PREPARED IN COOPERATION WITH THE
COLORADO DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER RESOURCES,
OFFICE OF THE STATE ENGINEER; THE DENVER BOARD OF WATER COMMISSIONERS;
AND ADAMS, ARAPAHOE, DOUGLAS, ELBERT, AND EL PASO COUNTIES

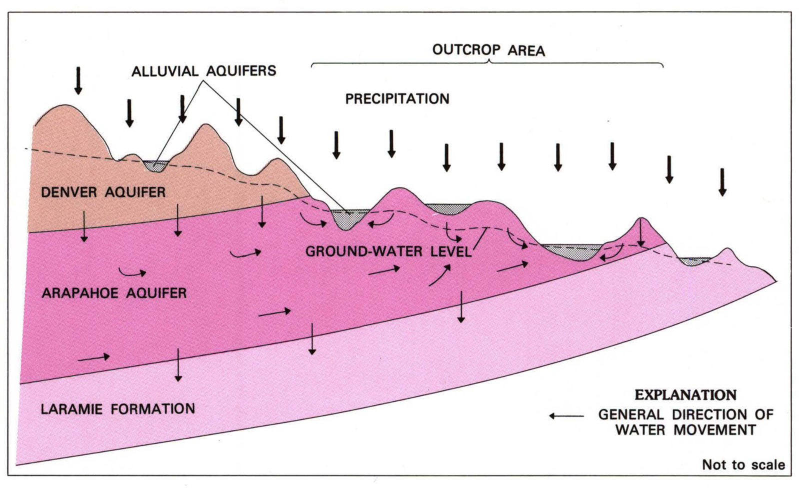

FIGURE 7.—DIAGRAM OF GROUND-WATER MOVEMENT

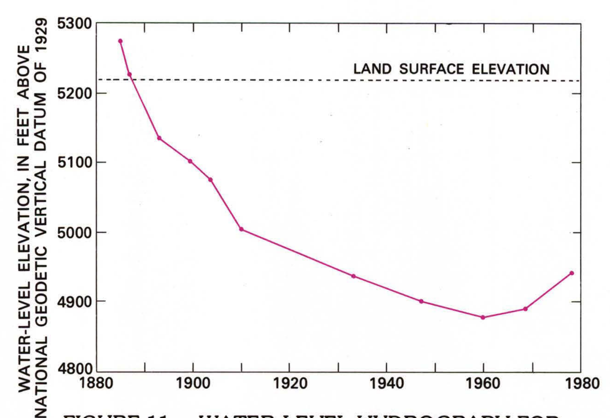

FIGURE 11.—WATER-LEVEL HYDROGRAPH FOR THE AQUIFER NEAR THE STATE CAPITOL BUILDING

HYDROLOGIC CONDITIONS

Most precipitation that falls on the land surface runs off in streams and creeks, is evaporated from the soil surface, or is consumed by vegetation. In addition, a small part of the precipitation usually percolates to depth and recharges the ground-water supply. The adjacent diagram of ground-water movement (fig. 7) illustrates the principal methods of recharge to the Arapahoe aquifer. In the outcrop area, recharge occurs as deep infiltration of precipitation in the highland areas between stream channels, or as infiltration of water from alluvial aquifers located above the water level in the bedrock aquifer. In the central part of the aquifer, downward movement of water from the overlying Denver aquifer is probably the principal source of recharge in this 3,100-square-mile area.

Most of the water moves laterally through the conglomerate and sandstone beds from areas of recharge toward areas of discharge. This can occur on both a local and a regional scale. On a local scale, water moves from the highland recharge areas in the outcrop through the upper part of the aquifer to the discharge areas in nearby stream valleys. On a regional scale, water moves from outcrop recharge areas, or from the central part of the study area, into deeper parts of the aquifer and discharges in more remote stream valleys. In the stream valleys, water from the Arapahoe aquifer discharges into streams, into the alluvial aquifers along the stream channels, or is consumed by vegetation growing in the valleys. Although most of the water in the Arapahoe aquifer flows laterally through the aquifer, some water may discharge by moving downward from the Arapahoe aquifer into the underlying Laramie-Fox Hills aquifer. In addition to these long-standing processes of natural discharge, relatively recent discharge occurs from pumping wells. In areas where pumping has caused significant water-level declines, natural discharge no longer may occur and pumpage may be the only ground-water discharge.

Perennial streams that are cut into the Arapahoe Formation may be supplemented either directly or indirectly by ground-water discharge from the Arapahoe aquifer. Streamflow is directly supplemented by springs and seeps that occur as a result of natural discharge of water from the Arapahoe aquifer at the land surface. Streamflow is indirectly supplemented where water from the Arapahoe aquifer first discharges into alluvial aquifers and the water in the alluvial aquifer in turn discharges into the stream.

The 1978 potentiometric-surface map (fig. 8) shows the elevation of the standing-water level during 1978 in wells completed in the Arapahoe aquifer. The elevation of the potentiometric surface was highest in the southern part of the aquifer and lowest to the north near Brighton. Water in the aquifer moves from points of higher water-level elevation to points of lower water-level elevation along paths that are perpendicular to the potentiometric contours shown on the map. The arrows on the map indicate the general direction of this water movement. In the northern, eastern, and southern parts of the aquifer, water generally is moving from the south-central part of the area toward the margins of the aquifer. The relatively sharp bends in the potentiometric contours near some small streams are the result of water moving from the aquifer into the stream valleys. Near the western edge of the aquifer, water is moving either approximately parallel to the aquifer limit or is moving east from the aquifer limit toward the South Platte River.

Ground water flows from the west, northwest, and southeast into a major trough in the potentiometric surface extending along the South Platte River to the area northeast of Brighton. The trough was originally shallower, being formed by the natural discharge of ground water into the South Platte River and its tributaries, but it has been deepened and expanded during the past 100 years by pumping in the area. The aggregate rate of pumping from wells in the trough has exceeded the rate of natural discharge from the aquifer and, in some areas, has reversed the direction of ground-water movement between the Arapahoe aquifer and adjacent aquifers. As a result, much of the ground water moving into the trough is now removed from the trough by pumping rather than by natural discharge.

The 1978 potentiometric surface in the Arapahoe aquifer was generally 50 to 100 feet below the water level in the alluvial aquifer along the South Platte River in the reach from Welby to Fort Lupton. The potential thus exists for water to move into the Arapahoe aquifer from the alluvial aquifer in this area. The Arapahoe aquifer is overlain by the Denver aquifer along that part of the trough in the potentiometric surface extending from Welby to Chatfield Reservoir. In this area the potentiometric surface in the Arapahoe aquifer is generally 50 to 300 feet lower than the potentiometric surface in the Denver aquifer, creating the potential for downward movement of water from the Denver aquifer into the Arapahoe aquifer. The Arapahoe aquifer overlies the Laramie-Fox Hills aquifer along the trough in the potentiometric surface north of Denver. In this area, the potentiometric surface in the Arapahoe aquifer is 0 to 300 feet higher than the potentiometric surface in the underlying Laramie-Fox Hills aquifer. Between Golden and Littleton the potentiometric surface in the Arapahoe aquifer is generally 100 to 300 feet lower than that in the Laramie-Fox Hills aquifer. These differences in the potentiometric surfaces would allow water to flow from the Arapahoe aquifer into the Laramie-Fox Hills aquifer north of Denver and from the Laramie-Fox Hills aquifer into the Arapahoe aquifer between Golden and Littleton.

The differences in potentiometric-surface elevations between adjacent aquifers indicate the direction ground water may move, but do not indicate how much movement, if any, is actually occurring. The volume of water that is moving vertically into or out of the Arapahoe aquifer in these areas is not known, but is probably small due to the low permeability of the intervening shale layers.

In the central part of the aquifer, water-level data for the Arapahoe aquifer are unavailable and the potentiometric surface cannot be accurately defined. However, in rural areas, water levels in the Arapahoe aquifer seem to be similar to, or a few tens of feet lower than those in the Denver aquifer. In areas where ground-water pumpage is large, such as the suburban area south of Denver, water levels in the Arapahoe aquifer are 100 to 300 feet below the water levels in the Denver aquifer. If, as these data indicate, the shape of the potentiometric surface is generally similar in the two aquifers, then the general direction of water movement in the Denver aquifer also will indicate the general direction of water movement in the central part of the Arapahoe aquifer. It thus seems likely that a ground-water divide occurs in the Arapahoe aquifer near a line from Monument to Calhan. If so, ground water north of the divide moves in a northerly direction while ground water south of the divide moves in a southerly direction.

Water-level measurements made between 1956 and 1960 in wells completed in the Arapahoe aquifer were used to estimate the 1958 potentiometric surface. These data were adequate to define this surface only in the northwestern part of the area, as shown on the adajacent map (fig. 9). The direction of ground-water movement in 1958 was similar to the direction of movement during 1978.

The difference in potentiometric-surface elevations between 1958 and 1978 is the change in water level that has occurred in the aquifer during the 20-year period. Water-level declines have exceeded 200 feet in a 135-square-mile area southeast of Denver and have exceeded 50 feet in a much larger but less well-defined area as shown on the accompanying map (fig. 10). Water-level rises have exceeded 100 feet in a 60-square-mile area under the north-central part of the Denver metropolitan area, while in other parts of the Denver area only moderate water-level changes have occurred. This pattern of water-level change likely is the result of a post-1958 decrease in the rate of pumping in the metropolitan area coupled with an increase in pumping in the surrounding suburban areas. The 1958 to 1978 water-level-change data from wells at a few scattered locations in other parts of the Arapahoe aquifer generally show water-level rises or declines of less than 50 feet with no consistent pattern in these areas.

The accompanying hydrograph (fig. 11) shows the elevations of the potentiometric surface in the Arapahoe aquifer between 1885 and 1978. The hydrograph is based on water-level measurements made in wells located near the State Capitol Building in downtown Denver. The wells were all of similar construction and existed for varying lengths of time during the 93-year period. Prior to 1890 the potentiometric surface in this area was above land surface and it was common for water to flow without being pumped from wells completed in the Denver and Arapahoe aquifers. The discovery in 1883 that wells drilled in this area would flow led to a rapid increase in the number of wells (Emmons and others, 1896) and is primarily responsible for the initial rapid decline in the water level in the aquifer. As the water level fell below land surface it became necessary to pump the wells which led to further water-level declines. The rate of decline was not as rapid between 1910 and 1960, possibly due to a decrease in pumping caused by the increasing availability of municipal water supplied from surface-water sources. The water-level rise between 1960 and 1978 is the probable result of a continued decrease in pumping from the Arapahoe aquifer in the metropolitan area. Between 1885 and 1960 water levels in the aquifer are shown to have declined about 400 feet with about 340 feet of decline still present in 1978.

Wells completed in the Arapahoe aquifer generally yield from 0.5 to 10 gallons per minute per foot of drawdown. Therefore, if the water level in a well declines 100 feet while the pump is operating, the well probably would yield between 50 and 1,000 gallons per minute. Three factors that affect the yield of a well are: (1) The thickness of water-yielding material penetrated by the well, (2) the permeability of the material, and (3) the distance the water level in the well can be drawn down while the pump is operating. Thus, a well completed in a large thickness of permeable sandstone at sufficient depth to allow a significant water-level drawdown while pumping would yield more water than a well completed in a thin, less permeable sandstone that has a water level near the base of the sandstone.

METRIC CONVERSION FACTORS

The inch-pound units used in this report may be converted to metric units by use of the following conversion factors:

To convert inch-pound units	Multiply by	To obtain metric units
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
gallon per minute	0.06309	liter per second
gallon per minute per foot	0.2070	liter per second per meter

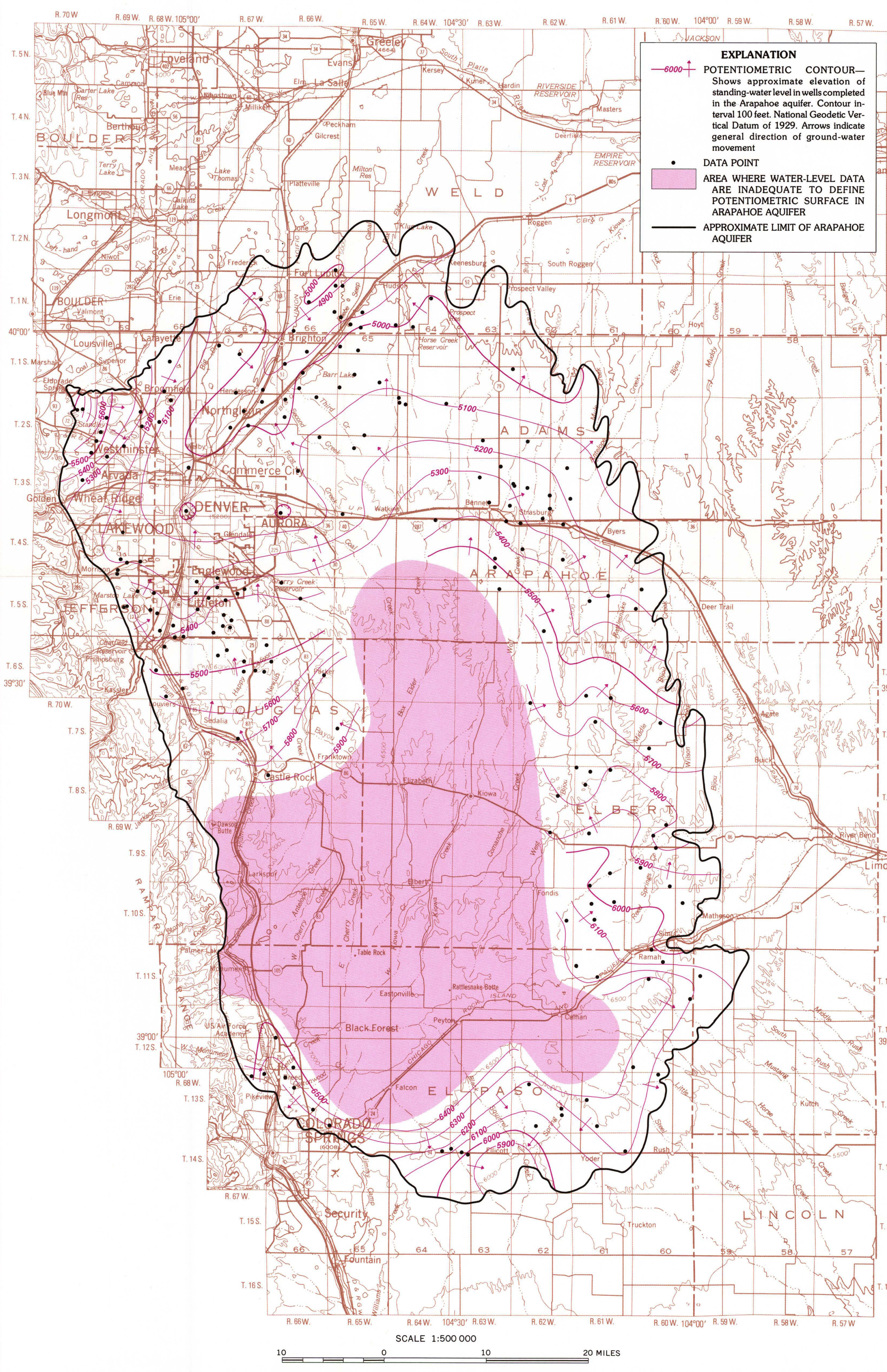

FIGURE 8.—MAP SHOWING ELEVATION OF POTENTIOMETRIC SURFACE IN THE AQUIFER, 1978

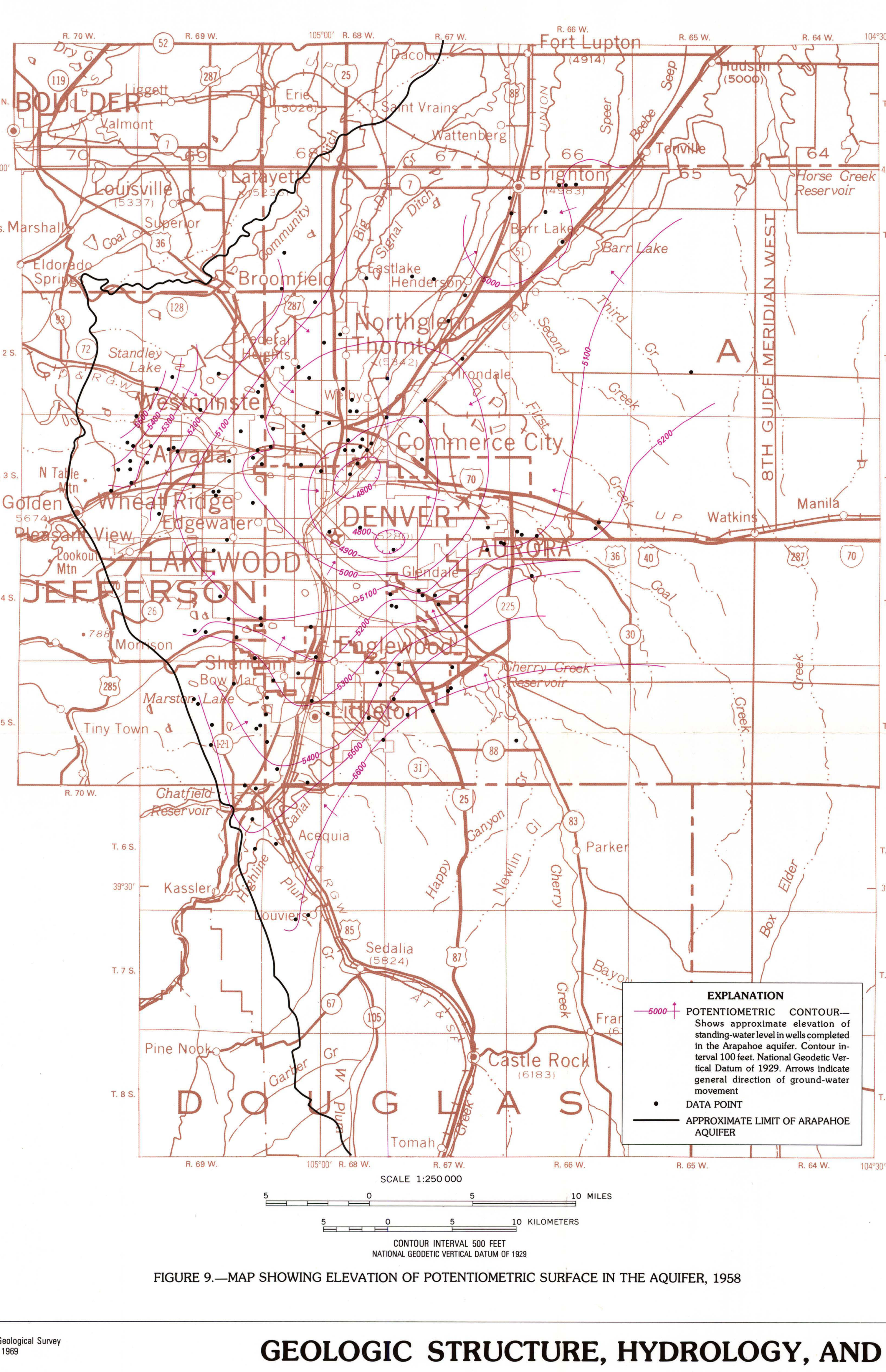

FIGURE 9.—MAP SHOWING ELEVATION OF POTENTIOMETRIC SURFACE IN THE AQUIFER, 1958

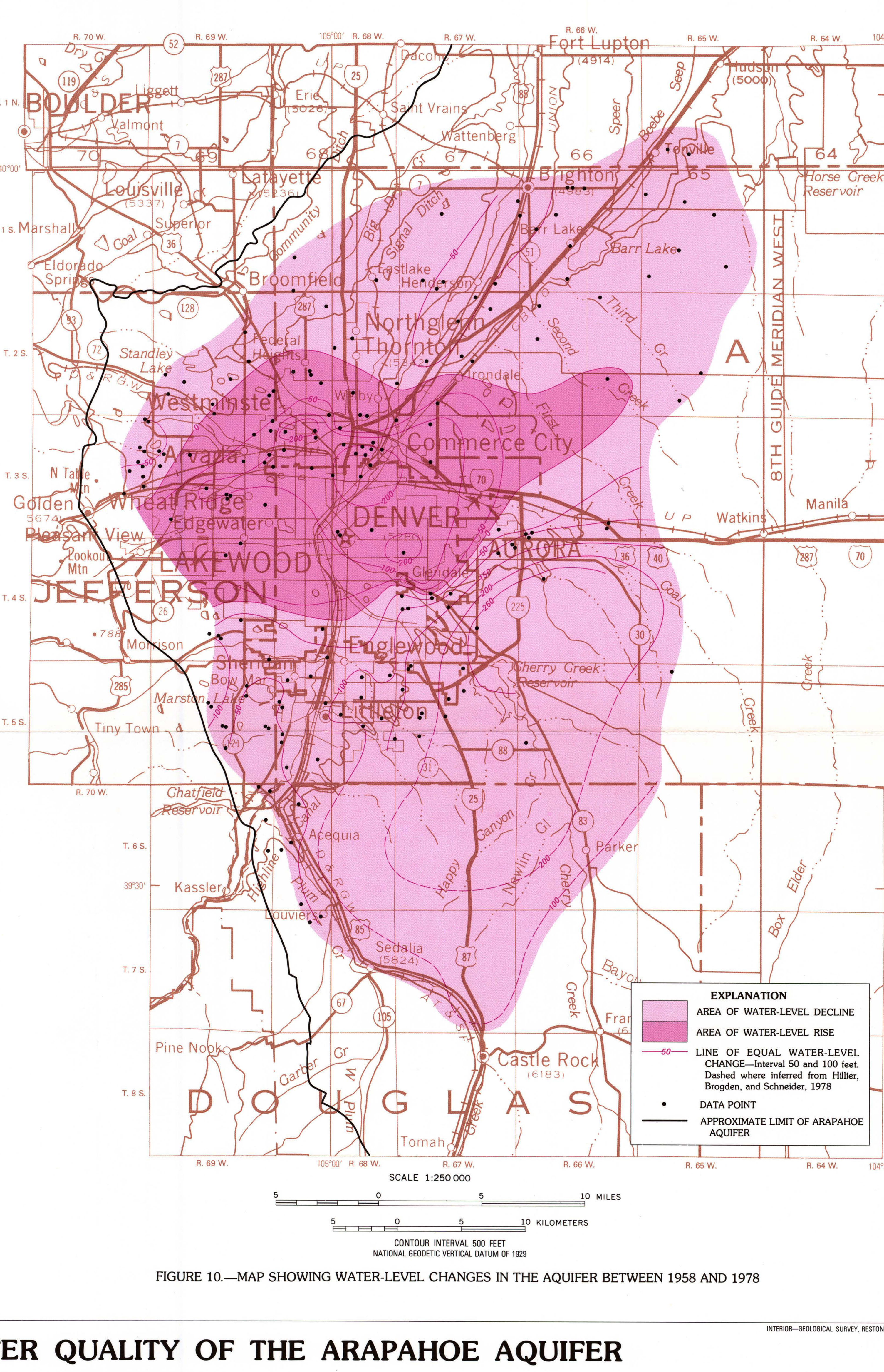

FIGURE 10.—MAP SHOWING WATER-LEVEL CHANGES IN THE AQUIFER BETWEEN 1958 AND 1978

Base from U.S. Geological Survey
State base map, 1969

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1981

GEOLOGIC STRUCTURE, HYDROLOGY, AND WATER QUALITY OF THE ARAPAHOE AQUIFER IN THE DENVER BASIN, COLORADO

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