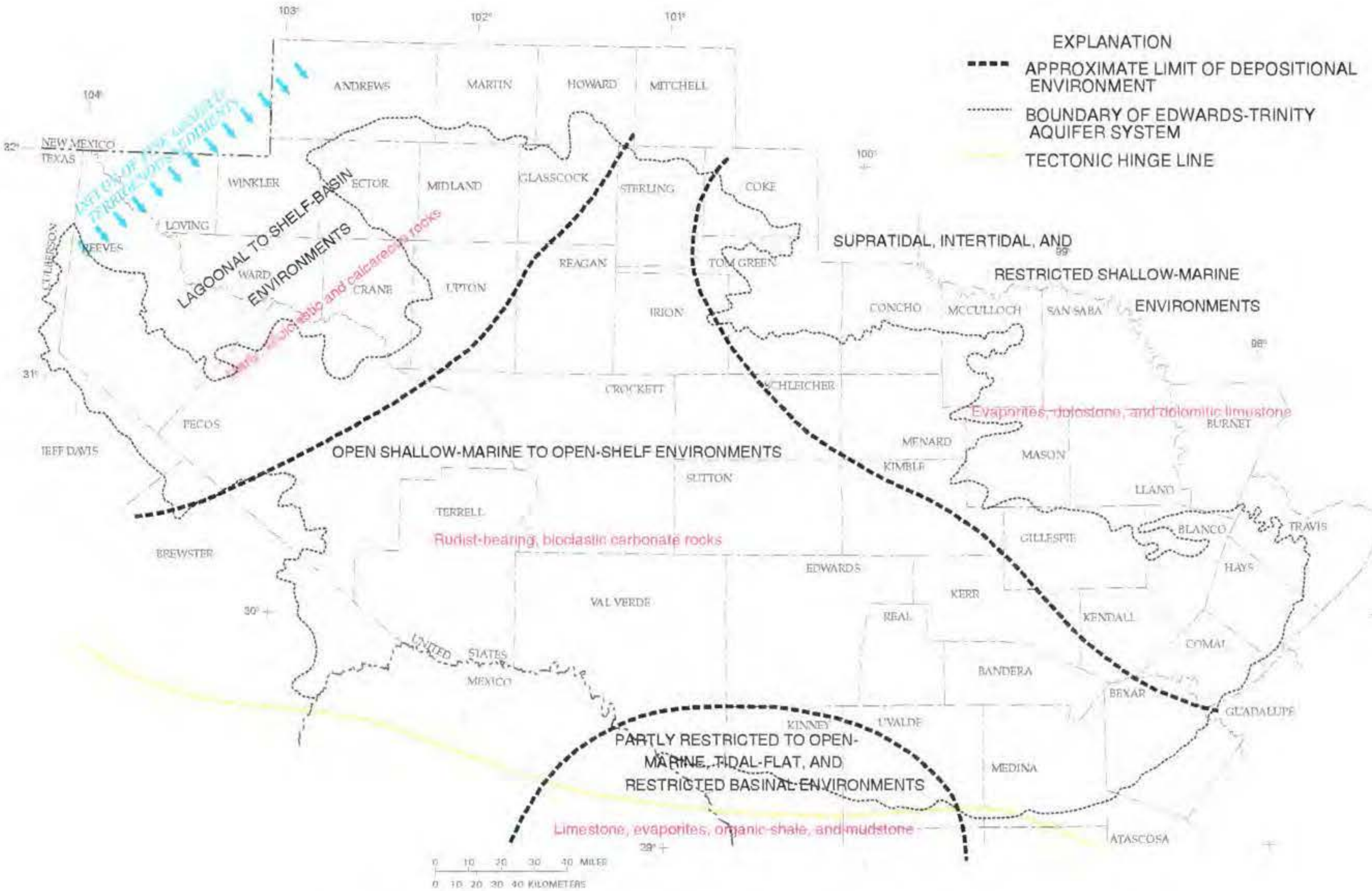


FIGURE 13.—General distribution of the prevailing depositional environments during Fredericksburgian through early Washitan time in west-central Texas, and the resulting rock types.

The San Marcos arch was dominated by shallow-water deposits upon tidal flats that frequently underwent uplift, subaerial exposure, and erosion. The parts of the Kainer and Person Formations (Rose, 1972) that formed over this arch are characterized by lateral facies changes, structural thinning, and erosional surfaces.

Although depositional environments on the central Texas platform and on the San Marcos arch generally became shallower during Fredericksburgian through early Washitan time, major subsidence south of a tectonic hinge line (figs. 6, 13) kept parts of southwestern Texas and northern Mexico more deeply submerged. The tectonic hinge line (Smith, 1981, p. 4) extended from the San Marcos arch westward across the southern parts of Medina, Uvalde, and Kinney Counties to the Big Bend area of Texas (fig. 3). Greater rates of subsidence south of the hinge line caused fundamental differences between the lithology of rocks deposited on the southwestern flank of the central Texas platform and those deposited in the Maverick basin (C.I. Smith, University of Texas at Arlington, oral commun., 1989).

In contrast to many depositional breaks north of the tectonic hinge line, the persistently submerged Maverick basin received sediment almost continuously during Fredericksburgian through most of Washitan time. Depositional environments inside the basin generally were buffered from those more typical of the central Texas platform by an intervening zone of comparatively unrestricted circulation, moderate-to-high wave and current energy, and aggressive reef growth (the Devils River trend, figs. 6, 10). The resulting bank of carbonate sediment and reef debris is mapped as the Devils River Formation (fig. 11, pl. 1). The Devils River trend on the west and north, together with the Stuart City reef trend on the east and south, nearly encircled the Maverick basin and helped isolate the lithofacies of the Maverick basin from those elsewhere in the study area.

Bioclastic limestone of the West Nueces Formation (Lozo and Smith, 1964) formed mostly below wave base during early stages of the Maverick basin when the area typically was dominated by partly restricted to open-marine environments and approximately normal seawater. Later, as water salinities increased, the intertidal to shallow subtidal environments that produced the West Nueces Formation and lower parts of the McKnight Formation gave way to evaporite precipitation on a broad mudflat that sloped inland from the Stuart City reef trend (Miller, 1984). Water depths that initially had increased between the Stuart City reef trend and the Devils River trend suddenly reversed in response to accelerated rates of subsidence (C.I. Smith, University of Texas at Arlington, oral commun., 1989) south of the tectonic hinge line (figs. 6, 13). The associated basinward increase in water depth caused gypsiferous tidal flat deposits near the top of the lower McKnight sequence to prograde northward, over the West Nueces Formation, into the Devils River trend (fig. 12, *L–L′*).

Water circulation deteriorated markedly inside the Maverick basin as the stature of the Stuart City and Devils River (reef) trends evolved and the basin continued to deepen. A thin-bedded, finely laminated sequence of mudstone, which composes middle parts of the McKnight Formation, formed in an euxinic, basinal environment (Carr, 1987, p. 70) that produced dark organic shale and petroliferous limestone, with minor amounts of sulfur. As water depths subsequently decreased to perhaps 150 or 200 ft, thin beds of anhydrite and argillaceous mudstone accumulated in slightly fresher water to form upper parts of the McKnight Formation. The McKnight Formation eventually was covered with more than 300 ft of dense, medium- to thick-bedded mudstone that composes the lower two-thirds of the Salmon Peak Formation (Humphreys, 1984). The lower few hundred feet of the Salmon Peak Formation formed in open to partly restricted basinal environments, where water depths probably ranged from about 300 to about 600 ft. Toward the end of Salmon Peak deposition (late Washitan time), the Stuart City reef trend began to disintegrate and the connection improved between the Maverick basin and open sea (C.I. Smith, University of Texas at Arlington, oral commun., 1989). The uppermost 75 to 100 ft of the Salmon Peak Formation formed as partly reworked grainstone and wackestone deposits prograded southward from the Devils River trend.

Concurrent with deposition inside the Maverick basin, the surrounding Devils River trend produced a stratigraphically undifferentiable bank of partly to completely dolomitized miliolid, shell-fragment, and rudist-bearing limestone (Lozo and Smith, 1964, p. 291–297). Nodular, burrowed, dolomitic, and evaporitic rock sequences that compose lower parts of the Devils River Formation were laid down during Fredericksburgian time in partly restricted tidal flat environments somewhat similar to those on the southwestern flank of the central Texas platform (Miller, 1984). Deeper water and comparatively unrestricted circulation allowed rudist reefs to flourish during most of Washitan time around the northern perimeter of the Maverick basin, where upper parts of the Devils River Formation formed in mostly open shallow-marine environments of moderate-to-high wave and current energy. The reefs might have emerged from the sea intermittently during middle Washitan time when they are believed to have been extensively leached, dolomitized, and recrystallized (R.W. Maclay, U.S. Geological Survey, written commun., 1987).

The geologic histories of the Maverick basin and the Devils River trend are complex because of wide ranging depositional, tectonic, and diagenetic conditions. For detailed accounts of these conditions and their effects, the reader is referred to Humphreys (1984, p. 34–59) and Miller (1984, p. 3–33).

Toward the end of early Washitan time and continuing into late Washitan time, the sea withdrew from the central Texas platform in response to tectonic upwarping of the Comanche shelf (Rose, 1972, p. 71). Soil and caliche horizons developed on emergent northwestern parts of the central Texas platform (Smith and Brown, 1983, p. 23). Freshwater marl and limestone formed in marshy environments on the lower-lying southeastern margin of the platform (Halley and Rose, 1977, p. 213–215). Approximately 100 ft of lower Washita strata was eroded from the crest of the San Marcos arch and upper surfaces of the remaining rocks were karstified (Hammond, 1984). Much of the paleokarst and many of the caverns that today occur in the Edwards Plateau (Kastning, 1983) probably originated during the Washitan episodes of subaerial exposure.

The open sea returned during Washitan time and the Georgetown Formation—a nodular, slightly argillaceous, generally thin-bedded limestone—was deposited over the San Marcos arch. Bioclastic sand and carbonate mud belonging to upper parts of the Segovia and Fort Lancaster Formations were deposited during this time over the central Texas platform in relatively shallow, well-circulated seawater (Rose, 1972, p. 71). A shoaling-upward pattern of deposition prevailed around the northern margin of the Maverick basin, where the deposits reflect the effects of sediment reworking and moderate-to-high wave and current velocities. The upper part of the Salmon Peak Formation formed when a tongue of mostly grainstone prograded southward over the Maverick basin from the Devils River trend (fig. 12, *L–L′*). By this time, the rate of reef growth in the Devils River trend probably exceeded the rate of subsidence in the Maverick basin (Humphreys, 1984, p. 56).

Following regional uplift near the end of Washitan time and the additional erosion of sediments from the crest of the central Texas platform, the open sea returned once again to west-central Texas. The Comanche shelf was blanketed by the Del Rio Clay. Silt, clay, and marly limestone of this relatively thin, open-marine deposit topped the Maverick basin, which by late Washitan time was no longer a distinct depositional basin. Carbonate sedimentation decreased sharply as fine-grained, terrigenous sediment began to dominate and impede the growth of carbonate-producing organisms in environments no longer sheltered by the Maverick basin or Stuart City reef trend (C.I. Smith, University of Texas at Arlington, oral commun., 1989).

Following uplift of the central Texas Platform just before the end of Washitan time, erosion stripped much—and in places, all—upper Washita strata from the study area. The sea returned near the end of Washitan time and blanketed west-central Texas with an open-shelf mudstone known today as the Buda Limestone.

Gulfian Epoch: Eaglefordian through Navarroan Ages

During Eaglefordian (early Gulfian) through Navarroan (late Gulfian) time, the Buda Limestone was covered with 2,000 to perhaps 4,000 ft of sandstone, shale, marl, and chalk (Waters and others, 1955, p. 1,831). Except for some Eagle Ford sediments in the southwestern part of the study area that possibly were deposited by high-energy oceanic currents (C.I. Smith, University of Texas at Arlington, oral commun., 1989), most of the Gulf strata formed in low-energy, open-shelf environments. Accordingly, most of the Gulf strata are fine-grained, strongly cemented, and virtually impermeable to ground water (Maclay and Small, 1986, table 1).

Near the end of the Cretaceous Period, the study area entered a prolonged interval of uplift in association with the Laramide orogeny and Basin and Range deformation of northern Mexico (Henry and Price, 1985; Ewing, 1991). Subsequent erosion has removed most Gulf strata from the study area. The remaining Gulf rocks include sparse outcrops and shallow subcrops of Eagle Ford and Austin strata in the Edwards Plateau and in the Trans-Pecos and relatively thick, steeply dipping Eagle Ford-through-Navarro strata above the Ouachita structural belt (fig. 6). The Cretaceous rocks of the study area are separated from the Cenozoic rocks by a major unconformity (Adkins, 1933).

POST-CRETACEOUS HISTORY

The post-Cretaceous geologic history of west-central Texas was dominated by widespread uplift and erosion, concurrent with deposition in the Gulf of Mexico. During the Cenozoic Era, a thick succession of offlapping deltaic deposits built the Gulf Coastal Plain with detritus eroded from Paleozoic and Mesozoic rocks on the uplifted continental interior (Wilhelm and Ewing, 1972). Cenozoic deposits in the study area include thick deposits of Tertiary and Quaternary alluvium along the Pecos River and sparse remnants of the (1) upper Tertiary Ogallala Formation, (2) Pliocene (Uvalde gravel) and Pleistocene terrace deposits, and (3) Holocene streambed deposits. Only the thick deposits of Cenozoic alluvium along the Pecos River markedly affect the hydrology of the Edwards-Trinity aquifer system.

A large volume of Cretaceous rock was removed from the northwestern part of the study area during late Mesozoic through early Cenozoic time as the result of structural deformation, salt dissolution, and erosion along what is now the Pecos River valley. As Paleozoic sediments in the Delaware basin (fig. 6) were uplifted in association with the Laramide orogeny (Henry and Price, 1985), deformation of massive Upper Permian salt deposits caused faulting and fracturing within the overlying Triassic and Cretaceous strata (Wessel, 1988, fig. 14). Solution channels formed in the deep subsurface as fresh ground water penetrated the structurally deformed terrain and dissolved halite, gypsum, and anhydrite from the Upper Permian rocks (Maley and Huffington, 1953). Eventually, the overlying strata collapsed into the hollow subsurface, forming two elongate troughs (pl. 2) between the southeastern corner of New Mexico and the northwestern part of Pecos County (Ashworth, 1990). The troughs filled during Tertiary and Quaternary time with more than 1,500 ft of talus and alluvial fill, known as the Cenozoic Pecos alluvium.

During early Tertiary time, as uplift dominated the western part of the study area, sediments east of the Ouachita structural belt (fig. 6) continued to subside into the Gulf of Mexico (Walper and Miller, 1985). Tensile stresses accumulated in the Cretaceous rocks where they arched over the Ouachita structural belt (Flawn, 1956, p. 32). The crustal tension culminated between late Oligocene through early Miocene time (Weeks, 1945) with a series of discontinuous, generally en echelon and mostly down-to-the-southeast faults. These faults profoundly changed the landscape of central Texas (fig. 14).

The Balcones fault zone is defined by a series of high-angle normal faults that are aligned with the Ouachita structural belt where it bends around the southeastern margin of the Llano uplift (fig. 6). The faults disrupt Lower Cretaceous through Paleocene strata at the surface (Murray, 1961, p. 176) and extend downward into Paleozoic rocks of the Ouachita facies (fig. 5). The alignment of the faults probably is influenced by lines of weakness, including relic faults, in the Ouachita structural belt (Flawn and others, 1961, p. 190). Maximum vertical displacements are observed over the San Marcos arch in Bexar, Comal, Hays, and Travis Counties. Weeks (1945, p. 1,734) estimated that the total vertical displacement across the Balcones fault zone was about 1,200 ft near San Antonio and about 900 ft near Austin.

The Balcones faulting disrupted the lateral continuity of Cretaceous strata (fig. 14) and initiated hydrogeologic conditions that ultimately produced the Edwards aquifer of the Balcones fault zone (Maclay and Small, 1986), one of the most permeable and productive aquifers in the Nation. The Cretaceous strata were displaced vertically, fractured intensively, and rotated differentially within a series of southwest-to-northeast trending fault blocks that characterize the fault zone. Ground-water flow shifted toward the northeast in response to rejuvenated hydraulic gradients in that direction and high-angle barrier faults that blocked old, southeastward flowpaths. New flowpaths developed subparallel to the strike of the fault zone as evaporites and soluble calcareous constituents (other carbonate minerals and allochems) dissolved from the fractured strata and discharged to downgradient springs and streams.

Springs originated in topographically low areas where barrier faults intercepted the lateral flow of confined water at depth and diverted it to the surface along paths of least resistance (Abbott, 1977). Aquifers developed as flowpaths converged toward spring outlets, and the rocks became more permeable through dissolution. Solution channels spread outward from the springs, and zones of honeycombed and cavernous porosity evolved into major conduits of ground-water flow (Woodruff and Abbott, 1986, p. 77). The major springs (fig. 3) persisted and control modern potentiometric levels and discharge patterns (Bush and others, 1993).

Streams that before the faulting had meandered gulfward under low gradients were out of equilibrium with the faulted topography. Although most of the old (pre-fault) watercourses had flowed generally eastward, headward erosion by the new (post-fault) streams cut northwestward across the Balcones escarpment (fig. 3) toward the Edwards Plateau. Many of the older, east-flowing streams were pirated by the younger, higher-gradient streams that formed normal to the escarpment (Woodruff and Abbott, 1986, fig. 5). The rates of downcutting increased after piracy, as larger volumes of discharge resulted from the newly acquired headwaters.

Stream erosion eventually breached the overlying, low-permeability Gulf rocks and provided discharge areas for aquifers in the underlying, more permeable Comanche rocks. All but minor remnants of Fredericksburg and Washita strata were removed from a 20- to 50-mi-wide area between the Balcones fault zone and the Edwards Plateau. This area, the Hill Country, is characterized today by vast outcrops of irregularly eroded Trinity strata.

The rocks in the Hill Country, Edwards Plateau, and Trans-Pecos mostly were excluded from the large-scale normal faulting, intensive fracturing, and subsequent dissolution that controlled the origin of the Edwards aquifer in the Balcones fault zone.

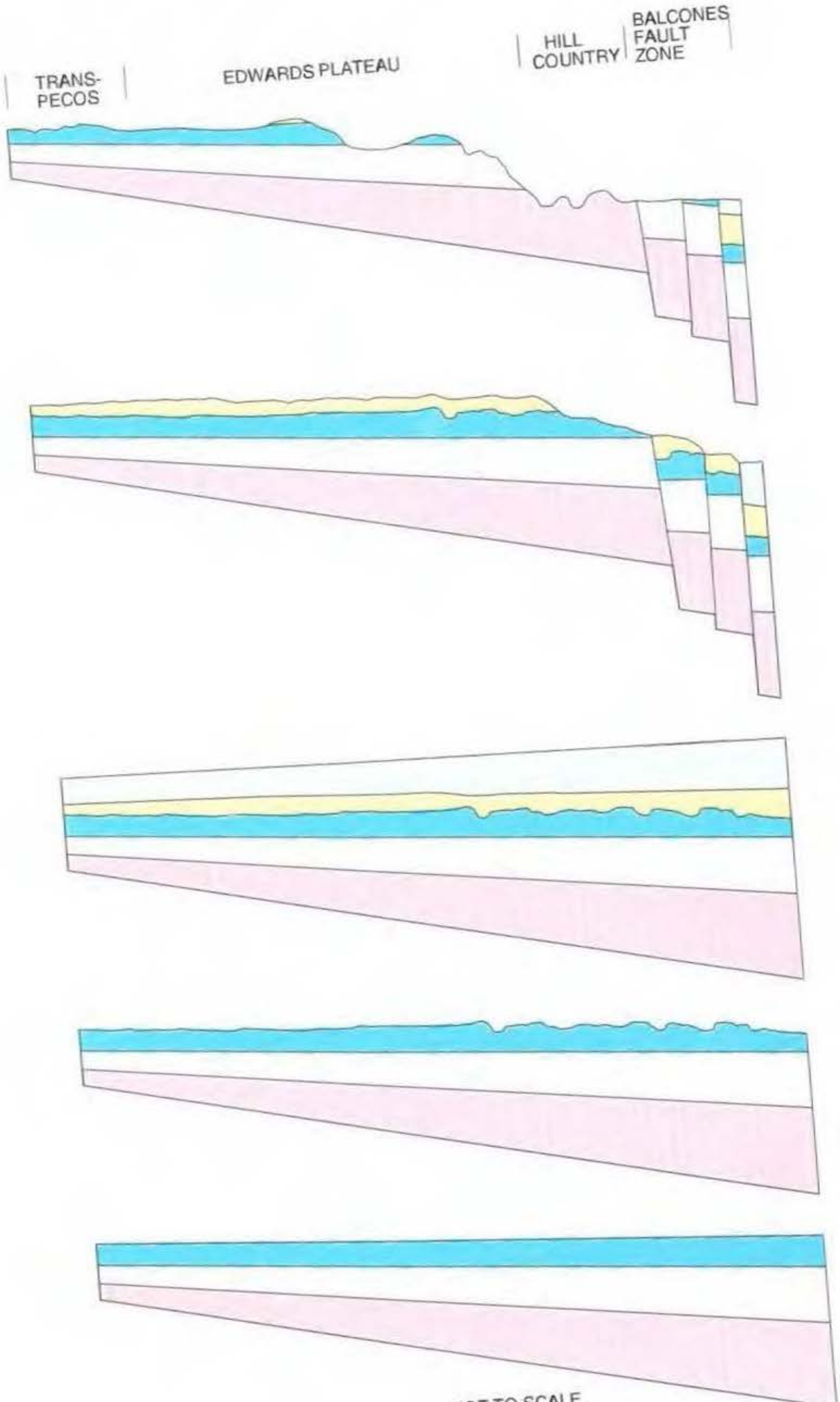


FIGURE 14.—Progression of major depositional, tectonic, and diagenetic

QUATERNARY

Base level of surface drainage lowers as streams erode deeper into uplifted strata west of Balcones fault zone; Hill Country stripped of most post–Trinity strata; hydraulic conductivity of strata outside fault zone decreases through cementation, recrystallization, and replacement; hydraulic conductivity of Edwards Group inside fault zone increases through dissolution and dedolomitization; joint cavities, solution channels, and honeycombed zones continue to enlarge—increasing the transmissivity of Edwards aquifer; dynamic equilibrium between freshwater and saline water reached across freshwater/saline–water transition zone.

TERTIARY: Oligocene – Miocene Epochs

Cretaceous strata displaced vertically as much as 1,200 feet in Balcones fault zone by high–angle normal faults, culminating tensional buildup in strata above Ouachita structural belt, as Gulf of Mexico subsides; fractures in fault zone widen as erosional unloading progresses; ground–water flow diverted toward northeast by barrier faults; hydraulic conductivity increases through dissolution of previously buried evaporites, magnesium calcite, and aragonitic constituents as meteoric water enters faulted terrain and circulates through fractures and downdropped paleokarst; dolomite replaced by calcite through dedolomitization; micrite recrystallizes to coarse microspar and pseudospar; headward erosion toward upthrown Edwards Plateau initiates dissection of terrain west of fault zone; Gulf strata eroded and redeposited gulfward.

LATE CRETACEOUS

Karst, marl, soil, and caliche surfaces buried by upper Washita strata (following regional subsidence) and Gulf strata (following collapse of Stuart City reef trend); calcite cementation abates; karst development ceases; carbonate sediments undergo compaction, with stylolitization in deeply buried facies.

LATE–EARLY CRETACEOUS: Following middle Washitan uplift

Lower Washita strata exposed subaerially following uplift of Comanche shelf; approximately 100 feet of strata eroded from crest of San Marcos arch; San Marcos arch and central Texas platform locally karstified; primary porosity enlarged through dissolution of evaporitic and calcareous constituents in shallow zones of freshwater circulation, with carbonate cementation downgradient; freshwater marl, soil, and caliche horizons formed over central Texas platform.

EARLY CRETACEOUS

Trinity, Fredericksburg, and lower Washita strata deposited mainly in terrestrial, supratidal, intertidal, and shallow marine environments on slowly subsiding carbonate platform in lee of Stuart City reef trend; aragonitic constituents, high–magnesium calcite, and evaporites leached early by locally circulated meteoric water; breccia zones formed by collapse of overlying beds; supratidal carbonate deposits dolomitized and gypsum precipitated; aragonite and magnesium calcite cements formed in marine environments.

EXPLANATION

GULF ROCKS

Eaglefordian through Navarroan age

COMANCHE ROCKS

Late Washitan age

Early Washitan age

Fredericksburgian age

Trinitian age

events affecting development of the Edwards-Trinity aquifer system.

Consequently, the hydraulic characteristics of the Trinity and Edwards-Trinity aquifers more closely resemble those of each other than those of the Edwards aquifer.

Outside the Balcones fault zone, the dominant effects of carbonate diagenesis (Bathurst, 1975) on the hydraulic characteristics of the Edwards-Trinity aquifer system have resulted most importantly from cementation, recrystallization, and neomorphism. (Neomorphism is a comprehensive term to describe processes of recrystallization and replacement where the mineralogy might have changed or where the mechanism of change is impossible to distinguish (Folk, 1962, p. 20–21).) While cementation destroyed primary intergranular porosity, recrystallization sharply reduced the intercrystalline porosity of most carbonate rocks. The mineralogically unstable minerals, high-magnesium calcite and aragonite, mostly were replaced by low-magnesium calcite, the most stable form of calcium carbonate. Because cementation, recrystallization, and replacement typically reduced or obliterated the primary porosity of most carbonate rocks outside the fault zone, the hydraulic conductivity of aquifers in the Hill Country, Edwards Plateau, and Trans-Pecos typically has decreased over geologic time.

Within the Balcones fault zone, however, the hydraulic conductivity of carbonate strata typically has increased over time as the result of large-scale normal faulting, coupled with the associated fracturing and subsequent dissolution. The faulting vertically displaced the terrain, which increased hydraulic gradients and helped initiate a dynamic regime of shallow ground-water flow. In addition to forming new porosity (within the fractures), the fracturing increased the hydraulic conductivity by interconnecting voids that, before the faulting, had been isolated. The dissolution of evaporites and soluble calcareous constituents formed moldic and other forms of fabric-selective porosity (Choquette and Pray, 1970) that increased hydraulic conductivity locally. Dissolution along fractures and bedding planes formed joint cavities and solution channels that eventually became the principal conduits of regional ground-water flow (Woodruff and Abbott, 1986, p. 77). The increases in hydraulic conductivity were greatest in shallow parts of the fault zone because fractures typically close with increasing depth below land surface and dissolution is most active near the interval of water-table fluctuation (LeGrand and Stringfield, 1971, p. 1,286).

A dynamic regime of shallow freshwater circulation probably has existed in the Balcones fault zone since Miocene time (Ellis, 1986), after the brunt of the faulting ruptured the thick overburden of hydraulically tight Gulf strata and exposed the relatively permeable upper Comanche strata to meteoric conditions (fig. 14). The concentration of high-angle faults and associated fractures facilitated the percolation of meteoric water and extended the depth of freshwater diagenesis. The partial pressure of dissolved carbon dioxide, derived from the atmosphere and soil to form carbonic acid, increased the solubility of calcareous constituents. Previously leached strata (paleokarst) provided incipient avenues through which meteoric water could enter and dissolved constituents could exit the shallow subsurface. The hydraulic conductivity of the Edwards aquifer increased rapidly in humid post-fault environments, as evaporites (principally anhydrite and gypsum), other unstable minerals (such as aragonite and high-magnesium calcite), and allochems (fossil parts, intraclasts, pellets, and oolites) dissolved along fractures, bedding planes, and burrows (Abbott, 1975, p. 255–267).

Additional increases in the hydraulic conductivity of the Edwards aquifer resulted from dedolomitization (Maclay and Small, 1986, p. 31), a form of incongruent dissolution in which dolomite in the presence of dissolved gypsum is replaced by calcite. Dedolomitization is a near-surface phenomenon (De Groot, 1967) prompted by the addition of calcium ions through the dissolution of gypsum and the removal of magnesium ions through freshwater flushing (Back and others, 1983). Although dedolomitization, by itself, might not necessarily increase hydraulic conductivity, the resulting "calcite after dolomite," or dedolomite, can be more soluble than the original dolomite (Evamy, 1967). The enhanced hydraulic conductivity of dolomitic strata in the Balcones fault zone probably results most importantly through the dissolution of the secondary calcite that resulted from dedolomitization.

Dedolomite in the Edwards aquifer does not appear to have resulted from pre-Miocene diagenesis, nor does it appear related either to ancient or to recent weathering surfaces (Ellis, 1986, p. 109). Dedolomitization in the Balcones fault zone would have required the rapid influx of meteoric water and the rapid flushing of magnesium-rich brines. The widespread existence of dedolomite to depths of 650 ft on the freshwater side of the freshwater/saline-water transition zone, coupled with its absence on the saline-water side, is evidence that dedolomitization in the fault zone took place since the Balcones faulting initiated conditions that ultimately produced the Edwards aquifer. Most dedolomite in the Edwards aquifer probably formed during the last 15 to 20 million years (R.W. Maclay, U.S. Geological Survey, written commun., 1990).

TABLE 2.—*Approximate maximum thickness of lithostratigraphic units that compose the Edwards-Trinity aquifer system, west-central Texas*

Lithostratigraphic unit	Thickness (feet)	Source of thickness data
Navarro Group	500	Maclay and Small, 1986, table 1
Taylor Group	500	Do.
Austin Group	350	Do.
Eagle Ford Group	250	Do.
Buda Limestone	200	Small and Ozuna, 1993, table 1
Del Rio Clay	170	C.I. Smith, written commun., 1989
Georgetown Formation	60	Rose, 1972, fig. 16
Salmon Peak Formation	500	Humphreys, 1984, fig. 2
Devils River Formation	700	Maclay and Small, 1986, table 1
Boracho Formation	410	Brand and Deford, 1958, fig. 2
Fort Lancaster Formation	405	C.I. Smith, written commun., 1989
Segovia Formation	380	Rose, 1972, fig. 23
Person Formation	260	Rose, 1972, fig. 15
McKnight Formation	285	Carr, 1987, p. 21
Finlay Formation	165	Small and Ozuna, 1993, table 1
Fort Terrett Formation	300	Rose, 1972, fig. 21
West Nueces Formation	260	Miller, 1984, p. 9
Kainer Formation	400	Rose, 1972, fig. 14
Maxon Sand	200	C.I. Smith, written commun., 1989
Glen Rose Limestone	1,530	Welder and Reeves, 1964, table 1
Cox Sandstone	170	Brand and Deford, 1958, fig. 2
Yearwood Formation	180	Do.
Basal Cretaceous sand	395	Romanak, 1988, p. 21; Wessel, 1988
Hensel Sand/Bexar Shale Member of Pearsall Formation	210	Imlay, 1945, table 2
Cow Creek Limestone/Cow Creek Limestone Member of Pearsall Formation	88	Do.
Hammett Shale/Pine Island Shale Member of Pearsall Formation	130	Amsbury, 1974, fig. 12
Sycamore Sand	50	DeCook, 1963, table 3
Sligo Formation	240	Imlay, 1945, table 2
Hosston Formation	880	Do.

STRATIGRAPHIC CONDITIONS

The geology of west-central Texas has been studied extensively by the petroleum industry, academic institutions, and government agencies. Several correlation charts, reflecting different interpretations by different workers, are published for strata that compose the Edwards-Trinity aquifer system.

The Cretaceous nomenclature of west-central Texas was synthesized for plate 1 from several publications. By combining the pertinent chronostratigraphic and lithostratigraphic nomenclature with aquifer and confining unit terminology, plate 1 summarizes the relation between stratigraphy and ground-water hydrology in the RASA study area (fig. 1). Because the correlation chart was compiled from several sources, the stratigraphic names do not necessarily conform to current usage of the U.S. Geological Survey. The aquifer names (except for the High Plains aquifer of Weeks and others (1988)) were adopted from the Texas Water Plan (Texas Water Development Board, 1990, p. 1–5 and 1–6). The approximate maximum thicknesses of the lithostratigraphic units that compose the Edwards-Trinity aquifer system are shown in table 2.

Hydrogeologic sections through various parts of the study area show the vertical distribution of strata that contain the aquifers and confining units of the Edwards-Trinity aquifer system (pls. 2–8). The sections primarily are based on interpretation of borehole geophysical (electric) logs that were purchased from the Petroleum Information Corp. The locations of the 65 wells from which the borehole data were taken are shown in figure 15. Most of the stratigraphic contacts shown on the sections were interpreted from resistivity, spontaneous potential, and natural gamma ray logs that primarily were obtained from hydrocarbon exploration wells. A tracing of each electric log used for control is reproduced on the sections, and each well is described above the appropriate tracing(s). The descriptions cite (from top to bottom) the well operator name, lease or well name, well number, and altitude of land surface. The depth of the well, if known, is given below each tracing. The stratigraphic contacts interpreted from the electric logs are supplemented on the hydrogeologic sections with published stratigraphic and structural data from reports cited in the text.

ROCKS OF TRINITIAN AGE

The correlation of the Trinity strata (pl. 1) primarily is based on descriptions by Forgotson (1956), Lozo and Stricklin (1956, fig. 4), Brand and Deford (1958, fig. 2), Loucks (1977, fig. 4), and Smith and Brown (1983, fig. 3). The lateral and vertical distributions of the Trinity strata are summarized in figures 8 and 9, respectively.

Sediments in the Trinity outcrop between the top of Paleozoic rocks and the base of the Glen Rose Limestone were originally called the Travis Peak Formation (Taff, 1892; Hill and Vaughan, 1898; and Hill, 1901). After finding key disconformities and an additional shale unit within the original Travis Peak Formation, Lozo and Stricklin (1956) raised each member of the Travis Peak sequence to formational rank, and recommended that Travis Peak nomenclature be "*** deleted from modern stratigraphic terminology or reserved for use by laymen." However, in recognition of usage that continues locally, the term Travis Peak *equivalent* is applied in this report to the outcrop and shallow subcrop of Trinity strata in the Hill Country to represent the combined Sycamore Sand, Hammett Shale, Cow Creek Limestone, and Hensel Sand (pl. 1).

The Pearsall Formation was defined by Imlay (1945, p. 1,441) to include sediments above the Sligo Formation and below the Glen Rose Limestone that represent the subsurface equivalents of what at that time (1945) was recognized as the Travis Peak Formation of the outcrop (Taff, 1892; Hill and Vaughan, 1898; and Hill, 1901). The Pearsall Formation is applied in this report to the subcrop of Trinity strata in the Balcones fault zone where it contains the Pine Island Shale, Cow Creek Limestone, and Bexar Shale Members (pl. 1) and to the south-central part of Edwards County, where the formation is not differentiated into members (fig. 8).

The Hosston Formation typically is a siliciclastic siltstone and sandstone lithofacies in updip areas and a dolomitic mudstone and grainstone lithofacies in downdip areas. The downdip dolomitic sediments grade upward into evaporites and intertidal limestone and dolostone of the Sligo Formation (Bebout and others, 1981). From a shallow-marine carbonate lithofacies in downdip areas, the Sligo Formation grades updip, toward the Llano uplift (fig. 8), into the terrigenous clastic lithology of the Hosston Formation (fig. 9). Farther updip, the Hosston Formation grades into the Sycamore Sand (Lozo and Smith, 1964) of the outcrop area. The Sycamore Sand is a clastic unit composed predominately of quartzose sand and gravel, with some feldspathic and dolomitic detritus (Amsbury, 1974, p. 6).

The Hammett Shale (Lozo and Stricklin, 1956) in the Hill Country has the same stratigraphic position as the genetically similar Pine Island Shale Member of the Pearsall Formation (Forgotson, 1956) in the Balcones fault zone (pl. 1); the different nomenclature reflects the preferred usage in each area (Murray, 1961, p. 308–309). The Pine Island Shale Member extends eastward from the Balcones fault zone and is one of the most persistent Lower Cretaceous rock units in east Texas. The updip Hammett Shale typically is a burrowed mixture of clay, terrigenous silt, carbonate mud, silt-sized dolomite, and carbonate particles (Amsbury, 1974). The downdip Pine Island Shale Member primarily is a gray to black ("splintery") calcareous shale interbedded with dense gray limestone (Forgotson, 1957). The Hammett Shale and Pine Island Shale lithostrome interfingers vertically with the overlying Cow Creek Limestone and Cow Creek Limestone Member.

The largely bioclastic Cow Creek Limestone (Lozo and Stricklin, 1956) mostly is a regressive beach sequence on the southern flank of the Llano uplift (Stricklin and Smith, 1973). The lower part of the Cow Creek Limestone generally is a fine- to coarse-grained calcarenitic limestone, with large oyster fragments. The middle part is a silty calcarenite, containing carbonate concretions and fine quartz sand. The upper part is a crossbedded beach coquina, composed primarily of oyster-shell detritus, poorly sorted quartz grains, and scattered chert pebbles. The updip Cow Creek Limestone is overlain by the Hensel Sand, and the downdip Cow Creek Limestone Member of the Pearsall Formation (Forgotson, 1956) is overlain by the Bexar Shale Member (fig. 9, *H–H′*).

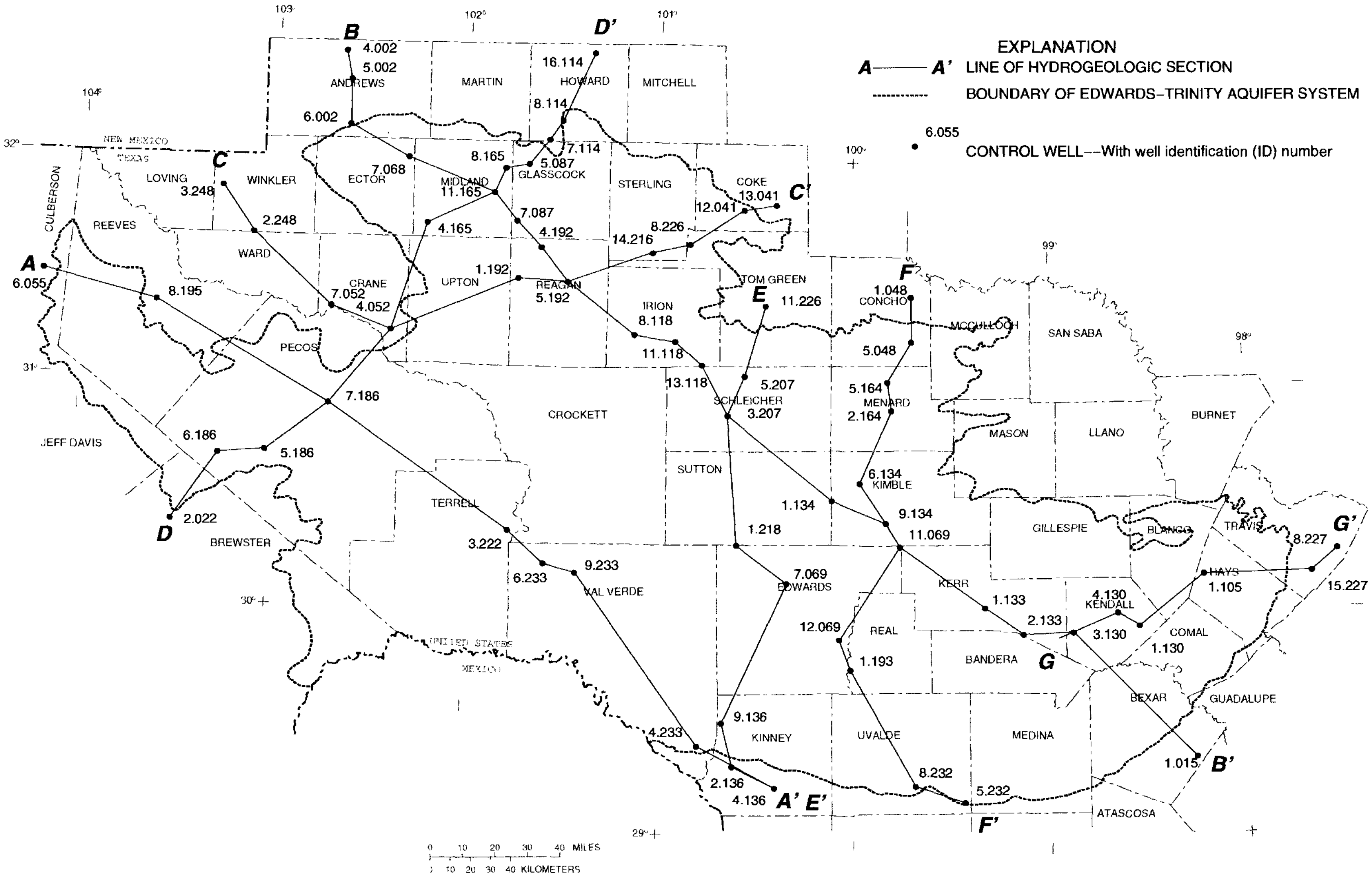


FIGURE 15.—Orientation of hydrogeologic sections (pls. 2–8) and location of wells used for control.

The Bexar Shale Member of the Pearsall Formation (Forgotson, 1956) typically is a mixture of dark mudstone, clay, and shale. The name is derived from Bexar County, where the unit is particularly distinct on electric logs (Forgotson, 1957, p. 2,347). In this report, the Bexar Shale Member applies to the gray to black calcareous shale with intermixed thin, dense, finely crystalline beds of limestone between the Cow Creek Limestone Member and Glen Rose Limestone throughout the Balcones fault zone (pl. 1). The Bexar Shale Member has been interpreted as the fine-grained, marine equivalent of the near-shore, terrigenous lithofacies of the Hensel Sand (Loucks, 1977, p. 106).

The Hensel Sand (Lozo and Stricklin, 1956) comprises a weakly cemented mixture of ferruginous clay, quartz and calcareous sand (crossbedded in places), and chert and dolomite pebbles, which typically form a basal conglomerate (Inden, 1974). The clastic sediments of this time-transgressive unit weather to a distinctive nonuniform rusty-yellow appearance. Downdip parts of the Hensel Sand on the western flank of the Llano uplift (fig. 9, *J–J′*) grade northwestward into the genetically similar basal Cretaceous sand. Updip parts of the Hensel Sand on the southern flank of the Llano uplift (fig. 9, *H–H′*) have been interpreted as the clastic, shoreward equivalent of the Glen Rose Limestone (Stricklin and others, 1971).

The Glen Rose Limestone (Lozo and Stricklin, 1956) is a sandy, fossiliferous limestone and dolostone unit, characterized by repetitious interbeds of calcareous marl, clay, and shale and laterally persistent stringers of gypsum and anhydrite. The (informal) lower member of the Glen Rose Limestone comprises mostly medium-thick beds of limestone, dolostone, and dolomitic limestone with diverse mollusk assemblages and locally distributed rudist reefs (Perkins, 1974). The (informal) upper member of the Glen Rose predominately is a thin- to medium-bedded sequence of nonresistant marls alternating with resistant beds of dolostone, mudstone, and bioclastic limestone (Stricklin and others, 1971). Reef structures mostly occur in the southeastern part of the Hill Country within uppermost intervals of the lower member (Perkins, 1974, p. 131–171). Characteristically, the upper member contains no evidence of reef formation and one or more evaporite stringers. The alternating lithology of the different interbeds within middle and upper parts of the Glen Rose Limestone imparts an uneven resistance to erosion, which renders a stairlike topographic profile to much of the Hill Country.

The calcareous, shallow-marine lithology of the Glen Rose Limestone grades northward into a quartzose clastic, terrestrial lithology of the Hensel Sand in the eastern part of the study area and the basal Cretaceous sand in the western part (fig. 8). The location of this carbonate-to-clastic facies transition, known as the Glen Rose pinchout, is approximated in figure 8 by the zigzag pattern between northern Blanco and southern Pecos Counties. In the southern parts of the Edwards Plateau and Trans-Pecos, the Glen Rose Limestone generally is overlain by the Maxon Sand.

The Maxon Sand (King, 1980, p. 21) predominately is a brownish, well indurated, coarse- to medium-grained, crossbedded sandstone, with lesser amounts of conglomerate, mudstone, and limestone (Butterworth, 1970, p. 4). The sandstone mainly is composed of quartz with minor amounts of feldspar and heavy minerals eroded from Permian and Triassic rocks northwest of the study area. The constituents generally are consolidated with calcite, hematite, and kaolinite cements. The Maxon Sand forms conspicuous ledges atop the Glen Rose Limestone where these units crop out along escarpments east of the Marathon uplift in northeastern Brewster and southern Pecos Counties (fig. 8). From Terrell County eastward, the Maxon Sand mostly is buried beneath the Fort Terrett Formation.

The (informal) basal Cretaceous sand (Smith and Brown, 1983) is the sole Trinity rock unit in the northern part of the study area (fig. 8, pl. 1). The basal Cretaceous sand underlies the updip wedge of Glen Rose Limestone in southwestern parts of the study area, where the sand is stratigraphically equivalent to the Hosston Formation, Hammett Shale, Cow Creek Limestone, and Hensel Sand (fig. 9, *J–J′*). North of the updip limit of the Glen Rose Limestone, the basal Cretaceous sand underlies either the Finlay or Fort Terrett Formations of Fredericksburgian age and includes sediments equivalent to the Maxon Sand. The basal Cretaceous sand of this report includes the "basement sands," "Trinity sand," and "basal Cretaceous sandstone" of previous reports, and it incorporates the Yearwood Formation and Cox Sandstone of Brand and Deford (1958).

The basal Cretaceous sand generally is observed as varying mixtures of sandstone, siltstone, and conglomerate. The major constituents are well-rounded fragments of quartz, chert, and feldspar derived from Permian and Triassic red beds. Calcite is the dominant cement, but dolomite, ankerite, silica, kaolinite, and hematite are prevalent locally (Romanak, 1988, p. 27). This diverse, areally extensive deposit generally is unfossiliferous and varies both vertically and laterally in color, texture, composition, and degree of cementation. The lower part of the unit generally is coarse grained; a fine- to medium-grained sandstone replaces a basal conglomerate in places. A finer grained, variegated middle section is crossbedded in places and indurated locally with calcareous cement. Upper parts of the unit might include small amounts of limestone and thin, calcareous shale interbeds.

ROCKS OF FREDERICKSBURGIAN AND WASHITAN AGES

The correlation of the Fredericksburg and Washita strata (pl. 1) primarily is based on descriptions by Brand and Deford (1958), Lozo and Smith (1964), Rose (1972), and Smith and Brown (1983). The correlation chart relates (1) the Edwards Group of Rose (1972) in the northeastern part of the Balcones fault zone and eastern part of the Edwards Plateau; (2) the Devils River, West Nueces, McKnight, and Salmon Peak Formations of Lozo and Smith (1964) in the southwestern part of the Balcones fault zone and south-central part of the Edwards Plateau; (3) the Finlay and Boracho Formations of Brand and Deford (1958) in the northwestern part of the Trans-Pecos and western part of the Edwards Plateau; and (4) the Fort Terrett and Fort Lancaster Formations of Smith and Brown (1983) in the southeastern part of the Trans-Pecos and north-central part of the Edwards Plateau. The lateral and vertical distributions of the Fredericksburg and lower Washita strata are summarized in figures 11 and 12, respectively.

The Edwards Group of Rose (1972) includes all of the Fredericksburg strata and the lower part of the Washita strata in the northeastern part of the Balcones fault zone and in the eastern part of the Edwards Plateau. In the northeastern part of the Balcones fault zone, the Edwards Group consists of the Kainer and Person Formations. In the eastern part of the Edwards Plateau, the Edwards Group consists of the Fort Terrett and Segovia Formations.

Across the western part of the Balcones fault zone, the southwestern part of the Hill Country, and the southern part of the Edwards Plateau, the Kainer, Person, Fort Terrett, Segovia, and Fort Lancaster rock sequences lose their identities against the Devils River trend, a narrow, semioval carbonate bank (figs. 11, 12, *L–L′*). The Devils River trend (fig. 6) bounds the northern part of the Maverick basin (Winter, 1962), which also is bound by the Stuart City reef trend on the south and by the San Marcos arch on the east. The Devils River trend, represented stratigraphically by the Devils River Formation (Miller, 1984), is a composite of dolostone, fossiliferous limestone, and reef debris (Lozo and Smith, 1964, p. 290–296). The lower part of the Devils River Formation is stratigraphically continuous with the lower, dolomitic part of the Fort Terrett Formation. However, because the Devils River Formation is relatively homogeneous from top to bottom, it is impractical to subdivide this formation, except to recognize the informal lower (dolomitic) and upper (limestone) parts.

The Fredericksburg and lower Washita rock units of the Maverick basin (Lozo and Smith, 1964) are the West Nueces, McKnight, and Salmon Peak Formations. The West Nueces Formation is a transgressive lithofacies that closely resembles the nodular shell-fragment limestone at the base of the Fort Terrett Formation and in lower parts of the Devils River Formation (Smith, 1979, p. 15). According to Maclay and Small (1983, p. 132), the McKnight Formation predominately is a euxinic deposit that "*** grades upward from thin-bedded carbonate mudstones to petroliferous shales and evaporites and terminates in a layer of pelleted grainstones." The Salmon Peak Formation (Humphreys, 1984) predominately is a dense, thick-bedded, deep-water mudstone that grades upward to a crossbedded, rudist-shell grainstone (Smith, 1979, p. 16).

Smith and Brown (1983) extended the Fort Terrett Formation (Rose, 1972) to include Fredericksburg strata in the central and western parts of the Edwards Plateau and in most of eastern Pecos and Terrell Counties of the Trans-Pecos (fig. 11). The Fort Terrett Formation shows strong lateral continuity, featuring a basal transgressive unit overlain by a distinctive burrowed zone, in turn overlain by thin- to medium-bedded bioclastic limestone and dolomitic strata. Although the effects of dolomitization and neomorphic alteration within the formation are prevalent in the eastern part of the Edwards Plateau (Rose, 1972, p. 29–46), they are much less common in the western part. Interbedded gypsum of the "Kirschberg evaporite zone," or a collapse breccia resulting from dissolution of the gypsum, is most common in the northeastern part of the Edwards Plateau.

The Fort Terrett Formation grades into the Finlay Formation (Brand and Deford, 1958) near the western limits of the study area, where the Finlay Formation unconformably overlies the basal Cretaceous sand of Trinitian age (figs. 11, 12, K–K′). The Finlay Formation is composed mostly of gray, massive to thick-bedded, cherty and marly limestone, with interbeds of gray to brown quartz sandstone and shale near the base and thin- to thick-bedded fossiliferous limestone near the top (Reaser and Malott, 1985). The Fort Terrett Formation grades southward through the Big Bend area of Texas (fig. 3) into the Telephone Canyon and Del Carmen Formations (figs. 11, 12, *M–M′*) of northern Mexico (Smith, 1970).

The Boracho Formation unconformably overlies the Finlay Formation and includes all of the Fredericksburg and Washita strata between the Finlay Formation and the Del Rio Clay, or the Buda Limestone where the Del Rio Clay is absent. The Boracho Formation (Brand and Deford, 1958) characteristically is limestone and marl, with a dominantly marly lower part. The upper part mostly is composed of massive, argillaceous limestone that typically forms a steep slope below a caprock of Buda Limestone.

The Fort Lancaster Formation (Smith and Brown, 1983), composed of uppermost Fredericksburg and lowermost Washita strata in the north-central part of the Edwards Plateau and eastern part of the Trans-Pecos, is equivalent to the Segovia Formation on the east and the Boracho Formation on the west (figs. 11, 12, *K–K′*). The Fort Lancaster Formation was deposited mostly in open shallow-marine to open-shelf environments (Scott and Kidson, 1977, p. 174) on the southwestern flank of the central Texas platform in water that deepened toward the Fort Stockton basin (figs. 6, 10). Relatively thick-bedded, rudist-bearing limestone helps distinguish eastern parts of the Fort Lancaster Formation from the generally thinner-bedded dolostone and dolomitic limestone of the Segovia Formation that formed concurrently in intertidal and restricted shallow-marine environments atop the central Texas platform. The Fort Lancaster Formation thickens toward the west and south and shows a decreasing density of rudists and of miliolid and shell-fragment grainstones toward the west and north, with an increasing incidence of ammonites, pelecypods, and marly sediments (C.I. Smith, University of Texas at Arlington, oral commun., 1989). The Fort Lancaster Formation grades southward through the Big Bend area of Texas into the Sue Peaks and Santa Elena Formations (figs. 11, 12, *M–M′*) of northern Mexico (Smith, 1970).

The marly, nodular limestone that composes basal parts of the Fort Lancaster and Sue Peaks Formations erodes to a distinctive, grass-covered slope over much of the Edwards Plateau and Trans-Pecos (Smith and Brown, 1983, p. 19). The outcrop characteristics of this ammonite-bearing horizon have helped geologists map the Fredericksburgian-Washitan boundary in the field for more than 100 years.

The Del Rio Clay on the San Marcos arch consists of bluish-gray, calcareous clay and gypsiferous silt and shale, with abundant marine megafossils and pyrite (University of Texas, Bureau of Economic Geology, 1983). In the eastern part of the Edwards Plateau, the Del Rio Clay typically is a yellowish-brown, poorly indurated calcareous clay that in places contains thin reddish-brown silty streaks and coquinoid lenses of small oysters (Rose, 1972, p. 43). In the Trans-Pecos and western part of the Edwards Plateau, the unit is fossiliferous locally—containing some ammonites—and mostly consists of interbedded, thin, calcareous and siliceous flagstones and marly limestone (Adkins, 1933, p. 388–396). The Del Rio Clay almost everywhere contains pyrite that typically weathers to limonite and characteristically renders a rusty-yellow outcrop. From a maximum thickness of about 170 ft near the town of Del Rio (fig. 11), the formation thins in all directions—but most sharply toward the north, where it occurs mainly as scattered, thin remnants atop the Edwards Plateau.

The Buda Limestone on the San Marcos arch is a light gray, porcellaneous limestone with pelagic foraminifera, fragile mollusk fragments, and microspherulites (Rose, 1972, p. 27). In the eastern part of the Edwards Plateau, this open-shelf limestone consists of nodular micrite, mollusk-fragment biomicrite, and marly interbeds (Rose, 1972, p. 43). In the Trans-Pecos and western part of the Edwards Plateau—where the unit typically is exposed as a light gray to white caprock on mesas that characterize the recently uplifted landscape—the Buda Limestone is slightly argillaceous, locally cross-bedded, and extremely hard (Brand and Deford, 1958, p. 385). Whereas fractured surfaces of Buda Limestone generally are hackly or conchoidal, weathered surfaces typically cast a nodular appearance.

ROCKS OF EAGLEFORDIAN THROUGH NAVARROAN AGES

The Del Rio Clay and Buda Limestone of Washitan age (Comanchean Series) are overlain in the Balcones fault zone by Eagle Ford, Austin, Taylor, and Navarro sediments of the Gulfian Series (pl. 1). The Eagle Ford-Navarro rock sequence is thickest in the Balcones fault zone where it forms the bulk of the Navarro-Del Rio confining unit. Collectively, the contributing units range from more than 1,200 to nearly 2,000 ft thick (table 2). The Eagle Ford, Austin, Taylor, and Navarro Groups consist primarily of interbedded shale, siltstone, limestone, chalk, and marl (University of Texas, Bureau of Economic Geology, 1974a; 1983).

EDWARDS-TRINITY AQUIFER SYSTEM

The Cretaceous strata of the study area thicken from less than 1,000 ft thick in the area of outcrop and shallow subcrop (fig. 4) to more than 10,000 ft thick near the ancestral shelf edge (McFarlan, 1977, p. 5). The Edwards-Trinity aquifer system is within the updip, western part of this sediment wedge. Terrigenous clastic and terrestrial deposits of early Trinitian age grade upward into supratidal and intertidal evaporitic and dolomitic rocks and shallow-marine, lagoonal, and basinal carbonate strata of late Trinitian, Fredericksburgian, and Washitan age. A thick, downfaulted remnant of mostly open-shelf sediments of Eaglefordian through Navarroan age confines a small, southeastern part of the aquifer system. The relation between the stratigraphic and hydrogeologic units that compose the Edwards-Trinity aquifer system is summarized on plate 1.

The Cretaceous strata of the Edwards-Trinity aquifer system (pl. 1) are divided regionally into three aquifers and two confining units (fig. 2). The aquifers, from east to west and top to bottom, are (1) the Edwards aquifer in the Balcones fault zone; (2) the Trinity aquifer in the Balcones fault zone and Hill Country; and (3) the Edwards-Trinity aquifer in the Edwards Plateau and Trans-Pecos. The Navarro-Del Rio confining unit extends over about 70 percent of the Balcones fault zone, and the Hammett confining unit is present beneath about 80 percent of the Hill Country and less than 10 percent of the Edwards Plateau.

These aquifer and confining-unit divisions are based on regional contrasts in hydraulic conductivity that determine the relative capacity of the different rock units to transmit ground water over tens of square miles. The hydraulic conductivity of the strata was inferred largely from aquifer-test and specific-capacity data and an inherent, general relation between the stratigraphy and hydraulic conductivity. The aquifer-test and specific-capacity data were obtained mainly from Walker (1979), Rees and Buckner (1980), Ashworth (1983), Baker and others (1986), and Maclay and Small (1986). A general relation between the stratigraphy and the hydraulic conductivity exists because the stratigraphy reflects the spatial distribution of the individual rock units, and each rock unit resulted from a unique combination of depositional, tectonic, and diagenetic conditions. These same conditions control the distribution of hydraulic conductivity. Therefore, the hydraulic conductivity of strata for which hydraulic data were not available was estimated from the relation between stratigraphy and hydraulic conductivity where data are available to infer that relation.

The regional aquifers comprise strata that mainly are permeable as the result of fractures, joint cavities, and porosity caused by the dissolution of evaporites and relatively unstable carbonate constituents. The confining units comprise comparatively impermeable strata that are continuous over more than 100 mi^2 and affect regional patterns of ground-water circulation. The confining units mostly are calcareous mudstone, siltstone, and shale of low-energy terrigenous and open-shelf environments. Because of the regional scope of the RASA study and the need to generalize from site-specific data, the aquifers include some confining strata and the confining units contain some strata permeable enough to supply small amounts of water to a few wells in limited areas.

HYDRAULIC CHARACTERISTICS

POTENTIOMETRIC SURFACE

The regional distribution of hydraulic head in the Edwards-Trinity aquifer system under long-term average, near-predevelopment (historical) conditions is shown in figure 16. The potentiometric-surface map is based on water levels measured in nearly 1,800 wells between 1915–69 (Bush and others, 1993). Because pumpage was negligible when most of the water levels were measured, the potentiometric-surface data represent predevelopment or near predevelopment conditions in most areas. However, water levels in Bexar, Reeves, Pecos, Reagan, and Upton Counties might reflect the effects of minor ground-water development.

The most important controls on hydraulic head in the Edwards-Trinity aquifer system are the slope on the base of the aquifer system (fig. 7), topographic relief (fig. 3), and the location of springs and streams (fig. 3). The base of the aquifer system (Barker and Ardis, 1992) generally slopes from northwest to southeast, and this is the prevailing direction of ground-water flow as indicated by the potentiometric contours in figure 16. The altitude of land surface decreases about 2,500 ft from northwest to southeast, and the potentiometric surface typically is a subdued replica of the associated topography. The strong influence of springs and streams on the shape of the potentiometric surface indicates that the distribution of hydraulic head and the direction of ground-water flow largely are controlled by the areas of ground-water discharge.

The hydraulic heads used to construct the potentiometric map (Bush and others, 1993) range from nearly 800 ft below land surface in Terrell County to nearly 100 ft above land surface in Bexar County. Most of the water levels are within 200 ft of land surface, except in the central part of the aquifer system where they mostly range from 200 to 400 ft below land surface. Although the topographic influences on hydraulic head generally are most obvious in the lower-lying areas of relatively shallow ground water, the potentiometric surface is graded in places toward the Colorado River, Pecos River, and Rio Grande—all major drains that are incised deeply into the rocks that form the Edwards-Trinity aquifer.

Except where the aquifer system is anisotropic, the flow of ground water is normal to the potentiometric contours (fig. 16). Thus, the prevailing direction of flow in the study area is toward major springs and perennial streams (fig. 3). The influence of the three largest streams—the Colorado River, the Pecos River, and the Rio Grande—is apparent over most of the Hill Country, Edwards Plateau, and Trans-Pecos from the steep

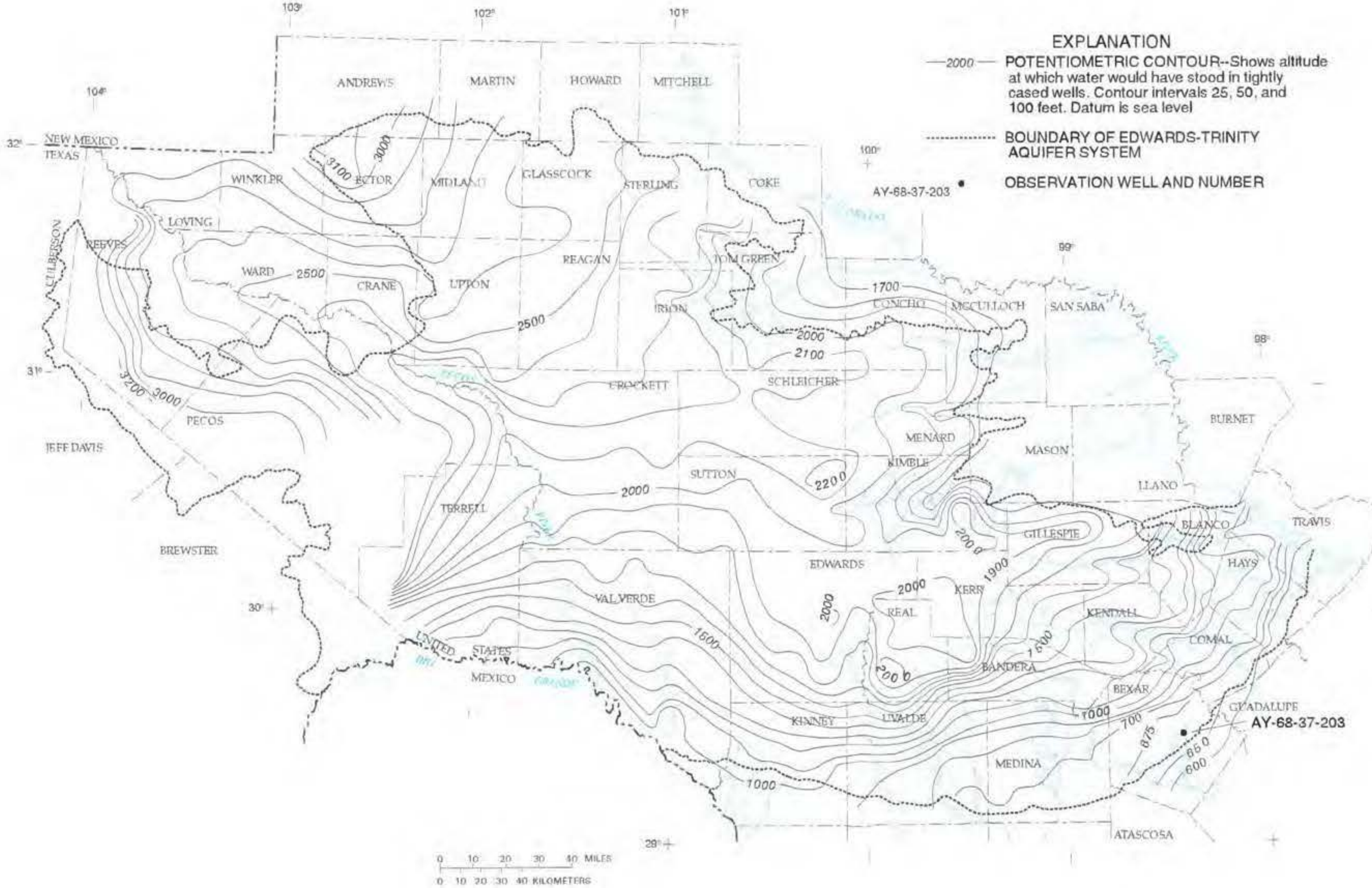


FIGURE 16.—Historical (1915–69) potentiometric surface of the Edwards-Trinity aquifer system and of selected contiguous hydraulically connected units. (Modified from Bush and others, 1993.)

hydraulic gradients toward these regional drains. The potentiometric contours sweep upstream where the streams draining eastern and southern margins of the Edwards Plateau are sustained largely by base flow.

The en echelon geologic structure and the resulting distribution of transmissivity in the Balcones fault zone make the regional potentiometric-surface map (fig. 16) a misleading indicator of the direction of most ground-water flow in large parts of the Edwards aquifer (Arnow, 1963, p. 29–30). The regional potentiometric contours indicate that under typical, isotropic conditions most of the ground water should flow southeastward toward the freshwater/saline-water transition zone. However, many of the Balcones faults (fig. 6) are barrier faults, which impede or block the southeastward flow of ground water, so that most of the water is diverted northeastward (Maclay and Small, 1986, p. 39). The fracture network, as well as the associated joint cavities and solution channels that are subparallel to the barrier faults, impart an anisotropic pattern of hydraulic conductivity and a dominant southwest-to-northeast component of transmissivity. Although the southwest-to-northeast gradients are comparatively small, the transmissivity tensors aligned with the fault zone are great enough to move large amounts of ground water from recharge areas in the southwestern part of the fault zone to major springs in the northeastern part (figs. 3, 4).

SATURATED THICKNESS

The saturated thickness of the Edwards-Trinity aquifer system under long-term average, near predevelopment (historical) conditions is shown in figure 17. The saturated thickness, which generally is more than 500 ft in the southern part of the aquifer system, typically decreases to less than 100 ft near the northern limits of the study area. The saturated thickness is more than 500 ft throughout the Balcones fault zone and over the southeastern two-thirds of the Hill Country. The saturated thickness decreases to less than 100 ft over the northwestern third of the Hill Country where the Trinity aquifer thins against Precambrian rocks of the Llano uplift. In the Edwards Plateau, the saturated thickness grades from more than 500 ft in the southern one-half of the area to less than 100 ft along the northern margin. In the Trans-Pecos, the saturated thickness varies over short distances from more than 500 ft to less than 100 ft, reflecting rugged relief on the base of the aquifer system and contiguous hydraulically connected units.

Local variations from the regional patterns of saturated thickness result from structural troughs and ridges on the base of the aquifer system (Barker and Ardis, 1992). Subregional increases in saturated thickness in parts of Kimble, Sutton, and Terrell Counties result from northwest-to-southeast plunging troughs in the pre-Cretaceous rocks that form the base of the aquifer system. A ridge of Permian rock extending southward from southwestern Concho County, through western Menard County, to northwestern Kimble County is responsible for a conspicuous, lobate-shaped pattern of less than 100-ft saturated thickness across this area.

Just as topographic highs and lows (fig. 3) produce highs and lows in the potentiometric surface (fig. 16), the relief in the potentiometric surface affects the distribution of saturated thickness (fig. 17). Areas of lesser saturated thickness associated with areas of lower hydraulic head are present throughout the study area; however, such areas are especially prominent in the Hill Country and along the northeastern margin of the Edwards Plateau. The relation is evident mostly along the upper reaches of the Concho, San Saba, Llano, Pedernales, Blanco, and Guadalupe Rivers.

The map of saturated thickness (fig. 17) extends beyond the boundary of the Edwards-Trinity aquifer system in parts of Crane, Pecos, Reeves, Upton, and Ward Counties. Here, the map depicts the saturated thickness of the Cenozoic Pecos alluvium aquifer (Ashworth, 1990, p. 12), which is connected hydraulically to the Edwards-Trinity aquifer in those counties.

In western parts of the Edwards Plateau and in the Trans-Pecos, the Edwards-Trinity aquifer is underlain by the Dockum aquifer (Ashworth, 1990, p. 6; Texas Water Development Board, 1990, fig. 1–2). Where the Edwards-Trinity aquifer overlies the Dockum aquifer (fig. 2), the saturated thickness of the regional ground-water-flow system might be considered from 100 to 200 ft greater than that shown in figure 17 for the Edwards-Trinity aquifer alone.

TRANSMISSIVITY

Transmissivity equals the product of hydraulic conductivity and saturated thickness, both of which vary spatially. Saturated thickness also can vary with time as a result of seasonal or long-term changes in hydraulic head. Although hydraulic conductivity varies greatly as a function of direction inside the Balcones fault zone, hydraulic conductivity typically is small outside the fault zone. Although saturated thickness is uniformly large inside the fault zone, it varies greatly outside the fault zone.

The regional distribution of transmissivity in the Edwards-Trinity aquifer system (fig. 18) was ascertained from the results of aquifer tests, geologic observation, and computer simulation. First, estimates of transmissivity from the results of 29 aquifer tests (based

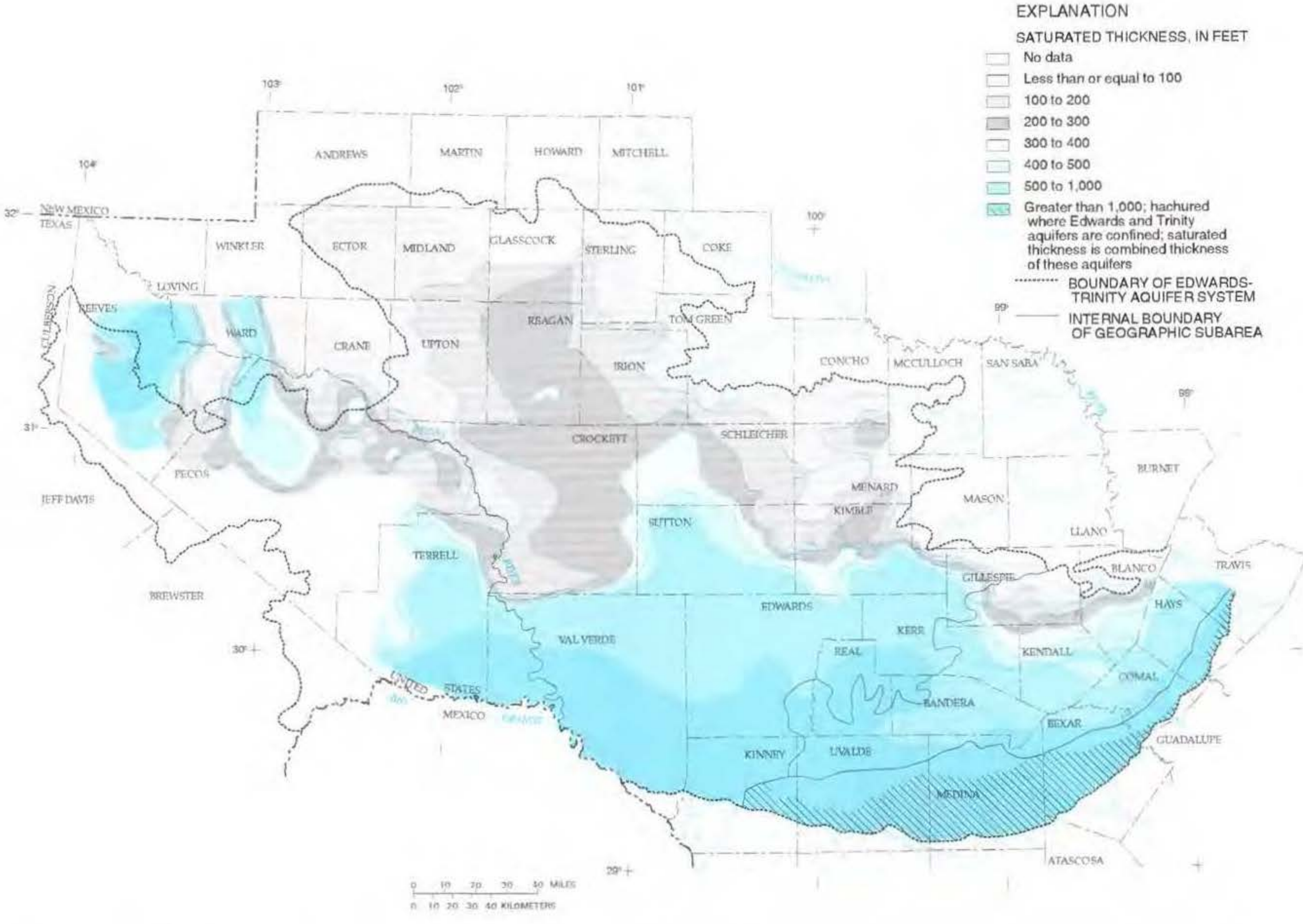


FIGURE 17.—Historical (1915–69) distribution of saturated thickness in the Edwards-Trinity aquifer system and in selected contiguous hydraulically connected units. (Modified from Ardis and Barker, 1993.)

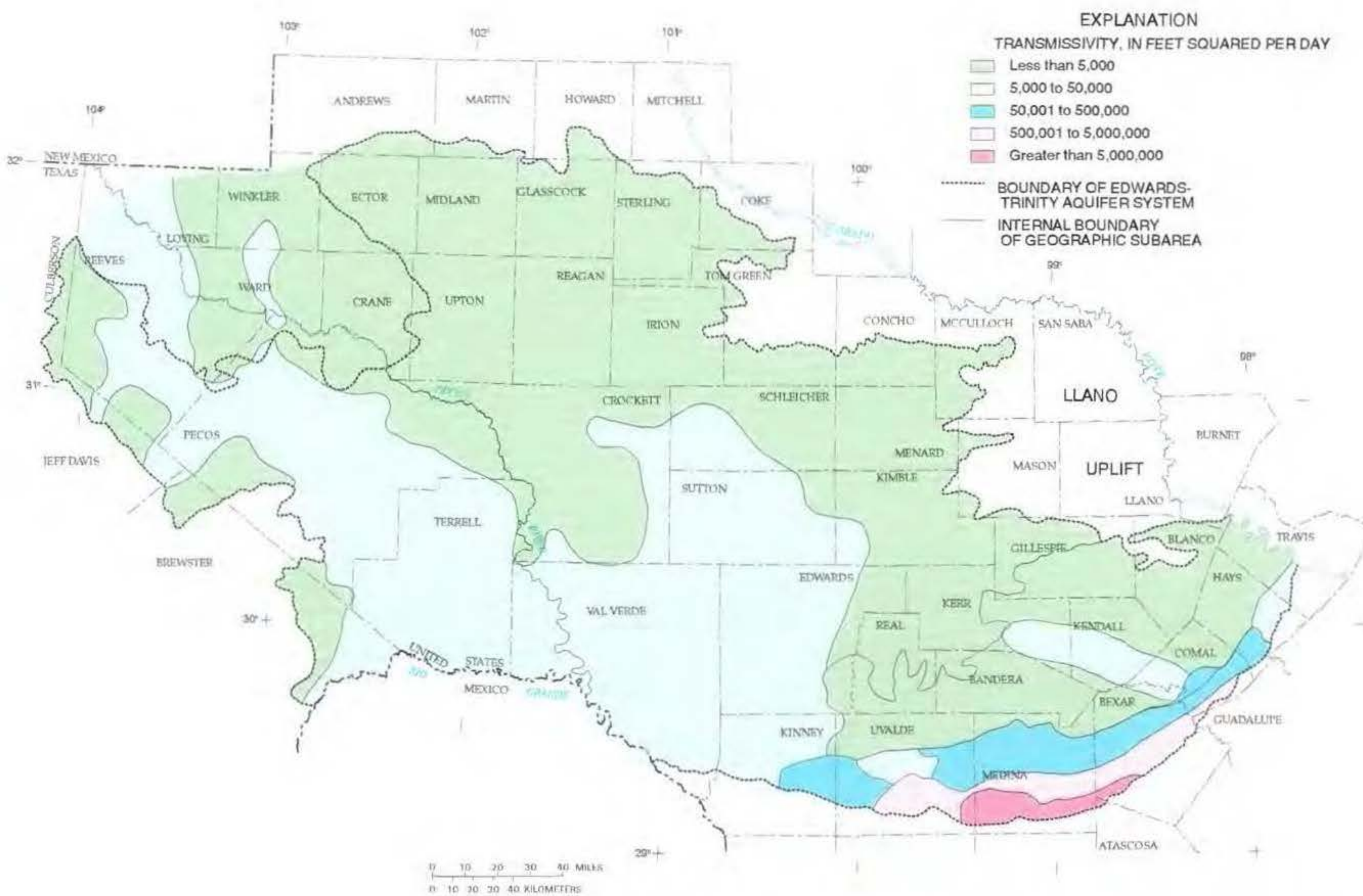


FIGURE 18.—Regional distribution of transmissivity in the Edwards-Trinity aquifer system and in selected contiguous hydraulically connected units. (Modified from Kuniansky and Holligan, 1994.)

on Theis, 1935) were combined with estimates derived from 269 observations of specific capacity (based on Bedinger and Emmett, 1963). Second, a transmissivity map was constructed for the Hill Country, Edwards Plateau, and Trans-Pecos from the individual estimates of transmissivity. Third, this transmissivity map was combined with a published map of transmissivity for the Edwards aquifer in the San Antonio area of the Balcones fault zone (Maclay and Land, 1988, fig. 19). Fourth, the preliminary map of transmissivity for the entire aquifer system was refined during the calibration of a computer model of ground-water flow. The preliminary transmissivity data were adjusted through the trial-and-error process of minimizing the differences between simulated and observed hydraulic conditions in the aquifer system (Kuniansky and Holligan, 1994).

The final distribution of transmissivity generally reflects larger values for the Hill Country, Edwards Plateau, and Trans-Pecos than those initially obtained from the aquifer-test and specific-capacity data. The initial values were based on data from wells that typically do not penetrate the aquifer system fully; however, the model-calibrated values necessarily incorporate the effects of the total saturated thickness (fig. 17).

Transmissivity in the Edwards-Trinity aquifer system ranges from less than 5,000 to more than 5,000,000 ft^2/d. Transmissivity in the Edwards aquifer in the Balcones fault zone ranges from about 10,000 to more than 5,000,000 ft^2/d (Maclay and Land, 1988, p. A26) and probably averages about 750,000 ft^2/d (Maclay and Small, 1986, fig. 20). Transmissivity in the Trinity and Edwards-Trinity aquifers ranges from less than 1,000 to about 50,000 ft^2/d and probably averages less than 10,000 ft^2/d (Walker, 1979; Rees and Buckner, 1980; Ashworth, 1983).

The Balcones faulting triggered the processes responsible for the sizable contrasts between the hydraulic characteristics of the Edwards aquifer and those of the Trinity and Edwards-Trinity aquifers. Although the neomorphic alteration of some strata in the Balcones fault zone has caused a net overall decrease in total porosity, the effects of dissolution overwhelmingly have enhanced the porosity and hydraulic conductivity of the Edwards aquifer (Maclay and Small, 1986, p. 28, 32). The difference between the transmissivity of the Edwards aquifer and that of the deeper Trinity aquifer in the Balcones fault zone is attributable to the effects of fractures that close with depth and a history of comparatively dynamic ground-water flow near the surface. The faulting increased hydraulic gradients across the vertically displaced terrain, which enhanced the percolation of meteoric water from land surface and increased the velocity of shallow ground-water flow. A dynamic regime of shallow ground-water flow evolved that promoted dissolution and enhanced the transmissivity of the Edwards aquifer. Cementation, recrystallization, and replacement resulting from deep burial and comparatively sluggish ground-water movement combined to diminish the transmissivity of the underlying Trinity aquifer, as well as the transmissivity of aquifers outside the fault zone.

The transmissivity of the Trinity aquifer in the Hill Country and of the Edwards-Trinity aquifer in the Edwards Plateau and Trans-Pecos also is small compared with the transmissivity of the Edwards aquifer in the Balcones fault zone. Secondary calcite has occluded most of the primary porosity in carbonate rocks outside the fault zone (Jacka, 1977, p. 191–195) where cavernous porosity (Kastning, 1983; 1986) associated with large-scale faulting and aggressive dissolution is comparatively localized, or above the present-day saturated zone. Variations in transmissivity outside the fault zone probably result more from differences in saturated thickness (Ardis and Barker, 1993) than from differences in tectonic and diagenetic activity.

Outside the Balcones fault zone, transmissivity generally is largest (greater than 5,000 ft^2/d) in areas where the saturated thickness exceeds 500 ft; transmissivity generally is smallest (less than 5,000 ft^2/d) in the northern part of the study area, where the saturated thickness generally is less than 500 ft. The regional distributions of transmissivity (fig. 18) and saturated thickness (fig. 17) indicate that, outside the Balcones fault zone, hydraulic conductivity probably averages about 10 ft/d. Within the Balcones fault zone, where the saturated thickness everywhere is greater than 500 ft, hydraulic conductivity probably averages between 100 and 1,000 ft/d.

AQUIFERS

The characteristics of each of the three regional aquifers are summarized below. The summary begins with the Edwards aquifer, the easternmost and most permeable aquifer in the aquifer system.

EDWARDS AQUIFER

The Edwards aquifer in the Balcones fault zone (Texas Water Development Board, 1990, fig. 1–1) is one of the most productive subsurface reservoirs of potable water in the world. The aquifer lies within the lower part of Washita strata and occupies all Fredericksburg strata in the fault zone. The U.S. Environmental Protection Agency recognizes the Edwards aquifer as a sole-source aquifer in the San Antonio area (van der Leeden and others, 1990, p. 713–715), where it serves the domestic, public-supply, industrial, and agricultural needs of more than 1 million people. The economies of Medina and Uvalde Counties, west of San Antonio, primarily are based on farming and ranching activities, much of which depends on water pumped from the Edwards aquifer. Northeast of San Antonio, the Edwards aquifer discharges through Comal and San Marcos Springs (fig. 3), whose flows are important to the success of recreational economies, the survival of several threatened or endangered plant and animal species, and the maintenance of downstream fish and wildlife habitats and water supplies. Droughts and the resulting less-than-normal recharge rates and (or) greater-than-normal withdrawal rates periodically cause water-level declines and springflow reductions. The demands for water are expected to continue increasing throughout the central Texas area to sustain agricultural, industrial, and municipal activities and to ensure the survival of threatened and endangered species. Water managers and planners as well as the affected citizens understandably are concerned about the future of the Edwards aquifer and the unique ground-water resource it represents.

Ground-water conditions in the Edwards aquifer have evolved from tectonic and diagenetic events superimposed upon depositional products of the San Marcos arch (Rose, 1972), Devils River trend (Lozo and Smith, 1964), and Maverick basin (Winter, 1962). The part of the Edwards aquifer that formed on the San Marcos arch and in the Devils River trend extends from the Colorado River through eastern Uvalde County (fig. 2). The part of the Edwards aquifer that formed in the Maverick basin extends from central Uvalde County through central Kinney County. This section of the report discusses ground-water conditions in the Edwards aquifer east of central Uvalde County in rocks (fig. 11) that formed on the San Marcos arch (the Georgetown, Person, and Kainer Formations) and in the Devils River trend (the Devils River Formation). Ground-water conditions in equivalent rocks that formed in the Maverick basin (the Salmon Peak, McKnight, and West Nueces Formations) are discussed under "Edwards Plateau," because the hydraulic conditions in western Uvalde and eastern Kinney Counties (at the westernmost end of the Balcones fault zone) are most like those in the Edwards-Trinity aquifer in the southern part of the Edwards Plateau.

The Edwards aquifer is hydraulically unconfined in the outcrop area of the Edwards Group (Rose, 1972, pl. 2) and in the outcrop areas of the Devils River, Salmon Peak, McKnight, and West Nueces Formations across parts of Kinney, Medina, and Uvalde Counties (fig. 2). The Edwards aquifer is confined in the downdip area beneath the Navarro-Del Rio confining unit. The confined part of the aquifer is bound on its downdip (gulfward) margin by a freshwater/saline-water transition zone of brackish water. The concentrations of dissolved solids downdip of the transition zone exceed 1,000 mg/L (Maclay and others,1980, p. 13) and rapidly increase in a gulfward direction to more than 250,000 mg/L (Maclay and Land, 1988, p. A12) near the Stuart City reef trend (fig. 6). The concentration of dissolved solids in the Edwards aquifer updip of the transition zone ranges from about 250 to 300 mg/L (Pavlicek and others, 1987, p. 3).

Diagenetic differences between rocks of the saline-water zone and those of the Edwards aquifer were attributed by Ellis (1986, p. 101) to the effects of vastly different pore-water chemistries since the Miocene Epoch, when the majority of the normal (down-to-the-southeast) faulting in the Balcones fault zone is believed to have taken place. Although the saline-water zone is saturated with respect to calcite, dolomite, gypsum, celestite, strontianite, and fluorite, water in the Edwards aquifer is saturated only with respect to calcite (Pearson and Rettman, 1976, p. 19). The rocks of the highly permeable Edwards aquifer mostly are calcitic, dedolomitized, and neomorphically altered to coarse microspar and pseudospar. The comparatively impermeable rocks of the saline-water zone mostly are dolomitic and contain unoxidized organic material, including petroleum, and accessory minerals such as pyrite, gypsum, and celestite (Maclay and Small, 1986, p. 28). The negligible hydraulic conductivity of these rocks is sustained by a scarcity of permeability-enhancing features (such as open fractures) to interconnect the generally minor interparticle and intercrystalline porosity that is characteristic of the saline-water zone (Kozik and Richter, 1979, p. 26).

As a result of the Balcones faulting and associated fracturing, large volumes of freshwater began to infiltrate strata within the fault zone that previously had been isolated from meteoric conditions. The Edwards aquifer subsequently resulted from joint cavities and solution channels (some cavernous in extent) that evolved as fractures and bedding planes widened through dissolution (Abbott, 1975). Additionally, the preferential dissolution of evaporites and other soluble minerals, fossil parts, and burrow filling has rendered a honeycombed or vuggy porosity to much of the aquifer (Hovorka and others, 1995).

Ground-water flow in the Edwards aquifer largely is controlled by an anisotropic pattern of hydraulic conductivity. The anisotropy originates from the effects of barrier faults, which displaced the strata vertically so that permeable rock is juxtaposed opposite impermeable strata (pl. 3), thus blocking or impeding ground-water flow in directions normal to the faults. The increases in hydraulic conductivity that resulted from post-fault dissolution were greatest along joint cavities and solution channels aligned with the fault zone. The resultant vectors of transmissivity therefore trend approximately N. 40° to 70° E. (Collins, 1995). Because the faults are most abundant across northern Medina, central Bexar, southern Comal, southern Hays, and central Travis Counties (Baker and others, 1986, fig. 2; Maclay and Small, 1986, fig. 3), the strongest anisotropy exists east of Uvalde County. The anisotropy is so dominant in the subcrop of the Edwards aquifer in Bexar County (Arnow, 1963, p. 29–31) that most ground-water flow appears to nearly parallel the equipotential lines on regional potentiometric maps of the San Antonio area (Maclay and Small, 1986, fig. 23).

From upgradient parts of the outcropping recharge area, ground water generally flows downdip in a southerly direction. The barrier faults typically block the southeastward flow of ground water and divert it northeastward, along flowpaths aligned with the fault zone (Arnow, 1963, p. 29–31). In some places, a secondary network of transverse faults obstructs the major northeast-trending flowpaths, imposing internal boundaries that further divert or compartmentalize the flow system (Maclay and Small, 1983, p. 135–145). As a result, local patterns of ground-water flow can be extremely complex, making predictions about future responses to prolonged drought or additional pumping difficult to determine (G.E. Groschen, U.S. Geological Survey, written commun., 1994).

The Edwards aquifer primarily is recharged by the (1) seepage from streams draining the Hill Country, where the streams flow onto permeable outcrop areas of the Edwards Group and Devils River Formation (Puente, 1978); (2) infiltration of precipitation in the outcrop areas; (3) subsurface inflow across the updip margin of the Balcones fault zone where the Trinity aquifer is laterally adjacent to downfaulted Edwards strata (Veni, 1994); and (4) diffuse upward leakage from the underlying Trinity aquifer. Recharge rates vary considerably with time, depending upon antecedent conditions and the frequency and intensity of precipitation. Although the actual rates of recharge cannot be measured, estimates of recharge routinely are made for water-management purposes.

The estimates of recharge to the Edwards aquifer from sources (1) and (2) above range from about 44,000 acre-ft during 1956 to about 2,500,000 acre-ft during 1992, and total recharge from these sources has averaged about 680,000 acre-ft/yr since the mid-1930's (Bader and others, 1993, table 4.1). The amount of water entering laterally from the Hill Country is unknown; however, a preliminary estimate (assuming an average hydraulic gradient of 20 ft/mi and an average transmissivity of 5,000 ft^2/d) indicates that this inflow probably exceeds 100,000 acre-ft/yr. The rates of diffuse upward leakage also are unknown; however, the preliminary results of computer simulation (Kuniansky and Holligan, 1994) indicate a long-term average rate of about 10,000 acre-ft/yr.

Most ground-water discharge takes place as (1) springflow, (2) withdrawals by industrial-, irrigation-, and public-supply wells, (3) diffuse upward leakage to Upper Cretaceous strata, and (4) leakage to the Colorado River. Springflow has averaged about 400,000 acre-ft/yr since the mid-1930's (Slade and others, 1986, p. 69; Bader and others, 1993, table 5.1). After steadily increasing from about 100,000 acre-ft/yr during the 1930's to an average 470,000 acre-ft/yr during the 1980's, ground-water withdrawals recently have tapered to an average 420,000 acre-ft/yr during 1990–93 (Bader and others, 1993; Bill Couch, Barton Springs-Edwards Aquifer Conservation District, oral commun., 1993). The rates of leakage from the aquifer to the Upper Cretaceous strata and to the Colorado River are unknown; however, they undoubtedly are considerably smaller than the rates of springflow and pumpage.

Most of the ground water for public-supply use is withdrawn near San Antonio, where water levels in a key U.S. Geological Survey observation well (AY–68–37–203, fig. 16) have varied between a low of 612.5 ft above sea level in 1956 to a high of 703.3 ft above sea level in 1992 (Bader and others, 1993, table 2.1). Although droughts and floods have caused substantial short-term fluctuations in ground-water levels, long-term hydrographs indicate no net decline (or rise) of water levels in the San Antonio area over the last 80 years (R.W. Maclay, U.S. Geological Survey, written commun., 1990).

TRINITY AQUIFER

The Trinity aquifer (Texas Water Development Board, 1990, fig. 1–1), which consists entirely of Trinity strata, dominates the ground-water hydrology of the Hill Country (5,300 mi^2). As a result of the Balcones faulting and subsequent erosion, most Fredericksburg strata and practically all Washita strata have been removed from the Hill Country. However, a few domestic- and stock-supply wells in interstream areas of northwestern Bandera, northern Kendall, and eastern Kerr Counties are completed in the Fort Terrett Formation. Likewise, the Devils River Formation could contribute to the water supply in small parts of southern Real and northern Uvalde Counties.

The Trinity aquifer includes three relatively permeable zones that are separated vertically by two relatively impermeable intervals. The upper Trinity permeable zone comprises the upper member of the Glen

Rose Limestone. The middle Trinity permeable zone comprises the lower member of the Glen Rose Limestone, the Hensel Sand, and the Cow Creek Limestone. The lower Trinity permeable zone comprises the Sycamore Sand, updip, and the Sligo and Hosston Formations, downdip.

The upper Trinity permeable zone is separated from the middle Trinity permeable zone by thin, hydraulically tight interbeds within the upper part of the Glen Rose Limestone. According to Ashworth (1983, p. 33), these interbeds are "*** laterally continuous, alternating resistant and nonresistant beds of blue shale, nodular marl, and impure fossiliferous limestone." Ground water in interstream areas of the Hill Country commonly is perched atop these interbeds, above the base level of the adjacent streams. Because of their relatively high stratigraphic position, the interbeds typically are breached by steep-sided stream channels that are connected hydraulically to the regional potentiometric surface (Kuniansky, 1990).

The middle Trinity permeable zone (fig. 19) generally is separated from the lower Trinity permeable zone (fig. 20) by the Hammett confining unit (fig. 21), which is composed of the Hammett Shale. The hydraulic distinction between the middle and lower permeable zones lessens northward, as the Hammett Shale pinches out against the Llano uplift. However, the Hammett Shale is areally continuous and relatively impermeable throughout most of the Hill Country where typically it is about 50 ft thick. Dislocation of the Pine Island Shale Member (downdip equivalent of the Hammett Shale) by high-angle normal faults disrupts the confining effect of the shale in the Balcones fault zone. Thus, the Hammett confining unit is limited to most of the Hill Country and a small southeastern part of the Edwards Plateau (figs. 2, 21; pl. 1).

The hydrology of the Trinity aquifer varies greatly in the Hill Country in response to its depth below land surface and diverse diagenetic history. Whereas unconfined conditions typically prevail within a few hundred feet of land surface, ground water generally is confined in the deeper strata. Although the evolution of stable minerals has diminished the hydraulic conductivity of most downgradient, subcropping strata, the leaching of evaporites and unstable carbonate constituents has enhanced the hydraulic conductivity of some upgradient, outcropping rocks. The Glen Rose Limestone is unusually permeable in outcrop and shallow subcrop areas of northern Bexar and southwestern Comal Counties, where the unit is cavernous (Kastning, 1986; Veni, 1994). Sinkholes in streambeds atop the Glen Rose Limestone frequently intercept surface water to provide substantial amounts of recharge to the Trinity aquifer (Ashworth, 1983, p. 10). The quartzose clastic facies of the updip Hensel Sand include some of the most permeable (albeit, typically unsaturated) sediments in the Hill Country. Because outcrop surfaces of the Cow Creek Limestone characteristically are riddled with moldic porosity from the dissolution of mollusk shells, most of its outcrop area is highly permeable and particularly receptive to recharge.

Vertical differences in hydraulic head are common within the Trinity aquifer. The greatest and most widespread head differences generally occur across downdip parts of the Hammett Shale, an areally extensive confining unit that ranges from about 40 to 80 ft thick over most of the Hill Country (Amsbury, 1974, p. 18). Ashworth (1983, figs. 16–18) reports that differences in hydraulic head across the Hammett confining unit exceed 100 ft over parts of eastern Bandera, Kendall, and eastern Kerr Counties. Differences in head also are caused by strongly cemented, thin interbeds of claystone, marl, and shale that are interspersed throughout the upper and middle parts of the Trinity aquifer, but most commonly within the Glen Rose Limestone. Water levels in the Glen Rose Limestone near the southeastern corner of Edwards County are more than 200 ft higher than those in the underlying Hosston Formation.

The Trinity aquifer is recharged, in order of importance, by the (1) lateral subsurface inflow of ground water from the Edwards Plateau, (2) infiltration of precipitation on the outcrop area, and (3) seepage of surface water from shallow, tributary streams in upland areas. The strongly cemented, hydraulically tight interbeds in the upper and middle parts of the Trinity aquifer impede the downward percolation of precipitation. Meteoric water that infiltrates the interstream areas moves laterally atop the dense interbeds more readily than it percolates vertically through them. Ground water emerges from springs and seeps along the tops of the impermeable bedding where the bedding is breached by the rugged topography of the Hill Country. Thus, instead of percolating to deeper permeable zones, much of the water in shallow parts of the Trinity aquifer discharges to the deeply entrenched, perennial streams that drain the area (Ashworth, 1983, p. 47).

Streamflow gains in the Hill Country subsequently are lost downstream in the Balcones fault zone where the streams cross faults that juxtapose nonleaky streambeds composed of Glen Rose Limestone with permeable streambeds on the outcrop of the Edwards aquifer. Discharge from the Trinity aquifer additionally occurs as lateral subsurface inflow (Veni, 1994) and diffuse upward leakage to the Edwards aquifer and through wells that withdraw water for domestic, industrial, irrigation, public-supply, and stock uses. Ground-water withdrawals from the Trinity aquifer averaged between

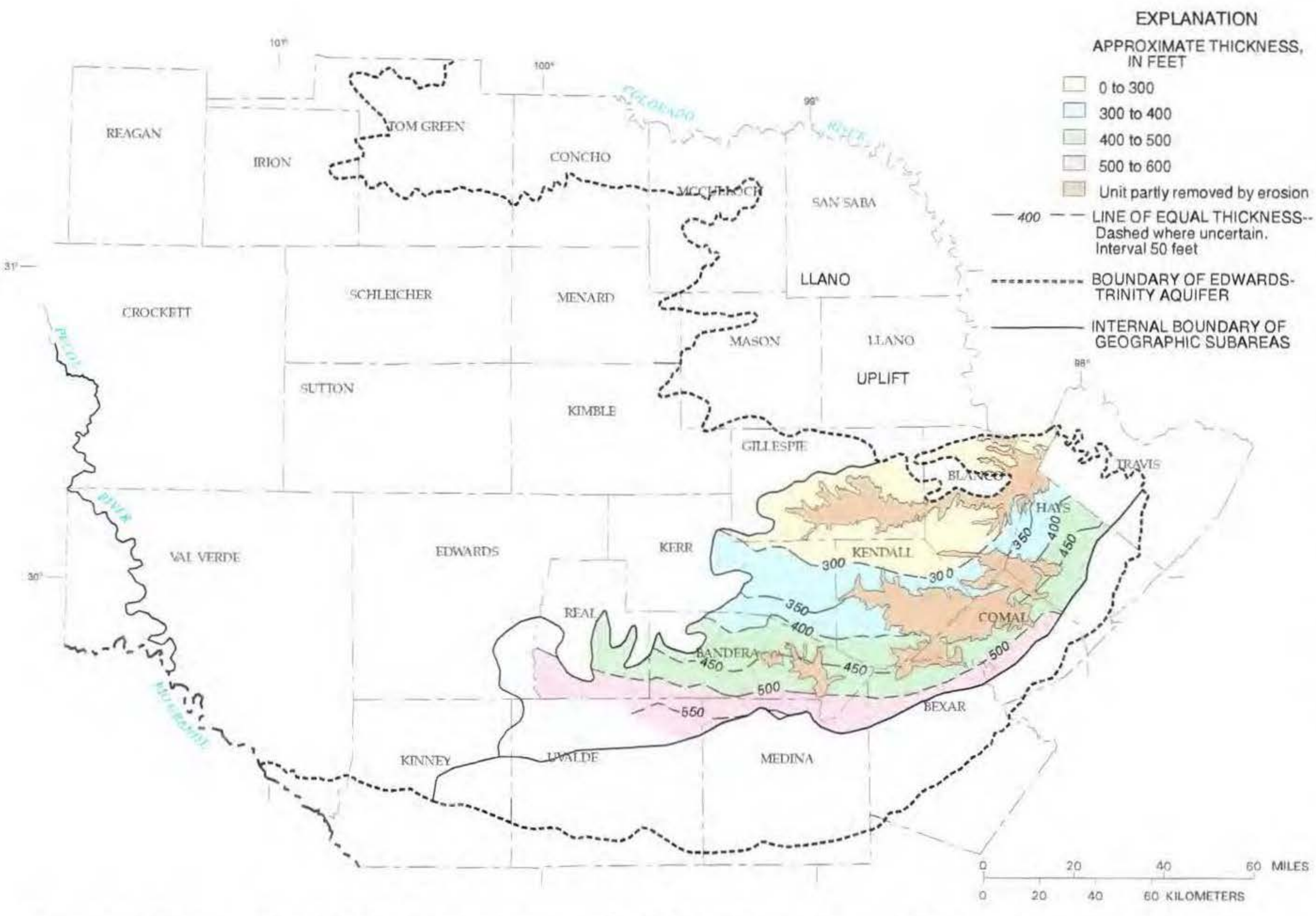


FIGURE 19.—Thickness of the middle Trinity permeable zone in the Trinity aquifer of the Edwards-Trinity aquifer system. (Modified from Ashworth, 1983.)

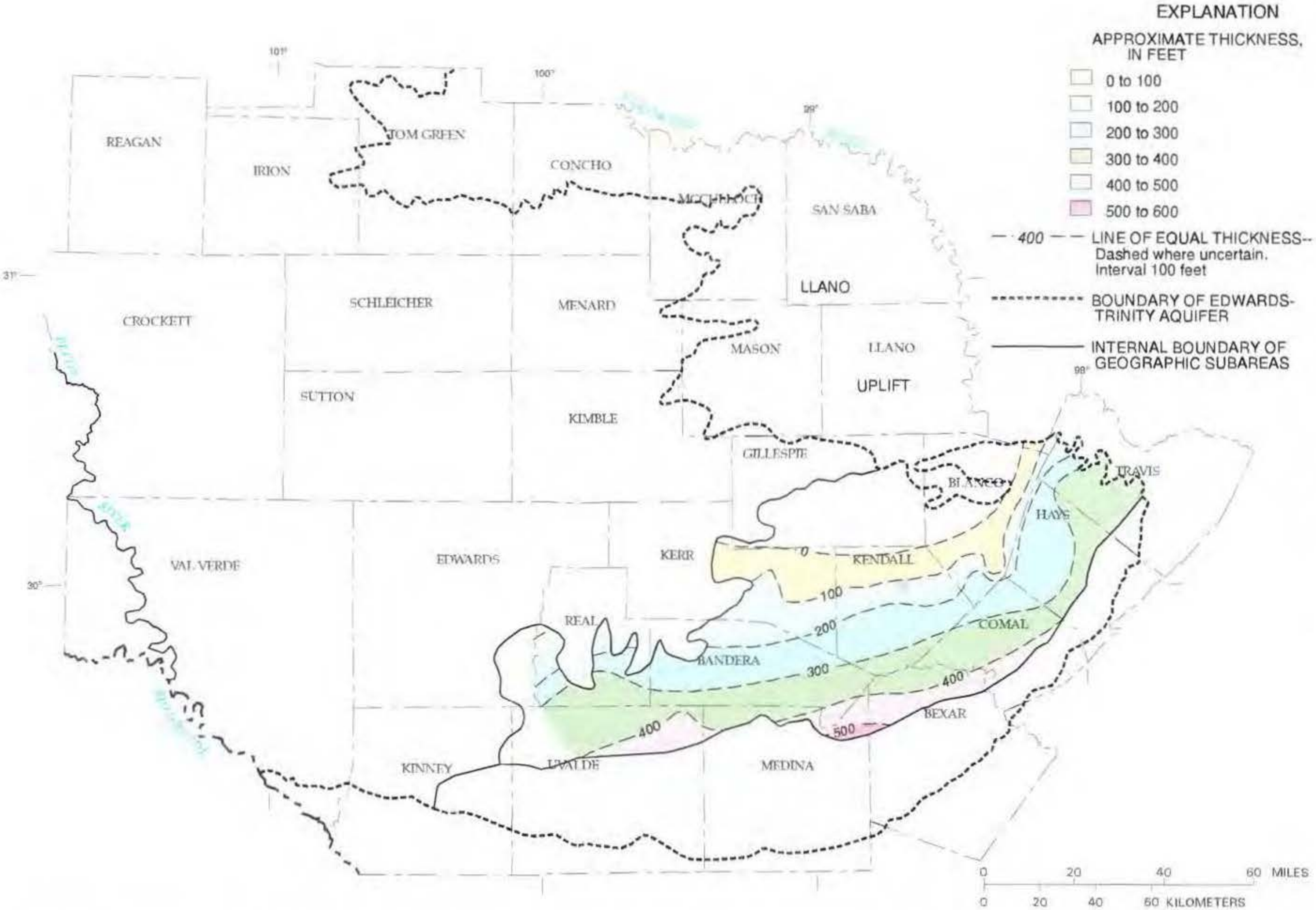


FIGURE 20.—Thickness of the lower Trinity permeable zone in the Trinity aquifer of the Edwards-Trinity aquifer system. (Modified from Amsbury, 1974; Ashworth, 1983.)

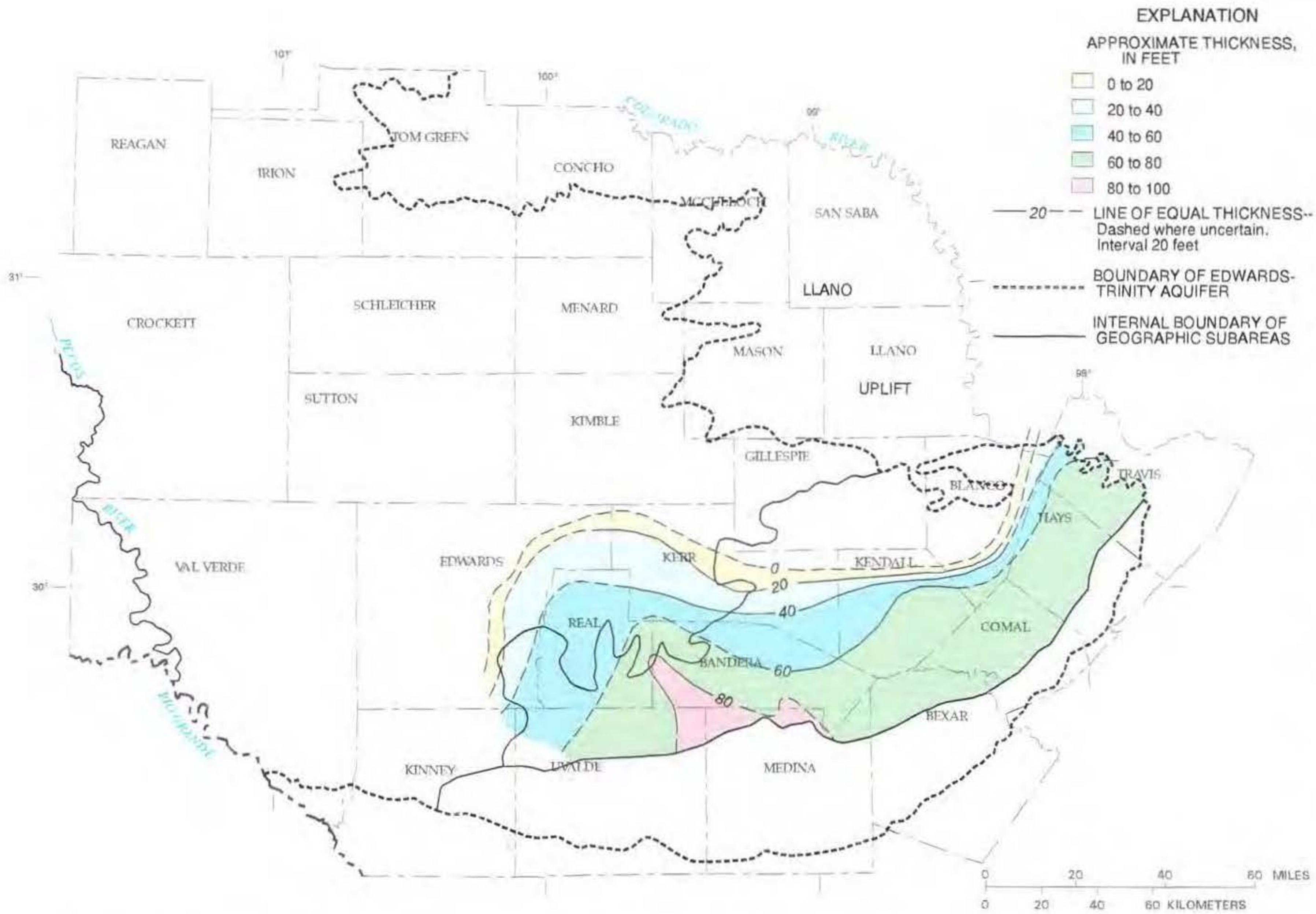


FIGURE 21.—Thickness of the Hammett confining unit in the Edwards-Trinity aquifer system. (Modified from Amsbury, 1974.)

10,000 and 15,000 acre-ft/yr during 1975–76 (Lurry and Pavlicek, 1991) and totaled about 13,500 acre-ft during 1990 (D.L. Lurry, U.S. Geological Survey, written commun., 1994).

Long-term hydrographs of ground-water levels in the Hill Country indicate that water levels can vary greatly over short periods. Water levels typically vary 50 ft or more between winter highs and summer lows. The seasonal variances are greatest in wells that are less than about 100 ft deep. Because the hydraulic conductivity generally is small and most high-demand wells are prone to large drawdowns during extended periods of ground-water withdrawals, the Trinity aquifer in the Hill Country generally is affected by drought more quickly than is the Edwards aquifer in the Balcones fault zone.

The transmissivity of the Trinity aquifer is highly variable because the saturated thickness varies with hydraulic head (fig. 16) and the altitude of the underlying pre-Cretaceous rocks (fig. 7), both of which can change greatly over a short distance in the Hill Country (Barker and Ardis, 1992; Bush and others, 1993). Transmissivity values, as derived from aquifer tests and estimated from specific-capacity data (Ashworth, 1983), range from less than 1,000 to about 50,000 ft^2/d. From the results of a regional ground-water-flow model, transmissivity appears to average less than 10,000 ft^2/d (Kuniansky and Holligan, 1994). The transmissivity of the Trinity aquifer in the Balcones fault zone mostly is undetermined; however, sparse data indicate that it is negligible compared to that of the overlying Edwards aquifer, and that it is no larger than that of the Trinity aquifer in the Hill Country.

EDWARDS-TRINITY AQUIFER

The Edwards-Trinity aquifer (Texas Water Development Board, 1990, fig. 1–1) extends over about 24,000 mi^2 of the Edwards Plateau and about 9,700 mi^2 of the Trans-Pecos. None of the rock units that compose this widespread aquifer is uniformly permeable. However, the rocks are combined regionally into one aquifer because no single rock unit stands out as substantially more or less permeable than the rest.

Edwards Plateau

The Edwards-Trinity aquifer in the Edwards Plateau includes all of the Fredericksburg and Trinity strata, plus all Washita rocks below the Del Rio Clay or the Buda Limestone (where the Del Rio Clay is absent). The Washita and Fredericksburg strata are the most important water-producing rocks over more than two-thirds of the Edwards Plateau. Except where the Washita and Fredericksburg strata are absent or thinly saturated, the hydrologic characteristics of the Trinity strata largely are untested. Water wells generally do not penetrate below the base of Fredericksburg strata (fig. 22) unless the Washita and Fredericksburg strata have failed to provide sufficient amounts of potable water. The Fredericksburg rocks generally are the most reliable sources of potable water in the area because the Trinity strata taper to zero or negligible thickness against the Llano uplift (fig. 8) and the regional ground-water-flow system is below the base of Washita rocks in most northern parts of the Edwards Plateau.

The Washita and Fredericksburg rocks are the principal water-producing zones south of northern Concho, Irion, Reagan, Tom Green, and Upton Counties (fig. 2), except where they are breached along the valleys of the Concho, Guadalupe, Llano, Pecos, Pedernales, and San Saba Rivers (fig. 3). In these topographically low areas, the Glen Rose Limestone, Hensel Sand, and basal Cretaceous sand supplement the stream-valley alluvium as major sources of ground water. Although the Washita rocks are used only minimally for water supply in the northern Edwards Plateau, they become more important sources of ground water as they thicken and become increasingly saturated toward the south. Where the Fort Lancaster Formation (west) and Segovia Formation (east) occupy the highest elevations in the Edwards Plateau, they generally are unsaturated, thinly saturated, or contain only perched ground water. However, the Fort Lancaster and Segovia Formations, in addition to the Devils River and Salmon Peak Formations (in the Devils River trend and Maverick basin, respectively), are important water-producing units in parts of Edwards, Kinney, and Val Verde Counties.

The Salmon Peak Formation is "moderately to very permeable" near the top (Maclay and Small, 1986, table 1). The lower part of the Salmon Peak Formation is nearly impermeable, except where fractured. The McKnight Formation locally contains permeable pockets of leached evaporites, but mostly it is considered nearly impermeable. Although the upper part of the West Nueces Formation is "moderately permeable," the lower part is nearly impervious to ground water (Maclay and Small, 1986, table 1).

The Devils River Formation is "very permeable and porous," especially in middle and upper parts of the unit that contain collapse breccia or vuggy zones of leached rudists (Maclay and Small, 1986). The upper and middle parts of the formation compose the principal water-producing zone in southern Edwards County and in central Val Verde County. The Devils River Formation supplies large amounts of irrigation water in western parts of the Balcones fault zone (in Medina and Uvalde Counties), where this unit is considered a major aquifer (Maclay and Small, 1986, table 1).

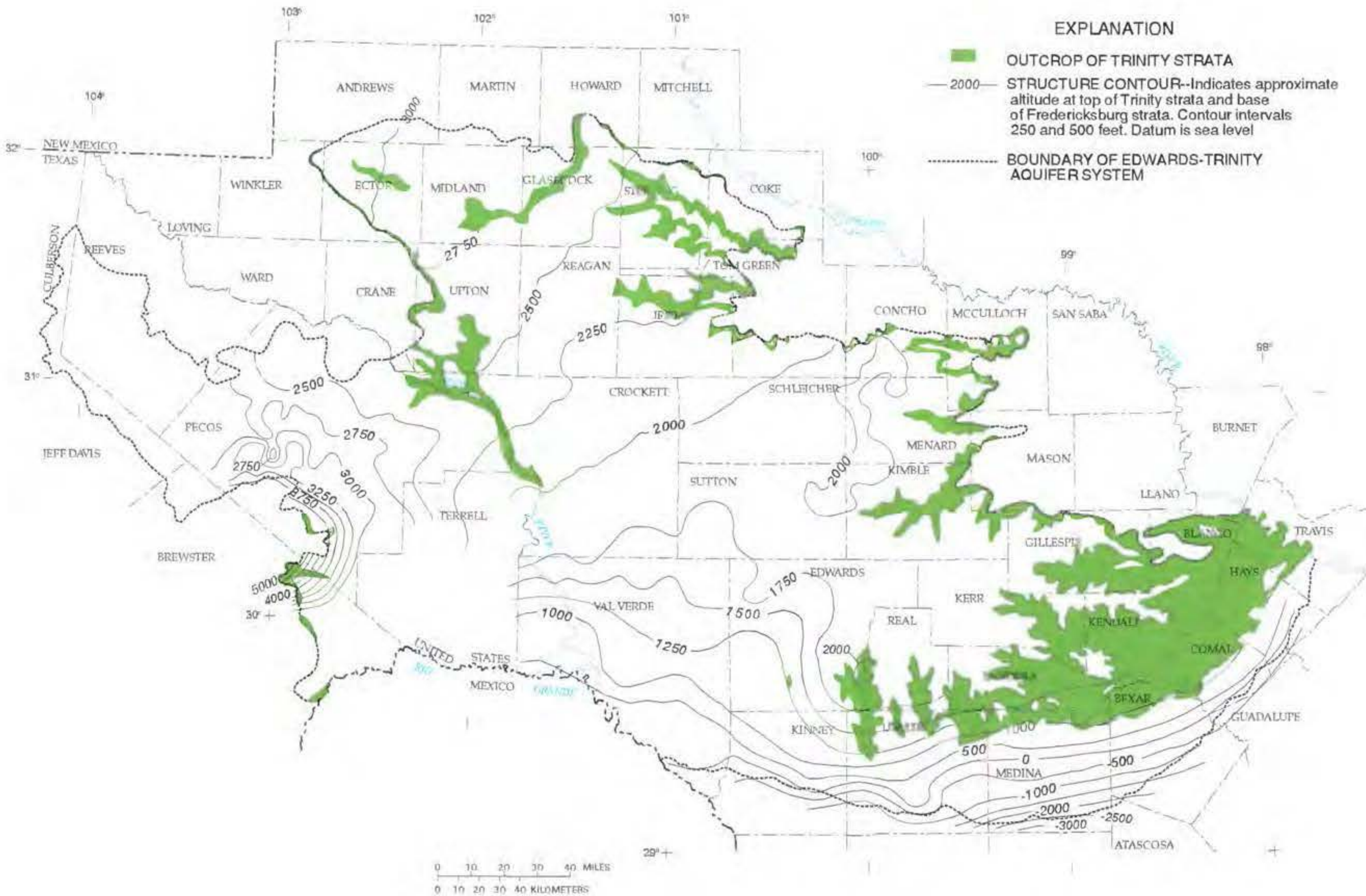


FIGURE 22.—Configuration of the top of Trinity strata and base of Fredericksburg strata in west-central Texas.

The Fort Terrett Formation provides most of the ground water used on the Edwards Plateau. The "burrowed zone" (pl. 1), near the base of this formation, might be the most permeable part of the Edwards Group outside the intensively fractured Balcones fault zone. The permeable nature of the burrowed zone results from the preferential leaching of burrow fillings, leaving a honeycombed pattern of porosity in the remaining rock (Rose, 1972, p. 34). The overlying "Kirschberg evaporite zone" (pl. 1) also is highly permeable where it is brecciated as a result of post-depositional leaching and structural collapse. Although the zones of Kirschberg breccia west of the Balcones fault zone mostly are unsaturated, the breccia enhances recharge in eastern parts of the Edwards Plateau by permitting comparatively large amounts of precipitation to infiltrate the subsurface.

With the exception of a few areas with shallow alluvial aquifers, the basal Cretaceous sand of Trinitian age is the most important water-producing unit in Ector, Glasscock, Midland, Sterling, and Upton Counties and along the Pecos River valley in Crockett County (fig. 8). The basal Cretaceous sand might supply nearly as much ground water as that pumped from Fredericksburg rocks in southern Irion, southeastern Reagan, and southern Tom Green Counties. Few water wells are deep enough to penetrate the basal Cretaceous sand over most of Crockett, Edwards, Schleicher, Sutton, and Val Verde Counties.

The Trinity units most likely to contain potable ground water in southern parts of the Edwards Plateau (northwestern Bandera, eastern Edwards, western Kerr, and northern Real Counties) are the lower member of the Glen Rose Limestone, the Hensel Sand, and the Cow Creek Limestone. The hydraulic characteristics of the much deeper Pearsall (undivided), Sligo, and Hosston Formations mostly are unknown. However, these lower Trinity units generally are more than 750 ft below land surface in this area. Because freshwater recharge to such depths is minimal in southern parts of the Edwards Plateau, water in the Pearsall, Sligo, and Hosston Formations probably contains dissolved constituents in concentrations (Walker, 1979, p. 93–95) that exceed the local standards for drinking water (Texas Department of Health, 1977).

The Hammett Shale, which is continuous and hydraulically tight over most of the Hill Country (fig. 3), grades northwestward across Edwards County into the comparatively permeable basal Cretaceous sand (figs. 8, 9, *J–J′*). Accordingly, the effectiveness of the Hammett confining unit diminishes west of the Hill Country, as the shale grades into sand. The Trinity strata are connected hydraulically to the overlying Fredericksburg strata, therefore, over most of the Edwards Plateau.

Water-producing zones in the Edwards Plateau mostly are confined or semi-confined, except in the shallowest zones and near the outer margins of Fredericksburg strata where the underlying Trinity sediments crop out. No confining unit is extensive enough to be mapped west and north of the western and northern limits of the Hammett confining unit (fig. 2). However, the effects of many discontinuous low-permeability beds accumulate with increasing depth below land surface to confine some deeper parts of the Edwards-Trinity aquifer. Unconfined conditions dominate where gaining streams are incised into sandy Trinity sediments along the Concho, Guadalupe, Llano, Pecos, Pedernales, and San Saba Rivers (fig. 3). From generally unconfined or semi-confined conditions in the west, the Edwards-Trinity aquifer becomes progressively more confined toward the southeast in response to an increasing thickness of overlying low-permeability beds, in that direction. Observations of diurnal changes in barometric pressure, water levels that rise above the top of water-producing zones, and entrapped hydrogen sulfide gas prompted Walker (1979, p. 49) to suggest that "*** water-table conditions may not be as prevalent as previously reported." Previous reports of unconfined conditions were based on observations from older, relatively shallow wells in the Edwards Plateau.

The Edwards-Trinity aquifer merges hydraulically with locally permeable Paleozoic strata around the western and southern flanks of the Llano uplift in Gillespie, Mason, and McCulloch Counties (fig. 2). In this area, deeply eroded Paleozoic and Precambrian rocks (fig. 7) form a subtle topographic basin (fig. 5), where a shallow ground-water regime has developed along fractures and joint cavities. Water from the northeastern fringe of the Edwards-Trinity aquifer merges with the shallow flow regime of the Marble Falls, Ellenburger-San Saba, and Hickory aquifers (Barker and Ardis, 1992) before discharging into the Colorado River and northeastward-flowing tributaries that drain the Llano area (figs. 2, 3).

The Edwards-Trinity aquifer overlies the Dockum Group of Triassic age in large parts of Crockett, Ector, Irion, Reagan, and Sterling Counties. Where middle parts of the Dockum Group are composed of sandy sediments that contain freshwater (Barker and Ardis, 1992), they comprise the Dockum aquifer (Texas Water Development Board, 1990, p. 1–6). Where upper, less permeable parts of the Dockum Group are absent, the Dockum aquifer merges in places with the basal Cretaceous sand of the Edwards-Trinity aquifer (fig. 2, pl. 4). In such places, the depth of ground-water circulation might increase a few hundred feet to the lower part of the Dockum Group—or to the top of Permian red beds, where the lower Dockum unit is absent. Water from the Dockum aquifer varies considerably in quantity and quality. However, well yields characteristically are less than a few hundred gallons per minute, and the water typically contains sodium, sulfate, chloride, and fluoride in concentrations (Ashworth and Christian, 1989) that exceed the local standards for drinking water (Texas Department of Health, 1977).

The Edwards-Trinity aquifer pinches out below the Ogallala Formation of Tertiary age along the northwestern edge of the Edwards Plateau (pl. 3) in Andrews, Glasscock, Howard, and Martin Counties (fig. 2). Coarse sand and gravel of the Ogallala Formation, which forms the High Plains aquifer (Gutentag and others, 1984, p. 8–13) in northwest Texas, fill erosional channels atop the basal Cretaceous sand in the northwestern part of the study area. Water discharging in a southeasterly direction from the southern tip of the High Plains aquifer recharges the northwestern fringe of the Edwards-Trinity aquifer.

From the northwestern part of the Edwards Plateau, water in the Edwards-Trinity aquifer generally flows southeastward along hydraulic gradients that average about 10 ft/mi. Local exceptions to the regional ground-water-flow pattern result from topographic and drainage variations and depressions in the potentiometric surface caused by pumping wells. The maximum hydraulic head in the Edwards-Trinity aquifer is in northwestern Ector County at about 3,100 ft above sea level, and the minimum hydraulic head, in southern Val Verde County, is about 2,000 ft above sea level (Bush and others, 1993). In the southwestern part of the Edwards Plateau, ground water discharges to the Pecos River and Rio Grande. In the northeast, ground water discharges to the Colorado River and its tributaries. In the southeast, ground water discharges to headwater reaches of the Frio, Guadalupe, Medina, and Nueces Rivers (fig. 3) and as lateral subsurface inflow to the Hill Country.

Most recharge to the Edwards-Trinity aquifer results from the infiltration of precipitation from land surface and from seepage losses through streambeds of intermittent streams. Discharge from the aquifer mainly occurs through (1) springs in the stream-dissected northeastern and southeastern fringes of the Edwards Plateau; (2) base flow to gaining reaches of the Concho, Llano, and Pecos Rivers; and (3) wells pumped for domestic, irrigation, and stock water. Recharge and discharge each average less than 1 in/yr over the Plateau, increasing from less than 0.5 in/yr in the western part to more than 0.5 in/yr in the extreme eastern part of the area (E.L. Kuniansky, U.S. Geological Survey, written commun., 1990).

Lurry and Pavlicek (1991) reported that during 1975–76 about 80 percent (100,000 acre-ft) of the average annual pumpage from the Edwards-Trinity aquifer in the Edwards Plateau (nearly 130,000 acre-ft/yr) was used for irrigation, stock, and rural domestic activities. Walker (1979, p. 76) estimated that about 72 percent of the total pumpage during 1972 was for irrigation. Irrigation pumpage from Glasscock and Midland Counties alone accounted for more than one-third of all pumpage during the mid-1970's (Lurry and Pavlicek, 1991). Since the mid-1970's, annual withdrawals from the Edwards-Trinity aquifer have fluctuated between about 85,000 acre-ft (during 1985) and about 128,000 acre-ft (1990) (D.L. Lurry, U.S. Geological Survey, written commun., 1992).

Ground-water levels in the Edwards Plateau mostly vary in response to short-term fluctuations in recharge and long-term variations in discharge. Most of the fluctuation in recharge results from cyclic patterns in precipitation, and most of the variation in discharge results from pumpage trends. Water levels have declined where and when the rates of recharge and natural discharge (evapotranspiration, springflow, and base flow) have not compensated for increasing rates of ground-water withdrawal.

During the last 50 years, water levels have declined more than 50 ft in northwestern parts of the Edwards Plateau, including parts of Ector, Glasscock, Midland, Reagan, Sterling, and Schleicher Counties (Walker, 1979, p. 96–100). Data from an observation well in Reagan County indicate more than 100 ft of decline since 1950 (Bush and others, 1993). The nearly continuous, long-term nature of water-level decline in many wells reflects a direct relation to a rapid increase in the number of irrigation wells that began about 1946 and continued through the 1960's.

Since the late 1970's, water levels in most parts of the Edwards Plateau have stabilized or begun to recover, reflecting the results of recent efforts to reduce the need for irrigation and to conserve water (J.B. Ashworth, Texas Department of Water Resources, written commun., 1991). Water-level hydrographs for central parts of the Edwards Plateau reflect a cyclic relation between recharge and precipitation: (1) declining water levels during most of the 1960's, when precipitation was below normal; (2) rising water levels during most of the 1970's, when precipitation was above normal; and (3) declining water levels during most of the 1980's, when precipitation was below normal. Many of the highest recorded water levels during the past 30 years in Crockett, Edwards, Kimble, Schleicher, and Sutton Counties occurred during the middle-to-late 1970's.

Transmissivity is relatively small in the Edwards Plateau, where it averages about 100 to 1,000 times less than that in the Balcones fault zone. Estimates of transmissivity from aquifer-test and specific-capacity data indicate that it probably is less than 5,000 ft^2/d over most of the Edwards Plateau (Walker, 1979, p. 72–75). Exceptions are in the southern part of the Edwards Plateau where Trinity rocks thicken southward into the Rio Grande Embayment (fig. 6) and wells completed in the relatively permeable Devils River Formation yield up to 500 gal/min. Results of a ground-water-flow model indicate that transmissivity probably averages about 10,000 ft^2/d over parts of Edwards, Terrell, and Val Verde Counties where the Cretaceous sediments are thickest (Kuniansky and Holligan, 1994).

Trans-Pecos

The Edwards-Trinity aquifer in the Trans-Pecos (fig. 3) includes all the Fredericksburg and Trinity strata plus all Washita rocks below the Del Rio Clay or the Buda Limestone (where the Del Rio Clay is absent). The hydrogeologic framework of Pecos, Reeves, and Terrell Counties is complicated structurally. The structural complexity results from the collapse of salt-laden Permian rocks that underlie much of the area and crustal deformation south and west of the area during Cenozoic time (Henry and Price, 1985). Less is understood about the Edwards-Trinity aquifer in the Trans-Pecos than perhaps any other part of the Edwards-Trinity aquifer system.

The Edwards-Trinity aquifer does not dominate the ground-water-flow system in the Trans-Pecos as it does in the Edwards Plateau. On average, the Edwards-Trinity aquifer is less permeable than the contiguous, hydraulically connected Cenozoic Pecos alluvium aquifer (fig. 2). The average hydraulic conductivity of the Edwards-Trinity aquifer probably is no greater than that of the most permeable part of the underlying Dockum aquifer. Therefore, the combined influence of all of the interconnected permeable rocks should be considered when conceptualizing the regional flow system in the Trans-Pecos.

The hydraulic conditions of the Washita and Fredericksburg rocks in the Trans-Pecos largely are unpredictable because the available hydrogeologic data are sparse and inconclusive. Most of the Washita strata and much of the Fredericksburg strata in Pecos and Terrell Counties are unreliable sources of ground water because they are relatively impermeable or lie above the regional ground-water-flow system. The hydraulic characteristics of the Washita and Fredericksburg strata in Reeves County have not been differentiated from those of the underlying Trinity rocks (Ogilbee and others, 1962). Where the Washita and Fredericksburg strata are saturated in eastern Pecos and Terrell Counties, they provide small amounts of water to stock-supply wells. Southwest of Fort Stockton in west-central Pecos County, limestone of the Finlay Formation contains a fault-controlled network of interconnected solution channels that has yielded up to 2,500 gal/min to irrigation-supply wells (Armstrong and McMillion, 1961, p. 59). In areas where solution channels have not developed, the equivalent strata yield considerably less water (100 to 500 gal/min) to individual wells. The discharge from many wells and most springs in southwestern Pecos County has decreased over the years because ground-water withdrawals have lowered water levels below solution channels that comprise the zones of greatest hydraulic conductivity.

Trinity strata in the Trans-Pecos include the basal Cretaceous sand and, in southern parts of Pecos and Terrell Counties, the Glen Rose Limestone and Maxon Sand (fig. 8). The Trinity Group generally is less than 500 ft thick in the Trans-Pecos, where much of it is unsaturated or marginally permeable. The availability of ground water from the Trinity Group largely remains untested in Terrell County, and the Maxon Sand and upper few hundred feet of Glen Rose Limestone generally are not saturated in Brewster County. Neither the Glen Rose Limestone nor the Maxon Sand is present in Reeves County, and the hydrologic aspects of the basal Cretaceous sand have not been distinguished from that of other Cretaceous strata in this area (Ogilbee and others, 1962, p. 27). Although the basal Cretaceous sand is only about 150 ft thick near Fort Stockton (fig. 11), this coarse-grained, quartzose unit is an important source of ground water in Pecos County (Armstrong and McMillion, 1961, p. 57, 62). The basal Cretaceous sand yields as much as 500 gal/min of water to individual industrial-, irrigation-, and public-supply wells in Pecos County.

The Edwards-Trinity aquifer is connected hydraulically to the Cenozoic Pecos alluvium, which fills two structural troughs in parts of Crane, Loving, Pecos, Reeves, Ward, and Winkler Counties (fig. 2). The troughs formed as large volumes of salt dissolved from deeply buried Permian rocks (Maley and Huffington, 1953), and much of the overlying Permian, Triassic, and Cretaceous strata collapsed and was transported from the area by the ancestral Pecos River. The alluvium predominately is an unconsolidated to semi-consolidated mixture of gravel, sand, silt, clay, and caliche. Although the alluvium is highly permeable in most areas, its hydraulic conductivity varies greatly because of differences in the degrees of sorting and consolidation. Where the alluvium is saturated and permeable, it comprises the Cenozoic Pecos alluvium aquifer (Texas

Water Development Board, 1990, fig. 1–1). Where the sediments are strongly cemented with hardpan (a calcareous precipitate), ground water frequently is perched above the regional potentiometric surface. The Cenozoic Pecos alluvium aquifer (fig. 2) is the primary source of water for irrigation in northern Reeves and northwestern Pecos Counties (Ashworth, 1990, p. 12).

The Cenozoic Pecos alluvium rests on Permian and Triassic red beds in northern Reeves County, where the alluvium in places is greater than 1,500 ft thick (pl. 2). Thinner deposits cover the north-facing flank of the southernmost trough, whose floor is composed of Cretaceous strata of the Edwards-Trinity aquifer (Ashworth, 1990, figs. 3, 5). Because the Cenozoic Pecos alluvium is connected hydraulically to the Edwards-Trinity aquifer, the base of the alluvium is considered the base of the regional ground-water-flow system where the Edwards-Trinity rocks are absent (Barker and Ardis, 1992).

The Edwards-Trinity aquifer overlies the Dockum Group of Triassic age in parts of Pecos and Reeves Counties (pl. 2). The upper part of the Dockum Group is absent in some areas, causing sand of the Dockum aquifer (middle part of the Dockum Group) to merge with the basal Cretaceous sand of the Edwards-Trinity aquifer (fig. 2). In these areas, the depth of regional ground-water flow might increase a few hundred feet below the base of the Edwards-Trinity aquifer system (Barker and Ardis, 1992). The Dockum aquifer has been a major source of public-supply water in northeastern Reeves County, where it also provides some water for livestock.

Although the Dockum aquifer directly underlies the Edwards-Trinity aquifer in northwestern Crockett and northeastern Reeves Counties, the extent and importance of the Dockum aquifer is uncertain across most of Pecos County (fig. 2). The Edwards-Trinity aquifer is directly underlain in this area by Permian and Triassic red beds that have not been differentiated (pls. 2, 5). The uppermost Permian rock unit is a red siltstone, cemented with gypsum and calcite, that resembles the lower part of the overlying Dockum Group. (The lower part of the Dockum Group is composed largely of reworked Upper Permian strata.) The undifferentiated red beds in Pecos County range from zero to about 1,500 ft thick; however, no part of the interval appears to be a particularly viable source of potable ground water. According to Armstrong and McMillion (1961, p. 37), the red beds of Permian and Triassic age yield "*** small amounts of water at various locations." Where the middle Dockum unit is present in Pecos County, it probably is thinner and less permeable than the Dockum aquifer of adjacent counties.

The Trans-Pecos aquifers primarily are recharged through the infiltration of storm runoff resulting from precipitation on the northern flanks of the Barilla, Davis, and Glass Mountains and on the eastern flanks of the Apache and Delaware Mountains (fig. 3). The headwaters of the streams that drain these mountains mostly are confined to narrow channels with nearly impervious streambeds. The high-gradient headwater channels empty into comparatively low-gradient arroyos atop porous alluvial fans at the base of the mountains. During prolonged storms, runoff fills the mountain channels and flows into the arroyos, from which water percolates to the Edwards-Trinity and Cenozoic Pecos alluvium aquifers.

Considerable recharge takes place in south-central Pecos County where the arroyos traverse coarse alluvium that overlies cavernous limestone of the Edwards-Trinity aquifer. Sinkholes in the limestone greatly expedite the recharge process (Armstrong and McMillion, 1961, p. 46; pl. 14). Some recharge might occur as lateral subsurface inflow from strata deep within the mountains in northern Brewster and Jeff Davis Counties. However, such inflow is considered unlikely because these strata are faulted, folded, and tilted to the extent that flow through them probably would be impeded, if not blocked entirely (Rees and Buckner, 1980, fig. 3). Much of the springflow in the Balmorhea area of Reeves County (fig. 3) that follows prolonged periods of precipitation has been traced to the infiltration of precipitation and storm runoff in a narrow anticlinal valley along the eastern escarpment of the Davis Mountains (White and others, 1941, p. 112). The results of more recent geochemical analyses by LaFave and Sharp (1987) indicate that a substantial part of the sustained (long-term) recharge to these springs might originate from relatively remote locations in and near the Apache Mountains.

Recharge has been induced in parts of the Trans-Pecos as a result of water-level decline caused by the withdrawal of water for irrigation. In response to water-level decline in the Cenozoic Pecos alluvium aquifer, hydraulic gradients between the Pecos River and the aquifer have reversed from their predevelopment direction in parts of Pecos (Armstrong and McMillion, 1961, p. 52) and Reeves Counties (Ogilbee and others, 1962, p. 33). The Pecos River now loses streamflow to the aquifer in parts of northwestern Pecos and north-central Reeves Counties, where the aquifer originally discharged to the river. Leakage from the Pecos River is not necessarily beneficial to the aquifer, as the concentrations of chloride and dissolved solids in this stream can exceed 5,000 and 15,000 mg/L, respectively (Grozier and others, 1966).

Although water levels declined more than 200 ft in parts of Reeves County and more than 100 ft in parts of Pecos County, decreasing rates of ground-water withdrawal since the mid-1960's have allowed water levels to recover as much as 75 ft in some wells (Bush and others, 1993). The reductions in irrigation pumpage occurred in response to (1) greater-than-normal precipitation during much of 1966–90; (2) fuel and labor costs that began to escalate during the 1970's; and (3) depressed profits in the agricultural marketplace during the last 30 years. An undetermined fraction of the irrigation water in shallow water-table areas percolates back to the saturated zone, thereby reducing the effects of ground-water withdrawal in some low-lying areas of the Trans-Pecos. Despite this return flow and the decreasing rates of withdrawal, water-level hydrographs indicate that water levels have not returned to predevelopment levels in Pecos County (Small and Ozuna, 1993); nor have water levels recovered fully in Reeves County (Sharp, 1989, p. 129).

Whereas well withdrawals in the Trans-Pecos were negligible through about 1945, withdrawal rates accelerated along with agricultural expansion following World War II. Between about 1946 and the late 1950's, the number of irrigation-supply wells increased annually by almost 25 percent. Pumpage in Pecos and Reeves Counties from the Cenozoic Pecos alluvium and Edwards-Trinity aquifers, combined, increased to about 550,000 acre-ft/yr by the late 1950's (Armstrong and McMillion, 1961, p. 44; Ogilbee and others, 1962, p. 34). Owing in part to economic pressures and water conservation since the mid-1960's, pumpage from the Edwards-Trinity aquifer alone decreased to about 450,000 acre-ft/yr by 1975–76. All but about 1,600 acre-ft/yr of the 1975–76 pumpage occurred in Pecos and Reeves Counties, where about 95 percent of the water was used for irrigation (Lurry and Pavlicek, 1991). Ground-water withdrawals from the Edwards-Trinity aquifer in the Trans-Pecos have continued to decrease—to about 60,000 acre-ft/yr during 1990 or less than 15 percent of the 1975–76 rate (D.L. Lurry, U.S. Geological Survey, written commun., 1992).

Springflow from the Trans-Pecos aquifers has decreased substantially as the result of water-level declines caused by ground-water withdrawals for irrigation. Although the combined springflow in Pecos and Reeves Counties averaged nearly 85,000 acre-ft/yr during the mid-1940's (Armstrong and McMillion, 1961, p. 43–44; Ogilbee and others, 1962, p. 28), this springflow averaged less than 40,000 acre-ft/yr during the 1980's. Before 1946, about 48,000 acre-ft/yr of water discharged from springs in Pecos County; by 1958, this discharge had decreased to less than 2,000 acre-ft/yr (Armstrong and McMillion, 1961, p. 47). Despite short-term surges in springflow during 1986-88 (Small and Ozuna, 1993, fig. 13), springflow has been negligible in Pecos County since 1961.

The development of ground water in the Trans-Pecos has reduced the loss of ground water to evapotranspiration. Increases in the depth of water below land surface have reduced the consumptive use by phreatophytes. Evapotranspiration losses to phreatophyte growth is locally important in the Pecos River valley, where the tap roots of salt cedar, mesquite, and alfalfa can exceed 50 ft in length.

Transmissivity values for the Edwards-Trinity aquifer are difficult to obtain and highly variable; fewer than 10 values from the results of aquifer tests are reported for Pecos and Reeves Counties (Armstrong and McMillion,1961; Ogilbee and others, 1962). Transmissivity values reported for thicker parts of the Cenozoic Pecos alluvium in north-central Reeves County are as large as 20,000 ft^2/d (Ogilbee and others, 1962, p. 37). Although the transmissivity of Fredericksburg strata that contain a large number of solution channels in west-central Pecos County is unknown, the results of aquifer tests in relatively unaltered carbonate strata of the same age indicate values of less than 1,000 ft^2/d. The analyses of drawdown and recovery data from wells completed in the basal Cretaceous sand provide transmissivity values ranging from about 500 to 1,000 ft^2/d.

CONFINING UNITS

The characteristics of the two regional confining units are summarized below. The summary begins with the Navarro-Del Rio confining unit, the easternmost and most massive confining unit in the aquifer system.

NAVARRO-DEL RIO CONFINING UNIT

The Navarro-Del Rio confining unit confines downdip parts of the Edwards aquifer in the Balcones fault zone (fig. 2; pls. 3, 7). From top to bottom, this confining unit includes the Navarro Group, Taylor Group, Austin Group, Eagle Ford Group, Buda Limestone, and Del Rio Clay. According to Baker and others (1986, p. 9), these rock units "*** yield little or no water or a very small amount of water to mostly shallow dug wells." Together, these units form a regional barrier to vertical ground-water flow. Although these strata are displaced vertically in the Balcones fault zone, their combined thickness typically exceeds 1,200 ft, or nearly 10 times the maximum thickness of the Hammett confining unit (table 2). Despite the vertical displacement of its individual parts, the rock sequence as a whole is regionally continuous within the fault zone, so that the

Navarro-Del Rio confining unit effectively confines water within the Edwards aquifer (Baker and others, 1986, fig. 16; Maclay and Small, 1986, fig. 11).

Thin, scattered remnants of the Del Rio Clay and Buda Limestone, plus minor outcrops of Gulf strata, overlie the Edwards-Trinity aquifer system in parts of the Edwards Plateau and Trans-Pecos. None of these rock units is known to yield significant amounts of ground water. However, they are not regarded as confining units west of the Balcones fault zone, where they are discontinuous and not underlain directly by saturated rock.

HAMMETT CONFINING UNIT

The Hammett confining unit is composed of the Hammett Shale, a blanketlike deposit of dark calcareous and dolomitic shale, with finely laminated interbeds of limestone and sand (Ashworth, 1983, p. 27). The Hammett confining unit is restricted to most of the Hill Country and a small southeastern part of the Edwards Plateau where structural disruption of the hydraulically tight Hammett Shale has been minor (pls. 3, 7, 8). From negligible thickness on the southern flank of the Llano uplift (fig. 8), the Hammett confining unit gradually thickens in a downdip direction to more than 80 ft thick in northern Medina and northeastern Uvalde Counties (fig. 21). The unit generally varies between 40 and 60 ft thick in the Hill Country (Amsbury, 1974, p. 18). Because of its plastic consistency, the shale typically will slide into the bore of an uncased well. Therefore, boreholes through the unit must be cased and grouted within a few hours of being drilled (D.A. Muller, Texas Water Development Board, oral commun., 1990). Vertical displacement of the Pine Island Shale Member of the Pearsall Formation probably prevents this downdip equivalent of the Hammett Shale from being an effective regional confining unit within the Balcones fault zone.

SUMMARY

The Edwards-Trinity aquifer system, which underlies about 42,000 mi^2 of west-central Texas, is composed of nearly flat-lying carbonate strata of Comanchean (mostly Early Cretaceous) and Gulfian (Late Cretaceous) age. The Cretaceous rocks of the aquifer system thin toward the northwest atop generally massive, comparatively impermeable and structurally complex pre-Cretaceous rocks. From predominately terrigenous clastic sediments in the east and terrestrial deposits in the west, the rocks of early Trinitian (Comanchean) age grade upward into supratidal and intertidal evaporitic and dolomitic rocks and shallow-marine, lagoonal, and basinal carbonate strata of late Trinitian, Fredericksburgian, and Washitan (Comanchean) age. A thick, downfaulted remnant of mostly open-shelf sediments of Eaglefordian through Navarroan (Gulfian) age confines a small, southeastern part of the aquifer system.

The regional aquifer system contains three aquifers: (1) the Edwards aquifer in the Balcones fault zone; (2) the Trinity aquifer in the Balcones fault zone and Hill Country; and (3) the Edwards-Trinity aquifer in the Edwards Plateau and Trans-Pecos. The aquifers are laterally adjacent except in the Balcones fault zone, where a downfaulted part of the Trinity aquifer is overlain by the Edwards aquifer. The permeable strata mainly result from fractures and joint cavities, solution channels, and fabric-selective forms of porosity caused by the dissolution of evaporites, other soluble minerals, and assorted allochems.

The aquifer system contains two regional confining units. The Navarro-Del Rio confining unit confines downdip parts of the Edwards aquifer in the Balcones fault zone. The Hammett confining unit confines basal parts of the Trinity and Edwards-Trinity aquifers in the Hill Country and Edwards Plateau, respectively. The confining units mostly are composed of calcareous mudstone, siltstone, and shale.

The depositional, tectonic, and diagenetic characteristics of the Cretaceous rocks of the Edwards-Trinity aquifer system are strikingly different from those of the underlying pre-Cretaceous rocks. The typically medium- to thin-bedded Cretaceous strata of the aquifer system mostly dip southeastward atop generally massive, westward-dipping Paleozoic and Triassic units. The unconformity between the Cretaceous rocks of the aquifer system and the pre-Cretaceous complex marks a major shift in the geologic evolution of the study area. This hiatus in the rock record spans about 60 million years of crustal warping and erosion between the deposition of terrestrial red beds during Late Triassic time and the deposition of terrigenous clastic and shallow-marine carbonate sediments during Early Cretaceous time.

The Early Cretaceous sea encroached slowly westward upon a rolling peneplain of folded and faulted pre-Cretaceous rocks. While alluvial plains inland of the transgressing sea were dominated by clastic deposition, shallow offshore environments—characterized by warm, generally clear seawater—promoted the biogenic accumulation of calcium carbonate.

Trinity deposition was characterized by a cyclic pattern of shoreline advance and retreat superimposed upon an overall pattern of marine transgression. The resulting lithofacies are diachronous toward the Llano uplift and reflect the effects of shallower water and shoreline advancement toward the

northwest. The Trinity strata were deposited during three transgressive-regressive cycles of sedimentation. These cycles consist of the (1) Sycamore Sand (Hosston Formation, downdip) and Sligo Formation; (2) Hammett Shale (Pine Island Shale Member, downdip) and Cow Creek Limestone (Cow Creek Limestone Member, downdip); and (3) Hensel Sand (Bexar Shale Member, downdip) and Glen Rose Limestone. The basal Cretaceous sand and Maxon Sand were deposited in fluvial-deltaic settings west of the Llano uplift.

The Fredericksburg and lower Washita strata of west-central Texas were deposited upon the Comanche shelf, a carbonate platform sheltered by the Stuart City reef trend from storm waves and deep ocean currents in the ancestral Gulf of Mexico. Depositional environments were controlled by the (1) distribution and rates of subsidence and uplift, (2) influx of fine-grained terrigenous sediment, and (3) extent of water circulation, or degree of restriction relative to that of the open sea. The Kainer and Person Formations formed over the San Marcos arch, a structural high dominated by tidal flats that frequently underwent uplift, subaerial exposure, and erosion. The eastern part of the Fort Terrett Formation and the Segovia Formation formed near the crest of the central Texas platform mostly in supratidal to restricted shallow-marine environments. The western part of the Fort Terrett Formation and the Fort Lancaster Formation formed mostly in open shallow-marine to open-shelf environments transitional to the central Texas platform and Fort Stockton basin. The Finlay Formation formed in the Fort Stockton basin, when the basin primarily was a broad, open lagoon; the Boracho Formation was deposited later in a deeper, shelf-basin environment. The West Nueces, McKnight, and Salmon Peak Formations formed within the persistently submerged Maverick basin. The depositional environments inside the Maverick basin generally were buffered from those on the central Texas platform by the intervening Devils River trend, in which the Devils River Formation formed.

During late Oligocene through early Miocene time, large-scale normal faulting created the Balcones fault zone, where the Cretaceous strata were displaced vertically, fractured intensively, and rotated differentially within a series of southwest-to-northeast trending fault blocks. Ground-water flow shifted toward the northeast in response to rejuvenated hydraulic gradients in that direction and high-angle barrier faults that blocked the older southeastward flowpaths. New flowpaths developed subparallel to the strike of the fault zone as evaporites and soluble calcareous constituents dissolved from the fractured strata and discharged to downgradient springs and streams. Springs originated in topographically low areas where barrier faults intercepted confined water at depth and diverted it to the surface. Ground-water conduits enlarged through carbonate dissolution along flowpaths that converged toward the springs. The major springs persisted to control modern potentiometric levels and discharge patterns. Stream erosion eventually breached the overlying, low-permeability Gulf rocks and provided discharge areas for aquifers in the underlying, more permeable Comanche rocks.

The Balcones faulting triggered processes responsible for sizable contrasts between the hydraulic characteristics of the Edwards aquifer and those of the Trinity and Edwards-Trinity aquifers. The faulting increased hydraulic gradients in the fault zone, which enhanced the percolation of meteoric water from land surface and increased the velocity of shallow ground-water flow. A dynamic regime of shallow ground-water flow evolved that promoted dissolution. Dissolution along fractures and bedding planes formed joint cavities and solution channels that became the principal conduits of regional ground-water flow in the Edwards aquifer.

The rocks in the Hill Country, Edwards Plateau, and Trans-Pecos mostly were excluded from the large-scale normal faulting, intensive fracturing, and subsequent dissolution that controlled the origin of the Edwards aquifer in the Balcones fault zone. Consequently, the hydraulic characteristics of the Trinity and Edwards-Trinity aquifers more closely resemble those of each other than those of the Edwards aquifer. As the transmissivity of the Edwards aquifer increased over geologic time, cementation, recrystallization, and replacement resulting from deep burial and comparatively sluggish ground-water movement combined to diminish the transmissivity of the Trinity and Edwards-Trinity aquifers.

The saturated thickness of the aquifer system ranges from more than 500 ft in the southern part of the aquifer system to less than 100 ft near the northern part. The saturated thickness is more than 500 ft throughout the Balcones fault zone and over the southeastern two-thirds of the Hill Country. The saturated thickness decreases to less than 100 ft over the northwestern third of the Hill Country where the Trinity aquifer thins against Precambrian rocks of the Llano uplift. In the Edwards Plateau, the saturated thickness grades from more than 500 ft in the southern one-half of the area to less than 100 ft along the northern margin. In the Trans-Pecos, the saturated thickness ranges over short distances from more than 500 ft to less than 100 ft, reflecting the rugged relief at the base of the aquifer system.

The Edwards aquifer in the Balcones fault zone is one of the most productive subsurface reservoirs of potable water in the world. The Edwards aquifer is recognized as the sole source of ground water in the San Antonio area, where it serves the domestic, public-supply, industrial, and agricultural needs of more than a million people and sustains several threatened or endangered plant and animal species. The Edwards aquifer lies within the Georgetown, Person, and Kainer Formations in the northeastern part of the fault zone and within the Devils River, West Nueces, McKnight, and Salmon Peak Formations in the southwestern part. Ground-water flow largely is controlled by an anisotropic pattern of hydraulic conductivity and a dominant southwest-to-northeast component of transmissivity, both of which result from barrier faults, fractures, joint cavities, and solution channels that are aligned with the fault zone. Transmissivity ranges from about 10,000 to more than 5,000,000, ft^2/d and probably averages about 750,000 ft^2/d. After steadily increasing from about 100,000 acre-ft/yr during the 1930's to an average 470,000 acre-ft/yr during the 1980's, ground-water withdrawals recently have tapered to an average 420,000 acre-ft/yr during 1990–93. Although water levels and springflows periodically are reduced by less-than-normal recharge and (or) greater-than-normal pumpage caused by drought, long-term hydrographs for the San Antonio area indicate no net decline (or rise) in water levels over the last 80 years.

The Trinity aquifer, composed entirely of Trinity strata in the Balcones fault zone and Hill Country, dominates the ground-water hydrology of the Hill Country, where most Fredericksburg and practically all Washita strata are absent. Strongly cemented, hydraulically tight interbeds in the upper and middle parts of the Trinity aquifer impede the downward percolation of precipitation. Ground water in the interstream areas commonly is perched above the regional ground-water-flow system and the base level of adjacent streams. Meteoric water that infiltrates the interstream areas moves laterally atop the dense interbeds more readily than it percolates vertically through them. Ground water emerges from springs and seeps along the tops of the impermeable bedding where the bedding is breached by the topography. Thus, instead of percolating to deeper permeable zones, much of the water in shallow parts of the Trinity aquifer discharges to the deeply entrenched, perennial streams that drain the Hill Country. Streamflow gains in the Hill Country subsequently are lost in the downstream Balcones fault zone where the streams cross faults onto permeable streambeds in the outcrop area of the Edwards aquifer. Water also discharges from the Trinity aquifer through wells and as lateral subsurface inflow and diffuse upward leakage to the Edwards aquifer. Ground-water withdrawals from the Trinity aquifer have remained relatively stable since the mid-1970's, averaging between 10,000 and 15,000 acre-ft/yr during 1975–76 and totaling about 13,500 acre-ft during 1990. Long-term hydrographs indicate that water levels can vary greatly over short periods, typically varying 50 ft or more between winter highs and summer lows. The Trinity aquifer generally is affected by drought more quickly than the Edwards aquifer. Transmissivity ranges from less than 1,000 to about 50,000 ft^2/d and appears to average less than 10,000 ft^2/d.

The Edwards-Trinity aquifer in the Edwards Plateau includes all the Fredericksburg and Trinity strata plus all Washita rocks below the Del Rio Clay or the Buda Limestone. Washita and Fredericksburg rocks provide the principal water-producing zones in the Edwards Plateau, except where these rocks are breached along the valleys of the Concho, Guadalupe, Llano, Pecos, Pedernales, and San Saba Rivers. Along these valleys, middle and lower Trinity rock units supplement stream-valley alluvium as major sources of ground water. The basal Cretaceous sand is an important water-producing unit in northwestern parts of the area and along the Pecos River valley where the Washita and Fredericksburg rocks have been removed by erosion. Water-producing zones in the Edwards Plateau mostly are confined or semi-confined, except in the shallowest zones and near the outer margins of Fredericksburg strata where the Trinity sediments crop out. From generally unconfined or semi-confined conditions in the west, the Edwards-Trinity aquifer becomes progressively more confined toward the southeast. Since 1975–76, when ground-water withdrawals averaged nearly 130,000 acre-ft/yr, pumpage has fluctuated between about 85,000 acre-ft (during 1985) and about 128,000 acre-ft (1990). Water-level hydrographs for central parts of the Edwards Plateau reflect a cyclic relation between recharge and precipitation: (1) declining water levels during most of the 1960's, when precipitation was below normal; (2) rising water levels during most of the 1970's, when precipitation was above normal; and (3) declining water levels during most of the 1980's, when precipitation was below normal. Many of the highest recorded water levels during the past 30 years in Crockett, Edwards, Kimble, Schleicher, and Sutton Counties occurred during the middle-to-late 1970's. Although transmissivity probably is less than 5,000 ft^2/d over most of the Edwards Plateau, it probably averages about 10,000 ft^2/d in southern parts of the area, where the Cretaceous sediments are thickest.

The Edwards-Trinity aquifer in the Trans-Pecos includes all the Fredericksburg and Trinity strata plus all Washita rocks below the Del Rio Clay or the Buda Limestone. The structural complexity of the Trans-Pecos results from the collapse of Permian rocks that underlie much of the area and crustal deformation during Cenozoic time. Water from the Edwards-Trinity aquifer is supplemented locally by water from the Cenozoic Pecos alluvium aquifer and the Dockum aquifer. Water levels and springflow declined in response to accelerating rates of ground-water withdrawal following World War II. From negligible pumpage before 1945, pumpage from the Cenozoic Pecos alluvium and Edwards-Trinity aquifers, combined, increased to about 550,000 acre-ft/yr by the late 1950's. Although water levels declined more than 200 ft in parts of the Trans-Pecos, decreasing withdrawals since the mid-1960's have allowed water levels to recover as much as 75 ft in some wells. Pumpage from the Edwards-Trinity aquifer, alone, decreased from about 450,000 acre-ft/yr during the mid-1970's to about 60,000 acre-ft during 1990. Springflow decreased from an average of nearly 85,000 acre-ft/yr during the mid-1940's to less than 40,000 acre-ft/yr during the 1980's. Transmissivity values for the Edwards-Trinity aquifer are difficult to obtain and highly variable in the Trans-Pecos. Although transmissivity values as large as 20,000 ft^2/d are reported for thicker parts of the Cenozoic Pecos alluvium, values of less than 1,000 ft^2/d are indicated for relatively unaltered carbonate strata of Fredericksburgian age. Transmissivity in the basal Cretaceous sand ranges from about 500 to 1,000 ft^2/d.

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Maps

Geologic Quadrangle Maps are multicolor geologic maps on topographic bases in 7.5- or 15-minute quadrangle formats (scales mainly 1:24,000 or 1:62,500) showing bedrock, surficial, or engineering geology. Maps generally include brief texts; some maps include structure and columnar sections only.

Geophysical Investigations Maps are on topographic or planimetric bases at various scales; they show results of surveys using geophysical techniques, such as gravity, magnetic, seismic, or radioactivity, which reflect subsurface structures that are of economic or geologic significance. Many maps include correlations with the geology.

Miscellaneous Investigations Series Maps are on planimetric or topographic bases of regular and irregular areas at various scales; they present a wide variety of format and subject matter. The series also includes 7.5-minute quadrangle photogeologic maps on planimetric bases that show geology as interpreted from aerial photographs. Series also includes maps of Mars and the Moon.

Cost Investigations Maps are geologic maps on topographic or planimetric bases at various scales showing bedrock or surficial geology, stratigraphy, and structural relations in certain coal-resource areas.

Oil and Gas Investigations Charts show stratigraphic information for certain oil and gas fields and other areas having petroleum potential.

Miscellaneous Field Studies Maps are multicolor or black-and-white maps on topographic or planimetric bases for quadrangle or irregular areas at various scales. Pre-1971 maps show bedrock geology in relation to specific mining or mineral-deposit problems; post-1971 maps are primarily black-and-white maps on various subjects such as environmental studies or wilderness mineral investigations.

Hydrologic Investigations Atlases are multicolored or black-and-white maps on topographic or planimetric bases presenting a wide range of geohydrologic data of both regular and irregular areas; principal scale is 1:24,000, and regional studies are at 1:250,000 scale or smaller.

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U.S. DEPARTMENT OF THE INTERIOR

MARCH 3, 1849

Reference 33

State & County QuickFacts

Try the today and tell us what you think!

Ector County, Texas

People QuickFacts	Ector County	Texas
Population, 2014 estimate	153,904	26,956,958
Population, 2013 estimate	149,522	26,505,637
Population, 2010 (April 1) estimates base	137,133	25,146,104
Population, percent change - April 1, 2010 to July 1, 2014	12.2%	7.2%
Population, percent change - April 1, 2010 to July 1, 2013	9.0%	5.4%
Population, 2010	137,130	25,145,561
Persons under 5 years, percent, 2013	8.9%	7.3%
Persons under 18 years, percent, 2013	29.6%	26.6%
Persons 65 years and over, percent, 2013	9.7%	11.2%
Female persons, percent, 2013	49.8%	50.3%
White alone, percent, 2013 (a)	91.3%	80.3%
Black or African American alone, percent, 2013 (a)	4.8%	12.4%
American Indian and Alaska Native alone, percent, 2013 (a)	1.4%	1.0%
Asian alone, percent, 2013 (a)	1.0%	4.3%
Native Hawaiian and Other Pacific Islander alone, percent, 2013 (a)	0.2%	0.1%
Two or More Races, percent, 2013	1.3%	1.8%
Hispanic or Latino, percent, 2013 (b)	56.4%	38.4%
White alone, not Hispanic or Latino, percent, 2013	37.3%	44.0%
Living in same house 1 year & over, percent, 2009-2013	81.6%	82.8%
Foreign born persons, percent, 2009-2013	13.7%	16.3%
Language other than English spoken at home, pct age 5+, 2009-2013	43.4%	34.7%
High school graduate or higher, percent of persons age 25+, 2009-2013	72.9%	81.2%
Bachelor's degree or higher, percent of persons age 25+, 2009-2013	13.5%	26.7%
Veterans, 2009-2013	7,071	1,583,272
Mean travel time to work (minutes), workers age 16+, 2009-2013	20.4	25.0
Housing units, 2013	55,041	10,255,642
Homeownership rate, 2009-2013	65.7%	63.3%
Housing units in multi-unit structures, percent, 2009-2013	19.9%	24.2%
Median value of owner-occupied housing units, 2009-2013	$91,200	$128,900
Households, 2009-2013	49,962	8,886,471
Persons per household, 2009-2013	2.80	2.82
Per capita money income in past 12 months (2013 dollars), 2009-2013	$24,247	$26,019
Median household income, 2009-2013	$51,466	$51,900
Persons below poverty level, percent, 2009-2013	15.9%	17.6%

Business QuickFacts	Ector County	Texas
Private nonfarm establishments, 2013	3,582	547,190[1]
Private nonfarm employment, 2013	62,316	9,663,567[1]
Private nonfarm employment, percent change, 2012-2013	8.4%	3.3%[1]
Nonemployer establishments, 2012	10,478	2,014,124
Total number of firms, 2007	11,745	2,164,852
Black-owned firms, percent, 2007	2.0%	7.1%
American Indian- and Alaska Native-owned firms, percent, 2007	1.6%	0.9%
Asian-owned firms, percent, 2007	1.6%	5.3%

Native Hawaiian and Other Pacific Islander-owned firms, percent, 2007	F	0.1%
Hispanic-owned firms, percent, 2007	30.5%	20.7%
Women-owned firms, percent, 2007	26.3%	28.2%
Manufacturers shipments, 2007 ($1000)	2,049,699	593,541,502
Merchant wholesaler sales, 2007 ($1000)	2,004,269	424,238,194
Retail sales, 2007 ($1000)	2,090,614	311,334,781
Retail sales per capita, 2007	$16,222	$13,061
Accommodation and food services sales, 2007 ($1000)	228,555	42,054,592
Building permits, 2013	1,290	147,460

Geography QuickFacts	Ector County	Texas
Land area in square miles, 2010	897.69	261,231.71
Persons per square mile, 2010	152.8	96.3
FIPS Code	135	48
Metropolitan or Micropolitan Statistical Area	Odessa, TX Metro Area	

1: Includes data not distributed by county.

(a) Includes persons reporting only one race.
(b) Hispanics may be of any race, so also are included in applicable race categories.

D: Suppressed to avoid disclosure of confidential information
F: Fewer than 25 firms
FN: Footnote on this item for this area in place of data
NA: Not available
S: Suppressed; does not meet publication standards
X: Not applicable
Z: Value greater than zero but less than half unit of measure shown

Source U.S. Census Bureau: State and County QuickFacts. Data derived from Population Estimates, American Community Survey, Census of Population and Housing, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits
Last Revised: Wednesday, 22-Apr-2015 09:03:46 EDT

Reference 34

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations (BFEs) shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Texas Central State Plane Coordinate System (FIPS 4203). The **horizontal datum** was NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or State Plane Coordinate Systems used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS InformationServices
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242** or visit its website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was provided in digital format by the City of Odessa GIS Department and the Texas Statewide Strategic Mapping Program.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables *in the Flood Insurance Study report (which contains authoritative hydraulic data)* may reflect stream channel distances that differ from what is shown on this map.

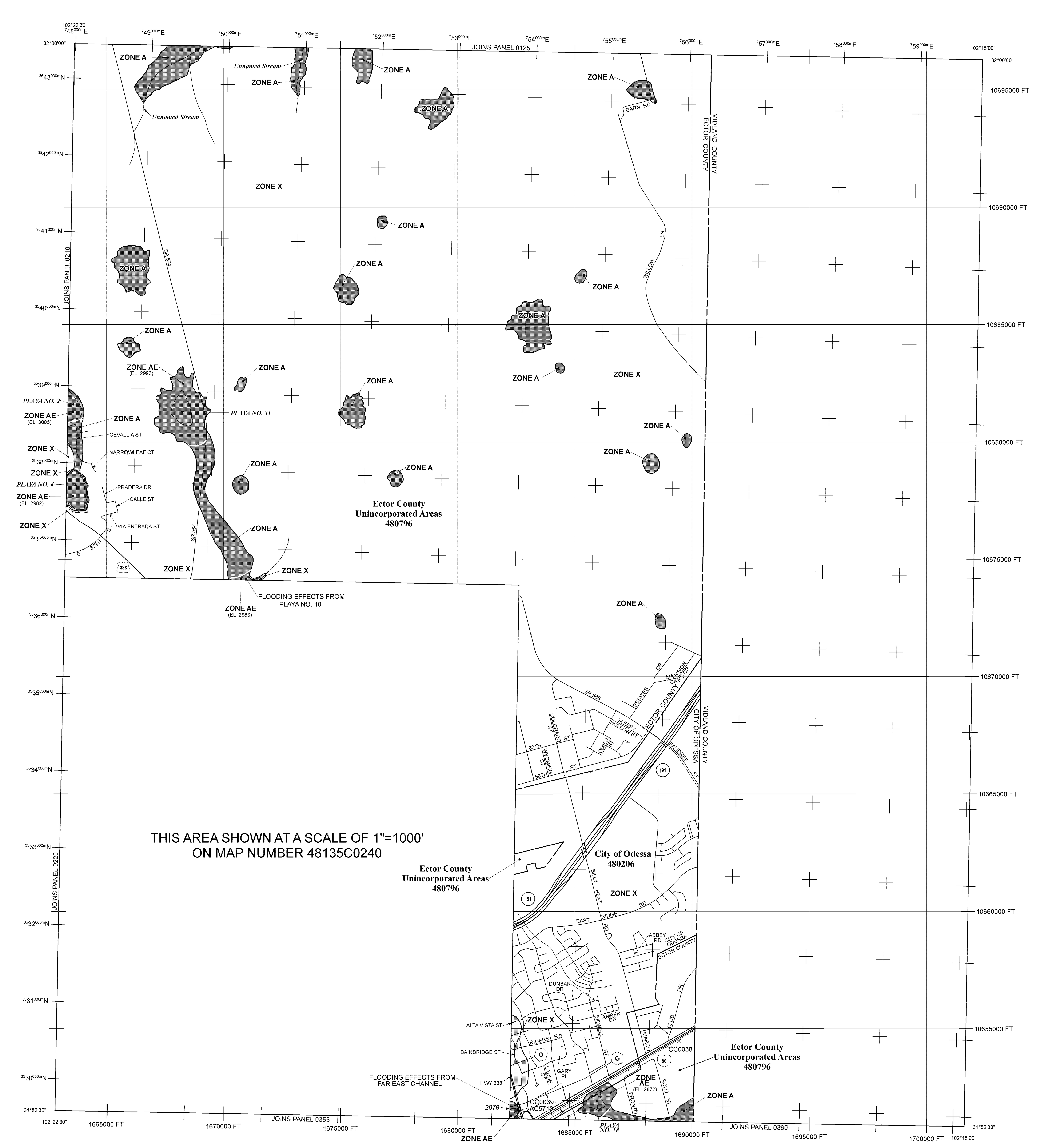
Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

For information on available products associated with this FIRM fisit the **FEMA Map Service Center** website at http://msc/fema/gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map** how to order products or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange at **1-877-FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip/.

The **"profile base lines"** depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the "profile base line", in some cases, may deviate significantly from the channel centerline or appear outside the SFHA.



LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Areas to be protected from 1% annual chance flood event by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	Floodplain boundary
	Floodway boundary
	Zone D boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths, or flood velocities
513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988

A —— A	Cross section line
23 - - - - 23	Transect line
97°07'30", 32°22'30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
4275000mE	1000-meter Universal Transverse Mercator grid ticks, zone 13
6000000 FT	5000-foot grid values: Texas State Plane coordinate system, Central Zone (FIPSZONE = 4203), Lambert projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
● M1.5	River Mile

MAP REPOSITORIES
Refer to Map Repositories List on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
March 4, 1991

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
October 20, 1998

March 15, 2012 - to update corporate limits, to change Special Flood Hazard Areas, to update map format, to add roads and road names, to incorporate previously issued Letters of Map Revision, and to reflect updated topographic information.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'

1,000 0 1,000 2,000 3,000 4,000 FEET

600 0 600 1,200 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0250E

FIRM

FLOOD INSURANCE RATE MAP

ECTOR COUNTY, TEXAS

AND INCORPORATED AREAS

PANEL 250 OF 525

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
ECTOR COUNTY, UNINCORPORATED AREAS	480796	0250	E
ODESSA, CITY OF	480206	0250	E

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
48135C0250E

MAP REVISED
MARCH 15, 2012

Federal Emergency Management Agency

Reference 35

Precipitation Maps for the USA

24-hour duration storms for Return Periods of 2, 5, 10, 25, 50, and 100 year rainfall events

Geographic boundaries for SCS Rainfall Distributions

Graph showing SCS 24-hour cumulative rainfall distribution

To: Rainfall-Runoff Calculation Detention Storage Calculation
Unit Conversions LMNO Engineering home page

The rainfall distribution type (I, IA, II, or III) and quantity of precipitation are required inputs to our hydrology (rainfall-runoff, peak discharge) calculation and detention storage calculation. For regions within the USA, use the figures below to determine rainfall distribution type and quantity of precipitation. For regions outside the USA, determine which rainfall distribution type best matches your region; find the precipitation quantity from local precipitation maps.

All figures are from:
U.S. Soil Conservation Service. Technical Release 55: Urban Hydrology for Small Watersheds. USDA (U.S. Department of Agriculture). June 1986. On the web in .pdf format at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf .

Quick links on this page:
SCS 24-hr rainfall distribution type graph
Geographic boundaries within the USA for SCS rainfall distributions
24-hr duration rainfall maps of USA with return periods of: 2-yr 5-yr 10-yr 25-yr 50-yr 100-yr

Fig. B-1. SCS 24-hour rainfall distributions (SCS, 1986):

(y-axis reads "Fraction of 24-hour rainfall" and x-axis reads "Time, hours")

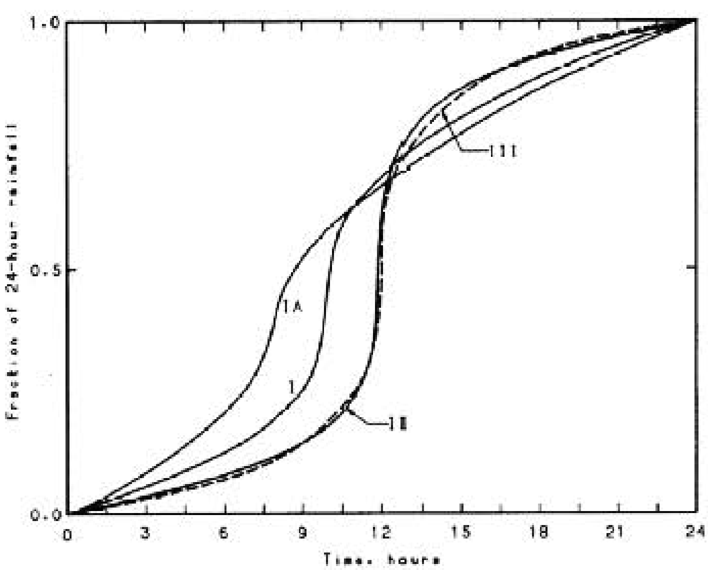


Figure B-1.—SCS 24-hour rainfall distributions.

Fig. B-2. Approximate geographic boundaries for SCS rainfall distributions (SCS, 1986):

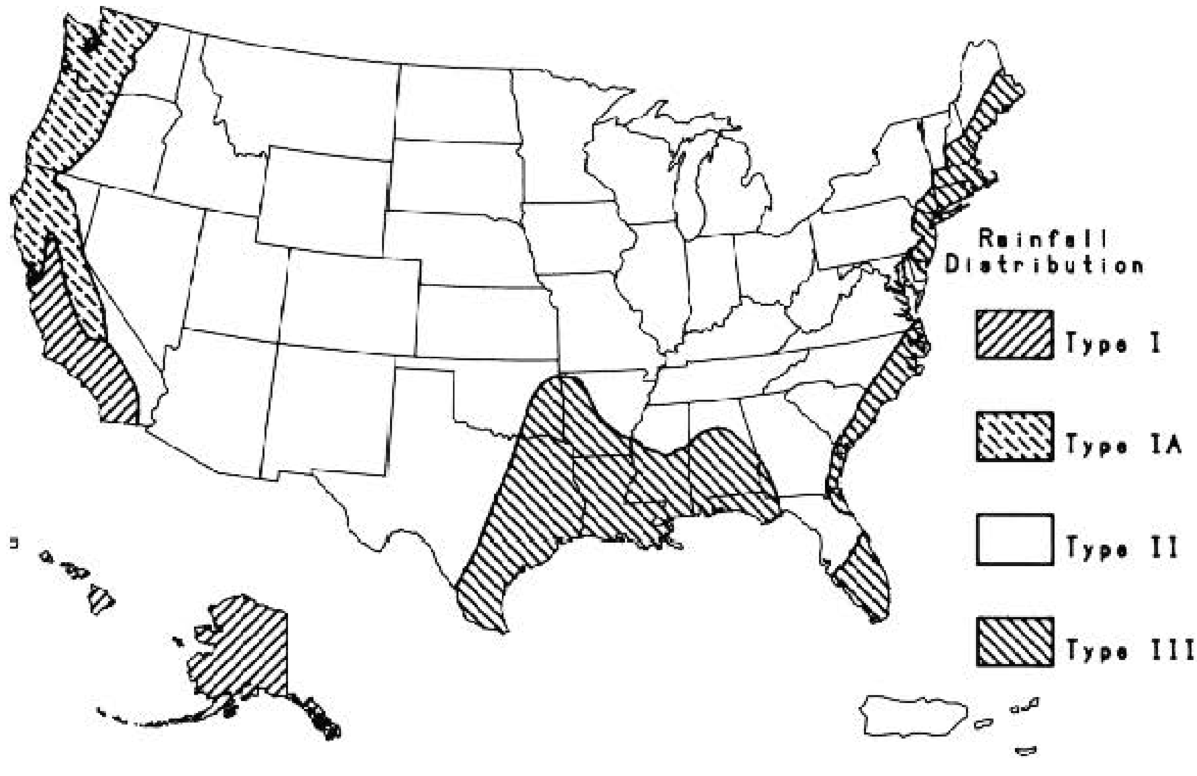


Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

Fig. B-3. 2-Year Return Period, 24-hour Duration Precipitation, inches (SCS, 1986):

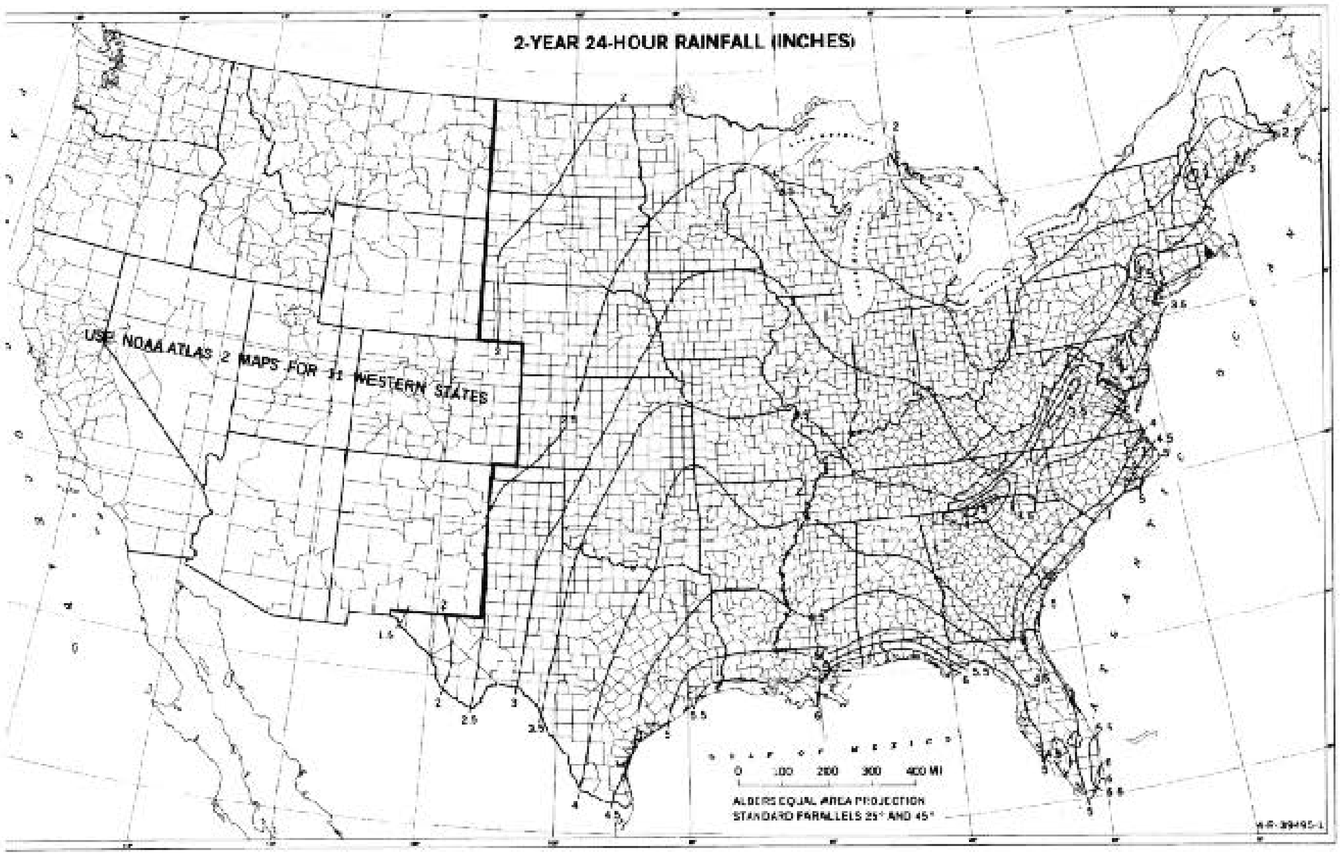


Figure B-3.—Two-year, 24-hour rainfall.

Fig. B-4. Five Year Return Period, 24 hour Duration Precipitation, inches (SCS, 1986):

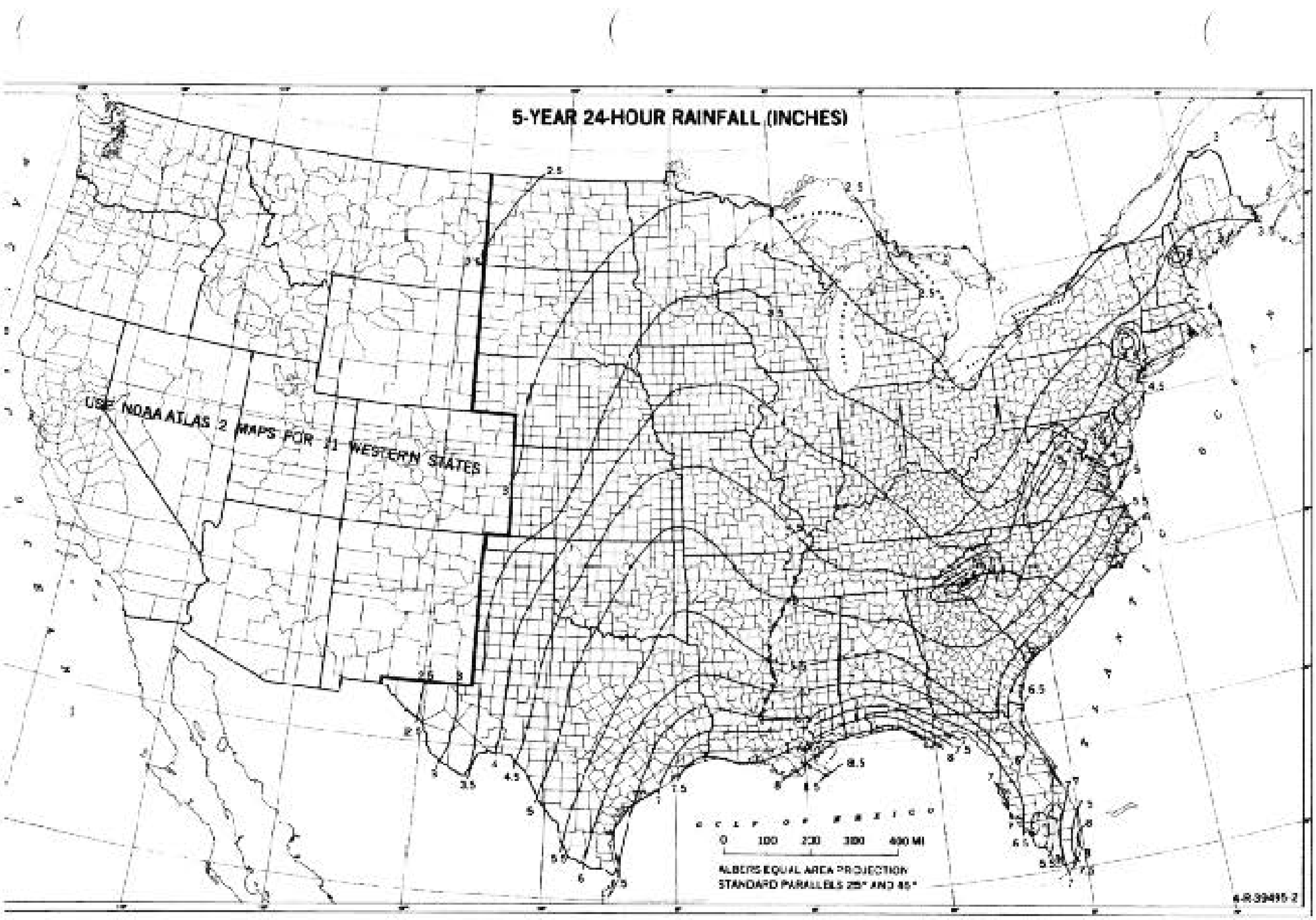


Figure B-4.—Five-year, 24-hour rainfall.

Fig. B-5. Ten Year Return Period, 24 hour Duration Precipitation, inches (SCS, 1986):

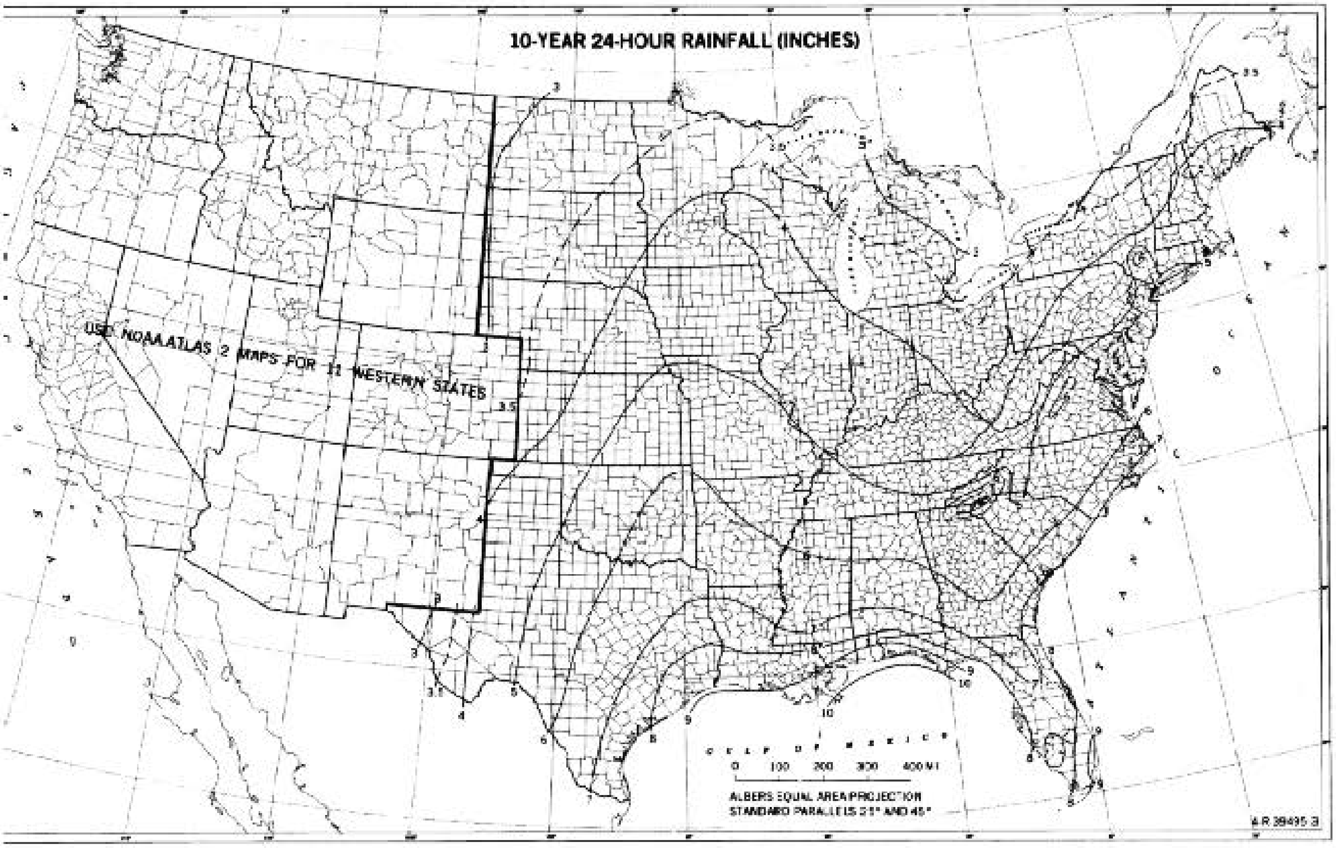


Figure B-5.—Ten-year, 24-hour rainfall.

Fig. B-6. 25-Year Return Period, 24 hour Duration Precipitation, inches (SCS, 1986):

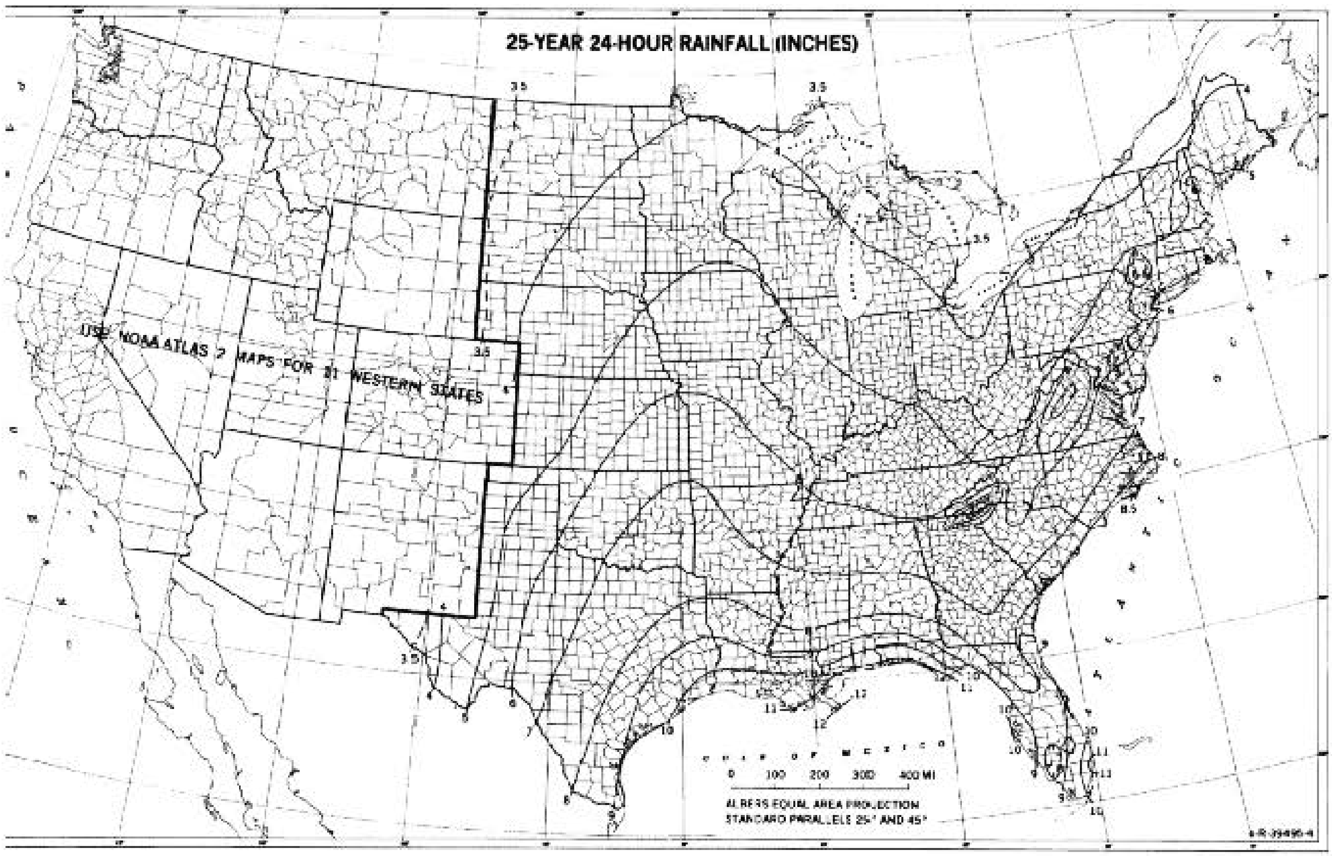


Fig. B-7. 50-Year Return Period, 24 hour Duration Precipitation, inches (SCS, 1986):

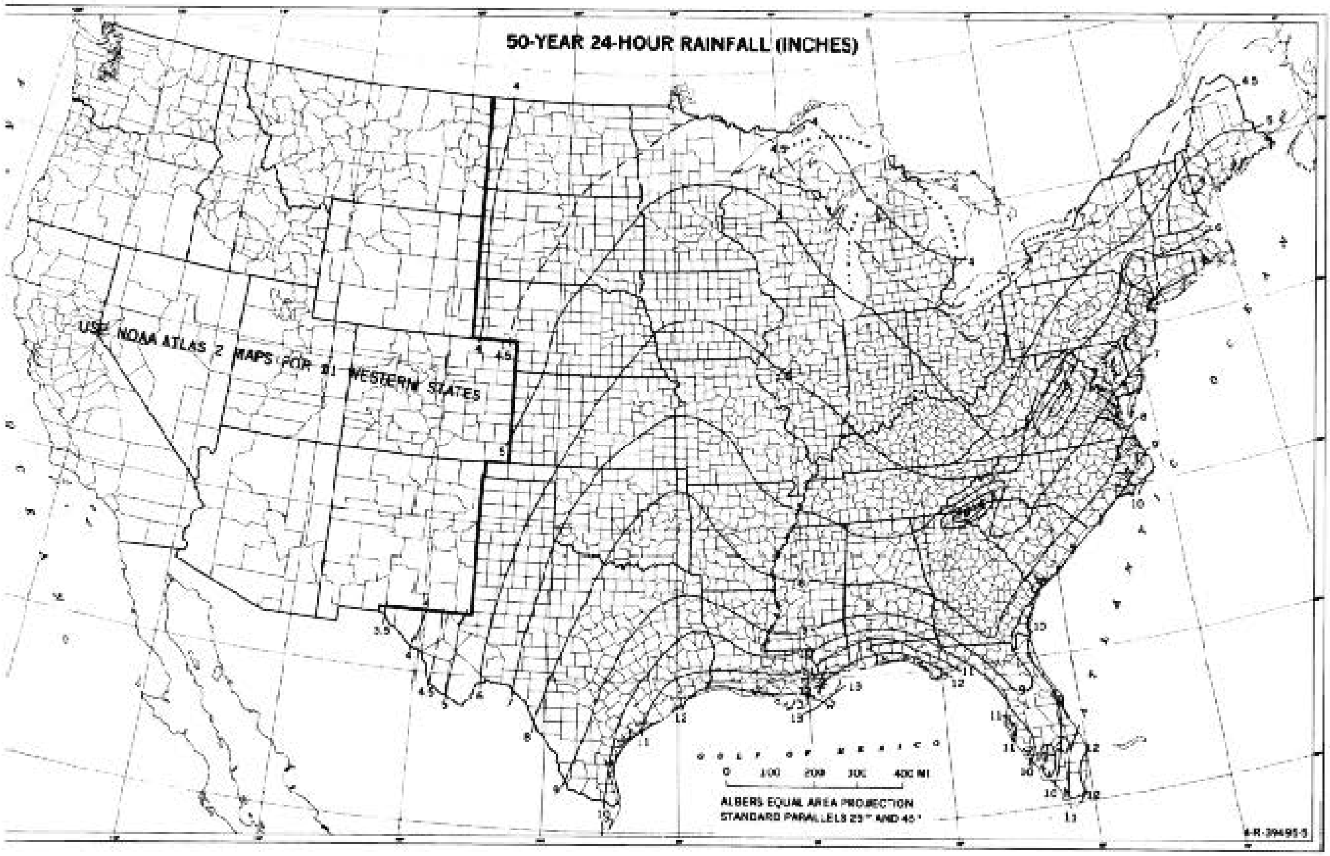
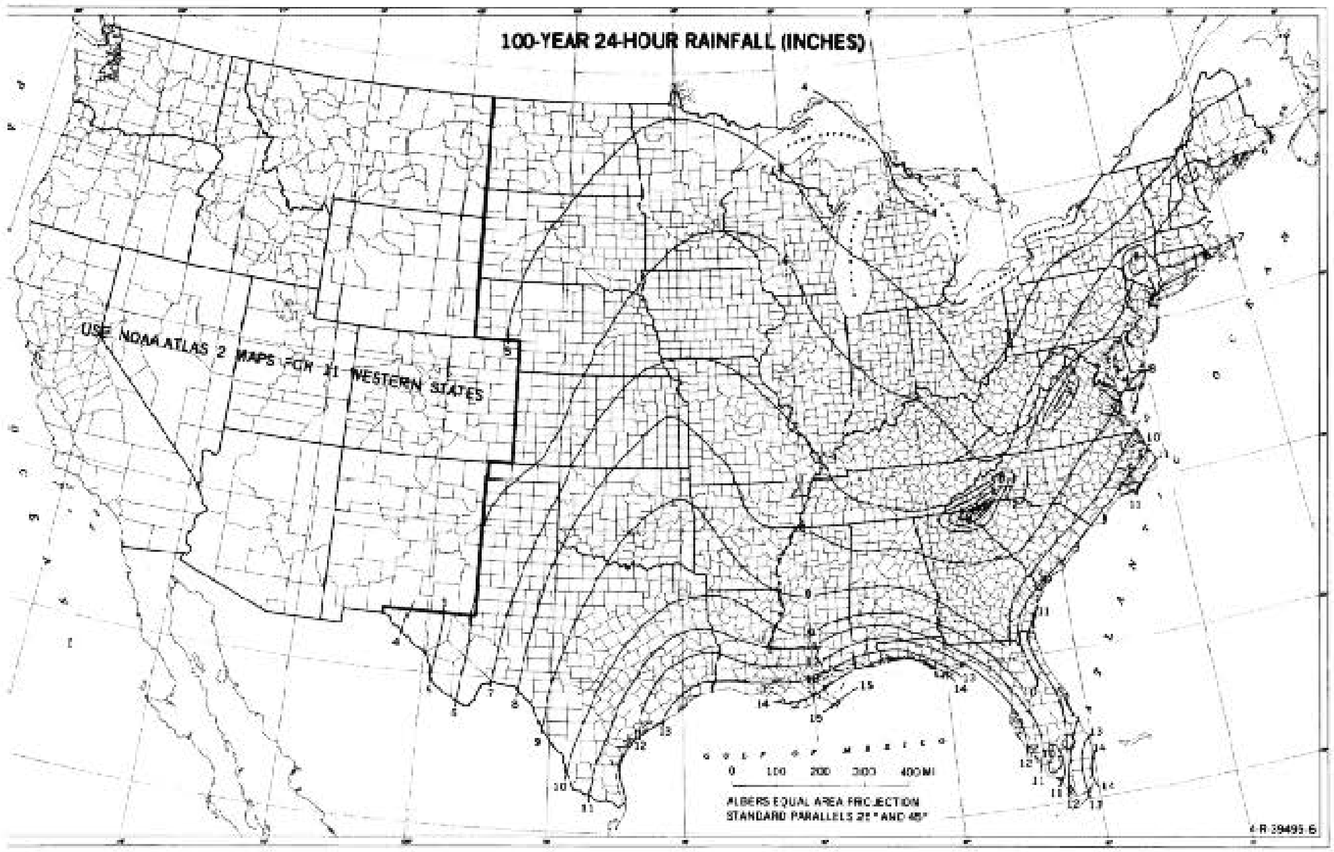
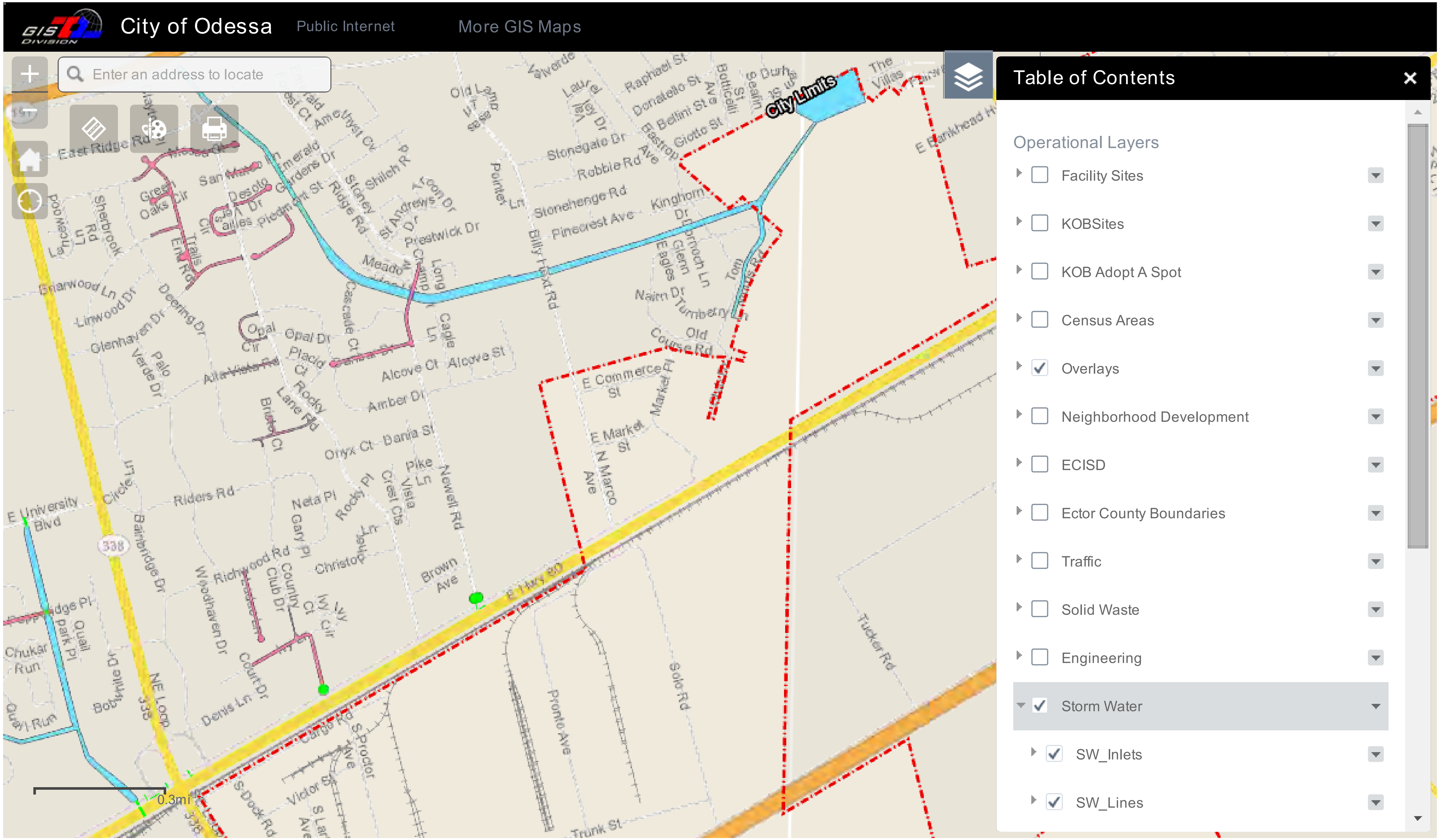


Figure B-7.—Fifty-year, 24-hour rainfall.

Fig. B-8. 100-Year Return Period, 24 hour Duration Precipitation, inches (SCS, 1986):


100-YEAR 24-HOUR RAINFALL (INCHES)
USE NOAA ATLAS 2 MAPS FOR 11 WESTERN STATES
GULF OF MEXICO
0 100 200 300 400 MI
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°

Reference 36



GIS DIVISION
City of Odessa
Public Internet
More GIS Maps
Enter an address to locate
Table of Contents
Operational Layers
Facility Sites
KOBSites
KOB Adopt A Spot
Census Areas
Overlays
Neighborhood Development
ECISD
Ector County Boundaries
Traffic
Solid Waste
Engineering
Storm Water
SW_Inlets
SW_Lines
City Limits
0.3mi
E Hwy 80
E University Blvd
Stonegate Dr
Robbie Rd
Stonehenge Rd
Pinecrest Ave
Prestwick Dr
Billy Hext Rd
E Commerce St
E Market St
N Marco Ave
Alcove Ct
Alcove St
Amber Dr
Bania St
Onyx Ct
Riders Rd
Richwood Rd
Brown Ave
Denis Ln
Pronto Ave
Trunk St
Solo Rd
Tucker Rd
Glenhaven Dr
Linwood Dr
Briarwood Ln
Deering Dr
Newell Rd
Nairn Dr
Old Course Rd
Kinghorn Dr

Reference 37

ECTOR COUNTY

BIRDS

		Federal Status	State Status
American Peregrine Falcon	*Falco peregrinus anatum*	DL	T

year-round resident and local breeder in west Texas, nests in tall cliff eyries; also, migrant across state from more northern breeding areas in US and Canada, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.

Arctic Peregrine Falcon	*Falco peregrinus tundrius*	DL	

migrant throughout state from subspecies' far northern breeding range, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.

Baird's Sparrow	*Ammodramus bairdii*		

shortgrass prairie with scattered low bushes and matted vegetation; mostly migratory in western half of State, though winters in Mexico and just across Rio Grande into Texas from Brewster through Hudspeth counties

Bald Eagle	*Haliaeetus leucocephalus*	DL	T

found primarily near rivers and large lakes; nests in tall trees or on cliffs near water; communally roosts, especially in winter; hunts live prey, scavenges, and pirates food from other birds

Ferruginous Hawk	*Buteo regalis*		

open country, primarily prairies, plains, and badlands; nests in tall trees along streams or on steep slopes, cliff ledges, river-cut banks, hillsides, power line towers; year-round resident in northwestern high plains, wintering elsewhere throughout western 2/3 of Texas

Mountain Plover	*Charadrius montanus*		

breeding: nests on high plains or shortgrass prairie, on ground in shallow depression; nonbreeding: shortgrass plains and bare, dirt (plowed) fields; primarily insectivorous

Peregrine Falcon	*Falco peregrinus*	DL	T

both subspecies migrate across the state from more northern breeding areas in US and Canada to winter along coast and farther south; subspecies (F. p. anatum) is also a resident breeder in west Texas; the two subspecies' listing statuses differ, F.p. tundrius is no longer listed in Texas; but because the subspecies are not easily distinguishable at a distance, reference is generally made only to the species level; see subspecies for habitat.

Prairie Falcon	*Falco mexicanus*		

open, mountainous areas, plains and prairie; nests on cliffs

Snowy Plover	*Charadrius alexandrinus*		

formerly an uncommon breeder in the Panhandle; potential migrant; winter along coast

ECTOR COUNTY

BIRDS		Federal Status	State Status
Sprague's Pipit	*Anthus spragueii*	C	

only in Texas during migration and winter, mid September to early April; short to medium distance, diurnal migrant; strongly tied to native upland prairie, can be locally common in coastal grasslands, uncommon to rare further west; sensitive to patch size and avoids edges.

Western Burrowing Owl *Athene cunicularia hypugaea*

open grasslands, especially prairie, plains, and savanna, sometimes in open areas such as vacant lots near human habitation or airports; nests and roosts in abandoned burrows

Western Snowy Plover *Charadrius alexandrinus nivosus*

uncommon breeder in the Panhandle; potential migrant; winter along coast

MAMMALS		Federal Status	State Status
Black-footed ferret	*Mustela nigripes*	LE	

extirpated; inhabited prairie dog towns in the general area

Black-tailed prairie dog *Cynomys ludovicianus*

dry, flat, short grasslands with low, relatively sparse vegetation, including areas overgrazed by cattle; live in large family groups

Gray wolf	*Canis lupus*	LE	E

extirpated; formerly known throughout the western two-thirds of the state in forests, brushlands, or grasslands

Pale Townsend's big-eared bat *Corynorhinus townsendii pallescens*

roosts in caves, abandoned mine tunnels, and occasionally old buildings; hibernates in groups during winter; in summer months, males and females separate into solitary roosts and maternity colonies, respectively; single offspring born May-June; opportunistic insectivore

Swift fox *Vulpes velox*

restricted to current and historic shortgrass prairie; western and northern portions of Panhandle

REPTILES		Federal Status	State Status
Spot-tailed earless lizard	*Holbrookia lacerata*		

central and southern Texas and adjacent Mexico; moderately open prairie-brushland; fairly flat areas free of vegetation or other obstructions, including disturbed areas; eats small invertebrates; eggs laid underground

Texas horned lizard	*Phrynosoma cornutum*		T

open, arid and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky; burrows into soil, enters rodent burrows, or hides under rock when inactive; breeds March-September

ECTOR COUNTY

PLANTS	Federal Status	State Status

Havard's machaeranthera *Xanthisma viscidum*

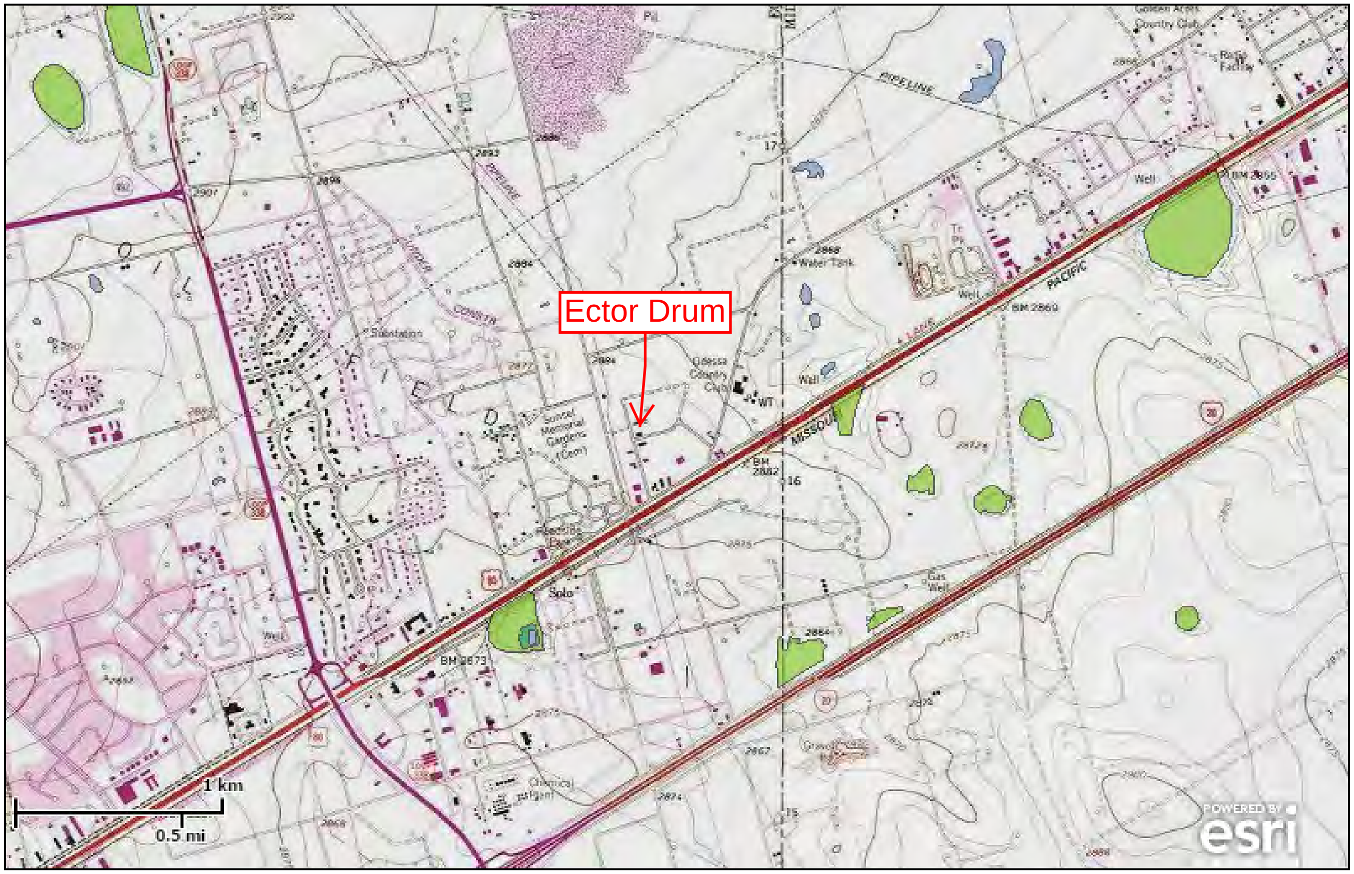
Occurs on calcareous or sandy soils in Chihuahuan Desert shrublands or mesquite grasslands.

Reference 38

U.S. Fish and Wildlife Service

National Wetlands Inventory

Apr 13, 2015



Wetlands

- Freshwater Emergent
- Freshwater Forested/Shrub
- Estuarine and Marine Deepwater
- Estuarine and Marine
- Freshwater Pond
- Lake
- Riverine
- Other

Riparian

- Herbaceous
- Forested/Shrub

Riparian Status

- Digital Data

User Remarks:

Reference 39


N Marco Ave
© 2015 INEGI
© 2015 Google
© 2015 Google
4 ft
Google earth
lat 31.885955° lon -102.294862° elev 2885 ft
Eye alt 2890 ft


© 2013 Google
E Market S
© 2015 Google
© 2015 Google
6 ft
Google earth
lat 31.886346° lon -102.293490° elev 2801 ft
Eye alt 2890 ft

Reference 40

Map Unit Description

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Ector and Crane Counties, Texas

Fa—Faskin-Urban land complex

Map Unit Setting

National map unit symbol: 1yyp
Elevation: 0 to 4,000 feet
Mean annual precipitation: 8 to 60 inches
Mean annual air temperature: 54 to 73 degrees F
Frost-free period: 180 to 310 days
Farmland classification: Not prime farmland

Map Unit Composition

Faskin and similar soils: 70 percent
Urban land: 25 percent

Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Faskin

Setting

Landform: Plains
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Loamy eolian deposits from the blackwater draw formation of pleistocene age

Typical profile

H1 - 0 to 8 inches: fine sandy loam
H2 - 8 to 52 inches: sandy clay loam
H3 - 52 to 80 inches: sandy clay loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 50 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 8.7 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: Sandy loam 12-17" pz (R077DY047TX)

Description of Urban Land

Setting

Down-slope shape: Convex
Across-slope shape: Linear

Typical profile

H1 - 0 to 40 inches: variable

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s

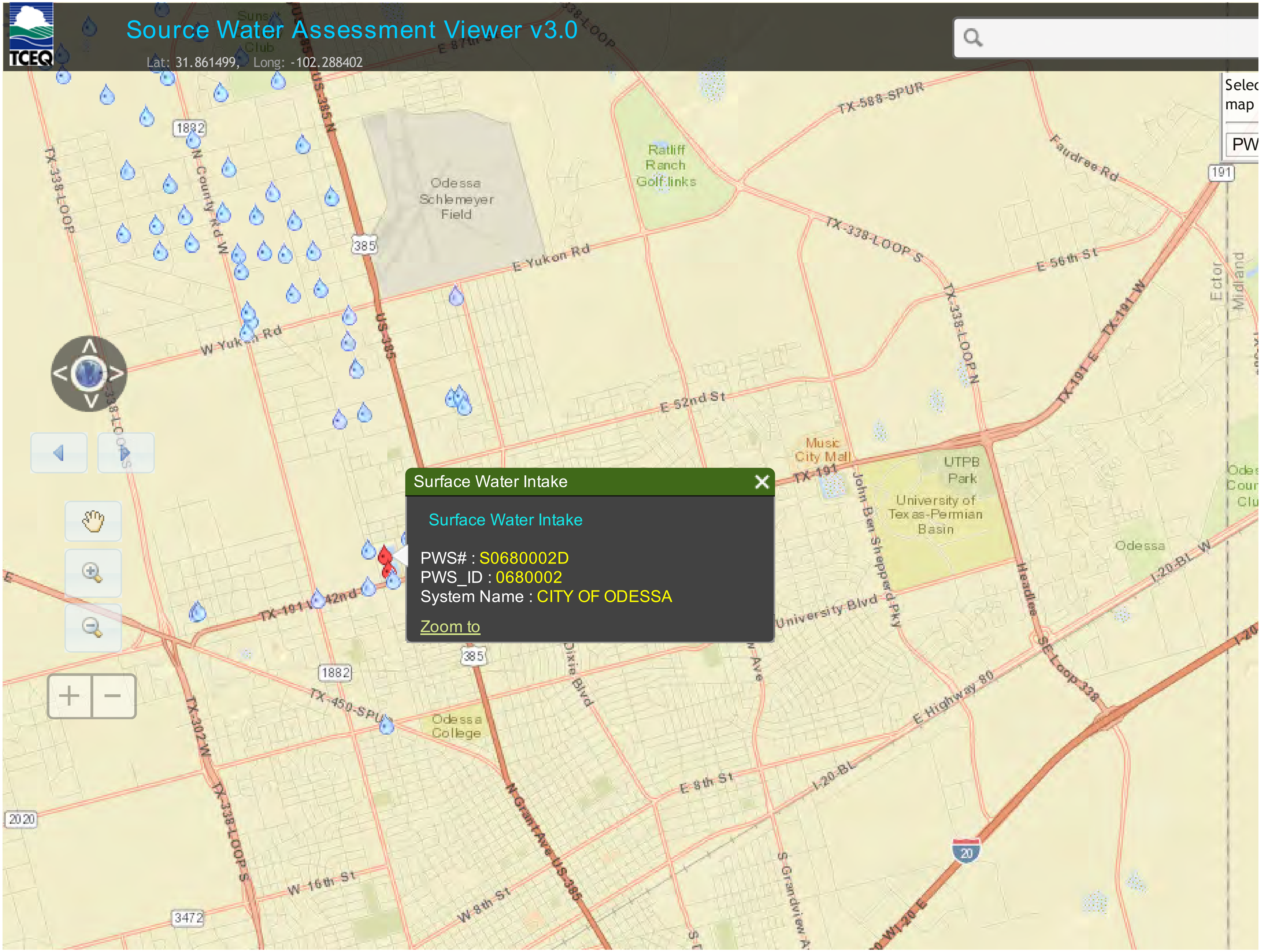
Minor Components

Unnamed, minor components
Percent of map unit: 5 percent

Data Source Information

Soil Survey Area: Ector and Crane Counties, Texas
Survey Area Data: Version 11, Sep 30, 2014

Reference 41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Source Water Assessment Viewer v3.0
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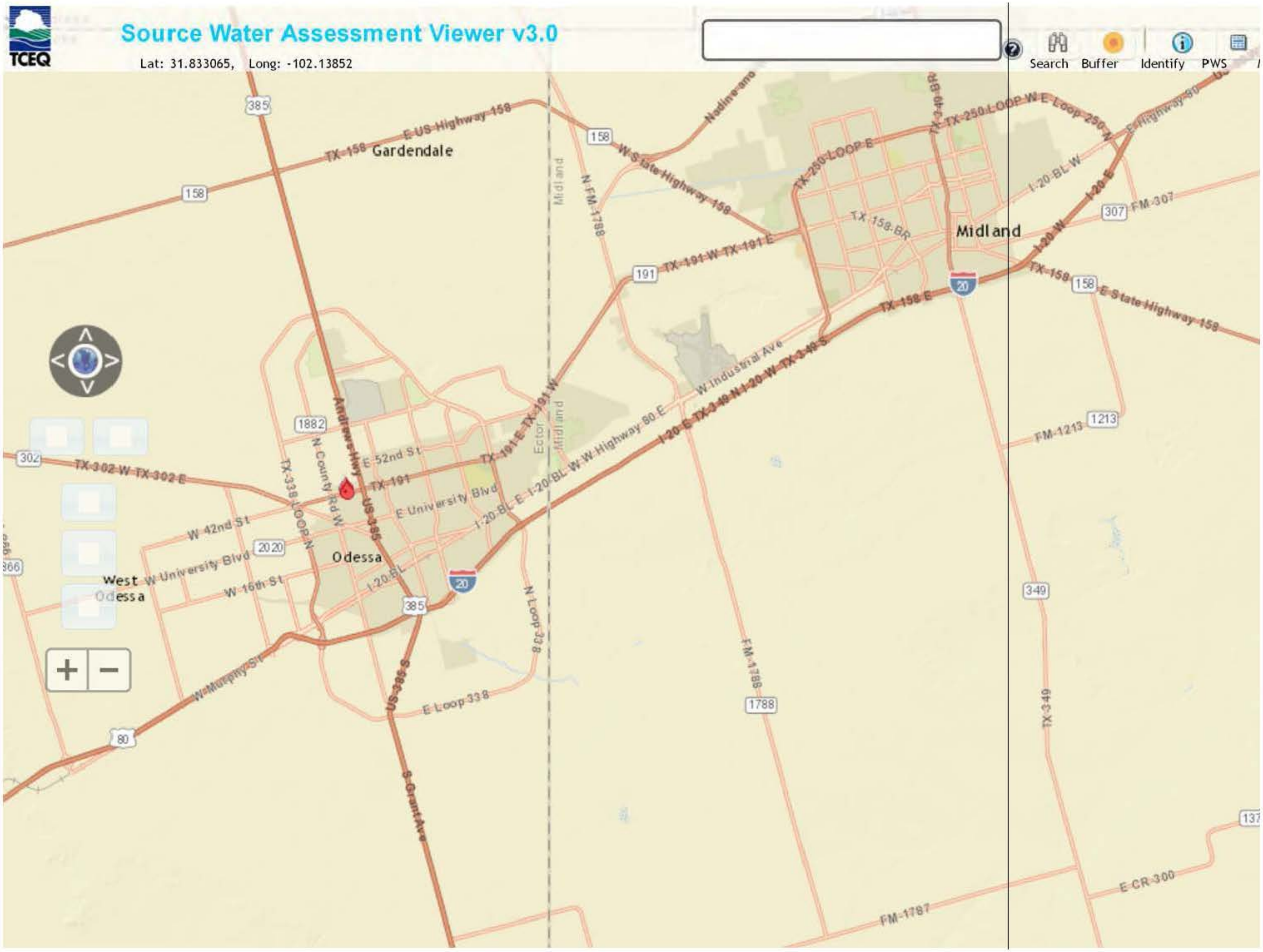
Surface Water Intake
Surface Water Intake
PWS# : S0680002D
PWS_ID : 0680002
System Name : CITY OF ODESSA
Zoom to
Odessa Schlemeyer Field
Ratliff Ranch Golf links
Music City Mall
UTPB Park
University of Texas-Permian Basin
Odessa College
Odessa
TX-588-SPUR
TX-338-LOOP S
TX-338-LOOP N
TX-191-W
TX-191-E
TX-191
E Yukon Rd
W Yukon Rd
E 52nd St
E 56th St
E 8th St
W 16th St
W 8th St
University Blvd
John Ben Shepperd Pkwy
E Highway 80
I-20-BL
I-20-BL W
SE Loop 338
TX-450-SPUR
TX-302 W
TX-338-LOOP S
N County Rd W
US-385 N
US-385
N Grant Ave US-385
Dixie Blvd
S Grandview Av
Faudree Rd
Ector
Midland
1882
385
191
2020
3472
20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Buffer
Identify
PWS
Gardendale
Midland
Odessa
West Odessa
E US Highway 158
TX-158
W State Highway 158
TX-191 W TX-191 E
TX-250 LOOP E
TX-158-BR
E State Highway 158
FM-307
FM-1213
W Industrial Ave
I-20 E TX-349 N I-20 W TX-349 S
TX 158 E
E 52nd St
TX-191
E University Blvd
W 42nd St
W University Blvd
W 16th St
W Murphy St
TX-302 W TX-302 E
TX-338 LOOP N
N County Rd W
Andrews Hwy
US-385
US-385 S
S Grant Ave
E Loop 338
N Loop 338
FM-1788
N FM-1788
TX-349
E CR-300
FM-1787
Ector
Midland
385
158
191
1882
302
2020
366
80
307
1213
349
1788
20

Texas Commission on Environmental Quality

TELEPHONE MEMO TO THE FILE

Please complete with typewriter or black pen.

Call to: Energy Coil & Rigging LLC

Call from: Kristen Kochelek

Date of call: 5/26/15

File no.: Ector Drum

Phone no.: (432) 362-0596

Subject: Status of Property When You Purchased it

Information for file:

Spoke with: Tommy Southall

Empty Drums outside when they purchased the parcel in 2012. He asked them to move them, and they took them away/across the street.

Signed Kristen Kochelek

Reference 43

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 **Publication Date: 06/20/2014**

Chemical: Arsenic **CAS Number: 007440-38-2**

TOXICITY

Parameter	Value	Unit	Source
Oral RfD:	3.0E-04	mg/kg/day	IRIS
Inhal RfD:	4.2E-06	mg/kg/day	CALEPA
RfC	1.5E-05	mg/m^3	CALEPA
Oral Slope:	1.5E+00	(mg/kg/day)^-1	IRIS
Oral Wt-of-Evid:	A		IRIS
IUR:	4.3E-03	(µg/m3)^-1	IRIS
IUR Wt-of-Evid:	A		IRIS
Inhal Slope:	1.5E+01	(mg/kg/day)^-1	IRIS
Oral ED10:	7.0E-03	mg/kg/day	EPA_ED10
Oral ED10 Wgt:	A		EPA_ED10
Inhal ED10:	7.0E-03	mg/kg/day	EPA_ED10
Inhal ED10 Wgt:	A		EPA_ED10
Oral LD50:	1.4E+02	mg/kg	RTECS
Dermal LD50:		mg/kg	
Gas Inhal LC50:		ppm	
Dust Inhal LC50:		mg/L	
ACUTE			
Fresh CMC:	3.4E+02	µg/L	NRWQC
Salt CMC:	6.9E+01	µg/L	NRWQC
CHRONIC			
Fresh CCC:	1.5E+02	µg/L	NRWQC
Salt CCC:	3.6E+01	µg/L	NRWQC
Fresh Ecol LC50:	1.5E+03	µg/L	ECOTOX
Salt Ecol LC50:	3.9E+02	µg/L	ECOTOX

PERSISTENCE

Parameter	Value	Unit	Source
LAKE- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
RIVER- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
Log Kow:	6.8E-01		PHYSPROP

PHYSICAL CHARACTERISTICS

Parameter	Value	Unit	
Metal Contain:	Yes		
Organic:	No		
Gas:	No		
Particulate:	Yes		
Radionuclide:	No		
Rad. Element:	No		
Molecular Weight:	7.4E+01		
Density:	5.7E+00	g/mL @	25.0 °C

MOBILITY

Parameter	Value	Unit	Source
Vapor Press:	2.5E-09	Torr	PHYSPROP
Henry's Law:	7.7E-01	atm-m3/mol	PHYSPROP
Water Solub:		mg/L	
Distrib Coef:	2.9E+01	ml/g	SSG
Geo Mean Sol:	2.0E+04	mg/L	CRC

BIOACCUMULATION

Parameter	Value	Unit	Source
FOOD CHAIN			
Fresh BCF:	4.0E+00		VERSAR
Salt BCF:	3.5E+02		VERSAR
ENVIRONMENTAL			
Fresh BCF:	1.2E+04		ECOTOX
Salt BCF:	3.5E+02		VERSAR
Log Kow:	6.8E-01		PHYSPROP
Water Solub:			
Geo Mean Sol:	2.0E+04	mg/L	CRC

OTHER DATA

Melting Point:	8.1E+02	°C
Boiling Point:	6.1E+02	°C
Formula:	As	

CLASS INFORMATION

Parent Substance

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 **Publication Date: 06/20/2014**

Chemical: Arsenic **CAS Number: 007440-38-2**

ASSIGNED FACTOR VALUES

AIR PATHWAY

Parameter	Value
Toxicity:	10000
Gas Mobility:	
Gas Migration:	

GROUND WATER PATHWAY

Parameter		Value
Toxicity:		10000
Water Solub:		
Distrib:		2.9E+01
Geo Mean Sol:		2.0E+04
Mobility		
Liquid	Karst:	1.0E+00
	Non Karst:	1.0E-02
Non Liq	Karst:	1.0E+00
	Non Karst:	1.0E-02

SOIL EXPOSURE PATHWAY

Parameter	Value
Toxicity:	10000

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value
Toxicity:	10000
Persistence	
River:	1
Lake:	1

HUMAN FOOD CHAIN

Parameter	Value
Toxicity:	10000
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	5
Salt:	500

ENVIRONMENTAL

Parameter	Value
Fresh Tox:	10
Salt Tox:	100
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	50000
Salt:	500

BENCHMARKS

AIR PATHWAY

Parameter	Value	Unit
NAAQS/ NESHAPS:		µg/m3
Cancer Risk:	5.6E-07	mg/m3
Non Cancer Risk:	1.5E-05	mg/m3

GROUND WATER PATHWAY

Parameter	Value	Unit
MCL/ MCLG:	1E-02	mg/L
Cancer Risk:	4.4E-05	mg/L
Non Cancer Risk:	4E-03	mg/L

SOIL EXPOSURE PATHWAY

Parameter	Value	Unit
Cancer Risk:	7.1E-01	mg/kg
Non Cancer Risk:	3E+01	mg/kg

RADIONUCLIDE

Parameter	Value	Unit
MCL:		pCi/L
UMTRCA:		pCi/kg
CANCER RISK		
Air:		pCi/m3
DW:		pCi/L
FC:		pCi/kg
Soil Ing:		pCi/kg
Soil Gam:		pCi/kg

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value	Unit
MCL/MCLG:	1E-02	mg/L
Cancer Risk:	4.4E-05	mg/L
Non Cancer Risk:	4E-03	mg/L

HUMAN FOOD CHAIN

Parameter	Value	Unit
FDAAL:		ppm
Cancer Risk:	2.1E-03	mg/kg
Non Cancer Risk:	4E-01	mg/kg

ENVIRONMENTAL

Parameter	Value	Unit
ACUTE		
Fresh CMC:	3.4E+02	µg/L
Salt CMC:	6.9E+01	µg/L
CHRONIC		
Fresh CCC:	1.5E+02	µg/L
Salt CCC:	3.6E+01	µg/L

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 **Publication Date: 06/20/2014**

Chemical: Chromium **CAS Number: 007440-47-3**

TOXICITY

Parameter	Value	Unit	Source
Oral RfD:	3.0E-03	mg/kg/day	IRIS
Inhal RfD:	2.2E-06	mg/kg/day	IRIS
RfC	8.0E-06	mg/m^3	IRIS
Oral Slope:		(mg/kg/day)^-1	
Oral Wt-of-Evid:			
IUR:		(µg/m3)^-1	
IUR Wt-of-Evid:			
Inhal Slope:		(mg/kg/day)^-1	
Oral ED10:		mg/kg/day	
Oral ED10 Wgt:			
Inhal ED10:	2.5E-03	mg/kg/day	SPHEM
Inhal ED10 Wgt:			
Oral LD50:		mg/kg	
Dermal LD50:		mg/kg	
Gas Inhal LC50:		ppm	
Dust Inhal LC50:		mg/L	
ACUTE			
Fresh CMC:		µg/L	
Salt CMC:		µg/L	
CHRONIC			
Fresh CCC:		µg/L	
Salt CCC:		µg/L	
Fresh Ecol LC50:	2.2E+01	µg/L	ECOTOX
Salt Ecol LC50:	2.2E+02	µg/L	ECOTOX

PERSISTENCE

Parameter	Value	Unit	Source
LAKE- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
RIVER- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
Log Kow:	2.3E-01		PHYSPROP

PHYSICAL CHARACTERISTICS

Parameter	Value	Unit	
Metal Contain:	Yes		
Organic:	No		
Gas:	No		
Particulate:	Yes		
Radionuclide:	No		
Rad. Element:	No		
Molecular Weight:	5.1E+01		
Density:	7.1E+00	g/mL @	25.0 °C

MOBILITY

Parameter	Value	Unit	Source
Vapor Press:	4.2E-09	Torr	PHYSPROP
Henry's Law:	2.4E-02	atm-m3/mol	PHYSPROP
Water Solub:		mg/L	
Distrib Coef:	8.5E+02	ml/g	BAES
Geo Mean Sol:	1.6E+06	mg/L	CRC

BIOACCUMULATION

Parameter	Value	Unit	Source
FOOD CHAIN			
Fresh BCF:	1.3E+00		ECOTOX
Salt BCF:	3.0E+02		ECOTOX
ENVIRONMENTAL			
Fresh BCF:	1.2E+02		ECOTOX
Salt BCF:	3.0E+02		ECOTOX
Log Kow:	2.3E-01		PHYSPROP
Water Solub:			
Geo Mean Sol:	1.6E+06	mg/L	CRC

OTHER DATA

Melting Point:	1.9E+03	°C
Boiling Point:	2.6E+03	°C
Formula:	Cr	

CLASS INFORMATION

Parent Substance

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 **Publication Date: 06/20/2014**

Chemical: Chromium **CAS Number: 007440-47-3**

ASSIGNED FACTOR VALUES

AIR PATHWAY

Parameter	Value
Toxicity:	10000
Gas Mobility:	
Gas Migration:	

GROUND WATER PATHWAY

Parameter		Value
Toxicity:		10000
Water Solub:		
Distrib:		8.5E+02
Geo Mean Sol:		1.6E+06
Mobility		
Liquid	Karst:	1.0E+00
	Non Karst:	1.0E-02
Non Liq	Karst:	1.0E+00
	Non Karst:	1.0E-02

SOIL EXPOSURE PATHWAY

Parameter	Value
Toxicity:	10000

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value
Toxicity:	10000
Persistence	
River:	1
Lake:	1

HUMAN FOOD CHAIN

Parameter	Value
Toxicity:	10000
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	5
Salt:	500

ENVIRONMENTAL

Parameter	Value
Fresh Tox:	10000
Salt Tox:	1000
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	500
Salt:	500

BENCHMARKS

AIR PATHWAY

Parameter	Value	Unit
NAAQS/ NESHAPS:		µg/m3
Cancer Risk:		mg/m3
Non Cancer Risk:	8E-06	mg/m3

GROUND WATER PATHWAY

Parameter	Value	Unit
MCL/ MCLG:	1E-01	mg/L
Cancer Risk:		mg/L
Non Cancer Risk:	4E-02	mg/L

SOIL EXPOSURE PATHWAY

Parameter	Value	Unit
Cancer Risk:		mg/kg
Non Cancer Risk:	2E+02	mg/kg

RADIONUCLIDE

Parameter	Value	Unit
MCL:		pCi/L
UMTRCA:		pCi/kg
CANCER RISK		
Air:		pCi/m3
DW:		pCi/L
FC:		pCi/kg
Soil Ing:		pCi/kg
Soil Gam:		pCi/kg

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value	Unit
MCL/MCLG:	1E-01	mg/L
Cancer Risk:		mg/L
Non Cancer Risk:	4E-02	mg/L

HUMAN FOOD CHAIN

Parameter	Value	Unit
FDAAL:		ppm
Cancer Risk:		mg/kg
Non Cancer Risk:	4E+00	mg/kg

ENVIRONMENTAL

Parameter	Value	Unit
ACUTE		
Fresh CMC:		µg/L
Salt CMC:		µg/L
CHRONIC		
Fresh CCC:		µg/L
Salt CCC:		µg/L

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 **Publication Date: 06/20/2014**

Chemical: Copper **CAS Number: 007440-50-8**

TOXICITY

Parameter	Value	Unit	Source
Oral RfD:	4.0E-02	mg/kg/day	HEAST
Inhal RfD:		mg/kg/day	
RfC		mg/m^3	
Oral Slope:		(mg/kg/day)^-1	
Oral Wt-of-Evid:	D		IRIS
IUR:		(µg/m3)^-1	
IUR Wt-of-Evid:	D		IRIS
Inhal Slope:		(mg/kg/day)^-1	
Oral ED10:		mg/kg/day	
Oral ED10 Wgt:			
Inhal ED10:		mg/kg/day	
Inhal ED10 Wgt:			
Oral LD50:	4.1E+02	mg/kg	RTECS
Dermal LD50:		mg/kg	
Gas Inhal LC50:		ppm	
Dust Inhal LC50:		mg/L	
ACUTE			
Fresh CMC:	2.3E+00	µg/L	NRWQC
Salt CMC:	4.8E+00	µg/L	NRWQC
CHRONIC			
Fresh CCC:	1.4E+00	µg/L	NRWQC
Salt CCC:	3.1E+00	µg/L	NRWQC
Fresh Ecol LC50:	1.6E-01	µg/L	ECOTOX
Salt Ecol LC50:	5.6E-02	µg/L	ECOTOX

PERSISTENCE

Parameter	Value	Unit	Source
LAKE- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
RIVER- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
Log Kow:	-5.7E-01		PHYSPROP

PHYSICAL CHARACTERISTICS

Parameter	Value	Unit	
Metal Contain:	Yes		
Organic:	No		
Gas:	No		
Particulate:	Yes		
Radionuclide:	No		
Rad. Element:	No		
Molecular Weight:	6.3E+01		
Density:	8.9E+00	g/mL @	25.0 °C

MOBILITY

Parameter	Value	Unit	Source
Vapor Press:	4.2E-09	Torr	PHYSPROP
Henry's Law:	2.4E-02	atm-m3/mol	PHYSPROP
Water Solub:		mg/L	
Distrib Coef:	3.5E+01	ml/g	BAES
Geo Mean Sol:	3.3E+04	mg/L	CRC

BIOACCUMULATION

Parameter	Value	Unit	Source
FOOD CHAIN			
Fresh BCF:	8.8E+04		ECOTOX
Salt BCF:	5.1E+05		ECOTOX
ENVIRONMENTAL			
Fresh BCF:	8.8E+04		ECOTOX
Salt BCF:	5.1E+05		ECOTOX
Log Kow:	-5.7E-01		PHYSPROP
Water Solub:			
Geo Mean Sol:	3.3E+04	mg/L	CRC

OTHER DATA

Melting Point:	1.0E+03	°C
Boiling Point:	2.5E+03	°C
Formula:	Cu	

CLASS INFORMATION

Parent Substance

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 **Publication Date: 06/20/2014**

Chemical: Copper **CAS Number: 007440-50-8**

ASSIGNED FACTOR VALUES

AIR PATHWAY

Parameter	Value
Toxicity:	100
Gas Mobility:	
Gas Migration:	

GROUND WATER PATHWAY

Parameter		Value
Toxicity:		100
Water Solub:		
Distrib:		3.5E+01
Geo Mean Sol:		3.3E+04
Mobility		
Liquid	Karst:	1.0E+00
	Non Karst:	1.0E-02
Non Liq	Karst:	1.0E+00
	Non Karst:	1.0E-02

SOIL EXPOSURE PATHWAY

Parameter	Value
Toxicity:	100

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value
Toxicity:	100
Persistence	
River:	1
Lake:	1

HUMAN FOOD CHAIN

Parameter	Value
Toxicity:	100
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	50000
Salt:	50000

ENVIRONMENTAL

Parameter	Value
Fresh Tox:	1000
Salt Tox:	1000
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	50000
Salt:	50000

BENCHMARKS

AIR PATHWAY

Parameter	Value	Unit
NAAQS/ NESHAPS:		µg/m3
Cancer Risk:		mg/m3
Non Cancer Risk:		mg/m3

GROUND WATER PATHWAY

Parameter	Value	Unit
MCL/ MCLG:	1.3E+00	mg/L
Cancer Risk:		mg/L
Non Cancer Risk:	6E-01	mg/L

SOIL EXPOSURE PATHWAY

Parameter	Value	Unit
Cancer Risk:		mg/kg
Non Cancer Risk:	3E+03	mg/kg

RADIONUCLIDE

Parameter	Value	Unit
MCL:		pCi/L
UMTRCA:		pCi/kg
CANCER RISK		
Air:		pCi/m3
DW:		pCi/L
FC:		pCi/kg
Soil Ing:		pCi/kg
Soil Gam:		pCi/kg

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value	Unit
MCL/MCLG:	1.3E+00	mg/L
Cancer Risk:		mg/L
Non Cancer Risk:	6E-01	mg/L

HUMAN FOOD CHAIN

Parameter	Value	Unit
FDAAL:		ppm
Cancer Risk:		mg/kg
Non Cancer Risk:	5E+01	mg/kg

ENVIRONMENTAL

Parameter	Value	Unit
ACUTE		
Fresh CMC:	2.3E+00	µg/L
Salt CMC:	4.8E+00	µg/L
CHRONIC		
Fresh CCC:	1.4E+00	µg/L
Salt CCC:	3.1E+00	µg/L

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 **Publication Date: 06/20/2014**

Chemical: Lead **CAS Number: 007439-92-1**

TOXICITY

Parameter	Value	Unit	Source
Oral RfD:		mg/kg/day	
Inhal RfD:		mg/kg/day	
RfC		mg/m^3	
Oral Slope:		(mg/kg/day)^-1	
Oral Wt-of-Evid:			
IUR:		(µg/m3)^-1	
IUR Wt-of-Evid:			
Inhal Slope:		(mg/kg/day)^-1	
Oral ED10:		mg/kg/day	
Oral ED10 Wgt:			
Inhal ED10:		mg/kg/day	
Inhal ED10 Wgt:			
Oral LD50:		mg/kg	
Dermal LD50:		mg/kg	
Gas Inhal LC50:		ppm	
Dust Inhal LC50:		mg/L	
ACUTE			
Fresh CMC:	6.5E+01	µg/L	NRWQC
Salt CMC:	2.1E+02	µg/L	NRWQC
CHRONIC			
Fresh CCC:	2.5E+00	µg/L	NRWQC
Salt CCC:	8.1E+00	µg/L	NRWQC
Fresh Ecol LC50:	4.4E+02	µg/L	ECOTOX
Salt Ecol LC50:	1.0E+02	µg/L	ECOTOX

PERSISTENCE

Parameter	Value	Unit	Source
LAKE- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
RIVER- Halflives			
Hydrolysis:		days	
Volatility:		days	
Photolysis:		days	
Biodeg:		days	
Radio:		days	
Log Kow:	7.3E-01		PHYSPROP

PHYSICAL CHARACTERISTICS

Parameter	Value	Unit	
Metal Contain:	Yes		
Organic:	No		
Gas:	No		
Particulate:	Yes		
Radionuclide:	No		
Rad. Element:	No		
Molecular Weight:	2.0E+02		
Density:	1.1E+01	g/mL @	25.0 °C

MOBILITY

Parameter	Value	Unit	Source
Vapor Press:	3.0E-09	Torr	PHYSPROP
Henry's Law:	2.4E-02	atm-m3/mol	PHYSPROP
Water Solub:		mg/L	
Distrib Coef:	9.0E+02	ml/g	BAES
Geo Mean Sol:	1.0E+04	mg/L	CRC

BIOACCUMULATION

Parameter	Value	Unit	Source
FOOD CHAIN			
Fresh BCF:	1.5E+03		ECOTOX
Salt BCF:	5.0E+03		ECOTOX
ENVIRONMENTAL			
Fresh BCF:	5.3E+05		ECOTOX
Salt BCF:	5.0E+03		ECOTOX
Log Kow:	7.3E-01		PHYSPROP
Water Solub:			
Geo Mean Sol:	1.0E+04	mg/L	CRC

OTHER DATA

Melting Point:	3.2E+02	°C
Boiling Point:	1.7E+03	°C
Formula:	Pb	

CLASS INFORMATION

Parent Substance

SUPERFUND CHEMICAL DATA MATRIX

Last Modified Date: 01/30/2014 | **Publication Date: 06/20/2014**

Chemical: Lead | **CAS Number: 007439-92-1**

ASSIGNED FACTOR VALUES

AIR PATHWAY

Parameter	Value
Toxicity:	10000
Gas Mobility:	
Gas Migration:	

GROUND WATER PATHWAY

Parameter		Value
Toxicity:		10000
Water Solub:		
Distrib:		9.0E+02
Geo Mean Sol:		1.0E+04
Mobility		
Liquid	Karst:	1.0E+00
	Non Karst:	1.0E-02
Non Liq	Karst:	1.0E+00
	Non Karst:	1.0E-02

SOIL EXPOSURE PATHWAY

Parameter	Value
Toxicity:	10000

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value
Toxicity:	10000
Persistence	
River:	1
Lake:	1

HUMAN FOOD CHAIN

Parameter	Value
Toxicity:	10000
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	5000
Salt:	5000

ENVIRONMENTAL

Parameter	Value
Fresh Tox:	1000
Salt Tox:	1000
Persistence	
River:	1
Lake:	1
Bioaccumulation	
Fresh:	50000
Salt:	5000

BENCHMARKS

AIR PATHWAY

Parameter	Value	Unit
NAAQS/ NESHAPS:		µg/m3
Cancer Risk:		mg/m3
Non Cancer Risk:		mg/m3

GROUND WATER PATHWAY

Parameter	Value	Unit
MCL/ MCLG:	1.5E-02	mg/L
Cancer Risk:		mg/L
Non Cancer Risk:		mg/L

SOIL EXPOSURE PATHWAY

Parameter	Value	Unit
Cancer Risk:		mg/kg
Non Cancer Risk:		mg/kg

RADIONUCLIDE

Parameter	Value	Unit
MCL:		pCi/L
UMTRCA:		pCi/kg
CANCER RISK		
Air:		pCi/m3
DW:		pCi/L
FC:		pCi/kg
Soil Ing:		pCi/kg
Soil Gam:		pCi/kg

SURFACE WATER PATHWAY

DRINKING WATER

Parameter	Value	Unit
MCL/MCLG:	1.5E-02	mg/L
Cancer Risk:		mg/L
Non Cancer Risk:		mg/L

HUMAN FOOD CHAIN

Parameter	Value	Unit
FDAAL:		ppm
Cancer Risk:		mg/kg
Non Cancer Risk:		mg/kg

ENVIRONMENTAL

Parameter	Value	Unit
ACUTE		
Fresh CMC:	6.5E+01	µg/L
Salt CMC:	2.1E+02	µg/L
CHRONIC		
Fresh CCC:	2.5E+00	µg/L
Salt CCC:	8.1E+00	µg/L