Inventory and Water Quality of Springs of Ellis County, Oklahoma

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INTRODUCTION

From 1992 through 1993, the U.S. Geological Survey, in cooperation with the Oklahoma Geological Survey, made an inventory of springs in Ellis County, Oklahoma. It was part of a 4-year Statewide project begun in 1983, suspended in 1986, and reactivated in 1990. The Ellis County work is reported here.

Purpose and Scope

The objective of the project is a Statewide inventory of springs including water-quality analyses and discharge measurements. Water-quality parameters analyzed include major ions and nutrients; temperature, pH, alkalinity, and specific conductance were determined in the field.

Ellis County, the area examined here, lies in western Oklahoma at the Texas state line, north of the Canadian River, and just southeast of the Oklahoma Panhandle; see Figure 1 and also the discussion of physiography and land use below.

This report presents water-quality tables, a table of discharge measurements and water use, a table of current land-use, and bar charts showing monthly precipitation for 1992 through 1993 and a 30-year running average. A map shows the geology, streams, springs, roads, and towns.

Acknowledgments

Cooperation of the landowners on whose property these springs are located is greatly appreciated; without their help this survey could not have been made. Land-use information was provided by the Soil Conservation Service, of the U.S. Department of Agriculture. The Oklahoma Climatological Survey contributed climatic information, and Scott Christenson of the U.S. Geological Survey provided information and help with water-quality interpretation.

Methods of Study

A list of legal descriptions was compiled from a survey of wells and springs made in the 1930s by the Works Projects Administration. Then field crews for the U.S. Geological Survey obtained from the county treasurer's office the names and addresses of current landowners. Next, letters asking permission to measure and sample the springs were sent to many of the landowners; others were contacted by telephone or in person. Field crews were given locations of other springs by landowners and local residents. The crews observed the areas around springs for land and water use, took photographs when possible, measured discharge, collected water samples, and measured field parameters. Specific conductance, pH, and temperature were measured with portable meters. Alkalinity was determined by incremental titration of filtered samples. Water-quality samples were collected with churn samplers or sample bottles (depending on size of the spring), and analyzed by the Oklahoma Geological Survey.

The Local Identifier

Spring locations are specified by latitude and longitude to the nearest second and by a local identifier based on the Oklahoma public-land survey grid. The local identifier con-

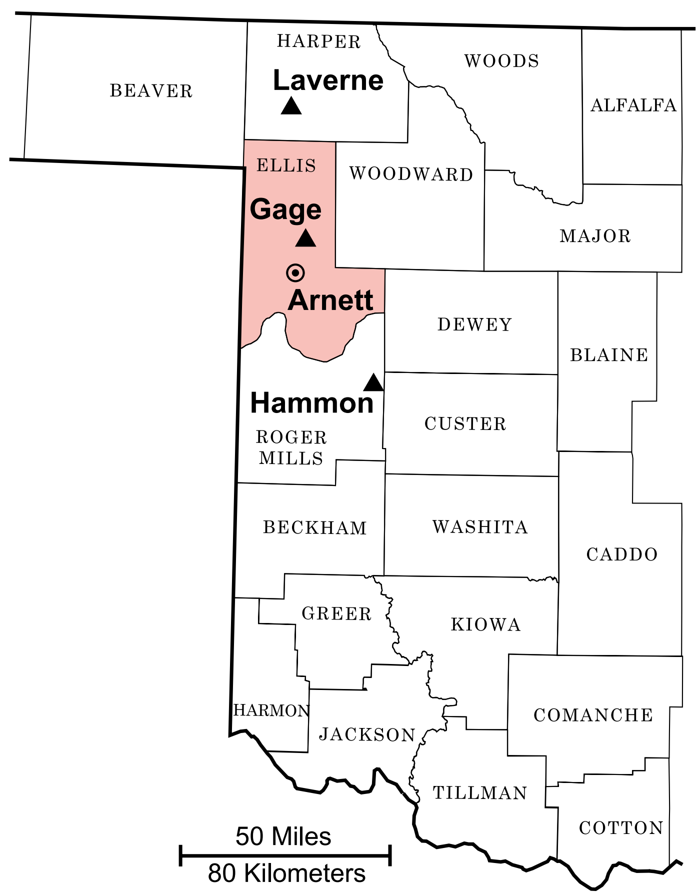

Figure 1. Ellis County is located in northwestern Oklahoma. The towns of Laverne, Gage, and Hammon contain weather stations (▲); Arnett is the county seat.

sists of township and range followed by the section number and a series of letters designating quarter-section subdivisions from largest to smallest. Then a sequence number is added to make the local identifier unique, as shown in Figure 2. An arbitrary number is assigned to each spring, in numerical order of latitude and longitude.

For example: spring 1 is identified as 355234099425201—which is to say lat 35°52′34″N, long 99°42′52″W, sequence number 1. (A zero separates latitude and longitude, and another sets off the sequence number.)

Spring 1 is further identified as 16N–24W–11–ACD, which expands to Township 16 North, Range 24 West, and in Section 11 the spring is found in the southwest quarter (D) of the southwest quarter (C) of the northeast quarter (A).

PHYSIOGRAPHY

Ellis County lies in the Osage Plains section of the Central Lowland physiographic province (Havens and Christenson, 1983, p. 6). The altitude above sea level is 2,100 ft in the north, 2,400 ft at center, and 2,000 ft near the Canadian River in the south. The Osage Plains are generally flat and featureless, but in Ellis County canyons have been cut by streams leading to the Canadian River in the south and to Wolf Creek, which flows northeasterly across the center of the county.

LAND USE

Ellis County is L-shaped, bounded on the north by Harper County, on the east by Woodward and Dewey Counties, on the south by Roger Mills County (across the Canadian River), and on the west by the state of Texas. This county is predominantly rural, with 563,833 acres of rangeland, 208,355 acres of cropland, and 5,327 acres of pastureland (Charles Cail, U.S. Department of Agriculture, Consolidated Farm Service Agency, personal communication, 1993; see also Table 1). The northern part of the county is mostly open grassland with nonirrigated cropland and some low- and high-density

TABLE 1. — LAND USE IN ELLIS COUNTY

Category	Name	Acres
1	Cropland	189,377.44
2	Cropland — irrigated	18,977.28
4	Rangeland — open grassland	173,128.14
5	Rangeland — sagebrush and sand, low density — canopy <20%	70,285.13
6	Rangeland — sagebrush and sand, high density — canopy >20%	200,210.30
7	Rangeland — shinnery oak, low density — canopy <15%	10,081.68
8	Rangeland — shinnery oak, high density — canopy >15%	98,780.70
11	Rangeland — juniper or Eastern red cedar, low density <100 plants per acre	2,164.60
12	Rangeland — juniper or Eastern red cedar, high density >100 plants per acre	2,441.35
16	Rangeland — cottonwood, elm, hackberry, willow, high density — canopy >20%	6,622.28
24	Rangeland — yucca or cactus — high density >100 plants per acre	118.61
25	Pastureland	4,082.09
27	Pastureland — irrigated	1,245.38
45	Farmsteads — area >5 acres	158.14
51	Quarries and gravel pits — area >5 acres	39.54
57	Cemetery (rural)	9.88
96	Water and bare sand channel	8,500.24
97	Urban and built-up land	1,897.73
98	Water	474.43
	Total	**788,594.94**

Source of data: U.S. Department of Agriculture, Soil Conservation Service, Consolidated Farm Service Agency.

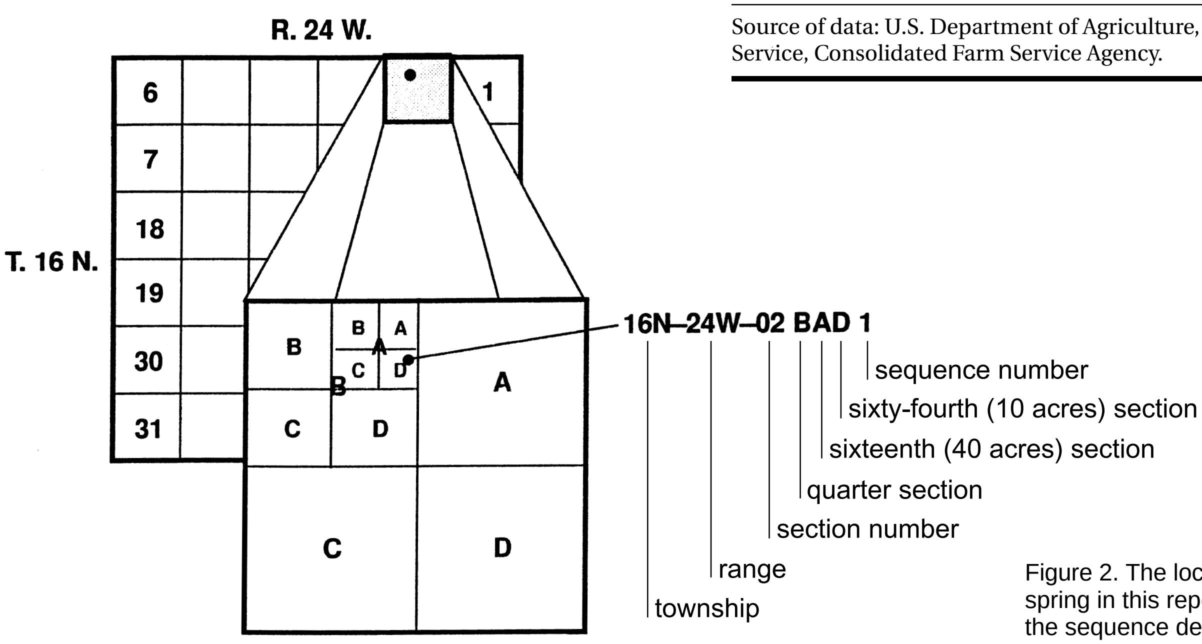

Figure 2. The local identifier for each spring in this report is determined by the sequence depicted here.

rangeland of sagebrush and sand. The southern part is mostly nonirrigated cropland with some open grassland and irrigated cropland. The southeastern part of the county is mostly low-density rangeland with shinnery oak, some open grassland, and a few acres of cropland. The county population, according to the 1990 census, totals 4,497; Arnett, the county seat, has a population of 547 (1990 census); other towns are Fargo—population 299, Gage—473, and Shattuck—1,454 (Oklahoma State Department of Commerce, Oklahoma City, personal communication, 1993).

HISTORICAL NOTES

Springs have contributed financial and historical worth to nearby communities. Presence of a spring has been considered a promise of good fortune; the lack of a spring, or lessened flow, could reverse fortune. In Ellis County, two springs (7 and 8 in Table 2) on the site of the old Grand settlement have affected local history. Grand, now a ghost town, was established in 1892 when the Cheyenne Arapaho Reservation was opened for settlement. Grand became the county seat in 1893 after the courthouse in Ioland burned (Ioland was about 10 mi south of Harmon), but another reason for the change was the exceedingly bad quality of Ioland's water (Morris, 1978, p. 94–95). Grand, in a grove near a spring then called Robinson Springs, was reported to have good water. But Grand was so far from the center of the county that the people voted to move the county seat to Arnett in 1908. The move left Grand almost deserted; today a dirt road leads to the site of the old settlement, and only a grove and remnants of an old bank vault mark the town site (Morris, 1978, p. 94–95).

CLIMATE

Cool winters and hot summers dominate the climate. The average annual temperature is about 57° Fahrenheit. Daily maximum temperatures average 47°F in January and 95°F in July; daily minimum temperatures average 19°F in January and 68°F in July. The average annual precipitation is about 22 in. Precipitation increases slightly from west to east across the county. Precipitation is at a maximum in the spring and at a minimum in winter, with the next highest rainfall in late summer. The average monthly precipitation ranges from ~3.5 in. in May to ~0.4 in. in January. About 70% of the average annual precipitation falls during the warm season (April through September). Snow falls on about 7 days a year, with an average annual accumulation of ~12 in. (Howard Johnson, Oklahoma Climatological Survey, personal communication, 1993). Monthly precipitation for the inventory period, 1992 and 1993, at Laverne, Gage, and Hammon is graphed in Figures 3, 4, and 5. Those sites were chosen to illustrate the trend of increasing precipitation from west to east (Fig. 1).

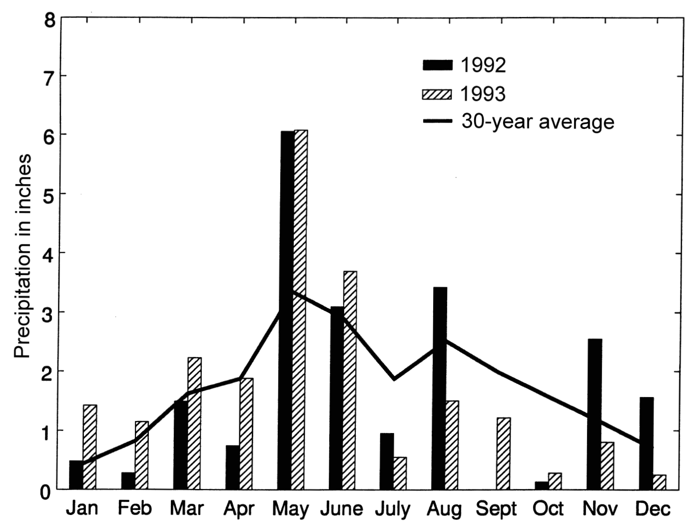

Figure 4. Precipitation in 1992 and 1993, at Gage, Ellis County. (National Oceanic and Atmospheric Administration, Climatological Data, Oklahoma.)

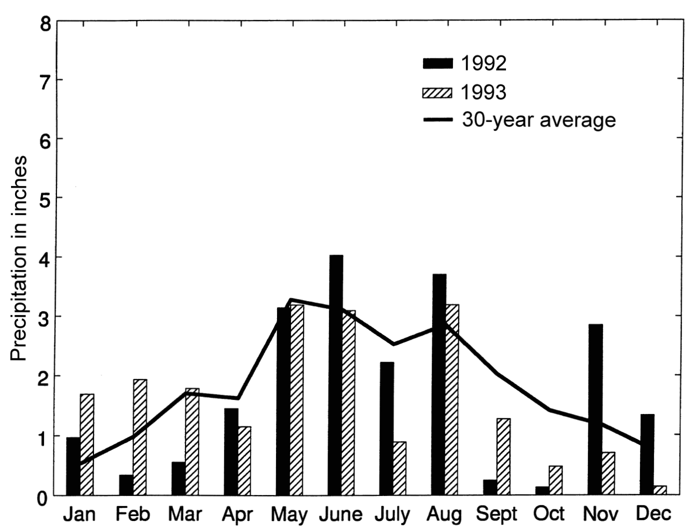

Figure 3. Precipitation in 1992 and 1993, at Laverne, Harper County. (National Oceanic and Atmospheric Administration, Climatological Data, Oklahoma.)

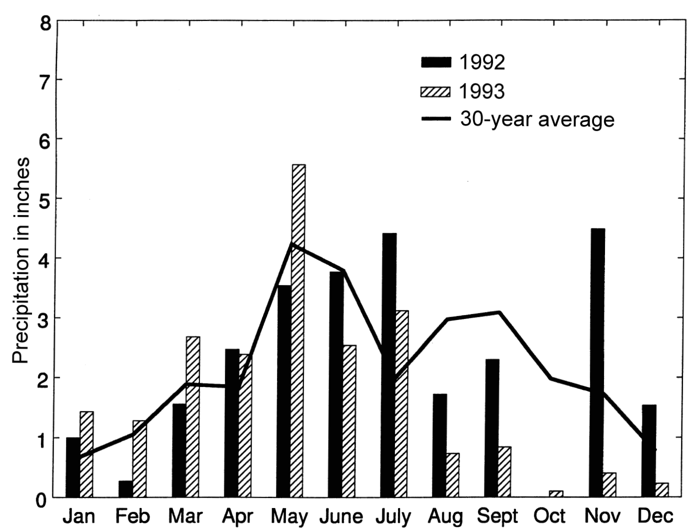

Figure 5. Precipitation in 1992 and 1993, at Hammon, Roger Mills County. (National Oceanic and Atmospheric Administration, Climatological Data, Oklahoma.)

TABLE 2. — LOCATION, DISCHARGE, AND WATER USE OF ELLIS COUNTY SPRINGS

Spring no.	Site identifier	Local identifier	Spring name	Date discharge measured	Discharge (gal/min)	Water use
1	355234099425201	16N–24W–11 ACD 1	Okla. Wildlife Spring 3	08-14-92	0.07	Livestock and wildlife
2	355337099431301	16N–24W–02 BDB 1	Okla. Wildlife Spring 2	08-14-92	28.0	Livestock
3	355340099430801	16N–24W–02 BAD 1	Okla. Wildlife Spring 1	08-14-92	27.6	Household and livestock
4	355404099435301	17N–24W–35 CAC 1	West Creek Spring 3	07-30-92	1	Livestock and wildlife
5	355411099435001	17N–24W–35 CAB 1	West Creek Spring 2	07-30-92	1	Livestock and wildlife
6	355419099435001	17N–24W–35 BDC 1	West Creek Spring 1	07-30-92	7.5	Livestock and wildlife
7	355847099473601	17N–24W–06 ADA 1	Grand Spring 1	07-30-92	31.9	Household and fishing; site of old Grand settlement
8	355848099474101	17N–24W–06 ADB 1	Grand Spring 2	07-30-92	45.4	Household and fishing; site of old Grand settlement
9	355903099470201	18N–24W–32 CDD 1	Johnson Spring 3	08-13-92	20.9	Livestock and wildlife
10	355906099364601	18N–23W–36 CCC 1	Davison Ranch Spring 2	08-21-92	1.08	Livestock and wildlife
11	355917099363601	18N–23W–36 CBD 1	Davison Ranch Spring 1	08-21-92	2.36	Livestock and wildlife
12	355947099531201	18N–26W–32 ADA 1	Jenkins Springs	07-27-93	123	Livestock
13	355958099462701	18N–24W–29 DDD 2	Johnson Spring 2	08-13-92	0.09	Livestock and wildlife
14	355958099462801	18N–24W–29 DDD 1	Johnson Spring 1	08-13-92	1.33	Livestock and wildlife
15	360051099500601	18N–25W–23 CDD 1	Parker Spring	NA	NA	Irrigation
16	360056099305401	18N–22W–23 DCC 1	Gillispie Spring 1	09-23-92	19.2	Livestock and wildlife
17	360059099570001	18N–26W–23 CCA 1	Flock Springs	07-27-93	10	Livestock and wildlife
18	360107099475401	18N–24W–19 DBC 1	Word Springs	07-22-93	35	Household and livestock
19	360119099551601	18N–26W–24 ACD 1	Henderson Springs 4	08-04-93	25	Livestock and wildlife
20	360123099462101	18N–24W–21 BCB 1	Peck Spring 1	09-11-92	18.4	Livestock and wildlife
21	360132099551101	18N–26W–24 AAC 1	Henderson Spring 1	08-04-93	5	Livestock and wildlife
22	360134099550401	18N–26W–24 AAD 1	Henderson Spring 2	08-04-93	20	Livestock and wildlife
23	360144099545901	18N–26W–13 DDA 1	Henderson Spring 3	07-27-93	5	Livestock
24	360156099561901	18N–26W–14 DBD 1	Trails End Farm Spring	08-04-93	0.10	Livestock and wildlife
25	360202099513301	18N–25W–15 CBA 1	Richards Spring	07-20-93	0.25	Livestock
26	360222099304701	18N–22W–14 ABC 1	Harris Spring 3	08-28-92	12.9	Livestock and wildlife
27	360222099523201	18N–25W–16 BAC 1	Wayland Spring 1	07-20-93	0.10	Livestock
28	360226099524901	18N–25W–16 BBB 1	Wayland Springs 2	07-20-93	1	Livestock
29	360240099540601	18N–25W–07 DDB 1	Peck Spring 2	09-11-92	21.1	Livestock and wildlife
30	360245099480701	18N–24W–07 CDA 1	Elmer Knowles Spring	07-22-93	50	Livestock and wildlife
31	360251099295301	18N–22W–12 CAD 1	Harris Spring 2	08-28-92	9.35	Livestock and wildlife
32	360254099513301	18N–25W–10 CBA 1	Marvel Spring	08-04-93	0.29	Livestock
33	360300099442701	18N–24W–08 BCC 1	McCorkle Springs	07-22-93	210	Livestock and wildlife
34	360321099374301	18N–23W–11 BBA 1	Wagnon Spring 1	09-18-92	6.73	Livestock
35	360321099374501	18N–23W–11 BBB 1	Wagnon Spring 2	09-18-92	4.49	Livestock
36	360323099381101	18N–23W–10 ABA 1	Cadwell Spring 3	09-18-92	22.7	Livestock
37	360333099383501	18N–23W–03 CDB 1	Cadwell Spring 2	09-18-92	0.10	Livestock
38	360336099303701	18N–22W–02 DDB 1	Hutchison Spring 2	08-26-92	4.71	Livestock and wildlife
39	360336099305001	18N–22W–02 DCB 1	Hutchison Spring 1	08-26-92	3.27	Livestock and wildlife
40	360342099300701	18N–22W–01 CBD 1	Berry Spring 1	09-01-92	27.3	Livestock and wildlife
41	360343099465601	18N–24W–05 DBC 1	Davis Spring	07-22-93	50	Livestock and wildlife
42	360349099384101	18N–23W–03 CAB 1	Cadwell Spring 1	09-18-92	0.17	Livestock
43	360355099305901	18N–22W–02 BDD 1	Harris Spring 1	09-01-92	15.3	Livestock and wildlife
44	360433099273801	19N–21W–32 DCB 1	Baker Spring 4	09-23-92	240	Livestock and wildlife
45	360441099273701	19N–21W–32 DBB 1	Baker Spring 3	09-23-92	4.37	Livestock and wildlife
46	360445099510501	19N–25W–34 DBD 1	Redelsperger Springs	07-20-93	450	Livestock and wildlife
47	360454099274801	19N–21W–32 BDA 1	Baker Spring 2	09-23-92	17.9	Livestock and wildlife

(continued on next page)

TABLE 2. — LOCATION, DISCHARGE, AND WATER USE OF ELLIS COUNTY SPRINGS *(continued)*

Spring no.	Site identifier	Local identifier	Spring name	Date discharge measured	Discharge (gal/min)	Water use
48	360459099273601	19N–21W–32 ABC 1	Baker Spring 1	09-23-92	5.13	Livestock and wildlife
49	360515099575101	19N–26W–27 CDC 1	Herbel Springs 2	07-27-93	1.50	Livestock, fishing, and wildlife
50	360530099573701	19N–26W–27 DBB 1	Herbel Springs 1	07-27-93	0.10	Livestock
51	360620099572101	19N–26W–22 DAC 1	Farris Springs	07-22-93	22	Livestock and wildlife
52	360629099280101	19N–21W–20 CBA 1	Coram Spring 3	09-25-92	1.68	Livestock and wildlife
53	360632099562101	19N–26W–23 ADC 1	Knowles Spring	08-04-93	0.50	Livestock and wildlife
54	360635099574501	19N–26W–22 BDD 1	Pudwill Springs	07-22-93	4.90	Livestock
55	360637099275601	19N–21W–20 BDB 2	Coram Spring 2	09-25-92	0.31	Livestock and wildlife
56	360639099275501	19N–21W–20 BDB 1	Coram Spring 1	09-25-92	1.80	Livestock and wildlife
57	360712099274801	19N–21W–17 CAD 1	Bowman Spring 4	09-25-92	37.0	Livestock and wildlife
58	360716099281201	19N–21W–17 CBB 2	Bowman Spring 2	09-25-92	19.2	Livestock and wildlife
59	360716099281401	19N–21W–17 CBB 1	Bowman Spring 1	09-25-92	3.20	Livestock and wildlife
60	360717099281001	19N–21W–17 CBB 3	Bowman Spring 3	09-25-92	25.7	Livestock and wildlife
61	360728099283501	19N–21W–18 ACD 1	Bowman Spring 5	09-29-92	45.2	Livestock and wildlife
62	361119099553701	20N–26W–24 CDD 1	Higginbotham Spring	09-16-93	18.3	Livestock
63	361327099394501	20N–23W–09 CAB 1	Molloy Spring 1	09-24-93	0.10	Livestock
64	361339099390801	20N–23W–09 ADB 1	Molloy Spring 3	09-24-93	60	Livestock
65	361340099394001	20N–23W–09 BDB 1	Molloy Spring 2	09-24-93	0.10	Livestock
66	361353099535301	20N–25W–05 CCC 1	Wayland Spring 3	07-20-93	2.20	Livestock and wildlife
67	361616099482601	21N–24W–30 ADB 1	Berry Spring	08-05-93	42.6	Livestock
68	361642099364401	21N–23W–24 DCB 1	Reininger Spring	09-18-92	10	Livestock and wildlife
69	361657099482301	21N–24W–19 DBA 1	Barnes Springs	08-05-93	42	Livestock
70	361925099362301	21N–23W–01 DAD 1	Benbrook Spring	09-24-93	0.10	Livestock
71	362120099453901	22N–24W–27 BDC 1	Harris Spring	09-24-93	10	Livestock and wildlife
72	362209099473001	22N–24W–20 DBB 1	Elliott Springs	07-29-93	54	Livestock and wildlife
73	362215099474001	22N–24W–20 BDD 1	Herber Springs	07-29-93	48	Livestock and wildlife
74	362329099482101	22N–24W–18 AAB 1	Miller Springs	07-29-93	35	Livestock and wildlife
75	362829099395201	23N–23W–16 ACA 1	Eight-Mile Springs	07-20-93	77	Livestock and wildlife
76	362845099383101	23N–23W–10 DDD 1	Brewers Spring	07-28-92	1	Livestock and wildlife
77	363036099415801	24N–23W–31 DCA 1	Murphy Springs	07-23-93	1.70	Livestock and wildlife
78	363126099470501	24N–24W–29 DDA 1	Dugger Spring 2	09-29-93	0.60	Livestock and wildlife
79	363209099471601	24N–24W–29 AAB 1	Dugger Spring 1	09-29-93	54	Livestock and wildlife
80	363328099395401	24N–23W–16 DBA 1	Burgess Springs	07-23-93	4.80	Livestock and wildlife
81	363444099525601	24N–25W–09 ABB 1	Corless Spring	09-29-93	30	Livestock

GEOLOGY

Narrow bands of the Rush Springs Formation and Cloud Chief Formation, both of Permian age, crop out in northeastern and southern Ellis County (Fig. 6). The Rush Springs Formation, consisting of orange-brown fine-grained sandstone, with some interbedded red-brown shale, silty shale, and gypsum beds, is overlain by the Cloud Chief Formation, which consists of red-brown and greenish-gray shale and siltstone, with some thin dolomite beds at the base of the formation (Morton, 1980). A small outlier of the Kiowa Formation (Cretaceous), composed of shale and limestone, is found in the northeast corner. Most of the county is covered by the Ogallala Formation (Tertiary), consisting of gravel, sand, silt, clay, caliche, and limestone, locally cemented with calcium carbonate. Quaternary alluvial and terrace deposits occur along the major streams (Morton, 1980).

GROUND WATER

The High Plains aquifer consists of the Ogallala Formation (Tertiary) and Quaternary alluvium and terrace deposits that are in hydraulic continuity. In some areas of bedrock highs, parts of the underlying Triassic, Jurassic, or Cretaceous rocks contain fresh water and are considered to be part of the High Plains aquifer (Havens and Christenson, 1983, p. 11). The High Plains is a water-table aquifer, except in some areas where lenses of clay may cause local confinement. Water in the aquifer moves generally to the east-southeast; the water table slopes ~14 ft/mi. Discharge to streams along major valleys

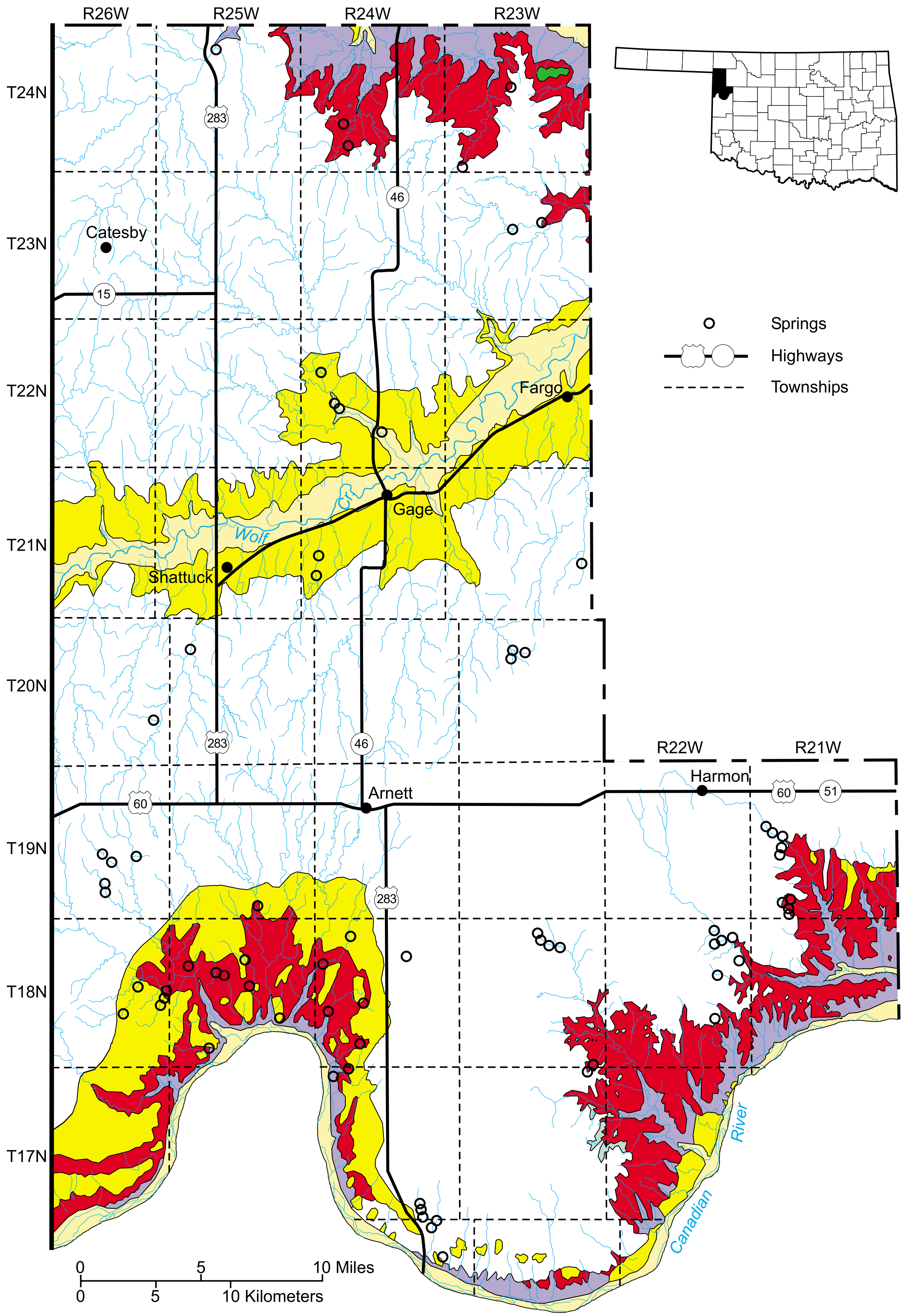

Figure 6. The geology and drainage of Ellis County determine the location of springs and also affect highway routes and town sites. *(Explanation on facing page.)*

Explanation for Figure 6

The stratigraphic nomenclature and age determinations used herein are those accepted by the Oklahoma Geological Survey and do not necessarily agree with those of the U.S. Geological Survey.

Qal ALLUVIUM
Lenticular and interfingering deposits of gravel, sand, silt, and clay, generally light tan to gray. Thickness along major streams ranges up to 100 feet and probably averages 40 feet; along minor streams the thickness ranges up to 45 feet and probably averages 20 feet.

UNCONFORMITY
Qt TERRACE DEPOSITS
Lenticular and interfingering deposits of light tan to gray gravel, sand, silt, clay, and volcanic ash. Sand dunes are common in many places. Thickness ranges up to 150 feet and averages about 60 feet.

UNCONFORMITY
To OGALLALA FORMATION
Gravel, sand, silt, clay, caliche, and limestone, locally cemented with calcium carbonate. Generally light tan to gray to white. Thickness ranges up to 400 feet and probably averages 150 feet.

UNCONFORMITY
Kk KIOWA FORMATION
Gray and yellow shale and limestone, with many Texigryphaea shells locally. At base is 5 to 10 feet of greenish-gray sandstone in places. Thickness ranges up to 140 feet with top eroded.

UNCONFORMITY
Pdy DOXEY FORMATION
Red-brown shale and siltstone, with greenish-gray calcareous siltstone at base. Exposed thickness is 30 feet, with top eroded.

Pcc CLOUD CHIEF FORMATION
Red-brown and greenish-gray shale and siltstone with some orange-brown fine-grained sandstone and siltstone. Thickness ranges up to 160 feet, with top eroded in many places.

Pr RUSH SPRINGS FORMATION
Orange-brown fine-grained sandstone, commonly cross-bedded, with some interbedded red-brown shale, silty shale, and gypsum beds. Thickness is about 190 feet in southern part and 90 feet near Kansas border, with top eroded in many places.

causes local variations in the water table (Havens and Christenson, 1983, p. 11).

Although most rain falls in spring and summer, most ground-water recharge occurs in late winter and early spring, when vegetation is dead or dormant and evaporation and transpiration are at a minimum. Thus water levels are highest in early spring and begin to decline in late spring or early summer. The levels continue to decline during summer and into autumn, when they are at their lowest. In late autumn they begin to rise as evaporation and transpiration decrease. The cycle may be disrupted if rain in summer is abnormally heavy—or light (Morton 1980).

SPRINGS

Ground water becomes a flowing spring where the water table intersects the ground surface. Some springs are formed by a perched water table: as rainwater percolates downward it may encounter an impermeable layer creating a localized zone of saturation, perched at a distance above the regional water table. The quality of spring water is related to the type of rock through which the water flows, for the water dissolves minerals in the rock and acquires some of their qualities.

Discharge

For this inventory, discharge measurements were made by estimation, by wading while using a current meter and wading rod, and by volumetric methods. Discharge was estimated by measuring flow channel depth and width and estimating the flow velocity. Wading measurements were made by multiplying the width of the spring channel times average depth times average velocity. Volumetric measurements were made by recording the time necessary to fill a container of known volume. In this report, discharge is given in gallons per minute (Table 2). Spring 46 had the greatest discharge at 450 gal/min; spring 1 had the least, at 0.07 gal/min.

Water Quality

Water-quality samples were collected from 24 of 81 springs in Ellis County. Results of chemical analysis are shown in Table 3. Water from 18 of 24 springs had dissolved solids less than 500 milligrams per liter. Water from 20 of 24 springs (exceptions were springs 3, 25, 31, and 32) had calcium as the dominant cation and bicarbonate as the dominant anion (Table 4). A cation or anion is considered to be dominant if it constitutes more than 50% of the total dissolved cations or

Spring no.[a]	Date sampled	Temp., water (°C)	Temp., air (°C)	Agency collecting sample[b]	Agency anayzing sample[b]	Specific conductance (μS/cm)[c]	pH, water whole, field, standard units	Carbonate, water, dissolved, IT[d], field (mg/L)	Bicarbonate, water dissolved, IT[d], field (mg/L)	Nitrogen, nitrate total (mg/L as N)	Nitrogen NO_2+NO_3 dissolved (mg/L as N)	Hardness total (mg/L as $CaCO_3$)	Hardness noncarbonate dissolved field (mg/L as $CaCO_3$)
3	08-14-92	16.5	—	1028	84041	893	7.1	0	254	4.53	4.53	340	130
10	08-21-92	16.5	—	1028	84041	676	7.2	0	320	0.160	0.160	250	0
12	08-27-93	17.0	24.0	1028	84041	523	7.6	0	256	3.25	3.25	220	5
14	08-13-92	22.0	—	1028	84041	376	8.2	0	234	1.12	1.12	180	0
16	09-23-92	17.0	—	1028	84041	490	7.3	0	242	5.09	5.09	210	14
18	07-22-93	18.0	30.0	1028	84041	550	7.6	0	267	1.74	1.74	220	1
23	07-27-93	20.0	39.0	1028	84041	505	7.7	0	221	4.82	4.82	180	0
25	07-20-93	19.0	30.5	1028	84041	1,570	7.2	0	217	9.06	9.06	540	360
29	09-11-92	18.0	—	1028	84041	522	7.7	0	209	5.20	5.20	200	26
31	08-28-92	18.0	—	1028	84041	—	7.8	0	278	0.700	0.700	130	0
32	08-04-93	20.5	27.0	1028	84041	644	7.9	0	395	1.71	1.71	260	0
37	09-18-92	19.0	—	1028	84041	408	7.2	0	273	—	<0.100	200	0
43	09-01-92	16.5	—	1028	84041	520	7.4	0	326	0.980	0.980	180	0
46	07-20-93	17.0	34.0	1028	84041	510	7.2	0	257	2.66	2.66	210	0
48	09-23-92	15.0	—	1028	84041	700	7.2	0	294	2.93	2.93	280	35
49	07-27-93	17.0	38.0	1028	84041	426	7.7	0	216	0.810	0.810	200	25
52	09-25-92	16.0	—	1028	84041	780	7.2	0	428	0.130	0.130	290	0
53	08-04-93	16.5	22.5	1028	84041	598	7.4	0	393	—	<0.100	290	0
64	09-24-93	17.5	19.5	1028	84041	620	7.3	0	313	4.29	4.29	260	0
67	08-05-93	21.5	26.0	1028	84041	656	7.8	0	390	—	<0.100	300	0
74	07-29-93	17.0	33.0	1028	84041	559	7.8	0	312	0.770	0.770	270	10
75	07-19-93	22.0	34.5	1028	84041	580	7.6	0	315	0.110	0.110	250	0
79	09-29-93	17.5	25.0	1028	84041	517	7.4	0	246	1.14	1.14	210	8
81	09-29-93	17.5	23.0	1028	84041	397	7.4	0	244	1.38	1.38	200	3

TABLE 3. — WATER-QUALITY ANALYSES FOR SPRINGS IN ELLIS COUNTY, OKLAHOMA

[a]See Table 1.
[b]Agency codes: 1028—U.S. Geological Survey, 84041—Oklahoma Geological Survey.
[c]μS/cm, microsiemens per centimeter.
[d]IT, incremental titration.

anions calculated in milliequivalents per liter. Thus water from most of the sampled springs generally was low in dissolved solids and of a calcium-bicarbonate water type. Of the four springs that did not fit this general pattern, springs 3 and 25 had dissolved solids concentrations greater than 500 mg/L, spring 31 had sodium as the dominant cation (although bicarbonate remained the dominant anion), and spring 32 had enough dissolved calcium and sodium such that calcium does not constitute more than 50% of the cations. Most of the springs sampled discharged hard water—180 milligrams per liter or more of calcium carbonate.

Hardness is expressed in terms of calcium carbonate. If water requires an excessive amount of soap to form a lather, or forms incrustation on faucets or vessels in which it stands or is heated, it is hard water (Symons, 1946).

Water-quality Table 5 shows the median concentration in milligrams per liter of each major ion. The table also shows the 25th and 75th percentiles for each ion; 25% of the data are less than the 25th percentile and 75% of the data are less that the 75th percentile. Percentiles show the distribution of the concentrations of major ions in water produced by springs in Ellis County.

No spring sampled exceeded the water-quality limits for drinking water set by the Environmental Protection Agency (U.S. Environmental Protection Agency, 1994) for any measured constituent. The primary maximum contaminant levels are set to protect public health. The secondary maximum contaminant levels are for aesthetic reasons related to public acceptance of drinking water (U.S. Environmental Protection Agency, 1994). Water from spring 25 came close to exceeding the primary and secondary maximum contaminant levels for nitrite plus nitrate, chloride, and sulfate. The nitrite plus nitrate concentration was 9.06 milligrams per liter (the primary maximum contaminant level is 10 milligrams per liter). The chloride concentration was 240 milligrams per liter (the secondary maximum contaminant level is 250) and the sulfate concentration was 210 milligrams per liter (secondary maximum contaminant level, 250).

TABLE 3. — WATER-QUALITY ANALYSES FOR SPRINGS IN ELLIS COUNTY, OKLAHOMA *(continued)*

Spring no.[a]	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium adsorption ratio	Sodium (%)	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate, dissolved (mg/L)	Silica, dissolved (mg/L)	Total alkalinity water, dissolved, IT[d], field (mg/L as $CaCO_3$)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Solids, dissolved (tons per acre-ft)
3	97	23	48	1	24	2.2	120	52	34	208	654	521	0.89
10	82	11	43	1	27	2.0	51	20	32	262	410	399	0.56
12	74	7.4	23	0.7	19	1.7	16	28	29	210	334	319	0.45
14	51	12	21	0.7	20	2.0	14	12	38	192	278	270	0.38
16	73	7.4	16	0.5	14	1.8	17	13	27	198	322	297	0.44
18	73	9.2	32	0.9	24	1.5	14	36	35	219	356	340	0.48
23	62	6.3	8.7	0.3	9	1.0	3.4	<10	23	181	262	—	—
25	150	37	99	2	29	2.2	240	210	23	178	1,140	912	1.55
29	68	6.7	31	1	25	0.80	31	30	21	171	340	314	0.46
31	44	6.0	63	2	50	1.8	4.9	32	24	228	316	315	0.43
32	61	26	43	1	26	1.3	6.0	22	21	324	396	382	0.54
37	72	3.8	22	0.7	20	0.80	18	<10	32	224	302	—	—
43	60	6.2	57	2	41	2.2	5.4	21	28	267	348	344	0.47
46	71	7.2	30	0.9	24	1.9	22	18	31	211	344	319	0.47
48	89	13	32	0.8	20	2.7	55	30	29	241	463	408	0.63
49	74	4.2	6.9	0.2	7	0.80	22	13	46	177	320	277	0.44
52	94	14	47	1	26	2.8	37	22	35	351	480	463	0.65
53	99	11	9.6	0.2	7	0.40	7.2	<10	82	322	436	—	—
64	87	9.6	18	0.5	13	0.30	19	10	33	257	378	350	0.51
67	86	20	21	0.5	13	3.5	28	<10	37	320	404	—	—
74	77	18	18	0.5	13	3.8	21	24	44	256	402	363	0.55
75	86	8.1	26	0.7	18	2.0	17	12	44	258	378	350	0.51
79	70	8.4	24	0.7	20	1.6	28	22	41	202	346	321	0.47
81	69	7.6	9.2	0.3	9	1.8	12	12	31	200	291	269	0.40

Most of the springs sampled were used by livestock or wildlife. Water from springs 3, 7, 8, and 18 was used by households.

SUMMARY

In 1992–1993, the median discharge of 81 springs in Ellis County was 9.68 gal/min, ranging from 450 gal/min by spring 46 down to 0.07 gal/min by spring 1. Water from 18 of 24 springs had dissolved solids <500 mg/L. Water from 20 of 24 springs had calcium as the dominant cation and bicarbonate as the dominant anion. Water was generally low in dissolved solids and of a calcium-bicarbonate water type. No spring sampled violated the water-quality standards for drinking water set by the Environmental Protection Agency, but spring 25 came close.

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TABLE 4. — Chemical Analyses of Major Ions in Milliequivalents per Liter for Springs in Ellis County, Oklahoma

	Cations				Anions			
Spring no.[a]	Calcium, dissolved	Magnesium, dissolved	Sodium, dissolved	Potassium, dissolved	Chloride, dissolved	Sulfate, dissolved	Bicarbonate, dissolved, IT[b], field	NO_2+NO_3, dissolved as nitogen
3	4.841	1.893	2.088	0.057	3.386	1.083	4.164	0.324
10	4.092	0.906	1.871	0.052	1.439	0.417	5.245	0.012
12	3.693	0.609	1.001	0.044	0.452	0.583	4.196	0.233
14	2.545	0.988	0.914	0.052	0.395	0.250	3.836	0.080
16	3.643	0.609	0.696	0.047	0.480	0.271	3.967	0.364
18	3.643	0.758	1.392	0.039	0.395	0.750	4.377	0.125
23	3.094	0.519	0.379	0.026	0.096	<0.208	3.623	0.345
25	7.685	3.045	4.307	0.057	6.771	4.373	3.557	0.647
29	3.394	0.552	1.349	0.021	0.875	0.625	3.426	0.372
31	2.196	0.494	2.741	0.047	0.139	0.667	4.557	0.050
32	3.044	2.140	1.871	0.034	0.170	0.459	6.475	0.123
37	3.593	0.313	0.957	0.021	0.508	<0.208	4.475	<0.007
43	2.994	0.511	2.480	0.057	0.153	0.438	5.344	0.070
46	3.543	0.593	1.305	0.049	0.621	0.375	4.213	0.190
48	4.442	1.070	1.392	0.070	1.552	0.625	4.819	0.210
49	3.693	0.346	0.301	0.021	0.621	0.271	3.541	0.058
52	4.691	1.153	2.045	0.072	1.044	0.459	7.015	0.010
53	4.941	0.906	0.418	0.011	0.204	<0.208	6.442	<0.007
64	4.342	0.790	0.783	0.008	0.536	0.209	5.131	0.307
67	4.292	1.646	0.914	0.090	0.790	<0.208	6.393	<0.007
74	3.843	1.482	0.783	0.098	0.593	0.500	5.114	0.055
75	4.292	0.667	1.131	0.052	0.480	0.250	5.163	0.008
79	3.493	0.692	1.044	0.041	0.790	0.459	4.032	0.082
81	3.444	0.626	0.401	0.047	0.339	0.250	4.000	0.099

[a]See Table 1.
[b]IT, incremental titration.

TABLE 5. — STATISTICAL SUMMARY OF SELECTED WATER-QUALITY DATA COLLECTED FROM AUGUST 1992 TO SEPTEMBER 1993 FOR ELLIS COUNTY SPRINGS

Water-quality constituent	Sample size	Max.	Min.	Mean	Percent of samples in which values were less than or equal to those shown (median in percentage)				
					95	75	50	25	5
Specific conductance in microsiemens per centimeter at 25°C	24	1,570	376	610	1,434	656	550	505	380
pH, whole, field (standard unit)	24	8.2	7.1	7.5	8.1	7.7	7.4	7.2	7.1
pH, whole, laboratory (standard unit)	24	8	7.2	7.5	8.0	7.7	7.5	7.4	7.2
Carbonate, dissolved, incremental titration (mg/L as carbonate)	24	0	—	—	—	—	—	—	—
Bicarbonate, dissolved (mg/L as bicarbonate)	24	428	209	288	420	319	270	242	211
Nitrite plus nitrate dissolved (mg/L as nitrogen)	24	9.06	<0.10	2.20[a]	5.20	3.25	1.14	0.16	<0.10
Calcium, dissolved (mg/L as calcium)	24	150	44	78	137	87	74	68	46
Magnesium, dissolved (mg/L as magnesium)	24	37	3.8	12	34	14	8.8	6.8	3.9
Sodium, dissolved (mg/L as sodium)	24	99	7	31	90	43	25	18	7
Sodium adsorption ratio	24	2.0	0.2	0.8	2.0	1.0	0.7	0.5	0.2
Potassium, dissolved (mg/L as potassium)	24	3.8	0.3	1.8	3.7	2.2	1.8	1.1	0.3
Chloride, dissolved (mg/L as chloride)	24	240	3	34	210	30	18	12	4
Sulfate dissolved (mg/L as sulfate)	24	210	<10	28[a]	52	28	20	12	<10
Silica, dissolved (mg/L as silica dioxide)	24	82	21	34	73	38	32	27	21
Alkalinity, dissolved, IT[b] (mg/L as calcium carbonate)	24	351	171	236	344	261	222	198	172
Residue, dissolved at 180°C (mg/L)	24	1,140	262	404	1,018	408	352	320	266
Specific conductance (µS/cm)[c]	24	1,510	399	609	1,364	659	549	495	408
Alkalinity (mg/L as calcium carbonate)	24	348	170	236	341	262	227	200	171

[a]Value is estimated by using a log-probability regression to predict the values of data below the detection limit.
[b]IT, incremental titration.
[c]µS/cm, microsiemens per centimeter.