Ground-Water Resources of the Lower Mesilla Valley Texas and New Mexico

By E. R. LEGGAT, M. E. LOWRY, *and* J. W. HOOD

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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[Plates are in pocket]

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By E. R. LEGGAT, M. E. LOWRY, and J. W. HOOD

ABSTRACT

The lower Mesilla Valley extends southward from the vicinity of Anthony, Tex., to the gorge of the Rio Grande north of El Paso and westward from the Franklin Mountains to the east edge of La Mesa. The increase in the use of ground water for the public water supply of El Paso and for supplemental irrigation, when the surface-water allotments were inadequate, emphasized the need for an investigation of the ground-water resources of the lower Mesilla Valley.

The deep and medium aquifers in the Santa Fe group, whose maximum thickness is at least 2,000 feet, are the major sources of ground water for public supply. The alluvium (shallow aquifer), which supplies water chiefly for irrigation and to a lesser extent for industrial and municipal supply, has a maximum thickness of about 150 feet.

The Santa Fe group is recharged by precipitation on the surface of the uplands. The alluvium is recharged by seepage from drains, irrigation canals, and the river, from excess surface water applied to the land, from precipitation on the valley floor, and from the upward movement of water from the Santa Fe group.

Ground water is discharged by evapotranspiration in areas of high water table, by seepage to the drains and river, by underflow at the south end of the valley, and by wells. Except in the uplands, water in the Santa Fe is under confined (artesian) conditions; water in the alluvium is under unconfined (water-table) conditions.

Pumpage of ground water for irrigation and for the public supply of El Paso increased from 1951 through 1956. Irrigation pumpage decreased in 1957 and 1958, when surface-water allotments were increased. In 1958 the city of El Paso wells pumped an average of 6.8 million gallons per day from the deep and medium aquifers of the Santa Fe, an increase of 4.3 million gallons per day from the quantity pumped in 1957. The 1958 pumpage from the medium and deep aquifers is estimated to be about 50 percent of the annual recharge to the Santa Fe.

Aquifer tests in the El Paso city well field northwest of Canutillo indicate substantial leakage between the shallow, medium, and deep aquifers. The coefficients of transmissibility averaged about 60,000 gallons per day per foot in the deep aquifer, 35,000 in the medium aquifer, and 150,000 in the shallow aquifer.

The quantity of fresh water in storage in the Texas part of the valley is estimated to be 560,000 acre-feet, of which 150,000 acre-feet is in the alluvium.

Less than half the fresh water in storage however, may be recovered by wells, owing to the possibility of salt-water contamination.

North and west of Canutillo, water in the medium and deep aquifers of the Santa Fe is satisfactory for municipal use. The water in the alluvium is relatively fresh but more mineralized than that in the Santa Fe. South of Canutillo, the water in the alluvium is highly mineralized but, generally, is of better quality than the water in the underlying Santa Fe.

Pumping from the medium and deep aquifers may result in the percolation of water of poor quality from the shallow aquifer. Large-scale pumping from the alluvium is possible because of large amounts of recharge from seepage of excess surface water applied to the land and from drain flow.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The purpose of the investigation was to determine the quantity and quality of ground water available in the lower Mesilla Valley for the public supply of El Paso and for industrial and irrigation use. Fieldwork was begun in 1952 but was interrupted in December 1953. The investigation was resumed in 1957 and completed in December 1958. Well records, drillers' logs, sample logs, water-level measurements, and chemical analyses of samples of water on which this report is based are on file with the U.S. Geological Survey. The report contains maps showing the location of wells, the altitude of water levels in various wells, the approximate decline of the water table, and hydrographs showing the fluctuations of water levels in selected wells. Aquifer tests were made at the sites of 15 wells to determine the hydraulic characteristics of the water-bearing formations in the valley. During the course of the investigation, the geology of the valley was studied and geologic sections were prepared. Diagrams and tables show the quality of samples of water from selected wells, from the Rio Grande, and from drains. Wells are numbered to conform to a 10-minute grid system established during the ground-water investigation of the Hueco Bolson in 1954. The grids are identified by letters of the alphabet. Inside the grids the individual wells are numbered consecutively, beginning in the northwest corner. Because the fieldwork and preparation of the report were interrupted, however, it was not possible to maintain the consecutive numbering of the individual wells.

The investigation was made by the U.S. Geological Survey in cooperation with the Texas Board of Water Engineers and the city of El Paso and is part of a statewide program of ground-water investigation. The investigation was made under the administrative direction of A. N. Sayre and P. E. LaMoreaux, successive chiefs of the Ground Water Branch of the U.S. Geological Survey, and under the supervision of R. W. Sundstrom, district engineer in charge of ground-water investigations in Texas.

LOCATION AND EXTENT OF AREA

The report area includes about 135 square miles in the southern part of the Mesilla Valley, extending from the vicinity of Anthony to the gorge of the Rio Grande about 4 miles north of El Paso. (See pl. 1 and fig. 1.) The lower Mesilla Valley is divided approximately in half by the Texas-New Mexico boundary line; data on several wells in New Mexico are included in the report. The towns of White Spur, Anthony, and Canutillo are near the east edge of the valley in Texas. The village of La Union, N. Mex., near the west edge, is directly across the valley from Canutillo. The valley is served by the Atchison, Topeka, and Santa Fe Railway, by U.S. Highway 80, and by several county roads.

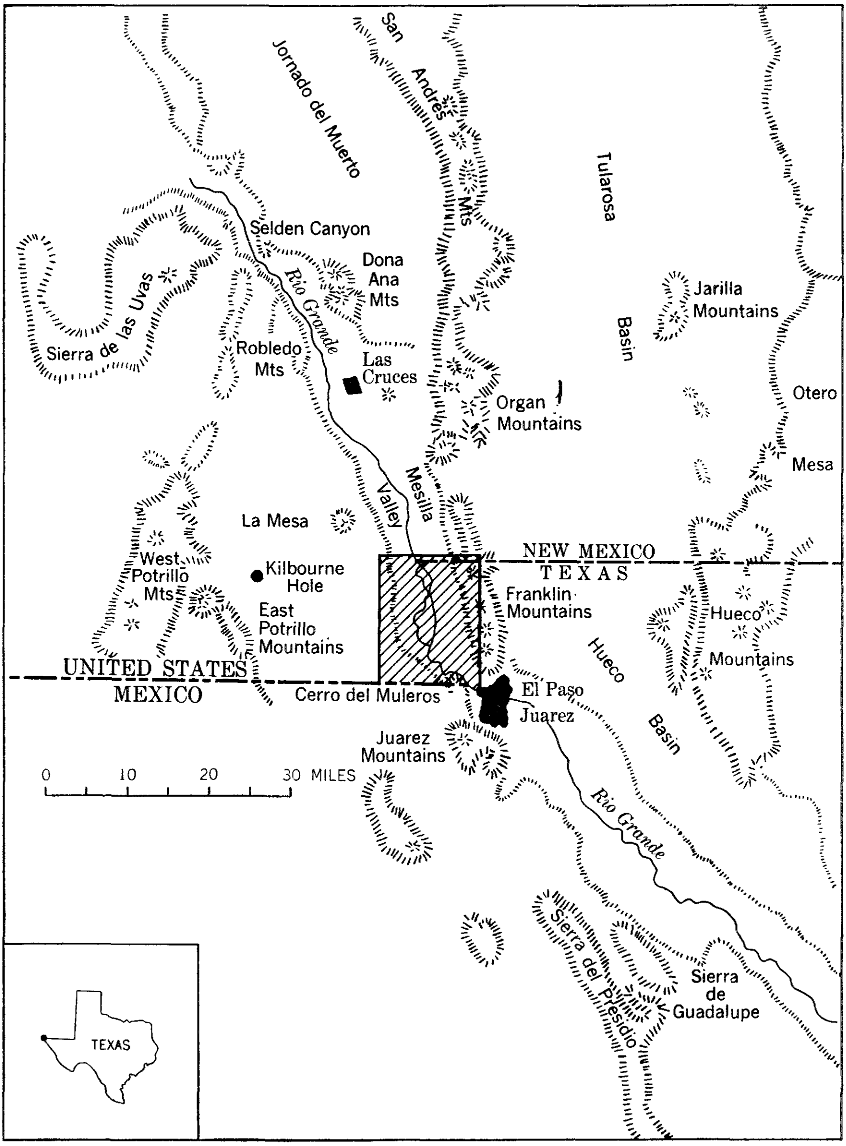
El Paso, the largest city on the United States-Mexico border, lies on the south and southeast flanks of the Franklin Mountains. The population of the metropolitan area in 1957 was estimated to be 250,000. El Paso is a business, livestock, and railroad center, a port of entry from Mexico, and the headquarters of Fort Bliss and Biggs Air Force Base. Industries include smelters, oil refineries, cotton gins, oil mills, textile mills, breweries and soft-drink plants, food-processing plants, and creameries.

PREVIOUS INVESTIGATIONS

Ground-water conditions in the gorge of the Rio Grande north of El Paso and in parts of the Mesilla Valley were first described by Slichter (1905.) He investigated the underflow of the Rio Grande at the narrows above El Paso, the site of a proposed international dam. Lee (1907) in his report on the water resources of the Rio Grande Valley gave data on wells in the Mesilla Valley. He also discussed the quantity, source, and probable discharge of ground water in the Mesilla Valley. Sayre and Livingston (1945) discussed in detail the geology and ground-water resources of the El Paso area. The geologic descriptions of Sayre and Livingston have been most helpful and have been used freely in the geologic discussion in this report.

Other useful reports are by Dunham (1935) on the geology of the Organ Mountains; by Bryan (1938) on the geology and ground-water conditions of the Rio Grande depression; by Conover (1954) on the Rincon and Mesilla Valleys in New Mexico; and by Kottlowski (1958) on the geologic history of the Rio Grande near El Paso.

Ground-water studies at the Federal Correctional Institution near La Tuna were made in 1930, 1935, and 1937, but the reports were not published. Sundstrom (1952) prepared a report on the investigation made in 1952, which incorporated some of the data collected in the earlier investigations.



From West Texas Geological Society, 1958

FIGURE 1.—Physiographic map of parts of Texas, New Mexico, and Mexico showing the location of the lower Mesilla Valley.

ACKNOWLEDGMENTS

The writers appreciate the cooperation and the information contributed by officials of the El Paso Public Service Board, the U.S. Bureau of Reclamation, the U.S. Soil Conservation Service, the International Boundary and Water Commission, and the El Paso Electric Co. The landowners and drillers in the area cooperated generously by furnishing well logs and data.

TOPOGRAPHY

The lower Mesilla Valley is cut into the unconsolidated deposits of La Mesa bolson. The steep-walled valley slopes at the rate of 4.5 feet per mile from the town of Anthony to the gorge of the Rio Grande. The relatively level valley floor ranges in width from less than a thousand feet at the gorge of the Rio Grande to 4.5 miles at Anthony. At the south end of the valley, the Rio Grande flows through a narrow gorge between the Franklin Mountains, which form the eastern boundary of the valley, and the Cerro de Muleros, a conical hill. Mount Franklin, the highest peak of the Franklin Mountains, rises to an altitude of 7,149 feet, about 3,400 feet above the Rio Grande flood plain. Sierra del Cristo Rey (altitude 4,576 feet), the highest point of the Cerro de Muleros, rises 845 feet above the Rio Grande.

The La Mesa surface, which is the second highest of four erosional surfaces recognized by Dunham (1935, p. 178–185), is a broad plain that extends as a nearly unbroken surface from Las Cruces, N. Mex., southward into Mexico. East of the Rio Grande the La Mesa surface consists of dissected pediments on the flanks of the Franklin Mountains. The various erosional surfaces are due to pedimentlike planation and local stream terracing. They were built up and dissected by tributary streams from the uplands and then graded to particular flood-plain levels of the Rio Grande. The lower surfaces are terrace levels, which are almost entirely the work of tributary streams (Kottlowski, 1958, p. 53).

CLIMATE

The lower Mesilla Valley is arid, and its climate is characterized by a wide range in temperature, low humidity, high evaporation, and low precipitation. According to U.S. Weather Bureau records, the mean annual temperature at El Paso from 1887 to 1958 was about 63° F. Figure 2 shows the average monthly temperature during this period. Large diurnal temperature changes are common. Summer temperatures during the day frequently rise to more than 90° F and occasionally to more than 100° F and dip to the 60's at night. Winter temperatures below freezing occur on an average of about 45 days per year. Small amounts of snow fall nearly every year but seldom remain on the ground for more than a few hours. The growing season, from the last killing frost in the spring to the first killing frost in the fall, averages about 200 days. Sandstorms occur at any time during the year; however, storm frequency and intensity are greatest in March and April.

The average relative humidity is less than 50 percent, indicating a high rate of evaporation. The evaporation from a free-water surface averages 107.43 inches, or about 12 times the average annual precipitation. Figure 2 shows the average monthly evaporation at Ysleta from 1948 to 1958.

Rainfall is insufficient for the growth of any except desert vegetation, and irrigation is necessary for crops, gardens, and lawns. The average annual precipitation at El Paso for the period 1878–1958 was 8.71 inches. More than half the precipitation is concentrated during the summer in brief but heavy thundershowers. Although the time distribution of rainfall is advanageous for agrciulture, the amount is inadequate and must be supplemented by irrigation from surface- or ground-water supplies. Figure 3 shows the maximum, minimum, and mean monthly precipitation at El Paso from 1878 to 1958.

GEOLOGY

The Mesilla Valley was formed by the downcutting of the Rio Grande in La Mesa bolson. La Mesa is a structural basin filled with unconsolidated or slightly consolidated deposits of Tertiary and Quaternary age derived from the erosion of bordering highlands. The highlands were reduced in late Tertiary time and later rejuvenated to form the present ranges.

The main body of sediments in the lower Mesilla Valley belong to the Santa Fe group of middle(?) Miocene to Pleistocene(?) age (Spiegel and Baldwin, 1963). Sediments of more recent age overlie the Santa Fe group as outwash-fan deposits, windblown deposits, and alluvium laid down by the Rio Grande. As the alluvium is derived from the erosion of the Santa Fe group and consequently shows similar characteristics, it is difficult to determine the contact between the alluvium and the Santa Fe.

CONSOLIDATED ROCKS

Consolidated rocks in and near the lower Mesilla Valley include both igneous and sedimentary rocks ranging in age from Precambrian to Tertiary. Most of the igneous rocks are Precambrian or Tertiary in age; the sedimentary deposits are pre-Tertiary. The largest areas of outcrop are in the Franklin and Organ Mountains. In the area between the Franklin Mountains and the Cerro de Muleros, andesite porphyry crops out. Cretaceous limestone and shale are exposed on

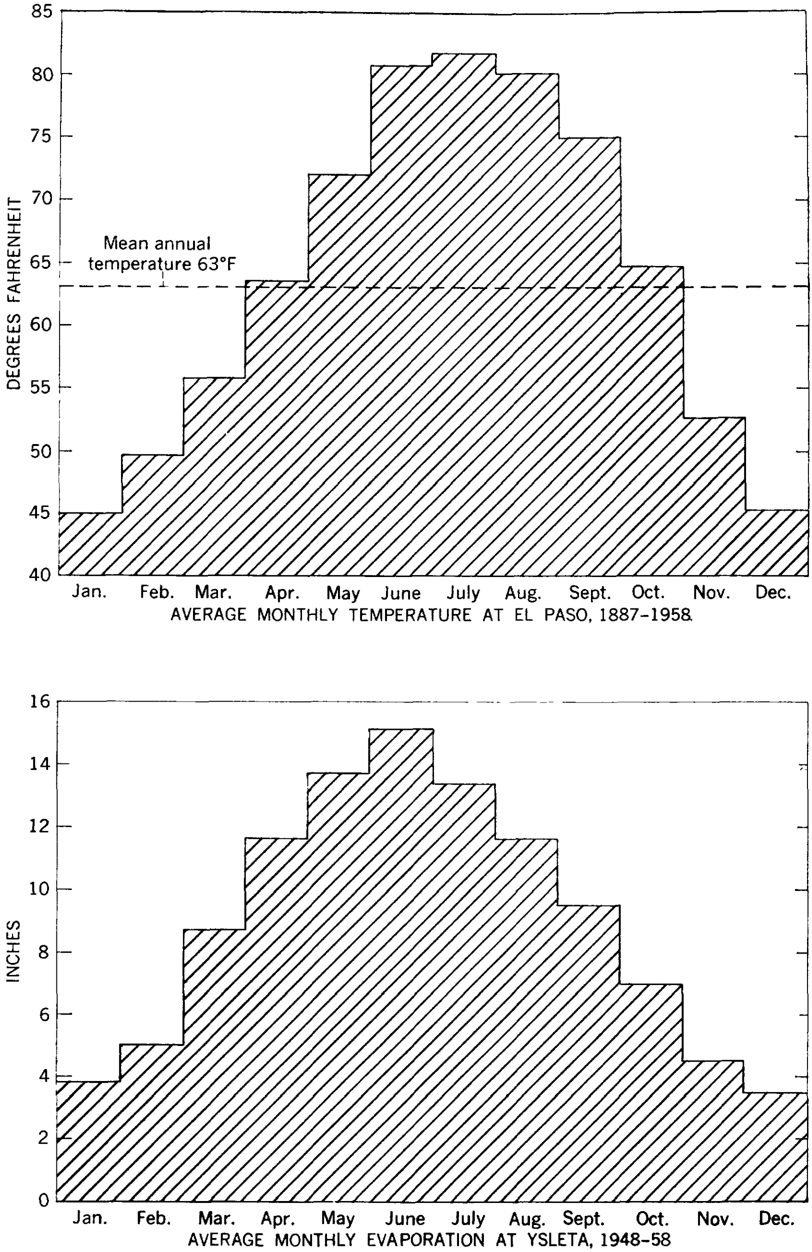


FIGURE 2.—Monthly temperature at El Paso and monthly evaporation at Ysleta, Tex. (From records of U.S. Weather Bureau.)

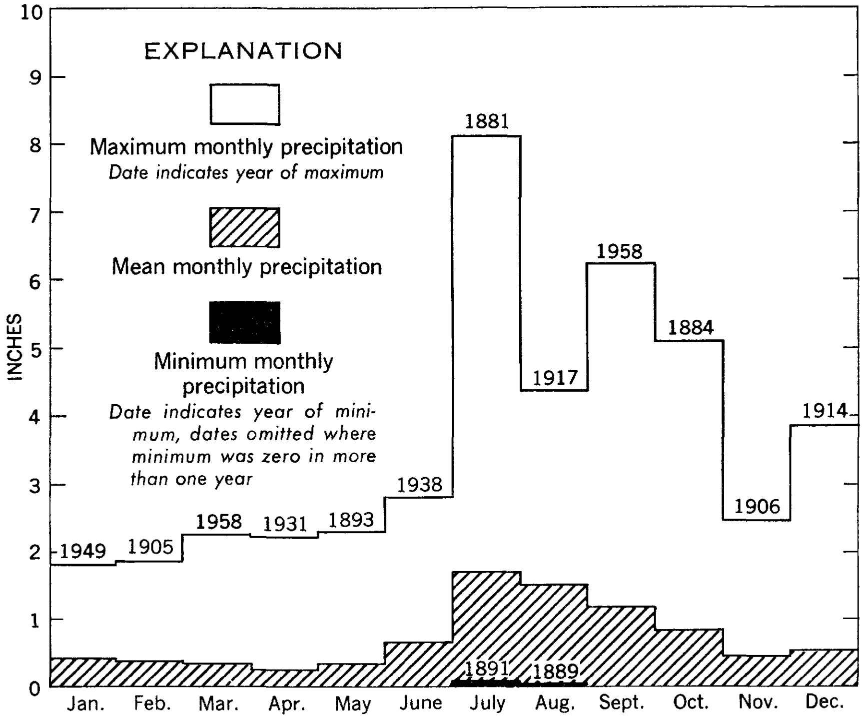


FIGURE 3.—Maximum, minimum, and mean monthly precipitation at El Paso, Tex., 1878–1958. (From records of U.S. Weather Bureau.)

the flanks of the igneous core of the Cerro de Muleros. The obstruction of the lower end of the valley by andesite, which was intruded prior to deposition of the Santa Fe group, materially affects the quality of water in the valley. Cretaceous sedimentary rocks are exposed around cores of Tertiary volcanic rocks (andesite porphyry) about 2 miles northeast of White Spur.

Most of the wells that penetrate consolidated rocks are either on the uplands between the flood plain and the Franklin Mountains north and northwest of the Cerro de Muleros or in the Rio Grande gorge. Several wells which range in depth from 83 to 1,573 feet and which have been drilled to the bedrock beneath the water-bearing Santa Fe group north and northwest of the Cerro de Muleros do not obtain water from consolidated rocks. Well U–59 in the gorge obtains a moderate supply of water satisfactory for industrial use from consolidated rocks of Cretaceous age.

Several wells penetrated bedrock below varied thicknesses of alluvium in the upland east and southeast of White Spur. Well U–12, depth 1,690 feet, obtained water from limestone and sandstone at 1,590 feet. The well which reportedly yielded 200 gpm (gallons per minute) was abandoned because of the high fluoride content of the water. Six wells (Q–158 to Q–163) probably obtain small quantities of water from bedrock; however, it is possible that some of them obtain water from the overlying alluvium.

Well Q–138, depth 1,074 feet, known as Lippincott well in the south-central part of the valley, is reported to have flowed salty water. According to the driller's log, well Q–138 penetrated sandy zones in the bedrock below 822 feet that contained small quantities of water.

On the upland east of U.S. Highway 80, eight wells penetrated bedrock at depths ranging from 177 feet (Q–77) to 820 feet (Q–72). Only well Q–76 was tested; it yielded small quantities of potable water from "black rock," probably of Pennsylvanian age.

An abnormally high thermal gradient of ground water in the medium and deep aquifers of the Santa Fe group suggests that the temperature of the ground water is affected by the latent heat of the igneous rocks that are scattered throughout the area. In six wells in the medium and deep aquifers, the thermal gradient ranged from 1°F per 33 feet to 1°F per 41 feet, which is considerably greater than the thermal gradient in the Hueco Bolson.

In general, the consolidated rocks in the lower Mesilla Valley are not a source for moderate or large supplies of ground water.

UNCONSOLIDATED DEPOSITS

Unconsolidated deposits in the lower Mesilla Valley consist of sand, gravel, clay, silt, caliche, and conglomerate. According to Bryan (1938, p. 205), most of the sediments in La Mesa bolson belong to the Sante Fe group. The unconsolidated deposits contain the shallow, medium, and deep aquifers. Although these aquifers are discussed as separate water-bearing units, they are hydraulically connected. The shallow alluvial deposits and a part of the underlying Sante Fe group compose the shallow aquifer. The bulk of the Santa Fe group comprises the medium and deep aquifers.

SANTA FE GROUP

The Santa Fe group underlies the lower Mesilla Valley and is exposed in nearly all the arroyos between the flood plain and the Franklin Mountains and in the bluffs at the east edge of La Mesa. In the uplands east of the Rio Grande, the top of the Santa Fe, which consists mostly of coarse sand and gravel containing some caliche-cemented boulders, probably is correlative with the Pleistocene cap of the Santa Fe, as defined by Spiegel and Baldwin (1963). A thick series of red to brown silty clay and fine to medium sand or poorly consolidated sandstone and thick-bedded conglomerate underlies the coarse sediments.

Characteristic responses in electric logs of eight wells northwest of Canutillo suggest that the Santa Fe may be subdivided into two units. In electric logs, the curve on the right side of the baseline represents the relative resistivity of the individual beds. A deflection of the resistivity curve to the right (increase in resistance) usually indicates a fresh water-bearing sand. Sand beds containing brackish or salty water have low resistance and cause little or no deflection of the resistivity curve. The approximate base of fresh water was determined from interpretation of electric logs and from water analyses. It is not possible to determine on the basis of available data if the units can be correlated over a large part of the valley.

The lower unit (the deep aquifer of the well field northwest of Canutillo) is composed of unconsolidated fine to medium sand; the percentage of clay is smaller than in the upper unit. The low, but uniform, resistivity response in the well field suggests that the sand in the lower unit is uniform, thick bedded, and relatively free of interbedded shale or clay. The lower unit reaches a maximum thickness of at least 1,000 feet in well Q–178; electric logs indicate that the lower unit thickens to the north and west.

The upper unit of the Santa Fe, which contains the medium aquifer and a part of the shallow aquifer of the El Paso well field, is exposed in arroyos above the flood plain and in the bluffs of La Mesa. It consists of alternating layers of varied thickness of fine to coarse sand, gravel, and reddish-brown silty clay. Locally the sand is cross-bedded, lenticular, and predominantly medium grained. The fact that the clay is evenly bedded in many exposures along Mesa Road (U.S. 80) indicates that clay layers may extend laterally for considerable distances.

The following section near Anapra, Dona Ana County, N. Mex., was measured by Sayre (Sayre and Livingston, 1945, p. 32). The top 7 feet, consisting of sediments of Recent and Pleistocene age, is underlain by sediments of the upper part of the upper unit of the Santa Fe. The sand and gravel underlying the Recent and Pleistocene sediments may be equivalent to the Pleistocene cap of the Santa Fe group.

	Feet
Topsoil, very sandy, reddish-buff, partly removed.	
Caliche, hard, dense, white; grades downward into very fine gray sand	7
Sand, moderately fine, light-gray, uncemented; contains layers of gravel and igneous-rock pebbles, mostly derived from lava flows	5
Clay, sandy, brown	1
Quartz sand, medium; mixed with pellets of calcium carbonate	.5
Sand, medium to coarse, salt and pepper	6
Clay, sandy, brown to gray	2
Sand, medium to coarse, light-gray, crossbedded; contains some coarse gravel	45
Sand, clayey, fine, massive, light-buff; contains irregular lenses of clean sand. Tubes of sand cemented with calcium carbonate are near the base	9
Sand, extremely fine, gray; layers of coarse sand near middle	14
Clay, gray, much disturbed and broken	1.3
Sand, medium, gray; laminated layers of alternating black and white sand near base	30
Sand, clayey, light-buff, crossbedded	1.5
Sand, medium, loose, gray	6
Sand, fine, buff to gray, crossbedded; pellets of clay and caliche on bedding planes	2.5
Covered; mostly sand	25
Clay, light-buff, and sandy clay	6
Sand, fine, light-gray, crossbedded	5
Clay, laminated, light-buff, and sandy clay	2.5
Sand, fine, gray, crossbedded	3
Clay, massive, light-buff	2.5
Sand, fine, massive, yellowish-buff, cemented; grades into gray sand near base; partly covered	30
Clay, chocolate-brown, and interbedded light-buff massive sandstone	11
Sand, brown, crossbedded, partly covered	10
Clay, silty, buff- to chocolate-brown	9
Total	234.8

In the flood plain, the upper unit reaches a depth of 470 feet in well Q–86, 678 feet in well Q–178, and possibly 1,100 feet in well Q–144. According to electric logs and drillers' logs, the maximum thickness of the upper unit is at least 1,000 feet and perhaps as much as 1,400 feet.

Electric logs and drillers' logs reveal that in the flood plain a thick-bedded limestone conglomerate underlies the lower unit but that east of the flood plain the conglomerate occurs within the Santa Fe. The conglomerate, derived from limestone that probably is of Cretaceous age (Virgil Barnes, oral communication, Feb. 27, 1957), has a maximum observed thickness of 160 feet in well Q–173. According to the electric and driller's logs of well Q–173, the conglomerate is underlain by clay, sand, and gravel. Although the sediments underlying the conglomerate probably are Santa Fe in age, they are not included in the lower unit. Plates 2 and 3 show that the conglomerate lies at a greater depth north and west of well Q–173. Well Q–178, depth

1,705 feet, did not penetrate the conglomerate. The highly resistive zone between 1,280 and 1,380 feet in well Q–178 is an igneous sill underlain by sand, shale, and clay of the lower unit of the Santa Fe. The igneous rock penetrated by well Q–178 may be associated with the series of volcanic rocks interbedded with the Santa Fe group of sediments near Las Cruces, N. Mex.

The maximum thickness of the Santa Fe group in the lower Mesilla Valley is not known; unconsolidated sediments were penetrated to a depth of 1,705 feet in well Q–178. The original thickness of the unconsolidated sediments in the area, whose surface is about 300 feet lower than La Mesa, may have been about 2,000 feet. Because the sediments thicken toward the center of the basin, however, it is probable that the maximum thickness of the Santa Fe is considerably greater.

The medium and deep aquifers of the Santa Fe group are the major sources of ground water for public supply in the valley. Many wells obtain water from both the Santa Fe and the alluvium. Yields as large as 3,000 gpm of fresh water have been obtained from the Santa Fe north and northwest of Canutillo. South and southwest of Canutillo, the water in the Santa Fe is brackish or salty. Small to moderate quantities of fresh water have been obtained from the Santa Fe in the upland east of the Rio Grande, where the saturated thickness is much less.

ALLUVIUM

The alluvium consists of poorly sorted sand, gravel, clay, and silt, the thickest section of which is the valley fill in the flood plain. On La Mesa and the lower terraces, the alluvium is thin, generally consisting of a veneer of windblown sand or a cap of coarse gravel.

The maximum thickness of the alluvium is not known. Bryan (1938, p. 218) stated that the depth of gravel in the riverbed may be taken as a rough measure of the depth of scour in great floods. Because of the shifting riverbed, the gravel may be penetrated at different depths in wells that are relatively near together; thus, individual beds cannot be correlated from well to well. Conover (1954, p. 25) reported that the alluvium near Las Cruces, N. Mex., is about 220 feet thick. Slichter (1905, fig. 2) showed the maximum depth of the fill in the gorge to be not more than 86 feet. Gravel or very coarse sand was penetrated in 29 wells at depths ranging from 42 to 130 feet. Therefore, it may be assumed that the thickness of the alluvium probably does not exceed 150 feet.

The alluvium in the valley is the major source of ground water for irrigation and for industrial use. Yields as large as 3,015 gpm have been obtained. The water in the alluvium varies in quality. Generally, it is more mineralized than the water in the river or in the underlying Santa Fe, but south of Canutillo, the water in the alluvium is less mineralized than the water in the Santa Fe.

GROUND WATER

HISTORY OF DEVELOPMENT

Prior to 1950, the principal use of ground water in the lower Mesilla Valley was domestic. In 1922 the city of El Paso drilled two test wells in the south end of the valley. Chemical analyses of samples showed that the water in the two wells, one of which is known as the Lippincott well (Q–138), was too highly mineralized for most purposes. Mr. Paul Harvey, owner of the waterworks at White Spur, drilled several wells in the vicinity in search of water suitable for public supply. Of 11 wells drilled in 1946, only 8 produced water of satisfactory quality. In 1951 and 1952, the city of El Paso drilled six wells in the shallow aquifer about 1 mile northwest of Canutillo. The water was pumped into the river for delivery to the treatment plant in El Paso. Because of excessive transmission losses, however, a pipeline capable of delivering 20 mgd (million gallons per day) was built. In 1955, six more wells were drilled in the shallow-well field. The total capacity of the wells in the shallow-well field is about 15 mgd.

In 1953 nine test wells were drilled in the valley as a part of the cooperative exploratory program in the Hueco Bolson. The wells were electrically logged, and chemical analyses were made of water samples from various depths. As a result of the program, the city drilled six wells in the period 1956–58 about 3 miles northwest of Canutillo, five wells ranging in depth from 1,072 to 1,262 feet and one well 550 feet deep. The wells, which obtain water from the deep and medium aquifers, have a total capacity of about 16 mgd.

Small quantities of ground water were used as supplemental supplies for irrigation for many years before 1954. In 1946 only 2 large-capacity wells were being used; during the period 1946–50 the number of irrigation wells increased to 16. Because of the decrease of surface water in storage in Elephant Butte and Caballo Reservoirs, N. Mex., the use of ground water for irrigation as a supplement to surface water increased rapidly. During 1951, 54 irrigation wells were drilled; by the end of 1954, about 250 wells were used to irrigate 15,000 acres of cotton and alfalfa with 40,000 acre-feet of water (Smith, 1956, p. 10). In October 1957, the Bureau of Reclamation reported that approximately 205 irrigation wells were in operation.

The large-scale industrial use of ground water began in 1951, when the American Smelting and Refining Co. and the El Paso Electric

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Co. drilled 40 test wells in the south end of the valley. As a result of this program, a well field of 10 wells was developed. The industrial use of ground water increased each year, except in 1958, when the American Smelting and Refining Co. abandoned its well field.

OCCURRENCE AND MOVEMENT

The principles of the occurrence and movement of ground water in rocks have been described by Meinzer (1923a, p. 2–192; 1923b; 1942, p. 385–497) and Wenzel (1942) among others. The occurrence and movement of ground water in the lower Mesilla Valley are discussed briefly here.

In the lower Mesilla Valley, ground water occurs under water-table (unconfined) and artesian (confined) conditions. In the alluvium of the flood plain and the Santa Fe group in the uplands, water is unconfined and does not rise in wells above the level at which it is first found.

In the valley, where the relatively impermeable clay of the Santa Fe group probably retards the movement of water between the deep and shallow aquifers, the water is confined under sufficient pressure to cause it to rise above the water table in the shallow deposits and in some wells to cause it to flow. For example, in January 1957 the water level in well Q–172 rose 1.25 feet above the land surface and about 8 feet above the water table in the alluvium.

The general direction of ground-water flow in the uplands is toward the Rio Grande. Conover (1954, p. 32) stated "ground water does not flow southward under La Mesa to Mexico but rather, from the Mexican boundary * * * northward and eastward to the Rio Grande." There is a ground-water divide in the pass between the Organ and Franklin Mountains. West of the divide, ground water flows toward the Rio Grande.

Plate 4 shows by contour lines the configuration of the water table in the alluvium in the lower Mesilla Valley in 1957. The movement of ground water, which is at right angles to the contours, generally is toward the south, except where large or concentrated withdrawals of ground water have formed cones of depression. The depressions, roughly conical in shape, are produced in a water table or piezometric surface by pumping. The gradient of the water table in the alluvium from the town of Anthony to the 3,736-foot contour near the forge is about 4 feet per mile, approximately the same as that of the river. On La Mesa, the water-table gradient from Strauss, N. Mex., eastward to the 3,745-foot contour was about 7 feet per mile in 1953. In the deep-well field 3 miles northwest of Canutillo, the gradient of the piezometric surface was not obtained because of interference from pumping. The piezometric surface is the imaginary surface to which the artesian water will rise in tightly cased wells that penetrate the aquifer. It is probable, however, that the gradient approximates that of the water table in the shallow aquifer.

RECHARGE

Ground water in the lower Mesilla Valley is derived as follows: From direct infiltration of precipation; from seepage from canals and laterals from the Rio Grande; from irrigation water applied to the land; and from ground-water flow from the uplands.

Precipitation on the valley floor probably does not contribute appreciable quantities of water to the ground-water reservoir. Most of the precipitation occurs in showers during the summer, when the evaporation rate is high; it does not reach the water table except during wet periods.

Most of the recharge to the shallow ground-water reservoir is derived from seepage from canals, laterals, and from irrigation water applied to the land. The quantity derived from each source is difficult to determine, but Conover (1954, p. 77) estimated that during an average year the irrigation water applied to the land in excess of crop requirements was about 17 percent of the gross diversion from the Rio Grande. Guyton and Scalapino in a consulting report to the El Paso Public Service Board estimated the annual recharge from canals, laterals, and irrigated lands to be at least 2 acre-feet per acre of land irrigated and generally somewhat more, or at least 36,000 acre-feet. This amounts to about 50 percent of the water applied for irrigation. Before large withdrawals of ground water for irrigation, the water derived from seepage from canals, laterals, and irrigated lands actually was in transit to the drains and to the river. Conover (1954, p. 44) estimated that from 1930 to 1946 the average return of drain flow in the Mesilla Valley was 52 percent of the reported net diversion from the river.

When surface-water supplies are adequate, the Rio Grande is an effluent, or gaining, stream during most of the year and in effect is a drain for La Mesa bolson. As a result of large-scale pumping, however, the river temporarily becomes an influent, or losing, stream locally, where the water table is lower than the riverbed. In January 1953 the Rio Grande was effluent from Anthony south to the gorge. Losses from the river to the ground-water reservoir became evident in 1955; in 1957 they were considerable, owing to the large increase in the withdrawal of ground water for irrigation and public supply. For example, Duisberg (1957, p. 67) reported that transmission losses for the Rio Grande project below Caballo Reservoir were low before 1950, but that in 1955 they were about 65 percent and in 1956 about 75 percent of the flow.

In addition, the city of El Paso in 1955 pumped about 10 mgd into the river for delivery to the treatment plant in the city. Duisberg (1957, p. 67) reported that the water flowed in the river for about 5 miles before returning to the ground-water reservoir. Plate 4 shows that the river in 1957 continued to lose water between Vinton Bridge and Canutillo, although it is effluent between Anthony and Vinton Bridge.

The river between Vinton Bridge and Canutillo forms the east edge of the El Paso shallow well field and is within the cone of depression created by withdrawals from the field. Because losses to or gains from the river change seasonally and yearly in rseponse to pumping and other factors, it is not possible to determine the amount of recharge to the ground-water reservoir that is derived from the Rio Grande.

The accretion of ground water to the lower Mesilla Valley from the adjoining uplands and from the upper Mesilla Valley is about 12,000 acre-feet per year, or 11 mgd. The average gradient of the water table in La Mesa between Strauss and the flood plain is approximately 7 feet per mile. If the transmissability (defined on p. AA28) of the sediments in this area is about 50,000 gpd per ft, somewhat less than the transmissability of the Santa Fe group in the valley, the flow toward the valley would be about 0.5 cfs (cubic feet per second) per lineal mile, or about 5 mgd from La Mesa to the river. The accretion of ground water from the uplands on the east side of the valley may be somewhat higher because of greater precipitation in the mountains and the greater permeability of the arroyo beds. Conover (1954, p. 36) estimated the average accretion from the uplands on the east side of the valley to be about 0.7 cfs per mile, or about 6 mgd.

In addition to the flow from the adjoining uplands, ground water from New Mexico enters the Texas part of the valley. It is estimated that approximately 5.3 mgd moves across the New Mexico State line at Anthony into the Texas part of the lower Mesilla Valley. The estimate is based on a gradient of 4.5 feet per mile and a transmissibility of 260,000 gpd per ft. If it is assumed that the gradient in the Santa Fe group is equivalent to that in the alluvium, approximately 2.2 mgd, or about 40 percent, of the water that enters the valley near Anthony is in the Santa Fe. Inasmuch as most of the recharge from the adjoining uplands is into the Santa Fe, it is estimated that the total natural recharge to the Santa Fe is about 13 mgd, or about 14,500 acre-feet per year. Thus, the annual natural recharge to the ground-water reservoir in the lower Mesilla Valley is at least 16 mgd, or nearly 18,000 acre-feet.

Although the three aquifers, as defined on page AA9, function as a single hydrologic system, water may move from one aquifer to another in response to a change in pressure. Before 1957, water discharged from the shallow aquifer was replaced, in part, by water leaking from the underlying aquifers. Since pumping began from the medium and deep aquifers, however, water may move from the shallow to the deeper aquifers.

When the ground-water reservoir is full, any additional water becomes drain flow. When storage space is created by lowering the water table below the bed of the drains, drain flow represents a potential source of recharge to the ground-water reservoir.

DISCHARGE

Ground water is discharged from the lower Mesilla Valley as follows: By drains; by seepage into the Rio Grande; by evaporation from the drains, the river, and water-table ponds; by transpiration; by underflow at the south end of the valley; and from wells.

After release of water from Elephant Butte Reservoir in 1916 for irrigation, seepage from the river and canals caused a rise in the water table that necessitated construction of drains to prevent waterlogging. Conover (1954, p. 66) stated that the average gradient of the water table down the valley in 1954 was the same as it was in 1917, the effect of the drains having been an overall lowering of the water table. Thus, the net effect of the drains did not change the balance between natural recharge to and discharge from the ground-water reservoir.

The annual discharge, in acre-feet, of the Montoya Drain, which includes drain flow from the Nemexas and West Drains, is shown in the following table taken from records of the U.S. Bureau of Reclamation.

Year	Nemexas	West	Montoya [1]
1946	16, 690	54, 810	77, 760
1947	13, 610	42, 550	58, 890
1948	14, 910	40, 210	65, 830
1949	16, 460	46, 630	76, 580
1950	18, 190	43, 780	73, 100
1951	12, 020	25, 350	43, 760
1952	10, 240	16, 950	26, 940
1953	9, 370	14, 760	30, 920
1954	2, 380	3, 700	10, 200
1955	695	1, 080	4, 420
1956	490	824	3, 210
1957	908	1, 006	4, 300
1958	3, 740	3, 630	15, 660
Average	9, 200	22, 700	37, 000

[1] Also contains flow from Nemexas and West Drains.

In the period 1946–58, drain flow ranged from 3,210 acre-feet in 1956 to 77,760 acre-feet in 1946, averaging 37,000 acre-feet. The average discharge from drain flow seems to be in the same order of magnitude as the recharge estimated from seepage from canals and laterals and excess irrigation water applied to the land. From 1946 to 1950, when surface-water supplies for irrigation were adequate, drain flow was relatively uniform. Between 1950 and 1957, drain flow decreased because of the decrease in surface-water allotments and the increase in use of ground water as a supplemental irrigation supply.

The amount of discharge of ground water by seepage into the Rio Grande in the lower Mesilla Valley has not been determined. Since 1950 the amount of ground water discharged by seepage into the river probably has decreased because of the increase in ground-water withdrawals for irrigation and the concomitant decline in the water table. In 1953 ground water was discharged to the river from north of Vinton Bridge to the gorge, but in 1957 seepage to the Rio Grande was confined to that part of the river north of Vinton Bridge.

Discharge of ground water by underflow at the gorge is small. According to Slichter (1905, p. 13), ground-water flow in the alluvium in the gorge did not exceed 11,200 cubic feet per day, or 94 acre-feet annually.

Prior to large-scale irrigation with surface water, a great part of the ground water in the valley was discharged by evapotranspiration. The average annual discharge of ground water by evapotranspiration was balanced approximately by the average annual natural recharge.

Before 1951 the amount of water pumped from wells was small because most of the irrigated land had surface-water rights, and the surface-water supply from Elephant Butte Reservoir was adequate. From 1951 to 1957, pumpage for irrigation increased markedly because of a shortage of surface water available for irrigation. In addition, large amounts of ground water were pumped for municipal and industrial supplies.

Annual irrigation pumpage of ground water is considered to be the difference between the surface-water allotment and the quantity of water required for irrigation. Figure 4 shows the total annual pumpage from the ground-water reservoir in the lower Mesilla Valley from 1953 to 1958, including municipal and industrial pumpage.

The increase in pumpage of ground water from 24,000 acre-feet in 1953 to 59,500 acre-feet in 1956 is due mainly to the decrease in surface-water allotment from 1.9 acre-feet to 0.39 acre-foot per acre during this period. In 1957 and 1958, ground-water pumpage was estimated to be 46,000 and 17,000 acre-feet, respectively. This decrease was due to the above-normal precipitation and a concomitant increase in sur-

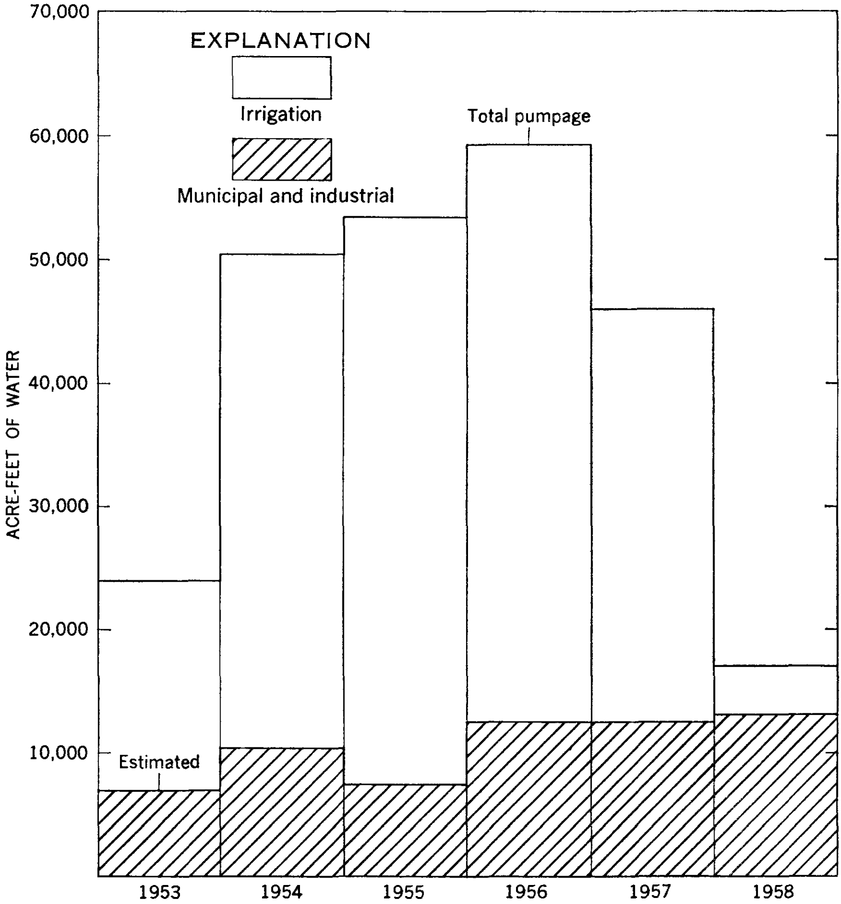

FIGURE 4.—Annual pumpage of ground water in the lower Mesilla Valley, 1953–58.

face-water allotment during this period. According to the records of the U.S. Bureau of Reclamation, surface-water allotments in 1957 and 1958 were 1.1 and 4.0 acre-feet per acre, respectively.

Before 1957 most of the pumpage in the lower Mesilla Valley was from the alluvium. In 1957 the city of El Paso pumped approximately 3,120 acre-feet of water from the deep and medium aquifers of the Santa Fe. In 1958 pumpage from the Santa Fe by the city increased to 8,100 acre-feet, or about 6.8 mgd.

FLUCTUATIONS OF WATER LEVELS

The water levels in wells in the lower Mesilla Valley fluctuate almost continuously, the magnitude of the fluctuations being greater in the medium and deep aquifers than in the shallow. Fluctuations that are not the result of pumping generally are smaller than those caused by pumping. These include fluctuations caused by changes in atmospheric pressure, loading and unloading the aquifer, earthquakes, and changes in the rates of natural recharge and discharge.

Fluctuations caused by changes of atmospheric pressure have a rhythmic pattern and are inverse to the change in pressure; that is, as the barometric pressure rises, water levels decline. The effect of the changes of atmospheric pressure on water levels is due to the ability of the less permeable beds in the aquifer to resist the transmission of changes in barometric pressure. The full effect of the pressure change is transmitted directly down the well, however, and the water level fluctuates accordingly. This is due to intervening relatively impermeable clay layers that act as partial barriers to the passage of water between the aquifers.

Figure 5 shows fluctuations of water level due to variations in the load on an aquifer in selected wells in the city of El Paso well field. The water levels in wells Q–176 (deep aquifer), Q–180 (medium aquifer), and Q–182 (shallow aquifer) fluctuate in response to wells pumping from different aquifers.

Figure 5 shows that when well Q–173 in the deep aquifer was shut down the water level instantly declined in well Q–182 in the shallow aquifer. Soon after well Q–173 was shut down, the water level in Q–182 gradually returned to approximately its initial position. The starting of pumping in well Q–180 in the medium aquifer caused a sharp rise of 0.85 foot in the water level in Q–182. Within 15 minutes after pumping began in Q–180, the water level in Q–182 started to decline; within 24 hours the water level returned to its initial position. While pumping from the medium aquifer continued, the water level in the alluvium continued to decline. During the same test, the water level in Q–176 in the deep aquifer at first declined, but within a few minutes rose about 0.6 foot; about 9 hours after pumping started from the medium aquifer, the water level in Q–176 began a gradual decline.

Figure 6 shows that after 15 days of continuous pumping from the medium aquifer, the water level in Q–176 declined 1.6 feet below a point extrapolated on the trend of the water level prior to the start of pumping; this decline indicates movement of water from the deep aquifer to the medium. The water level in well Q–180 (medium aquifer) responded instantly to the shutting down of well Q–173 in the deep aquifer (fig. 5). At first the decline in well Q–180 was rapid but decreased slowly until shortly after pumping started. The water in well Q–180 returned to its original level soon after the sharp initial decline because of a decrease in barometric pressure. The water level then resumed its decline, although at a rate somewhat less than before Q–173 was shut down.

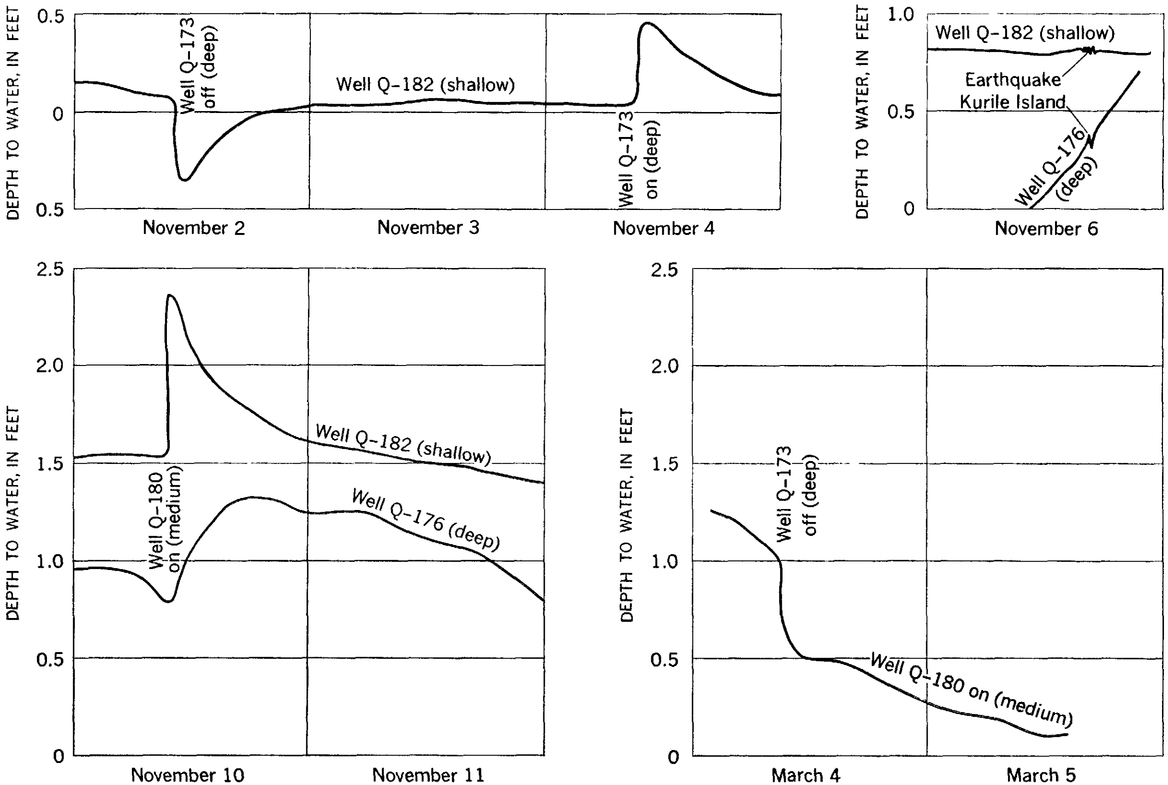

FIGURE 5.—Fluctuations of water levels due to variations in the load on an aquifer in selected wells in the El Paso city well field northwest of Canutillo, Tex., 1958.

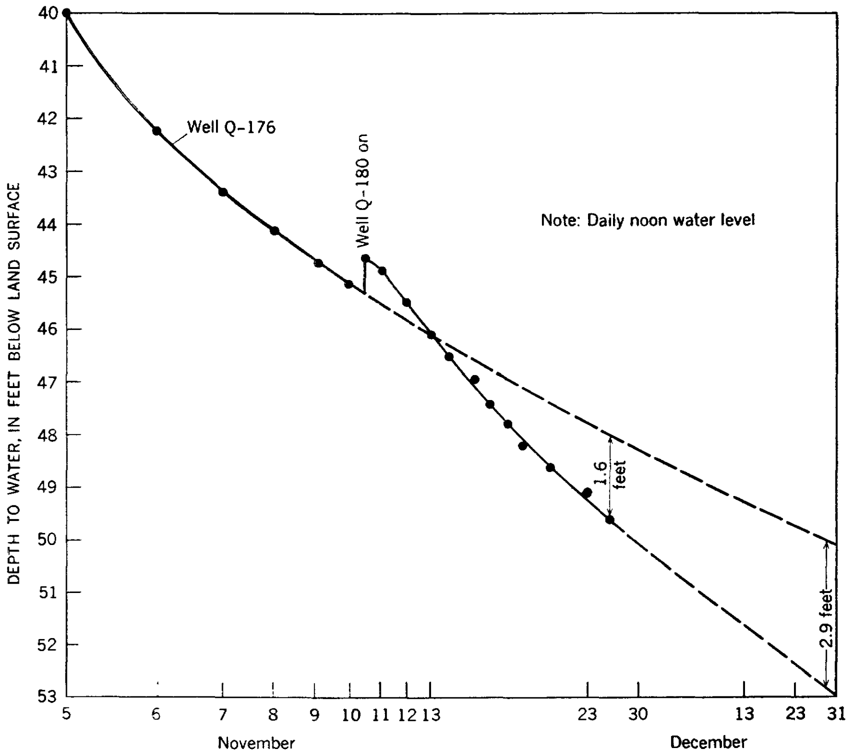

FIGURE 6.—Fluctuations of water level in well Q–176 (deep aquifer) due to pumping of well Q–180 (medium aquifer) in the El Paso city well field northwest of Canutillo, Nov. 10 to Dec. 31, 1958.

Similar fluctuations have been observed in New Jersey (Barksdale and others, 1936), in Long Island, N.Y. (Jacob, 1939), and in Easton, Md., and in Houston, Tex. Thompson (Barksdale and others, 1936, p. 88) explained the phenomenon on the basis of dilatency, which is the property of a compacted granular material to expand in total volume when subjected to lateral pressure. Barksdale, Sundstrom, and Brunstein (1936, p. 90) suggested that the starting of pumping in a well places a sudden load on the foundation of the pump, due primarily to the force required to lift the water to the surface and also for a brief time to the force required to accelerate the water. The effect of the loading would, of course, not be apparent in observation wells tapping the same sand as the pumped well, but it might be observed in wells tapping sands either above or below the sand tapped by the pumped well. The compressive force exerted when a well is turned on or off, although small, results in a compression of the relatively impermeable sediments in the water-bearing sand; as a consequence, the hydrostatic pressure increases instantaneously to the maximum. As pumping continues the aquifer adjusts to the load, and the water level approaches asymptotically its initial position. When the pump is shut down, representing an instantaneous removal of the load, the reverse action takes place. Although the load exerted on the pump foundation is small, the instantaneous rate at which the load is applied on the foundation may account for the large rise or fall in the water level in the Canutillo area.

On Long Island, where the fluctuations were due to the passing of heavily loaded trains near the well, the magnitude of the water-level fluctuations, according to Jacob (1939, p. 668), should depend on the weight and the velocity of the train. In the Canutillo area, however, the magnitude of the fluctuations depends on the rate of application of the load and on the distance from the impressed load to the affected well. If the distance is too great, the confined water has sufficient time to escape laterally and the pressure is dissipated. These fluctuations, resulting from variations in the load, indicate that the elasticity of the aquifer is not perfect and that the aquifers are imperfectly connected.

Fluctuations in water levels due to earthquakes have been observed in several wells equipped with recording gages. For example, figure 5 shows a maximum displacement of water level of less than 0.02 foot in well Q–182 in the shallow aquifer caused by the earthquake of November 6, 1959, which had its epicenter in the Kurile Islands in the North Pacific. The water level in well Q–176 in the deep aquifer had a maximum displacement of about 0.07 foot. These data indicate that the magnitude of the change varies with different aquifers in the same locality according to the depth of the aquifer and the degree of confinement.

Large fluctuations of water levels usually result from withdrawals of ground water, the magnitude of the fluctuations diminishing with distance from the point of withdrawal. The fluctuations of water levels in 10 observation wells measured monthly by the U.S. Bureau of Reclamation are shown in plate 5. The approximate change of the water table in the lower Mesilla Valley from 1953 to 1959 is shown in plate 6.

The hydrographs of 10 observation wells (pl. 5), which are scattered throughout the valley, show a general agreement but differ in the magnitude of fluctuations. In most wells the water levels generally were relatively stable through 1950 except for seasonal variations, although in several wells a downward trend started in 1948 and 1949. The uniformity in the water levels suggests that the supply of surface water for irrigation was adequate. The water level in each well indicates a yearly cycle, the highest levels occurring during the growing season because of recharge from infiltration of surface water applied to the land and the lowest levels occurring during the winter in response to the discharge of ground water into the drains and the river. In any well the minimum level, which is controlled largely by the elevation of the bottom of a nearby drain or the river, occurs just before irrigation begins in the spring. The net changes in the water levels, therefore, are based on the measurements made in January and February before irrigation begins.

In 1950 when it was apparent that the supply of surface water in Elephant Butte Reservoir would be insufficient to allot a full water supply to lands in the lower Mesilla Valley, many wells were drilled to obtain a supplemental supply of water for irrigation. Figure 7 shows that the annual discharge of the Rio Grande below Caballo Dam averaged about 700 cfs from 1951 to 1953, as compared to an average annual discharge of 1,000 cfs from 1946 to 1950. Coincident with the reduction in diversion of surface water for irrigation and the accompanying increase in the use of ground water as a supplemental supply, the water levels in 10 observation wells declined an average of 0.6 foot from January 1951 to January 1954. The area of greatest decline was in the northern part of the valley.

As the supply of surface water for irrigation continued to decrease through 1956, ground-water withdrawals increased and were accompanied by a marked decline in the water table in the alluvium. Records of the U.S. Bureau of Reclamation show that the discharge of the Rio Grande below Caballo Dam from 1954 to 1956 decreased to an annual average of about 320 cfs; consequently, the diversions from the river decreased from 1.9 acre-feet per acre in 1953 to 0.39 acre-foot per acre in 1956. As a result, the decline of water levels in 10 wells ranged from 0.5 foot to 7.3 feet, averaging 3.5 feet from 1954 through 1956 (pl. 5). Plate 5 shows also that owing to the large withdrawals of ground water for irrigation, the water levels generally were highest just before irrigation began in the spring and lowest during the growing season. Most water levels rose in 1957 and 1958 owing to the above-normal precipitation and the accompanying increase in the surface-water allotment for irrigation and the substantial decrease in the withdrawal of ground water. According to the Bureau of Reclamation, the surface-water allotment was 1.3 acre-feet per acre in 1957 and 4.0 acre-feet in 1958. As a result, the withdrawals of ground water for irrigation decreased from 47,000 acre-feet in 1956, the highest of record, to 33,000 acre-feet in 1957 and to 4,100 acre-feet in 1958. From 1957 through 1958 the rise in the water levels in 10 wells ranged from 0.5 foot to 8.4 feet and averaged 4.3 feet (pl. 5).

The water levels in 92 wells measured during the period January 1957 through January 1959 showed an average rise of 5.5 feet, of which

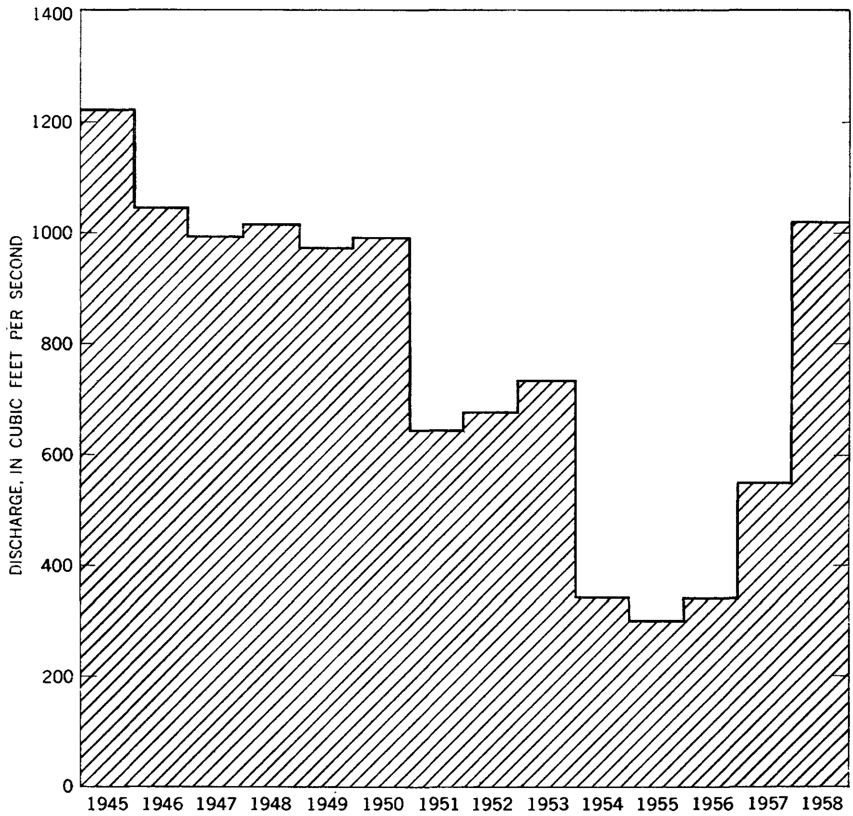

FIGURE 7.—Mean annual discharge of the Rio Grande below Caballo Dam, N. Mex., 1945–58.

3.8 feet was in 1958. The maximum rise, 16.6 feet, was in the vicinity of the shallow well field northwest of Canutillo. In the south end of the valley, the water table rose a maximum of 6.0 feet. In a small area northeast of the shallow well field and east of U.S. Highway 80, where surface-water rights are not available and irrigation was from ground water only, the water declined a maximum of 6.4 feet.

In summary, between 1946 and 1956, water levels in 10 wells declined an average of 0.6 foot. These data show that large quantities of ground water can be pumped from the alluvium over a considerable period of drought without seriously depleting the ground-water supply, owing to substantial recharge when surface-water allotments are adequate.

The hydrographs of the daily fluctuations of water levels in five wells in the city of El Paso well field in 1957–58 are shown in plate 7. Wells Q–86 and Q–182 are in the alluvium (shallow aquifer); well Q–180 is in the medium aquifer; and wells Q–176 and Q–181 are in the deep aquifer. The similarity of water-level fluctuations in these wells indicates a degree of interconnection of the three aquifers. On February 4, 1958, when wells Q–172 and Q–174 were shut down, water levels rose in Q–180 and Q–86. On November 1, 1958, when pumping began in wells Q–173 and Q–174, water levels declined in well Q–180 in the medium aquifer and well Q–182 in the shallow aquifer. The fact that decline was more pronounced in Q–180 than in Q–182 is due to the more direct hydraulic connection between the medium and deep aquifers. The withdrawal of water from the deep aquifer results in a reduction of pressure; consequently, water moves from the medium aquifer into the deep in response to the change in pressure. Moreover, this pressure change is reflected in the shallow aquifer, and water moves vertically into the medium aquifer but at a considerably lower rate. The water levels in Q–180 and Q–182 declined when Q–173 and Q–174 were pumped and rose when Q–172 was started. The decline in Q–180 and Q–182 was due to the distance of the wells that imposed the load on the aquifer from the observation wells.

Plate 8 shows the fluctuations of the water levels in four wells in 1958 and part of 1959, three of which (Q–172, Q–173, and Q–176) are in the deep aquifer and one (Q–180) in the medium aquifer. The data show that water levels in the wells become relatively stable soon after pumping begins. This evidence indicates that interformational leakage is substantial and that the movement of water in the three aquifers has been altered in the vicinity of the wells. Prior to the start of pumping from the medium and deep aquifers, the hydraulic pressure gradient was upward—that is, water moved from the deep to the medium aquifer and, in turn, moved upward into the shallow aquifer replacing water that was discharged naturally or artificially. Pumping from the deep aquifer reverses this direction of movement. Water then moves from the shallow into the medium and thence into the deep aquifer. When pumping began from the medium aquifer, however, the pressure head in the deep aquifer as well as the shallow was greater, thus causing water to move from the shallow and deep aquifer into the medium.

CHARACTERISTICS OF WELLS

Data concerning the yields and specific capacities are available for 75 wells, 61 of which obtain water from the shallow aquifer; 6 from the medium and deep aquifers of the Santa Fe group, and 8 from the Santa Fe and consolidated sediments underlying the uplands.

The yields of the 61 wells in the shallow aquifer, either measured or reported, ranged from 25 to 3,015 gpm. Most of the wells used for irrigation and for which records are available had yields greater than 1,000 gpm. In the south end of the valley, the yields of 13 wells (grid U) in the alluvium ranged from 35 to 1,025 gpm. In the upland area east of the flooded plain, the yields of 8 wells ranged from 40 to 660 gpm. Three of these wells obtain water from the Santa Fe and their average yield is about 500 gpm. The yields of the remaining five wells, which tap the consolidated sediments, are considerably smaller, averaging about 75 gpm. In the well field northwest of Canutillo, the yields of four wells in the deep aquifer of the Santa Fe ranged from 2,025 to more than 3,000 gpm. The yield of one well in the medium aquifer was 2,205 gpm.

The specific capacity of a well generally is expressed as the ratio of the yield, in gallons per minute, to the drawdown, in feet. The term might imply that the ratio of yield to drawdown is constant, but the specific capacity of a well is only an approximation because of the effects imposed by the rate of withdrawal and the element of time. Moreover, a comparison of the specific capacities as an indication of aquifer productivity is subject to considerable error unless the methods of well construction and the degree of development are taken into account. The use of a gravel envelope and of screens increases the effective diameter of the well by offering a larger open area for the passage of water than is provided by slotted casing. This results in reduced entrance velocities, thereby decreasing the drawdown and increasing the specific capacity. The specific capacities of properly developed wells having gravel envelopes and screens probably best represent the capacity of the aquifer to transmit water.

The specific capacities of wells in the alluvium vary widely. The specific capacities of 13 irrigation wells ranged from 5.4 to 108, averaging 46 gpm per foot of drawdown. In the south end of the valley (grid-U), the specific capacities of 15 wells used for public and industrial supplies ranged from 3.0 to 22 gpm per foot of drawdown. These data indicate that the permeability of the alluvium decreases southward.

In the shallow well field northwest of Canutillo, the specific capacities of six wells equipped with gravel envelope and mill-slotted casing ranged from 13 to 61 gpm per foot of drawdown. It is probable that the low specific capacities in three of the wells is due to incomplete development of the wells. Five wells in the deep aquifer equipped with gravel envelope and mill-slotted casing had specific capacities ranging from 19.7 to 30.7 and averaging 25.3 gpm per foot of drawdown. The specific capacity of well Q–180 in the medium aquifer was 14.0 gpm per foot of drawdown. The low specific capacity of well Q–180, as compared to the average for wells in the shallow and deep aquifers, probably is due to the character of the sand in the medium aquifer. Electric and sample logs show that the sand in the medium aquifer is finer than that in the shallow aquifer and that it contains more clay than the sand in the deep aquifer. It is probable that the specific capacities of the wells in the deep aquifer have been reduced because of a decrease in the size of the screen openings necessitated by the fine sand. Records show that well Q–172 had a specific capacity of 27.4, but, because of the quantity of sand pumped during operation of the well, a screen with smaller openings was used in newer wells drilled in the deep sand. The specific capacities of the four wells drilled after well Q–172 averaged 23.2 gpm per foot of drawdown.

Wells capable of yielding large volumes of water may be drilled in almost every part of the flood plain in the lower Mesilla Valley. In the southern part of the valley, however, the yields of most wells may be expected to be small. Wells drilled in the uplands probably will produce only small to moderate quantities of water because of a lesser saturated thickness of the aquifer.

HYDROLOGIC CHARACTERISTICS OF WATER-BEARING MATERIALS

Aquifer tests were made at the sites of eight municipal wells in the shallow aquifer, six wells in the deep aquifer, and one well in the medium aquifer to determine the coefficients of transmissibility and storage, which govern the ability of an aquifer to transmit and to yield water. The results of the tests are shown in the following table.

Well	Aquifer	Coefficient of transmissibility (gpd per ft)	Coefficient of storage
Q–82	Alluvium	158, 000	----------
83	-----do	145, 000	----------
84	-----do	110, 000	----------
86	-----do	155, 000	0. 001
90	-----do	140, 000	----------
91	-----do	150, 000	----------
165	-----do	121, 000	----------
166	-----do	104, 000	----------
180	Santa Fe (medium)	34, 000	----------
172	Santa Fe (deep)	60, 000	. 0007
173	-----do	59, 000	----------
174	-----do	73, 500	----------
175	-----do	49, 500	----------
176	-----do	60, 000	. 0007
178	-----do	57, 000	----------

The coefficient of transmissibility (T) may be defined as the rate of flow of water in gallons per day at the prevailing water temperature through a vertical strip of the aquifer 1 foot wide extending the full height of the aquifer under a unit hydraulic gradient. The volume of water that will flow each day through each foot of the aquifer is the product of the coefficient of transmissibility and the hydraulic gradient. The smaller the coefficient of transmissibility, the greater the hydraulic gradient must be for water to move through the aquifer at a given rate.

The coefficient of storage (S) is the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Under artesian conditions, the volume of water released from or taken into storage is determined by the compressibility of the aquifer and expansion of the water. Under water-table conditions, the coefficient of storage is practically equal to the specific yield, which is defined as the volume of water released from or taken into storage in response to a change in head attributed partly to the gravity drainage or refilling and partly to compressibility of the water and aquifer material in the saturated zone.

The coefficient of storage (S) is the volume of water released from the results of the pumping tests by means of a formula developed by Theis (1935, p. 519–524). A discussion of the formula, the assumptions upon which it is based, and its application is given by Wenzel (1942).

Recovery tests in eight wells in the shadow well field show that the coefficients of transmissibility ranged from 104,000 to 158,000 gpd per ft and averaged 135,000. These coefficients probably are representative of the alluvium, although some water is obtained from the underlying Santa Fe. Aquifer tests of the alluvium failed to show conclusively the connection between the Rio Grande and the ground-water reservoir. Analyses of the test data showed that the water levels in the observation wells were higher than the theoretical water levels. Although the Rio Grande is a contributing stream when the water table is below the streambed, it is probable that slow drainage of excess irrigation water applied to the land has retarded the expansion of the cone of depression. The relation between ground and surface water, however, is clearly shown by the absence of flow in the river between Vinton Bridge and Canutillo Bridge during periods of heavy ground-water withdrawals from the shallow well field. The large withdrawals of ground water from the shallow aquifer reduces the drain flow; in some places, the entire drain flow has been intercepted. The river, as well as the drains, performs as a line source of recharge, and the effect of a pumping well upon the flow of a drain or the river may be computed on the basis of the formula developed by Theis (1941, p. 736). Conover (1954, p. 119) showed diagrammatically that the flow of a drain would be reduced by 63 percent of the pumping rate after 3 months of continuous pumping of a well 0.25

mile from the drain, by 73 percent after 6 months, and 81 percent after 1 year. The effect of the pumping of a well upon the flow of the drain or the river decreases with distance from the line source.

Aquifer tests at the Federal Correctional Institution at Anthony reported by Sundstrom (1952, p. 6) indicated that the coefficient of transmissibility ranged from 30,000 to 60,000 gpd per ft. In the southern part of the valley, the coefficient of transmissibility determined at the site of well U–38 was about 63,000 gpd per ft. These tests indicate that the wells are screened principally in the Santa Fe.

Aquifer tests at the sites of six wells screened in the deep aquifer showed that the coefficients of transmissibility ranged from 49,500 to 73,500 gpd per ft and averaged about 60,000 gpd per ft. The relatively wide range in transmissibility is due to the varied thicknesses of the contributing sections of the aquifer. The small range in coefficients of permeability, from 146 to 150 gpd per sq ft, in five of the tests indicates that throughout most of the well field the Santa Fe group is composed of relatively homogeneous sediments. The coefficient of permeability is defined as the rate of flow of water in gallons per day through a cross section of 1 square foot under a unit hydraulic gradient, or through a section 1 foot high and 1 mile wide under a gradient of 1 foot per mile.

In September 1957 an aquifer test was made at the site of well Q–180 in the medium aquifer. The coefficients of transmissibility and of permeability determined from the test were 34,000 gpd per ft and 128 gpd per sq ft, respectively.

Under water-table conditions the specific yield is difficult to determine from short-term aquifer tests, because it depends on the time involved in dewatering the part of the aquifer within the cone of depression. Although most of the cone may be dewatered in a relatively short period of time, dewatering may continue at a decreasing rate for years. Thus, specific yields obtained from aquifer tests of short duration generally are too low. The specific yield of the shallow aquifer, as determined from the tests, ranged from 0.0006 to 0.001. A specific yield of 0.0006 may be low for alluvium, but it is probable that the water-bearing material contained clay layers that were fairly well distributed and widespread. Fine-grained sediments retain a considerable part of the water against the pull of gravity and hence have a low specific yield. Sundstrom (1952, p. 4) reported a specific yield of about 5 percent in tests made at the Correctional Institution. As the duration of pumping increases, however, the specific yield should increase to 10 or 15 percent. Conover (1954, p. 103) estimated that the specific yield of the valley fill in the Rincon and Mesilla Valleys was about 25 percent.

The coefficient of storage obtained from tests at the sites of wells Q–172 and Q–176 in the deep aquifer averaged 0.0007. The data from well Q–176 showed that after pumping the well for 24 hours the drawdown was less than the predicted drawdown. This evidence indicates that recharge to the aquifer occurred. The coefficient of storage for the deep and medium aquifers ultimately may reach 0.1 percent, the specific yield estimated for the shallow aquifer.

If geologic and hydrologic conditions are favorable, the coefficient of transmissibility and specific yield may be used to predict the performance of the well field.

The curve in figure 8 show the theoretical drawdown in water levels

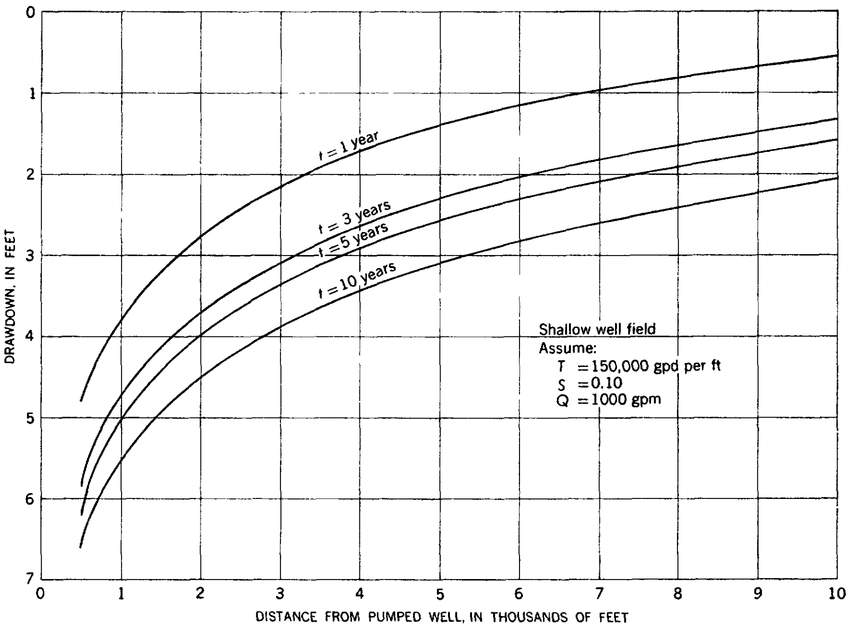

FIGURE 8.—Theoretical drawdown in an infinite aquifer (alluvium) due to pumping.

in the alluvium at the end of various periods of time (t), 1, 3, 5, and 10 years, at various distances from a well pumping 1,000 gpm. The decline at any point is directly proportional to the rate of pumping (Q). The curve is based on a probably conservative specific yield of 10 percent and on the assumption of no recharge to the aquifer; consequently, drawdowns should be less than those indicated on the graph.

The results of aquifer tests of the deep aquifer and the absence of a confining bed as shown by the electric logs indicate that considerable quantities of water may leak from water-bearing sediments through varied thicknesses of clay and into the deep aquifer. Although the clay beds are relatively impermeable, water may pass through or around them in response to a change in pressure. As the head in the deep aquifer is lowered by pumping, the pressure differential may be sufficient to change the direction of movement of water. Before pumping began in June 1957, water moved upward from the deep aquifer to the shallow aquifer. A change in pressure in the deep aquifer may reduce or reverse the movement, if the change is sufficiently large. This effect was considered in preparing figure 9. The curves show the effect

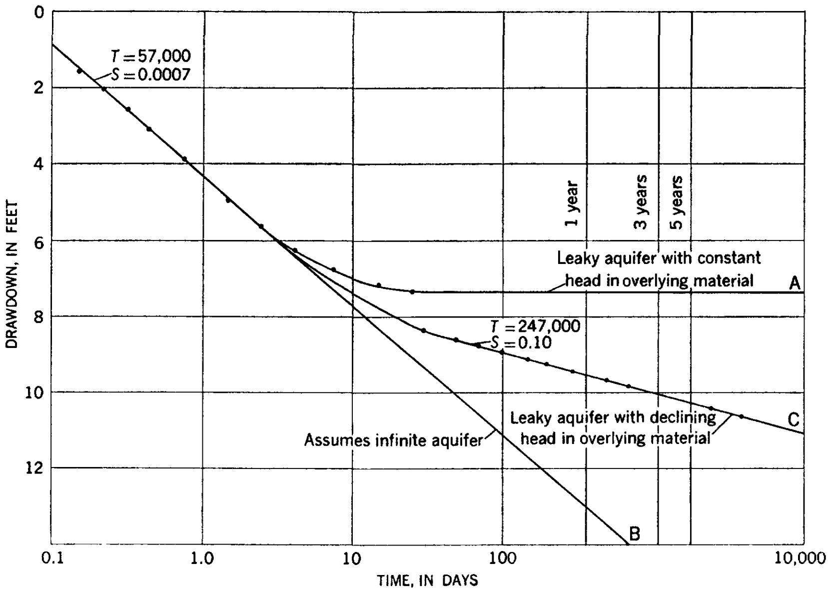

FIGURE 9.—Theoretical drawdown 1,600 feet from a well pumping 1,000 gpm.

on the water levels with respect to time 1,600 feet from a well pumping 1,000 gpm for varying hydraulic conditions.

Curve *A* assumes that water is leaking into the deep aquifer while the head in the overlying aquifer remains constant. Curve *B* assumes that all water comes from artesian storage in the deep aquifer, which is assumed to be infinite in areal extent. Curve *C* assumes leakage between aquifers accompanied by a declining head in the overlying aquifers based on a leakance factor determined from the test at the site of well Q–172 in the deep aquifer. Curve *C* represents more fully the conditions in the deep well field. After 24 hours of pumping, the curve is based on the studies made by Hantush and Jacob (1955, p. 95) on nonsteady flow in leaky systems. Figure 10 shows the theoretical drawdown at various distances and time of a well pumping 1,000 gpm. When the well is pumped, the rate of decline of water level is rapid at

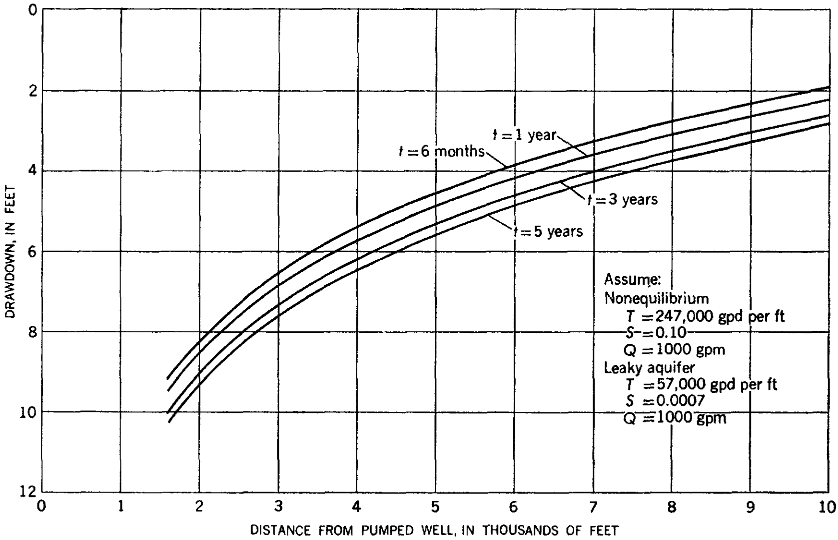

FIGURE 10.—Theoretical drawdown in an infinite aquifer (Santa Fe group) due to pumping. Computed according to the formulas for nonequilibrium and leaky-aquifer conditions.

first. As pumping continues, leakage from the overlying sediments is sufficient to reduce the rate of decline; thus, equilibrium in the cone of depression is approached. If pumping continues for a long period of time, water from the shallow aquifer will replace water pumped from the medium or deep aquifers.

A comparison of the theoretical and the actual drawdown of the water level in the observation well Q–176 from February 1957 through December 1958 due to pumping from the deep and medium aquifers is shown in the following table. The distance from well Q–176 is given in feet.

Well pumped	Aquifer	Discharge (gpm)	Time of pumping (days)	Distance from well Q–176 (feet)	Drawdown in well Q–176 (feet)
Q–172	Deep	2,075	531	1,600	19.9
173	do	2,075	354	1,600	19.6
174	do	2,075	318	4,350	10.2
180	Medium	2,180	51	1,600	2.9
Theoretical					52.6
Measured					51.9

The difference of 0.7 foot between the theoretical and the measured drawdown may be attributed to a substantial rise of the water table in the shallow aquifer during 1958.

GROUND WATER IN STORAGE

According to available data, at least 45 million acre-feet of saturated sediments underlies the lower Mesilla Valley. Chemical analyses of samples of water from 127 wells show that about 65 percent of the ground water in the Santa Fe group and alluvium in the valley is too high in mineral content for use as municipal supplies. In this report, fresh water is defined as water that contains less than 250 ppm (parts per million) of chloride. Water that contains more than 250 ppm of chloride is considered to be highly mineralized and, according to standards of the U.S. Public Health Service, is not suitable for municipal supplies. In several small areas, ground water is considered fresh, although the sulfate and dissolved-solids content is somewhat in excess of the limits recommended by the Public Health Service of 250 and 1,000 ppm, respectively.

Analyses of samples of water from wells and test wells indicate that the greatest volume of fresh ground water is in the area northwest of Canutillo and that fresh water-bearing sand thins toward the south and east. The volume of fresh water in storage in the alluvium and Santa Fe in the Texas part of the valley is at least 560,000 acre-feet, and in the New Mexico part the volume of fresh water is at least 980,000 acre-feet. More than 1,540,000 acre-feet of fresh water is in storage in the lower Mesilla Valley; about 150,000 acre-feet is in the alluvium in the Texas part of the valley.

The estimate of the volume of fresh water in storage in the lower Mesilla Valley probably is conservative. The specific yield of 10 percent used in the estimate probably is low; the area of the Santa Fe group used for computation extends only to the west edge of the irrigated area. The estimate of the volume of saturated material is based on known thicknesses of materials; it does not include water-bearing sediments that may lie at great depth in the northwestern part. If the specific yield of the saturated material is as much as 25 percent, as estimated by Conover (1954, p. 103), the volume of fresh water would total at least 3,850,000 acre-feet, of which 1,400,000 acre-feet is in Texas.

All the fresh water in storage cannot be withdrawn by wells. In those parts of the aquifer where fresh water is underlain by highly mineralized water, perhaps less than half the fresh water can be recovered before the remainder becomes unsatisfactory for municipal supply.

Sufficient data are not available to determine the volume of water in storage that is suitable for irrigation or industrial use. A substantial part of the water that is unsuitable for public supply might be used for irrigation, particularly if the chloride content is not excessive and if large quantities of water can be applied for leaching of salts from the soils. Some industries may be able to use part of the water.

QUALITY OF WATER

The results of the chemical analyses of water samples from 127 wells in the lower Mesilla Valley are shown in a report by Leggat, Lowry, and Hood (1962, p. 174–191).

Except for hardness and percent sodium, the analyses are given in parts per million, an expression of the concentration by weight of each constituent in a million unit weights of water. Hardness is expressed as equivalent calcium carbonate ($CaCO_3$). Generally, water having a hardness of less than 60 ppm is classified as soft; from 61 to 120 ppm as moderately hard; and more than 120 ppm as hard. Specific conductance, which is the electrical conductivity of the water, and pH are expressed in appropriate units for the property measured.

GROUND WATER

It is not possible to define exact limits of mineral content beyond which ground water cannot be used for specific purposes. Water for municipal and domestic supplies, however, should conform as nearly as possible to the standards established by the U.S. Public Health Service (1946) for use on interstate carriers. The concentrations of chemical substances preferably should not exceed the indicated limits:

Constituent	*Parts per million (ppm)*
Iron (Fe) and Manganese (Mn) together	0.3
Magnesium (Mg)	125
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1.5
Nitrate (NO_3)	45
Dissolved solids	[1] 500

[1] 1,000 permitted.

Fluoride content of water in domestic supplies should not exceed 1.5 ppm. Water that contains fluoride in excess of this amount may cause mottling of tooth enamel if the water is used continuously (Dean and others, 1935). Data collected by various agencies have demonstrated that fluoride in drinking water in quantities less than 1.5 ppm reduces the incidence of tooth decay (Dean and others, 1942). The Texas State Department of Health recommends as desirable a fluoride content of 1–1.5 ppm.

The more important factors that affect the quality of ground water for irrigation are dissolved-solids content, percent sodium, residual sodium carbonate (equivalents per million of carbonate and bicarbonate in excess of calcium and magnesium), and boron content. An equivalent per million (epm) is the expression of the concentration in terms of chemical equivalents rather than by weight. Water having a percent sodium of more than 80 (Wilcox, 1948, p. 27), a residual sodium carbonate of more than 2.5 epm, or a boron content greater than 1.25 ppm for sensitive crops and 3.75 ppm for tolerant crops is generally considered unsuitable for irrigation (U.S. Salinity Laboratory Staff, 1954, p. 81). Other factors, such as climate, soil type, crop, and quantity of water used may be equally significant and under optimum conditions may permit the satisfactory use of water with a high percent sodium or a high boron content.

In the lower Mesilla Valley, the quality of ground water varies both areally and with depth. Samples of water collected from wells near the south end of the valley and from wells along the east boundary were high in dissolved-solids content. It was not possible to ascertain if certain samples from the shallow aquifer were from the alluvium or from the Santa Fe group. Water from many shallow wells obtain water from both sources.

SANTA FE GROUP

Fresh water in the Santa Fe group extends to a depth of at least 1,200 feet in well Q–178. Electric logs and drill-stem tests indicate that the base of fresh water is progressively shallower toward the south and east. Plate 2 shows the progressive thinning southward of the fresh water-bearing sands in the Santa Fe.

In the city of El Paso deep-well field, water from below 200 feet is satisfactory for municipal use. Analyses of water from well Q–172 show that the water is soft and low in dissolved-solids content. Drill-stem samples from depths between 200 and 500 feet in the deep wells and a sample of water from well Q–180 in the medium aquifer contained more dissolved solids than the deep aquifer.

Fresh water from the Santa Fe probably could be used for irrigation. Analyses of samples of water from the deep-well fields suggest that the water may be used for irrigation. Although the percent sodium generally exceeds 80, the residual sodium-carbonate and the boron content of the samples from Q–172 are lower than the recommended limits. Chemical analyses of more water samples will be necessary in order to determine the suitability of fresh water for irrigation from the Santa Fe.

The south edge of the body of fresh water in the deep aquifer extends to a line through Canutillo. South of Canutillo, the water from the Santa Fe increases in mineral content until it becomes unfit for most uses. Sayre and Livingston (1945, p. 7) reported that two test wells in the lower Mesilla Valley drilled in 1922 yielded salt water.

The El Paso Electric Co. reported that water from well U–65, depth 600 feet, contained 1,750 ppm of sulfate, 790 ppm of chloride, and 4,080 ppm of dissolved solids.

The southward increase in mineral content of the water in the Santa Fe may be partly due to incomplete flushing from the Santa Fe and partly to the concentration of the ground water in the alluvium by evapotranspiration. Playa lakes probably occupied the Rio Grande depression. Owing to the Rio Grande cutting through the gorge and into the Mesilla Valley and owing to damming by intrusive andesite, salt water in the ancient lake sediments probably was not flushed out at the south end of the valley. According to Slichter (1905, fig. 3), "The rapid rate of increase in the dissolved solids at a depth of about 40 feet [in the gorge near El Paso] indicates that the water below such depth is stagnant or without appreciable movement."

The flow through the gorge was estimated by Slichter as not exceeding 11,200 cubic feet per day, or about 50 gpm. The largest part of the natural discharge of ground water from the valley is by evapotranspiration, resulting in concentration of the mineral content of the ground water. On La Mesa, well P–6, depth 950 feet, yielded water that was suitable for municipal and domestic supply. On the upland east of the flood plain, water from the Santa Fe ranges from fresh to brackish. In the area between Canutillo and Vinton Bridge, water in most wells is satisfactory for domestic use, although the chloride or sulfate content may slightly exceed the recommended limits. South and north of this area the water is high in chloride and dissolved-solids content.

ALLUVIUM

Most wells in the flood plain range in depth from 80 to 200 feet. Therefore, many of these wells yield a mixture of waters from the Santa Fe group and the alluvium. North of Canutillo and west of the Rio Grande in the area of the city well field, water from the alluvium is relatively fresh but contains more dissolved solids than the water in the Santa Fe. The quality of the water in the shallow well field varies laterally and also at different periods of time. The marked change in the quality of water in the shallow well field from 1952 to 1957 was partly due to the infiltration of water from the Rio Grande and to the infiltration of surface water applied to the land. Figure 11 shows the chloride content of water from six wells in the shallow well field and of water from the Rio Grande. The greatest increase in the chloride content was in wells Q–82 and Q–90, which are in the center of heavily irrigated areas. The chloride content in wells Q–83 and Q–84 increased at a rate similar to the increase in the chloride content of the river.

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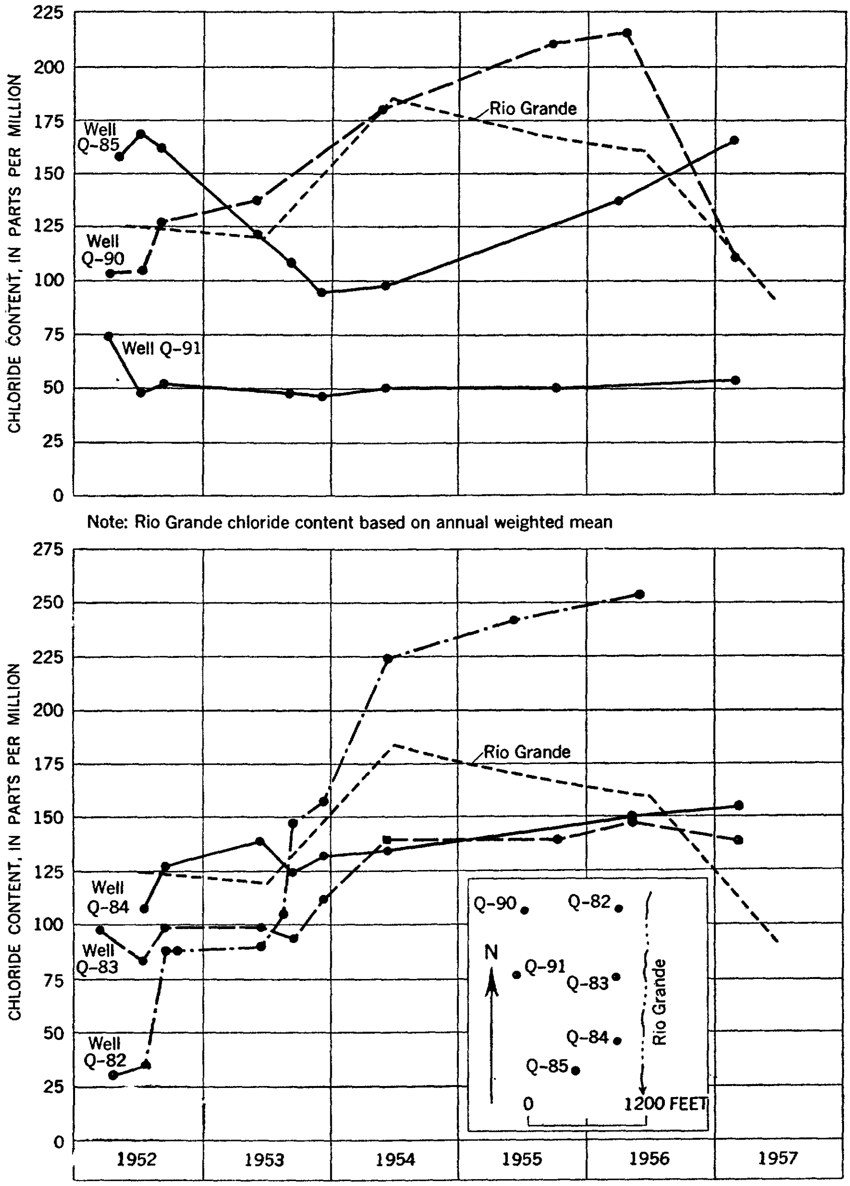

FIGURE 11.—Chloride content of water from wells in the alluvium and from the Rio Grande, 1952–57.

During periods of large flow, the river water may be more dilute in mineral content than ground water in the shallow-well field. For example, in 1957 the weighted average of chloride content of the water in the Rio Grande was less than 100 ppm (the lowest from 1952 to

1957). Because of the decrease in the quantity of ground water pumped for irrigation and the application of large quantities of surface water of low chloride content, the water in well Q–90 decreased in chloride content. No records are available to show the change in the quality of the water in well Q–82 in 1957. In the area east of the Rio Grande between Vinton Bridge and Anthony, water in the alluvium is more highly mineralized than that in the alluvium northwest of Canutillo. Records show that water at a depth less than 200 feet ranges in chloride content from 190 ppm in well Q–27 to 6,240 ppm in well Q–178. In most of the wells, the chloride content exceeded 300 ppm. The area between Vinton Bridge and Anthony is drained by the East Drain, which, according to Conover (1954, p. 87)

> * * * apparently has water of higher concentrations than found in the irrigation water * * *. [In explaining the poor quality of the water in the East Drain, he proposed that] water east of the valley toward the Franklin Mountains also has a high concentration of dissolved solids and enters the drain, or that similar water occurs in the valley in this area and has not been completely flushed by excess irrigation water applied to the lands.

Because of the shallow water table in the area, mineralization of the ground water probably was increased further by evapotranspiration.

South of Canutillo, the alluvium contains water that is rather high in dissolved-solids content but that is generally of better quality than the water in the underlying Santa Fe group. In the south end of the valley, the El Paso Electric Co. and the American Smelting and Refining Co. obtained water from the alluvium. The water in four wells had a chloride and sulfate content of less than 250 ppm. Fresh water in this area is attributed to recharge from precipitation on the surficial sandy deposits overlying the alluvium. Until November 1955, the White Water Works supplied water to the community of White Spur and nearby residential areas. Analyses of water from five wells, U–1, U–2, U–4, U–6, and U–7, had a chloride content exceeding 340 ppm, except well U–4, which had a chloride content of 92 ppm but a sulfate content of 288 ppm.

CONSOLIDATED ROCKS

Several wells on the uplands bordering the Franklin Mountains and at the south end of the valley yield water from consolidated rocks. Well Q–76 obtained hard water for stock use from a black rock, probably of Pennsylvanian age. Chemical analysis of a sample of the water showed more than 300 ppm of chloride and 1,000 ppm of dissolved solids. At the south end of the valley, well U–59 yielded water high in dissolved-solids, chloride, and sulfate content. Water that is unsuitable for domestic or municipal uses but satisfactory for some industrial uses is obtained from sand and limestone of Early Cretaceous age. On the west slope of the Franklin Mountains, well U–12 yielded water high in calcium, magnesium, and iron content from a limestone of undetermined age between 1,600 and 1,690 feet deep. The well was abandoned and plugged in 1953 because of the high fluoride content (5.6) in the water.

SURFACE WATER

Records of chemical data from the International Boundary and Water Commission's files show that the water of the Rio Grande increases in dissolved-solids content between Leasburg, N. Mex., and El Paso, Tex. (See fig. 12.) During the period 1930–57, the dissolved-solids content increased from an average of 0.77 ton per acre-foot at Leasburg Dam to 1.10 tons per acre-foot at El Paso, an increase of nearly 45 percent in 50 miles. A ton per acre-foot is equivalent to 735.5 ppm of dissolved solids. Most of the increase in sodium salts of sulfate and chloride is attributed to the accretion of drain water. The following table shows that the chloride content of water in the Rio Grande at El Paso is highest during the nongrowing season and is lowest from March to September, when surface water is released for irrigation. During the winter, the water in the Rio Grande consists largely of return flow from the drains.

Month	1952	1953	1954	1955	1956	1957	1958
January	288	281	377	490	705	710	830
February	309	312	318	570	805	815	870
March	246	88	230	259	169	375	83
April	198	93	169	172	126	227	78
May	142	124	171	234	262	490	69
June	92	92	175	185	142	126	69
July	80	96	167	124	137	57	74
August	76	110	124	153	172	45	76
September	112	128	286	131	176	65	87
October	246	259	190	274	775	375	175
November	260	293	525	507	770	1,090	268
December	268	330	505	700	742	920	--------
Weighted mean	125	119	184	170	160	90	--------

The water in the drains in the lower Mesilla Valley varies widely in quality, but is usually higher in dissolved-solids content than the river water at El Paso. During part of 1955 and 1956, however, the water in the river at El Paso was higher in dissolved solids than the water in Montoya Drain owing to the low flow of the river and to the discharge into the river of concentrated effluent from the El Paso electric plant. Figures 13 and 14 show that the quality of the water, as specific conductance (micromhos), in Montoya and Anthony Drains varies more or less inversely with the quantity of drain flow. The specific conductance is a measure of the ability of the water to carry an electric current and is therefore an indication, within rather wide

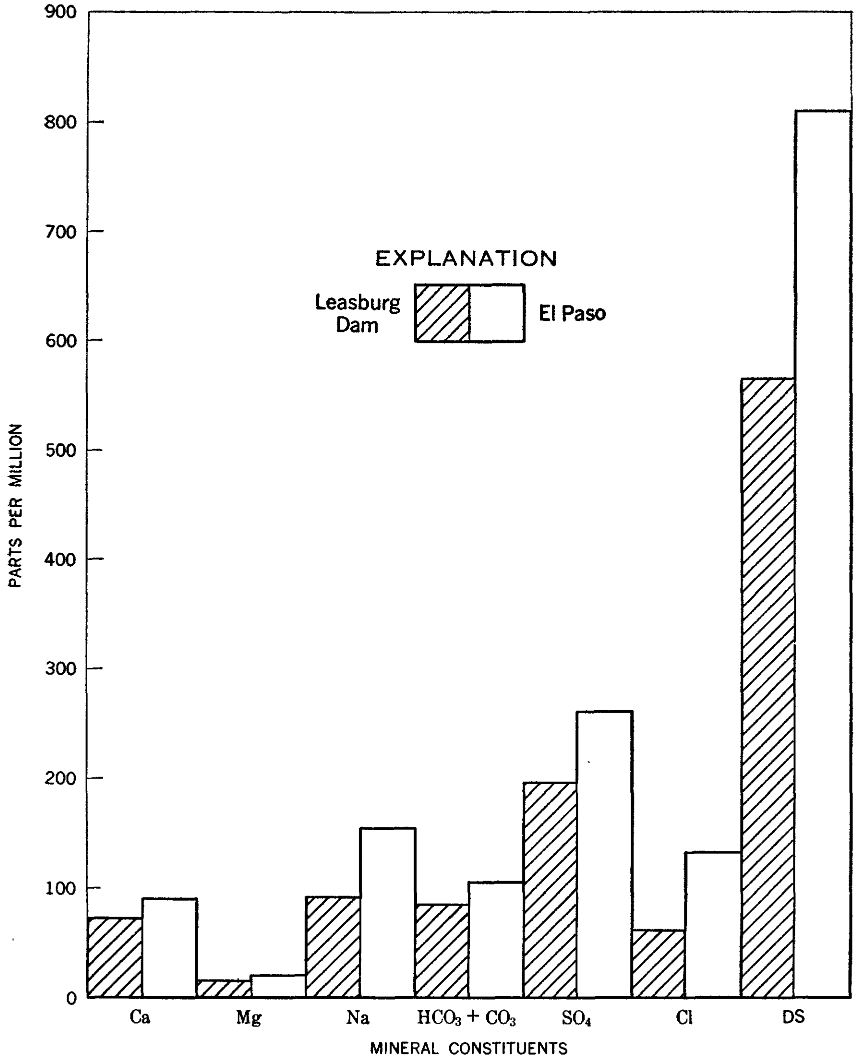

FIGURE 12.—Average chemical quality of water from the Rio Grande at Leasburg Dam, N. Mex., and at El Paso, Tex.

limits, of the ionic strength of the water. These data show that water in Anthony Drain is higher in mineral content that that in Montoya Drain.

In general, the drain water increases in dissolved-solids content from the upper to the lower end of the West Drain (fig. 15). The increase is due principally to the accretion of ground water in mineralization, which increases toward the lower end of the valley, and also to the concentration of the dissolved salts in the drain water by evapotranspiration.

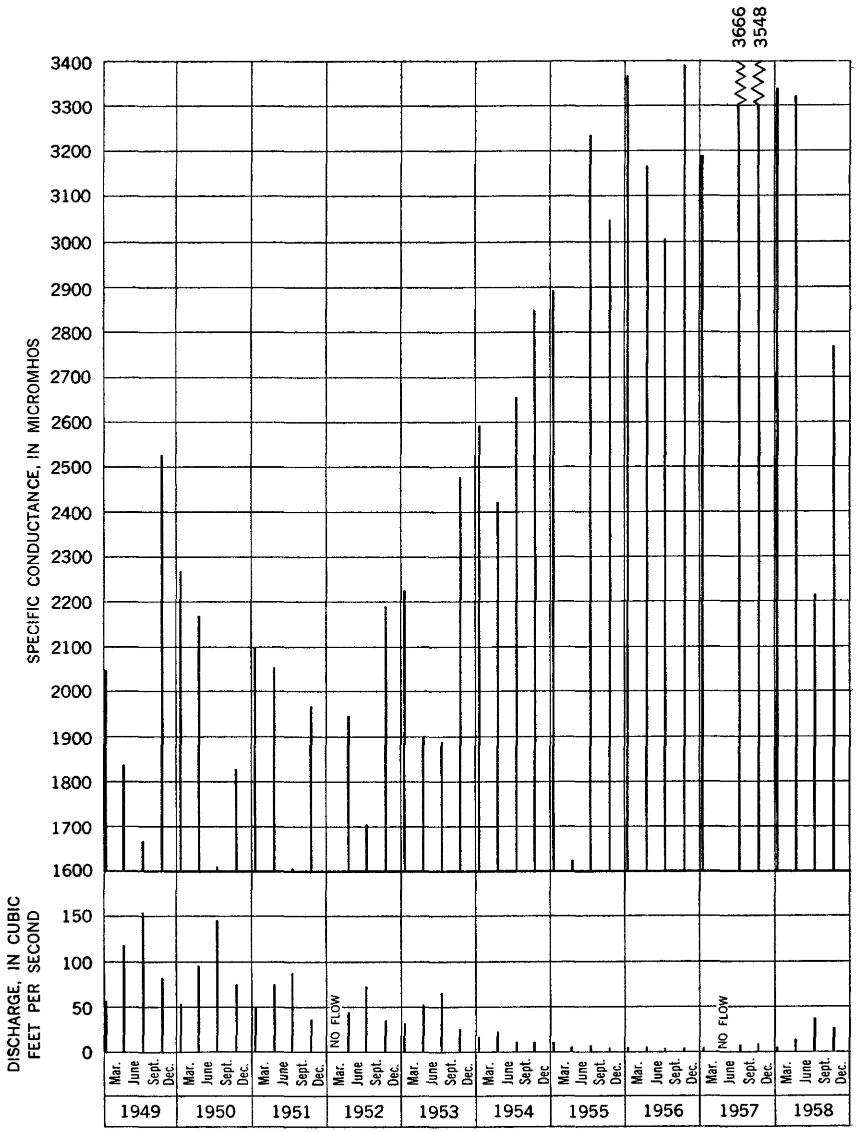

FIGURE 13.—Quality and discharge of water in Montoya Drain, 1949–58.

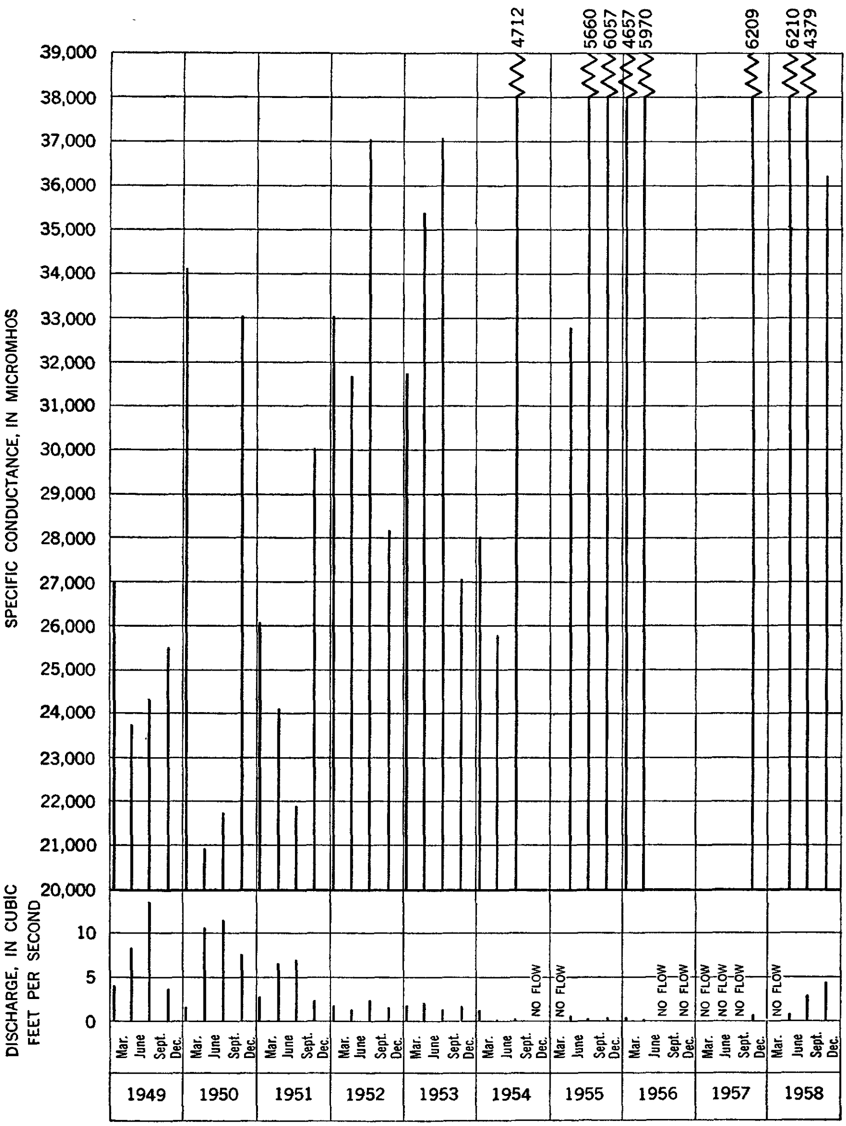

Figure 14.—Quality and discharge of water in Anthony Drain, 1949–58.

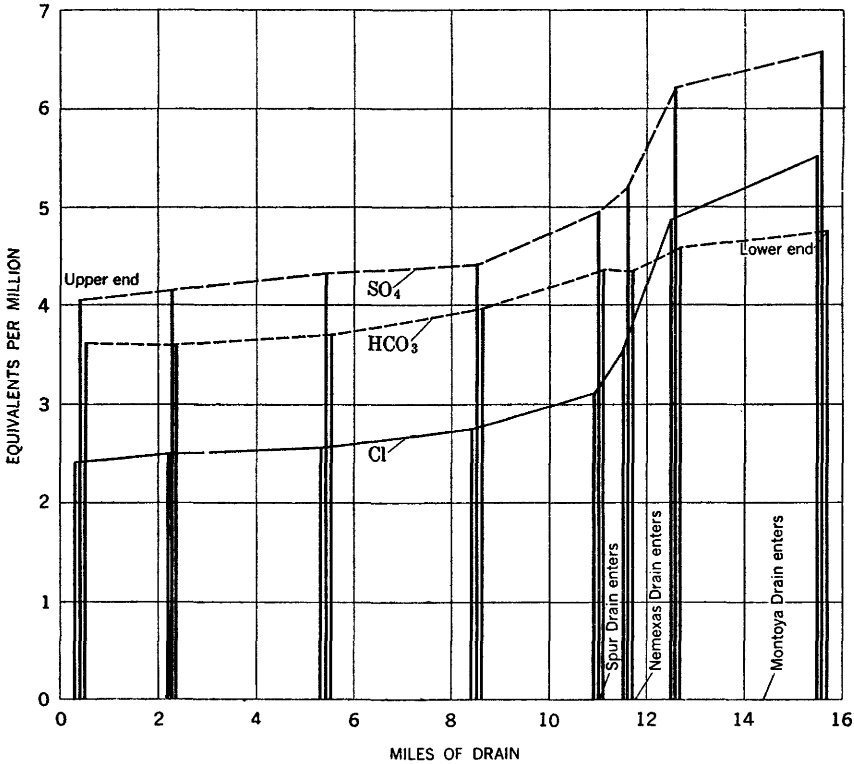

FIGURE 15.—Increase in mineralization of water from the upper to the lower end of West Drain.

FUTURE DEVELOPMENT

The quantity of ground water discharged as drain flow from the lower Mesilla Valley indicates that additional supplies can be developed from wells tapping the shallow, medium, and deep aquifers, with little permanent loss of ground-water storage. Unmeasured, but substantial, amounts of reclaimable ground water are discharged by seepage into the Rio Grande and by evapotranspiration. If the water table is lowered below river level, seepage from the Rio Grande will add to recharge of the ground-water reservoir.

The future development of ground water in the lower Mesilla Valley is affected in several ways: (1) the demand for ground water for irrigation is extremely variable because it depends upon the availability of surface water; (2) the quality of most of the water in the shallow aquifer is unsuitable for public supplies and for some industrial uses; (3) the quality of water in the medium and deep aquifers may deteriorate as a result of leakage of water of poor quality from the shallow aquifer and from encroachment of salt water from underlying and adjoining beds, if withdrawals from the deep aquifer are excessive; (4) the surface-water supply will be reduced if ground-water withdrawals in the valley are increased; and (5) the salt content of the water in the shallow aquifer will increase if the drain flow is reduced substantially.

Drain flow is directly related to the allotment of surface water for irrigation and to the withdrawals of ground water from any of the three aquifers. If surface-water supplies are inadequate, ground-water withdrawals may become so large that drain flow will cease, and the water in the shallow aquifer will increase in dissolved solids content. Thus, if the shallow aquifer is to remain a source of supplemental supply for irrigation, withdrawals of water must not be so great that the drain flow is stopped or is reduced to a point that would result in an unfavorable salt balance in the irrigated area.

The rated capacity of wells drilled in the shallow aquifer during the period 1951–56 probably is adequate to meet the demands for supplemental irrigation water even during prolonged periods of severe shortage of surface water. The demand for irrigation water reached a maximum in 1958 when nearly all the land was being irrigated in this area. About 5 percent of the land, or about 1,000 acres, uses ground water exclusively for irrigation; 95 percent uses surface water supplemented by ground water when allotments are inadequate. The crops require about 3 feet of water annually; thus the demand for ground water ranges from about 3,000 acre-feet per year, when surface-water supplies are adequate (as in 1958), to as much as 50,000 acre-feet per year during extended periods of surface-water shortages.

Development of additional water supplies from the shallow aquifer for uses other than irrigation appears feasible. Withdrawals of water for public supply from the shallow aquifer, however, should not exceed the capacity of the present El Paso shallow well field, about 17,000 acre-feet per year, or 15 mgd. The field includes nearly all the area underlain by water suitable in quality for public supply. Additional development from the shallow aquifer should be limited to water of poor quality which can be used by industries.

The flow from Montoya Drain represents a large part of the water that could be pumped from wells without seriously depleting the amount of water in storage. The records of flow for the period 1946–50 show that about 70,000 acre-feet per year of ground water could be pumped when surface-water allotments are adequate. Surface water was in short supply every year from 1951 to 1957; an increase in pumpage and a decrease in the recharge rate to the ground-water reservoir reduced the average drain flow for the period to 17,000 acre-feet per year, a loss of 53,000 acre-feet per year from the rate of the period 1946–50. The average pumping rate from 1951 to 1957 was 36,000 acre-feet per year. About one-third of the water pumped was returned to the aquifer as seepage. Ground water used for irrigation and municipal supplies accounted for about half of the drain-flow loss, or about 26,000 acre-feet per year; the other half was caused by a decrease in the recharge rate caused by the application of less surface water to the land. The average decrease in the recharge rate was greater than 26,000 acre-feet per year, because part of the water pumped was withdrawn from storage. In 1958, when surface water was adequate, the drain flow did not increase as much as expected, because ground water in storage was replenished.

The greatest potential source of water for municipal and industrial supplies is the medium and deep aquifers. In 1958 the city of El Paso pumped an average of 6.8 mgd from the medium and deep aquifers. The rated capacities of the pumps is 19 mgd, or about 6 mgd greater than recharge to the aquifers. Pumping at capacity rates might result ultimately in the encroachment of salt water, which overlies, underlies, or adjoins the fresh water. Encroachment may be kept to a minimum (1) if withdrawals of ground water do not exceed the rate of recharge, (2) if withdrawals are as remote as possible from salt-water bodies, and (3) if withdrawals are chiefly from the deep aquifer. Large withdrawals of ground water from the medium aquifer might accelerate the contamination of the fresh-water body by increasing the rate of downward movement from the shallow aquifer.

As a conservative estimate, at least 200,000 acre-feet of fresh water can be recovered from storage in the Texas part of the valley. This estimate does not include ground water in the New Mexico part of the valley, which would replace the water withdrawn from the Texas part of the valley. The rate at which fresh water in the medium and deep aquifers is depleted will depend upon the withdrawal rate.

On the basis of past records, it appears that from all three aquifers development of ground-water supplies in addition to irrigation supplies could total about 30,000 acre-feet per year, 16,000 acre-feet of which may be safely obtained from the medium and deep aquifers.

SUMMARY AND CONCLUSIONS

The middle and deep aquifers of the Santa Fe group are the most important sources of ground water in the lower Mesilla Valley for the municipal supply of El Paso. The shallow aquifer, which consists of Recent alluvium and a part of the Santa Fe, is used extensively as a supplemental supply for irrigation and to a small extent as a source for municipal and industrial supplies.

Recharge to the Santa Fe, estimated to be 13 mgd, is derived from precipitation on the bordering uplands and from the valley in New Mexico north of Anthony. The amount of recharge to the Recent alluvium from infiltration of irrigation water varies in accordance with the amount of water applied to the land. During periods when the surface-water supply is normal, the potential annual accretion to the alluvium is at least 36,000 acre-feet. When the water table is high and the drains are flowing, most of the 36,000 acre-feet of recharge will be returned to the river as drain flow.

Aquifer tests indicate that the three aquifers (deep, medium, and shallow) in the city of El Paso well field near Canutillo are hydraulically connected; pumpage from one affects the water level in the others. The tests showed substantial leakage between the aquifers. Therefore, water higher in dissolved-solids content will percolate from the shallow aquifer into the medium and subsequently into the deep aquifer to replace the water of better quality that has been withdrawn.

Fresh water occurs in the Santo Fe from at least the New Mexico-Texas State line southward to a line approximately through Canutillo. South of this line, the dissolved-solids content of the water in the Santa Fe increases until it becomes unfit for most uses. The quality of water in the Recent alluvium varies widely. North of Canutillo and west of U.S. Highway 80, the water in the alluvium is of good quality, but its dissolved-solids content is greater than that of the water in the underlying Santa Fe. Because most of the recharge to the alluvium is from infiltration of water applied to the land and from seepage from drains, canals, and the river the quality of the ground water varies according to the quantity and quality of the surface water available for irrigation. South of Canutillo, the water in the Recent alluvium is high in mineral content but generally is of better quality than the water in the underlying Santa Fe.

The use of ground water for irrigation in the lower Mesilla Valley is inversely related to the supply of surface water. During periods when surface-water storage in Elephant Butte Reservoir is normal, pumpage for irrigation is negligible. Since 1957, pumpage of ground water for the municipal supply of El Paso has increased each year, and in 1958 water usage for minicipal supply exceeded the pumpage of ground water for irrigation. In 1958 the city of El Paso pumped an average of 6.8 mgd from the medium and deep acquifers of the Santa Fe, or about 50 percent of the estimated recharge to the Santa Fe.

It is estimated that 560,000 acre-feet of fresh water is stored in the alluvium and the Santa Fe in the Texas part of the valley and an additional 980,000 acre-feet in the part of the valley in New Mexico. About 150,000 acre-feet is in the alluvium in Texas. In the areas where the fresh-water beds are overlain or underlain by salt water, probably less than half of the fresh water can be recovered.

The large amount of ground water discharged as drain flow from the lower Mesilla Valley indicates that additional supplies can be obtained from wells tapping the shallow, medium, and deep aquifers. In addition to irrigation supplies, the three acquifers can furnish long-term sustained supplies totaling about 30,000 acre-feet per year, 16,000 acre-feet of which may be safely developed from the medium and deep aquifers.

Results of the investigation indicate that the ground-water resources of the lower Mesilla Valley are insufficient to furnish a large sustained supply of ground water for the increasing needs of the city of El Paso. Detailed planning and proper development will be necessary to obtain maximum recovery without serious contamination of the water supply. Such planning should include (1) the collection of records of well construction, (2) well performance, (3) periodic water-level measurements, (4) pumpage records, and (5) chemical analyses of water samples.

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