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

INTRODUCTION

The Denver ground-water basin underlies a 6,700-square-mile area extending from Greeley in the north to Colorado Springs in the south, and from the Front Range in the west to near Limon in the east. The four major bedrock aquifers that occur in the basin are the Laramie-Fox Hills aquifer (the deepest aquifer), the Arapahoe aquifer, the Denver aquifer, and the Dawson aquifer (the uppermost aquifer). The Laramie-Fox Hills aquifer, which is the subject of this report, underlies the entire area of the basin in east-central Colorado (index map, fig. 1) and is an important source of water for residents in the northern Denver suburban area and in the rural areas of eastern Jefferson, Arapahoe, and Elbert Counties, Adams County, and southern Weld and El Paso Counties. About 90 percent of the estimated 1,700 wells completed in the aquifer supply water to residents and livestock. The remaining wells supply water for commercial and industrial use and limited irrigation of commercial crops.

The continuing increase in population in rural communities and suburban areas near Denver has produced increasing demands for ground-water supplies. As a result, the number of wells obtaining water from the Laramie-Fox Hills aquifer has steadily increased and the increased pumpage has caused local water-level declines in the aquifer. In sparsely populated areas, water-level declines have not been significant; however, near some more urbanized areas, the average rate of water-level decline has exceeded 15 feet per year. Continued increases in population will likely cause increasing demands for water from the Laramie-Fox Hills aquifer and will continue the water-supply problems faced by residents who depend on this bedrock aquifer for water.

This study was undertaken to better define the water-supply potential of the four major bedrock aquifers in the Denver basin. Findings related to the Laramie-Fox Hills aquifer made during the first 2 years of the investigation are presented in this report to provide water users with timely ground-water resources information that can be used to better manage and develop the water supply of the aquifer. Similar reports for the Dawson aquifer, the Denver aquifer, and the Arapahoe aquifer have been completed (Robson and Romero, 1981a, 1981b; Robson, Romero, and Zawistowski, 1981). The hydrologic data used in preparing these reports are available in Major and others (1981) and McConaghy and others (1964), and in the Colorado District Office of the U.S. Geological Survey in Lakewood, Colo.

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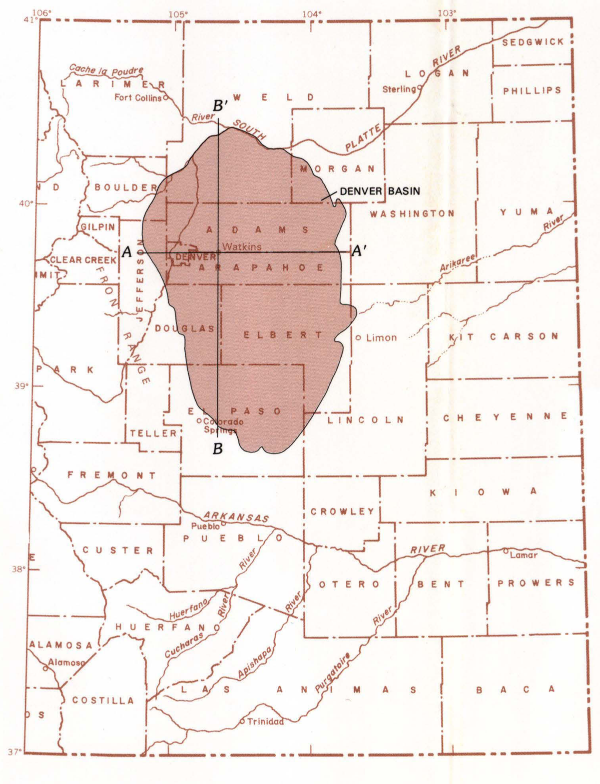

FIGURE 1.—INDEX MAP SHOWING LOCATION OF DENVER BASIN, AND GENERALIZED GEOLOGIC SECTION

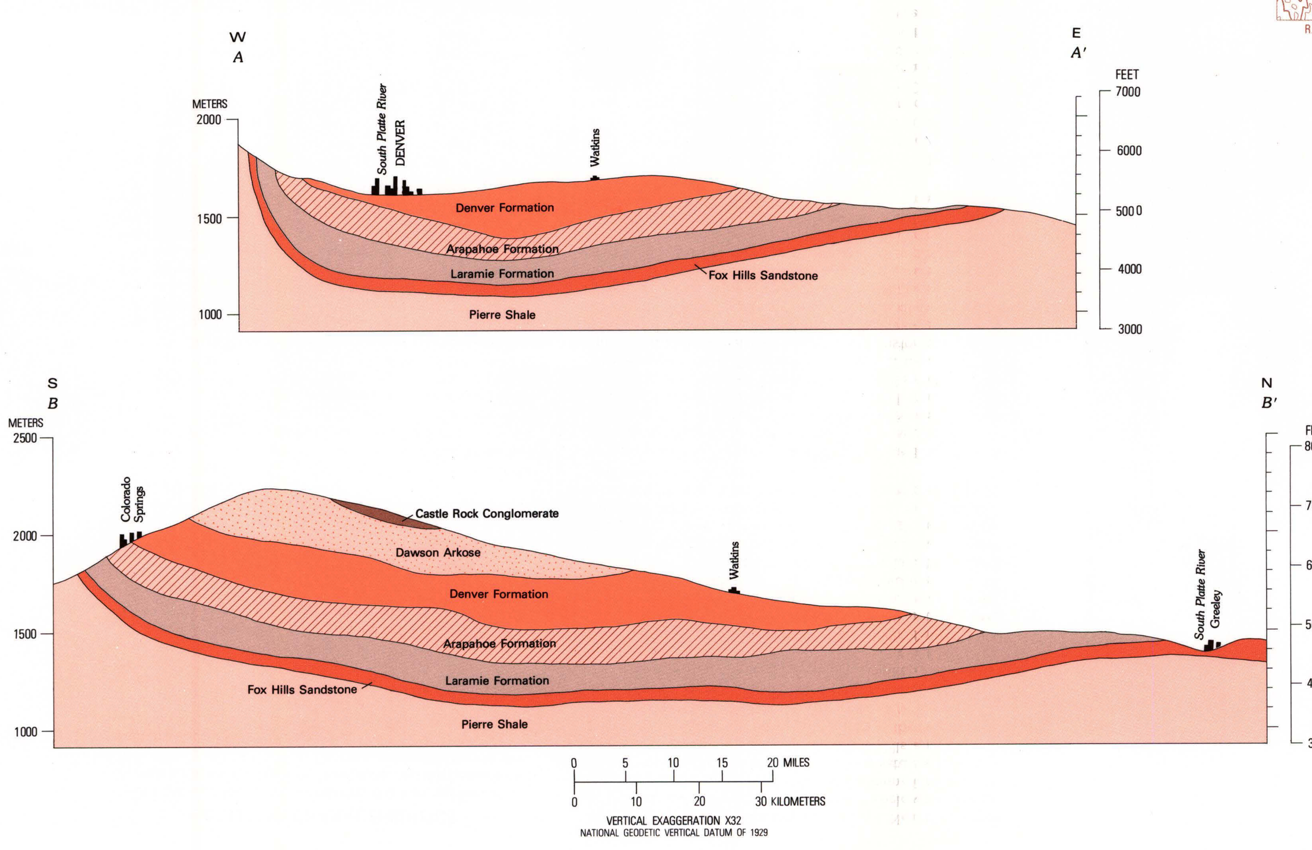

FIGURE 2.—GENERALIZED GEOLOGIC SECTIONS THROUGH THE DENVER BASIN
(Trace of sections located in figure 1)

GEOLOGIC CHARACTERISTICS

The geologic formations containing the four aquifers of the Denver basin are the Fox Hills Sandstone, and the Laramie and Arapahoe Formations of Late Cretaceous age, the Denver Formation of Late Cretaceous and early Tertiary age, and the Dawson Arkose of Tertiary age (Romero, 1976). These formations occur in a sequence of layers as shown by the generalized geologic sections drawn from west to east and from south to north through the basin (fig. 2). The northern, eastern, and southern parts of the basin form a shallow bowl, the sides of which dip gently toward the west-central part of the basin. Along the western edge of the basin, sedimentary formations are upturned along the Precambrian crystalline rocks of the Front Range and dip steeply to the east as a result of faulting and the gradual upward movement of the Rocky Mountains. The Pierre Shale of Late Cretaceous age underlies the Fox Hills Sandstone and is considered to be the base of the major bedrock-aquifer system due to its great thickness (as much as 8,000 feet) and its minimal permeability.

The Laramie-Fox Hills aquifer occurs in the basal sandstone units of the Laramie Formation and the upper sandstone and siltstone units of the underlying Fox Hills Sandstone. In a few areas, siltstone and sandstone units occurring in the uppermost part of the Pierre Shale are also included in the Laramie-Fox Hills aquifer. The thickness of the Laramie-Fox Hills aquifer ranges from zero near the aquifer boundary to between 200 and 300 feet in the central part of the aquifer. The part of the Laramie-Fox Hills aquifer within the Fox Hills Sandstone is generally 150 to 200 feet thick and is composed of an overlying bed of very fine grained silty sandstone 40 to 50 feet thick underlain by 100 to 150 feet of shaley siltstone and interbedded shale. Elongated lenticular concretions containing iron minerals are common in the Fox Hills Sandstone in some areas. The part of the Laramie-Fox Hills aquifer within the Laramie Formation is generally 50 to 100 feet thick and is composed of very fine to medium grained sandstone with interstitial silt and clay. Locally, the sandstone is separated into upper and lower members by interceding shale beds 10 to 20 feet thick. A shale bed 5 to 20 feet thick commonly separates the Laramie part of the aquifer from the Fox Hills part. The Fox Hills part of the aquifer is of marine origin, consisting of shoreline deposits, whereas the Laramie part of the aquifer is transitional from marine to brackish water and is continental in origin. Coal seams are common in the Laramie Formation, and the lowermost of these is useful in identifying the upper limit of the aquifer.

Core samples from the Laramie-Fox Hills aquifer reveal that the deeply buried sandstones and siltstones are friable, and generally light to medium gray with a "salt and pepper" appearance. Zones containing iron-sulfide minerals are present in some areas. Sandstone and siltstone samples from outcrops range from unconsolidated to very hard, depending on the presence of iron cements formed from the oxidation of iron-sulfide minerals. Outcrop colors range from white through various shades of light brown and orange.

In the northwest part of the basin, near Boulder County, numerous local faults have offset the strata in the Fox Hills Sandstone and Laramie Formation. This may have occurred in part during deposition of these formations, for marked changes in bedding thickness have been observed across some fault zones. In some places the geologic structure and hydrology near these faults is localized and marked differences in aquifer characteristics occur over short distances. Results presented in this report describe the general geologic and hydrologic conditions in this area but do not show details of local conditions.

The 400 to 500 feet of Laramie Formation overlying the Laramie-Fox Hills aquifer forms an upper boundary for the aquifer. Laramie strata above the aquifer are composed of gray through black shale, coal seams, and thin beds of gray siltstone and sandstone. The uppermost 50 to 100 feet are composed of fine to very coarse grained sandstone, which, for hydrologic purposes, has been included in the Arapahoe aquifer. The Pierre Shale underlies the Fox Hills Sandstone and consists of 5,000 to 8,000 feet of shale with thin layers of siltstone and sandstone. The Pierre Shale forms the base of the Laramie-Fox Hills aquifer and those siltstone and sandstone layers present in the upper part of the shale generally are not considered to be part of the Laramie-Fox Hills aquifer. However, in local areas, these siltstone and sandstone units may be in close proximity to the Fox Hills Sandstone and, for hydrologic purposes, are considered to be part of the Laramie-Fox Hills aquifer.

In part of the outcrop area near the margins of the aquifer the Laramie Formation and Fox Hills Sandstone are exposed at the surface or buried under a thin layer of soil. In other parts of this area, the formations are buried under 20 to 100 feet of sand and gravel deposited in the valleys of the South Platte River and many of the smaller streams crossing the area. Near the margins of the aquifer, the ground-water level may be below the geologic unit forming the top of the aquifer and the formations that normally comprise the aquifer may not be fully saturated. In these partially saturated areas, the Laramie-Fox Hills aquifer is assumed to extend from the base of the aquifer to the potentiometric surface (a surface that shows the elevation of the standing-water levels in wells completed in the aquifer).

The map showing the elevation and configuration of the base of the Laramie-Fox Hills aquifer (fig. 3) indicates that the base is bowl shaped and ranges in elevation from a high of about 6,000 feet at Colorado Springs to a low of about 3,500 feet in the area between Aurora and Parker. The aquifer limit shown on the map is the approximate extent of saturated sediments in the Laramie-Fox Hills aquifer. Beyond this limit it is unlikely that a well completed in the Laramie Formation or Fox Hills Sandstone would yield usable quantities of water. Although the Laramie-Fox Hills aquifer extends north of Greeley, the hydrologic boundary formed by the South Platte River was chosen as the northern limit of the study area.

The depth to the base of the aquifer may be determined by subtracting the elevation of the base of the aquifer from the elevation of the land surface. The depths shown on the adjacent map (fig. 4) were calculated for each section (1 square mile) of land in the area, using average land surface and structural elevations in each section. The depth to the base of the aquifer is as much as 3,200 feet between Larkspur and Eastonville and is in excess of 1,500 feet throughout much of the west-central part of the aquifer. This map provides a quick means of estimating the depth to the base of the aquifer but is somewhat generalized due to the use of average elevations. If, for example, a water well is to be drilled into the aquifer, this map shows the approximate well depth required to fully penetrate the aquifer. A more accurate depth estimate can be made by subtracting the elevation of the base of the aquifer at the well site from the land-surface elevation at the well site.

The extent, elevation, and configuration of the geologic structure at the top of the Laramie-Fox Hills aquifer is shown on the accompanying map (fig. 5). The top of the aquifer has a bowl shape similar to the base of the aquifer and ranges in elevation from about 5,900 feet near Rush to about 3,700 feet south of Cherry Creek Reservoir. The thickness of the aquifer can be determined by one of two methods depending on the location of the point of interest. If the point of interest is (1) within the limit of the geologic structure forming the top of the aquifer, the thickness is the difference between the elevations of the top and base of the aquifer. If the point of interest is (2) located in the partially saturated zone, the difference between the elevation of the potentiometric surface (fig. 8, shown on the second map sheet) and the elevation of the base of the aquifer must first be determined. If the point of interest is not located in an area occupied by an alluvial aquifer, this difference is the thickness of the Laramie-Fox Hills aquifer. If the point of interest is in an area occupied by an alluvial aquifer, the thickness of the alluvial aquifer must be subtracted from the above difference to determine the thickness of the Laramie-Fox aquifer. Because alluvial aquifers 20 to 100 feet thick commonly occur in the valleys of larger streams in the area, the thickness of the Laramie-Fox Hills aquifer under an alluvial aquifer will be 20 to 100 feet less than the above difference.

The bedrock-aquifer thickness calculated by either of the above methods includes the thickness of the water-yielding sandstone and siltstone as well as the thickness of the nonwater-yielding shale. Because the thickness of the water-yielding beds are of particular interest, the map of total sandstone and siltstone thickness (fig. 6) was prepared to show the thickness of only these materials. Near the margins of the aquifer there is generally less than 100 feet of water-yielding material in the aquifer, while near Littleton and Calhan more than 200 feet of sandstone and siltstone occur. Schneider (1980) showed that the total sandstone thickness in the aquifer in the southeastern part of Boulder County ranges from less than 50 feet to more than 300 feet. This is in contrast to the thickness shown in figure 6, which generally does not exceed 170 feet in this area. The difference in thickness is apparently due to (1) a difference in the techniques used in the two studies to estimate sandstone thickness, and (2) the possible inclusion by Schneider of sandstone thicknesses in formations below those considered in this study. A comparison of total aquifer thickness to total sandstone and siltstone thickness within the aquifer indicates that the Laramie-Fox Hills aquifer contains about 60 percent sandstone and siltstone and about 40 percent shale. By comparison, the overlying Arapahoe aquifer contains about 40 percent conglomerate, sandstone, and siltstone, and about 60 percent shale.

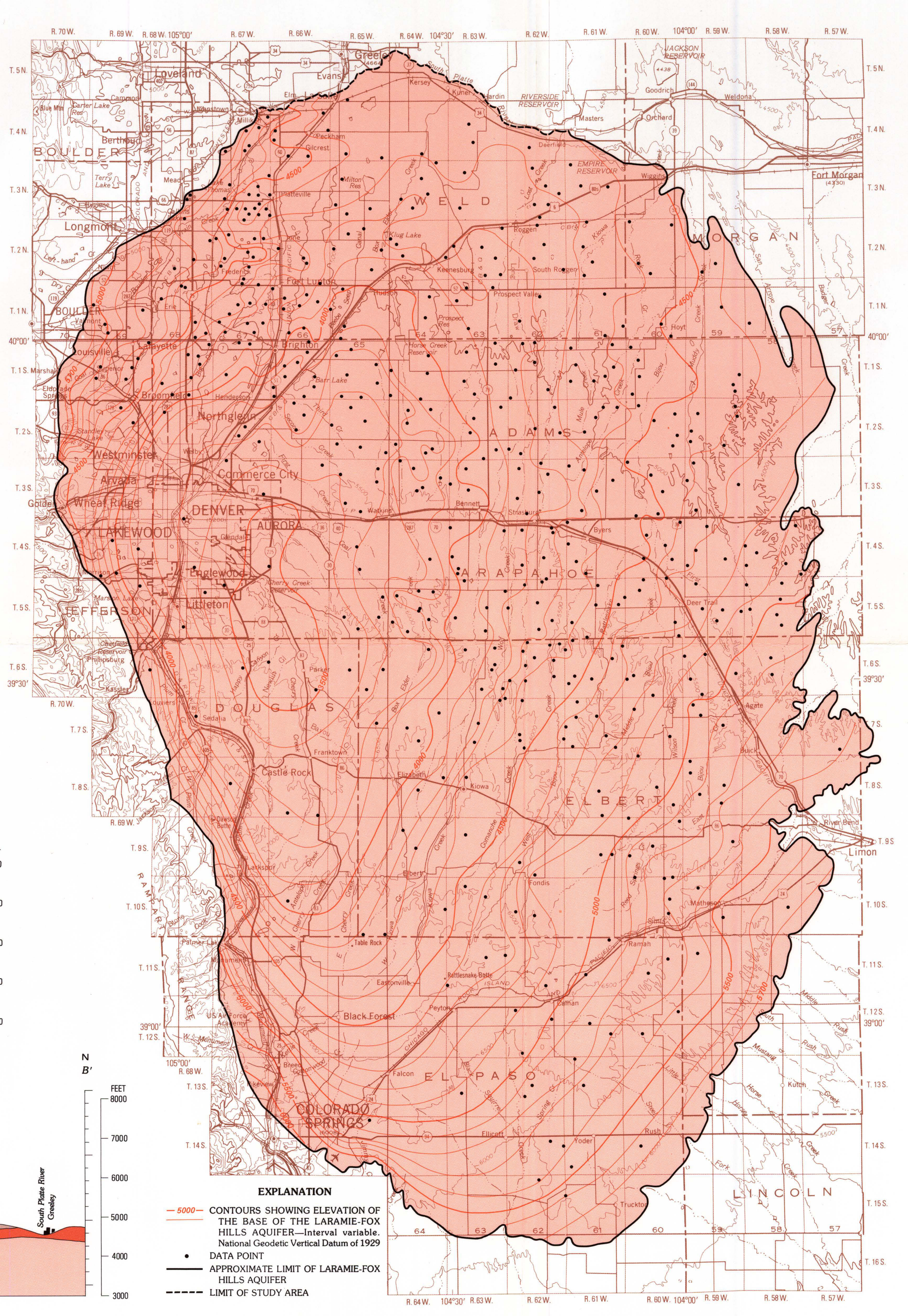

FIGURE 3.—MAP SHOWING ELEVATION AND CONFIGURATION OF THE BASE OF THE AQUIFER

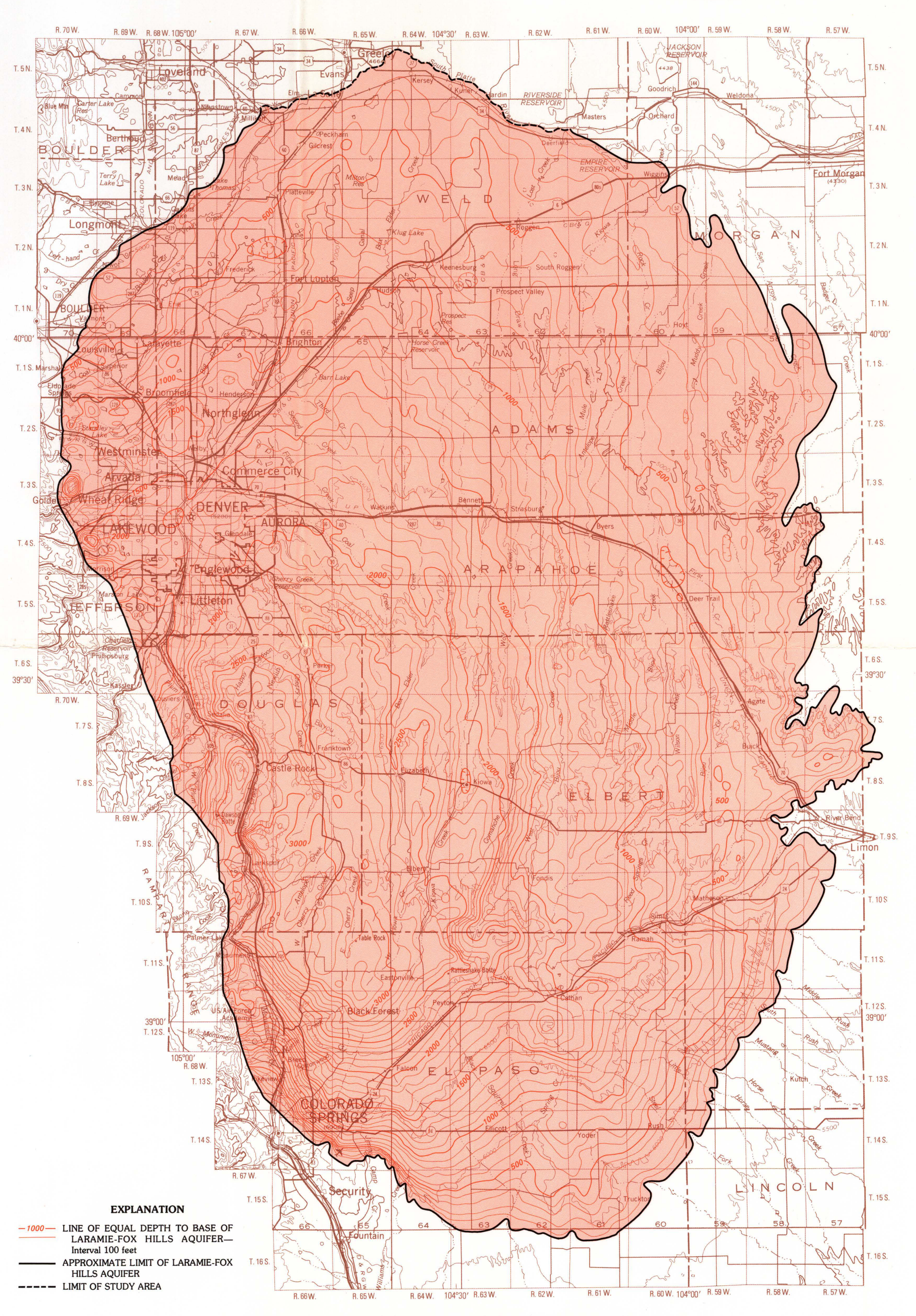

FIGURE 4.—MAP SHOWING DEPTH TO THE BASE OF THE AQUIFER

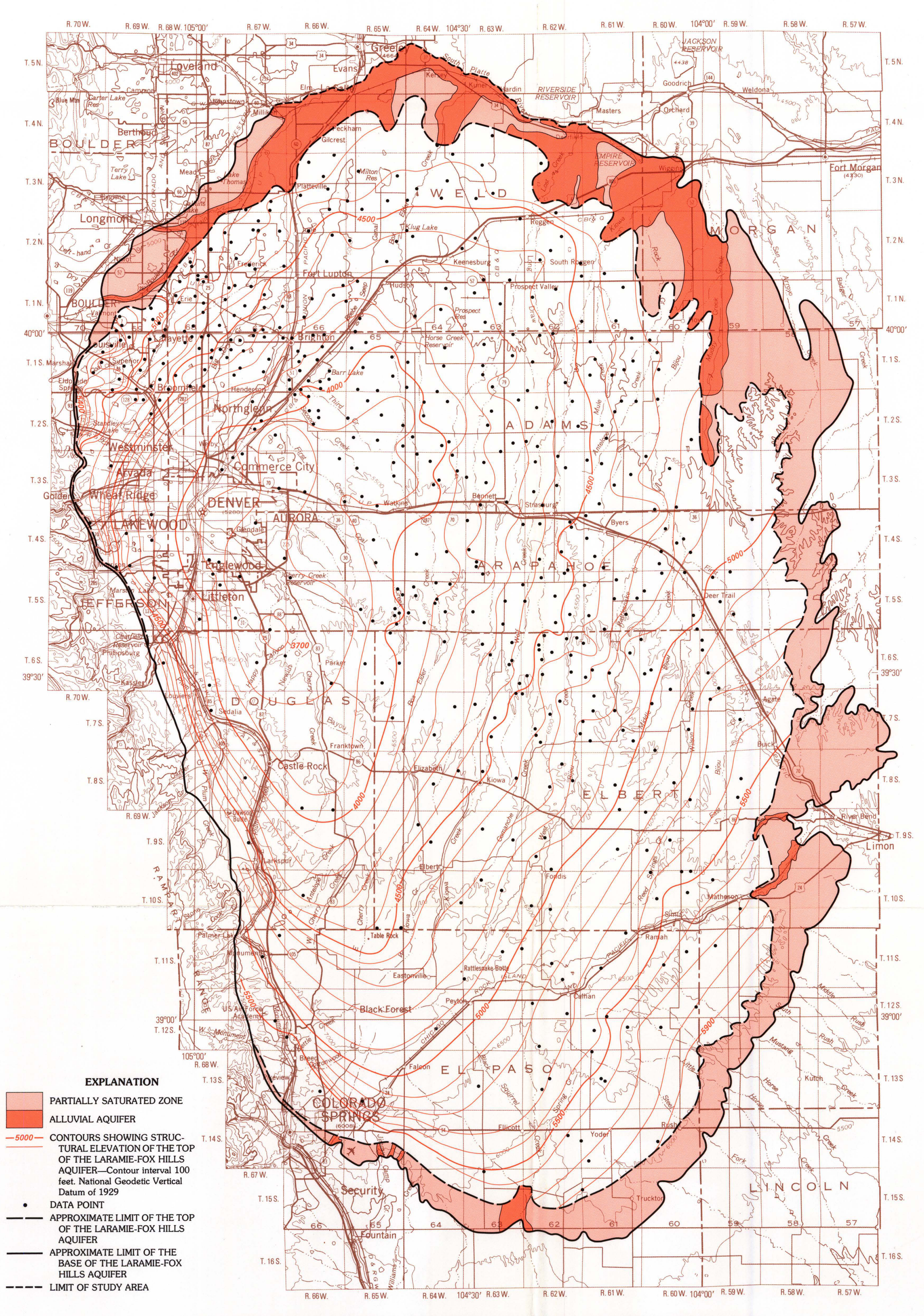

FIGURE 5.—MAP SHOWING ELEVATION AND CONFIGURATION OF THE TOP OF THE LARAMIE-FOX HILLS AQUIFER AND LOCATION OF ALLUVIAL AQUIFERS IN THE PARTIALLY SATURATED ZONE

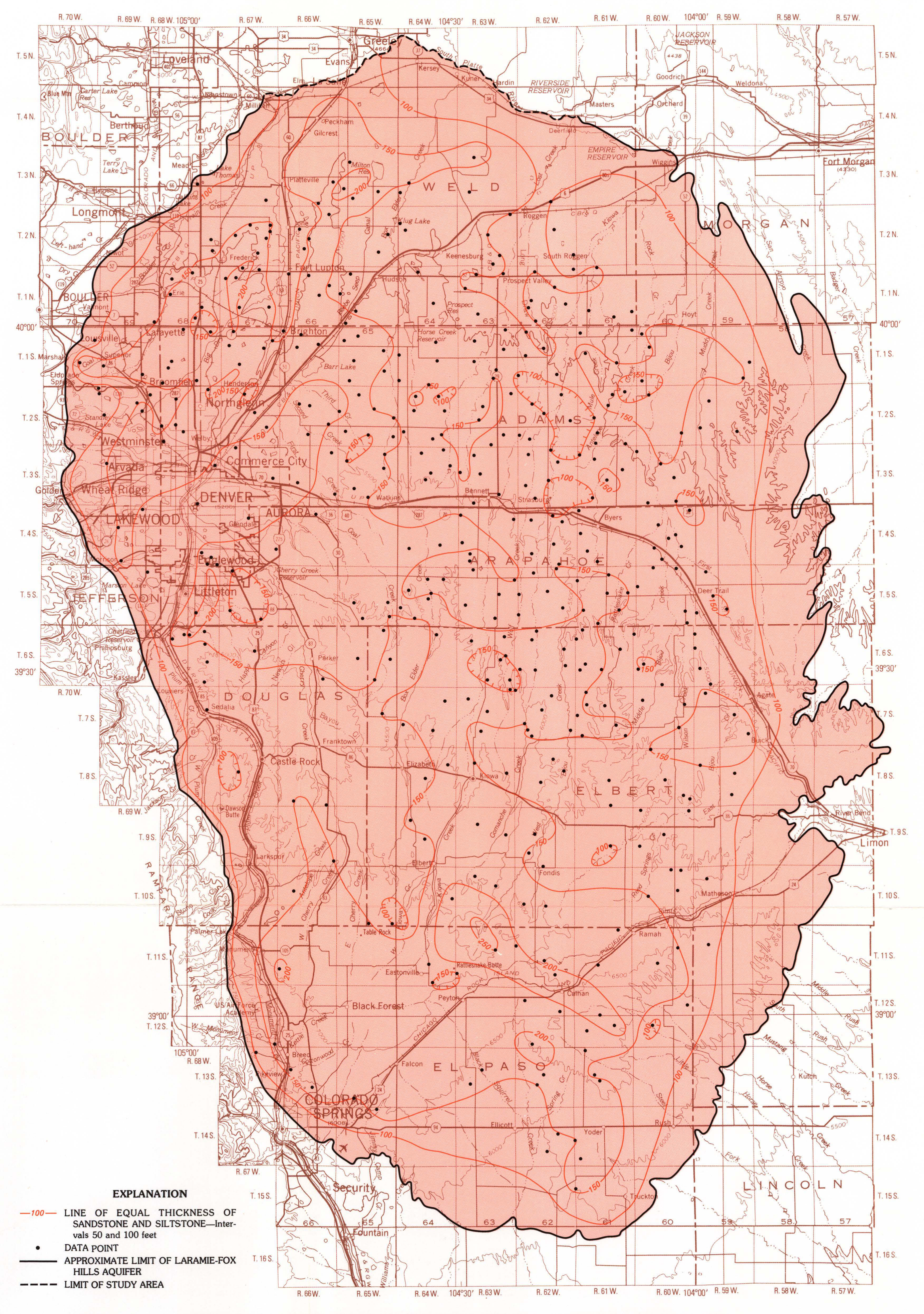

FIGURE 6.—MAP SHOWING TOTAL THICKNESS OF SANDSTONE AND SILTSTONE IN THE AQUIFER

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

SCALE 1:500 000
10 0 10 20 30 40 50 MILES
10 0 10 20 30 40 50 KILOMETERS
CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOLOGIC STRUCTURE, HYDROLOGY, AND WATER QUALITY OF THE LARAMIE-FOX HILLS AQUIFER IN THE DENVER BASIN, COLORADO

By
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Division of Water Resources, Office of the State Engineer

1981

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