In cooperation with the Texas Parks and Wildlife Department

Compilation of Historical Water-Quality Data for Selected Springs in Texas, by Ecoregion

Data Series 230

Cover. One orifice of Comal Springs in Landa Park at New Braunfels, Texas.

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Data Series 230

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
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Conversion Factors and Datum

SI to Inch/Pound

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Flow rate	
cubic meter per second (m^3/s)	70.07	acre-foot per day (acre-ft/d)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
liter per second (L/s)	15.85	gallon per minute (gal/min)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Specific conductance is shown in microsiemens per centimeter at 25 degrees Celsius (µS/cm).

Concentrations of chemical constituents in water are shown in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Horizontal Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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Abstract

Springs are important hydrologic features in Texas. A database of about 2,000 historically documented springs and available spring-flow measurements previously has been compiled and published, but water-quality data remain scattered in published sources. This report by the U.S. Geological Survey, in cooperation with the Texas Parks and Wildlife Department, documents the compilation of data for 232 springs in Texas on the basis of a set of criteria and the development of a water-quality database for the selected springs. The selection of springs for compilation of historical water-quality data in Texas was made using existing digital and hard-copy data, responses to mailed surveys, selection criteria established by various stakeholders, geographic information systems, and digital database queries. Most springs were selected by computing the highest mean spring flows for each Texas level III ecoregion. A brief assessment of the water-quality data for springs in Texas shows that few data are available in the Arizona/New Mexico Mountains, High Plains, East Central Texas Plains, Western Gulf Coastal Plain, and South Central Plains ecoregions. Water-quality data are more abundant for the Chihuahuan Deserts, Edwards Plateau, and Texas Blackland Prairies ecoregions. Selected constituent concentrations in Texas springs, including silica, calcium, magnesium, sodium, potassium, strontium, sulfate, chloride, fluoride, nitrate (nitrogen), dissolved solids, and hardness (as calcium carbonate) are comparatively high in the Chihuahuan Deserts, Southwestern Tablelands, Central Great Plains, and Cross Timbers ecoregions, mostly as a result of subsurface geology. Comparatively low concentrations of selected constituents in Texas springs are associated with the Arizona/New Mexico Mountains, Southern Texas Plains, East Central Texas Plains, and South Central Plains ecoregions.

Introduction

Springs and seeps are natural features in the bedrock or soil that function as discrete or clustered outlets to convey ground water to the surface. Ground water discharges through one orifice, multiple orifices, or seeps in the rock or soil. Springs commonly occur on hill slopes or valleys where a permeable rock unit overlies relatively impermeable strata, or along faults where a permeable rock unit is offset and abuts an impermeable unit. Other springs are the result of emergent alluvial underflow, karst features, or geothermal activity. Some areas are characterized by a high spatial density of springs; these include karstic environments, faults expressed at the land surface, valleys, and escarpments. Springs commonly form the head of a stream valley, a knickpoint of upstream valley incision, or a vertical step in streambed elevation.

Spring flow commonly is a substantial or even primary contributor to the base flow of rivers and streams. In particular, during drought conditions, springs account for almost the entire flow along some river reaches. Springs often flow at a constant rate if sourced by a relatively large ground-water recharge area or by an aquifer of low transmissivity (Brune, 1981). Fluctuations in spring flow can be attributed to either climatic conditions or ground-water withdrawals, and flow variation is exaggerated for springs with small recharge areas of high transmissivity (Brune, 1981). Water-quality data for spring flow can be used to determine flow paths and rock units that were in contact with the ground water (Cartwright and others, 2002; Grasby and others, 2000). For example, a dissolved solids concentration of 1,000 milligrams per liter or more might indicate long residence times or sulfur or halite deposits beneath the surface. The temperature of spring water can indicate the depth of the water source (Brune, 1981), such that springs near the mean annual surface temperature have shallow flow paths relative to springs warmer than mean annual surface temperature.

The importance of springs in identifying the sites of human habitation is evident from prehistoric artifacts that have been found at numerous springs across Texas (Brune, 1981; Shiner, 1983). Sites near springs were originally selected to provide a water supply for many cities in Texas, including Austin, Big Spring, Brackettville, Del Rio, Dickens, Fort Stockton, Jacksboro, Lampasas, New Braunfels, Salado, San Antonio, San Marcos, Uvalde, and Waco. Historical forts in Texas located near springs include Fort Clark, Fort McKavett, Fort Richardson, and Fort Stockton.

Springs also serve as habitat for numerous species (Hubbs, 2001). Many springs in Texas are habitat for endangered or threatened species or both: for example the Barton Springs salamander (*Eurycea sosorum*), Texas wild rice (*Zizania texana*) downstream of San Marcos Springs in San Marcos, and the fountain darter (*Etheostoma fonticola*) in Comal Springs in New Braunfels. In West Texas, the Comanche Springs pupfish (*Cyprinodon elegans*) resides in San Solomon Spring; Comanche Springs generally has been dry since 1962 (Brannan and others, 2003).

In Texas, springs are a highly visible component of the hydrologic cycle. Federal and State agencies, resource conservation groups, water managers, municipalities, landowners, and even people who use springs or spring-fed rivers for recreation give close attention to the quantity and quality of water discharging from springs. From the perspective of many individuals and entities, springs serve as an indicator of the quality and availability of ground water (Bonacci, 1995).

In 2003, the U.S. Geological Survey (USGS), in cooperation with the Texas Water Development Board (TWDB), published a database of Texas springs and spring-flow measurements (Heitmuller and Reece, 2003). Data sources for this database were limited, however, to digital spreadsheets from the TWDB and Capitol Environmental Services, the USGS National Water Information System (NWIS), and hard-copy annual Water-Data Reports and Water-Supply Papers of the USGS. Heitmuller and Reece (2003) represents only springs with verified geographic coordinates in Texas; the authors of that publication acknowledge the existence of many springs not included in the database.

Following the publication of Heitmuller and Reece (2003), a series of meetings were held at the USGS office in Austin, Texas, between December 2003 and March 2004 to organize further investigative efforts related to springs in Texas. Participants in the meetings represented the interests of Federal and State agencies, nonprofit organizations, universities, research centers, and private landowners. One outcome of the meetings was a project by the USGS, in cooperation with the Texas Parks and Wildlife Department, to select primary springs in Texas and compile existing water-quantity and water-quality data for those springs into a database. The database then would serve as a platform for future water-quality and spring-flow monitoring. The selection of springs would be based on criteria that include spring flow, historical and cultural importance, water use, habitat to unique species, and linkage to aquifers or streamflow. An important consideration in the scope of the work was to ensure an adequate regional representation of springs.

Purpose and Scope

The purpose of this report is to document the compilation of a water-quality database for selected primary springs throughout Texas. The report also documents the sources and procedures used to select springs for the water-quality database and provides maps of selected constituents and explanations of spring water quality for level III Texas ecoregions. Level III ecoregions are land areas identified by the U.S. Environmental Protection Agency (2004) with similar geology, physiography, vegetation, climate, soils, land use, and hydrology (Griffith and others, 2004).

Review of Existing Data

Before 1894, no systematic data collection was done on springs in Texas, although a few discrete pre-1894 spring-flow estimates are available. The first systematic data collection on a Texas spring was in 1894, when the USGS began to monitor the flow of Barton Springs in Austin. Spring-flow monitoring on other major Texas springs began soon thereafter, in 1895, at Comal Springs in New Braunfels, Las Moras Springs in Brackettville, and San Felipe Springs in Del Rio. The next documentation of springs and spring flow in Texas was done in the 1940s and 1950s by the Texas Board of Water Engineers (TBWE), now the TWDB. Records of wells and springs were published by county in TBWE ground-water resources reports (see Baker, 2005). These records contain spring names, owners, aquifer associations, and discrete spring-flow and water-quality measurements. The TWDB continued the compilation of spring records by county beginning in 1957. Additionally, a study of the geohydrology of Comal, San Marcos, and Hueco Springs (William F. Guyton & Associates, 1979) was sponsored by the TWDB.

The most substantial springs and spring-flow documentation in Texas was done by Gunnar Brune in the 1970s. Brune (1975) presents site information, water quality, and spring-flow declines for 281 major and historical Texas springs. This report was a prelude to Brune (1981), a detailed compilation of all known springs in 183 counties in Texas. In addition to written accounts of visits to these springs, many spring-flow and water-quality measurements are provided. Currently (2006), a publication of springs for the remaining counties is not available.

Acknowledgments

The authors are grateful to Larry McKinney, Cindy Loeffler, Chad Norris, and David Bradsby of the Texas Parks and Wildlife Department for providing information and helpful suggestions during preparation of this report.

Procedures for Data Compilation

The selection of springs for compilation of historical water-quality data in Texas was made using existing digital and hard-copy data, responses to mailed surveys, selection criteria established by various stakeholders, geographic information systems (GIS), and various database queries. Field and laboratory work were not a component of this compilation; sources were limited to previously published data.

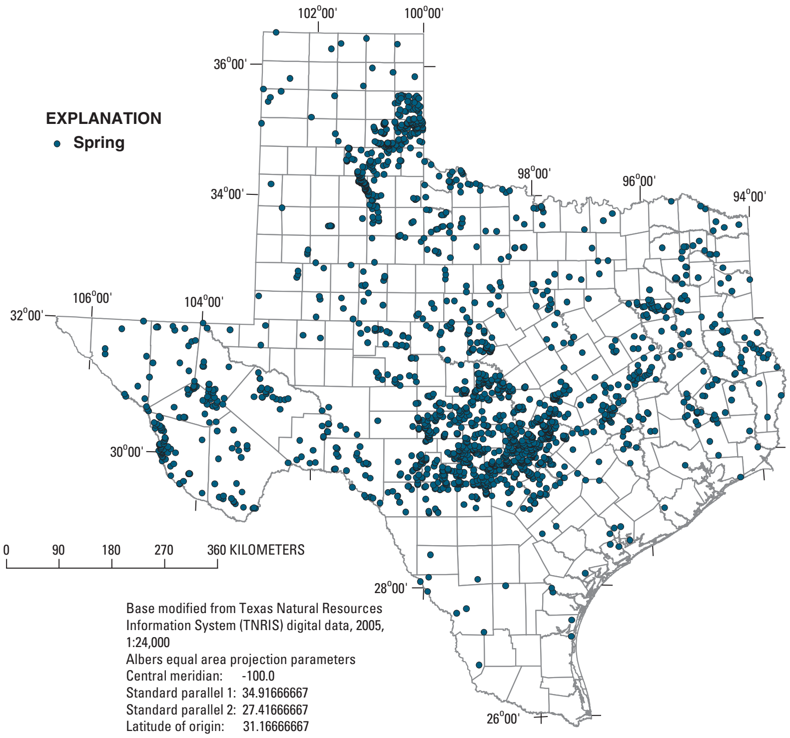

Figure 1. Locations of selected springs in Texas (from Heitmuller and Reece, 2003).

Spring and Spring-Flow Database

The primary data source for spring and spring-flow information is Heitmuller and Reece (2003), which contains geographic coordinates, spring names, site information, and known spring-flow measurements. Heitmuller and Reece (2003) contains 2,061 springs (fig. 1) and more than 7,300 spring-flow measurements, not including daily spring-flow values from USGS continuous-record gaging stations. Following the release of Heitmuller and Reece (2003), 1,895 spring-flow measurements from Brune (1975, 1981) were added to the database. The inclusion of these data into Heitmuller and Reece (2003) required an analysis and removal of duplicate flow measurements. The result was a comprehensive database of all known springs and spring-flow measurements in Texas. This comprehensive database of springs and spring-flow measurements is the source of the data used for analysis of spring flow for this report.

The comprehensive database of spring-flow measurements was used to compute mean spring flow of all springs. For the few springs that are continuously monitored, including Comal, San Marcos, and Barton Springs, the mean data published in volumes 1–5 of USGS "Water Resources Data, Texas, Water Year 2004" (Aragon Long and others, 2005) were used. For other springs that comprise multiple orifices, an effort was made to compute combined mean spring flow. Examples include Leona Springs in Uvalde County and Salado Springs in Bell County, among others. This is consistent with methods used by the USGS and Brune (1975, 1981). No-flow measurements for the period of record also were used to compute mean spring flow.

Springs Categorized by Ecoregions

Springs in the comprehensive database were categorized into 12 level III ecoregions associated with Texas (table 1). As summarized by Griffith and others (2004), "Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources," and "ecological regions are hierarchical and can be identified through the analysis of the spatial patterns and the composition of biotic and abiotic phenomena that affect or reflect differences in ecosystem quality and integrity." Level III ecoregions in Texas were developed to serve as a spatial framework for assessment of ecosystems (U.S. Environmental Protection Agency, 2004). Areas within each Texas level III ecoregion have similar geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (Griffith and others, 2004). Level III ecoregions were chosen as a regional framework for assessment of Texas springs because (1) the entire State is represented, (2) all springs can be associated with an ecoregion, and (3) the differences in geology, physiography, hydrology, and other factors between ecoregions should be reflected in the water quality of springs. The number of level III ecoregions in Texas, therefore, reflects

Table 1. Number and percentage of total springs in database for Texas level III ecoregions (Heitmuller and Reece, 2003).

[km^2, square kilometers]

Ecoregion ID	Ecoregion name	Ecoregion area (km^2)	Number of springs in database	Percentage of all springs in database
23	Arizona/New Mexico Mountains	219	3	0.15
24	Chihuahuan Desert	91,362	206	10.0
25	High Plains	84,063	43	2.09
26	Southwestern Tablelands	60,185	304	14.8
27	Central Great Plains	46,693	135	6.55
29	Cross Timbers	51,920	129	6.26
30	Edwards Plateau	74,963	818	39.7
31	Southern Texas Plains	53,492	36	1.75
32	Texas Blackland Prairies	43,381	107	5.19
33	East Central Texas Plains	54,809	149	7.23
34	Western Gulf Coastal Plain	59,787	16	.78
35	South Central Plains	63,977	115	5.58
	TOTALS FOR TEXAS	**684,851**	**2,061**	**100**

the desired diversity and level of regional assessment. Aquifers were not used to categorize springs because not all springs emerge from a State-of-Texas-designated aquifer. River basins were not used to categorize springs because river basins can extend across a number of ecoregions.

A limitation of the ecoregion categorization is that some springs with relatively long flow paths or large recharge areas emerge in a different ecoregion than the ecoregion contributing the water. For example, this limitation is particularly evident along relatively sharp ecoregion boundaries, including the Caprock escarpment between Ecoregions 25 and 26 and the Balcones escarpment between Ecoregions 30, 31, and 32. The water quality of large springs in Ecoregions 31 and 32, including Comal, San Marcos, Barton, San Antonio, San Felipe, and Las Moras Springs, is correctly associated with the carbonate hydrogeology of Ecoregion 30 (Edwards Plateau). The water quality of numerous springs included in Ecoregion 26 is correctly associated with the Ogallala aquifer in Ecoregion 25 (High Plains). Additionally, the scale at which ecoregion boundaries are digitally represented is not sufficient to capture every detail of the actual landscape. For example, the boundary between Ecoregions 25 and 26 is straighter than the actual Caprock escarpment, effectively crossing the escarpment many times. As a result, some springs below the escarpment are assigned to Ecoregion 25 (High Plains), and others are assigned to Ecoregion 26 (Southwestern Tablelands). Regional water-quality assessments are presented for the digital ecoregions because of the ease that GIS provides in assigning springs. Furthermore, the region to which the spring contributes surface flow also is hydrologically connected to the spring.

Some ecoregions are relatively dry, flat, or not spatially extensive and do not have many springs; other ecoregions are relatively wet, sloped, or spatially extensive and have many springs. For example, Ecoregion 34 (Western Gulf Coastal Plain) is relatively flat and is represented by only 16 springs in the database. However, the highly conductive (to flow) hydrology and relatively steep topography of Ecoregion 30 (Edwards Plateau) is represented by 818 springs in the comprehensive database. The number of springs for each ecoregion was divided by the total number of springs in the database to determine the percentage of springs in each ecoregion (table 1).

Following categorization of springs into level III ecoregions, the largest springs within each ecoregion (table 2) were ranked by mean spring flow. The 10 largest springs in Texas are listed in table 3. The order generally agrees with the ranking of Brune (1981). The lower ranking of Comanche Springs reflects a number of no-flow measurements made since 1981. The rankings in tables 2 and 3 are somewhat tenuous, however, as mean spring flow was computed from available measurements. Comal, Barton, and San Marcos Springs have continuous flow data, some springs have hundreds of discrete measurements, and other springs have very few discrete measurements over short periods of record.

Spring Survey for Selected Stakeholders in Texas

The selection of springs for historical water-quality and spring-flow data entry and analysis for this report was facilitated by a survey (fig. 2) mailed to stakeholders across Texas. More than 400 surveys were sent to numerous Federal and State agencies, water districts, nonprofit organizations, and other

Table 2. Largest springs in each Texas level III ecoregion on basis of mean spring flow for entire period of record.

[Mean spring flow computed mostly from discrete measurements, but some time-averaged values used to extend period of record. m^3/s, cubic meters per second]

Ecoregion ID	Station number	Spring name	County	Period of record or year visited	Mean spring flow (m^3/s)
23	08407600	Smith Spring	Culberson	1968–76	0.0024
24	[1]08448500	Goodenough Springs	Val Verde	1921–68	[2]4.1342
	08427500	San Solomon Springs	Reeves	1900, 1904, 1919–25, 1931–36, 1941–86, 1990, 1997, 2001–04	.8665
	[3]08444500	Comanche Springs	Pecos	1899, 1904, 1919–25, 1932–84, 1992	[4].8014
	305331103013201	Leon Springs	Pecos	1920, 1932–33, 1946–50, 1958, 1962, 1971	.3086
	[3]08425500	Phantom Lake Spring	Jeff Davis	1900, 1904, 1931–34, 1941–2004	[4].2282
25	333230101423201	Buffalo Springs	Lubbock	1907, 1924, 1937, 1939, 1969–76	.0665
26	343251100252201	Estelline Salt Springs	Hall	1943, 1946, 1954, 1960–63	.1063
	350727100085801	[5]DU–56–33–307	Collingsworth	1967	.0908
	324530100423101	Camp Springs	Scurry	1924	.0567
	350749100174801	Elm Creek Spring no. 1	Collingsworth	1947–1978	.0556
	350330100083201	Wolf Springs	Collingsworth	1938, 1967, 1971, 1977	.0450
27	345918100204601	Wischkaemper Springs	Collingsworth	1967, 1971, 1977	.0314
	352430100061101	Wheeler Springs	Wheeler	1967, 1971, 1977	.0180
	345920100473001	[5]JA–12–02–304	Donley	1968	.0140
29	08146500	San Saba Springs	San Saba	1939, 1952, 1957, 1959–2004	.2664
	310320098110001	Hancock Springs	Lampasas	1886, 1900–1902, 1906, 1910, 1924, 1931, 1942, 1957–75	.2194
	311213098543901	Baker Spring	San Saba	1938, 1952, 1957, 1961–62, 1971, 1989	.1118
30	08168000	Hueco Springs	Comal	1924, 1928–29, 1937, 1944–2003	1.1695
	301619099523801	Big Paint Springs	Edwards	1939, 1955, 1962	[6].6700
	[1]294031100563101	Slaughter Bend Springs	Val Verde	1921, 1925, 1928, 1971, 1976	.6570
	08149500	Seven Hundred Springs	Edwards	1939, 1952, 1956, 1959–2004	.5658
	293031098543101	Diversion Dam Springs	Medina	1921, 1923–35, 1939, 1948, 1950–57, 1960, 1962–1969	.5628
31	08452800	San Felipe Springs	Val Verde	1889, 1895–1939, 1952–71, 1997	2.4579
	08204000	Leona Springs	Uvalde	1925, 1931, 1934–35, 1939, 1946–47, 1965–74, 1976–2002	.6580
	08456300	Las Moras Springs	Kinney	1895–96, 1899–1900, 1902, 1904–06, 1910, 1912, 1925, 1928, 1939–2000	.5802
32	08168710	Comal Springs	Comal	1932–2004	[7]8.1553
	08170000	San Marcos Springs	Hays	1956–2004	[7]4.9272
	08155500	Barton Springs	Travis	1978–2004	[7]1.8406
	08177818	San Antonio Springs	Bexar	1895–1963, 1970–2004	1.2658
	08104300	Salado Springs	Bell	1902–03, 1934, 1948, 1950–73, 1975, 1981	.5223
33	323030095533101	Riley Spring	Van Zandt	1979	.0170
	291657098020801	Sutherland Springs	Wilson	1949, 1954, 1968	.0156
	322117095545601	Roher Springs	Henderson	1995	.0117
34	29343109423101	Smith Springs	Galveston	1975	.0013
35	313331095313101	Elkhart Creek Springs	Houston	1965	.0963
	312731095323101	Hays Branch Springs	Houston	1965	.0510
	312731095303101		Houston	1965	.0500

[1] Currently beneath surface of Lake Amistad.

[2] Computed from monthly mean spring flow for period of record.

[3] Now generally dry.

[4] Includes numerous no-flow measurements.

[5] Name derived from Texas State well number.

[6] Based only on three measurements.

[7] Computed from continuous daily spring flow.

Table 3. Largest springs in Texas on basis of mean spring flow for entire period of record.

[Mean spring flow computed mostly from discrete measurements, but some time-averaged values used to extend period of record. m^3/s, cubic meters per second]

Station number	Spring name	County	Level III ecoregion ID	Period of record or year visited	Mean spring flow (m^3/s)
08168710	Comal Springs	Comal	32	1932–2004	[1]8.1553
08170000	San Marcos Springs	Hays	32	1956–2004	[1]4.9272
[2]08448500	Goodenough Springs	Val Verde	24	1921–68	[3]4.1342
08452800	San Felipe Springs	Val Verde	31	1889, 1895–1939, 1952–71, 1997	2.4579
08155500	Barton Springs	Travis	32	1978–2004	[1]1.8406
08177818	San Antonio Springs	Bexar	32	1895–1963, 1970–2004	1.2658
08168000	Hueco Springs	Comal	30	1924, 1928–29, 1937, 1944–2003	1.1695
08427500	San Solomon Springs	Reeves	24	1900, 1904, 1919–25, 1931–36, 1941–86, 1990, 1997, 2001–04	.8665
[4]08444500	Comanche Springs	Pecos	24	1899, 1904, 1919–25, 1932–84, 1992	[5].8014
301619099523801	Big Paint Springs	Edwards	30	1939, 1955, 1962	[6].6700

[1] Computed from continuous daily spring flow.

[2] Currently beneath surface of Lake Amistad.

[3] Computed from monthly mean spring flow for period of record.

[4] Now generally dry.

[5] Includes numerous no-flow measurements.

[6] Based on only three measurements.

water-resource entities in Texas. Emphasis was on surveying local recipients; most surveys were mailed to the distributed offices of larger agencies. Recipients included the Texas Parks and Wildlife Department, the Texas Commission on Environmental Quality, the Texas Water Development Board, the Texas Historical Commission, the Texas Department of Agriculture, regional water planning groups, ground-water conservation districts, river authorities, selected university faculty, numerous nonprofit organizations, and private individuals. Surveys were also sent to Federal agencies with a presence in Texas, including the USGS (Water Science Centers), U.S. Fish and Wildlife Service, and U.S. Department of Agriculture, Natural Resources Conservation Service.

The survey was designed for a flexible response and encouraged recipients to provide information on springs important to their jurisdiction or within their expertise. Relative importance could be attributed to large or persistent spring flow; historical or cultural significance; habitat for endangered, threatened, or other species of concern; water use; contribution to surface water; aquifer association; or other unique environmental characteristics. All survey responses were reviewed and tabulated; of 416 surveys mailed out, 54 responses were made through mail, e-mail, or phone. Of these, 34 reported no known springs or did not provide any specific springs in their response. However, the small number of responses, both with and without information on specific springs, represented a considerable variety of stakeholders across most of Texas. Fifty-eight springs were reported to match one or more elements of the criteria described above.

Application of Criteria to Selected Springs for Water-Quality Database

Springs primarily were selected for the water-quality database of this report by (1) mean spring-flow ranking and (2) spring-survey response. Springs with the highest mean spring flow were selected for each ecoregion. To ensure that all level III ecoregions were adequately represented in the database, the number of springs selected for each ecoregion corresponded to the percentage of all Texas springs in that ecoregion (table 1). This percentage was applied to a goal of about 200 springs for the entire State; the goal of about 200 springs

Name: ______________________________

Organization: ______________________________

Location: ______________________________

Telephone: ______________________________

E-mail: ______________________________

Check all that apply. Please provide specific details under 'Justification', including name of species, aquifer name, use of water, and so forth, to the extent you are able.

Spring: ______________________________

County: ______________________________

Importance:

- ☐ Regionally large spring flow ___ Currently ___ Historically
- ☐ Historically / culturally significant
- ☐ Habitat for endangered, threatened, or species of concern
- ☐ Water-use ☐ Source of water to large river basins
- ☐ Importance to an aquifer
- ☐ Unique environmental characteristics ☐ Other

Justification: ______________________________

____

____

Figure 2. Excerpt of survey mailed to numerous stakeholders across Texas.

was established during stakeholder meetings between December 2003 and March 2004. For example, Ecoregion 24 (Chihuahuan Desert) contains 206 springs, or about 10 percent of all springs in the database. To ensure adequate representation in the water-quality database, about 10 percent of springs in Ecoregion 24 were selected, or 20 springs. Ecoregion 23 (Arizona/New Mexico Mountains) was the only ecoregion that did not contain at least 1 percent of all Texas springs. Nonetheless, the largest spring in this ecoregion was selected. This method resulted in the selection of 209 springs.

Following the quantitative method of selecting springs on the basis of mean spring flow, qualitative methods were used to select additional springs. Eleven springs were selected on the basis of only the responses to mailed surveys, especially if the springs were mentioned in Brune (1975). Additionally, four springs that were not selected, but that the authors felt were important on the basis of history or recreational use, were added to the water-quality database. These included Hamilton Springs in Travis County, Krause Springs in Burnet County, Chinati Hot Springs in Presidio County, and Carrizo Springs in Dimmit County, among others.

Finally, for some large areas of the State not represented by the selected springs, the spring-flow database (Heitmuller and Reece, 2003) and spring-flow measurements from Brune (1975, 1981) were assessed to select the largest springs in those areas. Eight springs were selected by this method. For example, in north-central Texas a large area that includes parts of Ecoregions 27, 29, and 32 was not represented by any springs. For this area, four springs with the largest mean spring flow were chosen, including Buffalo Springs in Clay County, Browder Springs in Dallas County, PX–32–52–503 in Johnson County, and Pierson Spring in Bosque County.

A total of 232 springs were selected for inclusion in the water-quality database of this report (fig. 3; table 4, at end of report) using both quantitative and qualitative methods, including mean spring flow, responses to mailed surveys, Brune (1975), and judgment by the authors based on geographic coverage and other criteria. Most springs were chosen by an assessment of mean spring flow for each ecoregion. The springs represent all level III ecoregions in Texas, eight of nine major aquifers (fig. 4), 11 of 21 minor aquifers (fig. 5), and 16 of 23 river basins in the State (fig. 6). Major and minor aquifers are those designated as such by the TWDB (Ashworth and Hopkins, 1995).

Spring Water-Quality Database

All selected springs and associated spring-flow measurements were entered into a new database. A table was created in this database to store water-quality data, including concentrations of selected constituents, specific conductance, pH, and temperature (fig. 7). Water-quality data were obtained from (1) TBWE hard-copy bulletins, (2) TWDB hard-copy reports, (3) Brune (1975, 1981), (4) the TWDB well information database (Texas Water Development Board, 2005), and (5) the USGS NWIS digital database (U.S. Geological Survey, 2001). TBWE bulletins are organized by county or river basin and contain data on wells and springs; most were published in the 1950s and early 1960s. TWDB reports are similar to TBWE bulletins and have been published from 1965 to the present (2006). Brune (1975, 1981) contains water-quality data for a number of springs. Measurements from the TWDB well information database were queried for the selected springs. The NWIS database serves as the storage for all hydrologic data of the USGS. All water-quality measurements were manually entered except those from the TWDB water-quality database and NWIS, which were digitally imported. Duplicate measurements in two or more sources were removed.

The temporal range in water-quality data for springs in Texas spans from the late 19th century to the present (2006). Sampling and laboratory techniques have changed considerably since the earliest samples and measurements were obtained, resulting in greater accuracy and precision of data in more recent years. Additionally, numerous water-quality measurements from the late 19th and early 20th centuries do not have quality-assurance or quality-control data available. Of more than 51,000 individual water-quality values in the database, about 11,500 measurements do not have quality-assurance codes. The water-quality assessments provided for each level III ecoregion in Texas include all available measurements, as temporal extension of the data was desired. For ecoregions with few data, some bias might be introduced through earlier water-quality samples obtained and measured with different technology. Seasonal bias also might be inherent because spring flow and associated concentrations of selected constituents vary with seasonal changes in precipitation and aquifer capacity. Database queries show that water quality of Texas springs has been sampled fairly consistently for each of the four seasons, even for ecoregions with few data.

Historical Water-Quality Data for Selected Springs, by Ecoregion

A total of 11,675 individual values for various water-quality constituents and properties (table 5, at end of report) were used to compute statistical summaries of water-quality data for selected springs in Texas. More than 50,000 individual values are provided in the database, the difference representing additional water-quality constituents, such as ammonia, cadmium, and many organic compounds that are not presented in this report. Water-quality constituents and properties used in the analyses and presented on maps are listed in table 6 (at end of report). A map of the spatial distribution of water-quality values for springs in each Texas ecoregion is shown in figure 8. Ecoregion 32 (Texas Blackland Prairies) has the highest number of values (5,387) because some of the largest and most frequently monitored springs in Texas issue from that ecoregion, including Comal, San Marcos, Barton, and San Antonio Springs. Ecoregion 23 (Arizona/New Mexico Mountains) has only 13 water-quality values because of its small size and associated representation in the database.

A brief assessment of the water-quality data is presented for each level III ecoregion in Texas. The mean, median, and standard deviation of water-quality constituents and properties for selected springs in Texas, by ecoregion, are listed in table 7 (at end of report). Censored data, or data reported as less than a reporting level, were included as one-half the reporting level in the computation of summary statistics for each ecoregion. The minimum and maximum water-quality values, by ecoregion, are listed in table 8 (at end of report). Water-quality standards, mostly for drinking water, for selected constituents and properties are listed in table 9 (at end of report). Not all constituents and properties discussed in this report have water-quality standards. Maps showing the distribution of median water-quality values (table 7) are presented in figures 9–25. The authors recognize that some springs have considerably more water-quality data than others, which influences the summary statistics for each ecoregion. Of 1,474 visits for water-quality sampling entered in the database, five springs (Barton, Comal, Hueco, Old Mill, and San Marcos) account for 876 sampling visits. Barton Springs has the greatest number of sampling visits with 479. As a result, water-quality summary statistics for Ecoregion 32 (Texas Blackland Prairies) are greatly influenced.

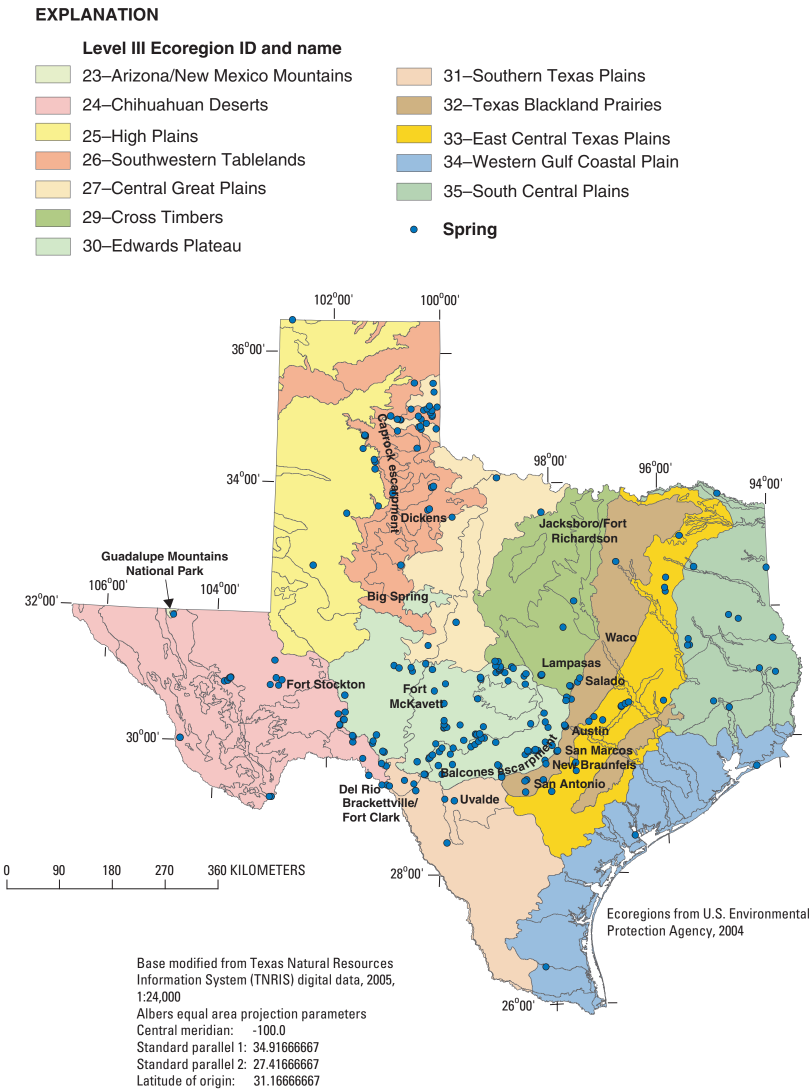

Figure 3. Springs selected for inclusion in the water-quality database of springs in Texas, by ecoregion.

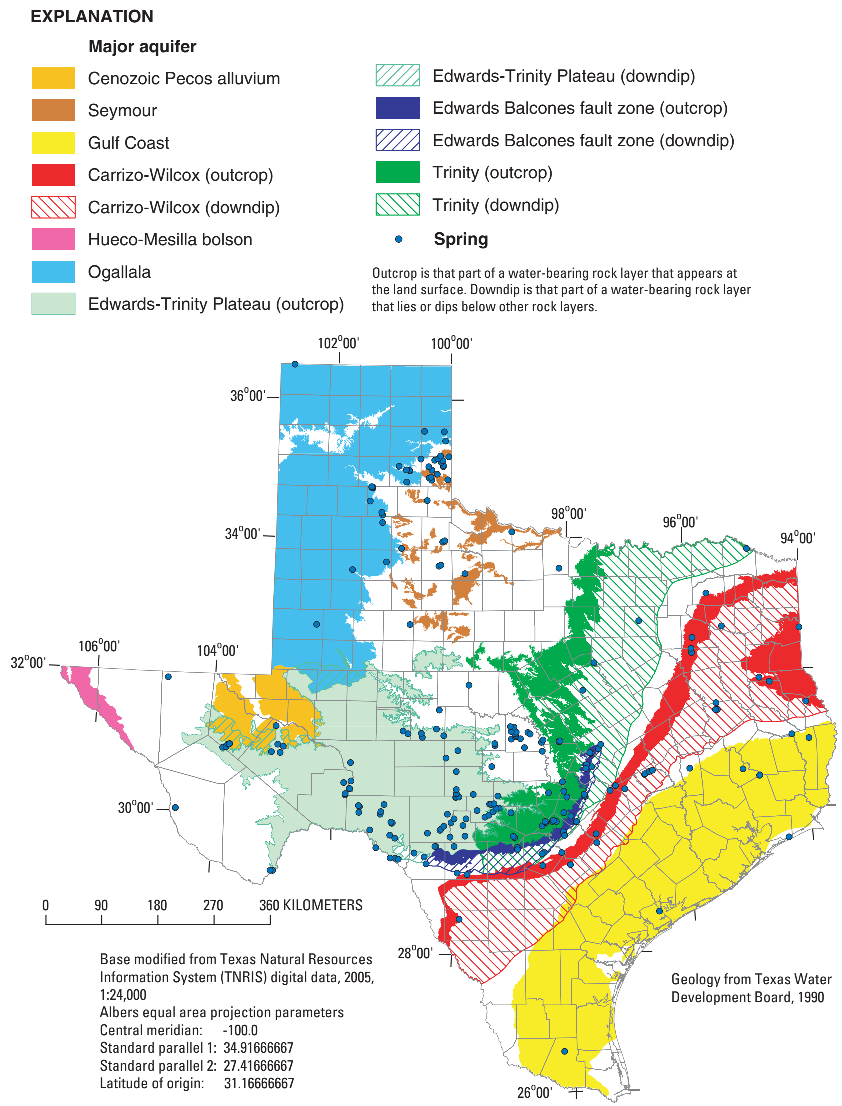

Figure 4. Major aquifers in Texas and springs selected for inclusion in the water-quality database of springs in Texas.

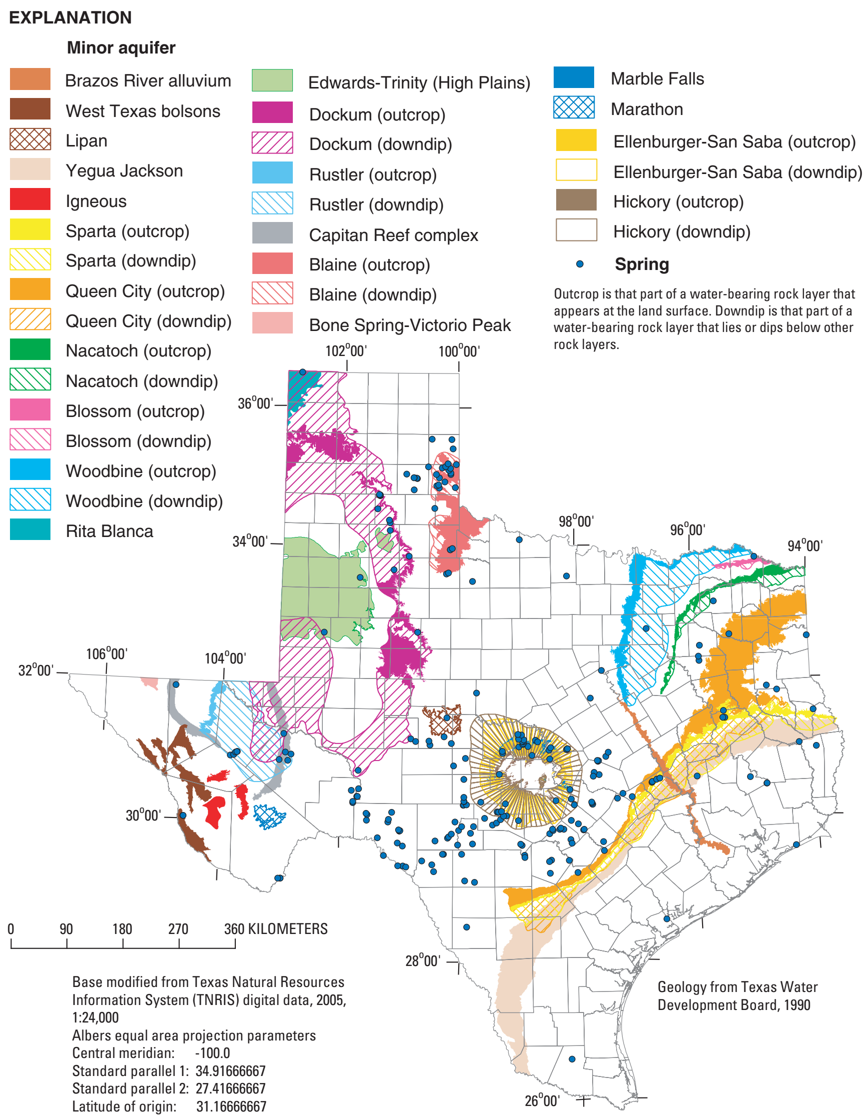

Figure 5. Minor aquifers in Texas and springs selected for inclusion in the water-quality database of springs in Texas.

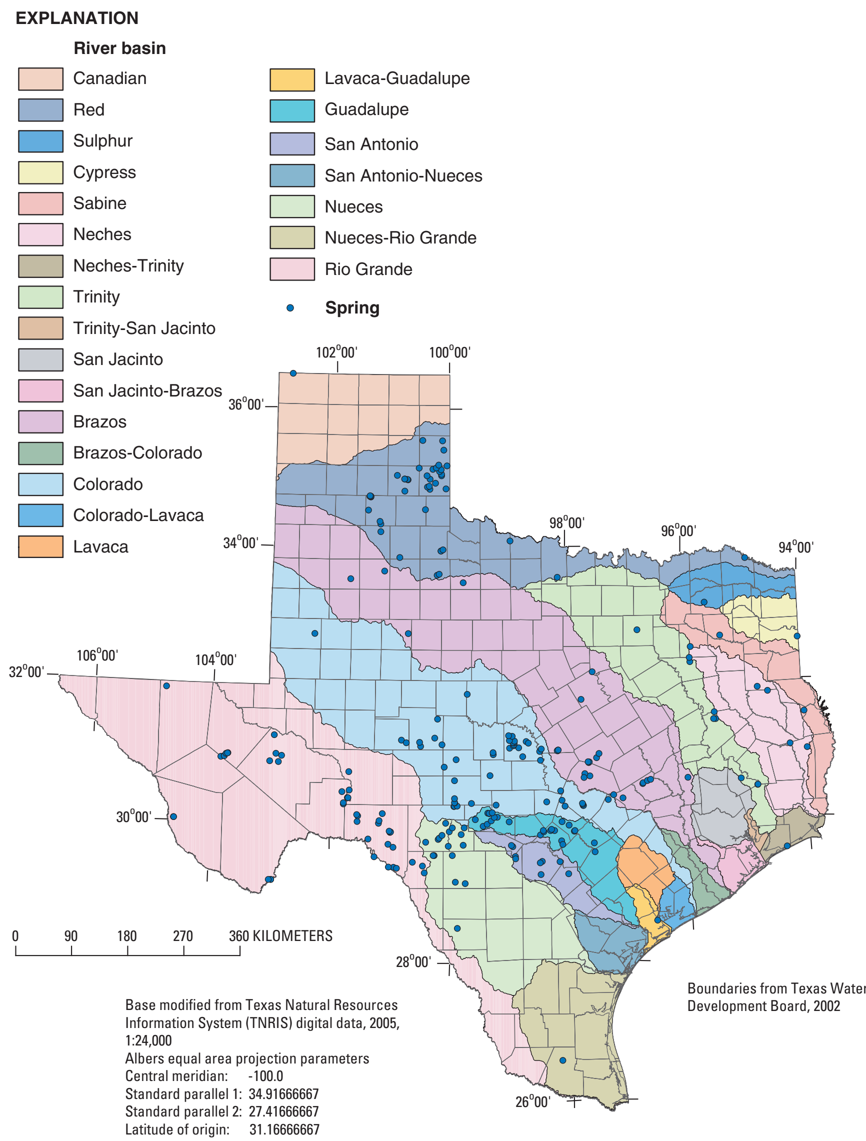

Figure 6. River basins in Texas and springs selected for inclusion in the water-quality database of springs in Texas.

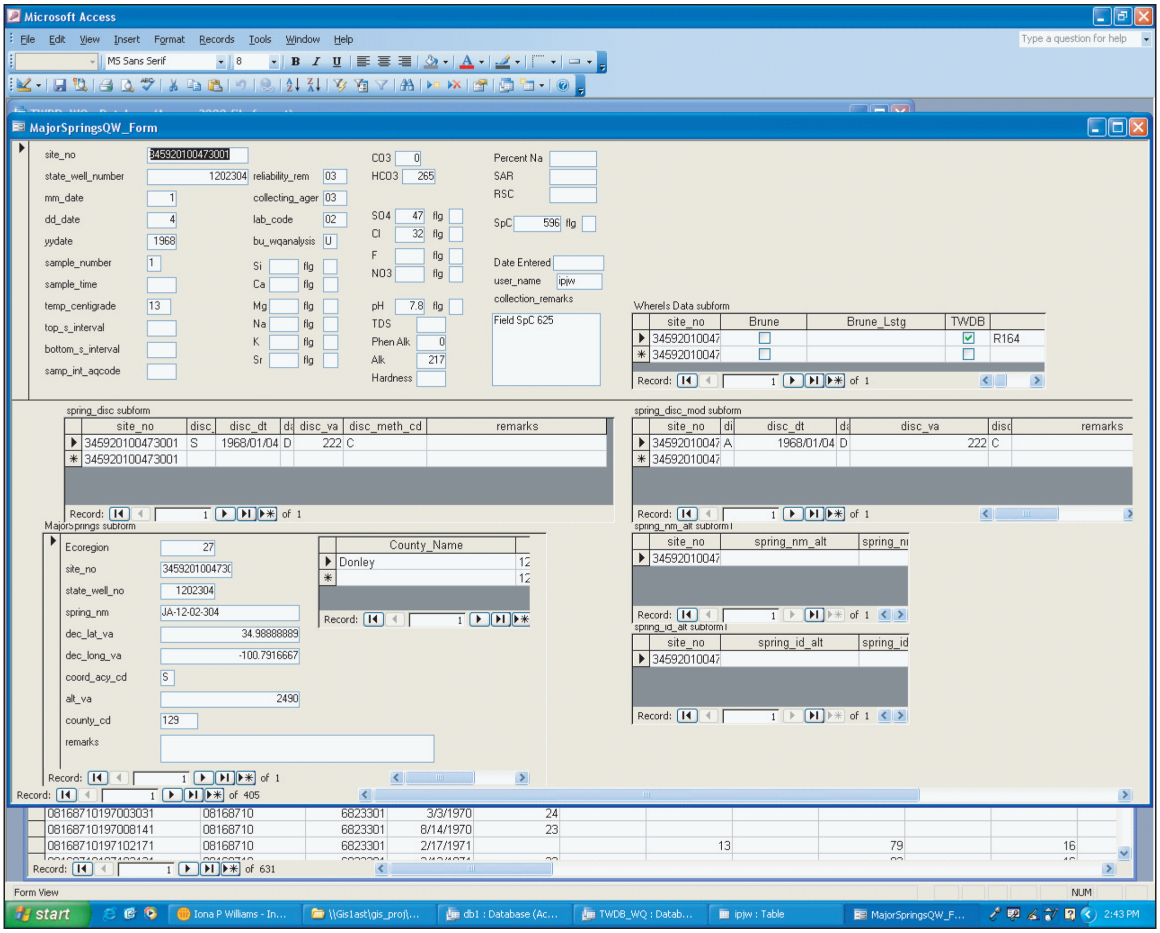

Figure 7. Screen capture of data-entry interface for water-quality database of springs in Texas.

Arizona/New Mexico Mountains

The Arizona/New Mexico Mountains (Ecoregion 23) is represented by one spring in the water-quality database, Smith Spring. The inclusion of only one spring is attributed to the very small area of the ecoregion (219 square kilometers) in Texas and the availability of only three springs in the database. Smith Spring in Guadalupe Mountains National Park issues from the Capitan Reef Complex aquifer, associated with a Permian carbonate reef platform (Ashworth and Hopkins, 1995) in the Guadalupe Mountains. Analysis of one sample from Smith Spring shows a dissolved solids concentration of 299 milligrams per liter, calcium concentration of 76 milligrams per liter, and bicarbonate concentration of 358 milligrams per liter. The concentrations of silica (10 milligrams per liter), sodium (2 milligrams per liter), and chloride (2 milligrams per liter) were lower than mean concentrations in selected springs of the other Texas level III ecoregions.

Chihuahuan Deserts

The Chihuahuan Deserts (Ecoregion 24) is represented by 29 springs in the water-quality database. A few of the selected springs in the Chihuahuan Deserts have comparatively long (Uliana and Sharp, 2001) or deep flow paths and spring waters characterized by high median concentrations of constituents and warm temperatures. Selected springs in the Chihuahuan Deserts have the highest median concentrations of calcium (177 milligrams per liter), magnesium (73 milligrams per liter), sodium (390 milligrams per liter), potassium (17 milligrams per liter), strontium (3.4 milligrams per liter), sulfate (383 milligrams per liter), chloride (246 milligrams per liter), fluoride (1.7 milligrams per liter), dissolved solids (1,343 milligrams per liter), and hardness as calcium carbonate (514 milligrams per liter) of all the level III ecoregions in Texas. Additionally, median specific conductance (3,220 microsiemens per centimeter at 25 degrees Celsius) and temperature (25 degrees Celsius) were the highest among springs of the level III ecoregions.

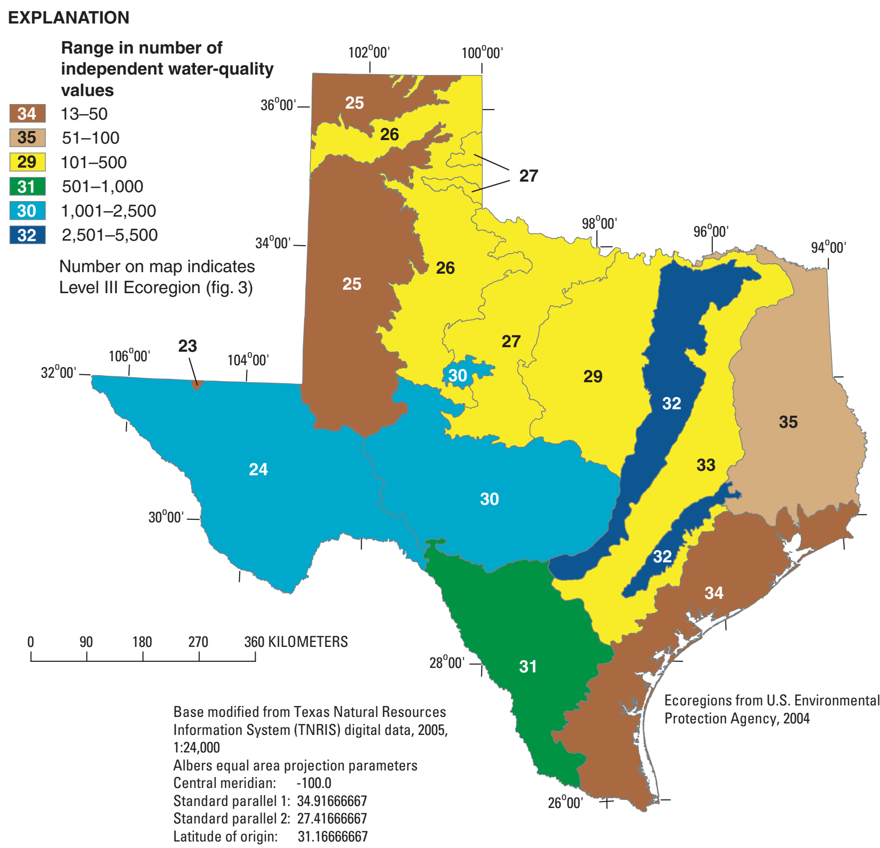

Figure 8. Spatial distribution of 11,675 water-quality values for selected springs in Texas, by ecoregion.

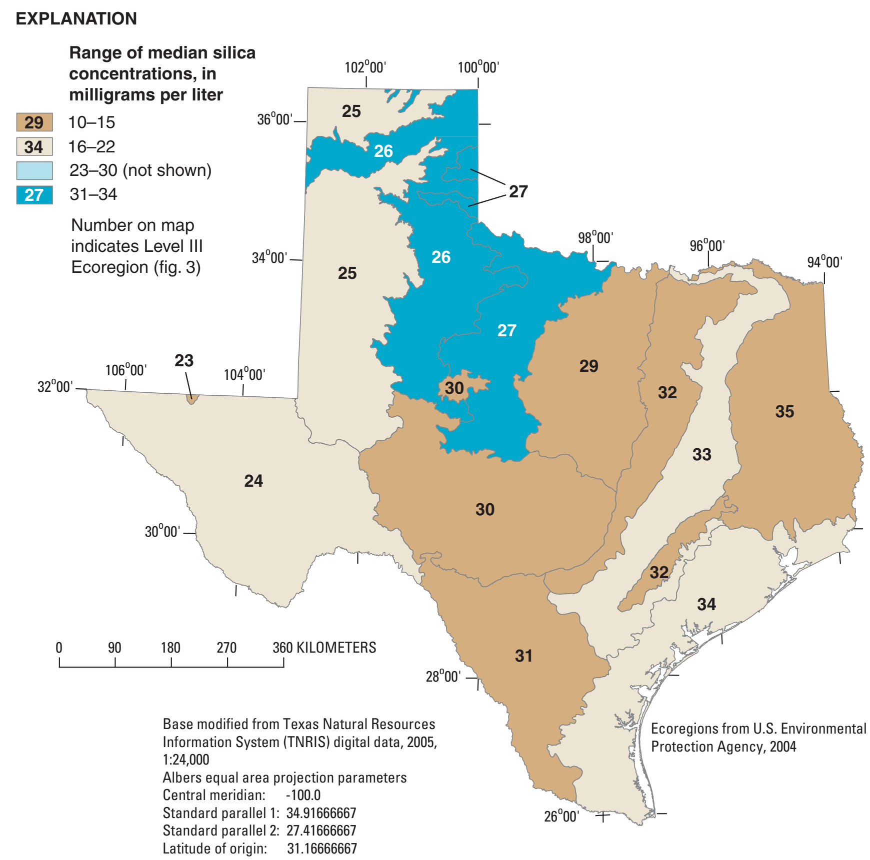

Figure 9. Range of median silica concentrations for selected springs in Texas, by ecoregion.

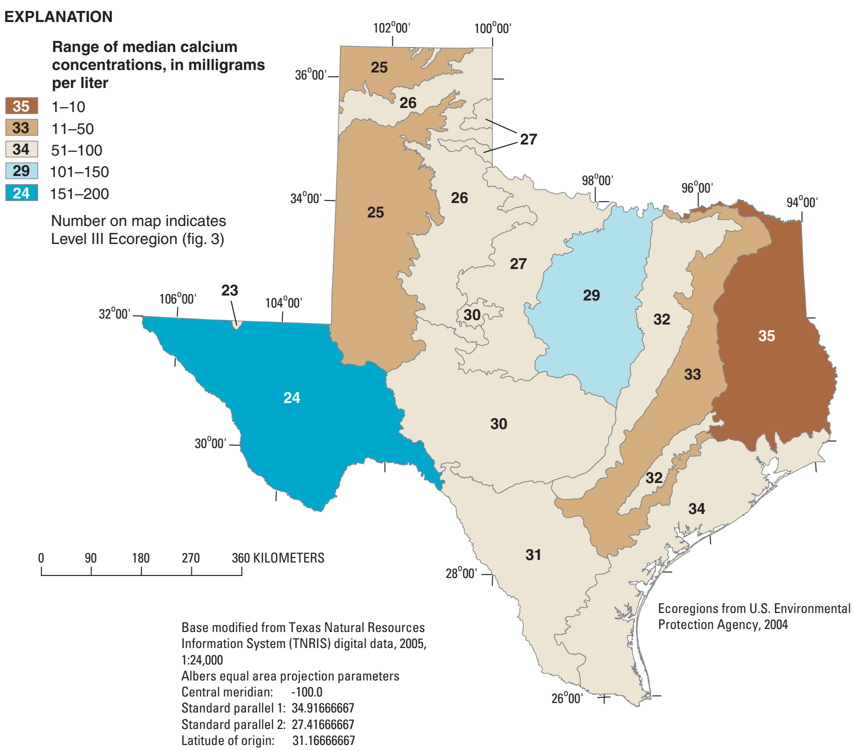

Figure 10. Range of median calcium concentrations for selected springs in Texas, by ecoregion.

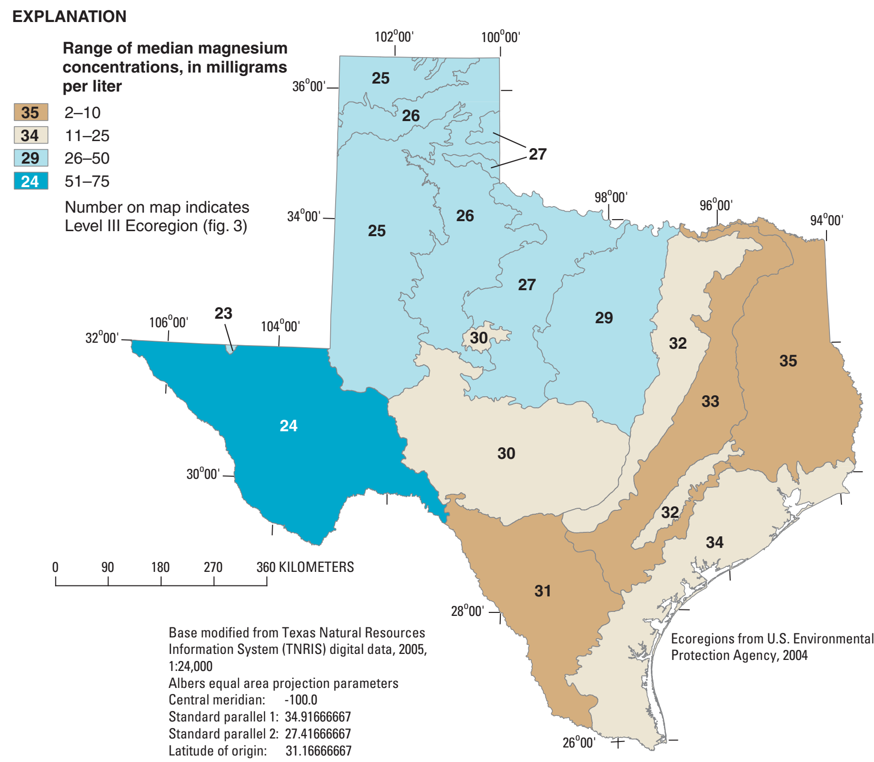

Figure 11. Range of median magnesium concentrations for selected springs in Texas, by ecoregion

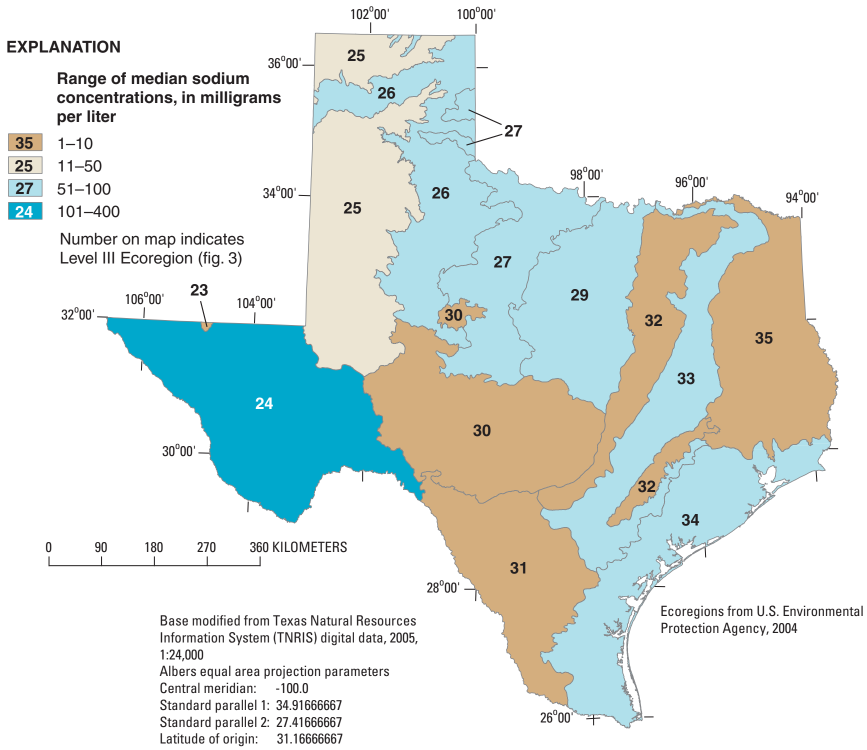

Figure 12. Range of median sodium concentrations for selected springs in Texas, by ecoregion.

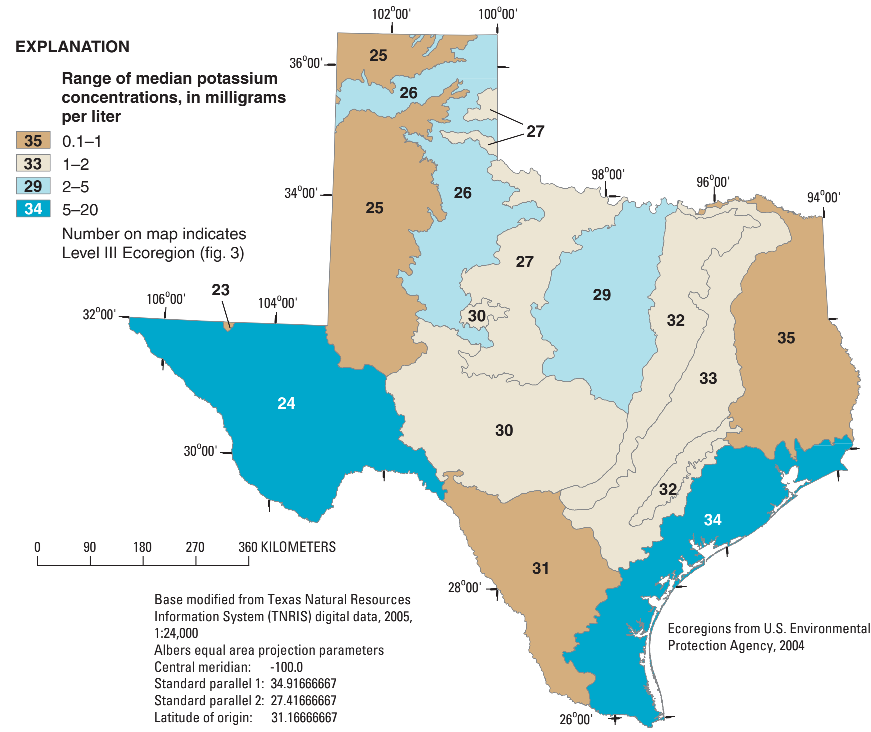

Figure 13. Range of median potassium concentrations for selected springs in Texas, by ecoregion.

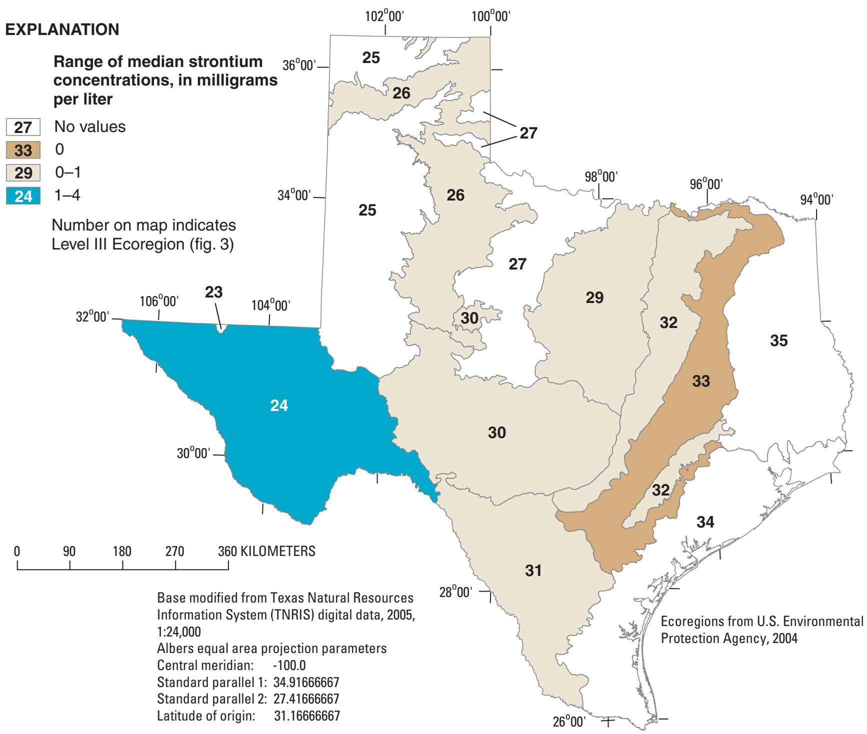

Figure 14. Range of median strontium concentrations for selected springs in Texas, by ecoregion.

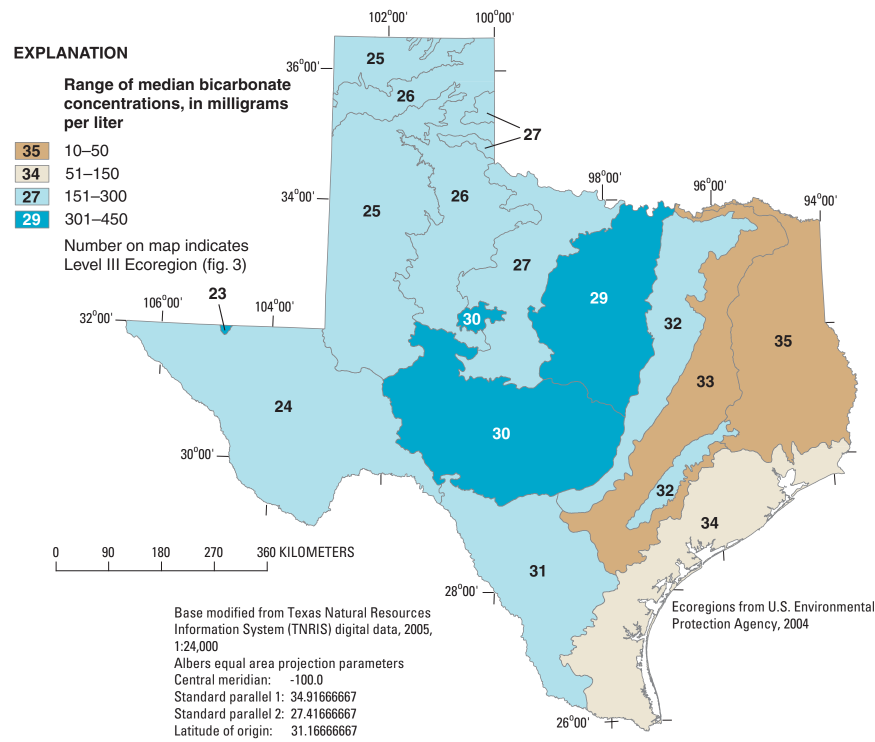

Figure 15. Range of median bicarbonate concentrations for selected springs in Texas, by ecoregion.

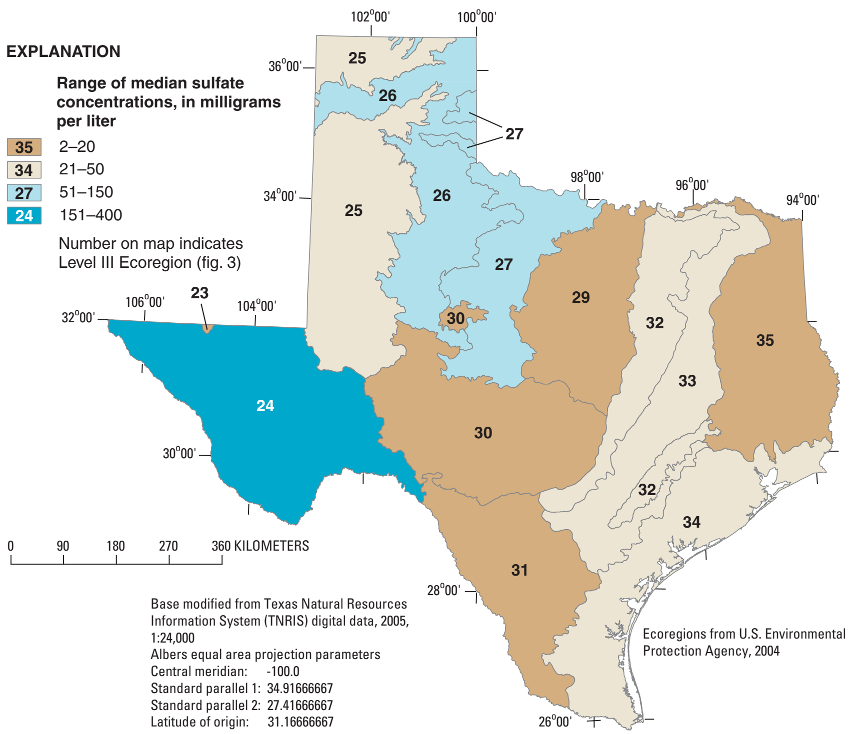

Figure 16. Range of median sulfate concentrations for selected springs in Texas, by ecoregion.

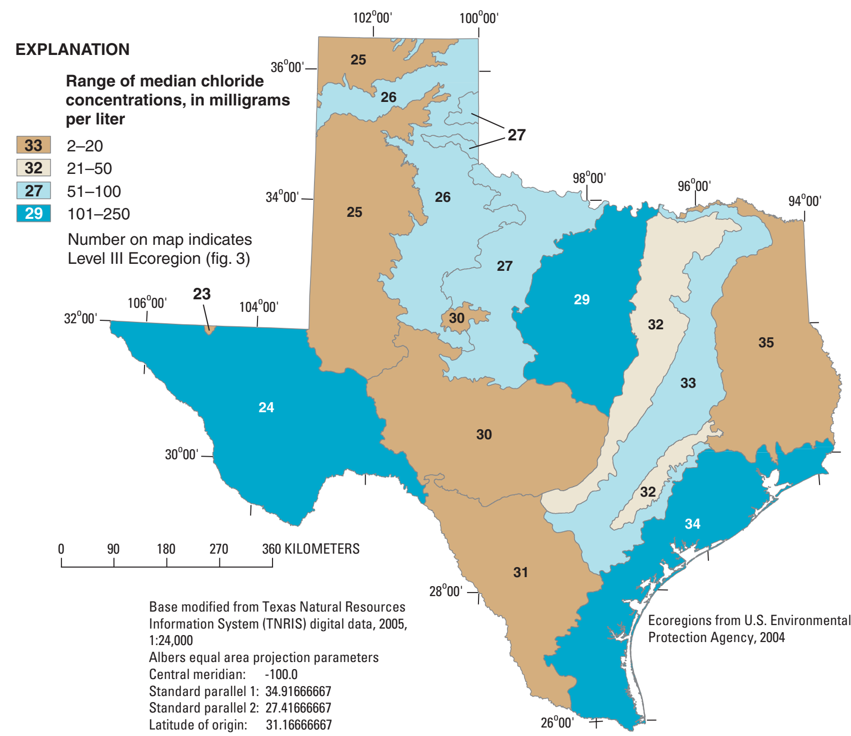

Figure 17. Range of median chloride concentrations for selected springs in Texas, by ecoregion.

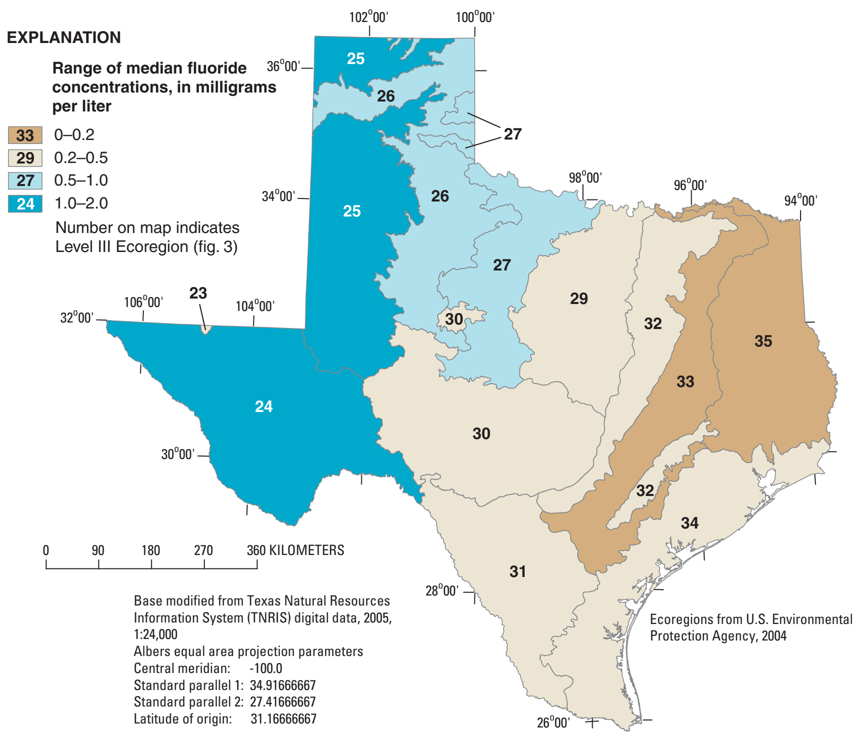

Figure 18. Range of median fluoride concentrations for selected springs in Texas, by ecoregion.

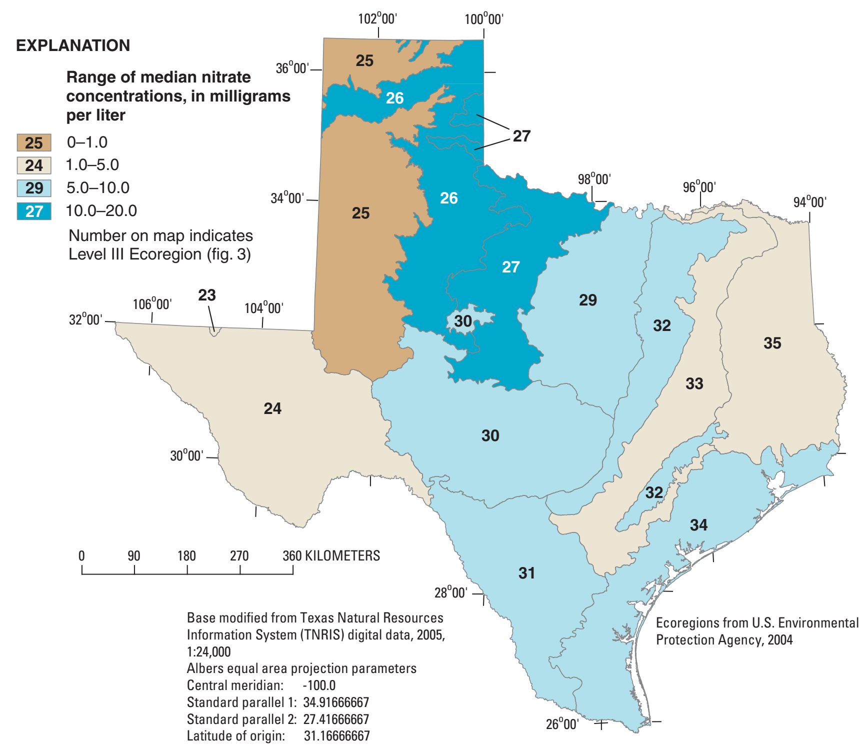

Figure 19. Range of median nitrate nitrogen concentrations for selected springs in Texas, by ecoregion.

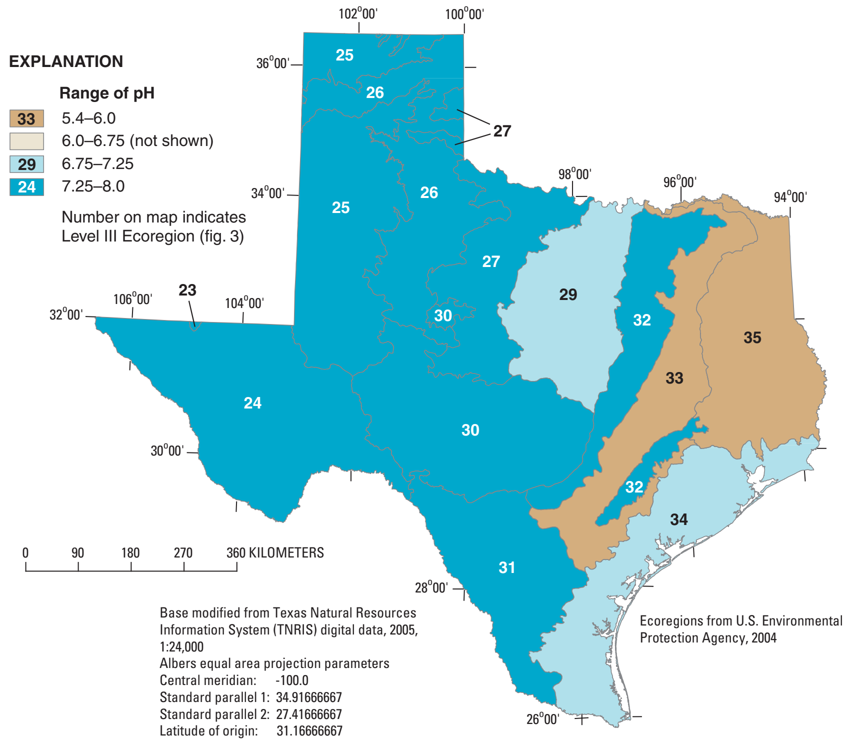

Figure 20. Range of median pH for selected springs in Texas, by ecoregion.

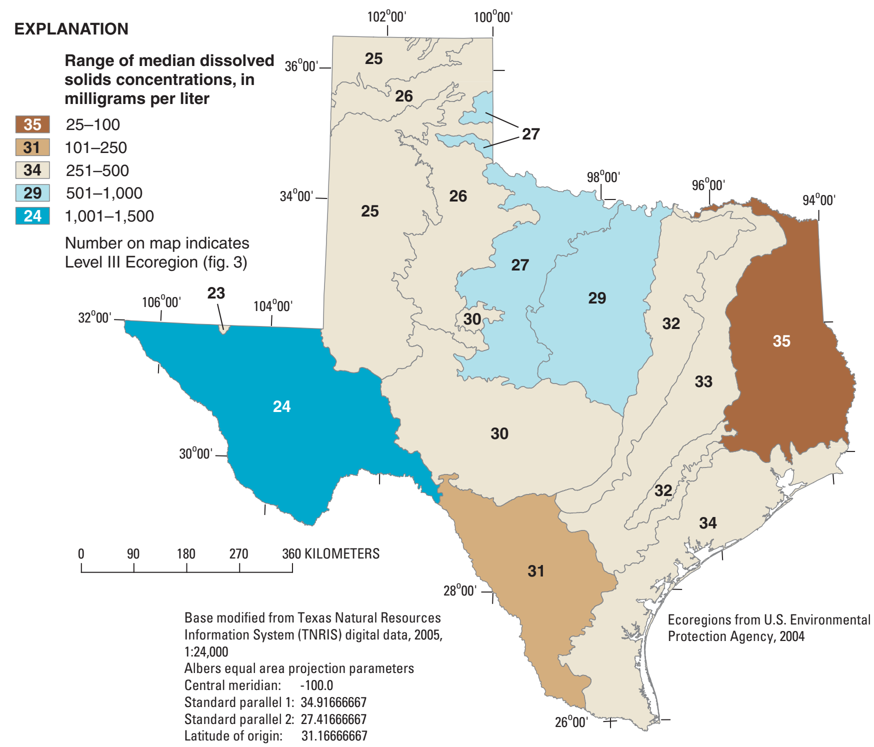

Figure 21. Range of median dissolved solids concentrations for selected springs in Texas, by ecoregion.

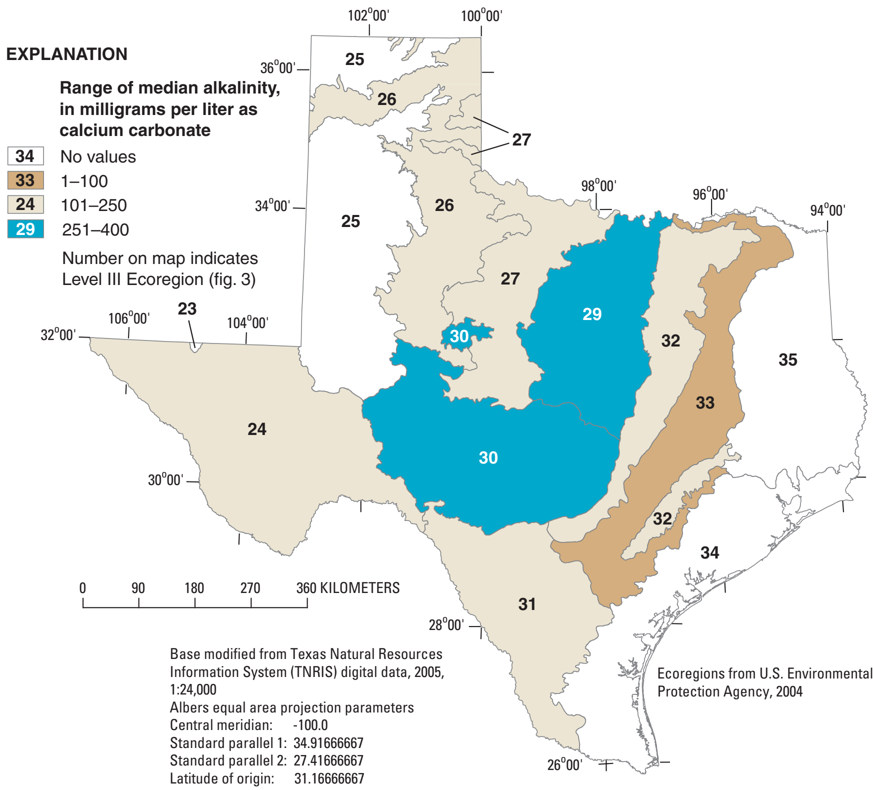

Figure 22. Range of median alkalinity for selected springs in Texas, by ecoregion.

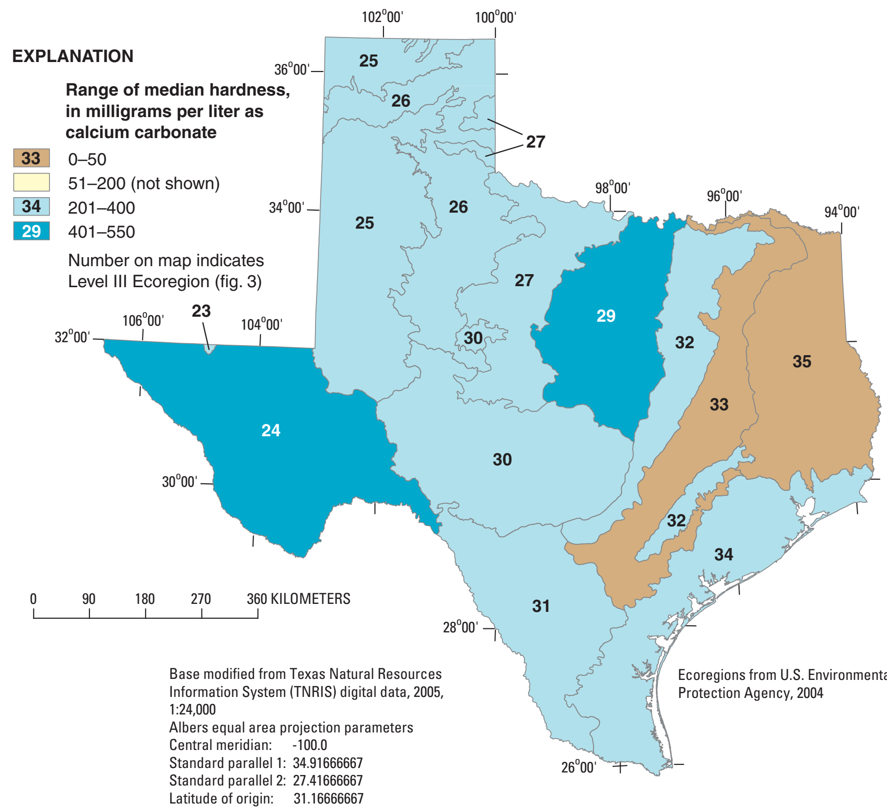

Figure 23. Range of median hardness for selected springs in Texas, by ecoregion.

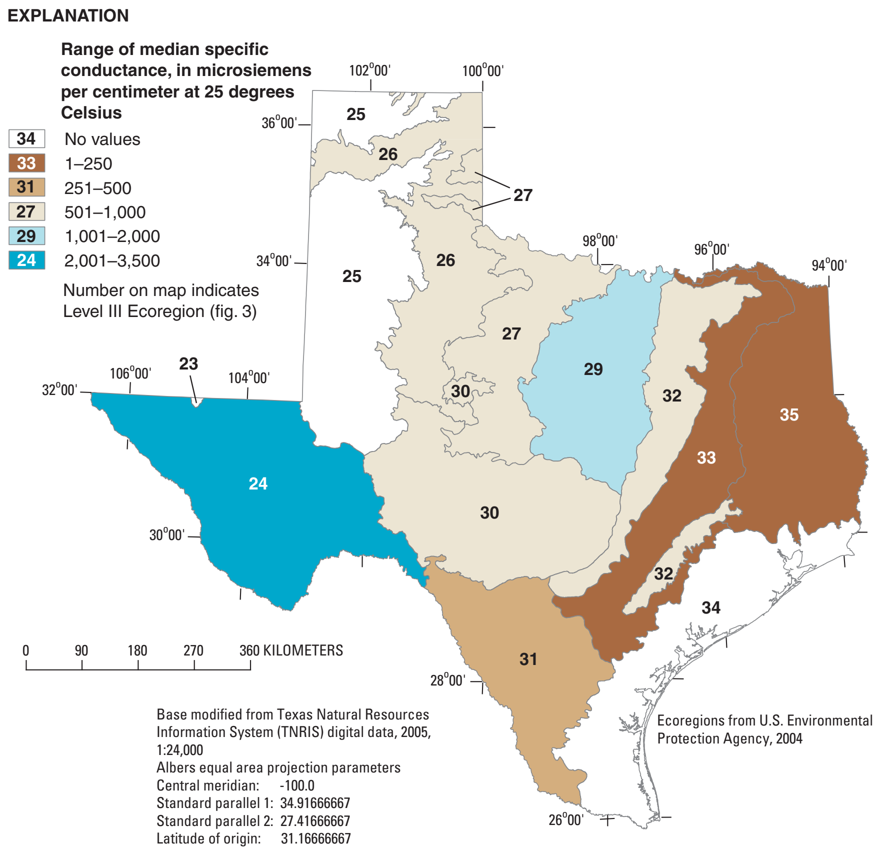

Figure 24. Range of median specific conductance for selected springs in Texas, by ecoregion.

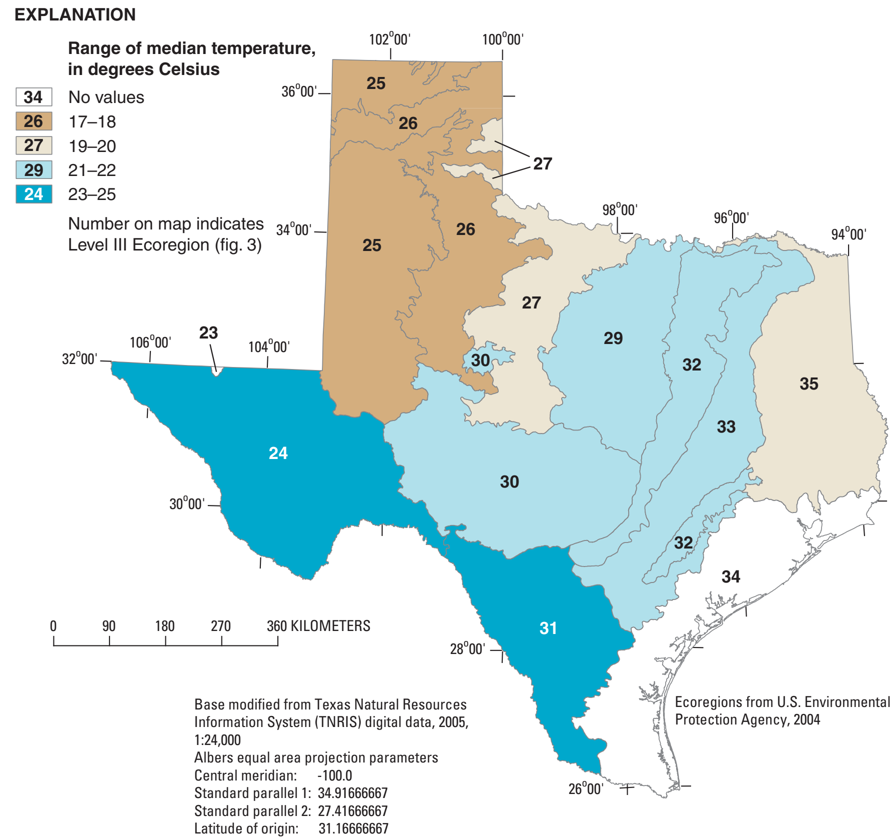

Figure 25. Range of median temperature for selected springs in Texas, by ecoregion.

High Plains

The High Plains (Ecoregion 25) is represented by only six springs in the water-quality database because of the small number of springs for this ecoregion in the database. In Texas, the High Plains is noted more for recharge to the Ogallala aquifer than discharge to springs within the boundaries of the ecoregion, although springs associated with the Ogallala aquifer are abundant at the Caprock escarpment in adjacent Ecoregion 26 (fig. 3). Only two of the six springs are well within the boundaries of the High Plains ecoregion; the remaining four springs are at the Caprock escarpment. The few water-quality data for springs in the High Plains indicate that spring flow contains low to moderate concentrations of selected constituents; however, median pH (8.0) is the highest of any spring in level III ecoregions in Texas. The few data available from the small number of sizeable springs in the High Plains and variability of the data likely do not provide a reliable evaluation of water quality in the ecoregion. A variety of small springs and seeps, many at playa lakes, in the High Plains are listed in Brune (1981).

Southwestern Tablelands

The Southwestern Tablelands (Ecoregion 26) is represented by 29 springs in the water-quality database. This comparatively large number of springs is attributed to the high spatial density (table 1) of springs along the Caprock escarpment. Many of the springs in the Southwestern Tablelands of Texas flow from the Blaine aquifer and commonly are noted for producing saline water. Other selected springs that flow from the Ogallala aquifer along the Caprock escarpment and from the Seymour aquifer commonly report high salinity and nitrate (nitrogen) concentrations (Ashworth and Hopkins, 1995). Selected springs in the Southwestern Tablelands have the highest or second highest median concentrations of silica (32 milligrams per liter) and nitrate (20 milligrams per liter) of all springs in Texas level III ecoregions.

Central Great Plains

The Central Great Plains (Ecoregion 27) is represented by 15 springs in the water-quality database. Many of the springs selected for Ecoregion 27 flow from the Ogallala aquifer; others flow from the Seymour aquifer. Springs discharging from the Ogallala aquifer are reported to have high concentrations of calcium and hard waters (Brune, 1981), and parts of the Seymour aquifer have been reported to have high nitrate concentrations (Ashworth and Hopkins, 1995). Median concentrations of silica (34 milligrams per liter), magnesium (35 milligrams per liter), sulfate (112 milligrams per liter), nitrate (12 milligrams per liter), and dissolved solids (670 milligrams per liter) in selected springs of the Central Great Plains are the highest or second highest of any spring in level III ecoregions. Problems associated with springs contributing high concentrations of selected constituents to surface-water bodies in the ecoregion is a water-management issue (Ward, 1963). Conversely, the habitats of some inland fish species depend on the maintenance of these same high concentrations (Hubbs and others, 1991).

Cross Timbers

The Cross Timbers (Ecoregion 29) is represented by 14 springs in the water-quality database. Most of the selected springs in Ecoregion 29 are along the southern boundary with Ecoregions 30 (Edwards Plateau) and 32 (Texas Blackland Prairies) (fig. 3). Springs selected in the southern part of the Cross Timbers flow from aquifers normally associated with the Edwards Plateau and Blackland Prairie, including the Edwards (Balcones fault zone), Ellenburger-San Saba, Marble Falls, and Trinity aquifers. Spring flow from the Ellenburger-San Saba and Marble Falls aquifers can be highly mineralized within short distances of recharge zones (Ashworth and Hopkins, 1995); springs of the Edwards and Trinity aquifers often are hard, alkaline, and have high bicarbonate concentrations. Selected springs in the Cross Timbers have the highest, or second or third highest, median concentrations of calcium (110 milligrams per liter), magnesium (34 milligrams per liter), sodium (83 milligrams per liter), potassium (4.6 milligrams per liter), bicarbonate (410 milligrams per liter), chloride (141 milligrams per liter), dissolved solids (616 milligrams per liter), alkalinity as calcium carbonate (368 milligrams per liter), hardness as calcium carbonate (408 milligrams per liter), and specific conductance (1,090 microsiemens per centimeter at 25 degrees Celsius) among springs of all level III ecoregions. The highly variable values are attributed to the difference between the water quality of springs (associated with the Edwards Plateau) in the southern part of the ecoregion and springs in the northern part of the ecoregion. San Saba Springs is represented by 27 sampling visits, greatly influencing summary statistics. Spring flow in the Cross Timbers contributes to base flow of the Trinity, Brazos, and Colorado Rivers.

Edwards Plateau

The Edwards Plateau (Ecoregion 30) is represented by 88 springs in the water-quality database. This large number is attributed to the high spatial density (table 1) of springs in the ecoregion. Selected springs of the Edwards Plateau issue from the Edwards (Balcones fault zone), Edwards-Trinity (Plateau), Trinity, Ellenburger-San Saba, and Marble Falls aquifers. These carbonate aquifers are associated with hard water and high concentrations of calcium and bicarbonate (Ashworth and Hopkins, 1995). Selected springs in the Edwards Plateau have the second, third, or fourth highest median concentrations of calcium (90 milligrams per liter), bicarbonate (323 milligrams per liter), nitrate (8.1 milligrams per liter), and alkalinity as calcium carbonate (270 milligrams per liter) of all springs in level III ecoregions. Hueco Springs is represented by 92 sampling visits, greatly influencing summary statistics. Spring flow in the ecoregion constitutes the base flow of numerous Texas rivers, including the Colorado, Guadalupe, San Antonio, and Nueces Rivers.

Southern Texas Plains

The Southern Texas Plains (Ecoregion 31) is represented by seven springs in the water-quality database. The small number is attributed to the semiarid climate and flat topography of the ecoregion. Most of the springs selected in the Southern Texas Plains are located along the northern boundary with Ecoregion 30 (Edwards Plateau) (fig. 3) and are associated with the Edwards (Balcones fault zone) and Edwards-Trinity (Plateau) aquifers. Springs are sparse throughout most of the ecoregion; Carrizo Springs is the only spring not associated with the Edwards or Edwards-Trinity aquifers. Selected springs in the Southern Texas Plains have the second, third, or fourth lowest median concentrations of magnesium (7 milligrams per liter), sodium (6 milligrams per liter), potassium (0.9 milligram per liter), sulfate (7 milligrams per liter), chloride (10 milligrams per liter), and dissolved solids (245 milligrams per liter) of all springs in level III ecoregions. The largest springs in the ecoregion, San Felipe, Las Moras, and Leona Springs, are represented by 55 sampling visits, greatly influencing summary statistics. Spring flow in the ecoregion contributes to the base flow of the Rio Grande and the Nueces River.

Texas Blackland Prairies

The Texas Blackland Prairies (Ecoregion 32) is represented by 11 springs in the water-quality database. Similar to Ecoregion 31 (Southern Texas Plains), selected springs of the Texas Blackland Prairies are along the boundary with Ecoregion 30 (Edwards Plateau) and are associated with the Edwards (Balcones fault zone) aquifer. Many of the largest springs in Texas are along the Balcones escarpment separating Ecoregions 30 and 32 (fig. 3), including Comal, San Marcos, Barton, and San Antonio Springs. Selected springs in the Texas Blackland Prairies have median concentrations of selected constituents mostly in the mid-range of median concentrations from selected springs of other level III ecoregions, although the median strontium concentration is the second highest (0.7 milligram per liter). Selected springs in Ecoregion 32 have the most water-quality measurements of springs in any Texas ecoregion (5,387 individual measurements). The preferential sampling of Barton, Comal, Old Mill, and San Marcos Springs greatly influences summary statistics. Spring flow in the ecoregion contributes a large part of the base flow to numerous Texas rivers, including the Colorado, Guadalupe, and San Antonio Rivers.

East Central Texas Plains

The East Central Texas Plains (Ecoregion 33) is represented by 15 springs in the water-quality database. Selected springs in the East Central Texas Plains are associated with (roughly from southwest to northeast) the Carrizo-Wilcox, Queen City, Sparta, and Yegua Jackson aquifers. Median concentrations of calcium (14 milligrams per liter), magnesium (2 milligrams per liter), bicarbonate (44 milligrams per liter), fluoride (0.1 milligram per liter), alkalinity as calcium carbonate (79 milligrams per liter), hardness as calcium carbonate (44 milligrams per liter), and specific conductance (138 microsiemens per centimeter at 25 degrees Celsius) were the lowest or second lowest of all springs in level III ecoregions. Median pH (5.4) shows spring flow to be somewhat acidic.

Western Gulf Coastal Plain

The Western Gulf Coastal Plain (Ecoregion 34) is represented by three springs in the water-quality database, each spring separated by a considerable distance. The small number is attributed to the flat topography of the ecoregion. The three selected springs have very little flow and issue from the Gulf Coast aquifer. The few water-quality data for the selected springs indicate that median concentrations of sodium (97 milligrams per liter), potassium (12 milligrams per liter), and chloride (244 milligrams per liter) are the second highest of all springs in level III ecoregions.

South Central Plains

The South Central Plains (Ecoregion 35) is represented by 14 springs in the water-quality database. Selected springs in the South Central Plains are associated with (roughly from southwest to northeast) the Carrizo-Wilcox, Queen City, Sparta, Yegua Jackson, and Gulf Coast aquifers. Median concentrations of calcium (1 milligram per liter), magnesium (2 milligrams per liter), sodium (4 milligrams per liter), bicarbonate (12 milligrams per liter), sulfate (2 milligrams per liter), chloride (6 milligrams per liter), nitrate (1.5 milligrams per liter), dissolved solids (25 milligrams per liter), hardness as calcium carbonate (10 milligrams per liter), and specific conductance (34 microsiemens per centimeter at 25 degrees Celsius) were the lowest or second lowest of all springs in level III ecoregions. Median pH (5.6) shows spring flow to be slightly acidic

Summary

A digital database of spring locations and spring-flow measurements in Texas has been recently compiled. Following the publication of this database, a series of stakeholder meetings were held regarding springs in Texas. A need was identified to aggregate water-quality data for a wide variety of Texas springs into a digital database. To address this need, the published database of spring locations and spring-flow measurements was updated, and springs were ranked by mean spring flow for each level III ecoregion in Texas. Springs with the highest mean spring flow in each ecoregion were selected for inclusion in the water-quality database. Additionally, the selection of springs for historical water-quality and spring-flow data entry and analysis was facilitated by a survey mailed to stakeholders across Texas. In total, 232 springs were selected for inclusion in the water-quality database. The springs represent all level III ecoregions in Texas, a large percentage of aquifers, and most of the river basins in the State. A brief assessment of the water-quality data for springs in Texas shows that very few data are available in Ecoregions 23 (Arizona/New Mexico Mountains), 25 (High Plains), 33 (East Central Texas Plains), 34 (Western Gulf Coastal Plain), and 35 (South Central Plains). More water-quality data are available for Ecoregions 24 (Chihuahuan Deserts), 30 (Edwards Plateau), and 32 (Texas Blackland Prairies). In general, selected constituent concentrations in Texas springs, including silica, calcium, magnesium, sodium, potassium, strontium, sulfate, chloride, fluoride, nitrate, dissolved solids, and hardness as calcium carbonate, are comparatively high in Ecoregions 24 (Chihuahuan Deserts), 26 (Southwestern Tablelands), 27 (Central Great Plains), and 29 (Cross Timbers), mostly as a result of subsurface geology. In general, comparatively low concentrations of selected constituents in Texas springs are associated with Ecoregions 23 (Arizona/New Mexico Mountains), 31 (Southern Texas Plains), 33 (East Central Texas Plains), and 35 (South Central Plains), closely resembling the water quality of major and minor aquifers in those areas. To more comprehensively assess water quality of springs in Texas, additional data collection and monitoring are needed statewide.

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Table 4. Texas springs selected for water-quality and spring-flow database.

Station number	Spring	County	Level III ecoregion	River basin
08407600	Smith Spring	Culberson	23	Rio Grande
[1]08425500	Phantom Lake Spring	Jeff Davis	24	Rio Grande
[2]08427000	Giffin Springs	Reeves	24	Rio Grande
[1]08427500	San Solomon Springs	Reeves	24	Rio Grande
08429000	West Sandia Spring	Reeves	24	Rio Grande
08430000	East Sandia Spring	Reeves	24	Rio Grande
08444500	Comanche Springs	Pecos	24	Rio Grande
08448500	Goodenough Springs	Val Verde	24	Rio Grande
08451300	Cantu Spring	Val Verde	24	Rio Grande
291053102593401	Hot Springs	Brewster	24	Rio Grande
291056102571401	Rio Grande Village Spring no. 4	Brewster	24	Rio Grande
291057102571101	Rio Grande Village Spring no. 1	Brewster	24	Rio Grande
292335101011501	McKee Springs	Val Verde	24	Rio Grande
294731101213101	Dead Man Springs	Val Verde	24	Rio Grande
300220104355801	Chinati Hot Spring no. 1	Presidio	24	Rio Grande
300223104355401	Chinati Hot Spring no. 2	Presidio	24	Rio Grande
300231101323101	Cox Springs	Val Verde	24	Rio Grande
300725101320001	[3]YR–54–60–302	Val Verde	24	Rio Grande
300826101325801	Howard Springs	Val Verde	24	Rio Grande
301731101463101	Sweetwater Springs	Terrell	24	Rio Grande
301831101463101	Geddis Springs	Terrell	24	Rio Grande
302259101424001	Richland Springs	Terrell	24	Rio Grande
302300101420001	Wolf Spring	Terrell	24	Rio Grande
302811101481401	T–5 Springs	Terrell	24	Rio Grande
302943101405901	[3]HJ–54–35–203	Crockett	24	Rio Grande
305331103013201	Leon Springs	Pecos	24	Rio Grande
305831102493201	San Pedro Springs	Pecos	24	Rio Grande
305851103453301	Saragosa Spring	Reeves	24	Rio Grande
310002102551101	Diamond Y Springs	Pecos	24	Rio Grande
311606102573201	Santa Rosa Spring	Pecos	24	Rio Grande
324430102183201	Balch Springs	Gaines	25	Colorado
333230101423201	Buffalo Springs	Lubbock	25	Brazos
342221101125501	[3]BL–11–47–102	Briscoe	25	Red
344330101224401	[3]BL–11–21–308	Briscoe	25	Red
344358101235101	[3]BL–11–21–302	Briscoe	25	Red
362930102473201	Buffalo Springs	Dallam	25	Canadian
07307700	Roaring Springs	Motley	26	Red
324530100423101	Camp Springs	Scurry	26	Brazos
333600100130101	Spring no. 1	King	26	Red
333700100110101	Spring no. 4	King	26	Red
333930101073201	Couch Springs	Crosby	26	Brazos
335700100090102	Salt Springs	Cottle	26	Red
335800100070101	Spring no. 5	Cottle	26	Red
341333101115201	[3]JW–11–55–204	Floyd	26	Red
342007101120101	[3]BL–11–47–201	Briscoe	26	Red
343205101250801	[3]BL–11–29–801	Briscoe	26	Red
343251100252201	Estelline Salt Springs	Hall	26	Red

Table 4. Texas springs selected for water-quality and spring-flow database—Continued.

Station number	Spring	County	Level III ecoregion	River basin
344357101225001	[3]BL–11–21–306	Briscoe	26	Red
344409101223901	[3]BL–11–21–305	Briscoe	26	Red
344430101233201	Hulsey Springs	Briscoe	26	Red
344847100471001	Bitter Creek Springs	Donley	26	Red
345034100204801	Roscoe Springs	Collingsworth	26	Red
345225100231901	O'Hair Springs	Collingsworth	26	Red
350210100234801	[3]DU–56–19–903	Collingsworth	26	Red
350213100083001	[3]DU–56–39–903	Collingsworth	26	Red
350222100550701	[3]JA–55–78–801	Donley	26	Red
350330100083201	Wolf Springs	Collingsworth	26	Red
350551100104501	[3]DU–56–32–208	Collingsworth	26	Red
350727100085801	[3]DU–56–33–307	Collingsworth	26	Red
350749100174801	Elm Creek Springs	Collingsworth	26	Red
350844100320701	[3]DU–55–29–905	Collingsworth	26	Red
350900100140101	[3]DU–55–57–702	Collingsworth	26	Red
351048100025401	[3]DU–55–65–502	Collingsworth	26	Red
351130100113101	Lehman Springs	Wheeler	26	Red
353243100282901	Fort Elliot Springs	Wheeler	26	Red
313132100121701	Indian Springs	Tom Green	27	Colorado
315302099421401	Pecan Spring	Coleman	27	Colorado
332933099460901	[3]RS–21–34–323	Knox	27	Brazos
333330098083101	Buffalo Springs	Clay	27	Red
340530098570501	China Springs	Wichita	27	Red
345055100035601	Sand Springs	Collingsworth	27	Red
345307100213201	[3]DU–12–06–704	Collingsworth	27	Red
345544100145201	[3]DU–12–07–405	Collingsworth	27	Red
345835100434401	[3]JA–12–03–109	Donley	27	Red
345853100442701	[3]JA–12–03–103	Donley	27	Red
345916100471001	[3]JA–12–02–303	Donley	27	Red
345918100204601	Wischkaemper Springs	Collingsworth	27	Red
345920100473001	[3]JA–12–02–304	Donley	27	Red
352430100061101	Wheeler Springs	Wheeler	27	Red
353230100073101	Rathjen Springs	Wheeler	27	Red
08103500	Hannah Springs	Lampasas	29	Brazos
08146500[1]	San Saba Springs	San Saba	29	Colorado
304313097441101	Cowan Creek Spring	Williamson	29	Brazos
305250097395401	[3]AX–58–03–911	Bell	29	Brazos
305317097392401	[3]AX–58–03–909	Bell	29	Brazos
305331097403101	Warwick Springs	Bell	29	Brazos
310031097293101	Childers Springs	Bell	29	Brazos
310320098110001	Hancock Springs	Lampasas	29	Brazos
310331098113101	Swimming Pool Springs	Lampasas	29	Brazos
311213098543901	Baker Spring	San Saba	29	Colorado
311632098564401	Richland Springs	San Saba	29	Colorado
311706099003101	Hall Springs	San Saba	29	Colorado
314731097463101	Pierson Spring	Bosque	29	Brazos
321119097342601	[3]PX–32–52–503	Johnson	29	Brazos
08127200	Anson Springs	Tom Green	30	Colorado

Table 4. Texas springs selected for water-quality and spring-flow database—Continued.

Station number	Spring	County	Level III ecoregion	River basin
08129000	Spring Creek Springs	Irion	30	Colorado
[1]08129500	Dove Creek Springs	Irion	30	Colorado
[1]08143900	Springs at Fort McKavett	Menard	30	Colorado
[1]08149395	Tanner Springs	Edwards	30	Colorado
[1]08149500	Seven Hundred Springs	Edwards	30	Colorado
08165700	Welch Springs	Kerr	30	Guadalupe
08165710	Fessenden Springs	Kerr	30	Guadalupe
[2]08168000	Hueco Springs	Comal	30	Guadalupe
[2]08170990	Jacob's Well Spring	Hays	30	Guadalupe
08179700	Nisbet Springs	Medina	30	San Antonio
293031098543101	Diversion Dam Springs	Medina	30	San Antonio
293331099573101	Spring Creek Spring	Uvalde	30	Nueces
293331100153101	Schwander Springs	Kinney	30	Nueces
293331100163101	Silver Springs	Kinney	30	Nueces
294031100563101	Slaughter Bend Springs	Val Verde	30	Rio Grande
294103098571101	Wonder Hole	Bandera	30	San Antonio
294131100013101	Camp Wood Spring	Real	30	Nueces
294159098583201	Cold Springs	Bandera	30	San Antonio
294231099463101	Spring Branch Springs	Real	30	Nueces
294308101012901	Gillis Springs	Val Verde	30	Rio Grande
294501100240101	Kickapoo Springs	Edwards	30	Nueces
294731100113101	Paint Bluff Springs	Edwards	30	Nueces
294831100103101	Roberts Springs	Edwards	30	Nueces
295108098292901	Honey Creek Spring	Comal	30	Guadalupe
295131100083101	Pulliam Springs	Edwards	30	Nueces
295146099483701	Big Springs	Real	30	Nueces
295329100593201	[3]YR–70–01–703	Val Verde	30	Rio Grande
295332100593301	[3]YR–70–01–704	Val Verde	30	Rio Grande
295338098260101	[4]A–16 Comal	Comal	30	Guadalupe
295348100585901	Dolan Springs	Val Verde	30	Rio Grande
295410100003001	McCurdy Springs	Edwards	30	Nueces
295415097550601	Seep Springs	Hays	30	Guadalupe
295431098153101	Cranes Mill Springs	Comal	30	Guadalupe
295431098193101	Wolfe Springs	Comal	30	Guadalupe
295431101003101	Finegan Springs	Val Verde	30	Rio Grande
295437098263501	Spring Branch Springs	Comal	30	Guadalupe
295531098183101	Bishop Spring	Comal	30	Guadalupe
295731099453101	Chittim Springs	Real	30	Nueces
295731099573101	Morriss Spring	Real	30	Nueces
295852099264001	Lynx Haven Springs	Kerr	30	Guadalupe
295901098005001	Fern Bank Springs	Hays	30	Guadalupe
300031099223101	Mystic Springs	Kerr	30	Guadalupe
300113101111101	Hudspeth Springs	Val Verde	30	Rio Grande
300127100040601	Hackberry Springs	Edwards	30	Nueces
300231099003101	Cypress Springs	Kerr	30	Guadalupe
300331099183101	Kelly Springs	Kerr	30	Guadalupe
300331101103101	Pecan Springs	Val Verde	30	Rio Grande
300435099342201	Fish and Wildlife Springs	Kerr	30	Guadalupe

Table 4. Texas springs selected for water-quality and spring-flow database—Continued.

Station number	Spring	County	Level III ecoregion	River basin
300631099123101	Goat Springs	Kerr	30	Guadalupe
300631099153101	Henderson Springs	Kerr	30	Guadalupe
300931101073101	Juno Springs	Val Verde	30	Rio Grande
301002099203401	Ellebracht Springs	Kerr	30	Guadalupe
301031099173101	Fall Springs	Gillespie	30	Guadalupe
301531098043101	Barton Creek Springs	Hays	30	Colorado
301619099523801	Big Paint Springs	Edwards	30	Colorado
301649097464901	Deep Eddy Spring	Travis	30	Colorado
301702099133301	[3]KK–56–47–701	Gillespie	30	Colorado
301738097470701	Power House Spring	Travis	30	Colorado
301836099381001	Water Hole Spring	Kimble	30	Colorado
301903099550501	Christmas Canyon Spring	Kimble	30	Colorado
301919099550701	Junior Canyon Spring	Kimble	30	Colorado
302036098072801	Hamilton Springs	Travis	30	Colorado
301921098225001	Crofts Spring	Blanco	30	Colorado
302249099550701	Coleman Springs	Kimble	30	Colorado
302848098084301	Krause Springs	Burnet	30	Colorado
303825099551401	[3]RK–56–17–801	Kimble	30	Colorado
304002097450201	Knight Springs	Williamson	30	Brazos
304231099193101	Kothmann Springs	Mason	30	Colorado
304531101413101	Live Oak Spring	Crockett	30	Rio Grande
305528098283001	Boiling Springs	San Saba	30	Colorado
305631099533101	Wilkinson Springs	Menard	30	Colorado
305849098462401	Heck Springs	San Saba	30	Colorado
310043099160501	Indian Mound Springs	McCulloch	30	Colorado
310224099161101	Hudson-Pipe Springs	McCulloch	30	Colorado
310309098291001	Gorman Springs	San Saba	30	Colorado
310514098273001	Sulphur Spring	San Saba	30	Colorado
310618098593801	Deep Creek Spring	San Saba	30	Colorado
310625098502201	Wallace Springs	San Saba	30	Colorado
310812098554201	Fleming Springs	San Saba	30	Colorado
310914098550401	Sloan Springs	San Saba	30	Colorado
310927100074601	Kickapoo Spring	Tom Green	30	Colorado
311028098403801	Crystal Springs	San Saba	30	Colorado
311048098544601	Hart Spring	San Saba	30	Colorado
311101098560101	Flemming Spring	San Saba	30	Colorado
311131100303101	Mill Spring	Tom Green	30	Colorado
311248098594401	Springs on Maxwell Ranch	San Saba	30	Colorado
311506100150401	Lipan Spring	Tom Green	30	Colorado
08204000	Leona Springs	Uvalde	31	Nueces
08452800	San Felipe Springs	Val Verde	31	Rio Grande
08454800	Mud Springs	Kinney	31	Rio Grande
08454890	Pinto Springs	Kinney	31	Rio Grande
[2]08456300	Las Moras Springs	Kinney	31	Rio Grande
283031099523101	Carrizo Springs	Dimmit	31	Nueces
291031099543101	Soldiers Camp Springs	Uvalde	31	Nueces
08104300	Salado Springs	Bell	32	Brazos
[2]08155500	Barton Springs	Travis	32	Colorado

Table 4. Texas springs selected for water-quality and spring-flow database—Continued.

Station number	Spring	County	Level III ecoregion	River basin
[1]08155503	Old Mill Springs	Travis	32	Colorado
[2]08168710	Comal Springs	Comal	32	Guadalupe
[2]08170000	San Marcos Springs	Hays	32	Guadalupe
[1]08177818	San Antonio Springs	Bexar	32	San Antonio
[1]08178090	San Pedro Springs	Bexar	32	San Antonio
291631098293101	Mitchell Lake Spring	Bexar	32	San Antonio
292731098103101	Martinez Springs	Bexar	32	San Antonio
304113097390101	Berry Springs	Williamson	32	Brazos
324630096473101	Browder Springs	Dallas	32	Trinity
291657098020801	Sutherland Springs	Wilson	33	San Antonio
293527097353101	Sour Springs	Gonzales	33	Guadalupe
294402097354700	Soda Springs	Caldwell	33	Guadalupe
302030097210601	[3]AT–58–46–106	Bastrop	33	Colorado
302128097061701	[3]RZ–58–48–103	Lee	33	Brazos
302431097153101	Lawhon Springs	Lee	33	Brazos
303324096461001	[3]BS–59–26–608	Burleson	33	Brazos
303407096454701	Spring Lake Springs	Burleson	33	Brazos
303601096412601	[3]BS–59–27–209	Burleson	33	Brazos
303700096381301	Pettis Spring	Burleson	33	Brazos
303737096003200	Kellum Springs	Grimes	33	Brazos
321735095543001	[3]LT–34–41–603	Henderson	33	Trinity
322117095545601	Roher Springs	Henderson	33	Trinity
323030095533101	Riley Spring	Van Zandt	33	Trinity
330830095373101	Sulphur Springs	Hopkins	33	Sulphur
263513098105001	Santa Anita Seeps	Hidalgo	34	Nueces-Rio Grande
283456096351801	San Luis Springs	Calhoun	34	Lavaca-Guadalupe
293431094243101	Smith Springs	Galveston	34	Neches-Trinity
302904094504501	[3]SB–61–34–107	Liberty	35	Trinity
302906094504101	[3]SB–61–34–108	Liberty	35	Trinity
303514095070701	Harris Springs	San Jacinto	35	Trinity
305929093592101	Buck Spring	Jasper	35	Neches
310333094162501	Boykin Spring	Jasper	35	Neches
312731095303101	Caney Creek Springs	Houston	35	Trinity
312731095323101	Hays Branch Springs	Houston	35	Trinity
313331095313101	Elkhart Creek Springs	Houston	35	Trinity
314948094363101	Tonkawa Springs	Nacogdoches	35	Neches
315343094465301	Sulphur Springs	Rusk	35	Neches
323531094033101	Coushatta Spring	Harrison	35	Cypress
323932095224501	Dumas Spring	Wood	35	Sabine
324030095241201	Peacock Spring	Wood	35	Sabine
334530094533101	Bryarly Springs	Red River	35	Red

[1] Active partial-record USGS station.

[2] Active continuous USGS station.

[3] Name derived from Texas state well number.

[4] Name from reports of Texas Board of Water Engineers or Texas Water Development Board.

Table 5. Number of values used to compute mean, median, and standard deviation of selected water-quality constituents and properties for selected springs in Texas, by ecoregion.

[--, no values]

Level III ecoregion ID	Silica	Calcium	Magnesium	Sodium	Potassium	Strontium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate nitrogen	pH	Dissolved solids	Alkalinity	Hardness	Specific conductance	Temperature	Total
23	1	1	1	1	1	--	1	1	1	1	1	1	1	--	1	--	--	13
24	115	123	123	119	69	35	156	168	174	67	111	91	150	129	166	159	142	2,097
25	1	4	4	4	1	--	4	5	5	1	1	1	4	--	4	--	2	41
26	22	21	23	24	12	2	25	30	31	16	23	22	24	10	22	19	15	341
27	9	14	14	14	2	--	18	15	16	11	11	14	12	8	14	11	11	194
29	21	31	31	31	15	3	33	33	33	22	29	25	32	18	32	34	35	458
30	121	126	124	131	75	33	166	181	195	90	137	109	177	119	199	148	175	2,306
31	32	39	39	39	25	18	40	42	42	29	37	32	41	34	40	33	27	589
32	469	84	84	98	49	310	183	559	557	65	79	440	485	212	545	625	543	5,387
33	5	9	9	9	3	2	12	13	13	4	5	5	11	6	11	5	6	128
34	2	3	3	3	1	--	3	4	4	1	2	1	4	--	3	--	--	34
35	3	5	5	5	1	--	9	8	9	4	6	6	7	--	7	6	6	87
TOTAL	801	460	460	478	254	403	650	1,059	1,080	311	442	747	948	536	1,044	1,040	962	11,675

Table 6. Water-quality parameter codes and description of selected constituents and properties used in statistical summaries and maps for selected springs in Texas.

Constituent or property	U.S. Geological Survey parameter code	Description
Silica	00955	Silica, water, filtered, milligrams per liter
Calcium	00910	Calcium, water, unfiltered, milligrams per liter as calcium carbonate
Magnesium	00920	Magnesium, water, unfiltered, milligrams per liter as calcium carbonate
Sodium[1]	00929	Sodium, water, unfiltered, recoverable, milligrams per liter
	00933	Sodium plus potassium, water, filtered, milligrams per liter as sodium
Potassium	00937	Potassium, water, unfiltered, recoverable, milligrams per liter
Strontium	01080	Strontium, water, filtered, micrograms per liter[2]
Bicarbonate	00440	Bicarbonate, water, unfiltered, fixed endpoint (pH 4.5) titration, field, milligrams per liter
Sulfate	00945	Sulfate, water, filtered, milligrams per liter
Chloride	00940	Chloride, water, filtered, milligrams per liter
Fluoride	00951	Fluoride, water, unfiltered, milligrams per liter
Nitrate nitrogen	71850	Nitrate nitrogen, water, unfiltered, milligrams per liter
pH	00403	pH, water, unfiltered, laboratory, standard units
Dissolved solids	70301	Residue, water, filtered, sum of constituents, milligrams per liter
Alkalinity	00410	Acid neutralizing capacity, water, unfiltered, fixed endpoint (pH 4.5) titration, field, milligrams per liter as calcium carbonate
Hardness	00900	Hardness, water, milligrams per liter as calcium carbonate
Specific conductance	00095	Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius
Temperature	00010	Temperature, water, degrees Celsius

[1] Sodium summary statistics and maps applied to all values for both parameter codes.

[2] Strontium converted from micrograms per liter to milligrams per liter for analysis.

Table 7. Mean, median, and standard deviation values of selected water-quality constituents and properties for selected springs in Texas, by ecoregion.

[Values in following order: mean; median; standard deviation from the mean. mg/L, milligrams per liter; na, not applicable; --, no values; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius]

Level III eco-region ID	Silica (mg/L)	Calcium (mg/L)	Magne-sium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Strontium (mg/L)	Bicar-bonate (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
23	10; 10; na	76; 76; na	26; 26; na	2; 2; na	0.5; 0.5; na	--; --; --	358; 358; na	5; 5; na	2; 2; na
24	21; 19; 8.6	182; 177; 107	72; 73; 63	356; 390; 299	15; 17; 8.9	3.6; 3.4; 2.3	258; 267; 37	497; 383; 519	389; 246; 448
25	19; 19; na	49; 49; 7.8	29; 28; 7.3	34; 32; 21	0.5; 0.5; na	--; --; --	308; 300; 49	146; 41; 254	296; 15; 617
26	35; 32; 15	178; 78; 281	33; 28; 37	543; 57; 2,398	3.8; 3.4; 2.7	0.3; 0.3; 0.08	260; 247; 91	490; 75; 1,091	1,664; 69; 6,487
27	29; 34; 12	214; 100; 222	63; 35; 70	299; 76; 675	1.2; 1.2; 1.1	--; --; --	268; 259; 83	470; 112; 773	442; 56; 1,284
29	11; 12; 2.0	115; 110, 35	36; 34; 16	183; 83; 265	9.6; 4.6; 11	0.4; 0.4; 0.08	395; 410; 87	18; 12; 13	326; 141; 488
30	12; 11; 3.1	90; 90; 34	22; 18; 14	58; 8; 213	2.4; 1.3; 4.2	0.4; 0.3; 0.5	329; 323; 75	20; 13; 40	75; 13; 318
31	12; 12; 2.5	75; 75; 7.0	7; 7; 1.5	7; 6; 3.8	1.5; 0.9; 2.6	0.2; 0.2; 0.05	241; 244; 16	7; 7; 2.7	10; 10; 1.4
32	12; 12; 1.2	81; 80; 7.8	19; 17; 4.0	14; 10; 11	1.4; 1.4; 0.2	0.9; 0.7; 0.5	295; 288; 26	29; 27; 19	28; 21; 73
33	46; 16; 45	23; 14; 22	5; 2; 4.0	151; 69; 248	2.0; 1.2; 1.8	0.0; 0.0; 0.01	244; 44; 411	74; 24; 87	131; 64; 195
34	20; 20; 11	65; 51; 29	38; 25; 41	188; 97; 198	12; 12; na	--; --; --	262; 79; 337	86; 47; 112	298; 244; 244
35	23; 10; 26	1.4; 1; 1.1	1; 2; 0.7	7; 4; 5.9	0.1; 0.1; na	--; --; --	45; 12; 102	6; 2; 10	14; 6; 26

Level III eco-region ID	Fluoride (mg/L)	Nitrate nitrogen (mg/L)	pH	Dissolved solids (mg/L)	Alkalinity (mg/L)[1]	Hardness (mg/L)[1]	Specific conductance (µS/cm)	Tempera-ture (°C)
23	0.3; 0.3; na	1.6; 1.6; na	7.5; 7.5; na	299; 299; na	--; --; --	296; 296; na	--; --; --	--; --; --
24	1.6; 1.7; 0.9	5.7; 2.2; 8.1	7.4; 7.4; 0.4	1,610; 1,343; 1,422	213; 220; 29	663; 514; 509	2,628; 3,220; 1,867	25; 25; 5.6
25	1.5; 1.5; na	0.2; 0.2; na	8.0; 8.0; na	330; 318; 67	--; --; --	243; 240; 39	--; --; --	17; 17; 5.9
26	1.1; 0.6; 1.2	16; 20; 13	7.7; 7.6; 0.3	4,569; 468; 13,968	226; 221; 34	428; 232; 845	5,077; 869; 18,823	17; 18; 4.8
27	0.8; 0.6; 0.4	12; 12; 9.4	7.7; 7.6; 0.5	1,723; 670; 2,589	228; 222; 74	795; 397; 804	1,036; 880; 700	16; 19; 6.9
29	0.3; 0.2; 0.2	5.4; 5.7; 3.0	7.2; 7.2; 0.6	898; 616; 827	336; 368; 66	430; 408; 147	1,371; 1,090; 921	23; 22; 2.2
30	0.3; 0.2; 1.0	8.8; 8.1; 7.8	7.3; 7.3; 0.4	434; 324; 593	275; 270; 50	305; 290; 118	637; 582; 420	21; 22; 2.5
31	0.2; 0.2; 0.1	9.0; 8.2; 5.2	7.3; 7.3; 0.4	245; 245; 22	198; 200; 9.8	214; 214; 19	425; 429; 38	23; 23; 2.0
32	0.3; 0.2; 0.2	6.6; 5.9; 3.6	7.4; 7.3; 0.3	347; 350; 43	244; 241; 20	297; 300; 35	607; 604; 76	22; 22; 1.5
33	0.3; 0.1; 0.4	5.1; 2; 6.4	6.0; 5.4; 1.4	463; 443; 539	481; 79; 726	77; 44; 66	400; 138; 438	20; 21; 1.5
34	0.3; 0.3; na	6.5; 6.5; 3.5	7.2; 7.2; na	851; 483; 772	--; --; --	323; 230; 234	--; --; --	--; --; --
35	0.1; 0.1; 0.0	4.0; 1.5; 4.7	5.7; 5.6; 0.8	40; 25; 38	--; --; --	15; 10; 11	172; 34; 305	20; 19; 3.9

[1] Alkalinity and hardness in milligrams per liter of calcium carbonate.

Table 8. Minimum and maximum values of selected water-quality constituents and properties for selected springs in Texas, by ecoregion.

[Values in following order: minimum; maximum. mg/L, milligrams per liter; --, no values; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius]

Level III ecoregion ID	Silica (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Strontium (mg/L)	Bicarbonate (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
23	10–10	76–76	26–26	1.7–1.7	0.5–0.5	--	358–358	4.8–4.8	1.6–1.6
24	7.6–62	26–526	5.0–335	2.0–1,580	0.8–35	0.5–9.9	115–355	2.3–2,410	8.6–2,660
25	19–19	40–59	22–39	13–58	0.5–0.5	--	265–366	12–600	6.0–1,400
26	12–68	40–1,210	5.0–179	8.0–11,800	0.5–8.2	0.2–0.4	115–560	7.0–4,400	5.4–32,000
27	10–47	16–617	6.0–233	27–2,582	0.5–2.0	--	112–443	16–2,593	8.0–5,219
29	5.9–15	25–249	6.1–87	8.0–1,320	1.0–38	0.3–0.5	88–469	7.0–63	7.6–2,470
30	2.0–26	15–273	6.0–98	0.7–1,640	0.5–21	0.1–2.6	98–473	1.0–412	6.0–2,790
31	9.0–22	44–88	2.7–11	0.9–24	0.5–14	0.1–0.3	174–270	4.3–19	8.0–14
32	4.0–18	56–101	13–31	2.8–65	0.5–2.4	0.1–3.2	234–425	1.5–423	4.2–1,720
33	11–96	0.5–60	1.0–12	1.5–786	0.8–4.0	0.0–0.0	2.0–1,082	2.0–219	3.0–558
34	12–27	46–98	6.2–84	52–416	12–12	--	55–651	3.0–247	63–640
35	6.0–52	0.1–2.5	0.5–2.0	1.6–16	0.1–0.1	--	2.4–316	0.5–30	2.0–84

Level III ecoregion ID	Fluoride (mg/L)	Nitrate nitrogen (mg/L)	pH	Dissolved solids (mg/L)	Alkalinity (mg/L)[1]	Hardness (mg/L)[1]	Specific conductance (µS/cm)	Temperature (°C)
23	0.3–0.3	1.6–1.6	7.5–7.5	299–299	--	296–296	--	--
24	0.1–4.3	0.0–42	6.7–8.6	154–7,315	94–291	95–2,690	260–10,600	9.0–44
25	1.5–1.5	0.2–0.2	8.0–8.0	270–416	--	207–284	--	13–21
26	0.1–4.5	0.0–33	7.1–8.2	2.6–61,100	188–270	1.6–4,170	388–82,800	7.0–23
27	0.2–1.8	0.2–31	6.8–8.9	2.5–8,857	126–363	73–2,337	311–2,690	6.7–26
29	0.0–1.0	0.0–10	5.9–8.3	261–4,450	119–384	125–980	515–5,740	16–28
30	0.0–10	0.0–80	6.3–8.2	121–5,350	149–386	7.3–1,310	366–4,220	11–30
31	0.0–0.6	3.6–35	6.3–8.0	167–301	169–214	134–265	347–578	16–25
32	0.1–1.2	0.7–20	6.4–8.4	198–540	179–419	94–360	7.0–1,090	7.1–28
33	0.0–0.9	0.2–15	4.7–7.9	32–1,916	4.0–1,770	10–197	40–878	17–21
34	0.3–0.3	4.0–9.0	7.2–7.2	430–2,008	--	150–590	--	--
35	0.0–0.1	0.2–10	4.6–7.0	12–122	--	4.0–30	15–787	18–28

[1] Alkalinity and hardness in milligrams per liter of calcium carbonate.

Table 9. Water-quality standards of selected constituents and properties.

[mg/L, milligrams per liter; EPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; NSDWR, National Secondary Drinking Water Regulations; CCC, criterion continuous concentration; CMC, criteria maximum concentration]

Constituent or property	Standard concentration	Information	Information source
Fluoride	4.0 mg/L	EPA MCL[1]; potential health effects include bone disease and mottled teeth (in children)	http://www.epa.gov/safewater/mcl.html#1
Nitrate nitrogen	10 mg/L	EPA MCL[1]; potential health effects include serious illness and possible death for infants younger than 6 months	http://www.epa.gov/safewater/mcl.html#1
Chloride	250 mg/L	EPA NSDWR[2]	http://www.epa.gov/safewater/mcl.html#1
Fluoride	2.0 mg/L	EPA NSDWR[2]	http://www.epa.gov/safewater/mcl.html#1
pH	6.5–8.5	EPA NSDWR[2]	http://www.epa.gov/safewater/mcl.html#1
Sulfate	250 mg/L	EPA NSDWR[2]	http://www.epa.gov/safewater/mcl.html#1
Dissolved solids	500 mg/L	EPA NSDWR[2]	http://www.epa.gov/safewater/mcl.html#1
Alkalinity	20 mg/L	EPA CCC[3]	http://www.epa.gov/waterscience/criteria/wqcriteria.html
Chloride	860 mg/L	EPA CMC[4]	http://www.epa.gov/waterscience/criteria/wqcriteria.html
Chloride	230 mg/L	EPA CCC[3]	http://www.epa.gov/waterscience/criteria/wqcriteria.html
Hardness	1,000 mg/L	Common upper limit for use by chemical industry	http://www.epa.gov/waterscience/criteria/goldbook.pdf

[1] MCL is highest level of contaminant allowed in drinking water.

[2] NSDWR is non-enforceable guideline regulating contaminants that might cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

[3] CCC is estimate of highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

[4] CMC is estimate of highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.