Report 349

Updated Evaluation of Water Resources in Part of North-Central Texas 1990-1999

November 1999

Texas Water Development Board
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Updated Evaluation of Water Resources in Part of North-Central Texas, 1990-1999

by
Lon Langley

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ABSTRACT

This updated evaluation of water resources of part of north-central Texas includes all or portions of Collin, Cooke, Dallas, Delta, Denton, Ellis, Fannin, Grayson, Hood, Hunt, Johnson, Kaufman, Lamar, Montague, Navarro, Parker, Red River, Rockwall, Tarrant, and Wise Counties. This report is in response to Senate Bill 1, passed in 1997 by the 75th Texas Legislature. This Act calls for the identification of areas in the state experiencing or expected to experience critical groundwater problems within the next 25-year period.

A reduction in groundwater withdrawals since 1990 has slowed water-level declines in some parts of the study area. Water levels in the Antlers and Twin Mountains Formations of the Trinity aquifer have remained stable since 1989 with the exception of Wise, Tarrant, and Johnson Counties. Water-level declines of about 100 feet have occurred in southwestern Wise County. The Dallas-Fort Worth metroplex area in northeastern Tarrant County has experienced water-level declines of 200 feet. Minor water-level declines of approximately 50 feet have occurred in southern Johnson County. The northern parts of Johnson County, as well as southern Denton and Tarrant Counties, have experienced a rise in water levels from 50 to 200 feet. Water levels have not changed significantly in the Paluxy Formation of the Trinity aquifer. Southern Wise County and Denton County have undergone minor water-level declines of 5 to 30 feet. Water levels in the Woodbine aquifer have remained stable with the exception of northern Collin County, the central to northeastern portion of Denton County, and northern Grayson County where declines of 10 to 60 feet have been observed.

Overall, groundwater quality has not degraded appreciably since the last reporting period in 1990. Average TDS values for the Antlers and Twin Mountains Formations of the Trinity aquifer were 718 mg/l. The Paluxy Formation of the Trinity aquifer had average TDS values of 607 mg/l. The Woodbine aquifer had the highest TDS values, averaging 877 mg/l. This is primarily due to high sulfate levels associated with extensive lignite beds.

Groundwater use is projected to decline in the study area, which would allow for conservation of groundwater reserves. Continual conversion to surface water use within the study area should allow future demands to be met. These projections suggest that adequate supplies of usable surface and groundwater exist to meet current and future needs of the study area through the year 2030.

INTRODUCTION

North-central Texas is the most populous region in the State, containing 24 percent of the population and is expected to more than double by 2050 (TWDB, 1997). The area accounts for approximately 6 percent of the State's annual water use. By 2050, water use in this area is expected to increase about 90 percent (TWDB,1997). Water is important to sustain the area's growing population and an economy. Although there has not been any major water deficits in the area, groundwater levels have declined 100 to 1,100 feet in the Trinity aquifer and 200 to 400 feet in the Woodbine aquifer since 1900 (Mace and others, 1994).

This report is an update to Texas Water Development Board (TWDB) Report 318, *Evaluation of Water Resources in Part of North-Central Texas,* by Baker and others, published in January 1990. TWDB Report 318 was prepared in response to the 1985 passage of House Bill 2 by the 69th Texas Legislature. This Act, in part, focused on addressing areas of the State where groundwater quality and quantity were deteriorating. This report is in response to Senate Bill 1 (SB-1), passed in 1997 by the 75th Texas Legislature. This Act requires identification of those areas of the State that are experiencing or are expected to experience critical water problems within the immediately following 25-year period. This may include shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, and contamination of groundwater supplies. Presently, no groundwater districts have been created in the study area.

This report updates the hydrogeological conditions, water demands, and water availability in the study area. Water levels and water quality were used to assess the current status of the groundwater resource and possible future trends. Population, historical water use, and projected water demands were compiled from TWDB reports and databases and analyzed for the study area.

The study area is in north-central Texas (Figure 1) and is defined by the Red River to the north, the outcrop edge of the Trinity aquifer to the west, the downdip limit of the Woodbine aquifer to the east (as defined by the slightly saline line), and the southern boundaries of Hood, Johnson, and Ellis Counties to the south. The study area lies within the Red, Sulphur, Sabine, Trinity, and Brazos River basins. It encompasses all or parts of Collin, Cooke, Dallas, Delta, Denton, Ellis, Fannin, Grayson, Hood, Hunt, Johnson, Kaufman, Lamar, Montague, Navarro, Parker, Red River, Rockwall, Tarrant, and Wise Counties.

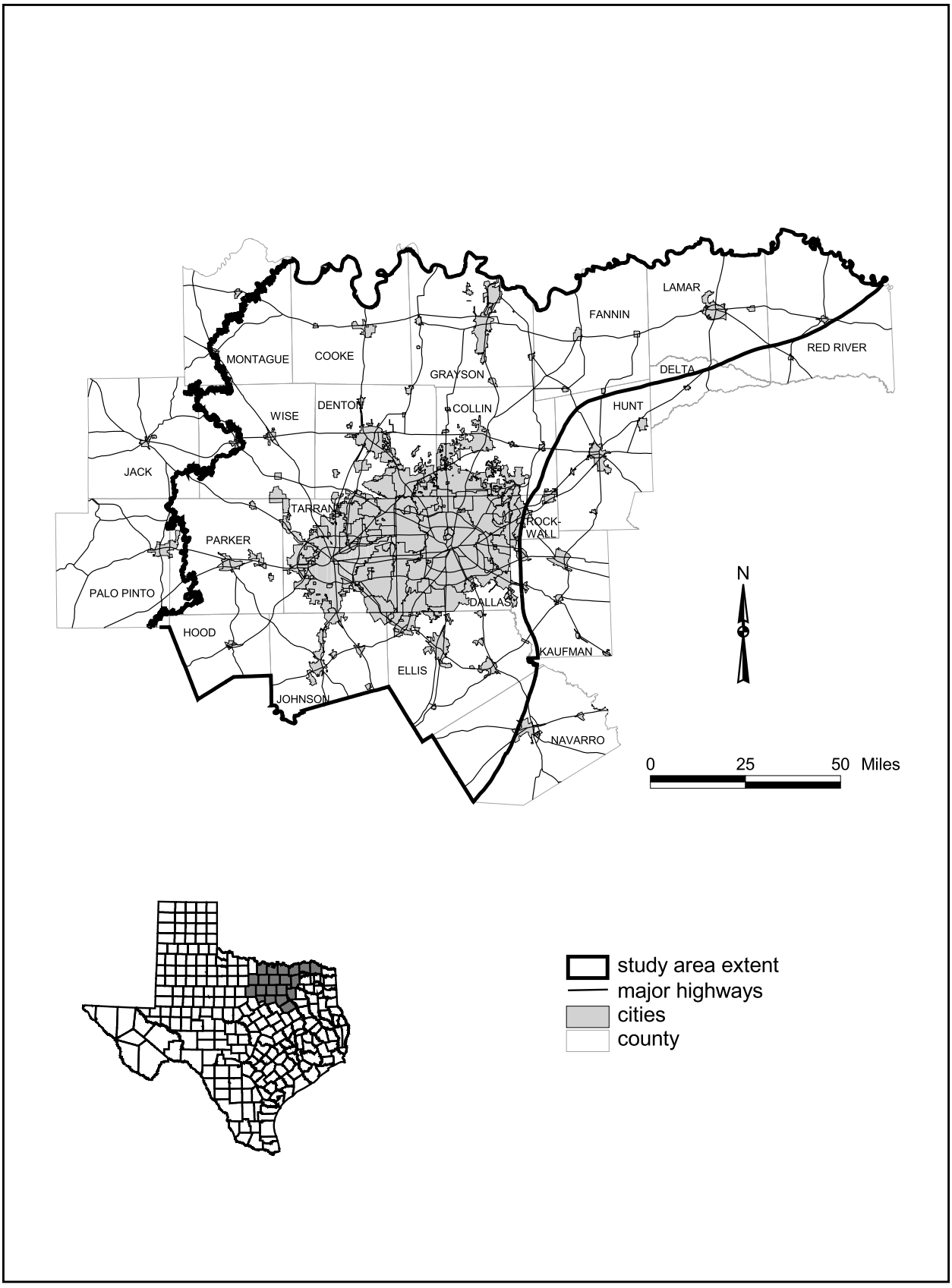

Figure 1. Location of the study area in north-central Texas.

HYDROGEOLOGY

Groundwater flow and the groundwater resource is controlled, in part, by the geology in the region, water levels, and precipitation as it relates to recharge, and water quality.

Geology

The primary aquifers in the area include the Trinity and Woodbine aquifers with minor amounts of water also produced from the Blossom and Nacatoch Sands. These aquifers are briefly discussed below. The geology and hydrogeology of the study area are discussed in more detail by Muller and Price (1979), Nordstrom (1982), and Baker and others (1990).

The Trinity aquifer is composed of Cretaceous age formations of the Trinity Group and extends through the central part of Texas from the Red River to the north and through the Hill Country to the south (Ashworth and Hopkins, 1995). The Trinity aquifer is the only major aquifer within the study area (Figure 2) and includes the Antlers, Twin Mountains, and Paluxy Formations. The Antlers Formation consists of the Twin Mountains and Paluxy Formations where the Glen Rose Formation confining layer pinches out. Because the Antlers and Twin Mountains Formations are closely related hydrologically, they are often discussed together (e.g. Baker and others, 1990).

Outcrops of the Antlers Formation are located mainly in Montague, Wise, and Cooke Counties. The Antlers Formation is about 400 feet in thickness near the outcrop and increases to about 900 feet in southeast Grayson County. The Twin Mountains Formation outcrops in the western part of the study area in Hood, Parker, and Wise Counties. The thickness of the Twin Mountains Formation varies from less than 200 feet near the outcrop to approximately 1,000 feet at the downdip limit of fresh to slightly saline water. The Paluxy Formation outcrops in Hood, Parker, Tarrant, and Wise Counties. The thickness of the Paluxy Formation varies considerably, from about 400 feet in the northern part of the study area to less than 100 feet in the southern part (Nordstrom, 1982).

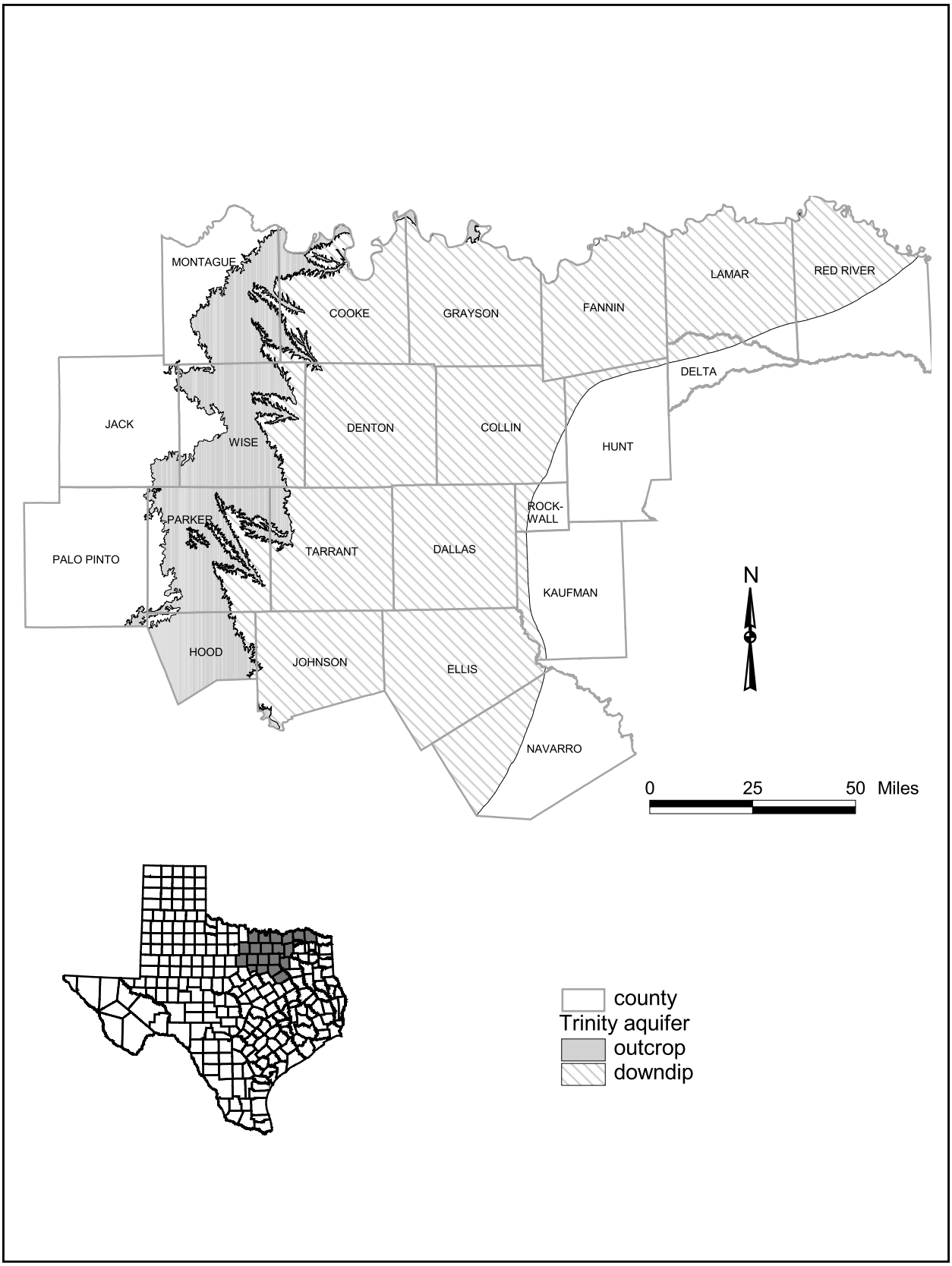

Figure 2. Location of the Trinity aquifer in the study area.

Minor aquifers in the area consist of the Woodbine Formation, the Blossom Sand and the Nacatoch Sand (Figure 3). The Woodbine Formation outcrops in Johnson, Tarrant, Denton, Cooke, and Grayson Counties (Baker and others, 1990). The Woodbine Formation trends in a north-south direction extending from the Red River to the north and to northern McLennan County to the south. The thickness of the Woodbine Formation ranges from about 230 feet near the southern extent of the outcrop to approximately 700 feet near the downdip limit of fresh to slightly saline water.

The Blossom Sand outcrops in central Fannin, Lamar, and Red River Counties. The Nacatoch Sand is exposed in Delta, Hunt, Kaufman, Lamar, Navarro, and Red River Counties (Baker and others, 1990). Because wells from these aquifers typically produce small yields of usable water (Baker and others, 1990), they will not be discussed in this report. The Blossom and Nacatoch Sands are discussed in more detail by Muller and Price (1979), Nordstrom (1982), Ashworth (1988), and McLaurin (1988).

Water-Level Fluctuations

Water-level changes from 1989 to the present are shown in contour maps, hydrographs, and tables constructed using groundwater-level elevation data from the TWDB groundwater database for the Antlers and Twin Mountains Formations, the Paluxy Formation, and the Woodbine Formation (TWDB, 1998a; control data in Appendix A). Most of the wells used to investigate water levels in TWDB Report 318 (Baker and others, 1990) are also used in this report. Wells 19-23-701, 32-37-702, and 33-19-301 were not used due to unreliable water-level measurements owing to well problems and were replaced with nearby wells 19-15-701, 19-60-601, and 33-50-502, respectively.

Groundwater flow in the Antlers and Twin Mountains Formations of the Trinity aquifer is generally to the east-southeast (Figure 4). A cone of depression caused by heavy pumpage is centered in northern-eastern Tarrant County and extends into Dallas and Denton Counties (Figure 4). Another potential cone of depression may exist in northwest Ellis County. The largest change in water level between 1989 and 1997 is centered around the city of Euless within the Dallas-Ft. Worth metroplex (Figure 5). Water-level declines in this area range from 50 to 200 feet and extend from northeastern Tarrant County to western Dallas County. Water levels have risen approximately 150 feet in southern Denton County and 200 feet in southeastern Tarrant County and southwestern Dallas County. Water levels have recovered in northern Johnson County but continue to decline in the southern part of the county.

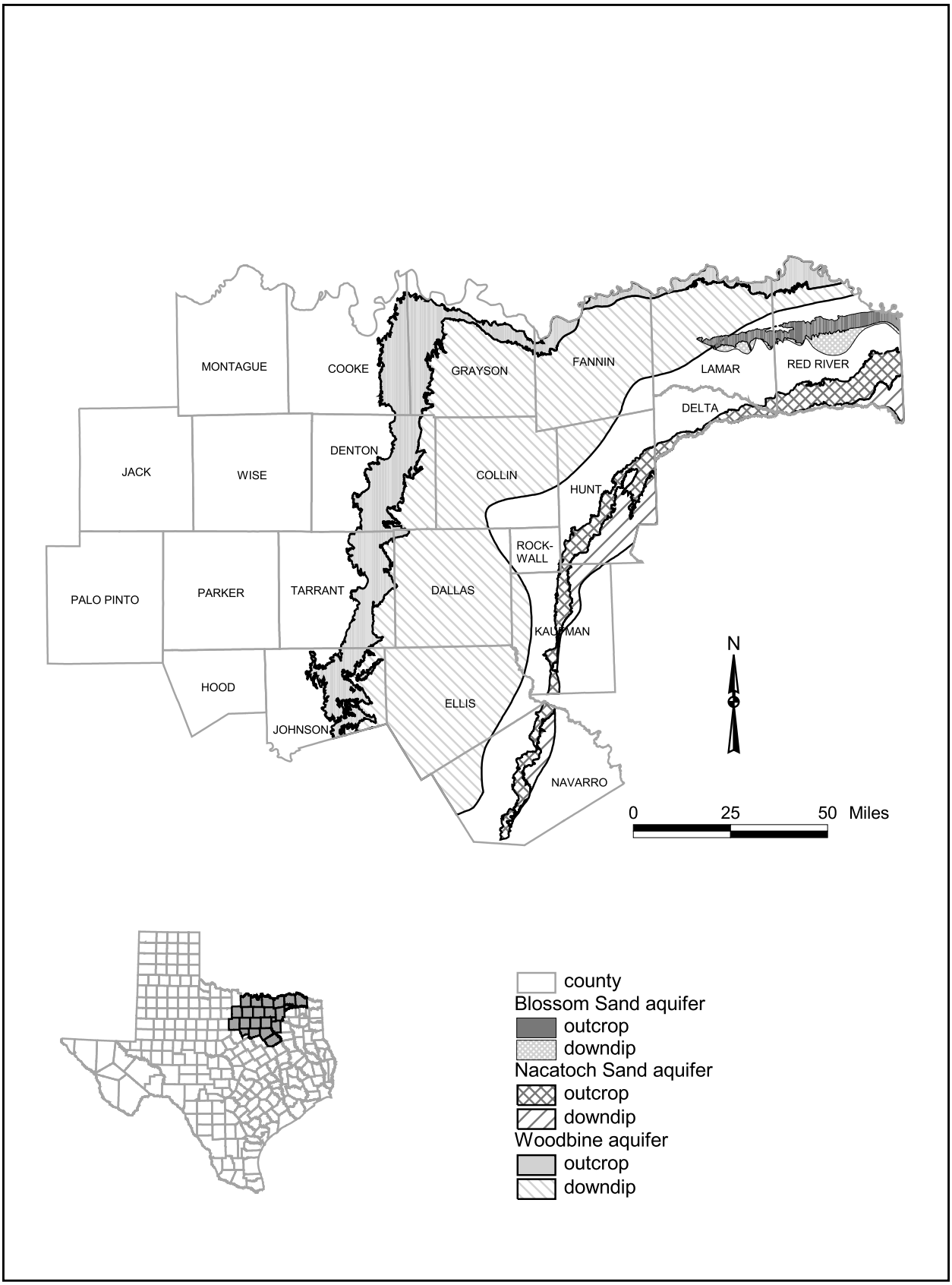

Figure 3. Location of minor aquifers in the study area.

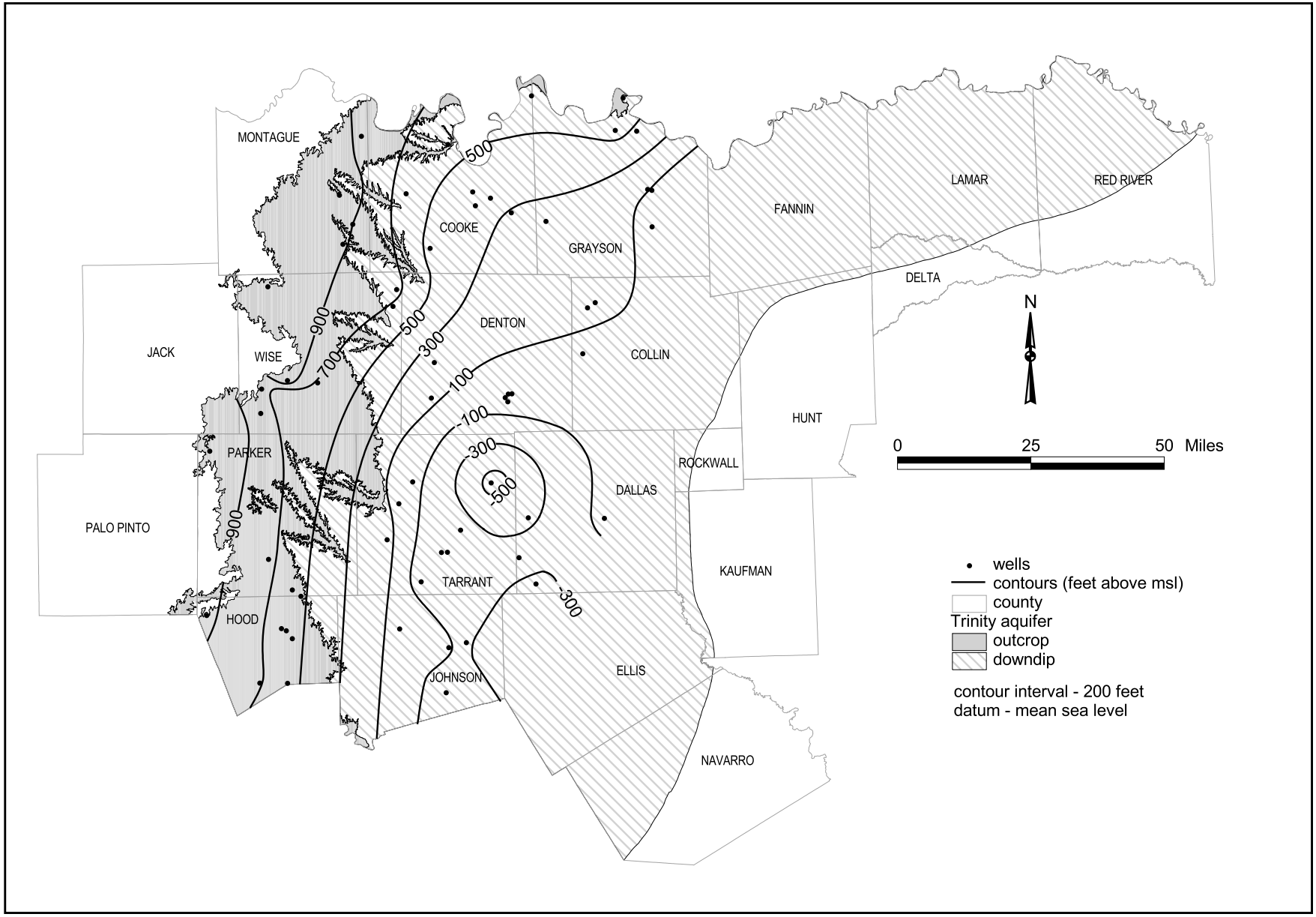

Figure 4. Approximate water-level elevations in the Antlers and Twin Mountains Formations, Trinity aquifer, winter 1997.

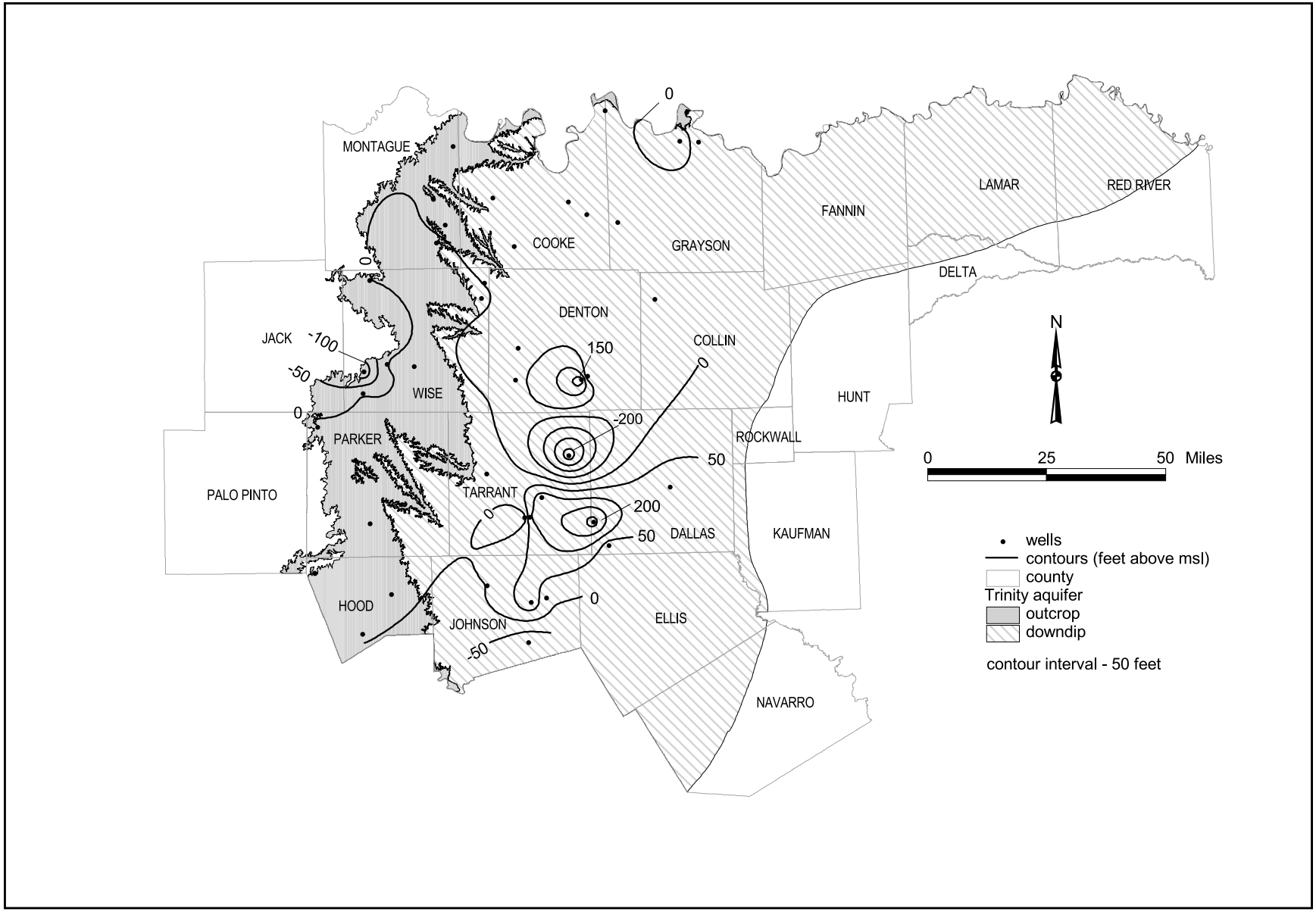

Figure 5. Approximate water-level differences in the Antlers and Twin Mountains Formations, Trinity aquifer, between 1989 and 1997.

Water levels in individual wells in the Antlers and Twin Mountains Formations show a variety of historical water-level changes (Figure 6). Some wells show little change over the past 30 years (19-20-801, 19-51-901, 19-15-701) while others show overall declines ranging from 200 to 500 ft (32-46-907, 19-24-702, 32-16-101). A well in Dallas County (33-19-101) shows a water-level decline of 143 feet from 1970 to 1985 and has recovered 99 feet since 1985. Since 1989, water levels in selected wells have declined as much as 235 feet and rebounded as much as about 75 feet (Table 1). Rates of water-level changes between 1989-1997 range from +8.33 to –29.36 feet per year (Table 1).

Groundwater flow in the Paluxy Formation is generally to the east-southeast (Figure 7). Water levels have declined in the northern portion of the aquifer and risen for most of the southern portion since 1989 (Figure 8). The greatest water-level differences between 1989 to 1997 occur north of Parker and Tarrant Counties. Water-level elevations in Denton County have decreased 15 to 35 feet, while most of Tarrant County shows an increase of 5 to 25 feet (Figure 8).

Well ID	County	Formation	Measurement Period	Average Yearly Difference(ft)	Total Water- Level Difference (ft)
19-20-801	Montague	Antlers	1970-1989 1989-1997	+2.20 -0.26	+41.87 -2.09
19-51-901	Wise	Twin Mtns	1970-1989 1989-1997	-0.02 +0.52	-0.41 +4.14
32-46-907	Johnson	Trinity	1972-1989 1989-1997	-22.41 -12.50	-381.00 -100.00
19-15-701	Cooke	Antlers	1970-1989 1989-1997	-1.40 -1.52	-26.65 -12.17
19-24-702	Cooke	Antlers	1960-1989 1989-1997	-7.00 -4.12	-181.90 -32.99
33-19-101	Dallas	Twin Mtns	1970-1989 1989-1998	-6.26 +8.33	-118.81 +74.98
32-16-101	Tarrant	Twin Mtns	1970-1989 1989-1997	-10.68 -29.36	-203.00 -234.85

Table 1. Water-level differences within the Antlers and Twin Mountains Formations, Trinity aquifer (based on data from TWDB, 1998a).

Water levels in individual wells in the Paluxy Formation show a variety of historical water-level changes (Figure 9). Two wells show little change over the past 30 years (19-60-601, 32-02-101) while one shows an overall decline of about 220 ft (18-49-101). A well in Tarrant County (32-16-201) shows large historical variations including a 220 foot rise between 1972 and 1976 and 25 to 100 ft variations since 1980. Since 1989, water levels in selected wells have declined as much as 55 feet and rebounded less than 3 feet (Table 2). Rates of water-level changes between 1989-1997 range from +0.36 to –13.75 feet per year (Table 2).

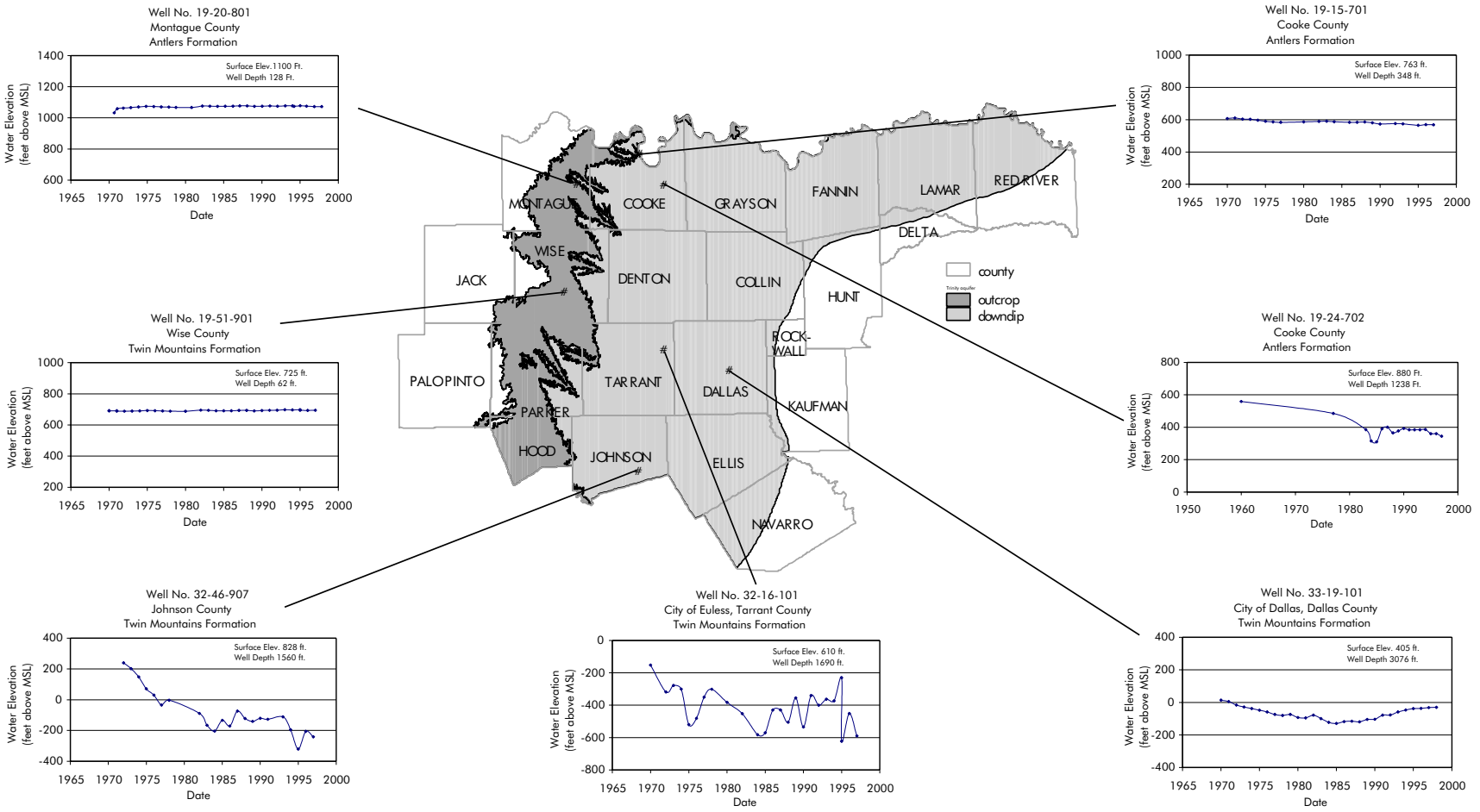

Figure 6. Hydrographs of selected wells in the Antlers and Twin Mountains Formations, Trinity aquifer.

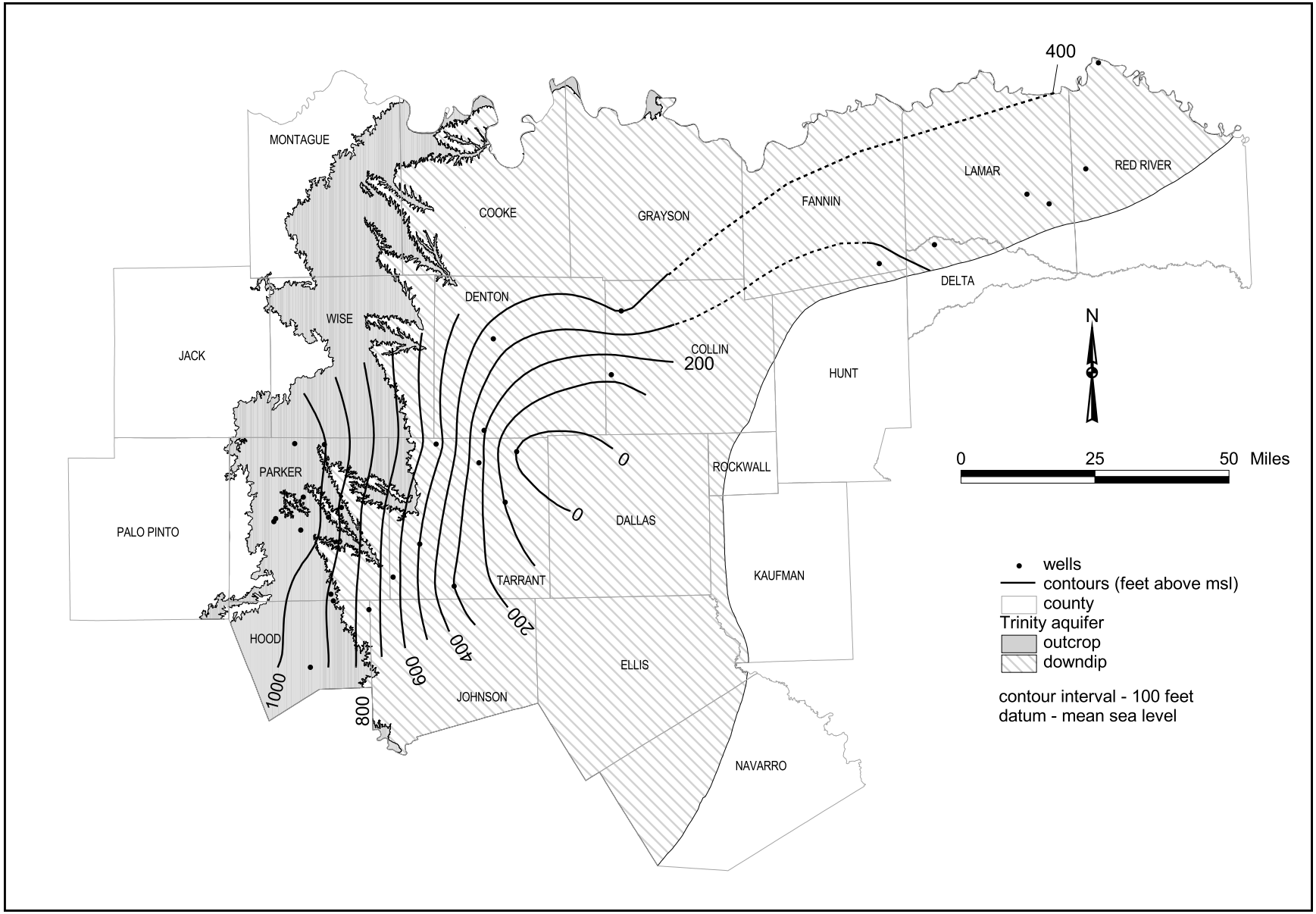

Figure 7. Approximate water-level elevations in the Paluxy Formation, Trinity aquifer, 1997.

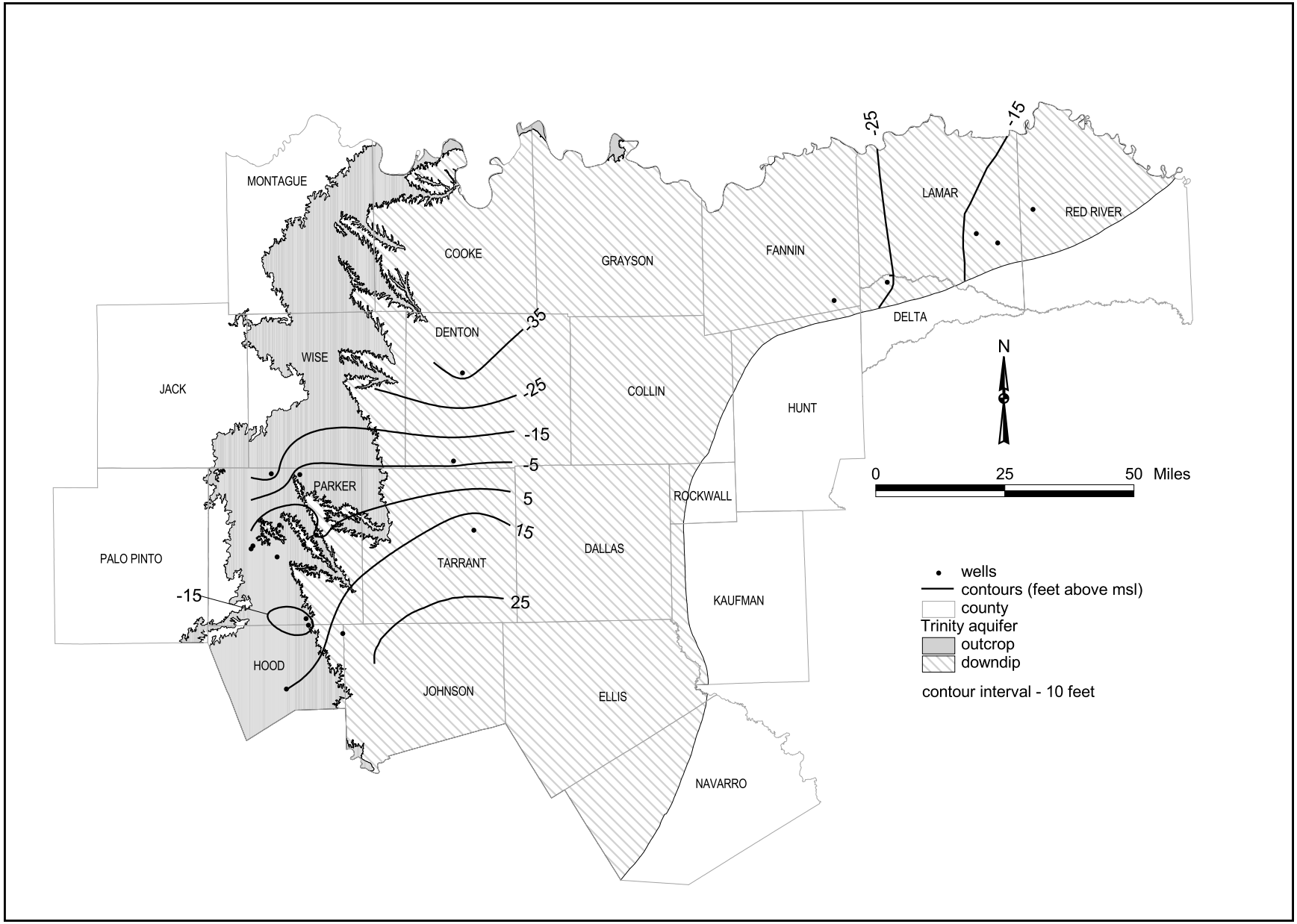

Figure 8. Approximate water-level differences in the Paluxy Formation, Trinity aquifer, between 1989 and 1997.

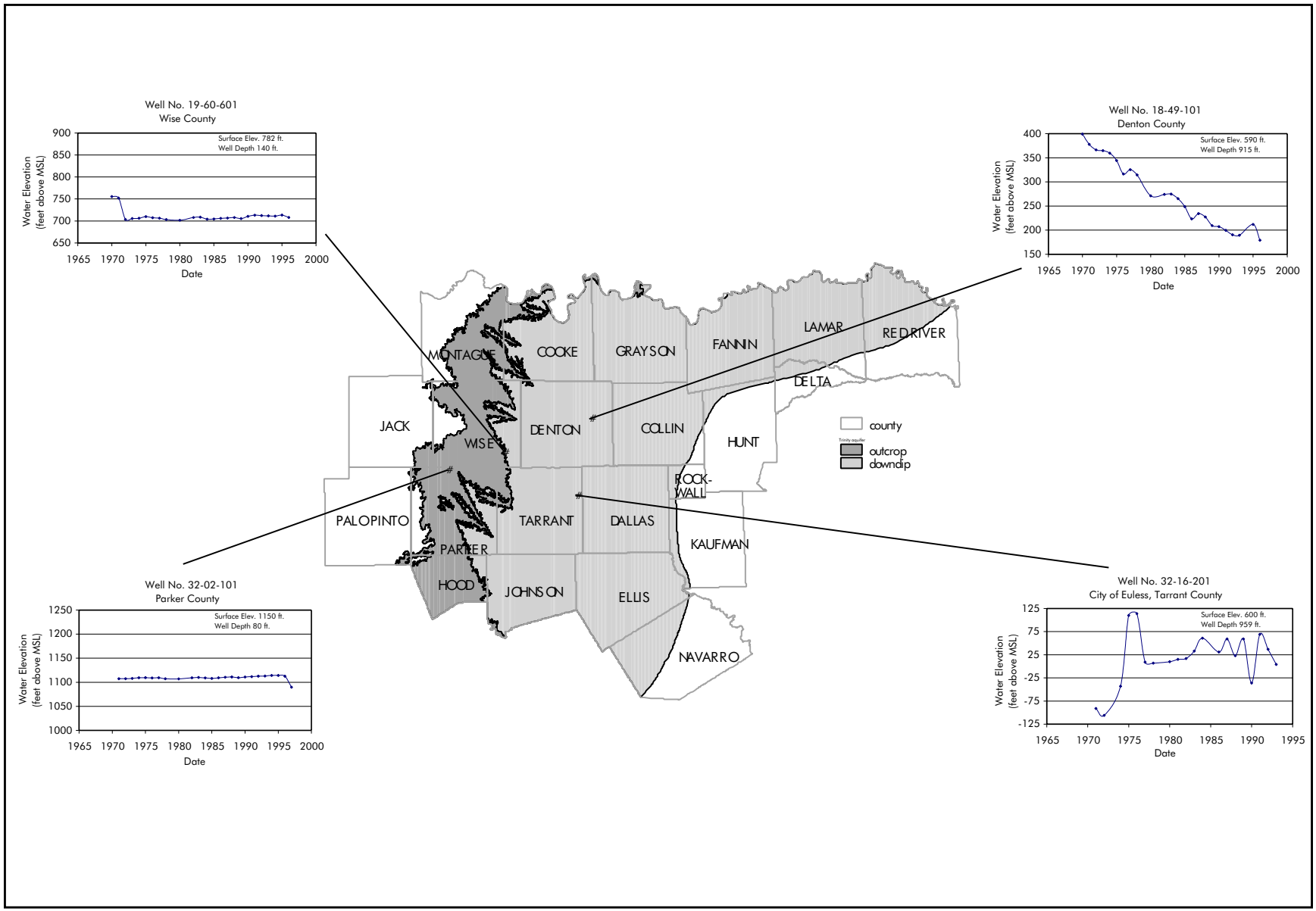

Figure 9. Hydrographs of selected wells in the Paluxy Formation, Trinity aquifer.

Well ID	County	Formation	Measurement Period	Average Yearly Difference(ft)	Total Water- Level Difference (ft)
19-60-601	Wise	Paluxy	1970-1989	-2.63	-50.03
			1989-1996	+0.36	+2.52
32-02-101	Parker	Paluxy	1971-1989	+0.11	+2.03
			1989-1997	-2.47	-19.75
18-49-101	Denton	Paluxy	1970-1989	-9.99	-189.99
			1989-1996	-4.31	-30.16
32-16-201	Tarrant	Paluxy	1971-1989	+8.33	+150.00
			1989-1993	-13.75	-55.00

Table 2. Water-level differences within the Paluxy Formation, Trinity aquifer (based on data from TWDB, 1998a).

Groundwater flow in the Woodbine aquifer is generally to the east-southeast (Figure 10). Water-level elevations have not changed significantly since 1989 (Figure 11). The greatest water-level differences occur in northern Collin County, the central to northeastern portion of Denton County, eastern Cooke County, and northern Grayson County (Figure 11). Water levels have declined an average of 10 feet over most of this area, with declines of 60 feet observed in the northern part of Grayson County. Water levels in Johnson County have remained steady from 1989 to 1997.

Water levels in individual wells in the Woodbine aquifer show a variety of historical water-level changes (Figure 12). Some wells show little change over the past 30 years (18-25-301, 32-39-505, 17-12-101) while others show overall declines (18-50-202, 18-38-302, 33-50-502). A well in Fannin County (18-38-302) shows a decline of about 179 feet from 1971 to 1989 with generally stable water levels since 1989. Since 1989, water levels in selected wells have declined as much as 42 feet and rebounded less than 3 feet (Table 3). Rates of water-level changes between 1989-1997 range from +0.34 to –5.94 feet per year (Table 3).

Well ID	County	Formation	Measurement Period	Average Yearly Difference(ft)	Total Water- Level Difference (ft)
18-25-301	Grayson	Woodbine	1971-1989	-0.67	-12.07
			1989-1997	-0.17	-1.38
18-50-202	Collin	Woodbine	1969-1989	-1.25	-25.05
			1989-1997	-1.16	-9.27
32-39-505	Johnson	Woodbine	1966-1989	-0.90	-20.69
			1989-1997	+0.10	+0.82
17-12-101	Lamar	Woodbine	1959-1989	+0.14	+4.12
			1989-1997	+0.34	+2.70
18-38-302	Fannin	Woodbine	1971-1989	-9.94	-179.00
			1989-1997	-0.48	-3.80
33-50-502	Ellis	Woodbine	1971-1989	+0.14	+2.45
			1989-1996	-5.94	-41.60

Table 3. Water-level differences within the Woodbine aquifer (based on data from TWDB, 1998a).

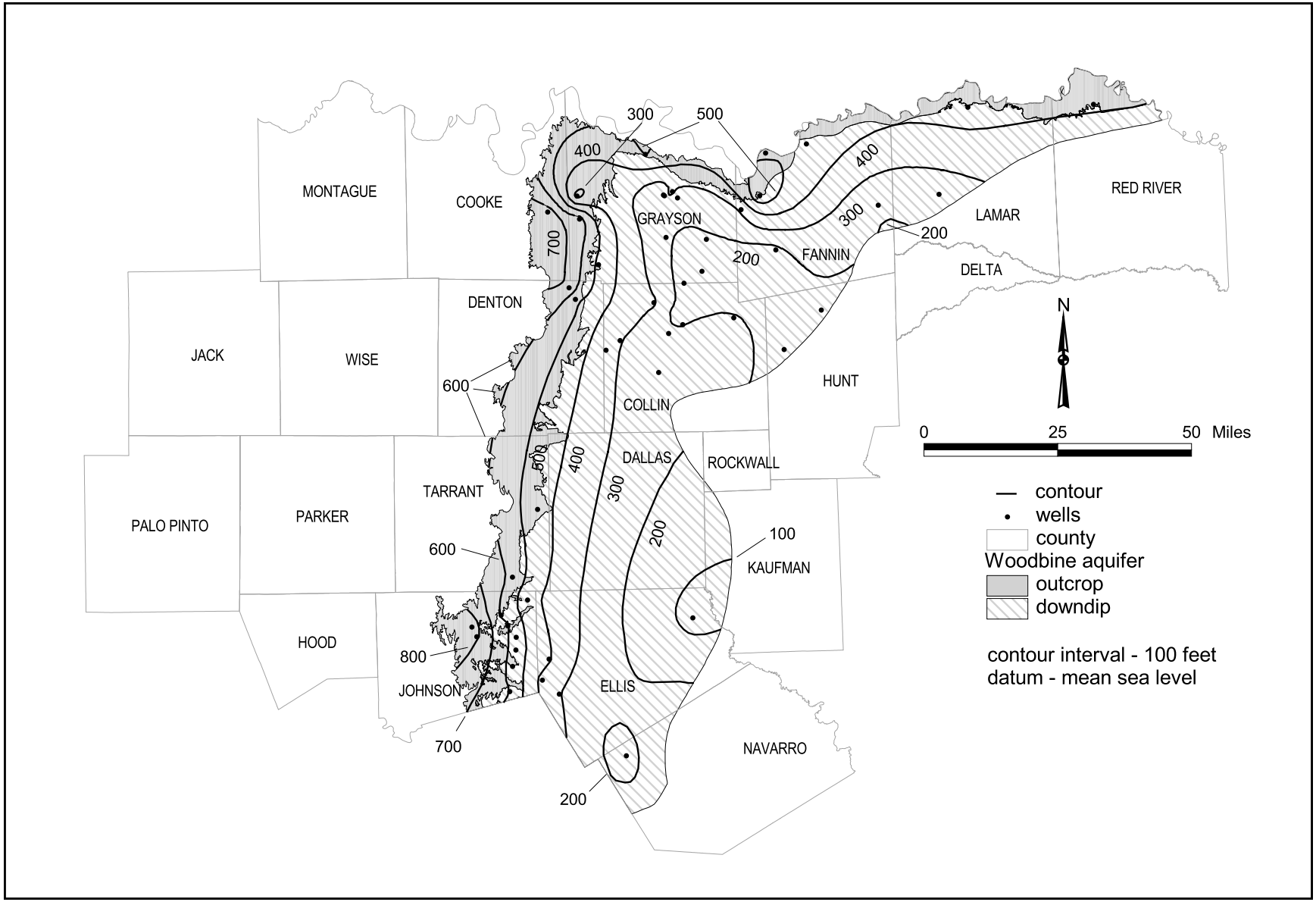

Figure 10. Approximate water-level elevations in the Woodbine aquifer, 1997.

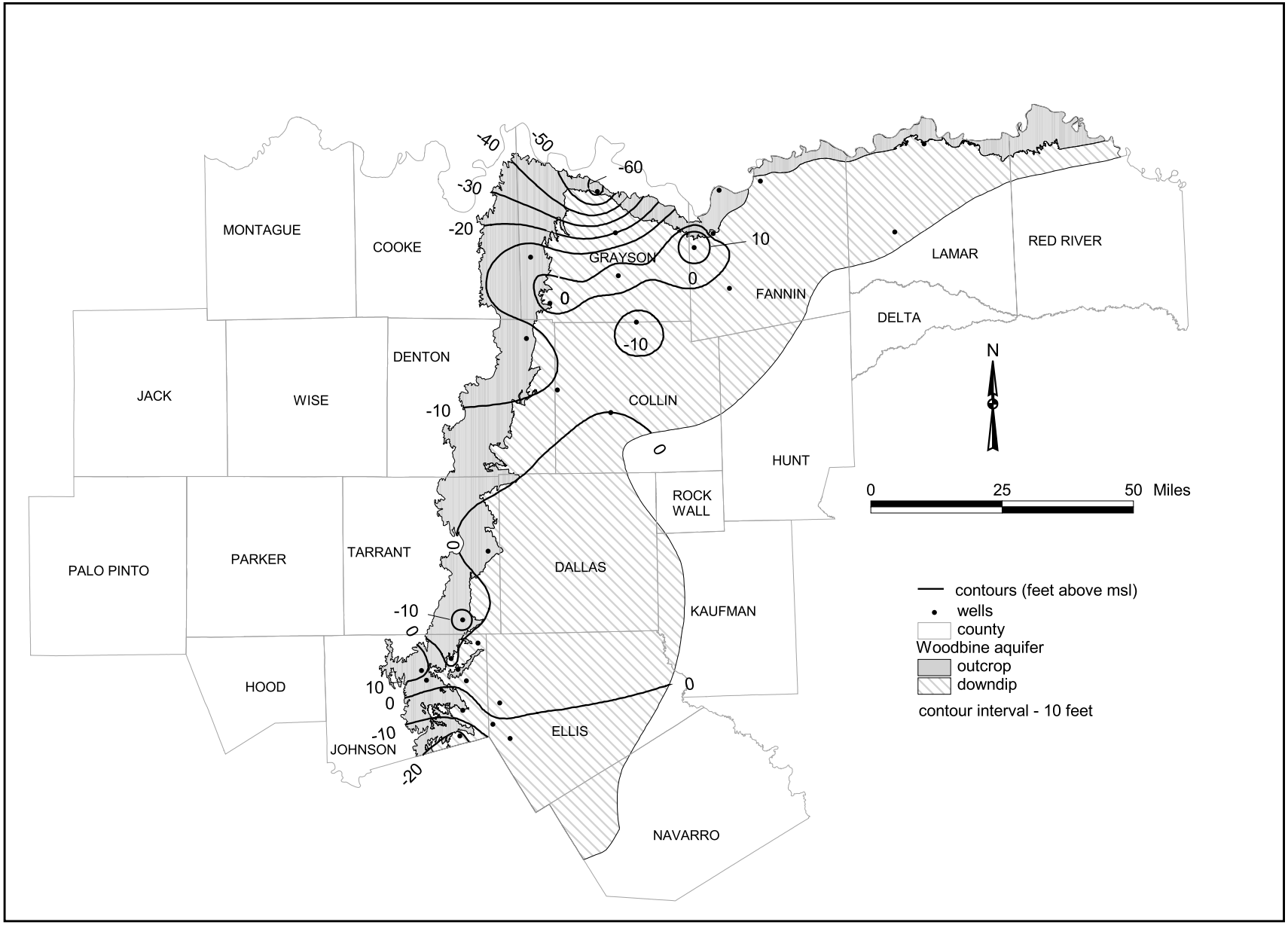

Figure 11. Approximate water-level differences in the Woodbine aquifer, between 1989 and 1997.

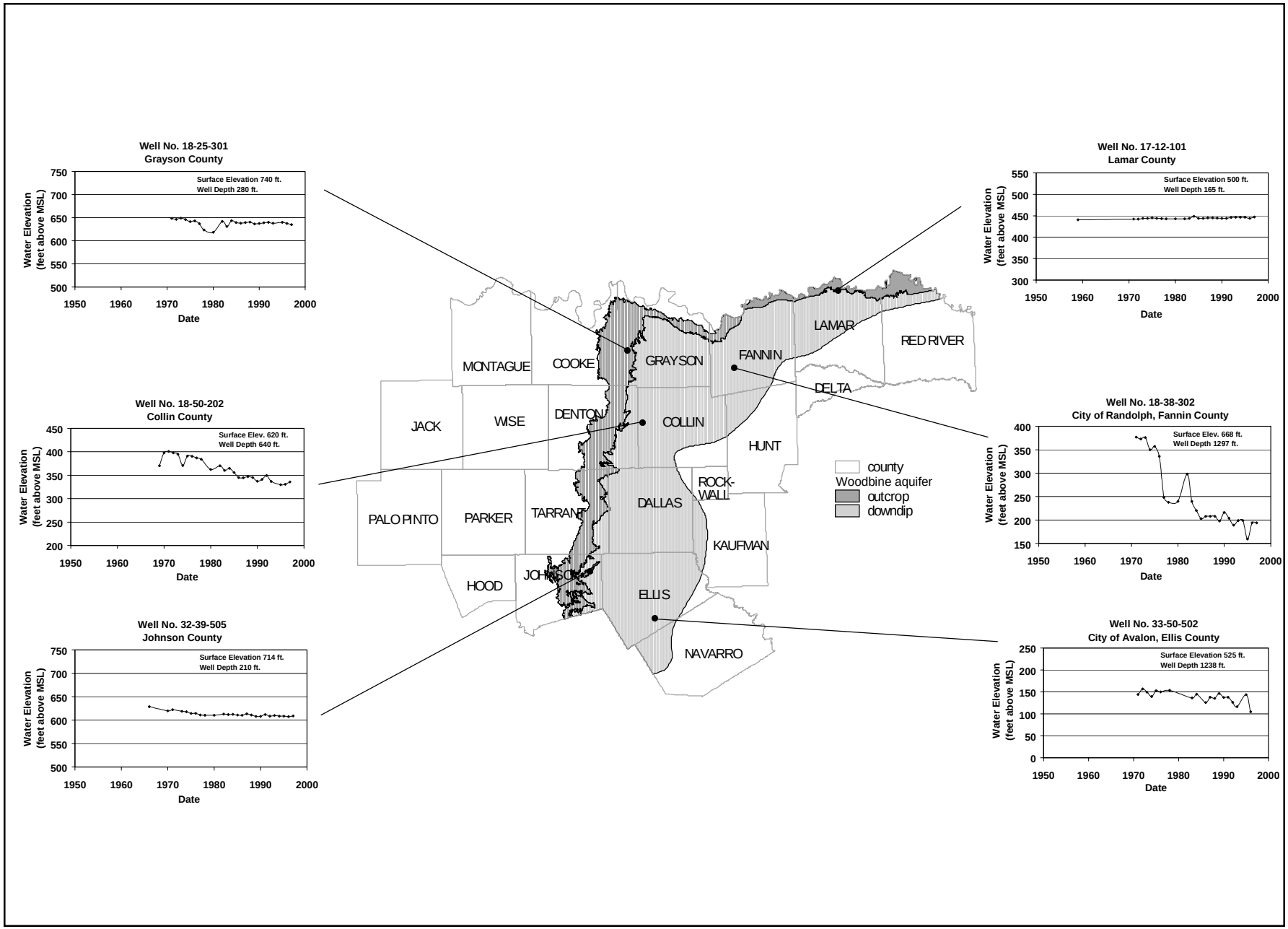

Figure 12. Hydrographs of selected wells in the Woodbine aquifer.

Precipitation

The primary source of recharge to the Trinity and Woodbine aquifers is infiltration from precipitation falling on the outcrop (Nordstrom, 1982). The amount of recharge to the Trinity and Woodbine aquifers is estimated to be less than one inch per year (Nordstrom, 1982). This amounts to about 3 percent of average annual precipitation in the area.

Annual precipitation varies from 28-32 inches in the western part of the study area to 44-48 inches in the eastern part (Nordstrom, 1982). From 1960 through 1996, average annual precipitation at the Weatherford gage, located on the Trinity outcrop, has been 33 inches with a minimum of 19 inches in 1963 and a maximum of 49 inches in 1991 (Figure 13). Precipitation has been above average from 1989 through 1996.

From 1965 through 1996, average annual precipitation at the Denton SE gage, located on the Woodbine outcrop, has been 38 inches with a minimum of 27.5 inches in 1972 and a maximum of 57 inches in 1981 (Figure 14). Precipitation has been above average from 1992 through 1995.

Water Quality

The TWDB collected water samples following standard procedures (Nordstrom and Beynon, 1991) from the Trinity and Woodbine aquifers between 1990 to 1998 throughout the study area. Samples were analyzed for major anions and cations and selected trace elements including nitrate, nitrogen (as NO_3), sulfate, chloride, sodium, calcium, magnesium, silica, total potassium, strontium, carbonate, bicarbonate, and fluoride.

Measured concentrations were compared to the primary constituent levels. Primary constituent levels are the maximum contaminant levels for a pollutant that is allowed in drinking water which will cause no adverse effects on human health. Secondary constituent levels are usually based on reasons such as color, taste, odor, staining, and scaling and are recommended limits (30 TAC §290, 1999).

Maximum contaminant levels (MCLs) for applicable constituents (30 TAC §290, 1999) include:

- a secondary constituent level of 1,000 mg/l for TDS,
- a primary constituent level of 10 mg/l for nitrate as nitrogen,
- a primary constituent level of 44.3 mg/l for nitrate as nitrate,
- a secondary constituent level of 300 mg/l for sulfate,
- a secondary constituent level of 300 mg/l for chloride,
- a primary constituent level of 4.0 mg/l for fluoride, and
- a secondary constituent level of 2.0 mg/l for fluoride.

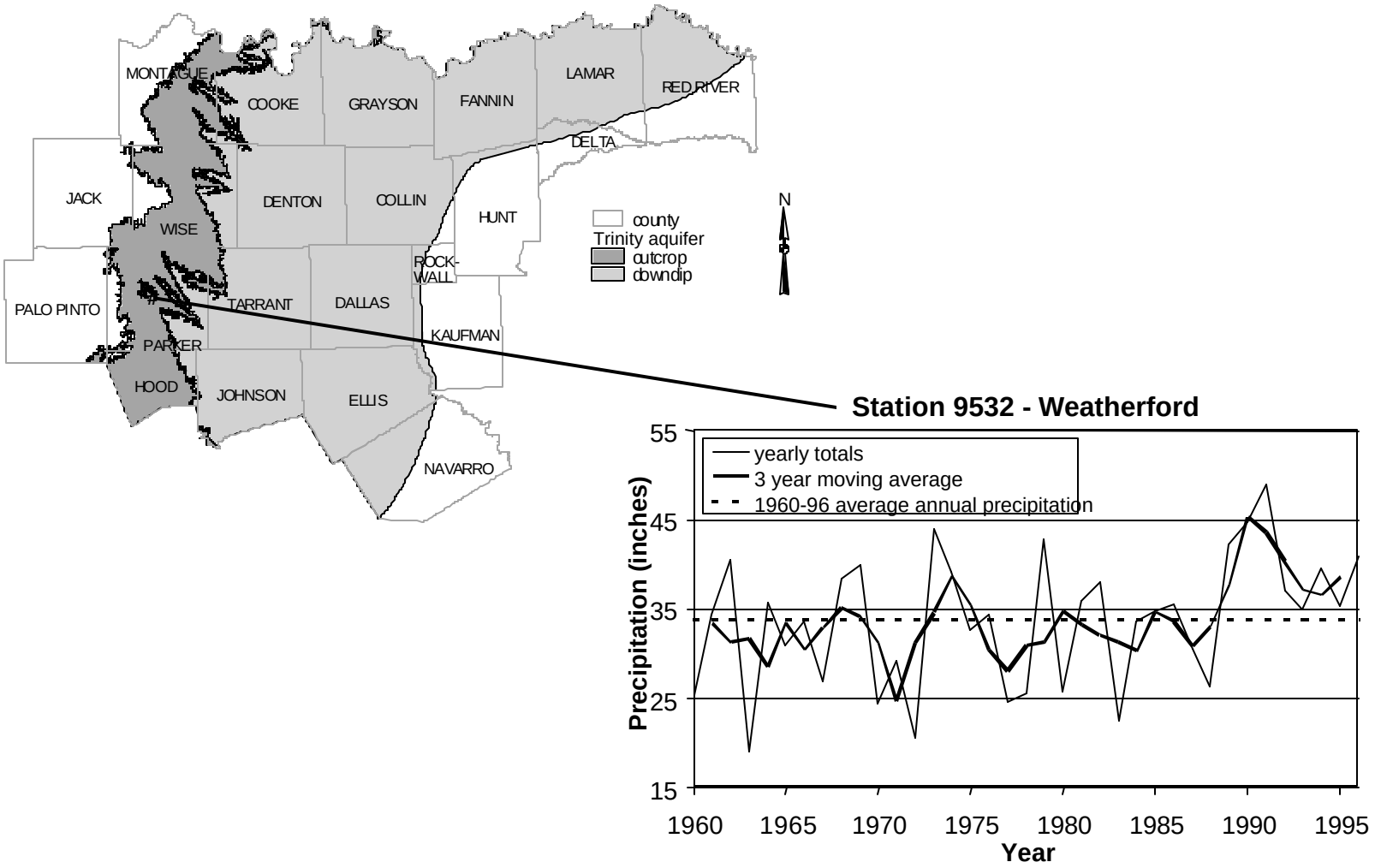

Figure 13. Precipitation at the Weatherford gage, 1960-1996

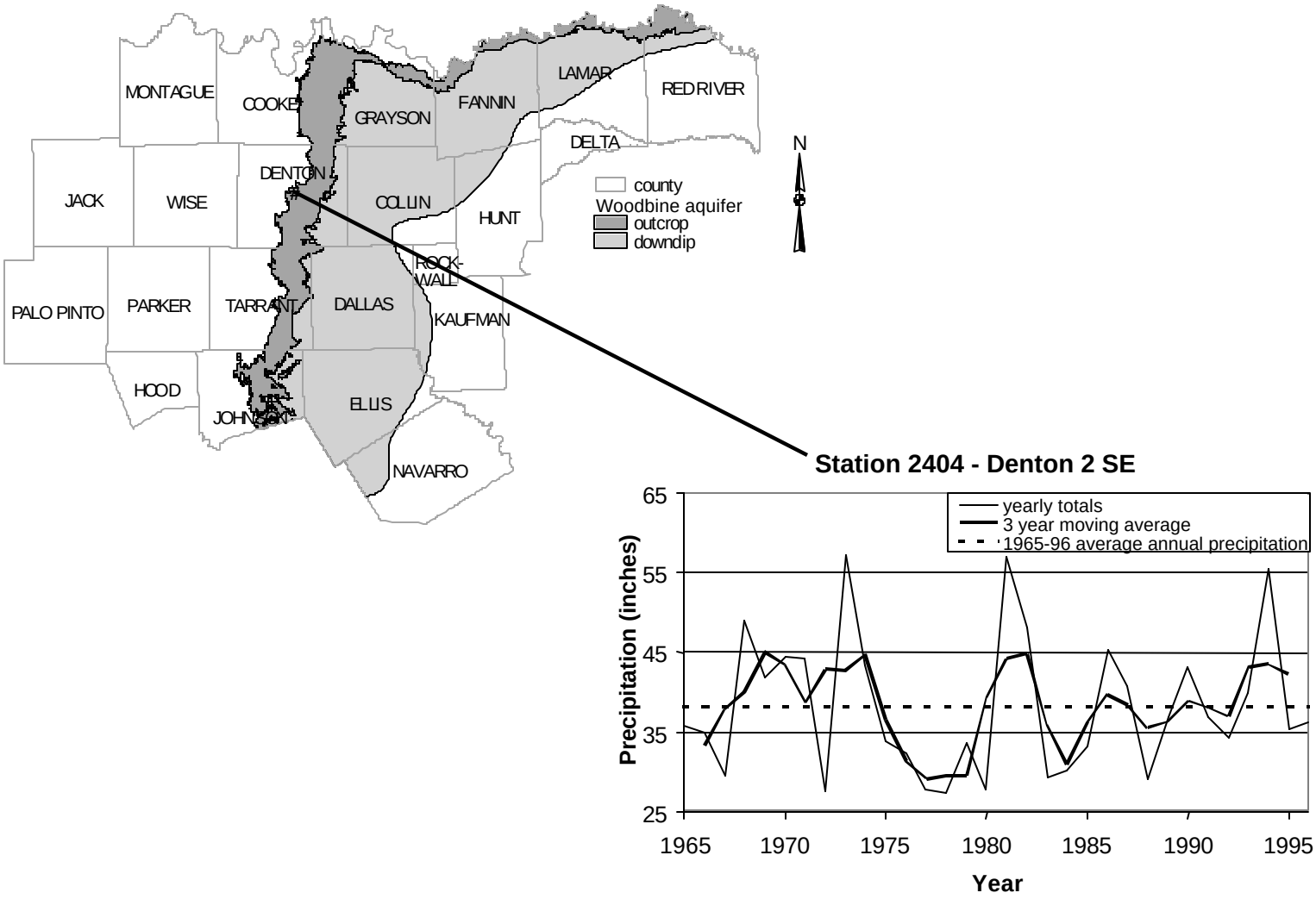

Figure 14. Precipitation at the Denton 2SE gage, 1965-1995.

TDS concentrations for groundwater samples from the Antlers and Twin Mountains Formations of the Trinity aquifer tend to increase downdip, towards the eastern part of the study area (Figure 15). Twenty wells exhibited TDS concentrations in excess of the secondary constituent level. Only 2 wells showed TDS concentrations above 2,000 mg/l. Chloride concentrations averaged 98 mg/l (Table 4), with 12 samples exceeding secondary constituent levels. Sodium concentrations had an average of 245 mg/l (Table 4). Nitrate concentrations averaged 1.00 mg/l (Table 4) with 5 samples exceeding primary constituent levels.

Parameter	No. of Samples	Average *(mg/l)*	Minimum *(mg/l)*	Maximum *(mg/l)*
TDS	131	717.67	221.00	2,038.00
Chloride	131	98.21	3.00	647.00
Sodium	131	245.26	8.80	657.00
Nitrate as N	129	1.00	<0.04	18.50
Sulfate	131	103.10	12.00	725.00
Fluoride	131	0.90	0.04	3.06

Table 4. Groundwater quality in the Antlers and Twin Mountains Formations, Trinity aquifer (based on data from TWDB 1998a).

Sulfate levels had an average of 103 mg/l (Table 4) with 4 samples exceeding 300 mg/l. The average fluoride concentration was 0.90 mg/l (Table 4) with the highest concentration reading 3.06 mg/l.

The highest TDS, chloride, and sodium levels were recorded in samples from well 32-06-104, located in north-central Tarrant County. The TDS concentration was 3,302 mg/l, chloride was 1,822 mg/l, and sodium was 1,210 mg/l. This area exhibits higher than normal TDS values possibly due to contamination from oil and gas production, as well as various other industries (Baker and others, 1990). Therefore, this well was not included in computing the average concentrations above.

Well 33-26-301, located in south-central Dallas County, is owned by the City of Lancaster and is currently used for backup purposes only. The TDS concentration was 2,038 mg/l, with chloride, sodium, and sulfate concentrations of 326 mg/l, 657 mg/l, and 725 mg/l, respectively, and probably reflects natural conditions.

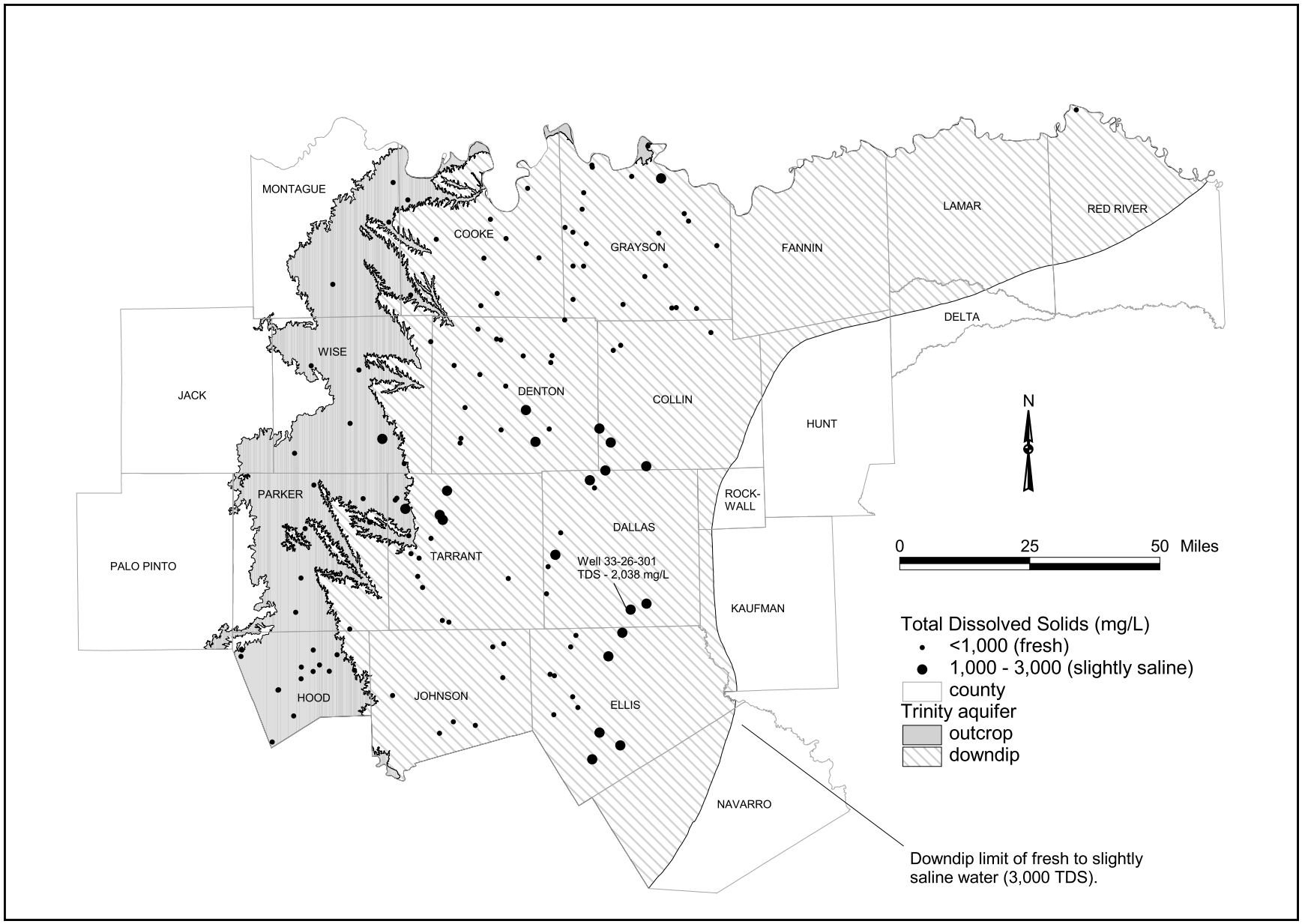

Figure 15. TDS concentrations in the Antlers and Twin Mountains Formations, Trinity aquifer, 1990-1998.

The majority of samples exhibiting elevated TDS, chloride, sodium, and sulfate concentrations were collected from the Twin Mountains Formation. The areas showing high TDS concentrations include north-central Tarrant County and parts of Denton, Collin, Dallas, and Ellis Counties. Current TDS ranges are not significantly higher than historical values reported by Baker and others (1990).

In general, groundwater quality in the Paluxy Formation of the Trinity aquifer has remained acceptable throughout the study area. TDS concentrations for water samples collected from the Paluxy Formation averaged 607 mg/l (Table 5) with only 4 out of 51 wells sampled showing TDS concentrations above the secondary constituent level (Figure 16). The highest TDS concentration was 1,339 mg/l and was recorded at an irrigation well (18-58-503) located in Collin County. Chloride, sodium, sulfate and nitrate concentrations for this well were 31 mg/l, 431 mg/l, 590 mg/l and <0.04 mg/l, respectively.

Parameter	No. of Samples	Average *(mg/l)*	Minimum *(mg/l)*	Maximum *(mg/l)*
TDS	51	606.70	203.00	1,339.00
Chloride	51	36.08	4.00	273.00
Sodium	51	187.76	7.10	444.00
Nitrate as N	51	1.00	<0.04	25.85
Sulfate	51	101.25	0.89	590.00
Fluoride	51	1.06	0.17	4.10

Table 5. Groundwater quality in the Paluxy Formation, Trinity aquifer (based on data from TWDB, 1998a).

Chloride and nitrate as nitrogen levels averaged 36 mg/l and 1 mg/l, respectively, and were all within primary constituent levels with the exception of one nitrate sample (Table 5). The highest nitrate concentration originated from well 32-10-603, located north of Weatherford in Parker County. This well is designated as a public supply well and had a nitrate level of 25.85 mg/l.

Sulfate and fluoride levels averaged 101 mg/l and 1.0 mg/l, respectively (Table 5). One sulfate sample (from well 18-58-503, described above) and one fluoride sample (from well 32-39-805, located in Johnson County) exceeded secondary constituent levels.

Woodbine Aquifer

Generally, TDS concentrations increase downdip towards the eastern part of the study area (Figure 17). Average TDS was 877 mg/l (Table 6) with the highest concentration (2,278 mg/l) from a public supply well (32-47-805) for the city of Grandview in southeastern Johnson

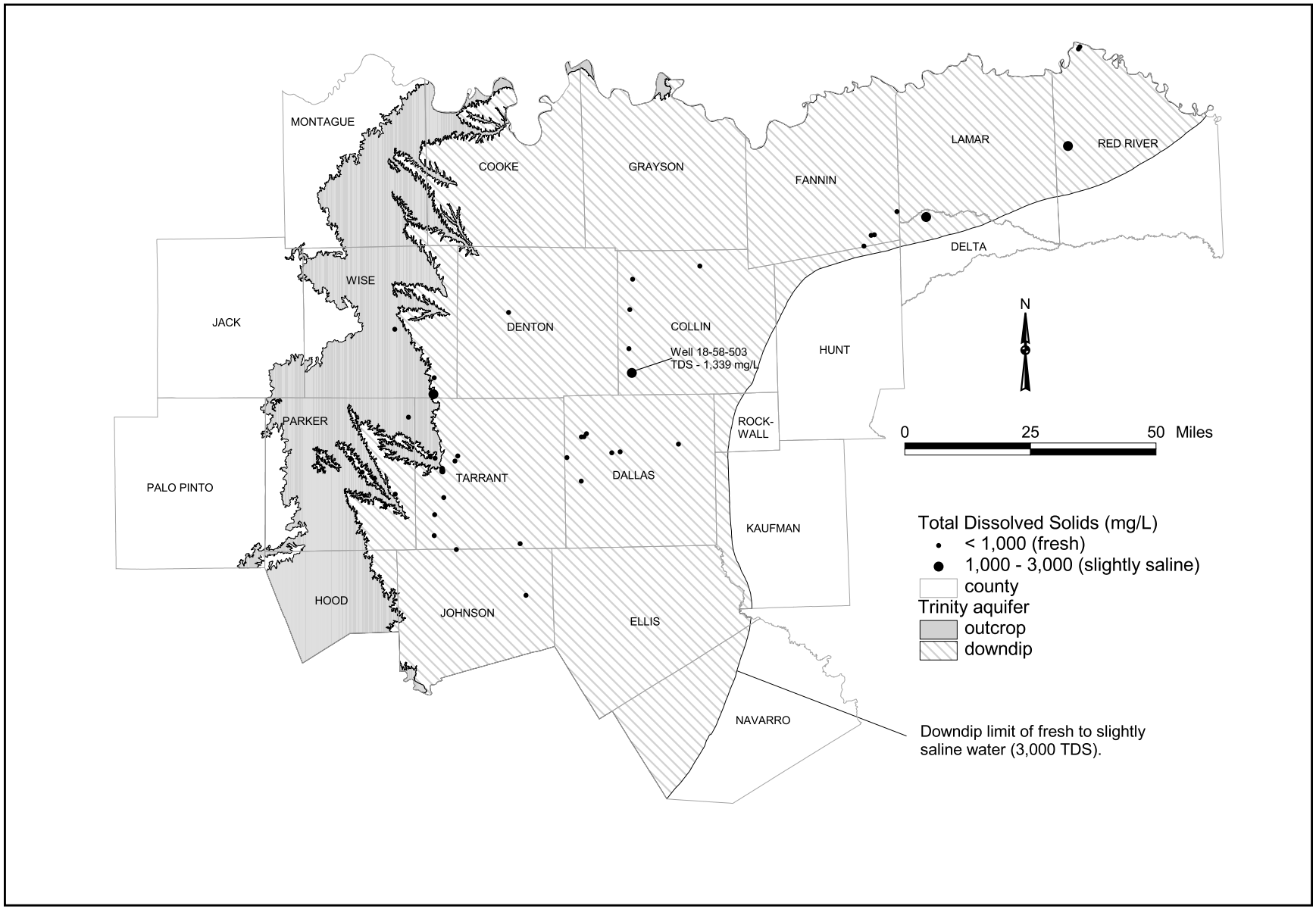

Figure 16. TDS concentrations in the Paluxy Formation, Trinity aquifer, 1990-1998.

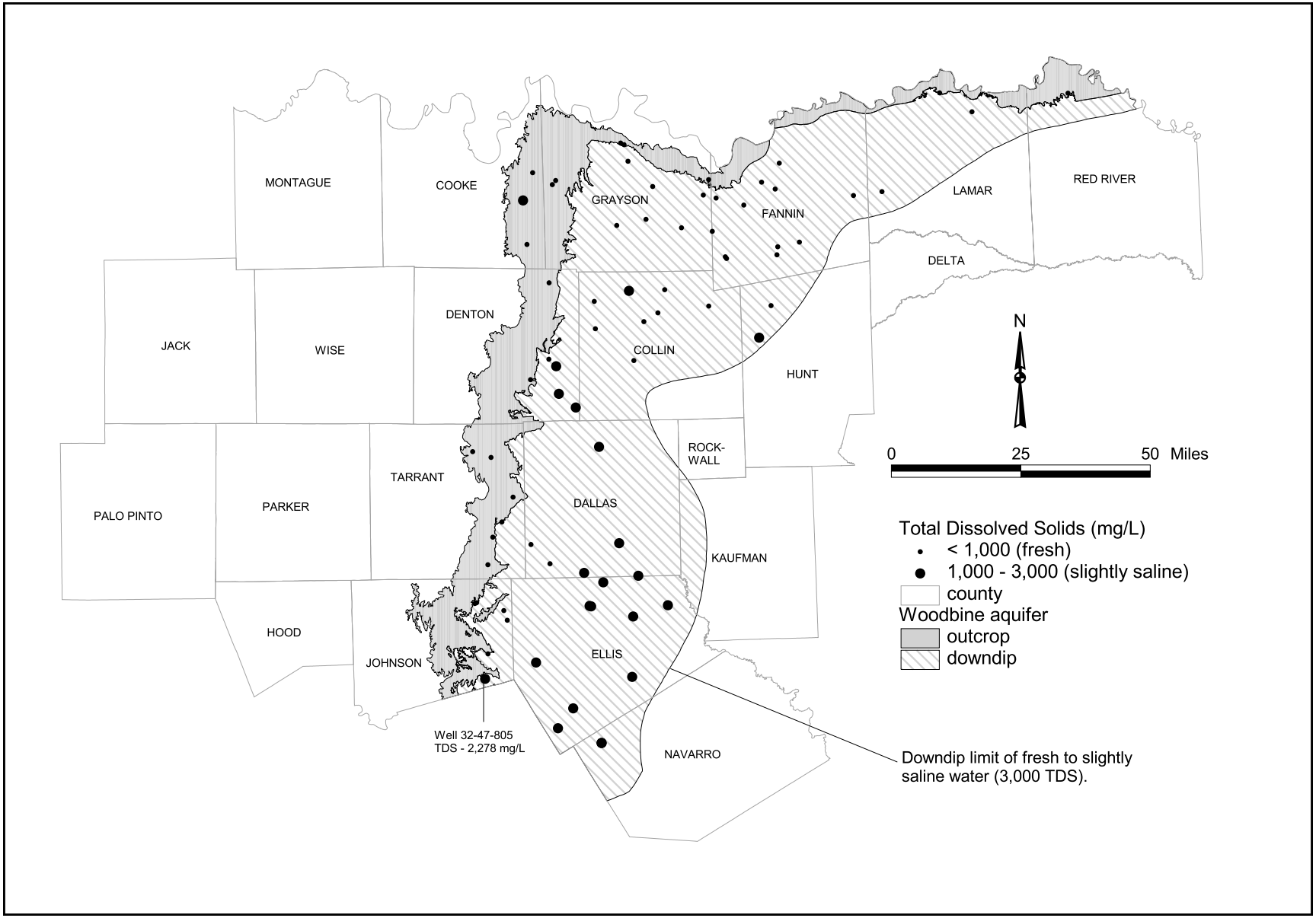

Figure 17. TDS concentrations in the Woodbine aquifer, 1990-1998.

County. Chloride had an average concentration of 86 mg/l (Table 6) with 5 wells exceeding secondary constituent levels. Well 18-55-401, a public supply well owned by Caddo Basin Special Utility District located in Greenville (Hunt County), had the highest chloride concentration of 507 mg/l.

Parameter	No. of Samples	Average *(mg/l)*	Minimum *(mg/l)*	Maximum *(mg/l)*
TDS	76	877.39	83.00	2,278.00
Chloride	76	85.88	4.07	507.00
Sodium	76	311.76	9.53	825.00
Nitrate as N	76	0.67	<0.04	10.41
Sulfate	76	209.18	5.42	1,263.00
Fluoride	76	1.30	0.24	6.27

Table 6. Groundwater quality of the Woodbine aquifer (based on data from TWDB, 1998a).

Concentrations of nitrate (as nitrogen) averaged 0.67 mg/l with only one well exceeding primary constituent levels throughout the Woodbine aquifer. The highest nitrate concentration (10.41 mg/l) was recorded at a private well (18-13-803) in Grayson County.

Historically, the Woodbine aquifer has exhibited high sulfate levels associated with extensive lignite beds, especially in the southern outcrop areas of Tarrant and Johnson counties (Baker and others, 1990). Recent groundwater sampling results indicate that sulfate levels have remained elevated with 28 percent of the sampled wells exceeding secondary constituent levels. Elevated sulfate concentrations (>300 mg/l) were observed in 21 wells, with 4 wells containing concentrations above 500 mg/l. The wells are generally located downdip of the outcrop, towards the east.

WATER DEMANDS

Water demands are the projected needs for water in an area. Projected water demands are based on population projections, extrapolation of historical water use, and assumptions on water use.

Population

Population estimates by the TWDB are divided into 2 categories: major city and county-other. Cities that are county seats or have a population of at least 1,000 people are classified as major cities. All other cities and the rural county population are classified as county-other. Population estimates for both major city and county-other were divided using Geographic Information System (GIS) techniques on the basis of 1990 census data from the Bureau of Census statistics. Data for 1985 and 1995 (Table 7) are estimates based on county demographic data and Bureau of Census statistics for 1980 and 1990. Projected populations to 2030 (Table 7) are based on projections used in *Water for Texas, A Consensus-based Update to the State Water Plan* (TWDB, 1997).

North-central Texas is the most populated region in the State, containing 24 percent of the state's population with 4.12 million people in 1990 (TWDB, 1997). From 1985 to 1995, the population in the study area increased by 22 percent (Table 7), and is expected to increase 63 percent from 1995 to 2030 (Table 7). The 1985, 1990, and 1995 populations for cities, rural areas, and counties included in the study area, along with future projections through the year 2030, are shown in Table 7 (TWDB, 1998b).

Historical Water Use

An estimated total of 86,982 acre-feet of groundwater was pumped from the study area for municipal, manufacturing, steam-electric, mining, irrigation and livestock purposes in 1995 (Table 8). This reflects a 19 percent reduction in overall groundwater pumpage from the previous 10 years.

	1985	1990*	1995	2000	2010	2020	2030
Collin County [1]							
Allen	13,260	18,309	25,349	36,269	71,847	90,582	107,716
Celina	1,784	1,737	2,069	2,354	2,816	3,476	4,060
Dallas [2]	2,443	26,325	27,423	28,678	30,407	34,329	37,262
Fairview	1,178	1,554	2,189	2,461	3,051	3,855	4,581
Farmersville	2,810	2,640	3,178	3,537	4,125	4,999	5,761
Frisco [2]	4,557	6,141	12,331	13,783	32,295	39,227	45,450
Garland	14	15	16	22	25	31	35
Lucas	1,682	2,205	3,059	2,969	3,909	5,135	6,263
McKinney	19,568	21,283	29,492	32,950	50,712	58,632	65,912
Melissa	0	557	764	803	1,085	1,158	1,269
Murphy	1,202	1,547	2,195	1,855	2,265	2,834	3,343
New Hope	0	523	587	557	578	589	623
Parker	1,482	1,235	1,422	1,585	1,975	2,505	2,984
Plano [2]	102,806	128,713	167,858	186,713	253,734	340,688	397,380
Princeton	4,436	2,321	3,187	2,156	2,115	2,112	2,108
Prosper	0	1,018	1,281	1,356	1,743	2,256	2,726
Richardson [2]	6,333	9,979	11,381	11,828	12,620	14,007	15,358
Sachse [2]	49	194	287	472	565	635	738
Wylie	4,448	8,662	10,268	12,373	16,698	21,188	25,293
County Other [2]	20,678	31,724	38,143	44,729	34,724	78,279	143,903
Total	**188,730**	**266,682**	**342,479**	**387,450**	**527,289**	**706,517**	**872,765**
Cooke County							
Gainesville	14,101	14,256	14,843	14,531	15,667	17,052	18,023
Muenster	1,298	1,387	1,473	1,453	1,566	1,705	1,802
County Other [2]	13,615	16,384	16,112	16,535	17,860	17,941	18,081
Total	**29,014**	**32,027**	**32,428**	**32,519**	**35,093**	**36,698**	**37,906**
Dallas County							
Addison	6,995	8,783	10,579	11,892	14,382	16,128	17,893
Balch Springs	18,286	17,406	18,606	21,998	24,747	26,774	27,802
Carrollton [2]	32,204	40,024	47,400	48,387	53,102	56,692	58,280
Cedar Hill [2]	11,014	19,926	23,749	27,203	37,205	48,309	62,751
Cockrell Hill	4,085	3,746	4,168	4,057	4,153	4,270	4,267
Combine [2]	0	434	469	504	590	682	762
Coppell	7,813	16,878	23,608	23,368	32,345	42,230	55,062
Dallas [2]	989,758	966,168	1,006,575	1,005,780	1,039,119	1,071,352	1,104,535
De Soto	22,404	30,544	34,147	35,571	45,670	55,264	63,870
Duncanville	33,569	35,748	37,021	39,323	42,924	45,691	46,865
Farmers Branch	27,999	24,250	24,974	25,381	26,665	29,021	31,039
Garland [2]	168,772	180,635	189,626	196,391	213,697	227,069	232,590

*Based on 1990 Census.

Table 7. Historical and projected populations for the study area (TWDB, 1998b).

	1985	1990*	1995	2000	2010	2020	2030
Dallas County (continued)							
Glenn Heights [2]	1,174	3,768	4,678	5,010	5,972	6,889	7,763
Grand Prairie [2]	84,261	81,527	88,306	88,257	95,439	96,990	100,536
Grapevine [2]	54	83	94	99	110	122	133
Highland Park	9,158	8,739	9,635	8,905	9,071	9,497	10,137
Hutchins	3,777	2,719	2,842	3,085	3,594	4,290	5,235
Irving	124,672	155,037	169,265	177,002	188,410	205,810	229,994
Lancaster	18,958	22,117	26,050	24,640	28,184	30,759	32,146
Lewisville [2]	0	555	683	768	1,021	1,352	1,611
Mesquite	83,080	101,484	112,701	117,742	138,042	159,638	180,723
Ovilla [2]	63	279	352	319	366	424	483
Richardson [2]	71,506	64,861	74,026	73,526	76,162	81,876	86,364
Rowlett [2]	9,215	19,907	27,485	24,689	31,309	39,178	49,564
Sachse [2]	2,797	5,152	6,840	9,082	15,948	18,735	21,435
Seagoville	8,942	8,969	10,059	12,846	18,938	21,443	23,602
Sunnyvale	1,885	2,228	2,733	2,666	3,413	4,292	5,448
University Park	23,853	22,259	22,156	22,528	22,797	23,163	24,008
Wilmer	3,169	2,479	2,599	2,665	2,840	3,027	3,155
County Other	12,267	6,105	5,940	61,174	110,613	225,826	296,551
Total	**1,781,730**	**1,852,810**	**1,987,366**	**2,074,858**	**2,286,828**	**2,556,793**	**2,784,604**
Delta County [1]							
County Other	762	767	815	709	695	694	687
Total	**762**	**767**	**815**	**709**	**695**	**694**	**687**
Denton County							
Argyle	1,313	1,575	1,828	1,916	2,369	2,898	3,496
Aubrey	1,250	1,138	1,278	1,991	2,396	2,959	3,588
Carrollton [2]	25,582	42,145	49,920	48,645	56,008	61,351	64,222
Copper Canyon	0	978	1,302	1,539	1,967	2,489	2,647
Corinth	1,843	3,994	5,432	6,441	10,214	14,878	20,135
Dallas [2]	168	14,338	14,894	18,217	19,748	21,854	25,203
Denton	51,420	66,270	73,646	77,090	90,051	104,283	119,486
Double Oak	0	1,664	2,013	2,203	2,881	3,643	4,474
Flower Mound	7,205	15,527	28,379	28,195	51,198	73,949	99,685
Frisco [2]	112	268	538	603	1,406	1,629	1,962
Hebron	0	1,128	1,364	1,590	2,156	2,798	3,484
Hickory Creek	1,917	1,893	2,103	2,845	3,569	4,410	5,349
Highland Village	3,880	7,027	10,839	12,603	17,499	22,395	24,551
Justin	0	1,234	1,506	1,982	2,890	3,886	4,941
Krum	0	1,542	2,026	2,444	3,271	4,121	5,222
Lake Dallas	3,665	3,656	4,250	4,029	4,558	5,214	6,050

*Based on 1990 Census.

Table 7. Historical and projected populations for the study area (TWDB, 1998b) *(continued).*

	1985	1990*	1995	2000	2010	2020	2030
Denton County (continued)							
Lewisville	26,162	45,966	56,730	61,953	82,070	105,051	129,831
Little Elm	0	1,255	1,385	2,094	3,099	4,226	5,381
Oak Point	0	645	927	969	1,145	1,329	1,517
Pilot Point	2,421	2,538	2,876	3,652	4,770	5,910	7,573
Plano[2]	2	40	50	57	78	100	130
Roanoke	0	1,616	2,203	2,397	3,204	4,125	5,113
Sanger	3,632	3,508	4,052	4,638	6,057	7,594	9,734
Shady Shores	0	1,045	1,280	1,387	1,712	2,092	2,522
Southlake [2]	18	242	284	625	1,109	1,341	1,740
The Colony	24,850	22,113	25,466	27,160	31,143	34,036	33,026
Trophy Club	0	3,992	4,586	4,998	7,397	10,087	12,859
County Other	35,554	26,308	32,280	63,693	109,240	170,540	241,634
Total	**190,994**	**273,645**	**333,437**	**385,956**	**523,205**	**679,188**	**845,555**
Ellis County							
Cedar Hill [2]	2	50	59	68	102	137	181
Ennis	13,211	13,883	14,567	14,723	16,437	18,484	20,605
Ferris [2]	2,406	2,212	2,314	2,284	2,719	3,236	3,766
Glenn Heights [2]	28	796	988	964	1,194	1,387	1,612
Grand Prairie [2]	6	3	3	65	122	220	220
Italy	1,570	1,699	1,906	2,239	2,719	3,235	3,745
Mansfield [2]	60	142	172	430	716	1,064	1,457
Midlothian	5,099	5,141	5,690	9,185	11,938	14,789	17,552
Ovilla [2]	1,418	1,748	2,201	2,011	2,495	3,006	3,500
Palmer	1,619	1,659	1,727	2,325	2,848	3,407	3,957
Red Oak	2,694	3,124	3,724	4,604	5,881	7,213	8,510
Waxahachie	17,158	18,168	19,181	22,454	26,692	31,330	35,953
County Other	27,984	36,148	43,368	45,569	57,004	69,013	80,653
Total	**73,255**	**84,773**	**95,900**	**106,921**	**130,867**	**156,521**	**181,711**
Fannin County							
Bonham	7,156	6,686	6,717	7,186	7,026	6,502	6,313
Honey Grove [2]	1,820	1,681	1,742	1,793	1,753	1,613	1,566
Leonard [2]	1,423	1,744	1,830	2,046	2,093	2,039	2,063
County Other [2]	14,206	15,283	15,785	15,667	16,094	17,254	17,893
Total	**24,605**	**25,394**	**26,074**	**26,692**	**26,966**	**27,408**	**27,835**
Grayson County							
Collinsville	0	1,033	1,144	1,131	1,193	1,265	1,331
Denison [2]	24,504	21,505	21,723	22,950	23,759	23,841	23,697

*Based on 1990 Census.

Table 7. Historical and projected populations for the study area (TWDB, 1998b) *(continued)*.

	1985	1990*	1995	2000	2010	2020	2030
Grayson County (continued)							
Howe [2]	2,471	2,173	2,192	2,250	2,545	2,635	2,776
Pottsboro	0	1,177	1,426	1,411	1,559	1,809	2,010
Sherman	31,460	31,601	32,465	32,889	35,134	36,378	38,340
Van Alstyne	2,127	2,090	2,257	2,388	2,595	2,930	3,202
Whitesboro [2]	3,323	3,209	3,323	3,301	3,340	3,286	3,268
Whitewright [2]	1,769	1,713	1,678	1,852	1,913	1,960	2,009
County Other [2]	31,020	30,520	31,780	33,947	34,239	36,539	38,069
Total	**96,674**	**95,021**	**97,988**	**102,119**	**106,277**	**110,643**	**114,702**
Hood County							
Granbury	5,038	4,045	4,854	6,469	7,837	9,399	10,925
County Other	20,556	24,936	27,144	29,485	36,392	44,041	51,733
Total	**25,594**	**28,981**	**31,998**	**35,954**	**44,229**	**53,440**	**62,658**
Hunt County [1]							
Wolfe City	1,657	1,505	1,561	1,620	1,753	1,842	1,976
County Other [2]	1,313	1,245	1,410	1,496	1,635	1,748	1,802
Total	**2,970**	**2,750**	**2,971**	**3,116**	**3,388**	**3,590**	**3,778**
Johnson County							
Alvarado	5,016	2,918	3,179	3,266	4,039	4,851	5,718
Burleson [2]	14,443	14,153	16,825	19,083	24,039	29,079	34,307
Cleburne	22,324	22,205	23,179	26,032	29,205	32,649	36,109
Grandview	1,348	1,245	1,296	1,511	1,650	1,805	1,958
Joshua	2,608	3,828	4,405	4,761	6,474	8,189	9,981
Keene [2]	3,156	3,944	4,433	4,636	4,994	5,412	6,732
Mansfield [2]	130	617	748	852	954	1,247	1,371
County Other [2]	38,648	48,255	53,124	59,337	74,097	88,936	103,550
Total	**87,673**	**97,165**	**107,189**	**119,478**	**145,452**	**172,168**	**199,726**
Kaufman County [1]							
Combine	785	895	1,712	1,108	1,303	1,499	1,666
Dallas [2]	1	7	7	8	8	8	8
Forney	1,155	1,083	1,247	1,527	1,753	1,913	1,973
County Other [2]	2,472	2,618	2,768	3,076	3,654	4,294	4,853
Total	**4,413**	**4,603**	**5,734**	**5,719**	**6,718**	**7,714**	**8,500**

*Based on 1990 Census.

Table 7. Historical and projected populations for the study area (TWDB, 1998b) *(continued).*

	1985	1990*	1995	2000	2010	2020	2030
Lamar County [1]							
Blossom	1,811	1,440	1,658	1,798	2,170	2,566	3,002
Paris [2]	26,252	24,699	25,257	25,035	25,464	26,047	26,507
Reno	1,169	1,784	2,284	2,201	2,465	2,774	3,090
County Other [2]	14,690	15,172	15,711	16,202	17,521	18,978	20,534
Total	**43,922**	**43,095**	**44,910**	**45,236**	**47,620**	**50,365**	**53,133**
Montague County [1]							
Bowie	4,688	4,047	4,344	3,953	3,872	3,793	3,630
Montague	233	500	490	479	470	460	440
Saint Jo [2]	1,210	1,048	1,123	1,084	1,102	1,134	1,163
County Other [2]	2,355	3,855	4,020	3,747	3,628	3,499	3,270
Total	**8,486**	**9,450**	**9,977**	**9,263**	**9,072**	**8,886**	**8,503**
Navarro County [1]							
Corsicana	1,702	1,650	1,717	1,745	1,850	1,937	2,014
County Other	6,936	9,038	9,447	10,056	11,056	11,837	12,599
Total	**8,638**	**10,688**	**11,164**	**11,801**	**12,906**	**13,774**	**14,613**
Parker County [1]							
Aledo	1,432	1,169	1,334	1,994	2,393	2,855	3,355
Azle [2]	1,235	1,203	1,420	1,844	2,179	2,398	2,642
Briar [2]	417	588	629	673	797	928	1,073
Reno	1,645	2,322	2,561	2,712	3,091	3,546	4,049
Springtown	2,578	1,740	1,917	2,432	3,149	3,873	4,638
Weatherford [2]	15,660	14,804	17,051	19,083	23,895	28,817	34,099
Willow Park	1,683	2,328	2,652	3,121	4,046	4,981	5,968
County Other [2]	30,327	37,926	42,316	45,356	55,739	66,377	77,974
Total	**54,977**	**62,080**	**69,880**	**77,215**	**95,289**	**113,775**	**133,798**
Red River County [1]							
Clarksville	4,724	4,311	4,345	4,162	4,135	4,068	3,865
County Other [2]	3,012	3,492	3,606	3,503	3,435	3,346	3,169
Total	**7,736**	**7,803**	**7,951**	**7,665**	**7,570**	**7,414**	**7,034**
Rockwall County [1]							
Dallas [2]	0	39	40	44	51	65	86
Heath [2]	1,774	2,108	2,829	3,018	4,254	5,957	8,084

*Based on 1990 Census.

Table 7. Historical and projected populations for the study area (TWDB, 1998b) *(continued).*

	1985	1990*	1995	2000	2010	2020	2030
Rockwall County [1] (continued)							
Rockwall	6,602	7,361	9,137	12,844	19,310	27,817	38,355
Rowlett [2]	1,323	2,713	3,744	5,120	9,753	14,071	19,417
Wylie	27	54	64	60	59	64	71
County Other [2]	3,454	4,253	5,345	6,969	8,569	12,266	17,400
Total	**13,180**	**16,528**	**21,159**	**28,055**	**41,996**	**60,240**	**83,413**
Tarrant County							
Arlington	231,684	261,721	286,545	318,653	336,400	366,760	384,917
Azle [2]	7,183	7,665	9,039	9,946	11,637	13,473	14,704
Bedford	32,269	43,762	45,974	48,998	50,000	50,000	50,000
Benbrook	18,072	19,564	22,595	23,964	26,522	29,354	30,807
Blue Mound	2,631	2,133	2,272	2,218	2,302	2,593	2,710
Briar [2]	914	2,409	2,626	3,559	4,509	5,445	5,713
Burleson [2]	1,415	1,960	2,330	2,415	2,638	2,957	3,105
Colleyville	8,533	12,724	15,270	24,524	36,762	47,451	49,795
Crowley	7,389	6,974	7,727	8,635	9,650	10,900	11,913
Dalworthington Gardens	1,347	1,758	2,149	2,265	3,260	3,749	4,067
Edgecliff	3,218	2,715	2,978	2,800	2,800	2,800	2,800
Euless	28,594	38,149	44,985	41,463	47,186	53,634	53,634
Everman	5,721	5,672	6,440	5,721	5,721	5,721	5,721
Forest Hill	13,960	11,482	11,477	12,195	12,717	13,580	13,621
Fort Worth	423,049	447,619	473,291	496,622	532,717	580,375	596,112
Grand Prairie [2]	6,903	18,086	19,600	26,212	37,990	50,934	53,453
Grapevine [2]	18,767	29,199	36,887	39,434	48,611	54,530	57,223
Haltom City	32,539	32,856	33,909	34,510	37,050	38,443	39,075
Hurst	34,861	33,574	39,083	36,127	37,899	39,989	39,324
Keller	6,419	13,683	16,640	24,761	31,592	38,146	41,677
Kennedale	2,880	4,096	4,909	6,428	10,087	11,974	13,710
Lake Worth Village	5,191	4,591	5,050	4,896	5,126	5,517	5,556
Mansfield [2]	11,500	14,848	17,083	25,181	32,396	43,903	52,745
North Richland Hills	40,410	45,895	50,128	60,255	72,558	86,349	98,247
Pantego	2,577	2,371	2,666	2,471	2,534	2,668	2,681
Pelican Bay	0	1,271	1,379	1,921	2,351	2,800	3,136
Richland Hills	9,575	7,978	8,691	8,886	10,379	12,109	13,618
River Oaks	8,121	6,580	7,185	6,838	6,838	6,838	6,838
Saginaw	7,413	8,551	9,661	10,546	12,062	13,757	14,802
Sansom Park Village	4,356	3,928	3,912	4,114	4,181	4,192	4,192
Southlake [2]	4,046	6,823	7,994	13,015	25,224	32,109	39,074
Watauga	18,472	20,009	21,880	21,845	23,850	25,700	27,480
Westworth Village	4,777	2,350	2,354	2,408	2,430	2,518	2,600
White Settlement	16,742	15,472	15,419	15,950	15,950	15,950	15,950

*Based on 1990 Census.

Table 7. Historical and projected populations for the study area (TWDB, 1998b) *(continued).*

	1985	1990*	1995	2000	2010	2020	2030
Tarrant County (continued)							
County Other	34,466	31,635	35,297	65,983	90,289	121,675	154,375
Total	**1,055,994**	**1,170,103**	**1,275,425**	**1,415,759**	**1,594,218**	**1,798,893**	**1,915,375**
Wise County [1]							
Boyd	962	1,041	1,146	1,499	1,749	1,968	2,188
Briar [2]	478	902	982	1,029	1,176	1,309	1,440
Decatur	4,925	4,252	4,623	4,982	5,761	6,453	7,139
Rhone	538	605	715	757	817	865	936
County Other	17,701	22,410	26,453	25,584	29,146	32,434	35,620
Total	**24,604**	**29,210**	**33,919**	**33,851**	**38,649**	**43,029**	**47,323**
Total Population	**3,723,951**	**4,113,575**	**4,538,764**	**4,910,336**	**5,684,327**	**6,607,750**	**7,403,619**

[1] County partially included in study area.

[2] City or county-other area partially within county included in study area.

*Based on 1990 Census.

Table 7. Historical and projected populations for the study area (TWDB, 1998b) *(continued).*

Aquifer	Use	1985	1990	1995
			(acre-feet per year)	
Trinity Aquifer				
	Municipal	76,626	71,027	58,994
	Manufacturing	3,990	4,077	3,211
	Power	3,203	889	241
	Mining	1,694	938	2,617
	Irrigation	814	711	745
	Livestock	3,644	3,830	4,067
	Total	**89,971**	**81,472**	**69,875**
Woodbine Aquifer				
	Municipal	8,823	9,353	10,407
	Manufacturing	1,394	1,030	1,126
	Power	359	206	314
	Mining	397	406	573
	Irrigation	5,441	2,613	3,031
	Livestock	1,289	1,470	1,656
	Total	**17,703**	**15,078**	**17,107**
Total-Study Area		**107,674**	**96,550**	**86,982**

Table 8. Estimated groundwater pumpage, 1985-1995 (TWDB, 1998a).

Total groundwater and surface water use in 1985, 1990, and 1995 for the counties and cities in the study area is summarized in Table 9. The total water use was derived by determining the amount of water used for each category for the portion of each county that fell within the study area. These amounts were then proportioned into surface and groundwater use based on county-wide percentages (TWDB, 1998a).

Estimated total water use in the study area for 1995 was 1,072,879 acre-feet. Municipal water use was the largest water use category, and amounted to 903,896 acre-feet in 1995 (Table 9). Manufacturing and power (steam-electric) uses were second and third and amounted to 79,130 and 30,702 acre-feet, respectively. Estimated groundwater use for this period was 92,704 acre-feet, which amounts to approximately 9 percent of the total water use. From 1985 to 1995, it is estimated that groundwater use has declined by 14,661 acre-feet (14 percent). Estimated surface water use has increased by 133,668 acre-feet (16 percent) for the same period (TWDB,1998a).

Projected Water Demands

Total projected water demands for the year 2000 are 1,277,761 acre-feet (Table 10). About 6 percent of these demands (70,515 acre-feet) are expected to be met through groundwater supplies. Estimated total water demands for the year 2030 are expected to be 1,623,218 acre-feet. Less than 4 percent of these demands are expected to be supplied by groundwater. Between the years 2000 and 2030, projected groundwater use is expected to decline by approximately 11 percent from 70,515 to 62,763 acre-feet per year (TWDB, 1998c).

	1985		1990		1995	
	Surface	**Ground**	**Surface**	**Ground**	**Surface**	**Ground**
			(acre-feet per year)			
Collin County[1]						
Allen	1,996	0	2,761	0	4,614	0
Celina	0	215	0	275	0	210
Dallas[2]	653	0	6,997	3	7,061	4
Fairview	239	0	315	0	569	0
Farmersville	534	0	307	0	413	0
Frisco[2]	317	517	887	515	2,923	30
Garland[2]	3	0	3	0	3	0
Lucas	371	0	374	0	429	0
McKinney	3,285	0	4,269	0	6,009	0
Murphy	324	0	292	0	364	0
Parker	228	0	284	0	270	0
Plano[2]	25,762	0	30,245	0	41,365	0
Princeton	335	0	289	0	312	0
Prosper	0	0	1	145	0	231
Richardson[2]	1,427	0	2,625	0	2,881	0
Sachse[2]	11	0	20	0	46	0
Wylie[2]	747	0	992	0	1,254	0
County Other[2]	3,302	1,191	4,202	2,042	5,364	2,607
Total Municipal Water Use	**39,534**	**1,923**	**54,863**	**2,980**	**73,877**	**3,082**
Other Water Use						
Manufacturing	823	204	1,980	93	1,320	145
Irrigation	0	0	0	0	64	0
Steam-Electric	578	482	1,076	559	1,947	115
Mining	71	0	64	0	338	0
Livestock	1,062	117	980	108	939	106
Total Water Use	**42,068**	**2,726**	**58,963**	**3,740**	**78,485**	**3,448**
Cooke County						
Gainesville	0	2,376	0	2,199	0	2,859
Muenster	0	251	0	194	0	264
County Other[2]	0	1,793	0	1,916	0	2,287
Total Municipal Water Use	**0**	**4,420**	**0**	**4,309**	**0**	**5,410**
Other Water Use						
Manufacturing	0	185	0	304	0	204
Irrigation	70	429	0	300	126	233
Steam-Electric	0	0	0	0	0	0

Table 9. Historical water use for the study area (TWDB, 1998a).

	1985		1990		1995	
	Surface	**Ground**	**Surface**	**Ground**	**Surface**	**Ground**
			(acre-feet per year)			
Cooke County (cont.)						
Mining	96	534	54	421	237	52
Livestock	944	944	1,009	1,009	1,164	1,164
Total Water Use	**1,110**	**6,512**	**1,063**	**6,343**	**1,527**	**7,063**
Dallas County						
Addison	3,566	17	3,590	0	4,984	0
Balch Springs	1,879	0	1,978	0	2,111	0
Carrollton[2]	7,740	78	8,008	0	8,495	0
Cedar Hill[2]	2,094	523	3,059	397	3,678	153
Cockrell Hill	505	0	375	0	431	0
Combine[2]	0	0	84	0	90	0
Coppell	1,775	91	3,228	0	5,097	0
Dallas[2]	264,718	0	256,800	128	259,223	104
De Soto	4,071	241	6,025	104	6,209	17
Duncanville	6,358	54	6,516	0	6,100	0
Farmers Branch	8,319	0	10,206	0	8,777	0
Garland[2]	31,542	0	31,908	0	32,074	0
Glenn Heights[2]	0	426	345	81	271	153
Grand Prairie[2]	8,451	5,611	9,020	5,073	11,490	479
Grapevine[2]	11	1	16	0	19	0
Highland Park	3,680	0	3,483	0	3,609	0
Hutchins	497	124	215	297	285	321
Irving	24,737	5,067	32,242	425	37,226	0
Lancaster	700	1,489	3,000	297	2,999	226
Lewisville[2]	0	0	96	0	115	0
Mesquite	14,602	0	17,295	0	20,824	0
Ovilla[2]	8	5	40	13	55	8
Richardson[2]	16,113	0	17,060	0	18,740	0
Rowlett[2]	1,968	0	2,938	0	4,495	0
Sachse[2]	655	0	533	0	919	0
Seagoville	1,340	0	1,018	0	1,208	0
Sunnyvalle	443	0	498	0	537	0
University Park	6,489	0	6,085	0	5,932	0
Wilmer	0	301	0	260	0	288
County Other	5,353	529	3,406	217	2,615	738
Total Municipal Water Use	**417,614**	**14,557**	**429,067**	**7,292**	**448,608**	**2,487**
Other Water Use						
Manufacturing	26,602	1,849	26,906	1,063	25,436	733

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	**Ground**	**Surface**	**Ground**	**Surface**	**Ground**
			(acre-feet per year)			
Dallas County (cont.)						
Irrigation	120	130	48	52	767	431
Steam-Electric	19,387	2,569	17,959	255	14,437	102
Mining	813	29	101	3	1,601	1,386
Livestock	382	42	484	53	464	52
Total Water Use	**464,918**	**19,176**	**474,565**	**8,718**	**491,313**	**5,191**
Delta County[1]						
County Other	34	39	38	41	53	29
Total Municipal Water Use	**34**	**39**	**38**	**41**	**53**	**29**
Other Water Use						
Manufacturing	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0
Steam-Electric	0	0	0	0	0	0
Mining	0	0	0	0	0	0
Livestock	172	19	189	21	93	10
Total Water Use	**206**	**58**	**227**	**62**	**146**	**39**
Denton County						
Argyle	0	413	0	206	106	272
Aubrey	110	0	0	125	0	139
Carrollton[2]	6,203	88	8,382	51	8,945	2
Corinth	626	0	535	0	646	0
Dallas[2]	45	0	3,805	8	3,835	2
Denton	10,187	6	12,585	76	12,669	25
Double Oak	0	0	0	253	72	230
Flower Mound	1,419	193	2,157	188	5,131	214
Frisco[2]	8	13	39	23	128	1
Hebron	0	0	0	142	0	173
Hickory Creek	0	325	83	144	85	150
Highland Village	0	598	35	1,141	256	1,420
Justin	0	0	0	147	0	197
Krum	0	0	0	164	0	191
Lake Dallas	0	474	291	190	352	206
Lewisville[2]	6,790	0	7,978	0	9,595	0
Little Elm	0	0	0	163	0	203
Pilot Point	0	357	0	359	0	392
Plano[2]	0	0	9	0	12	0

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Denton County (cont.)						
Roanoke	0	0	0	198	14	261
Sanger	0	446	0	458	0	465
Shady Shores	0	0	53	35	71	42
Southlake[2]	3	3	44	1	114	1
The Colony	1,714	807	1,777	1,093	2,348	461
Trophy Club	0	0	455	318	674	443
County Other	510	4,127	96	3,106	266	3,955
Total Municipal Water Use	**27,615**	**7,850**	**38,324**	**8,589**	**45,319**	**9,445**
Other Water Use						
Manufacturing	776	12	640	21	746	69
Irrigation	0	500	0	750	0	670
Steam-Electric	79	0	0	0	76	0
Mining	87	0	73	70	90	49
Livestock	681	681	704	704	711	711
Total Water Use	**29,238**	**9,043**	**39,741**	**10,134**	**46,942**	**10,944**
Ellis County						
Cedar Hill[2]	0	0	8	1	10	1
Ennis	2,337	0	2,254	0	2,020	0
Ferris	0	341	0	287	45	299
Glenn Heights[2]	0	10	73	17	58	32
Grand Prairie[2]	1	0	0	0	0	0
Italy	0	216	0	166	0	191
Mansfield[2]	9	0	19	0	26	0
Midlothian	0	783	280	559	887	0
Ovilla[2]	181	111	253	79	341	51
Palmer	0	201	0	186	0	200
Red Oak	0	385	1	356	121	343
Waxahachie	5,177	47	4,502	59	3,075	22
County Other	364	3,676	566	4,146	3,146	2,204
Total Municipal Water Use	**8,069**	**5,770**	**7,956**	**5,856**	**9,729**	**3,343**
Other Water Use						
Manufacturing	856	2,741	1,041	2,871	1,108	2,023
Irrigation	0	0	108	12	180	20
Steam-Electric	0	0	0	0	0	0
Mining	0	87	0	73	0	90
Livestock	829	92	946	105	1,176	131

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Ellis County (continued)						
Total Water Use	9,754	8,690	10,051	8,917	12,193	5,607
Fannin County						
Bonham	1,467	0	1,577	0	1,521	0
Honey Grove[2]	0	186	0	160	0	396
Leonard[2]	0	212	0	233	0	248
County Other[2]	108	1,550	108	1,789	339	1,849
Total Municipal Water Use	**1,575**	**1,948**	**1,685**	**2,182**	**1,860**	**2,493**
Other Water Use						
Manufacturing	25	0	33	2	32	27
Irrigation	2,871	907	930	362	1,311	2,919
Steam-Electric	6,006	356	6,517	209	4,626	316
Mining	0	0	0	0	0	0
Livestock	1,285	141	1,216	134	1,372	152
Total Water Use	**11,762**	**3,352**	**10,381**	**2,889**	**9,201**	**5,907**
Grayson County						
Collinsville	0	0	0	130	0	125
Denison	4,130	63	3,875	136	3,436	95
Howe[2]	0	310	0	289	0	282
Pottsboro	0	0	71	77	45	126
Sherman	0	3,453	0	4,090	2,643	3,391
Van Alstyne	0	318	0	348	0	290
Whitesboro[2]	0	555	0	359	0	526
Whitewright	0	169	0	247	0	256
County Other[2]	528	3,660	547	4,089	850	4,005
Total Municipal Water Use	**4,658**	**8,528**	**4,493**	**9,765**	**6,974**	**9,096**
Other Water Use						
Manufacturing	1,028	4,683	588	5,063	3,087	3,425
Irrigation	1,226	4,105	15	1,528	666	2,360
Steam-Electric	0	0	0	0	0	0
Mining	228	544	242	505	243	815
Livestock	1,001	110	923	101	1,187	130
Total Water Use	**8,141**	**17,970**	**6,261**	**16,962**	**12,157**	**15,826**

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Hood County						
Granbury	90	724	264	587	554	402
County Other	90	2,282	96	2,821	643	2,573
Total Municipal Water Use	**180**	**3,006**	**360**	**3,408**	**1,197**	**2,975**
Other Water Use						
Manufacturing	0	16	0	9	0	20
Irrigation	1,520	47	6,718	208	3,967	81
Steam-Electric	4,382	0	4,140	72	4,735	21
Mining	0	81	0	73	0	167
Livestock	360	360	280	280	314	314
Total Water Use	**6,442**	**3,510**	**11,498**	**4,050**	**10,213**	**3,578**
Hunt County[1]						
Wolfe City	239	99	143	28	107	0
County Other[2]	102	40	122	37	92	32
Total Municipal Water Use	**341**	**139**	**265**	**65**	**199**	**32**
Other Water Use						
Manufacturing	4	1	5	0	5	0
Irrigation	0	0	0	0	0	0
Steam-Electric	0	0	0	0	0	0
Mining	1	0	0	0	0	1
Livestock	14	1	10	1	10	1
Total Water Use	**360**	**141**	**280**	**66**	**214**	**34**
Johnson County						
Alvarado	0	314	0	310	22	331
Burleson[2]	1,730	1	1,759	1	2,128	2
Cleburne	3,584	329	3,380	41	3,915	44
Grandview	0	156	0	176	0	196
Joshua	0	249	323	24	651	24
Keene[2]	0	433	0	457	0	471
Mansfield[2]	19	0	82	0	115	0
County Other[2]	89	4,861	921	4,797	1,120	5,278
Total Municipal Water Use	**5,422**	**6,343**	**6,465**	**5,806**	**7,951**	**6,346**

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Johnson County (continued)						
Other Water Use	0	0	0	0	0	0
Manufacturing	711	321	364	584	265	717
Irrigation	0	0	0	0	0	0
Steam-Electric	0	0	0	0	0	0
Mining	473	87	0	27	0	324
Livestock	715	715	968	968	1,156	1,156
Total Water Use	**7,321**	**7,466**	**7,797**	**7,385**	**9,372**	**8,543**
Kaufman County[1]						
Combine[2]	226	0	258	0	135	0
Dallas[2]	0	0	2	0	2	0
Forney	70	0	129	0	175	0
County Other[2]	268	14	275	15	271	17
Total Municipal Water Use	**564**	**14**	**664**	**15**	**583**	**17**
Other Water Use						
Manufacturing	57	2	90	0	89	0
Irrigation	671	7	639	7	1,022	10
Steam-Electric	0	0	0	0	0	0
Mining	8	0	7	0	8	0
Livestock	128	14	123	14	123	14
Total Water Use	**1,428**	**37**	**1,523**	**36**	**1,825**	**41**
Lamar County[1]						
Blossom	118	0	126	0	127	0
Paris[2]	4,251	2	7,923	4	4,753	0
Reno	111	0	144	0	216	0
County Other[2]	1,251	763	1,673	748	1,380	319
Total Municipal Water Use	**5,731**	**765**	**9,866**	**752**	**6,476**	**319**
Other Water Use						
Manufacturing	5,607	0	4,459	0	5,295	0
Irrigation	4,667	0	3,290	1,410	4,612	0
Steam-Electric	0	0	0	0	0	0
Mining	23	0	19	0	21	0
Livestock	1,467	161	1,293	144	1,564	174

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Lamar County[1] (continued)						
Total Water Use	**17,495**	**926**	**18,927**	**2,306**	**17,968**	**493**
Montague County[1]						
Bowie	767	0	626	0	672	0
Montague	0	29	0	31	0	31
Saint Jo[2]	0	142	0	151	0	135
County Other[2]	29	253	71	335	67	357
Total Municipal Water Use	**796**	**424**	**697**	**517**	**739**	**523**
Other Water Use						
Manufacturing	0	0	0	0	0	0
Irrigation	80	43	110	47	106	128
Steam-Electric	0	0	0	0	0	0
Mining	52	173	23	142	172	136
Livestock	626	69	672	75	676	75
Total Water Use	**1,554**	**709**	**1,502**	**781**	**1,693**	**862**
Navarro County[1]						
Corsicana	290	0	255	0	279	0
County Other	776	56	1,071	87	976	71
Total Municipal Water Use	**1,066**	**56**	**1,326**	**87**	**1,255**	**71**
Other Water Use						
Manufacturing	594	0	648	0	1,029	0
Irrigation	0	0	0	0	0	0
Steam-Electric	0	0	0	0	0	0
Mining	0	34	0	31	0	33
Livestock	599	67	522	57	458	51
Total Water Use	**2,259**	**157**	**2,496**	**175**	**2,742**	**155**
Parker County[1]						
Aledo	0	134	0	184	0	143
Azle[2]	140	0	155	0	194	0
Briar[2]	0	57	0	77	0	82
Reno	36	101	24	181	13	232

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Parker County[1] (continued)						
Springtown	188	99	176	86	192	130
Weatherford[2]	1,934	0	2,012	20	2,346	70
Willow Park	0	232	0	363	0	366
County Other[2]	565	3,230	299	4,159	404	4,525
Total Municipal Water Use	**2,863**	**3,853**	**2,666**	**5,070**	**3,149**	**5,548**
Other Water Use						
Manufacturing	261	37	224	29	492	5
Irrigation	99	77	0	0	153	41
Steam-Electric	159	0	39	0	87	0
Mining	1,273	49	1,164	43	31	48
Livestock	1,215	134	1,160	129	1,193	133
Total Water Use	**5,870**	**4,150**	**5,253**	**5,271**	**5,105**	**5,775**
Red River County[1]						
Clarksville	0	581	383	322	483	297
County Other[2]	118	213	139	263	162	281
Total Municipal Water Use	**118**	**794**	**522**	**585**	**645**	**578**
Other Water Use						
Manufacturing	0	4	1	2	3	3
Irrigation	335	0	0	0	481	0
Steam-Electric	0	0	0	0	0	0
Mining	0	0	0	0	0	0
Livestock	397	264	349	232	427	285
Total Water Use	**850**	**1,062**	**872**	**819**	**1,556**	**866**
Rockwall County[1]						
Dallas[2]	0	0	10	0	10	0
Heath	320	0	248	0	460	0
Rockwall	1,250	0	1,530	0	1,884	0
Rowlett[2]	283	0	401	0	612	0
Wylie[2]	5	0	6	0	8	0
County Other[2]	893	12	1,074	22	1,209	102
Total Municipal Water Use	**2,751**	**12**	**3,269**	**22**	**4,183**	**102**

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Rockwall County[1] (continued)						
Other Water Use						
Manufacturing	0	0	5	0	10	0
Irrigation	0	0	0	0	0	0
Steam-Electric	0	0	0	0	0	0
Mining	0	0	0	0	0	0
Livestock	84	9	56	6	37	4
Total Water Use	**2,835**	**21**	**3,330**	**28**	**4,230**	**106**
Tarrant County						
Arlington	45,472	0	48,026	0	52,123	0
Azle[2]	810	0	989	0	1,235	0
Bedford	3,984	2,421	6,098	1,670	6,232	1,882
Benbrook	1,747	1,612	1,955	1,445	2,696	1,328
Blue Mound	0	211	0	232	0	215
Briar[2]	0	125	0	315	0	347
Burleson[2]	169	0	244	0	295	0
Colleyville	1,027	246	2,850	320	3,996	184
Crowley	693	155	624	219	717	113
Dalworthington Gardens	142	167	199	185	276	152
Edgecliff	414	0	410	0	357	0
Euless	3,039	1,724	4,703	1,190	4,809	1,128
Everman	3	658	210	376	135	458
Forest Hill	1,315	210	1,465	0	1,414	0
Fort Worth	95,003	95	105,315	105	100,095	100
Grand Prairie[2]	694	459	1,992	1,135	2,548	109
Grapevine[2]	3,683	342	5,469	0	7,437	0
Haltom City	4,340	248	4,575	0	4,497	0
Hurst	5,065	1,347	5,550	483	5,320	585
Keller	772	252	2,366	281	3,163	98
Kennedale	0	556	0	601	0	751
Lake Worth Village	218	470	247	458	387	315
Mansfield[2]	1,645	8	1,969	0	2,622	0
Newark	0	0	92	0	92	0
North Richland Hills	5,786	47	6,331	0	6,813	62
Pantego	0	442	0	577	0	551
Pelican Bay	0	0	0	94	0	112
Richland Hills	587	739	656	645	757	383
River Oaks	1,141	0	1,091	0	846	0
Saginaw	627	275	960	279	1,204	65
Sansom Park Village	30	401	0	437	0	529

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Tarrant County (continued)						
Southlake[2]	757	553	1,226	34	3,201	23
Watauga	2,646	21	2,760	0	2,974	27
Westworth Village	221	3	176	1	160	1
White Settlement	1,491	636	785	1,573	908	1,265
County Other	6,462	2,783	2,107	2,596	4,579	2,135
Total Municipal Water Use	**189,983**	**17,206**	**211,440**	**15,251**	**221,888**	**12,918**
Other Water Use						
Manufacturing	33,620	1,076	51,826	1,274	31,932	886
Irrigation	300	0	111	0	119	21
Steam-Electric	5,412	0	4,212	0	4,240	0
Mining	96	0	84	0	88	0
Livestock	502	502	418	418	403	403
Total Water Use	**229,913**	**18,784**	**268,091**	**16,943**	**258,670**	**14,228**
Wise County[1]						
Boyd	0	141	0	153	0	147
Briar[2]	0	65	0	118	0	130
Decatur	826	8	484	0	937	0
Rhone	75	0	84	0	99	0
County Other	459	1,726	436	2,190	512	2,572
Total Municipal Water Use	**1,360**	**1,940**	**1,004**	**2,461**	**1,548**	**2,849**
Other Water Use						
Manufacturing	22	1	28	0	24	0
Irrigation	356	89	106	74	127	96
Steam-Electric	0	0	0	0	0	0
Mining	481	81	2,741	36	12,029	158
Livestock	764	764	949	949	895	895
Total Water Use	**2,983**	**2,875**	**4,828**	**3,520**	**14,623**	**3,998**

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

	1985		1990		1995	
	Surface	Ground	Surface	Ground	Surface	Ground
			(acre-feet per year)			
Total of Study Area:						
Total Municipal Water Use	710,274	79,587	774,970	75,053	836,233	67,663
Other Water Use						
Manufacturing	70,986	11,132	88,838	11,315	70,873	8,257
Irrigation	12,315	6,334	12,075	4,750	13,701	7,010
Steam-Electric	36,003	3,407	33,943	1,095	30,148	554
Mining	3,702	1,699	4,572	1,424	14,858	3,259
Livestock	13,227	5,206	13,251	5,508	14,362	5,961
Total Water Use	846,507	107,365	927,649	99,145	980,175	92,704
Total Combined Water Use		953,872		1,026,794		1,072,879

[1] County partially included in study area.
[2] City or county other area partially within county included in study area.

Table 9. Historical water use for the study area (TWDB, 1998a) *(continued)*.

		2000	2010	2020	2030
			(acre-feet per year)		
Municipal Use					
Major Cities					
	Groundwater				
	Trinity Aquifer	22,158	18,147	17,936	18,286
	Woodbine Aquifer	4,398	4,581	4,923	5,324
	Total Groundwater	**26,556**	**22,728**	**22,859**	**23,610**
	Surface Water	958,345	1,044,793	1,083,239	1,121,364
	Subtotal	**984,901**	**1,067,521**	**1,106,098**	**1,144,974**
County Other					
	Groundwater				
	Trinity Aquifer	21,709	23,255	22,747	19,019
	Woodbine Aquifer	6,831	6,769	6,718	6,629
	Total Groundwater	**28,540**	**30,024**	**29,465**	**25,648**
	Surface Water	63,357	86,010	140,389	190,937
	Subtotal	**91,897**	**116,034**	**169,854**	**216,585**
Total Municipal Use		**1,076,798**	**1,183,555**	**1,275,952**	**1,361,559**
Other Uses					
	Groundwater				
	Trinity Aquifer	6,470	6,725	6,543	5,186
	Woodbine Aquifer	8,949	8,633	8,440	8,319
	Total Groundwater	**15,419**	**15,358**	**14,983**	**13,505**
	Surface Water	185,544	205,914	222,020	248,154
	Subtotal	**200,963**	**221,272**	**237,003**	**261,659**
Study Area					
	Groundwater				
	Trinity Aquifer	50,337	48,127	47,226	42,491
	Woodbine Aquifer	20,178	19,983	20,081	20,272
	Total Groundwater	**70,515**	**68,110**	**67,307**	**62,763**
	Surface Water				
	Total Surface Water	**1,207,246**	**1,336,717**	**1,445,648**	**1,560,455**
Total for Study Area		**1,277,761**	**1,404,827**	**1,512,955**	**1,623,218**

Table 10. Projected water demands by source type for the study area (TWDB, 1998c).

WATER AVAILABILITY

Water availability refers to the amount of water available for use in an area during drought of record conditions. Groundwater availability is determined by the amount of recharge and an acceptable amount of water removed from aquifer storage. Surface-water availability is defined by the firm yield of the reservoirs.

Groundwater Availability

The estimated annual groundwater availability of an aquifer is the estimated sustainable annual yield, or effective recharge, plus the acceptable amount of water that can be recovered from storage over a specified period of time. This estimate is made assuming withdrawals occur without causing irreversible effects such as land-surface subsidence or water-quality deterioration (Muller and Price, 1987). The estimated annual groundwater availability of the Trinity aquifer in the study area has been estimated to be about 63,000 acre-feet, which consists of 51,000 acre-feet of annual effective recharge and 12,000 acre-feet of groundwater recoverable from storage (Nordstrom, 1982). The annual effective recharge for the Trinity aquifer was determined using the trough method described by Klemt and others (1975).

Approximately 69,875 acre-feet of groundwater was pumped in 1995 (Table 8), which amounts to approximately 140 percent of the estimated effective recharge. The estimated annual groundwater recharge and availability of the Trinity aquifer in the study area for the year 2030 has been estimated to be about 49,981 acre-feet (TDWR,1990). Estimated groundwater demands from the Trinity aquifer for 2000 are expected to be 50,337 acre-feet, subsequently declining to 42,491 acre-feet by 2030 (Table 10) (TWDB, 1998c). Based on these figures, projected demands will be less than estimated annual effective recharge. However, recharge is mainly limited to outcrop areas, so local overdraft of the aquifer in confined areas will continue to result in water-level declines.

The total estimated groundwater availability for the Woodbine aquifer is approximately 24,500 acre-feet (Nordstrom, 1982). The annual effective recharge to the Woodbine aquifer is approximately 24,000 acre-feet per year and an additional 500 acre-feet of recoverable usable water in storage (Baker and others, 1990). Approximately 17,107 acre-feet of groundwater was pumped from the Woodbine aquifer in 1995 (Table 8) (TWDB, 1998a). The total estimated annual groundwater recharge and availability in the Woodbine aquifer for the year 2030 is approximately 24,500 acre-feet (TDWR, 1990). Water demand projections estimate groundwater use to rise to 20,178 acre-feet by the year 2000 and to be 20,272 acre-feet per year in 2030, only slightly above the year 2000 projections (Table 10) (TWDB, 1998c). Based on these projections, groundwater demands from the Woodbine aquifer will remain less than the estimated annual effective

recharge. As previously mentioned, recharge is limited mainly to outcrop areas. Overdraft of the aquifer can result in water-level declines in confined areas of the aquifer.

Even though regional annual effective recharge estimates exceed projected demands as a whole, Cooke, Denton, Grayson, Johnson, Parker, Tarrant, and Wise counties have experienced continuing local water-level declines in the Antlers, Twin Mountains, Paluxy, and Woodbine Formations. Based on the available estimates of effective recharge and estimated groundwater availability (Table 11) and historical groundwater pumpage and estimated supply (Table 12), groundwater use significantly exceeds available supply in Cooke, Denton, Grayson, Johnson, Parker, and Tarrant Counties. Continued production at similar rates could result in additional water level declines and depletion from storage. Continued conversion to surface water use will be necessary to compensate for the lack of groundwater availability in these areas. The 1997 State Water Plan (TWDB, 1997) for the above counties shows a gradual switch to surface water through 2030 to make up for a lack of groundwater availability (Table 13).

Surface Water Availability

There are 34 major surface water reservoirs with storage capacities greater than 5,000 acre-feet within the study area that contribute all or part of their respective yields to meet water needs (Figure 18). These reservoirs have a combined capacity of approximately 10,221,501 acre-feet of water and have a combined firm yield of approximately 1,979,470 acre-feet of water per year (Table 14) (TWDB, 1997).

Based on current surface-water supplies, adequate amounts of water exist to supply the needs of the study area through the year 2030.

County	Aquifer	Annual Effective Recharge	Annual Recoverable Storage	Estimated Average Annual Groundwater Availability (acre-feet)						
				1985	1990	1995	2000	2010	2020	2030
Cooke County	Trinity	3,753	776	4,529	4,529	4,529	4,529	4,529	4,529	3,753
	Woodbine	440	0	440	440	440	440	440	440	440
	Total	**4,193**	**776**	**4,969**	**4,969**	**4,969**	**4,969**	**4,969**	**4,969**	**4,193**
Denton County	Trinity	5,123	991	6,114	6,114	6,114	6,114	6,114	6,114	5,123
	Woodbine	1,010	0	1,010	1,010	1,010	1,010	1,010	1,010	1,010
	Total	**6,133**	**991**	**7,124**	**7,124**	**7,124**	**7,124**	**7,124**	**7,124**	**6,133**
Grayson County	Trinity	3,088	346	3,434	3,434	3,434	3,434	3,434	3,434	3,088
	Woodbine	5,710	0	5,710	5,710	5,710	5,710	5,710	5,710	5,710
	Total	**8,798**	**346**	**9,144**	**9,144**	**9,144**	**9,144**	**9,144**	**9,144**	**8,798**
Johnson County	Trinity	2,504	365	2,869	2,869	2,869	2,869	2,869	2,869	2,504
	Woodbine	866	0	866	866	866	866	866	866	866
	Total	**3,370**	**365**	**3,735**	**3,735**	**3,735**	**3,735**	**3,735**	**3,735**	**3,370**
Parker County	Trinity	3,210	681	3,891	3,891	3,891	3,891	3,891	3,891	3,210
	Woodbine	0	0	0	0	0	0	0	0	0
	Total	**3,210**	**681**	**3,891**	**3,891**	**3,891**	**3,891**	**3,891**	**3,891**	**3,210**
Tarrant County	Trinity	4,996	0	4,996	4,996	4,996	4,996	4,996	4,996	4,996
	Woodbine	766	0	766	766	766	766	766	766	766
	Total	**5,762**	**0**	**5,762**	**5,762**	**5,762**	**5,762**	**5,762**	**5,762**	**5,762**
Wise County	Trinity	4,163	805	4,968	4,968	4,968	4,968	4,968	4,968	4,163
	Woodbine	0	0	0	0	0	0	0	0	0
	Total	**4,163**	**805**	**4,968**	**4,968**	**4,968**	**4,968**	**4,968**	**4,968**	**4,163**

Table 11. Estimated groundwater availability for Cooke, Denton, Grayson, Johnson, Parker, Tarrant and Wise Counties (TDWR, 1990).

		1985	1990	1995
			(acre-feet per year)	
Cooke County				
	Estimated Supply	4,969	4,969	4,969
	Estimated Pumpage	6,392	6,223	6,656
	Difference	-1,423	-1,254	-1,687
Denton County				
	Estimated Supply	7,124	7,124	7,124
	Estimated Pumpage	9,038	10,235	10,807
	Difference	-1,914	-3,111	-3,683
Grayson County				
	Estimated Supply	9,144	9,144	9,144
	Estimated Pumpage	18,101	17,145	15,356
	Difference	-8,957	-8,001	-6,212
Johnson County				
	Estimated Supply	3,735	3,735	3,735
	Estimated Pumpage	8,035	7,950	9,010
	Difference	-4,300	-4,215	-5,275
Parker County				
	Estimated Supply	3,891	3,891	3,891
	Estimated Pumpage	4,351	5,133	5,802
	Difference	-460	-1,242	-1,911
Tarrant County				
	Estimated Supply	5,762	5,762	5,762
	Estimated Pumpage	17,822	14,952	13,329
	Difference	-12,060	-9,190	-7,567
Wise County				
	Estimated Supply	4,968	4,968	4,968
	Estimated Pumpage	3,669	3,776	4,285
	Difference	1,299	1,192	683

Table 12. Historical groundwater pumpage and supply for Cooke, Denton, Grayson, Johnson, Parker, Tarrant and Wise Counties, as per the *1997 Consensus State Water Plan*.

		2000	2010	2020	2030
			(acre-feet per year)		
Cooke County	Groundwater	5,594	3,454	3,290	3,140
	Surface Water	1,805	4,659	4,783	4,935
	Total	**7,399**	**8,113**	**8,073**	**8,075**
Denton County	Groundwater	7,124	7,048	7,124	6,133
	Surface Water	72,913	91,767	110,697	126,216
	Total	**80,037**	**98,815**	**117,821**	**132,349**
Grayson County	Groundwater	8,809	8,811	7,977	8,061
	Surface Water	16,929	17,170	18,162	18,658
	Total	**25,738**	**25,981**	**26,139**	**26,719**
Johnson County	Groundwater	3,077	3,005	3,014	3,119
	Surface Water	17,818	20,026	21,767	24,456
	Total	**20,895**	**23,031**	**24,781**	**27,575**
Parker County	Groundwater	5,790	5,981	6,198	5,824
	Surface Water	7,813	9,166	10,106	12,538
	Total	**13,603**	**15,147**	**16,304**	**18,362**
Tarrant County	Groundwater	5,678	5,668	5,670	5,654
	Surface Water	340,694	370,012	374,176	396,261
	Total	**346,372**	**375,680**	**379,846**	**401,915**
Wise County	Groundwater	4,968	4,968	4,968	4,163
	Surface Water	11,877	12,525	13,308	15,124
	Total	**16,845**	**17,493**	**18,276**	**19,287**

Table 13. Future water allocations based on the *1997 Consensus State Water Plan*.

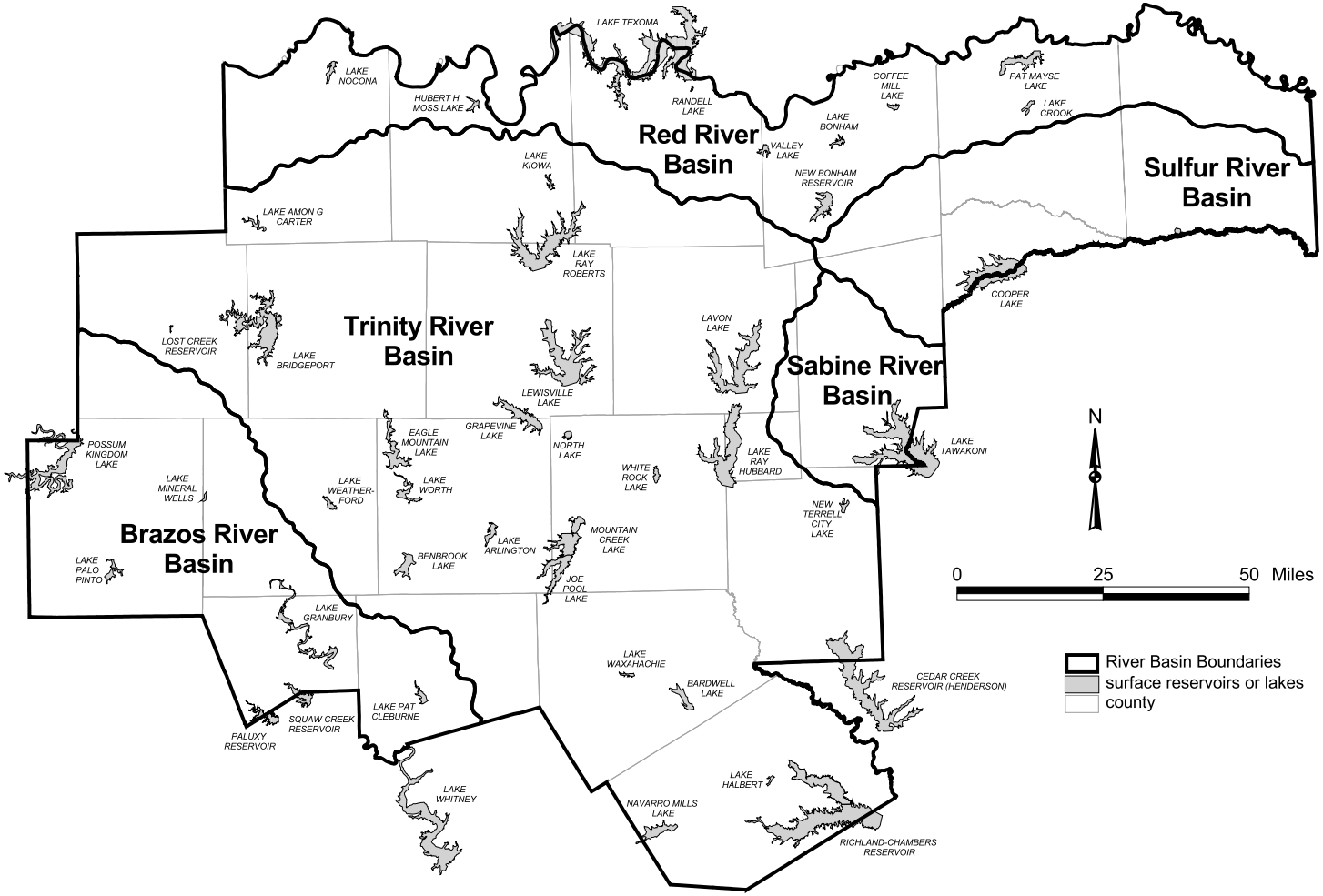

Figure 18. Surface reservoirs and river basins within and in the vicinity of the study area.

River Basin	Reservoir	Capacity (acre-feet)	Firm Yield (acre-feet)
Red River	Nocona	25,400	4,500
	Hubert H. Moss	23,210	6,300
	Texoma	2,643,300	150,000
	Pat Mayse	124,500	59,900
	Bonham	12,000	7,240
	Randall	5,400	5,280
	Crook	9,664	1,000
	Total	**2,843,474**	**234,220**
Sulphur River	Cooper	310,000	142,850
	Total	**310,000**	**142,850**
Sabine River	Tawakoni	888,130	235,160
	Total	**888,130**	**235,160**
Trinity River	Bridgeport	386,420	79,000
	Eagle Mountain	190,460	80,600
	Amon Carter	28,589	2,600
	Worth	38,130	2,400
	Weatherford	18,650	2,000
	Benbrook	85,865	9,800
	Grapevine	188,550	27,240
	Ray Roberts	799,600	110,000
	Lewisville	640,986	110,800
	Arlington	38,740	7,050
	Joe Pool	181,200	16,900
	Lavon	456,500	104,000
	Ray Hubbard	490,000	63,100
	Terrell	8,580	1,650
	Cedar Creek	637,050	162,500
	Waxahachie	13,500	2,400
	Bardwell	54,900	8,300
	Halbert	7,420	600
	Navarro Mills	63,300	23,100
	Richland Chambers	1,103,816	233,000
	Total	**5,432,256**	**1,047,040**
Brazos River	Possum Kingdom	551,818	233,500
	Palo Pinto	27,650	14,100
	Mineral Wells	6,760	1,500
	Granbury	135,683	66,500
	Pat Cleburne	25,730	4,600
	Total	**747,641**	**320,200**

Table 14. Reservoir capacity and firm yield (TWDB, 1999).

Basin Totals	**Capacity** (acre-feet)	**Firm Yield** (acre-feet)
Red River Basin	2,843,474	234,220
Sulphur River Basin	310,000	142,850
Sabine River Basin	888,130	235,160
Trinity River Basin	5,432,256	1,047,040
Brazos River Basin	747,641	320,200
Total for Study Area	**10,221,501**	**1,979,470**

Table 14. Reservoir capacity and firm yield (TWDB, 1997) *(continued)*.

CONCLUSIONS

Water levels have remained relatively stable within the Antlers and Twin Mountains Formations of the Trinity aquifer since 1989 with the exception of Wise, Tarrant, and Johnson Counties. The southwestern part of Wise County has shown water-level declines of about 100 feet. Additionally, water-level declines of 200 feet have occurred in northeastern Tarrant County within the Dallas-Fort Worth metroplex. Minor water-level declines of approximately 50 feet have occurred in southern Johnson County. Southern Denton and Tarrant Counties, as well as northern Johnson County have experienced a rise in water levels from 50 to 200 feet.

Water sampling of wells in the Antlers and Twin Mountains Formations show TDS concentrations to be generally low in the outcrop area and elevated downdip to the east. Average TDS concentrations for the Antlers and Twin Mountains Formations were 718 mg/l. Average sodium concentrations were 245 mg/l.

Water levels in the Paluxy Formation of the Trinity aquifer have not changed significantly since 1989. The greatest water-level declines have occurred in southern Wise County and in Denton County where declines of 5 to 35 feet have been recorded. Water levels have risen 5 to 25 feet in most of Tarrant and Parker County. TDS concentrations averaged 607 mg/l in the Paluxy Formation. Average sodium concentrations were approximately 188 mg/l.

Water-level elevations for the Woodbine aquifer have been stable since 1989 with the exception of northern Collin County, the central to northeastern portion of Denton County, and northern Grayson County. Water levels have declined an average of 10 feet in parts of Denton and Collin Counties. Water-level declines of 60 feet have been observed in northern Grayson County.

The highest reported TDS concentrations within the study area are in the Woodbine aquifer, with most of the elevated concentrations occurring downdip. These high TDS concentrations are primarily due to high sulfate concentrations associated with extensive lignite beds. The Woodbine aquifer had an average TDS concentration of 877 mg/l with sodium concentrations averaging 311 mg/l and sulfates averaging 209 mg/l.

Groundwater use is projected to decline in the study area, which would allow for conservation of groundwater reserves. Continued conversion to surface water from groundwater should allow future demands to be met and is necessary to reduce water-level declines in Cooke, Denton, Grayson, Johnson, Parker, Tarrant, and Wise Counties. These projections suggest that adequate supplies of usable surface and groundwater exist to meet current and future needs of the study area through the year 2030.

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APPENDIX

Figure A-1. Water-level elevations for selected wells in the Antlers and Twin Mountains Formations, Trinity aquifer, 1997.

Figure A-2. Water-level differences for selected wells in the Antlers and Twin Mountains Formations, Trinity aquifer, between 1989-1997.

Figure A-3. Water-level elevations for selected wells in the Paluxy Formation, Trinity aquifer, winter 1997.

Figure A-4. Water-level differences for selected wells in the Paluxy Formation, Trinity aquifer, between 1989-1997.

Figure A-5. Water-level elevations for selected wells in the Woodbine aquifer, 1997.

Figure A-6. Water-level differences for selected wells in the Woodbine aquifer, between 1989-1997.

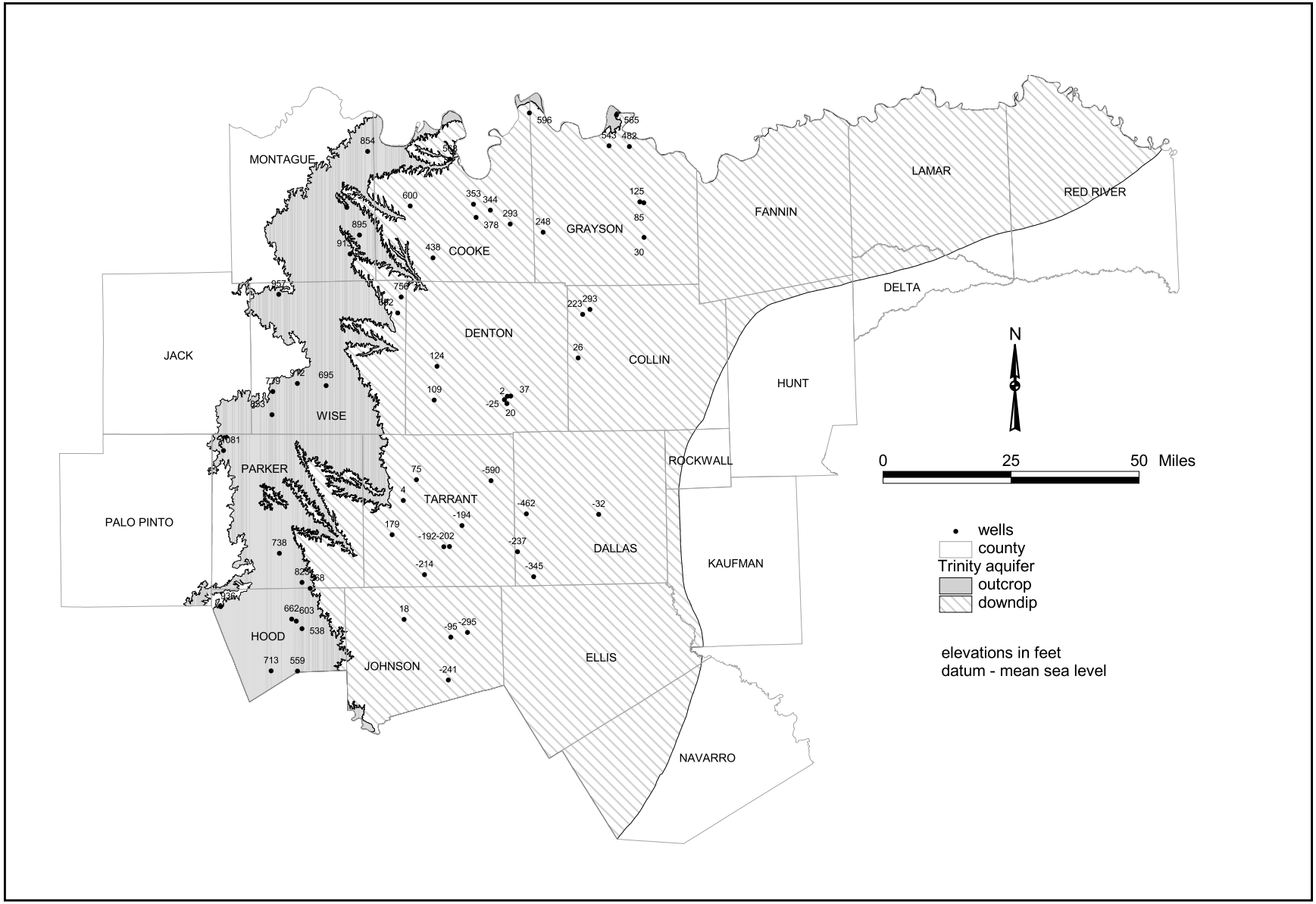

Figure A-1. Water-level elevations for selected wells in the Antlers and Twin Mounains Formations, Trinity aquifer, 1997.

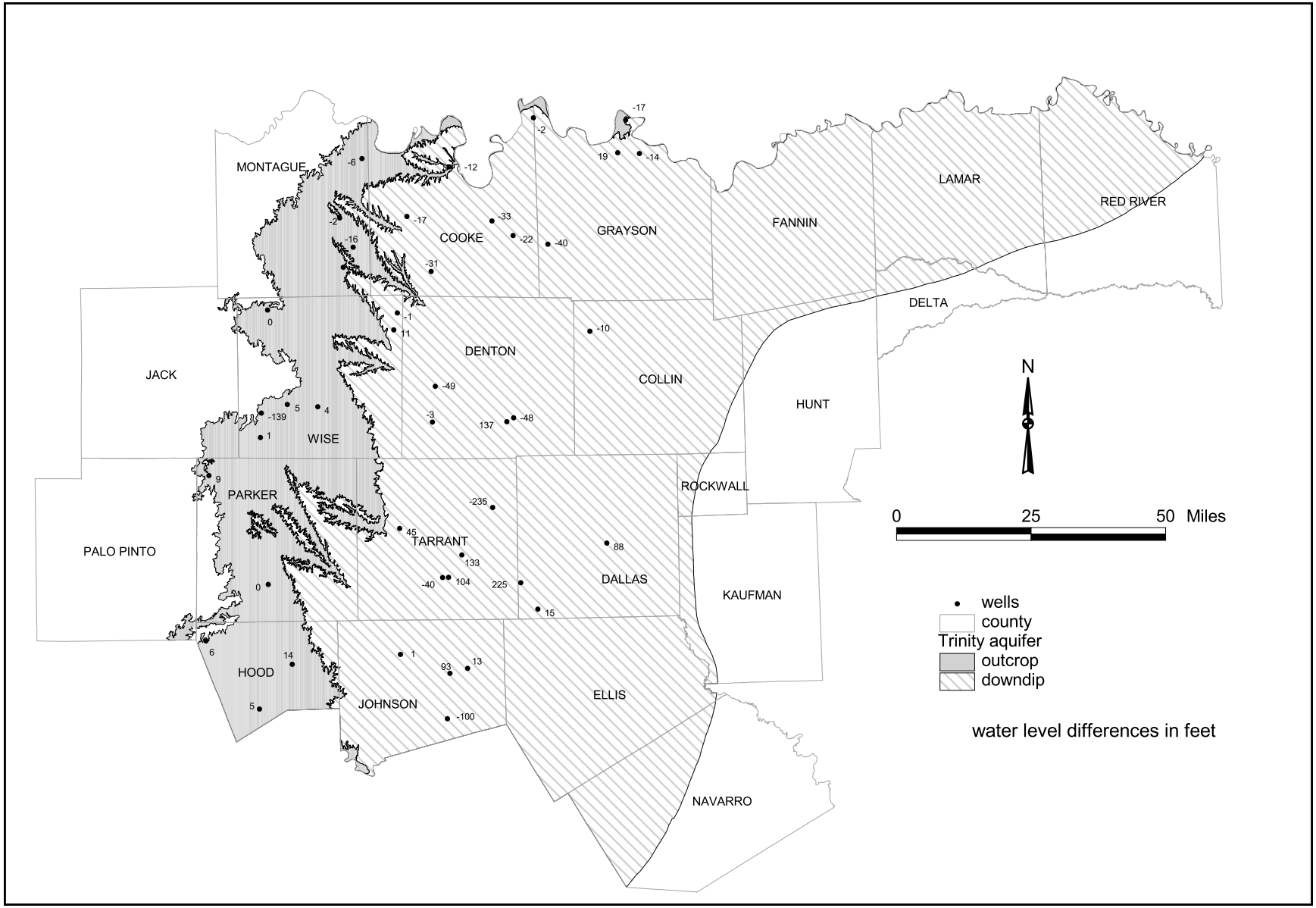

Figure A-2. Water-level differences for selected wells in the Antlers and Twin Mountains Formations, Trinity aquifer, between 1989-1997.

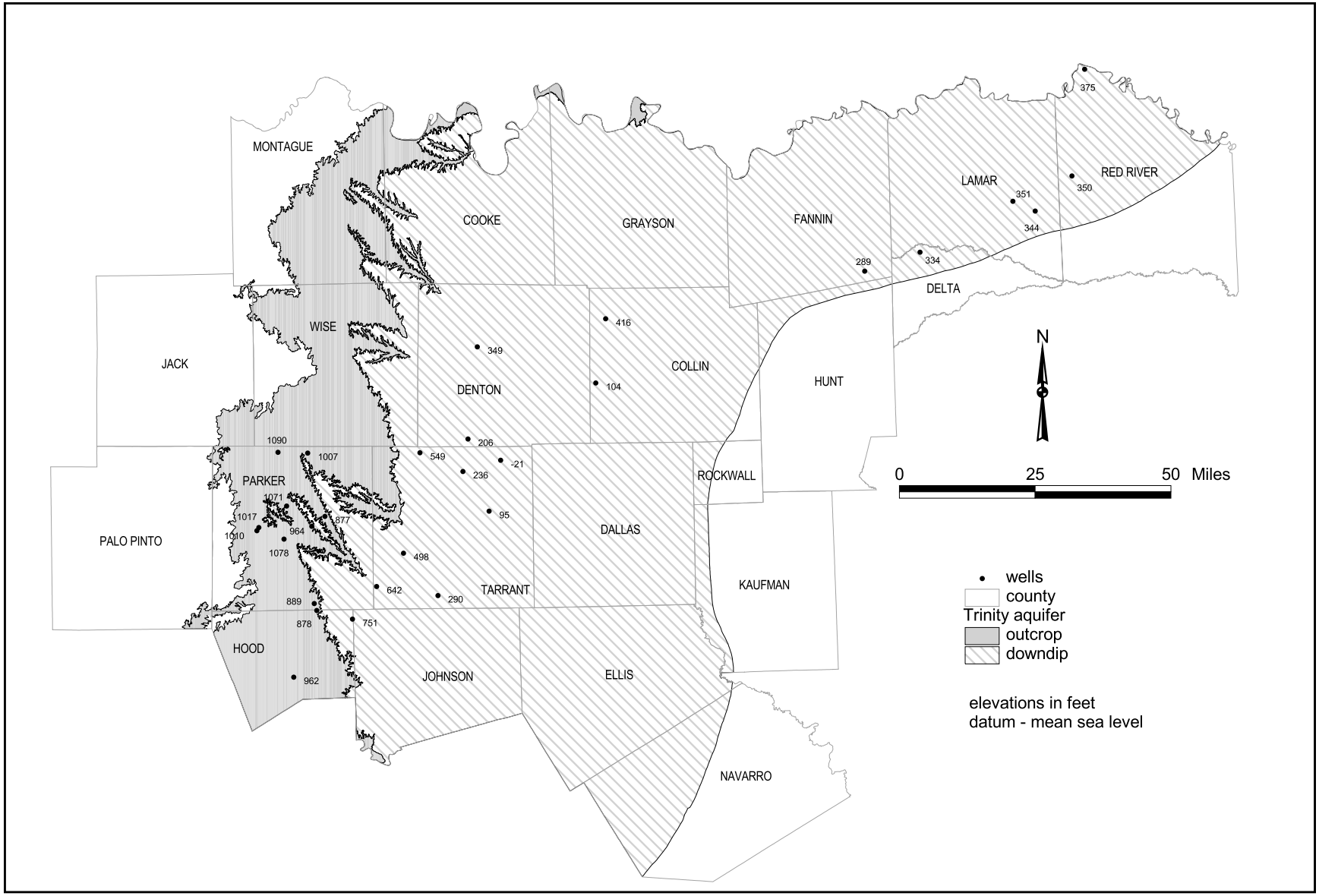

Figure A-3. Water-level elevations for selected wells in the Paluxy Formation, Trinity aquifer, winter 1997.

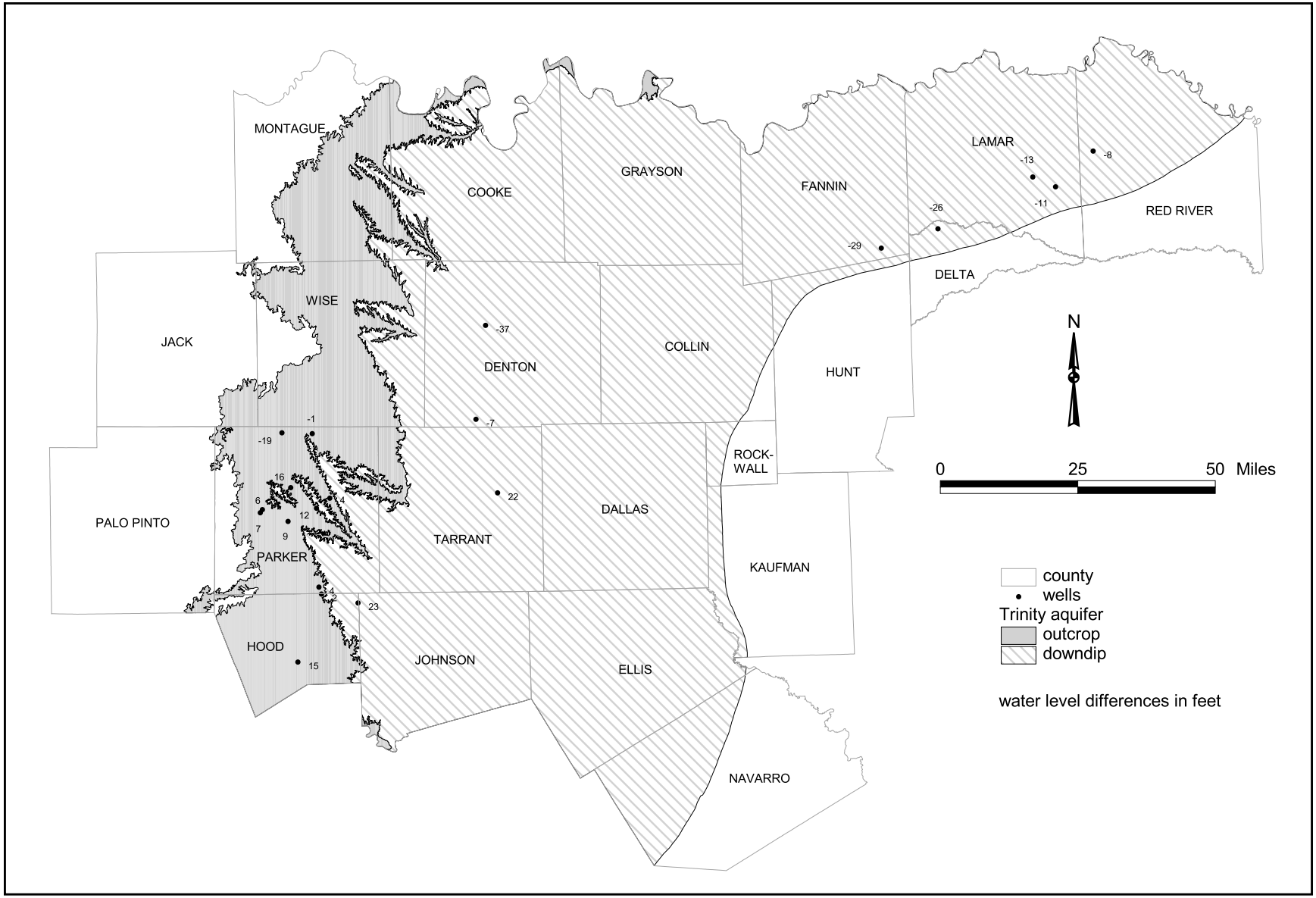

Figure A-4. Water-level differences for selected wells in the Paluxy Formation, Trinity aquifer, between 1989-1997.

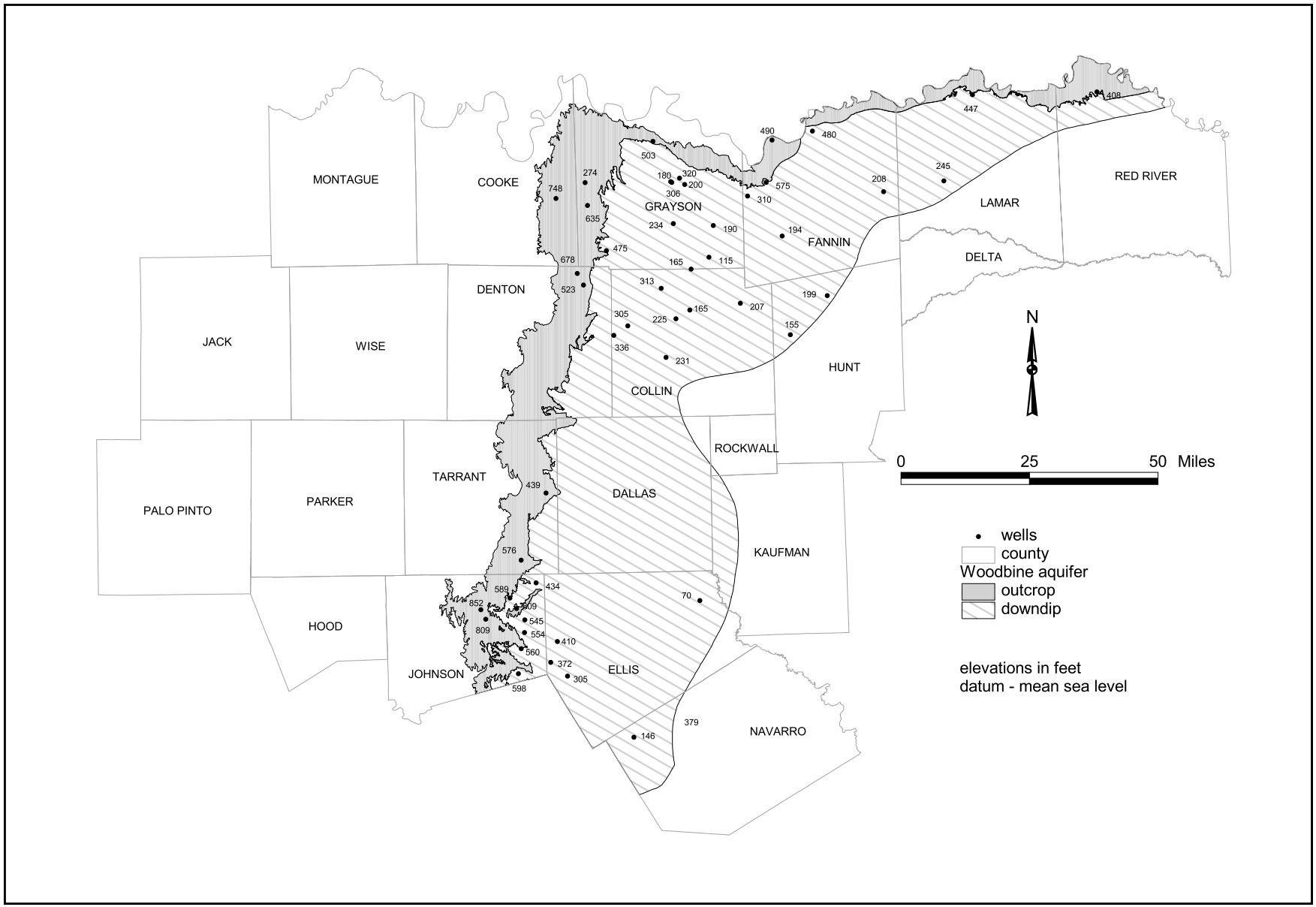

Figure A-5. Water-level elevations for selected wells in the Woodbine aquifer, 1997.

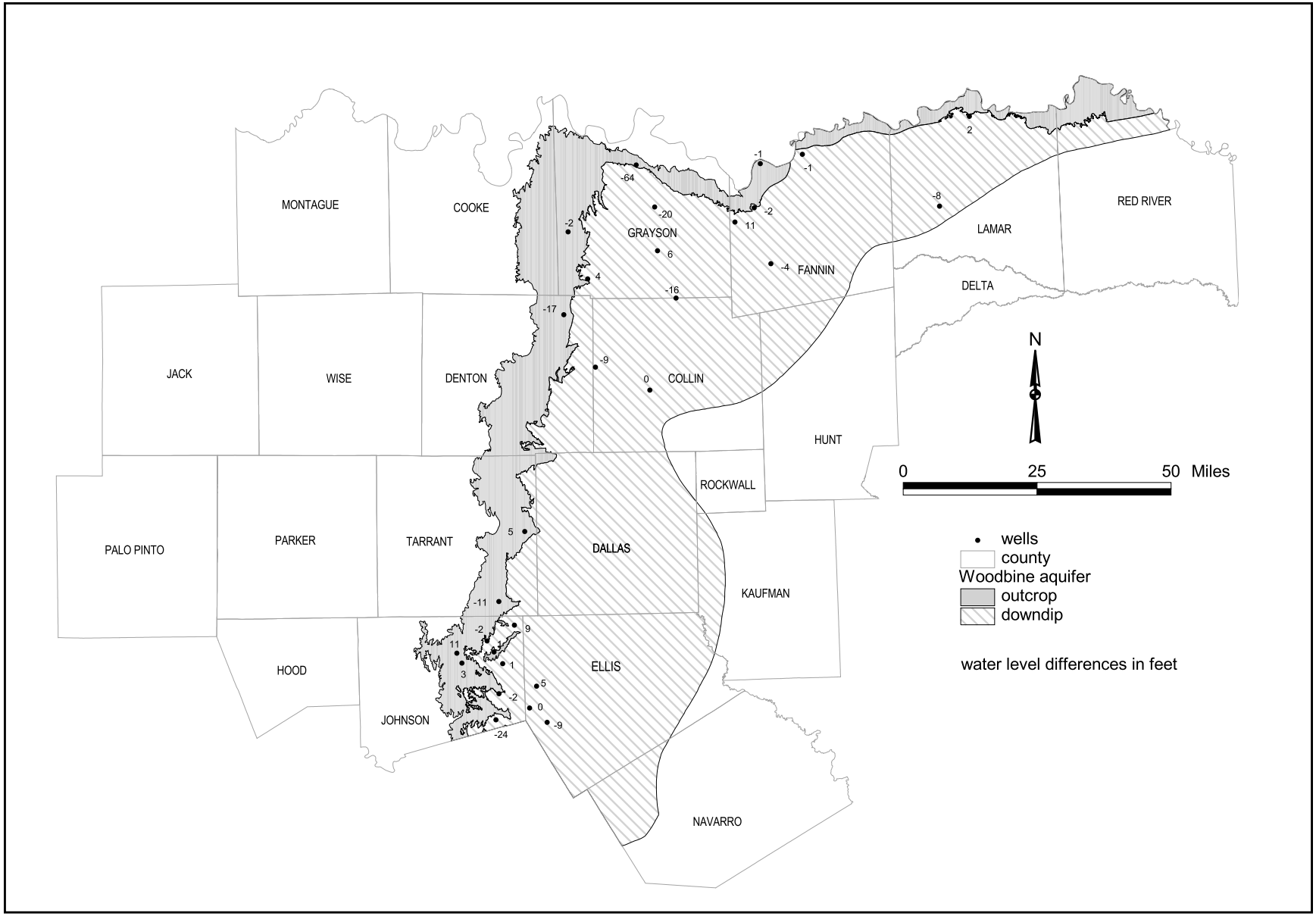

Figure A-6. Water-level differences for selected wells in the Woodbine aquifer, between 1989-1997.