UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

HYDROGEOLOGIC CHARACTERISTICS OF THE VALLEY-FILL AQUIFER IN THE ARKANSAS RIVER VALLEY, BENT COUNTY, COLORADO

By

R. Theodore Hurr and John E. Moore

Prepared in cooperation with the
COLORADO WATER CONSERVATION BOARD
and the
SOUTHEASTERN COLORADO WATER CONSERVANCY DISTRICT

OPEN-FILE REPORT
Subject to Revision

Colorado District
Denver, Colorado
March 1971

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INTRODUCTION

Water resources of the Arkansas River valley support the irrigation economy of the third most productive irrigated area in Colorado, which has been farmed and irrigated for more than 100 years. The reach of the valley from Pueblo to the Kansas State line is the major irrigated area. The principal crops are corn, barley, sorghum, sugar beets, melons, onions, beans, and wheat. Supplemental irrigation is necessary to assure the success of most crops because the climate of the valley is semiarid; the mean annual precipitation is only 12 inches. In 1968 about 143,000 acres were under irrigation and the agricultural production in Pueblo, Otero, Crowley, Bent, and Prowers Counties was valued at about $26 million (Colorado Department of Agriculture, 1970).

The Arkansas River originates in the Rocky Mountains where altitudes exceed 14,000 feet. The river flows southeastward through the mountains, and downstream from Pueblo it flows eastward across the plains to Kansas. The reach of the valley from Pueblo to the Kansas State line is underlain by unconsolidated clay, silt, sand, and gravel deposits. The saturated part of these valley-fill deposits form an aquifer which is unconfined (see fig. 1 index map). The valley-fill aquifer in this reach is from 0 to more than 250 feet thick and contains about 2 million acre-feet of water in storage. The aquifer is hydraulically connected to the Arkansas River.

Irrigation water is diverted from the Arkansas River and also pumped from wells. Surface-water diversions averaged 760,000 acre-feet per year and ground-water withdrawals 140,000 acre-feet per year during 1958-68. Surface-water irrigation started in 1859 and today (1971) 24 canals divert water from the Arkansas River for application on the land between Pueblo and the Kansas State line. Streamflow is derived from precipitation--chiefly

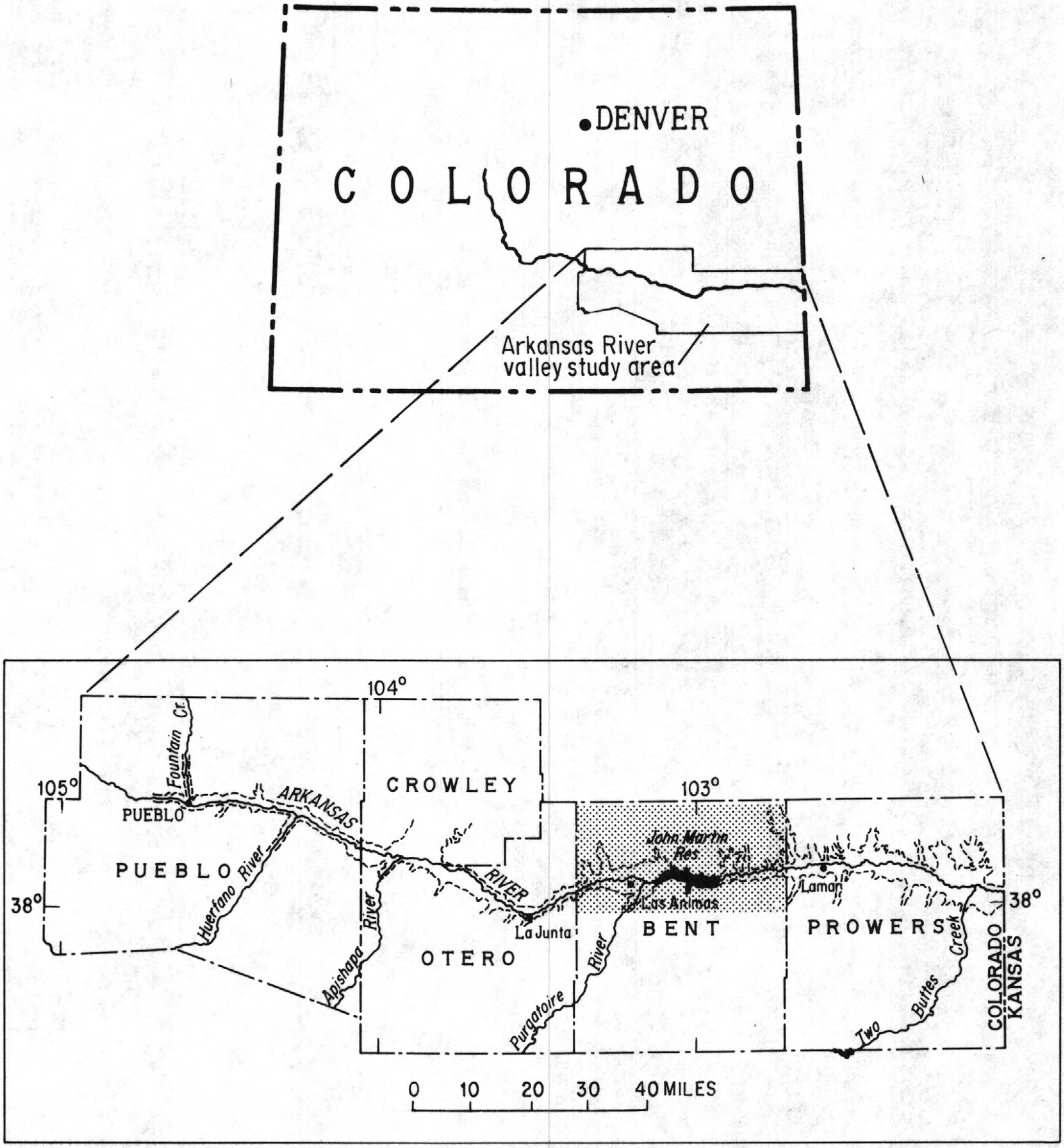

FIGURE 1. Index map showing location of report area (shaded) and extent of valley-fill aquifer (dashed line).

snowmelt in the Rocky Mountains. In late summer the surface-water supply is commonly inadequate to meet irrigators' needs. Wells drilled mostly between 1950 and 1965 provide irrigation water when surface supplies are deficient. In 1969 there were 1,348 irrigation wells tapping the valley-fill aquifer in the Arkansas Valley (Major and others, 1970). Ground-water withdrawal for irrigation averaged 83,000 acre-feet per year from 1950-59 and 140,000 acre-feet per year from 1960-69. Although irrigation wells have improved the supply, not all irrigation requirements can be met.

Ground-water withdrawal by wells has caused legal disputes between ground-water and surface-water users because irrigation wells intercept water that otherwise would reach the Arkansas River. Streamflow has been substantially reduced and some reaches of the river that formerly were gaining are now losing during all or part of the year. In 1965, the State of Colorado enacted laws to regulate irrigation wells. The law places irrigation wells under the Colorado Appropriation Doctrine and gives the State Engineer the power to regulate construction of wells and withdrawal of water from aquifers. As surface-water rights are senior to nearly all ground-water rights in the Arkansas Valley, conjunctive use water-management schemes are strongly influenced by senior surface-water appropriation rights. Colorado is faced today (1971) with the perplexing problem of preserving the Appropriation Doctrine as expressed in the State Constitution, and at the same time, maintaining the existing irrigation economy that has evolved from conjunctive use of ground and surface water. In 1970 the State Legislature enacted water laws that allow changing the point of diversion of water from a surface diversion to a well diversion. Additional legislation is planned to further integrate the ground- and surface-water supply.

PURPOSE OF INVESTIGATION

The investigation on which this report is based is a part of a comprehensive evaluation of the water resources of the Arkansas River valley undertaken by the U. S. Geological Survey in cooperation with the Colorado Water Conservation Board and the Southeastern Colorado Water Conservancy District. The study reach extends 150 miles from Pueblo to the Kansas State line (see fig. 1 index map). The water-resources investigation of the stream-aquifer system in the Arkansas River valley, which began in 1963, is being made to provide information about the water resources for planning, management, and administration of the supply.

The objectives of the investigation are to define the effects of present water use, to determine the relation between ground and surface water, and to evaluate the effects of proposed changes in water law and management. The major steps in the study are: (1) Inventory the water resources, (2) describe the hydrogeologic character of the aquifer, (3) document and evaluate the effects of development, (4) construct and verify models to aid in the evaluation of the hydrology, and (5) develop models to test water-management plans and to optimize water use.

PURPOSE AND SCOPE OF REPORT

This report describes the hydrogeologic characteristics of the valley-fill aquifer in a 36-mile reach of the Arkansas River valley in Bent County, southeastern Colorado. The description consists of maps showing the extent of the aquifer, water-table contours, bedrock configuration, depth to water, saturated thickness, and transmissivity.

Methods of Study

Information presented in this report is based on data collected from 1963 to 1968 and published in basic-data reports by Broom and Irwin (1963), and Major, Hurr, and Moore (1970). Hydrogeologic data were obtained from test holes, wells, and observation wells. Test holes were drilled both by contractors and by the U.S. Geological Survey. Values for the transmissivity map were estimated from pumping tests, well logs, a saturated thickness map, and a water-table contour map using the methods described by Jenkins (1963) and Hurr (1966). The extent of the aquifer was determined by surface mapping and test drilling.

HYDROGEOLOGY

The Bent County reach of the Arkansas Valley is underlain by saturated valley-fill alluvium consisting of gravel, sand, silt, and clay of Pleistocene to Holocene age. The alluvium occupies a trough eroded in the shale, limestone, and sandstone bedrock of Cretaceous age. The bedrock is relatively impermeable and acts as a barrier to ground-water movement (see fig. 2A saturated thickness map, fig. 2B bedrock configuration map, and fig. 2C geohydrologic sections). The saturated permeable materials constitute the valley-fill aquifer that ranges from 0 to 60 feet thick and from 1 to 5 miles wide.

The aquifer is recharged mainly by infiltration of applied irrigation water and precipitation and discharged by seepage to the river by evapotranspiration and by withdrawals from wells. Water-table contours (see fig. 3A depth to water map and fig. 3B water-table contour map) show that ground water flows generally eastward, and toward the river from irrigated areas north and south of the river.

In Bent County, the river is a gaining stream most of the year owing to ground-water return flow of applied irrigation water. A major part of the ground-water return flow is available for downstream irrigation supplies. Ground-water return flow is greatest below Las Animas because the valley-fill aquifer narrows from 5 miles to 1 mile wide, forcing ground-water underflow into the stream. For example, between the Las Animas gage and the Fort Lyon Hospital (5.8 miles) measurements of flow in the Arkansas River on October 31, 1967 and March 29, 1969 showed gains of 47 cfs (cubic feet per second) and 17 cfs, respectively. Between the Bent-Otero County line and the Las Animas gage (10.5 miles) measurements showed gains of 1.7 cfs and 15 cfs on the same days. A large amount of ground water is also discharged by evapotranspiration in the river flood plain, where the water table generally is less than 10 feet below the land surface (see fig. 3A depth to water map and fig. 3B water-table contour map). Phreatophytes (saltcedar, cottonwood, and salt grass) commonly grow in areas near the stream, the greatest density of growth being where the depth to ground water is less than 5 feet. Studies of evapotranspiration in the Arkansas Valley have shown that as much as 3 feet of water per year, or about 34,000 acre-feet per year, are discharged to the atmosphere from localities where the depth to water is less than 10 feet (Bittinger and Stringham, 1963; Moulder and others, 1963).

Maximum withdrawals of ground water in Bent County occurred in 1964 when about 34,000 acre-feet of water was pumped from 225 irrigation wells and six municipal wells (Major and others, 1970). The yields of the wells range from 100 gpm (gallons per minute) to 2,500 gpm, and vary considerably from place to place, due mainly to variation in saturated thickness and hydraulic conductivity of the aquifer. The grain size of material in the valley-fill aquifer generally increases with depth. The upper part of the aquifer material generally is fine to medium sand and that in the lower part is fine to coarse gravel. The aquifer materials, which consist of well-rounded fragments of igneous and metamorphic rocks, are remarkedly well-sorted. The average hydraulic conductivity is about 4,000 gallons per day per square foot.

The map of aquifer transmissivity (fig. 4) is based on saturated thickness and hydraulic conductivity. Transmissivity is the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. The transmissivity map can be used in making estimates of well yield. For example, a properly constructed and developed well which has a drawdown of about 50 percent of the saturated thickness would yield from 200 to 400 gpm when the transmissivity is 50,000 to 100,000 gallons per day per foot and from 1,800 to 3,800 gpm when it is 200,000 to 300,000 gallons per day per foot. The transmissivity map also provided data for construction of electrical analog and digital models of the Arkansas River valley. The models have been used to define the operation of the stream-aquifer system and to predict effects of changes in water management and water administration. Some of the major water-management factors that will be evaluated include: (1) Conjunctive use of ground and surface water, (2) seasonally fluctuating water supplies that do not coincide with crop requirements, (3) waterlogged river bottom lands, (4) use of water by phreatophytes, (5) progressive downvalley increase of dissolved solids in ground and surface water due to irrigation, (6) obligation to satisfy Interstate Compact with Kansas, and (7) administration of trans-mountain diversion water.

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GPO 834-912