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Water-Level Changes in the High Plains Aquifer, 1980 to 1995

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

The High Plains aquifer underlies one of the major agricultural areas in the world, including parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Ground-water irrigation expanded rapidly after 1940 in the area underlain by the High Plains aquifer (called the "High Plains region" in this report): 1949—2.1 million acres; 1959—6.1 million acres; 1969—9.0 million acres; 1978—12.9 million acres; and 1980—13.7 million acres (Gutentag and others, 1984; Thelin and Heimes, 1987). In 1990, 95 percent of the water withdrawn from the High Plains aquifer, 15.7 million acre-feet, was used for irrigation (Marilee Horn, U.S. Geological Survey, written commun., 1996).

Water-level declines appeared in the High Plains aquifer soon after extensive ground-water irrigation development began. By 1980, water levels in the High Plains aquifer in parts of Texas, Oklahoma, and southwestern Kansas had declined more than 100 feet. In response to these declines, the U.S. Geological Survey, in cooperation with numerous Federal, State, and local water-resource agencies, began a ground-water monitoring program in 1988 to assess water-level change in the aquifer annually, using water-level measurements in more than 7,000 wells. The water-level measurements are made in winter or early spring, when water levels generally represent nonpumping conditions.

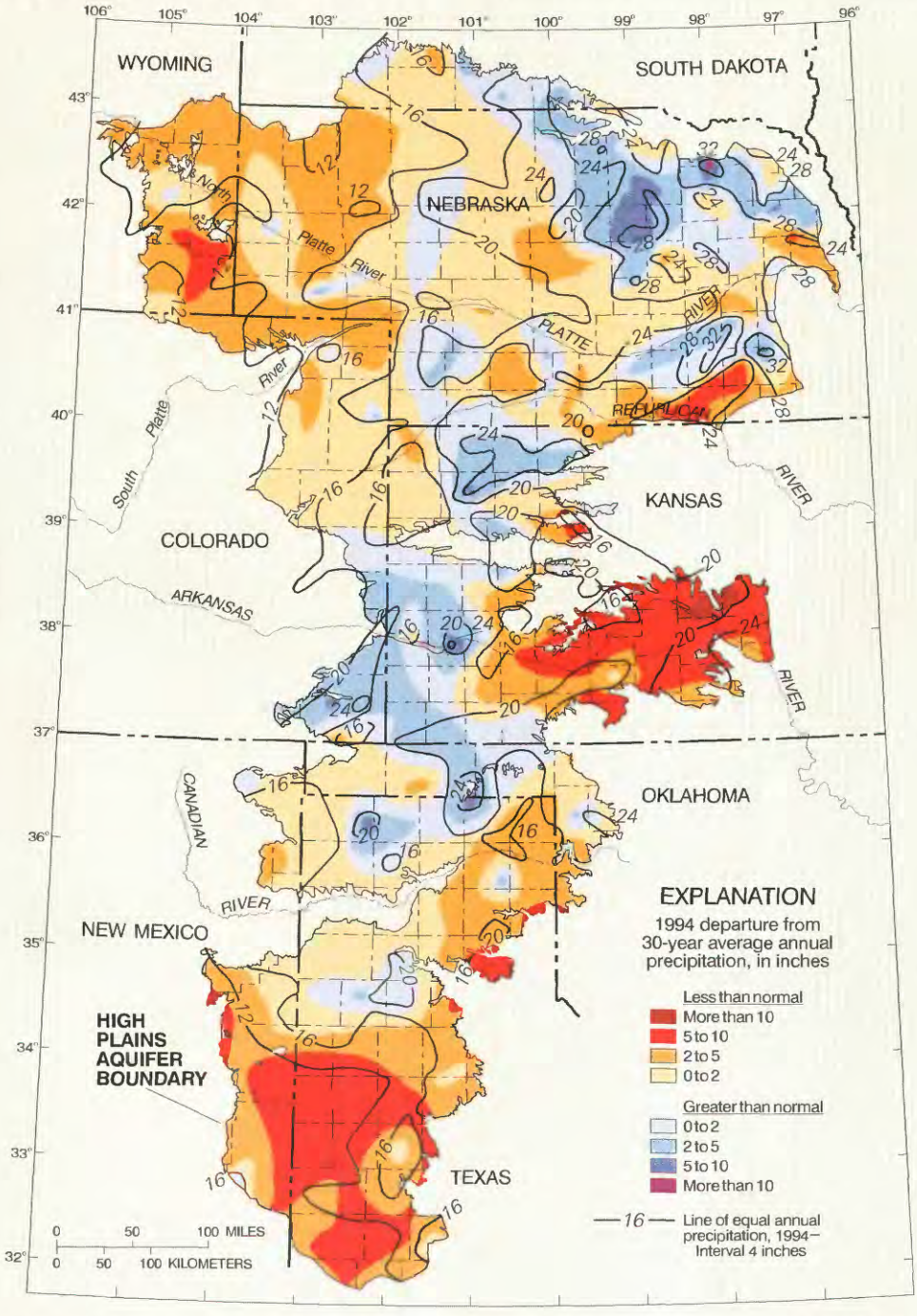

Figure 1. Annual precipitation, 1994, and departure from 30-year normal (1961-90).

FACTORS AFFECTING WATER-LEVEL CHANGE

Water-level change in an aquifer results from an imbalance between recharge and discharge. Human activities, such as pumping wells and diverting streams, have contributed to this imbalance in many parts of the High Plains aquifer, resulting in substantial water-level change over time.

Precipitation is the primary source of recharge to the High Plains aquifer (Gutentag and others, 1984). Other sources of recharge include seepage from streams, canals, and reservoirs, and irrigation return flow. Estimated average annual potential recharge to the High Plains aquifer from precipitation and irrigation return flow, using generalized soil and vegetation characteristics and 1951-80 climatic data, ranges from 0.25-0.50 inch in the western portion of the High Plains region to 4-6 inches in the eastern portion of the High Plains region (Dugan and Zelt, in press). In 1994, the average area-weighted precipitation in the High Plains region was 1.30 inches less than normal (table 1); however, the precipitation pattern varied (fig. 1). The average area-weighted precipitation in the High Plains region by State ranged from 3.48 inches less than normal in New Mexico to 0.16 inch greater than normal in South Dakota (table 1).

Natural discharge from the High Plains aquifer occurs as evapotranspiration where the water table is near the land surface and as seepage from the aquifer where the water table intersects the land surface. Under natural conditions, this type of discharge would tend to balance long-term natural recharge. Under current conditions, water is artificially discharged from the aquifer predominantly by pumping wells for irrigation. Where pumpage exceeds recharge, water is removed from storage and the water table declines. Part of this loss from storage may be alleviated by decreases in natural discharge or by increases in induced recharge from streams.

The rate of withdrawal per irrigated acre can be estimated by a crop's consumptive irrigation requirements (CIR), which is the minimum irrigation required to maintain adequate soil water for optimal plant growth. This requirement, which is unique for each crop, is dependent largely on (1) potential evapotranspiration, (2) the growth characteristics of the crop, (3) soil water available at the beginning of the irrigation season, and (4) irrigation-season precipitation.

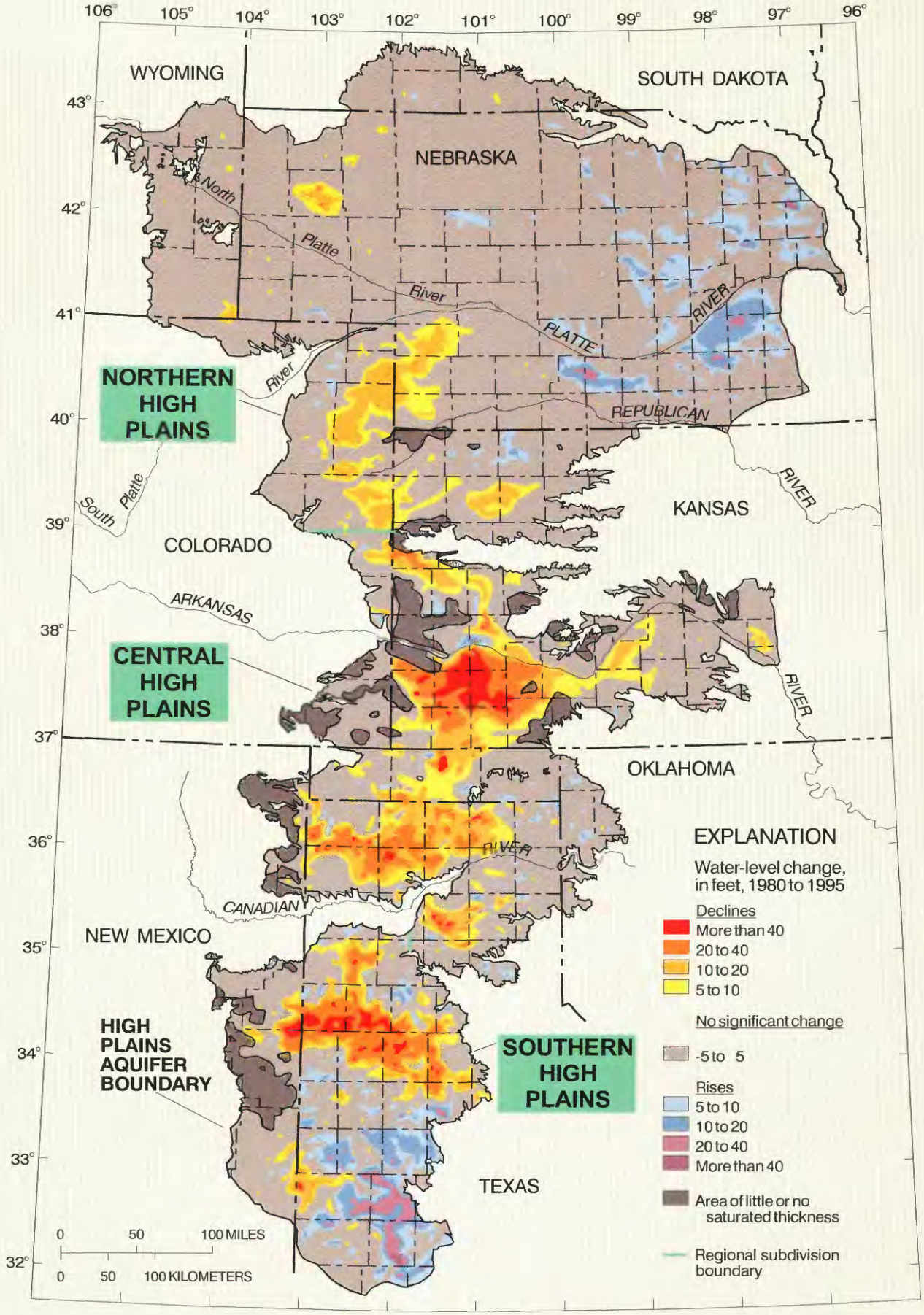

Figure 2. Water-level change in the High Plains aquifer, 1980 to 1995, and subdivisions of the aquifer.

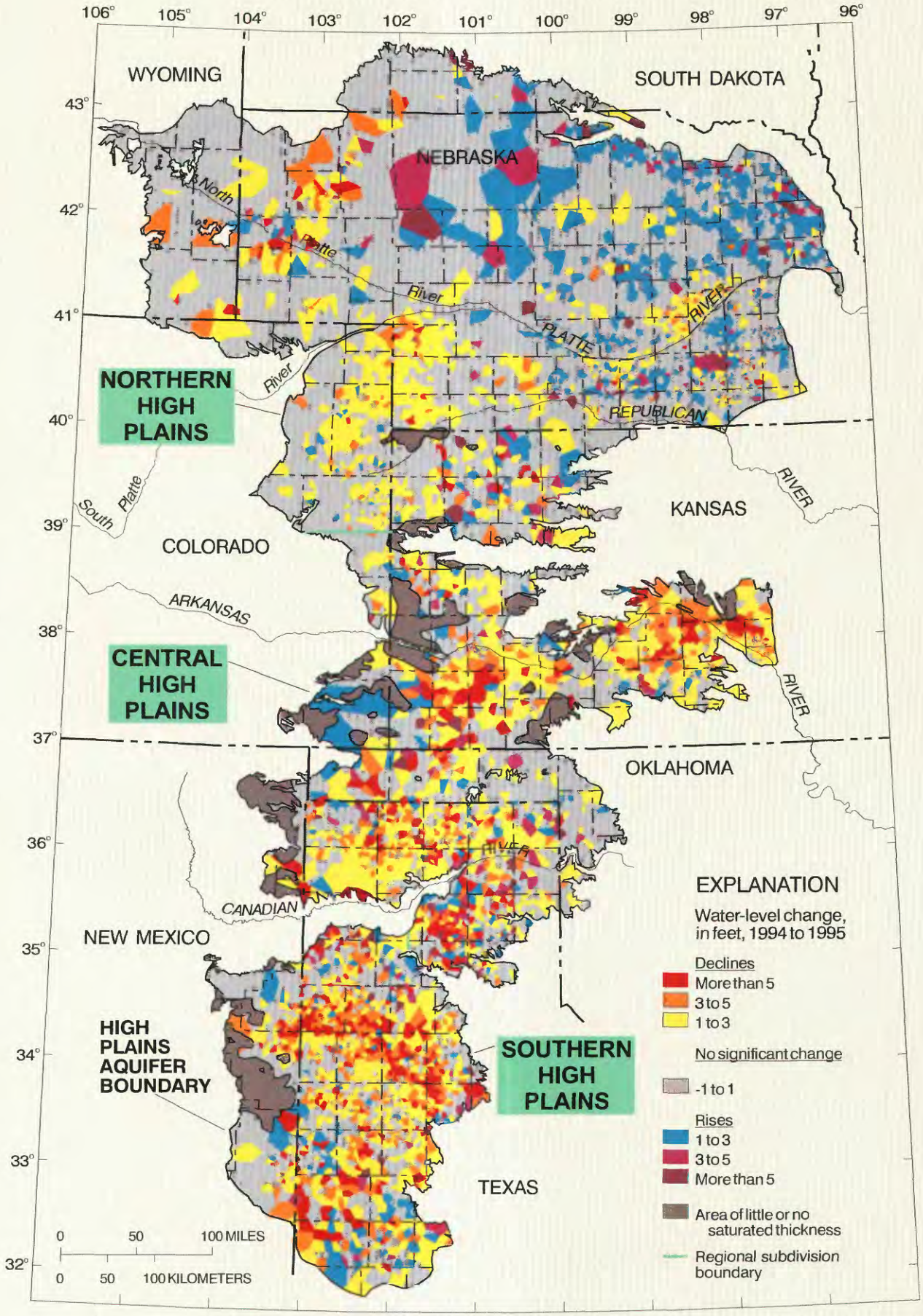

Figure 3. Water-level change in the High Plains aquifer, 1994 to 1995, and subdivisions of the aquifer.

The average annual CIR for corn, the principal irrigated crop in the High Plains region, is 18.5 inches in the southern and central High Plains region and 13 inches in the northern High Plains region (McGrath and Dugan, 1993; Dugan and Zelt, in press).

WATER-LEVEL CHANGE, 1980 TO 1995

The geographic patterns of water-level change in the High Plains aquifer from 1980 to 1995 differ in some areas from the pattern of change observed from predevelopment to 1980. Large water-level declines have continued in parts of the High Plains aquifer in Texas, Oklahoma, and southwestern Kansas (fig. 2). However, some areas of substantial decline prior to 1980 in Texas and Nebraska have generally had either water-level rises or considerably slower rates of decline since 1980.

The average area-weighted water level in the High Plains aquifer (table 2) declined 9.9 feet from predevelopment (1940) to 1980—about 0.25 foot annually—and 2.39 feet from 1980 to 1995—about 0.16 foot annually. The rate of change from 1980 to 1995 by State ranged from a decline of 0.50 foot per year in Kansas to a rise of 0.12 foot per year in Nebraska.

The smaller rate of water-level decline in the High Plains aquifer after 1980 occurred even though irrigated acreage in 1980 was more than double (14 million acres) the predevelopment-to-1980 average annual irrigated acreage (6 million acres) (Gutentag and others, 1984; Thelin and Heimes, 1987). Factors that appear to have contributed to the smaller rate of water-level decline are: (1) a decrease in ground-water withdrawals from the High Plains aquifer for irrigation—ground-water withdrawals for irrigation were 18.0 million acre-feet in 1980 and 15.7 million acre-feet in 1990 (Thelin and Heimes, 1987; Marilee Horn, written commun., 1996); (2) greater than normal precipitation—average annual precipitation in the High Plains region for 1981-94 was 21.82 inches or 1.23 inches greater than normal (table 1); (3) a decrease in irrigated acreage in areas, such as in parts of the southern High Plains region, with large potential rates of aquifer depletion; (4) use of more efficient irrigation technology, such as low-energy, precision application nozzles on center pivots; (5) improved farm-management practices, including irrigation scheduling, reuse of irrigation return flow, and the conversion to alternative crops or crop varieties with smaller consumptive irrigation requirements; (6) local regulation of ground-water withdrawals for irrigation and development of irrigated land; and (7) economic considerations that have forced marginal land out of irrigated production.

WATER-LEVEL CHANGE, 1994 TO 1995

The average area-weighted water level in the High Plains aquifer declined 0.66 foot from 1994 to 1995 (table 2). This decline contrasts with an average rise of 0.56 foot from 1993 to 1994 and an average rise of 0.21 foot from 1992 to 1993. The water-level decline in the High Plains aquifer from 1994 to 1995 may be partially attributed to increased ground-water withdrawals for irrigation in 1994 because precipitation in the High Plains region averaged 1.30 inches less than normal in 1994 (table 1) while precipitation was an average of 4.24 inches greater than normal in 1993 and 2.03 inches greater than normal in 1992 (Dugan and Cox, 1994; Dugan and Sharpe, 1996).

Although the average area-weighted water level declined in the High Plains aquifer from 1994 to 1995 and the average area-weighted precipitation in the High Plains region was less than normal in 1994, precipitation (fig.1) and water-level change (fig. 3) present different patterns. Water-level declines exceeding 3 feet were common in the central and southern High Plains aquifer, and water-level declines of at least 1 foot occurred in the western part of the northern High Plains aquifer. The average area-weighted water-level decline by State ranged from 0.40 foot in Oklahoma to 1.77 feet in Texas (table 2). The 1994 precipitation pattern varied from more than 5 inches less than normal to more than 5 inches greater than normal in those parts of the High Plains region with widespread water-level declines from 1994 to 1995. Water-level rises of at least 1 foot were common from 1994 to 1995 in the eastern portion of the northern High Plains aquifer; the average area-weighted water level rose 0.10 foot in South Dakota and 0.17 foot in Nebraska (table 2). The water-level rises from 1994 to 1995 in the eastern portion of the northern High Plains aquifer were generally associated with normal to more than 5 inches greater than normal precipitation.

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Table 1. Average area-weighted precipitation and comparison to 30-year normal precipitation (1961-90) in the High Plains region, 1994 and 1981 to 1994.

[Data from National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina (1951-94)]

State	1994		1981-94	
	Average precipitation (inches)	Departure from 30-year normal (inches)	Average annual precipitation (inches)	Departure from 30-year normal (inches)
Colorado	16.12	-0.29	17.21	+1.04
Kansas	19.60	-1.51	23.16	+.96
Nebraska	20.91	-.43	24.40	+1.32
New Mexico	12.98	-3.48	18.18	+1.67
Oklahoma	19.65	+.03	22.88	+1.00
South Dakota	18.68	+.16	20.91	+1.44
Texas	16.05	-2.62	20.37	+1.39
Wyoming	12.02	-2.97	15.36	+.86
High Plains	**18.32**	**-1.30**	**21.82**	**+1.23**

Table 2. Average area-weighted water-level change in the High Plains aquifer, predevelopment to 1980, 1980 to 1995, and 1994 to 1995

State	Area-weighted water-level change (feet)		
	Predevelopment to 1980	1980 to 1995	1994 to 1995
Colorado	-4.2	-4.18	-0.72
Kansas	-9.9	-7.52	-1.20
Nebraska	0	+1.84	+.17
New Mexico	-9.8	-3.14	-.91
Oklahoma	-11.3	-2.76	-.40
South Dakota	0	-.60	+.10
Texas	-33.7	-4.79	-1.77
Wyoming	0	-3.40	-.78
High Plains	**-9.9**	**-2.39**	**-0.66**

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