Chapter 7

Groundwater Resources

Chapter 7

Groundwater Resources

Texas recognizes 9 major and 21 minor aquifers that provide approximately 59 percent of the water used within the state. Groundwater is and will continue to be an important source of water for Texas.

To assess the quality and quantity of groundwater in Texas, TWDB operates three monitoring programs that complement other local, state, and federal monitoring programs within the state. Two of these programs monitor groundwater levels and one monitors water 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.

Changes in groundwater levels vary throughout the state. In some areas, the levels have remained nearly constant, while in others they have declined by as much as 1,000 feet in the last 100 years.

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, TWDB has obtained or developed models for all major aquifers and eight 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.

Existing groundwater supplies—the amount of groundwater that can be produced with current permits and existing infrastructures—are projected to decrease 32 percent between 2010 and 2060, from about 8.5 million acre-feet per year to about 5.8 million acre-feet per year.

Groundwater availability—the amount of water from an aquifer that is available for use as determined by the planning groups—is projected to decrease 22 percent, from 12.7 million acre-feet per year in 2010 to 9.9 million acre-feet per year by 2060.

Groundwater is and will continue to be an important source of water for Texas. Before 1940, groundwater provided less than 1 million acre-feet of water per year to Texans. Since the drought of the 1950s, groundwater production has been about 10 million acre-feet per year. In 2003, groundwater provided 59 percent of the 15.6 million acre-feet of water used in the state. Farmers used about 79 percent of this groundwater to irrigate crops, and municipalities relied on groundwater for about 36 percent of their water supplies.

TWDB recognizes 30 major and minor aquifers, each with their own characteristics and abilities to produce water. Along with a number of other local, state, and federal agencies, TWDB monitors the water quality and water levels of these aquifers. This information assists groundwater managers and water planners in estimating groundwater supplies and availability. It is also used to develop groundwater availability models, which aid groundwater managers and water planners in better understanding and using this vital natural resource in Texas.

7.1 Aquifers of Texas

Texas has numerous aquifers that are capable of producing groundwater for household, municipal, industrial, and agricultural uses. TWDB recognizes nine major aquifers—aquifers that produce large amounts of water over large areas (Figure 7.1)—and 21 minor aquifers—aquifers that produce minor amounts of water over large areas or large amounts of water over small areas (Figure 7.2). 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 (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.

Based on the results of groundwater availability modeling, other scientific studies, and public comment, TWDB adjusted the boundaries of some of the aquifers of Texas for this state water plan,

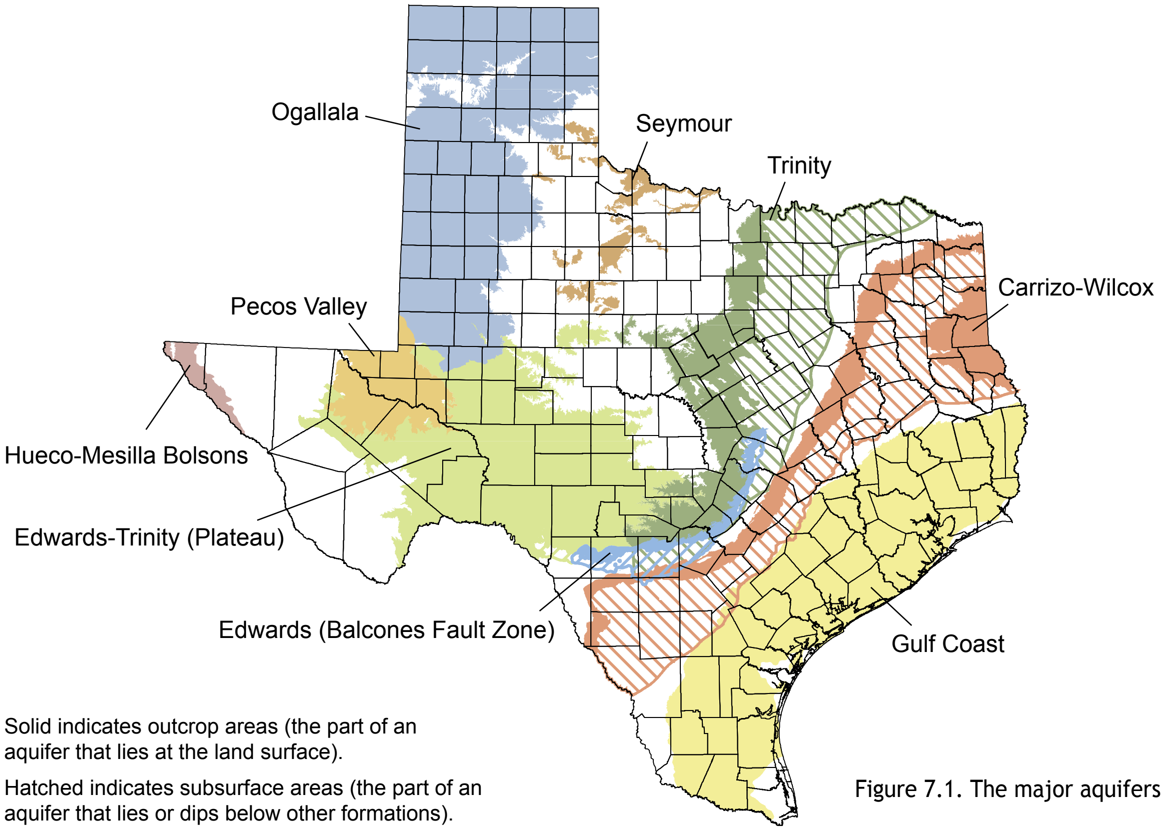


Figure 7.1. The major aquifers of Texas.

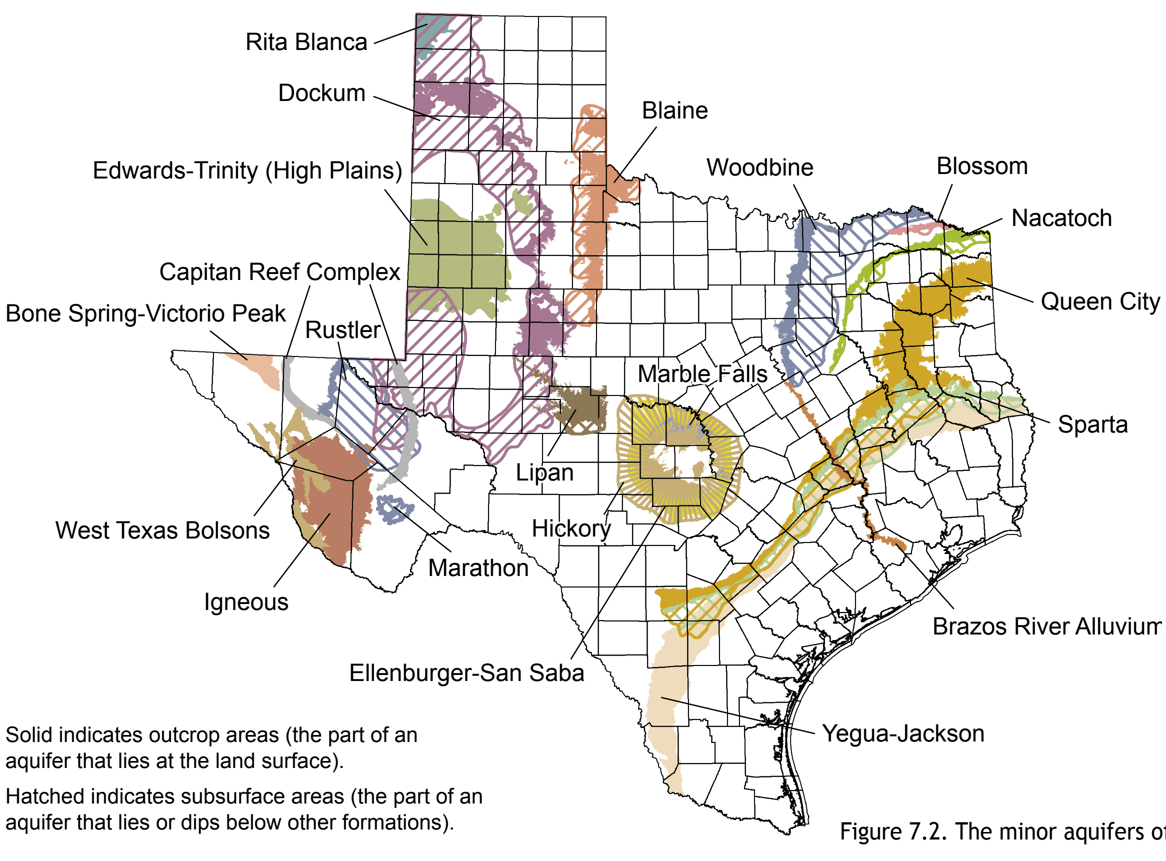


Figure 7.2. The minor aquifers of Texas.

including the Blaine, Bone Spring–Victorio Peak, Edwards (Balcones Fault Zone), Igneous, Lipan, Ogallala, Pecos Valley (formerly the Cenozoic Pecos Alluvium), Seymour, and Trinity aquifers.

7.1.1 Revision of the Boundaries of Selected Aquifers

TWDB periodically updates the maps of Texas' aquifers to add newly recognized aquifers or to update aquifer boundaries. For example, TWDB added the Yegua-Jackson Aquifer as a minor aquifer of Texas in the 2002 State Water Plan. For the 2007 State Water Plan, TWDB has not added any new aquifers; however, TWDB has adjusted the boundaries of several of the state's aquifers, including the Blaine (Figure 7.3), Bone Spring-Victorio Peak (Figure 7.4), Edwards (Balcones Fault Zone) (Figure 7.5), Igneous (Figure 7.6), Lipan (Figure 7.7), Ogallala (Figure 7.8), Pecos Valley (Figure 7.8), Seymour (Figure 7.9), and Trinity (Figure 7.10) aquifers. TWDB made changes based on groundwater availability modeling studies, other scientific studies, and comments from the public supported by existing information. Details of these changes are included in Appendix 7.1. In addition, TWDB has changed the name of the Hueco-Mesilla Bolson Aquifer to the Hueco-Mesilla Bolsons Aquifer to reflect that the aquifer is made of sediments in two separate bolsons: the Hueco Bolson and the Mesilla Bolson. For more information on these aquifers and their boundaries, please see Ashworth and Flores (1991) and Ashworth and Hopkins (1995).

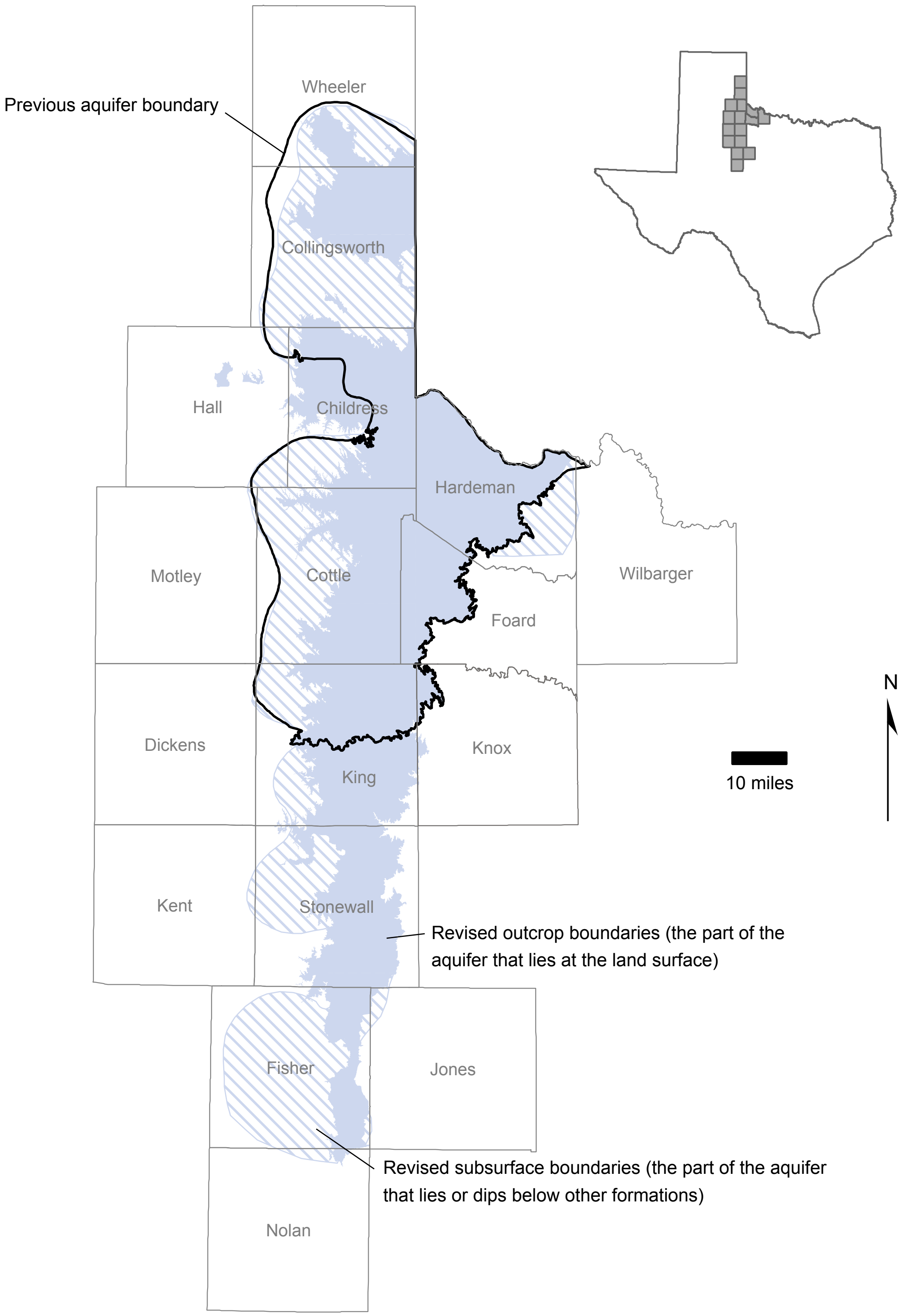


Figure 7.3. Revised and previous boundaries for the Blaine Aquifer.

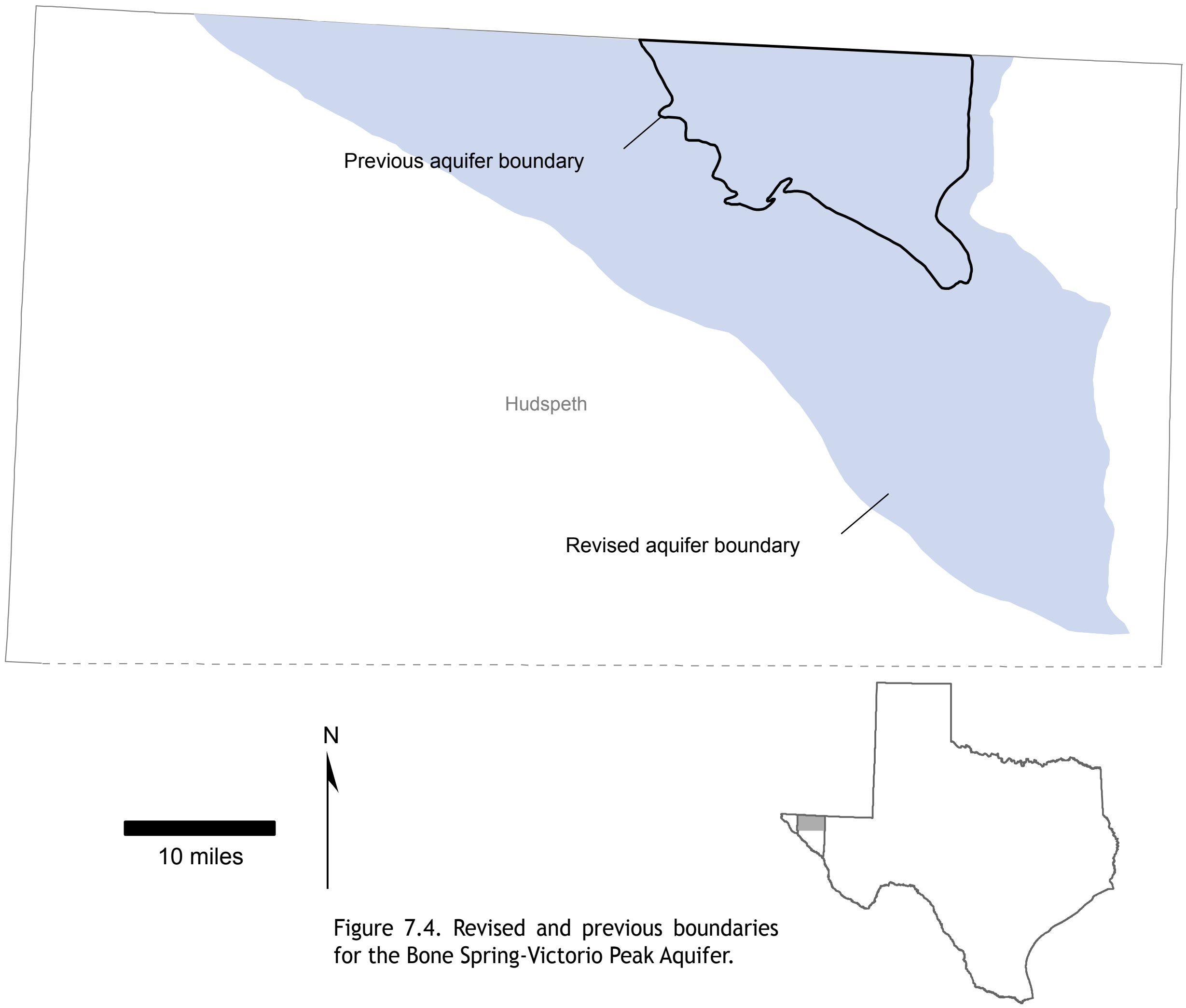


Figure 7.4. Revised and previous boundaries for the Bone Spring-Victorio Peak Aquifer.

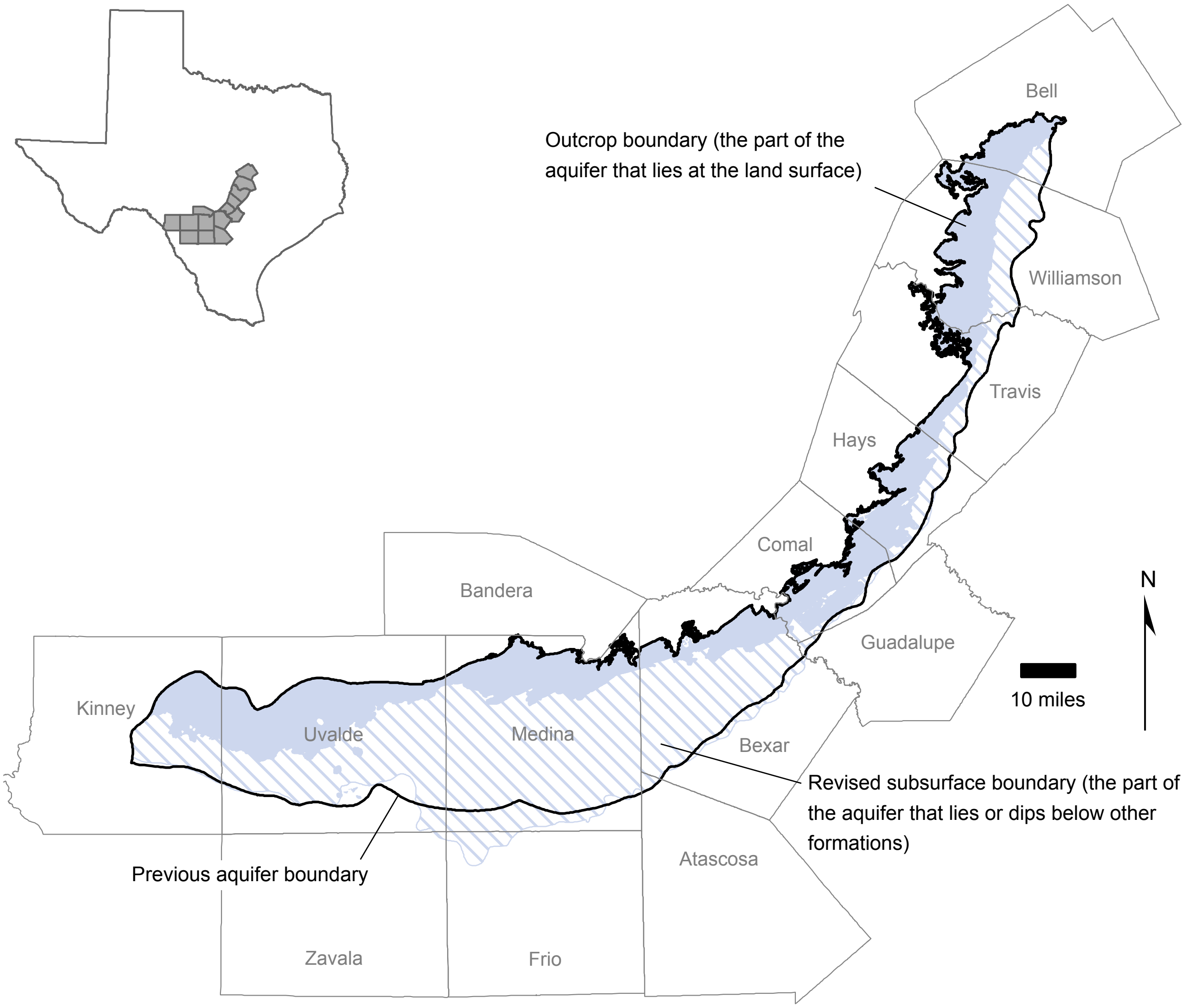


Figure 7.5. Revised and previous boundaries for the Edwards (Balcones Fault Zone) Aquifer.

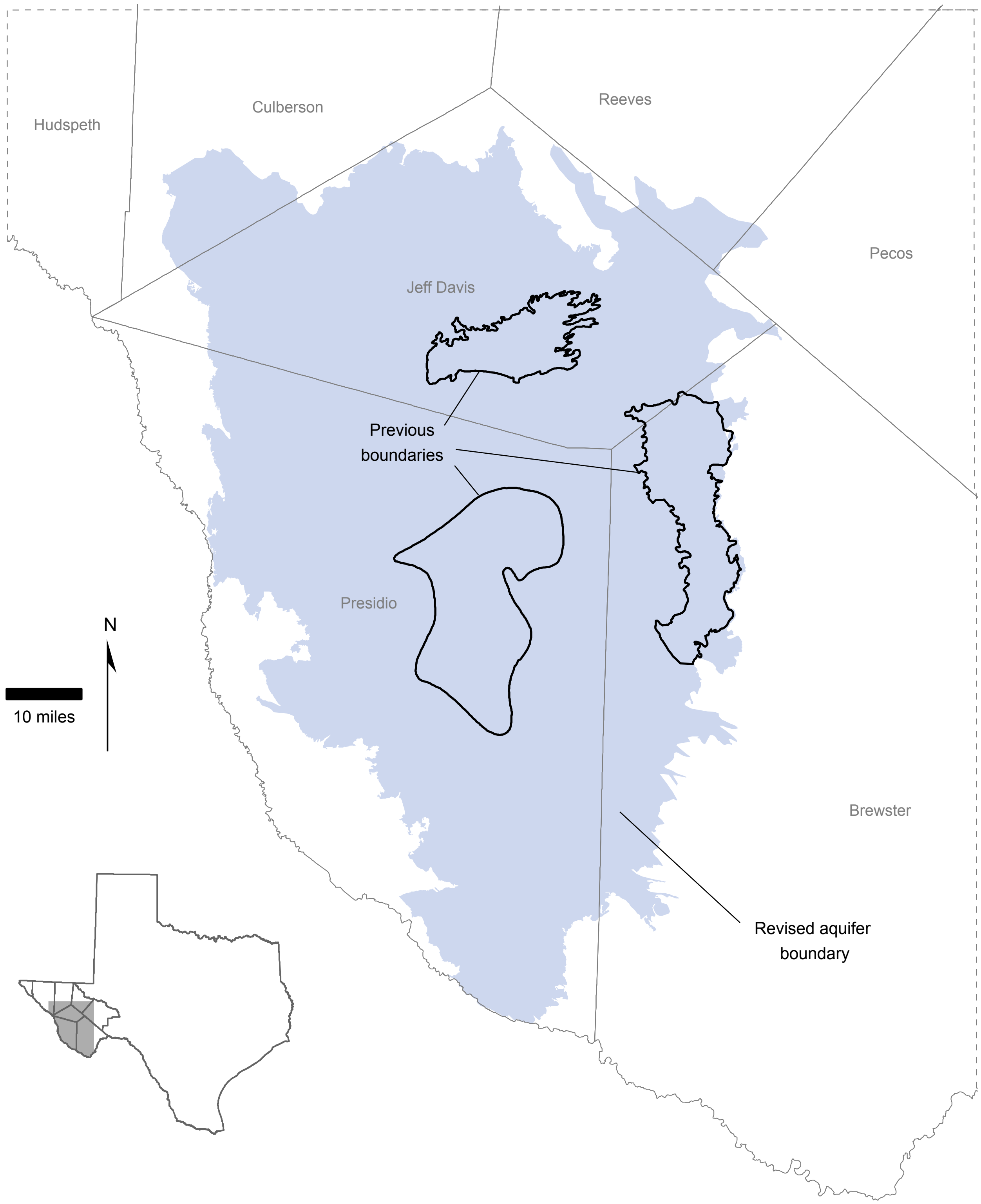


Figure 7.6. Revised and previous boundaries for the Igneous Aquifer.

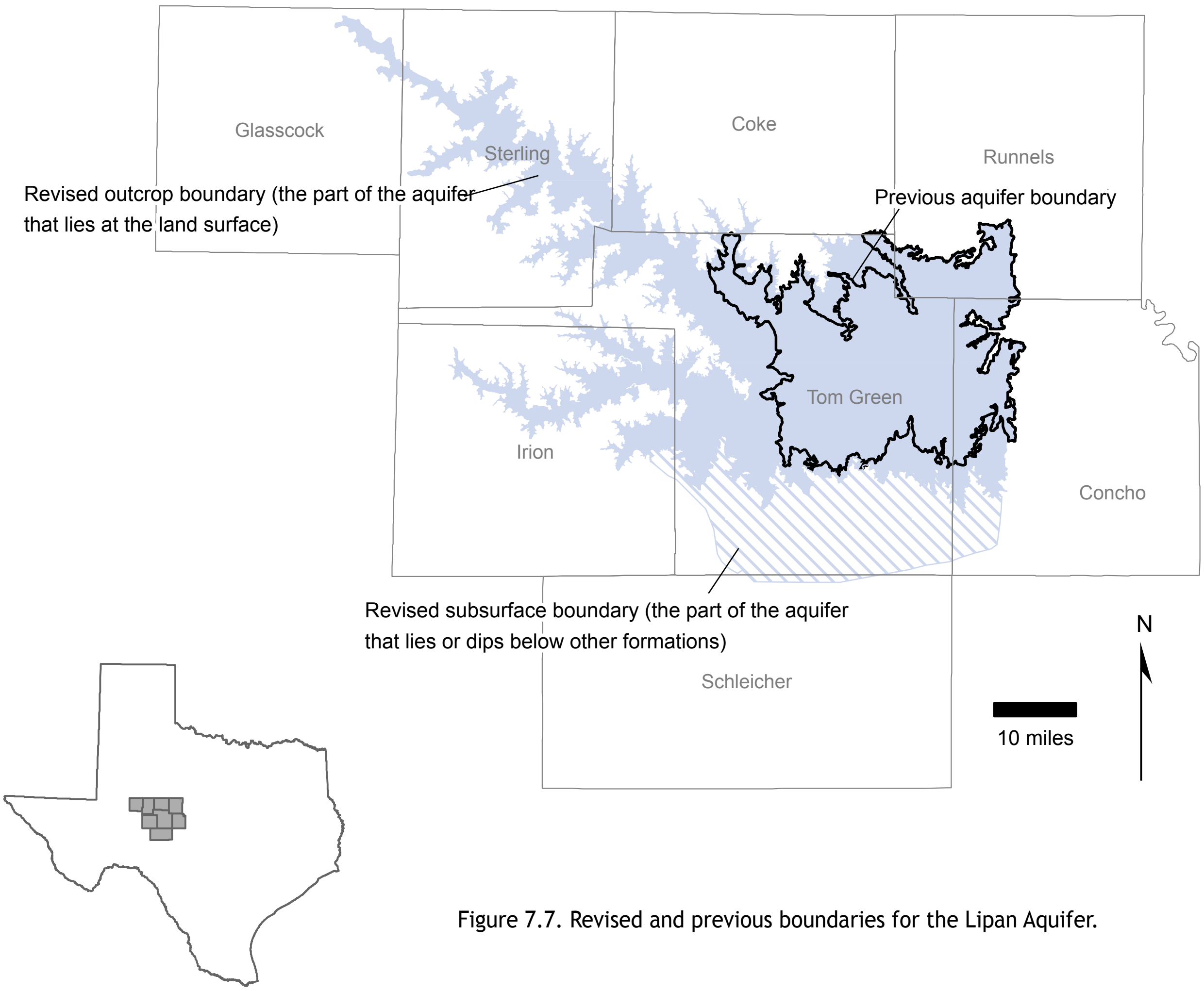


Figure 7.7. Revised and previous boundaries for the Lipan Aquifer.

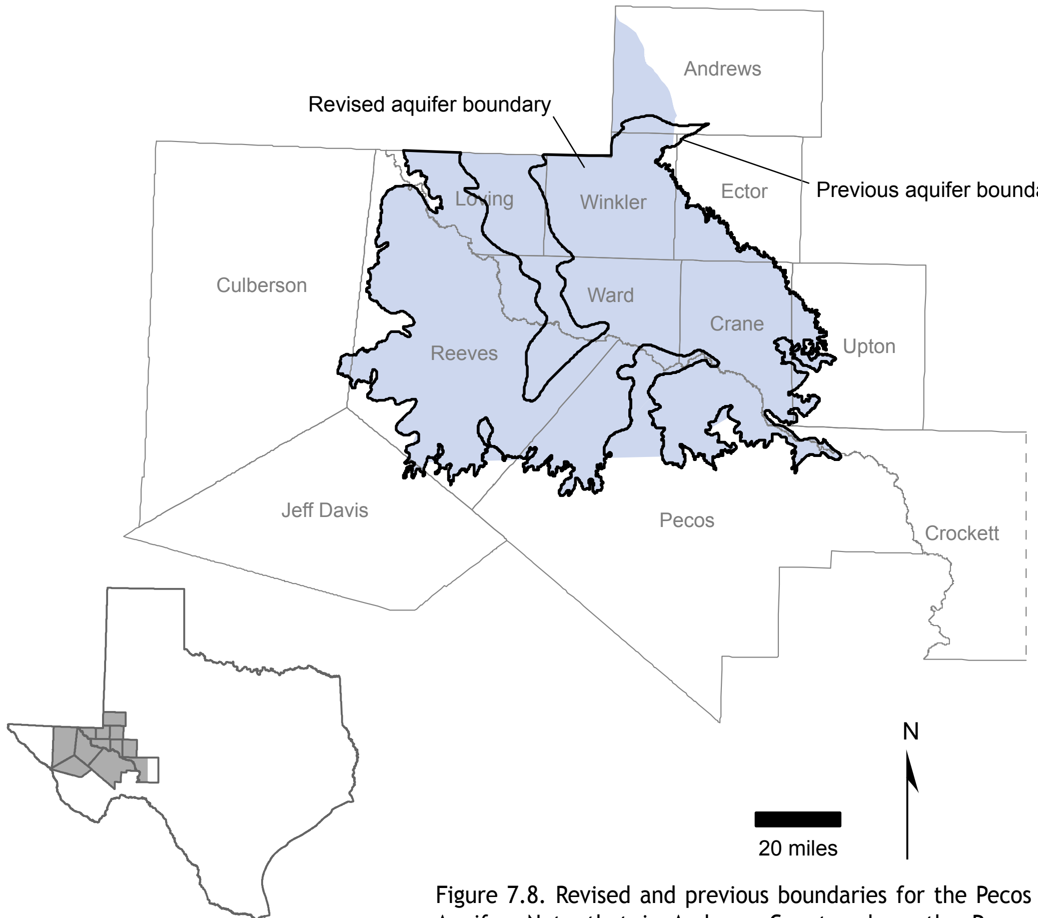


Figure 7.8. Revised and previous boundaries for the Pecos Valley Aquifer. Note that in Andrews County where the Pecos Valley Aquifer has been expanded, it has replaced the Ogallala Aquifer.

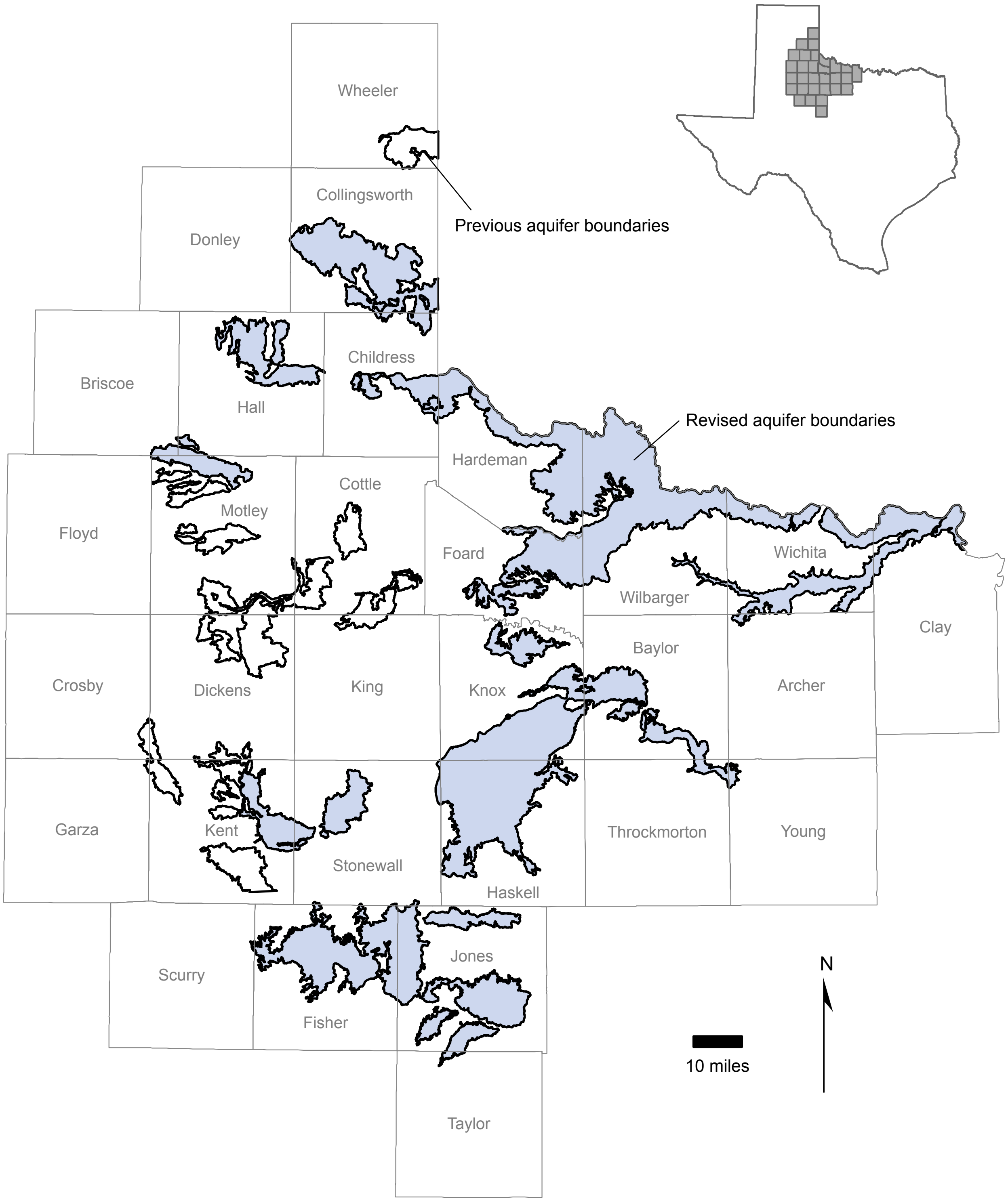


Figure 7.9. Revised and previous boundaries for the Seymour Aquifer.

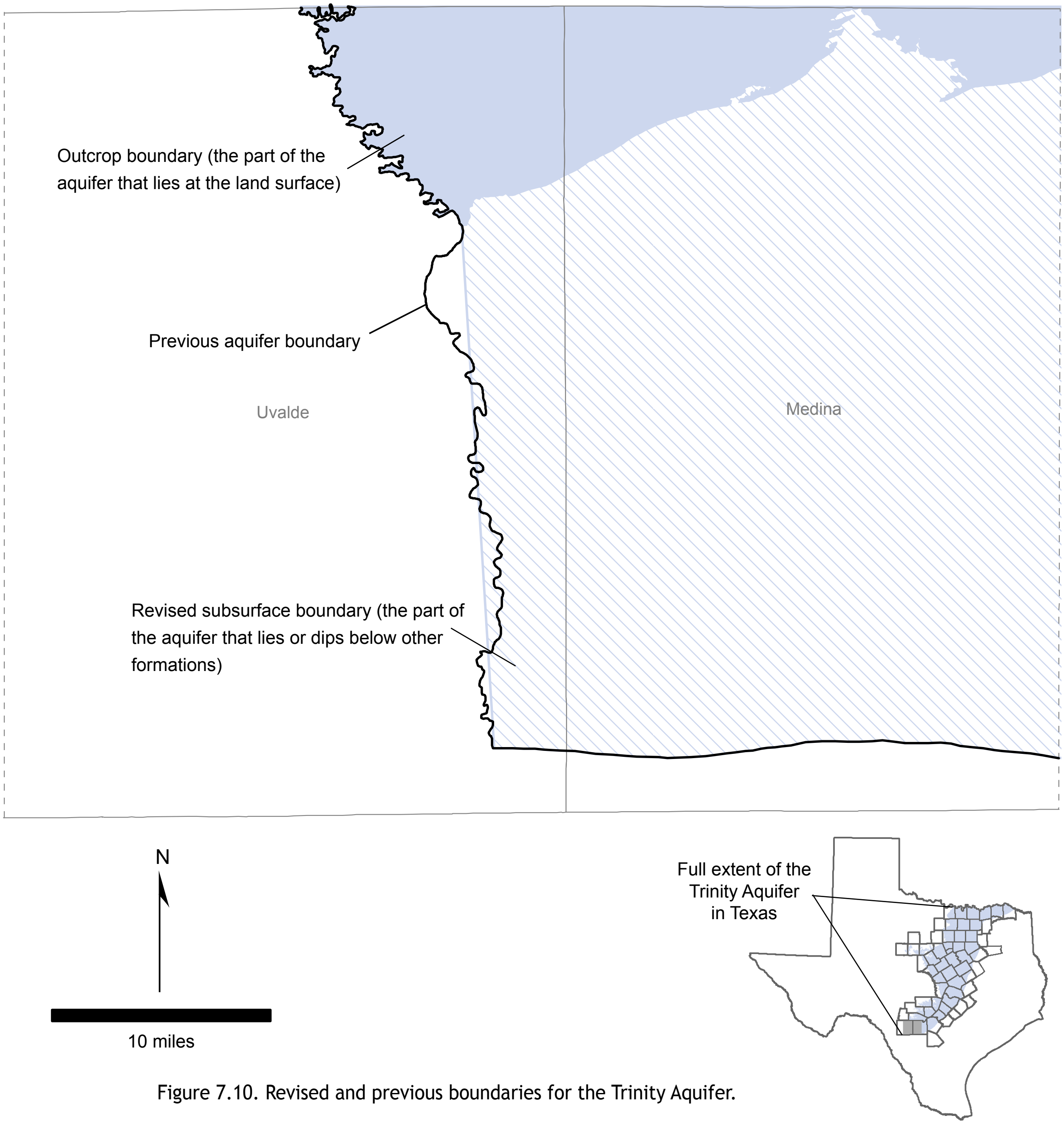


Figure 7.10. Revised and previous boundaries for the Trinity Aquifer.

7.1.2 Aquifer Summaries

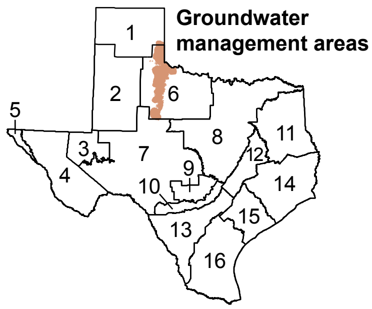
Following are 30 one-page summaries for the major and minor aquifers of Texas. These summaries include location maps of the aquifers relative to groundwater management areas, planning groups, and groundwater conservation districts; a discussion and list of aquifer properties and characteristics; and projections of groundwater supplies, including supplies to be obtained from implementing water management strategies from the state water plan. Note that these 30 aquifers do not represent all of the groundwater in Texas—there are also numerous small aquifers not included here that are important locally to homeowners, ranchers, and others. The planning groups estimated the statewide groundwater availability of these aquifers, referred to as "other" aquifers, to be about 220,000 acre-feet per year. Some of the planning groups based this estimate on reported historical use.

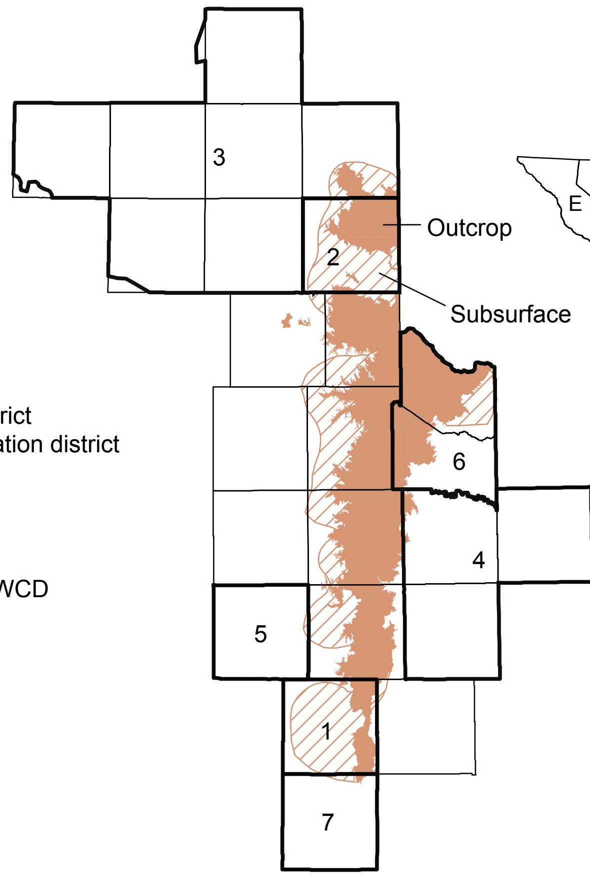
Each one-page summary includes a list of the following aquifer characteristics: (1) area of aquifer (if the aquifer is entirely exposed at the land surface); (2) area of outcrop and area in subsurface (if the aquifer is not entirely exposed at the land surface); (3) availability (from the regional water plans); (4) proportion of aquifer with groundwater conservation districts (based on surface area); and (5) number of counties containing the aquifer (no matter how small the portion of the aquifer is in the county).

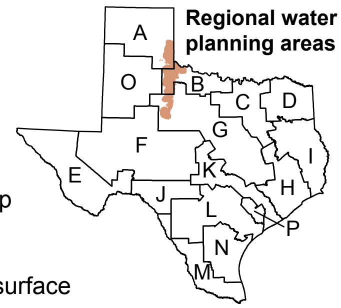
These summaries include several terms that may be unfamiliar to a nontechnical reader:

- Alkaline—Water with a pH greater than 7.0; opposite of acidic
- Artesian aquifer—Same as a confined aquifer
- Brackish groundwater—Water with total dissolved solids between 1,000 and 10,000 milligrams per liter
- Confined aquifer—Aquifer that is under pressure because of overlying sediments that partly seal the aquifer
- Fresh groundwater—Groundwater with total dissolved solids less than 1,000 milligrams per liter
- Hard water—Water that leaves an insoluble residue when used with soap or forms scale, such as in a water heater; generally associated with high levels of calcium and magnesium
- Outcrop—Area where a geologic formation is exposed at the land surface
- Primary drinking water standards—Legally enforceable limits for dissolved constituents in public water supply systems
- Radionuclide—Atom that emits radioactivity
- Reallocation—Moving water supplies from one water user group to another
- Redevelop a well field—Process of increasing yields in a well field; may include the installation of new pumping equipment
- Recharge—Amount of water that infiltrates to the water table of an aquifer
- Salinity—Concentration of dissolved salts in water
- Secondary drinking water standards—Nonenforceable guidelines for dissolved constituents that may affect the cosmetic or aesthetic quality of drinking water
- Slightly saline—Water with total dissolved solids between 1,000 and 3,000 milligrams per liter
- Soft water—Water with low amounts of calcium and magnesium; opposite of hard water
- Subsidence—Situation occurring when groundwater pumping allows sediments to compress and lower the land surface
- Temporary overdraft—Situation occurring when pumping is allowed to exceed groundwater availability for a defined period of time
- Total dissolved solids—Amount of dissolved material in water; fresh water has a total dissolved solids concentration less than 1,000 milligrams per liter
- Unconfined—Aquifer that is not under pressure

Blaine Aquifer







GCD = Groundwater conservation district
UWCD = Underground water conservation district

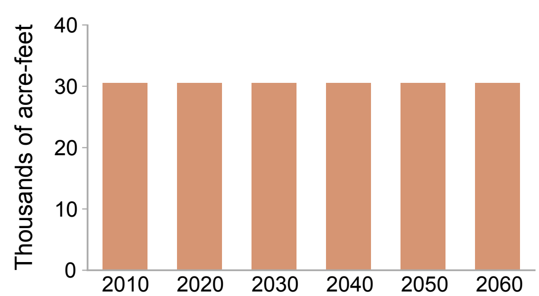
1. Clear Fork GCD
2. Collingsworth County UWCD
3. Panhandle GCD
4. Rolling Plains GCD
5. Salt Fork UWCD
6. Tri-County GCD
7. Wes-Tex GCD

The Blaine Aquifer is a minor aquifer located at the east end of the High Plains in North Texas. It is composed of red, silty shale, gypsum, anhydrite, salt, and dolomite. Saturated thickness reaches 300 feet, but freshwater saturated thickness averages 137 feet in the aquifer. 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 to 3,000 milligrams per liter, most contain moderately saline water, with total dissolved solids primarily between 3,000 to 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 to irrigate highly salt-tolerant crops. In areas where the groundwater is used for irrigation, water levels fluctuate seasonally. The planning groups did not recommend any water management strategies using the Blaine Aquifer.

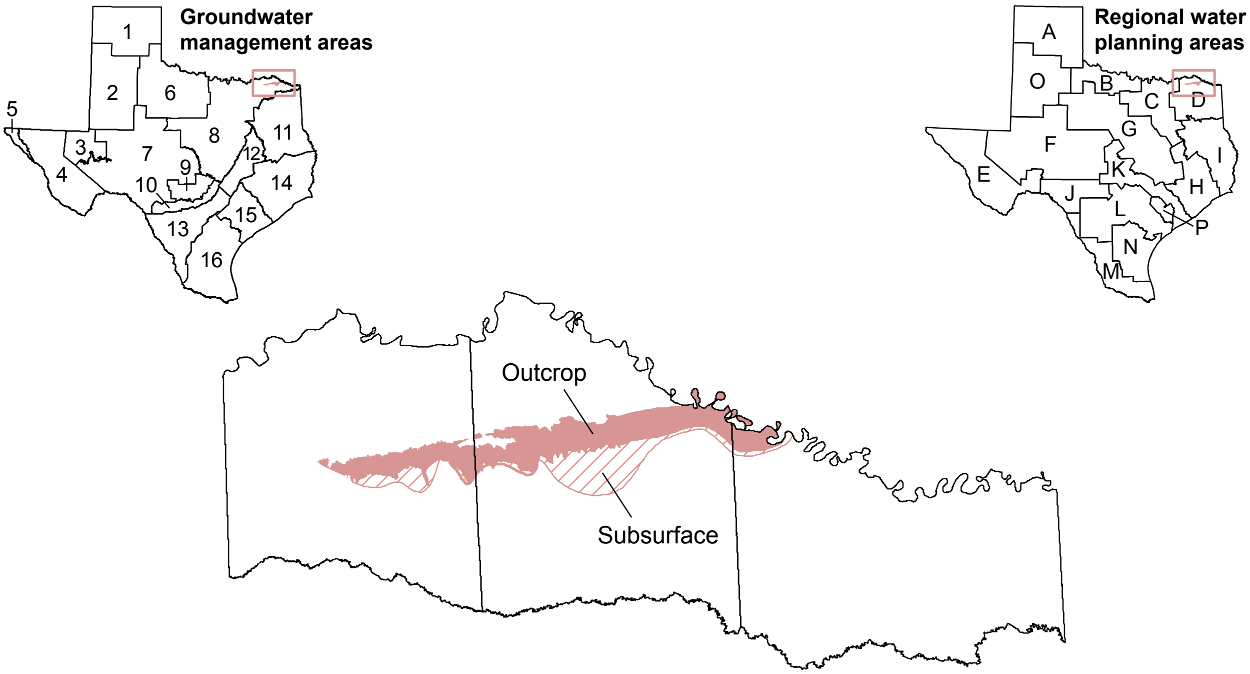
Aquifer characteristics

- Area of outcrop: 3,443 square miles
- Area in subsurface: 2,203 square miles
- Availability: 315,183 acre-feet per year (2010) to 313,933 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 48 percent
- Number of counties containing the aquifer: 16

Groundwater supplies with implementation of water management strategies



Blossom Aquifer

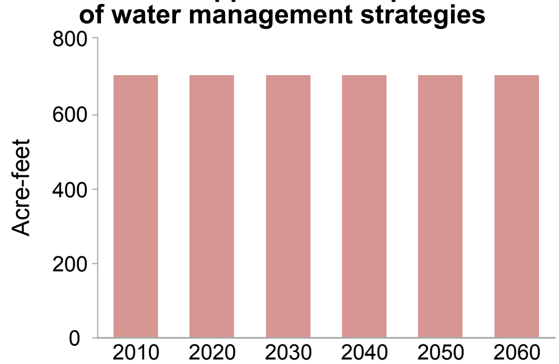


The Blossom Aquifer is a minor aquifer located in Bowie, Red River, and Lamar counties in the northeast corner of Texas. The aquifer consists of the Blossom Sand Formation, composed of alternating sequences of sand and clay. In places, the aquifer is as much as 400 feet thick, although no more than about 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 six 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 Water Supply Corporation in Red River County have historically pumped the greatest amounts from the aquifer, resulting in 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 planning groups did not recommend any water management strategies using the Blossom Aquifer.

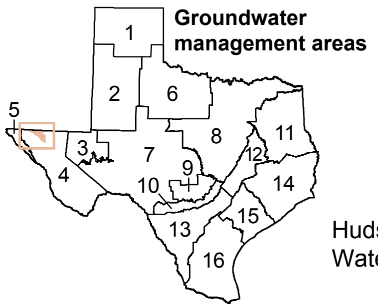
Aquifer characteristics

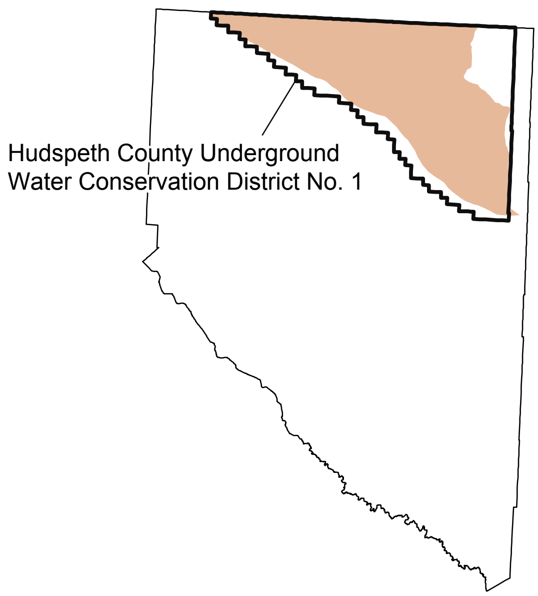
- Area of outcrop: 182 square miles
- Area in subsurface: 95 square miles
- Availability: 2,270 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 0 percent
- Number of counties containing the aquifer: 3

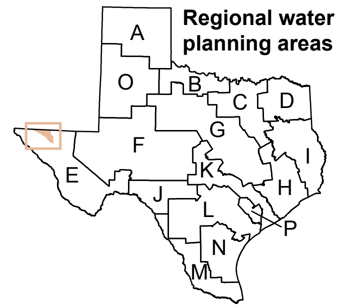
Groundwater supplies with implementation of water management strategies



Bone Spring-Victorio Peak Aquifer





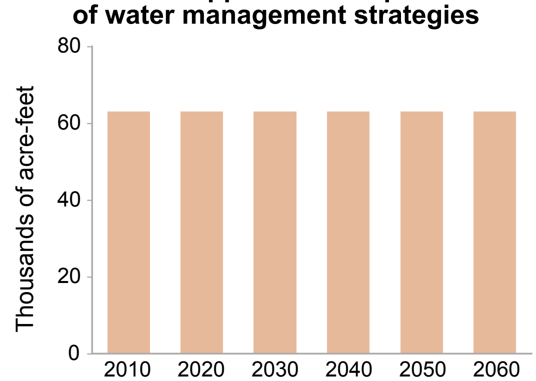


The Bone Spring-Victorio Peak Aquifer is a minor aquifer located in northern Hudspeth County. The principal water-bearing units in the aquifer are the Bone Spring and Victorio Peak limestones, with a combined total thickness up to 2,000 feet. Both formations produce water from solution cavities along fractures. Water quality 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. Since the late 1940s, pumping has been the principal means of discharge for the aquifer. Significant amounts of groundwater have been pumped and are being pumped from the aquifer in the Dell Valley area. 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 likely due to irrigation pumping. However, water levels over the last 30 years have been relatively constant except for the last few years when water levels have declined due to drought. The Region E Planning Group 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.

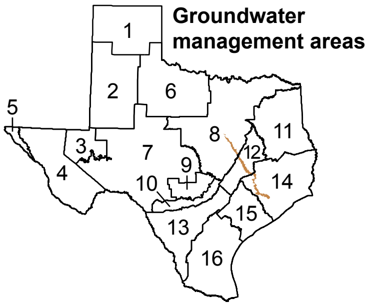
Aquifer characteristics

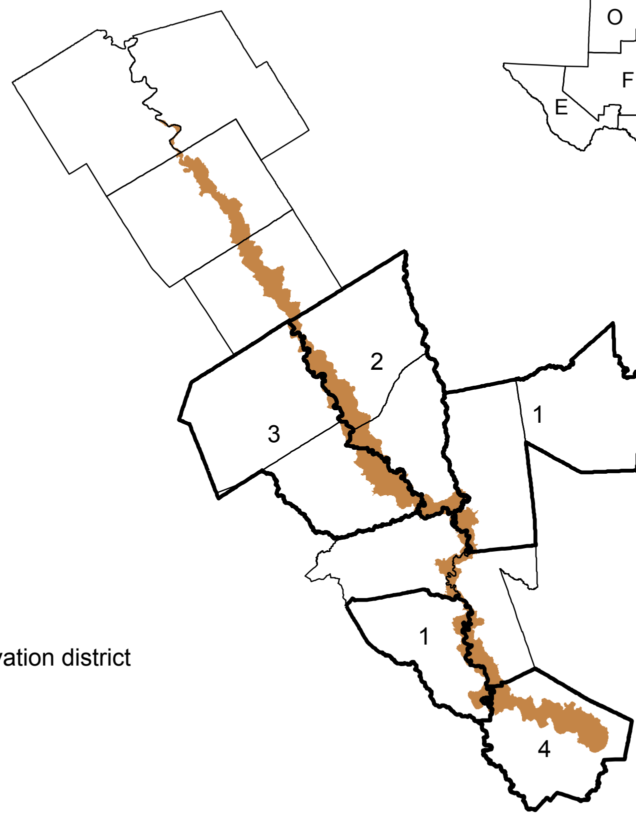
- Area of aquifer: 710 square miles
- Availability: 63,000 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 100 percent
- Number of counties containing the aquifer: 1

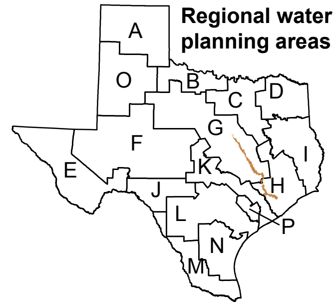
Groundwater supplies with implementation of water management strategies



Brazos River Alluvium Aquifer







1. Bluebonnet GCD
2. Brazos Valley GCD
3. Post Oak Savannah GCD
4. Fort Bend SD

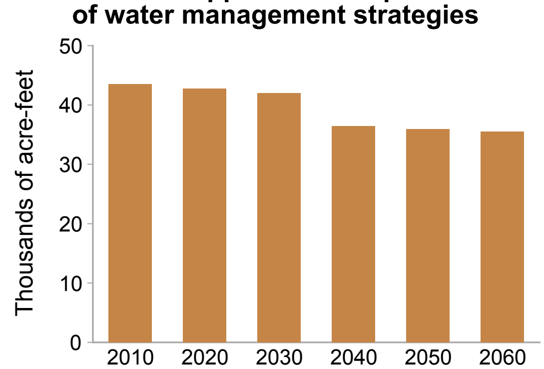
GCD = Groundwater conservation district
SD = Subsidence district

The Brazos River Alluvium Aquifer is a minor aquifer found along the Brazos River in east central Texas. Groundwater is contained in alluvial floodplain and terrace deposits consisting of clay, silt, sand, and gravel; overall thickness averages 50 feet but exceeds 100 feet in isolated areas. 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 up to 3,000 milligrams per liter in some wells. Nearly all groundwater withdrawn from the aquifer is used for irrigation, and no significant water level declines have occurred. The planning groups did not recommend any water management strategies using the Brazos River Alluvium Aquifer.

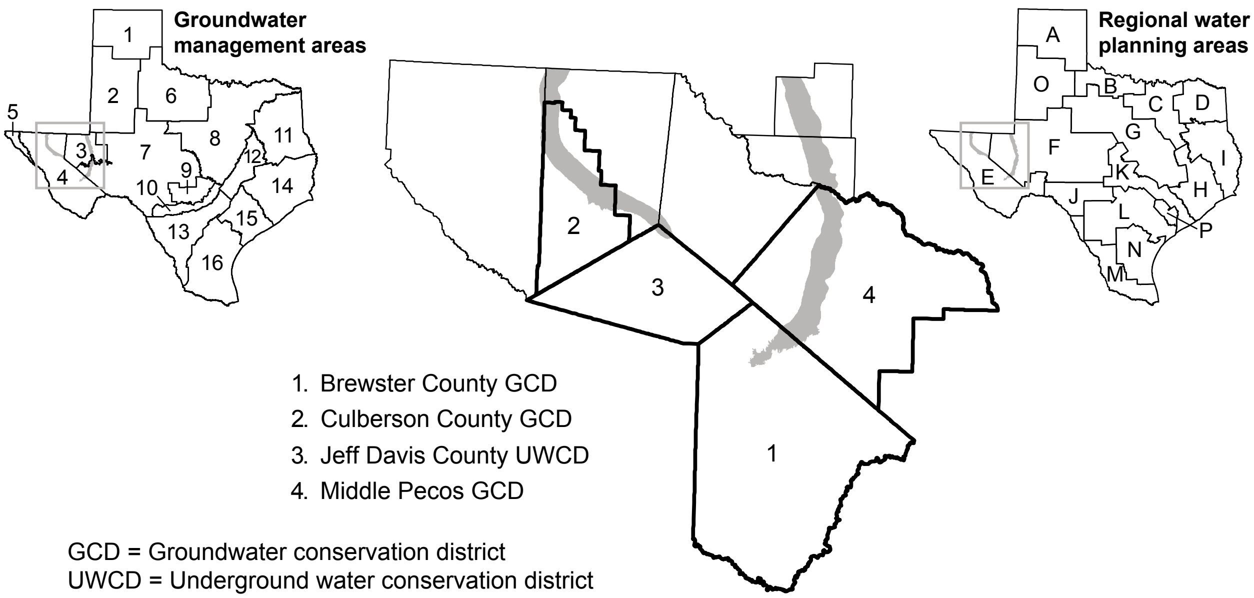
Aquifer characteristics

- Area of aquifer: 1,053 square miles
- Availability: 99,632 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 65 percent
- Number of counties containing the aquifer: 13

Groundwater supplies with implementation of water management strategies



Capitan Reef Complex Aquifer

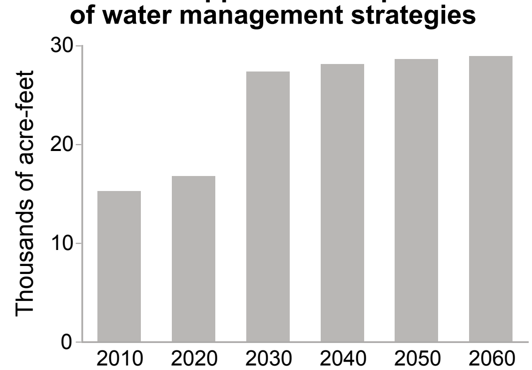


The Capitan Reef Complex Aquifer is a minor aquifer located in Culberson, Hudspeth, Jeff Davis, Brewster, Pecos, Reeves, Ward, and Winkler counties. It is exposed in mountain ranges of Far West Texas and elsewhere occurs in the subsurface. The aquifer is composed of up to 2,360 feet of massive, cavernous dolomite and limestone. Water-bearing formations include the Capitan Limestone, Goat Seep Limestone, and most of the Carlsbad facies of the Artesia Group, including the Grayburg, Queen, Seven Rivers, Yates, and Tansill formations. 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 for 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 located 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 Region E Planning Group 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.

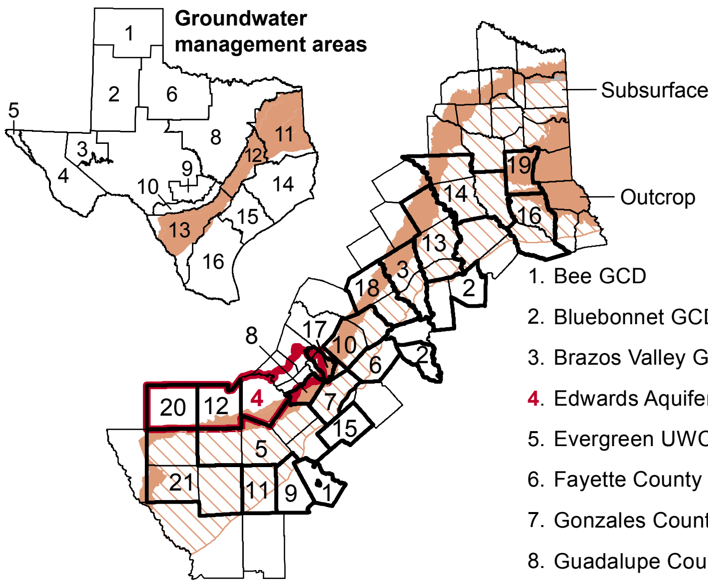
Aquifer characteristics

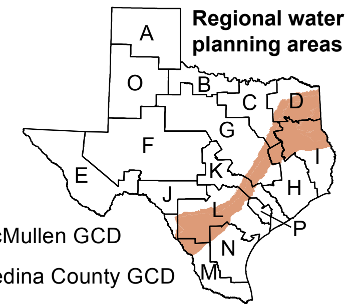
- Area of aquifer: 1,842 square miles
- Availability: 52,150 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 60 percent
- Number of counties containing the aquifer: 8

Groundwater supplies with implementation of water management strategies



Carrizo-Wilcox Aquifer





1. Bee GCD
2. Bluebonnet GCD
3. Brazos Valley GCD
4. Edwards Aquifer Authority
5. Evergreen UWCD
6. Fayette County GCD
7. Gonzales County UWCD
8. Guadalupe County GCD
9. Live Oak UWCD
10. Lost Pines GCD
11. McMullen GCD
12. Medina County GCD
13. Mid-East Texas GCD
14. Neches & Trinity Valleys GCD
15. Pecan Valley GCD
16. Pineywoods GCD
17. Plum Creek CD
18. Post Oak Savannah GCD
19. Rusk County GCD
20. Uvalde County UWCD
21. Wintergarden GCD

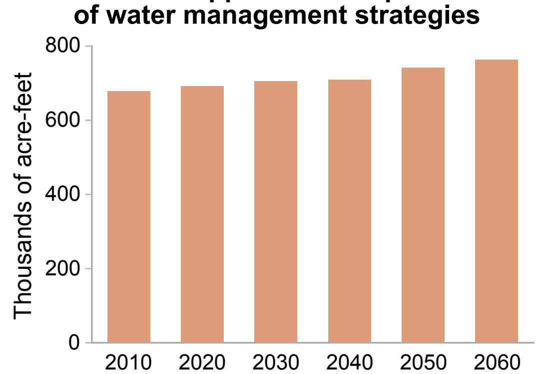
GCD = Groundwater conservation district
UWCD = Underground water conservation district
CD = Conservation District

The Carrizo-Wilcox Aquifer is a major aquifer extending from the Louisiana border to the Mexican border 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 in the deeper subsurface portions of the aquifer, and portions 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 just over half the water pumped, and pumping for municipal supply accounts for another 40 percent. Water level declines have occurred in the Winter Garden area due to irrigation pumping and in the northeastern part of the aquifer due to municipal pumping. The planning groups 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.

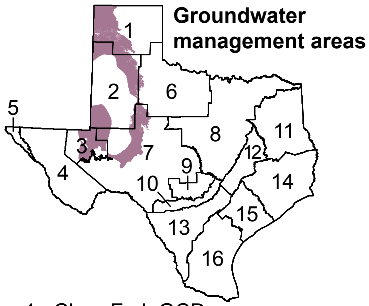
Aquifer characteristics

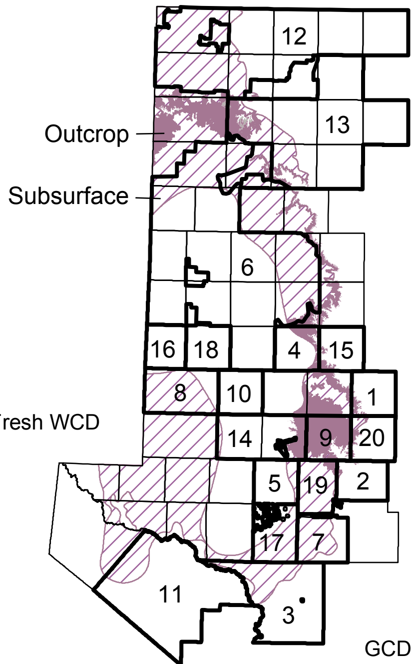
- Area of outcrop: 11,186 square miles
- Area in subsurface: 25,409 square miles
- Availability: 1,014,753 acre-feet per year (2010) to 1,010,793 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 63 percent
- Number of counties containing the aquifer: 66

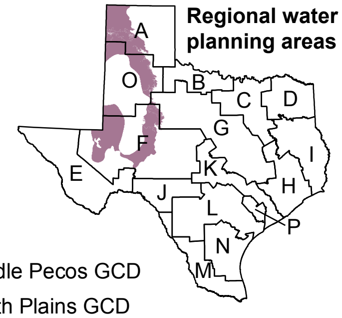
Groundwater supplies with implementation of water management strategies



Dockum Aquifer







1. Clear Fork GCD
2. Coke County UWCD
3. Emerald UWCD
4. Garza County Underground and Fresh WCD
5. Glasscock GCD
6. High Plains UWCD No.1
7. Irion County WCD
8. Llano Estacado UWCD
9. Lone Wolf GCD
10. Mesa UWCD
11. Middle Pecos GCD
12. North Plains GCD
13. Panhandle GCD
14. Permian Basin UWCD
15. Salt Fork UWCD
16. Sandy Land UWCD
17. Santa Rita UWCD
18. South Plains UWCD
19. Sterling County UWCD
20. Wes-Tex GCD

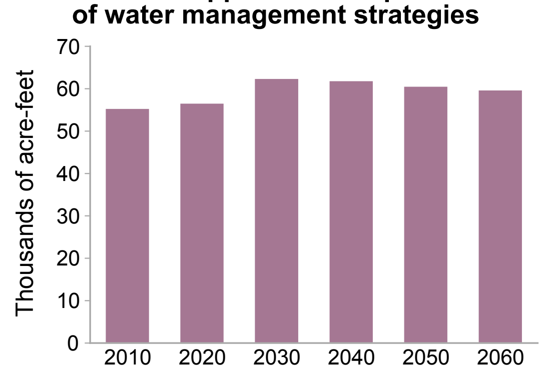
GCD = Groundwater conservation district
UWCD = Underground water conservation district
WCD = Water conservation district

The Dockum Aquifer is a minor aquifer found in the northwest part of the state. It consists of sand and conglomerate interbedded with layers of silt and shale. The water quality in the aquifer is generally poor—with fresh water in outcrop areas in the east to brine in the western subsurface portions of the aquifer—and 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 water-flooding operations, particularly in the southern High Plains. Water level declines and rises have occurred in different areas of the aquifer. The planning groups recommended several water management strategies that use the Dockum Aquifer, including new wells, desalination, and reallocation.

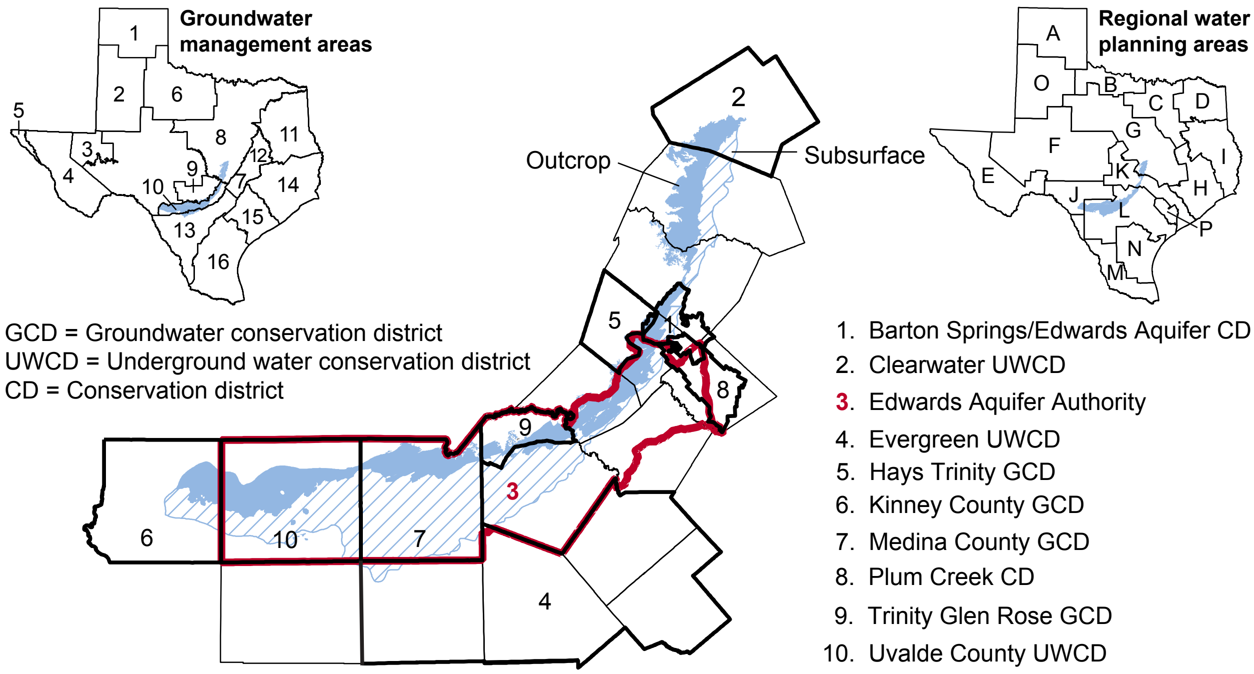
Aquifer characteristics

- Area of outcrop: 3,519 square miles
- Area in subsurface: 21,992 square miles
- Availability: 406,138 acre-feet per year (2010) to 248,720 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 55 percent
- Number of counties containing the aquifer: 46

Groundwater supplies with implementation of water management strategies



Edwards (Balcones Fault Zone) Aquifer

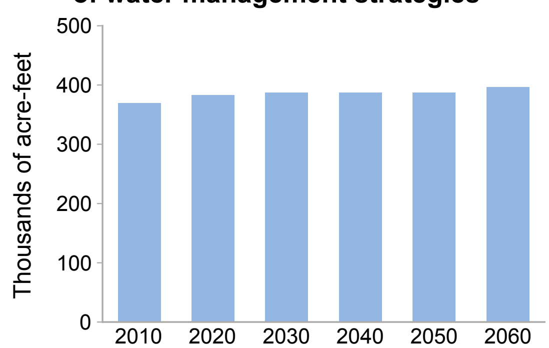


The Edwards (Balcones Fault Zone) Aquifer is a major aquifer in the south central part of the state. It consists primarily of partially dissolved limestone that creates a highly permeable aquifer. Aquifer thickness ranges from 200 to 600 feet, and freshwater saturated thickness averages 560 feet in the southern part of the aquifer. Water quality, 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. 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 planning groups 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.

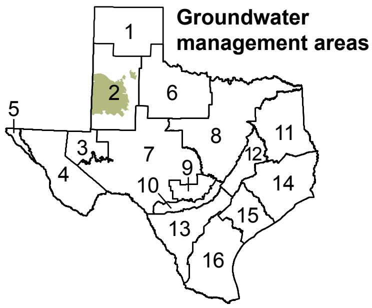
Aquifer characteristics

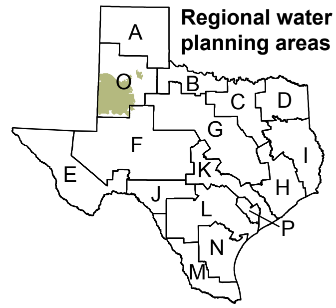
- Area of outcrop: 1,560 square miles
- Area in subsurface: 2,314 square miles
- Availability: 373,811 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 90 percent
- Number of counties containing the aquifer: 13

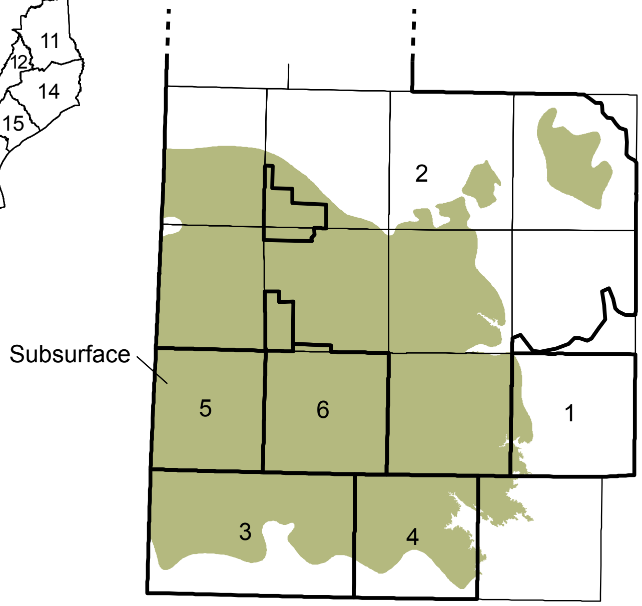
Groundwater supplies with implementation of water management strategies



Edwards-Trinity (High Plains) Aquifer







1. Garza County Underground and Fresh WCD
2. High Plains UWCD No. 1
3. Llano Estacado UWCD
4. Mesa UWCD
5. Sandy Land UWCD
6. South Plains UWCD

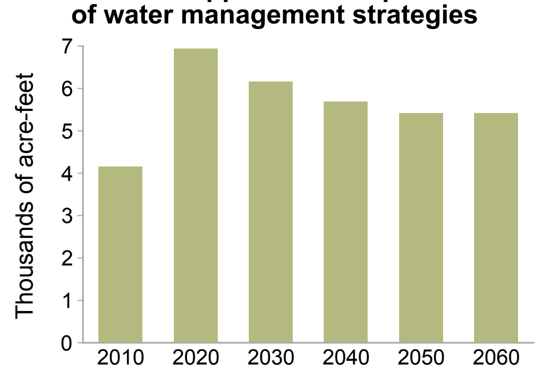
UWCD = Underground water conservation district
WCD = Water conservation district

The Edwards-Trinity (High Plains) Aquifer, a minor aquifer found in West Texas, consists of sandstone in the Antlers Formation (Trinity Group) and limestone of the Comanche Peak and Edwards formations. Freshwater saturated thickness averages 126 feet. Water in the aquifer is fresh to moderately saline, with total dissolved solids ranging from 400 to 8,000 milligrams per liter. The water typically contains more total dissolved solids than the overlying Ogallala Aquifer and is poorest in quality, with total dissolved solids in excess of 20,000 milligrams per liter, where overlain by saline lakes or the gypsum-rich Tahoka and Double Lakes formations. The aquifer primarily provides water for irrigation, and water level declines have occurred in some irrigated areas. The Region O Planning Group recommended constructing one or more brackish groundwater desalination plants to treat water from the Edwards-Trinity (High Plains) Aquifer in Lubbock County.

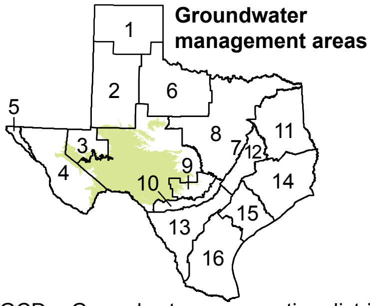
Aquifer characteristics

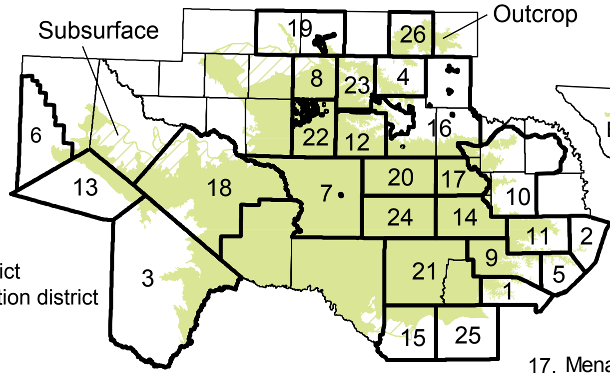
- Area of aquifer: 7,889 square miles
- Availability: 4,160 acre-feet per year (2010) to 2,065 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 95 percent
- Number of counties containing the aquifer: 14

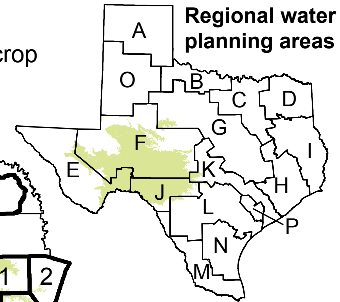
Groundwater supplies with implementation of water management strategies



Edwards-Trinity (Plateau) Aquifer







GCD = Groundwater conservation district
UWCD = Underground water conservation district
WCD = Water conservation district

1. Bandera County River Authority and Groundwater District
2. Blanco-Pedernales GCD
3. Brewster County GCD
4. Coke County UWCD
5. Cow Creek GCD
6. Culberson County GCD
7. Emerald UWCD
8. Glasscock GCD
9. Headwaters GCD
10. Hickory UWCD No. 1
11. Hill Country UWCD
12. Irion County WCD
13. Jeff Davis County UWCD
14. Kimble County GCD
15. Kinney County GCD
16. Lipan-Kickapoo WCD
17. Menard County UWCD
18. Middle Pecos GCD
19. Permian Basin UWCD
20. Plateau Underground Water Conservation & Supply District
21. Real-Edwards Conservation and Reclamation District
22. Santa Rita UWCD
23. Sterling County UWCD
24. Sutton County UWCD
25. Uvalde County UWCD
26. Wes-Tex GCD

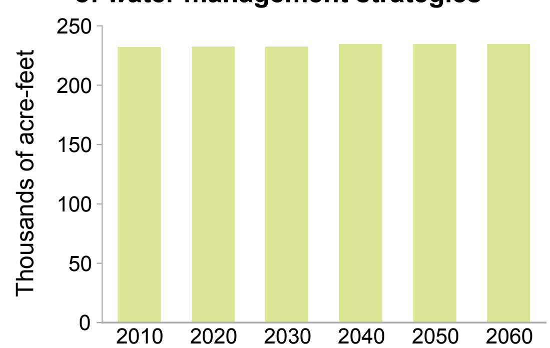
Note: The dark spots in Regan County are part of the Glasscock GCD. The dark spots in Crockett, Tom Green, Runnels, and Concho counties are areas that are not part of a GCD. Counties are named in Figure F.1.

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 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 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 planning groups 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.

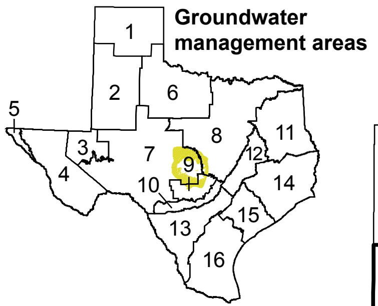
Aquifer characteristics

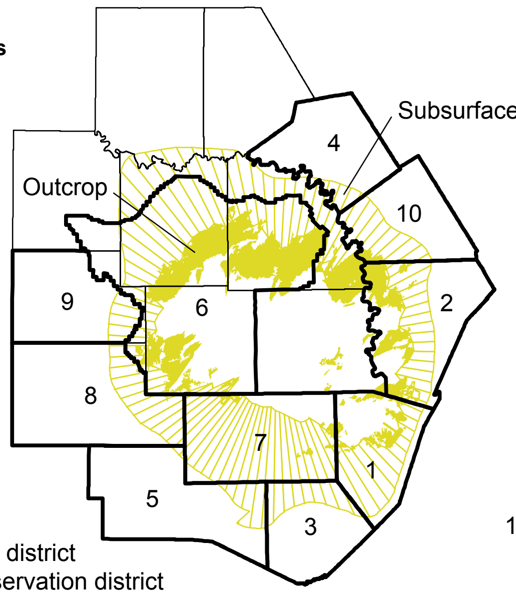
- Area of outcrop: 32,294 square miles
- Area in subsurface: 2,988 square miles
- Availability: 572,515 acre-feet per year (2010) to 572,517 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 71 percent
- Number of counties containing the aquifer: 40

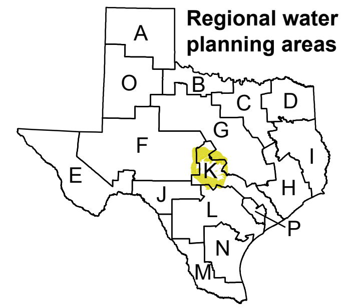
Groundwater supplies with implementation of water management strategies



Ellenburger-San Saba Aquifer







1. Blanco-Pedernales GCD
2. Central Texas GCD
3. Cow Creek GCD
4. Fox Crossing Water District
5. Headwaters GCD
6. Hickory UWCD No. 1
7. Hill Country UWCD
8. Kimble County GCD
9. Menard County UWCD
10. Saratoga UWCD

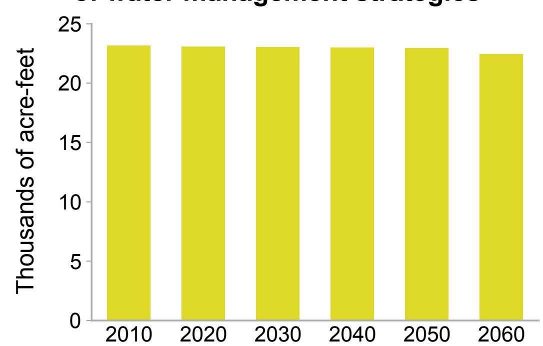
GCD = Groundwater conservation district
UWCD = Underground water conservation district

The Ellenburger-San Saba Aquifer is a minor aquifer found in parts of 16 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 formations occur as a sequence of limestone and dolomite that crops out in a circular pattern around the Llano Uplift. Maximum thickness of the aquifer is about 2,700 feet. Water is held in fractures, cavities, and solution channels often 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. Although water produced from the aquifer is inherently hard and usually has less than 500 milligrams per liter of total dissolved solids, water in the subsurface is slightly to moderately saline, with 1,000 to 6,500 milligrams per liter of total dissolved solids. Elevated concentrations of naturally occurring radium and radon are commonly found in excess of primary drinking water standards. The majority of groundwater is used for municipal supplies, with the remainder used for irrigation and livestock. A large portion of water flowing from San Saba Springs, the water supply for the city of San Saba, is believed to be from the Ellenburger-San Saba and Marble Falls aquifers. Water levels in the majority of wells measured by TWDB in the aquifer have not experienced significant declines. The planning groups recommended several water management strategies that use the Ellenburger-San Saba Aquifer, including developing a new well field in Llano County to supply the city of Llano, pumping additional water from existing wells, temporary overdrafting, and reallocating supplies from users with surpluses to users with needs.

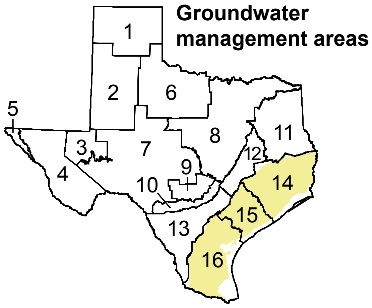
Aquifer characteristics

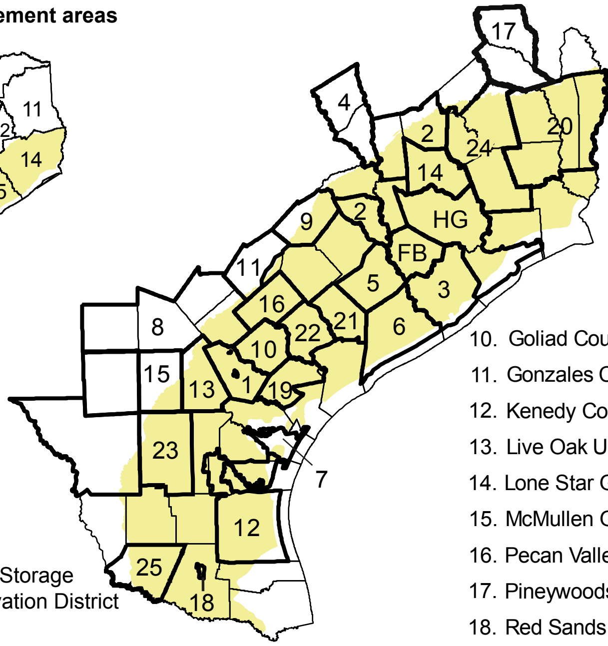
- Area of outcrop: 1,147 square miles
- Area in subsurface: 4,262 square miles
- Availability: 45,672 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 84 percent
- Number of counties containing the aquifer: 16

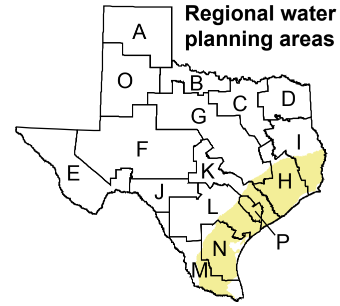
Groundwater supplies with implementation of water management strategies



Gulf Coast Aquifer







1. Bee GCD
2. Bluebonnet GCD
3. Brazoria County GCD
4. Brazos Valley GCD
5. Coastal Bend GCD
6. Coastal Plains GCD
7. Corpus Christi Aquifer Storage and Recovery Conservation District
8. Evergreen UWCD
9. Fayette County GCD
10. Goliad County GCD
11. Gonzales County UWC
12. Kenedy County GCD
13. Live Oak UWCD
14. Lone Star GCD
15. McMullen GCD
16. Pecan Valley GCD
17. Pineywoods GCD
18. Red Sands GCD
19. Refugio GCD
20. Southeast Texas GCD
21. Texana GCD
22. Victoria County GCD

Subsidence Districts:
HG Harris-Galveston
FB Fort Bend

Unconfirmed:
23. Duval County GCD
24. Lower Trinity GCD
25. Starr County GCD

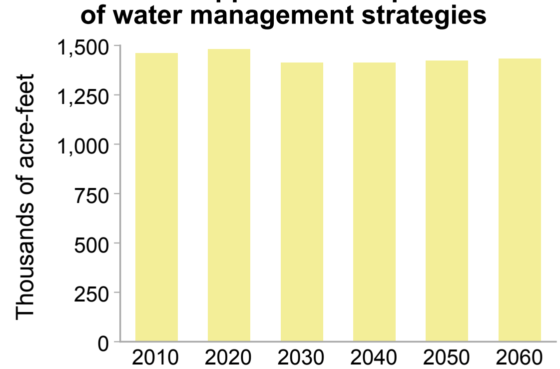
GCD = Groundwater conservation district, UWCD = Underground water conservation district

The Gulf Coast Aquifer is a major aquifer paralleling the Gulf of Mexico coastline from the Louisiana border to the Mexican border. 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 for 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 it 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, believed 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 up to 350 feet have led to land subsidence. The planning groups 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.

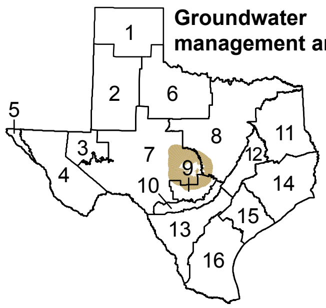
Aquifer characteristics

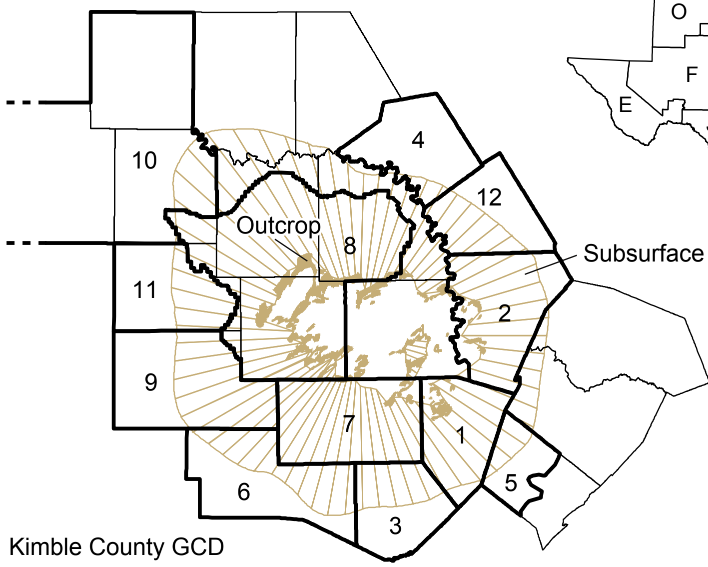
- Area of aquifer: 41,879 square miles
- Availability: 1,825,976 acre-feet per year (2010) to 1,681,738 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 73 percent
- Number of counties containing the aquifer: 54

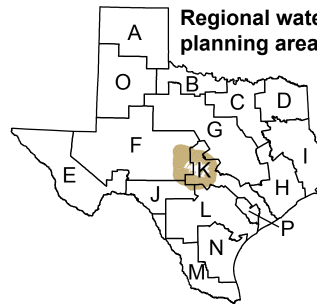
Groundwater supplies with implementation of water management strategies



Hickory Aquifer







1. Blanco-Pedernales GCD
2. Central Texas GCD
3. Cow Creek GCD
4. Fox Crossing Water District
5. Hays Trinity GCD
6. Headwaters GCD
7. Hill Country UWCD
8. Hickory UWCD No. 1
9. Kimble County GCD
10. Lipan-Kickapoo WCD
11. Menard County GCD
12. Saratoga UWCD

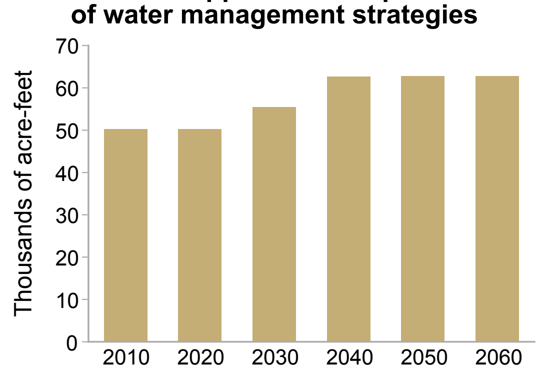
GCD = Groundwater conservation district
UWCD = Underground water conservation district
WCD = Water conservation district

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 planning groups 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 Planning Group recommended treating water from the aquifer and distributing it as drinking water through a bottled water program in Concho and McCulloch counties.

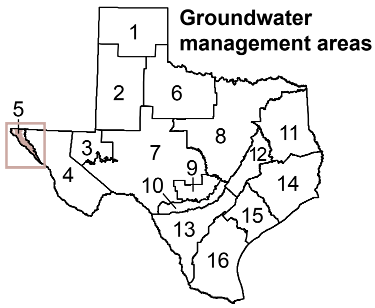
Aquifer characteristics

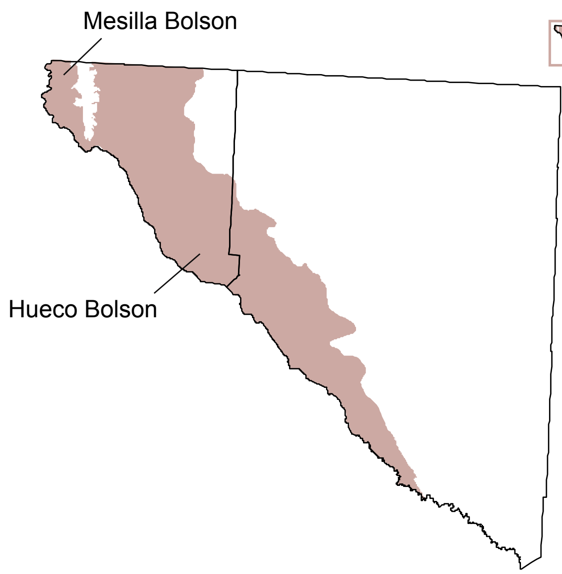
- Area of outcrop: 271 square miles
- Area in subsurface: 8,193 square miles
- Availability: 278,316 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 85 percent
- Number of counties containing the aquifer: 19

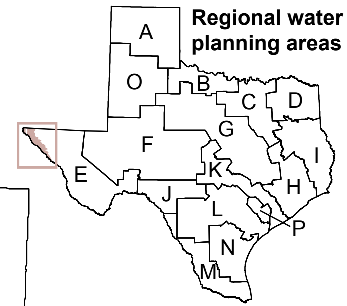
Groundwater supplies with implementation of water management strategies



Hueco-Mesilla Bolsons Aquifer





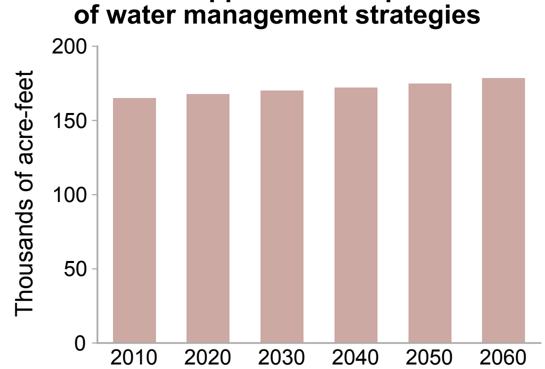


The Hueco-Mesilla Bolsons Aquifer, located east and west of the Franklin Mountains in Far West Texas, is recognized as a major aquifer in Texas. The aquifer is composed of basin-fill deposits of silt, sand, gravel, and clay in two basins, or bolsons: the Hueco Bolson, with a maximum thickness of 9,000 feet, and the Mesilla Bolson, with a maximum thickness of 2,000 feet. While 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. 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 due to municipal pumping in the Hueco Bolson. 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 are building the world's largest inland desalination plant in El Paso County. This plant will use brackish groundwater from the Hueco Bolson as its source water.

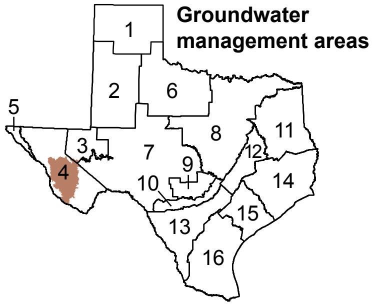
Aquifer characteristics

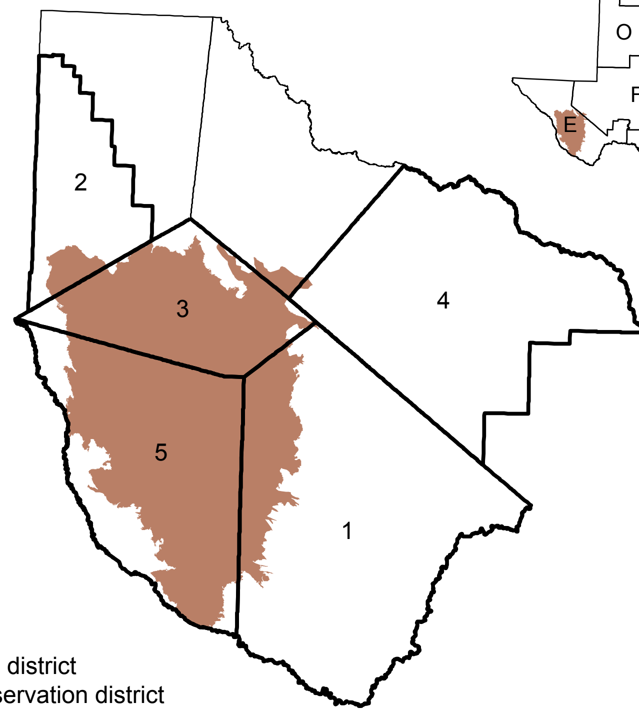
- Area of aquifer: 1,370 square miles
- Availability: 183,000 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 0 percent
- Number of counties containing the aquifer: 2

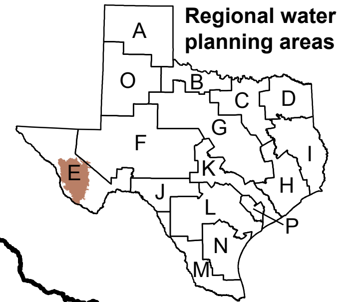
Groundwater supplies with implementation of water management strategies



Igneous Aquifer







1. Brewster County GCD
2. Culberson County GCD
3. Jeff Davis County UWCD
4. Middle Pecos GCD
5. Presidio County UWCD

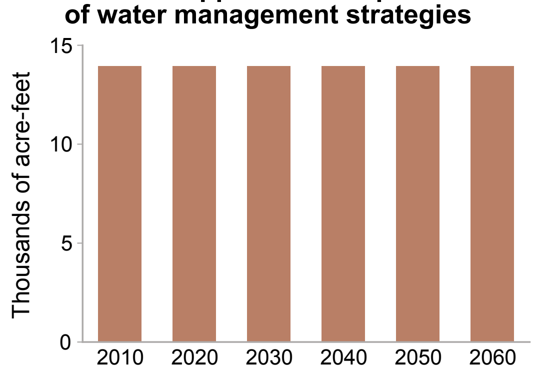
GCD = Groundwater conservation district
UWCD = Underground water conservation district

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 over 40 different named units up to 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 enhances 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 TWDB throughout the aquifer. The Region E Planning Group did not recommend any water management strategies using the Igneous Aquifer.

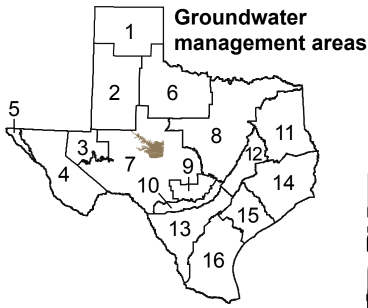
Aquifer characteristics

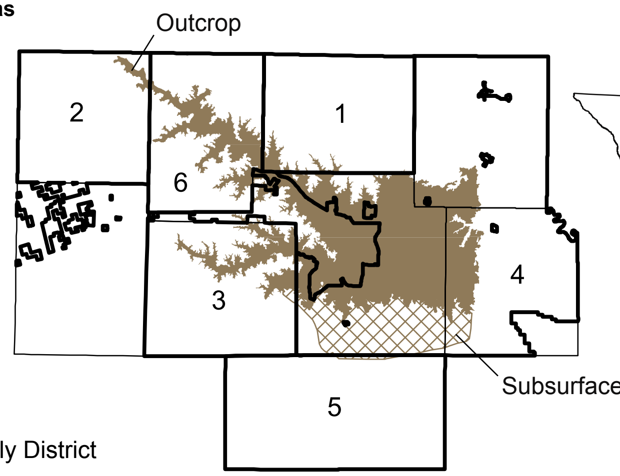
- Area of aquifer: 6,075 square miles
- Availability: 14,600 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 99 percent
- Number of counties containing the aquifer: 6

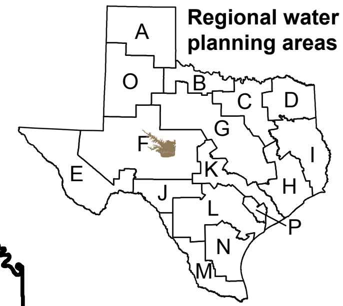
Groundwater supplies with implementation of water management strategies



Lipan Aquifer







1. Coke County UWCD
2. Glasscock GCD
3. Irion County WCD
4. Lipan-Kickapoo WCD
5. Plateau UWC and Supply District
6. Sterling County UWCD

Note: The dark spots in Regan County are part of the Glasscock GCD. The dark spots in Tom Green, Runnels, and Concho counties are areas that are not part of a GCD. Counties are named in Figure F.1.

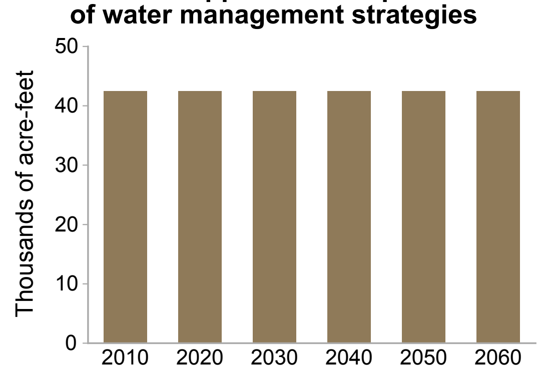
GCD = Groundwater conservation district
UWCD = Underground water conservation district
UWC = Underground water conservation
WCD = Water conservation district

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 older, underlying strata. The alluvium includes up to 125 feet of saturated sediments of the Leona Formation. 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. Groundwater in the alluvial deposits and the upper parts of the older rocks is hydraulically connected; therefore, most wells in the area are completed in both units. Groundwater in the alluvium ranges from fresh to slightly saline, containing between 350 to 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, municipal, domestic, and manufacturing uses. Due to 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 at a reduced rate. The planning groups did not recommend any water management strategies using the Lipan Aquifer.

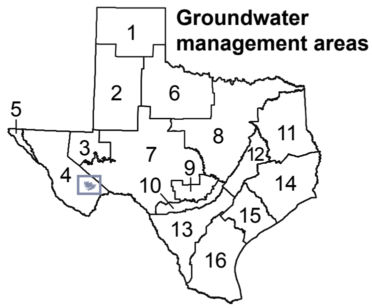
Aquifer characteristics

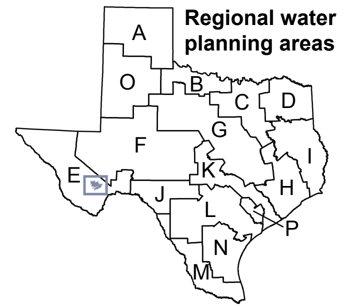
- Area of outcrop: 1,565 square miles
- Area of subsurface: 422 square miles
- Availability: 48,535 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 85 percent
- Number of counties containing the aquifer: 8

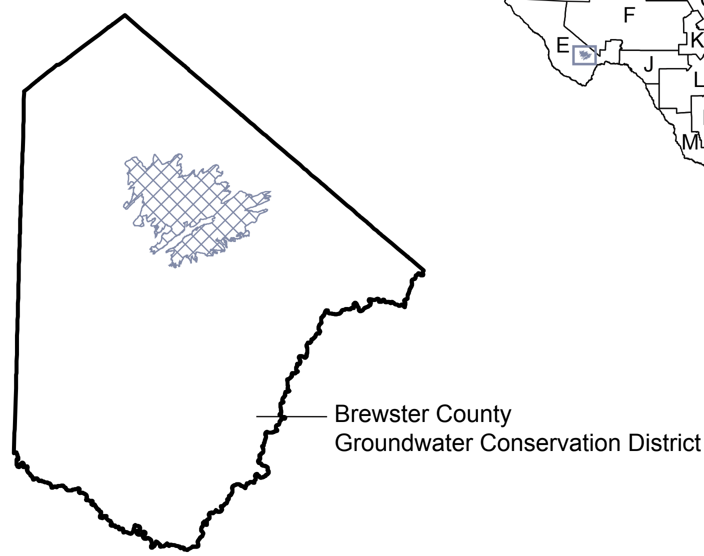
Groundwater supplies with implementation of water management strategies



Marathon Aquifer





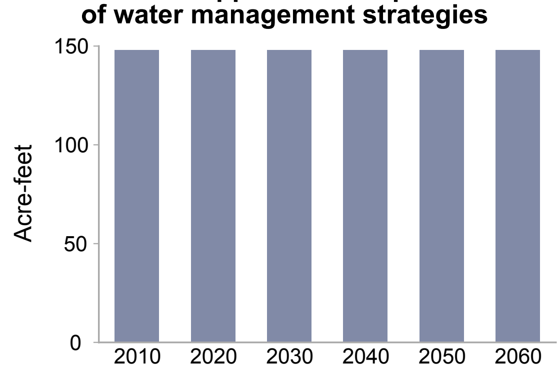


The Marathon Aquifer, a minor aquifer, occurs entirely within north central Brewster County. The aquifer consists of tightly folded and faulted rocks of the Gaptank Formation, the Dimple Limestone, the Tesnus Formation, the Caballos Novaculite, the Maravillas Chert, the Fort Pena Formation, and the Marathon 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 did not recommend any water management strategies using the Marathon Aquifer.

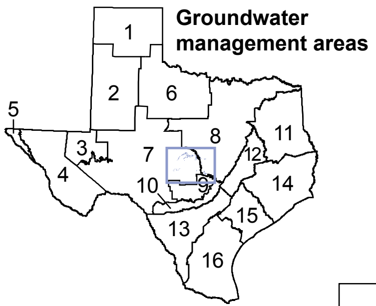
Aquifer characteristics

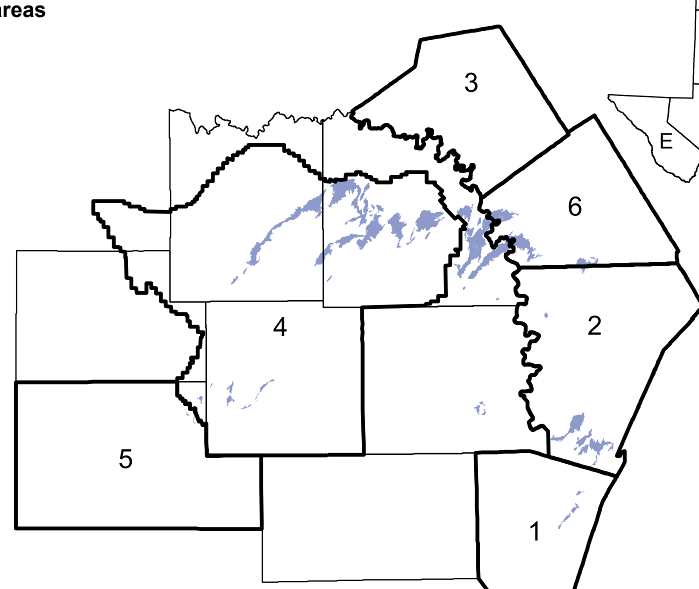
- Area of aquifer: 390 square miles
- Availability: 200 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 100 percent
- Number of counties containing the aquifer: 1

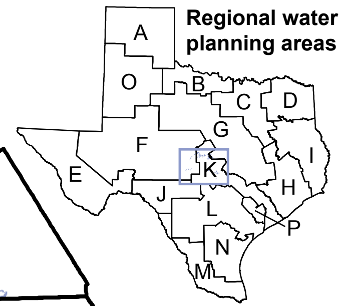
Groundwater supplies with implementation of water management strategies



Marble Falls Aquifer







1. Blanco-Pedernales GCD
2. Central Texas GCD
3. Fox Crossing Water District
4. Hickory UWCD No. 1
5. Kimble County GCD
6. Saratoga UWCD

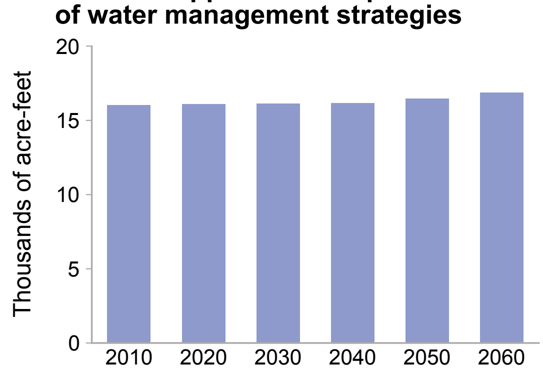
GCD = Groundwater conservation district
UWCD = Underground water conservation district

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 TWDB. The planning groups recommended drilling new wells in Burnet County as a water management strategy using the Marble Falls Aquifer.

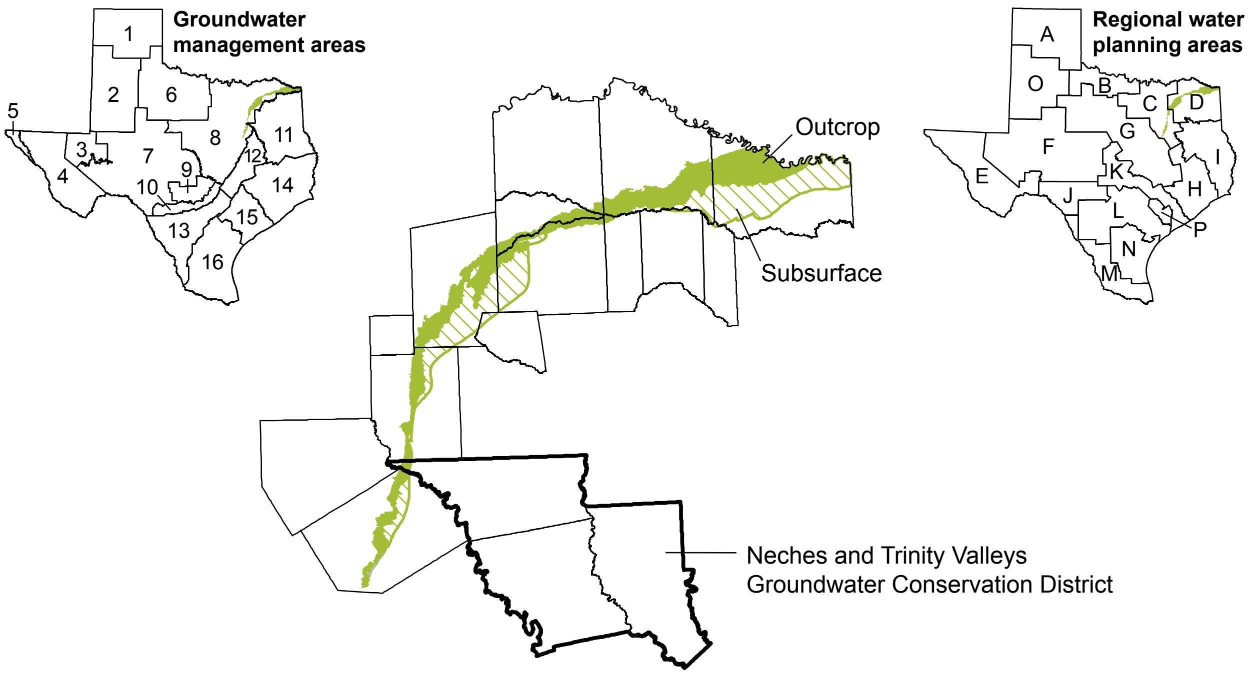
Aquifer characteristics

- Area of aquifer: 214 square miles
- Availability: 22,637 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 78 percent
- Number of counties containing the aquifer: 8

Groundwater supplies with implementation of water management strategies



Nacatoch Aquifer

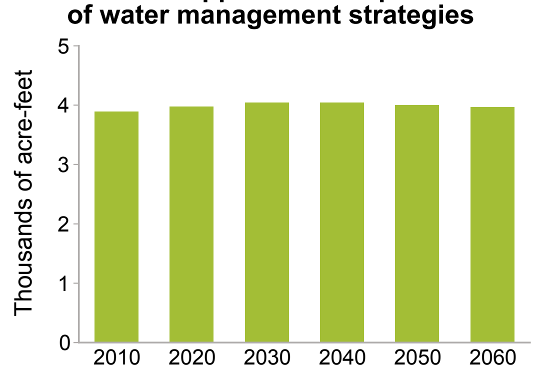


The Nacatoch Aquifer is a minor aquifer occurring in a narrow band across northeast Texas. The aquifer consists of the Nacatoch Formation, composed of sequences of sand separated by impermeable layers of mudstone or clay. Freshwater saturated thickness averages about 50 feet. The aquifer also includes a hydraulically connected cover of alluvium that is up to 80 feet thick along major drainages. Groundwater in this aquifer is usually under artesian conditions except in shallow wells where the Nacatoch Formation outcrops and water table conditions exist. The Mexia-Talco Fault Zone generally delineates the subsurface limit of the aquifer. The quality of groundwater in the aquifer is typically alkaline, high in sodium bicarbonate, and soft. In the subsurface, total dissolved solids 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 Region D Planning Group recommended new and supplemental groundwater wells in the Nacatoch Aquifer as a water management strategy.

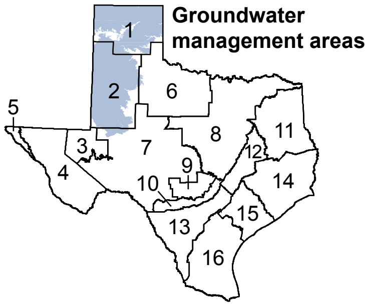
Aquifer characteristics

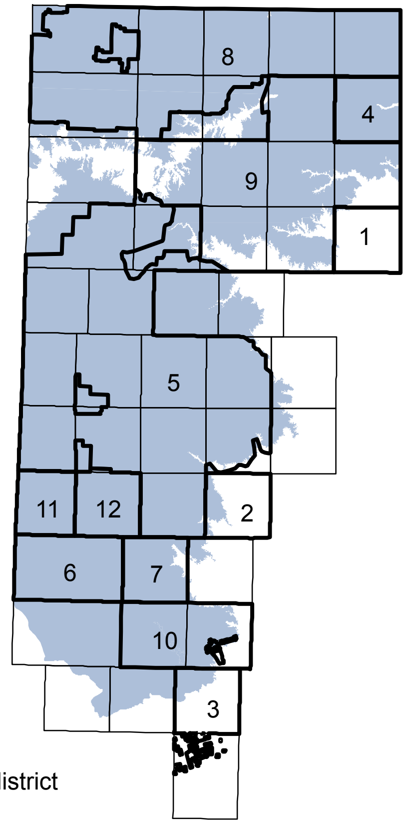
- Area of outcrop: 889 square miles
- Area in subsurface: 936 square miles
- Availability: 10,453 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 0.5 percent
- Number of counties containing the aquifer: 15

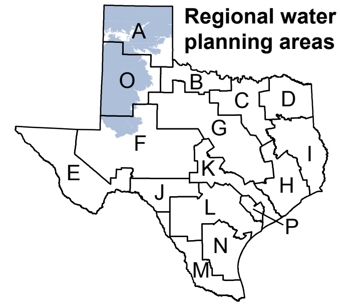
Groundwater supplies with implementation of water management strategies



Ogallala Aquifer







1. Collingsworth County UWCD
2. Garza County Underground and Fresh WCD
3. Glasscock GCD
4. Hemphill County UWCD
5. High Plains UWCD No. 1
6. Llano Estacado UWCD
7. Mesa UWCD
8. North Plains GCD
9. Panhandle GCD
10. Permian Basin UWCD
11. Sandy Land UWCD
12. South Plains UWCD

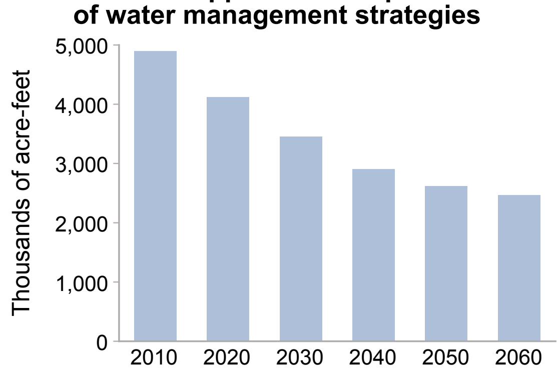
GCD = Groundwater conservation district
UWCD = Underground water conservation district
WCD = Water conservation district

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 with large areas containing total dissolved solids in excess of 1,000 milligrams per liter. Naturally occurring high levels of 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, primarily for irrigation. 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 planning groups for Region A and Region O recommended numerous water management strategies using the Ogallala Aquifer, including drilling new wells, developing well fields, overdrafting, and reallocating supplies.

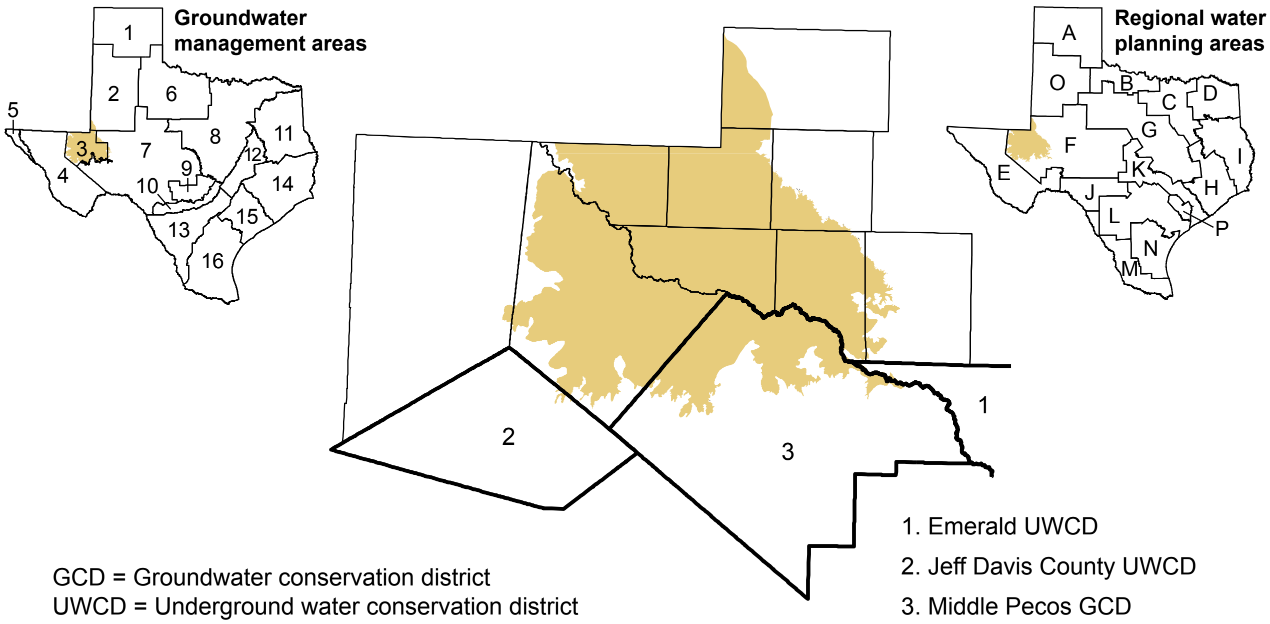
Aquifer characteristics

- Area of aquifer: 36,497 square miles
- Availability: 5,968,260 acre-feet per year (2010) to 3,534,124 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 81 percent
- Number of counties containing the aquifer: 47

Groundwater supplies with implementation of water management strategies



Pecos Valley Aquifer

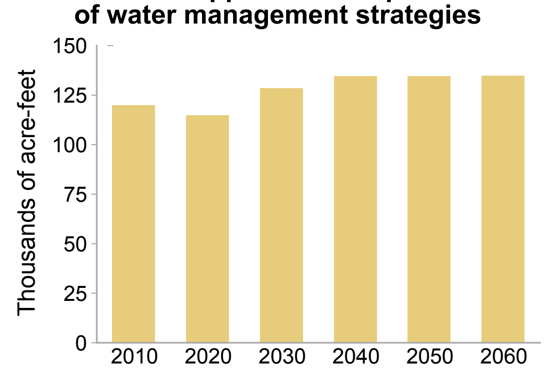


The Pecos Valley Aquifer is a major aquifer found in Far West Texas. Water-bearing sediments include alluvial and windblown deposits in the Pecos River Valley. These sediments fill several structural basins, the largest of which are the Pecos Trough in the west and Monument Draw Trough in the east. Thickness of the alluvial fill reaches 1,500 feet, and freshwater saturated thickness averages about 250 feet. The water quality is highly variable, typically hard, and generally better in the Monument Draw Trough where total dissolved solids are less than 1,000 milligrams per liter than in the Pecos Trough. 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 are in excess of primary 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 due to increased municipal and industrial pumping. The Region F Planning Group recommended several water management strategies that use the Pecos Valley Aquifer, including drilling new wells, developing two well fields in Winkler and Loving counties, and reallocating supplies.

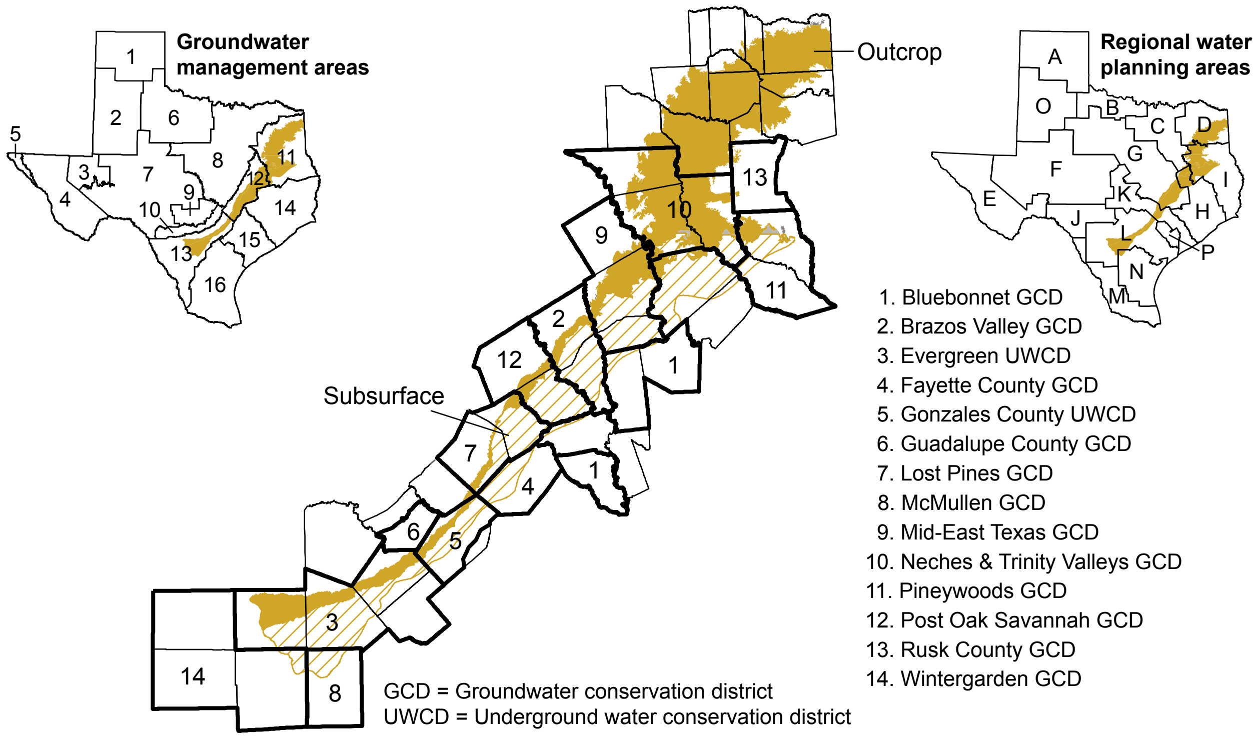
Aquifer characteristics

- Area of aquifer: 6,829 square miles
- Availability: 200,690 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 16 percent
- Number of counties containing the aquifer: 12

Groundwater supplies with implementation of water management strategies



Queen City Aquifer

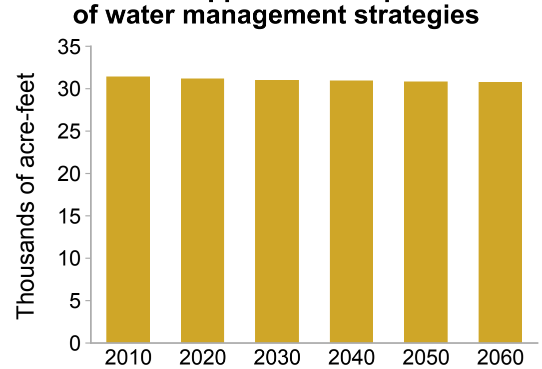


The Queen City Aquifer is a minor but widespread aquifer that stretches across the Texas upper coastal plain. Water is stored in the sand, loosely cemented sandstone, and interbedded clay layers of the Queen City Formation that reaches 2,000 feet in thickness in South Texas. Average freshwater saturation 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 planning groups 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.

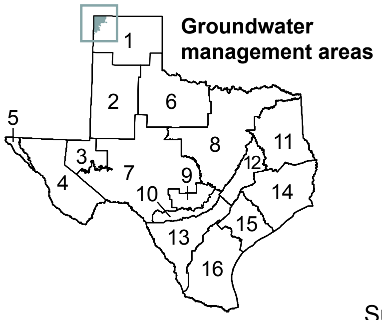
Aquifer characteristics

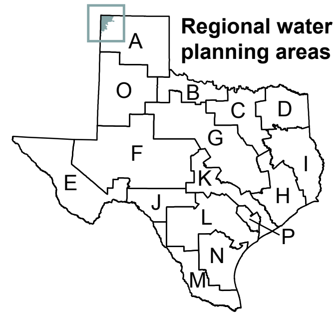
- Area of outcrop: 7,702 square miles
- Area in subsurface: 6,989 square miles
- Availability: 295,791 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 67 percent
- Number of counties containing the aquifer: 42

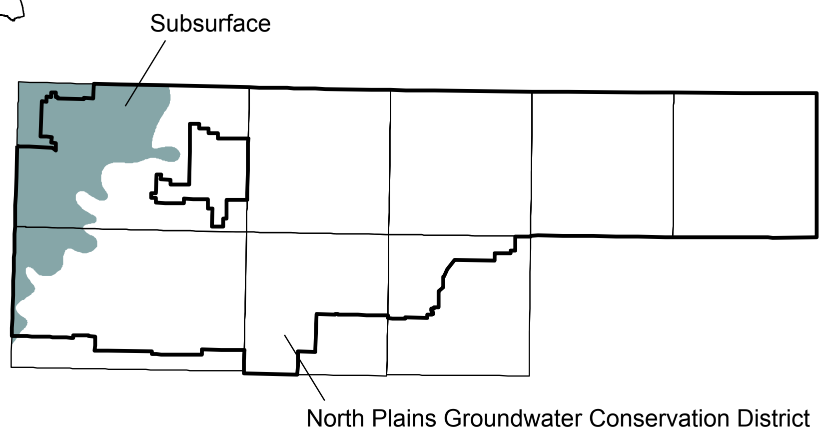
Groundwater supplies with implementation of water management strategies



Rita Blanca Aquifer





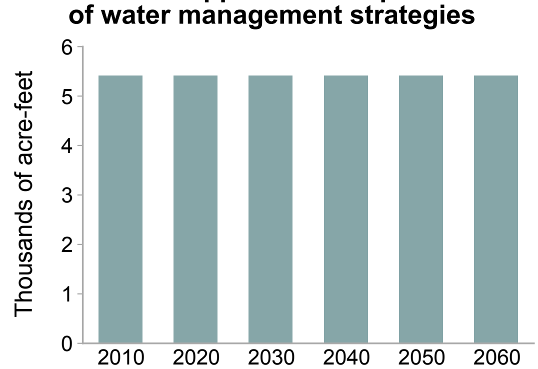


The Rita Blanca Aquifer, a minor aquifer, underlies the Ogallala Aquifer in the northwest corner of the Texas Panhandle. Groundwater occurs in the coarse-grained sand and gravel layers of the Lytle and Dakota formations as well as in the Exeter Sandstone and the Morrison Formation. The thickness of the 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, with Texline 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 Region A Planning Group did not recommend any water management strategies to increase supplies from the Rita Blanca Aquifer.

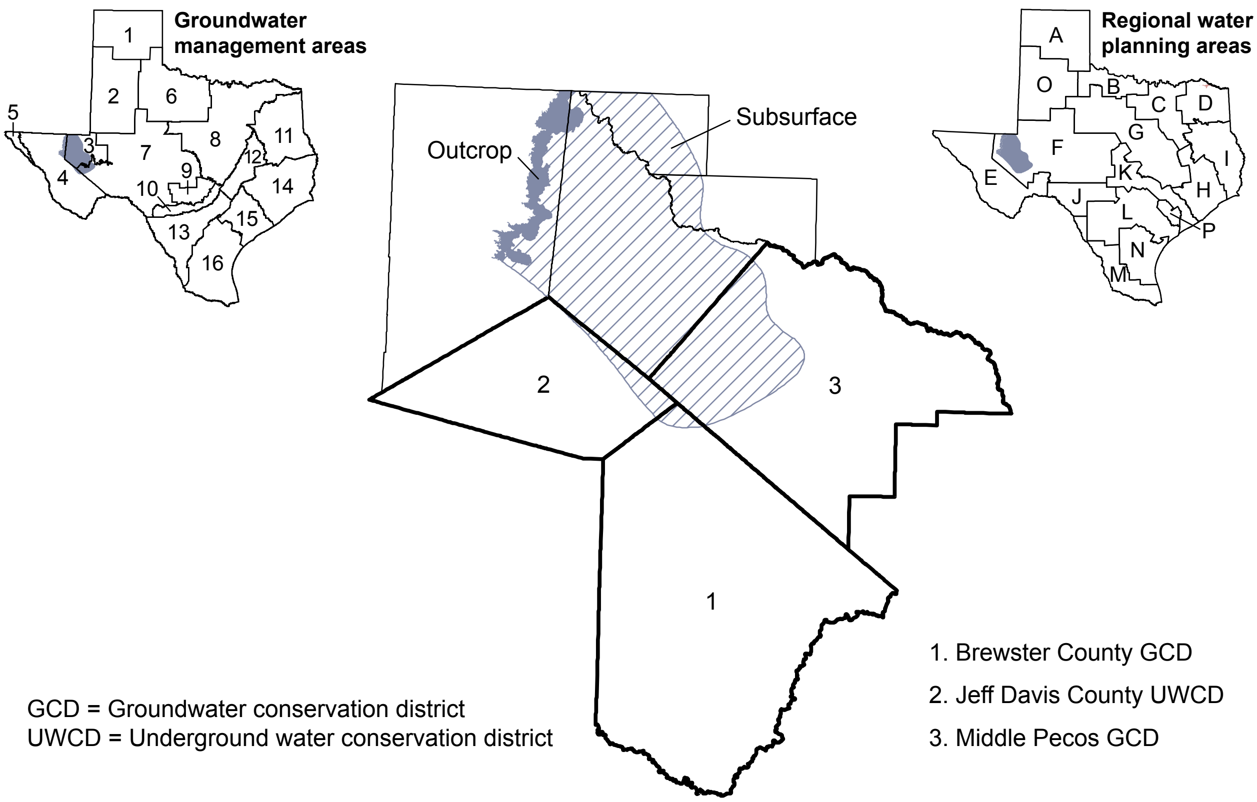
Aquifer characteristics

- Area of aquifer: 922 square miles
- Availability: 5,419 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 88 percent
- Number of counties containing the aquifer: 2

Groundwater supplies with implementation of water management strategies



Rustler Aquifer

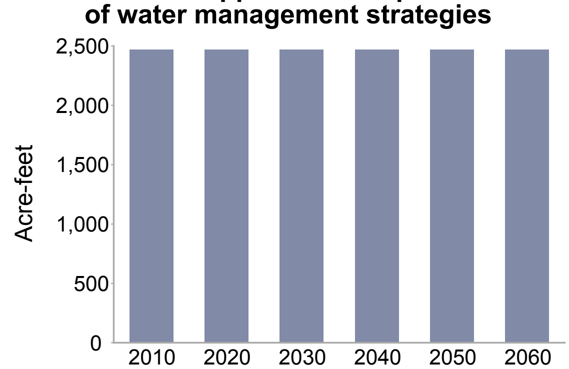


The Rustler Aquifer is a minor aquifer located in Brewster, Culberson, Jeff Davis, Loving, Pecos, Reeves, and Ward counties. The aquifer consists of the carbonates and evaporites of the Rustler Formation, which is 250 to 670 feet thick beneath outcrop areas and extends into the subsurface toward the center of the Delaware Basin to the east. 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 fresh water 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 water-flooding operations in oil-producing areas. Fluctuations in water levels over time most likely reflect long-term variations in water use patterns. The planning groups did not propose any water management strategies for the Rustler Aquifer.

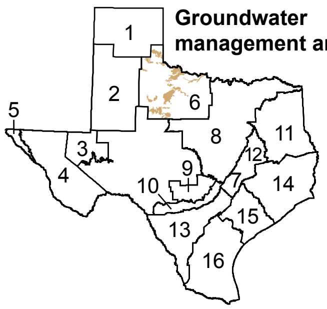
Aquifer characteristics

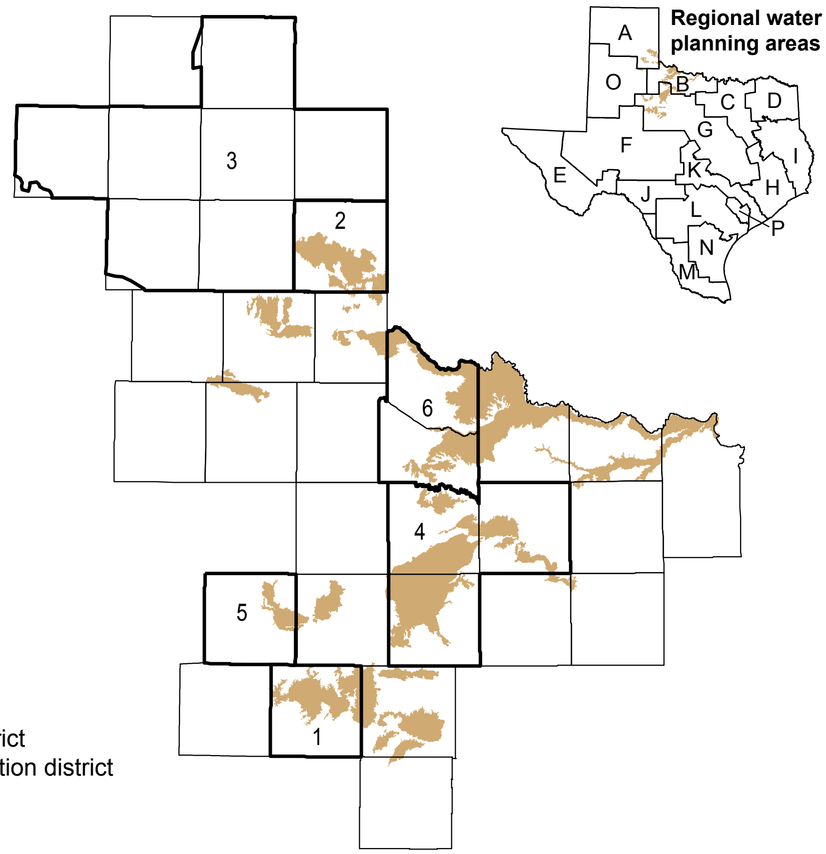
- Area of outcrop: 309 square miles
- Area in subsurface: 4,860 square miles
- Availability: 2,492 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 26 percent
- Number of counties containing the aquifer: 7

Groundwater supplies with implementation of water management strategies



Seymour Aquifer





1. Clear Fork GCD
2. Collingsworth County UWCD
3. Panhandle GCD
4. Rolling Plains GCD
5. Salt Fork UWCD
6. Tri-County GCD

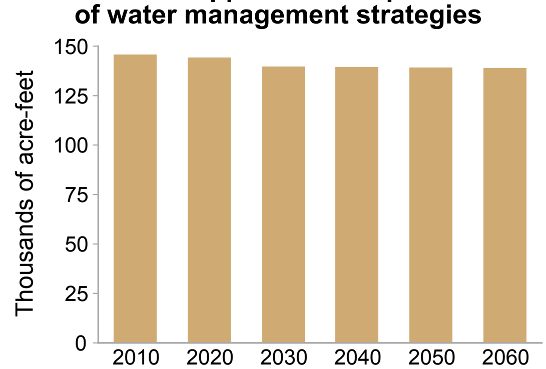
GCD = Groundwater conservation district
UWCD = Underground water conservation district

The Seymour Aquifer is a major aquifer extending across north central Texas. Water is contained in isolated patches of alluvium up to 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, with 3,000 to more than 10,000 milligrams per liter 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 primarily used for municipal supply. Water level declines have reduced the saturated thickness in some areas. The planning groups recommended several water management strategies that use the Seymour Aquifer, including drilling new wells, overdrafting, and constructing a nitrate removal plant in Wilbarger County.

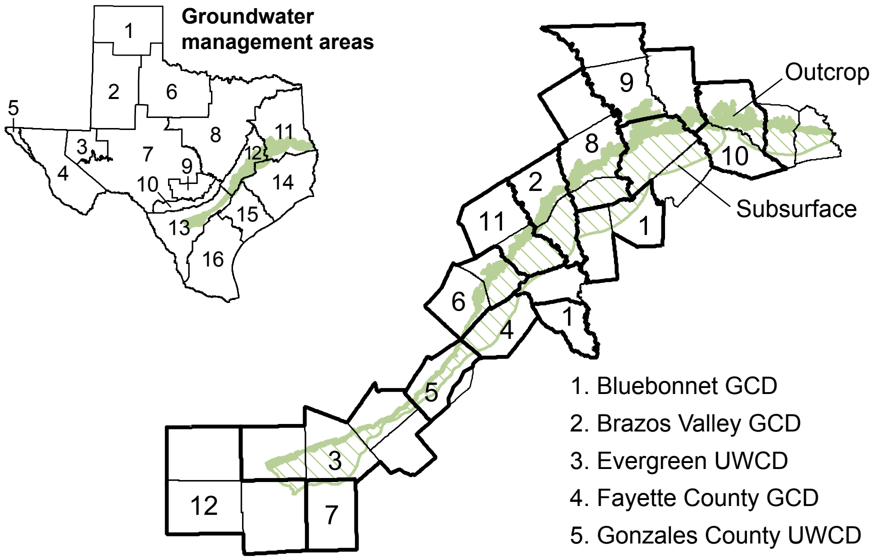
Aquifer characteristics

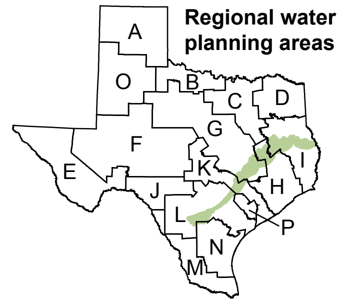
- Area of aquifer: 4,042 square miles
- Availability: 242,226 acre-feet per year (2010) to 227,580 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 52 percent
- Number of counties containing the aquifer: 25

Groundwater supplies with implementation of water management strategies



Sparta Aquifer





1. Bluebonnet GCD
2. Brazos Valley GCD
3. Evergreen UWCD
4. Fayette County GCD
5. Gonzales County UWCD
6. Lost Pines GCD
7. McMullen GCD
8. Mid-East Texas GCD
9. Neches & Trinity Valleys GCD
10. Pineywoods GCD
11. Post Oak Savannah GCD
12. Wintergarden GCD

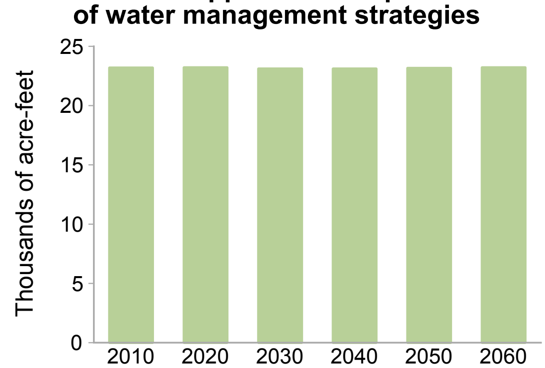
GCD = Groundwater conservation district
UWCD = Underground water conservation district

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 varies 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, water quality is usually fresh, with an average concentration of 300 milligrams per liter of total dissolved solids. However, it deteriorates with depth (below about 2,000 feet), with 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 Sands in Houston County and flows up to 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. There have been no significant water level declines throughout the aquifer in wells measured by TWDB. The planning groups recommended several water management strategies that use the Sparta Aquifer, including drilling more wells and increasing withdrawals from existing wells.

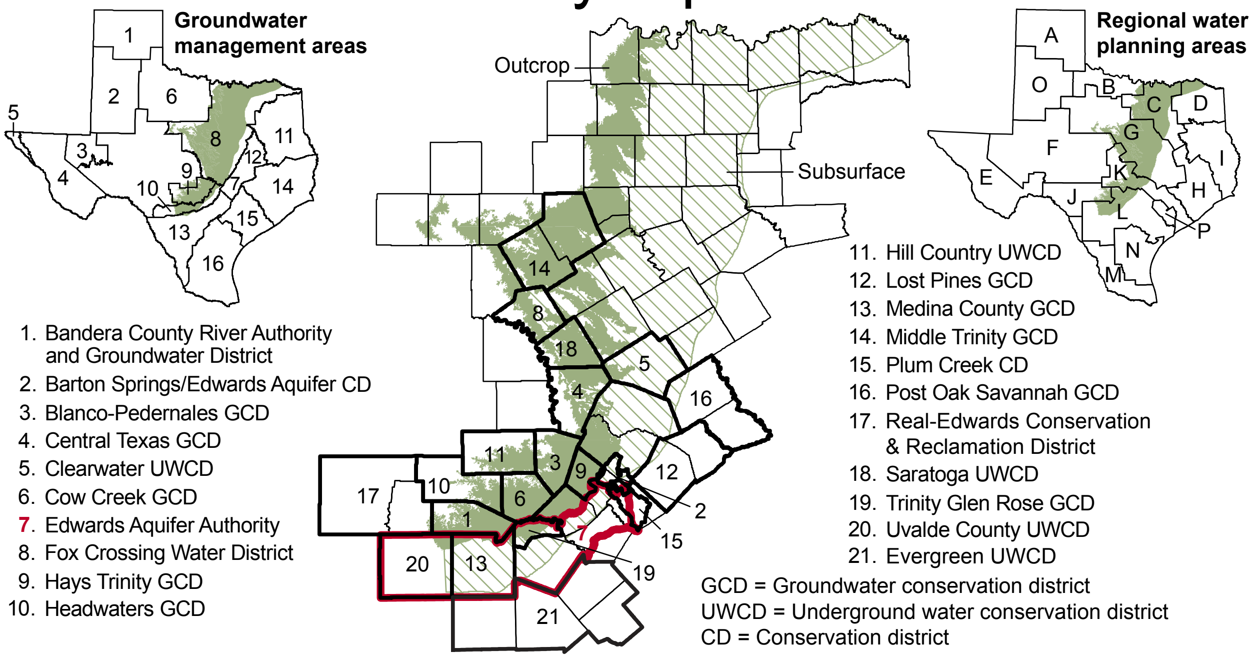
Aquifer characteristics

- Area of outcrop: 1,543 square miles
- Area in subsurface: 6,926 square miles
- Availability: 50,511 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 70 percent
- Number of counties containing the aquifer: 25

Groundwater supplies with implementation of water management strategies



Trinity Aquifer

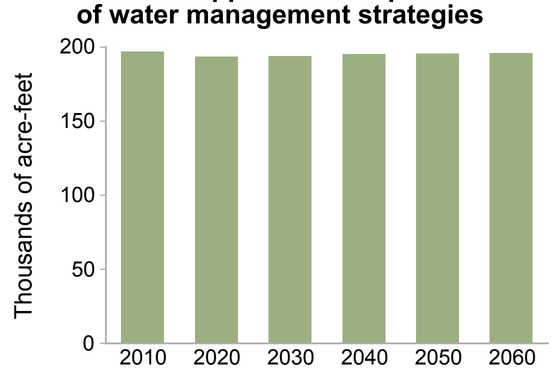


The Trinity Aquifer, a major aquifer, extends across much of the central and northeastern part of the state. It is composed of several individual aquifers contained within the Trinity Group. Although referred to differently in different parts of the state, they include the Antlers, Glen Rose, Paluxy, Twin Mountains, Travis Peak, Hensell, and Hosston aquifers. These aquifers consist of limestones, sands, clays, gravels, and conglomerates, and 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 below 1,000 milligrams per liter of total dissolved solids in the east and southeast to between 1,000 and 5,000 milligrams per liter of total dissolved solids, 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 Interstate 35 corridor from McClennan County to Grayson County. These declines are primarily attributed to municipal pumping and have lessened in the past decade as a result of increasing reliance on surface water. The planning groups 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, developing aquifer storage and recovery, and using surface water and groundwater conjunctively.

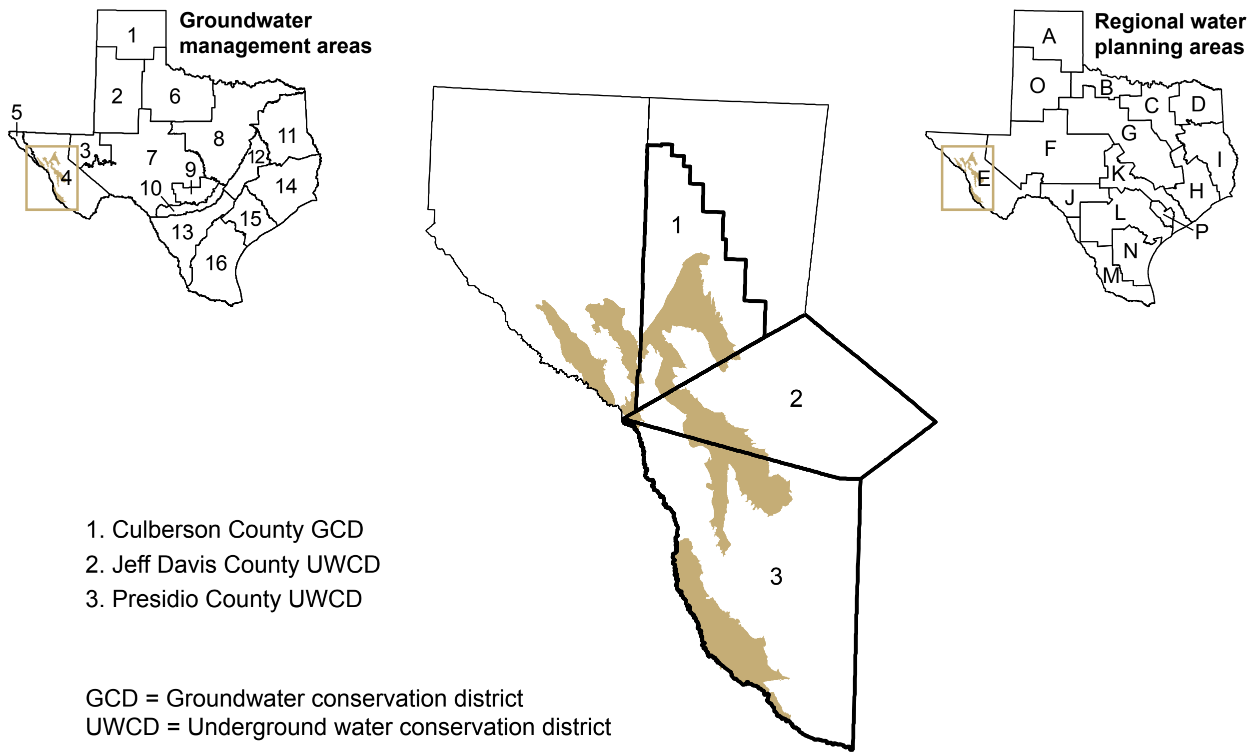
Aquifer characteristics

- Area of outcrop: 10,652 square miles
- Area in subsurface: 21,308 square miles
- Availability: 205,799 acre-feet per year (2010) to 202,603 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 32 percent
- Number of counties containing the aquifer: 61

Groundwater supplies with implementation of water management strategies



West Texas Bolsons Aquifer

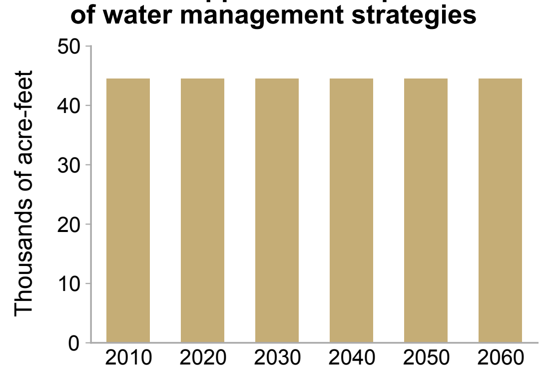


The West Texas Bolsons Aquifer is a minor aquifer located in several basins, or bolsons, in Far West Texas. The aquifer occurs as water-bearing, basin-fill deposits as much as 3,000 feet thick. It is composed of eroded materials that vary depending on the mountains bordering the basins and the manner 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 fresh, containing less than 1,000 milligrams per liter of total dissolved solids, to slightly to moderately saline, with 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 present, water levels have been in decline in the West Texas Bolsons, 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 did not recommend any water management strategies using the West Texas Bolsons Aquifer.

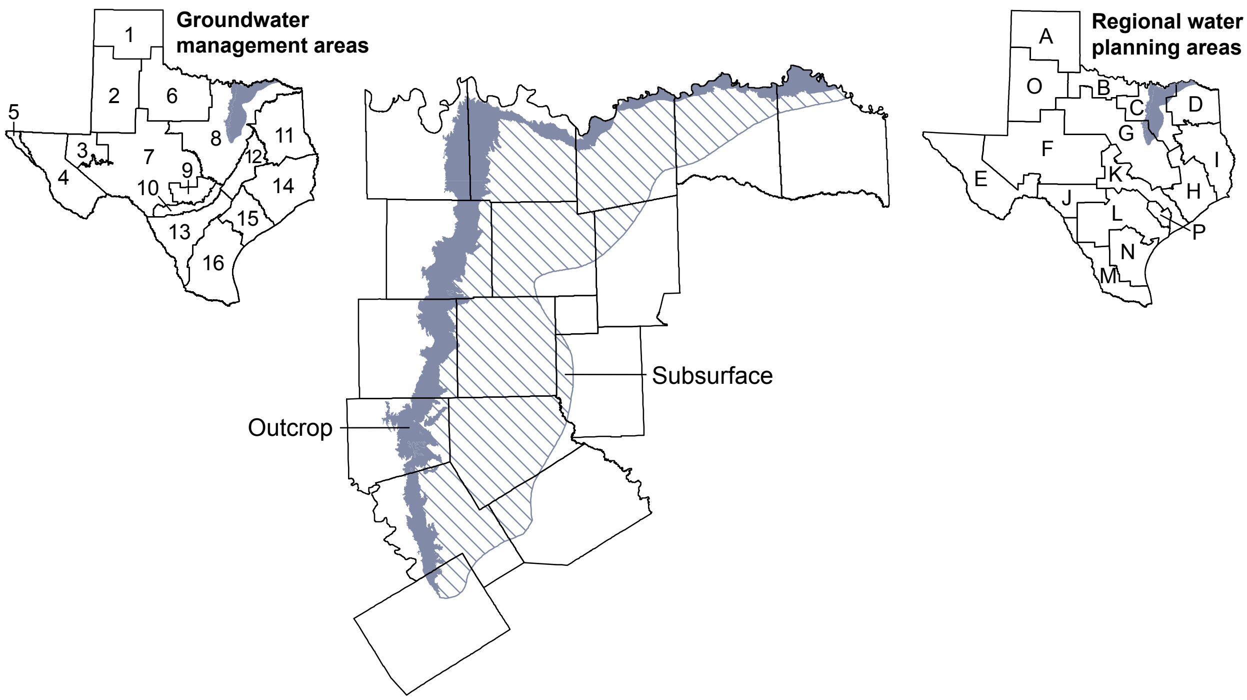
Aquifer characteristics

- Area of aquifer: 1,895 square miles
- Availability: 62,325 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 81 percent
- Number of counties containing the aquifer: 4

Groundwater supplies with implementation of water management strategies



Woodbine Aquifer

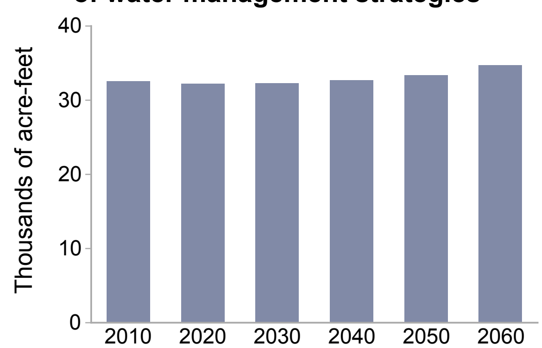


The Woodbine Aquifer is a minor aquifer located in northeast Texas. The aquifer overlies the Trinity Aquifer and consists of sandstone interbedded with shale and clay that form three distinct water-bearing zones. The Woodbine Aquifer reaches 600 feet in thickness in subsurface areas, and freshwater saturated thickness averages about 160 feet. Water quality and yield varies with the depth of the aquifer. The lower zones of the aquifer typically yield the most water, while 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 contains slightly to moderately saline water, ranging 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 planning groups 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, overdrafting, and reallocating supplies.

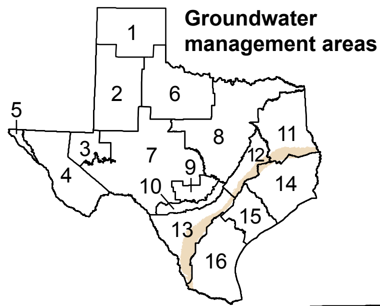
Aquifer characteristics

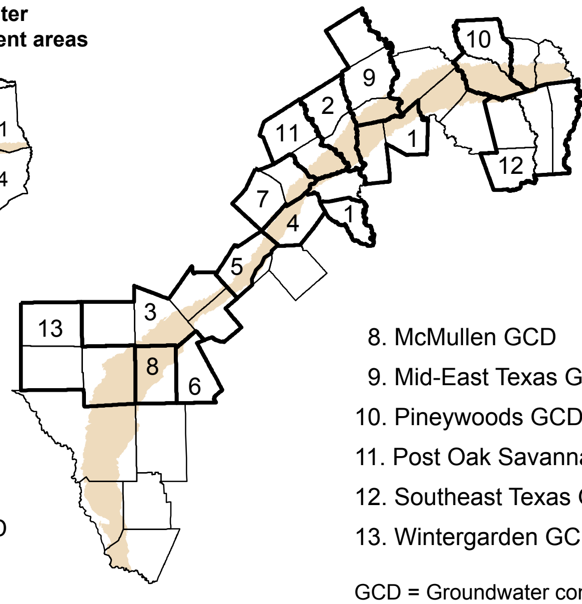
- Area of outcrop: 1,557 square miles
- Area in subsurface: 5,766 square miles
- Availability: 37,712 acre-feet per year (2010) to 38,072 acre-feet per year (2060)
- Proportion of aquifer with groundwater conservation districts: 0 percent
- Number of counties containing the aquifer: 17

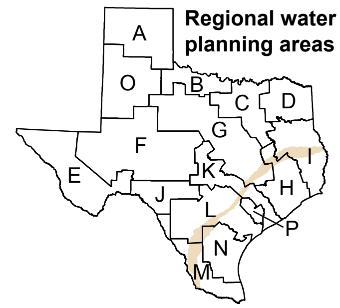
Groundwater supplies with implementation of water management strategies



Yegua-Jackson Aquifer







1. Bluebonnet GCD
2. Brazos Valley GCD
3. Evergreen UWCD
4. Fayette County GCD
5. Gonzales County UWCD
6. Live Oak UWCD
7. Lost Pines GCD
8. McMullen GCD
9. Mid-East Texas GCD
10. Pineywoods GCD
11. Post Oak Savannah GCD
12. Southeast Texas GCD
13. Wintergarden GCD

GCD = Groundwater conservation district
UWCD = Underground water conservation district

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 (comprised of 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. Great variability in water quality exists due 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 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 planning groups recommended several water management strategies that use the Yegua-Jackson Aquifer, including drilling more wells and desalinating the water.

Aquifer characteristics

- Area of aquifer: 10,904 square miles
- Availability: 24,720 acre-feet per year (2010 to 2060)
- Proportion of aquifer with groundwater conservation districts: 58 percent
- Number of counties containing the aquifer: 34

Groundwater supplies with implementation of water management strategies

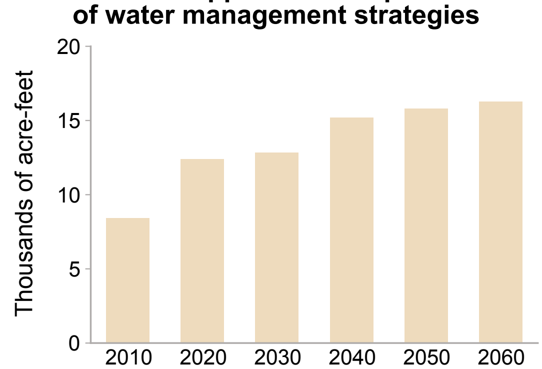
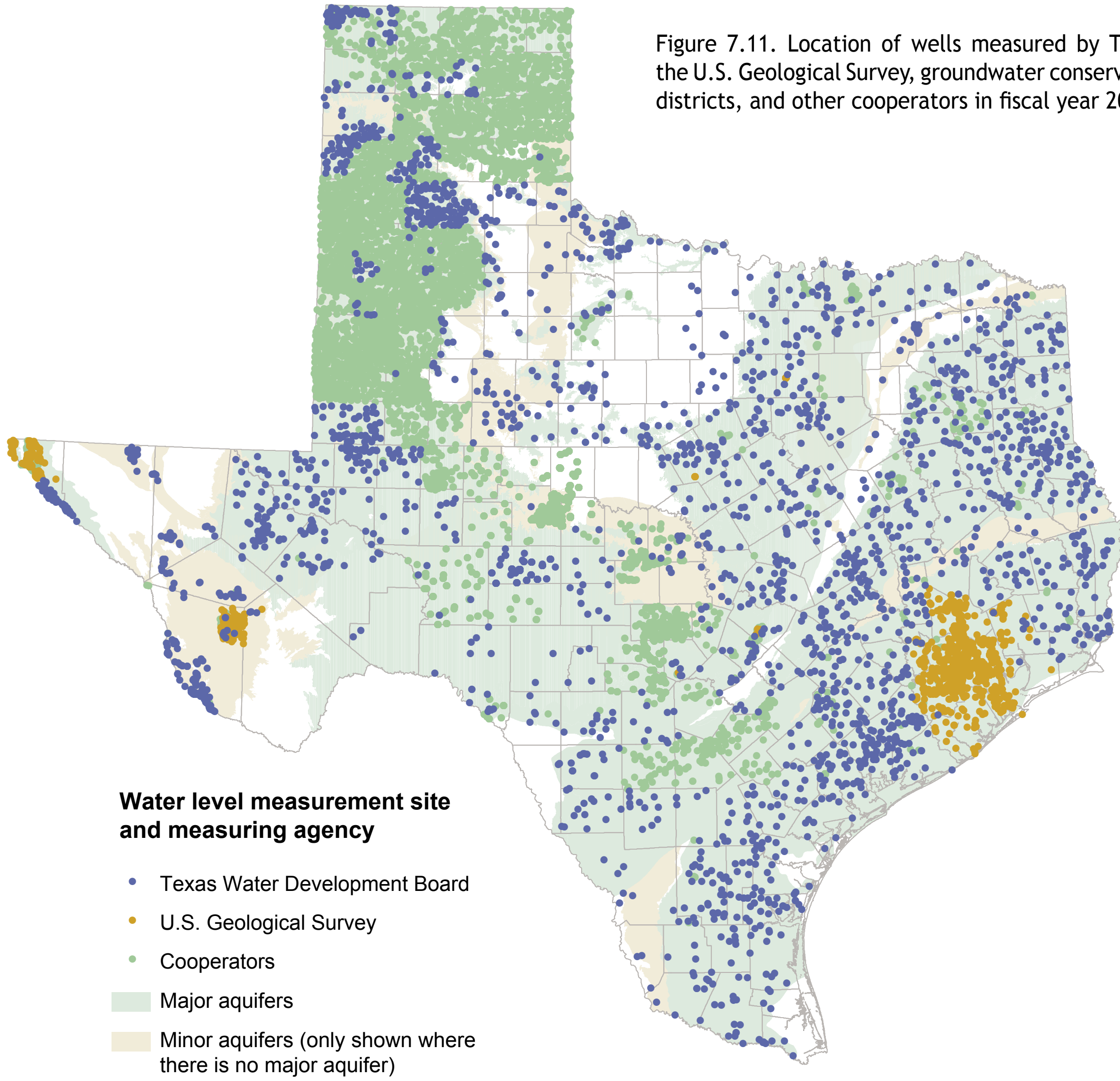


Figure 7.11. Location of wells measured by TWDB, the U.S. Geological Survey, groundwater conservation districts, and other cooperators in fiscal year 2005.



7.2 Groundwater Monitoring Programs

TWDB is one of several agencies collecting groundwater data throughout the state. Other local, state, and federal entities also monitor groundwater, including local water providers, municipalities, groundwater conservation districts, river authorities, the Texas Commission on Environmental Quality, and the U.S. Geological Survey. These organizations typically collect data for different purposes, yet their goals often overlap, and cooperation between organizations is common on a project-by-project basis. Many groundwater conservation districts measure water levels to track water level changes and understand how much water is available. The Texas Commission on Environmental Quality collects chemical information on organic and inorganic constituents in wells used for public drinking water throughout the state. The U.S. Geological Survey collects and analyzes water level and water quality information in localized parts of the state. TWDB strives to include as much information from other organizations as is feasible in its own groundwater database. This database is used throughout the state by landowners, groundwater conservation districts, regional water planning groups, universities, and state and federal agencies.

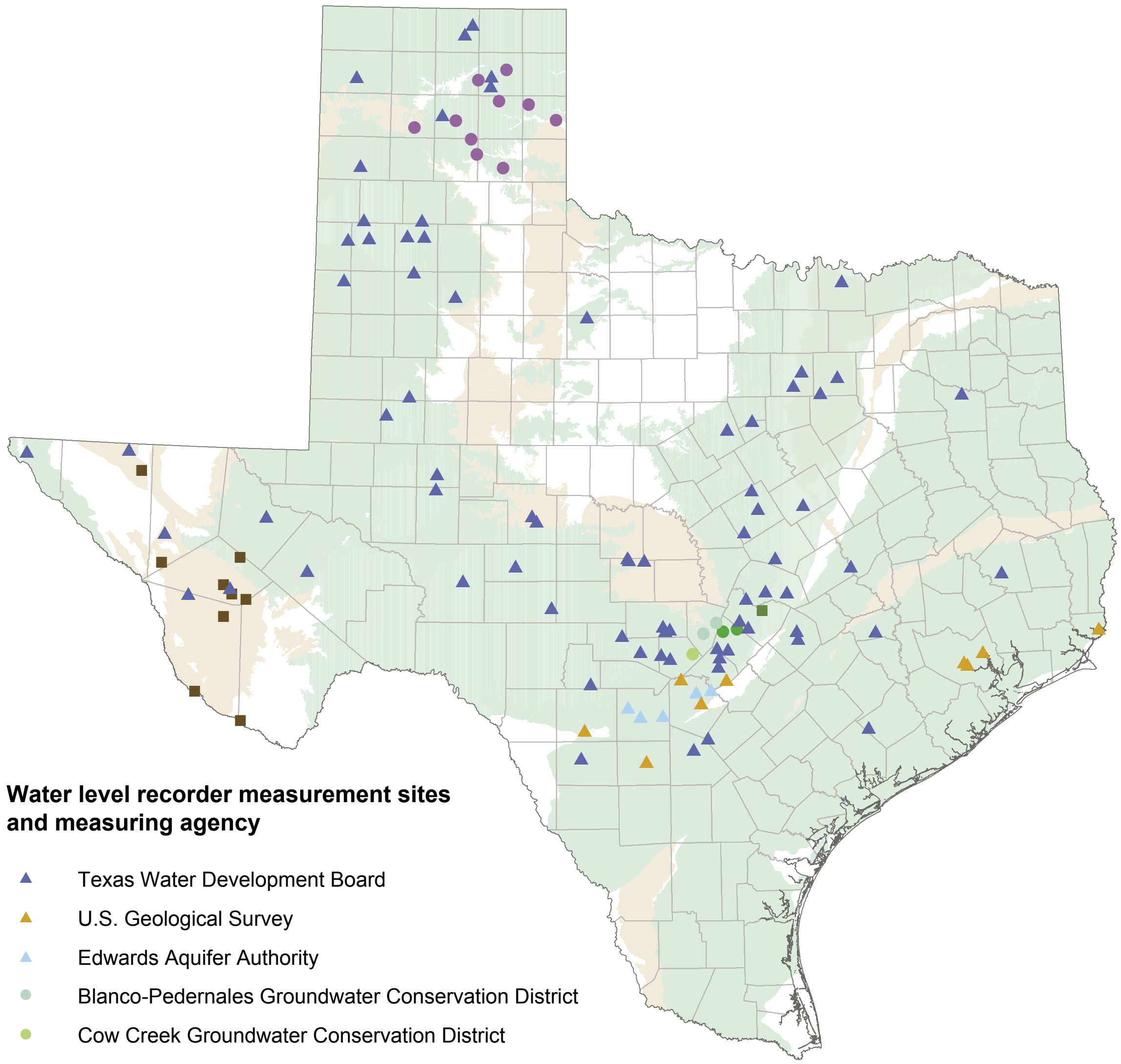


Figure 7.12. Location of recorder sites operated by TWDB and other entities as of September 2006.

7.2.1 Annual Groundwater Level Observation Program

The purpose of TWDB's groundwater level observation program is to detect trends in water levels over time on a regional basis, provide support for groundwater management and state and regional water planning, and collect information for groundwater modeling. In operation since 1957, the program relies on a network of approximately 8,000 observation wells. 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. TWDB collects over 2,000 water level measurements each year and receives at least another 11,000 measurements from other organizations, primarily groundwater conservation districts (some wells get measured multiple times; therefore, the number of measurements is greater than the num-

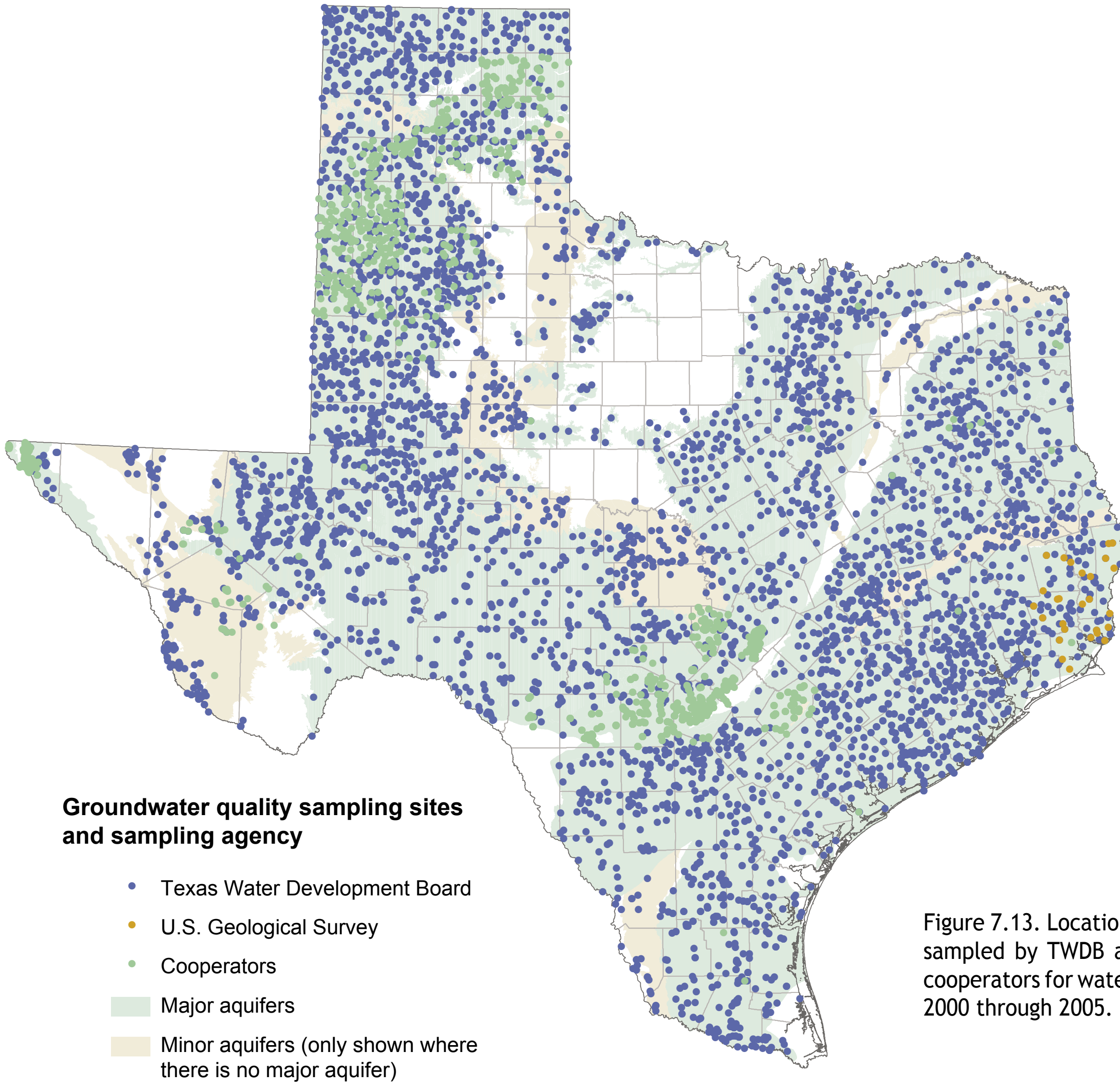


Figure 7.13. Location of wells sampled by TWDB and other cooperators for water quality, 2000 through 2005.

ber of wells measured). TWDB and others collect water levels from wells in nearly all of the state's counties (Figure 7.11).

TWDB measures water levels once a year to ascertain the aquifers' levels under static conditions. Some of the cooperating organizations, however, are able to collect more frequently, which provides even more information on the effects of pumping and seasonal changes on groundwater levels. Once collected, groundwater levels are stored in TWDB's groundwater database and are available at http://wiid.twdb.state.tx.us.

7.2.2 Automatic Groundwater Level Recorder Program

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 equipped to record water levels continuously—called recorders or recorder wells (Figure 7.12). The information from TWDB wells is transmitted daily to TWDB, where it is posted on the TWDB Web site at http://www.twdb.state.tx.us/data/waterwells/.

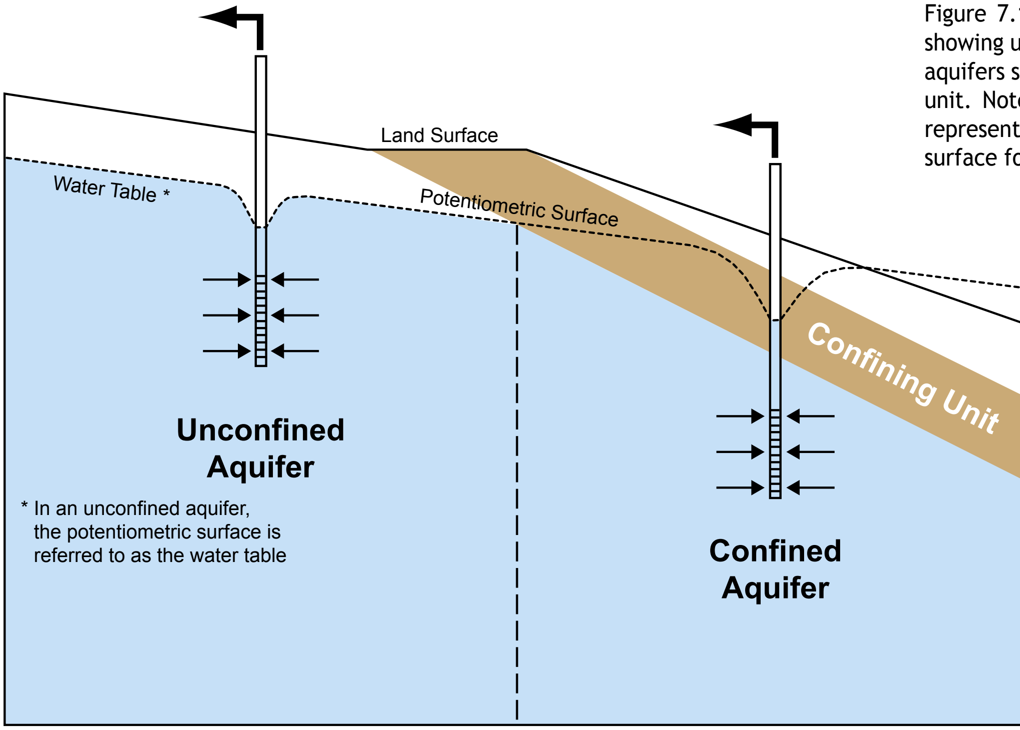


Figure 7.14. Schematic diagram showing unconfined and confined aquifers separated by a confining unit. Note that the dashed line represents the potentiometric surface for the confined aquifer.

Records of water level changes over time are essential information for anyone interested in understanding long-term changes in water levels or planning for future water use, including individual landowners, water suppliers, groundwater conservation districts, and planning groups. In past decades, TWDB operated or funded the maintenance of a few dozen recorder wells in a select number of aquifers, including the Ogallala and the Edwards (Balcones Fault Zone) aquifers. Since the passage of Senate Bill 1 in 1997, the number of recorder wells has expanded to many more sites. This is a trend that the agency expects to continue, particularly with the cooperation of other groups. The value of these daily water-level measurements will increase with time, as long-term measurements become available from an increasing number of sites.

7.2.3 Groundwater Quality Sampling Programs

In addition to monitoring groundwater levels, TWDB and other local, state, and federal organizations also monitor water quality. The purpose of TWDB's groundwater quality sampling program is to monitor natural, or ambient, water quality in each of the state's major and minor aquifers, observe any trends in water quality over time, and support state and regional water planning and groundwater management. Sample analyses include major ions, trace elements (primarily metals), and nutrients. Groundwater conservation districts may also 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, also monitor groundwater quality, although generally after treatment. In addition, the U.S. Geological Survey also collects water quality information in localized parts of the state to assess groundwater conditions, how conditions change over time, and how natural features and human activities affect these conditions.

TWDB annually samples water from 600 to 700 sites, and cooperators collect samples from at least 200 more sites. 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, while five or six major and minor aquifers are sampled each year (Figure 7.13).

7.3 Groundwater Levels

Water levels in an aquifer respond to changes in recharge—the amount of water that infiltrates to the water table of an aquifer—and changes in pumping. In a wet year, recharge to the aquifer may be high, adding water to the aquifer and causing water levels to rise. In a drought, when recharge is low, water levels may decline. When an aquifer is pumped, water levels also decline unless the pumping is in equilibrium with the aquifer.

How an aquifer responds to pumping depends on many factors: the rate of recharge, the rate at which water flows through the aquifer, the thickness of the aquifer, and the amount of water in the aquifer. It also depends on whether or not the aquifer is unconfined or confined. This latter hydraulic condition—whether or not an aquifer is unconfined or confined—significantly affects how water levels respond to pumping.

Unconfined aquifers are sometimes referred to as "water table aquifers." This type of aquifer, which occurs where the aquifer is exposed at the land surface, is defined as an aquifer in which the water table forms the upper boundary of the aquifer (Figure 7.14). The water level in a well in an unconfined aquifer coincides with the water table, which rises and falls in response to changes in recharge and discharge. These water level changes result from increases and decreases in the total amount of water in the aquifer. When water levels decline, water physically drains from the aquifer from the higher water level to the lower water level.

Confined aquifers are sometimes referred to as "artesian aquifers". These aquifers are overlain by confining units—layers of sediments or rock, such as clay and shale, that do not readily transmit groundwater (Figure 7.14). These aquifers usually occur well below the land surface, are completely saturated with groundwater, and are under pressure. Due to 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 lowering the potentiometric surface even though the aquifer continues to be fully saturated.

Examples of unconfined aquifers in Texas are the Ogallala, Pecos Valley, Seymour, Hueco-Mesilla Bolsons, West Texas Bolsons, and Brazos River Alluvium aquifers. The uppermost layer of the Edwards-Trinity (Plateau) Aquifer and the portions of the Edwards (Balcones Fault Zone), Trinity, Dockum, and Carrizo-Wilcox aquifers exposed at land surface are also unconfined aquifers. Examples of confined aquifers in Texas include the lower layers of the Edwards-Trinity (Plateau) aquifer; deeper parts of the Edwards (Balcones Fault Zone), Trinity, Dockum, and Carrizo-Wilcox aquifers; and the Edwards-Trinity (High Plains) Aquifer.

In general, withdrawing water from either type of aquifer will lead to some amount of water level decline. However, for the same amount of pumping, water level declines will be greater in a confined aquifer than in an unconfined aquifer. Excessive water level declines can lead to a number of potentially harmful consequences, such as reduced groundwater flow to springs and rivers, increased pumping costs, land subsidence, or even dry wells. For this reason, it is important to monitor water level changes and learn how individual aquifers respond to drought and withdrawals.

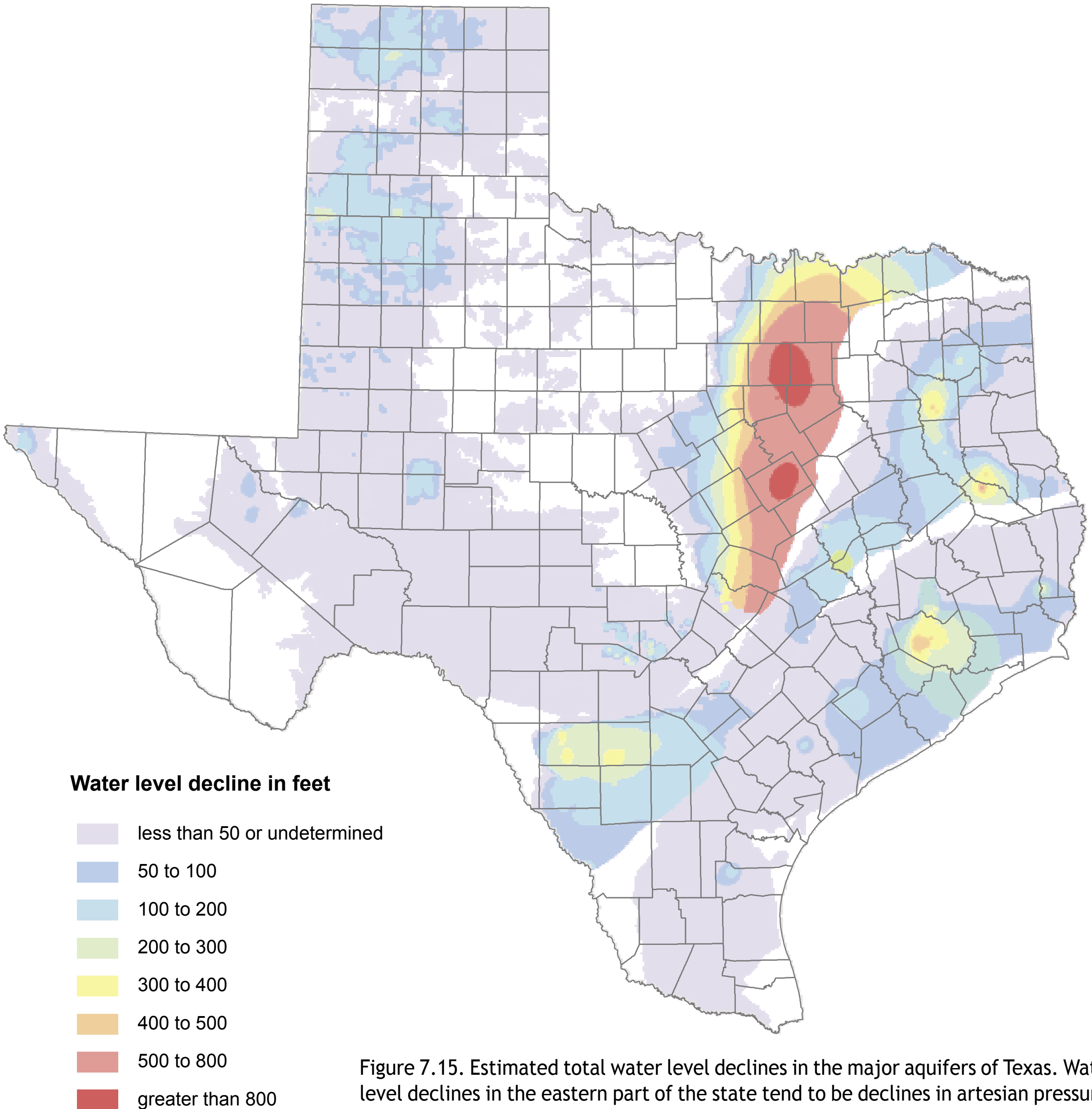


Figure 7.15. Estimated total water level declines in the major aquifers of Texas. Water level declines in the eastern part of the state tend to be declines in artesian pressure, while water level declines in the western part of the state tend to be declines in the water table. These estimates are from 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.

Total water level declines in the state's aquifers range from less than 50 feet to more than 1,000 feet (Figure 7.15). The largest water level declines are in the Trinity Aquifer, focused in the Dallas-Fort Worth and Waco areas. One hundred years ago, wells in much of the Trinity Aquifer flowed at the surface, and Waco was even known as "Geyser City" (Hill, 1901). However, uncapped flowing wells released so much of the artesian pressure in the Trinity Aquifer that most wells ceased to flow by the mid-1910s (Leggatt, 1957). The greatest water level declines—about 1,100 feet—have been in the Trinity Aquifer in Dallas County (Mace and others, 1994). 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. Similar to the

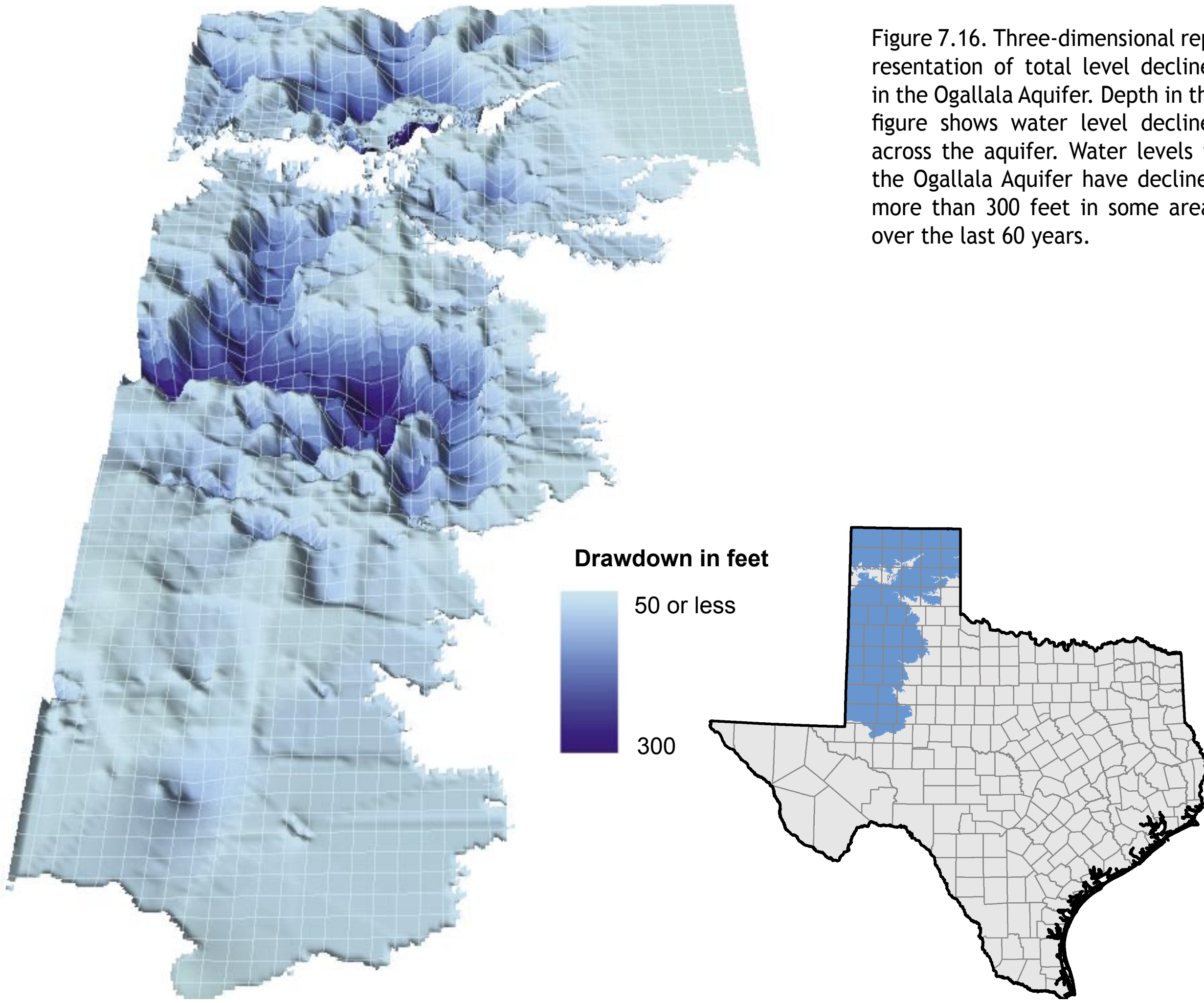


Figure 7.16. Three-dimensional representation of total level declines in the Ogallala Aquifer. Depth in the figure shows water level declines across the aquifer. Water levels in the Ogallala Aquifer have declined more than 300 feet in some areas over the last 60 years.

Trinity Aquifer, these water level declines are associated with declines in artesian pressure due to pumping. Water levels have also declined in the Ogallala Aquifer, with water table declines of more than 300 feet (Figure 7.16). All of these water level declines have been caused by groundwater withdrawals, primarily since the 1950s. Before the 1950s, it is estimated that Texans withdrew less than 2 million acre-feet of groundwater per year (Figure 7.17). 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 (Figure 7.18). 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 due to reduced pumping to prevent land subsidence. However, water levels have fallen more than 40 feet in the suburbs north of Houston.

7.4 Groundwater Quality

Water quality affects whether or not groundwater is suitable for drinking, agriculture, industry, or other uses. The quality of groundwater is affected by its natural environment as well as by contamination through human activity. In its natural environment, groundwater slowly dissolves minerals as

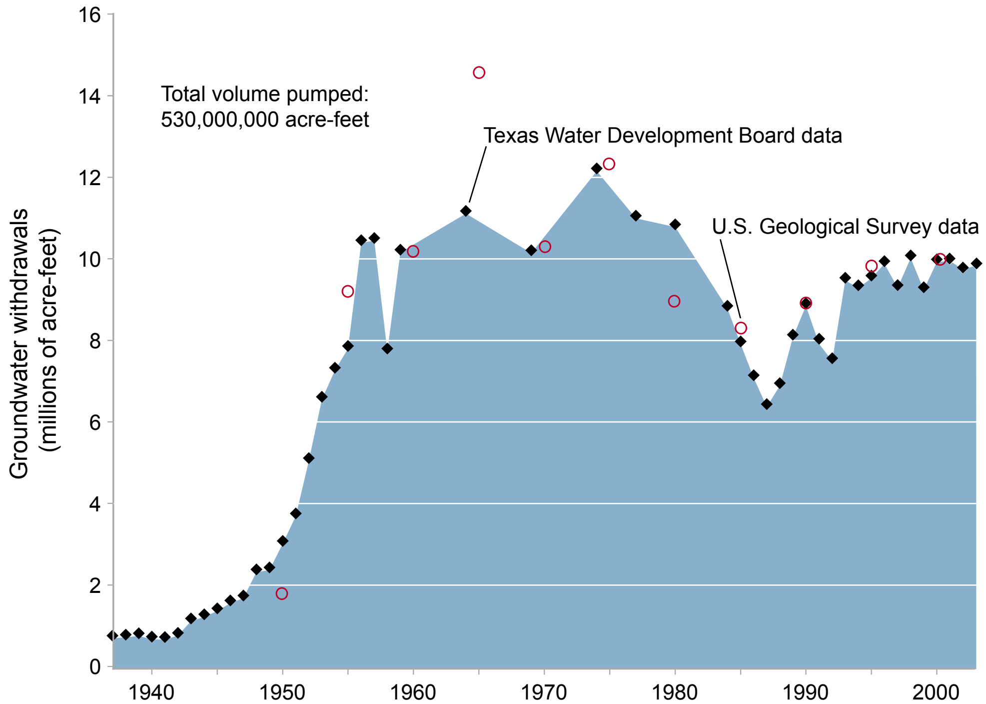


Figure 7.17. Historical estimates of groundwater withdrawals from the aquifers of Texas (data from TWDB water use database; MacKichan, 1951, 1957; MacKichan and Kammerer, 1961; Murray, 1968; Solley and others, 1983, 1988, 1993, 1998; Hutson and others, 2004).

it recharges and flows through an aquifer. In many cases, these dissolved minerals are harmless at the levels in which they are present in the groundwater. However, in some cases, groundwater may dissolve excessive amounts of certain minerals, making the water unsuitable for use.

Other groundwater contamination may result from leaking petroleum storage tank systems, an unlined or leaky salt water disposal pit, a leaking pipeline, a landfill, or overuse of pesticides and fertilizers, among other possibilities. These types of contamination are often localized to a single site but can also be widespread, covering areas used for agriculture or oil and gas production.

Information collected by local, state, and federal agencies has contributed significantly to the understanding of groundwater quality in Texas—an understanding that helps water suppliers and planning groups decide where to find additional groundwater supplies and determine the necessary treatment requirements.

7.4.1 Total Dissolved Solids (Salinity)

Total dissolved solids are a measure of the salinity of water and represent the amount of minerals dissolved in water, generally reported as milli-

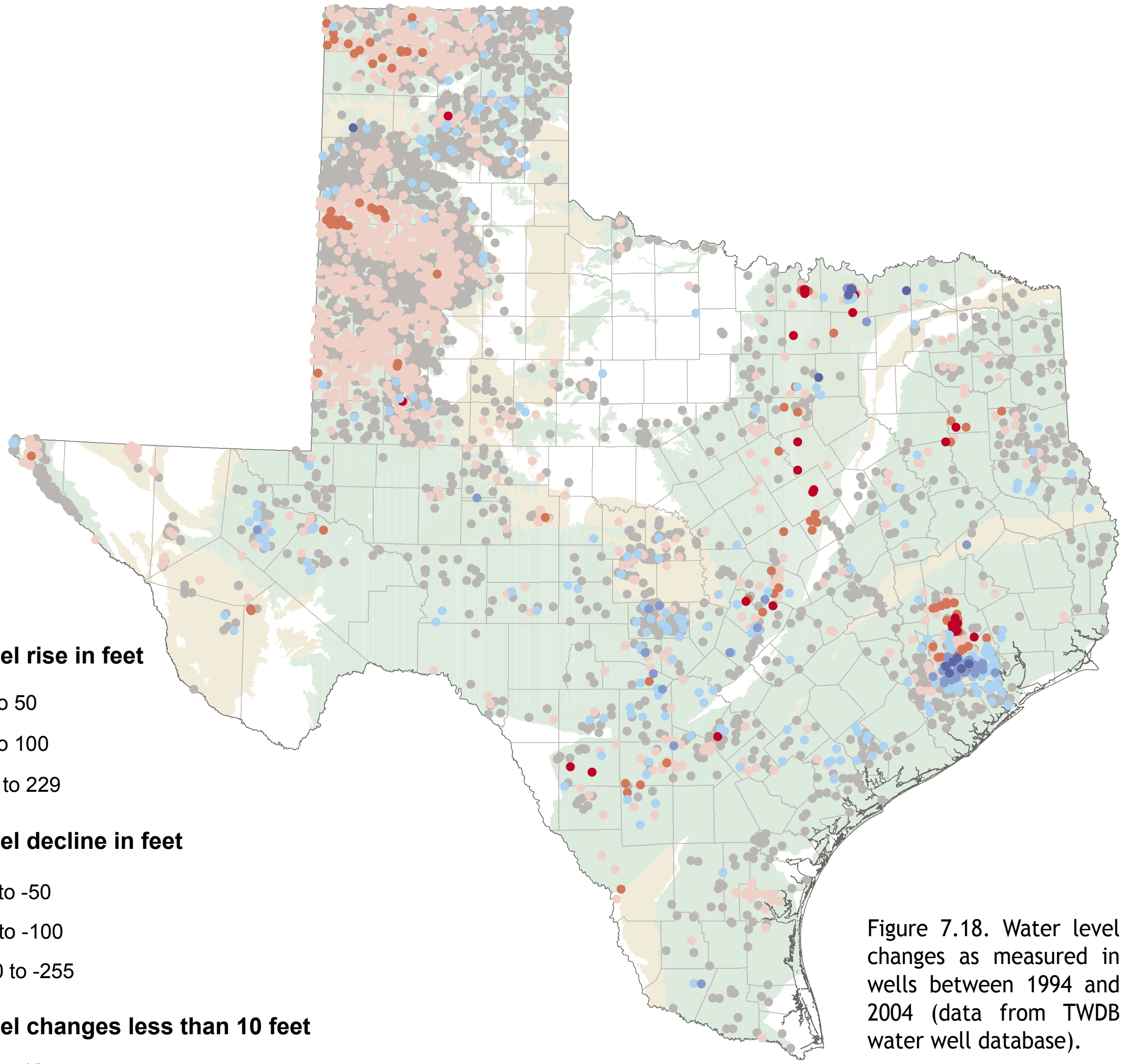


Figure 7.18. Water level changes as measured in wells between 1994 and 2004 (data from TWDB water well database).

grams 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 (Winslow and Kister, 1956). Water with total dissolved solids up to 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

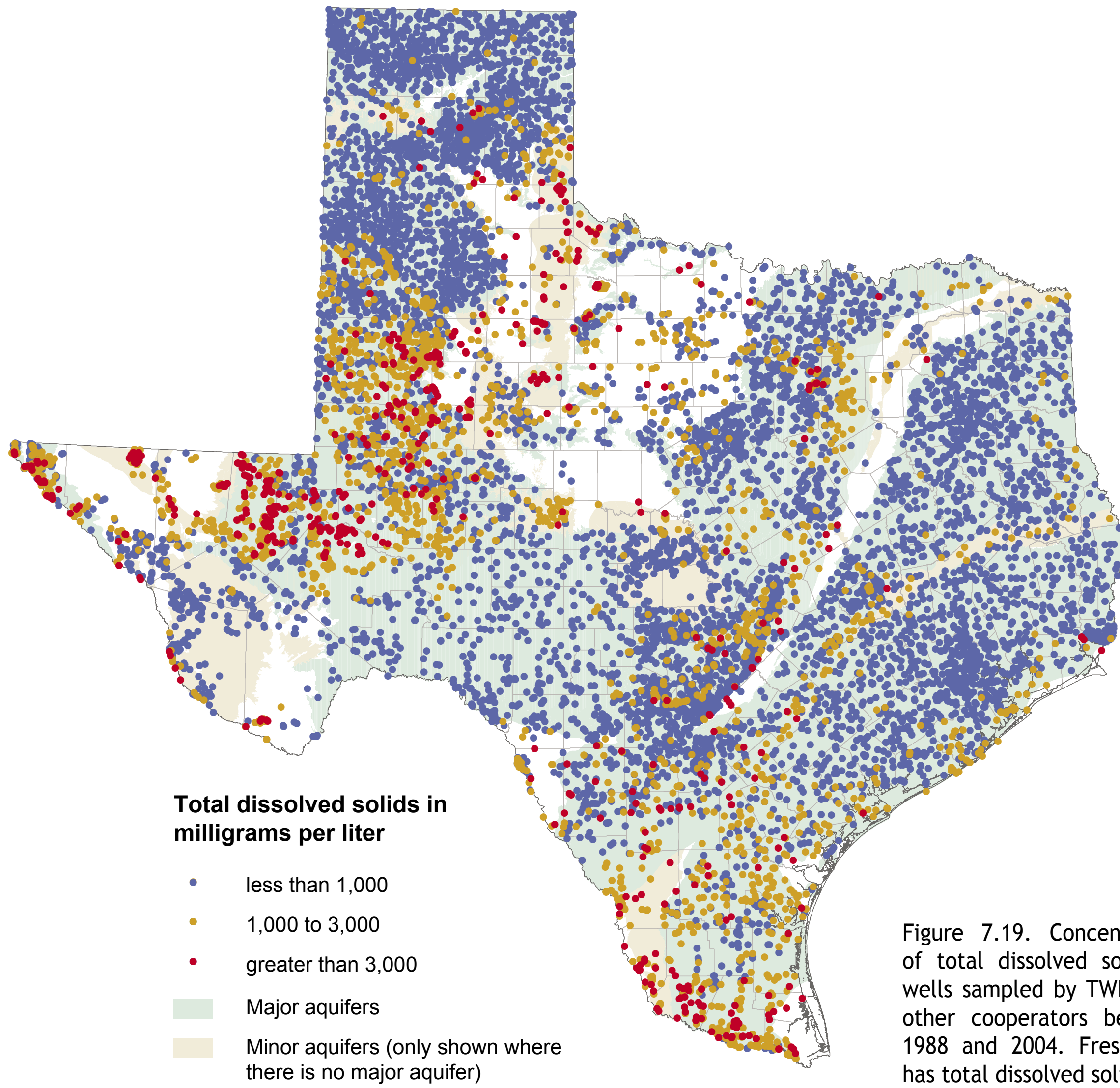


Figure 7.19. Concentration of total dissolved solids in wells sampled by TWDB and other cooperators between 1988 and 2004. Freshwater has total dissolved solids less than 1,000 milligrams per liter.

and 10,000 milligrams per liter, also called brackish groundwater (Winslow and Kister, 1956), 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 7.19).

7.4.2 Arsenic

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 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

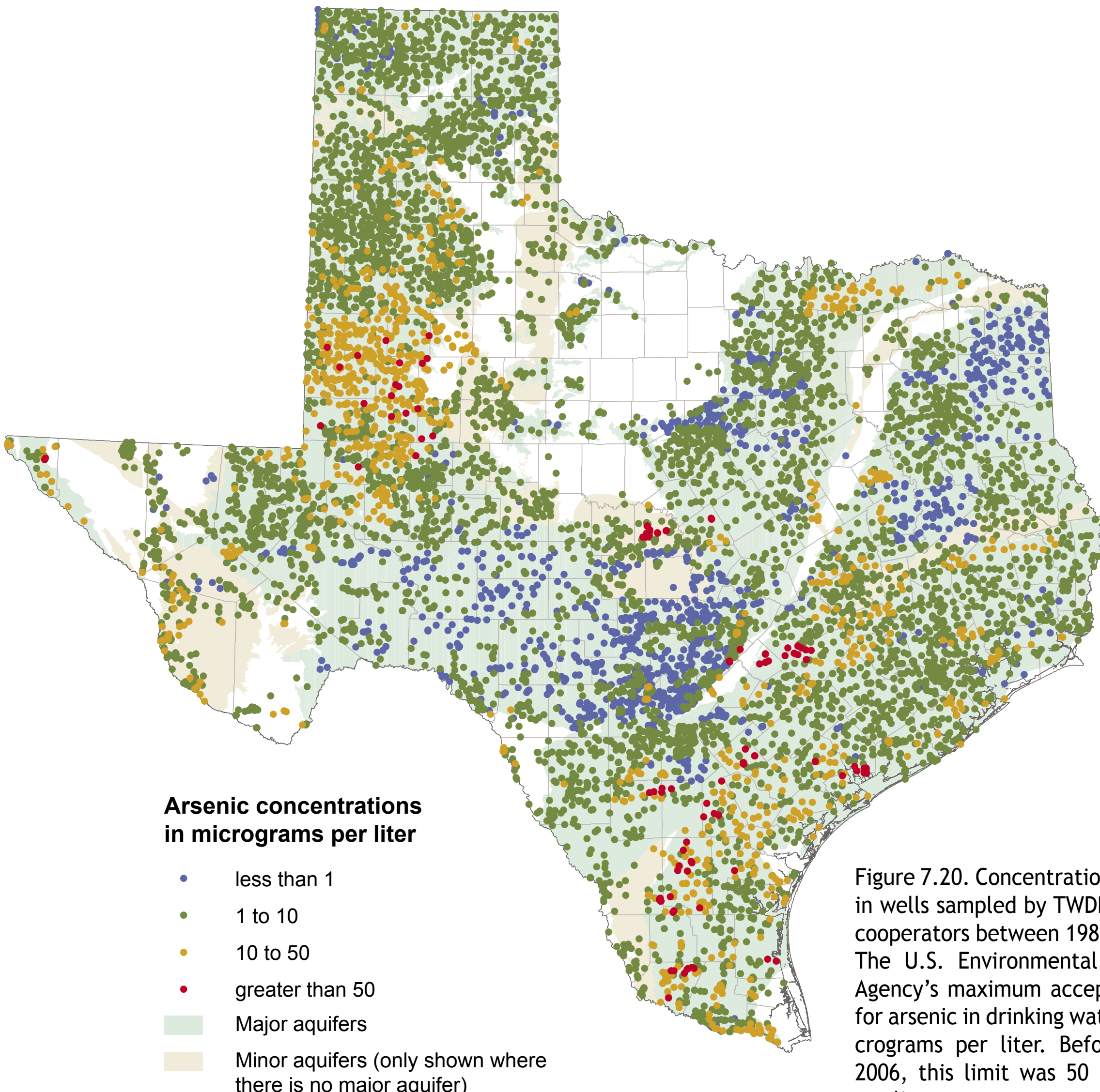


Figure 7.20. Concentration of arsenic in wells sampled by TWDB and other cooperators between 1988 and 2004. The U.S. Environmental Protection Agency's maximum acceptable limit for arsenic in drinking water is 10 micrograms per liter. Before January 2006, this limit was 50 micrograms per liter.

Coast Aquifer, West Texas in the southern half of the Ogallala Aquifer, and parts of Far West Texas in the Hueco-Mesilla Bolsons and West Texas Bolsons aquifers (Figure 7.20).

7.4.3 Radionuclides

A radionuclide is an atom with 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 7.21). The Edwards-Trinity (Plateau), Gulf Coast, and Ogallala aquifers also have significant numbers of wells with high levels of gross alpha radiation. Although 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

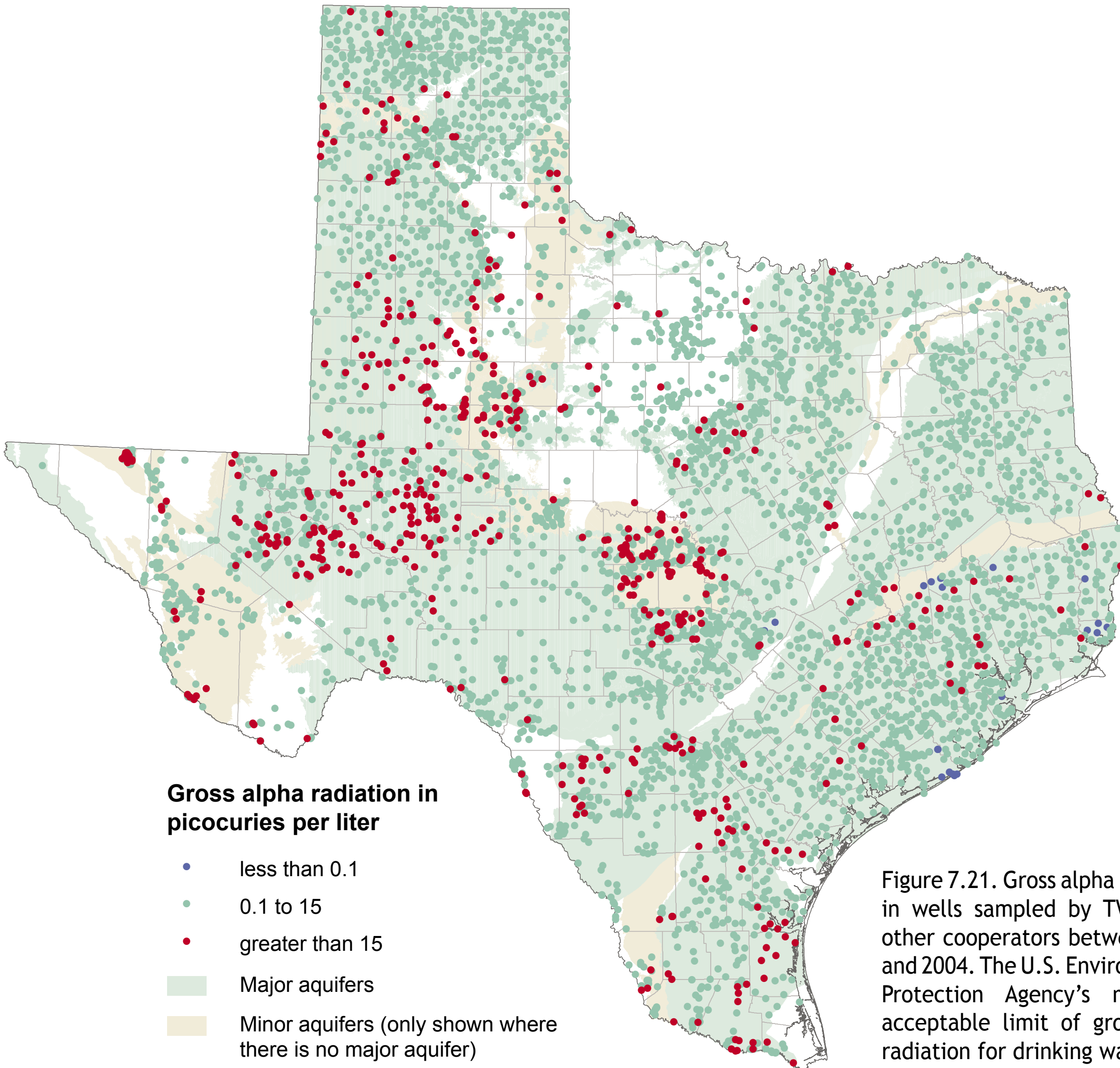


Figure 7.21. Gross alpha radiation in wells sampled by TWDB and other cooperators between 1988 and 2004. The U.S. Environmental Protection Agency's maximum acceptable limit of gross alpha radiation for drinking water is 15 picocuries per liter.

groundwater, blend it with another source, or find an alternative source of drinking water.

7.4.4 Nitrate

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 waste. 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, and if the source is fertilizer, then herbicides and pesticides are commonly found. The U.S. Environmental Protection Agency has 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 7.22). High levels of nitrate in water can cause methemoglobinemia, referred to as "blue baby syndrome," in infants under six months of age.

7.4.5 Other Contamination

According to the Texas Groundwater Protection Committee, there were 6,132 groundwater contamination cases in Texas that were either doc-

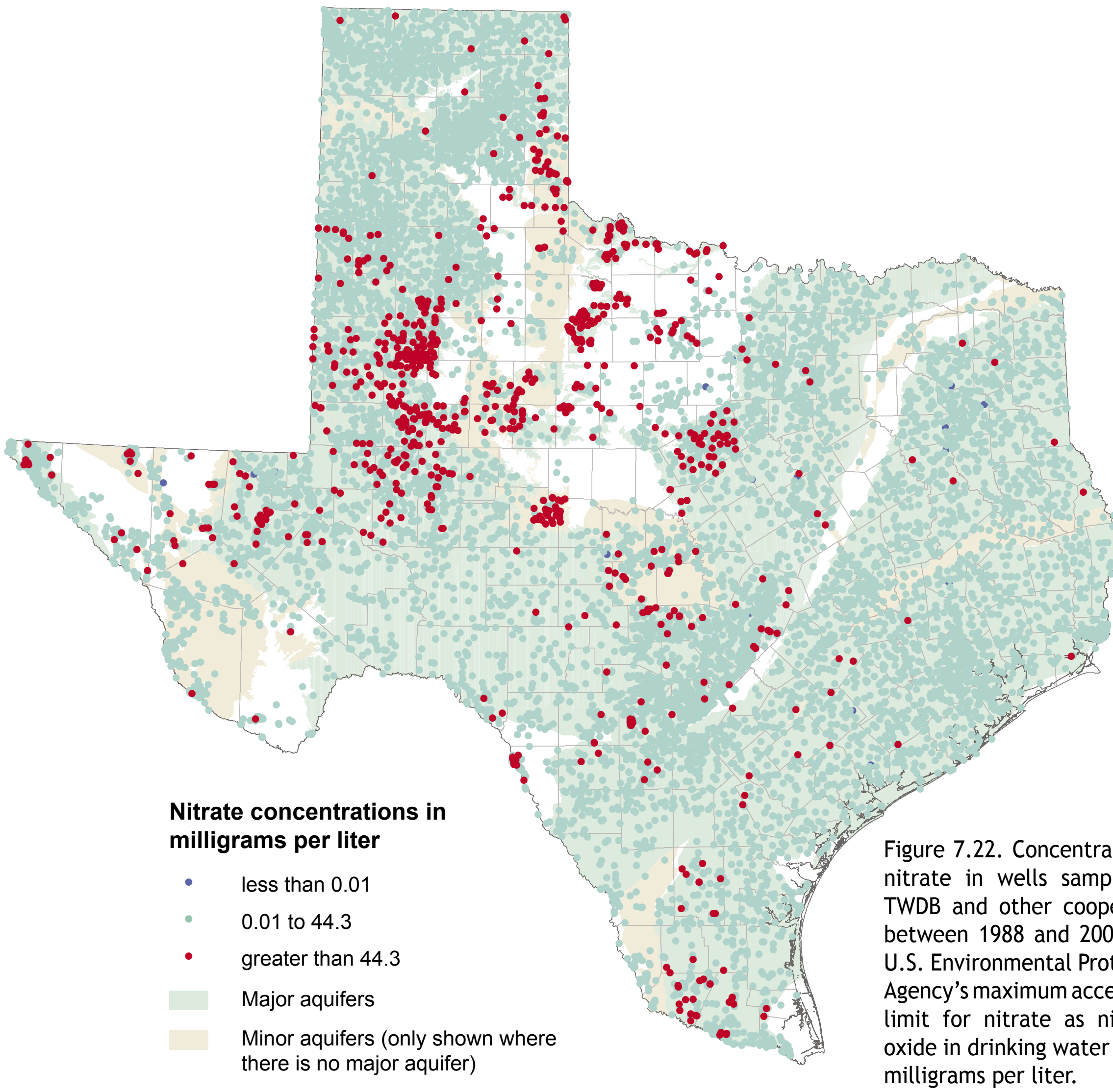


Figure 7.22. Concentration of nitrate in wells sampled by TWDB and other cooperators between 1988 and 2004. The U.S. Environmental Protection Agency's maximum acceptable limit for nitrate as nitrogen oxide in drinking water is 44.3 milligrams per liter.

umented or under enforcement in 2005 (TGPC, 2006). Each of these cases is under the jurisdiction of the Texas Commission on Environmental Quality or the Railroad Commission of Texas, which have programs to clean or protect the water at the contamination sites. The most commonly reported contaminants from human sources include gasoline, diesel, and other petroleum products. Every year the Texas Groundwater Protection Committee publishes a report—the *Joint Groundwater Monitoring and Contamination Report*—that lists each of the sites and their cleanup status. Of those cases in which contamination had been confirmed, the approximate activity status as of 2004 was that

- 3 percent of cases had no activity;
- 54 percent of sites had ongoing investigations;
- 18 percent of sites had corrective action planning and implementation;
- 7 percent of sites had monitoring action; and
- 18 percent of sites had action completed (TGPC, 2006; percentages are approximate because some sites had multiple statuses).

7.5 Groundwater Availability Modeling

TWDB groundwater availability models are computer-based, three-dimensional, numerical groundwater flow models to 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 shape, 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 based on different scenarios. Ongoing refinement and improvement of the groundwater availability models is essential to addressing the needs and concerns of these various entities so that they can manage and plan the use of groundwater supplies.

Groundwater availability models were an immediate outgrowth of the regional water planning process created by Senate Bill 1, 75th Legislative Session. TWDB developed the models in response to groundwater conservation district and planning group needs for better scientific tools to assist them in their management and planning efforts. Because of the demonstrated value of these models, statute now requires that groundwater conservation districts use these models, when available, in developing their groundwater management plans. When House Bill 1763, 79th Legislative Session, became effective on September 1, 2005, groundwater availability models became an even more important tool in managing the state's groundwater resources. This new law mandates that groundwater conservation districts and planning

groups use values of managed available groundwater, based on the desired future conditions of aquifers determined for the 16 groundwater management areas, in their management plans and regional water plans. As the groundwater management areas evaluate the desired future conditions of their aquifers, groundwater availability models will be used to estimate the managed available groundwater for each aquifer.

To cover the state's aquifers adequately, at least 31 models will be needed for the 30 major and minor aquifers in Texas. Some of the larger or more complex aquifers require more than one model, while some models incorporate a combination of aquifers. As required by law, TWDB developed or obtained the initial versions of 17 groundwater availability models for the state's nine major aquifers before October 1, 2004 (Figure 7.23). These nine aquifers currently supply approximately 95 percent of the groundwater produced in the state. Since October 2004, TWDB has developed or ob-

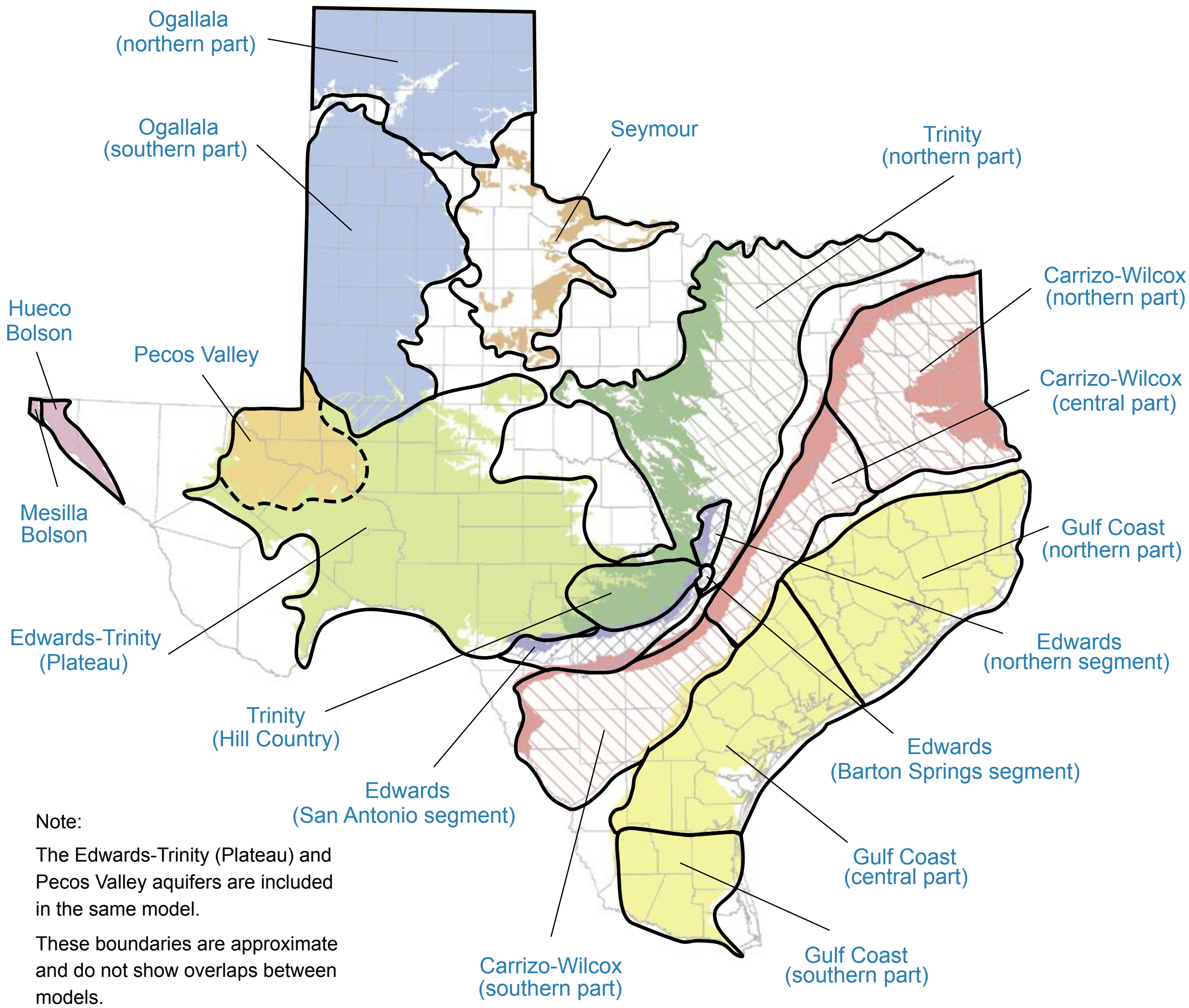


Figure 7.23. Approximate extent of groundwater availability models for the major aquifers of Texas. These models will need to be updated in the future to include new information as it becomes available. For downloadable copies of the model reports or for additional information on the models, please see www.twdb.state.tx.us/gam. Note that model boundaries are approximate and that the internal boundaries for the models of the Carrizo-Wilcox and Gulf Coast aquifers overlap.

tained initial versions of two additional models, as well as a number of additions and enhancements to existing models. Some of the initial models came from external cooperators, including El Paso Water Utilities, the Edwards Aquifer Authority, and the U.S. Geological Survey. One of the models, the model for the northern part of the Gulf Coast Aquifer, was supported jointly by TWDB, the U.S. Geological Survey, the Harris-Galveston Coastal Subsidence District, and the Fort Bend Subsidence District.

Currently, TWDB is working on obtaining or developing initial versions of models for the remaining minor aquifers in Texas. Thus far, seven of the minor aquifers and parts of another minor aquifer are included in existing groundwater availability models (Figure 7.24). The remaining 13 minor aquifers and parts of the West Texas Bolsons Aquifer not yet modeled will require 12 additional groundwater availability models. The Edwards-Trinity (High Plains) Aquifer will be added as a layer to the existing model for the southern part of the

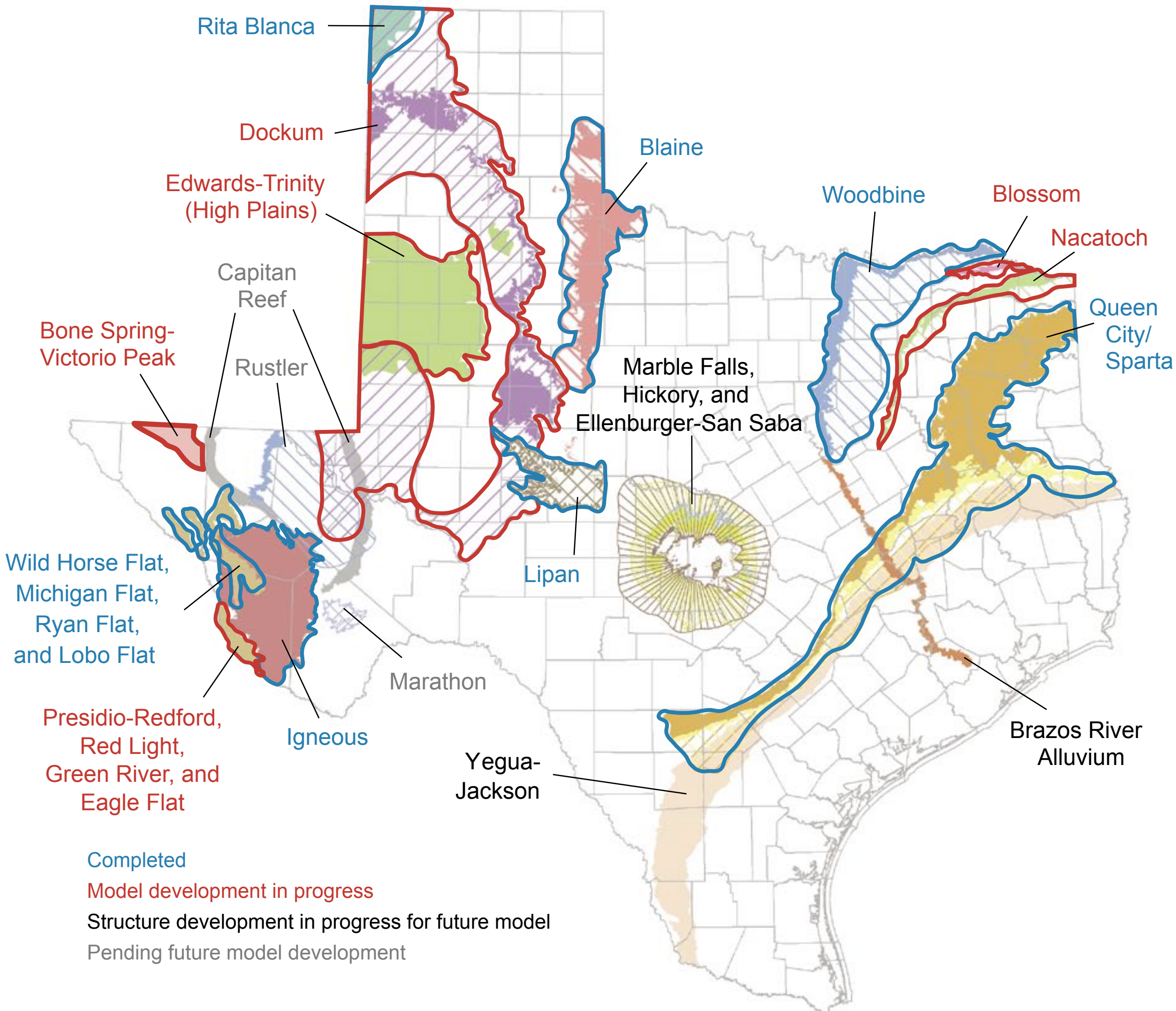


Figure 7.24. Approximate extent of completed and ongoing groundwater availability models for the minor aquifers of Texas. Completed models will need to be updated in the future to include new information as it becomes available. For downloadable copies of the model reports or for additional information on the status of ongoing models, please see www.twdb.state.tx.us/gam.

Ogallala Aquifer and, as a result, does not require its own model.

Updating and improving these initial models is a vital component of the groundwater availability modeling program. To accommodate the ongoing needs of the groundwater conservation districts, planning groups, regional water suppliers, and other model users, TWDB has already begun the process of updating and adjusting several existing groundwater availability models. For example, TWDB updated the three groundwater availability models of the Carrizo-Wilcox Aquifer and is currently updating the models of the Hill Country portion of the Trinity Aquifer and the southern part of the Ogallala Aquifer. TWDB currently plans to review the completed models every five years for possible updates or enhancements. To view modeling reports, request a model, or check the status of the program, please visit the TWDB Web site at www.twdb.state.tx.us/gam.

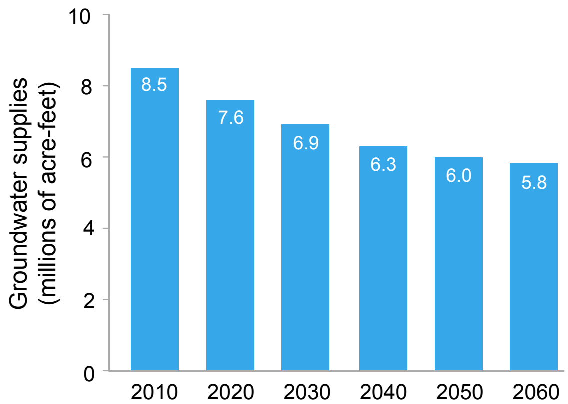


Figure 7.25. Projected existing groundwater supplies through 2060.

7.6 Existing Groundwater Supply Projections

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. A permit represents a legal limit on how much water can be produced. Therefore, even though a group of wells may be able to pump 2,000 acre-feet per year, the supply is limited to 1,000 acre-feet per year if the permit is for 1,000 acre-feet per year. On the other hand, if the permit is for 2,000 acre-feet per year but existing infrastructure—the current wells—can only pump 1,000 acre-feet per year, then the groundwater supply is 1,000 acre-feet per year. By calculating groundwater supply, water planners know how much groundwater can be used with current infrastructure and what needs to be done to meet needs in the future (for example, larger pumps, new wells, or pipelines).

Planning groups estimated that existing groundwater supplies will be about 8.5 million acre-feet per year in 2010 and will decline 32 percent to about 5.8 million acre-feet per year by 2060 (Figure 7.25, Table 7.1). The decline is due primarily to reduced supply from the Ogallala Aquifer as a result of depletion (about 2.5 million acre-feet per year reduction by 2060), as well as reduced supply from the Gulf Coast Aquifer due to mandatory reductions in pumping to prevent land surface subsidence (about 160,000 acre-feet per year reduction by 2060). In most cases, groundwater supplies either remain at current amounts or decrease by 2060.

7.7 Groundwater Availability Projections

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—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. For example, the Texas Legislature directed the subsidence districts in Fort Bend, Galveston, and Harris counties to decrease and limit groundwater production to prevent land subsidence. Another example is the Edwards (Balcones Fault Zone) Aquifer, most of which is regulated by the Edwards Aquifer Authority, for which the legislature has enacted limits to groundwater

Table 7.1. Existing groundwater supplies—the amount of groundwater that can be produced with current permits and existing infrastructures—for the major and minor aquifers

Existing groundwater supplies (acre-feet per year)							
Aquifer	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**Percent change[a]**
Blaine	30,525	30,527	30,528	30,530	30,530	30,530	0
Blossom	707	707	707	707	707	707	0
Bone Spring-Victorio Peak	63,000	63,000	63,000	63,000	63,000	63,000	0
Brazos River Alluvium	43,490	42,744	42,033	36,462	35,978	35,519	-18
Capitan Reef Complex	15,271	16,796	17,870	18,649	19,144	19,454	+27
Carrizo-Wilcox	559,904	558,319	552,725	543,903	534,931	532,600	-5
Dockum	53,820	53,659	59,747	58,072	56,662	55,314	+3
Edwards-Trinity (High Plains)	4,160	3,580	2,802	2,335	2,065	2,065	-50
Edwards (Balcones Fault Zone)	368,984	368,992	368,983	368,944	368,917	368,904	0
Edwards-Trinity (Plateau)	228,887	228,927	228,945	228,943	228,942	228,947	0
Ellenburger-San Saba	22,437	22,419	22,411	22,412	22,418	21,867	-3
Gulf Coast	1,282,456	1,204,544	1,151,575	1,142,294	1,132,316	1,122,251	-12
Hickory	50,019	50,108	50,187	50,261	50,326	50,425	+1
Hueco-Mesilla Bolsons	162,260	162,260	162,260	162,260	162,260	162,260	0
Igneous	13,946	13,946	13,946	13,946	13,946	13,946	0
Lipan	42,523	42,523	42,523	42,523	42,523	42,523	0
Marathon	148	148	148	148	148	148	0
Marble Falls	15,329	15,327	15,326	15,325	15,324	15,323	0
Nacatoch	3,781	3,871	3,903	3,896	3,856	3,824	+1
Ogallala	4,827,450	4,040,699	3,350,863	2,783,847	2,487,454	2,325,395	-52
Other	156,075	156,240	156,287	156,293	156,317	156,410	0
Pecos Valley	120,029	114,937	114,991	115,025	115,071	115,125	-4
Queen City	31,097	30,755	30,456	30,188	29,874	29,550	-5
Rita Blanca	5,419	5,419	5,419	5,419	5,419	5,419	0
Rustler	2,469	2,469	2,469	2,469	2,469	2,469	0
Seymour	144,903	143,583	139,051	138,763	138,502	138,249	-5
Sparta	22,809	22,724	22,632	22,573	22,505	22,441	-2
Trinity	165,694	164,792	163,649	163,181	161,474	161,000	-3
West Texas Bolsons	44,511	44,511	44,511	44,511	44,511	44,511	0
Woodbine	28,661	28,628	28,608	28,714	28,858	29,202	+2
Yegua-Jackson	7,285	7,285	7,285	7,285	7,285	7,285	0
Total	8,518,049	7,644,439	6,895,840	6,302,878	5,983,732	5,806,663	-32

Note: Supplies that do not change by more than 0.5 percent are shown as remaining the same.
[a] % represents the percent change from 2010 through 2060.

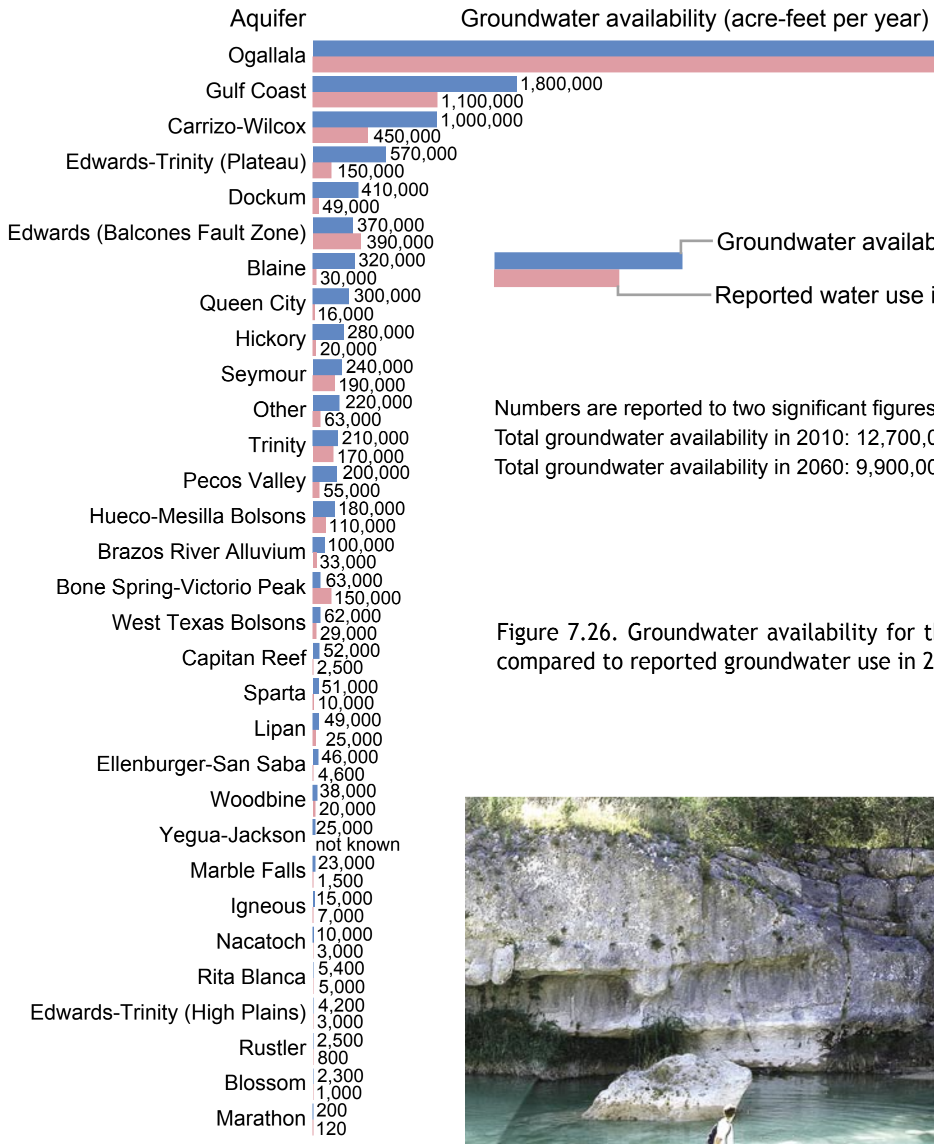


Figure 7.26. Groundwater availability for the aquifers of Texas in 2010 compared to reported groundwater use in 2003.

production. Groundwater management goals and rules can also limit groundwater availability. If a groundwater conservation district limits groundwater level declines to 50 feet, then groundwater availability within the district will reflect this management goal. Finally, planning group policy may also limit groundwater availability in the regional water plans. In those areas with no groundwater conservation districts, rule of capture would allow all the water in the aquifer to be available for use. However, planning groups often limit groundwater availability for planning purposes so that groundwater resources can be sustained over time.

TWDB rules require planning groups to consider groundwater management plans from groundwater conservation districts, which include information on the districts' views of groundwater availability (listed as "total usable amount of groundwater" in the groundwater management plans). However, planning groups were not required to use the districts' numbers. Many planning groups did use them, but some did not. In the future, planning groups will be required to use groundwater districts' desired future conditions for an aquifer as the basis for determining existing groundwater supplies.

Total groundwater availability in 2010, as assessed by the planning groups, is about 12.7 million acre-feet per year (Figure 7.26). Because of projected decreases in availability in the Dockum, Edwards-

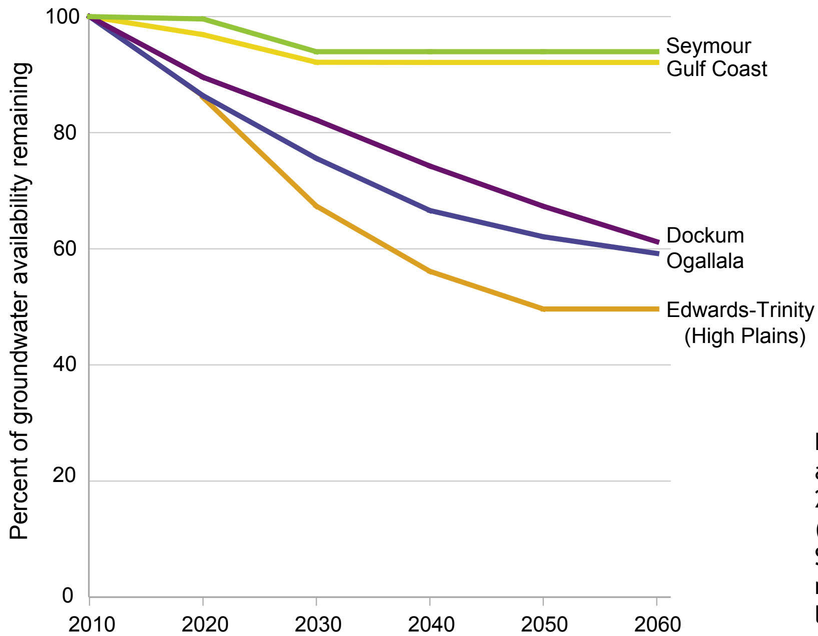


Figure 7.27. Percent of initial groundwater availability remaining between 2010 and 2060 for the Dockum, Edwards-Trinity (High Plains), Gulf Coast, Ogallala, and Seymour aquifers. All other major and minor aquifers have no declines or declines less than 2 percent.

Trinity (High Plains), Gulf Coast, Ogallala, and Seymour aquifers (Figure 7.27), this availability decreases to 9.9 million acre-feet per year by 2060. To determine availability, some planning groups used one of two policies: sustainability, in which an aquifer can be pumped indefinitely; or planned depletion, in which an aquifer is drained over a period of time. The South Texas Regional Water Planning Group, however, used a temporary value for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer until a better value is attained through the process of developing the Habitat Conservation Plan required by the U.S. Fish and Wildlife Service. Region H used values of availability for the Gulf Coast Aquifer to minimize or prevent land subsidence.

The groundwater availability numbers for 2010 and 2050 (12.7 and 10.1 million acre-feet per year, respectively) are different from the numbers in the 2002 State Water Plan (14.9 and 13.1 million acre-feet per year). This difference is primarily due to a change in policy by the Far West Texas and Plateau planning groups. These planning groups used planned depletion for many of their aquifers in their 2001 Regional Water Plans and are now using sustainability. Another important change from the 2002 State Water Plan is the reassessment of groundwater availability for the Hueco-Mesilla Bolsons Aquifer. Previous estimates suggested that the part of the aquifer in the Hueco Bolson would be depleted of fresh groundwater by 2030. A more recent assessment, based in part on a new groundwater availability model, suggests that groundwater production is nearly sustainable under current conditions.

References

Ashworth, J.B., and Flores, R.R., 1991, Delineation criteria for the major and minor aquifer maps of Texas: Texas Water Development Board Limited Publication 212, 27 p.

Ashworth, J.B., and Hopkins, J., 1995, Minor and major aquifers of Texas: Texas Water Development Board Report 345, 66 p.

Hill, R.T., 1901, Geography and geology of the Black and Grand prairies, Texas, with detailed descriptions of the Cretaceous formations and special reference to artesian waters: Twenty-first Annual Report of the United States Geological Survey, part VII, 666 p.

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268, 52 p.

Leggatt, E.R., 1957, Geology and ground-water resources of Tarrant County, Texas: Texas Board of Water Engineers Bulletin 5709, 187 p.

Mace, R.E., Dutton, A.R., and Nance, H.S., 1994, Water-level declines in the Woodbine, Paluxy, and Trinity aquifers of North-Central Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 413–420.

MacKichan, K.A., 1951, Estimated use of water in the United States in 1950: U.S. Geological Survey Circular 115, 13 p.

______1957, Estimated use of water in the United States in 1955: U.S. Geological Survey Circular 398, 18 p.

MacKichan, K.A., and Kammerer, J.C., 1961, Estimated use of water in the United States in 1960: U.S. Geological Survey Circular 456, 44 p.

Murray, C.R., 1968, Estimated use of water in the United States in 1965: U.S. Geological Survey Circular 556, 53 p. Available online at http://pubs.er.usgs.gov/pubs/cir/cir556

Solley, W.B., Chase, E.B., and Mann, W.B. IV, 1983, Estimated use of water in the United States in 1980: U.S. Geological Survey Circular 1001, 56 p.

Solley, W.B., Merk, C.F., and Pierce, R.R., 1988, Estimated use of water in the United States in 1985: U.S. Geological Survey Circular 1004, 82 p.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1993, Estimated use of water in the United States in 1990: U.S. Geological Survey Circular 1081, 76 p.

______1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 71 p.

TGPC (Texas Groundwater Protection Committee), 2006, Joint groundwater monitoring and contamination report—2004: Texas Commission on Environmental Quality Report SFR-056/05, variously paginated.

Winslow, A.G., and Kister, L.R., Jr., 1956, The saline water resources of Texas: U.S. Geological Survey Water Supply Paper 1365, 105 p.