Aquifers of Texas

by Peter G. George, Ph.D., P.G. • Robert E. Mace, Ph.D., P.G. •
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Texas Water
Development Board

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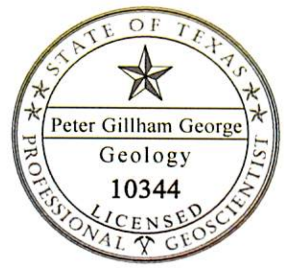

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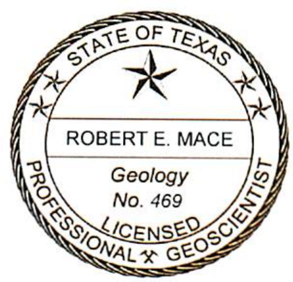

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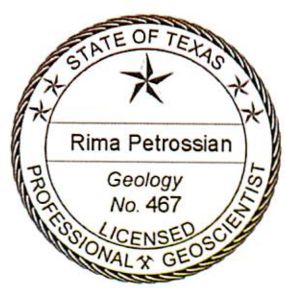

Cover photo: The Cow Creek Limestone of the Edwards-Trinity Plateau Aquifer at Hamilton Pool, Travis County, Texas
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1 Executive Summary

This report is an update to the Texas Water Development Board (TWDB) Report 345, *Major and Minor Aquifers of Texas*, published in 1995 and coauthored by John B. Ashworth and Janie Hopkins. Since the publication of that report more than 15 years ago, a great deal of information has become available through research at universities, state and federal agencies, and private environmental engineering firms as part of the TWDB's Groundwater Availability Modeling Program. The TWDB itself collects a large amount of data annually on water levels and water quality from wells around the state, which is incorporated into its groundwater availability models.

In addition to new research becoming available, the aerial extent of the aquifers has changed since 1995. In the 2007 Texas State Water Plan, the TWDB adjusted the boundaries of the Blaine, Bone Spring–Victorio Peak, Edwards (Balcones Fault Zone), Igneous, Lipan, Ogallala, Pecos Valley (formerly the Cenozoic Pecos Alluvium), Seymour, and Trinity aquifers. These changes are incorporated into the aquifer summaries presented in this report.

The aquifer summaries are short descriptions covering geology, hydrology, and water use, based largely on reports generated through the Groundwater Availability Modeling Program. The summaries are preceded by sections on groundwater in Texas, including the monitoring and modeling programs at the TWDB, a discussion of statewide groundwater issues, a summary of groundwater management in the state, and basic groundwater principles. The latter is included as a layman's guide to the state's groundwater resources.

As in any scientific report, the summary descriptions are based on current and past information. To keep the information current, aquifer descriptions will be updated and posted on the TWDB Web site as new research is completed.

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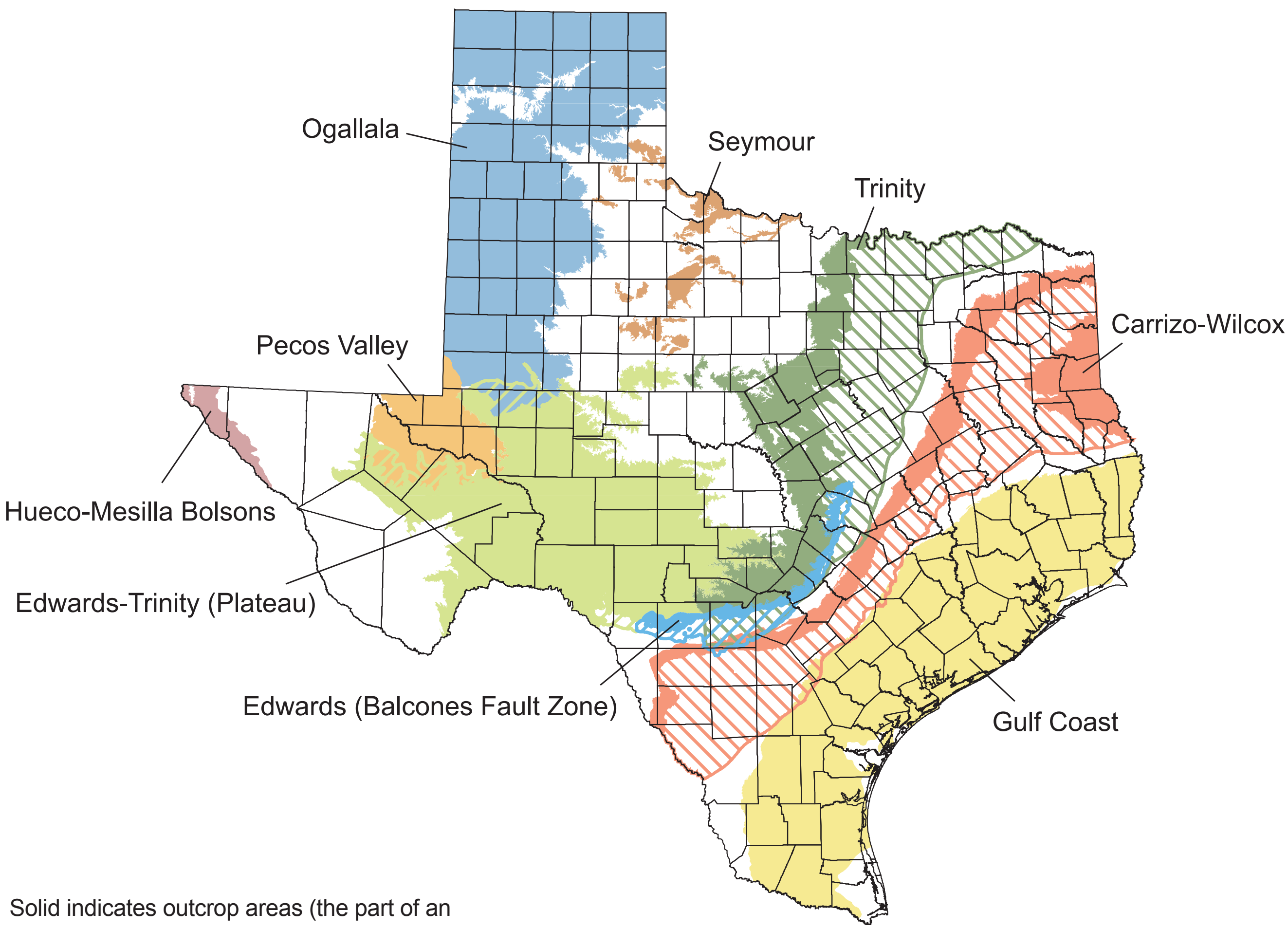
2 Introduction

Texas has numerous aquifers capable of producing groundwater for households, municipalities, industry, farms, and ranches. The Texas Water Development Board (TWDB) recognizes 9 major aquifers—aquifers that produce large amounts of water over large areas (Figure 2-1)—and 21 minor aquifers—aquifers that produce minor amounts of water over large areas or large amounts of water over small areas (Figure 2-2). These aquifers are a critical source of water for Texas, supplying 59 percent of the 15.6 million acre-feet of water used in the state in 2003. About 79 percent of this water is used for irrigation, with irrigators withdrawing most of this water from the Ogallala Aquifer alone (82 percent of all groundwater used for irrigation, or 6.0 million acre-feet per year). About 36 percent of water used to meet municipal demands is from groundwater. The number of aquifers appearing in reports and maps produced by the TWDB, and its predecessor agencies, has changed considerably over the years. In 1961, the



Solid indicates outcrop areas (the part of an aquifer that lies at the land surface).
Hatched indicates subsurface areas (the part of an aquifer that lies or dips below other formations).

Figure 2-1.
The major aquifers of Texas

Texas Board of Water Engineers recognized only nine "principal" aquifers in the first state water plan. By 2002, the number of named aquifers increased to 30 with the addition of the Yegua-Jackson Aquifer. This increase was mainly due to the addition of minor aquifers.

The mapped extent of the aquifers has also changed over time. In the most recent water plan of 2007, the TWDB adjusted the boundaries of the Blaine, Bone Spring–Victorio Peak, Edwards (Balcones Fault Zone), Igneous, Lipan, Ogallala, Pecos Valley (formerly the Cenozoic Pecos Alluvium), Seymour, and Trinity aquifers. These changes were based on groundwater availability modeling and other scientific studies, and comments from the public supported by existing information. The TWDB also changed the name of the Hueco-Mesilla Bolson Aquifer to the Hueco-Mesilla Bolsons Aquifer to reflect that the aquifer is made up of sediments in two separate bolsons: the Hueco Bolson and the Mesilla Bolson.

It should be noted that this report is an update to TWDB reports of Ashworth and Flores (1991) and Ashworth and Hopkins (1995). Since their publication, a great deal of information has become available through research at universities, state and federal agencies, and private environmental

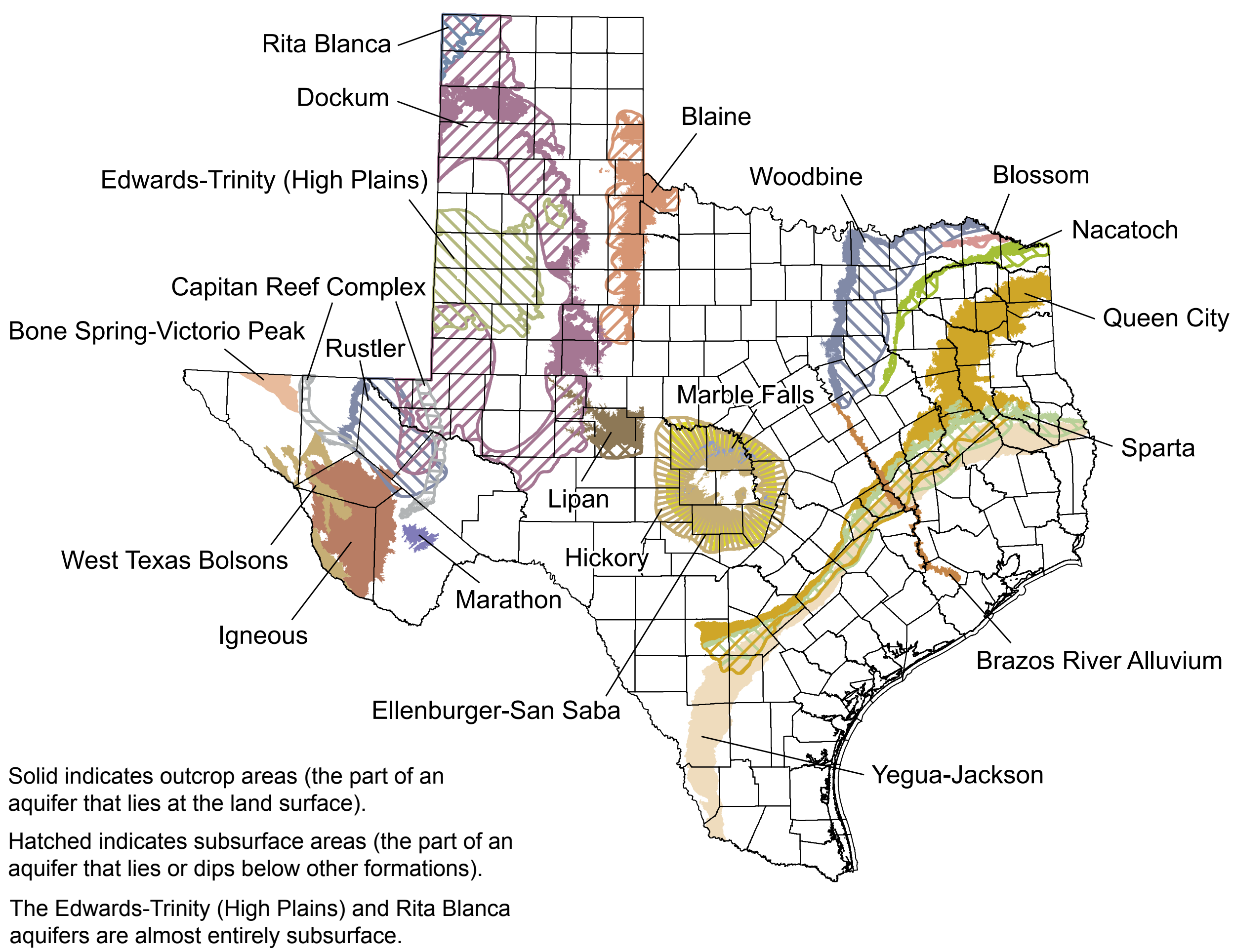


Figure 2-2.
The minor aquifers of Texas

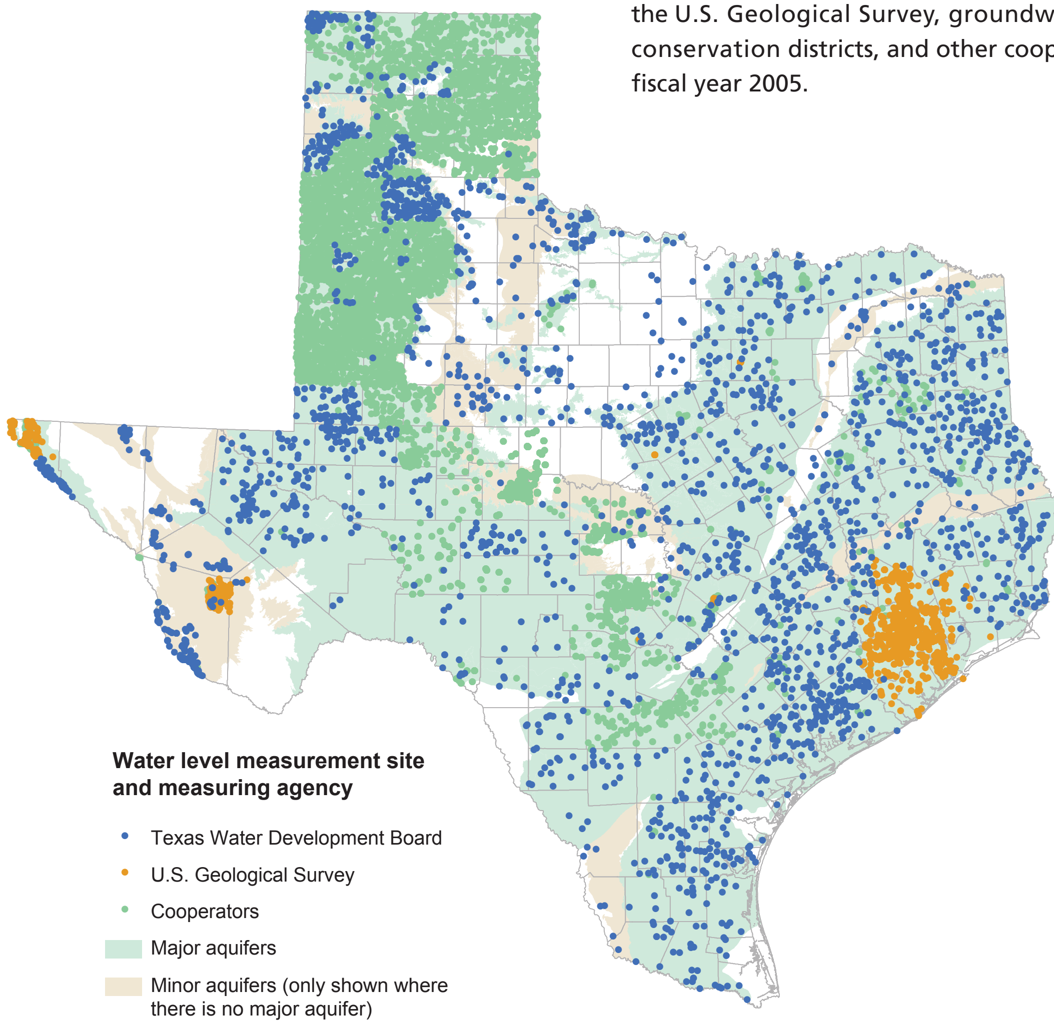


Figure 2-3. Location of wells measured by TWDB, the U.S. Geological Survey, groundwater conservation districts, and other cooperators in fiscal year 2005.

engineering firms as part of the Groundwater Availability Modeling (GAM) Program at the TWDB. The GAM reports have been particularly useful for this report in describing general aquifer characteristics. These characteristics are described at the end of individual reports for each aquifer.

2.1 TWDB Monitoring and Modeling Programs

To assess the quality and quantity of groundwater in Texas, the TWDB operates three monitoring programs that complement other local, state, and federal monitoring programs within the state. The first of the three is the annual groundwater level observation program. Its purpose is to detect trends in water levels over time on a regional basis, to provide support for groundwater management and state and regional water planning, and to collect information for groundwater modeling. In operation since 1957, the program relies on a network of approximately 8,000 observation wells (Figure 2-3). The majority of the wells—86 percent—are in major aquifers, with the remainder in minor or other undesignated aquifers, such as the Rio Grande Alluvium. The TWDB collects more than 2,000 water level measurements each year and receives at least another 11,000 measurements from other organizations, primarily groundwater conservation districts. Once collected, groundwater levels are stored in TWDB's groundwater database and are available on the agency's Web site at http://www.twdb.texas.gov.

The TWDB, along with other entities, operates a second groundwater level program to detect trends in groundwater levels on a daily basis at more than 100 specific well sites. These water levels are from wells called "recorders" or "recorder wells" equipped to record water levels continuously (Figure 2-4). The information from these wells is transmitted daily to the TWDB, where it is posted on the agency's Web site.

The final program involves monitoring groundwater quality. Its purpose is to monitor natural, or ambient, water quality in each of the state's major and minor aquifers, to observe any trends in water quality over time, and to support state and regional water planning and groundwater management. Sample analyses include major ions, trace elements (primarily metals), and nutrients. The TWDB annually samples water from 600 to 700 sites, and cooperators collect samples from at least 200 more. Most of the samples are collected from wells, but, on occasion, springs are also sampled. Through these collection efforts, all aquifers are sampled once every four to five years, and five or six major and minor aquifers are sampled each year (Figure 2-5). The water quality data collected by the TWDB and other outside

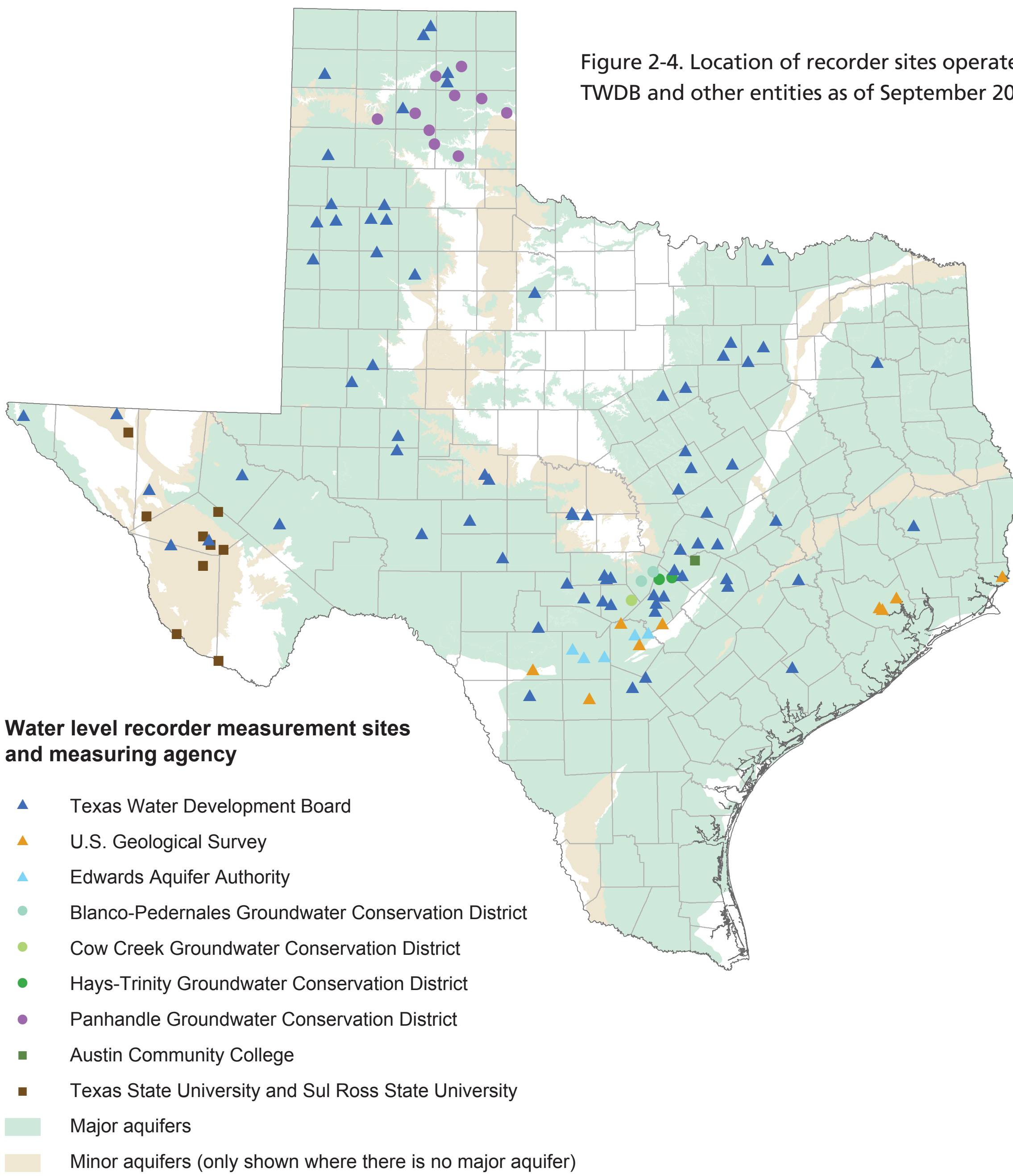


Figure 2-4. Location of recorder sites operated by TWDB and other entities as of September 2006.

groups are stored along with groundwater levels in the TWDB groundwater database. Other local, state, and federal organizations also monitor water quality. Groundwater conservation districts perform water quality analyses, usually at the request of well owners. Their analyses provide a general characterization of water quality based on concentrations of a few key constituents, such as bacteria, nitrate, total dissolved solids, and selected metals. Public water suppliers, as required by the Texas Commission on Environmental Quality, monitor groundwater quality, although generally after treatment. The U.S. Geological Survey collects water quality information in localized parts of the state to assess groundwater conditions and to determine how these conditions change over time and how natural features and human activities affect these conditions.

Groundwater availability models estimate current and future trends in the amount of water available for use from an aquifer. As part of its ongoing effort to provide vital, scientific information to the citizens and policy makers of Texas, the TWDB has obtained or developed models for all major aquifers and 8 of the 21 minor aquifers. In addition, the agency has begun to update some of the initial models and plans to review and update each model every five years.

TWDB groundwater availability models are computer-based, three-dimensional, numerical groundwater flow models that

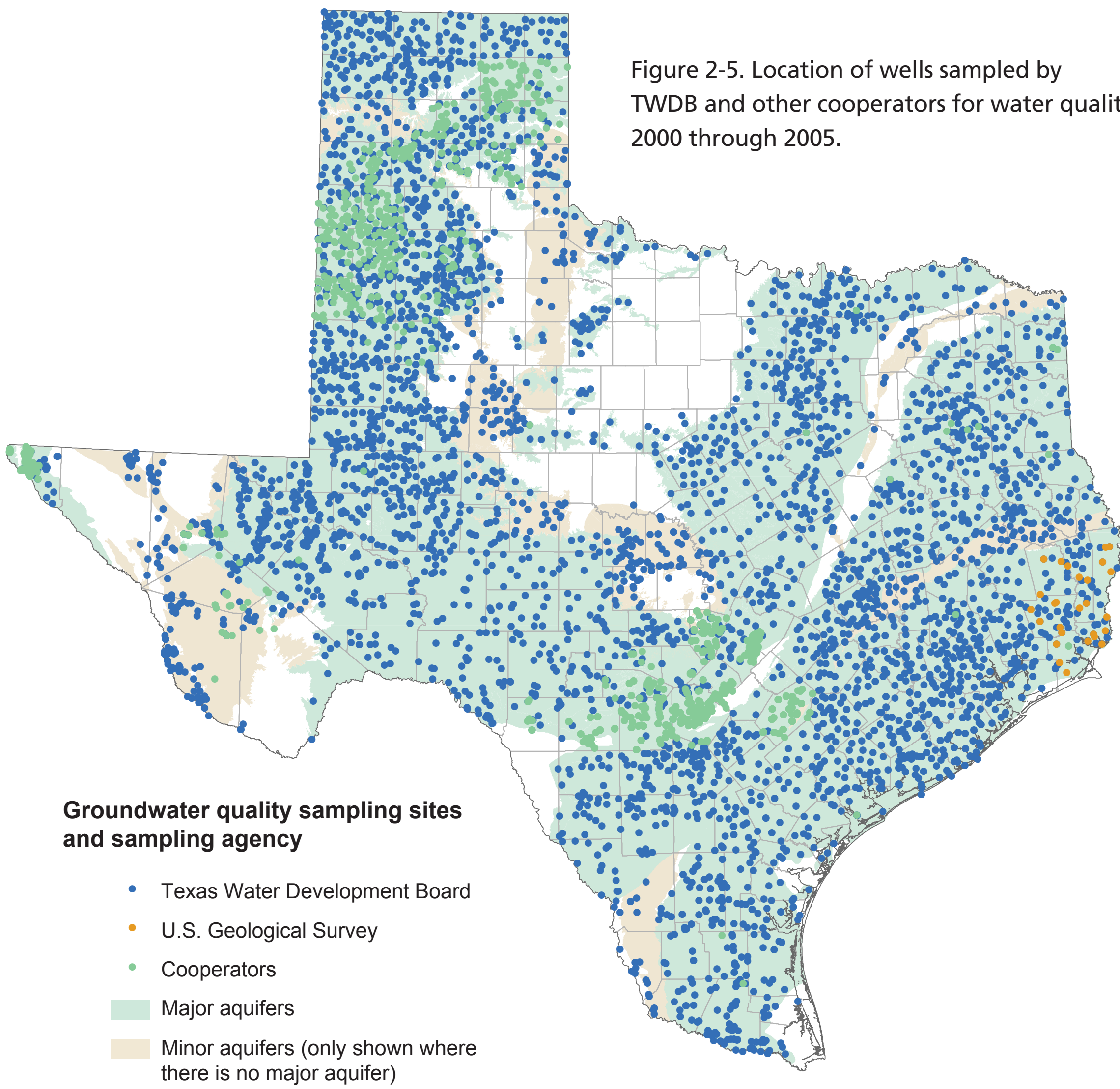


Figure 2-5. Location of wells sampled by TWDB and other cooperators for water quality, 2000 through 2005.

simulate groundwater flow systems at a regional scale. The models estimate current and future trends in the amount of water available for use from an aquifer. They are meant to be "living tools" that can be updated as new information becomes available, adapted to reflect changing aquifer conditions, or refined to better address the needs and concerns of the groups using them. Because the groundwater availability models simulate large areas, these models allow users to see the big picture and understand groundwater flow through all or large parts of an aquifer. Complex physical parameters such as hydrogeologic properties, groundwater levels, pumpage, recharge, aquifer geometry, and groundwater–surface water interactions are simplified into mathematical equations that the model solves. The models are then calibrated using historically measured water levels, spring flows, and base flows to streams and rivers as targets.

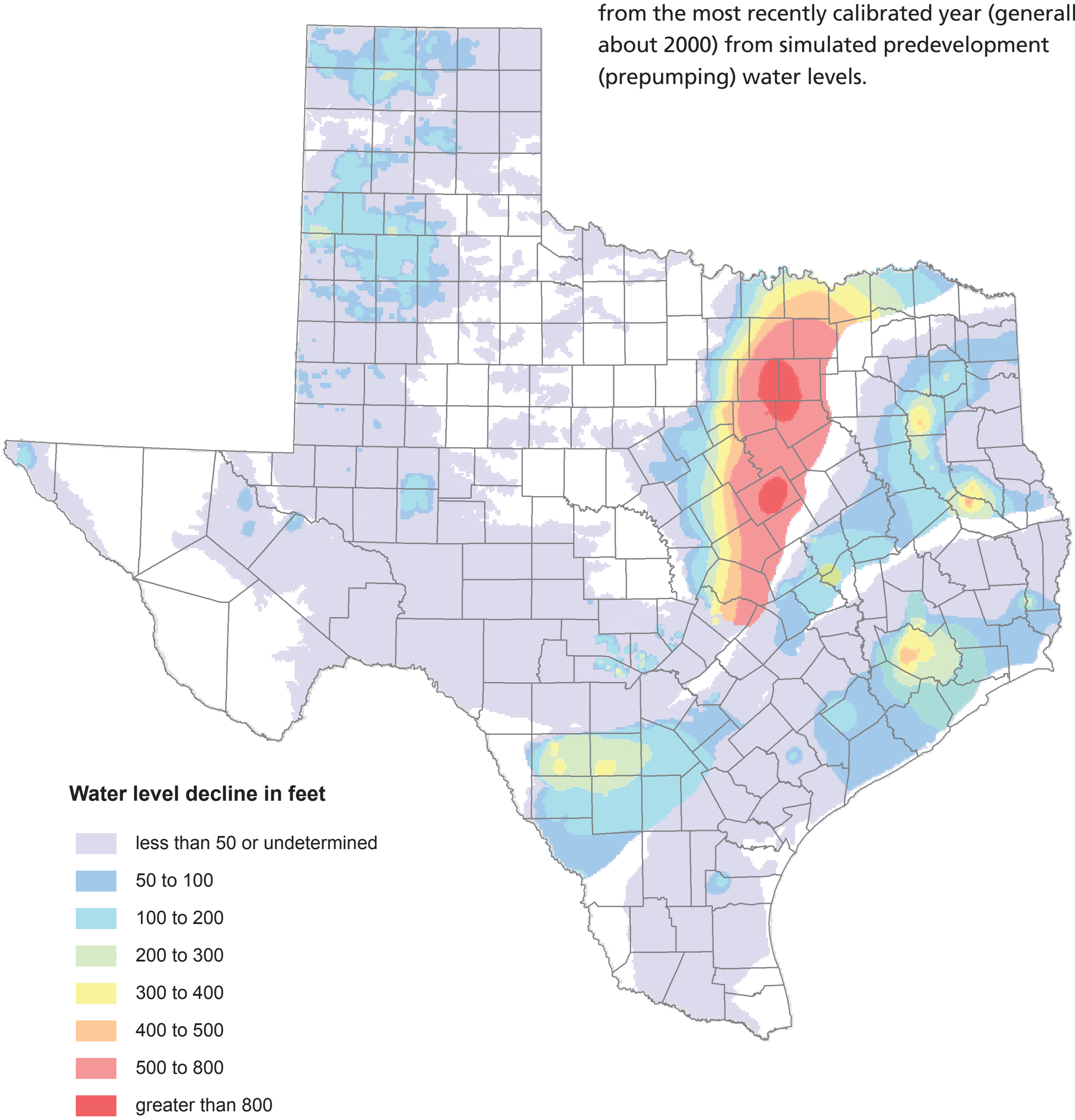
Once an initial model has been created and calibrated, it becomes a tool that groundwater conservation districts, planning groups, and others can use to estimate groundwater availability and predict future water levels and regional groundwater flow in their aquifers on the basis of different scenarios. Ongoing refinement and improvement of the groundwater availability models are essential to addressing the needs and concerns of these various entities so that they can manage and plan the use of groundwater supplies. To view modeling reports, request a model, or check the status of the program, visit the TWDB Web site.

2.2 Statewide Groundwater Issues

2.2.1 Water Levels

TWDB monitoring of water wells throughout the state has identified areas of significant water level declines (Figure 2-6). Total water level declines in the state's aquifers range from less than 50 feet to more than 1,000 feet. The largest water level declines are in the Trinity Aquifer, focused in the Dallas–Fort Worth and Waco areas (Figure 2-6). One hundred years ago wells in much of the Trinity Aquifer flowed at the surface, releasing so much artesian pressure that most ceased to flow by the mid-1910s. Other areas of large water level declines are in the Carrizo-Wilcox Aquifer in the Winter Garden irrigation area north of Laredo; near Lufkin, Nacogdoches, and Tyler; and in the Gulf Coast Aquifer near Houston. Water levels in the Ogallala Aquifer have also declined more than 200 feet. All of these water level declines have been caused by groundwater withdrawals, primarily since the 1950s. Before the 1950s, it is estimated

Figure 2-6. Estimated total water level declines in the major aquifers of Texas. Water level declines in the eastern part of the state tend to be declines in artesian pressure, whereas water level declines in the western part of the state tend to be declines in the water table. These estimates are from the groundwater availability models and are calculated by subtracting water levels from the most recently calibrated year (generally about 2000) from simulated predevelopment (prepumping) water levels.



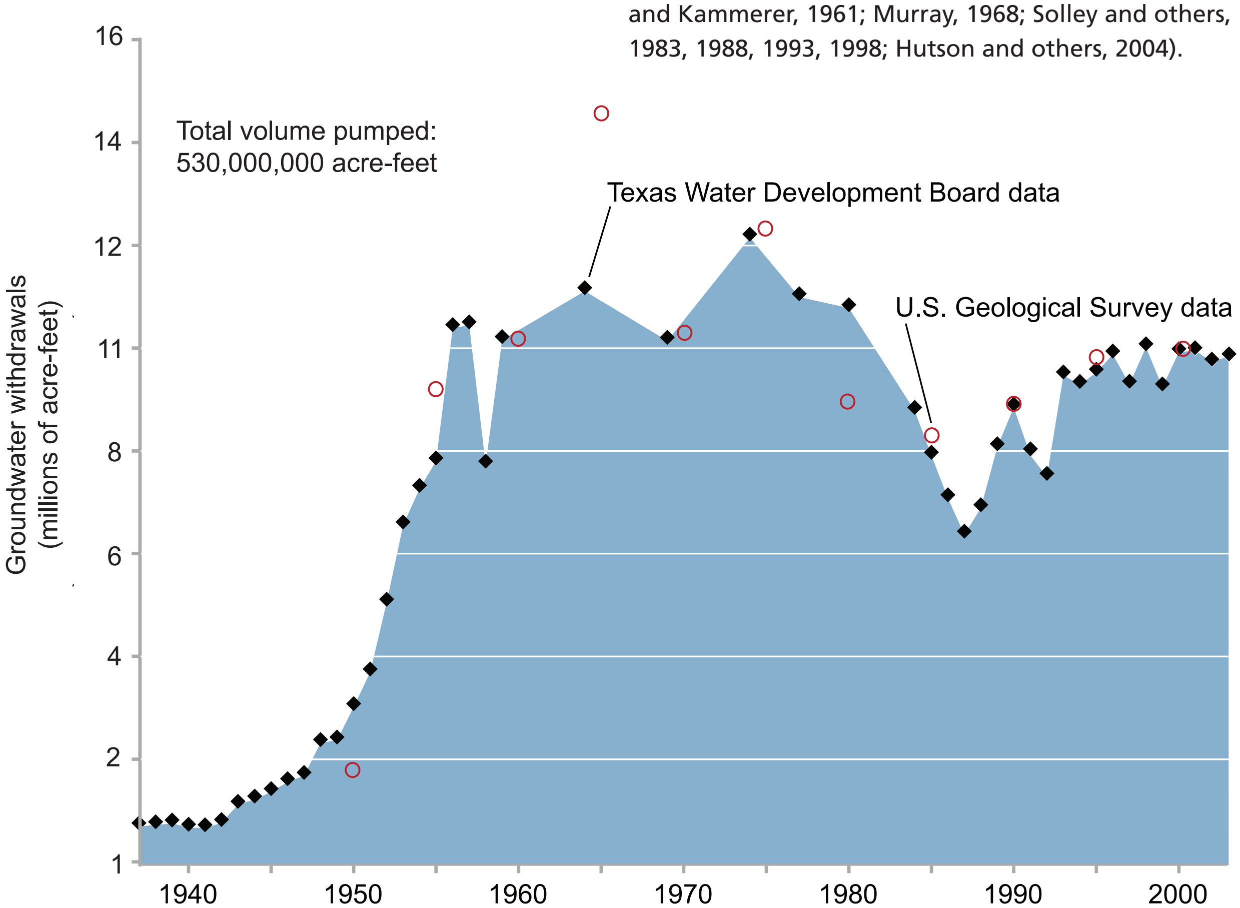


Figure 2-7. Historical estimates of groundwater withdrawals from the aquifers of Texas (data from the TWDB water use database; MacKichan, 1951, 1957; MacKichan and Kammerer, 1961; Murray, 1968; Solley and others, 1983, 1988, 1993, 1998; Hutson and others, 2004).

that Texans withdrew less than 2 million acre-feet of groundwater per year (Figure 2-7). After the 1950s, groundwater withdrawals have been estimated to be about 10 million acre-feet per year. (TWDB estimates withdrawals of about 9.2 million acre-feet in 2003). Between 1937 and 1993, about 530 million acre-feet of groundwater was withdrawn from the aquifers of Texas.

Between 1994 and 2004, water levels in the state's aquifers declined in some parts of the state and rose in others. Water levels continued to decline in much of the Ogallala Aquifer in West Texas, with declines greater than 40 feet in parts of the aquifer. However, other parts of the Ogallala Aquifer showed water level rises, presumably due to increased recharge resulting from fallow fields in areas of dry land farming. Water levels have risen more than 40 feet in 10 years in the Houston area because of reduced pumping to prevent land subsidence. Water levels have fallen more than 40 feet, however, in the suburbs north of Houston.

2.2.2 Groundwater Quality

Although the vast majority of groundwater used for drinking in Texas meets state and federal requirements for safety, in some parts of the state naturally occurring levels of total dissolved solids, arsenic, and radionuclides, as well as human-caused contamination, prevent the water from meeting those standards.

Total dissolved solids are a measure of the salinity of water and represent the amount of minerals dissolved in water, generally reported as milligrams per liter of water. If water is too saline, then it may not be drinkable without treatment, or it may not be suitable for irrigation. Water with total dissolved solids less than 1,000 milligrams per liter is considered fresh and is generally usable. Water with total dissolved solids of as much as 1,500 milligrams per liter may be used to irrigate crops, depending on the type of crop and the levels of salt, sodium, carbonate, bicarbonate, nitrogen, and boron. Water with total dissolved solids as high as 3,000 milligrams per liter may still be used for livestock. Water with total dissolved solids between 1,000 and 10,000 milligrams per liter, also called brackish groundwater, is a potential source of water for desalination. Much of the water in the state's aquifers is fresh; however, brackish groundwater is more common than fresh groundwater in the southern Gulf Coast area and in large parts of West Texas (Figure 2-8).

Although arsenic can occur both naturally and through human contamination, most of the arsenic in Texas groundwater is naturally occurring. Arsenic is a concern in drinking water because high levels of it can cause cancer and other health problems. Since January 2006, arsenic has become more of a concern because at that time the U.S. Environmental Protection Agency lowered the maximum acceptable level of arsenic in drinking water from 50 micrograms per liter to 10 micrograms per liter. Because this maximum acceptable level was lowered, many communities in Texas will now have to treat their

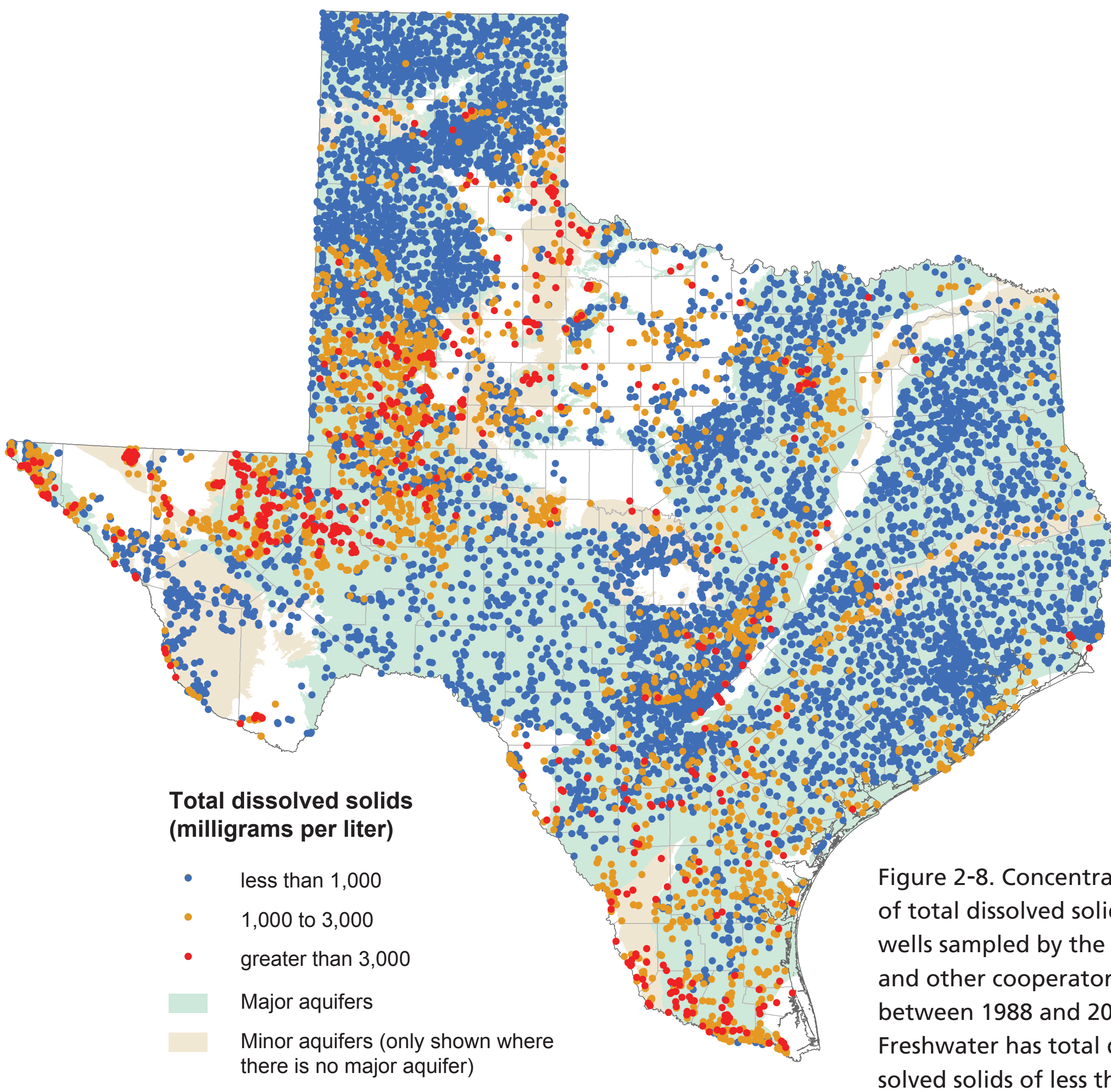


Figure 2-8. Concentration of total dissolved solids in wells sampled by the TWDB and other cooperators between 1988 and 2004. Freshwater has total dissolved solids of less than 1,000 milligrams per liter.

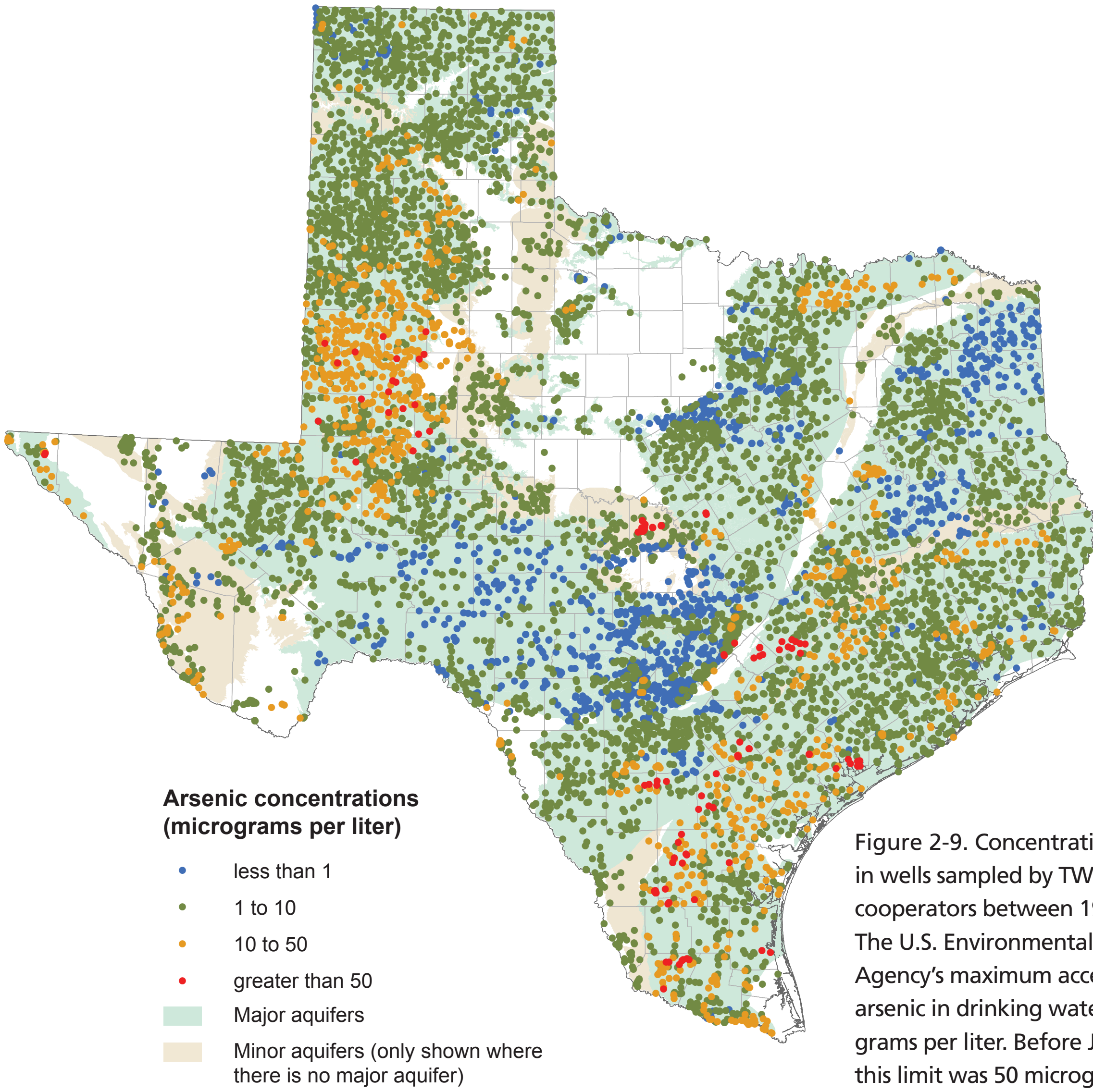


Figure 2-9. Concentration of arsenic in wells sampled by TWDB and other cooperators between 1988 and 2004. The U.S. Environmental Protection Agency's maximum acceptable limit for arsenic in drinking water is 10 micrograms per liter. Before January 2006, this limit was 50 micrograms per liter.

groundwater, blend it with another source, or find an alternative source of supply. Most of the groundwater in Texas with arsenic concentrations greater than 10 micrograms per liter is in southeast Texas in the Gulf Coast Aquifer, in West Texas in the southern half of the Ogallala Aquifer, and in parts of Far West Texas in the Hueco-Mesilla Bolsons and West Texas Bolsons aquifers (Figure 2-9).

A radionuclide is an atom having an unstable nucleus that emits radiation. One measure of radionuclides is gross alpha radiation, which represents the radiation emitted from uranium, radium, and radon. If groundwater contains enough radionuclides—most commonly radium, uranium, and radon gas—and if large enough quantities are consumed over time, there may be enough radiation to cause cancer and other health problems. The U.S. Environmental Protection Agency has set the maximum acceptable level of gross alpha radiation in drinking water at 15 picocuries per liter. Most groundwater in Texas with gross alpha radiation greater than the maximum acceptable level is found in the Hickory Aquifer in Central Texas and the Dockum Aquifer of West Texas (Figure 2-10). The Edwards-Trinity (Plateau), Gulf Coast, and Ogallala aquifers also have significant numbers of wells with high levels of gross alpha radiation. Although

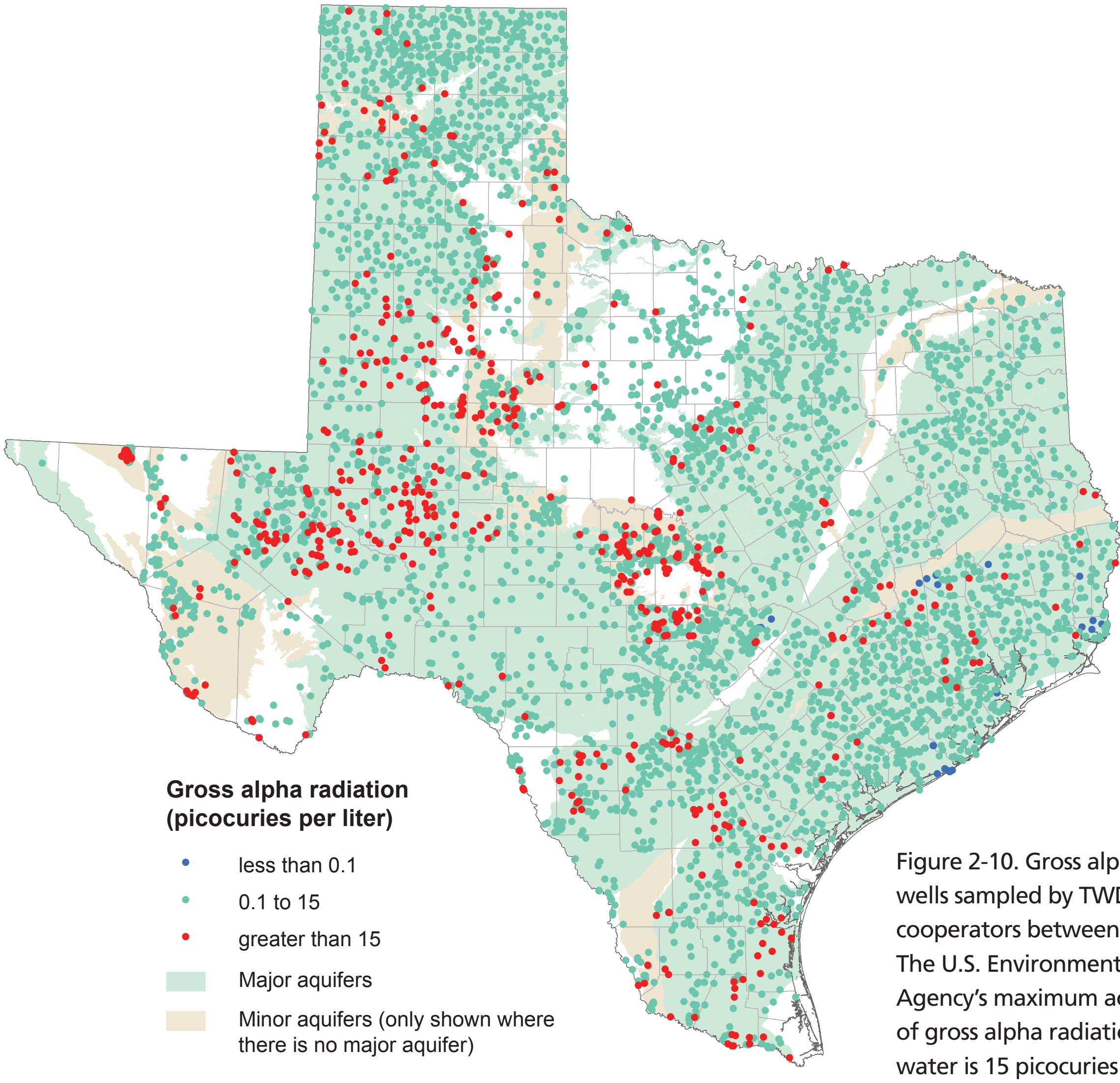


Figure 2-10. Gross alpha radiation in wells sampled by TWDB and other cooperators between 1988 and 2004. The U.S. Environmental Protection Agency's maximum acceptable limit of gross alpha radiation for drinking water is 15 picocuries per liter.

contamination from human activity can be a source of radionuclides, most of the radionuclides in Texas groundwater occur naturally. Where radionuclides are found in drinking water supplies, communities and water providers must treat the groundwater, blend it with another source, or find an alternative source of drinking water.

Although nitrate exists naturally in groundwater, elevated levels generally result from human activities, such as overuse of fertilizer and improper disposal of human and animal wastes. High levels of nitrate in groundwater often coexist with other contaminants: if the source is human and animal wastes, then bacteria, viruses, and protozoa are often present; if the source is fertilizer, then herbicides and pesticides are commonly found. The U.S. Environmental Protection Agency has established a maximum acceptable level of nitrate in drinking water of 10 milligrams of nitrogen per liter and 44.3 milligrams per liter of nitrogen oxide. Groundwater in Texas that exceeds this limit is located mostly in the Ogallala and Seymour aquifers, although parts of the Edwards-Trinity (High Plains), Dockum, and Trinity aquifers also have high levels of nitrate (Figure 2-11). High levels of nitrate in water can cause methemoglobinemia, referred to as "blue baby syndrome," in infants under six months of age.

2.2.3 Supply and Availability

Existing groundwater supply is the amount of groundwater that can be produced with current permits and existing infrastructures on an annual basis. Because permits and existing infrastructure, such as wells and pipelines, limit how much groundwater can be produced, groundwater supply can be—and often is—less than the total amount of groundwater that can be produced from an aquifer.

Regional water planning groups in Texas estimated that existing groundwater supplies would be about 8.5 million acre-feet per year in 2010 and decline 32 percent to about 5.8 million acre-feet per year by 2060 (Figure 2-12). The decline is due primarily to reduced supply from the Ogallala Aquifer as a result of depletion (reduction of about 2.5 million acre-feet per year by 2060), as well as reduced supply from the Gulf Coast Aquifer due to mandatory reductions in pumping to prevent land surface subsidence (reduction of about 160,000 acre-feet per year by 2060). In most cases, groundwater supplies either remain at current amounts or decrease by 2060.

Groundwater availability is the amount of water from an aquifer that is available for use. One might think that the amount of groundwater available for use is all of the water in the aquifer; however, that may not be—and probably is not—the case. Whereas groundwater supplies are limited by permits and existing infrastructure, groundwater availability is limited by law, groundwater management goals and rules, and planning group policy.

Total groundwater availability in 2010, as assessed by the planning groups, is about 12.7 million acre-feet per year (Figure 2-13). Because of projected decreases in availability in the Dockum, Edwards-Trinity (High Plains), Gulf Coast, Ogallala, and Seymour aquifers, this availability decreases to 9.9 million acre-feet per year by 2060.

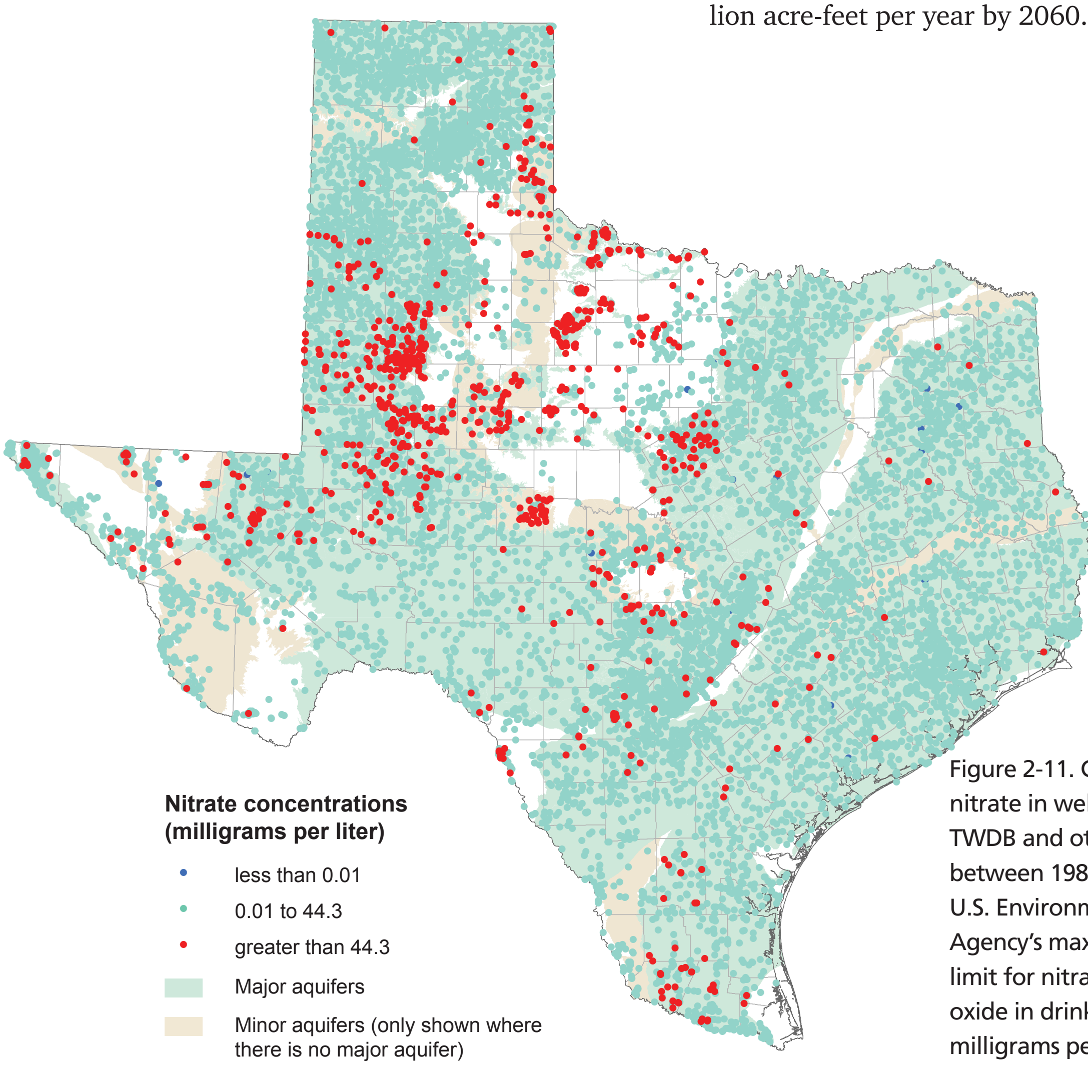


Figure 2-11. Concentration of nitrate in wells sampled by TWDB and other cooperators between 1988 and 2004. The U.S. Environmental Protection Agency's maximum acceptable limit for nitrate as nitrogen oxide in drinking water is 44.3 milligrams per liter.

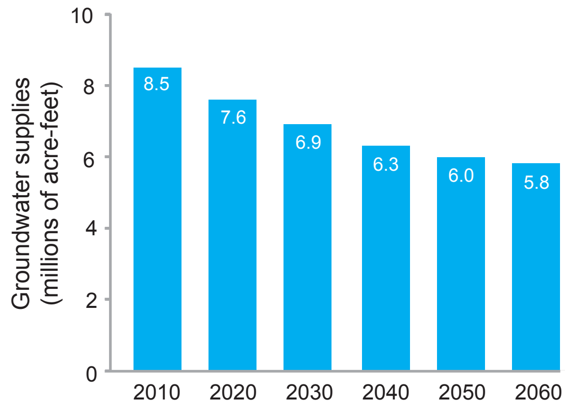


Figure 2-12. Projected existing groundwater supplies through 2060.

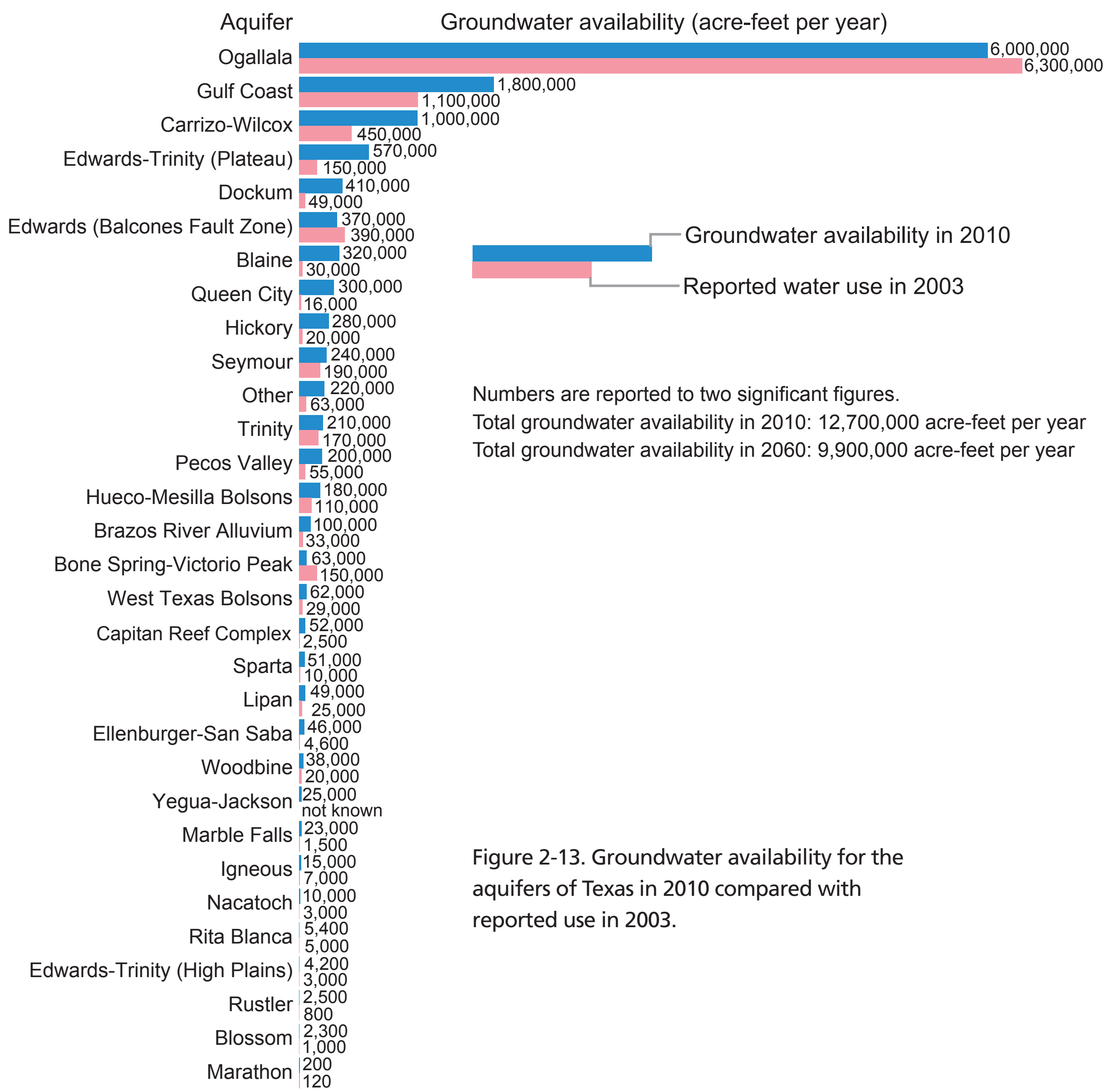


Figure 2-13. Groundwater availability for the aquifers of Texas in 2010 compared with reported use in 2003.

2.3 *Groundwater Management*

In 1949, the legislature passed regulations establishing groundwater conservation districts as political subdivisions of the state (Figure 2-14). The districts originated as a way of establishing local control of groundwater resources, as opposed to state control. Over the past 60 years, a total of 120 districts have sprung up. As of September 2010, Texans have created 96 districts serving around 66 percent of the land area. In areas without groundwater conservation districts, the common law rule of capture prevails, with the exception of any applicable county subdivision or city rules, if they exist. More information on groundwater conservation districts is available on the TWDB Web site.

The common law rule of capture was the basis for groundwater ownership prior to the development of groundwater management by district. The Texas judicial system heard the first groundwater dispute case in 1904, explicitly establishing rule of capture as the basis for groundwater ownership. This rule meant that landowners retain the right to capture and beneficially use groundwater from their property. Furthermore, this decision allows landowners having superior pumping capability to ignore conservation

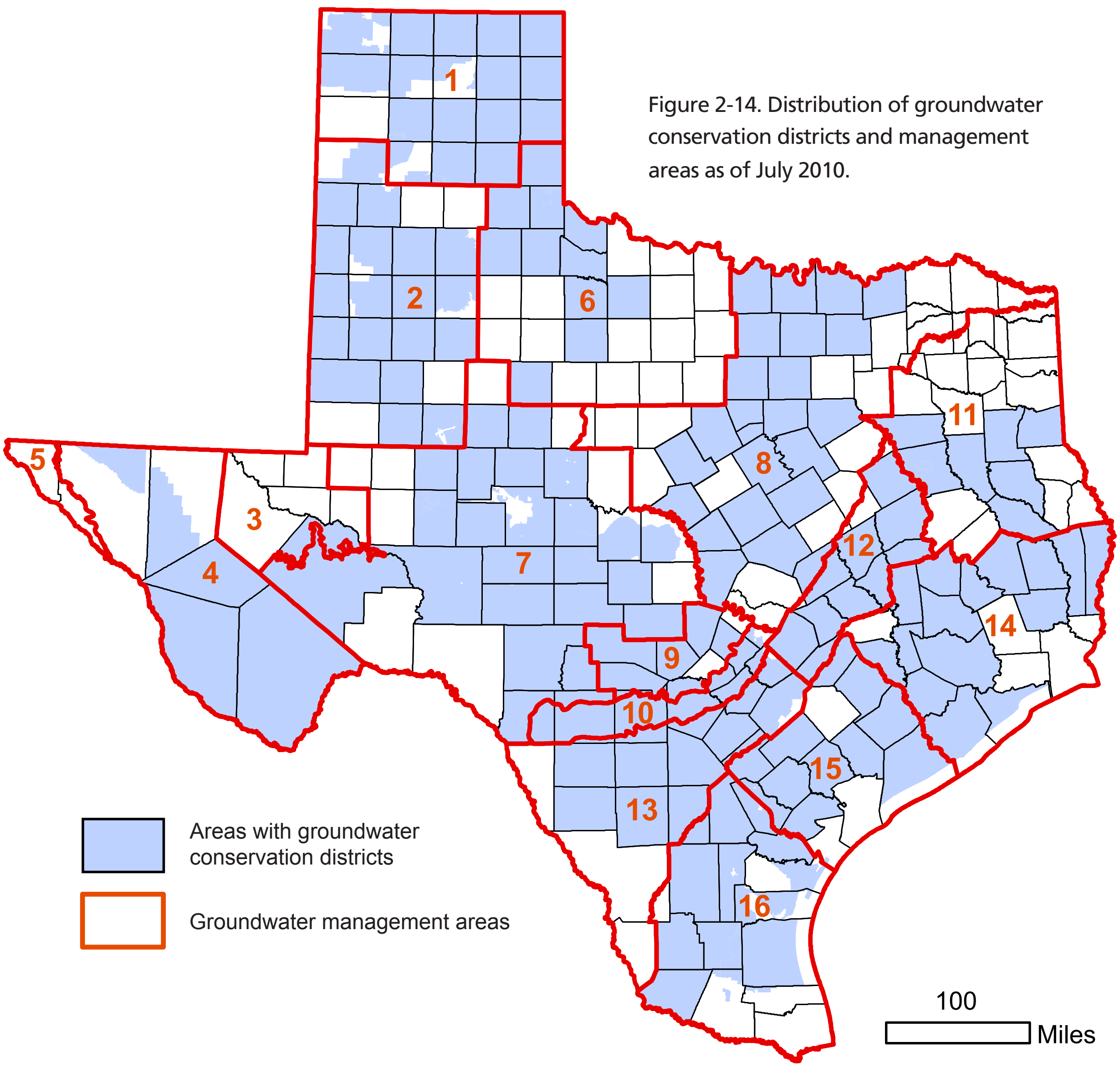


Figure 2-14. Distribution of groundwater conservation districts and management areas as of July 2010.

and to pump and pull groundwater into their well from surrounding properties and extract it without redress. Although the 1917 Texas Constitution addresses the state responsibility for conserving natural resources, it does not address groundwater specifically. Since then, the definition of water conservation has changed—conserving used to mean using water before it ran off property or traveled downstream in rivers to the Gulf of Mexico, quite the opposite of what it means today.

Texas Water Code Chapter 36 delineates the fundamental rules under which each district must operate. Through Chapter 36, groundwater conservation districts modify the rule of capture by respecting private ownership rights but reserve the option to register, permit, and establish production limitations or fees on the exploration and production of groundwater. According to Texas Water Code §36.117, all districts must exempt wells capable of producing up to or equal to 25,000 gallons per day, but they may choose to increase that amount. This exemption is restricted to domestic wells or wells serving as water supply for livestock or poultry on a 10-acre or larger piece of land. Wells permitted by the Railroad Commission of Texas for oil and gas operations are also exempt. Each district's enabling legislation or petition language indicates additional specific guidelines for that particular district to follow. Not all districts issued production permits, but in each district management plan, required by Senate Bill 1 in 1997, districts established the total usable amount of groundwater in the district, or groundwater availability.

In 2005, the legislature modified the process of establishing groundwater availability. Rather than allowing each district to develop an amount for its management plan, the legislature introduced a new collaborative process. Prior to that, in 2002, TWDB established 16 groundwater management areas, on the basis of aquifer and political boundaries, covering the entire state (Figure 2-14). These areas are composed of groundwater conservation districts within these areas, and each district has a vote on the future state of the aquifers in the region. The preferred state of an aquifer over the ensuing 50 years is called the desired future condition. Once a desired future condition is established, it is used to generate a quantity of groundwater that can be permitted—called managed available groundwater—to maintain or reach this adopted condition. Managed available groundwater is an annual rate used for issuing permits and is included in the regional water plans as the groundwater availability. Examples of desired future conditions include average drawdown rates and spring flow rates. At least every five years, or more often if the groundwater conservation districts choose, the districts consider and adopt desired future conditions for the relevant aquifers in their area.

2.4 Basic Groundwater Principles

Geologic *formations* are laterally continuous rock units having distinct lithologic characteristics that allow recognition and mapping from one outcrop or well to another. *Aquifers* are delineated by a formation or group of formations. Aquifers consist of subsurface rock or sediment that is porous and permeable. *Porosity* is the volume of pore space in rock or sediment, usually expressed as a percentage. This pore space can include openings between grains, fractures, and caverns. *Permeability* is a measure of how well a material can transmit water. Materials like gravel transmit water quickly and have high values of permeability. Materials such as shale transmit water poorly and have low permeability values. Permeability is primarily determined by the size of the pore spaces and their degree of interconnection.

Some of the largest aquifers in Texas, including the Ogallala, Gulf Coast, and Carrizo-Wilcox, consist of sedimentary rocks with intergranular porosity and relatively high permeability. Limestone aquifers, such as the Edwards (Balcones Fault Zone) Aquifer, contain water in crevices and caverns caused mainly by dissolution of the limestone by groundwater. The Igneous Aquifer in West Texas is an example of where groundwater flows through cracks, fractures, and joints developed in more competent igneous and volcanic rocks.

In addition to being porous and permeable, an aquifer must be able to store and transmit significant quantities of water. A measure of the ability of an aquifer to transmit water is its *hydraulic conductivity*. Hydraulic conductivity is defined as the volume of water that will move in a porous medium in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. In contrast to permeability, it is a function of the properties of the liquid as well as of the porous medium. A measure of an aquifer's ability to store water is its storativity value. *Storativity* is the volume of groundwater that an aquifer will release (or gain) per unit decline (or rise) in hydraulic head per unit area of aquifer (Figure 2-15). In an unconfined aquifer, the storativity value is equal to the specific yield. The *specific yield* represents the volume of groundwater released by pore-water drainage per unit drop in the water table per unit (horizontal) area of unconfined aquifer.

Unconfined aquifers are sometimes referred to as "water table aquifers." An unconfined aquifer is one in which the water table is at or near atmospheric pressure and is the upper boundary of the aquifer. Because the aquifer is not under pressure, the water level in a well is the same as the water table outside the well (Figure 2-15). Water levels in a well from an unconfined aquifer rise and fall in response to changes in recharge and discharge. When water levels decline, water physically drains from the aquifer from the higher water level to the lower water level. *Recharge* is the amount of water that infiltrates to the water table of an aquifer. This water may come from precipitation, streams, and lakes directly into a formation. Generally, only a small portion of the total precipitation seeps down through the soil 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 recharge 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. *Discharge* is the loss of water from an aquifer by either artificial or natural means. Artificial discharge occurs from flowing and pumped water wells, from drainage ditches, gravel pits, or other excavations that intersect the water table. Natural discharge occurs as springs, evaporation, transpiration, and leakage between formations.

Confined aquifers are sometimes referred

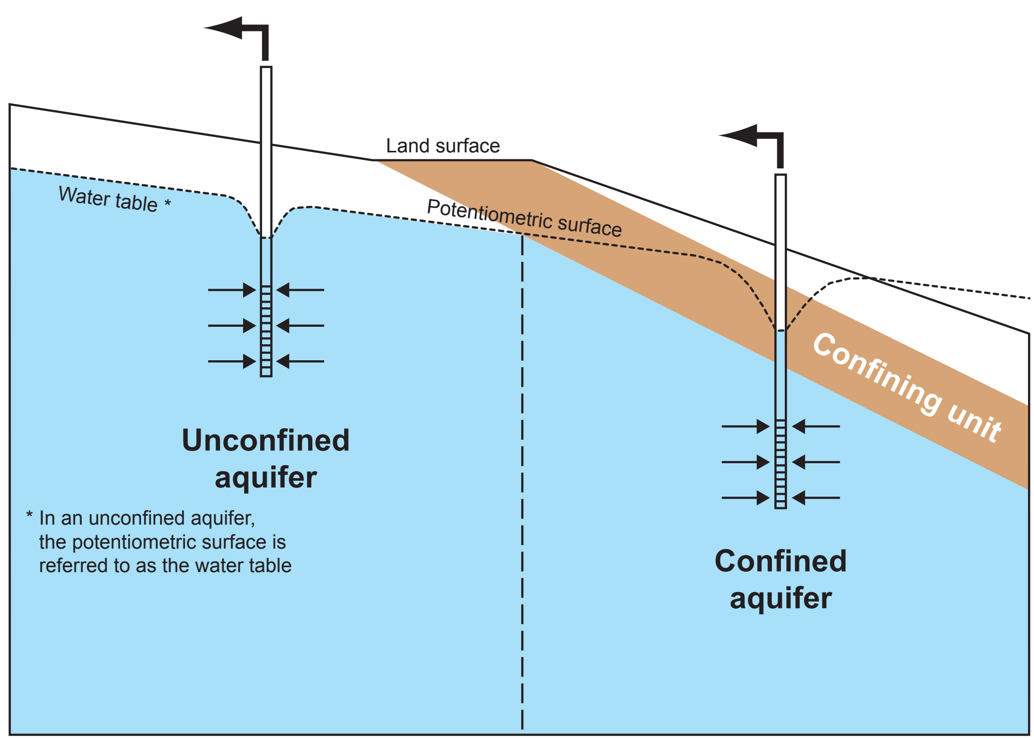


Figure 2-15. Schematic diagram showing unconfined and confined aquifers separated by a confining unit. Note that the dashed line represents the potentiometric surface for the confined aquifer.

to as “artesian aquifers.” These aquifers are overlain by confining units, such as clay and shale layers that do not readily transmit groundwater (Figure 2-15). These aquifers usually occur well below the land surface, are completely saturated with groundwater, and are under pressure. Because of this pressure, water in wells penetrating confined aquifers rises above the top of the aquifer. In some cases, water levels may rise above the land surface, resulting in a flowing well. The level to which water rises in a confined aquifer is the potentiometric surface of the confined aquifer. Pumping of wells reduces the water pressure in the aquifer, resulting in a lowering of the potentiometric surface even though the aquifer continues to be fully saturated.

Groundwater 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 groundwater is usually in the direction of the aquifer’s regional dip. Under water table conditions, the slope of the water table, and consequently the direction of groundwater movement, is 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 areas of groundwater pumping. 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 (Figure 2-15). 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.

The rate of groundwater movement in an aquifer is normally very slow, in the magnitude of a few feet to a few hundred feet per year. The rate of movement in a limestone aquifer, such as the Edwards (Balcones Fault Zone) Aquifer, is relatively greater than that in a sandstone aquifer, such as the Carrizo-Wilcox Aquifer, and can be miles per day.

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3 Aquifer Summaries

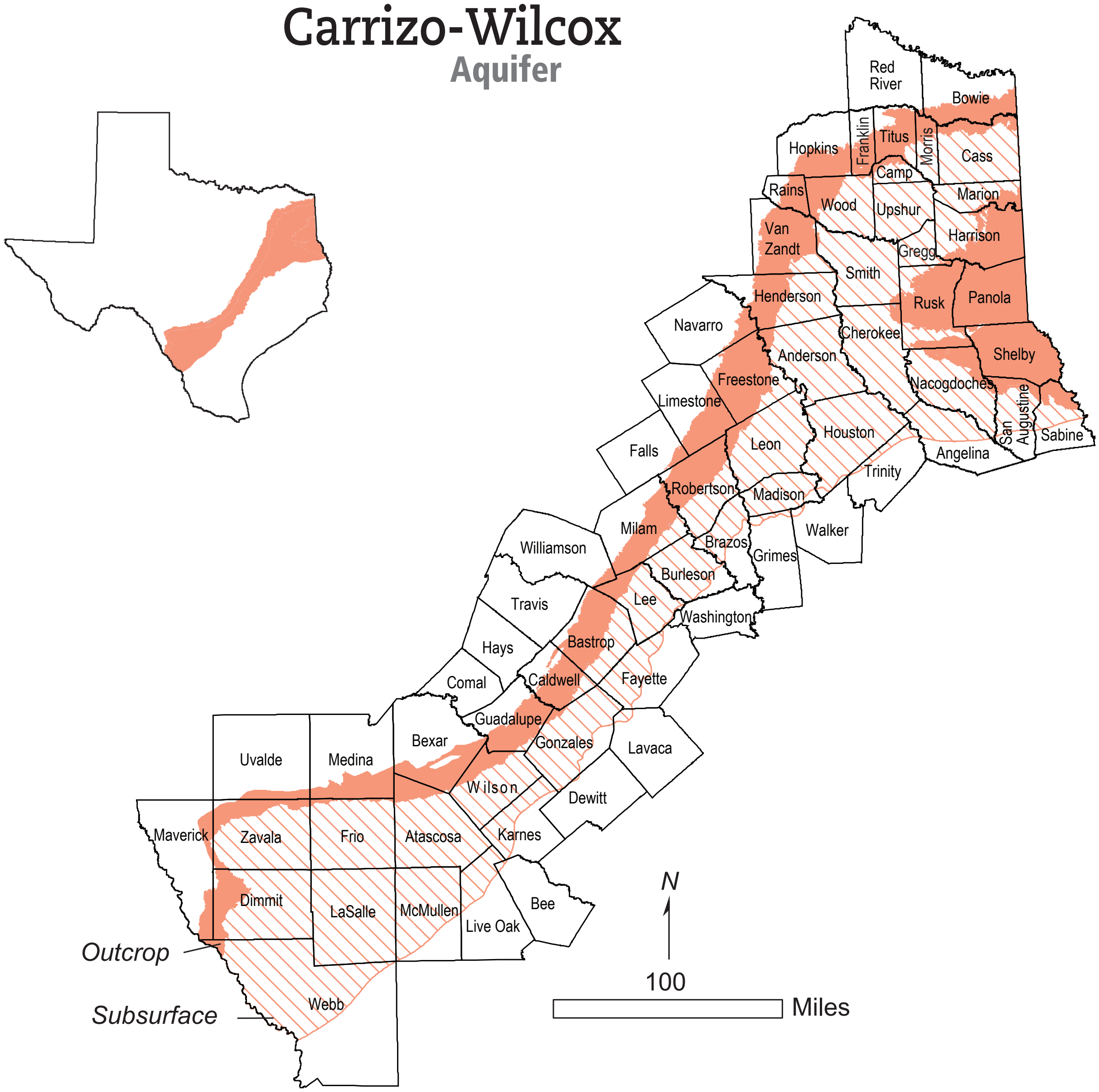
Aquifers summaries are listed in this section alphabetically in major and minor categories, along with additional references. The content for their description comes from TWDB reports and maps, TWDB groundwater availability modeling studies, scientific studies from outside institutions, and data from regional water planning groups in Texas. As TWDB groundwater availability modeling reports and other outside studies are completed or updated, this information will be incorporated into individual aquifer descriptions posted on the agency's Web site.

Photo (next page)

The Fort Terrett Formation of the Edwards-Trinity (Plateau) Aquifer west of Kerrville along Interstate 10. The Fort Terrett Formation is part of the Edwards Group and consists of carbonate rocks deposited in supratidal, intertidal, and subtidal depositional settings. It has a complex diagenetic history that affects groundwater flow.

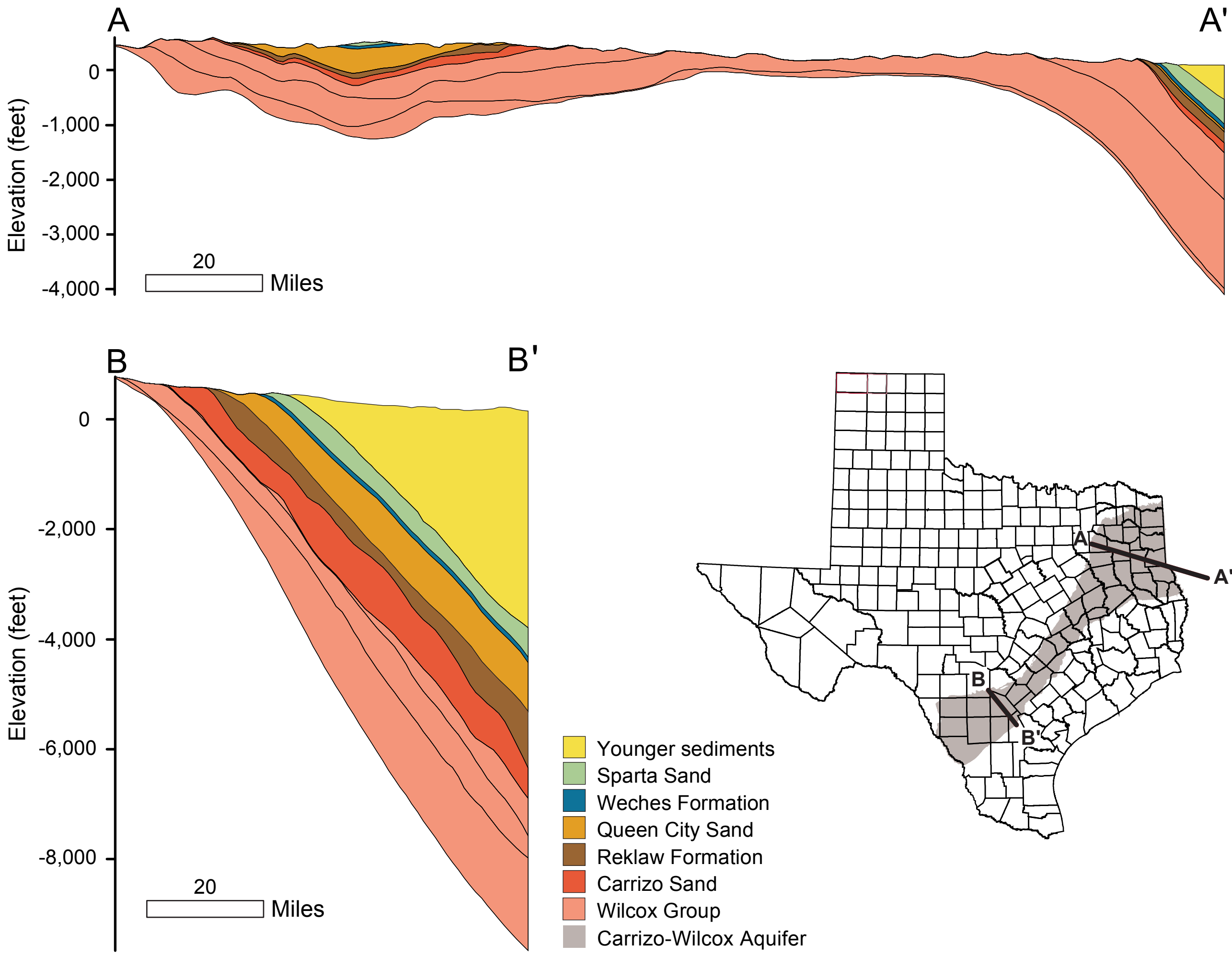
Major Aquifers

Carrizo-Wilcox
Aquifer

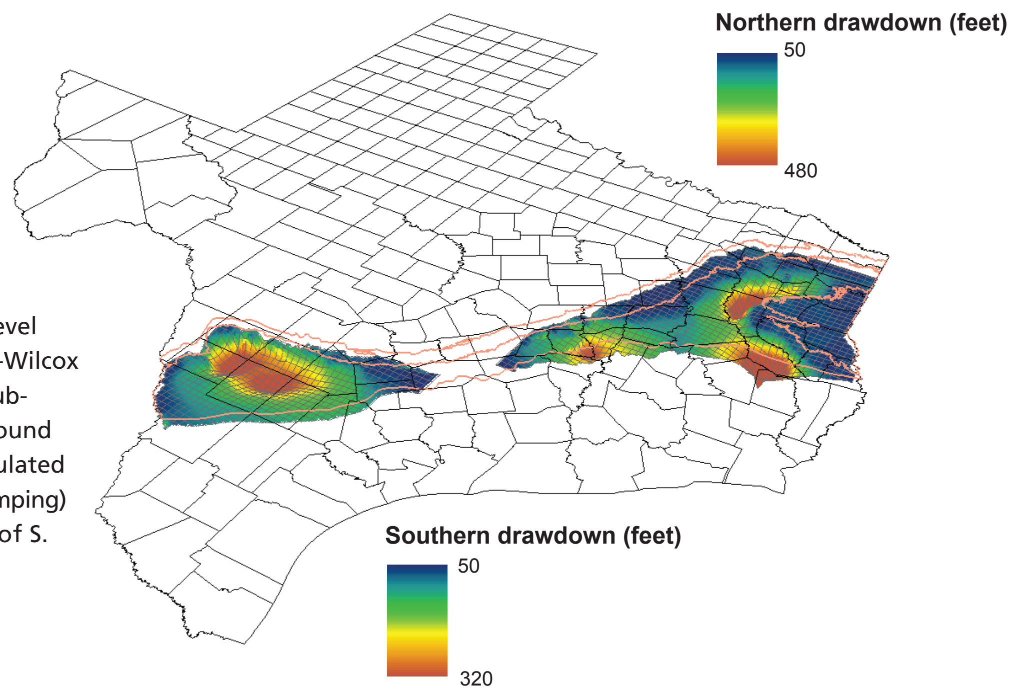


Carrizo-Wilcox Aquifer

The Carrizo-Wilcox Aquifer is a major aquifer extending from the Louisiana border to the border of Mexico in a wide band adjacent to and northwest of the Gulf Coast Aquifer. It consists of the Wilcox Group and the overlying Carrizo Formation of the Claiborne Group. The aquifer is primarily composed of sand locally interbedded with gravel, silt, clay, and lignite. Although the Carrizo-Wilcox Aquifer reaches 3,000 feet in thickness, the freshwater saturated thickness of the sands averages 670 feet. The groundwater, although hard, is generally fresh and typically contains less than 500 milligrams per liter of total dissolved solids in the outcrop, whereas softer groundwater with total dissolved solids of more than 1,000 milligrams per liter occurs in the subsurface. High iron and manganese content in excess of secondary drinking water standards is characteristic of the deeper subsurface portions of the aquifer. Parts of the aquifer in the Winter Garden area are slightly to moderately saline, with total dissolved solids ranging from 1,000 to 7,000 milligrams per liter. Irrigation pumping accounts for slightly more than half the water pumped, and pumping for municipal supply accounts for another 40 percent. Water levels have declined in the Winter Garden area because of irrigation pumping and in the



Structural cross section of the Carrizo-Wilcox Aquifer and overlying strata (modified from Kelly and others, 2004).

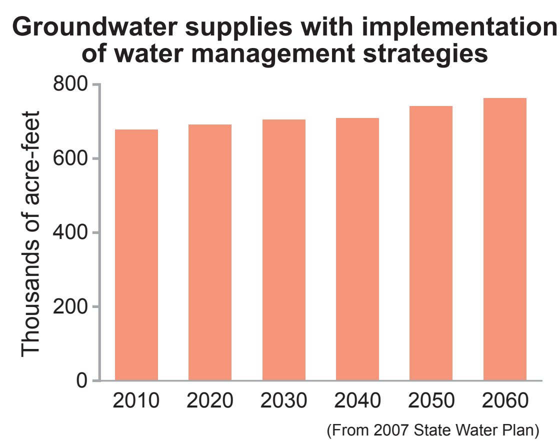


Estimated total water level declines for the Carrizo-Wilcox Aquifer calculated by subtracting water levels around the year 2000 from simulated predevelopment (prepumping) water levels (courtesy of S. Hamlin).

Part of the Rockdale Chamber of Commerce building built from sandstone of the Carrizo Formation.

The Carrizo Formation in Bastrop State Park. Yellow box defines area of top photograph.

northeastern part of the aquifer because of municipal pumping. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Carrizo-Wilcox Aquifer, including developing new wells and well fields, withdrawing additional water from existing wells, desalinating brackish water, using surface water and groundwater conjunctively, reallocating supplies, and transporting water over long distances.



Aquifer characteristics

- Area of outcrop: 11,186 square miles
- Area in subsurface: 25,409 square miles
- Proportion of aquifer with groundwater conservation districts: 63 percent
- Number of counties containing the aquifer: 66

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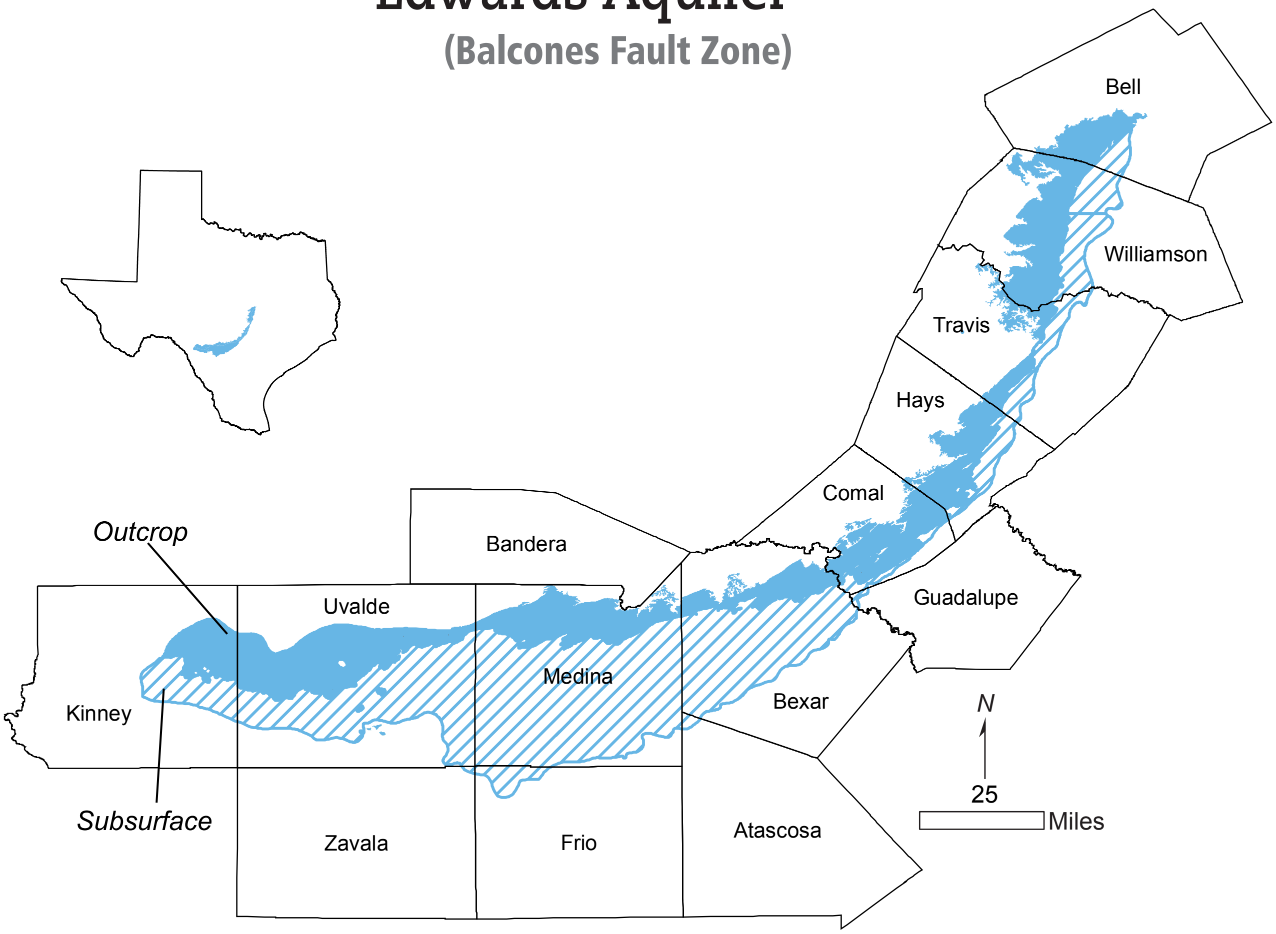
Edwards Aquifer

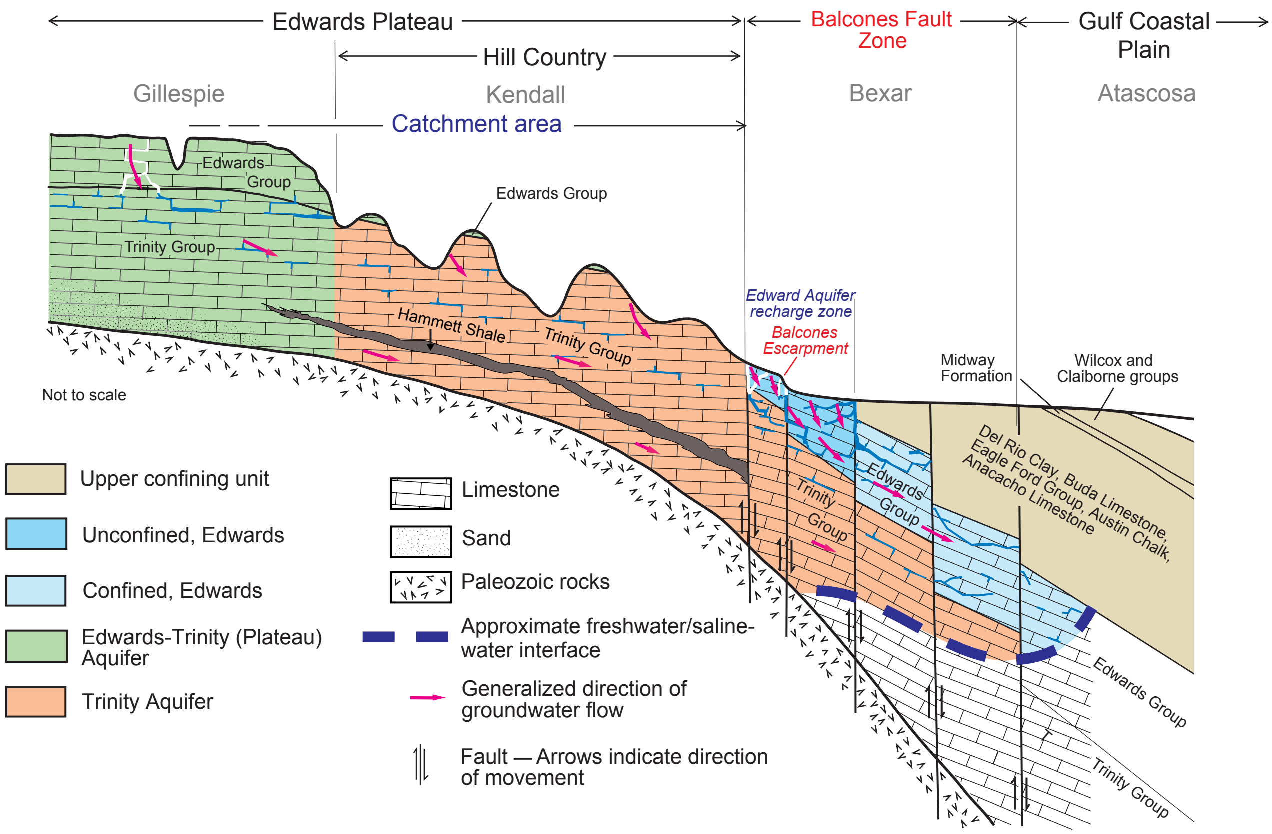
(Balcones Fault Zone)



The Edwards (Balcones Fault Zone) Aquifer is a major aquifer in the south-central part of the state. It consists primarily of partially dissolved limestone that creates a highly permeable aquifer. Aquifer thickness ranges from 200 to 600 feet, and freshwater saturated thickness averages 560 feet in the southern part of the aquifer. The groundwater, although hard, is generally fresh and contains less than 500 milligrams per liter of total dissolved solids. Water from the aquifer is primarily used for municipal, irrigation, and recreational purposes. San Antonio obtains almost all of its water supply from the Edwards (Balcones Fault Zone) Aquifer. The aquifer feeds several well-known springs, including Comal Springs in Comal County, which is the largest spring in the state, and San Marcos Springs in Hays County, which is the second largest. Hueco, San Pedro, San Antonio, and Leona springs also discharge from the aquifer. Because of the aquifer's highly permeable nature, water levels and spring flows respond quickly to rainfall, drought, and pumping. Although water levels periodically and seasonally decline rapidly in wells throughout the aquifer, they also rebound quickly with adequate rainfall. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Edwards (Balcones Fault Zone) Aquifer, including drilling new wells, constructing small dams along streambeds to enhance recharge to the aquifer, and reallocating supplies from irrigation to municipal users. They also recommended expanding an existing aquifer storage and recovery facility that stores water from the Edwards (Balcones Fault Zone) Aquifer in the Carrizo-Wilcox Aquifer in southern Bexar County.

The historical average (1928–2002) discharge at Comal Springs is approximately 287 cubic feet per second, which is more than 128,000 gallons of water every minute (all photos of this aquifer are courtesy of the Edwards Aquifer Authority).

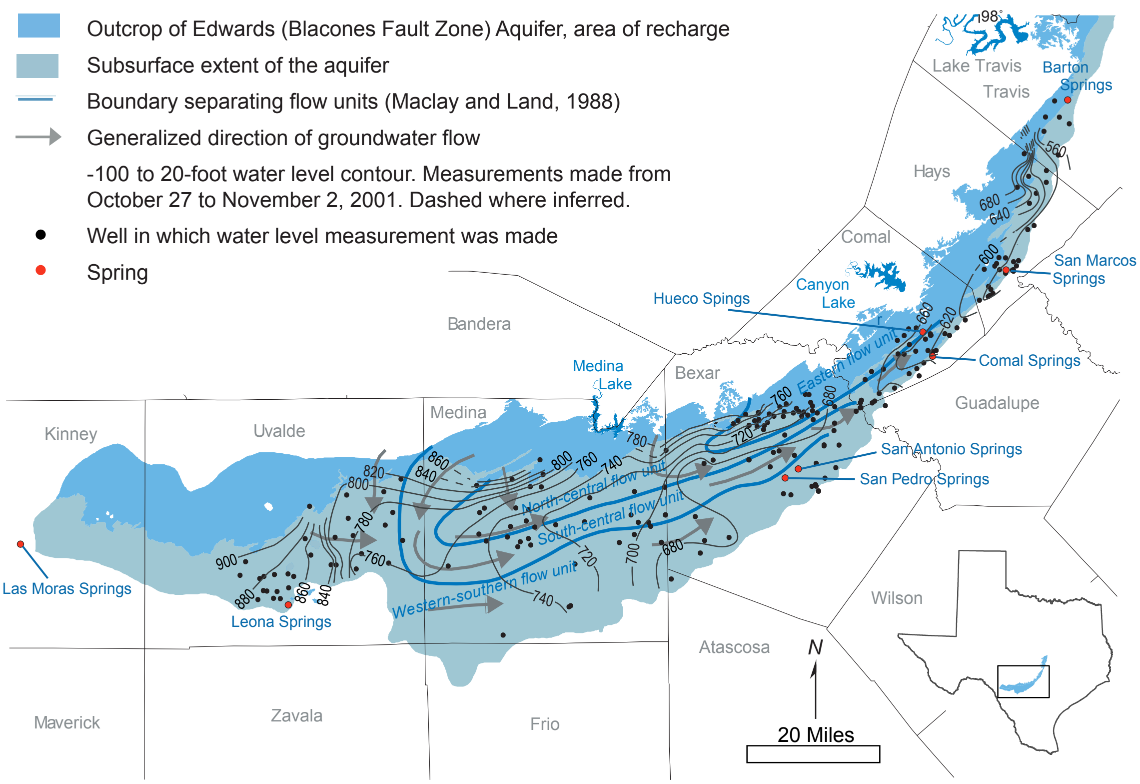
The Edwards (Balcones Fault Zone) Aquifer is contained within the Cretaceous-age Edwards Group limestone (Edwards Limestone) and associated units.



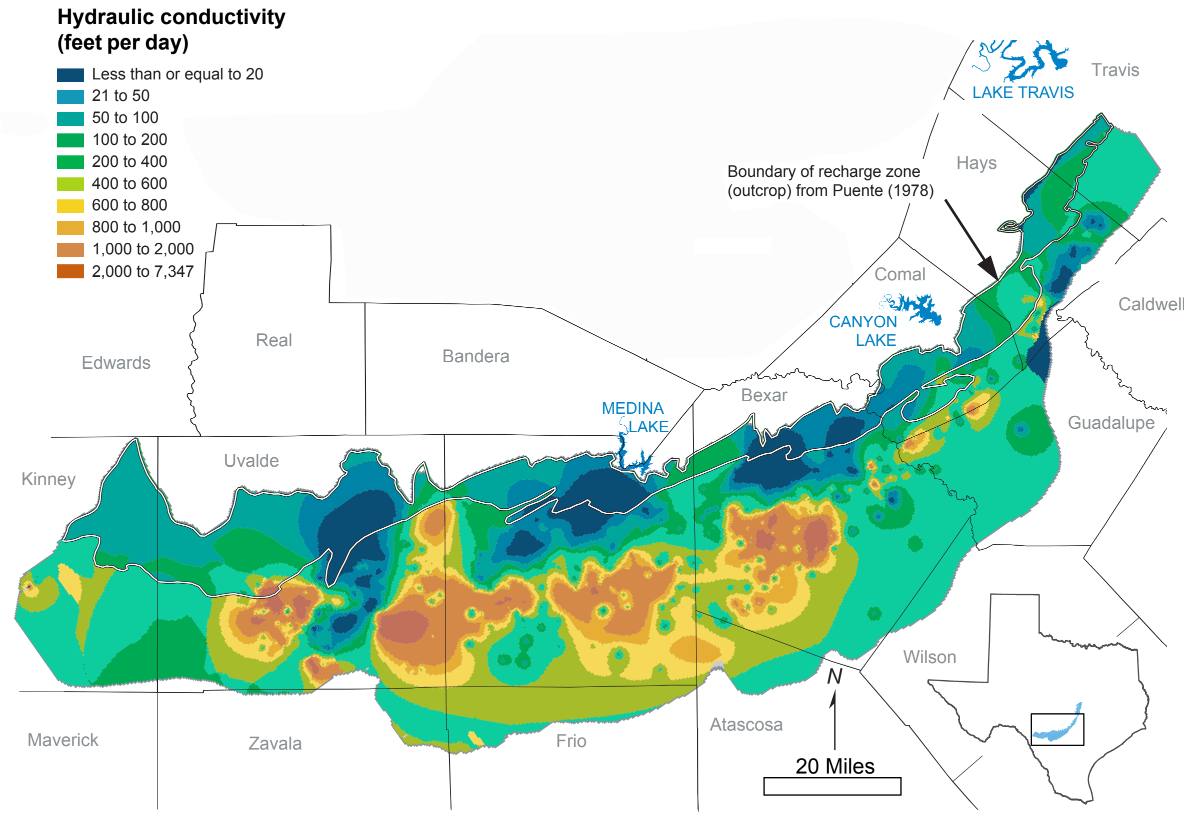
Diagrammatic cross section showing hydrogeologic framework and generalized groundwater flow through the Edwards (Balcones Fault Zone) Aquifer, San Antonio region, Texas (modified from Barker and Ardis, 1996; Lindgren and others, 2004).

Groundwater occurs in both the matrix and the small conduits that have dissolved from the rock (both shown here).

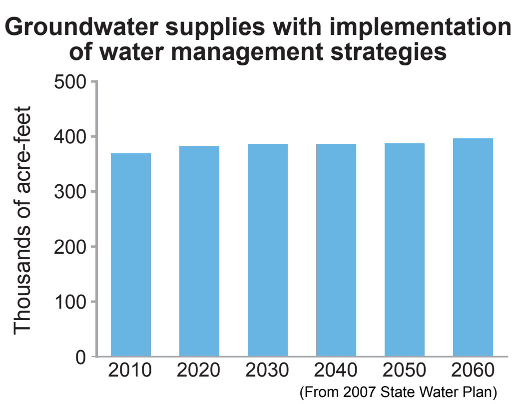
Streambeds such as this, with numerous fractures and faults on the surface, are common throughout the recharge zone.



Potentiometric surface and inferred groundwater flow in the Edwards (Balcones Fault Zone) Aquifer, San Antonio region, Texas (modified from Lindgren and others, 2004).



Distribution of horizontal hydraulic conductivity for the Edwards (Balcones Fault Zone) Aquifer, San Antonio region, Texas (modified from Painter and others, 2002; Lindgren and others, 2004).



Aquifer characteristics

- Area of outcrop: 1,560 square miles
- Area in subsurface: 2,314 square miles
- Proportion of aquifer with groundwater districts: 90 percent
- Number of counties containing the aquifer: 13

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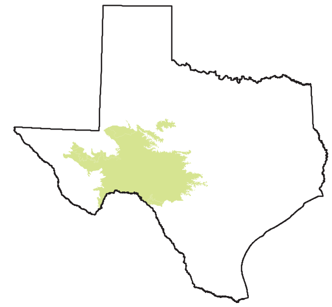
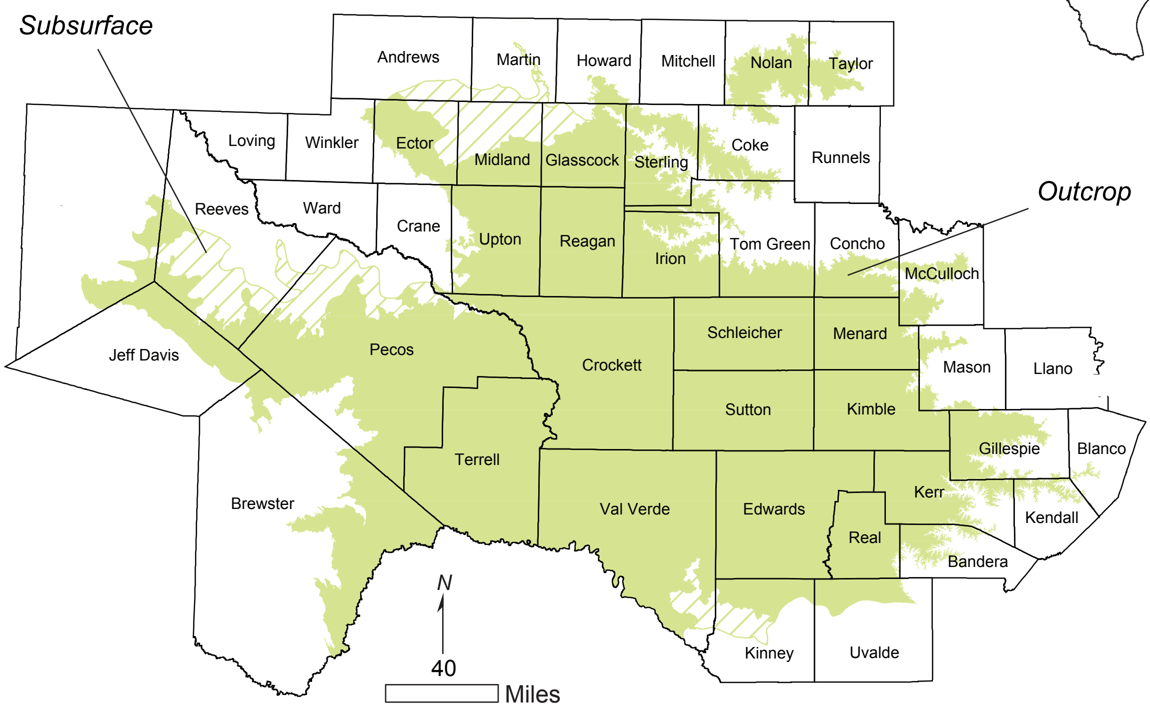
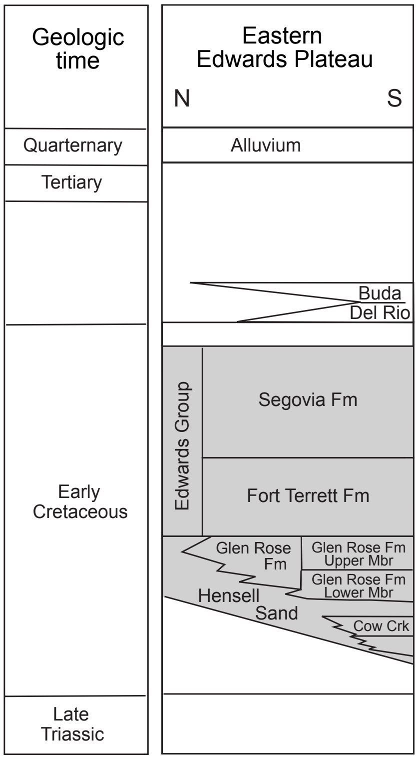
Edwards-Trinity (Plateau)
Aquifer



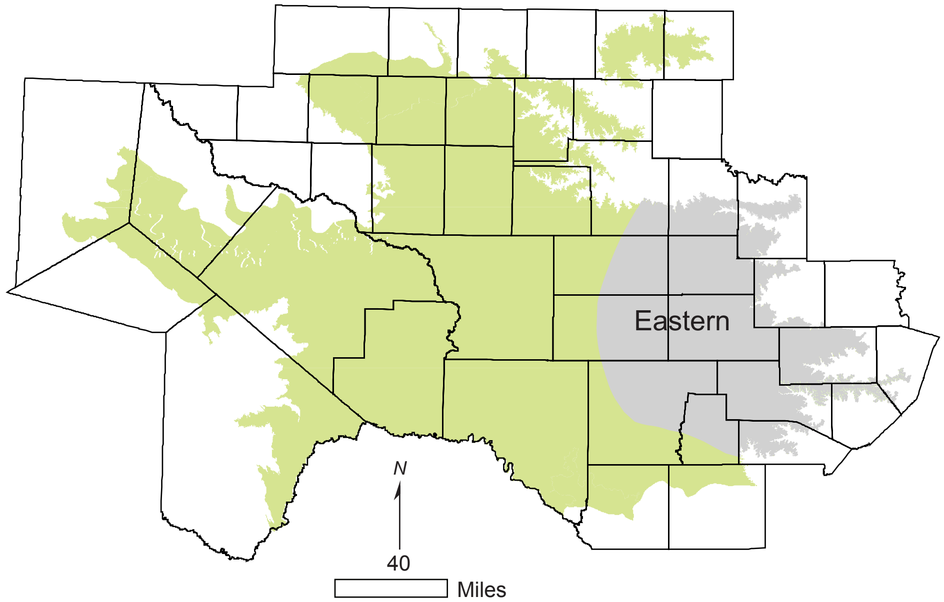


The Edwards-Trinity (Plateau) Aquifer is a major aquifer extending across much of the southwestern part of the state. The water-bearing units are composed predominantly of limestone and dolomite of the Edwards Group and sands of the Trinity Group. Although maximum saturated thickness of the aquifer is 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.

Stratigraphic chart of the eastern Edwards Plateau region



Crk=Creek, Fm=Formation; Mbr=Member



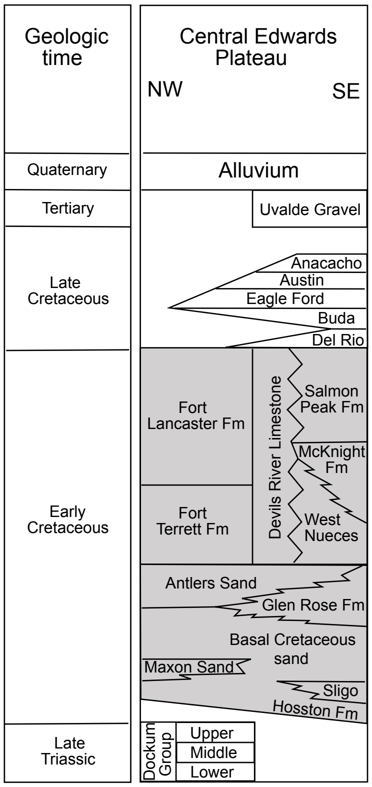
Segovia Formation near Junction, Texas.

Cow Creek Limestone at Hamilton Pool.

Fort Terrett Formation near Kerrville, Texas.

Upper Glen Rose Formation below Devils River Formation (darker gray unit) near Leakey, Texas.

Stratigraphic chart of the central Edwards Plateau region



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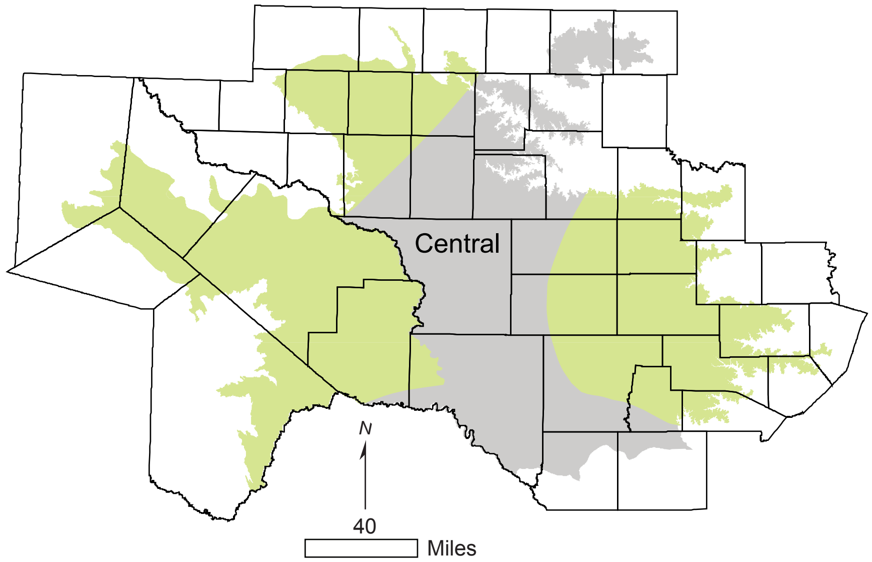
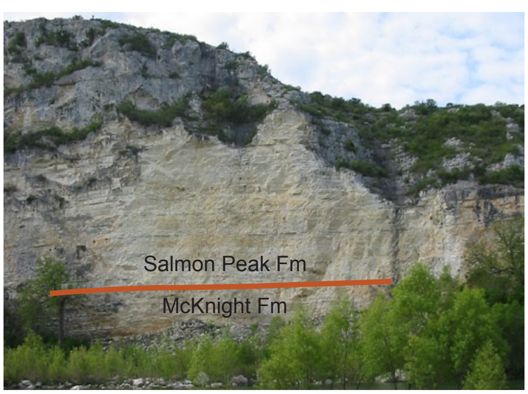
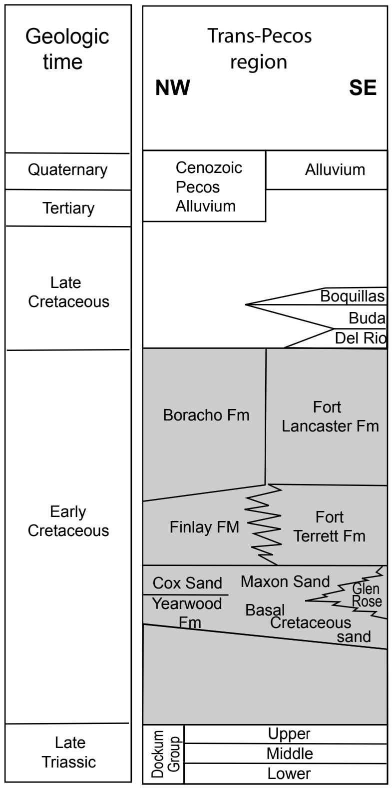




The McKnight and Salmon Peak formations along the West Nueces River in Kinney County, Texas (courtesy of R. Anaya, TWDB).

Looking north at the Pecos River Bridge and the Devils River Limestone along U.S. Highway 90.

Stratigraphic chart of the Trans-Pecos Edwards Plateau region.



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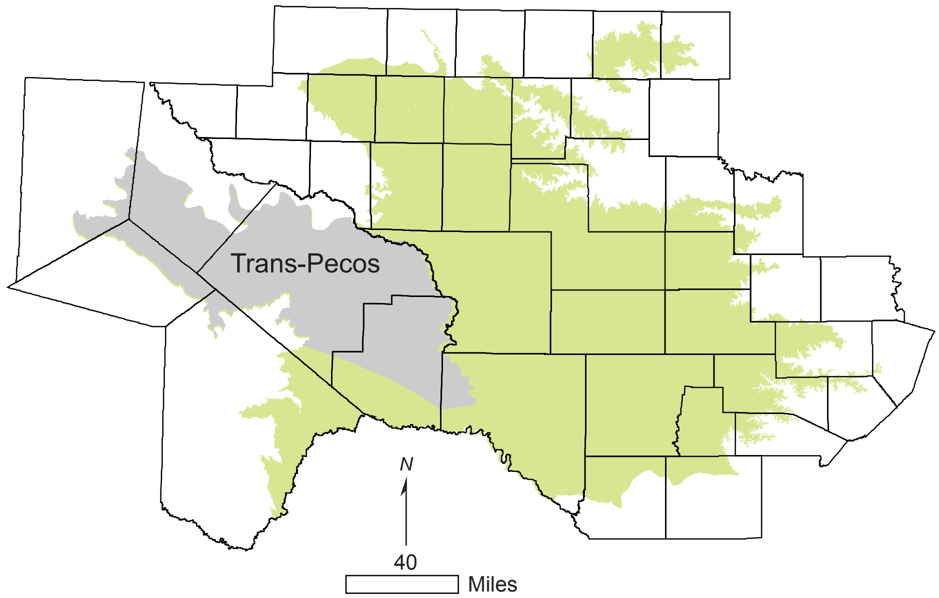
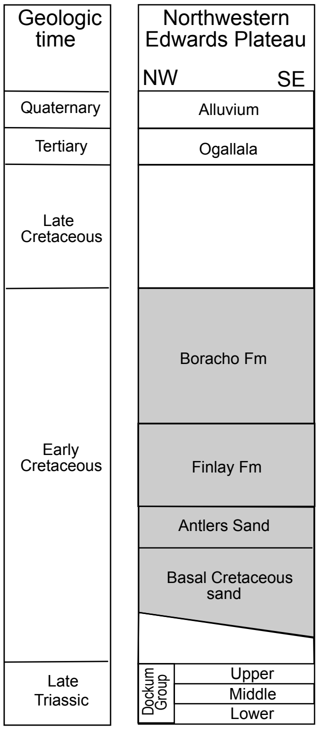


Early Cretaceous limestone and dolomite of the Fredericksburg Group (equivalent to the Fort Terrett Formation) along IH-35 between Bakersfield and Fort Stockton, Texas.

Fredericksburg Group rocks of the Edwards-Trinity (Plateau) Aquifer.

Stratigraphic chart of the northwestern Edwards Plateau region.



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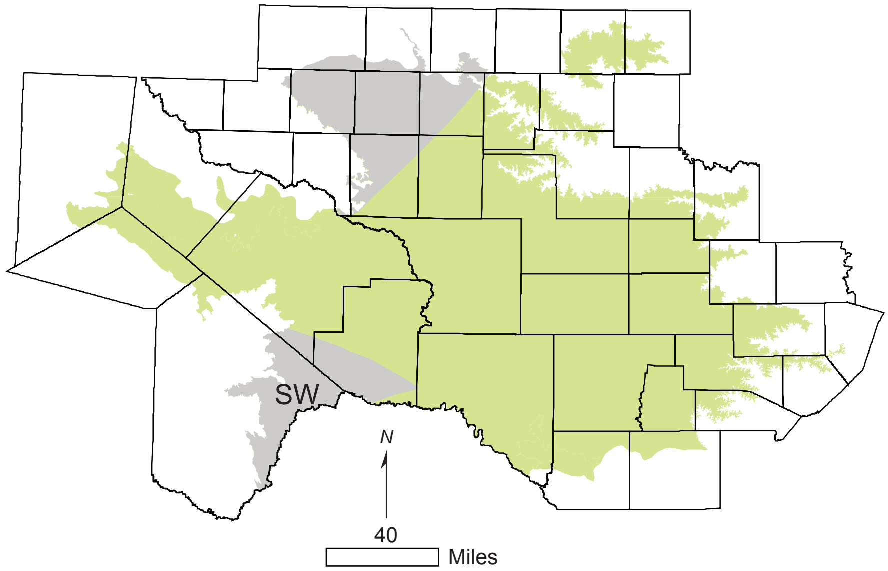
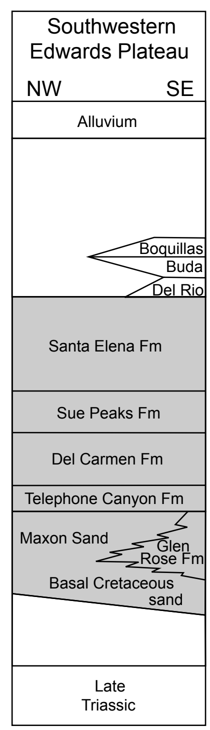


Looking southwest toward Santa Elena Canyon in Big Bend National Park (courtesy of Marius Jigmond, TWDB). Cretaceous rocks from the Glen Rose Formation to the Santa Elena Formation are well exposed along cliff walls.

Stratigraphic chart of the southwestern Edwards Plateau region.



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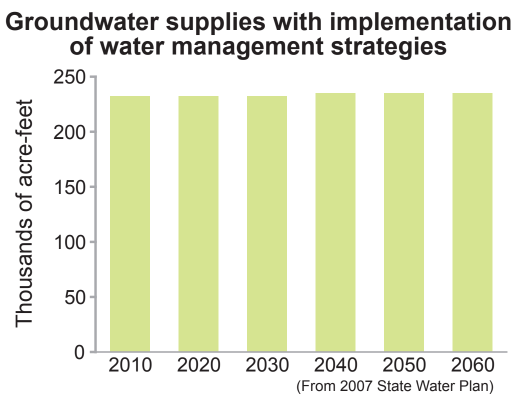
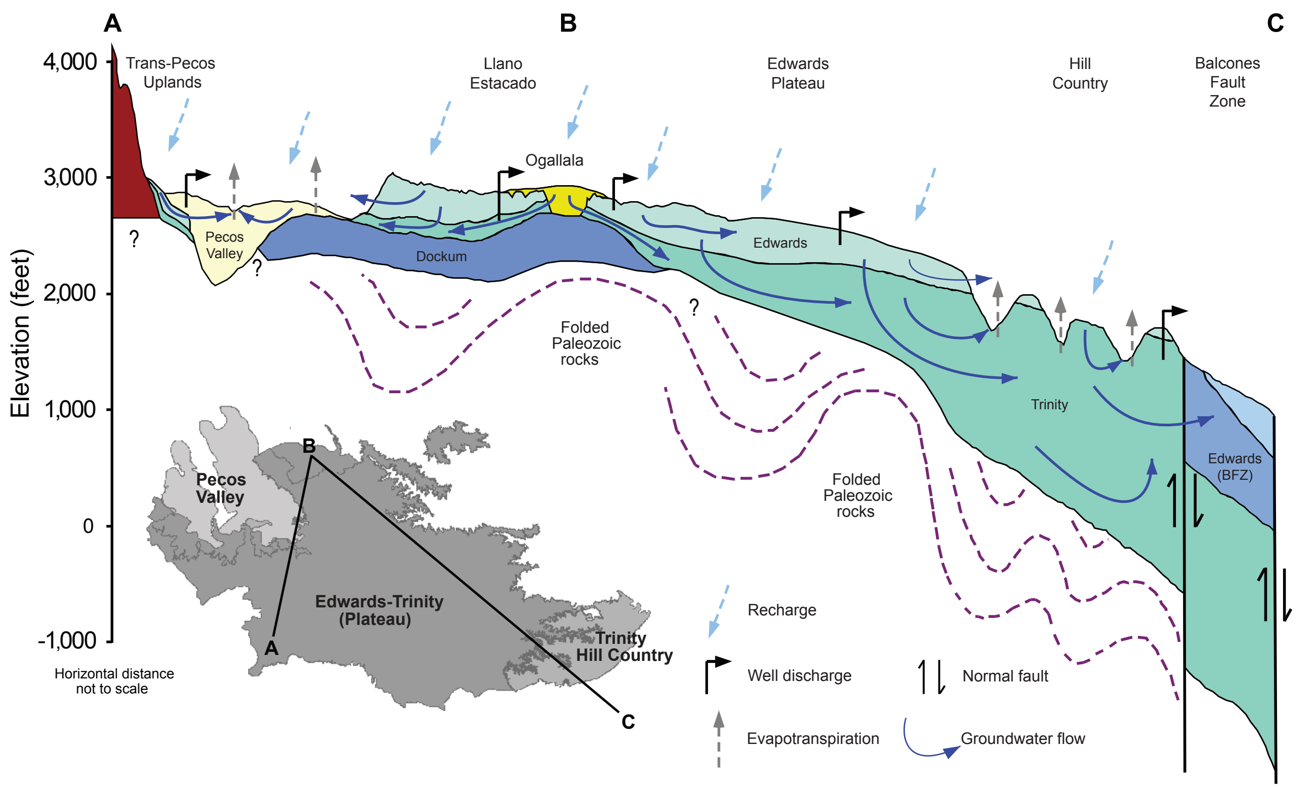


Aquifer characteristics

- Area of outcrop: 32,294 square miles
- Area in subsurface: 2,988 square miles
- Proportion of aquifer with with groundwater conservation districts: 71 percent
- Number of counties containing the aquifer: 40

Conceptual model of the Edwards-Trinity (Plateau) and Pecos Valley aquifers and Hill Country part of the Trinity Aquifer (modified from Anaya and Jones, 2004, 2009).
BFZ = Balcones Fault Zone



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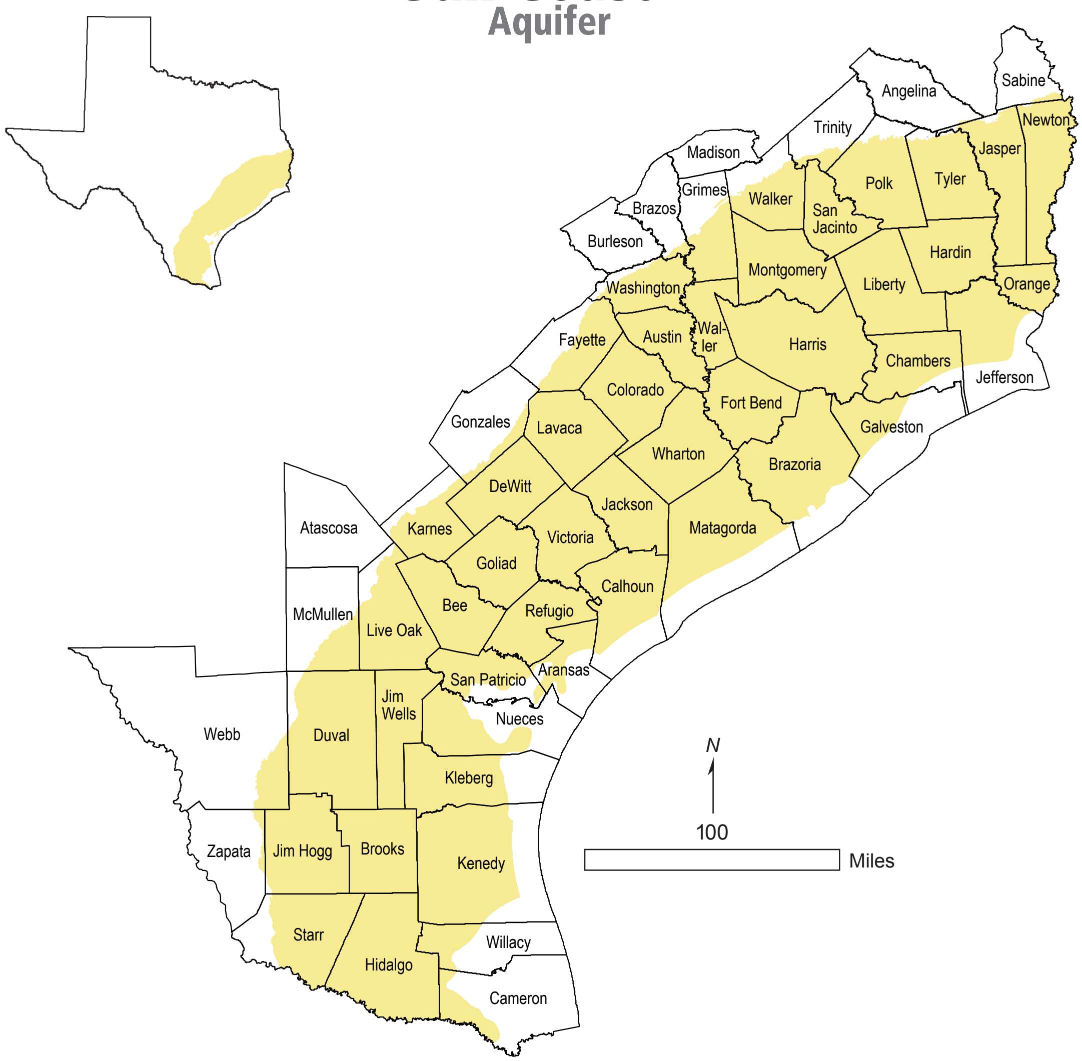
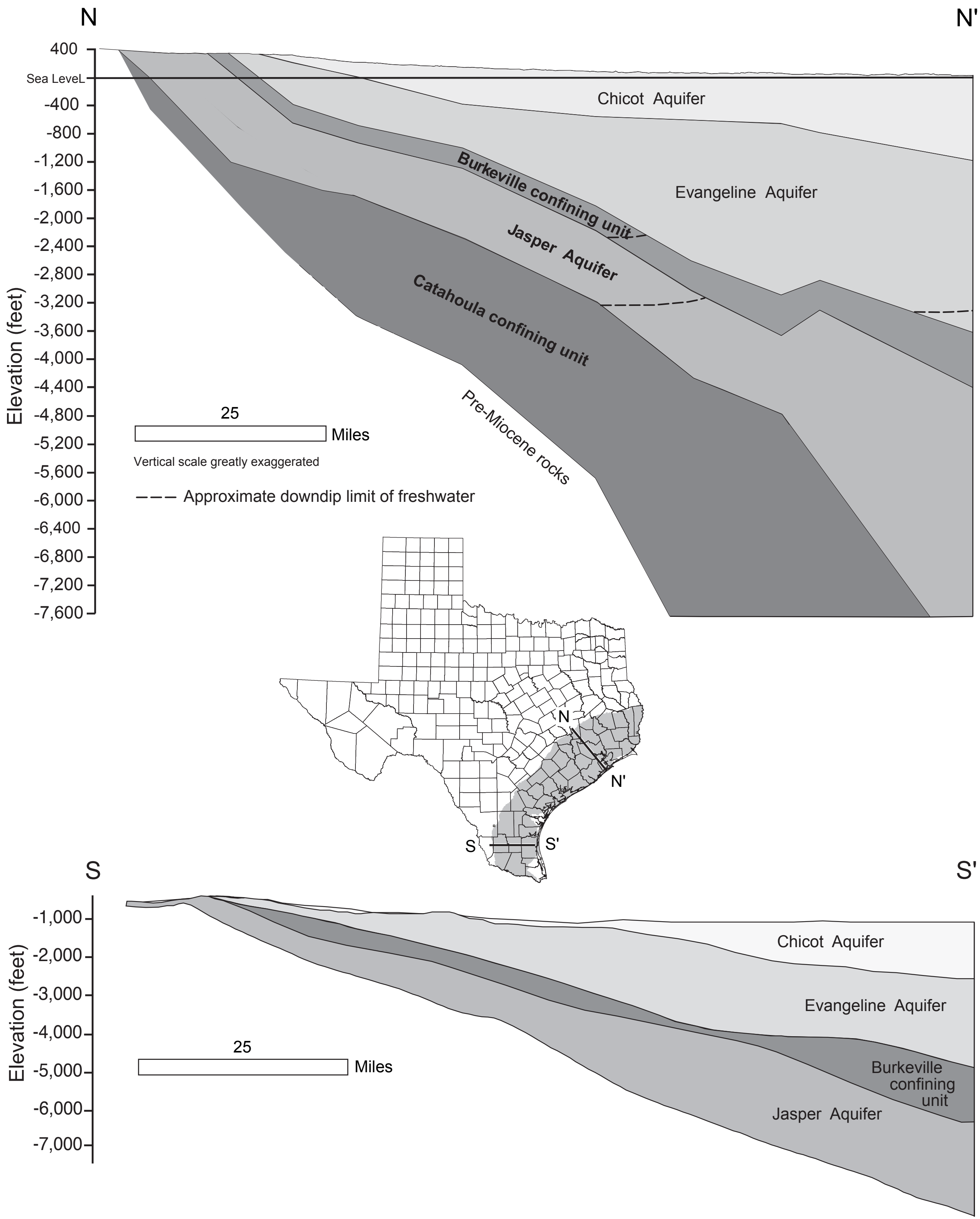
Gulf Coast
Aquifer



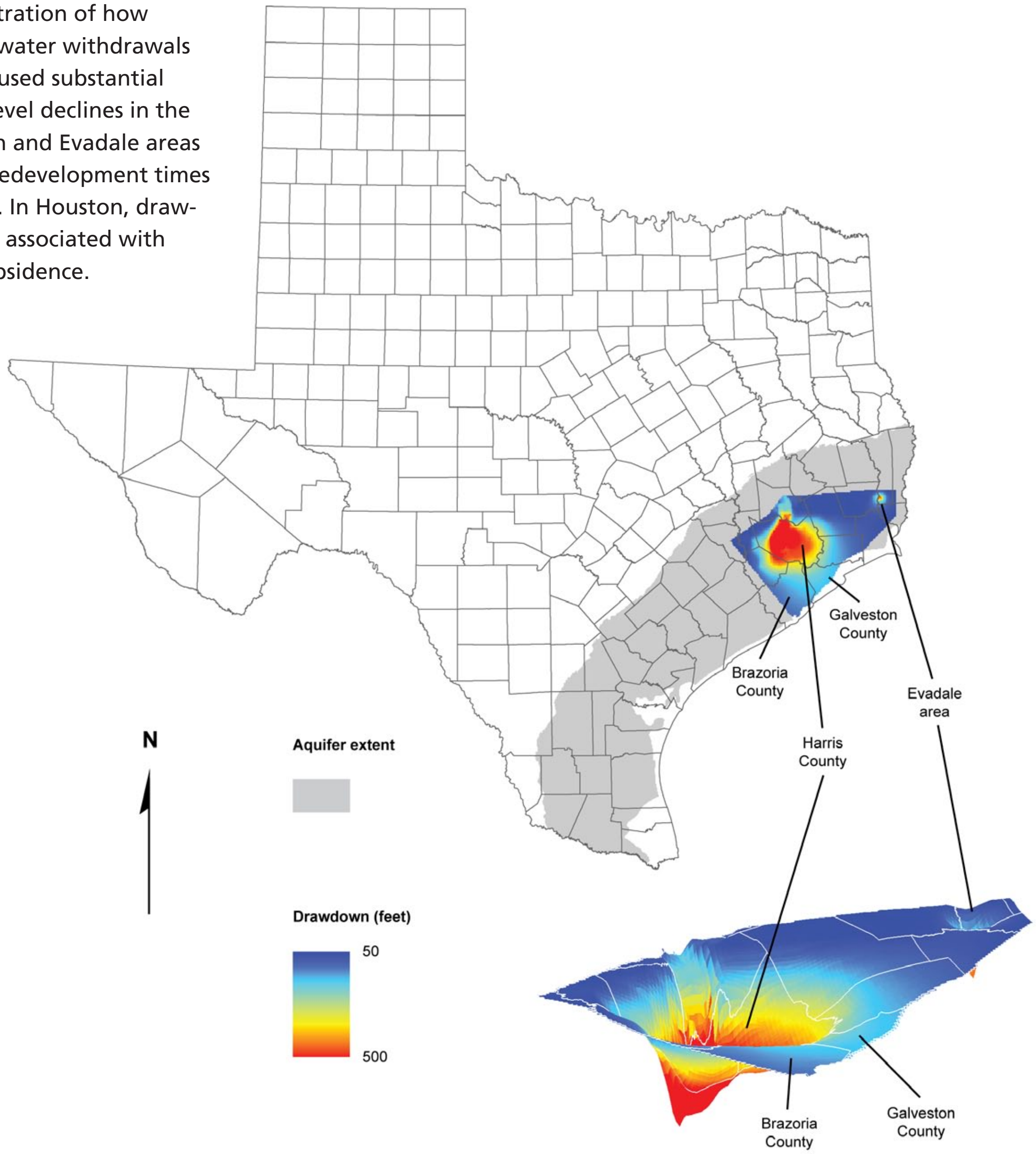
The Gulf Coast Aquifer

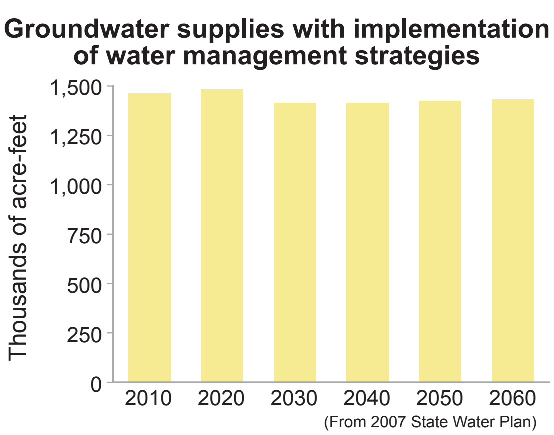
is a major aquifer paralleling the Gulf of Mexico coastline from the Louisiana border to the border of Mexico. It consists of several aquifers, including the Jasper, Evangeline, and Chicot aquifers, which are composed of discontinuous sand, silt, clay, and gravel beds. The maximum total sand thickness of the Gulf Coast Aquifer ranges from 700 feet in the south to 1,300 feet in the north. Freshwater saturated thickness averages about 1,000 feet. Water quality varies with depth and locality: it is generally good in the central and northeastern parts of the aquifer, where the water contains less than 500 milligrams per liter of total dissolved solids, but declines to the south, where it typically contains 1,000 to more than 10,000 milligrams per liter of total dissolved solids and where the productivity of the aquifer decreases. High levels of radionuclides, thought mainly to be naturally occurring, are found in some wells in Harris County in the outcrop and in South Texas. The aquifer is used for municipal, industrial, and irrigation purposes. In Harris, Galveston, Fort Bend, Jasper, and Wharton counties, water level declines of as much as 350 feet have led to land subsidence. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Gulf Coast Aquifer, including drilling more wells, pumping more water from existing wells, temporary overdrafting, constructing new or expanded treatment plants, desalinating brackish groundwater, developing conjunctive use projects, and reallocating supplies.



Cross sections across the Gulf Coast Aquifer (modified from Baker, 1979, 1986; Chowdhury and Mace, 2003; Kasmarek and Robinson, 2004).

An illustration of how groundwater withdrawals have caused substantial water level declines in the Houston and Evadale areas from predevelopment times to 2000. In Houston, drawdown is associated with land subsidence.





Aquifer characteristics

- Area of aquifer: 41,879 square miles
- Proportion of aquifer with groundwater conservation districts: 73 percent
- Number of counties containing the aquifer: 54

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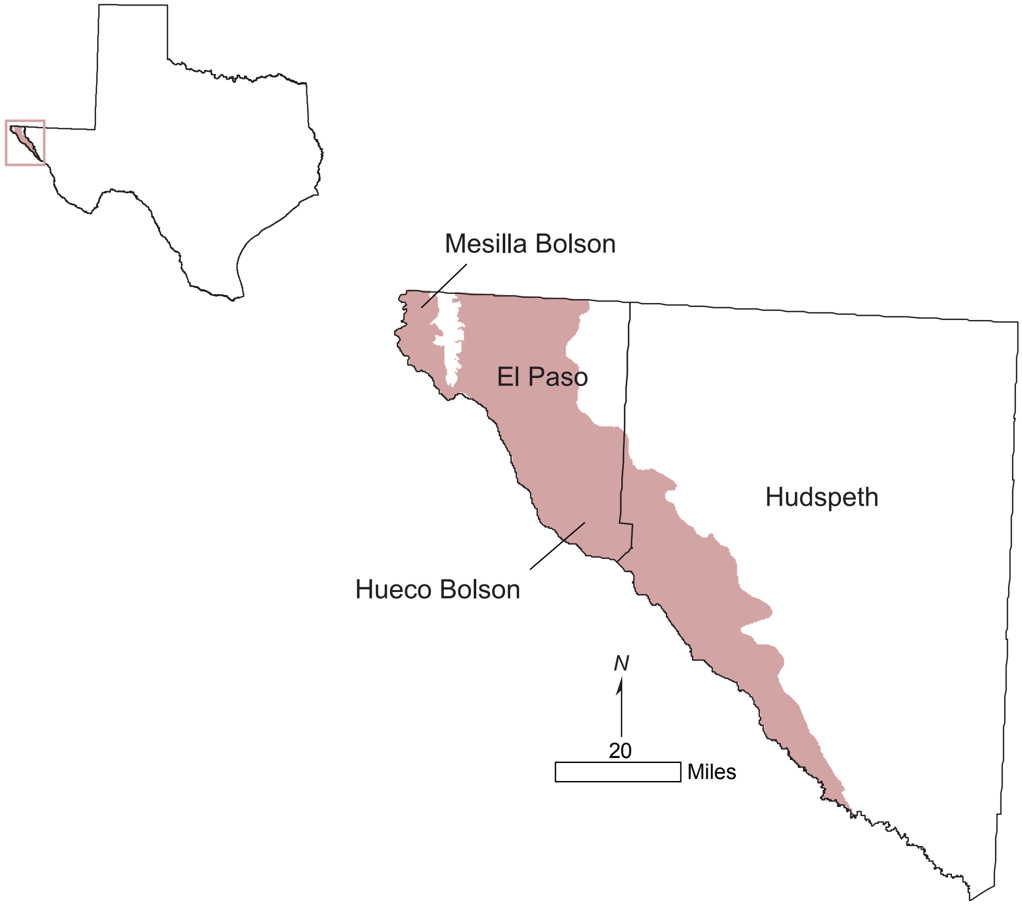
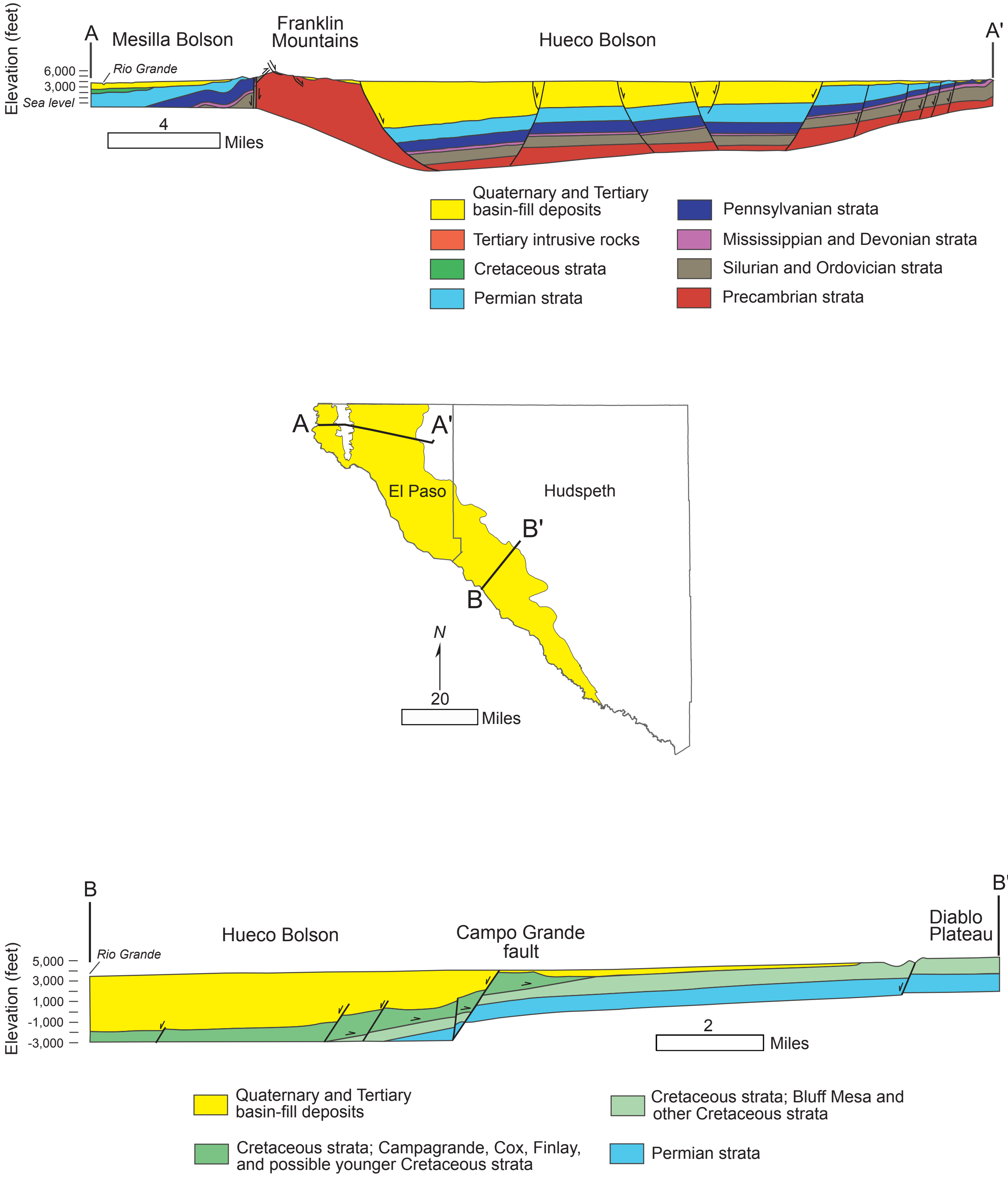
Hueco-Mesilla Bolsons

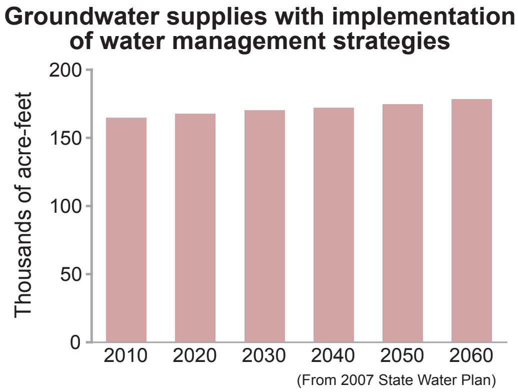
Aquifer



The Hueco-Mesilla Bolsons Aquifer, located east and west of the Franklin Mountains in Far West Texas, is recognized as a major aquifer in Texas. The aquifer is composed of basin-fill deposits of silt, sand, gravel, and clay in two basins, or bolsons: the Hueco Bolson, which has a maximum thickness of 9,000 feet, and the Mesilla Bolson, which has a maximum thickness of 2,000 feet. Although the Hueco and Mesilla bolsons share similar geology, very little water travels between them. The upper portion of the Hueco Bolson contains fresh to slightly saline water, ranging from less than 1,000 to 3,000 milligrams per liter of total dissolved solids. The Mesilla Bolson also contains fresh to saline water, ranging from less than 1,000 to 10,000 or more milligrams per liter of total dissolved solids. Its salinity typically increases to the south and in the shallower parts of the aquifer. In both aquifers, water level declines have contributed to higher salinity. The Hueco Bolson is the principal aquifer for the El Paso area and Ciudad Juarez in Mexico—nearly 90 percent of the water pumped from the Mesilla and the Hueco bolsons in Texas is used for public supply. Water levels have declined several hundred feet primarily owing to municipal pumping in the Hueco Bolson up to the late 1980s. Since that time, however, observation wells indicate that water levels have stabilized. The Region E Planning Group recommended the conjunctive use of water from the Rio Grande with groundwater from the Hueco-Mesilla Bolsons Aquifer as a water management strategy. In addition, El Paso and Fort Bliss have built the world's largest inland desalination plant in El Paso County. This plant uses brackish groundwater from the Hueco Bolson as its source water.



Cross sections across the Hueco-Mesilla Bolsons Aquifer (modified from Collins and Raney, 2000, 2002).



Aquifer characteristics

- Area of aquifer: 1,370 square miles
- Proportion of aquifer with ground water conservation districts: 0 percent
- Number of counties containing the aquifer: 2

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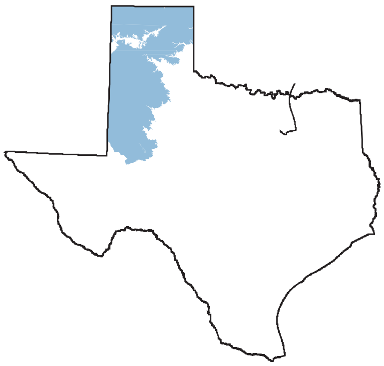
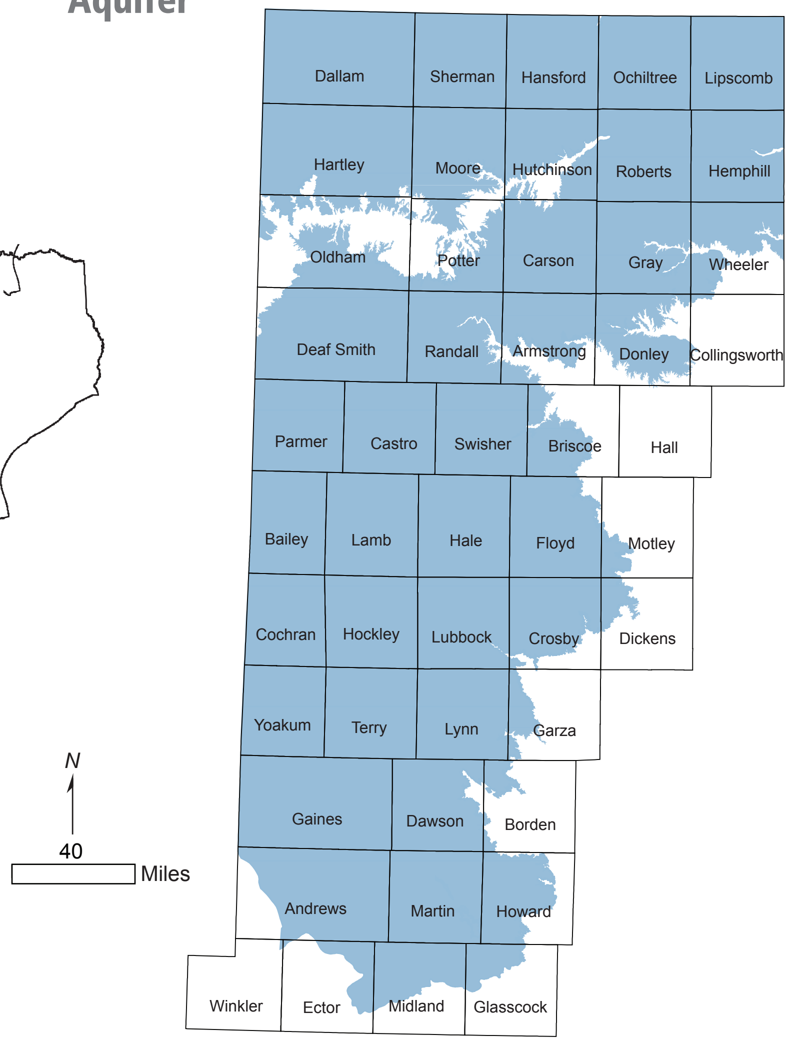
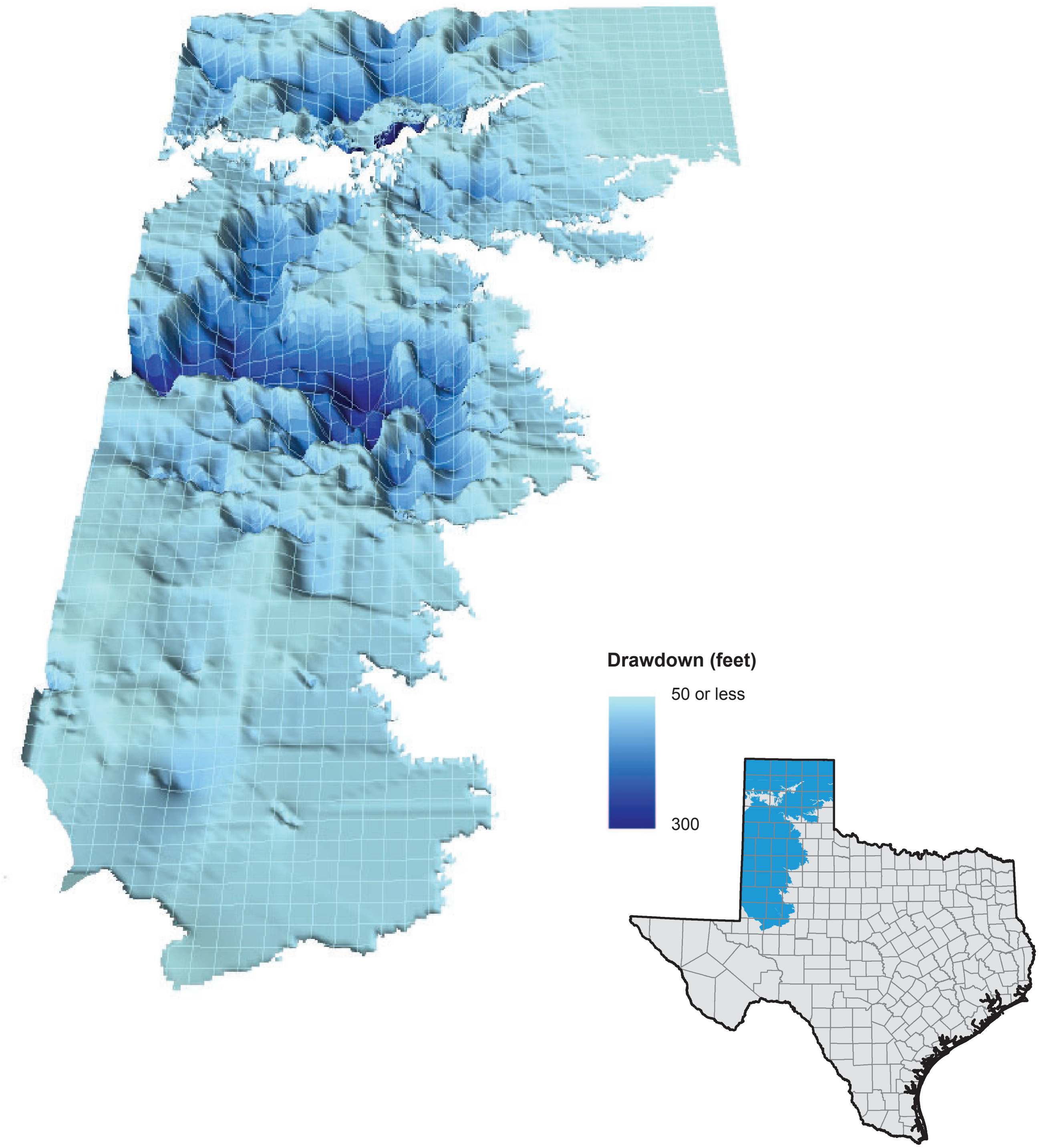
Ogallala
Aquifer

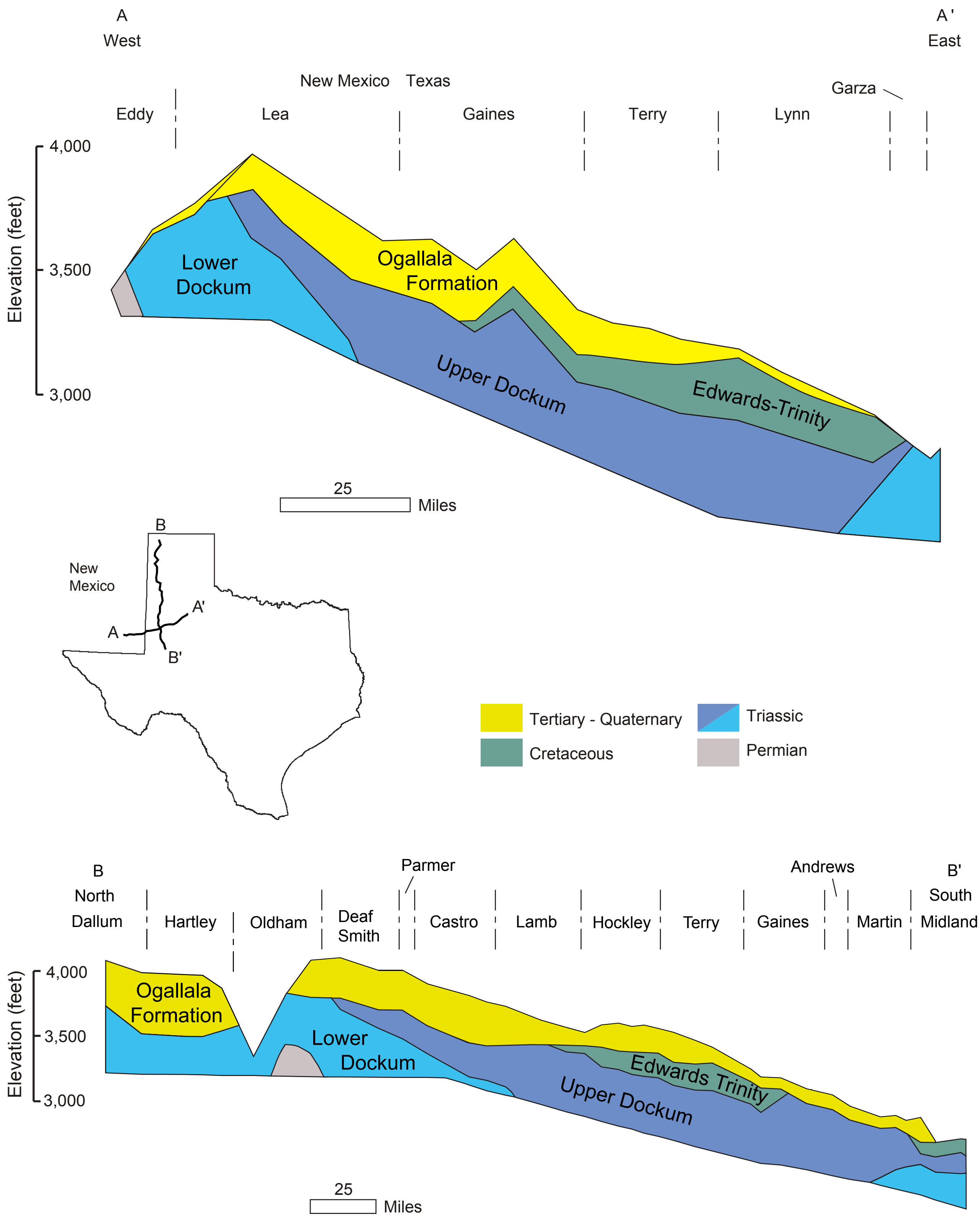




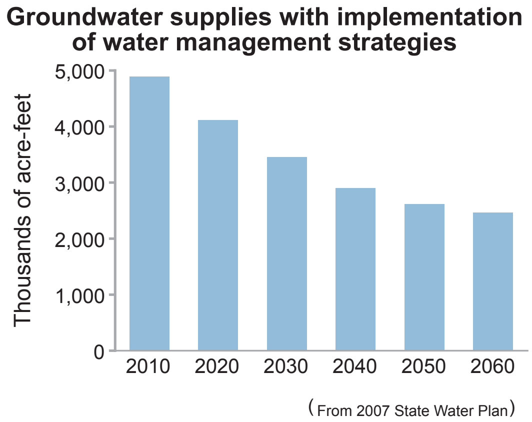
The Ogallala Aquifer is the largest aquifer in the United States and is a major aquifer of Texas underlying much of the High Plains region. The aquifer consists of sand, gravel, clay, and silt and has a maximum thickness of 800 feet. Freshwater saturated thickness averages 95 feet. Water to the north 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.



Total groundwater level declines in the Ogallala Aquifer over the last 60 years.



Geologic cross sections showing the relationship of the Ogallala Formation to underlying strata (modified from McGowen and others, 1977).



Ogallala Formation exposed as uppermost light-colored layer in Palo Duro Canyon State Park.

Aquifer characteristics

- Area of aquifer: 36,515 square miles
- Proportion of aquifer with groundwater conservation districts: 81 percent
- Number of counties containing the aquifer: 48

Ogallala Formation exposed near entrance to Palo Duro Canyon State Park.

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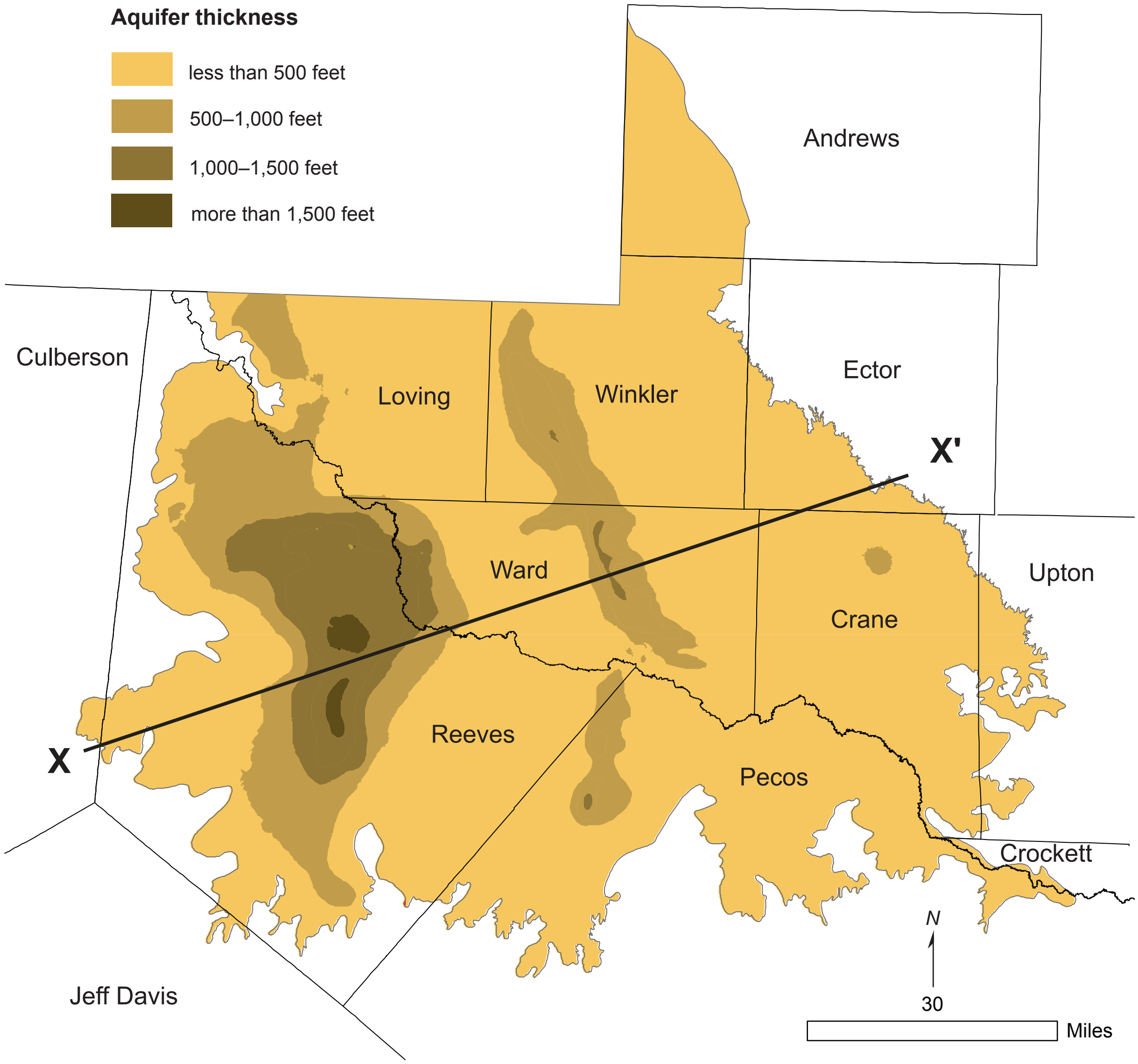
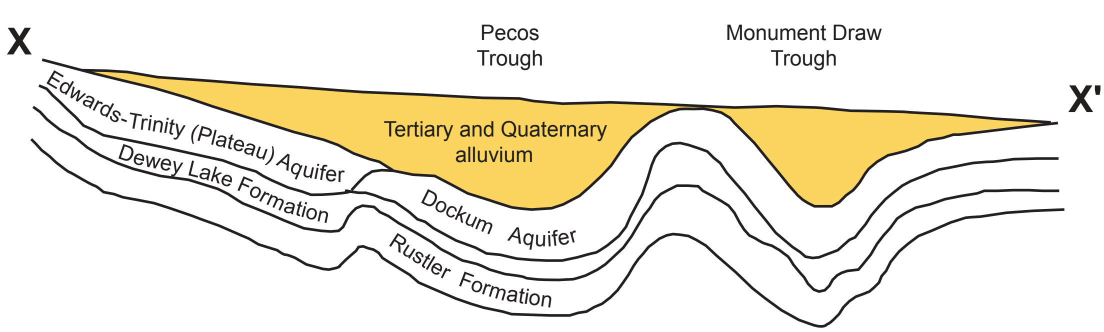
Pecos Valley
Aquifer

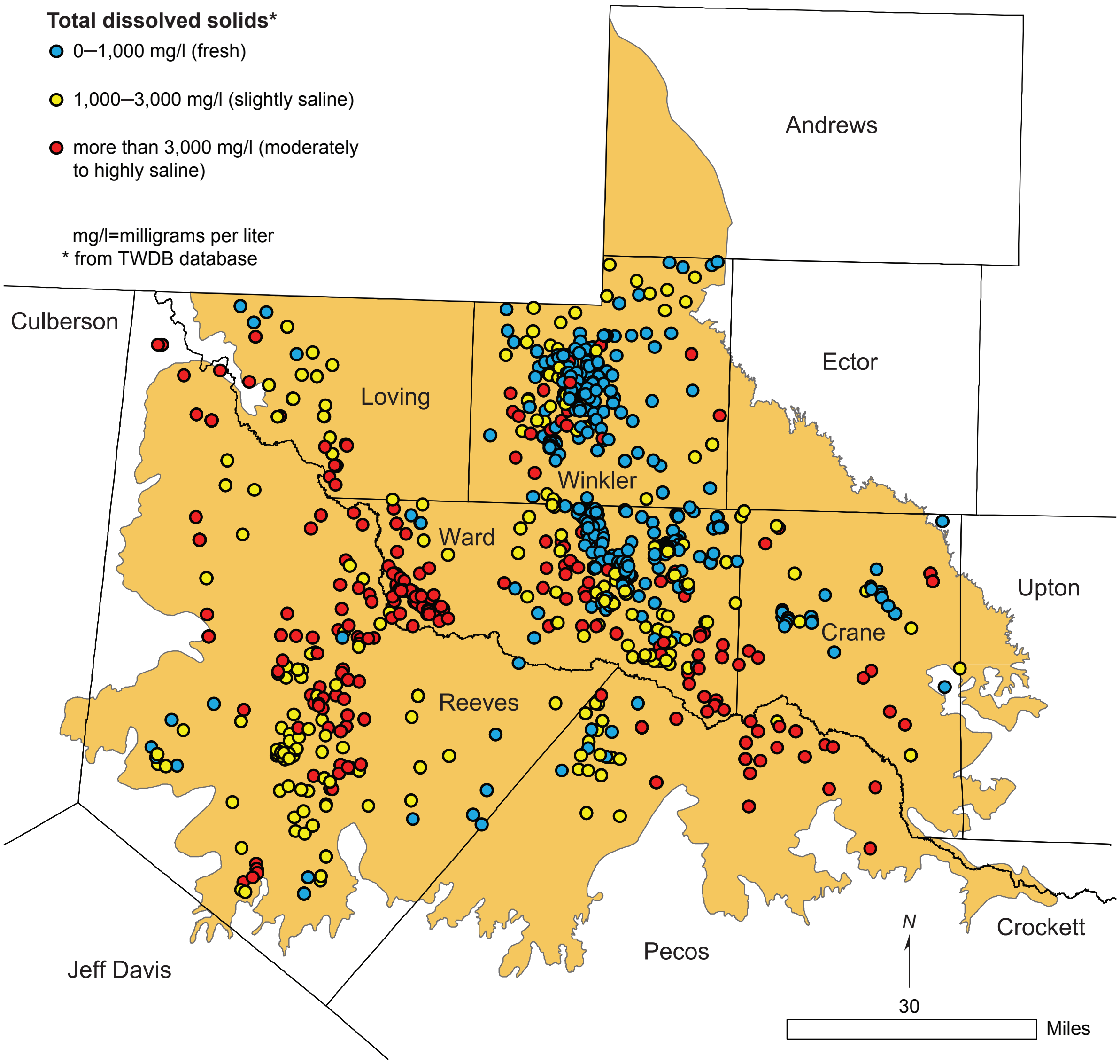
The Pecos Valley Aquifer is a major aquifer in West Texas. Water-bearing sediments include alluvial and windblown deposits in the Pecos River Valley. These sediments fill several structural basins, the largest of which are the Pecos Trough in the west and Monument Draw Trough in the east. Thickness of the alluvial fill reaches 1,500 feet, and freshwater saturated thickness averages about 250 feet. The water quality is highly variable, the water being typically hard, and generally better in the Monument Draw Trough than in the Pecos Trough. Total dissolved solids in groundwater from Monument Draw Trough are usually less than 1,000 milligrams per liter. The aquifer is characterized by high levels of chloride and sulfate in excess of secondary drinking water standards, resulting from previous oil field activities. In addition, naturally occurring arsenic and radionuclides occur in excess of primary drinking water standards. More than 80 percent of groundwater pumped from the aquifer is used for irrigation, and the rest is withdrawn for municipal supplies, industrial use, and power generation. Localized water level declines in south-central Reeves and northwest Pecos counties have moderated since the late 1970s as irrigation pumping has decreased; however, water levels continue to decline in central Ward County because of increased municipal and industrial pumping. The Region F Regional Water Planning Group recommended several water management strategies in their 2006 Regional Water Plan that would use the Pecos Valley Aquifer, including drilling new wells, developing two well fields in Winkler and Loving counties, and reallocating supplies.

Generalized cross sections across the Pecos Valley Aquifer (modified from Ashworth and Hopkins, 1995; Anaya and Jones, 2004; Jones 2008).



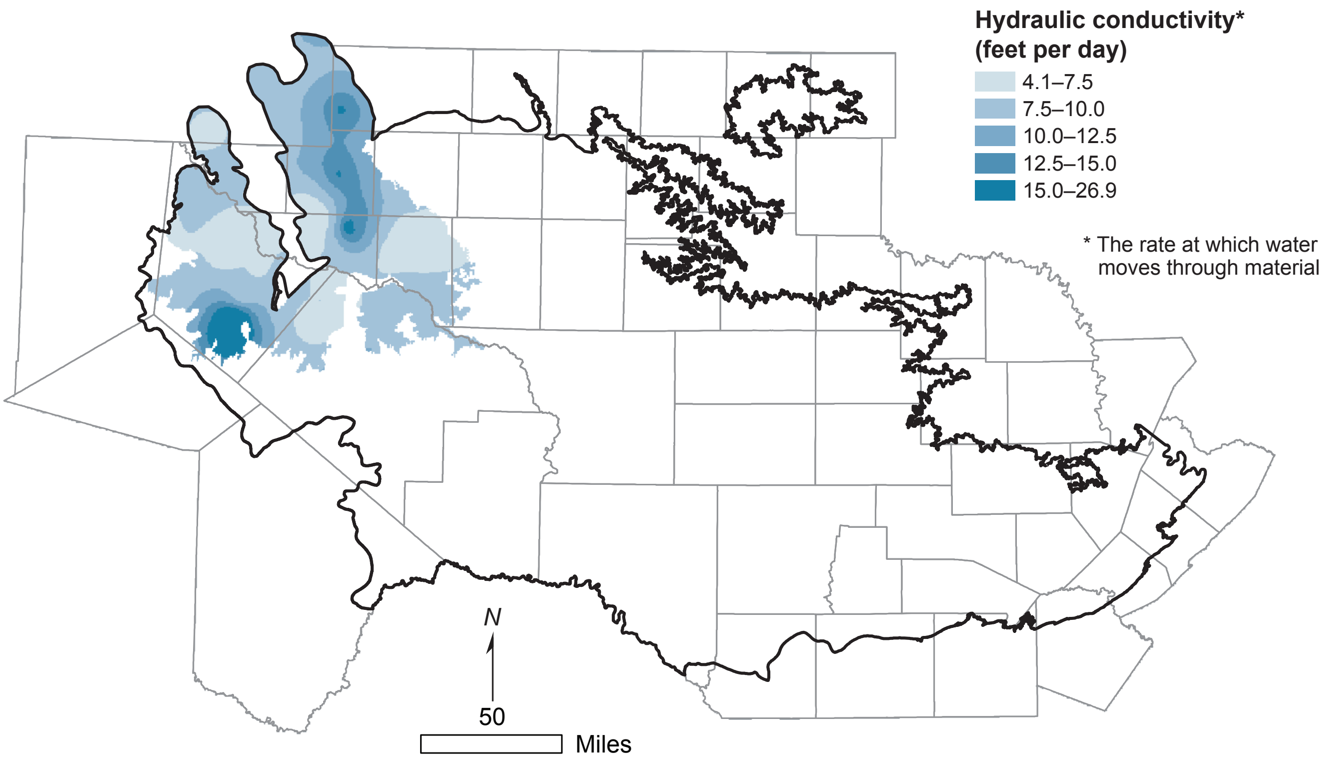


Total dissolved solids of wells from the Pecos Valley Aquifer.

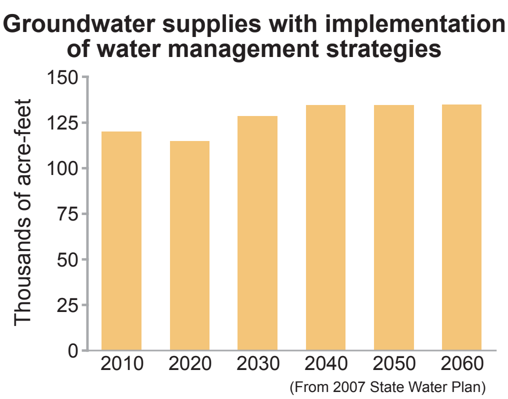


Alluvial sediments in Four Mile Draw north of Pecos, Texas.

Dune deposits at the Monahans Sandhills State Park.



Interpolated hydraulic conductivity for the Pecos Valley Aquifer (from Anaya and Jones, 2009).



Aquifer characteristics

- Area of aquifer: 6,829 square miles
- Proportion of aquifer with groundwater conservation districts: 16 percent
- Number of counties containing the aquifer: 12

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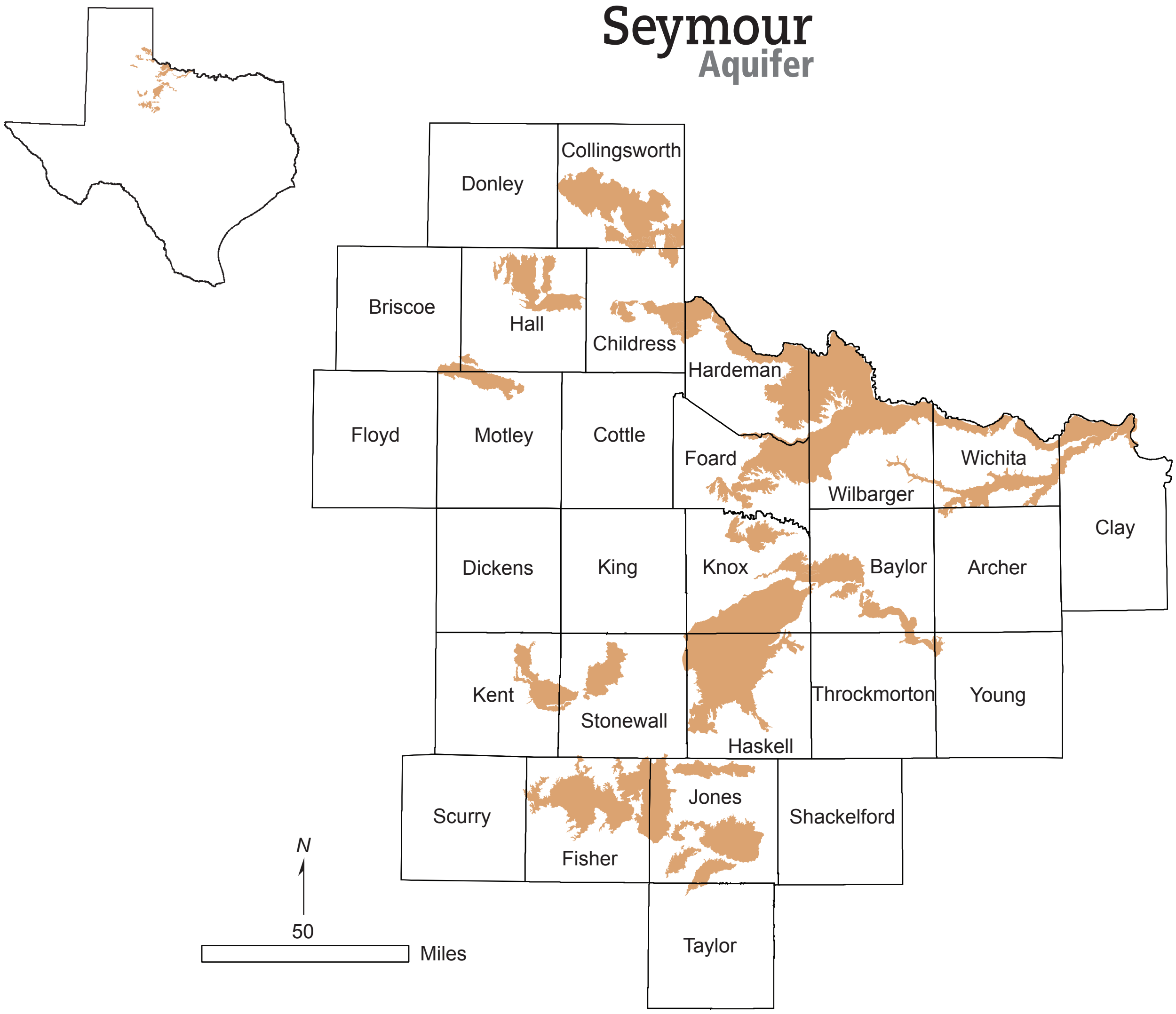
Seymour Aquifer

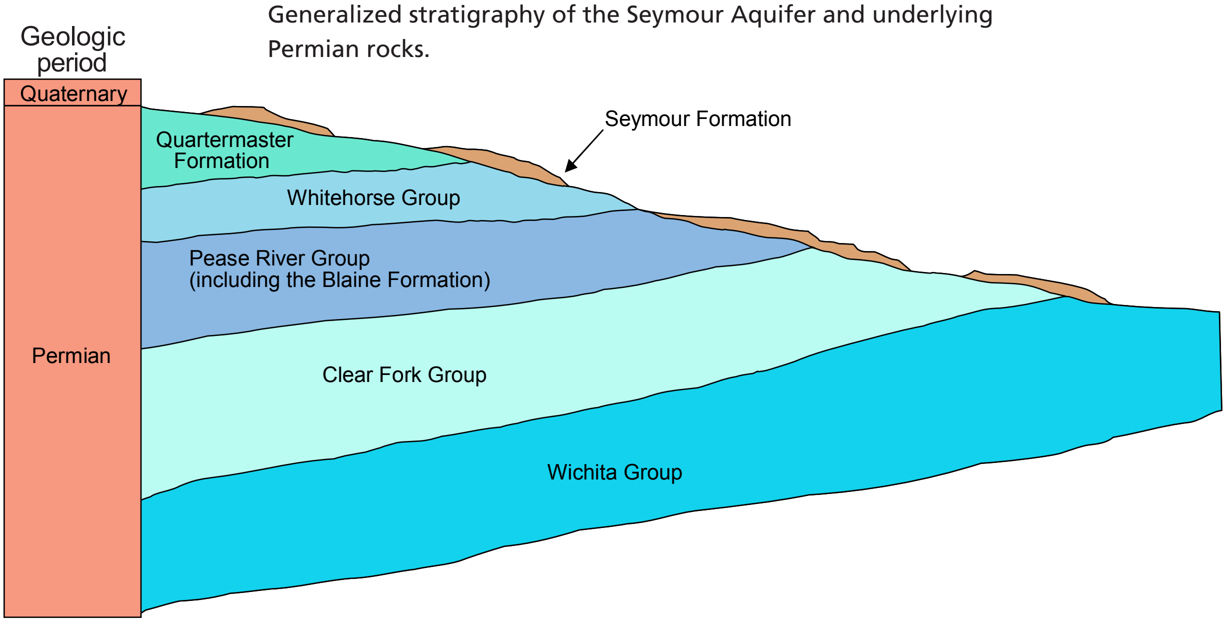


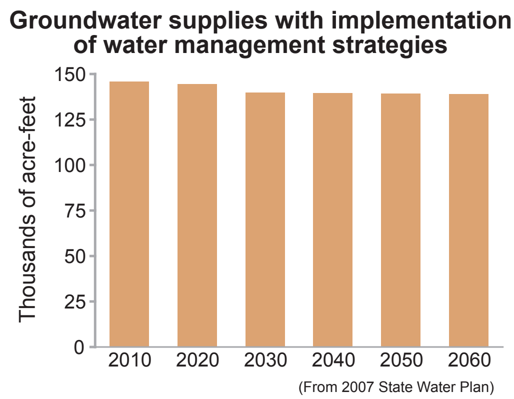
The Seymour Aquifer is a major aquifer extending across north-central Texas. The aquifer consists of Quaternary-age, alluvial sediments unconformably overlying Permian-age rocks. Water is contained in isolated patches of alluvium as much as 360 feet thick composed of discontinuous beds of poorly sorted gravel, conglomerate, sand, and silty clay. Water ranges from fresh to slightly saline, containing from approximately 100 to 3,000 milligrams per liter of total dissolved solids; however, moderately to very saline water, containing 3,000 to more than 10,000 milligrams per liter of total dissolved solids, exists in localized areas. Throughout its extent, the aquifer is affected by nitrate in excess of primary drinking water standards. Excess chloride also occurs throughout the aquifer. Almost all of the groundwater pumped from the aquifer—90 percent—is used for irrigation, with the remainder used primarily for municipal supply. Predictive groundwater availability modeling based on future estimates of pumping indicates that average water levels are not expected to change by more than several feet in the Seymour Aquifer, with or without a drought of record. Water levels in localized areas are predicted to decline in the Seymour Aquifer by as much as 30 feet. Actual water level declines have reduced the saturated thickness in some areas. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Seymour Aquifer, including drilling new wells, overdrafting, and constructing a nitrate removal plant in Wilbarger County.

The type locality of the Seymour Formation (Hibbard and Dalquest, 1966) located about 0.9 mile north of U.S. Highway 82, on the east side of Farm to Market 267, Knox County, Texas.

The yellow lines highlight the unconformable contact between Permian beds of the Clear Fork Group and the overlying Seymour Formation (as shown below in the generalized cross section).

Generalized stratigraphy of the Seymour Aquifer and underlying Permian rocks.





Aquifer characteristics

- Area of aquifer: 4,042 square miles
- Proportion of aquifer with groundwater conservation districts: 52 percent
- Number of counties containing the aquifer: 25

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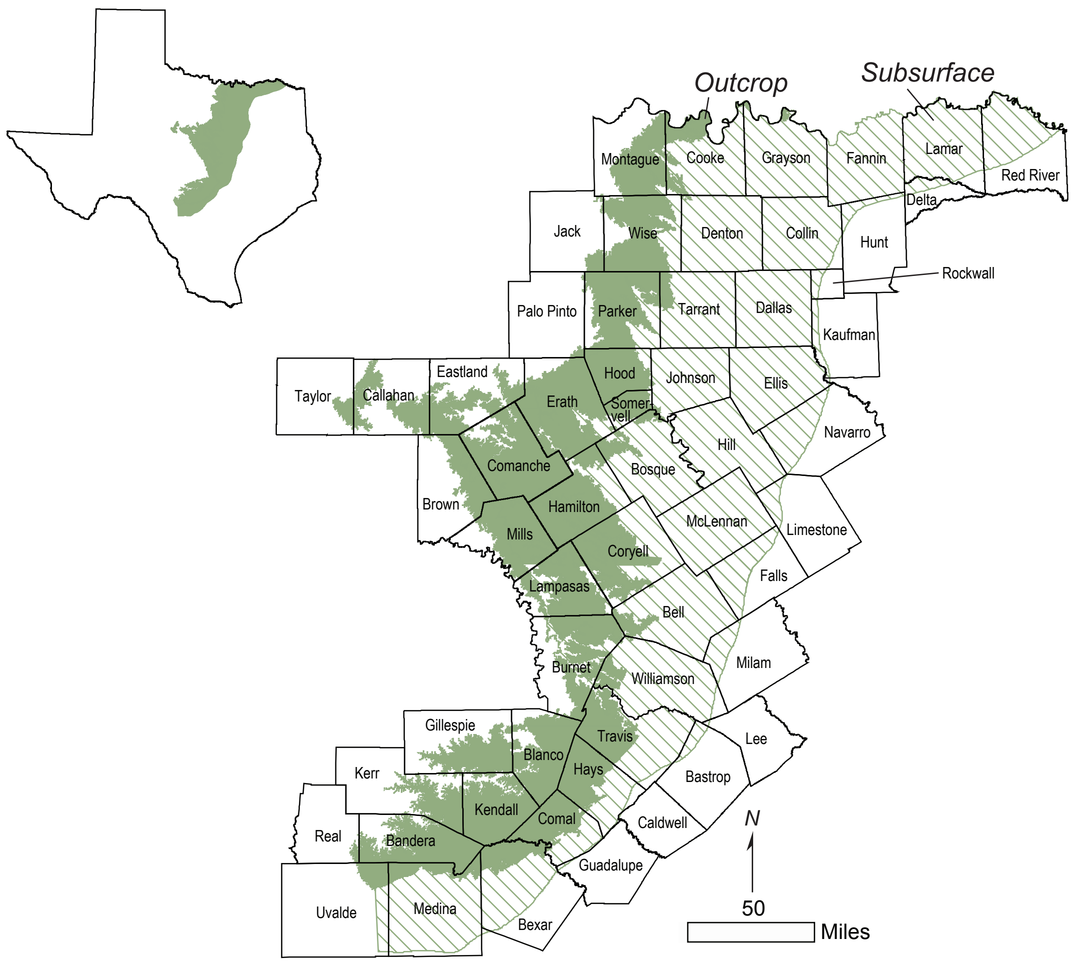
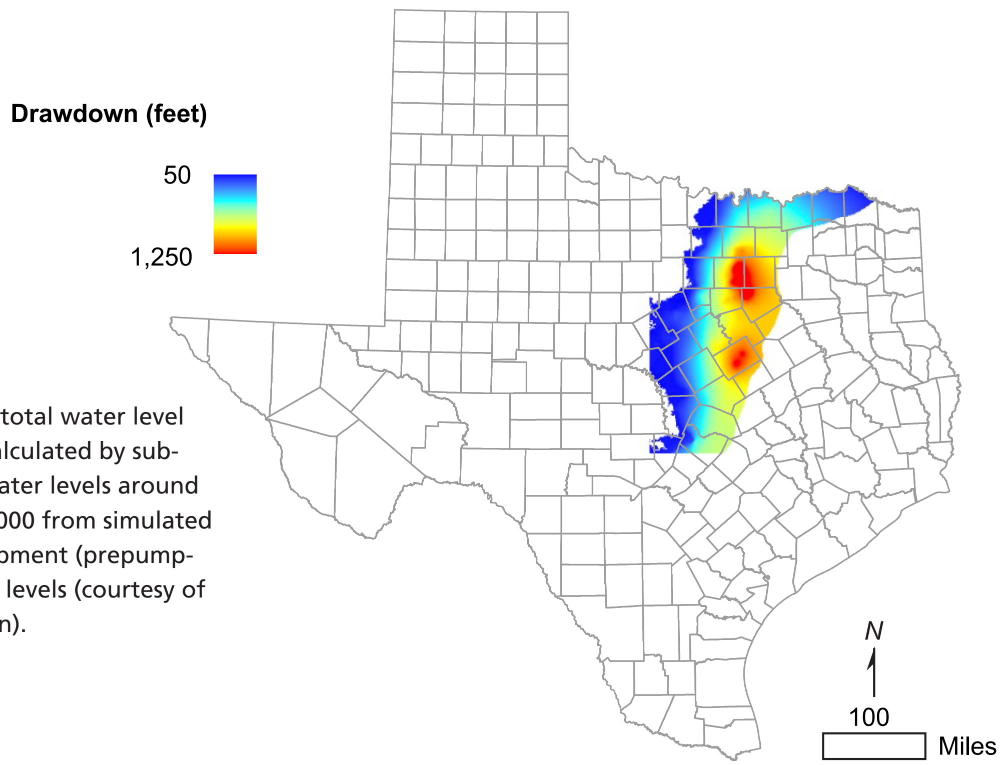
Trinity
Aquifer



The Trinity Aquifer,

a major aquifer, extends across much of the central and northeastern part of the state. It is composed of several smaller aquifers contained within the Trinity Group. Although referred to differently in different parts of the state, they include the Antlers, Glen Rose, Paluxy, Twin Mountains, Travis Peak, Hensell, and Hosston aquifers. These aquifers consist of limestones, sands, clays, gravels, and conglomerates. Their combined freshwater saturated thickness averages about 600 feet in North Texas and about 1,900 feet in Central Texas. In general, groundwater is fresh but very hard in the outcrop of the aquifer. Total dissolved solids increase from less than 1,000 milligrams per liter in the east and southeast to between 1,000 and 5,000 milligrams per liter, or slightly to moderately saline, as the depth to the aquifer increases. Sulfate and chloride concentrations also tend to increase with depth. The Trinity Aquifer discharges to a large number of springs, with most discharging less than 10 cubic feet per second. The aquifer is one of the most extensive and highly used groundwater resources in Texas. Although its primary use is for municipalities, it is also used for irrigation, livestock, and other domestic purposes. Some of the state's largest water level declines, ranging from 350 to more than 1,000 feet, have occurred in counties along the IH-35 corridor from McLennan County to Grayson County. These declines are primarily attributed to municipal pumping, but they have slowed over the past decade as a result of increasing reliance on surface water. The regional water planning groups, in their 2006 Regional Water Plans, recommended numerous water management strategies for the Trinity Aquifer, including developing new wells and well fields, pumping more water from existing wells, overdrafting, reallocating supplies, and using surface water and groundwater conjunctively.

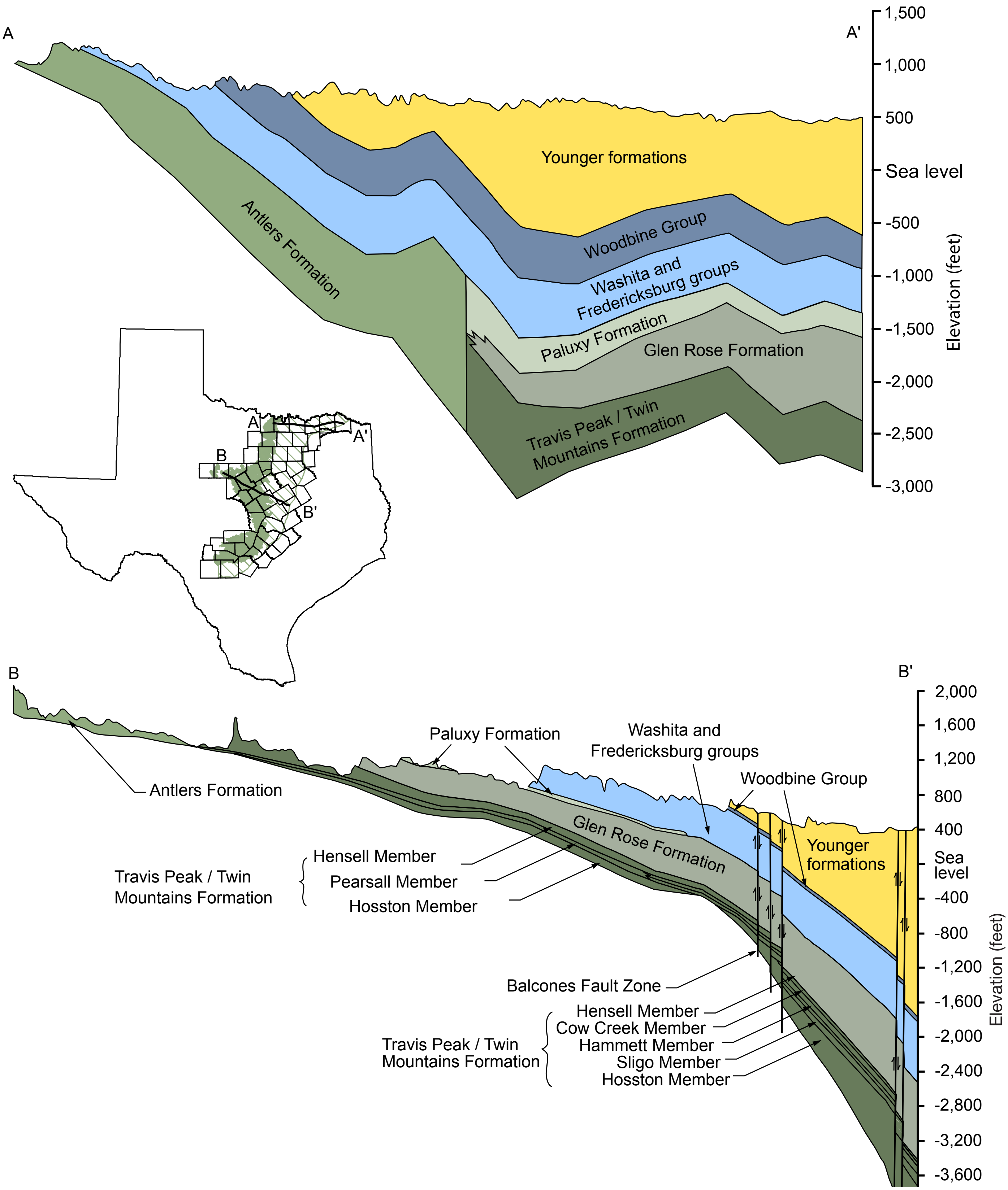


Estimated total water level declines calculated by subtracting water levels around the year 2000 from simulated predevelopment (prepumping) water levels (courtesy of H.S. Hamlin).

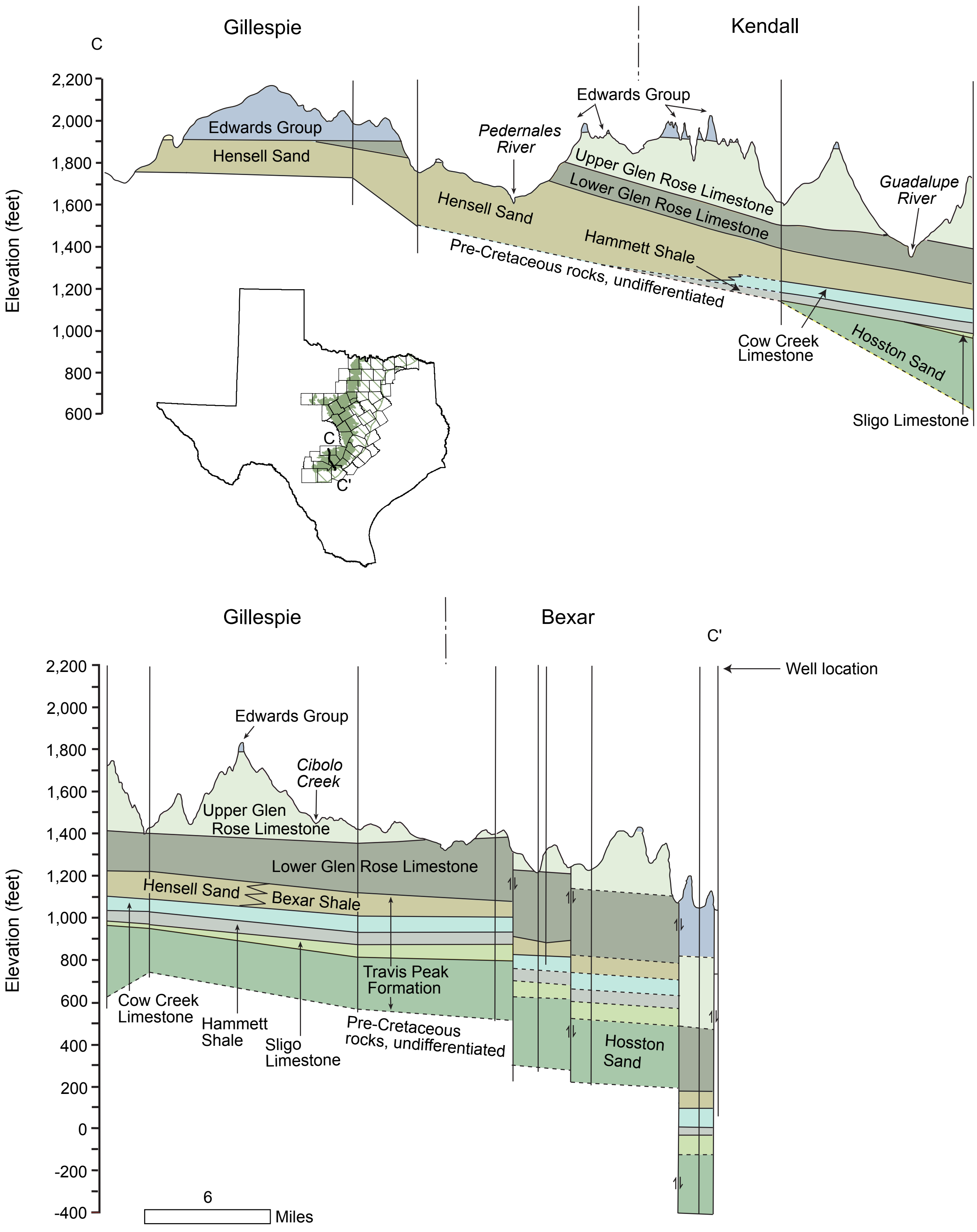
Upper Glen Rose Formation along Southwest Parkway southeast of Bee Cave, Texas.

Lower Glen Rose Formation along State Highway 71 northwest of Bee Cave, Texas (note 6-inch ruler).

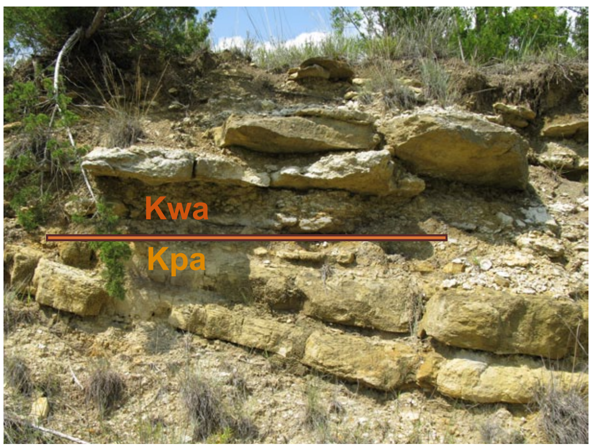
Structural cross sections across the northern Trinity Aquifer, shown in shades of green (modified from Klemt and others; 1975; Nordstrom, 1982).



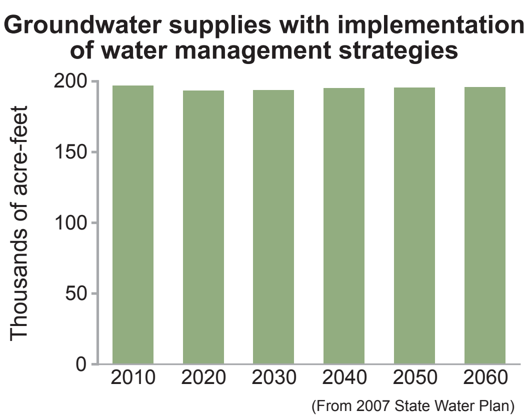
Structural cross section across the Trinity Aquifer in the Hill Country, including rocks from the Upper Glen Rose Formation to the Hosston Sand (modified from Ashworth, 1983; Mace and others, 2000b).



Theropod dinosaur track from the Glen Rose Formation at Dinosaur Valley State Park.



Paluxy Formation (Kpa) beneath the Walnut Formation (Kwa) along State Highway 67 southwest of Comanche, Texas.



Aquifer characteristics

- Area of outcrop: 10,652 square miles
- Area in subsurface: 21,308 square miles
- Proportion of aquifer with groundwater conservation districts: 32 percent
- Number of counties containing the aquifer: 61

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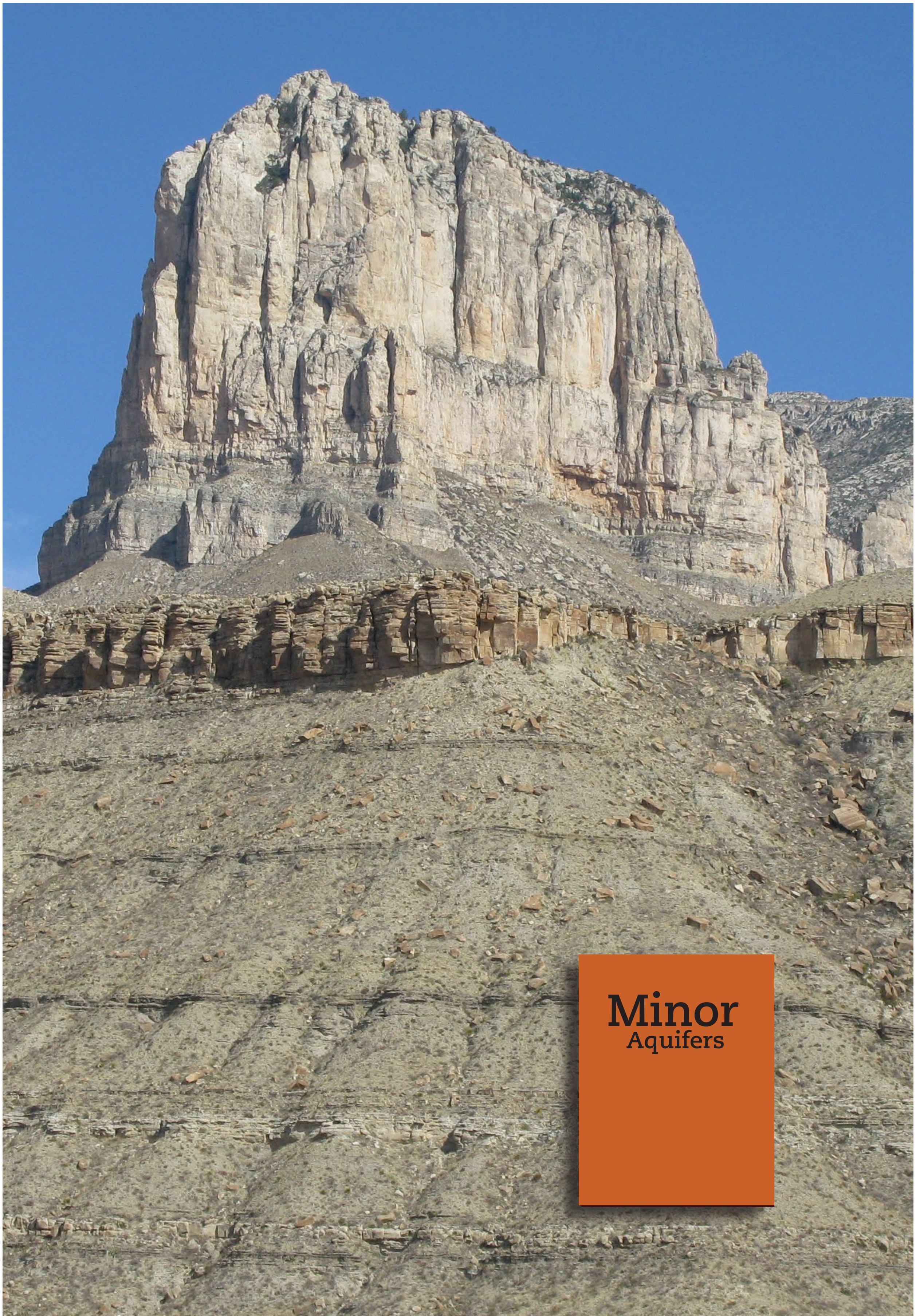
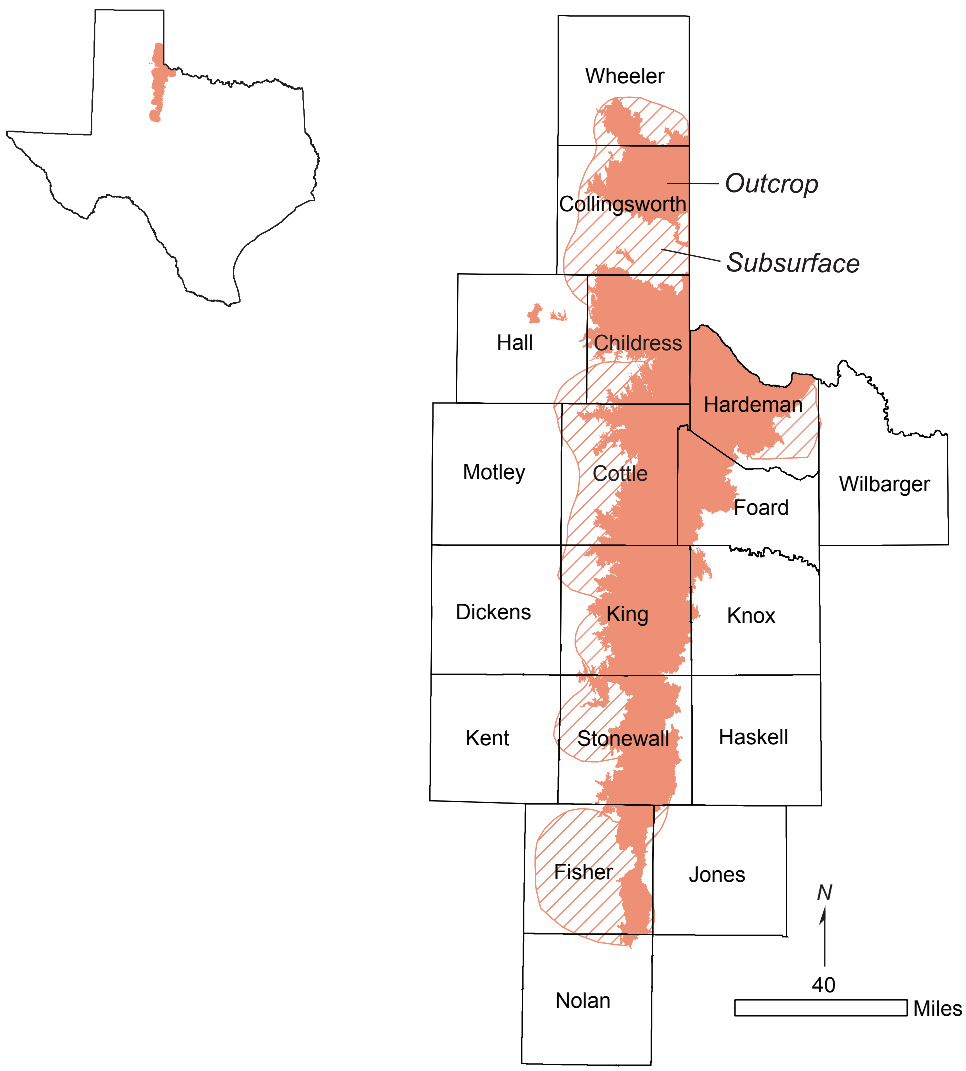


Minor Aquifers

Photo (previous page)

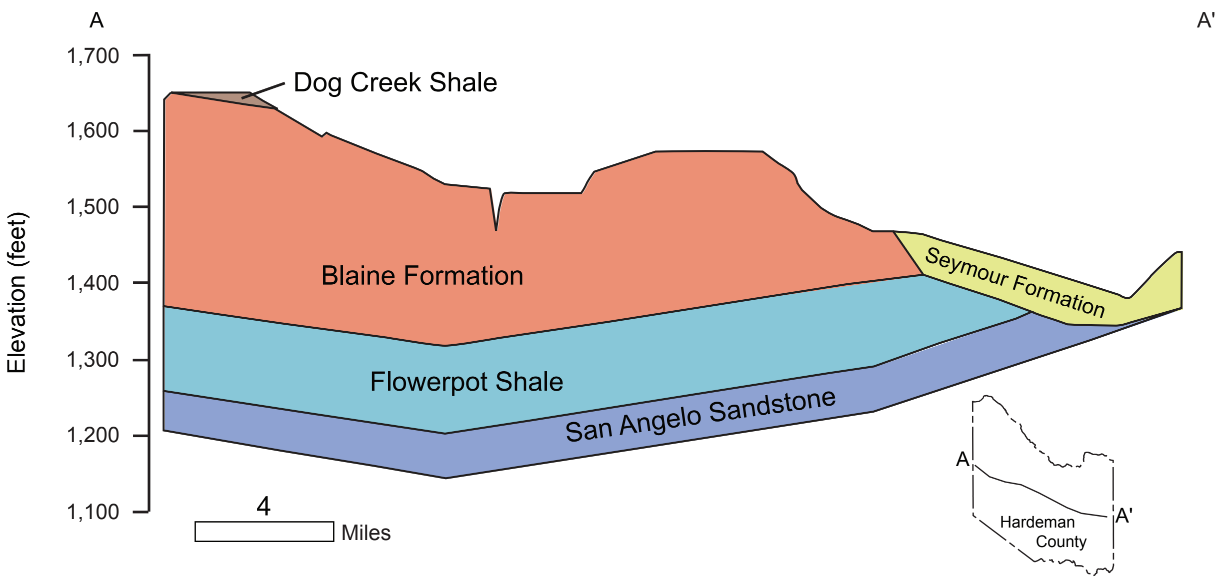
El Capitan at the southern end of the Guadalupe Mountains in northwest Culberson County, Texas. The upper part of the mountain is composed of forereef rubble facies of the Capitan Limestone, which is part of the Capitan Reef Complex Aquifer.

Blaine
Aquifer



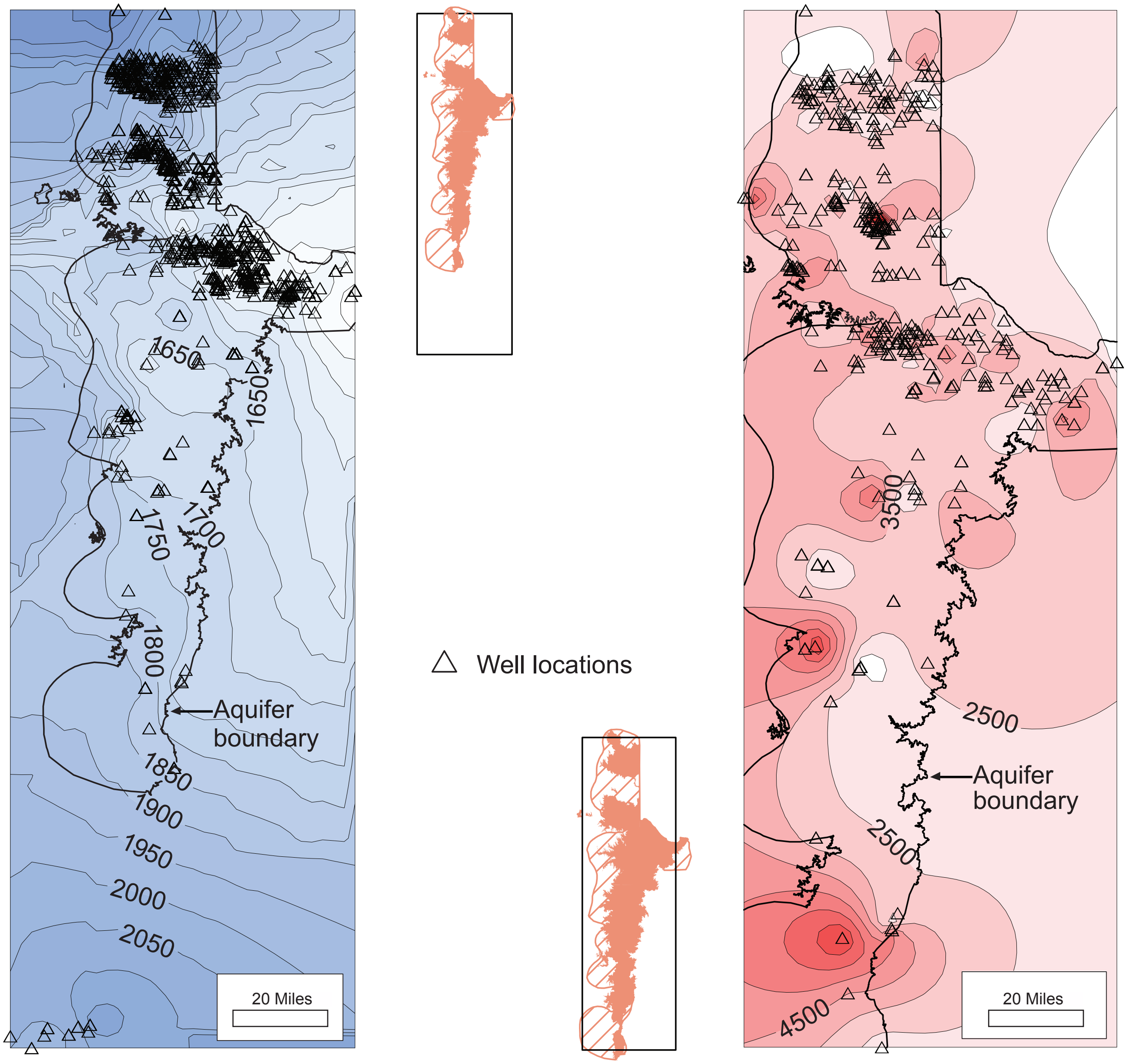
The Blaine Aquifer is a minor aquifer located at the east end of the High Plains in North Texas. The aquifer is part of the Permian Blaine Formation, which is composed of red silty shale, gypsum, anhydrite, salt, and dolomite. The formation consists of cycles of marine and nonmarine sediments deposited in a broad, shallow sea that once covered the southwestern United States. Saturated thickness reaches 300 feet in the aquifer, but freshwater saturated thickness averages 137 feet. Groundwater occurs primarily in solution channels and caverns within the beds of anhydrite and gypsum that contribute to the overall poor quality of the water. Although some wells contain slightly saline water, with total dissolved solids between 1,000 and 3,000 milligrams per liter, most contain moderately saline water, with total dissolved solids between 3,000 and 10,000 milligrams per liter, exceeding secondary drinking water standards for Texas. Sulfate values are also well in excess of the secondary drinking water standard of 300 milligrams per liter. Water from the Blaine Aquifer is used for livestock and for irrigation of crops that are highly tolerant of salt. In areas where the groundwater is used for irrigation, water levels fluctuate seasonally. Predictive modeling based on future estimates of pumping indicates that average water levels are not expected to change by more than several feet in the aquifer, with or without a drought of record. The regional water planning groups, in their 2006 Regional Water Plans, did not recommend any water management strategies using the Blaine Aquifer.

Exposures of the Blaine Formation along the South Wichita River near Guthrie, in King County, Texas.



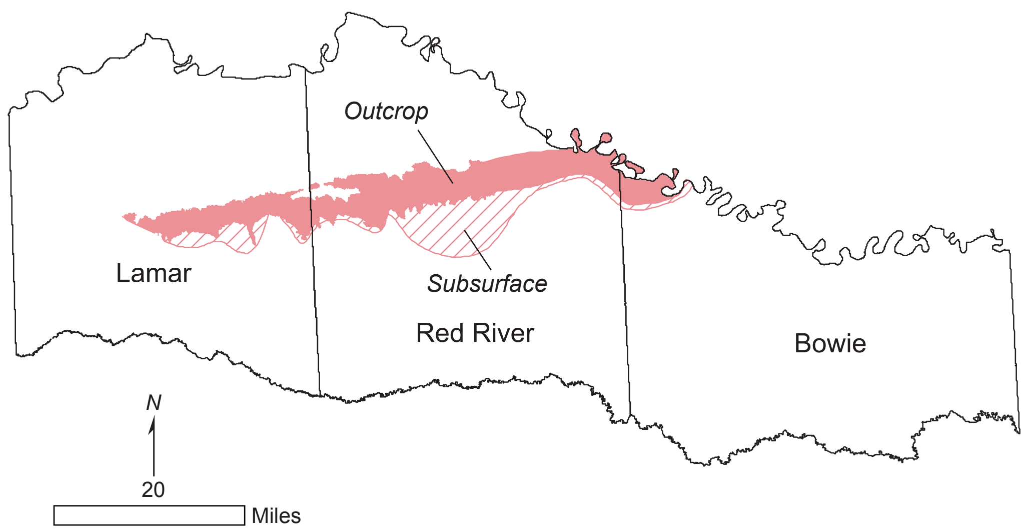
East-west structural cross section across Hardeman County (from Maderak, 1972).

The Blaine Formation, near Guthrie, Texas, consisting of red silty shale, gypsum, anhydrite, salt, and dolomite.

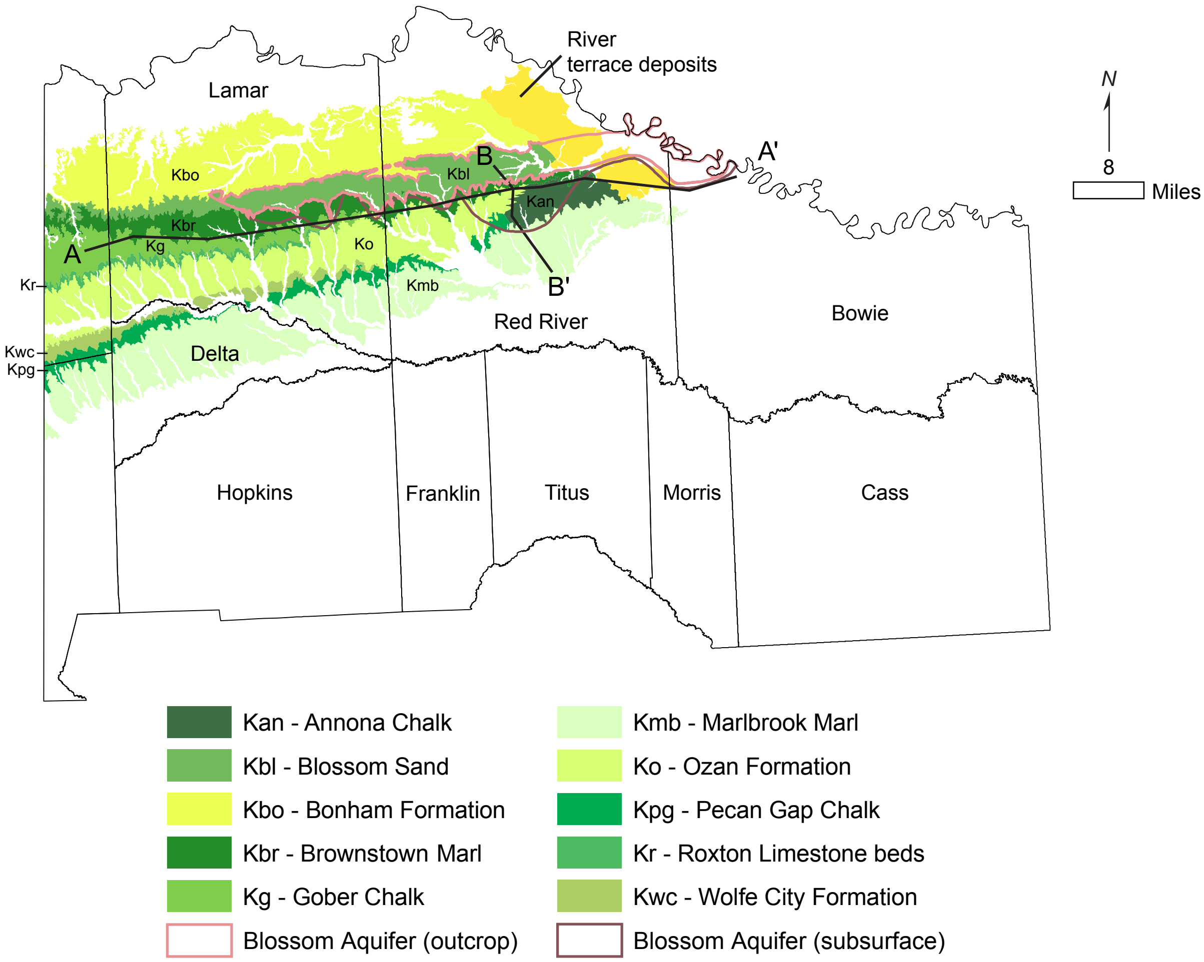


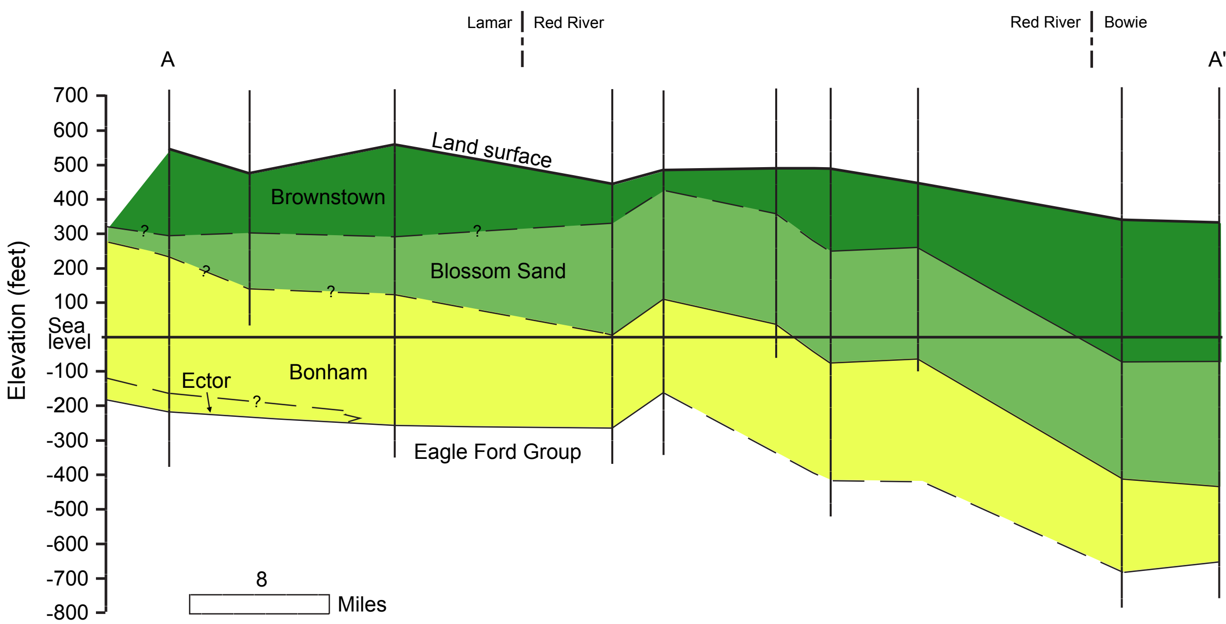
Contour maps of groundwater elevations (feet, *left*) and total dissolved solids (milligrams per liter, *right)* for the Blaine Aquifer.

Blossom
Aquifer

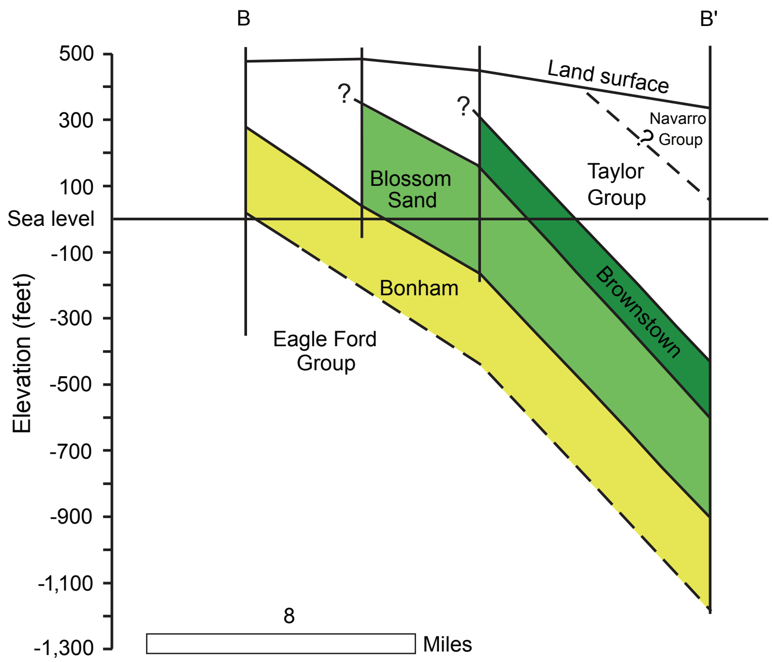


The Blossom Aquifer
is a minor aquifer located in Bowie, Red River, and Lamar counties in the northeast corner of Texas. The aquifer consists of the Blossom Sand Formation, composed of alternating sequences of sand and clay. In places, the aquifer is as much as 400 feet thick, although no more than about one-third of this thickness consists of sand, and freshwater saturated thickness averages 25 feet. The aquifer yields water of usable quality to wells located mostly in outcrop areas. However, in part of Red River County, slightly saline water, with total dissolved solids less than 3,000 milligrams per liter, extends underground for about 6 miles south of the outcrop. Groundwater in the Blossom Aquifer is generally soft, slightly alkaline, and, in some areas, high in sodium, bicarbonate, iron, and fluoride. Although water quality is not acceptable for irrigation, it is generally acceptable for nonindustrial uses. Municipal pumping accounts for a large percentage of total pumpage from the aquifer. Clarksville and the Red River County Water Supply Corporation in Red River County have historically pumped the greatest amounts from the aquifer, causing water level declines. In recent years, however, the rate of decline has slowed or even stabilized in some wells as a result of more surface water use in the area. The North East Texas Regional Water Planning Group, in its 2006 Regional Water Plan, did not recommend any water management strategies using the Blossom Aquifer.

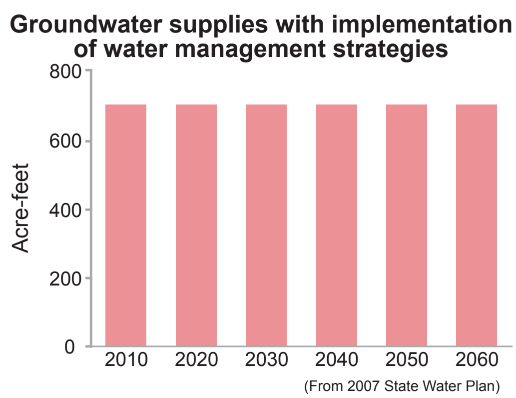




East-west geologic cross section along the Blossom Aquifer (modified from McLaurin, 1988).



North-south geologic cross section across the Blossom Aquifer (modified from McLaurin, 1988).



Aquifer characteristics

- Area of outcrop: 182 square miles
- Area in subsurface: 95 square miles
- Proportion of aquifer with groundwater conservation districts: 0 percent
- Number of counties containing the aquifer: 3

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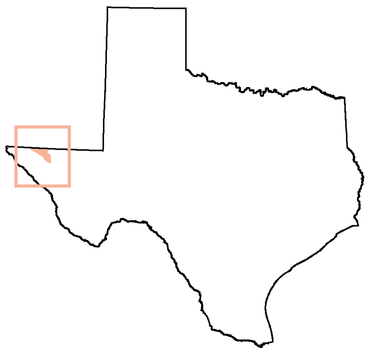
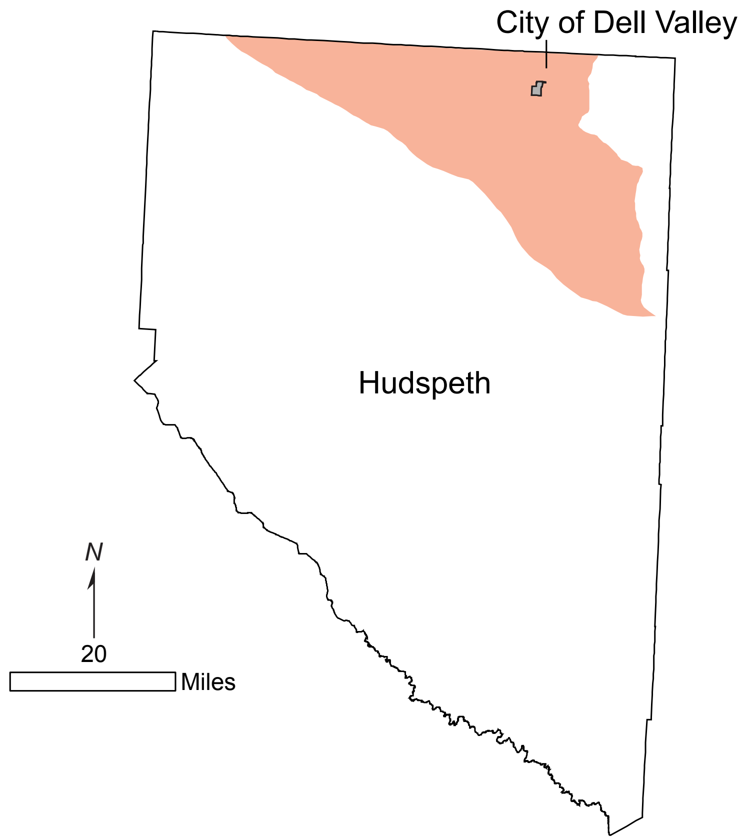
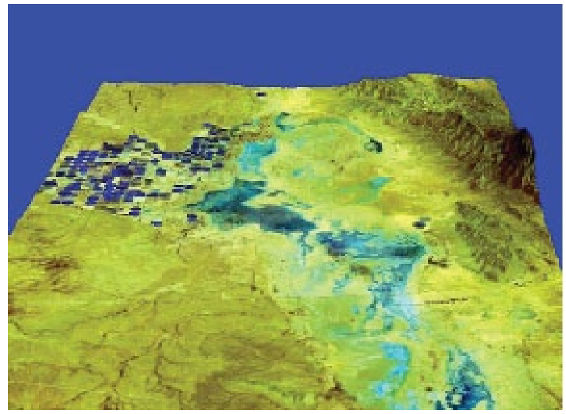
Bone Spring-Victorio Peak
Aquifer



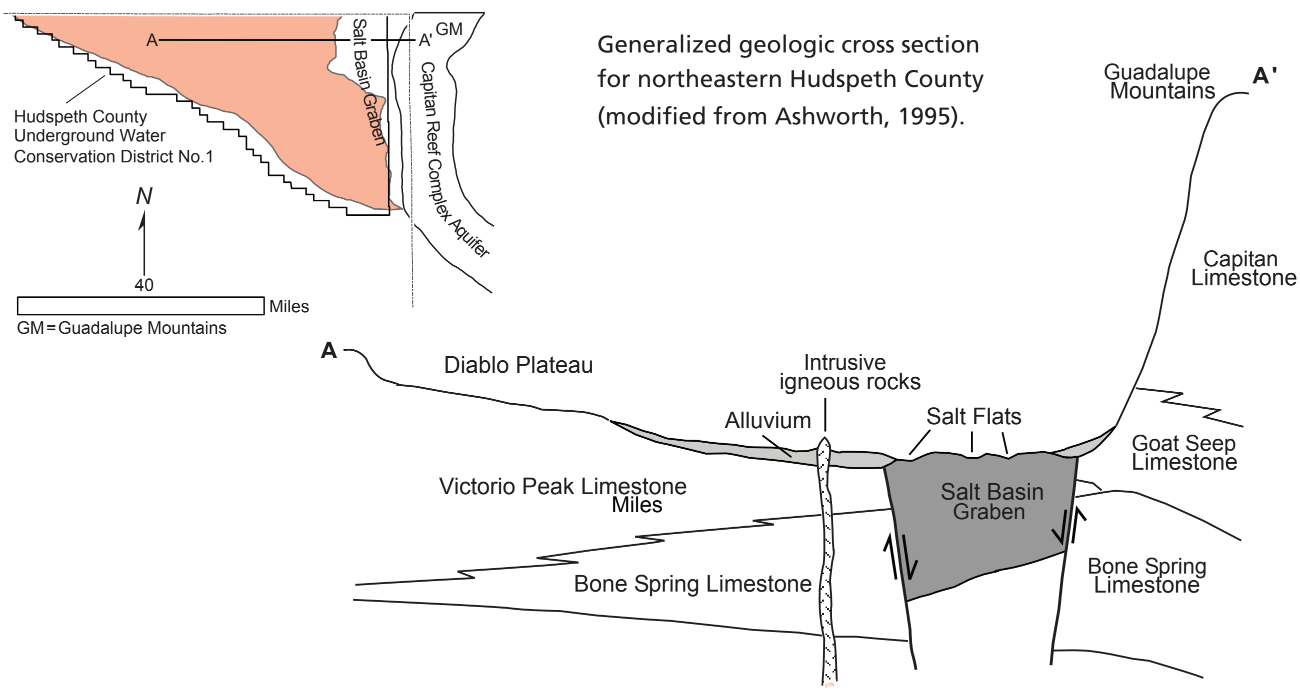


The Bone Spring–Victorio Peak Aquifer is a minor aquifer located in northern Hudspeth County. The principal water-bearing units in the aquifer are the Bone Spring and Victorio Peak limestones, both Permian in age. The formations produce groundwater from solution cavities developed along joints and fracture planes. Groundwater flows regionally toward the east-northeast through the aquifer, although a significant amount of groundwater also flows into the Dell Valley area from the Sacramento Mountains in New Mexico along a set of northwest-southeast-trending fractures. Water is generally slightly saline, with total dissolved solids of 1,000 to 3,000 milligrams per liter. In the Dell Valley area, total dissolved solids increase to 3,000 to 10,000 milligrams per liter. Water quality in this area appears to be controlled by two mechanisms: (1) groundwater flowing through the aquifer system and dissolving minerals along its flow path and (2) irrigation water percolating down through the soil zone. Significant amounts of groundwater have been pumped and are being pumped from the aquifer in the Dell Valley area. Since the late 1940s, pumping has been the principal means of discharge for the aquifer. Pumping to the south and west of the Dell Valley area is limited to scattered wells used for livestock or domestic purposes. Water levels have declined in the Dell Valley area from 5 to 60 feet, with an average of about 30 feet over a period of about 55 years. These declines are most likely due to pumping for irrigation. Water levels over the last 30 years, however, have been relatively constant, except for the last few years, during which water levels have declined because of drought. The Far West Texas Regional Water Planning Group, in its 2006 Regional Water Plan, recommended a water management strategy to redevelop and expand a well field in the Bone Spring–Victorio Peak Aquifer, desalinate the water, and transport it to El Paso County.

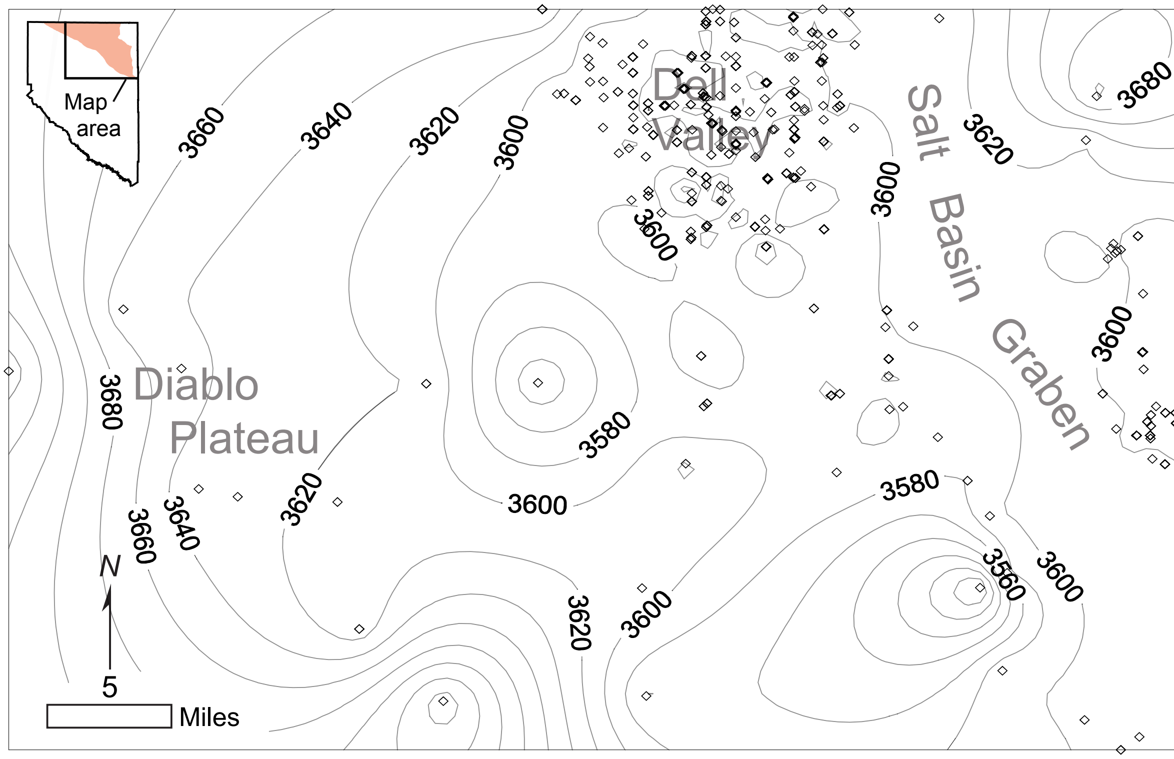
Irrigation in the Dell Valley area by D. Groeneveld (HydroBio, Inc.).



Satellite data showing blue areas of irrigation and playa discharge, Dell Valley (HydroBio, Inc.).



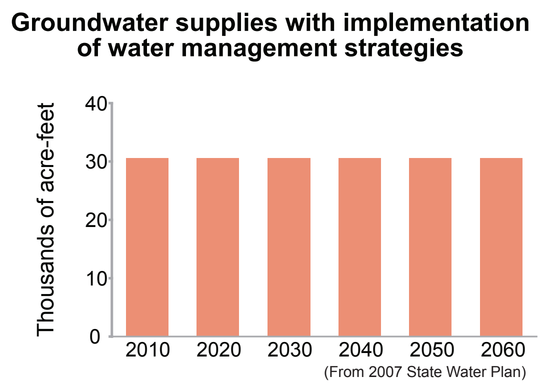
Generalized geologic cross section for northeastern Hudspeth County (modified from Ashworth, 1995).



Water level map for northwestern Hudspeth County, Texas (from George and others, 2005).

Cherty limestone and interbedded shale of the Bone Spring Limestone near El Capitan.

Cliffs of Bone Spring Limestone underlying Victorio Peak Limestone in the Sierra Diablo Mountains.



Aquifer characteristics

- Area of aquifer: 710 square miles
- Proportion of aquifer with groundwater conservation districts: 0 percent
- Number of counties containing the aquifer: 1

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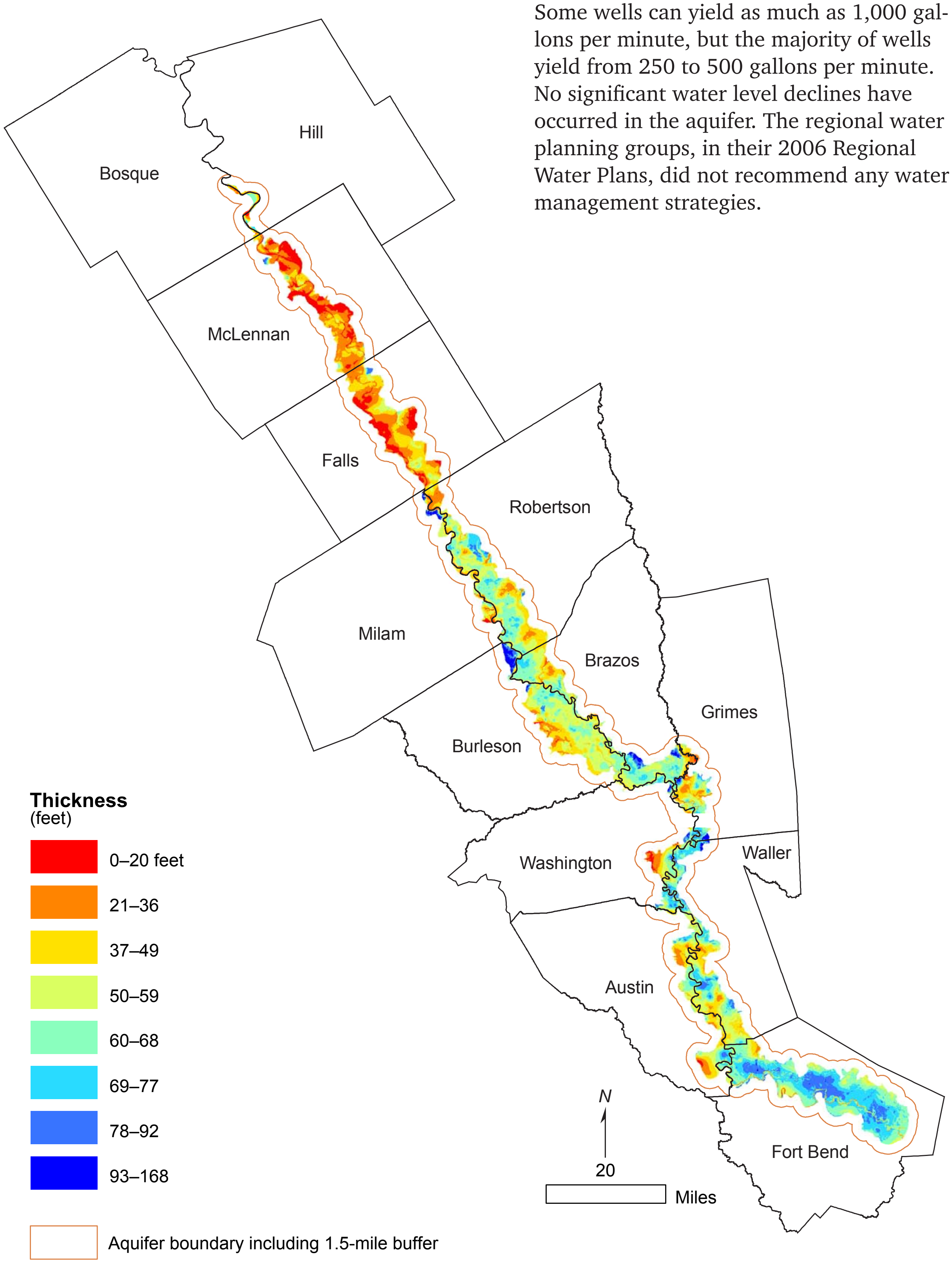
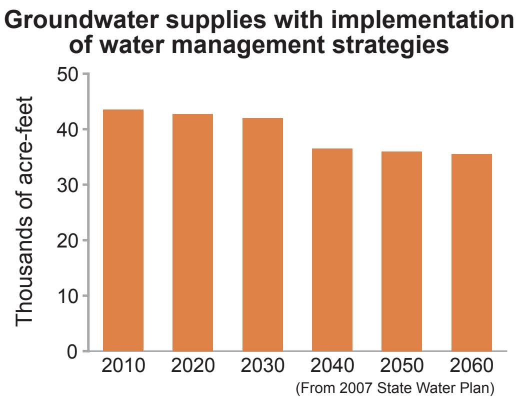
Brazos River Alluvium
Aquifer

The Brazos River Alluvium Aquifer is a minor aquifer found along the Brazos River in east-central Texas. The aquifer is as much as 7 miles in width and extends along 350 river miles from southern Bosque County to eastern Fort Bend County. Groundwater is contained in alluvial floodplain and terrace deposits, although the latter is not an appreciable source of water. The floodplain alluvium consists of fine to coarse sand, gravel, silt, and clay. These deposits have a complex geometry, with beds or lenses of sand and gravel that pinch out or grade vertically into finer material. In general, finer sediments occur in the upper part of the aquifer, and coarser material is in the lower part. The thickness of the aquifer ranges from negligible to 168 feet, with an overall average of about 50 feet. Water in the aquifer is very hard and fresh to slightly saline, generally containing less than 1,000 milligrams per liter of total dissolved solids but ranging to as much as 3,000 milligrams per liter in some wells. The aquifer is under water table conditions in most places and is used mainly for irrigation. The water table generally slopes toward the Brazos River, this direction indicating that the river is a gaining stream in most places. Recharge to the aquifer occurs from rainfall on the aquifer and subsequent downward leakage to the saturated zone. Discharge from the aquifer occurs through evapotranspiration, discharge to the river, and withdrawals from wells. Some wells can yield as much as 1,000 gallons per minute, but the majority of wells yield from 250 to 500 gallons per minute. No significant water level declines have occurred in the aquifer. The regional water planning groups, in their 2006 Regional Water Plans, did not recommend any water management strategies.



Thickness of the Brazos River Alluvium Aquifer, Bosque County to Fort Bend County, Texas (from Shah and others, 2007).



Aquifer characteristics

- Area of aquifer: 1,053 square miles
- Proportion of aquifer with groundwater conservation districts: 65 percent
- Number of counties containing the aquifer: 13

Brazos River alluvium near College Station, Texas.

References

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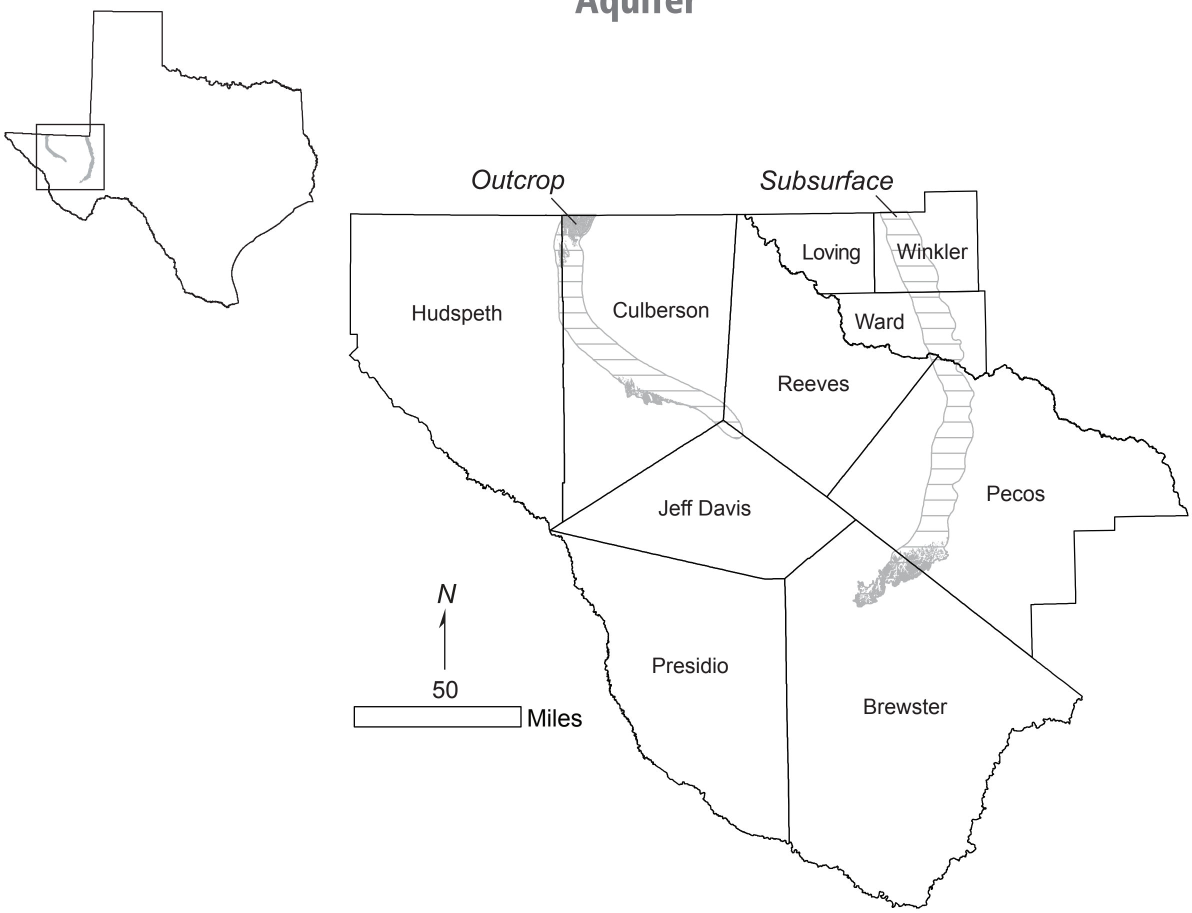
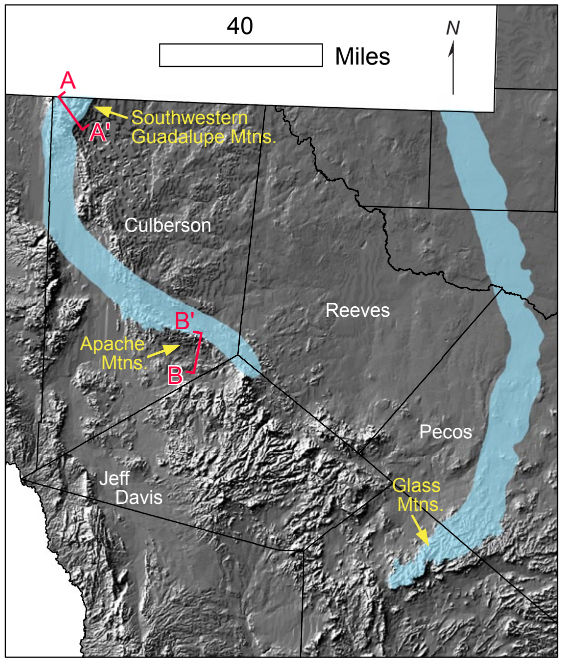
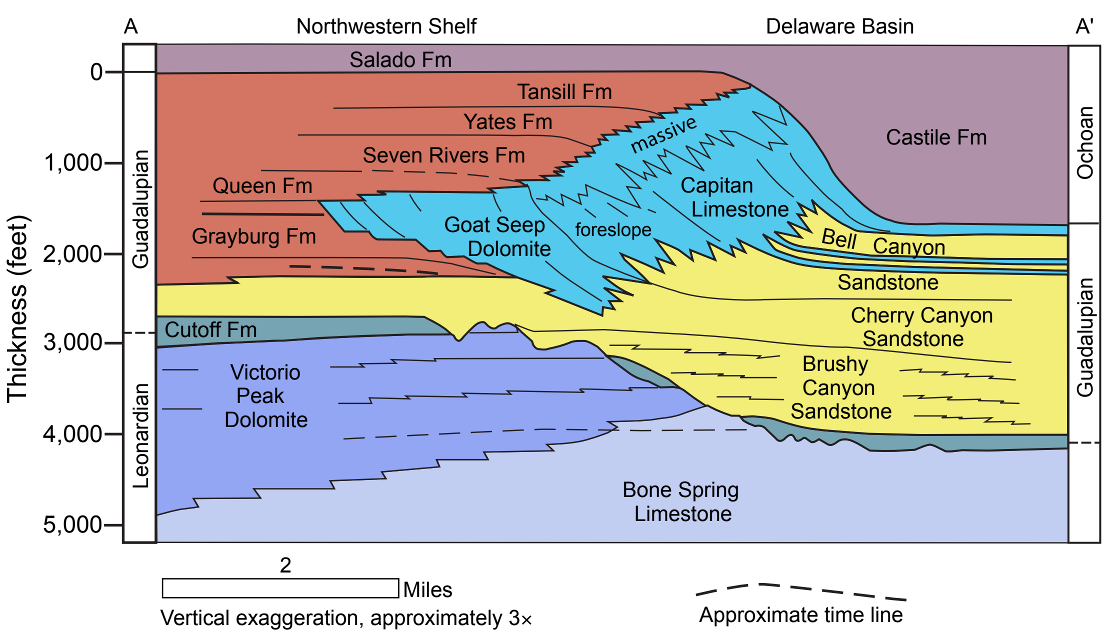
Capitan Reef Complex
Aquifer



The Capitan Reef Complex Aquifer is a minor aquifer located in Culberson, Hudspeth, Jeff Davis, Brewster, Pecos, Reeves, Ward, and Winkler counties. It is exposed in mountain ranges of Far West Texas; elsewhere it occurs in the subsurface. The aquifer is composed of as much as 2,360 feet of massive, cavernous dolomite and limestone. Water-bearing formations include the Capitan Limestone, Goat Seep Dolomite, and most of the Carlsbad facies of the Artesia Group, including the Grayburg, Queen, Seven Rivers, Yates, and Tansill formations. Water is contained in solution cavities and fractures that are unevenly distributed within these formations. Water from the Capitan Reef Complex Aquifer is thought to contribute to the base flow of San Solomon Springs in Reeves County. Overall, the aquifer contains water of marginal quality, yielding small to large quantities of slightly saline to saline groundwater containing 1,000 to greater than 5,000 milligrams per liter of total dissolved solids. Water of the freshest quality, with total dissolved solids between 300 and 1,000 milligrams per liter, is present in the west near areas of recharge where the reef rock is exposed in several mountain ranges. Although most of the groundwater pumped from the aquifer in Texas is used for oil reservoir flooding in Ward and Winkler counties, a small amount is used to irrigate salt-tolerant crops in Pecos, Culberson, and Hudspeth counties. Over the last 70 years, water levels have declined in some areas as a result of localized production. The Far West Texas Regional Water Planning Group, in its 2006 Regional Water Plan, recommended several water management strategies for the Capitan Reef Complex Aquifer, including redeveloping an existing well field, desalinating the water, and transporting it to El Paso County.



Cross section locations overlaying a Digital Elevation Model. Aquifer highlighted in blue. Mtns = Mountains.

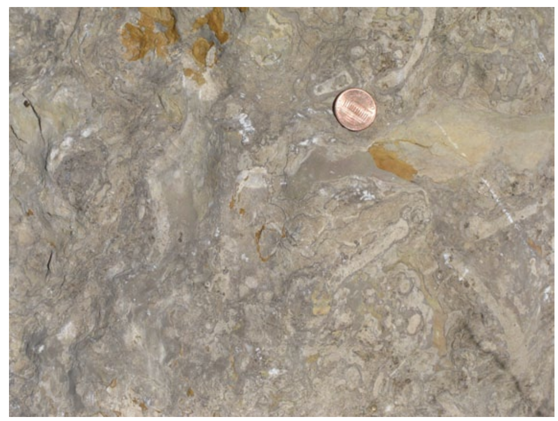


Stratigraphic cross section of Permian strata exposed in the Guadalupe Mountains in Texas along line A-A' (modified from King, 1948; Hayes, 1964; Tyrrell, 1969; Pray, 1988). Fm = Formation

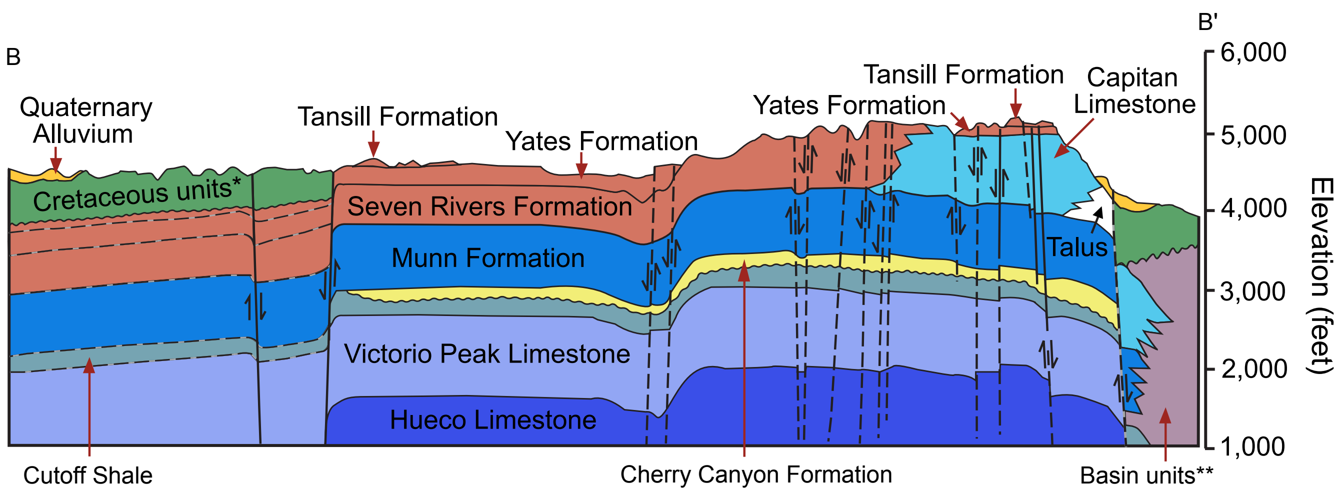
Capitan Limestone overlying basinal sandstones at El Capitan.

The Capitan Reef along the Permian Reef Geology Trail in McKittrick Canyon.

Outer-shelf facies of the Yates Formation behind and above the reef in McKittrick Canyon.



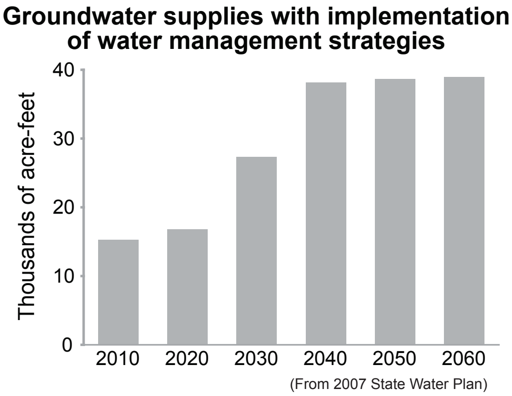
Reef limestone on the Permian Reef Geology Trail in McKittrick Canyon.



* includes Boracho Limestone (Levinson Member), Finlay Limestone, Cox Sandstone, Yearwood Formation

** includes Rustler Formation, Castile Limestone, Bell Canyon Sandstone, Cherry Canyon Sandstone

Stratigraphic cross section of Permian strata exposed in the Apache Mountains.



Aquifer characteristics

- Area of aquifer: 1,842 square miles
- Proportion of aquifer with groundwater conservation districts: 60 percent
- Number of counties containing the aquifer: 8

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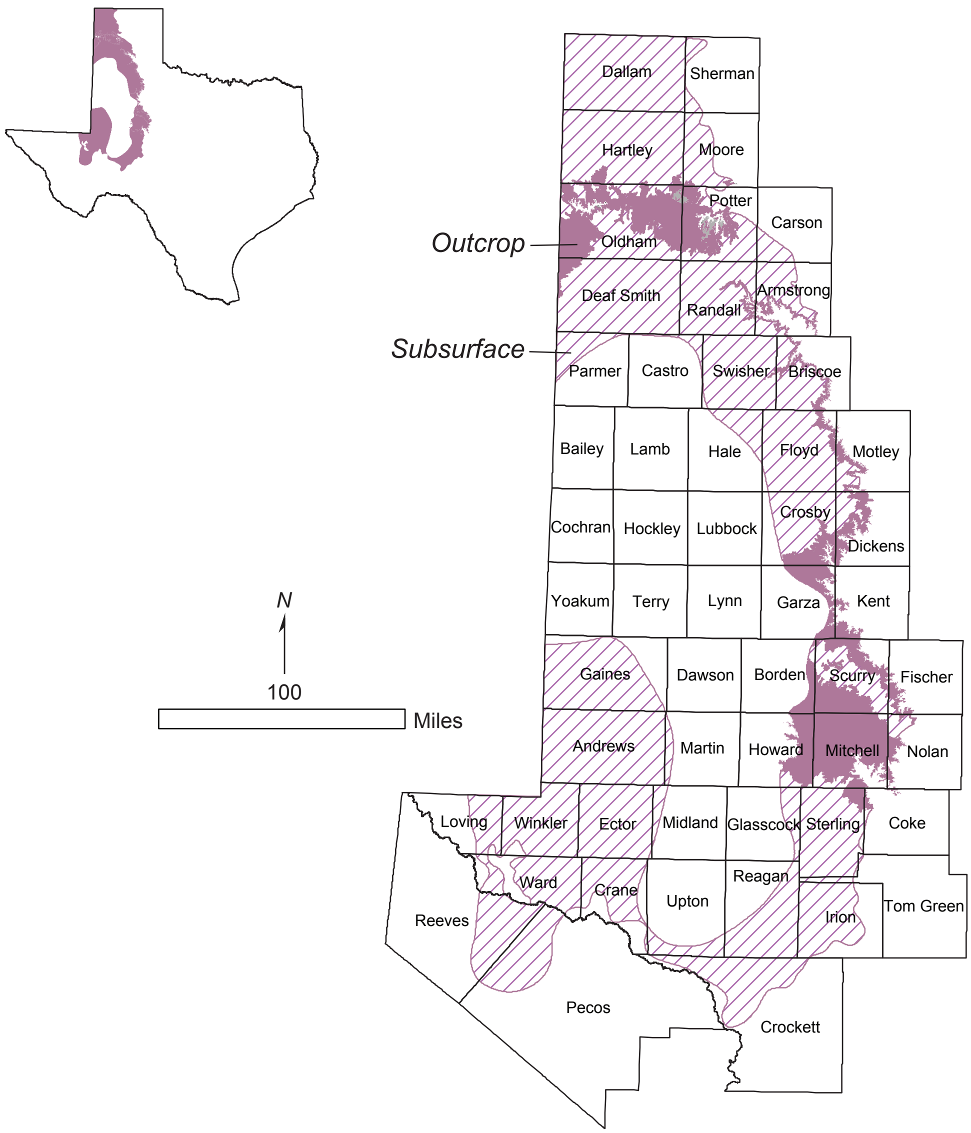
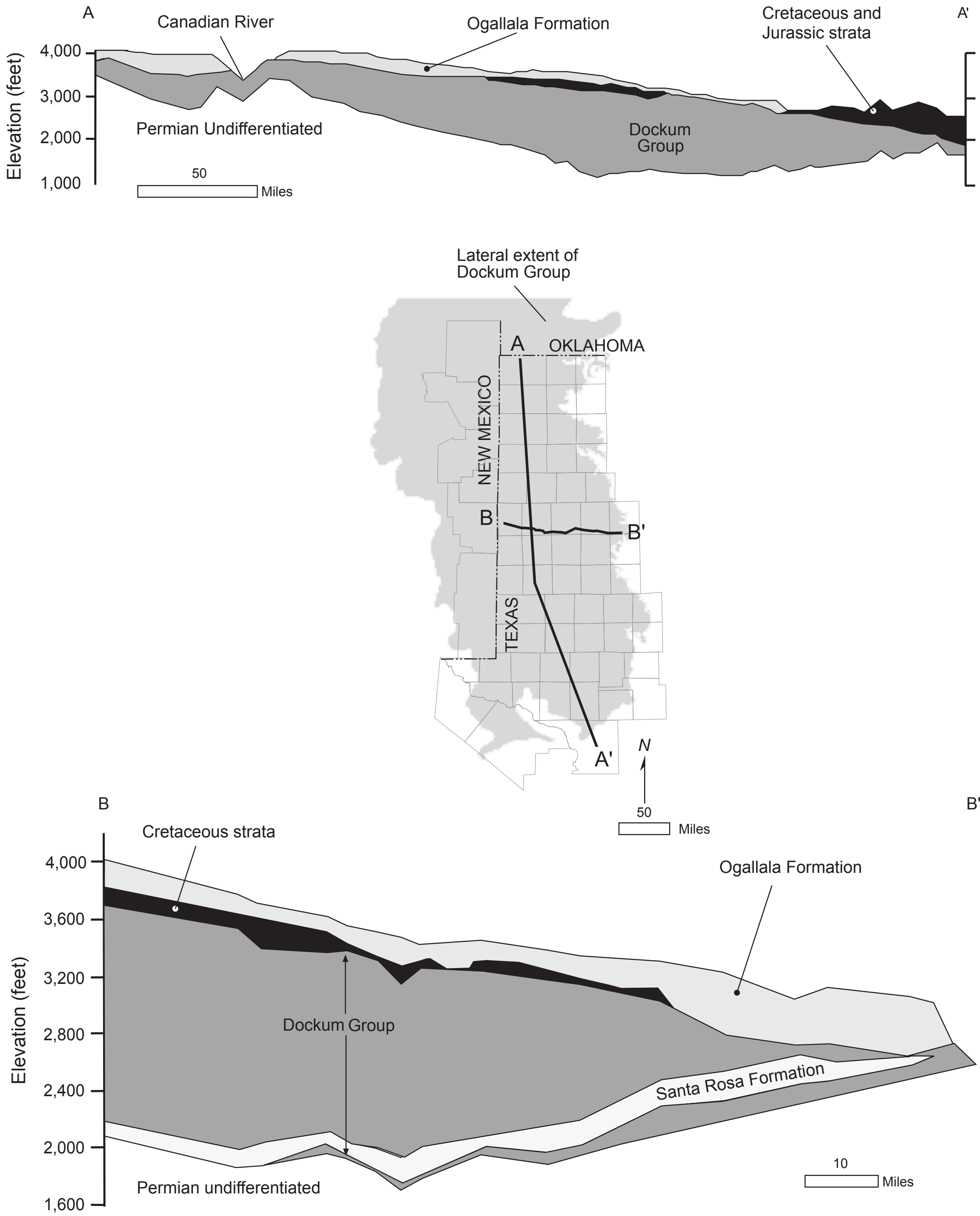
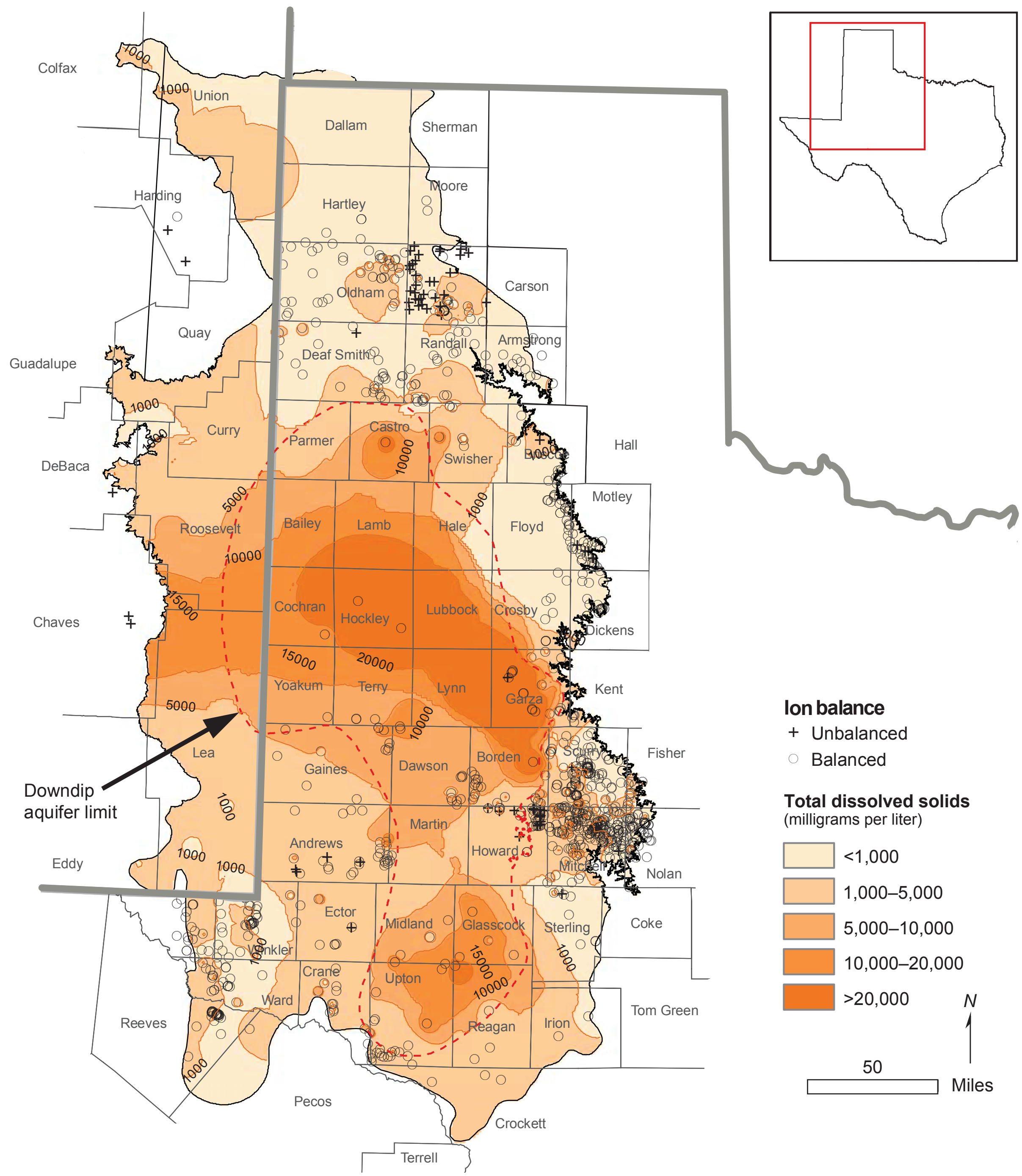
Dockum
Aquifer



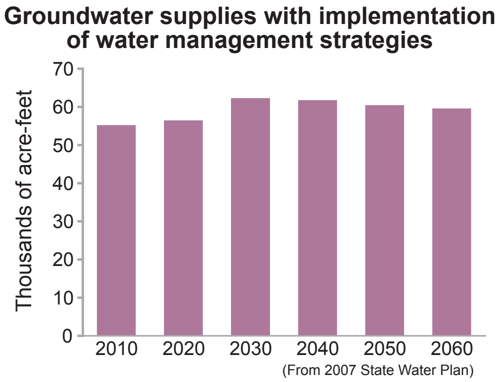
The Dockum Aquifer is a minor aquifer found in the northwest part of the state. It is defined stratigraphically by the Dockum Group and includes, from oldest to youngest, the Santa Rosa Formation, the Tecovas Formation, the Trujillo Sandstone, and the Cooper Canyon Formation. The Dockum Group consists 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 irrigation, municipal water supply, and oil field waterflooding operations, particularly in the southern High Plains. Water level declines and rises have occurred in different areas of the aquifer. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Dockum Aquifer, including new wells, desalination, and reallocation.



Geologic cross sections along (A-A') and across (B-B') the Dockum Aquifer (modified from Bradley and Kalaswad, 2003).



Total dissolved solids in groundwater from the Dockum Aquifer (from Ewing and others, 2008). mg/l=milligrams per liter



Aquifer characteristics

- Area of outcrop: 3,519 square miles
- Area in subsurface: 21,992 square miles
- Proportion of aquifer with groundwater conservation districts: 55 percent
- Number of counties containing the aquifer: 46

References

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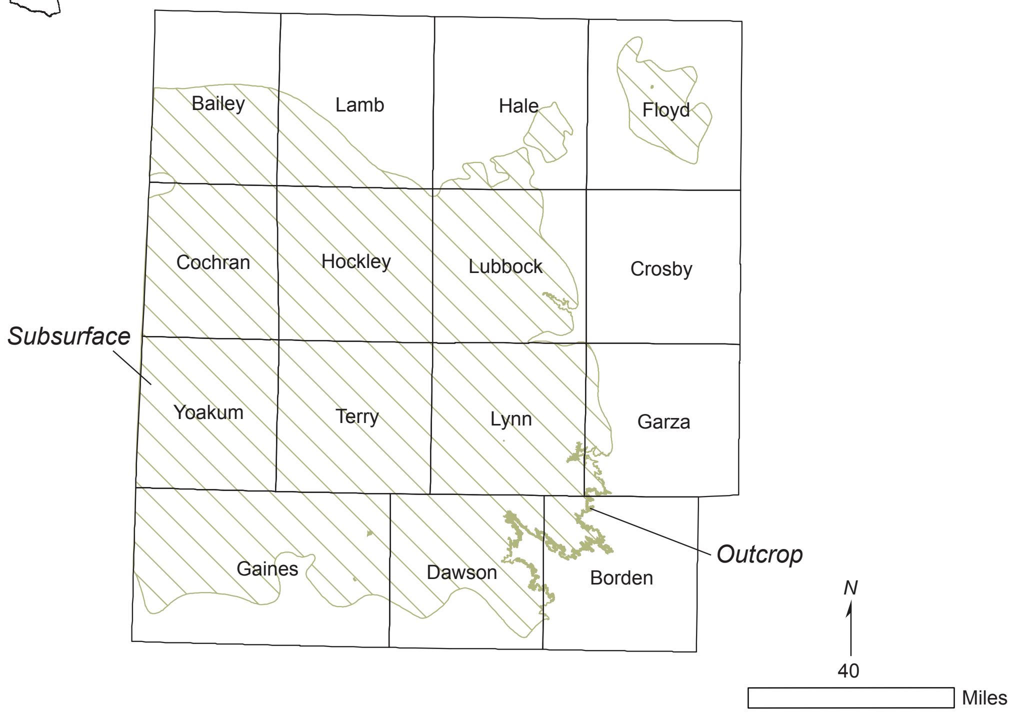
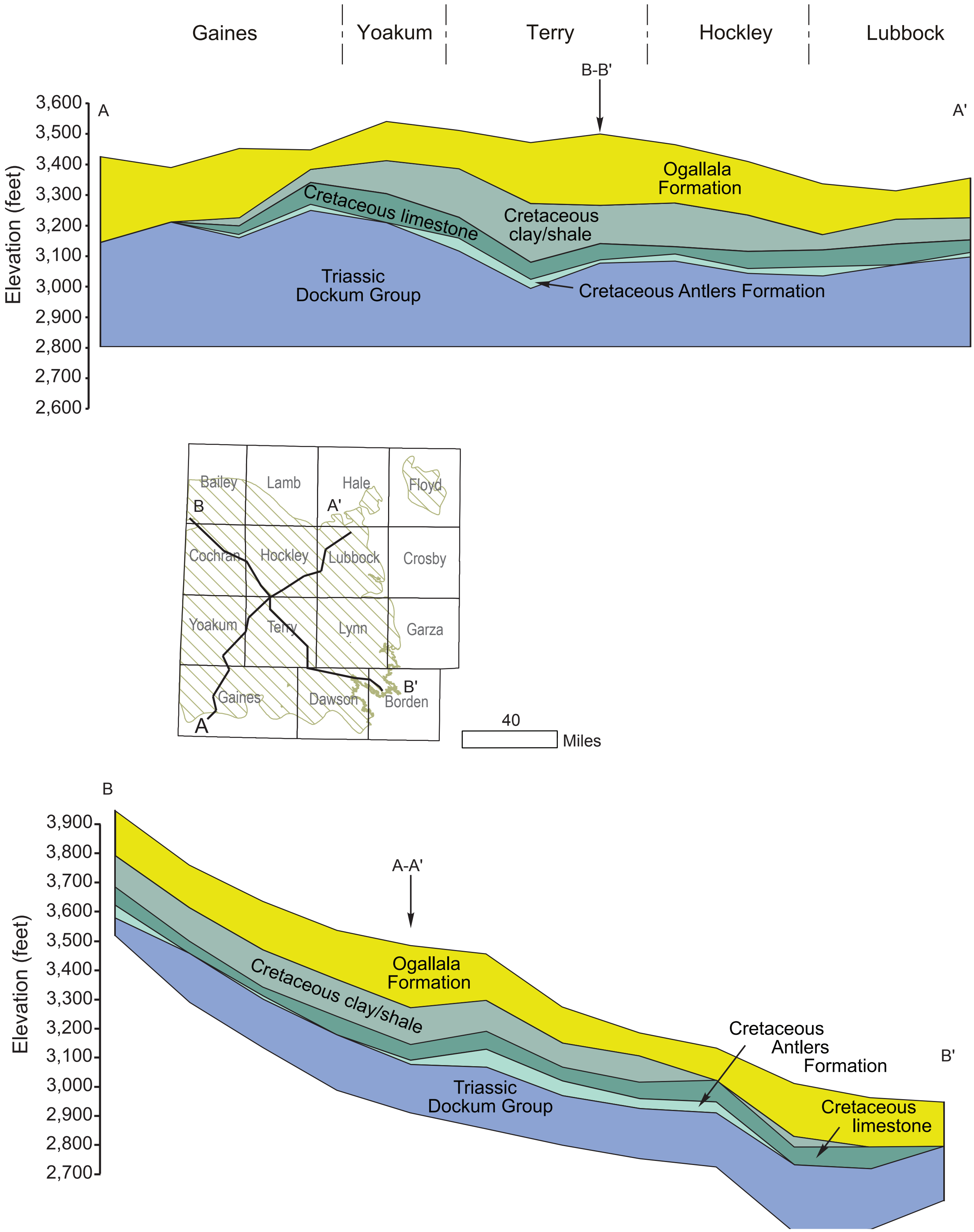
TWDB (Texas Water Development Board), 2007, Water for Texas 2007, Volume 2: Texas Water Development Board State Water Plan, 392 p.

The Dockum Aquifer (Tecovas Formation) in Palo Duro Canyon.

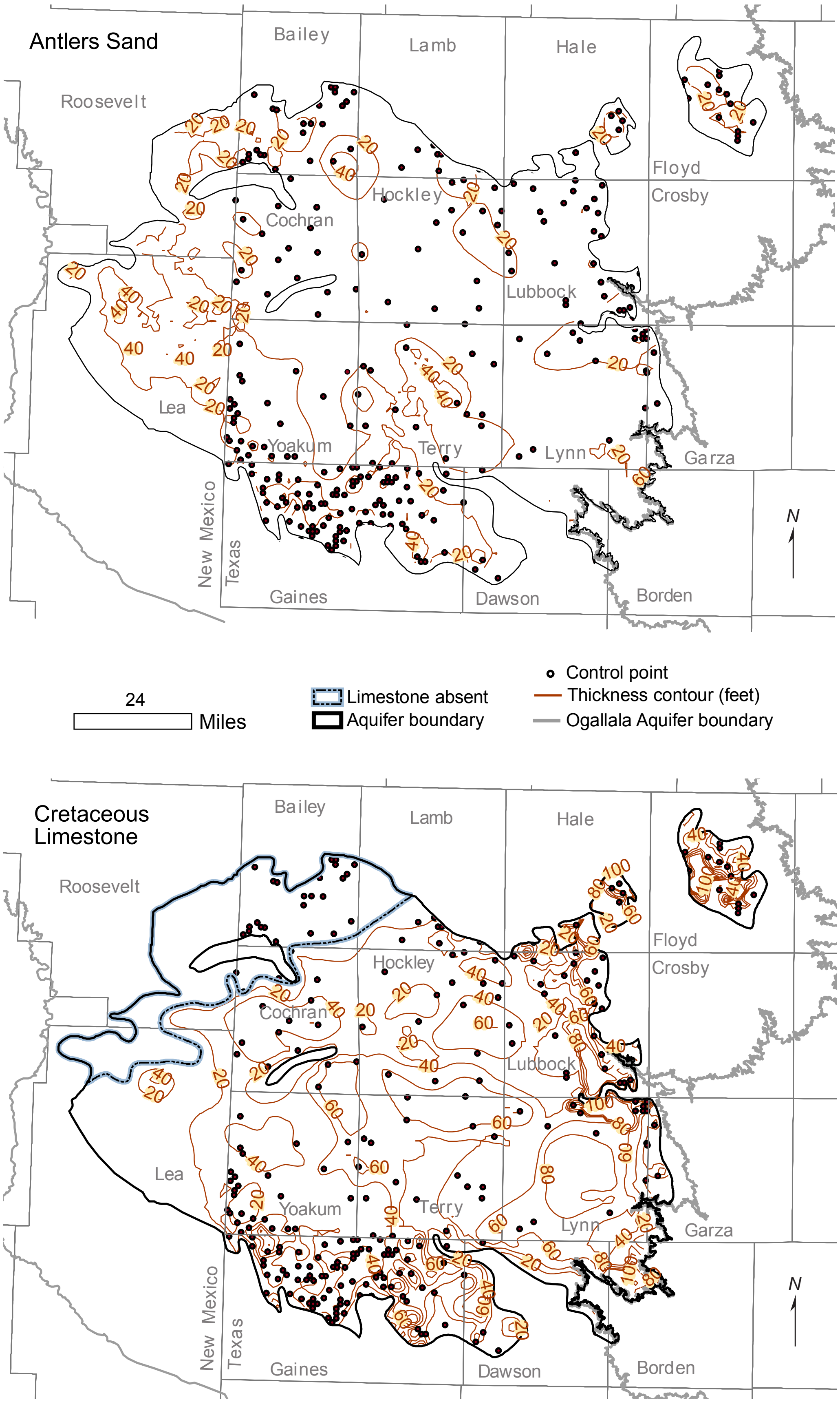
Edwards-Trinity (High Plains)
Aquifer



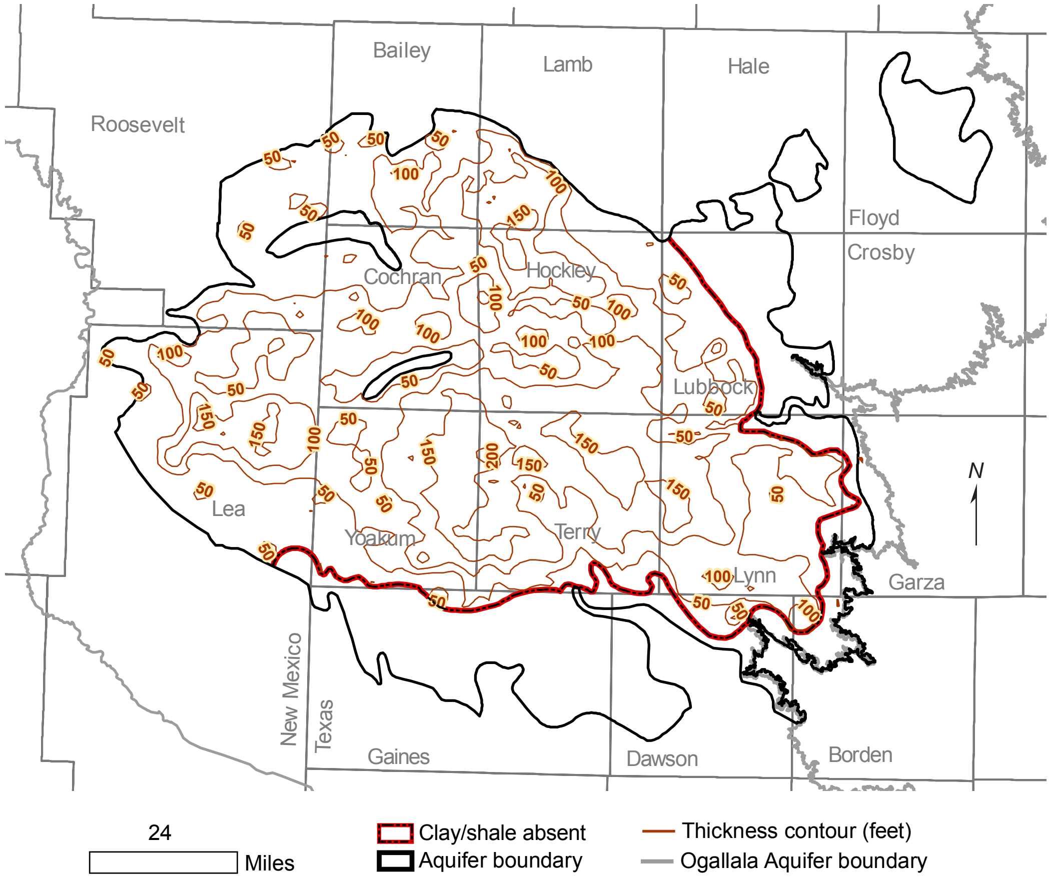
The Edwards-Trinity (High Plains) Aquifer is a minor aquifer that underlies about 9,000 square miles of the Ogallala Aquifer in western Texas and eastern New Mexico. Its water-producing units include sandstone of the Antlers Formation (Trinity Group) and limestone of the overlying Comanche Peak and Edwards formations. Regional groundwater flow in the aquifer is to the southeast, but locally flow is determined by the presence of Ogallala-filled paleochannels incised into the Cretaceous limestone. Recharge to the aquifer is primarily due to downward leakage from the younger Ogallala Aquifer. The greatest amount of recharge most likely occurs where low-permeability clay layers of the Duke Creek and Kiamichi formations, which lie between the Edwards-Trinity (High Plains) and Ogallala aquifers, are missing or thin or relatively permeable. Groundwater typically contains more total dissolved solids than does the overlying Ogallala Aquifer. It generally is slightly saline, with total dissolved solids ranging from 1,000 to 2,000 milligrams per liter, but can range from 400 to more than 3,000 milligrams per liter. Groundwater is poorest in quality, with total dissolved solids in excess of 20,000 milligrams per liter, where the aquifer is overlain by saline lakes or the gypsum-rich Tahoka and Double Lakes formations. Freshwater saturated thickness in the aquifer averages 126 feet. The aquifer provides water for irrigation, which uses approximately 95 percent of all groundwater that is pumped. Water level declines have occurred in some irrigated areas. Regional Water Planning Group O, in its 2006 Regional Water Plan, recommended constructing one or more brackish groundwater desalination plants to treat water from the Edwards-Trinity (High Plains) Aquifer in Lubbock County.



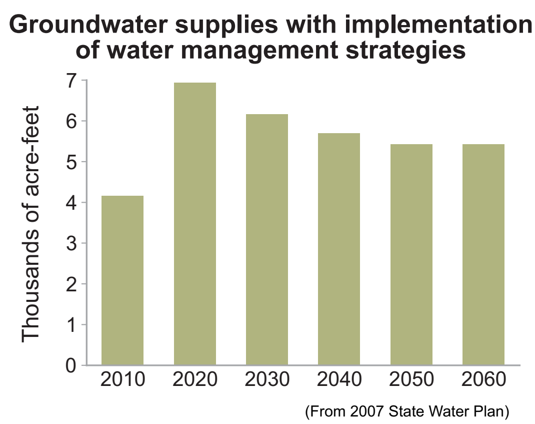
Geologic cross sections across the Edwards-Trinity (High Plains) Aquifer (modified from Blanford and others, 2008).



Thickness of the Antlers Sand, *above*, and Cretaceous Limestone, *below* (modified from Blanford and others, 2008).



The combined thickness of Cretaceous shale composed primarily of the Duck Creek and Kiamichi formations (modified from Blanford and others, 2008).



Aquifer characteristics

- Area of aquifer: 7,889 square miles
- Proportion of aquifer with groundwater conservation districts: 95 percent
- Number of counties containing the aquifer: 14

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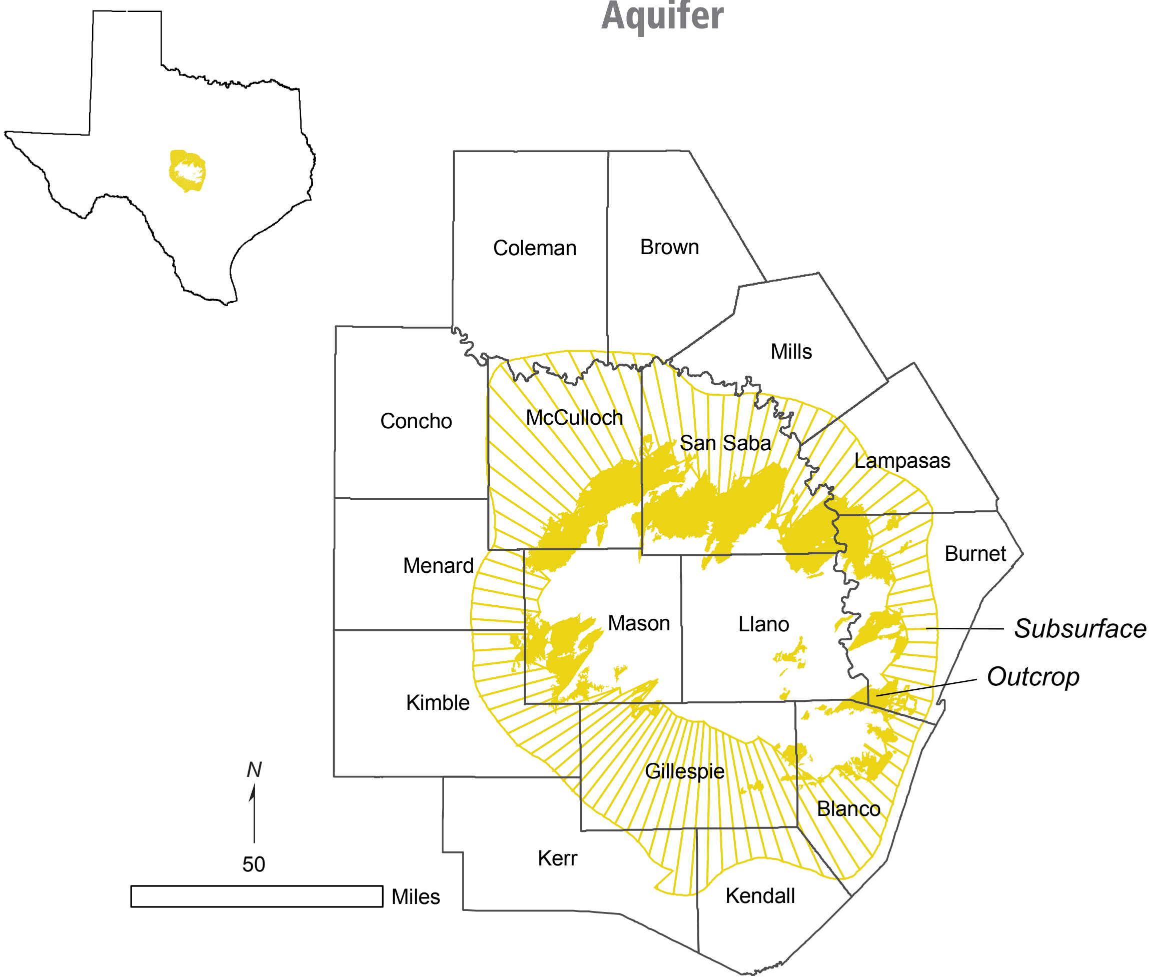
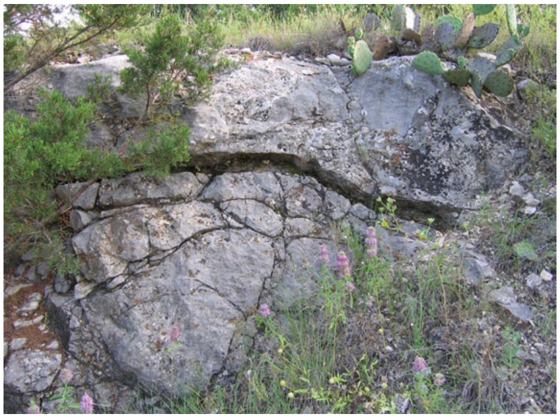
Ellenburger-San Saba
Aquifer

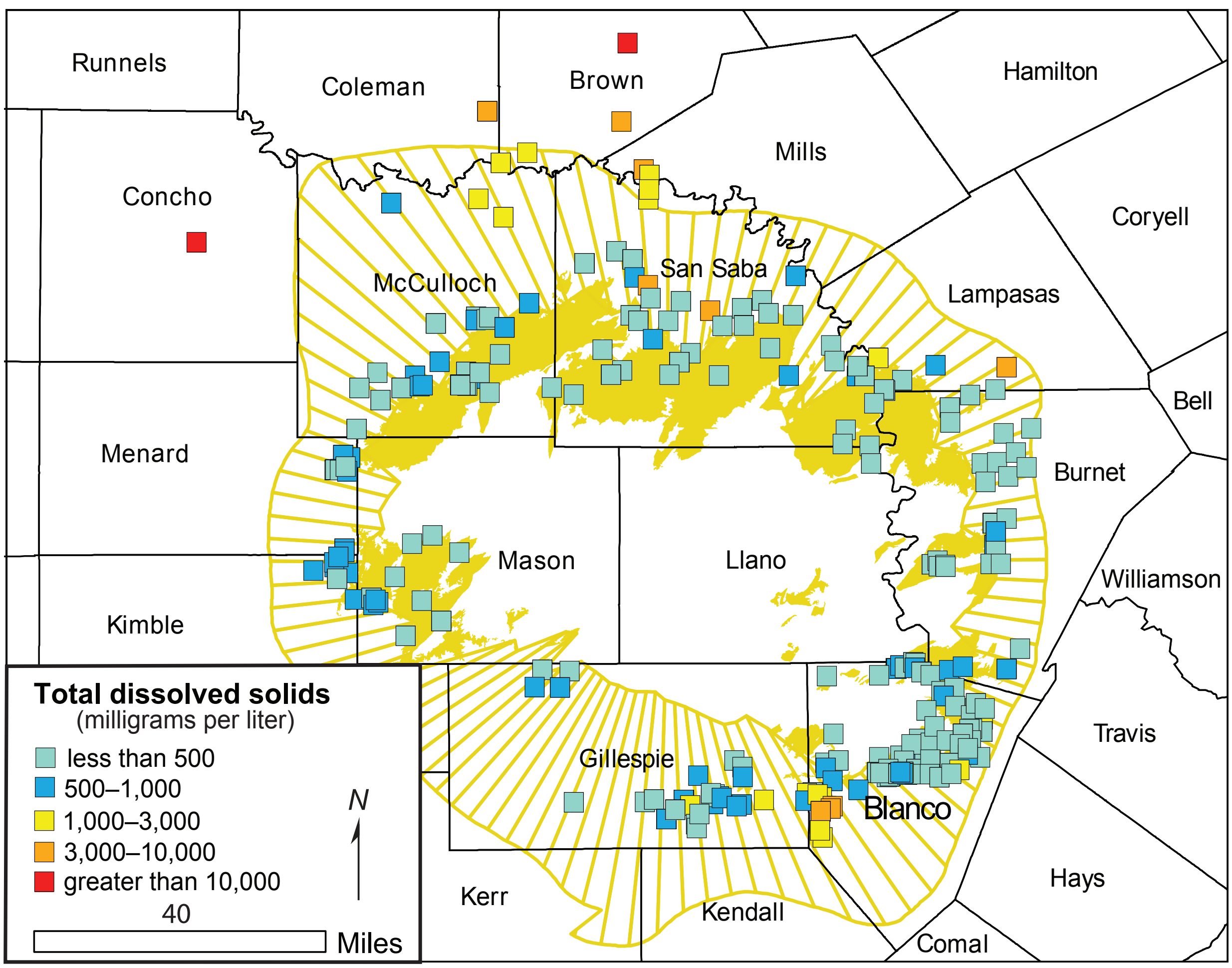


The Ellenburger–San Saba Aquifer is a minor aquifer that is found in parts of 15 counties in the Llano Uplift area of Central Texas. The aquifer consists of the Tanyard, Gorman, and Honeycut formations of the Ellenburger Group and the San Saba Limestone Member of the Wilberns Formation. The aquifer consists of a sequence of limestone and dolomite that crop out in a circular pattern around the Llano Uplift and dip radially into the subsurface away from the center of the uplift to depths of approximately 3,000 feet. Regional block faulting has significantly compartmentalized the aquifer. The maximum thickness of the aquifer is about 2,700 feet. Water is held in fractures, cavities, and solution channels and is commonly under confined conditions. The aquifer is highly permeable in places, as indicated by wells that yield as much as 1,000 gallons per minute and springs that issue from the aquifer, maintaining the base flow of streams in the area. Water produced from the aquifer is inherently hard and usually has less than 1,000 milligrams per liter of total dissolved solids. Fresh to slightly saline water extends downdip to depths of approximately 3,000 feet. Elevated concentrations of radium and radon also occur in the aquifer. Most of the groundwater is used for municipal purposes, and the remainder for irrigation and livestock. A large portion of water flowing from San Saba Springs, which is the water supply for the city of San Saba, is thought to be from the Ellenburger–San Saba and Marble Falls aquifers. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Ellenburger–San Saba Aquifer, including the development of a new well field in Llano County to supply the city of Llano, additional pumping from existing wells, temporary overdrafts, and the reallocation of supplies from users with surpluses to users with needs.

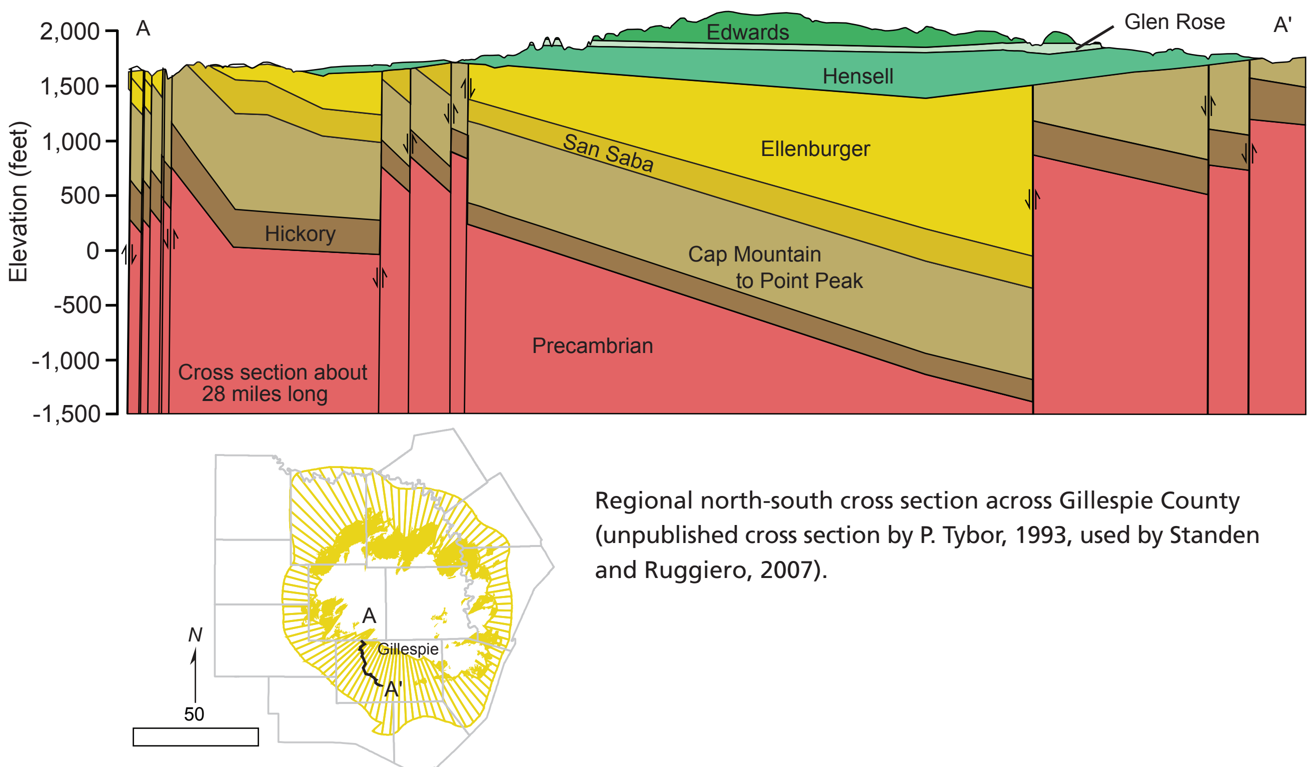


Gorman Formation, Ellenburger Group, southeast of Brady, Texas.

Tanyard Formation, Ellenburger Group, southeast of Brady, Texas.



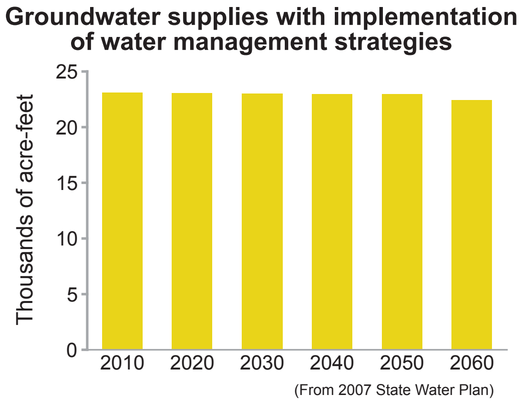
Total dissolved solids increase downdip and away from the Llano Uplift in wells that draw from the Ellenburger–San Saba Aquifer.



Regional north-south cross section across Gillespie County (unpublished cross section by P. Tybor, 1993, used by Standen and Ruggiero, 2007).

Honeycut Formation, Ellenburger Group, south of San Saba, Texas.

San Saba Limestone Member, southeast of Brady, Texas.



Aquifer characteristics

- Area of outcrop: 1,147 square miles
- Area in subsurface: 4,262 square miles
- Proportion of aquifer with groundwater conservation districts: 84 percent
- Number of counties containing the aquifer: 16

References

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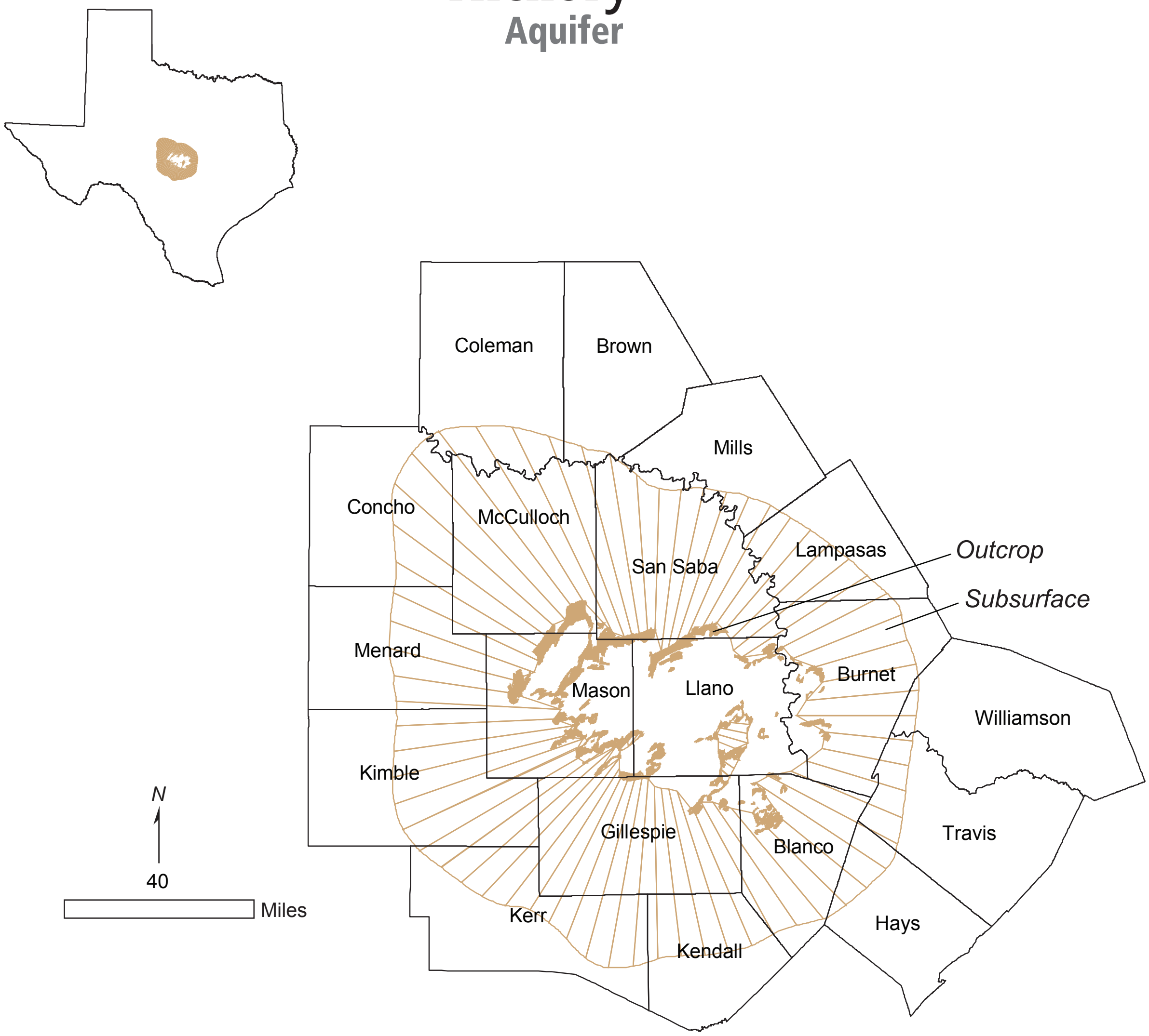
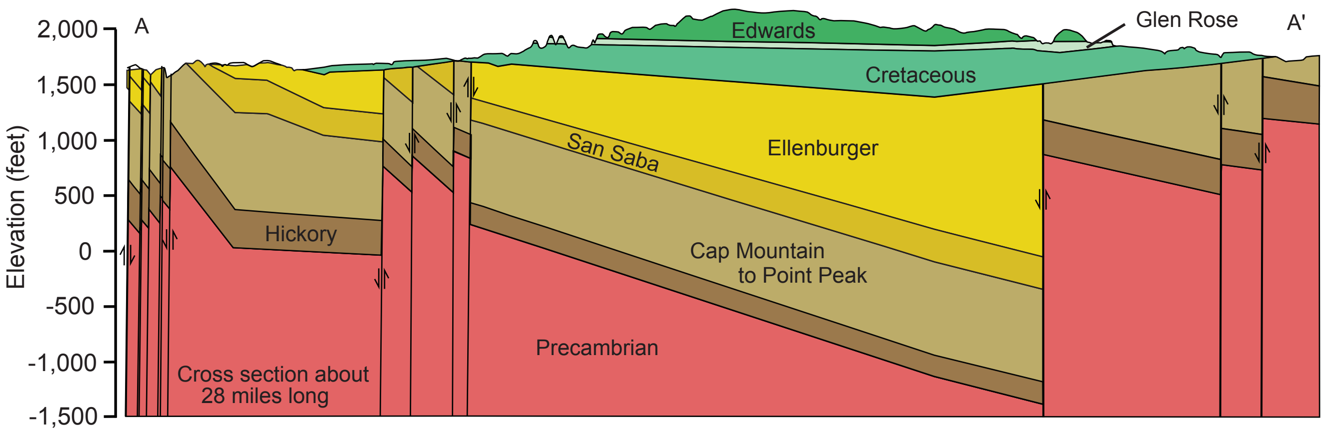
Hickory
Aquifer

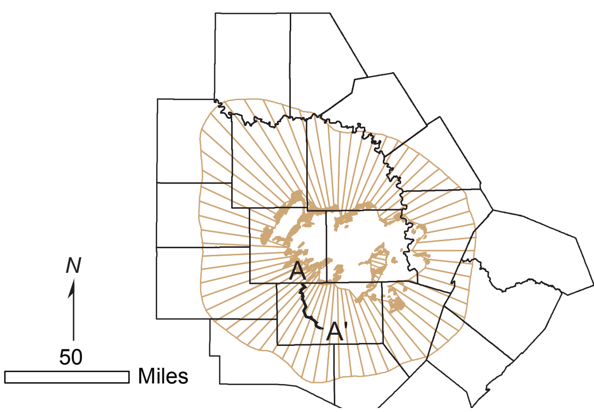


The Hickory Aquifer,
a minor aquifer found in the central part of the state, consists of the water-bearing parts of the Hickory Sandstone Member of the Riley Formation. The Hickory Aquifer reaches a maximum thickness of 480 feet, and freshwater saturated thickness averages about 350 feet. Although the groundwater is generally fresh, with total dissolved solids concentrations of less than 1,000 milligrams per liter, the upper portion of the aquifer typically contains iron in excess of the state's secondary drinking water standards. Of greater concern is naturally occurring radioactivity: gross alpha radiation, radium, and radon are commonly found in excess of the state's primary drinking water standards. The groundwater is used for irrigation throughout its extent and for municipal supply in the cities of Brady, Mason, and Fredericksburg. Slight water level fluctuations occur seasonally in irrigated areas. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Hickory Aquifer, including constructing new wells, pumping additional water from existing wells, and maintaining existing supplies through supplemental or replacement wells. In addition, the Region F Regional Water Planning Group recommended treating water from the aquifer and distributing it as drinking water through a bottled water program in Concho and McCulloch counties.

Faulted Hickory Sandstone exposed along State Highway 71 southeast of Llano, Texas.

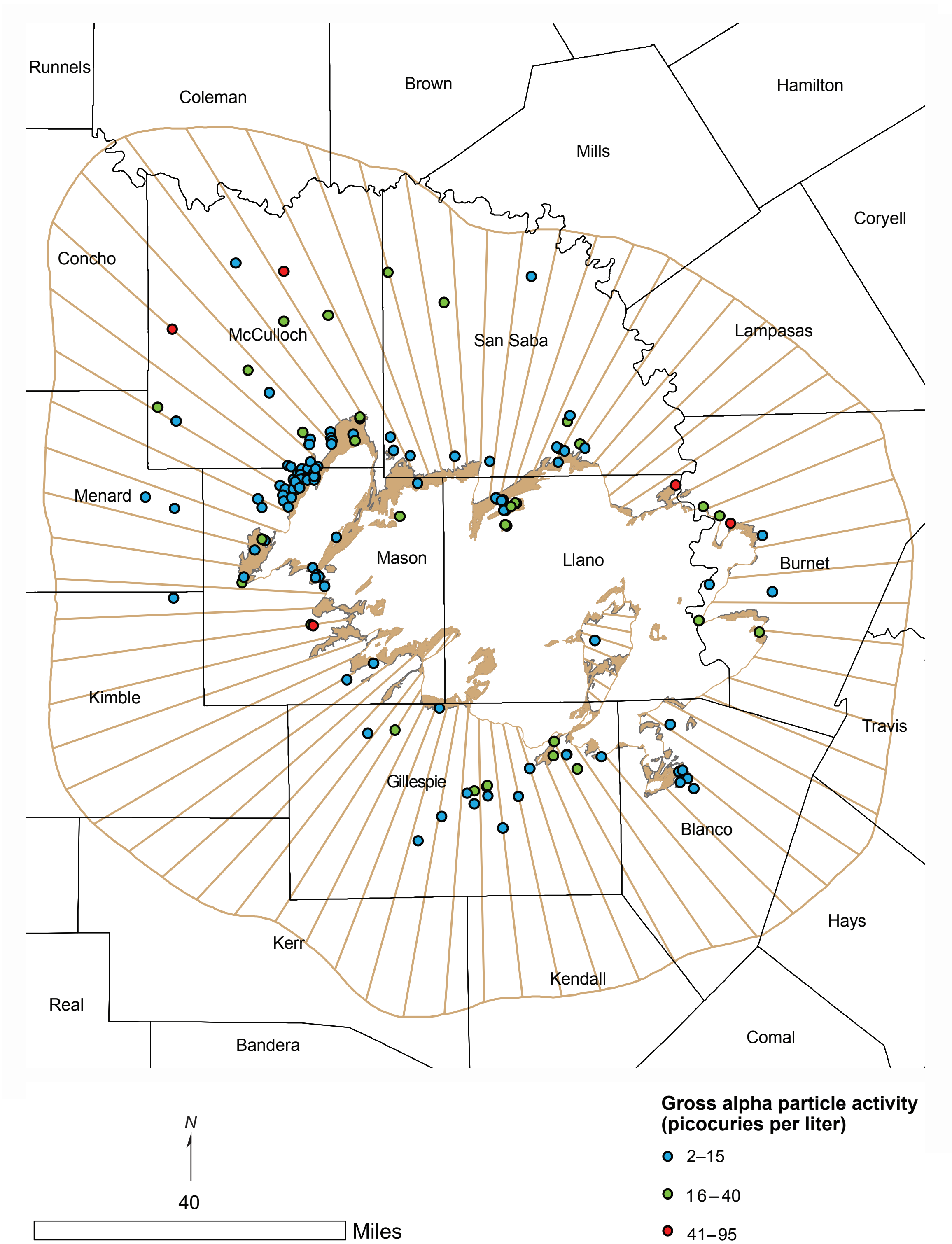
Hickory Sandstone. Note possible herringbone cross-bedding typical of tidal deposits (along State Highway 71).



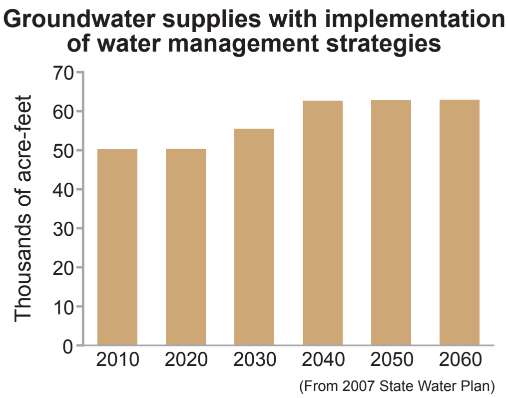


Regional north-south cross section across Gillespie County (unpublished cross section by P. Tybor, 1993, used by Standen and Ruggiero, 2007).

Hickory Sandstone exposed along State Highway 71 northwest of Llano, Texas.



Gross alpha particle activity in Hickory wells. The primary maximum concentration level for gross alpha particle activity, established by the Texas Commission on Environmental Quality, is 15 picocuries per liter.



Aquifer characteristics

- Area of outcrop: 271 square miles
- Area in subsurface: 8,193 square miles
- Proportion of aquifer with groundwater conservation districts: 85 percent
- Number of counties containing the aquifer: 19

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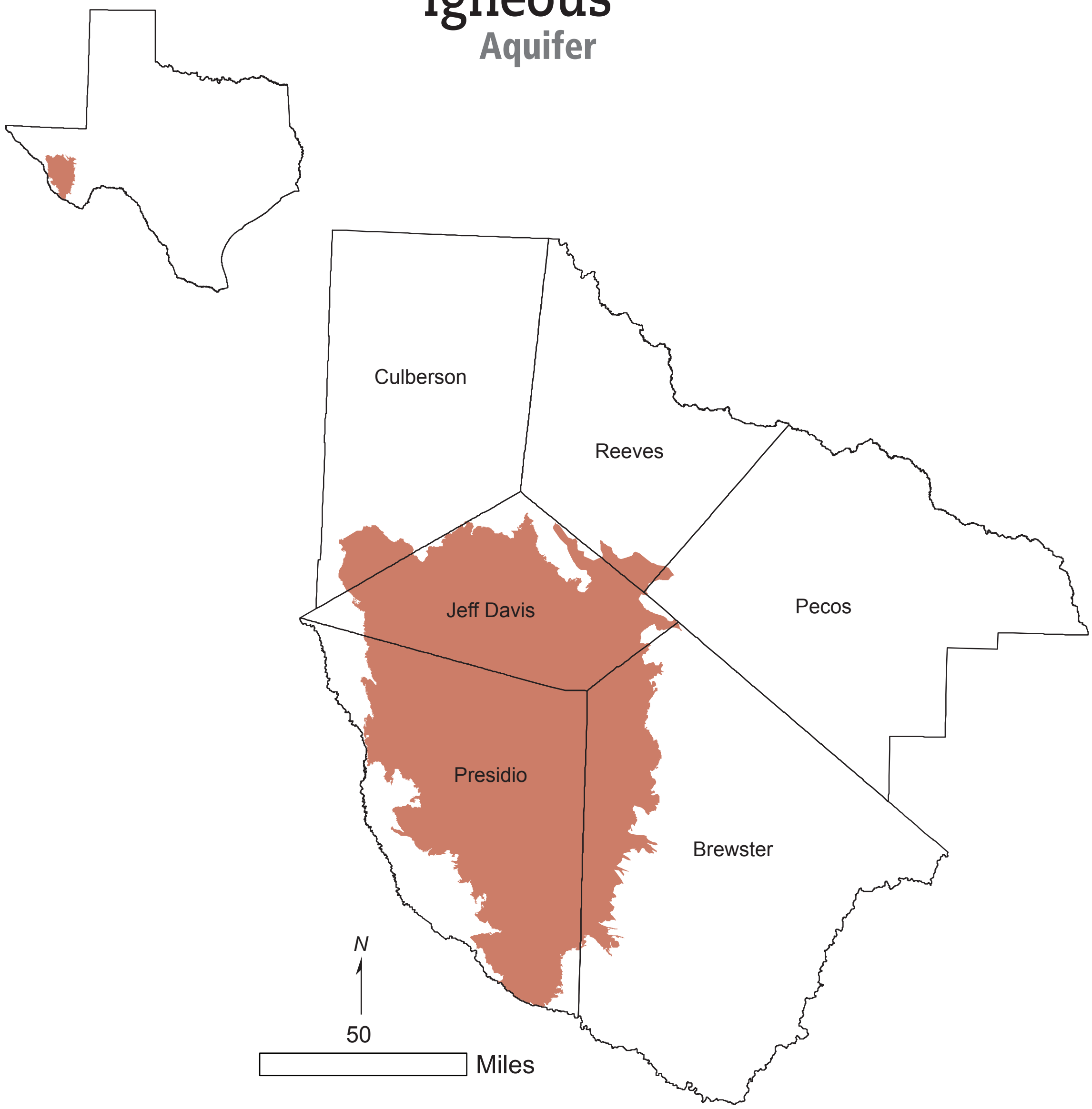
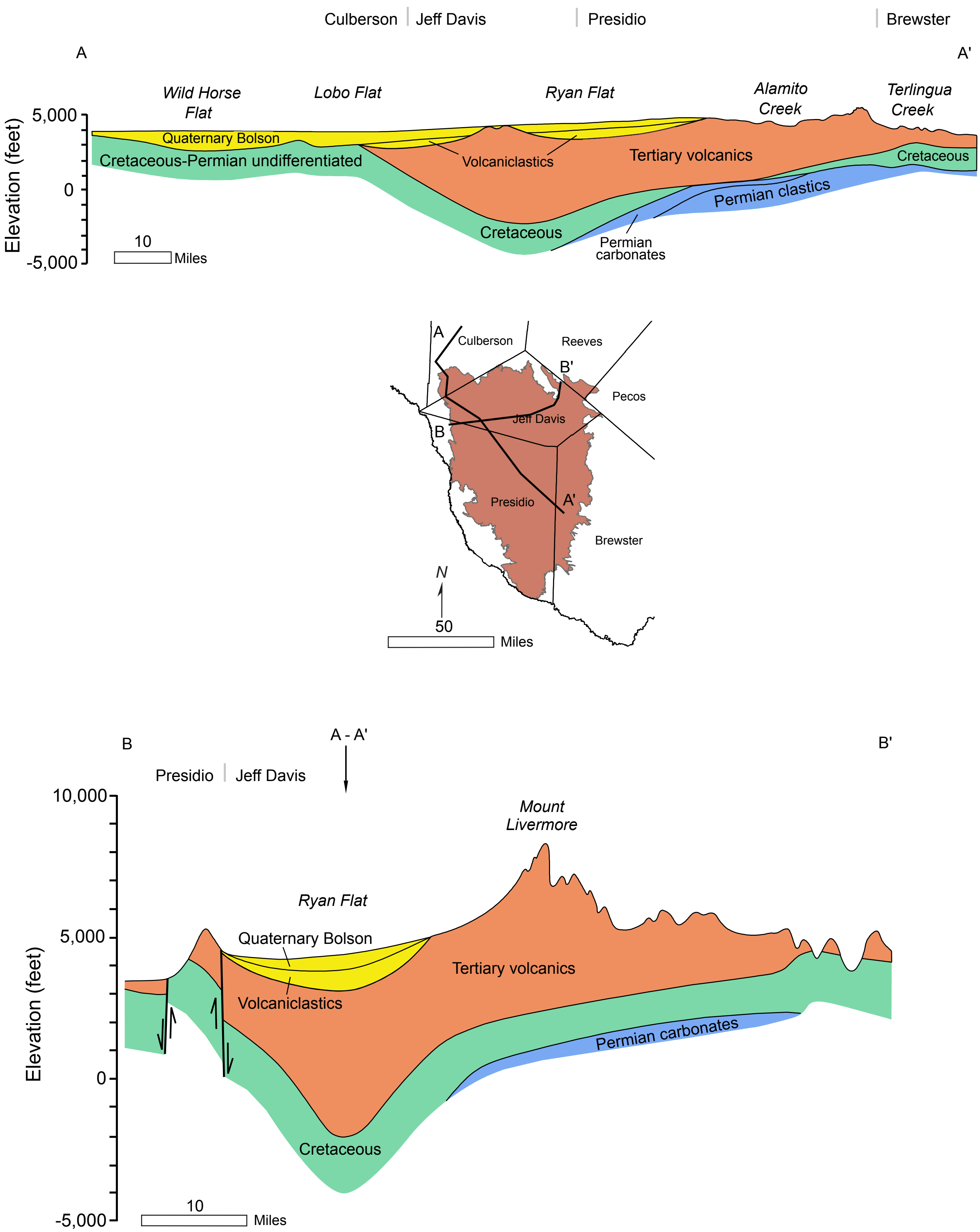
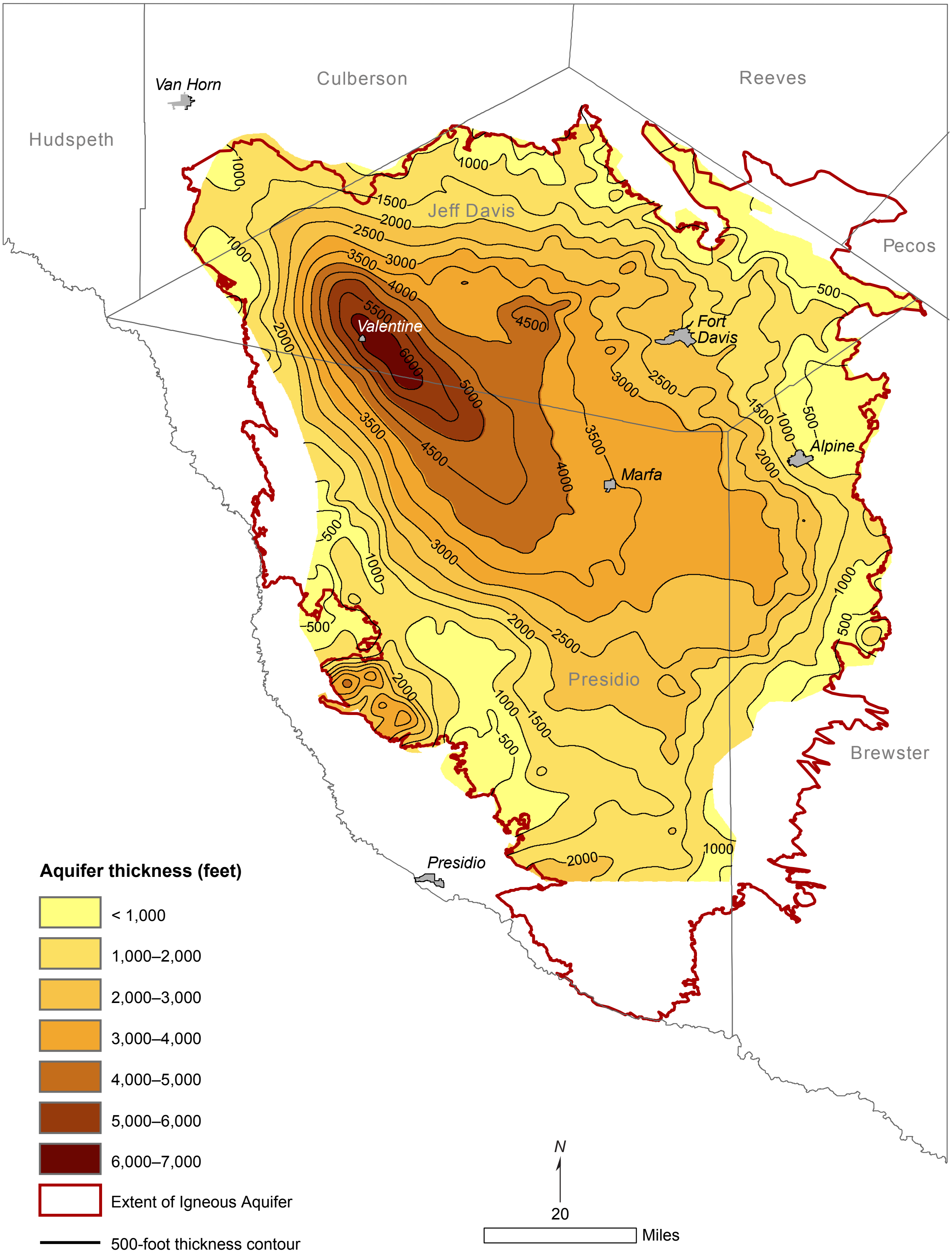
Igneous
Aquifer



The Igneous Aquifer,
located in Far West Texas, is designated as a minor aquifer. The aquifer consists of volcanic rocks made up of a complex series of welded pyroclastic rock, lava, and volcaniclastic sediments and includes more than 40 different named units as much as 6,000 feet thick. Freshwater saturated thickness averages about 1,800 feet. The best water-bearing zones are found in igneous rocks with primary porosity and permeability, such as vesicular basalts, interflow zones in lava successions, sandstone, conglomerate, and breccia. Faulting and fracturing enhance aquifer productivity in less permeable rock units. Although water in the aquifer is fresh and contains less than 1,000 milligrams per liter of total dissolved solids, elevated levels of silica and fluoride have been found in water from some wells, reflecting the igneous origin of the rock. Water is primarily used to meet municipal needs for the cities of Alpine, Fort Davis, and Marfa, as well as some agricultural needs. There have been no significant water level declines in wells measured by the TWDB throughout the aquifer. The Far West Texas Water Planning Group, in its 2006 Regional Water Plan, did not recommend any water management strategies using the Igneous Aquifer.



Geologic cross sections across the Igneous Aquifer (modified from Gates and others, 1980; Olson, 2002; Beach and others, 2004).

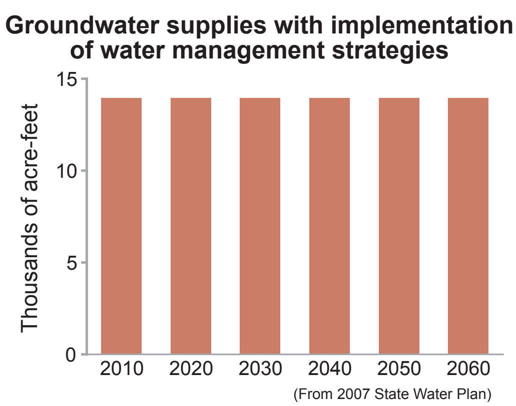


Thickness of the Igneous Aquifer (modified from Olson, 2002; Beach and others, 2004).

Tertiary volcanic rocks of the Igneous Aquifer taken in and around Davis Mountains State Park. Rocks are mainly rhyolites and rhyolitic ash-flow tuffs of the Barrel Springs and Sleeping Lion formations.

Volcanic rocks of the Barrel Springs Formation taken in Davis Mountains State Park.

Rock wall at entrance to Davis Mountains State Park displaying the variety of rock types in the area.



Aquifer characteristics

- Area of aquifer: 6,075 square miles
- Proportion of aquifer with ground-water conservation districts: 99 percent
- Number of counties containing the aquifer: 6

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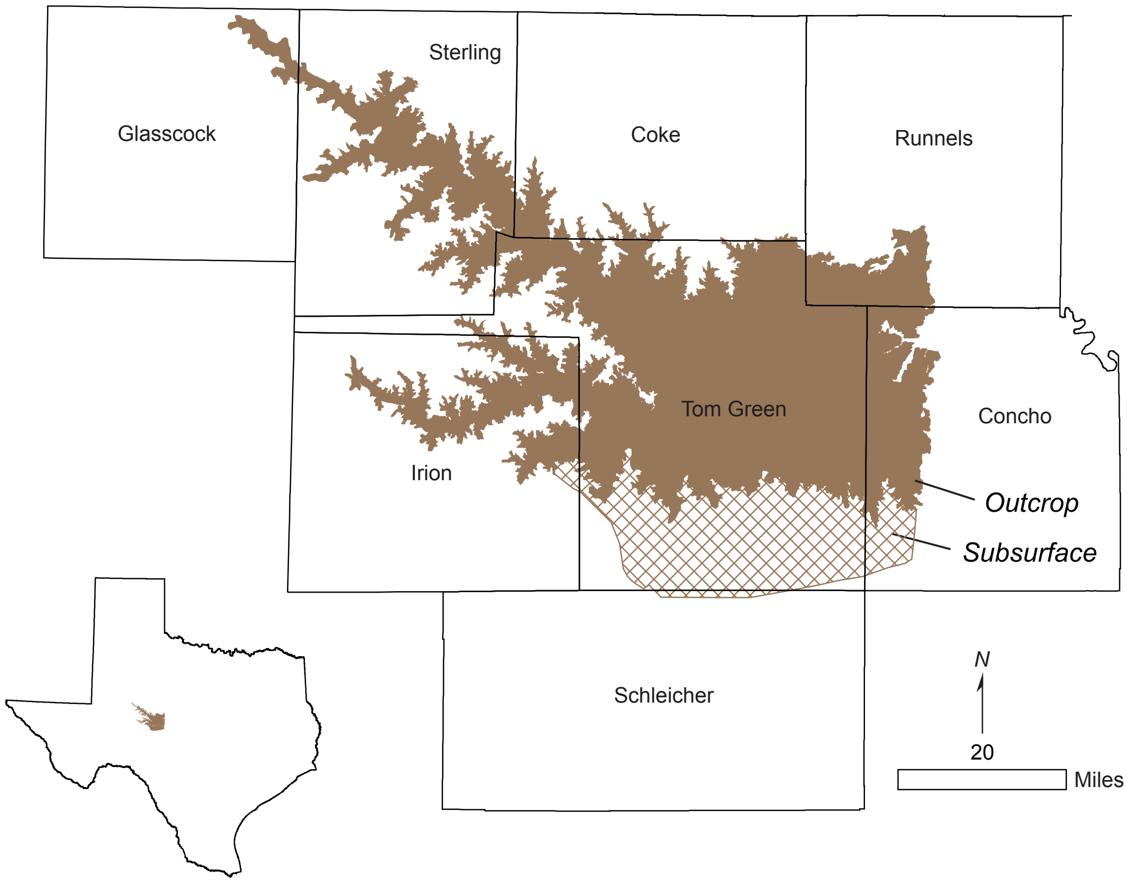
Lipan
Aquifer

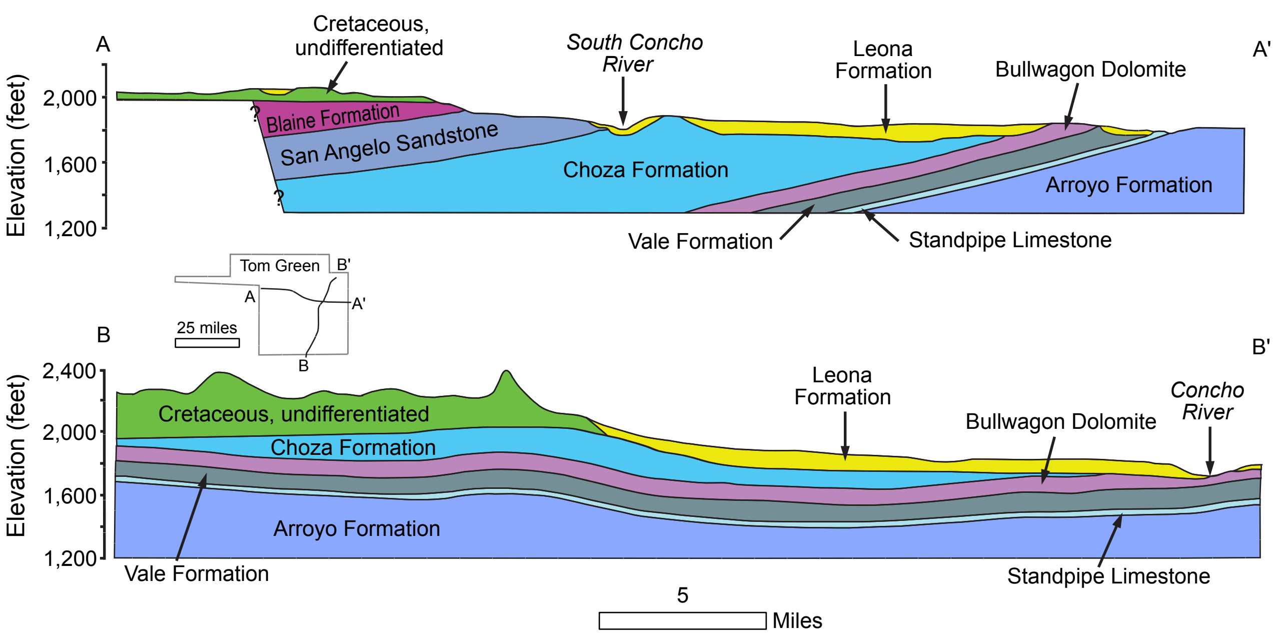


The Lipan Aquifer

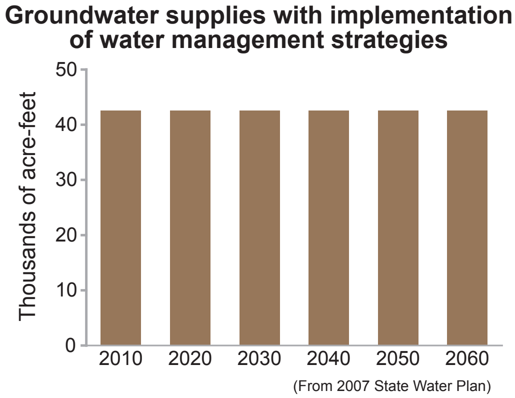
is a minor aquifer found in parts of Coke, Concho, Glasscock, Irion, Runnels, Schleicher, Sterling, and Tom Green counties in west-central Texas. The aquifer includes water-bearing alluvium and the updip portions of older, underlying strata. The alluvium includes as much as 125 feet of saturated sediments of the Quaternary Leona Formation. These deposits consist mostly of gravels and conglomerates cemented with sandy lime and layers of clay. The formation generally fines upward with conglomerates existing mainly in locations of thicker alluvium. The underlying strata include the San Angelo Sandstone of the Pease River Group and the Choza Formation, Bullwagon Dolomite, Vale Formation, Standpipe Limestone, and Arroyo Formation of the Clear Fork Group. These units are predominantly limestones and shales. Groundwater in the alluvial deposits and the upper parts of the older rocks is hydraulically connected, and most wells in the area are completed in both units. Groundwater flow in the Lipan Aquifer does not appear to be structurally controlled. Higher production wells appear to correspond to alluvial deposits overlying the Choza, Bullwagon, and Vale formations. In these areas, thick alluvial deposits with conglomerates lie near the contact with the Permian. Groundwater in the alluvium ranges from fresh to slightly saline, containing between 350 and 3,000 milligrams per liter of total dissolved solids, and is very hard. Water in the underlying parts of the Choza Formation and Bullwagon Dolomite tends to be moderately saline with total dissolved solids in excess of 3,000 milligrams per liter. The aquifer is primarily used for irrigation but also supports livestock and municipal, domestic, and manufacturing uses. Because of drought and heavy irrigation pumping in the late 1990s, water levels decreased significantly in some areas, and the aquifer could not be pumped through the entire irrigation season. In other areas, however, the aquifer could be pumped, but only at a reduced rate. The Region F Regional Water Planning Group did not recommend any water management strategies using the Lipan Aquifer in its 2006 Regional Water Plan.

View looking south from Cretaceous rocks toward the Leona Formation.

Rocks of the Leona Formation along Farm to Market 2288 at San Angelo State Park.



Geologic cross sections of the Lipan Aquifer in Tom Green County, Texas (modified from Willis, 1954).



Aquifer characteristics

- Area of outcrop: 1,565 square miles
- Area in subsurface: 422 square miles
- Proportion of aquifer with groundwater conservation districts: 85 percent
- Number of counties containing the aquifer: 8

Quaternary sediments of the Leona Formation at San Angelo State Park.

Gravels and clays of the Leona Formation along Farm to Market 2034 northwest of San Angelo, Texas.

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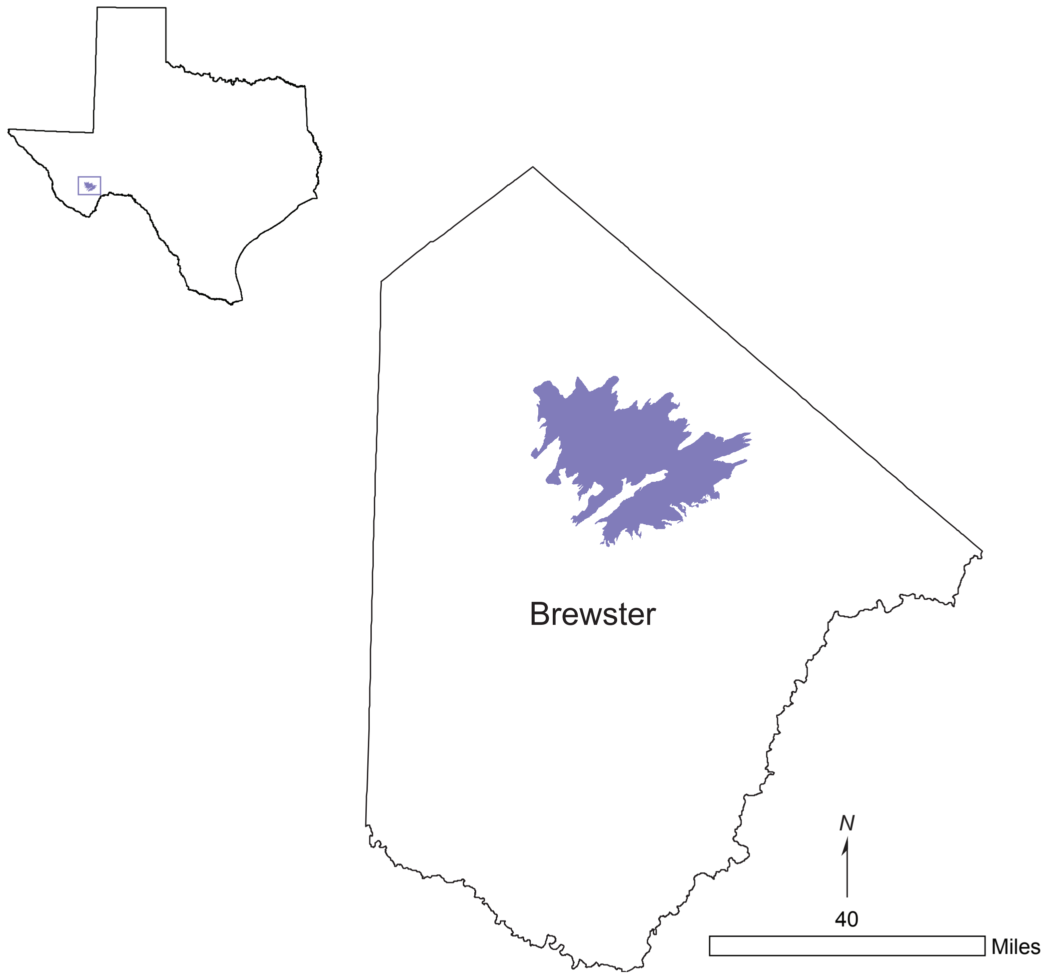
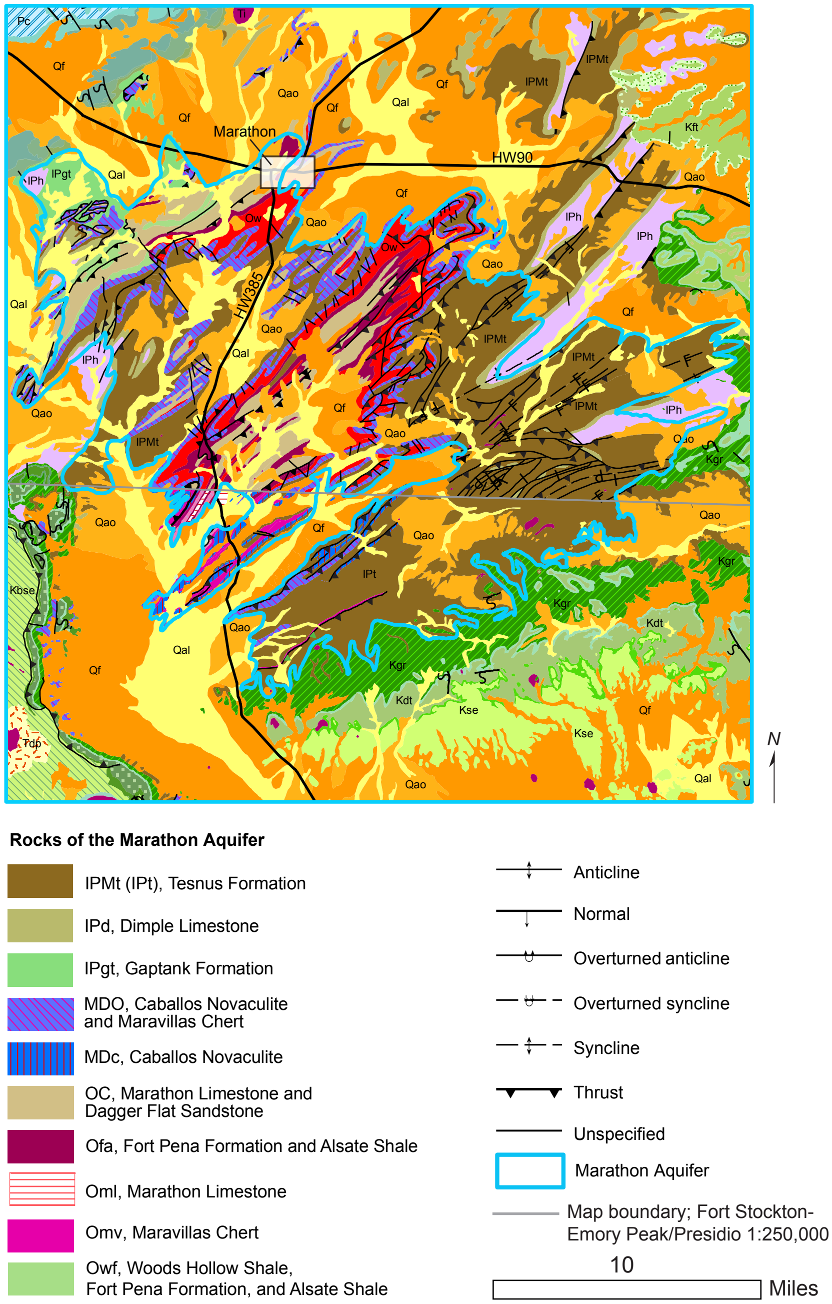
Marathon
Aquifer



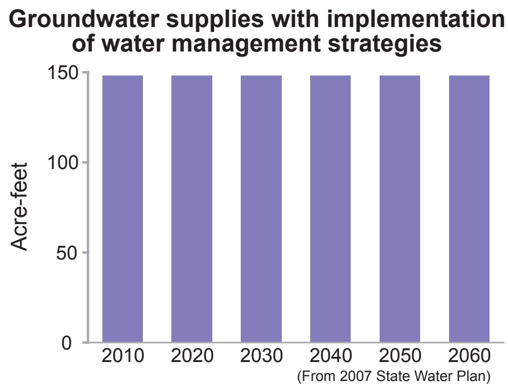
The Marathon Aquifer, a minor aquifer, occurs entirely within north-central Brewster County. The aquifer consists of tightly folded and faulted rocks of the Gaptank Formation, the Dimple Limestone, the Tesnus Formation, the Caballos Novaculite, the Maravillas Chert, the Fort Pena Formation, and the Marathon Limestone. Although maximum thickness of the aquifer is about 900 feet, well depths are commonly less than 250 feet. Water in the aquifer is under unconfined conditions in fractures, joints, and cavities; however, artesian conditions are common in areas where the aquifer rocks are buried beneath younger formations. The Marathon Limestone is at or near land surface and is the most productive part of the aquifer. Many of the shallow wells in the region actually produce water from alluvial deposits that cover parts of the rock formations. Total dissolved solids range from 500 to 1,000 milligrams per liter, and the water, although very hard, is generally suitable for most uses. Groundwater is used primarily for municipal water supply by the city of Marathon and for domestic and livestock purposes. The Region E Planning Group, in its 2006 Regional Water Plan, did not recommend any water management strategies using the Marathon Aquifer.



Geologic map of the Marathon Aquifer area based on the 1:250,000 Digital Geological Atlas of Texas (USGS and TWDB, 2006).

View to the east across the Marathon Aquifer from U.S. Highway 385 south of Marathon, Texas.

Rocks of the Marathon Aquifer are highly fractured, such as this exposure of the Caballos Novaculite.



Aquifer characteristics

- Area of aquifer: 390 square miles
- Proportion of aquifer with groundwater conservation districts: 100 percent
- Number of counties containing the aquifer: 1

References

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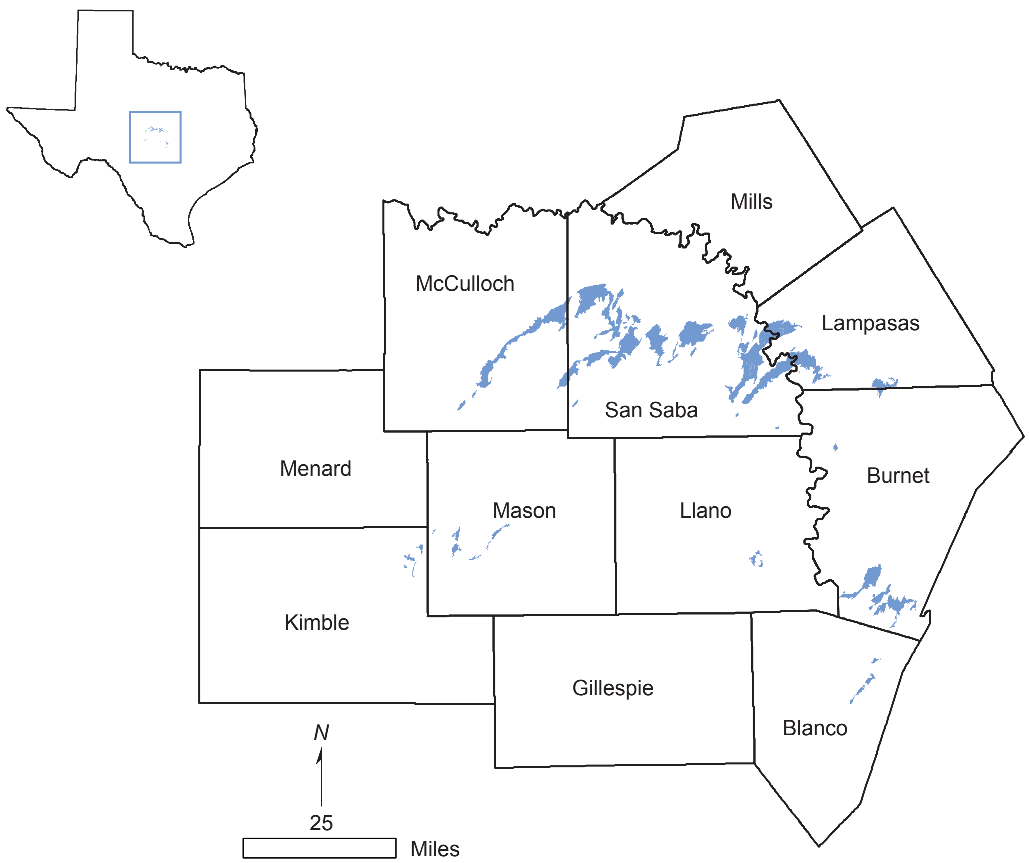
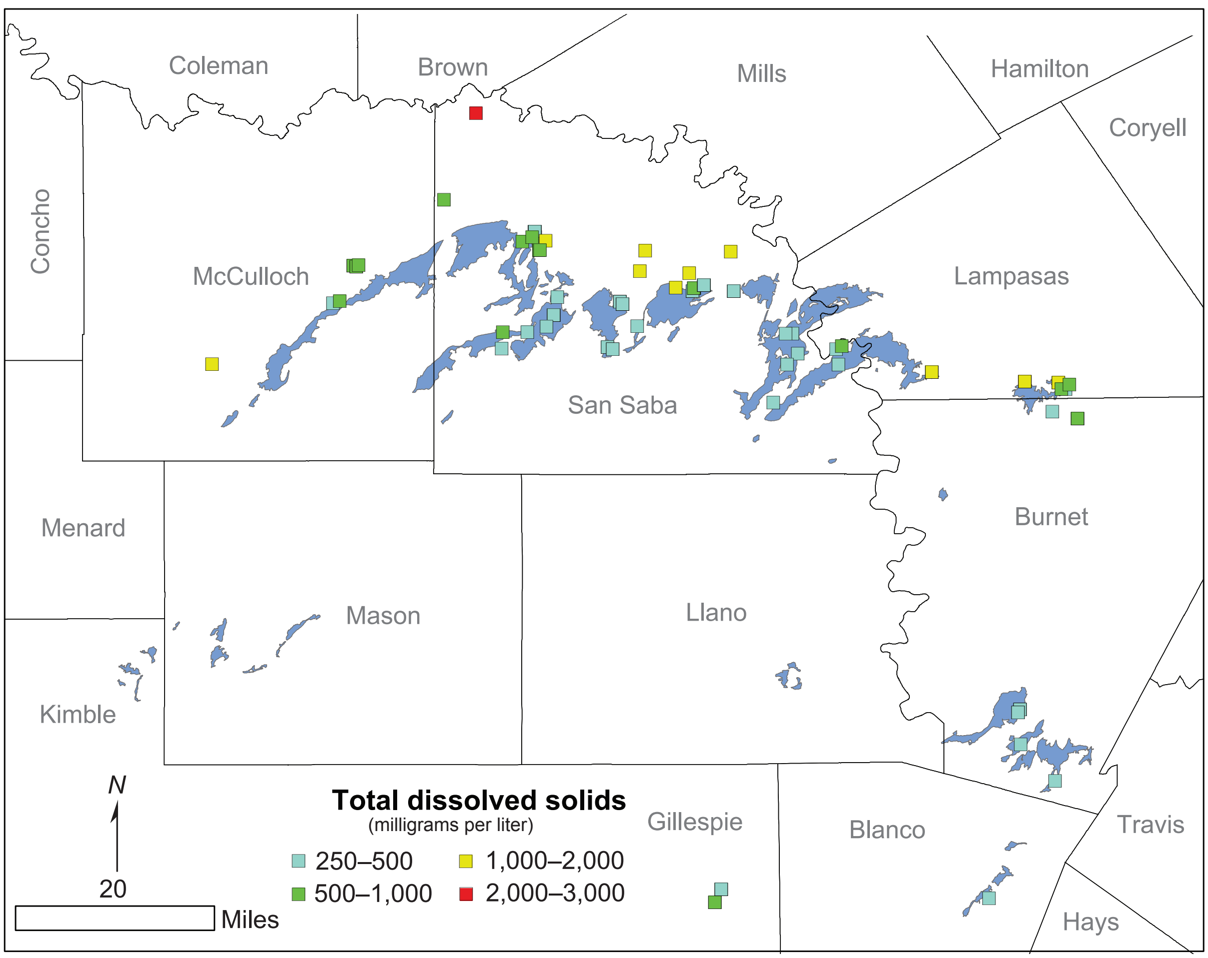
Marble Falls
Aquifer



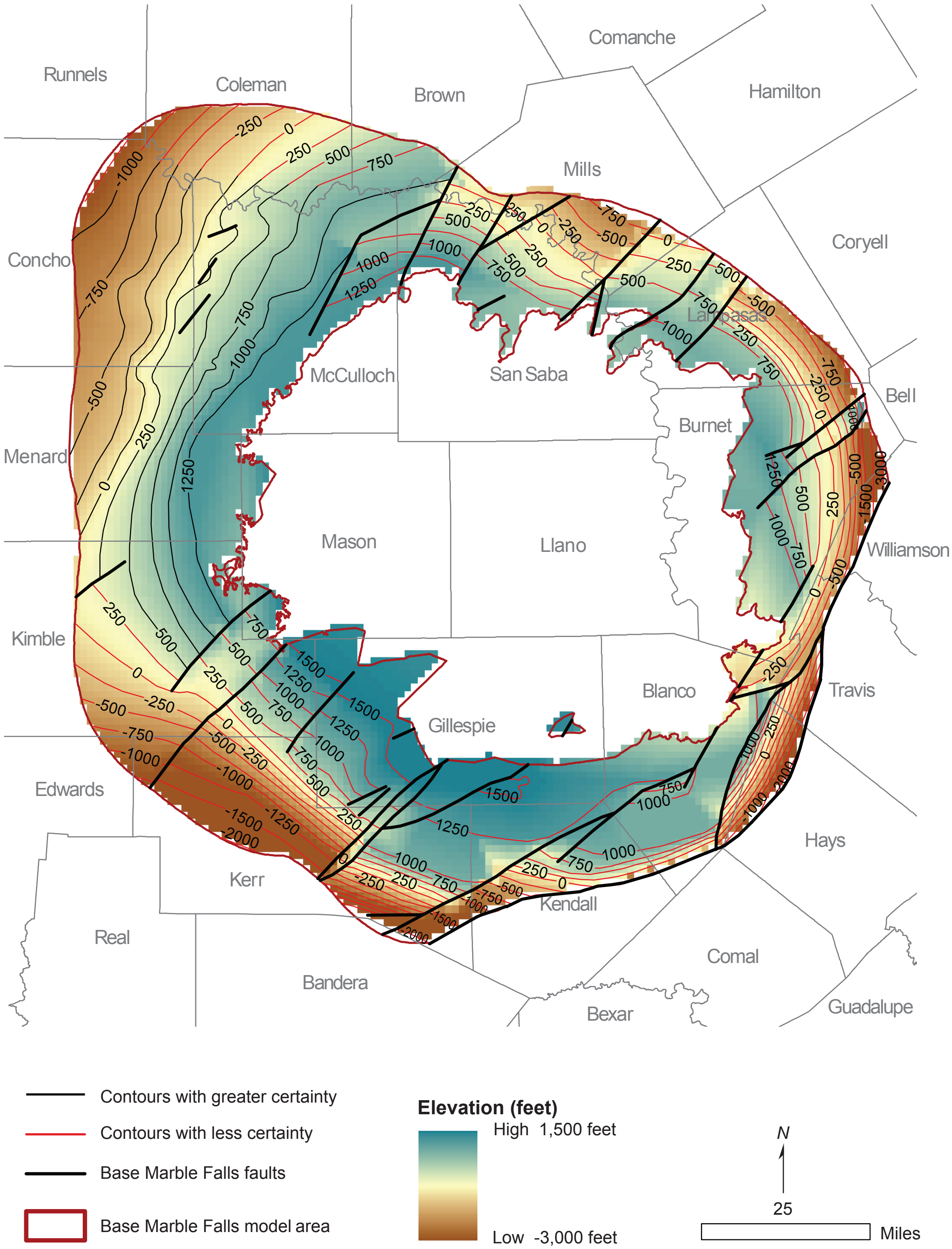
The Marble Falls Aquifer, a minor aquifer, occurs in several separated outcrops along the northern and eastern flanks of the Llano Uplift region of Central Texas. The subsurface extent of the aquifer is unknown. Groundwater occurs in fractures, solution cavities, and channels in the limestone of the Marble Falls Formation of the Bend Group. The aquifer is highly permeable in places, as indicated by wells that yield as much as 2,000 gallons per minute. Maximum thickness of the formation is 600 feet. Where underlying beds are thin or absent, the Marble Falls Aquifer may be hydraulically connected to the Ellenburger–San Saba Aquifer. Numerous large springs issue from the aquifer and provide a significant part of the base flow to the San Saba River in McCulloch and San Saba counties and to the Colorado River in San Saba and Lampasas counties.

Because the limestone beds composing this aquifer are relatively shallow, the aquifer is susceptible to pollution by surface uses and activities. For example, some wells in Blanco County have produced water with high nitrate concentrations. In the subsurface, groundwater becomes highly mineralized; however, the water produced from this aquifer is suitable for most purposes and generally contains less than 1,000 milligrams per liter of total dissolved solids. Water from the aquifer is used for municipal, agricultural, and industrial uses, and no significant water level declines have occurred in wells measured by the TWDB. The regional water planning groups, in their 2006 Regional Water Plans, recommended drilling new wells in Burnet County as a water management strategy using the Marble Falls Aquifer.

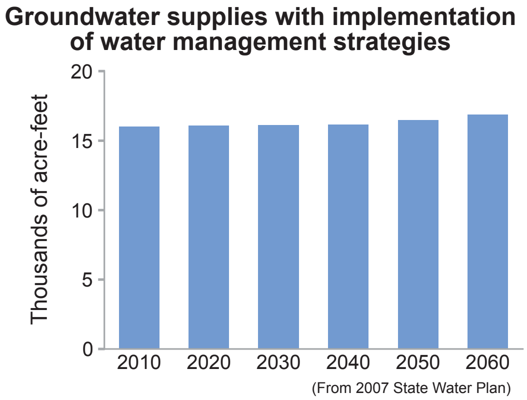
The Marble Falls Formation about 1.5 miles southeast of Brady, Texas, along State Highway 71.



Total dissolved solids in the Marble Falls Aquifer increase downdip to the north, away from the Llano Uplift.



Structure map for the base of the Marble Falls Formation (modified from Standen and Ruggiero, 2007).



Aquifer characteristics

- Area of aquifer: 214 square miles
- Proportion of aquifer with groundwater conservation districts: 78 percent
- Number of counties containing the aquifer: 8

References

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Preston, R.D., Pavilcek, D.J., Bluntzer, R.L., and Derton, J., 1996, The Paleozoic and related aquifers of Central Texas: Texas Water Development Board Report 346, 95 p.

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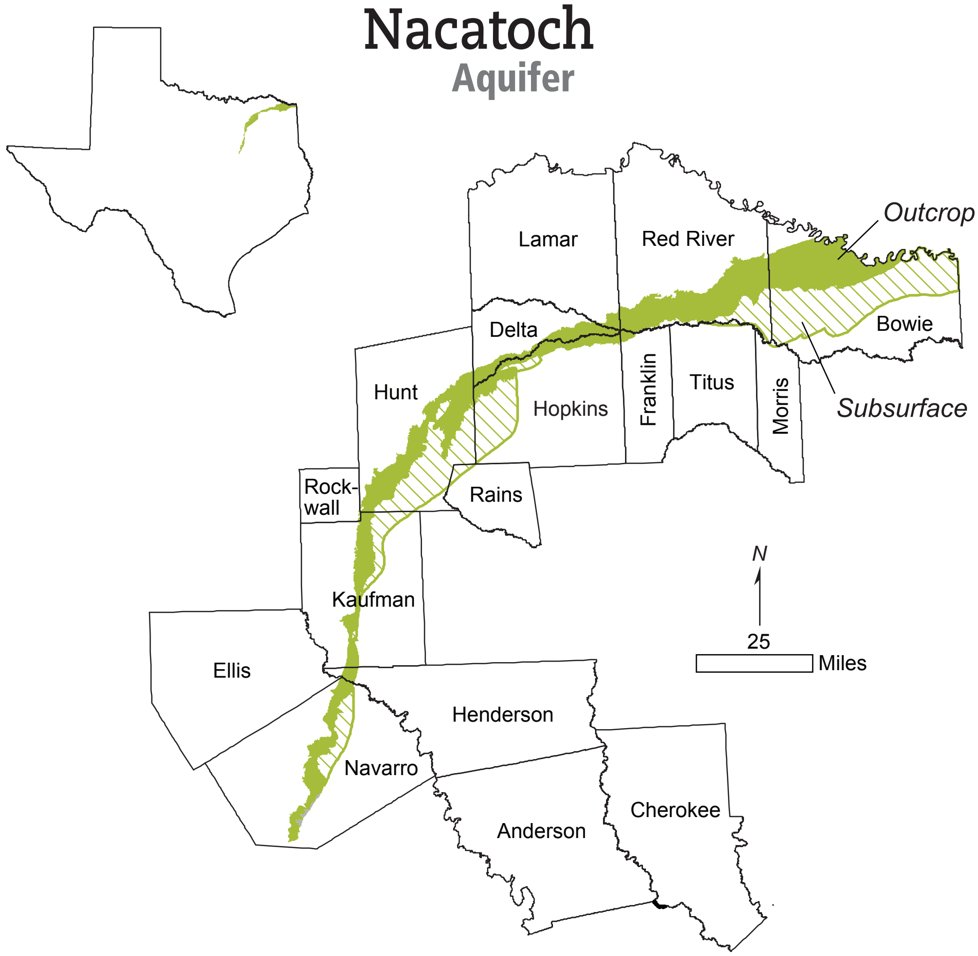
Warner, R.H., 1961, Structural geology of Carboniferous rocks near Marble Falls, Burnet County, Texas: University of Texas, Austin, master's thesis, 72 p.

Wiggins, W.D., III, 1982, Depositional history and microspar development in reducing pore water, Marble Falls Limestone: The University of Texas at Austin, Ph.D. thesis, 159 p.

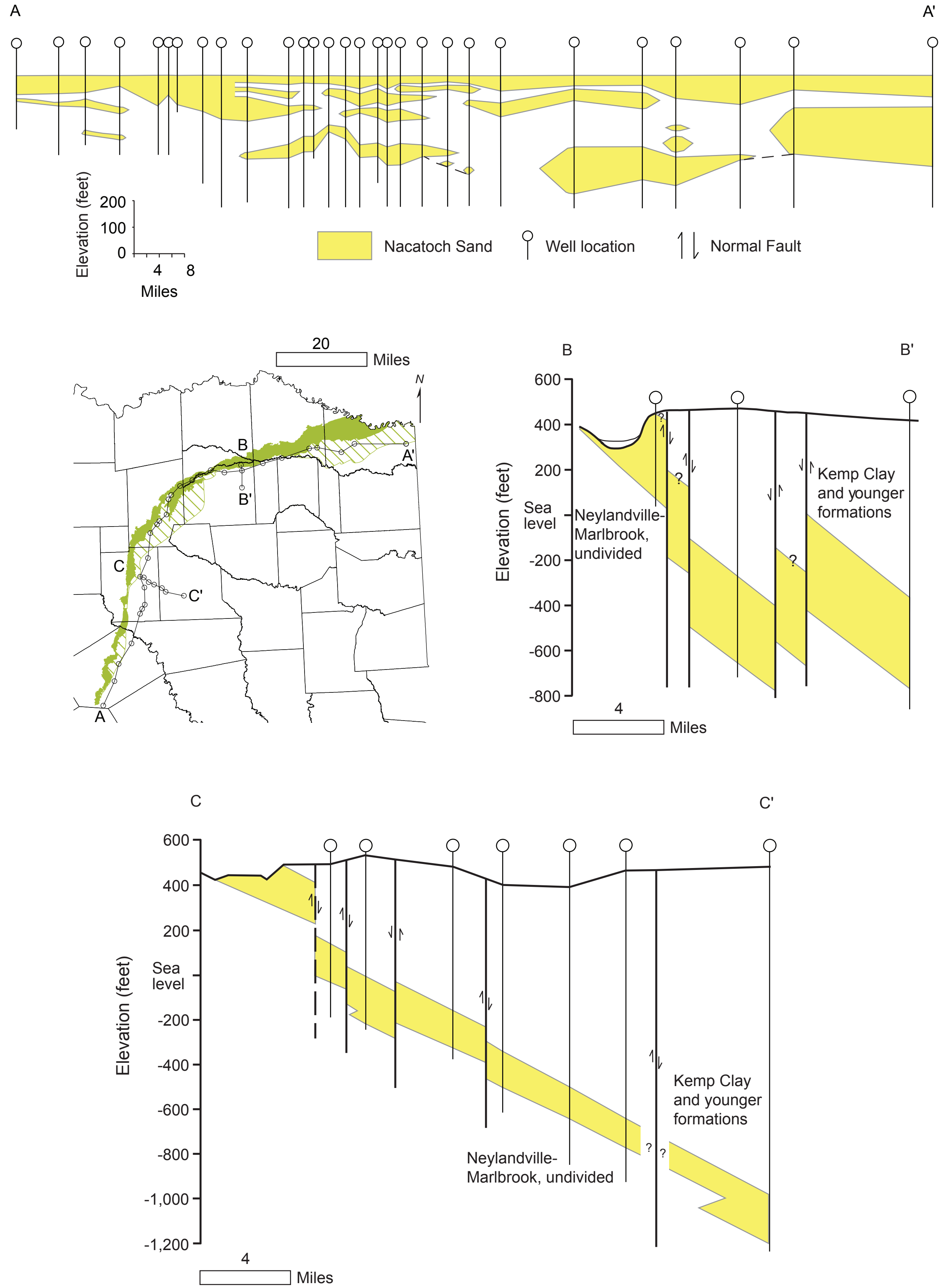
Winston, D., II, 1963, Stratigraphy and carbonate petrology of the Marble Falls Formation, Mason and Kimble counties, Texas: University of Texas, Austin, Ph.D. thesis, 344 p.

Nacatoch
Aquifer



The Nacatoch Aquifer

is a minor aquifer occurring in a narrow band across northeast Texas. The aquifer consists of the Nacatoch Sand, composed of sequences of sandstone separated by impermeable layers of mudstone or clay. These sandstones are marine in origin, coarsen upward, and are laterally discontinuous. The number of sand layers varies throughout the Nacatoch's extent, and the thickness of individual sand units ranges from more than 100 feet in the north to less than 20 feet to the south. Thickness of intervening mudstone units similarly ranges from more than 100 feet to only a few feet. Freshwater saturated thickness averages about 50 feet. The aquifer also includes a hydraulically connected cover of alluvium that is as much as 80 feet thick along major drainages. Groundwater in this aquifer is usually under artesian conditions except in shallow wells where the Nacatoch Formation crops out and water table conditions exist. The Mexia-Talco Fault Zone generally delineates the subsurface limit of the aquifer. The groundwater in the aquifer is typically alkaline, high in sodium bicarbonate, and soft. Total dissolved solids in the subsurface increase and are significantly higher south of the Mexia-Talco Fault Zone, where the water contains between 1,000 and 3,000 milligrams per liter of total dissolved solids. Water from the aquifer is extensively used for domestic and livestock purposes. The city of Commerce historically pumped the greatest amount from the Nacatoch Aquifer but has recently attempted to convert to surface water; however, because of recent droughts, the city has pumped 30 to 50 percent of its water from the aquifer. As a result of Commerce's reduced pumping, the declining water levels that had developed around Commerce in Delta and Hunt counties are stabilizing. The North East Texas Regional Water Planning Group, in its 2006 Regional Water Plan, recommended new and supplemental groundwater wells in the Nacatoch Aquifer as a water management strategy.



Geologic cross sections along and across the Nacatoch Sand (modified from Knight, 1984; Ashworth, 1988).

The Nacatoch Sand from a sand quarry located about 6.5 miles southwest of Quinlan, Texas, along Farm to Market 1565 (courtesy of L. Christian, TWDB).

Aquifer characteristics

- Area of outcrop: 889 square miles
- Area in subsurface: 936 square miles
- Proportion of aquifer with groundwater conservation districts: 0.5 percent
- Number of counties containing the aquifer: 15

References

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Knight, M.T., 1984, Deltaic sedimentation in the Nacatoch Formation (Late Cretaceous), northeast Texas: The University of Texas at Arlington, master's thesis, 202 p.

LBG-Guyton Associates, 2003, Brackish groundwater manual for Texas regional water planning groups: report prepared for Texas Water Development Board, 188 p.

LBG-Guyton Associates, and INTERA, Inc., 2007, Draft conceptual model for the Nacatoch Aquifer groundwater availability model: Prepared for Texas Water Development Board, 147 p.

McGowen, M.K., and Lopez, C.M., 1983, Depositional systems in the Nacatoch Formation (Upper Cretaceous), northeast Texas and southwest Arkansas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 137, 59 p.

Muller, D.A., and Price, R.D., 1979, Ground-water availability in Texas, estimates and projections through 2030: Texas Department of Water Resources, Report No. 238, 77 p.

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TWDB (Texas Water Development Board), 2007, Water for Texas 2007, Volume 2: Texas Water Development Board State Water Plan, 392 p.

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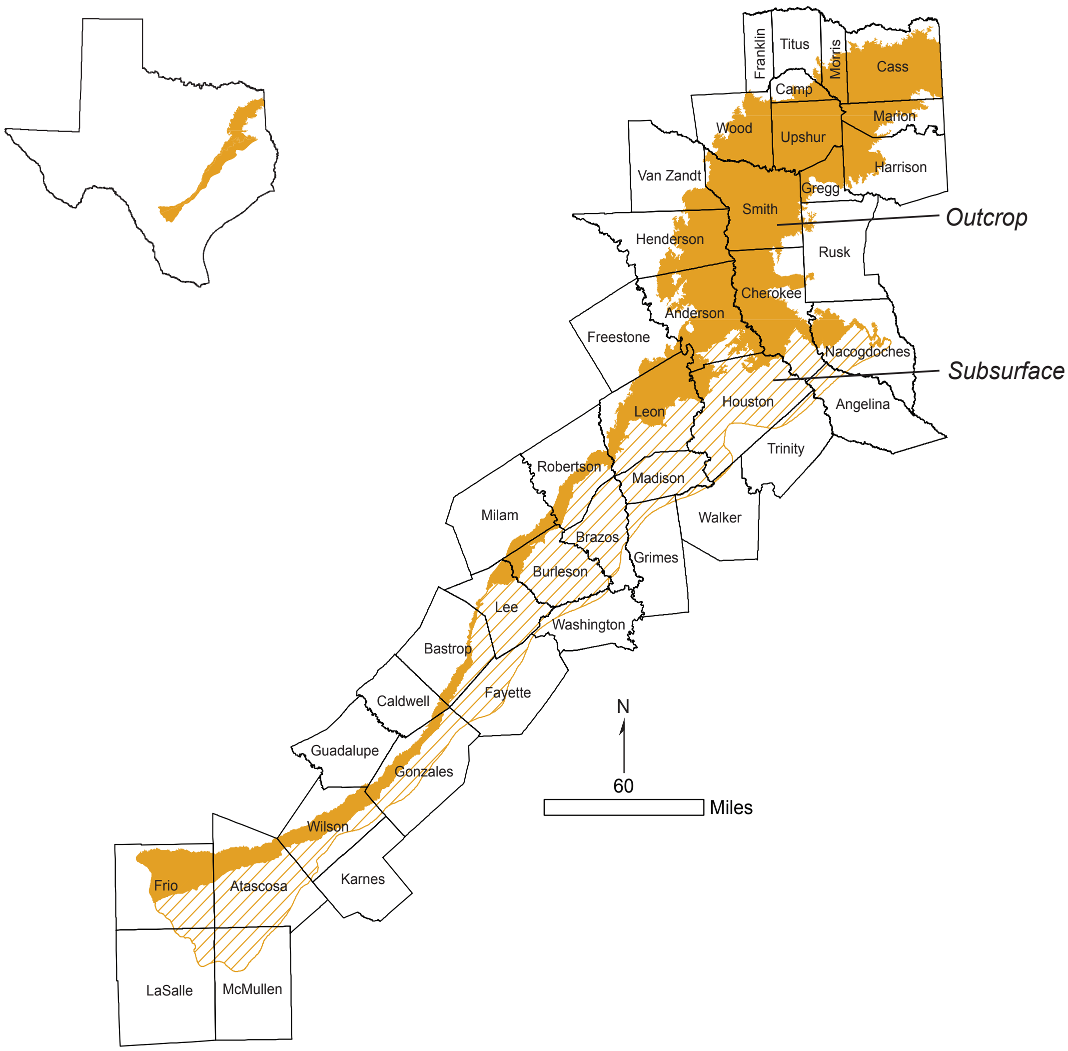
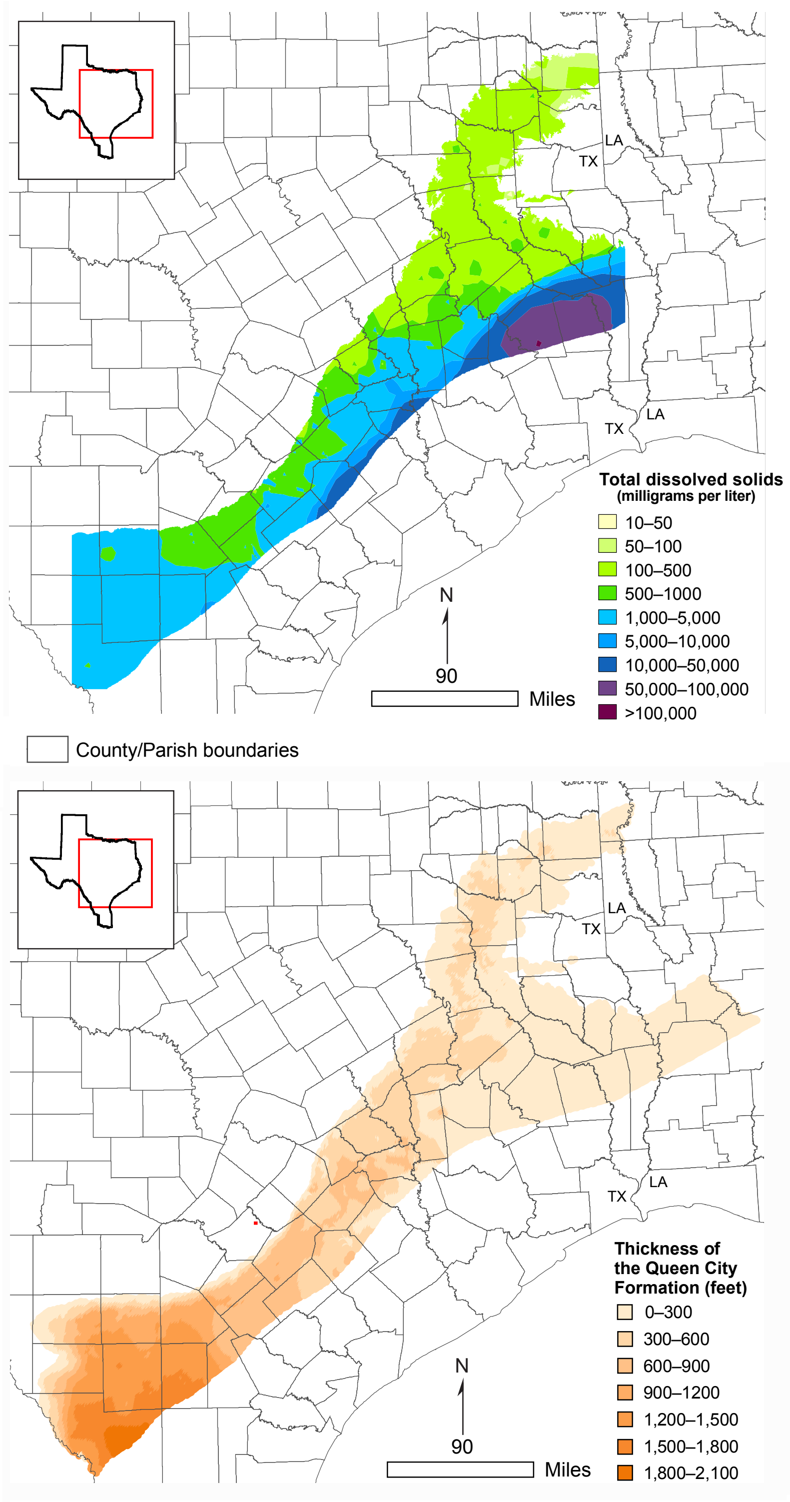
Queen City
Aquifer



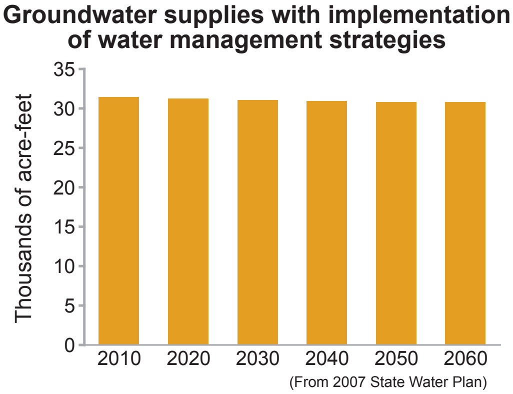
The Queen City Aquifer

is a minor but widespread aquifer that stretches across the Texas upper coastal plain. Water is stored in the sand, loosely cemented sandstone, and interbedded clay layers of the Queen City Formation that reaches 2,000 feet in thickness in South Texas. Average freshwater saturation in the Queen City Aquifer is about 140 feet. Water is generally fresh, with an average concentration of total dissolved solids of about 300 milligrams per liter in the recharge zone and about 750 milligrams per liter deeper in the aquifer. Although salinity decreases from south to north, areas of excessive iron concentration and high acidity occur in the northeast.

The aquifer is used primarily for livestock and domestic purposes, with significant municipal and industrial use in northeast Texas. However, water levels have remained fairly stable over time in the northern part of the aquifer. Water level declines are more common in the central (10 to 70 feet) and southern (5 to 130 feet) parts of the aquifer. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Queen City Aquifer, including drilling new and replacement wells, pumping additional water from existing wells, and temporary overdrafting.



Total dissolved solids, *above*, and thickness, *below*, for the Queen City Formation (from Kelley and others, 2004). Note that cross sections of the formation are included in the Carrizo-Wilcox Aquifer section.



Aquifer characteristics

- Area of outcrop: 7,702 square miles
- Area in subsurface: 6,989 square miles
- Proportion of aquifer with groundwater conservation districts: 67 percent
- Number of counties containing the aquifer: 42

References

Brown, E., 1997, Water quality in the Queen City Aquifer: Texas Water Development Board Hydrologic Atlas No. 6.

Galloway, W.E., Ganey-Curry, P.E., Liu, X., and Buffler, R.T., 2000, Cenozoic depositional history of the Gulf of Mexico Basin: American Association of Petroleum Geologists Bulletin, v. 84, no. 11, p. 1743–1774.

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Kelley, V., Deeds, N., Fryar, D., Nicot, J.-P., Jones, T., Dutton, A.R., Bruehl, G., Unger-Holtz, T., and Machin, J., 2004, Groundwater availability models for the Queen City and Sparta aquifers: INTERA Inc. and The University of Texas at Austin, Bureau of Economic Geology, prepared for Texas Water Development Board 770 p.

TWDB (Texas Water Development Board), 2007, Water for Texas 2007, Volume 2: Texas Water Development Board State Water Plan, 392 p.

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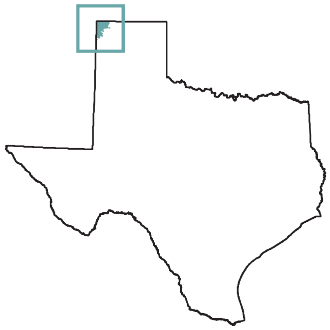
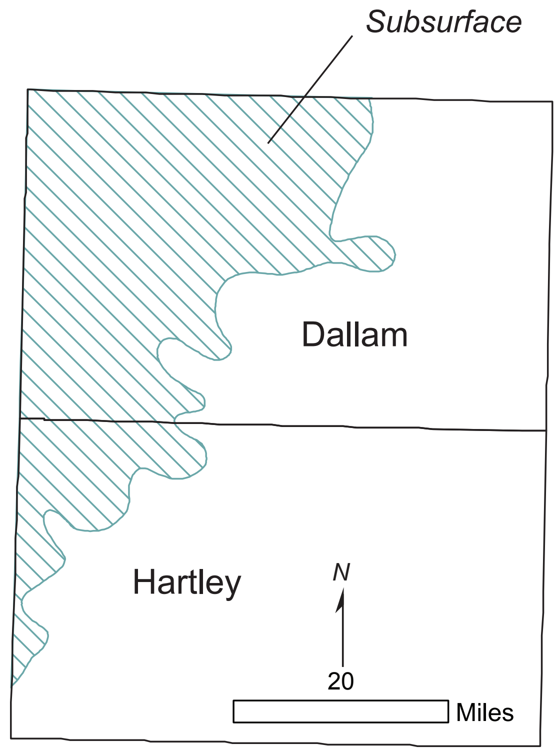
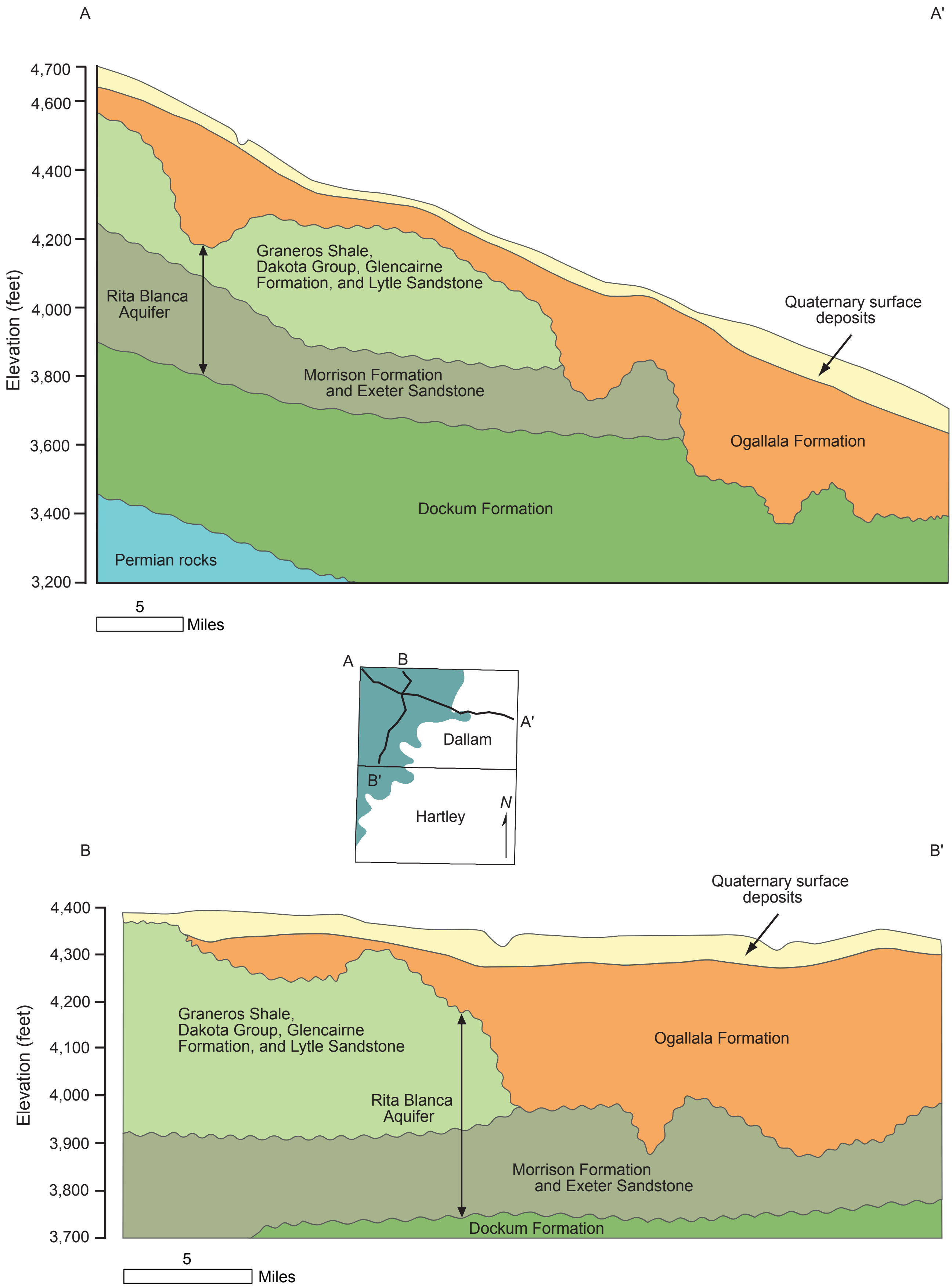
Rita Blanca
Aquifer

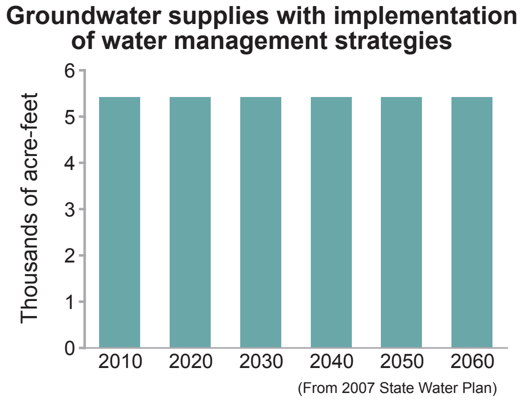




The Rita Blanca Aquifer, a minor aquifer, underlies the Ogallala Aquifer in the northwest corner of the Texas Panhandle. Groundwater occurs in the coarse-grained sand and gravel layers of the Lytle and Dakota formations as well as in the Exeter Sandstone and the Morrison Formation. The thickness of the aquifer is as much as 250 feet, and freshwater saturated thickness averages about 180 feet. In places, the Rita Blanca Aquifer is hydraulically connected to the Ogallala Aquifer and the underlying Dockum Aquifer. The total thickness of water-yielding rocks in these places is accordingly much greater. Water in the aquifer is usually fresh, containing less than 1,000 milligrams per liter of total dissolved solids, but very hard; however, some parts of the aquifer produce water that is slightly saline, containing more than 1,000 milligrams per liter of total dissolved solids. Irrigation accounts for most of the groundwater use from this aquifer, Texline being the only community that uses the aquifer for municipal water supply. Water levels in municipal wells have historically remained stable, whereas water levels in irrigation wells have declined steadily. The Panhandle Water Planning Group (Region A), in its 2006 Regional Water Plan, did not recommend any water management strategies to increase supplies from the Rita Blanca Aquifer.



Geologic cross sections across the Rita Blanca Aquifer (modified from Christian, 1989).



Aquifer characteristics

- Area of aquifer: 922 square miles
- Proportion of aquifer with groundwater conservation districts: 88 percent
- Number of counties containing the aquifer: 2

References

Christian, P., 1989, Evaluation of ground-water resources in Dallam County, Texas: Texas Water Development Board Report 315, 27 p.

Dutton, A.R., Reedy, R.C., and Mace, R.E., 2001, Saturated thickness in the Ogallala Aquifer in the Panhandle Water Planning Area—Simulations of 2000 through 2050 withdrawal projections: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Panhandle Water Planning Group, Panhandle Regional Planning Commission (contract number UTA01-462), 130 p.

Gutentag, E.D., Heimes, F.J., Krothe, N.C., Luckey, R.R., and Weeks, J.B., 1984, Geohydrology of the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Professional Paper 1400-B, 57 p.

Knowles, T., Nordstrom, P., and Klemt, W.B., 1984, Evaluating the ground-water resources of the High Plains of Texas: Texas Water Development Board Report 288, 4 vols.

Luckey, R.L., and Becker, M.F., 1999, Hydrogeology, water use, and simulation of flow in the High Plains aquifer in northwestern Oklahoma, southeastern Colorado, southwestern Kansas, north eastern New Mexico, and northwestern Texas: U.S. Geological Survey Water-Resources Investigations Report 99-4104, 68 p.

Peckham, D.S., and Ashworth, J.B., 1993, The High Plains aquifer system of Texas, 1980 to 1990, overview and projections: Texas Water Development Board Report 341, 34 p.

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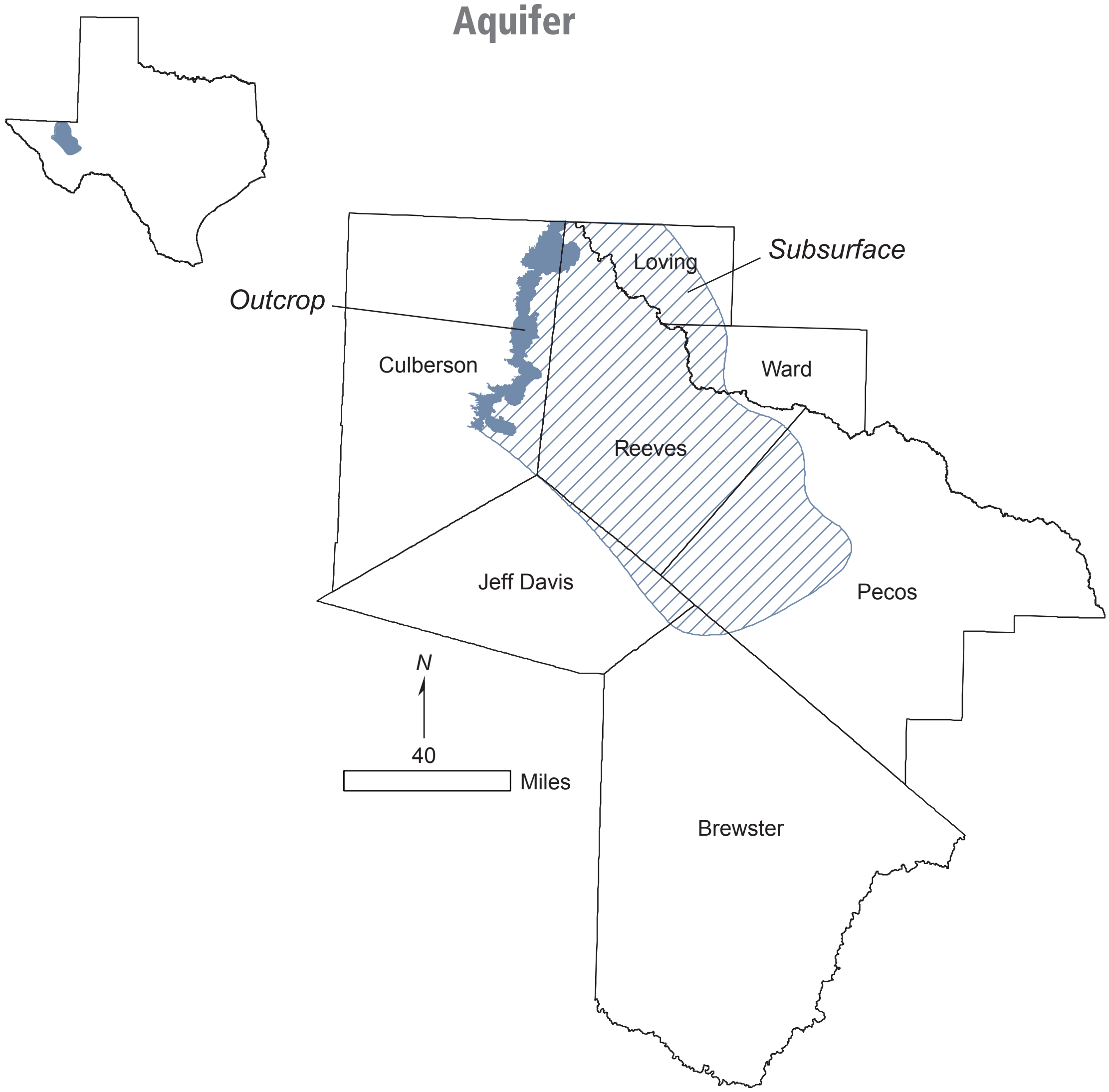
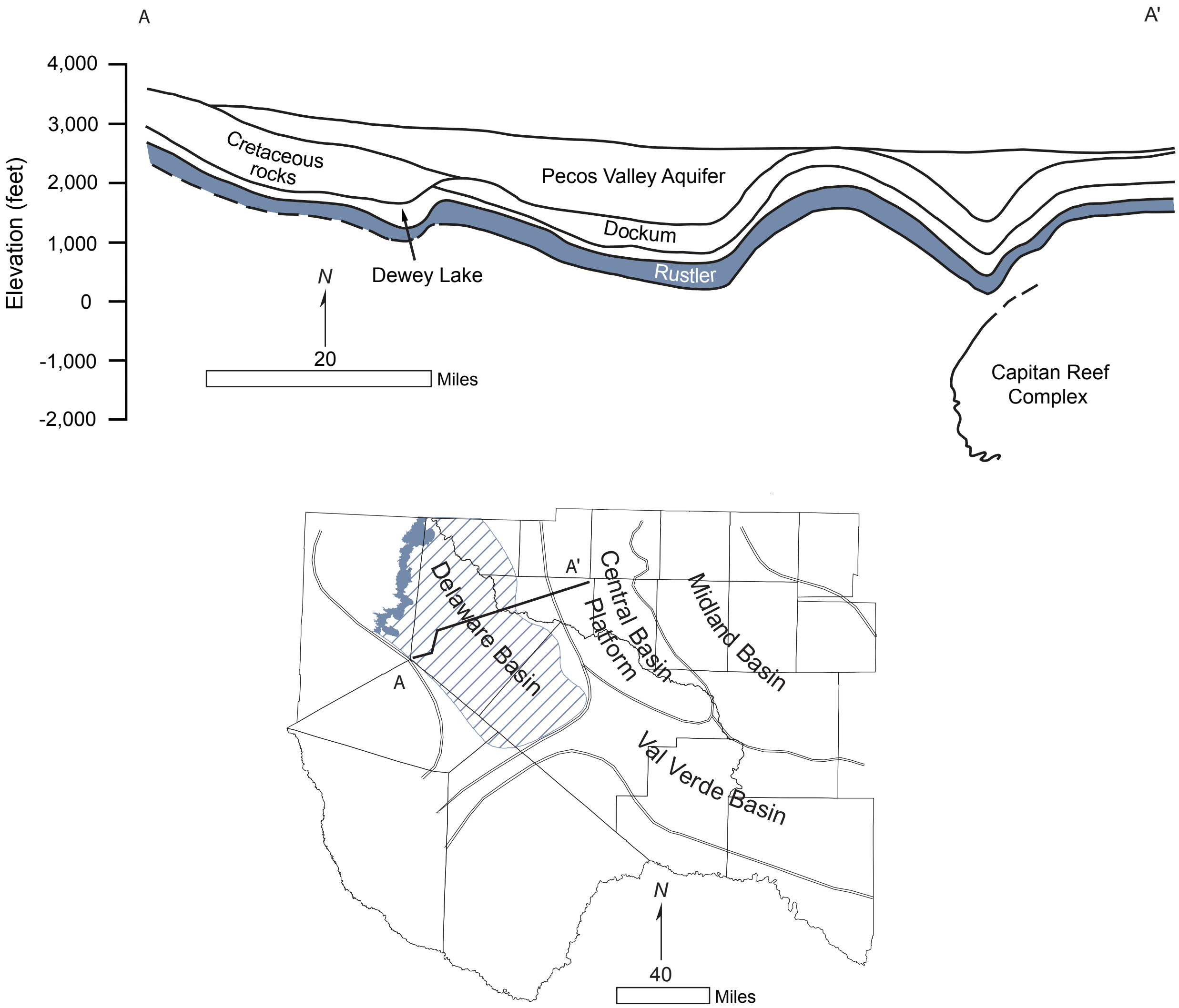
Rustler
Aquifer

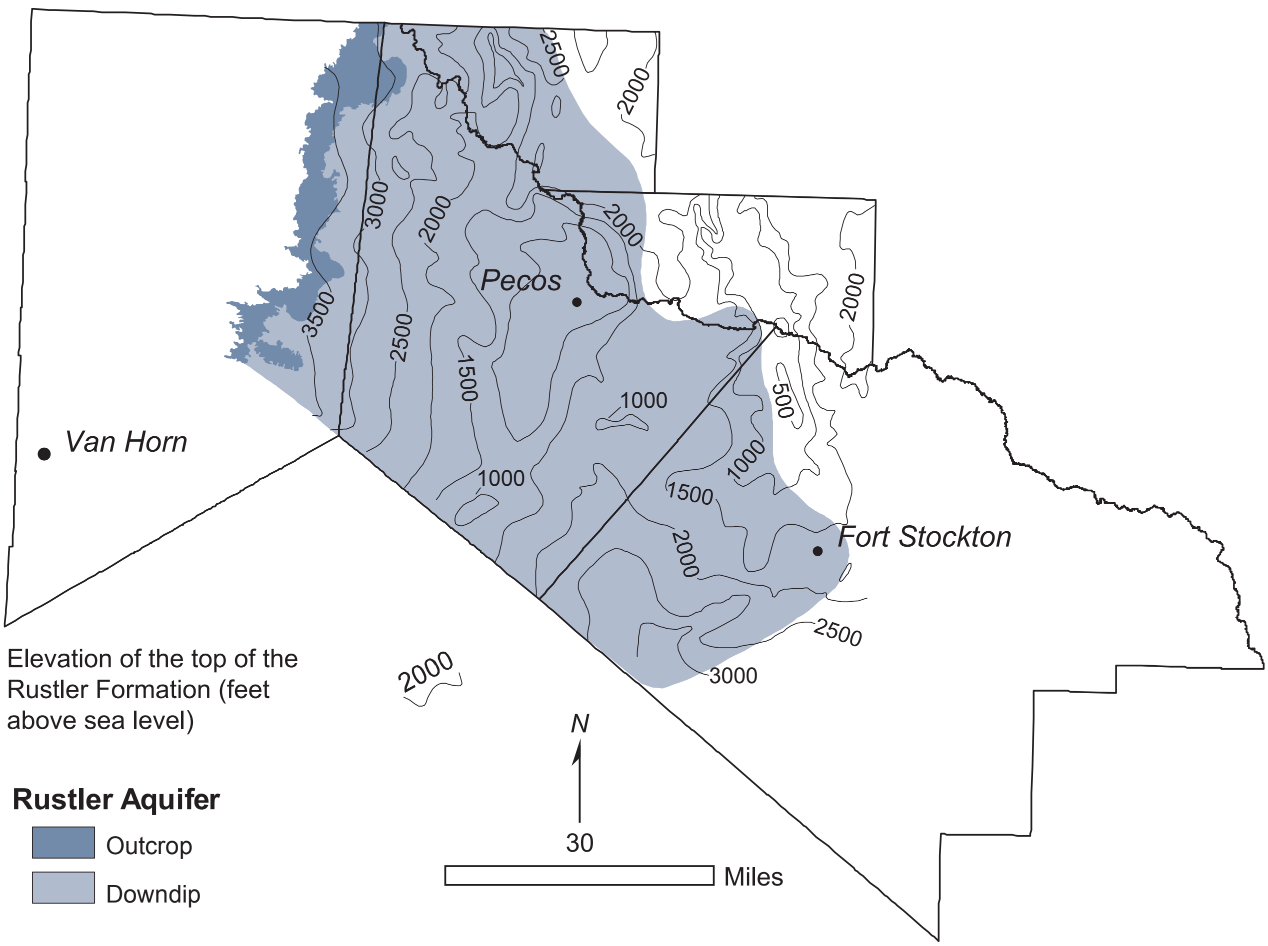


The Rustler Aquifer is a minor aquifer located in Brewster, Culberson, Jeff Davis, Loving, Pecos, Reeves, and Ward counties. The aquifer consists of the carbonates and evaporites of the Rustler Formation, which is the youngest unit of the Late Permian Ochoan Series. The Rustler Formation is 250 to 670 feet thick and extends downdip into the subsurface toward the center of the Delaware Basin to the east. It becomes thinner along the eastern margin of the Delaware Basin and across the Central Basin Platform and Val Verde Basin. There it conformably overlies the Salado Formation. Groundwater occurs in partly dissolved dolomite, limestone, and gypsum. Most of the water production comes from fractures and solution openings in the upper part of the formation. Although some parts of the aquifer produce freshwater containing less than 1,000 milligrams per liter of total dissolved solids, the water is generally slightly to moderately saline and contains total dissolved solids ranging between 1,000 and 4,600 milligrams per liter. The water is used primarily for irrigation, livestock, and waterflooding operations in oil-producing areas. Fluctuations in water levels over time most likely reflect long-term variations in water use patterns. The regional water planning groups in their 2006 Regional Water Plans did not propose any water management strategies for the Rustler Aquifer.

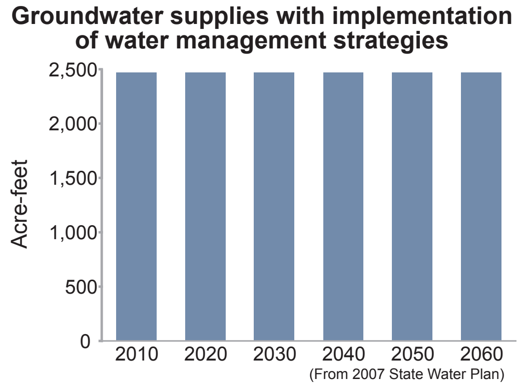


Geologic cross section across the Rustler Aquifer. Index map shows the major structures in the region (modified from Ashworth, 1990; Boghici and Van Broekhoven, 2001).

Rocks of the Rustler Formation are well exposed along Ranch to Market 652 in eastern Culberson County, Texas.



Structure map at the top of the Rustler Formation (modified from Hiss, 1976; Boghici and Van Broekhoven, 2001).



Aquifer characteristics

- Area of outcrop: 309 square miles
- Area in subsurface: 4,860 square miles
- Proportion of aquifer with groundwater conservation districts: 26 percent
- Number of counties containing the aquifer: 7

References

Armstrong, C.A., McMillion, L.G., 1961, Geology and ground-water resources of Pecos County, Texas: Texas Board of Water Engineers Bulletin 6106, 536 p.

Ashworth, J.B., 1990, Evaluation of ground-water resources in parts of Loving, Pecos, Reeves, Ward, and Winkler counties, Texas: Texas Water Development Board Report 317, 51 p.

Boghici, R., and Van Broekhoven, N.G., 2001, Hydrogeology of the Rustler Aquifer, Trans-Pecos Texas, *in* Mace, R.E., Mullican, W.F., III, and Angle, E.S., eds., Aquifers of West Texas: Texas Water Development Board Report 356, p.207–225.

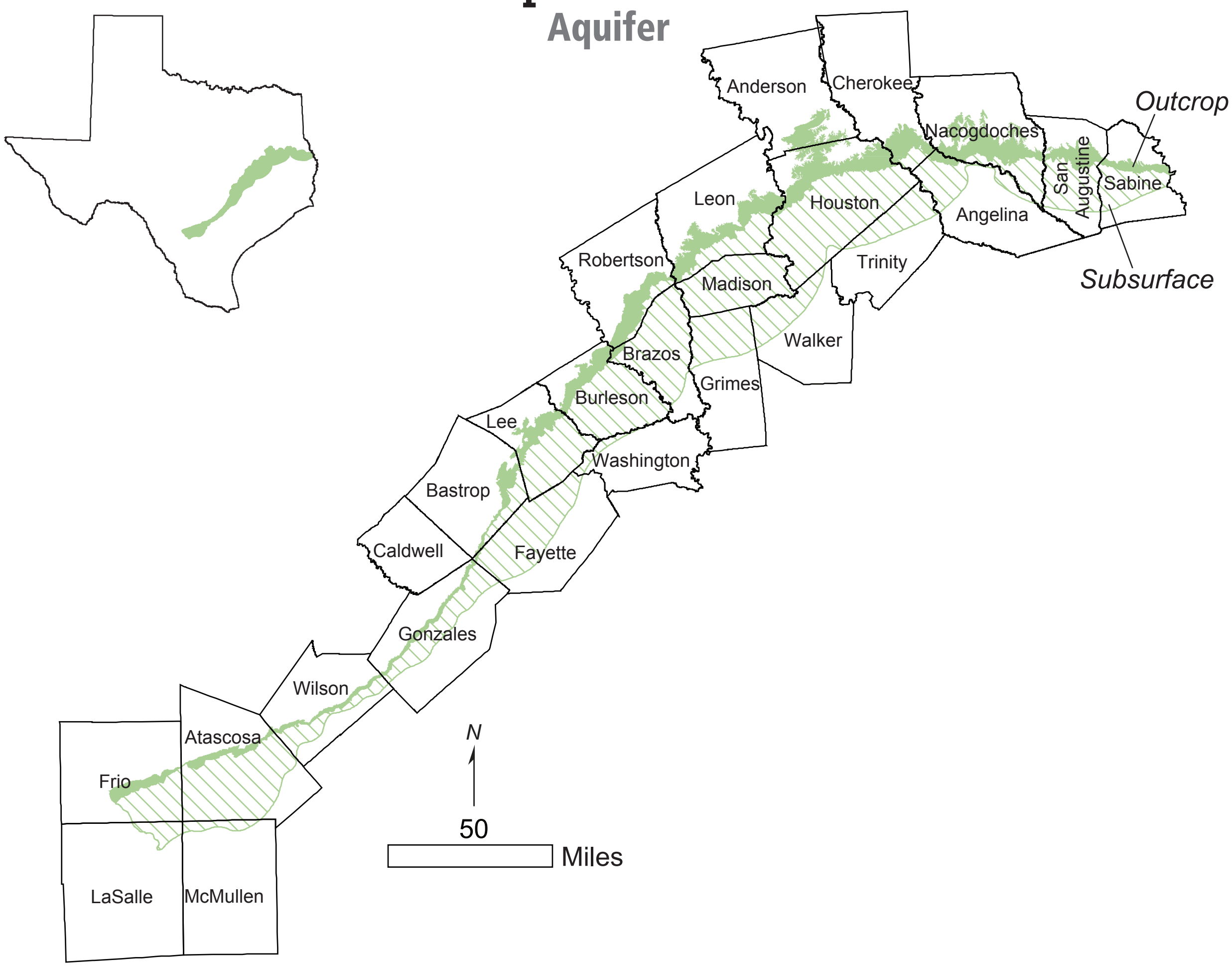
Hiss, W.L., 1976, Structure of the Permian Ochoan Rustler Formation, southeast New Mexico and West Texas: New Mexico Bureau of Mines and Mineral Resources Resource Map, one sheet, scale 1:510,000.

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 Bulletin, v. 64, no. 5, p. 539–546.

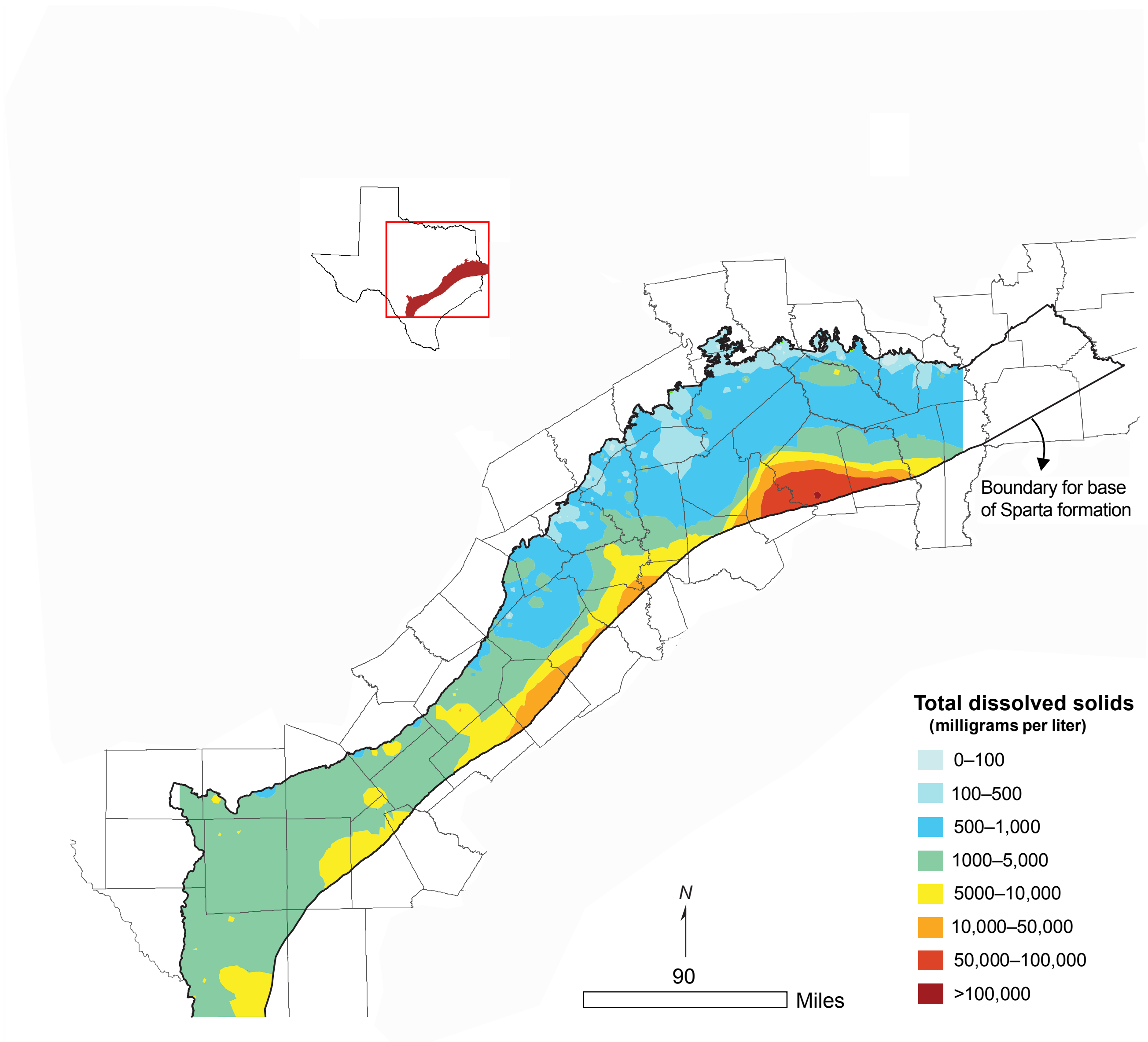
Richey, S.F., Wells, J.G., and Stephens, K.T., 1985, Geohydrology of the Delaware Basin and vicinity, Texas and New Mexico: U.S. Geological Survey Water-Resources Investigations Report 84-4077, 99 p.

TWDB (Texas Water Development Board), 2007, Water for Texas 2007, Volume 2: Texas Water Development Board State Water Plan, 392 p.

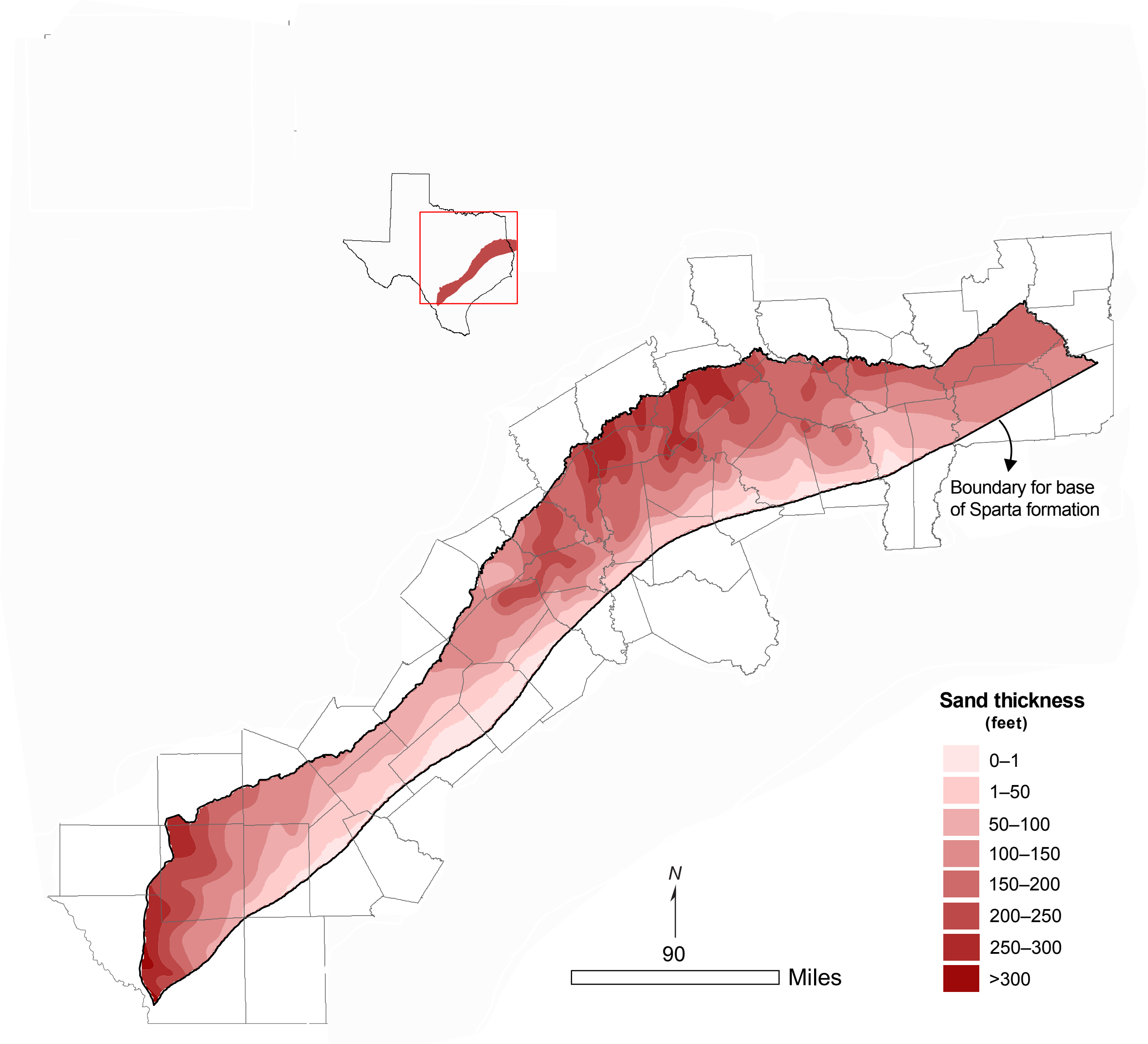
Sparta
Aquifer



The Sparta Aquifer
is a minor aquifer extending across East and South Texas, parallel to the Gulf of Mexico coastline and about 100 miles inland. Water is contained within a part of the Claiborne Group known as the Sparta Formation, a sand-rich unit interbedded with silt and clay layers and with massive sand beds in the bottom section. The thickness of the formation changes gradually from more than 700 feet at the Sabine River to about 200 feet in South Texas. Freshwater saturated thickness averages about 120 feet. In outcrop areas and for a few miles in the subsurface, the water is usually fresh, with an average concentration of 300 milligrams per liter of total dissolved solids; however, water quality deteriorates with depth (below about 2,000 feet), where groundwater has an average concentration of 800 milligrams per liter of total dissolved solids. Excess iron concentrations are common throughout the aquifer. Water from the aquifer is predominantly used for domestic and livestock purposes, and its quality has not been significantly impacted by pumping. Elkhart Creek Springs originates from the Sparta Sand in Houston County and flows at a rate of as much as 3.4 cubic feet per second. In some areas, such as in Houston and Brazos counties, the aquifer is used for municipal, industrial, and irrigation purposes. No significant water level declines have been detected throughout the aquifer in wells measured by the TWDB. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Sparta Aquifer, including drilling more wells and increasing withdrawals from existing wells.

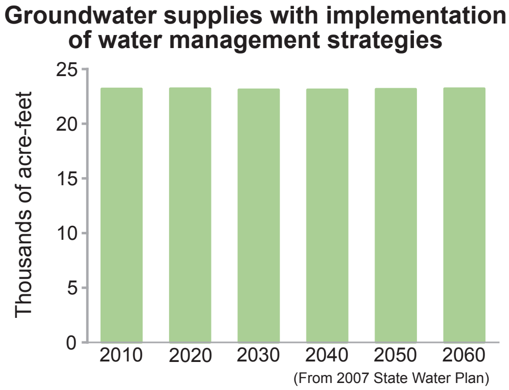


Total dissolved solids in the Sparta Aquifer (modified from Kelley and others, 2004). Note that cross sections of the Sparta Formation are included in the Carrizo-Wilcox Aquifer section.



Total sand thickness in the Sparta Aquifer (modified from Ricoy and Brown, 1977; Kelley and others, 2004).

The Sparta Formation along State Highway 39, Leon County, Texas.



Aquifer characteristics

- Area of outcrop: 1,543 square miles
- Area in subsurface: 6,926 square miles
- Proportion of aquifer with groundwater conservation districts: 70 percent
- Number of counties containing the aquifer: 25

References

Biri, M., 1997, Water quality in the Sparta Aquifer: Texas Water Development Board, Hydrologic Atlas No. 5.

Galloway, W.E., Ganey-Curry, P.E., Liu, X., and Buffler, R.T., 2000, Cenozoic depositional history of the Gulf of Mexico Basin: American Association of Petroleum Geologists Bulletin, v. 84, no. 11, p. 1743–1774.

Galloway, W.E., Liu, X., Travis-Neuberger, D., and Xue, L., 1994, High-resolution correlation cross sections, Paleogene section, Texas coastal plain: The University of Texas at Austin, Bureau of Economic Geology.

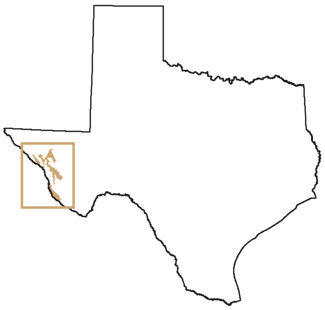
Kelley, V., Deeds, N., Fryar, D., Nicot, J.-P., Jones, T., Dutton, A.R., Bruehl, G., Unger-Holtz, T., and Machin, J., 2004, Groundwater availability models for the Queen City and Sparta aquifers: INTERA Inc. and The University of Texas at Austin, Bureau of Economic Geology, prepared for Texas Water Development Board, 770 p.

Payne, J.N., 1968, Hydrologic significance of the lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi, and Texas: U.S. Geological Survey Professional Paper 569 A, 17 p., 10 plates.

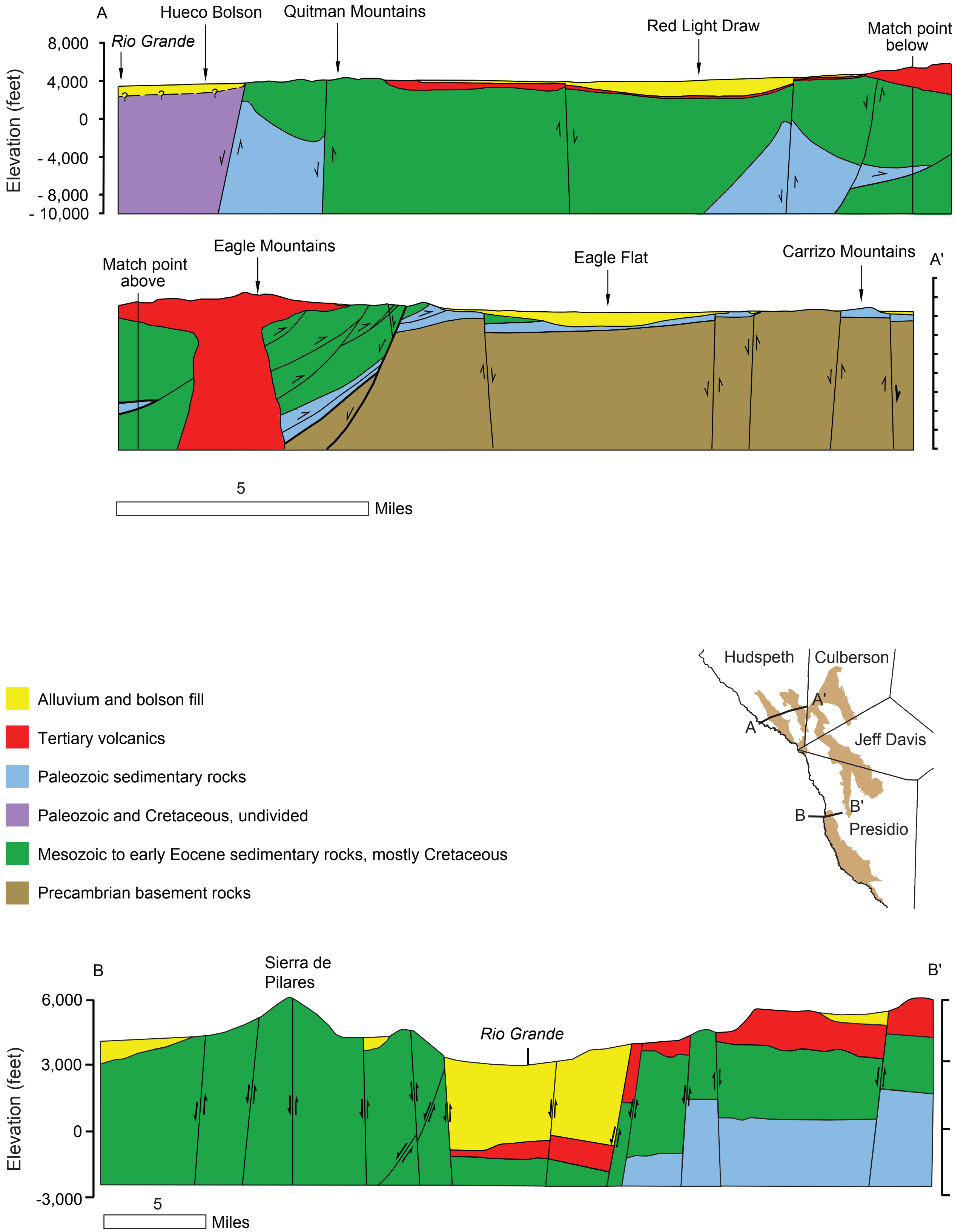
Ricoy, J.U., and Brown, L.F., Jr., 1977, Depositional systems in the Sparta Formation (Eocene) Gulf Coast Basin of Texas: Gulf Coast Association of Geological Societies Transactions, v. 27, p. 139–154.

TWDB (Texas Water Development Board), 2007, Water for Texas 2007, Volume 2: Texas Water Development Board State Water Plan, 392 p.

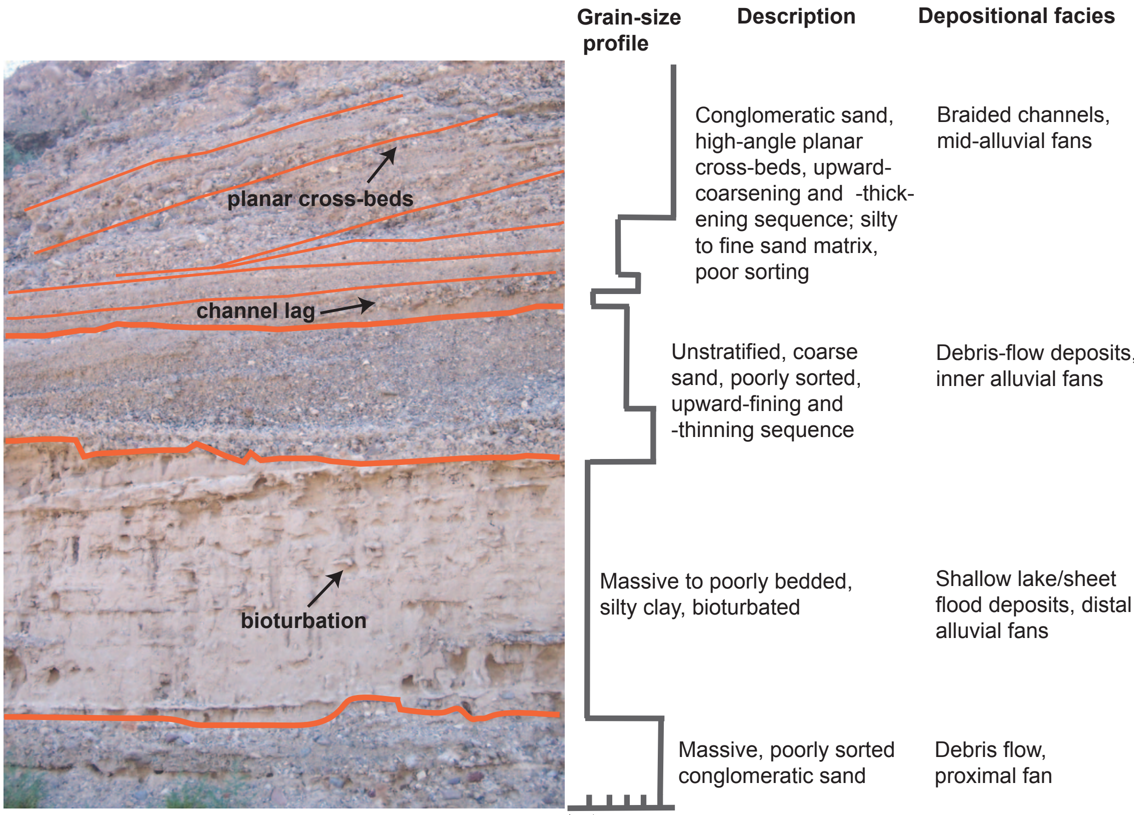
West Texas Bolsons
Aquifer



The West Texas Bolsons Aquifer is a minor aquifer located in several basins, or bolsons, in Far West Texas. The aquifer occurs as water-bearing, basin-fill deposits as much as 3,000 feet thick. It is composed of eroded materials that vary depending on the mountains bordering the basins and the manner in which the sediments were deposited. Sediments range from the fine-grained silt and clay of lake deposits to the coarse-grained volcanic rock and limestone of alluvial fans. Freshwater saturated thickness averages about 580 feet. Groundwater quality varies depending on the basin, ranging from freshwater, containing less than 1,000 milligrams per liter of total disdsolved solids, to slightly to moderately saline water, containing between 1,000 and 4,000 milligrams per liter of total dissolved solids. Groundwater is used for irrigation and livestock throughout the area and for municipal supply in the cities of Presidio, Sierra Blanca, Valentine, and Van Horn. From the 1950s to the present, water levels have been in decline in the West Texas Bolsons Aquifer, with the most significant declines occurring south of Van Horn in the Lobo Flats area and to the east in the Wild Horse Basin area. The Region E Planning Group, in its 2006 Regional Water Plan, did not recommend any water management strategies using the West Texas Bolsons Aquifer.



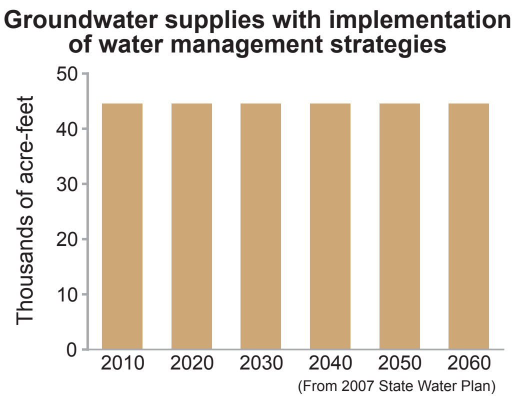
Geologic cross section across the northern West Texas Bolsons Aquifer, above (modified from Beach and others, 2008) and the southern Presidio Bolson, below (modified from Henry, 1979).



Exposure of Bolson sediments in the southern Presidio Bolson (description and photo by Ali Chowdury, TWDB)

Looking north across the Rio Grande at volcanic rocks, southern Presidio Bolson (courtesy of Shirley Wade, TWDB)


Alluvial sediments of the Presidio Bolson just east of Ruidosa, Texas, along the Pinto Canyon Road.



Aquifer characteristics

- Area of aquifer: 1,895 square miles
- Proportion of aquifer with groundwater conservation districts: 81 percent
- Number of counties containing the aquifer: 4

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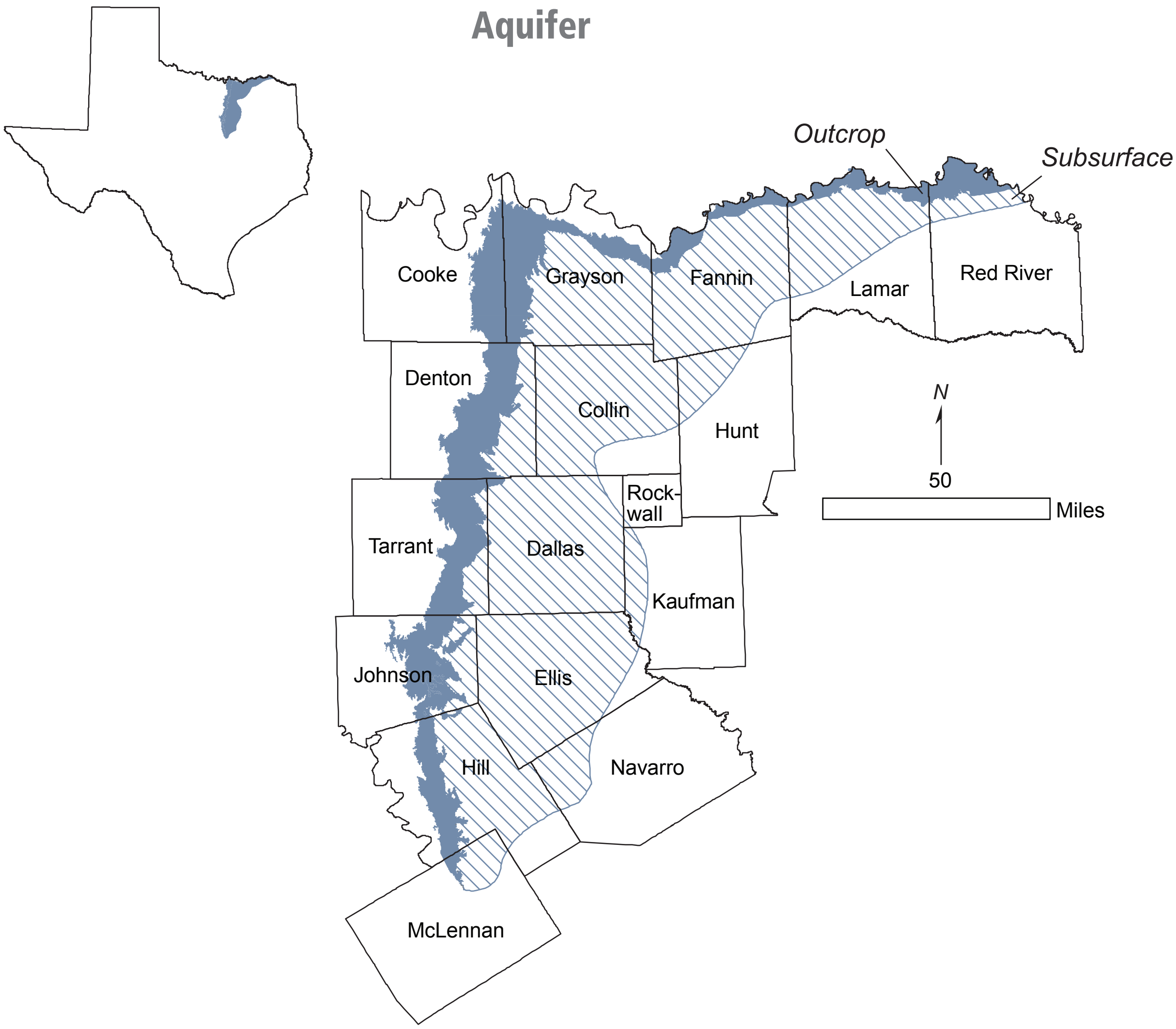
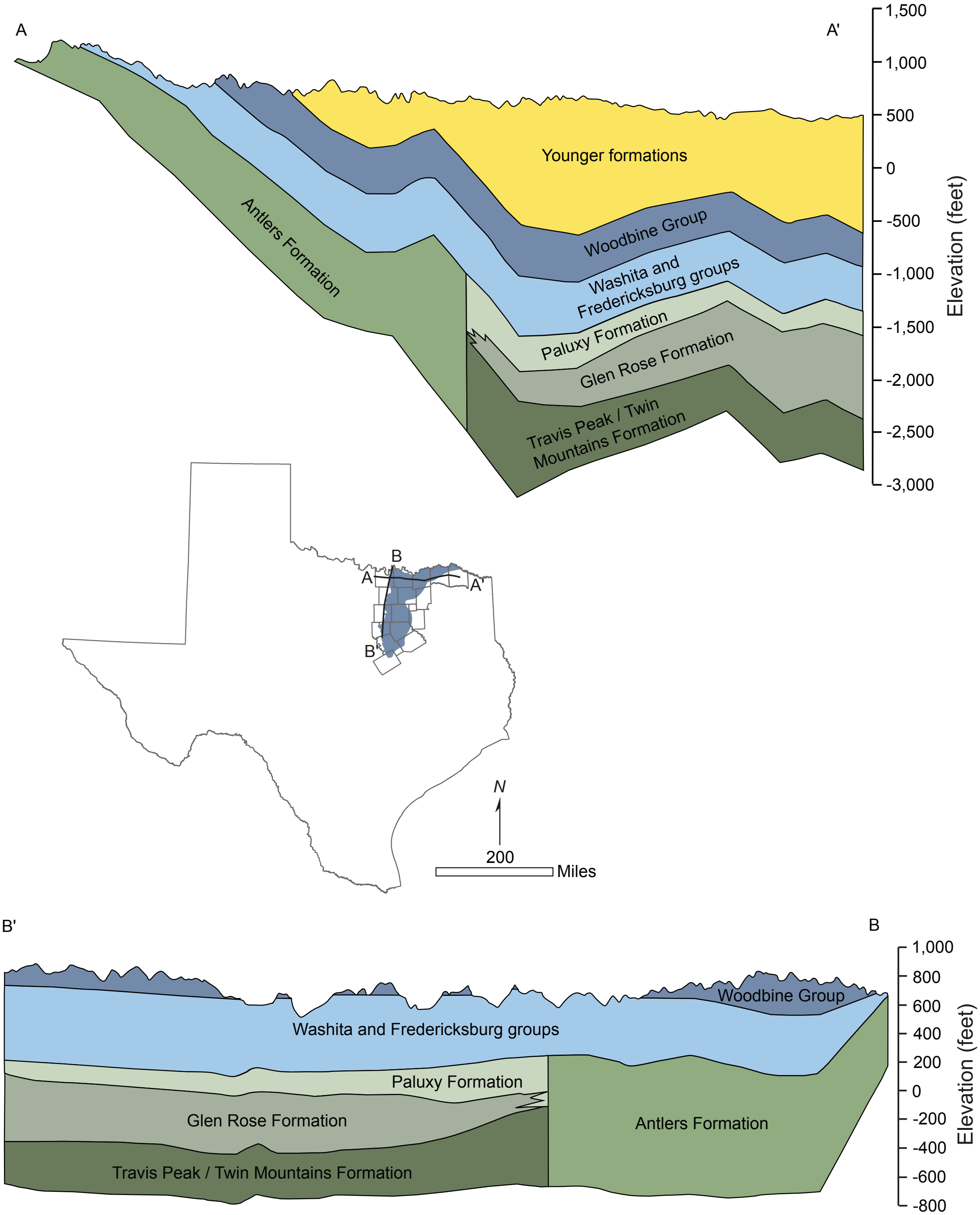
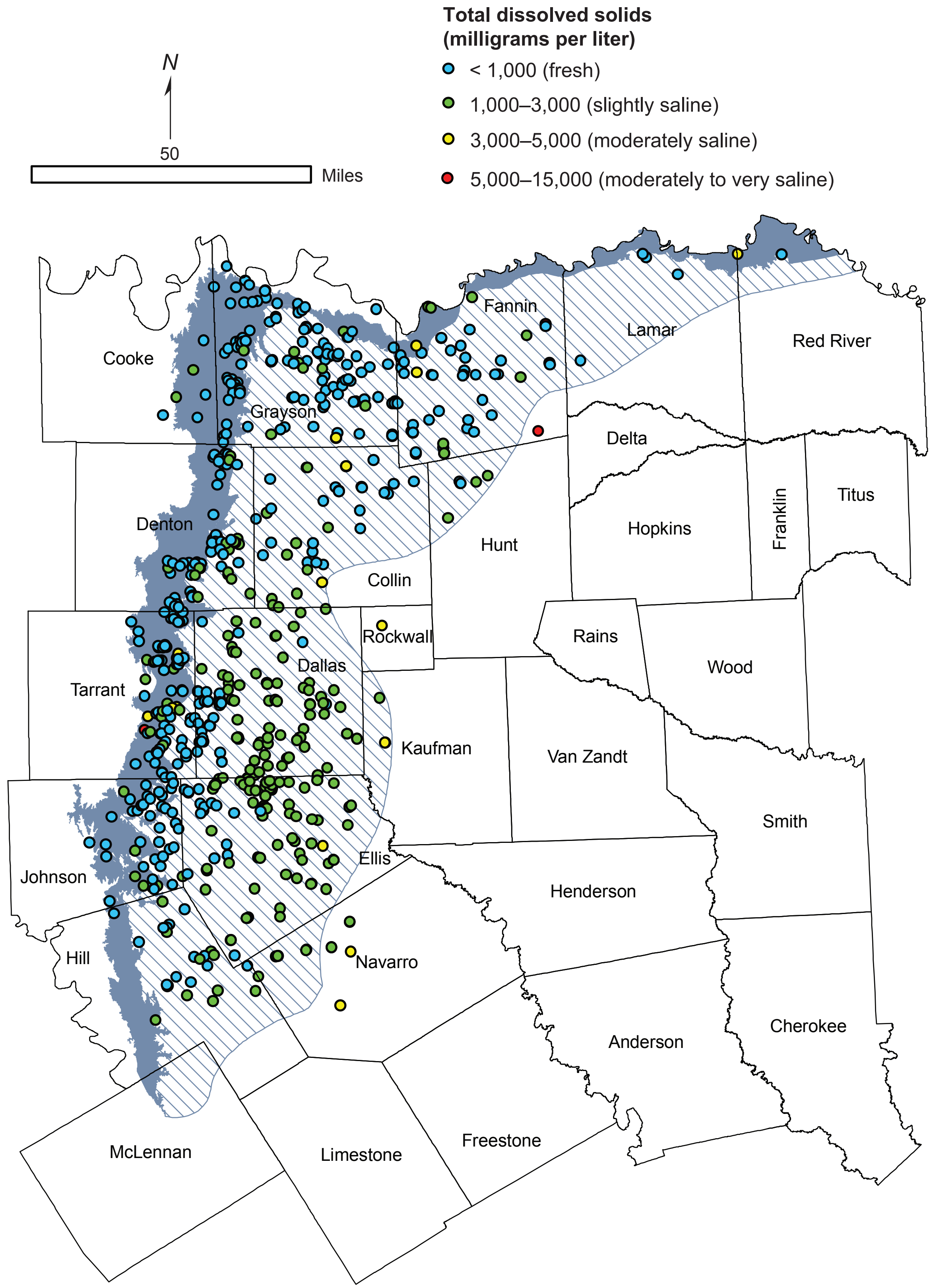
Woodbine
Aquifer



The Woodbine Aquifer
is a minor aquifer located in northeast Texas. The aquifer overlies the Trinity Aquifer and consists of sandstone interbedded with shale and clay that form three distinct water-bearing zones. The Woodbine Aquifer reaches 600 feet in thickness in subsurface areas, and freshwater saturated thickness averages about 160 feet. Water quality and yield vary with the depth of the aquifer. The lower zones of the aquifer typically yield the most water, whereas the upper zone yields limited water that tends to be very high in iron. In general, water to a depth of 1,500 feet is fresh, containing less than 1,000 milligrams per liter of total dissolved solids. Water at depths below 1,500 feet is slightly to moderately saline, containing from 1,000 to 4,000 milligrams per liter of total dissolved solids. The aquifer provides water for municipal, industrial, domestic, livestock, and small irrigation supplies. Large water level declines, due to heavy municipal and industrial pumping in the Sherman-Denison area of Grayson County, have moderated in the past decade as suppliers have switched to surface water. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Woodbine Aquifer, including constructing new wells, pumping more water from existing wells, developing supplemental wells to maintain current supplies, temporary overdrafting, and reallocating supplies.



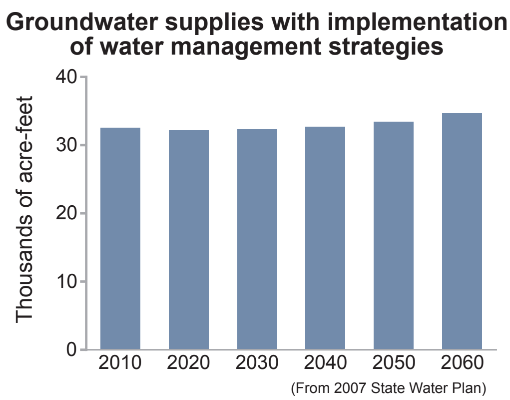
Structural cross sections along and across Woodbine Group rocks (modified from Nordstrom, 1982).



Total dissolved solids from Woodbine Aquifer wells (based on TWDB groundwater database).

Ferruginous sand of the Woodbine Formation 2 miles southwest of Denison, Grayson County, Texas (from Stephenson, 1919).

Lens of tuffaceous sand in laminated sandy clay of the Woodbine Formation along the Red River, Lamar County, Texas (from Ross and others, 1929).



Aquifer characteristics

- Area of outcrop: 1,557 square miles
- Area in subsurface: 5,766 square miles
- Proportion of aquifer with groundwater conservation districts: 0 percent
- Number of counties containing the aquifer: 17

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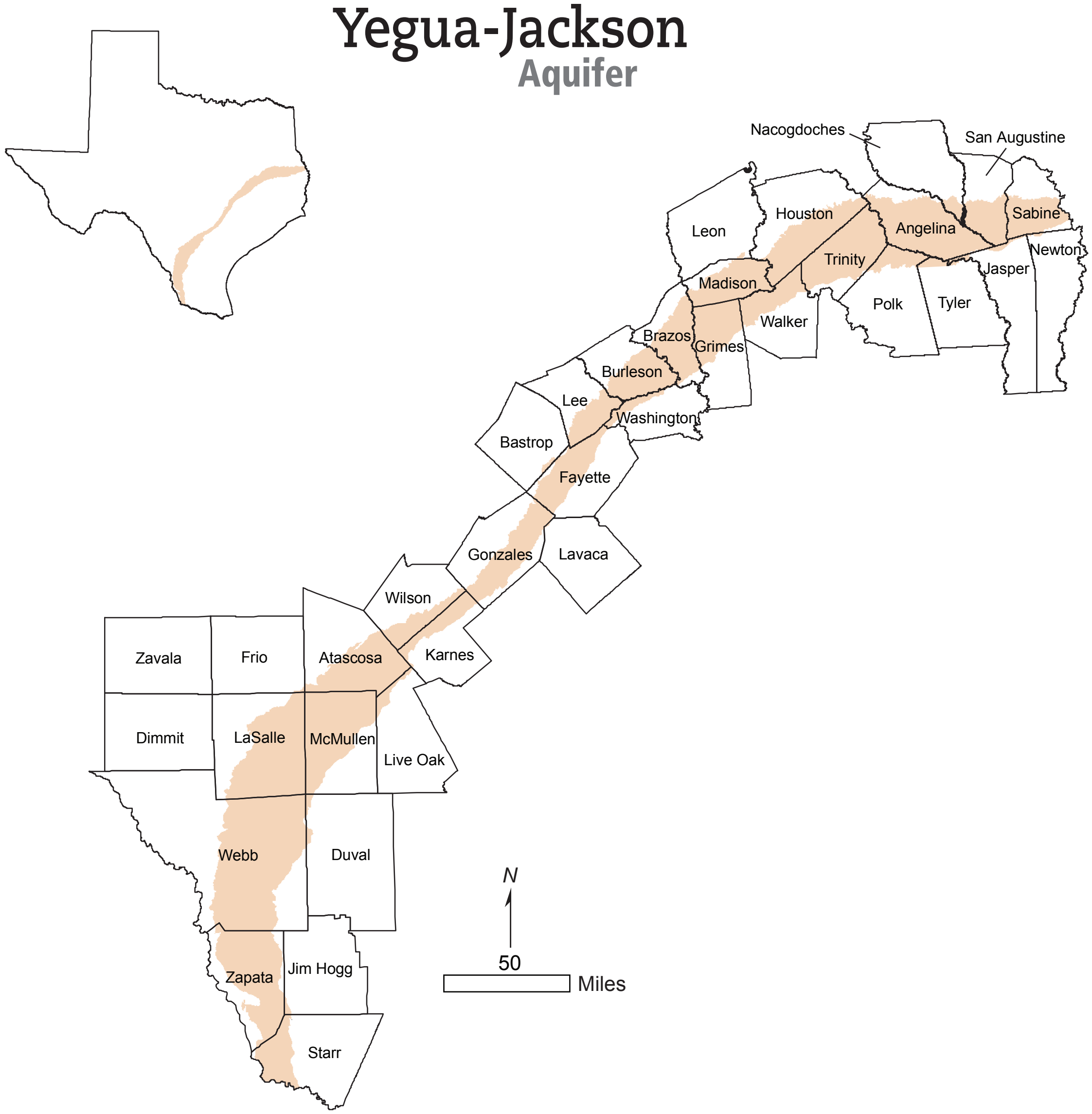
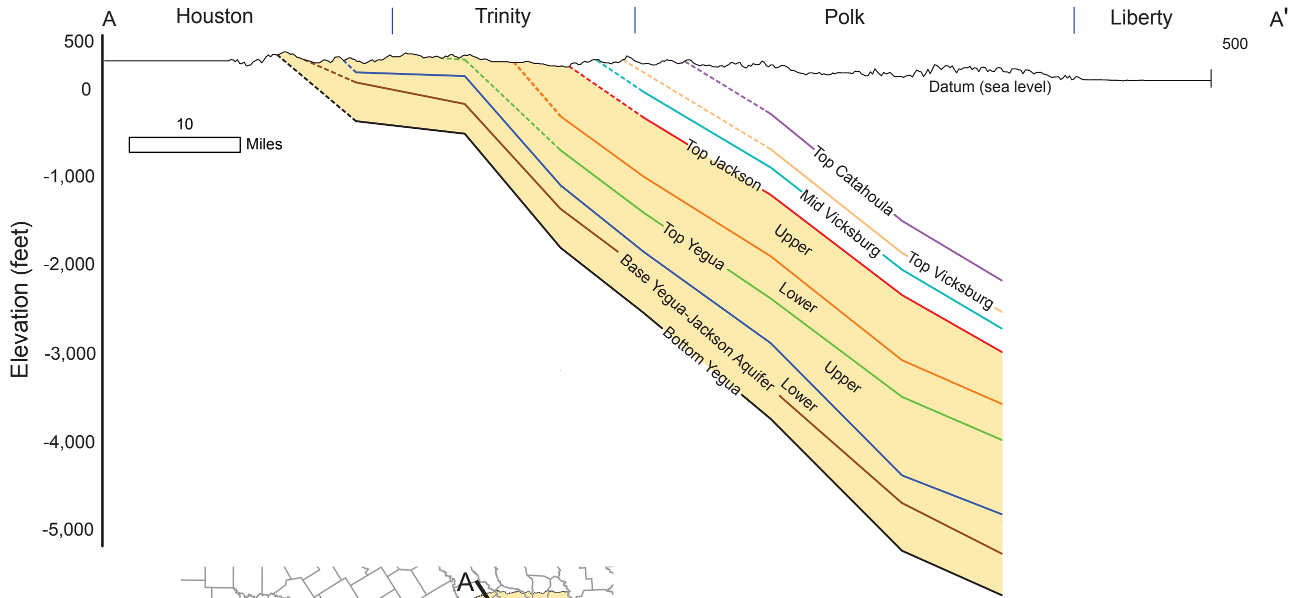
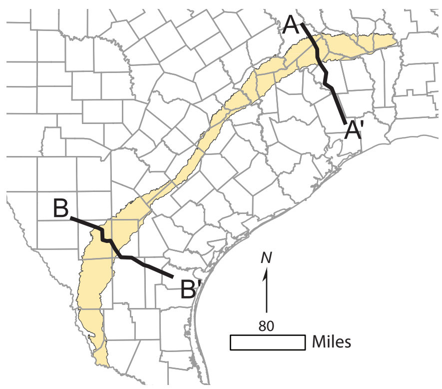
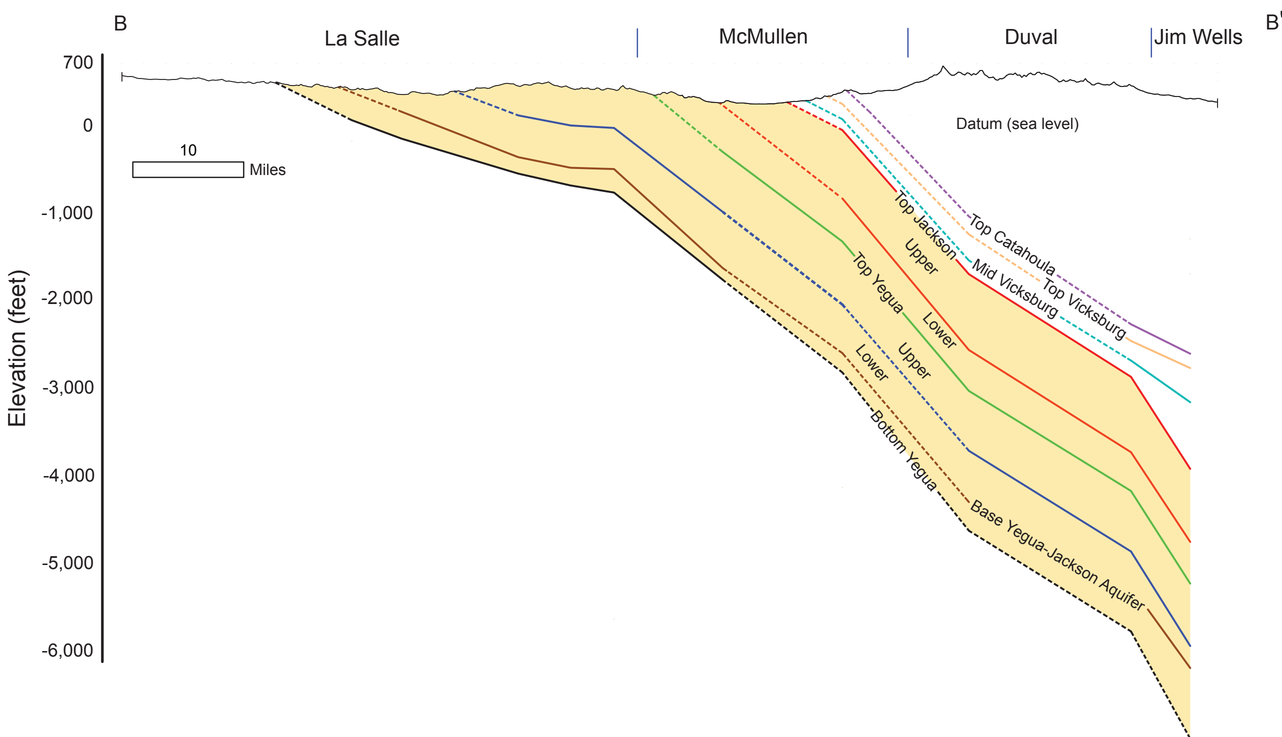
Yegua-Jackson
Aquifer



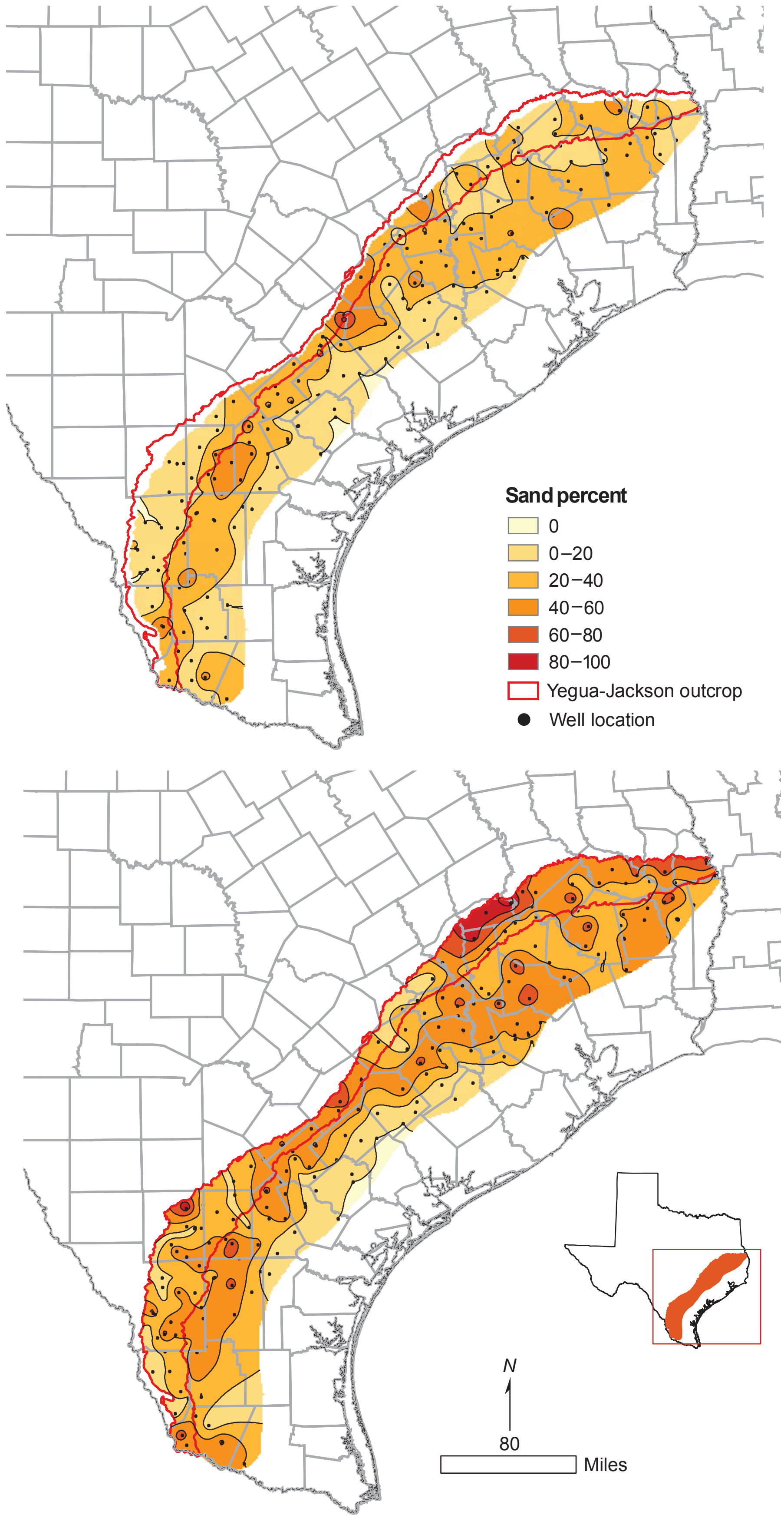
The Yegua-Jackson Aquifer is a minor aquifer stretching across the southeast part of the state. It includes water-bearing parts of the Yegua Formation (part of the upper Claiborne Group) and the Jackson Group (comprising the Whitsett, Manning, Wellborn, and Caddell formations). These geologic units consist of interbedded sand, silt, and clay layers originally deposited as fluvial and deltaic sediments. Freshwater saturated thickness averages about 170 feet. Water quality varies greatly owing to sediment composition in the aquifer formations, and in all areas the aquifer becomes highly mineralized with depth. Most groundwater is produced from the sand units of the aquifer, where the water is fresh and ranges from less than 50 to 1,000 milligrams per liter of total dissolved solids. Some slightly to moderately saline water, with concentrations of total dissolved solids ranging from 1,000 to 10,000 milligrams per liter, also occurs in the aquifer. No significant water level declines have occurred in wells measured by the TWDB. Groundwater for domestic and livestock purposes is available from shallow wells over most of the aquifer's extent. Water is also used for some municipal, industrial, and irrigation purposes. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Yegua-Jackson Aquifer, including drilling more wells and desalinating the water.



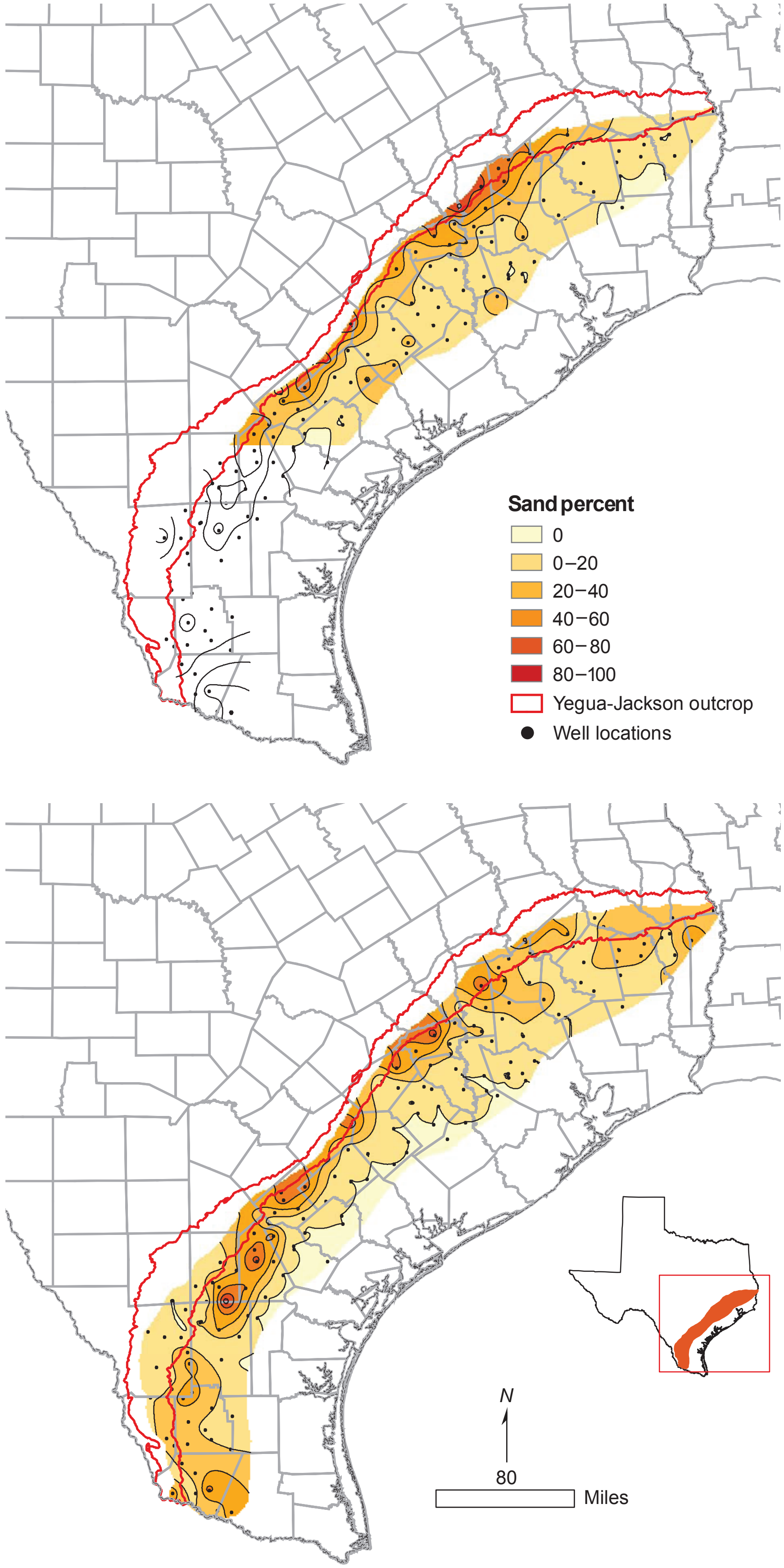




Geologic cross sections across the Yegua-Jackson Aquifer (modified from Knox and others, 2007).

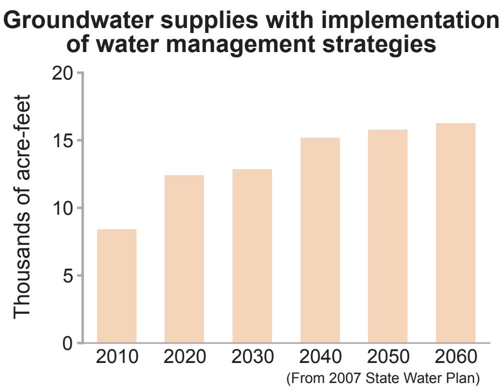


Percent-sand maps for the Upper, *above*, and Lower, *below*, Yegua layers (modified from Knox and others, 2007).



Percent-sand maps for the Upper, *above*, and Lower, *below*, Jackson layers (modified from Knox and others, 2007).

Yegua Formation just south of Dime Box, Texas (note: cross-bedding in right photograph).



Aquifer characteristics

- Area of aquifer: 10,904 square miles
- Proportion of aquifer with groundwater conservation districts: 58 percent
- Number of counties containing the aquifer: 34

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4 Possible Additions to the Aquifers of Texas

The TWDB periodically updates the maps of Texas' aquifers to add newly recognized aquifers or to update aquifer boundaries. For example, the TWDB added the Yegua-Jackson Aquifer as a minor aquifer of Texas in the 2002 State Water Plan. For the 2007 State Water Plan, the TWDB adjusted the boundaries of several of the state's aquifers, including the Blaine, Bone Spring–Victorio Peak, Edwards (Balcones Fault Zone), Igneous, Lipan, Ogallala, Pecos Valley, Seymour, and Trinity aquifers. The TWDB made changes on the basis of groundwater availability modeling and other scientific studies, and comments from the public supported by existing information. Details of these changes are included in an appendix to the 2007 State Water Plan and are incorporated into the aquifer summaries presented in this report.

Regional water planning groups in Texas include the major and minor aquifers in their planning process but also consider smaller, more local aquifers in their analysis. The TWDB categorizes these as "other" aquifers. Examples include the Austin Chalk, Precambrian igneous and metamorphic rocks in the Llano area, and the Colorado River alluvium (Figure 4-1). A list of all the aquifers associated with the TWDB groundwater database can be found in the Explanation of the Groundwater Database and Data Entry (User Manual 50) on the agency Web site. As groundwater use changes with time, it is possible that some of these other unofficial aquifers will be officially designated as an aquifer.

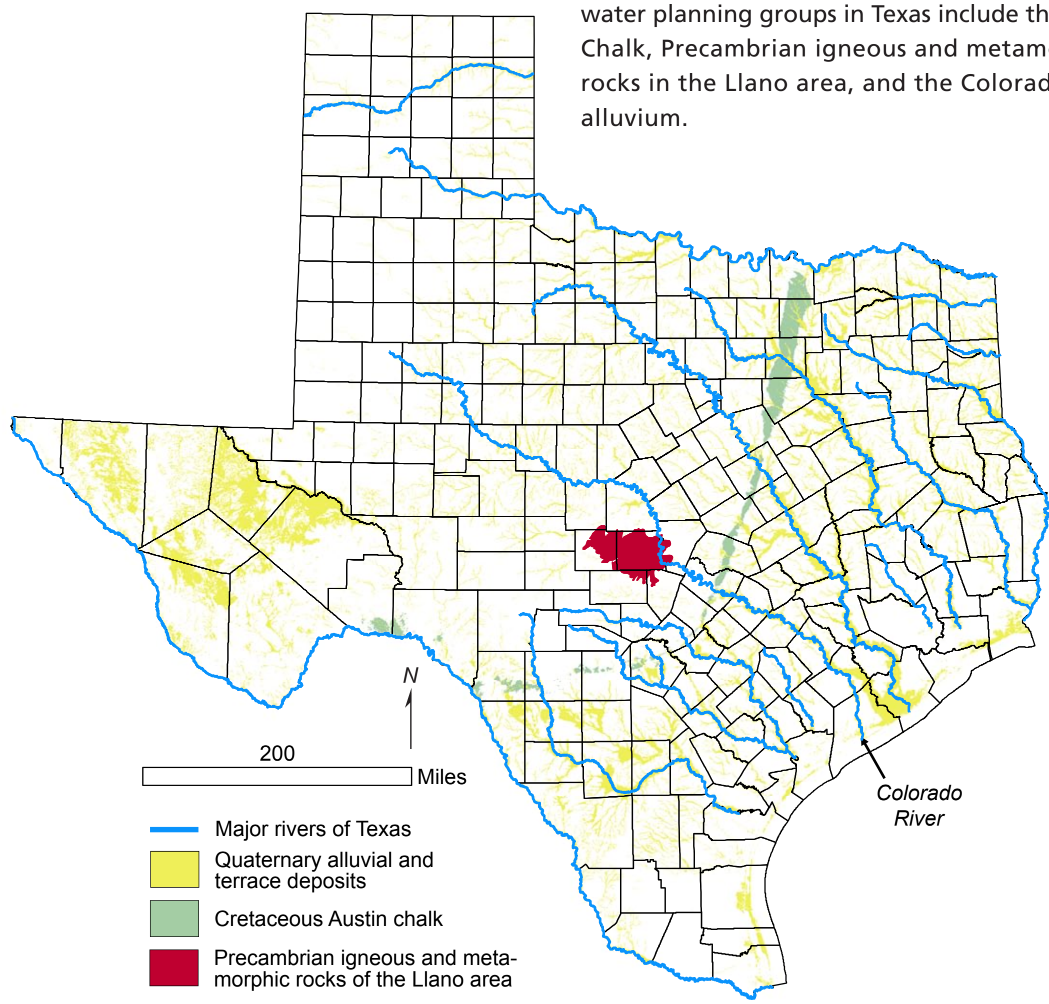

Figure 4-1. Other aquifers recognized by regional water planning groups in Texas include the Austin Chalk, Precambrian igneous and metamorphic rocks in the Llano area, and the Colorado River alluvium.

5 Acknowledgments

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