Ground Water in Fountain and Jimmy Camp Valleys El Paso County Colorado

By EDWARD D. JENKINS

With a section on COMPUTATIONS OF DRAWDOWNS CAUSED BY THE PUMPING OF WELLS IN FOUNTAIN VALLEY

By ROBERT E. GLOVER *and* EDWARD D. JENKINS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1583

Prepared in cooperation with the city of Colorado Springs and the Fountain Valley Water Users Association

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library has cataloged this publication as follows:

Jenkins, Edward D., 1916–

Ground water in Fountain and Jimmy Camp Valleys, El Paso County, Colorado. With a section on Computations of drawdowns caused by the pumping of wells in Fountain Valley, by Robert E. Glover and Edward D. Jenkins. Washington, U.S. Govt. Print. Off., 1964.

v, 66 p. illus., maps (1 col.) diagrs., tables. 24 cm. (U.S Geological Survey. Water-supply paper 1583)

Part of illustrative matter fold. in pocket.

Prepared in cooperation with the city of Colorado Springs and the Fountain Valley Water Users Association.

Bibliography: p. 62–64.

1. Water-supply—Colorado—El Paso Co. 2. Water, Underground—Colorado—El Paso Co. I. Glover, Robert Ellsworth, 1896–. II. Title: Fountain and Jimmy Camp Valleys, El Paso County, Colorado. III. Colorado Springs, Colorado. IV. Fountain Valley Water Users Association. (Series)

For sale by the Superintendent of Documents. U.S. Government Printing Office
Washington, D.C. 20402

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GROUND WATER IN FOUNTAIN AND JIMMY CAMP VALLEYS, EL PASO COUNTY, COLORADO

By Edward D. Jenkins

ABSTRACT

The part of Fountain Valley considered in this report extends from Colorado Springs to the Pueblo County line. It is 23 miles long and has an area of 26 square miles. The part of Jimmy Camp Valley discussed is 11 miles long and has an area of 9 square miles. The topography is characterized by level flood plains and alluvial terraces that parallel the valley and by rather steep hills along the valley sides. The climate is semiarid, average annual precipitation being about 13 inches. Farming and stock raising are the principal occupations in the valleys; however, some of the agricultural land near Colorado Springs is being used for housing developments.

The Pierre Shale and alluvium underlie most of the area, and mesa gravel caps the shale hills adjacent to Fountain Valley. The alluvium yields water to domestic, stock, irrigation, and public-supply wells and is capable of yielding large quantities of water for intermittent periods. Several springs issue along the sides of the valley at the contact of the mesa gravel and the underlying Pierre Shale.

The water table ranges in depth from less than 10 feet along the bottom lands to about 80 feet along the sides of the valleys; the saturated thickness ranges from less than a foot to about 50 feet.

The ground-water reservoir in Fountain Valley is recharged by precipitation that falls within the area, by percolation from Fountain Creek, which originates in the Pikes Peak, Monument Valley, and Rampart Range areas, and by seepage from irrigation water. This reservoir contains about 70,000 acre-feet of ground water in storage. The ground-water reservoir in Jimmy Camp Valley is recharged from precipitation that falls within the area, by percolation from Jimmy Camp Creek during periods of streamflow, and by seepage from irrigation water. The Jimmy Camp ground-water reservoir contains about 25,000 acre-feet of water in storage. Ground water is discharged from the area by movement to the south, by evaporation and transpiration in areas of shallow water table, by seepage into Fountain and Jimmy Camp Creeks, and through wells. About 3 to 4 mgd (million gallons per day) of ground water moves through the Fountain Valley alluvium at a velocity of about 15 feet per day. About 1 mgd of ground water moves through the Jimmy Camp Valley alluvium at a velocity of about 6 feet per day.

Most of the wells in the area are drilled, but a few are dug. Many large-diameter wells are used for irrigation and public supply; one of the wells

yields as much as 1,340 gpm (gallons per minute). Wells are used as a source of water or as a supplement to the deficiency in surface-water supply for the irrigation of about 5,000 acres of land in Fountain Valley and about 2,000 acres in Jimmy Camp Valley. Heavy pumping in certain areas causes a rapid decline in the water level, but when pumping ceases, the water table recovers rapidly. A special section on the effects of pumping selected wells in the valley is included in this report.

The chemical analyses of samples of water from 13 representative wells and of a composite sample of surface and ground water from one town supply show that ground water along the valleys is generally hard and becomes harder and more highly mineralized downstream. Water in the stream is of better quality than ground water.

INTRODUCTION

The development of water in the Fountain Valley watershed began with the influx of gold seekers following the discovery of gold in the Pikes Peak region in 1858. Early settlers found a small stream, then known as "Fontaine Que Bouille" (Boiling Spring Creek), lined with a heavy growth of cottonwood and willow, luxuriant grass in the valley, and ample grass cover on the plains and on the mountainside. A further discussion of Fontaine Que Bouille, or Fountain Creek, is taken from Sheldon's History of El Paso County (Sheldon, 1881, p. 416):

> Contributing more than all the other streams of the county, to the sanitary and industrial welfare of its people, comes the beautiful and poetically christened "Fontaine Que Bouille." Beginning its brief career virtually in the clouds, and first condescending to contact with terra firma at an elevation of over fourteen thousand feet above the sea, by numerous rills and brooklets, which flow from the north and east declivities of Pikes Peak, it finds its way to the plains through the Ute Pass and the cañon of Ruxton Creek, through Manitou and Colorado City, by Colorado Springs and Fountain City, and joins its fortunes with the Arkansas at Pueblo. Its approximate minimum volume at Colorado City as determined in 1862, is represented by a cross section of the stream measuring 2,200 inches, with a flow of 150 feet per minute. Its principal tributary, Monument Creek, at times an ugly channel, and at times a devastating flood, has its origin in the mountains of the northwestern part of the county, and flows thence along their base in a southerly direction to the neighborhood of Colorado Springs, and there looses itself in, or pollutes, with its muddy ichor, the waters of the fountain. It is utilized to considerable extent for purposes of irrigation, but like all kindred streams, fails of efficiency when the need is greatest.

Prior to 1858 Fountain Valley was the hunting ground of the Indian; the range of the trapper, hunter, and trader; and the habitat of buffalo, deer, elk, beaver, and other wild game. Domestic livestock rapidly replaced the wild game.

The influx of gold seekers increased the demand for agricultural products. A small tract of land in Fountain Valley was irrigated with surface water as early as 1860; by 1861 much of the arable land in the valley was taken up by settlers, and wheat, oats, corn, and some vegetables were being grown. The establishment of a flour mill in 1862 added incentive to the production of grain (Howbert, 1925). The surface-water supply was supplemented in 1912 by the construction of the first well to be used for irrigation. Industrialization also began after the discovery of gold, but was less rapid than the change in land use. The Denver and Rio Grande Western Railroad started construction of a line to Colorado Springs in 1871, and General Palmer and a group of business men organized the Colorado Springs Co. to attract settlers. Colorado Springs was incorporated in 1886 and the community of Colorado City on the west was annexed to Colorado Springs in 1892.

PURPOSE AND SCOPE OF THE INVESTIGATION

An investigation of the ground-water resources of Fountain and Jimmy Camp Valleys was begun in July 1954 by the U.S. Geological Survey in cooperation with the city of Colorado Springs and the Fountain Valley Water Users Association. The objective was to determine the origin, movement, and availability of ground water for domestic, stock, industrial, irrigation, and public supplies, and to determine the effects of pumping the wells that supply Colorado Springs on other wells in the valley and on the flow of Fountain Creek. The program was under the direct supervision of T. G. McLaughlin, district geologist for Colorado. E. A. Moulder, district engineer, who succeeded Mr. McLaughlin in 1959, critically reviewed the report and supervised its final compilation.

Ground water is one of the principal natural resources of the Fountain and Jimmy Camp Valleys because almost all domestic, stock, and industrial supplies, much of the irrigation and public supplies for the valley, and part of the public supply for Colorado Springs are derived from this source. There is, therefore, a need for an adequate understanding of this important natural resource and its relation to the streamflow of Fountain Creek in order to facilitate its orderly development.

LOCATION AND EXTENT OF THE AREA

The Fountain and Jimmy Camp Valleys area includes that part of El Paso County lying in Tps. 14 through 17 S., Rs. 65 and 66 W. The area lies between lat 38°30′ and 38°50′ N. and long 104°35′ and 104°50′ W. and contains about 35 square miles (fig. 1).

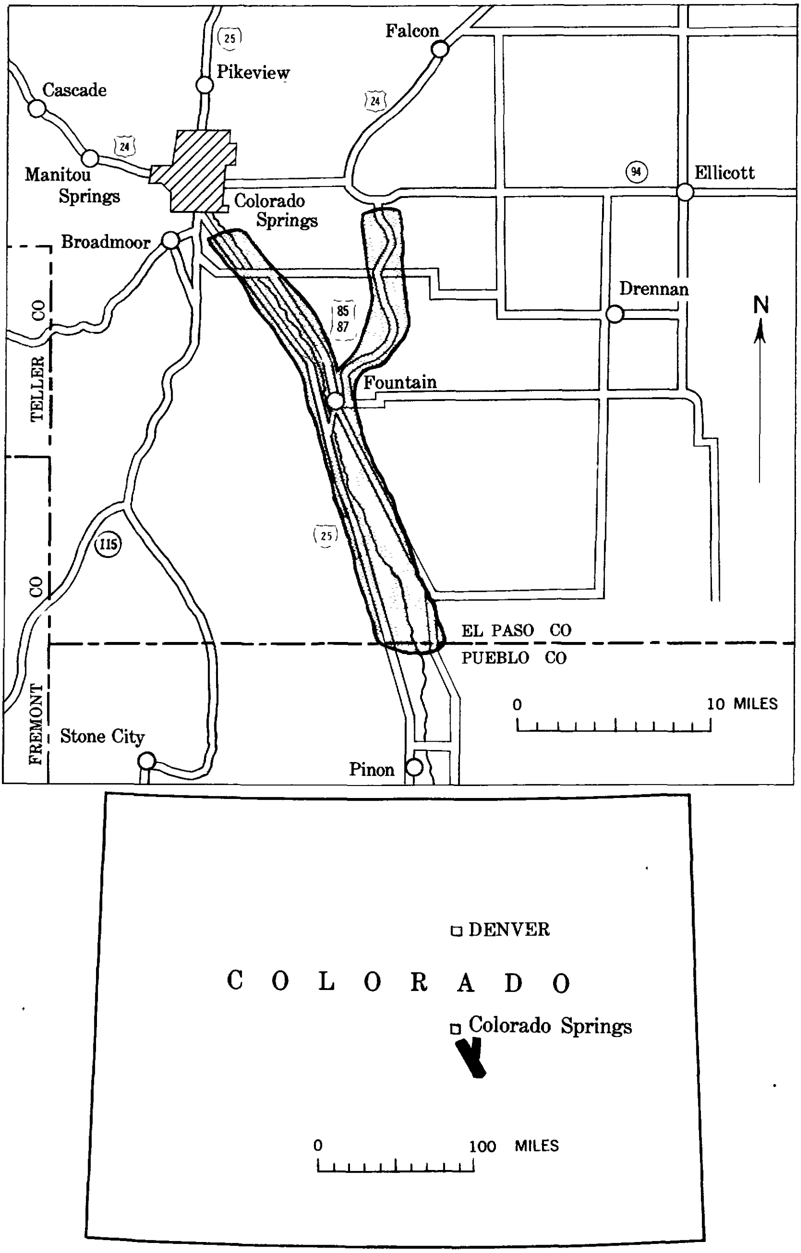

FIGURE 1.—Index maps showing area covered by this report.

PREVIOUS INVESTIGATIONS

Several studies relating to the geology or ground-water resources of all or part of the area under consideration have been made. Darton (1905; 1906) made a reconnaissance of the geology and ground-water resources of the central Great Plains and the Arkansas Valley, which included the Fountain Creek area. Finlay (1916) mapped the geology of the Colorado Springs quadrangle, and Dane, Pierce, and Reeside (1937) described the geology of a large area north of the Arkansas River in eastern Colorado; Dane also described the Pierre Shale underlying Fountain Valley. Griswold (1948) made a brief survey of geology and ground water in the Fountain Valley as a part of the Department of Agriculture watershed-management program. Code (1958) reported on the water-level fluctuations in eastern Colorado, which included measurements of several wells along Fountain Valley.

Records of wells, logs of wells and test holes, water level measurements of selected wells, and chemical analyses of water samples collected during the course of the investigation can be found in Basic Data Report Number 3 of the Ground Water Series (Jenkins, 1961), prepared cooperatively by the city of Colorado Springs, the Fountain Valley Water Users Association, the Colorado Water Conservation Board, and the U.S. Geological Survey. Chemical analyses are reported herein.

METHODS OF INVESTIGATION

Fieldwork on the project reported here was done between July 1954 and June 1955 by the writer, who was assisted by V. Foster during November and December 1954. Records of 218 wells and springs were obtained during the investigation. Information recorded includes measured and reported depths of wells, depths to water, yields of wells, drawdowns of water levels, thicknesses of materials penetrated in drilling, and the use and general chemical character of the water.

Samples of water collected from 13 representative wells and from 1 town supply in the area were analyzed to determine their mineral content. Most of the samples were analyzed in the chemical laboratory of the Quality of Water Branch of the Geological Survey at Denver, but a few were analyzed by the Utilities Department of the city of Colorado Springs and the Colorado Department of Public Health.

During the fieldwork, 36 test holes were drilled in Fountain Valley with a portable auger furnished by the Survey's Hydrologic Laboratory at Denver. Samples of the cuttings from the test holes were collected and studied by the writer, and the physical and hydrologic properties of selected samples were determined in the Hydrologic Laboratory. Altitudes of the test holes were determined by instrumental leveling. Additional logs of wells drilled in the area were furnished by well owners and well drillers.

Aquifer tests were made of 12 wells in the area to determine the coefficient of transmissibility and the specific yield of the aquifer.

The flow of Fountain Creek was measured at several points by G. N. Mesnier and C. B. Hamm of the Surface Water Branch and by the writer to determine changes in streamflow along the valley, especially in the areas of heavy pumping. Estimates of the amount of water pumped from large-capacity wells were determined from discharge and power records.

Field data were compiled on U.S. Geological Survey topographic quadrangles, scale, 1:24,000. Plate 1 shows the locations of wells and test holes. The altitudes of selected wells were determined by a level crew headed by V. M. Burtis.

WELL-NUMBERING SYSTEM

In this report all wells and test holes are numbered according to their location within the federal system of land subdivisions (fig. 2). The well number is composed of the township number, the range number, the section number, and lower-case letters that indicate the subdivision of the section in which the well is located. The first letter denotes the quarter section; the second, the quarter-quarter section or 40-acre tract; and the third, the quarter-quarter-quarter section or 10-acre tract. The letters are assigned in a counterclockwise direction beginning in the northeast quarter of the section or quarter-quarter section. Where two or more wells are within the smallest subdivision shown, the wells are numbered serially according to the order in which they were inventoried.

ACKNOWLEDGMENTS

The writer is indebted to the many residents of Fountain and Jimmy Camp Valleys who supplied information about their wells and who permitted test drilling on their land. Thanks are extended to J. M. Biery, F. T. Henry, and J. S. Nichols, officials of Colorado Springs, and to Hatfield Chilson, Clark Hanna, and R. J. Moses, who represented the Fountain Valley Water Users Association, for their cooperation in making much information available during the investigation. J. Coniff, E. F. Gobatti, and Mateyka Brothers, drillers, and several oil companies supplied many records including logs of wells and test holes drilled in the area. Many power-consumption records of irrigation wells were supplied by the Mountain View Electric As-

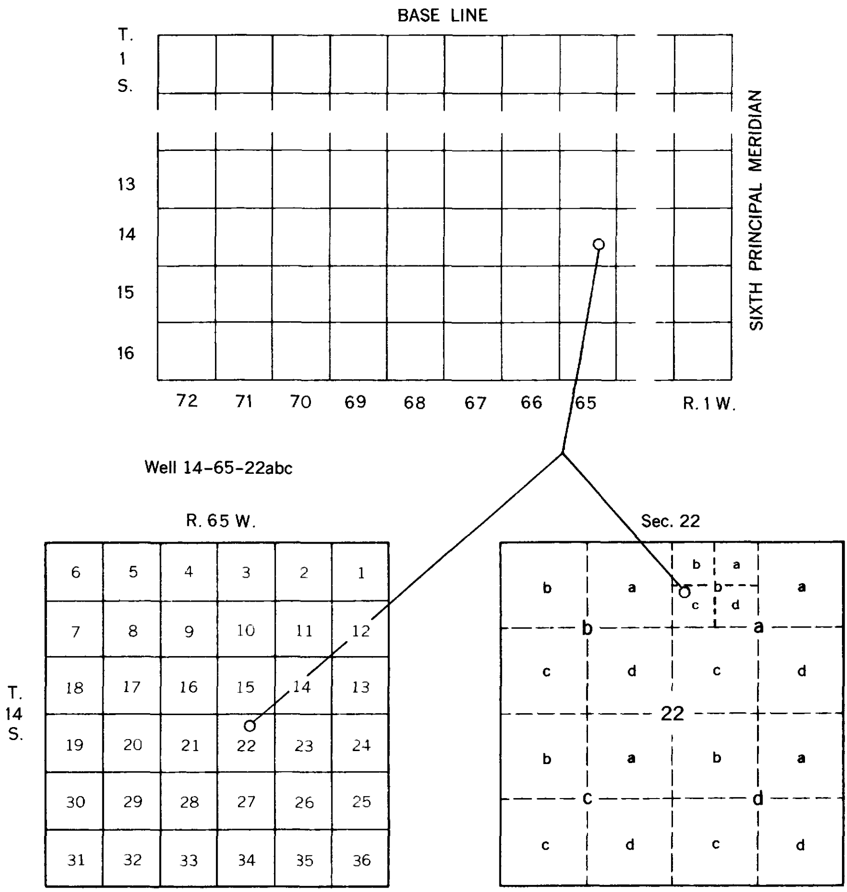

Figure 2.—Sketch showing well-numbering system.

sociation, Inc., the Utilities Department of the city of Colorado Springs, and the town of Fountain. Special thanks are extended to W. E. Code of Colorado State University for his helpful advice and for making available his record of observation wells in Fountain Valley, which he has maintained since 1944.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

All the area described herein lies in the Colorado Piedmont section of the Great Plains physiographic province. The total relief of the area is about 900 feet. Fountain Valley has a gradient of about 30 feet per mile and Jimmy Camp Valley about 45 feet per mile within the area of this report.

The headwaters of Fountain and Jimmy Camp are outside the area, as is the confluence of the Fountain and the Arkansas Valleys at Pueblo. Fountain Creek rises to the northwest in the Monument Valley, Pikes Peak, and Rampart Range areas; its tributary, Jimmy Camp Creek, rises in the Black Forest area to the northeast.

POPULATION

The population of the report area is largely urban and was between 10,000 and 15,000 in 1958. Fountain, the only town in the area of the report, had a population of 1,600 in 1960. Since the beginning of the investigation a new housing development, the community of Security Village, has been under construction and it had an estimated population of 9,000 in 1960. The metropolitan area of Colorado Springs, which is just outside the area of this report, had a population of about 100,000 in 1960.

AGRICULTURE

Livestock, dairy products, corn, and alfalfa are the principal agricultural products of the valleys; sweet corn and asparagus are lesser crops. Most of the irrigated lands in both valleys are irrigated with water from Fountain Creek and with water pumped from wells. More wells are drilled each year to supply the increasing demand for water within the report area. About 5,000 acres of land was irrigated from wells and surface water along Fountain Valley, and about 2,000 acres was irrigated along Jimmy Camp Valley in 1955.

CLIMATE

The climate of Fountain and Jimmy Camp Valleys is semiarid. The precipitation generally is low to moderate, the heaviest rains falling during the principal growing season May, June, July, and August (fig. 3*A*). The normal annual precipitation in the valleys ranges from 11 inches in the southern part to 15 inches in the northern part (fig. 3*B*). The normal precipitation at the Colorado Springs weather station for the period 1921 through 1950 was adjusted because of the change in location from downtown to Peterson Field in 1949. The normal annual precipitation for this period is 14.26 inches. The annual precipitation at Colorado Springs and Peterson Field is shown in figure 3*C*.

The temperatures in the area are moderate during the summer. The days are warm and the nights generally are cool. The winters are moderate, and the snowfall is light. The highest monthly normal temperature is 71.2°F., in July, and the lowest is 28.8°F., in January.

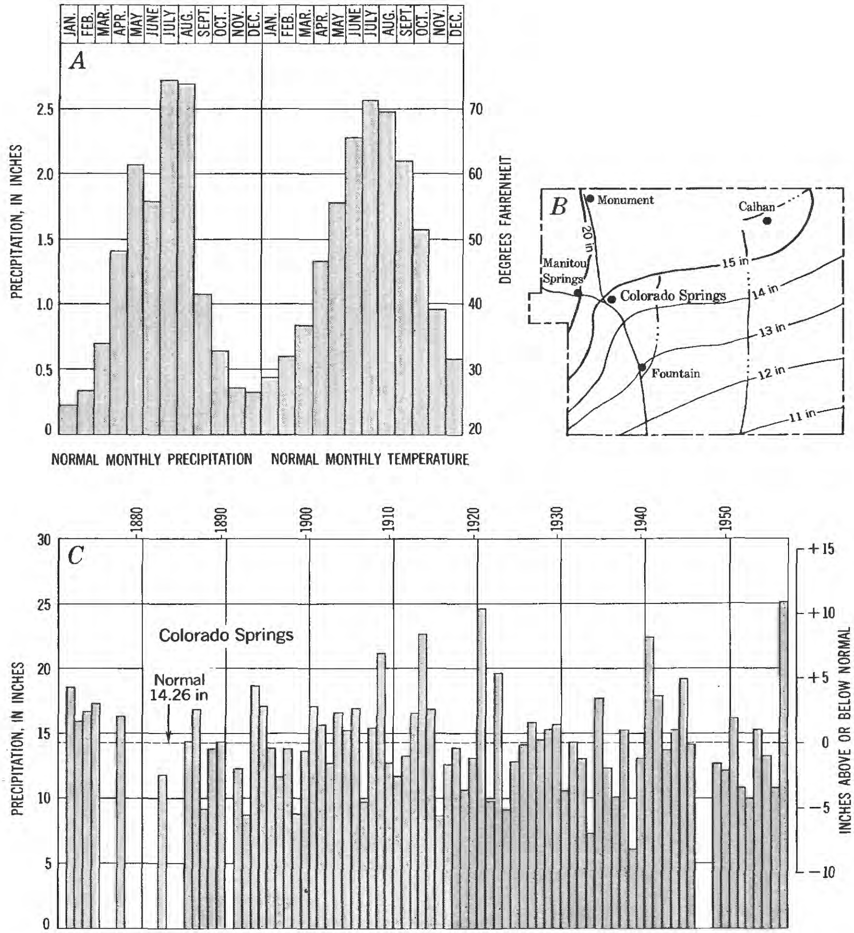

FIGURE 3.—*A*, Normal monthly precipitation and temperature in Fountain and Jimmy Camp Valleys; *B*, Distribution of precipitation in El Paso County; *C*, Annual precipitation at Colorado Springs from 1872 to 1947 and at Peterson Field from 1949 to 1958. Normals adjusted for the period 1921 through 1950. (Records from the U.S. Weather Bureau.)

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The rocks that crop out in the Fountain and Jimmy Camp Valleys are sedimentary and range in age from Late Cretaceous to Recent. The outcrop areas are shown in figure 4. The consolidated rocks, mostly of Late Cretaceous but in part of Tertiary age, consist of the Niobrara, Pierre, Fox Hills, Laramie, and Dawson Formations. The unconsolidated sediments are of Pleistocene and Recent age and include the alluvium underlying the flood plains and terraces of the valleys and scattered deposits of gravel that cap some of the mesas.

A generalized section of the geologic formations exposed in the area is given in table 1. The following descriptions of the geologic formations and their water-bearing properties are adapted in part from Finlay (1916) and McLaughlin (1946).

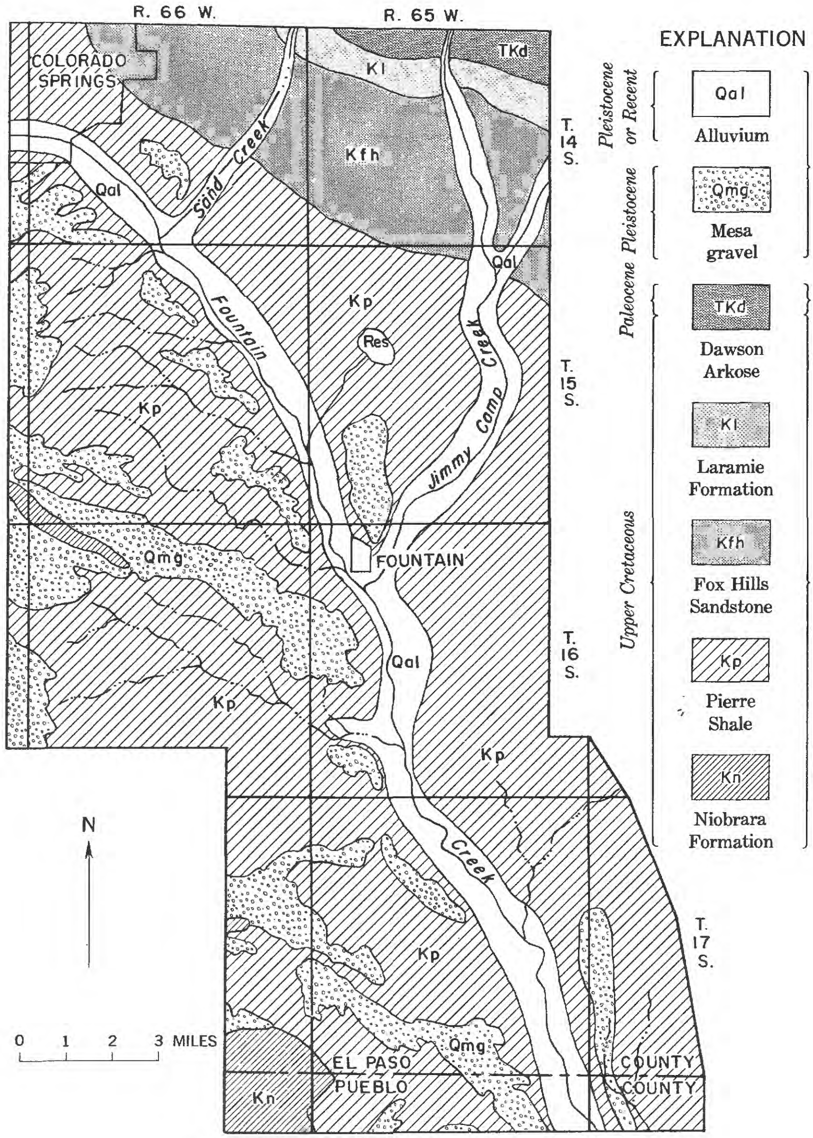

FIGURE 4.—Sketch map of the geology of the report area. (Modified from Finlay, 1916.)

TABLE 1.—*Generalized section of the geologic formations in the Fountain Valley area, El Paso County, Colo.*

System	Series	Formation	Thickness (feet)	Physical characteristics	Water yield
Quaternary	Recent and Pleistocene	Alluvium	0–100	Gravel and sand, containing thin beds of silt and clay.	Large quantities to domestic, irrigation, public-supply, and stock wells and to springs and seeps.
		Mesa gravel	0–75±	Poorly sorted boulders, cobbles, and gravel containing sand layers.	Small quantities from springs for domestic and stock use.
Tertiary and Cretaceous	Paleocene and Upper Cretaceous	Dawson Arkose	1,000±	Coarse varicolored conglomeratic sandstone with lenses of clay in upper part; arkosic sand and shale containing lignite, in lower part.	Small to moderate quantities to domestic and stock wells.
Cretaceous	Upper Cretaceous	Laramie	150–250	Black shale and seams of lignite interbedded with irregular beds of sandstone.	Small quantities to domestic and stock wells.
		Fox Hills Sandstone [1]	700	Massive white fine-grained sandstone in the upper part; underlain by greenish and brown fine-grained sandstone; interbedded with shale in lower part.	Moderate quantities to domestic and stock wells.
		Pierre Shale	2,700–4,000+	Dark-gray and blue-gray shale; calcareous concretions locally abundant.	Very small quantities to a few wells, principally from weathered zones. Yields no water in most places.
		Niobrara	400–500	Upper part gray shale with disseminated gypsum; middle part fine-grained sandy limestone and shale; lower part light-gray calcareous shale; bluish-gray limestone at base.	Small quantities.

[1] For the purpose of this report, the Fox Hills includes the massive A and B sandstones of the Laramie.

NIOBRARA FORMATION

The Niobrara Formation of Late Cretaceous age overlies the Carlile Shale in the southwest part of the area. The base of the formation consists of about 50 feet of bluish-gray limestone in beds as much as 2 feet thick, which are separated by calcareous shale. The beds of lime-

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stone are crossed by innumerable small veins of calcite. The outcrops of these basal beds in places form low ridges. Beds near the middle of the formation locally contain fine-grained sandy limestone and shale. The upper two-thirds of the formation consists of gray calcareous shale.

No wells tapping the Niobrara Formation were inventoried, although possibly small quantities of water can be obtained from wells drilled into the limestone beds of the lower part or into the sandy limestone and shale beds near the middle. Water obtained from this formation is usually of poor quality because of the mineral matter dissolved from the shale and limestone.

PIERRE SHALE

The Pierre Shale conformably overlies the Niobrara Formation. Only the upper part crops out in the area and it is poorly exposed owing to the moderately thick cover of soil masking the gentle slopes. Outcrops are difficult to find except in places where streams or gullies have made fresh cuts into the bedrock. The Pierre, where exposed in this area, consists of dark-gray to blue shale and sandy shale containing calcareous concretions. The formation is about 2,700 feet thick in the vicinity of sec. 4, T. 15 S., R. 66 W. Farther east the formation thickens to more than 4,000 feet. It is overlain in most of the area by mesa gravels and alluvium. At the head waters of Jimmy Camp Valley the Fox Hills Sandstone lies conformably upon the Pierre Shale.

The lowermost 500 feet of the Pierre is lead-gray shale which contains gypsum in fractures that cross the beds. Numerous layers of limonite-stained clayey fossiliferous limestone concretions, some of them as much as 3 feet in diameter, are found in this lowermost zone. The upper 500 feet of the formation contains limestone cores that are more resistant to weathering than the surrounding shale. The cores form small sharp conical hills about 50 feet in diameter, which were called "tepee buttes" by Gilbert and Gulliver (1895, p. 333–342). Such buttes are abundant in secs. 3 and 11, T. 17 S., R. 65 W. The limestone cores of the buttes are cylindrical or lenticular. Smaller limestone concretions are also abundant in the same upper zone.

The Pierre Shale and the Niobrara Formation are the least productive water-bearing formations in the area and generally yield water of very poor quality that is unsuitable for most uses. The minute pore spaces between the grains of clay, silt, and very fine sand, because of capillary attraction, will yield little or no water to wells. Where the exposed part of the formations has been weathered, water may fill the small spaces in joints or along bedding planes. Elsewhere solution openings in limestone lenses and concretions may store and transmit small amounts of water. In such places dug wells having a large storage capacity may produce enough water for domestic or stock use. Small quantities of water may be obtained from beds of fine-grained clayey sandstone near the top of the Pierre Shale.

Ability to recognize the Pierre Shale in the areas of outcrop and from well cuttings may prevent useless exploration for water. Some wells have been drilled deep into the Pierre in this area in fruitless attempts to find supplies of water; the Pierre Shale is practically barren of water except in a few sandy zones and in zones of surficial weathering. The Pierre Shale is more than 2,700 feet thick in this area and, if no water is found in the upper sandy and weathered zones, deeper drilling is generally useless.

FOX HILLS AND LARAMIE FORMATIONS

Three aquifers in the Fox Hills Sandstone in the report area are described here. These units are designated as the Milliken Sandstone Member and the A sandstone and B sandstone of the Laramie Formation. For the purpose of this report, the sandstone units of the Laramie Formation are included with the Fox Hills Sandstone.

The writer in some instances has met laymen, who misunderstanding the term "Fox Hills Sandstone," have failed to complete their wells through the three sandstone units. They believed they had penetrated the entire formation when the drill hole actually had penetrated only the uppermost unit. On the basis of mappability and hydrologic unity, G. H. Chase, (1960, oral communication) has found that placing the top of the Fox Hills Formation to include the massive sandstones of the Laramie A and B provides a logical contact, permits more satisfactory surface and subsurface mapping, and prevents misunderstanding of the hydrology.

Lovering and others (1932, p. 702–703) have spoken of the Fox Hills Formation rather than the Fox Hills Sandstone, and have so defined the formation to include several thick sandstone units. These include the units formerly known as the A sandstone and the B sandstone in ascending order of the Laramie Formation and the Milliken Sandstone Member of the Fox Hills. Van Horn (1957) has referred to the unit previously known as the B sandstone of the Laramie Formation as the top of the Fox Hills. Other geologists have adopted a similar nomenclature.

The Fox Hills Sandstone overlies the Pierre Shale in the northeastern part of the area. The lower part of the formation consists largely of interbedded greenish-gray sandstone and sandy shale. The upper part consists principally of three fairly thick sandstone units separated by varying thicknesses of shale. The lowermost of the three sandstone units is a uniform-grained, finely laminated to massive well-bedded sandstone. This unit, which has a thickness of about 50 feet, was named the Milliken Sandstone Member by Henderson (1920, p.

22–23). Fresh surfaces of this sandstone are dull green to yellowish green; many weathered surfaces are rich brown. The middle sandstone unit, which is the least massive of the three, includes lenticular sandstone interbedded with shale, some of which is carbonaceous. The uppermost sandstone, which has an average thickness of about 60 feet, is the most extensive of the three. It is massive, thick bedded, and resistant to weathering. The average grain size of this unit is greater than that of the other two sandstone units. Uniformity of grain size is characteristic of the unit. The quartzose sandstone of the upper two units generally has a white color; however conspicuous grains of black chert give it a characteristic salt and pepper appearance when it is examined closely. Locally it is iron stained.

No wells tapping the Fox Hills Sandstone were inventoried in this area; however it is known that many wells obtain water from the Milliken Sandstone Member and from the two sandstone units above it north and east of the report area. Wells drilled for the Air Force Academy, several miles north of Colorado Springs, were perforated opposite these sandstones and produce about 80 gpm each. Wells drilled into the Milliken Sandstone Member should each yield 10 to 30 gpm. Wells tapping the upper salt and pepper sandstone units yield 10 to 50 gpm.

The Laramie Formation consists of brownish-black or black shale interbedded with lenticular beds of sandstone and coal. The shale is silty, sandy, and lignitic. At certain horizons, thin beds of extremely fine-grained ferruginous sandstone are conspicuous. Commercial deposits of coal in the Laramie have been exploited in mines in Jimmy Camp Valley.

No wells tapping the Laramie Formation were inventoried in the report area; however, the writer knows of wells tapping this formation north and east of the report area. Water is obtained in small quantities from its many thin beds of sandstone. It is difficult to obtain water from the formation in some areas because of the thinness, lenticularity, and low permeability of the sandstone beds.

DAWSON ARKOSE

The Dawson Arkose of Paleocene and Late Cretaceous age overlies the Laramie Formation in the northernmost part of the area. It consists principally of varicolored arkosic conglomerate, sandstone, clayshale, carbonaceous shale, and coal. The lowermost part (about 100 feet) of the formation consists chiefly of clay and sandy clay containing many lenticular beds of siliceous, andesitic, and cherty sandstone. Above these lenses are many massive beds of arkose interbedded with carbonaceous materials and light-colored clay and shale. The uppermost part consists of coarse varicolored conglomeratic sandstones and lenses of clay. Some of the beds of the formation have been cemented by limonite. The Dawson Arkose has a maximum thickness of more than 2,500 feet 30 miles north of the area of this report. About 1,000 feet of the lower part of this formation has escaped erosion in the report area.

No wells tapping the Dawson Arkose were inventoried; however, water is obtained from wells in this formation. Yields of the wells generally are small to moderate, but in places north and east of the area, yields may be as much as 300 gpm. The Dawson Arkose is an important potential aquifer for the development of domestic and public-supply wells north of Colorado Springs.

MESA GRAVEL

Mesa gravel is found along the side of the valley of Fountain Creek, unconformably overlying the Pierre Shale (fig. 5) and the Niobrara Formation. The gravel consists mainly of angular fragments of granite. The larger pieces have rounded surfaces and show abrasion from stream transport. Particle sizes vary greatly; the largest are 3 to 4 feet, but most are less than an inch in diameter. The mesa gravel is poorly sorted and interbedded with numerous sandy layers. In addition to granite, the deposit includes many fragments of gneiss, schist, sandstone, limestone, quartz, and pegmatite. The formation is nearly everywhere unconsolidated. In places the grains and the surfaces of many particles have a caliche coating.

Several springs, which yield as much as 10 gpm each, issue along the west side of Fountain Valley at the contact of the mesa gravel and the Pierre Shale. Although the gravel is as much as 75 feet thick, it averages about 10 feet. This gravel is largely drained and contains only relatively small amounts of ground water.

ALLUVIUM

The alluvium in Fountain Valley consists of deposits of gravel and sand containing minor amounts of silt and clay. The materials were derived largely from the weathered granite, sandstone, limestone, and shale of the nearby mountain and upland areas. Some boulders have worked down from the mesa gravel onto the flood plain and the terraces. The coarsest materials were deposited in the bottom of a buried channel that extends the length of the valley. The materials in the alluvium of Fountain Valley range in size from fine sand to cobbles. Particle-size analyses of several samples of alluvium are discussed in the section on hydrologic and physical properties of alluvial sediments (p. 24) and are shown in figure 10. Additional information on the physical character of the alluvium of Fountain Valley was derived from logs of test holes drilled in Fountain Valley as a part of this investigation. Cross sections prepared from these and other logs show the relation of the alluvium to the underlying Pierre Shale and

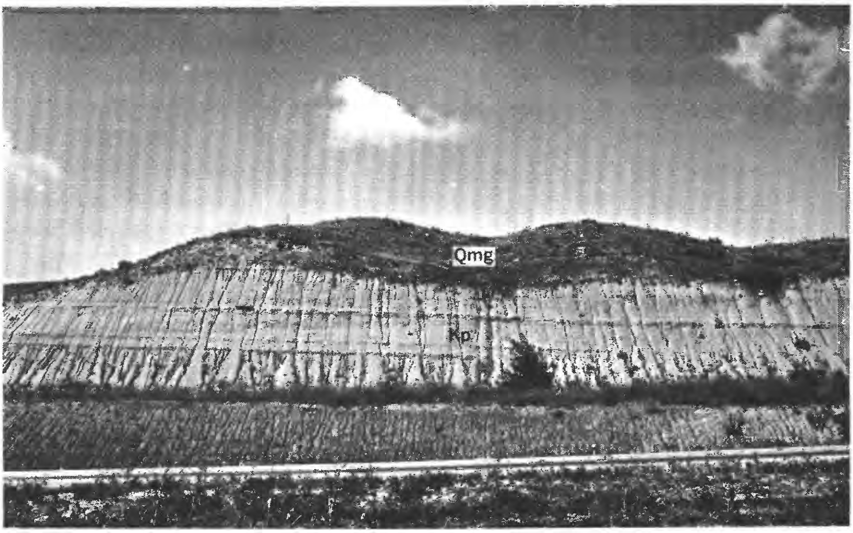

FIGURE 5.—Mesa gravel (Qmg) overlying the Pierre Shale (Kp) in road cut along new U.S. Interstate Highway 25 about 10 miles southeast of Colorado Springs.

the position of the water table relative to the stream (pl. 2). The cross sections show that the valley was cut deeply into the underlying shale and was then partly filled with sand and gravel to form the present alluvial aquifer, which yields abundant supplies of water to wells. Springs and seeps occur where the land surface intersects the water table. The thickness of the alluvium ranges from a few feet to 100 feet; the width of the aquifer ranges from about ½ to 1½ miles.

The alluvium of Jimmy Camp Creek Valley consists mainly of reworked deposits of sand, gravel, silt, and clay that have been derived primarily from the Fox Hills, Laramie, and Dawson Formations in adjacent upland areas. These alluvial deposits are finer grained and less permeable than those in Fountain Valley because of the finer grain size of the materials from which they were derived. The thickness of the alluvium ranges from a few feet to 100 feet. The width of the aquifer ranges from ½ to 1 mile.

Small areas of alluvium are found in draws or along small streams. The alluvium generally contains small amounts of sand and gravel derived from one or more of the following: the mesa gravel, the Fox Hills Sandstone, the Laramie Formation, or the Dawson Arkose.

Where saturated, the alluvial sediments will yield small to moderate quantities of water to wells. In the areas underlain by Pierre Shale, small deposits of alluvium that will supply water for domestic or stock supply can be located by test drilling, particularly in draws or along small streams.

GROUND WATER IN THE ALLUVIUM

PRINCIPLES OF OCCURRENCE

The following discussion of the occurrence of ground water refers to the report area. A more detailed discussion of the general occurrence can be found in Meinzer (1923, p. 2–102).

Below a certain level, which in the Fountain and Jimmy Camp Valleys area ranges from the land surface to about 80 feet below the surface, the permeable rocks are saturated with water. These saturated rocks are said to be in the zone of saturation, and the upper surface of this zone is called the "water table." Wells dug or drilled into the zone of saturation will become filled with ground water to the level of the water table.

The rocks that lie above the zone of saturation are said to be in the zone of aeration. The zone of aeration contains varying amounts of water whose movement is controlled chiefly by gravitational and capillary forces. The capillary forces vary in a given material, increasing as the moisture content decreases. In a fine-grained material the capillary forces may be many times greater than the gravitational forces. The resultant of these two forces determines the direction of movement. When the capillary forces are greater than the gravitational forces, the water may move in any direction, usually toward the area of least moisture content.

All the rocks penetrated by water wells in the Fountain and Jimmy Camp Valleys area are sedimentary and include sand, gravel, sandstone, silt, clay, and shale. The principal water-bearing rocks in the area are sand and gravel.

Gravel is superior to any other type of material in its ability to store and yield water in the report area. Coarse clean well-sorted gravel, such as is found in Fountain Valley, has high effective porosity, high permeability, and high specific yield. It can absorb water readily, store it in large quantities, and yield it to wells freely. In most parts of Jimmy Camp Valley, however, silt or sand is mixed with the gravel and reduces its porosity and permeability.

Sand ranks next to gravel as a water-bearing material. It differs from gravel in having smaller interstices; therefore, it will conduct water less readily and will yield water to wells less rapidly. Fine sand particles, which are more readily carried into wells by the water, cause problems in drilling and pumping in some wells. Proper well construction is especially important where fine sand is the main aquifer.

Sandstone is moderately good water-bearing material. A coarse-grained well-sorted sandstone, such as occurs locally in the Dawson Arkose, generally yields water freely, whereas the well-sorted fine-grained Fox Hills Sandstone yields water less readily.

Several wells in the valleys obtain all or part of their water from the Pierre Shale, but most of them have very small yields, for shale is one of the poorest water-bearing materials. If shale is not too tightly compacted, it may have a fairly high porosity and may contain considerable water; however, the interstices between the individual particles are so small that the water is held by molecular attraction and hence is not available to wells. Water available to wells in the shale is largely in joints, along bedding planes, or in weathered zones near the surface.

The yields of wells drilled into the alluvium of Fountain Valley range from a few to more than 1,300 gpm. The alluvial valley is narrow—generally less than 1 mile—and the buried channel is separated from the stream in many places by a shale ridge or barrier; thus, wells of large capacity can rapidly deplete the aquifer locally when many of them are pumped heavily for long periods of time. However, the buried channel meanders gently back and forth across the valley and lies beneath the present stream channel at several places where it is recharged by the stream, which tends to replace water removed by pumping (pls. 1 and 2). Water moves from the stream into the aquifer, where the water table is lower than the level of the stream, and water discharges from the aquifer into the stream, where the water table is higher than the level of the stream. (See fig. 12.)

Heavy pumping along Jimmy Camp Valley also causes a rapid decline in the water level. In the northern part of the report area in Jimmy Camp Valley, large-diameter wells have an average yield of about 300 gpm; those in the southern part have an average yield of about 600 gpm. The periods of recharge from the intermittent stream are limited to periods of streamflow following heavy precipitation.

Because this report is concerned almost entirely with the principal aquifer in heavily developed areas in Fountain and Jimmy Camp Valleys, the sections that follow pertain only to ground water in the alluvium.

HYDRAULIC PROPERTIES OF THE PRINCIPAL AQUIFER

DEFINITIONS

Field and laboratory tests were made to determine the ability of the alluvium to transmit and store water.

The capacity of water-bearing material for transmitting water under a hydraulic gradient is known as its "permeability." The field coefficient of permeability may be expressed as the number of gallons of water per day at the prevailing temperature that is transmitted through each mile-wide section of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient. The coefficient of transmissibility is a similar measure for the entire thickness of the water-bearing formation and may be expressed as the number of gallons of water per day transmitted through a mile-wide section of the aquifer under a gradient of 1 foot per mile—it is the field coefficient of permeability multiplied by the thickness of the aquifer in feet.

The volume of water that an aquifer releases from or takes into storage per unit of surface area of the aquifer per unit change in the component of head normal to that surface is called the "coefficient of storage." Under water-table conditions this coefficient is approximately equal to the "specific yield," which is the ratio of (1) the volume of water that a rock or soil, after being saturated, will yield by gravity to (2) its own volume. Under artesian conditions, in which aquifers are not dewatered by the withdrawal of water through wells, the coefficient of storage represents the water released from storage by the compression of the aquifer and by expansion of the water itself, and it is proportional to the thickness of the aquifer.

Not all water contained in the interstices of material, however, will be drained by gravity; some will be retained by molecular attraction. The volume of retained water, expressed as the ratio to the total volume of the material, is called the "specific retention" of the material. The specific yield and specific retention are together equal to the "porosity," which is the percentage of void space contained in a material. Thus, if 100 cubic feet of a saturated formation yields 25 cubic feet and retains 10 cubic feet of water under gravity, the specific yield is 0.25 or 25 percent, the specific retention is 0.10 or 10 percent, and the porosity is 0.35 or 35 percent.

AQUIFER TESTS

The coefficients of transmissibility and storage of the alluvial deposits of Fountain and Jimmy Camp Valleys were determined at 12 aquifer test sites and from analyses of samples at selected sites that were tested in the Geological Survey Hydrologic Laboratory at Denver. During the aquifer tests, the wells were pumped at a nearly uniform rate for a period of several hours to several days. The discharges of the wells and the depths to water level were measured at periodic intervals throughout the duration of pumping. For some tests, observation wells were drilled at selected distances from the pumped wells; their water levels also were measured periodically during pumping and drawdowns were determined (fig. 6). After pumping stopped, the water levels were measured periodically until they reached or approached their original position.

From the data gathered during the tests, the coefficient of transmissibility and the specific yield were computed by the Theis nonequilibrium formula (Theis, 1935, p. 519–524), the modified nonequilibrium formula described by Jacob (1946, p. 629–646), Cooper and Jacob (1946, p. 526–534), and the Thiem equilibrium formula (Thiem, 1906).

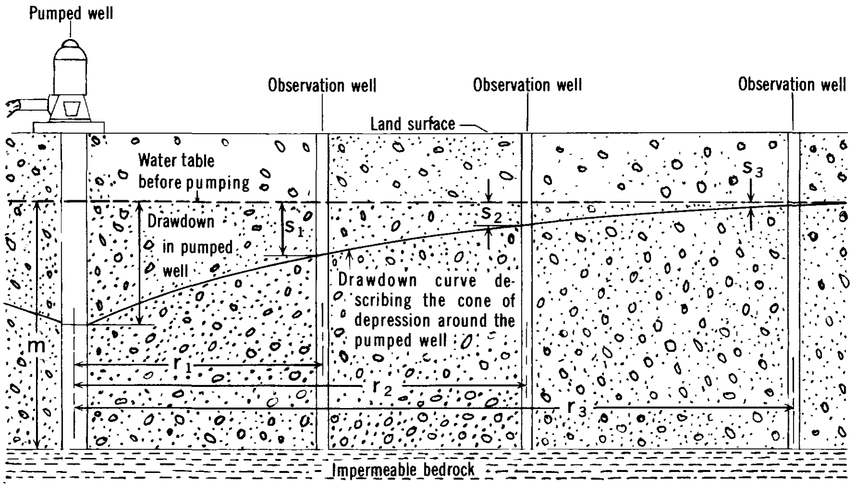

FIGURE 6.—Effect of pumping well on water table.

The Theis nonequilibrium formula is represented by the curve marked "type-curve trace" on figure 7. The points plotted on the graph show how closely the data conforms to the formula. The factors in this formula and others used in this report are as follows:

T=coefficient of transmissibility, in gallons per day per foot;
P=coefficient of permeability, in gallons per day per square foot;
S=coefficient of storage, or specific yield, dimensionless;
r=distance of observation point from pumped well, in feet;
t=time since pumping started, in days;
s=drawdown or recovery at any point in the cone of influence, in feet;
Q=discharge of pumped well, in gallons per minute;
m=saturated thickness of the aquifer, in feet.

The modified nonequilibrium formula described by Jacob was also used for determining coefficient of transmissibility and specific yield and is shown in figure 8.

A summary of the results of the aquifer tests is given in table 2. The coefficients of transmissibility ranged from 10,000 to 220,000 gpd per foot. The coefficients obtained from tests in Fountain Valley were larger than those from tests in Jimmy Camp Valley because the alluvial materials in Fountain Valley are much coarser. The specific yields, as indicated by the aquifer tests, ranged from 0.01 to 0.27 and are generally indicative of water-table conditions. Only two of the values are shown in table 2, however, because the others probably are in error owing to the fact that the other tests were not of sufficient duration to permit complete or nearly complete drainage of the sediments in the cone of depression.

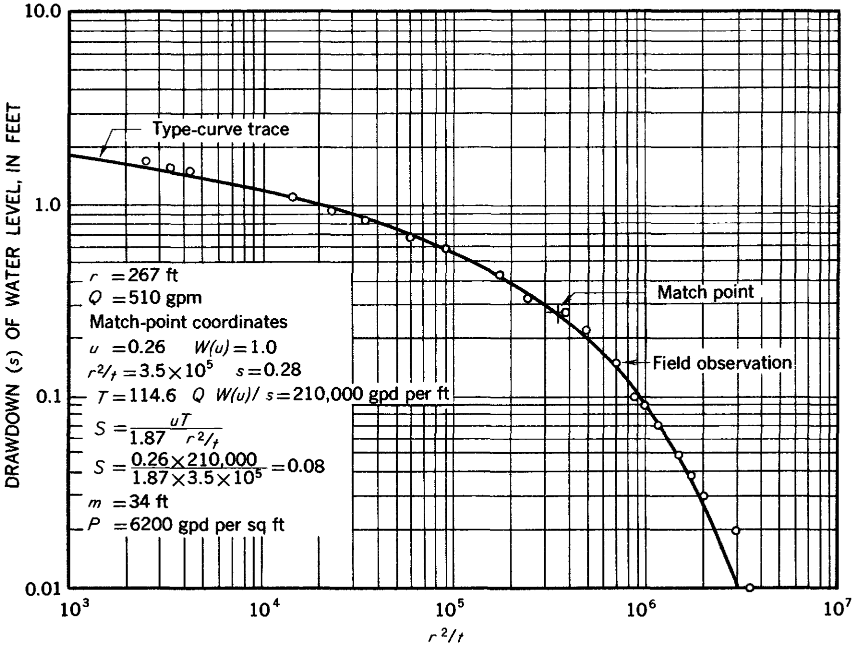

FIGURE 7.—Aquifer-test data superposed on the type curve. Data from test of well 15–66–14aac1.

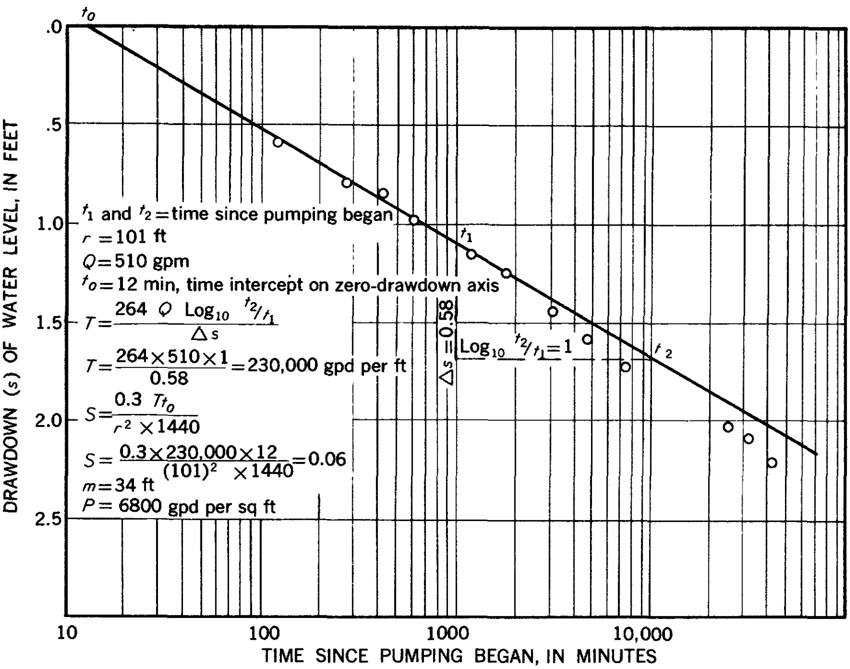

FIGURE 8.—Graph of aquifer-test data for application of modified Theis formula. Data from test of well 15–66–14aac1.

TABLE 2.—*Summary of the results of aquifer tests in Fountain and Jimmy Camp Valleys*

[Principal aquifer: AF, alluvium of Fountain Valley; AJ, alluvium of Jimmy Camp Valley; AS, alluvium of Sand Creek]

Well location	Owner	Principal aquifer	Depth of well (feet)	Depth to bedrock (feet)	Depth to water below measuring point (feet)	Total saturated thickness (feet)	Duration of pumping (hours)	Average pumping rate (gpm)	Drawdown (feet)	Specific capacity (gpm per ft)	Coefficient of transmissibility (gpd per ft)	Average coefficient of permeability (gpd per sq ft)	Radius of influence at end of pumping period (feet)	Specific yield (percent)	Water temperature (°F)	Date
14-65-27ddb1	Banning-Lewis Ranches.	AJ	80.8	80	27.3	53	7	330	35	9	40,000	750	1,000	--------	55	3-18-55
34aac1	do	AJ	82	82	25.9	57	24	300	38	8	20,000	350	2,000	--------	55	3-17-55
14-66-34cdd	K. J. M. Cormack	AS	97	88	72.9	16	5	78	10	8	10,000	620	--------	--------	55	7-29-55
16-65-3dcd4	Janitell Farms	AJ	61.8	66	23.3	44	96	275	29	9	60,000	1,360	1,200	--------	54	4-11-55
22dbb1	H. W. Houf	AJ	78.8	87	23.8	64	24	690	22	31	100,000	1,560	700	--------	54	5-19-56
15-66-14aac1	Security Village	AF	76.0	74	42.3	34	690	500	15	33	220,000	6,500	3,000	20	55	9-10-54
14abb	T. L. Bender	AF	55.7	55	26.8	29	56	670	10	67	140,000	4,800	--------	--------	53	7-19-54
16-65-16bba2	Rufus Marshall	AF	59.9	60	45.2	17	10	495	13	38	200,000	11,800	500	--------	55	10-20-54
32ada1	Clark Hanna	AF	52.3	49	24.4	27	79	525	14	38	150,000	5,500	1,200	--------	55	10-27-54
17-65-3ccb	do	AF	37.3	37	13.5	24	51	460	17	27	120,000	5,000	700	--------	54	11-1-54
23dda	Dan Holmes	AF	28.8	29	14.3	15	76	280	10	28	50,000	3,300	--------	--------	54	10-6-54
18-65-1bba1	Paige Ranch	AF	[1] 29	[1] 29	[1] 4.0	[1] 25	600	900	19	47	180,000	7,200	2,500	27	63	10-22-54

[1] Average battery of 2 wells.

Under water-table conditions, the apparent specific yield increases with time as additional water drains from that part of the aquifer within the cone of depression. Figure 9 shows the increase in specific yield with time as computed by modification of the Theis method for well 15–66–14aac1. An extension of the curve, thus plotted, approaches the probable value of 20 percent.

Field measurements of depletion were used to facilitate another method for computing specific yield. Records show that 1,550 acre-feet of ground water was pumped from the four city of Colorado Springs wells in the Widefield area during a 7-month period, August 1954 through February 1955, and that the pumping caused the water table to decline more than 9 feet in some areas (see pl. 4). The volume of dewatered sediments in the cone of depression that developed around the pumped wells was determined by planimetering the areas enclosed by lines of equal water-level decline (pl. 4) and amounted to 5,200 acre-feet. An approximate value for specific yield of the aquifer in that locality was computed by dividing the volume of water pumped by the volume of sediments in the cone of depression, that is, $S=\frac{1{,}550}{5{,}200}=30$ percent. The approximate value of specific yield in

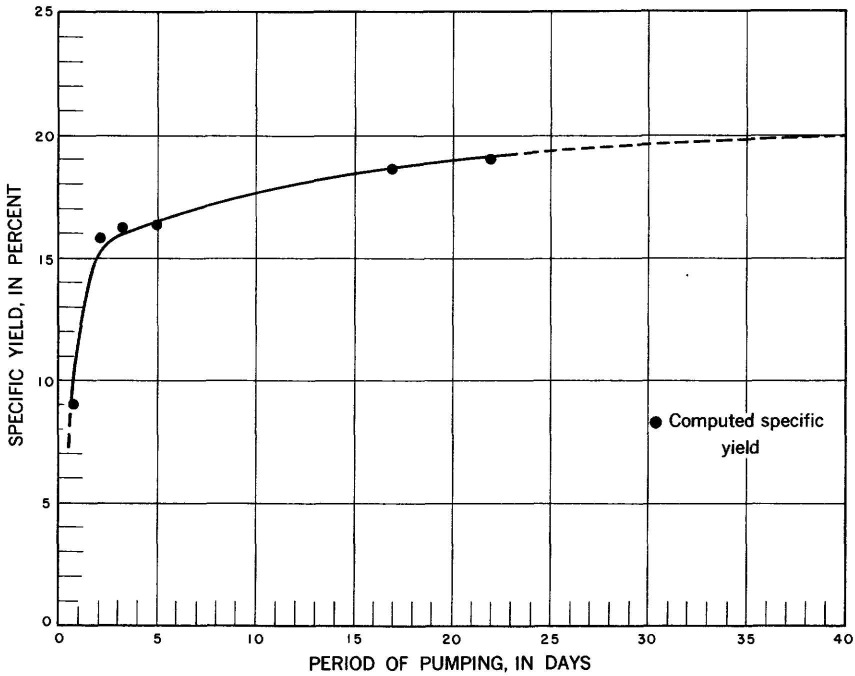

FIGURE 9.—Graph showing the increase in specific yield with time. Data from test of well 15–66–14aac1.

the southern part of the area was computed to be 27 percent at well 18–65–1bba. This value was determined by dividing the volume of water pumped by the volume of the cone of depression around a single pumped well after 25 days of pumping, that is, $S=\frac{100}{370}=27$ percent. These values show that the amount of recoverable water from this aquifer is great.

Measurements of water levels in observation wells within the cone of depression around the city of Colorado Springs wells showed that pumping effects did not extend to Fountain Creek. During this 7-month period, no significant amounts of water were added to, or withdrawn from, the volume of water in the aquifer, other than the amount pumped by the city of Colorado Springs. During the period only 5.4 inches of precipitation fell, of which 3.9 inches fell in August and September, a time of high evaporation; consequently the amount of recharge to the aquifer probably was small.

LABORATORY TESTS

Several representative samples of water-bearing materials from the alluvium in Fountain Valley were analyzed in the Geological Survey Hydrologic Laboratory; results are shown in table 3. These analyses were made for comparison with the results obtained from the field aquifer tests. The specific yields of these samples ranged from 18.6 to 35.3 percent, the specific retention ranged from 0.6 to 12.0 percent, and the porosity ranged from 28.7 to 39.6 percent. The coefficients of permeability ranged from 860 to 10,000 gpd per sq ft. These results

TABLE 3.—*Summary of laboratory determinations of hydrologic properties of alluvial sediments*

Location	Depth of sample (feet)	Specific retention (percent)	Porosity (percent)	Specific yield (percent)	Coefficient of permeability (gpd per sq ft)
15–66–3acc	35–45	9.4	37.4	28.0	4,200
15–66–10aab	15				3,600
	25				1,700
	35	1.6	31.3	29.7	3,500
	45	2.1	30.5	28.4	1,300
15–66–11bcd	42	1.2	28.7	27.5	3,100
	52	.7	30.2	29.5	5,800
	62	.6	30.5	29.9	5,900
	72	1.2	30.5	29.3	8,600
	79	3.0	29.8	26.8	5,200
15–66–14aac1	38	6.3	32.1	25.8	6,500
	70	2.0	34.0	32.0	1,800
15–66–14aac2	60	4.3	39.6	35.3	10,000
16–65–16bbb2		11.9	35.8	23.9	1,300
16–65–17aaa3	52	11.6	35.5	23.9	860
17–65–3cdb1	16–19	12.0	30.6	18.6	1,300
17–65–4dda	24–26	5.4	35.1	29.7	4,800
18–65–1bba	7				8,000

were consistent with the results of the field aquifer test given in table 2. A comparison between laboratory and field results at the location (15–66–14aac) is shown in the following tabulation:

Comparison of laboratory and field determinations

Saturated interval	Thickness (feet)	Coefficient of permeability (gpd per sq ft)	Laboratory determinations	Field determination
			Coefficient of transmissibility (gpd per ft)	Coefficient of transmissibility (gpd per ft)
42–49	7	6,500	45,500	
49–65	16	10,000	160,000	
65–76	11	1,800	19,800	
Total section	34		225,300	220,000

From the results of the field and laboratory tests, a value of 25 percent was selected for use in all computations in this report that require the use of the factor of specific yield.

In addition to the hydrologic properties mentioned above, the particle-size distribution in five samples of alluvial materials from Fountain Valley was determined in the laboratory, and the results are shown in figure 10. The curves of the samples indicate materials of high permeability. Such curves are also useful in selecting well screens.

SPECIFIC CAPACITY OF WELLS

The "specific capacity" of a well is the rate of its yield per unit of drawdown and is determined by dividing the pumping rate in gallons per minute by the drawdown in feet. For example, if a well yields 100 gpm with a drawdown of 10 feet, it has a specific capacity of $\frac{100}{10}$ or 10 gpm per foot. Specific capacity is a measure of well performance; its value will vary with the hydraulic properties of the aquifer and with well-construction factors, such as the diameter of the well, its depth of penetration into the aquifer, the type and amount of perforations in the casing, and the amount and type of well development.

The relation of the specific capacities of wells to the coefficients of transmissibility, as determined by 12 aquifer tests, is shown in figure 11. The scatter of points reflects differences in well construction, the effects of change in saturated thickness near the pumping well, and, to a small degree, the differences in the time that measurements were made. The average line drawn through the points expresses a relation that can be used to estimate the transmissibility of other wells

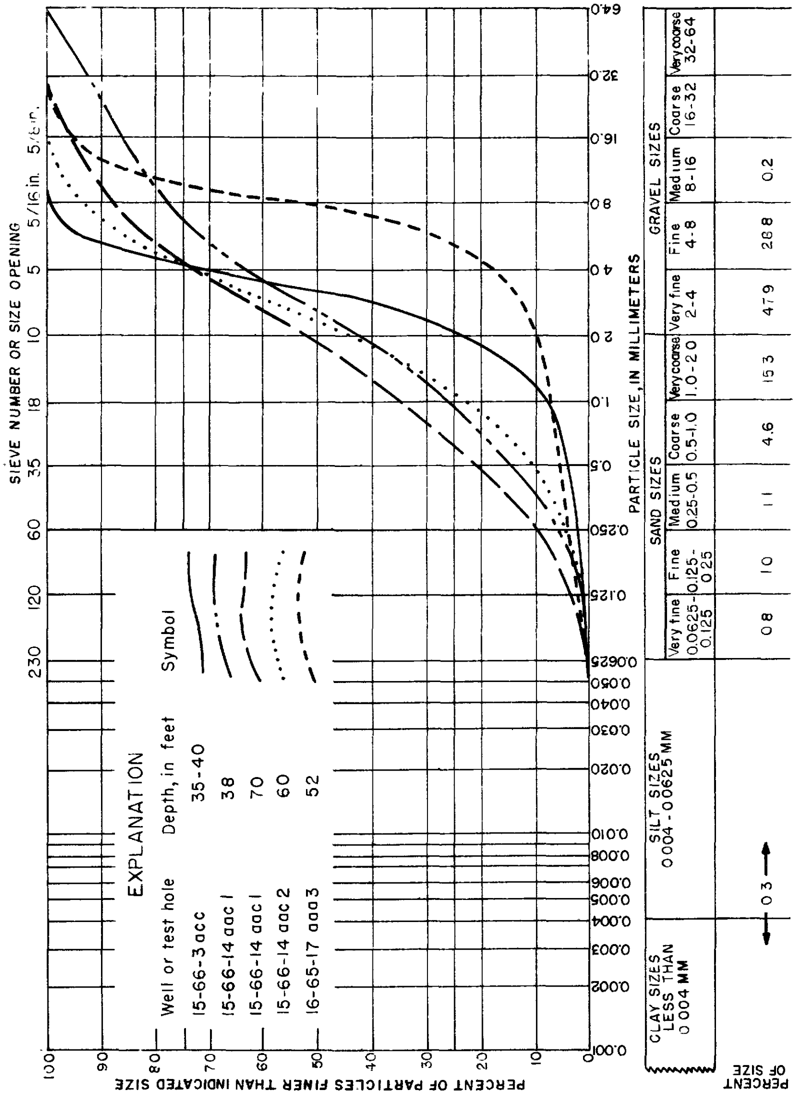

FIGURE 10.—Particle-size distribution in alluvial sediments taken from wells and test holes in Fountain Valley.

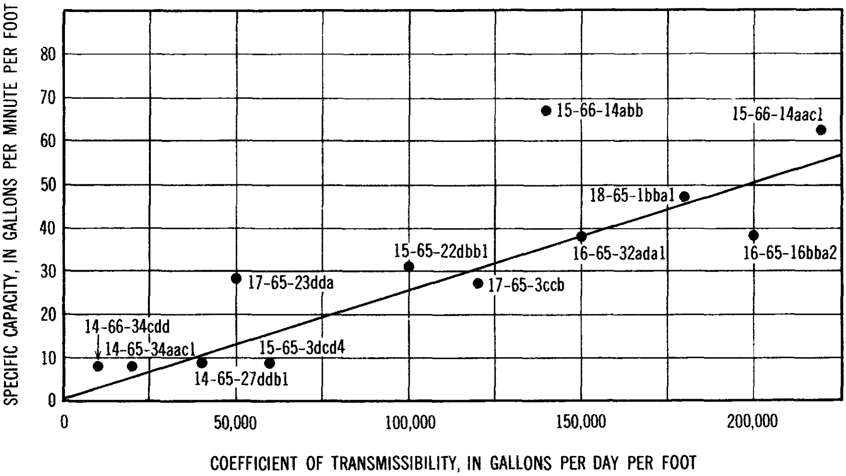

Figure 11.—Graph showing the relation of specific capacity of wells tapping the alluvium to the coefficient of transmissibility of the aquifer in the vicinity of the wells.

in the same general area from their specific capacities. This relation can be expressed by the following equation:

$$T=4{,}000\ C$$

where

T=coefficient of transmissibility,

C=specific capacity.

For example, if the specific capacity of a well is 50 gpm per foot, then the coefficient of transmissibility of the aquifer adjacent to the well would be about $4{,}000\times 50$, or 200,000, gpd per foot.

This method of estimating transmissibility should be used with caution because of the possible large error that may result from the affecting factors. One of the factors that may cause considerable error in this area is the reduction of saturated thickness. Many of the wells are pumped at near-capacity, and water levels are lowered to near the bottoms of the wells. The resulting decrease in saturated thickness causes greater drawdowns than assumed, which in turn yield a smaller value for specific capacity than would be indicated by the transmissibility.

Although the time of measurement is probably unimportant for most of the tests used to construct figure 11, a test on one well (15-66-14aacl) in Fountain Valley suggests that time can be an important factor. This well, which penetrated alluvium having a transmissibility of about 220,000 gpd per foot, had a specific capacity of 62 gpm per foot after pumping 1 day and 33 gpm per foot after pumping 29 days, during which time the water level in the aquifer was lowered about 2 feet and less saturation and a slightly lower transmissibility resulted.

The specific capacity value obtained after a pumping period of about 12 hours is suggested for general use with the equation.

The wells in this area generally are of similar construction and the error due to this factor probably is small.

UNDERFLOW

The determination of the permeability of the alluvium in a valley makes possible the determination of the underflow in that valley, if the cross-sectional area of the water-bearing materials and the gradient of the water table are also known. Estimates of the underflow at several places through the alluvium of Fountain and Jimmy Camp Valleys were made by substituting measured and estimated values in a modified form of Darcy's law, which may be written as:

Q=quantity of water passing through the cross section in gallons in which

Q=quantity of water passing through the cross section in gallons per day;

P=coefficient of permeability, in gallons per day per square foot;

I=hydraulic gradient of the water table, in feet per mile;

A=area of cross section, in mile-feet (width, in miles, times the thickness, in feet);

α=angle between the given cross section and a cross section oriented normal to the direction of the valley.

The coefficient of permeability was determined by means of acquifer tests (table 2) near the selected cross section; the hydraulic gradients and the angles α were determined from plate 1; and the areas were determined from the cross sections in plate 2 and from the data on saturated thickness in plate 1.

A summary of the rates of underflow in the alluvium and the changes in underflow that would occur from changes in water level are given in table 4. The rate of underflow through the four cross sections ranged from 2.7 to 4 mgd or about 3,000 to 4,500 acre-feet per year, and averaged about 3,500 acre-feet per year. The change in rate of underflow per foot of water-level decline ranged from 130 to 250 acre-feet per year and averaged about 190 acre-feet per year. The average change in rate of underflow per foot of change in water level in the aquifer along sections *A–A′* and *B–B′* is about 130,000 gpd or about 140 acre-feet per year. The hydrograph of plate 3 shows that the water level in the vicinity of these sections was about 4 feet higher in the fall of 1948 than in July 1954. Thus, lowering of the water level in this heavily pumped part of the Widefield channel during that period probably caused a reduction in underflow of about 600 acre-feet per year. The water-level decline and, hence, the decrease in underflow was caused in part by lower precipitation and streamflow but chiefly by the increased withdrawals of water from wells.

The underflow along Jimmy Camp Valley was computed to be 800,000 and 900,000 gpd, respectively, through cross sections *E–E′* and *F–F′* (pl. 1). The increase in underflow between these sections indicates that the maximum underflow of Jimmy Camp Valley may be about 1 mgd, or about 1,100 acre-feet per year near its confluence with Fountain Valley.

TABLE 4.—*Rates of underflow in Fountain and Jimmy Camp Valleys, July 1954*

Cross section (pl. 1)	Cross section of alluvium		Average gradient (feet per mile)	Average coefficient of permeability (gpd per sq ft)	Cosine α	Approximate underflow			Change in underflow represented by 1-foot rise or decline of the water table	
	Average width (miles)	Average thickness (feet)				Gallons per minute	Gallons per day	Acre-feet per year	Gallons per day	Acre-feet per year
A–A′	0.85	26	30	6,500	0.707	2,080	3,000,000	3,400	120,000	130
B–B′	.70	20	30	6,500	1.0	1,870	2,700,000	3,000	140,000	150
C–C′	.80	12	28	10,000	1.0	1,870	2,700,000	3,000	220,000	250
D–D′	1.5	19	28	5,000	1.0	2,780	4,000,000	4,500	210,000	240
E–E′	.70	16	50	1,400	1.0	550	800,000	900	50,000	56
F–F′	.6	25	38	1,600	.996	630	900,000	1,000	35,000	40

CONFIGURATION OF THE WATER TABLE AND MOVEMENT OF GROUND WATER

The water table in the Jimmy Camp and Fountain Valleys is an irregular surface that slopes in a general downstream direction. The irregularities reflect changes in recharge conditions from place to place, differences in permeabilities and thicknesses of water-bearing materials, and differences in the concentration of pumpage of ground water. The surface is mounded in areas where recharge is concentrated. Losses of irrigation water from ditches and fields, and concentration of water flowing into the valleys from tributaries, are typical conditions in areas of concentrated recharge.

Although the slope of the water table and hence the movement of ground water are in a general downstream direction, there is also movement to and from the stream depending upon whether the stream is a "gaining" or "losing" stream. Figure 12 shows the two conditions. Jimmy Camp Creek is a losing stream above Fountain, and Fountain Creek in most places is a gaining stream. Numerous seeps in the vicinity of the Barnes Ranch (sec. 25, T. 15 S., R. 66 W.) are visual evidence that this part of Fountain Creek is a gaining stream. During periods of heavy pumping in areas where the wells are concentrated, Fountain Creek becomes a losing stream because pumping lowers the water table below the level of the stream.

Calculations based on field and laboratory measurements of hydrologic properties indicate that water moves downstream through the

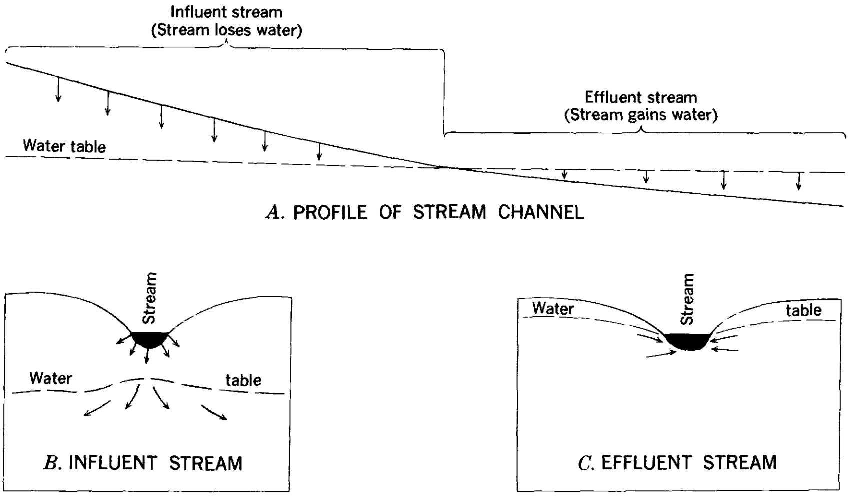

FIGURE 12.—Diagrammatic section showing the relation of a stream to the water table. *A*, Longitudinal section showing how stream loses and gains water; *B*, Transverse section across influent or losing part of the stream; *C*, Transverse section across effluent or gaining part of the stream.

alluvium of Fountain Valley at the rate of about 15 feet per day, or about 1 mile per year. Ground water moves more slowly in Jimmy Camp Valley owing to the lower permeability of the alluvial materials in this area. Calculations indicate that the rate of movement is about 6 feet per day or about ½ mile per year. These figures represent average values; actual values may be much more or less in local areas where gradients are considerably different than the average gradient.

WATER-LEVEL FLUCTUATIONS

Records of water levels in 51 wells were studied for this report and are published separately (Jenkins, 1961). The records for four of the wells extend back to 1944, and the balance cover the period 1954 through 1958. Selected records are shown graphically in plate 3 and figure 13. Some of the water level measurements have been published previously in Water-Supply Papers 1027, 1075, 1100, 1130, 1160, 1169, 1195, 1225, 1269, 1325, and 1408 (U.S. Geological Survey, 1945–55) and in Bulletin 500–S (Colorado State University, 1958). Subsequent measurements for these wells will be published in future reports of the U.S. Geological Survey and the State of Colorado.

Plate 3 shows that the decline for the period 1944–58 was slight. It also shows that in heavily pumped areas the water level can be lowered substantially; however, the water levels recover rapidly during periods of above-normal recharge and reduced pumping. An examination of the records of individual wells representative of different areas shows how the water table responds to various influencing factors.

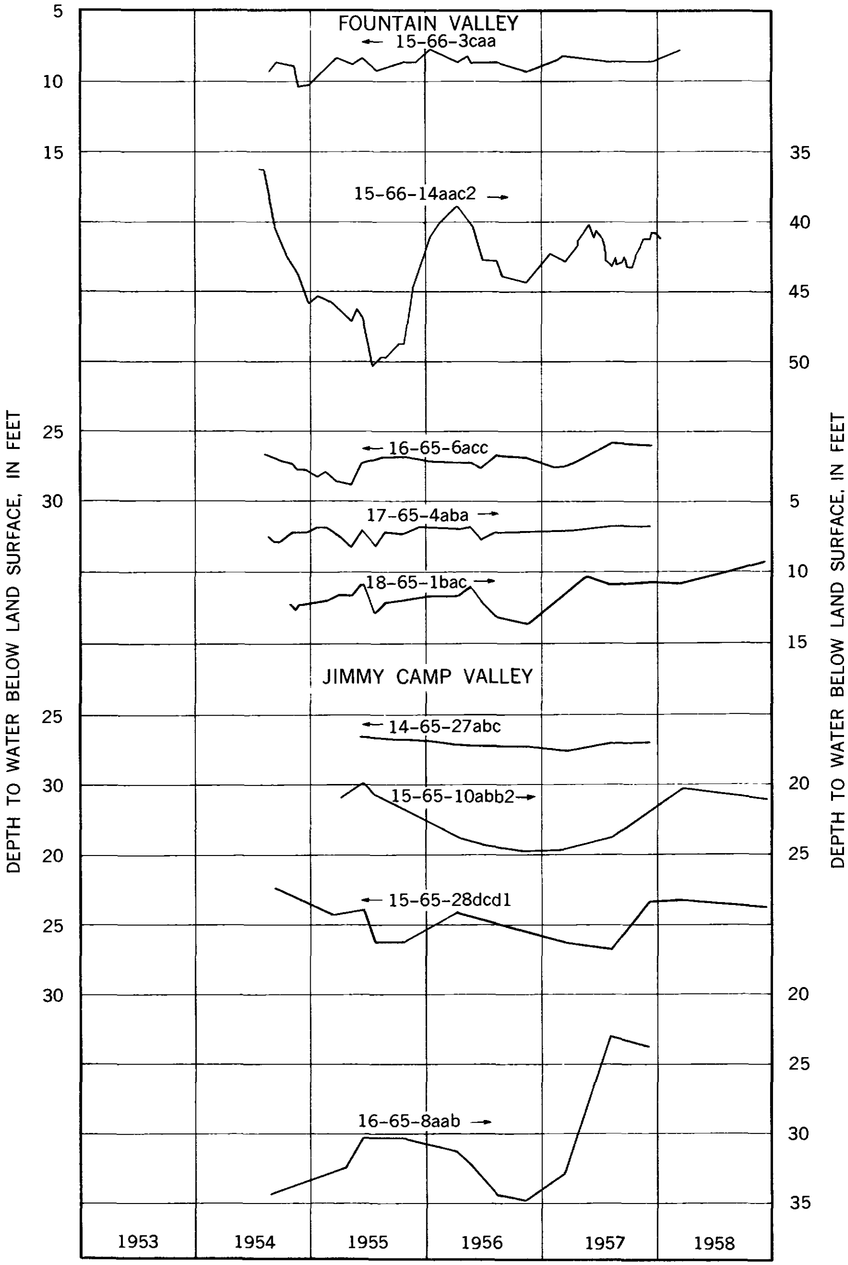

FIGURE 13.—Hydrographs showing the fluctuations of water levels in nine observation wells in Fountain and Jimmy Camp Valleys.

The water levels in wells 15–16–11bdc and 15–66–14abb, which are near the heavily pumped area in the Widefield channel, first declined and then rose sharply during the period 1954–58. The water levels declined abruptly during periods of heavy pumping by municipal users that began in 1954, and then rose rapidly after the pumping was decreased greatly or discontinued. The water level in well 15–66–25aaa, near the confluence of the Widefield channel and Fountain Creek and about 2½ miles downstream from the heavily pumped area, declined gradually from 1950 through 1956, and then rose rapidly during 1957. The rise during 1957 was due to above-normal precipitation and the resulting decrease in pumping.

The hydrographs show that the water level in the aquifer in the Widefield channel recovers rapidly after periods of heavy pumping; this rapid recovery indicates a high potential recharge rate. The aquifer is continually being recharged by percolation of water from the stream at two places (sec. 4, T. 15 S., R. 66 W. and sec. 24, T. 15 S., R. 66 W.) between which the depleted zone is rapidly replenished.

The water level in well 15–66–3caa (fig. 13) fluctuated only slightly because it is near the stream at the upper end of the Widefield channel where stream losses quickly increase or decrease in response to varying demands imposed by pumping. Well 15–66–14aac2 is in the heavily pumped area farther from the stream; its water level rose and declined rapidly in response to changes in the amount pumped. The water levels in wells 16–65–6acc and 17–65–4aba, which are near the stream, appear to be related to changes in streamflow. An increase in flow causes a rise in the stage of the stream, which in turn causes a rise in water level where the aquifer is hydraulically connected with the stream. The streamflow records shown on plate 3 are from a station about 6 miles southeast of Fountain.

The abrupt rises in water levels during 1957 in wells 16–65–17aaa1 (pl. 3) and 16–65–8aab (fig. 13) were caused chiefly by above-normal flow in Jimmy Camp Creek and by above-normal applications of surface water for irrigation. Jimmy Camp Creek, an intermittent stream, loses much of its flow to the ground-water reservoir. Measurements made along a 2-mile reach of the stream bed showed that 60 percent of an original flow of 10 second-feet was lost in that reach. In 1957, when above-average precipitation caused an abundance of surface water, a part of the flow from Fountain Creek was diverted into Jimmy Camp Creek: a part of it was used to irrigate land along Jimmy Camp Creek, and a part was used for irrigation in Fountain Valley. The large losses of the diverted water from Fountain Creek to Jimmy Camp Creek and flood flows in Jimmy Camp Creek accounted for a substantial part of the rise in water levels in the alluvium of Jimmy Camp Valley. The infiltration of water applied to the lands for irrigation and the heavy precipitation account for the remainder of the rise.

Well 18–65–1bac is in the southern part of the area where the land is irrigated with both surface water and ground water. During the pumping season the recharge to the ground-water reservoir tends to balance the depletion of the reservoir by pumping, and the water levels remain relatively stable.

Well 14–65–27abc is in the upper part of Jimmy Camp Valley in an area of little pumping, and its water level fluctuated very little during the period of record. The water level in well 15–65–10abb2, which is south of the area of heaviest pumping in Jimmy Camp Valley, shows the effect of heavy pumping from April 1955 to April 1957. The rise in water level in 1957 can be attributed both to the cessation of pumping by the city of Colorado Springs and to the increased precipitation. The water level in well 15–65–28dcd1 in Jimmy Camp Valley fluctuates in agreement with the seasonal pumping of ground water for irrigation, the fluctuations being typical in several areas. Surface water diverted from Fountain Creek enters Jimmy Camp Valley about 1½ miles downstream from well 15–65–10abb2, or about 2½ miles upstream from well 15–65–28dcd1, as shown in plate 1.

STORAGE

The maximum amount of ground-water storage in the valley deposits can be estimated by multiplying the volume of saturated materials by the specific yield. Estimates of the volume were obtained by multiplying the length of the valley by the average cross-sectional area as determined from the four cross sections shown in plate 2 and other cross-sectional areas determined from data on saturated thickness shown on plate 1. The calculations show that about 70,000 acre-feet of ground water is stored in Fountain Valley and about 25,000 acre-feet is stored in Jimmy Camp Valley.

The ground water stored in the alluvial deposits is especially useful during drought periods. When the amount of water being recharged to the aquifer is less than the combined rates of withdrawal and natural discharge, water is removed from storage. Thus, the amount of water that can be pumped during droughts is dependent largely on the amount in storage.

Only a part of the stored water can be recovered economically. The yield of wells decreases as the water level is lowered in the aquifer, and the well becomes impractical and uneconomical to pump, although a substantial quantity of water may remain in storage. The usable amount may be only half that shown by the computations.

GROUND-WATER RECHARGE

The ground-water reservoir of the alluvium of Fountain and Jimmy Camp Valleys in the area of this report is recharged by precipitation, by infiltration from streams, by seepage from canals, reservoirs, and irrigated fields, and by subsurface inflow from adjacent areas. The importance of each source varies from area to area.

PRECIPITATION

Precipitation is the initial source of all the recharge in the report area. Probably not more than 1½ inches of the normal annual precipitation in the area, however, recharges the aquifer; the remaining 12 to 15 inches runs off to the streams or is lost by evaporation and transpiration.

Recharge rates from precipitation probably are greatest during the early spring when the thawed ground is moist and evapotranspiration rates are low. Recharge during the summer months is more pronounced in the irrigated parts of the two valleys. The water has more opportunity to percolate to the water table when the soil is moist. In dryland areas most of the moisture is held by capillarity in the zone of aeration and, subsequently, is used by plants before is has an opportunity to percolate downward to the water table.

STREAMS

Most of the recharge from streams occurs where the creek bed is above the water table. The water table in most of the Fountain Valley alluvium is above stream level, and, therefore, water discharges from the aquifer to the stream. However, during periods of heavy pumping in areas where the wells are concentrated, the movement of water is from the stream to the aquifer.

The perennial flow of Fountain Creek is derived from precipitation in its drainage area of about 700 square miles, which includes the Pikes Peak, Rampart Range, and the Monument Valley areas. The makeup of the flow through the area of investigation is affected by the inflow from the Blue River watershed and upstream diversions within the Fountain Creek watershed. A part of the diverted water returns to the stream from sewage-treatment plants along the valley. The amount returned from the largest of these, the Colorado Springs plant, is shown in table 5. The increase in flow from the sewage plant reflects increased water consumption by the city. Other treatment plants that discharge to Fountain Creek include those serving Security Village and Fort Carson. The town of Fountain has a lagoon-type treatment plant; the effluent seeps into the shale or evaporates, but does not reach the stream. Below the Colorado Springs plant the owners of canal 4 have a right to divert 9.8 second-feet of streamflow, which includes the sewage effluent, for irrigation in Fountain and Jimmy Camp Valleys and on the upland area between the valleys.

The flows of Fountain Creek, Jimmy Camp Creek, and several irrigation ditches were measured at several temporary gaging stations in an attempt to detect changes in flow caused by ground-water discharge or recharge (pl. 1; table 6). Station L was at the site of a permanent gaging station maintained by the U.S. Geological Survey from 1938 to 1954, and a hydrograph of the flow at that station is given on plate 3. The records indicate that at the time of this study there was no appreciable loss or gain in streamflow along Fountain Creek, that the movement of water from the stream to the Widefield channel (pl. 1) was effectively prevented by the intervening shale barrier, and that the stream did not lose large quantities of water into the large cone of depression developed around the heavily pumped wells in the Widefield channel.

The record of the permanent gaging station (station L) shows that the average annual discharge at the station is about 40,000 acre-feet. Upstream from this gaging station are several canals that divert 15,000 to 25,000 acre-feet per year. Table 4 shows the ground-water underflow to be about 4,000 acre-feet per year, and table 7 shows the pumpage of ground water to be about 10,000 acre-feet per year. Most of the surface water diverted by canals and the ground water pumped from wells is used within the area. It is estimated that one-half of this amount returns to the stream or ground-water underflow above the gaging station. Consequently, the possible water development in Fountain Valley from both surface and underground sources is about 60,000 acre-feet per year.

The entire flow of Jimmy Camp Creek is diverted for irrigation near its confluence with Fountain Creek and does not normally contribute to the flow of Fountain Creek, except during periods of high runoff. The flow of Jimmy Camp Creek was measured twice during this investigation; the results are listed in table 6.

The wide sandy stream bed of Jimmy Camp Creek is dry most of the time. During periods of excessive rainfall, however, it may carry

TABLE 5.—*Return of water to Fountain Creek from the Colorado Springs sewage-treatment plant*

Year	Daily average return			Total annual return acre-feet
	Million gallons	Cubic feet per second	Acre-feet	
1955	7	11	22	7,800
1956	7.2	11	22	8,100
1957	8	12	25	9,000
1958	9.6	15	30	11,000

TABLE 6.—*Flow of Fountain and Jimmy Camp Creeks and of several ditches, in cubic feet per second, at various dates*
[Station locations shown on pl. 1]

Station	July 20, 1954	Jan. 13, 1955	Apr. 18, 1955	Apr. 19, 1955	July 9, 1955	June 27, 1956	Remarks
A			9.00				Fountain Creek.
B	3.02		8.58				Do.
C	3.28		9.44				Do.
D			9.39	8.11			Do.
E	4.40	2.14	13.83	8.64	5.49		Do.
F		2.41	12.73	9.03	5.39		Do.
G	2.35						Clover ditch return and Fort Carson sewage discharge.
H	2.62						Irrigation ditch diversion from Fountain Creek.
I	4.68						Fountain Creek.
J			.75			0.70	Jimmy Camp Creek.
K	6.45						Irrigation ditch diversion from Fountain Creek.
L	1.39						Fountain Creek. Permanent gaging station.
M	1.33						Fountain Creek.
N	1.16						Irrigation ditch diversion from Fountain Creek.

large quantities of water, some of which percolates through the permeable sandy channel and reaches the water table. The amount of water that percolates to the water table depends upon the size and duration of the flood, the amount and type of sediment carried by the flood, the condition and gradient of the channel, and the permeability of the underlying material.

CANALS, RESERVOIRS, AND IRRIGATION

The ground-water reservoir in this area is recharged substantially by the seepage of water from canals and reservoirs and from irrigated land supplied by the canals. Canal 4, which carries water from Fountain Creek to Little Johnson and Big Johnson Reservoirs, crosses sandy soil and probably loses large amounts of water to the underlying ground-water reservoir. The reservoirs also lose water, as shown by the seepage to the surface directly downstream from Big Johnson Reservoir, along the valley on the Fountain Valley School property, and along the draw in the SE¼ sec. 18 T. 15 S., R. 65 W. Water from Big Johnson Reservoir is used to irrigate some upland areas between Fountain and Jimmy Camp Valleys and areas in Fountain and Jimmy Camp Valleys. Part of this irrigation water eventually recharges the aquifers underlying the areas described. Several canals below the Widefield area divert water from Fountain Creek and cross the buried alluvial channel farther down the valley where the water has an opportunity to recharge the underlying aquifer.

Because the pumping of wells tends to lower it and the recharge from the application of surface water tends to raise it, the water table remains at a relatively constant level in areas where the land is irrigated with both surface and ground water. Where irrigation is with ground water alone, the water level tends to fluctuate more sharply as large quantities of water are pumped out of the aquifer and as a considerable part (perhaps 60 percent) of the water pumped returns to the aquifer by percolation through irrigated soils (see hydrographs in pl. 3 and fig. 13).

SUBSURFACE INFLOW

A considerable quantity of ground water enters the area by underflow through the alluvium of Fountain and Jimmy Camp Valleys, and smaller quantities enter through the tributary valleys. A small quantity of water is contributed along the sides of the valley by the mesa gravel and other surficial materials overlying the Pierre Shale. An estimate of the underflow at several locations across the valley is given in table 4. The underflow may differ from place to place and from time to time, because of the difference in cross-sectional areas, ground-water gradients, and permeabilities. The underflow along Fountain Creek ranged from 2.7 to 4 mgd, whereas the underflow along Jimmy Camp Creek ranged from 0.8 to 0.9 mgd (table 4).

The alluvial deposits are underlain by Pierre Shale, which does not readily transmit water; therefore, there is little or no subsurface inflow or outflow through the underlying shale. Interformational leakage between alluvium of the upper part of Jimmy Camp Valley and the Fox Hills Sandstone, Laramie Formation, and the Dawson Arkose is small because of the low permeability of the underlying consolidated rocks.

ARTIFICIAL RECHARGE

The alluvial aquifer in Fountain and Jimmy Camp Valleys could be recharged artificially by injection through wells and by spreading or ponding, if a supply of water were available. Fountain Valley should be a favorable area for artificial recharge because of the high coefficient of permeability and the specific yield of the aquifer. The aquifer in Jimmy Camp Valley could be recharged by these methods also, but at a lower rate because of the lower coefficient of permeability and the specific yield of the aquifer.

If the city of Colorado Springs should have an excess of water from its surface diversions at certain times in the year or during periods of above-normal runoff, treated water from their municipal system could be injected directly into the alluvial aquifer in Fountain Valley through the city's wells near Widefield. The unsaturated deposits of the alluvium could be used as an underground reservoir that is largely free from evaporation and from construction costs. Water could be injected into the aquifer through the wells at a rate comparable to the normal discharge of the wells, that is, at about 400 to 700 gpm per well, or an average of about 6 acre-feet per day through four wells. It is estimated, on the basis of data collected during this investigation, that an additional 5,000 acre-feet of water could be stored in the Widefield channel without causing waterlogging of the lowlands. Because ground water moves slowly (about 15 feet per day) and because the channel is bounded by shale on both sides (pl. 2, sections *A–A′*, *B–B′*), a large part of the recharge water injected during one season could be recovered in periods of heavy demand during the remainder of the year. Water could be withdrawn from the four injection wells or from a system of additional wells along the Widefield channel.

Although artificial recharge to the aquifer is physically possible, many problems would have to be overcome. The primary problem is legal: the securing of proper agreements with ground-water users in the Widefield area.

GROUND-WATER DISCHARGE

Water is discharged from the underground reservoirs of the Fountain and Jimmy Camp Valley area by transpiration and evaporation, by springs and seeps, by wells, and by subsurface outflow.

TRANSPIRATION AND EVAPORATION

Ground water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, and be discharged from the plants by transpiration. The depth from which plants will lift ground water varies according to the species of plants and the type of soil. The limit of lift by ordinary grasses and field crops is not more than a few feet; however, alfalfa, willows, cottonwoods, and certain types of desert plants may send their roots to depths of several tens of feet to reach the water table.

The discharge of ground water by transpiration and evaporation in the valleys is limited primarily to the areas where the water table is shallow. These areas generally are indicated by an abundance of cottonwood trees, such as are found along Fountain Valley and the lower part of Jimmy Camp Valley and which occupy about one-tenth of the total valley area. Where the water table is more than 20 feet below the land surface, the amount of water discharged from the ground-water reservoirs by these processes probably is negligble, but in the valley bottoms the discharge is considerable.

SPRINGS AND SEEPS

Some ground water is discharged from the ground-water reservoir through springs and seeps. Part of this loss is to perennial streams in those places where the level of the stream is below that of the adjacent water table, and part occurs as springs and effluent seepage along the sides of Fountain Valley at the contact of the mesa gravel and the underlying Pierre Shale. Springs from the mesa gravel are most common along the west side of the valley between the town of Fountain and the Pueblo County line. The measured yield of individual springs and seeps ranged from less than 1 to 360 gpm, as shown in plate 1.

WELLS

Another form of discharge from the ground-water reservoir is by pumping from wells drilled for irrigation and public supply. These wells penetrate all the water-bearing alluvial materials; they range in diameter from 16 to 24 inches and in yield from about 40 to more than 1,300 gpm. The combined yield of all the large-capacity wells in the valley is a major part of the total discharge, which has increased greatly since 1950 because of the increased use of ground water for irrigation and public supplies. Estimates of the amount of water pumped from these large-capacity wells from 1954 through 1956, as determined from discharge and power records, are given in table 7. It is possible to pump ground water at a rate exceeding the underflow (table 4), without seriously depleting the aquifer, for intermittent periods because of the large amount of ground water in storage (p. 33) compared to the amount pumped and because of the availability of recharge from streams of Fountain Creek at those places where the stream overlies the main part of the buried channel.

TABLE 7.—*Pumpage from large-capacity wells in Fountain and Jimmy Camp Valleys, in acre-feet*

Location	Pumpage, in acre-feet		
	1954	1955	1956
Fountain Valley	6,200	7,700	7,400
Jimmy Camp Valley	2,900	3,300	5,200

SUBSURFACE OUTFLOW

Water in the aquifer moves generally southward through the alluvium and leaves the area at the south boundary of the project area at the rate of about 4 mgd (4,500 acre-feet per year). Although the underflow at this point represents a loss of water from the project area, it does not represent a loss from the aquifer; rather, it is the water that moves through the aquifer across the south boundary of the project area into Pueblo County.

RECOVERY OF GROUND WATER

SPRINGS

Springs and seeps supply small quantities of water that are used for domestic purposes, for stock watering, and occasionally for irrigation. Springs that yield as much as 10 gpm each issue at the contact of the mesa gravel and the underlying Pierre Shale along the sides of Fountain Valley. Along Fountain and Jimmy Camp Creeks, where the land surface coincides with or intersects the water table, springs and seeps are found. A tile drain along the seep in sec. 34, T. 14 S., R. 66 W. was flowing at a rate of 360 gpm when measured.

WELLS

Nearly all the wells in the project area are equipped with pumps. Most irrigation and public-supply wells are equipped with vertical turbine pumps; however, a few wells are equipped with centrifugal pumps. Domestic and stock wells usually are equipped with a cylinder, jet, submersible turbine, or centrifugal pump. Most of the pumps are powered by electricity, but a few are operated by combustion engines, by windmills, or by hand. The horsepower of electric motors on irrigation pumps ranges from 5 to 30, and that of the motors on municipal pumps ranges from 5 to as much as 75.

UTILIZATION OF WATER

Specific data on 209 wells and 9 springs in the Fountain and Jimmy Camp Valleys area were obtained during this investigation. Of the wells, about 41 were used for domestic and stock supplies, 100 for irrigation, and 25 for public supplies. The remainder were unused or their use was in doubt. The inventory included most of the irrigation and public-supply wells, but only some of the domestic and stock wells and springs.

DOMESTIC AND STOCK SUPPLIES

Domestic wells supply water to homes for cooking, drinking, watering lawns and gardens, and washing. Stock wells supply a large part of the water for livestock—principally cattle, hogs, poultry, and sheep; some is supplied from surface source. Most of the domestic and stock wells are small-diameter drilled wells. Water used for domestic and stock supplies commonly is hard but otherwise is satisfactory. Withdrawals by wells for domestic and stock consumption constitute only a small part of the total ground-water use.

INDUSTRIAL SUPPLIES

The only industrial well in the area is used by the Daniels Sand Co. for washing commercial sand and gravel. The well (15–66–3bcc) is

24 inches in diameter and was drilled to a depth of 35 feet in the alluvium of Fountain Valley. The discharge was reported to be 250 gpm, the measured drawdown was 10 feet, and the annual pumpage was estimated to be 140 acre-feet per year.

PUBLIC SUPPLIES

The city of Colorado Springs, the town of Fountain, and Security Village have a total of 15 municipal wells in Fountain Valley, and the city of Colorado Springs had 27 additional municipal wells in Jimmy Camp Valley. Withdrawals for municipalities is a major part of the total ground-water use.

COLORADO SPRINGS

The Colorado Springs metropolitan area, which had an estimated population of 100,000 in 1960, is supplied primarily by surface water from the Pikes Peak, Rampart Range, Blue River, and South Platte River watersheds. Because of severe drought, an emergency ground-water supply was developed during 1954 to supplement the failing surface-water supply. Agreements were negotiated with landowners in Fountain Valley to permit the city to pump water from three irrigation wells and from one new well—all in the Widefield channel. The wells penetrate the alluvium and are bottomed in Pierre Shale at depths ranging from 69 to 75 feet. The wells have 24-inch casings and are equipped with 8-inch turbine pumps set at 66 feet and powered by 30-horsepower electric motors. The pump discharge was controlled by valves to prevent surging.[1] A nearby pumping station provided additional pressure to deliver the water to the city.

Before pumping into the Colorado Springs system began in July 1954, water levels in the wells ranged from 32 to 40 feet below land surface; after 15 months of continuous pumping at an average rate of 1,500 gpm, the depth to water in the four wells when the pumps were off ranged from 41 to 49 feet. A total of 2,960 acre-feet of ground water was supplied to the city from these wells during the period August 1, 1954, to October 24, 1955.

Water was also pumped from 27 smaller capacity wells in Jimmy Camp Valley. According to an agreement between Colorado Springs and three land owners in Jimmy Camp Valley, the wells were to be pumped for a period of 20 months beginning in April 1955. These wells had been drilled through the alluvium into the underlying Pierre Shale to depths ranging from 36 to 79 feet. They were equipped with 4- to 8-inch turbine pumps having bowl settings 5 to 10 feet above the base of the aquifer. Valves were placed on the

[1] "Surging" refers to the phenomena that occurs when the pumping rate exceeds the yield of the well. The water level in the well falls below the bottom of the pump, and air is pumped until suction lift is regained; this causes the discharge from the pump to fluctuate.

discharge pipe from each well to control the pumping rate. Water was discharged from the pumps into a 16-inch main and then flowed by gravity to the pumping station in Fountain Valley. The water levels in March 1955, before pumping into the Colorado Springs system began, ranged from 16 to 28 feet below land surface. By November 1956, 2,400 acre-feet of water had been withdrawn from the alluvium in Jimmy Camp Valley and the water table in the vicinity had declined 8 to 11 feet.

The water from the wells in both valleys is carried to a sump and booster station near the Widefield well field where it is chlorinated and pumped through a 16-inch main to the Colorado Springs water system. This system also supplies all or part of the water used by Fort Carson, the Broadmoor Hotel, South Suburban Water Co., and Stratton Meadows.

Water from wells 15–66–11cda1 and 15–66-14aac1 in Fountain Valley was analyzed as a part of this investigation and found to be hard; the concentration of other constituents is shown in table 8. A partial analysis of a sample of the water from well 14–65–34aac1 in Jimmy Camp Valley indicated that the water is hard.

The return flow from the city's water system is measured at the sewage-treatment plant. The plant is built on alluvium and Pierre Shale along the north side of Fountain Creek. The treated sewage from the plant discharges into Fountain Creek (table 5) and irrigation canal 4.

FOUNTAIN

Fountain (population 1,600 in 1960) formerly obtained its entire water supply from three reservoirs about 12 miles west of town, near the foothills. The reservoirs have a combined storage capacity of 19 million gallons. As the town grew, the supply became less adequate. Because the reservoirs were adequate to supply the town for only about 9 months a year, an additional supply was developed by drilling wells into the alluvium of Fountain Valley to supplement the surface-water supply during the 3 months of peak demand. Four wells were owned by the town in 1955. Three wells pump directly into the 6-inch mains that are connected to reservoirs west of town; the other well is not connected to the system and therefore is not used. One of the wells connected to the system (16–65–6daa) and the unused well 16–65–6acc were drilled prior to 1953. Well 16–65–6adc2, drilled in 1953, originally supplied only the high school but was later connected to the distribution system. Well 16–65–6adc1 was drilled in 1954 and connected to the system at that time. The unused well 16–65–6acc can supply an additional 200 to 500 gpm if needed. The average daily consumption of water in Fountain is about 166,000 gallons.

TABLE 8.—*Analyses of water from selected wells in Fountain and Jimmy Camp Valleys*

[Analytical results in parts per million. Geological source: AJ, Jimmy Camp Alluvium; AF, Fountain Valley Alluvium]

Well location	Depth (feet)	Geologic source	Date of collection	Temperature (°F)	pH	Specific conductance, in micromhos at 25°C	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
14-65-27ddb1 [1]	80.8	AJ	5-4-55	55	7.9	740	14	0.14	73	18	62	1.8
34aac1	82	AJ	5-6-55	55	7.9	807			75	6.8		
14-66-28ccc	55.8	AF	5-6-55	54	7.2	735			83	18		
15-65-28dcd1	58.8	AJ	5-6-55	54	7.7	1,600			144	27		
30cda	15.7	AF	5-6-55	53	7.9	1,110			105	30		
33cbd [1]	39.4	AJ	5-4-55	53	7.6			.04	102	15	188	2.9
15-66-3caa	28.8	AF	5-5-55	55	7.5	805			88	18		
11cdal [2]	69.5	AF	11-23-54	53	7.1	610			82	3.9	6.0	
14aac1	76.0	AF	5-7-55	55	7.7	620	21	.09	64	11	56	2.2
16-65-5ada	42.3	AJ	5-6-55	54	7.7	3,100			394	88		
(3)			5-6-55	57	7.7	195	9.5	.22	20	4.4	12	1.8
16-65-16bba2	59.9	AF	5-6-55	55	7.6	2,730			296	66		
17-65-3cca	31.9	AF	5-6-55	54	7.7	1,680			162	47		
26dcd	46.2	AF	5-6-55	55	7.6	1,980	16	.85	226	69	180	3.8

Well location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Percent sodium	SAR	Disolved solids	Hardness as $CaCO_3$	
									Total	Noncarbonate
14-65-27ddb1 [1]		160	11	0.4	1.0	34	1.7	840	256	46
34aac1	252		11						215	8
14-66-28ccc	138		18						281	168
15-65-28dcd1	310		23						470	216
30cda	210		28						386	214
33cbd [1]		430	25	.2	.8	56	4.6	1,075	318	12
15-66-3caa	220		25						294	113
11cdal [2]	183	50	18	.8	5.2	6	.2	500	237	72
14aac1	177	141	13	.5	13	37	1.7	409	204	60
16-65-5ada	228		48						1,340	1,160
(3)	71	26	2.8	2.8	.7	27	.6	115	68	10
16-65-16bba2	276		40						1,010	784
17-65-3cca	295		40						598	356
26dcd	334	854	32	2.4	7.8	31	2.7	1,560	848	574

1 Analysis furnished by the City of Colorado Springs.
2 Analyzed by the Colorado State Board of Health.
3 Town of Fountain, composite sample of surface and ground water taken from tap.

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Results of this study show that additional wells capable of yielding 200 to 500 gpm can be developed in the buried channel extending southeastward through the town.

A sample of water from the municipal supply at Fountain was analyzed and found to be soft. Inasmuch as ground water in the alluvium of Fountain Valley is hard, the sample probably represents largely surface water from the reservoirs. The results of the analysis are given in table 8.

To provide for sewage treatment, the town of Fountain in 1956 constructed two lagoons on the relatively impermeable Pierre Shale that reportedly prevent leakage into the alluvium and contamination of the ground-water reservoir.

SECURITY VILLAGE

Security Village (population 9,000 in 1960) is an unincorporated suburban housing development begun in 1954. It is in the Widefield School area and is supplied by four wells formerly used for irrigation and by five new wells. The wells are all drilled through the alluvial gravel of the Widefield channel and are bottomed in the underlying Pierre Shale. The wells range from 50 to 80 feet in depth and had water levels of about 40 feet in July 1954, before heavy pumping for municipal use began. The Security Village wells have 24-inch casings and are equipped with 4- to 8-inch turbine pumps powered by 30- to 75-horsepower electric motors. Water from the wells is pumped directly into 8- to 12-inch mains. An elevated storage tank and reservoir attached to the system have a capacity of 2 million gallons. At the beginning of this investigation, the four original wells had a combined yield of about 2,000 gpm. During periods of heavy pumping the yields declined, and the water table declined 5 to 13 feet but recovered to near their original levels and capacities after cessation of heavy pumping. In 1956 the wells pumped 720 acre-feet, or an average of 640,000 gpd. Although no samples of water from the Security Village wells were collected for chemical analysis, samples from nearby wells 15–66–11cda1 and 15–66–14aac1 were analyzed; the results are given in table 8 and are discussed on p. 46–52.

Security Village has a complete sewage-treatment plant that is built on Pierre Shale near Fountain Creek. The treated sewage from the plant discharges into Fountain Creek and contributes to its flow; the total discharge in 1956 was 150 acre-feet.

IRRIGATION SUPPLIES

Water diverted from Fountain Creek has been used for irrigation in Fountain and Jimmy Camp Valleys for a hundred years; however, the stream was soon overappropriated because the water rights granted exceeded the normal streamflow. Several of the early rights were purchased by the city of Colorado Springs. The lands served by these rights were then retired from irrigation until well development began, after which they were irrigated with water pumped from wells.

The first well to be used for irrigation in Fountain Valley (15-66-3dca1) was developed on the Pinello Ranch in 1912; the second irrigation well was constructed on the Bender Ranch in 1930 and was replaced by the present Bender well in 1948. Irrigation with water from wells increased rather slowly until 1940, after which it increased rapidly. By 1955 more than 70 irrigation wells in the Fountain Valley part of the project area were used to irrigate or to supplement the irrigation of about 5,000 acres. In 1955, 43 large-capacity wells along Jimmy Camp Valley were used as the sole source of supply or as a supplemental supply for the irrigation of about 2,000 acres. A few of these wells have been used for both irrigation and public supply.

Some of the irrigable land in the vicinity of Widefield and Fountain has been taken out of production and used as sites for housing developments. These developments use either the existing or new wells for municipal water supply.

YIELDS OF IRRIGATION WELLS

Irrigation wells in Fountain Valley yield from 70 to 1,340 gpm, and those in Jimmy Camp Valley yield from 40 to about 700 gpm. The average specific capacity (yield per foot of drawdown) of wells in Fountain Valley is about 38 gpm per foot, and the average of those in Jimmy Camp Valley is about 14 gpm per foot.

CONSTRUCTION OF LARGE-CAPACITY WELLS

Several methods have been used in constructing irrigation, public-supply, or other large-capacity wells in the Fountain and Jimmy Camp Valleys area. Some wells were drilled or dug by the owners, and others were constructed by excavating a sump where the water table is near the surface. However, most of the wells were drilled by professional well drillers by means of cable-tool, standard hydraulic-rotary, reverse hydraulic-rotary, and sand-pump methods.

Most of the large-capacity drilled wells in the area have casings 16 to 24 inches in diameter. Most irrigation wells use perforated casing, and many have gravel-pack type construction. Gravel-packed wells generally are drilled 8 to 12 inches larger than the casing diameter to accommodate the gravel pack. Most municipal-supply wells are similarly constructed, but some use screens instead of perforated pipe.

Following their completion and development, wells in this area generally are tested to determine the yield and drawdown. A pump is installed in such a manner that its intake is below the point of drawdown. The installation generally is completed by laying a concrete slab level with the top of the well casing. A 6-inch hole through the concrete slab at the side of the casing is sometimes provided so the well owner can add to the gravel pack; the pumping of fine material from the aquifer causes settlement of the gravel.

The wells that perform best in the report area generally have incorporated a combination of desirable features. These wells are drilled to bedrock (Pierre Shale), their casings are slotted or screened opposite all permeable material, the screen, slots, or gravel pack is designed to keep out all or nearly all the fine material after the well has been properly developed, and the space occupied by openings is great enough to minimize water entrance-losses without reducing the structural strength to the point of hazarding collapse of the casing.

Some well construction in the area violates some of these criteria and results in low yields, poor performance, pumping of sand, or short-lived wells. Careful attention to these pertinent points by both the owners and drillers can materially improve the efficiency of future wells.

Screen size and aggregate for gravel packs can be better selected if selection is based on sample analyses from the well. One way of analyzing particle-size distribution is shown on figure 10.

The interference effect among closely spaced wells can reduce the yield of the affected wells substantially. Some closely spaced wells in the area are less efficient than they would be if they had been spaced farther apart. Although the spacing problem is largely one of economics, data in this report suggest that spacing of 1,000 feet or more between large-capacity wells would reduce interference effects substantially throughout most of the area.

The reader is referred to the following reports for additional details on the methods of constructing and developing wells: Code (1929), Tolman (1937), Rohwer (1940), Bennison (1947), Wood (1950), Meeks (1952), Lockman [2] (1954), Gordon (1958), and Vaadia and Scott (1958).

QUALITY OF WATER

The samples analyzed (table 8) probably have a chemical quality representative of that of the ground water in the alluvium of Fountain and Jimmy Camp Valleys. The one tap sample suggests that the surface-water supply of the town of Fountain is of better quality than the best ground water in the area. Because some of the samples contain certain constituents in undesirable amounts, wells intended to furnish water for public supply and industrial purposes should be sampled and the water analyzed to determine its suitability for the intended use. Some of the common criteria that may affect the

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[2] Lockman, J. R., 1954, Selection of gravel pack for water wells in fine, uniform, unconsolidated aquifers: M. S. thesis in Colorado State Univ. Library.

use of water are summarized herein. An explanation of the many requirements of water for industrial use are beyond the scope of this report, as is a study of the properties of water that may affect its use for sanitary purposes; to insure against bacterial contamination users should avail themselves of the services of their appropriate public health agencies.

COMPOSITION OF NATURAL WATER

All natural water contains dissolved mineral matter. Water in contact with soils and rocks even for only a few hours will dissolve some mineral matter. The quantity of mineral matter dissolved by natural water depends chiefly on the type of rocks and soils with which the water comes in contact and the duration of the contact. Ground water usually contains more dissolved mineral matter than surface runoff because it remains in contact with soils and rocks for longer periods of time. The concentration of dissolved solids in a river water may be increased by drainage from mines and oil fields and by discharge of industrial and municipal wastes into the streams, and in irrigated areas by return drain waters.

EXPRESSION OF RESULTS

The dissolved mineral constituents in table 8 are reported in parts per million. A part per million is a unit of weight of a constituent in a million unit weights of water. Equivalents per million, though not given in this report, are sometimes preferred to the expression of results in parts per million. An equivalent per million is a unit chemical combining weight of a constituent in a million unit weights of water. Equivalents per million for any constituent are obtained by dividing the concentration of the constituent in parts per million by the chemical combining weight of the constituent. For convenience in making this conversion, the reciprocals of chemical combining weights of the most commonly reported constituents are given in the following tabulation.

Constituent	Reciprocals	Constituent	Reciprocals
Iron (F^{+3})	0. 537	Carbonate (CO_3^{-2})	0. 0333
Manganese (Mn^{+2})	. 0364	Bicarbonate (HCO_3^{-1})	. 0164
Calcium (Ca^{+2})	. 0499	Sulfate (SO_4^{-2})	. 0208
Magnesium (Mg^{+2})	. 0822	Chloride (Cl^{-1})	. 0282
Sodium (Na^{+1})	. 0435	Fluoride (F^{-1})	. 0526
Potassium (K^{+1})	. 0256	Nitrate (NO_3^{-1})	. 0161

Results in parts per million can be converted to grains per U.S. gallon by dividing by 17.12.

Total hardness as used in this report means the hardness expressed as calcium carbonate caused by calcium and magnesium in the water. The hardness equivalent to the carbonate and bicarbonate is called carbonate hardness and can be found by subtracting noncarbonate hardness from total hardness (table 8). Hydrogen-ion concentration is expressed on the pH scale. Specific-conductance values are expressed as micromhos per centimeter at 25°C. In many reports conductance is designated by the letter K and values expressed as above may be written $K \times 10^6$ at 25°C. A micromho is a millionth of a reciprocal ohm.

SUITABILITY OF WATER FOR DOMESTIC AND IRRIGATION USE

The chemical properties and constituents most likely to be of concern to residents of the report area are (1) dissolved solids, (2) specific conductance, (3) sodium-adsorption-ratio, (4) hardness, (5) iron, (6) fluoride, (7) nitrate, and (8) sulfate. For further information the reader is referred to the publication "Water Quality Criteria" (California State Water Pollution Control Board, 1952).

DISSOLVED SOLIDS AND SPECIFIC CONDUCTANCE

Dissolved solids is a measure of the total mineralization of water and is a significant criteria for most uses. In general, the suitability of water for most uses decreases with an increase in its mineral content. State and municipal authorities have widely adopted the standards set by the U.S. Public Health Service (1946) for drinking water used on common carriers in interstate commerce. The standards indicate that dissolved solids should not exceed 500 ppm, but, if such water is not available, as much as 1,000 ppm may be permitted. In some areas, the residents accustomed to more highly mineralized water appear to suffer no ill effects, though the water may be toxic to transient visitors. Stock have been known to survive on water containing as much as 10,000 ppm dissolved solids; however, their well-being may be noticeably affected by water containing more than 3,000 ppm.

The specific conductance of water samples from a number of wells in Fountain and Jimmy Camp Valleys (Jenkins, 1961) was determined in the field by means of a field conductivity set. The concentration in parts per million of dissolved solids in a solution is roughly equal to two-thirds of the specific conductance in micromhos at 25°C. For example, if the specific conductance were 600, then the amount of dissolved solids in solution would be about 400 parts per million. The amount of dissolved solids is given for the samples from only six wells in table 8, but the concentration of dissolved solids in samples from additional wells can be estimated by means of the specific conductance determination.

The concentrations of dissolved solids in the samples of water that was determined in the laboratory (table 8) ranged from 115 to 1,560 ppm and the specific conductance ranged from 195 to 3,100 micromhos at 25°C. The specific conductance and the dissolved-solids content increases downstream because the return flow of underground drainage water from irrigated lands is more highly mineralized than the natural flow. The return flow becomes highly mineralized because of the relatively slow movement of the water through the interstices of the unconsolidated alluvial materials and over the underlying shale bedrock and because of concentration by evaporation and transpiration of ground water that lies near the surface. The specific conductance of ground water along Fountain Valley, determined by field determinations, increased from 480 at well 14–66–33bca to 1,800 at well 18–65–1bba1, and the specific conductance along Jimmy Camp Valley increased from 740 at well 14–65–27ddb1 to 3,100 at well 16–65–5ada.

SODIUM-ADSORPTION-RATIO

The three indices used to show the suitability of water for irrigation in this report are percent sodium, sodium-adsorption-ratio (SAR), and specific conductance. Percent sodium and SAR are related to the sodium hazard; the specific conductance is related to the salinity hazard. The hazard increases as the numerical value of the indices increase. Although boron in relatively small concentrations can be a hazard to irrigated crops, no determinations of boron content were made. Six determinations plotted on figure 14, according to the standards suggested by the U.S. Salinity Laboratory (1954) for irrigation water in arid areas, show the water to be low in sodium, but three of the six determinations show that the water to be high in salinity. High salinity waters can be used successfully on soils having adequate drainage. Most of the soils in the valleys are permeable and afford good drainage. The good drainage and the dilution from rainfall and periodic surface-water applications suggest that even the high salinity water would be suitable. Supplemental measurements of conductance suggest that most of the ground water in the alluvial deposits is within the range indicated by the analyses in table 8 and, therefore, is suitable for irrigating land in the valleys.

HARDNESS

Water having a hardness of less than about 50 ppm generally is rated soft, and its treatment for the removal of hardness generally is not necessary. Hardness between 50 and 150 ppm does not seriously interfere with the use of water for most purposes, but it does increase the consumption of soap; its removal by a softening process is profitable for domestic use for laundries, and for some other industries. The ground-water samples collected in this area ranged in hardness from

204 to 1,340 ppm. None of the samples of water were soft, although the sample of tap water collected from the water supply of the town of Fountain, which was a mixture of surface and ground water, had a hardness of only 68 ppm. The water for the municipal supply of Fountain is therefore only slightly harder than the upper limit for soft water.

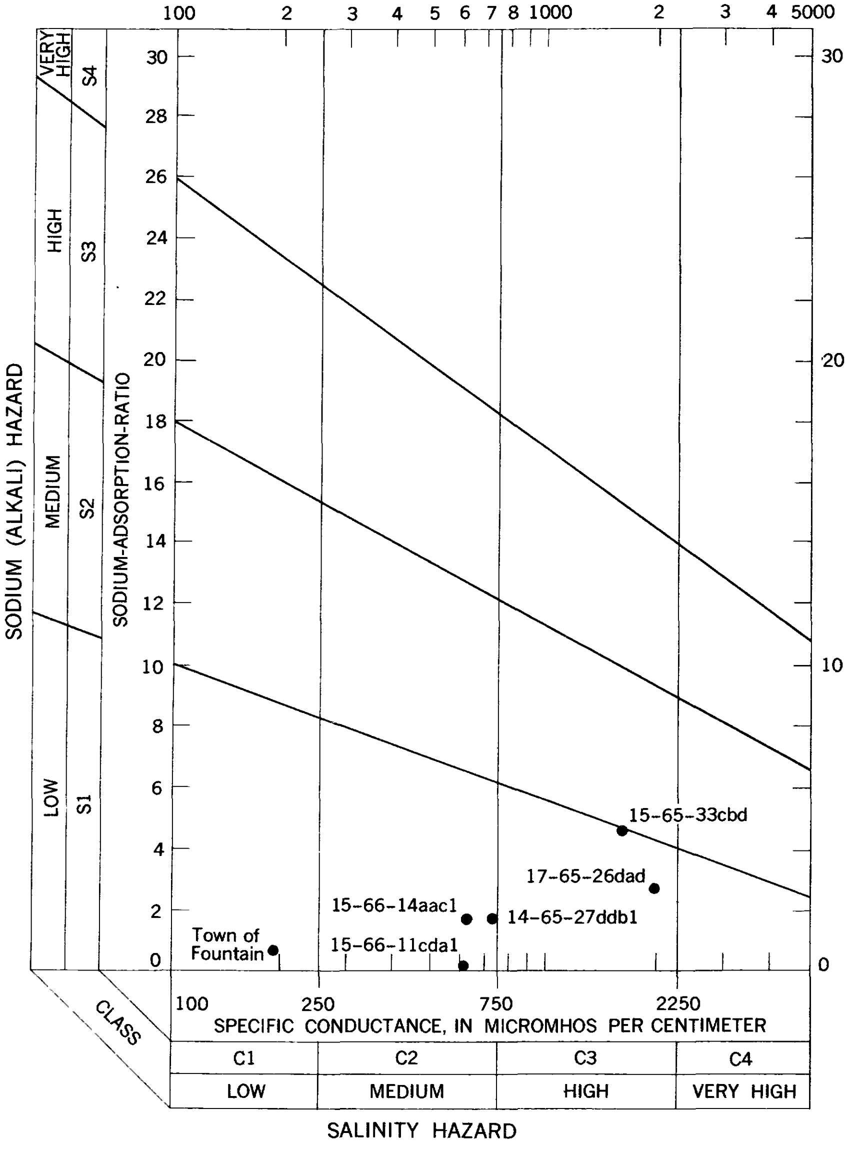

FIGURE 14.—Classification of water for irrigation use with regard to the sodium and salinity hazards. After U.S. Salinity Laboratory Staff (1954).

IRON

Next to hardness, iron is the constituent of natural water that in general receives the most attention. The quantity of iron in ground water may differ greatly from place to place, even though the water is derived from the same formation. If water contains more than 0.3 ppm, the excess may precipitate as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste to water and to stain cooking utensils, may be removed from most water by simple aeration and filtration, but some water requires the addition of lime or some other treatment.

The amount of iron in the samples of ground water from the alluvium in Fountain and Jimmy Camp Valleys ranged from 0.04 to 0.85 ppm, but only one of the five samples tested contained more than 0.3 ppm.

FLUORIDE

Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing excessive concentrations of fluoride during the period of formation of the permanent teeth. This condition becomes more noticeable as the quantity of fluoride in the water exceeds 1.5 ppm. Recent reports indicate that the incidence of tooth decay is decreased or prevented by use of water containing concentrations of fluoride of 0.8 to 1.5 ppm (California State Water Pollution Control Board, 1952, p. 257).

The concentration of fluoride as determined from six samples, ranged from 0.2 to 2.8 ppm, the highest concentration being from the municipal supply at Fountain, where a mixture of ground water and surface water is used. Additional sampling is needed to determine whether high fluoride content is a problem.

NITRATE

The concentration of nitrate in water used for drinking receives attention because nitrate-rich water may cause illness in infants when used in the preparation of formulas. Some nitrate can be dissolved from nitrate-bearing formations, but more commonly large concentrations of nitrate are derived from surficial sources. Nitrate compounds are very soluble and may be readily dissolved from soils having high concentrations of nitrate (in some cases from fertilizer) or from nitrogenous materials in privies, cesspools, and barnyards; hence, high concentrations of nitrate may indicate that the water contains harmful bacteria also. Large amounts of nitrate are commonly found in waters from dug wells and springs, which generally are not as well sealed from surface contamination as are deeper drilled wells.

Ninety parts per million of nitrate in water is considered by some authorities to be the lower limit dangerous to infants, whereas a concentration of 45 ppm is considered dangerous by others (Comly, 1945).

The concentration of nitrate was determined for six samples of water in Fountain and Jimmy Camp Valleys, including the composite sample of trap water collected from the municipal supply at Fountain. The concentration of nitrate ranged from 0.8 to 13 ppm and was well within the safe limits for human consumption.

SULFATE

Sodium and magnesium sulfate in heavy concentrations produce a cathartic effect on people and stock. Concentrations of sulfate less than 250 ppm are considered safe from this hazard. Two of the samples tested exceeded this amount, one sample from the south part of the area in Fountain Valley, and one from the south part of Jimmy Camp Valley.

CHANGES IN CHEMICAL CONTENT

The chemical content of water in the report area may be expected to change from time to time and from place to place. The surface water used for irrigation undoubtedly varies in quality; the mineral content of the water subsequently is concentrated to varying degrees by evapotranspiration. These and other factors tend to modify the quality of the water percolating through the ground. Periodic sampling, especially in problem areas, should be begun to show the variations and trends.

EFFECTS OF FURTHER DEVELOPMENT OF LARGE SUPPLIES OF WATER FROM WELLS

Further development of large supplies of water from wells may reduce the availability of surface water from Fountain Creek, deplete storage in the alluvium of Jimmy Camp Creek, create problems of reduced well yields periodically, and necessitate carefully planned pumping schedules to obtain maximum benefits. Proper use of the ground-water reservoir, however, can substantially increase the overall utility of the water resources in the valleys.

Special detailed studies in the Widefield area made as part of this investigation are most helpful for better understanding the hydraulic functions of the reservoir under certain pumping regimens.

WIDEFIELD AREA OF FOUNTAIN VALLEY

The problems in the Widefield area will become greater unless further development is carefully planned. Factors to consider in planning future developments are (1) the boundaries of the reservoir, (2) the usable storage space, (3) the amount, distribution, and times of withdrawals, (4) the effects on water levels from recharge and intermittent pumping, and (5) possible legal problems.

The aquifer in the Widefield area consists of an alluvial-filled former channel (Widefield channel) of Fountain Creek. It is cut in shale and hydraulically connected with the present-day perennial stream only at the upper and lower ends of the area where the stream crosses the old channel.

A part of the 10,000 acre-feet of storage is available for use during extended droughts and peak seasonal withdrawal periods. Its maximum utility, however, is dependent upon the distribution of withdrawals, but under any practical plan it probably would not exceed half the total storage.

Further development should be made near either the upper or lower ends of the Widefield area because the center part already is heavily developed. The opportunities for large sustained yields are best near the upper crossing of the stream and next best near the lower crossing. Yields near the upper end of the Widefield channel probably would be affected very little by existing pumping, whereas those at the lower end, away from the stream, may be affected appreciably by upgradient withdrawals, the effect being dependent upon the amount, timing, and proximity of upstream pumping.

The demands for water from the area are and probably will continue to be variable during the year and from year to year owing to the types of water uses. Because the major users are municipalities and irrigators, all of whom use much more water during the summer than in the winter, further development generally would be more effective if the new demands were greater during the winter. The pumpage records for 1954–56 (table 9) show marked variations in annual pumpage. Heavy pumping by the city of Colorado Springs began in the Widefield area on Aug. 2, 1954, during a period of serious drought, and continued for 15 months, the total withdrawal being 2,960 acre-feet.

Recharge to the buried channel can be substantially increased at either end when water levels in the vicinity of the stream are lowered by pumping. An increase in recharge, of course, reduces the amount of streamflow. Although insufficient data are available for an estimate, recharge from the stream probably would be at least 5,000 acre-feet per year under optimum conditions, and might be considerably more.

The availability of water in the central and lower parts of the Widefield channel may be substantially affected by upgradient withdrawals. These effects were carefully studied and are reported in detail in the following section.

Plate 4 shows the water-level decline at several intervals due to pumping during the period from Aug. 1, 1954, to November 1956. Successive maps show how the area of substantial water-level decline increased in size, especially in the downstream direction. The anomalous northward extension of the depressed area shown on the map for August 1955 was caused by an irrigator pumping in that vicinity. He discontinued pumping shortly thereafter. Following the cessation of pumping in October 1955 by the irrigators and by the city of Colorado Springs, the center of the depressed area migrated noticeably down the channel as the depression was being filled more rapidly at its upchannel end (see maps for January 1956 and April 1956). By April 1956 the deepest part of the depression had moved about 1 mile downstream and was only 4½ feet deep. Water levels near the center of the heavily pumped area were within 1½ feet of their positions before pumping started in August 1954. When pumping was resumed in April 1956, the center of the depressed area moved up the channel toward the center of pumping. The hydrographs in plate 3 and figure 13 and the water-level records show the varied effects on wells during the pumping and nonpumping periods and show in more detail the rates of decline and recovery.

These observations are significant to sound planning of ground-water development in the area. They show that heavy pumping can affect the water levels over a large area, that the effects extend down the channel much farther than up the channel, and that following cessation of pumping the effects upchannel are rapidly wiped out by recharge, whereas the effects downchannel last for much longer time and may become greater for a short time over a part of the area. If pumping had continued for a longer period, the depressed area would have extended to the stream crossing near the Barnes Ranch, and water would have moved from the stream into the aquifer. This movement of water into the aquifer probably would prevent the depressed area from migrating further downgradient.

TABLE 9.—*Pumpage in the Widefield area*

Use	Pumpage in acre-feet		
	1954	1955	1956
Municipal:			
City of Colorado Springs	1,155	1,805	1,125
Security Village		170	720
Industrial		140	140
Irrigation	2,595	1,730	1,075
Total	3,750	3,845	3,060

WIDEFIELD WATER CONTROVERSY

Because large-scale developments of ground water can and do affect appreciably the availability of water from neighboring wells and conceivably from the stream, legal problems of water rights must be considered in further developments in the Widefield area. The value of good ground-water data in solving these problems is demonstrated by the Widefield water controversy.

During the course of this study, a controversy arose between the owner of well 15–66–14abb (Bender well) and the city of Colorado Springs, which was pumping from wells 15–66–11cda1 and 2 (Venetucci wells), 15–66–11dcd (North Hayes well), and 15–66–14aac1 (South Hayes well). An agreement was drawn up in May 1957 whereby the city of Colorado Springs agreed to measure the water levels periodically in seven observation wells (15–66–11bca, 15–66–11caa1, 15–66–11dcb1, 15–66–13bcc2, 15–66–13cdd1, 15–66–14aac2, and 15–66–14aba1) and to refrain from pumping their production wells when the water levels in the observation wells declined below specified levels. The purpose of the stipulation was to maintain a gro. d-water reservoir level that was adequate to allow the Bender well to pump 600 gpm. The text of the civil action reads as follows:

COUNTY OF EL PASO CIVIL ACTION NO. 33752

Findings by Engineers in regard to pumping by the Defendants to be permitted in 1957.

The following findings are herewith submitted to the parties in the above action as a guide to pumping operations by the Defendants in accordance with the stipulation entered therein some months ago.

(1) Interference with pumping at full capacity at the Bender Well occurs when the depth to the water table thereat in the absence of pump is thirty-one (31) feet or more below the elevation of the ground at the well.

(2) To avoid interference by the Defendants with full-capacity pumping at the Bender Well, as defined in the aforesaid stipulation, pumping by the Defendants for the present should be limited as follows:

(a) The South Hayes Well (15–66–14aac1) may be pumped continuously until the Engineers otherwise determine. No interference by this well is expected this year because of its distance downgradient from the Bender Well.

(b) At the North Hayes Well (15–66–11dcd) pumping is to be discontinued when the water table in test well 15–66–14aba is 45.5 feet below the top of the casing thereat, and may be resumed when such water table reaches an elevation 44.5 feet below the top of the casing thereat.

(c) At the Venetucci Wells (15–66–11cda1&2) pumping is to be discontinued when the water table in test well 15–66–11dcb is 44.75 feet below the top of the casing ar d may be resumed when such water table reaches an elevation 44.00 feet below the top of the casing. The guides at this well may be changed if and when Security pumps its new well, which is approximately 400 feet North of test well 15–66–11dcb.

The pumping guides herein presented are based on capacity pumping by Bender as practiced until some time in August. New guides should be adopted for the later portion of the year.

Colorado Springs, Colorado

May 1, 1957

This agreement proved satisfactory, and the yield of the Bender well exceeded 600 gpm during the 1957 irrigation season. A more detailed history of this case is discussed by Jenkins and Moulder (1962, p. 21–32).

FOUNTAIN VALLEY BELOW THE WIDEFIELD AREA

There was no great increase in pumping of ground water downstream from the Widefield area during the course of this investigation. The hydrographs in figure 13 and the water-level measurements (Jenkins, 1961) show seasonal fluctuations of the water levels in this part of the valley but no serious lowering of the water table. The buried alluvial channel meanders across the valley and underlies Fountain Creek at several places where it can receive recharge by infiltration of streamflow in the creek (pl. 2). The buried channel is a continuation of the Widefield channel and is fairly well identified on plate 1 by the pattern of irrigation and public-supply wells.

Large amounts of water can be withdrawn from Fountain Valley in this area by seasonal pumping, or moderate amounts can be withdrawn continuously. If there is further development along this part of the valley and if large amounts of water are pumped continually, water-level declines comparable to those in the Widefield area may result. Some of the valley below the Widefield area is still irrigated by surface water, a part of which recharges the aquifer and helps sustain ground-water levels.

Both the ground-water underflow and the return flow to the stream would be affected if the surface-water rights in this area were sold and used elsewhere, because there would no longer be replenishment from irrigation.

JIMMY CAMP VALLEY

The city of Colorado Springs pumped water from wells in Jimmy Camp Valley from April 1955 to April 1957. The hydrographs in figure 13 and the water-level measurements (Jenkins, 1961) show that the water table declined as much as 13 feet in the vicinity of the pumped wells during this period. The cone of depression around each well enlarged and eventually coalesced into one large cone-shaped depression that migrated downstream, as did the cone of depression in the Widefield area. The cone in Jimmy Camp Valley did not move downstream far enough, however, to affect neighboring wells, for the wells here are more widely spaced than those in Fountain Valley. By the spring of 1958, after heavy pumping had ceased, the water levels had recovered almost to their position of 1955. Outside the area of heavy pumping in Jimmy Camp Valley, there was no serious lowering of water levels. Much of the land is irrigated with surface water diverted from Fountain Creek and with water pumped from wells; the water levels in these areas fluctuate seasonally.

The sediments from which the water is pumped in Jimmy Camp Valley lie in a former channel of Jimmy Camp Creek. The channel can be fairly well identified on plate 1 by the pattern of irrigation and other large-capacity wells. Jimmy Camp Creek is intermittent except in a short reach near its confluence with Fountain Creek, where ground water seeps into the creek at less than 1 cfs. For this reason, pumping can cause very little depletion of streamflow and the creek cannot be a continuous source of recharge to the aquifer.

Moderate amounts of water can be withdrawn from the alluvium in Jimmy Camp Valley by intermittent pumping, but the pumping of large amounts of water for long periods of time would cause a serious lowering of the water table and a corresponding reduction in the amount of water in storage. The aquifer would be recharged in part, however, by precipitation, by infiltration from canals and reservoirs, and from streamflow during periods of storm runoff and by irrigation.

COMPUTATIONS OF DRAWDOWNS CAUSED BY THE PUMPING OF WELLS IN FOUNTAIN VALLEY

By Robert E. Glover and Edward D. Jenkins

Because of pending litigation (see p. 54–56), special computations were made as a part of this study to determine the cause of the lowering of the water level in the vicinity of well 15–66–14abb.

Though all wells in the Widefield area were considered to be contributing to the lowering of the water level in well 15–66–14abb, some were found to have no appreciable effect and were not used in the computations because (1) the amount of water pumped from them was small, (2) the amount pumped from them in previous years had had no adverse effects on well 15–66–14abb, and (3) their distance from well 15–66–14abb was considerable. The wells that contributed significantly to the lowering of the water level in the vicinity of well 15–66–14abb during 1954 and 1955 were 15–66–11bcd, 15–66–11cda1 and 2, 15–66–11dcd, 15–66–14aac1, and 15–66–14abb. Computations were made to estimate the effects that the pumping of these principal wells had on the lowering of the water table in well 15–66–14abb during parts of 1954–55; the results compared favorably with the measured water levels.

The area of lowered water table is a few miles southeast of Colorado Springs in the vicinity of Widefield School and includes Security Village. As described previously (p. 53), the sediments from which the water is pumped lie in a former channel of Fountain Creek, which is referred to as the Widefield channel (pl. 1). The sediments are separated locally from Fountain Creek by a shale barrier that effectively prevents the movement of water between the stream and the aquifer adjacent to the stream, but they underlie and are in hydraulic continuity with the creek a few miles upstream and downstream from the area of heavy pumping (pls. 1 and 2). The Widefield channel has an average width of about 3,000 feet, and the sediments extend as much as 30 feet below the water table. The large-capacity wells are located at points where the sediments are thickest.

FIRST APPROXIMATION

BASIS OF THE COMPUTATIONS

The computations are based on the following assumptions, idealizations, and procedures:

1. It is assumed that all the water pumped comes from storage in the aquifer or from the points of contact with Fountain Creek.
2. The first approximation neglects the effect of drawdowns in reducing the cross-sectional areas of the saturated part of the aquifer and is made as a concession to mathematical difficulties. Later, a computation is made to evaluate the effect of the shortcomings of the first approximation.
3. It is assumed that the wells for which drawdowns are computed superimpose their effect upon an aquifer that has become stabilized under the effects of pumping from the other older wells in the general area.
4. The trench is bounded laterally by relatively impervious shale barriers, and the drawdown from pumping is increased by the hydrologic boundaries created by these barriers. The method of images is used to compute the additional drawdown caused by the hydrologic boundaries. In order to simplify computations, the irregular boundaries of the trench were replaced by straight, parallel boundaries, as shown in figure 15.
5. The monthly pumpage is idealized in making the computations shown in plate 5, but the total quantity of water withdrawn from the aquifer by the wells is taken into account.
6. The water pumped is removed completely from the aquifer and none returns to the aquifer.
7. Drawdowns are computed by use of the Theis formula (Theis, 1935, p. 519–24).

SECOND APPROXIMATION

The second approximation was made to evaluate the effect of the shortcomings of the first approximation; the effect at well 15–66–14abb, less than one-half foot, was considered to be negligible.

Field observations of the drawdowns indicate that the cone of depression of the water table produced by pumping the wells has a tendency to migrate southward down the valley, which has a gradient of about 30 feet to the mile. Inasmuch as the computations of the first approximation do not show the effect of the migration of the

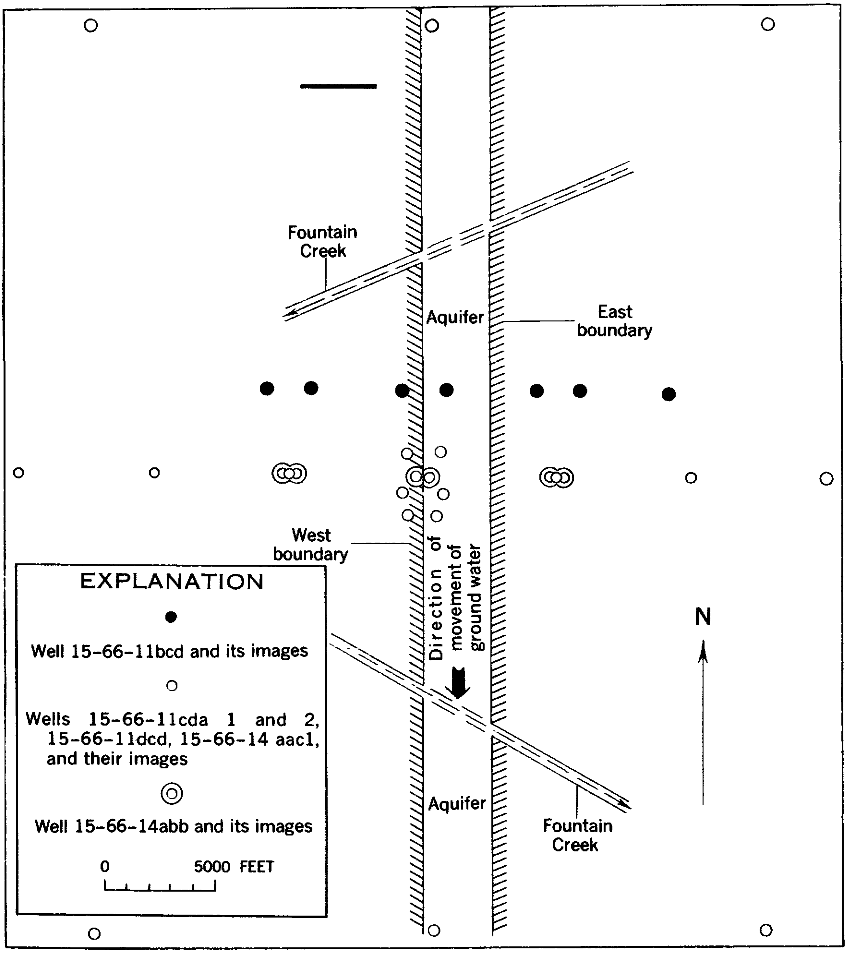

FIGURE 15.—Idealized map of the aquifier in the Widefield channel area showing the locations of pumped and image wells.

water-table depression, the second approximation was made in order to identify the cause and amount of the correction.

The correction obtained in this way, after allowing for the ability of Fountain Creek to maintain the ground-water levels in the aquifer at two points of contact about 10,000 feet from the wells, is shown on figure 16. These corrections evaluate (1) the effect of unwatering on the areas available for the flow of ground water and (2) the ground-water movement due to the gradient of the valley.

SUMMARY

The observed and computed effects of pumping wells in the vicinity of well 15-66-14abb are shown in plate 5. The computations were made on the basis of first-approximation formulas, as commonly used

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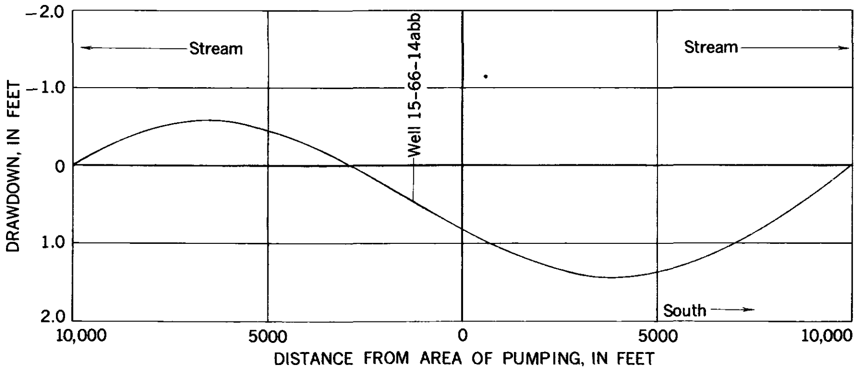

FIGURE 16.—Estimated corrections to apply to the drawdown, of the first approximation, after 15 months of pumping.

in engineering practices. It is recognized that such formulas must be used with caution to insure that they are not used beyond the range of their validity. A comparison of the first-approximation computations with the observed water levels revealed a striking discrepancy: the computed water-table depression appeared to be fixed in space, whereas the observed water levels indicated that the depression migrated toward the south. A second-approximation computation, made to correct in part the apparent discrepancies of the first approximation, revealed that the depression should migrate southward and that the computed water levels were in accord with the observed water levels. The computed water levels at well 15–66–14abb are not altered appreciably by the second-approximation computations.

The corrections made for the second approximation produce a rise in the computed ground-water level north of the wells and a decline in level south of the wells. At well 15–66–14abb, the correction will lower the computed water levels shown in plate 5*D* by about half a foot at the end of 15 months. The maximum rise in level is about 0.6 foot and the maximum lowering is about 1.5 feet. The correction explains the observed tendency of the ground-water depression caused by pumping to migrate southward. The cause of its migration, therefore, is identified; it is due to the southward gradient of the valley.

CONCLUSIONS

The total amount of water available to the Fountain Valley from ground and surface sources is roughly 60,000 acre-feet per year. The average annual discharge measured at station L is 40,000 acre-feet per year (pl. 1). Upstream, canals divert an additional 15,000 to 25,000 acre-feet per year. Ground water underflow amounts to about 4,000 acre-feet per year, and ground-water pumpage about 10,000. A part of the diverted and pumped water is not consumptively used and returns to the flow system above station L.

Ground water is available for irrigation and intermittent large-scale uses from the alluvial deposits that underlie the Fountain and Jimmy Camp Valleys. An estimated 95,000 acre-feet of ground water is stored in the alluvium of these two valleys in the report area. Wells that yield more than 1,000 gpm have been developed in the alluvium of Fountain Valley, and wells that yield as much as 700 gpm have been developed in the alluvium of Jimmy Camp Valley. The coefficient of permeability for the alluvium of Fountain Valley averages about 6,000 gpd per sq ft; that of Jimmy Camp Valley averages about 1,000 gpd per sq ft. The specific yield is about 25 percent in both valleys. The alluvium is recharged by precipitation, by infiltration from streams, canals, and irrigation, and by subsurface inflow from adjacent areas. Water is discharged from the alluvium by transpiration and evaporation, springs and seeps, wells, and subsurface outflow.

The aquifer can be depleted as well as replenished quite rapidly because of the limited amount of ground-water storage. Heavy pumping causes a lowering of the water level in the immediate area. If pumping continues for a long enough period, the depressed area will migrate downgradient, and yields of downgradient wells will be thereby reduced. Upgradient users are affected to a lesser degree by the downgradient users. Unsaturated deposits of the alluvium could be recharged artificially by injection through wells, or by spreading and flooding, if a supply of water were available; an underground reservoir essentially free from evaporation and construction costs would be created. Water so stored could be recovered within 1 to 2 years during periods of heavy demand without much loss to the stream.

The alluvial deposits yield hard water having moderate to high concentrations of dissolved solids. Ground water becomes harder and more mineralized down the valleys but generally is satisfactory for irrigation and domestic uses. The bedrock deposits of the Pierre Shale yield very small amounts of water of poor quality. The mesa gravel along the sides of the valleys yield small amounts of water through springs. The water is satisfactory for domestic and stock uses.

Additional hydrologic problems are anticipated in the future because of the relatively large number of irrigation and public-supply wells withdrawing large quantities of water from an aquifer that has a very limited extent and storage capacity and that is in contact with the present stream. Periodic measurements of water levels in selected observation wells and of the flow of Fountain Creek at selected sites should be continued to enable detection of the problems before they become serious and to provide information for planning further developments.

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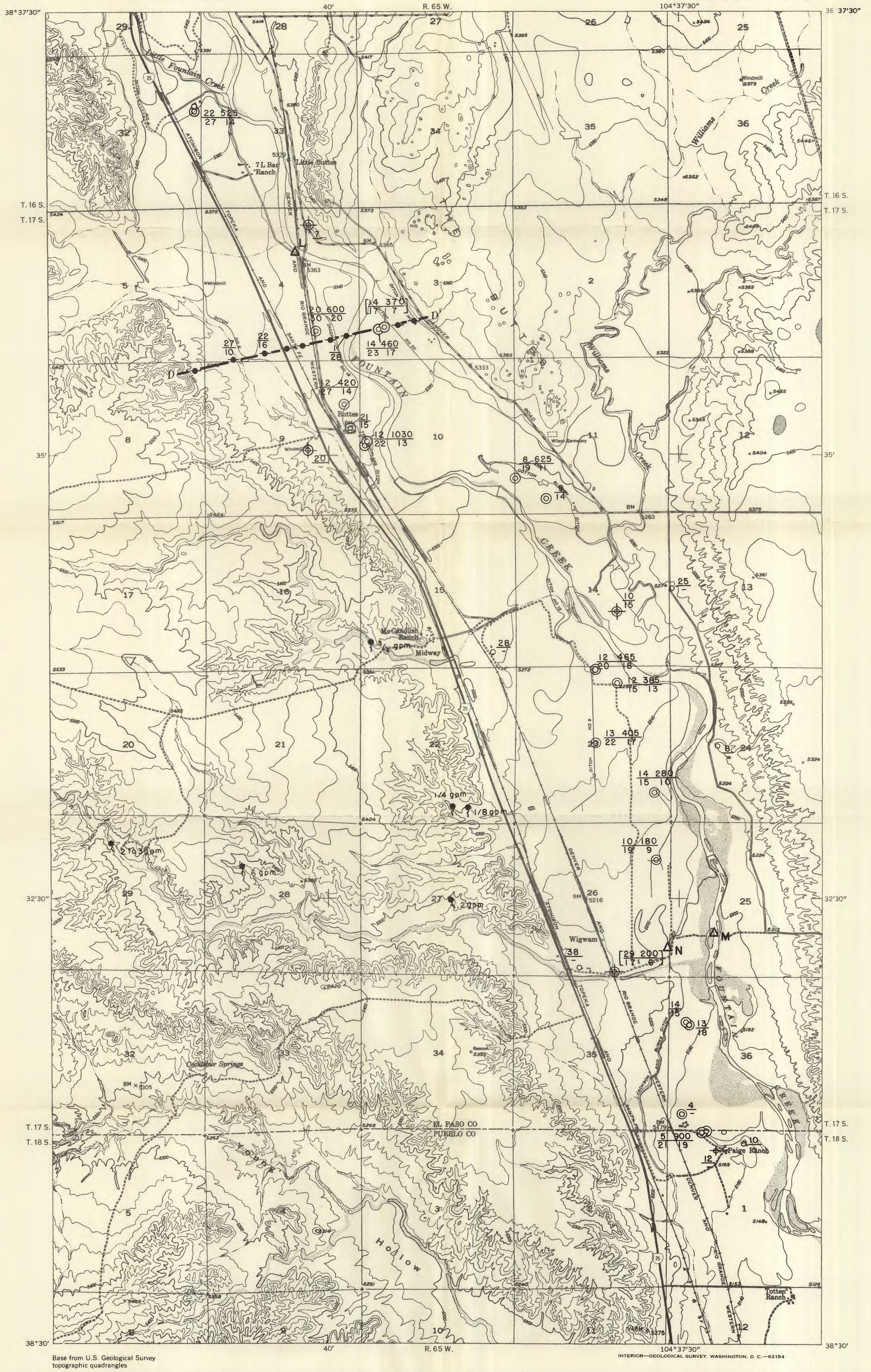


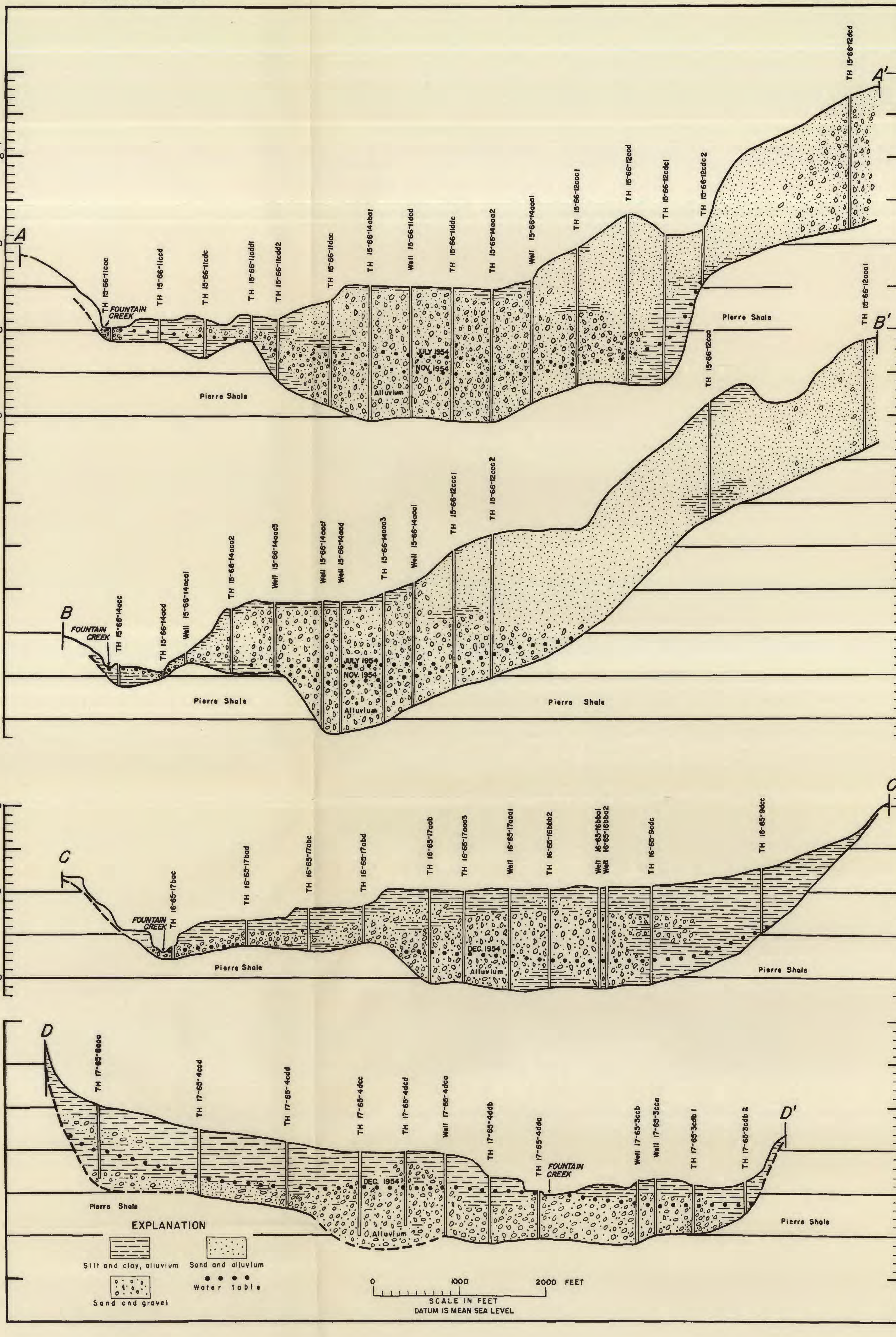
MAP OF FOUNTAIN AND JIMMY CAMP VALLEYS, EL PASO COUNTY, COLORADO SHOWING TOPOGRAPHY, LOCATION OF WELLS, TEST HOLES, AND STREAM-GAGING STATIONS, DEPTH TO WATER, SATURATED THICKNESS, MEASURED YIELD, AND MEASURED DRAWDOWN

SCALE 1:24 000

1 MILE

1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL



CROSS SECTIONS OF FOUNTAIN VALLEY SHOWING THE RESULTS OF TEST DRILLING
ALL SECTIONS ARE VIEWED LOOKING UPSTREAM

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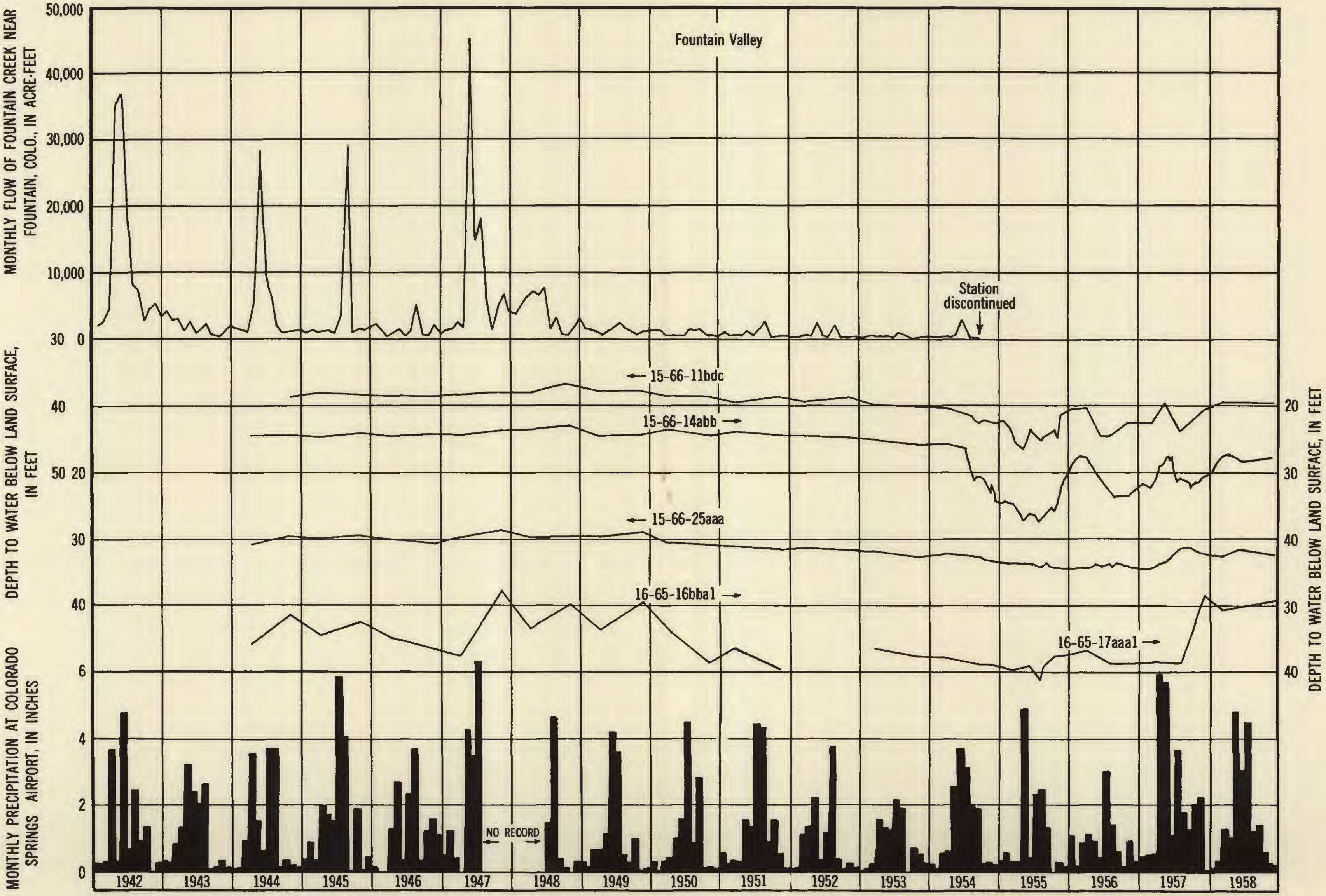

Precipitation data from U.S. Weather Bureau

HYDROGRAPHS SHOWING THE MONTHLY FLOW OF FOUNTAIN CREEK NEAR FOUNTAIN THE FLUCTUATIONS IN FOUR OBSERVATION WELLS IN FOUNTAIN VALLEY AND MONTHLY PRECIPITATION AT THE COLORADO SPRINGS AIRPORT

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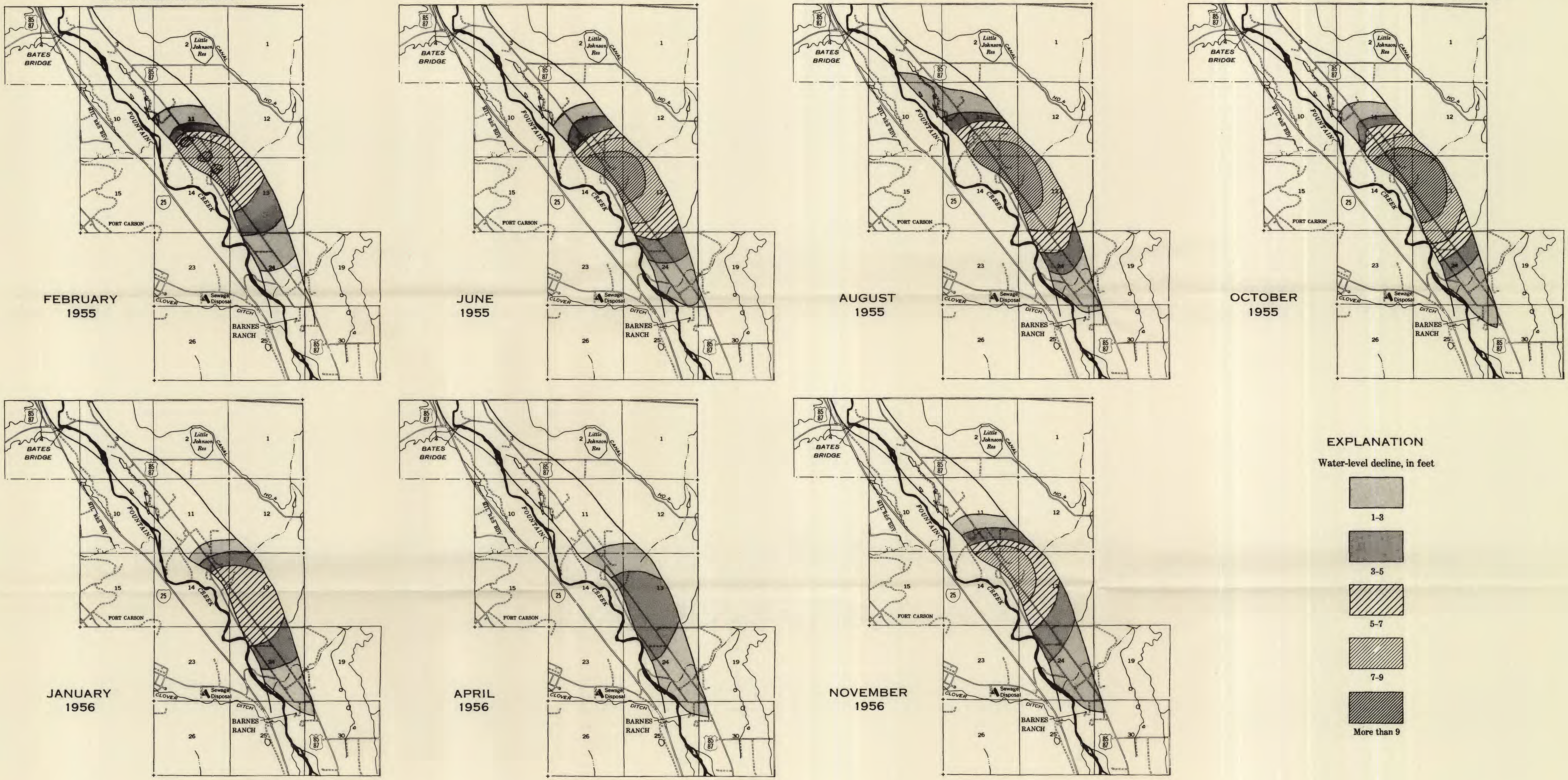

WATER-LEVEL DECLINE IN THE WIDEFIELD AREA AFTER AUGUST 1, 1954

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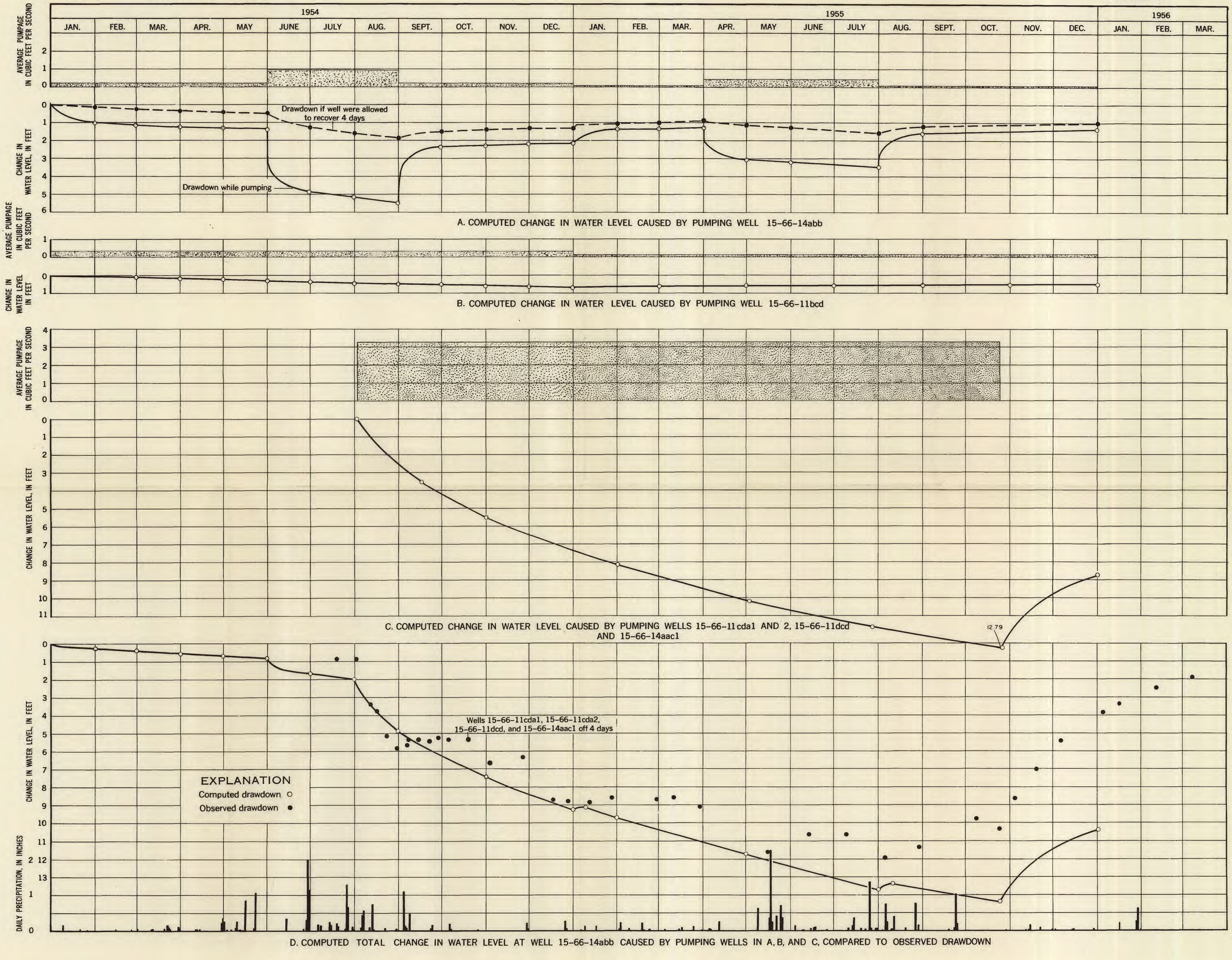

PUMPING RATES OF WELLS, DAILY PRECIPITATION AT COLORADO SPRINGS, AND COMPUTED CHANGES IN WATER LEVEL AT WELL 15-66-14abb CAUSED BY PUMPING SELECTED WELLS IN THE WIDEFIELD AREA

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