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UNITED STATES DEPARTMENT OF THE INTERIOR

GROUND-WATER RESOURCES OF THE EL PASO AREA, TEXAS

Prepared in cooperation with the
EL PASO WATER BOARD and the
TEXAS STATE BOARD OF WATER ENGINEERS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 919

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

Water-Supply Paper 919

GROUND-WATER RESOURCES
OF THE
EL PASO AREA, TEXAS

BY
A. N. SAYRE AND PENN LIVINGSTON

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1945

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

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By A. N. Sayre and Penn Livingston

ABSTRACT

El Paso, Tex., and Ciudad Juarez, Chihuahua, Mexico, and the industries in that area draw their water supplies from wells, most of which are from 600 to 800 feet deep. In 1906, the estimated average pumpage there was about 1,000,000 gallons a day, and by 1935 it had increased to 15,400,000 gallons a day.

The water-bearing beds, consisting of sand and gravel interbedded with clay, lie in the deep structural trough known as the Hueco bolson, between the Organ and Franklin Mountains on the west, the Hueco, Finlay, and Malone Mountains on the east, the Tularosa Basin on the north, and the mountain ranges of Mexico on the south. From the gorge above El Paso to that beginning near Fort Quitman, about 90 miles southeast of El Paso, the Rio Grande has eroded a flat-bottomed, steep-walled valley, 6 to 8 miles wide and 225 to 350 feet deep. No other large drainage channels have been developed on the bolson. The valley is known as the El Paso Valley, and the uneroded upland part of the bolson is called the Mesa.

In the lowest parts of the El Paso Valley, the water-table is nearly at the surface. The quality of the underground water in the valley varies greatly both vertically and laterally. To a depth of about 400 to 500 feet it is in general too highly mineralized for municipal use, but between about 500 and 900 feet good water may be obtained from several beds. In the beds between 500 and 900 feet the water level in wells is in places as much as 20 feet lower than that in the shallow beds. Beneath the Mesa the water level varies from about 200 feet beneath the surface, where the ground elevation is least, to about 400 feet where it is highest. The water beneath the Mesa in general is of satisfactory quality and contains less than 500 parts per million of dissolved solids.

The contour map of the water table beneath the Mesa shows that the ground water is moving toward the southeast, that is, toward the Rio Grande, and the recharge to the water bearing beds probably occurs along the east slopes of the Franklin and Organ Mountains. The hydraulic gradient in the deep water-bearing beds beneath the valley is also toward the river, except where it is locally altered by pumping, indicating that the water has a similar origin. The hydraulic gradient in the shallow water-bearing beds in the valley is toward the northeast, away from the river, showing that these beds receive their recharge from the river. A minor amount of recharge, however, probably comes from the mountains in Mexico, and some underflow may take place through the passes at the north and south ends of the Sierra del Paso del Norte. The amount of the total recharge is estimated at about 10 to 15 million gallons a day.

Two cones of depression in the water table have been formed by the pumping near El Paso—one in the vicinity of the Mesa well field, the other around the Montana well field in the valley. The water released from storage by the formation of the cone centering in the Mesa field was calculated at 22,000 acre-feet, but the total pumpage was estimated to have been 90,000 acre-feet. Thus, about one-fourth of the total pumpage was taken from storage; the remaining three-fourths apparently was taken from recharge. About 210,000 acre-feet of water has been pumped from the cone of depression in the El Paso Valley in and near El Paso. The volume of this cone could not be determined because there are artesian conditions in this area.

Computations were made of the amount of water that would be recovered from storage if, for a distance of 10 miles north of the Mesa well field, the water level in a series of wells were drawn down the same amount as the present drawdown in the wells in that field. The water that would be recovered from storage in the formation of this depression in the ground water surface was calculated at about 130,000

acre-feet, the equivalent of about 7½ years' supply at the 1935 rate of pumping. It is, of course, available in addition to the annual recharge.

The sudden increase in 1924 in the salt-water content of the water from El Paso well 3 (well 52), in the Montana well field, was shown to be the result of a leak in the casing at a depth of about 127 feet, and the well was successfully repaired during the investigation. However, the chloride content of all of the wells in the field has been increasing gradually. This may indicate that salty water is being pulled in from considerable distances or that the barriers between the fresh-water-bearing beds and the salt-water-bearing beds above them are not capable of preventing vertical movement of the ground water. The fact that in the valley the static water level in the shallow beds yielding poor water is higher than that in the deeper beds is disquieting, and if the level in the lower beds continues to decline, seepage from the river will eventually force the shallow highly mineralized water laterally and perhaps downward into the beds bearing fresh water. The pumpage from deep wells in the valley should be maintained at a minimum; eventually it may necessarily be discontinued because of increasing mineralization of the water. Additional wells should be drilled in the El Paso Valley only as needed to maintain the pumping at its present rate, but wells intended to supply large quantities of additional water should be drilled in the area north from the Mesa well field.

Measurements of the water levels in selected wells should be made at regular intervals, and samples of water should be collected and analyzed every 6 months to determine the accuracy of the conclusions regarding the quantity of potable water available for the El Paso supply. These records, if continued, also will give advance warning of conditions that would require decreasing the pumpage in existing wells or the development of new wells many years before the actual need for such changes arises.

INTRODUCTION

GEOGRAPHY

El Paso, which according to the 1940 census has a population of 96,810, is in the extreme western part of Texas on the Rio Grande, just below the pass between the Franklin Mountains and the Sierra del Paso del Norte in Mexico, known since Spanish times as "the Pass of the North." (See pl. 1.) The city lies like a great crescent around the south and southeast flanks of the Franklins, most of it within the Rio Grande Valley, but toward the northeast it extends onto the adjacent uplands, where it is adjoined by Fort Bliss, a cavalry and artillery post at which in 1939 some 2,500 troops were stationed. Ciudad Juarez, which has a population of 39,375 according to the Rand McNally commercial atlas for 1937, is across the river from El Paso. The valley downstream from these cities on both the American and Mexican sides of the river is thickly populated. The uplands bordering the valley, with the exception of the area around Fort Bliss, are very sparsely populated.

From a point about 50 miles upstream from El Paso the Rio Grande flows south-southeast in a broad, flat-bottomed valley along the west side of the Franklin and Organ Mountains. This valley is 6 to 8 miles wide and about 350 feet deep and is known as the Mesilla Valley, or locally as the Upper Valley. Irrigated with water impounded by Elephant Butte Dam, it constitutes a garden spot in the midst of the surrounding desert. The valley is bordered on the west by La Mesa, a broad, nearly level plain that extends from near Las Cruces, N. Mex., far southward into Chihuahua, Mexico, and on the east by a narrow plain the surface of which has about the same elevation as La Mesa. Near the southern end of the Franklins the Mesilla Valley is sharply constricted, and the river turns abruptly to the southeast entering a deep, narrow canyon along the north side of the Rodadero Hills or Cerro de Muleros, which lie within the pass between the Franklins and the Sierra del Paso del Norte. The El Paso Canyon is 3 to 4 miles long. Below the El Paso Canyon the river continues in a southeasterly direction through the broad El Paso Valley, locally referred to as the Lower Valley. The El Paso Valley, which is similar to the Mesilla Valley, is about 6 to 8 miles wide and 225 to 350 feet deep. Its broad flat bottom includes large areas of irrigated lands. The valley is carved diagonally across the Hueco bolson, a broad, gently tilted plain bounded on the east by the Hueco and Finlay Mountains, on the west by the Franklin Mountains, on the south by several groups of mountains constituting a part of the Sierra Madre Oriental chain of Mexico, and on the north near the Texas-New Mexico boundary by a similar plain, the Tularosa Basin. (See pl. 2.) From the floor of the El Paso Valley the surface slopes upward, at first gradually but becoming steep and abrupt where it meets the nearly level surface of the bolson floor. Thus, when one looks from the valley either to the north or south, the bolson looks like a broad, elevated tableland, and for this reason it is locally referred to as the Mesa.

PURPOSE AND SCOPE OF INVESTIGATION

Because El Paso is in an arid section of the country, public water supplies must be obtained from wells or from the Rio Grande, and it is of the utmost importance to the residents of the area to know to what extent each of these sources may be depended on for future supplies. For many years the water supply for El Paso and its industries and for Fort Bliss and Ciudad Juarez have been pumped from wells. In 1921 Lippincott[1] reported on the water supply of El Paso, making a special study of the possibility of obtaining the city supply from the Rio Grande. He found that at times the water in the Rio Grande at El Paso is too highly mineralized to use for a public supply. Therefore the use of river water for this purpose would involve the construction at heavy cost of a pipe line to a diversion point far up the river. Moreover, all the water available for diversion from the river is now being used for irrigation; obtaining the city supply from the river, therefore, would involve retiring a part of the irrigated lands from irrigation and should be considered only as a last resort. No other permanent streams are available for public supplies within a reasonable distance of the city. Therefore, the ground-water supplies must be utilized to the fullest extent possible, and a thorough investigation of the quantity and quality of ground water available for future use is essential to adequate planning of water-supply developments.

During the summer of 1934 the chloride content of El Paso city well 3 (well 52 of this report) in the Montana field increased rather suddenly from about 250 parts per million to nearly 400 parts. Attempts to locate the source of the contamination were unsuccessful and it was feared that the increase in chloride indicated that the beds yielding fresh water were being contaminated by salt water. Because the wells in the Montana field supplied a considerable proportion of the total

[1] Lippincott, J. B., Report on El Paso Water system by city Water Board (manuscript report, September 1921).

city supply, the failure of the field would be a serious blow. This situation tended to emphasize the need for a comprehensive investigation of the ground-water resources of the area, which should include determination of the cause of the increase in chloride in well 3 and whether other wells are likely to be affected, the extent and volume of the underground water reservoir, the rate at which the water held in the reservoir can be removed from storage, the amount of water that enters the reservoir annually from recharge, and the location of the areas in which wells are most likely to yield large quantities of potable water. The El Paso Water Board requested the assistance of the Texas Board of Water Engineers and the Federal Geological Survey. Mr. W. N. White of the Survey visited El Paso in December 1934 and made the preliminary investigation that has served as the basis for the present study. In 1935 the city appropriated funds for cooperation between the Geological Survey and the Texas State Board of Water Engineers. The present investigation was begun in July 1935, and the field work was actively carried on until August, 1936.

During the course of the investigation the geology of the area was studied with particular reference to the occurrence and source of the ground water. All the available well data were collected and studied, including logs of wells, records of casing and screen settings, developed capacity of the wells, total pumpage from the wells, and depth to the water level in each well that could be measured. Monthly water-level measurements were taken in selected wells, and pumping tests were made to determine the permeability and specific yield of the water-bearing beds. Numerous shallow test wells were bored in the valley to determine the slope of the shallow water table and the chemical character of the water. The Works Progress Administration supplied the labor for sinking these wells and for digging numerous trenches on the Mesa to determine the effect of the caliche in that area on the downward percolation of rainwater. Deep test wells were drilled to obtain samples of the water-bearing materials for the determination of permeability and specific yield. Water samples for chemical analysis were collected from most of the wells in the area, and the character of the water from various beds was determined by electrical conductivity tests and by chloride and hardness determinations made in the field on samples of water collected at intervals from wells that were pumped after being idle for a considerable period.

Resistivity measurements were made by J. H. Swartz and E. L. Stephenson at nearly 200 stations along two major traverses, one crossing the Hueco bolson from the Franklin Mountains to the Hueco Mountains and the other extending from the El Paso Valley to the New Mexico State boundary parallel to the Franklin Mountains and 2 to 3 miles to the east of them. Measurements also were made along several shorter traverses. The resistivity work was of an experimental nature and was financed partly by funds supplied by the Bureau of Mines. The labor was supplied by the Works Progress Administration, and transportation and most of the equipment used was supplied by the Geological Survey. The resistivity measurements supplemented more direct information from other sources on the location of areas in which highly mineralized water occurs, and on the location of faults.

The study was made under the direction of O. E. Meinzer, Geologist in Charge, Division of Ground Water, and W. N. White, in charge of ground-water investigation in Texas.

R. H. Colvin and J. H. Heuser were responsible for direct supervision of the Works Progress Administration labor used on the investigation. Mr. Colvin also ran levels and since 1936 has collected pumpage data and carried on the water-level observation program.

ACKNOWLEDGMENTS

The writers wish to acknowledge their indebtedness to the members of the El Paso Water Board. Messrs. W. E. Robertson, A. L. Hawley and L. R. Fiock, for their helpful cooperation at all times; to A. G. Classen, superintendent, and E. E. Nevins and L. E. Murphy, engineers, of the El Paso Waterworks for assistance during the course of the investigation and for information relative to the El Paso water system. Mr. E. Garcia Robledo of the Administracion de Agua, Ciudad Juarez, Chihuahua, Mexico, supplied valuable information on the wells and water supply system of that city. Mr. Armando Santacruz, Jr., Chairman of the Mexican section of the International Boundary Commission, and his assistants, A. M. Amor and H. G. Parte-arroyo, enabled the writers to obtain much hydrologic information in Ciudad Juarez that otherwise would have been unobtainable. Mr. Santacruz also detailed one of his hydrographers, Mr. J. J. Tafoya to assist the writers in geological and hydrological studies in Mexico adjacent to El Paso, greatly simplifying the work there. Especially grateful acknowledgment is due to Mr. F. H. Todd, formerly city engineer and now consulting engineer. Mr. Todd who has been collecting and studying well data in the El Paso area for many years, freely granted the writers access to these data and the miscellaneous, unrecorded information he had collected. The well owners and the residents of the area have been uniformly courteous and helpful, and their assistance is greatly appreciated.

HISTORY OF GROUND-WATER DEVELOPMENT

For many years the lack of shallow water on the Hueco bolson retarded, to a large extent, the development of that area for pasture. By 1904, however, some deep wells had been drilled, on the bolson, and Richardson[2] reported that the area afforded pasturage for thousands of head of cattle.

Water was first supplied to the city by pumping directly from the river, under a franchise granted to Sylvester Watts in 1882. The first well to furnish water for the city was known as the Watts well, which was dug about 1892,[3] a few hundred feet from the river and about in line with Third Street extended. It is reported to have been 13 feet in diameter and 60 feet deep. Near the bottom of the well 6-inch pipes were pushed out horizontally to the west, north, and south for distances of 104, 60, and 85 feet, respectively. The horizontal pipes were slotted after being placed. This well yielded a large amount of water, but the water was of unsatisfactory quality, as is indicated by an analysis published by Richardson[4] in 1908. Consequently, during the time that water was supplied chiefly from this well, drinking water was shipped into the city from Deming, N. Mex. The Watts well supplied the city until 1904, and from then until 1918 it was used during

[2] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (no. 166), p. 10, 1909
[3] Lippincott, J. B., op. cit. (manuscript report) p. 9, 1921.
[4] Richardson, G. B., op. cit. p. 11.

the summer to augment the supply from the Mesa field. It has not been used since 1918, but in 1923 it was tested and found to have a yield of 2,000 gallons a minute with a draw-down of only 24 feet.

It is not possible to find out who was responsible for the development of the deep wells on the Mesa, but among the early wells drilled in that area were those near Fort Bliss, drilled in 1901 by the El Paso & Southwestern Ry. (now the Southern Pacific) and at Hereford (now Newman, N. Mex.), drilled in 1902. In 1904 there were a number of deep wells on the Mesa and many shallow wells in the valley.[5]

The Watts' franchise expired about 1896, and in 1902 the International Water Company obtained a franchise, bought the waterworks, and, because the water from the Watts well was of unsatisfactory quality, started drilling wells on the Mesa north of Fort Bliss. Seven of these wells were completed by the end of 1904.[6] In succeeding years additional wells were drilled, but the water company was financially unable to keep up with the increasing demand for water. The deficiency was made up by water from the Watts well. In 1910 the city acquired the property of the water company and continued to drill additional wells, and by 1917 a total of 44 wells had been drilled in the Mesa field. These were pumped from a central plant by air lift, but the cost of operating and maintaining the plant was excessive because of the high lift, the comparatively low yield of the individual wells, and the inefficiency of pumping with air. Therefore it was decided to explore the gravels nearer the city and at lower elevations than at the Mesa field. In December 1917 construction was begun on city well 1 (well 50 of this report), at the corner of Madison and Montana Streets near the eastern limits of the city and in what is known as the Montana field. This well proved to be capable of delivering about 2,000,000 gallons a day and was put in service in 1919. City well 5 (well 41 of this report), at the corner of Grama and Morenci Streets, was completed in 1921 and had a capacity of 1,500,000 gallons a day. According to Lippincott,[7] these two wells furnished about half of the city water supply in 1921.

The Mesa wells were gradually abandoned as other deep wells were drilled nearer the city, and the field was finally abandoned in 1926. In 1921 the Mayor of El Paso appointed a Water Board to make plans for an adequate water supply for the city of El Paso, and they employed Mr. J. B. Lippincott as their consulting engineer. In his report Lippincott concluded that it would not be wise to develop the city water supply from wells in the existing fields any longer than was necessary, "because it is probably possible to obtain a more copious supply of water at a cheaper cost unmenaced by pollution and fitting into a plan of distribution in a better way, looking towards the ultimate supply from Elephant Butte Reservoir." To meet the immediate needs of the city he recommended the drilling of two more wells in the Montana field, and for future developments he recommended prospecting for water with test wells northwest of the city in the Mesilla Valley and the development of a ground-water supply in that area. Thus, when the city had sufficient funds to finance the development of a surface-water supply from Elephant Butte Reservoir, or some other reservoir on the Rio

[5] Slichter, C. S., Observations on the ground waters of Rio Grande Valley: U. S. Geol. Survey Water Supply Paper 141, 1905.
[6] Slichter, C. S., op. cit., p. 18.
[7] Lippincott, J. B., op. cit., p. 12.

Grande above the city, a part of the pipe line would be in place ready for use. Two test wells were drilled in the Mesilla Valley, but as both of them yielded salty water, the project to develop a supply of ground water in the Mesilla Valley was abandoned and developments were continued in the El Paso area. Deep wells have been drilled by the city in its business section and in the Montana and Mesa well fields to meet the increasing need for water. Wells also have been drilled in the city by industrial organizations, on the Mesa by the United States Government at Fort Bliss and by ranchers and others, and in Ciudad Juarez by private organizations and by the city waterworks. From 1928 to 1930 the proven area of potable water in the valley was extended to the southeast when two wells were drilled by the Pasotex Petroleum Co., one by the Texas Co., and one by the Nichols Copper Co. to obtain water for oil or copper refineries in the area just east of the city.

The table on page 51 shows the increase in the demand for fresh water in the El Paso-Juarez area from 1906 to 1941.

CLIMATE

The climate of the El Paso area is typical of the arid to semiarid parts of southwestern United States and northern Mexico. The majority of the days are clear and sunny and therefore warm. The nights are cool, because the altitude (3,700 to 7,000 feet) is such that the heat stored during the day is rapidly radiated away. The annual rainfall is about 9 inches and a large part of this occurs in heavy thundershowers in July, August, and September. There is usually a breeze and late in winter and in spring high winds and sand storms are common. The average humidity is very low, 38.8 percent, and therefore evaporation is high, as is shown in the following table.

Monthly and annual depth of evaporation (inches) at El Paso

[Compiled from the means of tri-daily determinations of dew-point and wet-bulb observations in thermometer shelter, U. S. Signal Service, 1887–88]

January	4.0	August	7.7
February	3.9	September	5.6
March	6.0	October	5.2
April	8.4	November	4.6
May	10.7	December	2.9
June	13.6	Annual	82.0
July	9.4		

Although the maximum temperature recorded is 106° F. and the minimum is −5° F., the usual annual range in temperature is not nearly so great as in more northerly areas. The mean monthly and annual temperature are given below as of 1930.

Mean monthly and annual temperature (°F.) at El Paso

Month	Maximum	Minimum	Average
January	57.6	32.3	44.9
February	62.2	36.6	49.5
March	42.2	69.1	55.8
April	77.1	49.6	63.8
May	85.2	57.9	71.9
June	93.6	68.0	80.6
July	92.8	69.3	81.6
August	91.0	67.9	79.7
September	86.1	62.2	74.2
October	77.0	50.9	64.0
November	65.6	39.3	52.4
December	56.5	32.9	44.9
Annual	76.1	50.8	63.6

The following tables taken from reports of the Weather Bureau show the precipitation from the beginning of the record to December 1936. The mean annual precipitation from the beginning of the record to 1927 is 9.16 inches, the highest annual precipitation is 21.81 in 1856 and the lowest is 2.22 inches in 1891.

Monthly precipitation at El Paso, El Paso County, Tex.

[Altitude 3,762 feet.]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1850	------	------	------	------	------	------	------	0.70	0.05	0.60	4.60	1.10	------
1851	0.00	0.90	0.00	0.00	0.70	0.02	1.05	2.49	------	------	------	------	------
1852–1853	------	------	------	------	------	------	------	------	------	------	------	------	------
1854	------	------	------	------	------	------	.10	5.71	3.70	1.54	.00	.50	------
1855	.00	.00	------	.00	------	.05	.16	1.12	7.22	1.05	1.25	.00	------
1856	.33	5.55	2.02	.00	.00	.58	2.20	3.38	7.00	.00	.75	.00	21.81
1857	.00	.50	.00	------	.00	.63	1.52	3.73	4.15	2.87	.07	------	------
1858	.25	.15	.06	.00	.00	.19	1.52	2.42	.40	.00	.01	.00	5.00
1859	.10	.10	.00	.01	.01	.03	1.60	.22	1.11	.70	.95	.00	4.83
1860	T	.24	.00	.01	.00	.30	.53	.08	.18	------	.20	.45	------
1861	.40	.00	------	------	------	------	------	------	------	------	------	------	------
1862–1864	------	------	------	------	------	------	------	------	------	------	------	------	------
1865	------	------	------	------	------	------	------	------	------	------	------	.40	------
1866	.00	.00	------	T	------	------	------	------	1.45	.00	.15	.11	------
1867	.04	.19	.24	.00	.05	.00	.47	.17	1.29	.30	.02	.07	2.84
1868	.47	.17	.05	------	------	------	------	------	------	------	------	------	------
1869	------	------	------	.00	.40	1.30	.26	5.14	T	.58	.24	.00	------
1870	.10	------	.00	------	.00	.04	1.43	4.01	.00	.05	T	.60	------
1871	.59	.00	.20	T	.33	1.54	1.20	.82	2.64	.01	.00	.28	7.61
1872	1.00	.00	T	.00	.05	1.83	2.72	.04	.58	.32	.06	1.08	7.68
1873	.64	.00	.30	.36	.07	1.34	.56	.98	.50	.00	1.02	.00	5.77
1874	.37	.34	.06	.52	.00	.26	.50	.96	1.08	1.38	.54	1.23	7.24
1875	.00	.88	.10	.08	T	.80	1.80	.92	1.87	.00	.00	.03	6.48
1876	.21	.00	.00	T	T	.50	T	4.74	3.76	.00	.25	.00	9.46
1877	------	------	------	------	------	------	------	------	------	------	------	------	------
1878	------	------	------	------	------	------	1.25	2.55	.66	1.02	.66	.11	------
1879	1.75	.83	.18	.07	.00	.08	2.47	.35	.04	.95	.01	.26	6.81
1880	1.01	T	.30	.10	.00	.00	6.54	3.60	.80	.47	.02	1.58	14.87
1881	.35	.24	.01	.22	1.83	.02	8.18	3.15	1.44	1.45	.50	.78	18.17
1882	.64	.78	.38	.00	.10	.43	1.26	2.82	.40	.00	1.46	.00	8.27
1883	.10	.40	2.09	.10	.02	.04	2.84	1.34	2.51	2.03	.61	.84	12.92
1884	.55	.84	.33	.91	T	.11	.46	3.98	3.68	5.15	.22	2.07	18.30
1885	.12	.03	.34	.04	1.27	2.63	1.06	.46	.22	.46	.31	.37	7.31
1886	.31	.44	.28	T	.01	1.03	1.62	1.85	1.16	.80	.52	.04	8.06
1887	.03	.15	.32	.09	.13	.34	.73	1.68	.94	.78	.56	1.01	6.76
1888	.32	1.51	.95	.74	.15	.42	1.39	1.32	.49	1.13	1.32	.05	9.79
1889	.76	.18	.67	.04	.00	.28	1.59	.04	2.64	.35	.55	.00	7.10
1890	.72	.02	.01	.06	T	.63	.95	3.25	1.81	.41	.35	.28	8.49
1891	.27	.09	.16	.00	.38	.40	.06	.13	.23	T	T	.50	2.22
1892	1.25	.57	.30	.11	T	T	1.14	.07	.12	.22	.93	.61	5.32
1893	.02	.52	.31	.00	2.28	T	2.08	3.15	2.08	T	.02	.42	10.88
1894	.33	.29	.13	.01	.01	.01	1.40	.64	.40	.39	.00	.63	4.24
1895	.65	.17	.05	T	2.11	.21	2.48	2.01	.28	.88	1.05	.31	10.20
1896	1.63	.14	T	T	T	.60	2.73	1.09	1.48	2.02	.04	.06	9.79
1897	.54	.00	.05	.14	.46	2.17	2.89	2.57	2.73	.77	T	.09	12.41
1898	.25	.04	.43	.81	.01	.46	1.46	1.00	.50	T	.16	1.04	6.16
1899	.06	.03	.23	.88	T	.61	3.08	.91	.64	.01	.64	.21	7.30
1900	.11	.43	.26	.02	.41	.27	2.38	.43	2.18	1.23	.23	T	7.95
1901	.35	.68	.47	.47	.05	.39	1.05	.34	.82	2.98	1.05	.03	8.68
1902	.57	.01	.00	.00	T	.01	3.27	2.85	1.86	.31	.49	.78	10.15
1903	.61	1.09	.15	.54	.29	2.50	1.19	1.73	3.52	.00	.00	.01	11.63
1904	T	.01	.00	.00	.06	.54	.59	2.24	3.50	3.51	.01	.84	11.30
1905	.86	1.88	1.46	1.38	.03	2.12	2.55	.53	2.29	1.28	2.40	1.02	17.80
1906	.87	1.37	.01	.40	.90	T	2.02	4.10	1.18	.44	2.50	1.20	14.99
1907	.42	T	T	.07	.10	.76	.35	2.50	.96	2.52	.73	T	8.41
1908	.10	.26	.35	.88	.01	.00	2.07	2.55	T	.12	.45	.15	6.94
1909	.04	.16	.77	.00	T	.05	1.62	.51	.60	.02	T	.56	4.33
1910	.21	.10	T	T	T	1.35	.60	1.18	.24	.02	.03	.30	4.03
1911	.36	.96	.43	.47	.39	2.36	3.43	.45	1.00	.43	.35	.24	10.77
1912	.00	.15	.27	.96	T	1.27	1.11	2.38	1.77	.50	.80	.48	10.14
1913	.34	1.26	.29	.14	T	.91	1.31	.54	.60	T	.97	.76	6.94
1914	.03	.53	.10	.47	1.23	1.47	4.91	1.85	.56	.80	1.13	3.94	17.02
1915	1.01	.59	1.34	.20	T	T	2.45	1.37	2.68	.18	.01	.43	10.26
1916	.66	.02	.34	.20	.43	.00	.59	3.07	.55	1.07	.52	.82	7.77
1917	.32	T	.07	T	.14	.36	.41	4.39	.76	T	.04	.00	6.49
1918	1.20	.01	.08	.00	.05	.83	1.52	1.66	.01	1.03	1.04	.78	8.21
1919	.08	.20	.62	.65	.14	.27	1.87	.72	3.03	.97	.93	.12	9.87
1920	1.06	.83	.22	.03	.03	.99	.84	1.33	.31	.57	T	T	6.21

Monthly precipitation at El Paso, El Paso County, Tex.—Continued.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1921	.06	.26	.04	.01	.31	.79	2.13	.35	2.49	.11	.22	.15	6.92
1922	.30	T	.16	.28	.36	.05	1.08	.27	1.07	.35	.29	.09	4.30
1923	.64	1.41	.33	.04	.01	.09	.20	2.96	.41	.58	.53	.93	8.13
1924	.40	.13	.41	.32	T	T	3.00	2.58	.14	.24	.01	.05	7.28
1925	.03	.05	T	T	.59	.17	1.40	2.16	1.03	.79	.02	.27	6.51
1926	.54	.17	1.49	1.11	.70	.11	3.31	.27	2.24	.89	.15	.73	11.73
1927	.05	.18	.28	T	.00	.10	2.52	1.34	1.04	.02	T	.72	6.25
1928	T	.71	.05	.22	.96	T	1.15	2.69	.04	1.47	.79	.13	8.21
1929	T	.29	.21	T	1.51	.54	3.01	1.18	.12	1.60	.33	.50	9.29
1930	.17	.16	.03	T	.62	.53	1.33	1.29	.04	.75	.74	.43	6.09
1931	.83	.89	.38	2.24	.06	1.34	.73	2.14	1.10	.14	.64	.30	10.79
1932	.17	.68	.03	T	1.46	.15	2.28	2.14	2.85	.53	.00	.65	10.95
1933	.19	.23	T	.09	.04	2.14	1.34	.27	.99	.60	.04	.00	5.93
1934	.01	.12	.24	.05	.37	.01	.19	.60	.17	.44	.21	.32	2.73
1935	.24	.47	.14	.02	.17	.09	.16	1.72	1.24	.14	.92	.34	5.65
1936	.57	.06	T	.11	.56	.34	.68	1.94	3.52	.32	1.32	.51	9.93
Mean	0.40	0.45	0.30	0.20	0.26	0.58	1.66	1.85	1.56	0.82	0.55	0.43	9.16

NOTE:—From August 1850 to December 1876 the values given are for Fort Bliss, which was then located 1½ miles northwest of El Paso on the Rio Grande.

Figure 1 gives the rainfall and the cumulative departure from mean annual precipitation from the beginning of the continuous record in 1879 to 1936, and it shows that from 1880 to 1884 the precipitation greatly exceeded the mean; that from 1885 to 1901, although there were occasional years in which the precipitation was above normal, it was generally less than normal; that from 1901 to 1915, with only four exceptions, the precipitation was greater than normal; and that from 1916 to 1936, with three notable exceptions, it has been greatly below normal, or normal.

A regional variation in precipitation was indicated by the records from three recording rain gages established and maintained during the investigation, one at the Emergency Landing Field near the Hueco Mountains, one at Newman, N. Mex., and one near Indian Springs in the Franklin Mountains. The gage at Newman was installed September 20, 1935. Up to September 23, 1936, it recorded a total rainfall of 6.62 inches, whereas the rainfall in El Paso during the same period was 7.77 inches. The gage at the Emergency Landing Field was established October 14, 1935, and removed July 25, 1936, during which period the total rainfall recorded was 3.83 inches. During that period the rainfall at El Paso was 3.50 inches. The gage at Indian Springs, which was installed October 9, 1935, and removed July 29, 1936, recorded a total rainfall of 4.65 inches during that period, while the gage at El Paso recorded a rainfall of 3.50 inches. These figures indicate that the rainfall in and near the Franklin Mountains was somewhat greater than that on the bolson at a considerable distance from the mountains, and that the rainfall in the Franklins was somewhat greater than that in El Paso, at the southern end of the mountains. The records, however, were not of sufficient duration to prove that the precipitation at these localities would be consistently greater or less than the precipitation at El Paso.

GEOMORPHOLOGY

The El Paso area presents an assemblage of topographic forms that does not permit it to be placed wholly in any physiographic province.[8]

[8] Richardson, G. B., U. S. Geol. Survey, Geol. Atlas, El Paso Folio (No. 166), p. 1, 1909.

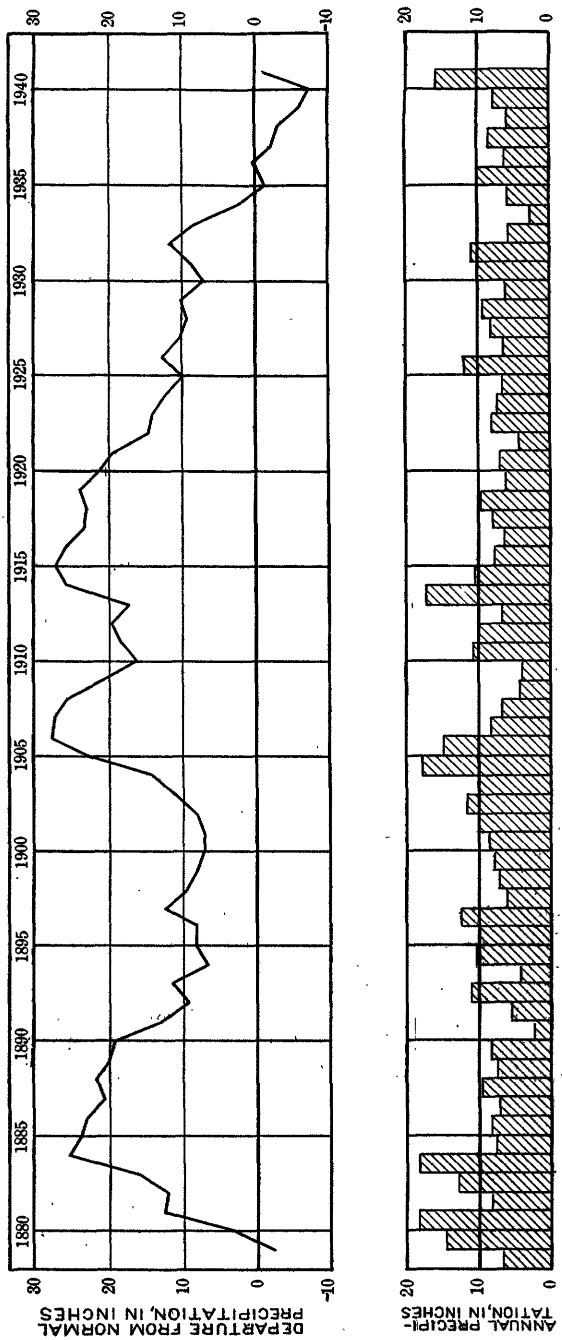

FIGURE 1.—Chart showing annual precipitation and departure from normal precipitation at El Paso, Tex.

The Franklin Mountains, with their complex systems of faults, and the Hueco and La Mesa bolsons are characteristic of the Basin and Range province. (See pl. 1). The intensely folded mountains south of the Rio Grande in Mexico are typical of the western branch of the Sierra Madre Oriental of Mexico. The Malone, Finlay, and Hueco Mountains[9] are arched into gentle folds that are probably an outer branch of the system of close folding of the western branch of the Sierra Madre Oriental of Mexico.

BOLSONS AND VALLEYS

HUECO BOLSON

The term bolson, from the Spanish for purse, was applied by Hill[10] to the intermontane basins of the Trans-Pecos region of Texas and New Mexico. In its usual sense the term means a closed basin with centripetal drainage. Hill, however, included under the name Hueco bolson all that part of the trough, having a length of some 200 miles and an average width of 25 miles, that lies between the Franklin-Organ-San Andreas and the Quitman-Malone-Finlay-Hueco-Sacramento chains of mountains. A few years later, Richardson[11] stated

> In a large way this intermontane lowland is a unit, but it is divided into two distinct parts by a low transverse divide a few miles north of the State boundary. The northern part, known as the Tularosa Desert, trends north and south, and is a closed basin with no drainage outlet. A large part of its surface is characterized by salt marshes and dunes of gypsiferous white sands. The southern part of the lowland trends northwest and southeast, contains no salt or gypsum, and is traversed by the Rio Grande.

Thus the Hueco bolson, locally known as the Mesa, lies south of a low indefinite divide which "on the west approaches within a few miles of the Texas State line but swings northward in the vicinity of the Jarilla Mountains."[12] The margin of the bolson extends along the east side of the Franklin Mountains to the Sierra del Paso del Norte a few miles south of the international boundary. (See pl. 1.) There it swings to the southeast along the Sierra del Presidio and the Sierra de Guadalupe to the Sierra de San Ignacio near Gaudalupe, Chihuahua, Mexico, from where it continues southeastward along the Rio Grande to Fort Quitman, Tex. Thence it follows north-northeast along the Quitman, Malone, and Finlay Mountains to the south end of the Huecos, and northward to the Jarilla Mountains. The average width of the bolson is about 20 to 25 miles. Its length is about 40 miles along the west side and 60 miles along its east side.

The Hueco bolson is a deep structural trough partly filled with detritus, having a total thickness of over 4,920 feet,[13] which has been washed into the basin from the adjacent mountains. Although the present surface has the appearance of a nearly level plain, actually it rises appreciably toward the east, somewhat less so toward the north. On the west side of the bolson, near Fort Bliss, the altitude is about

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[9] King, P. B., Outline of structural development of trans-Pecos Texas: Am. Assoc. Petroleum Geologists, Bull., vol. 19, p. 245, 1935.
[10] Hill, R. T., Physical geography of the Texas region: U. S. Geol. Survey Topographic Atlas, folio no. 3, p. 8, 1900.
[11] Richardson, G. B., op. cit., p. 2, 1909.
[12] Meinzer, O. E., and Hare, R. F., Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water Supply Paper 343, p. 11, 1915.
[13] Baker, C. L., Major structural features of trans-Pecos Texas, The Geology of Texas, vol. 11, Structural and economic geology: Texas Univ. Bull. 3401, p. 204, 1934.

3,900 feet above sea level, while on the east side, near the Hueco Mountains, it is about 4,200 feet, a rise of 300 feet in about 17 miles. On the west side near the New Mexico-Texas boundary, about 14 miles north from Fort Bliss, the altitude is about 4,000 feet, a rise of about 100 feet.

As shown by the U. S. Army topographic sheets of the Fort Bliss and Orogrande quadrangles, there are four shallow depressions, elongated in a north-south direction, along the west side of the bolson about 2 to 3 miles east of the Franklin Mountains. One of these is just north of Fort Bliss, another is about midway between Fort Bliss and the State line, a third is on the State line, and the fourth is south of the Dona Ana target range, in New Mexico about 5 miles north of the State line. These depressions form the lowest parts of the Hueco bolson. From them the surface rises rather rapidly and smoothly toward the Franklin Mountains across coalescing alluvial fans formed by recent outwash from the mountains. This even slope is interrupted over much of its extent near the mountains by an abrupt east-facing escarpment 10 to 50 feet high, but it continues unbroken in the floors of the narrow canyons carved into the bench above the escarpment.[14] The slope of the surface of the bench above the escarpment is somewhat more gentle than that below. Near the middle of the Franklin Range the altitude of this bench or terrace is about 4,250 feet; toward the south it becomes lower, and opposite Fort Bliss, near the southern end of the Franklins, the altitude is about 4,000 feet. Farther south only remnants of the bench remain, but these may be traced around the south end of the Franklins into the high terrace of the Rio Grande on the west side of the mountains.

Eastward from the line of depressions near the Franklins the bolson surface rises gently toward the Hueco Mountains. Two to four miles west of the main mass of the Huecos there are a number of hard-rock outliers, which rise sharply above the relatively smooth bolson, and in this area the surface begins to rise fairly rapidly across coalescing alluvial fans, reaching an altitude, near the base of the main mass of the mountains, of more than 4,250 feet above sea level.

Breaking the even surface of the bolson are at least six sharp east-facing escarpments, 10 to 30 or 40 feet high, which form the western boundary of long, narrow, asymmetrical depressions, of which the lowest part is near the escarpment and from which the surface rises eastward to the general level of the bolson over a distance of one-half to three-quarters of a mile. (See pl. 1.) Nearly all the depressions are somewhat sinuous, but all have a north-south trend. As indicated by their asymmetrical shape and sub-parallel trend, they are not drainage channels but definite structural features. In fact, the Hueco bolson has none but short poorly developed drainage channels near the Rio Grande Valley. The precipitation on the bolson is lost almost entirely by evaporation, infiltration, or transpiration. Numerous drainage channels cross the alluvial slopes near the mountains and some of this water enters the depressions and forms temporary lakes. There are also many draws along the valley of the Rio Grande that form reentrants in the valley wall, but with a few notable exceptions, such as the draw near Fort Bliss and San Felipe Draw near Fabens, these reentrants extend only a short distance into the bolson. South of the Rio Grande only a small part of the bolson surface remains, most of it having been

[14] This escarpment is well shown in plate 10 of U. S. Geol. Survey Water-Supply Paper 343.

dissected during the carving of the El Paso Valley. The terraces and benches formed then are well displayed near the Sierra de San Ignacio southeast of the village of Guadalupe, Mexico. The surface of the upper bench rises gradually to the pass between the Sierras de San Ignacio and de Guadalupe and to the pass between the Sierras de Guadalupe and del Presidio, but between the Sierras del Presidio and del Paso del Norte erosion by tributaries of the Rio Grande has formed an escarpment about 50 feet high, only a narrow remnant of the bolson surface remaining. It is evident, however, that it was originally continuous with the surface of the Samalayuca Valley. Similarly, near the north end of the Sierra del Paso del Norte the bolson is almost entirely destroyed by erosion, but at one time it was evidently continuous with the surface of La Mesa.

The dominant soil of the bolson is fine sand, classified chiefly as Reeves fine sand and Reeves fine sandy loam,[15] with which is mixed a small amount of silt and gravel. It supports a scattered vegetal cover consisting largely of mesquite with some creosotebush and sagebrush. The mesquite, which rarely grows more than 2 or 3 feet above ground, catches and holds the drifting sand, growing above the sand as it accumulates and anchoring it in place, thus forming innumerable small mesquite-covered dunes 4 to 5 feet high. (See pl. 3, *A*.) The soil in the depressions is silty or clayey, but the westernmost depression, because it is the lowest and widest and is subject to inundation by storm waters from the mountains during exceptionally heavy rains, shows the widest area of clayey soil. This soil supports a growth of grasses and low brush, mainly creosotebush. Except near their outer margins, the alluvial slopes of the Franklins and the Huecos are covered with gravel, which according to available well records and to the geophysical explorations carried on during the investigation extends to a depth of several hundred feet. This gravel supports a sparse vegetation of desert plants, including creosotebush, lechuguilla and varieties of yucca and of cactus.

TULAROSA BASIN

The Tularosa Basin, which is the northward extension of the Hueco bolson (pl. 1), has been described in considerable detail by Meinzer.[16]

LA MESA

West of the Franklin Mountains is another broad plain called La Mesa,[17] similar in general appearance to the Hueco bolson, which extends as a nearly unbroken surface from Las Cruces southward into Mexico and is bounded on the west by the Potrillo Mountains and on the east and north by the valley of the Rio Grande (Mesilla Valley). This plain, which originally extended northward from Las Cruces for about 100 miles and eastward to the Franklin Mountains, has since its formation been divided by the Rio Grande into a northern part known as the Jornado del Muerto, a southern part known as La Mesa, and an eastern part consisting of a dissected pediment about 350 feet above the river on the flanks of the Franklin Mountains. The surface of La Mesa

[15] Carter and others, Soil survey (reconnaissance) of the Trans-Pecos area, Texas: U. S Dept. of Agriculture, Bureau of Chemistry and Soils, series 1928 no. 35, pp. 27–28, 1928.
[16] Meinzer, O. E., and Hare, R. F., op. cit. (Water-Supply Paper 343), p. 13.
[17] Lee, W. T., Water resources of the Rio Grande Valley in New Mexico and their development: U. S. Geol. Survey Water-Supply Paper 188, pp. 9–11, 1907.

is nearly level and has practically no drainage lines except the short, steep-sided arroyos near the Rio Grande, but, like the Hueco bolson, it has a number of elongate, shallow depressions, which may be of structural origin. The surface of La Mesa also is marked by several circular craters, such as Kilbourne Hole, 1 to 2 miles in diameter and one hundred to several hundred feet deep, which, according to Darton,[18] were probably caused by a volcanic explosion. The altitude of the surface of La Mesa near Las Cruces is about 4,250 feet above mean sea level, which is the same as that of the southern part of the Jornado del Muerto. From Las Cruces the surface slopes gently toward the south and at the international boundary its altitude is about 4,100 feet. The slope continues south of the international boundary, without perceptible break, into the lake region of northern Chihuahua.

The surface of the northern part of La Mesa is covered chiefly with gravel, except in the vicinity of Afton, N. Mex., where there are several large areas covered by recent lava. Toward the south it becomes more sandy and near the International Boundary there is an area of migrating sand dunes, extending from several miles north of the boundary southward into Chihuahua, Mexico, a distance of 50 or 60 miles. South of Samalayuca, along the west side of the Sierra del Presidio, individual dunes attain a height of 200 to 300 feet and the dune area is 20 to 30 miles wide from east to west.

The materials underlying the La Mesa area are similar to those underlying the Hueco bolson, consisting of unconsolidated sand, clay and gravel. They have not been thoroughly explored, but in some places they are known to have a thickness of more than 1,000 feet.

LAKE REGION OF MEXICO

South of the international boundary, on the lowest parts of the surface of La Mesa are a number of lakes and lake beds. These are Laguna Palomas, 5 miles south of Columbus, N. Mex.; Laguna Tildio, about 25 miles southeast of Columbus; Laguna Guzman, 30 miles south of Columbus; Laguna Santa Maria, about 45 miles south of Columbus; the Barreal, an ancient lake bed about 50 miles southeast of Columbus; Laguna Federico, about 60 miles southwest of Columbus; and Laguna de los Patos, about 65 miles south of Ciudad Juarez. All except Laguna Federico lie near the southern margin of La Mesa. Laguna Federico is about 20 miles west of La Mesa and is separated from it by mountains.

The maximum extent of Laguna Guzman (see pl. 4, *A*) is about 16 miles from north to south and 5 to 7 miles from east to west.[19] It is 3,920 feet above mean sea level or about 220 feet above the Rio Grande at El Paso. The lake forms the terminus of Rio Casas Grandes (Rio Fusiles), which rises in the Sierra Madre Occidental to the west. Although normally a sizable lake, it was nearly dry in September 1935 and has been dry several times within the memory of residents living in the area. (See pls. 1 and 3, *B*.) It is reported that the use of water for irrigation from the Rio Casas Grandes and its tributaries has increased materially since the revolution, and this probably has played

[18] Darton, N. H., Guidebook of the Western United States: U. S. Geol. Survey Bull. 845, p. 134, 1933.
[19] Brand, D. D., The natural landscapes of northwestern Chihuahua: New Mexico Univ. Bull., vol. 5, no. 2, p. 70, 1937.

an important part in causing the present low stage of the lake. The wave-cut terraces north of the present lake and the wave-cut cliffs about 30 feet high on the west side of the lake indicate that it was formerly much larger and deeper than at present.

Laguna Santa Maria, which is 16 miles long in maximum extent and from 2 to 5 miles wide,[20] has an altitude of 3,820 feet above mean sea level or about 120 feet above the Rio Grande at El Paso. The lake is the terminus of Rio Santa Maria which rises in the mountains to the south. It was dry when visited in 1935 and, according to Brand,[21] even in normal years it probably is dry most of the year except for some pools around the springs at the lower end of the delta of the river. As in the case of Laguna Guzman, irrigation in the headwaters of the tributary stream may be partly responsible for the present low level of the lake. Brand says, "Former highwater marks along the northwestern shore indicate occasional rises of many feet, at times even to the covering of the springs which are now surrounded by vigorous growths of grama and other grasses." The ancient shore lines indicate that the lake was formerly much larger. It may have extended southeastward and included the Barreal, but it is now hemmed in on the west and east by lava and limestone hills, and on the north a great mass of lava (Sierra Malpais de la Laguna) shuts off a probable former connection with Laguna Guzman.

Laguna de los Patos has a maximum extent of about 8 miles north and south and about 3 miles east and west. It has an altitude of about 2,870 feet above mean sea level or about 170 feet above the Rio Grande at El Paso. It is fed by Rio Carmen, which rises in the mountains south of the lake, and by a number of springs, which emerge from the dunes that surround the lake. The water from most of the springs is somewhat mineralized, but it supports a growth of vegetation that includes grasses, tules, cattail, and cottonwoods. The lake was nearly dry when visited in 1935, but according to Brand[22] it was a permanent lake up to 1925 and is reported to have contained carp (?) and other fishes.

Laguna Palomas is a small lake or series of lakes fed chiefly by water from the Las Palomas spring. It is the terminus of the drainage basins of Las Palomas Arroyo and Mimbres River. These streams lose their water and become dry far upstream from the lake. Darton[23] reports that the flow of the Mimbres River generally does not extend far beyond Deming, N. Mex., but that occasionally it flows into a shallow lake in the wide valley east of the Florida and west of the Potrillo Mountains, and that for short periods in 1904, 1905, and 1906 the Mimbres flowed nearly to the Mexican boundary for the only time in 18 years. "In recent geologic time, however, it flowed through this valley and out into Palomas Lakes and other basins in Mexico." Palomas Arroyo empties directly into Laguna Palomas, "but ordinarily the flood waters even of cloud-bursts mostly sink in the porous bolson soil." Brand[24] states that at extreme flood periods the main Mimbres channel is near Arena, 14 miles east of Columbus, which would indicate that the Mimbres formerly flowed into Laguna Tildio. At present the

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[20] Brand, D. D., op. cit., p. 63.
[21] Brand, D. D., op. cit., p. 64.
[22] Brand, D. D., op. cit., p. 60.
[23] Darton, N. H., Geology and underground water of Luna County, N. Mex.: U. S. Geol. Survey Bull. 618, pp. 14, 111–112, 1916.
[24] Brand, D. D., op. cit., p. 71.

water from Laguna Palomas is conveyed by two canals to Laguna Tildio, 30 miles distant. As indicated by Brand, the Tildio Basin is about 12 miles broad and may extend from the bluffs north of Tildio tanks to the Barreal, a distance of about 40 miles. Southeast of Lake Guzman, some 10 miles northwest of the station of the National Railways of Mexico, Los Medanos (the sand dunes), and east of Lake Santa Maria, is the Barreal, a large level area, many miles across, of shiny-crusted clayey soil supporting almost no vegetation, presumably because alkaline ground water lies within a few inches of the surface. It is surrounded by wave-cut cliffs some 20 to 30 feet high. Since these cliffs are cut both in unconsolidated deposits and in igneous and metamorphosed rock, this area is without doubt the bed of a lake that formerly existed for a considerable period.

Springs are numerous in the lake region of Mexico. Las Palomas spring, which Brand considers to be fed by the underflow of the Arroyo Palomas, had a discharge of about three second-feet when visited in 1935. Carrizal Springs about 26 miles southwest of Villa Ahumada have a flow of several second-feet. Federico Springs southwest of La Ascension largely maintain the water level in Laguna Federico. Several springs in the vicinity of Samalayuca have a combined flow of several second-feet. In addition, there are large numbers of springs of varying sizes that were reported by local residents, but not visited by the writers. The water of the springs ranges in temperature from cool to hot, the hottest water recorded being 186° F.[25] in the Ojo Diablo at the Ojos Calientes de Santo Domingo. The water also varies widely in chemical character. Water from San Jose spring near Laguna de Los Patos had a total hardness of 36 and contained 208 parts per million of chloride. A sample of water from the deep artesian well at Villa Ahumada had a total hardness of 270 and contained 1,550 parts per million of chloride. A dug well at Samalayuca yielded water that had a hardness of 232 and contained 34 parts per million of chloride. The presence of the large number of springs in the lakes region of Mexico suggests that ground water is rather abundant and in general may be encountered at relatively shallow depths. However, although much of the water is of excellent quality, some of it is highly mineralized and would not be suitable for many purposes.

RIO GRANDE VALLEY

The flow of the Rio Grande in the upper half of its course is derived from a few normally small, permanent streams and from torrential rains that occur chiefly in the summer. Since no permanent streams enter the valley in the stretch between the Rio Puerco, about 200 miles above El Paso, and Fort Quitman, 90 miles below El Paso, the perennial flow of the river in this stretch is dependent upon the discharge at the mouth of the Rio Puerco. Before the construction of Elephant Butte Dam, about 125 miles above El Paso, this discharge was frequently insufficient, because of infiltration and evaporation losses, to maintain a flow in the vicinity of El Paso, and the river bed was often dry for months at a time. The river was subject to great and sudden floods, because the rainfall in the region occurs principally in the form of violent storms or cloudbursts.[26]

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[25] Brand, D. D., op. cit., p. 73.

[26] Lee, W. T., Water resources of the Rio Grande Valley in New Mexico and their development: U. S. Geol. Survey Water-Supply Paper 188, p. 1, 1907.

Since Elephant Butte Dam was constructed, it has served to store the waters of floods and the greater-than-normal discharge that usually results during spring from the melting of snow in the mountains. The stored water is allowed to enter the stream below the dam and a more or less constant flow is maintained at El Paso. However, violent rainstorms, which occur downstream from the dam, still cause more or less destructive floods.

The course of the Rio Grande has been described by Lee[27] and Bryan.[28] The river rises in the mountains of Colorado and flows alternately through a succession of broad basins filled with unconsolidated deposits and through narrow rock-walled canyons. From its headwaters and through New Mexico its course is essentially parallel to the north-south-trending mountains. A few miles northwest of El Paso its course becomes southeasterly and it cuts across the mountains through a narrow gorge and across the Hueco bolson to Fort Quitman, where it commences the great semicircular detour known as the Big Bend.

MESILLA VALLEY

From old Fort Selden, the Rio Grande flows for about 60 miles south, nearly to El Paso, in a flat-bottomed, steep-walled valley 5 or 6 miles wide and 350 feet deep that is cut along the east side of La Mesa. This valley is known as the Mesilla Valley. Its wide flood plain has been irrigated with water from the river since the early Spanish colonization, when, because of uncertainties in the flow of the river, the water supply for irrigation was more or less uncertain. With the construction of Elephant Butte Dam, a dependable supply of water has become available, and the valley has become a rich agricultural area.

Dunham[29] has recognized four erosion surfaces or former levels of the Rio Grande in Dona Ana County, as given below, the first two of which were also recognized by Lee.[30]

(1) The uppermost erosion surface, 700 feet above the level of the present Rio Grande, represented by a small area south of the Sierra de Las Uvas and west of Robledo.

(2) The Jornado-La Mesa surface, about 350 feet above the river and extending from San Marcial, N. Mex., through the Jornado del Muerto and thence southward across La Mesa into Mexico.

(3) The Picacho surface 100 feet above the river and well developed around the base of El Picacho Peak.

(4) The present river plain.

At the lower end of the Mesilla Valley the river turns abruptly southeastward into the El Paso Canyon, a gorge, 3 to 4 miles long that is cut through the limestones, shales, and deformed gravels between Cerro de Muleros and the Franklin Mountains. In this stretch the canyon is about one-quarter of a mile wide and about 300 feet deep. On the south side there is a bench about 200 feet above the river that appears to be an old erosion surface cut in solid rock. Lee[31] referred to rock terraces at the same altitude as the surface of La Mesa, but the writer observed no well-developed terraces at this altitude, although

[27] Lee, W. T., op. cit., p. 11.

[28] Bryan, Kirk, The geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Regional Planning, pt. 6, vol. 1, pt. 2, sec. 1, pp. 198–201, Nat. Resources Comm., 1938.

[29] Dunham, K. C., Geology of the Organ Mountains. New Mexico School of Mines Bureau of Mines and Mineral Resources, Bull. 11, pp. 178–181, 1935 (1936).

[30] Lee, W. T., op. cit. (Water-Supply Paper 188), pp. 11 and 12.

[31] Lee, W. T., op. cit. (Water-Supply Paper 188), p. 15.

there appeared to be small remnants of a 4,100-foot bench 350 feet above the river.

EL PASO VALLEY

Emerging from the El Paso Canyon the river enters the El Paso Valley, also called the Lower Valley, which is cut diagonally across the Hueco bolson to Fort Quitman about 90 miles below El Paso. The El Paso Valley is similar to the Mesilla Valley in form, but whereas the Mesilla Valley has a nearly uniform depth, the El Paso Valley becomes deeper downstream. Near El Paso it is a little over 200 feet deep and near Fabens, 30 miles below El Paso, it is about 330 feet deep. The El Paso Valley is about 6 to 8 miles wide and has a flood plain 4 to 5 miles wide, from which the sides of the valley rise rather steeply to the foot of an abrupt escarpment called the Valley Wall, Rock Rim, or Mesa Rim, which is perhaps 75 feet high, the last 10 to 40 feet being nearly perpendicular in many places because of the resistance to erosion of a layer of white caliche 2 to 6 feet thick that occurs 2 or 3 feet below the sandy surface of the bolson. The valley wall is quite sinuous because of the presence of the many dry washes or gulleys that extend from a few hundred feet to a mile or more into the bolson; one of these, San Felipe Draw, extends into the bolson nearly 5 miles.

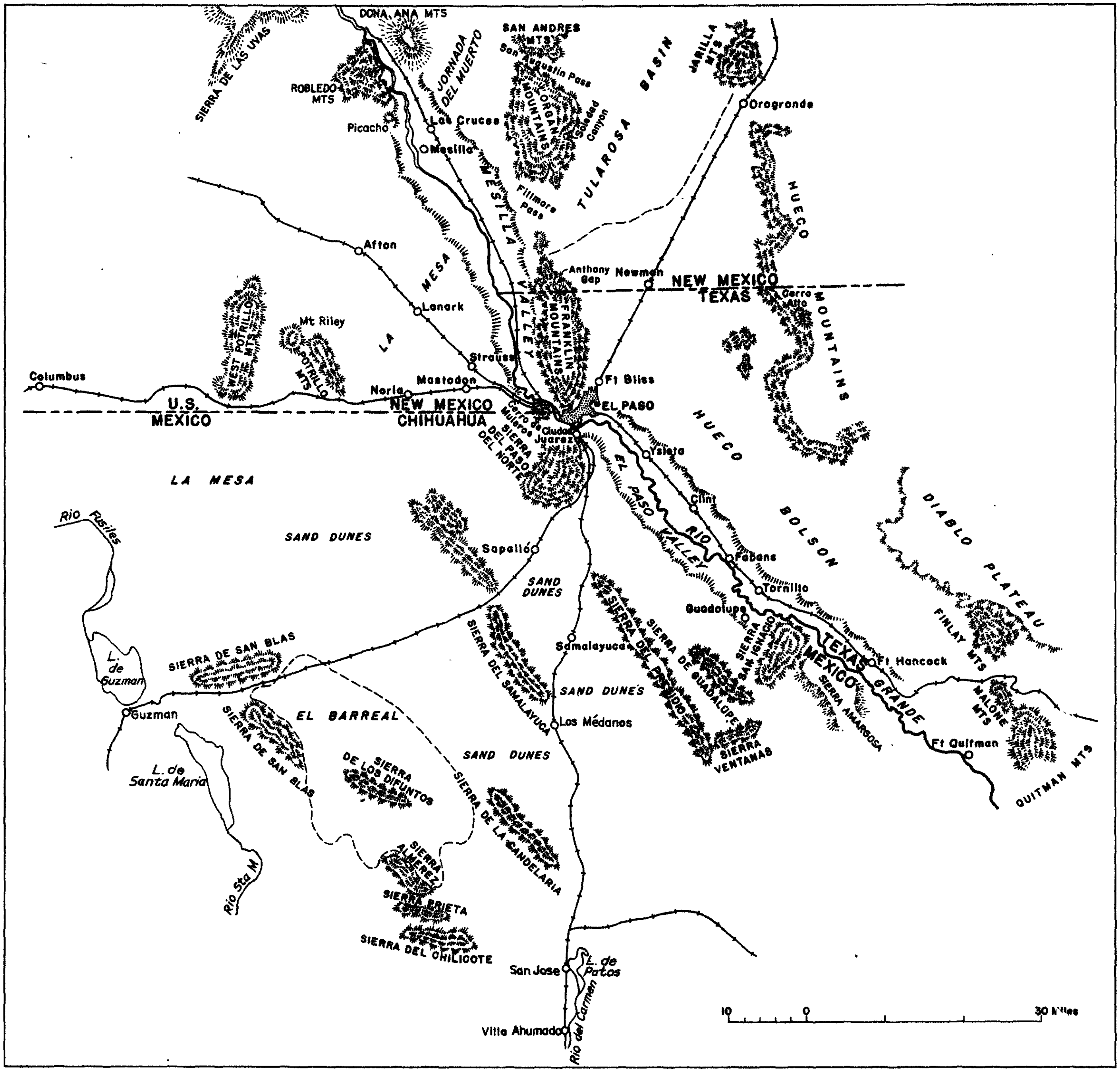
According to Bryan,[32] Daingerfield has distinguished two rather poorly developed erosion surfaces, which reach the river less than 100 feet above its level, and a terrace about 20 feet above the river. Although in most parts of the valley erosion surfaces and terraces are poorly preserved, because of the nonresistant character of the bolson deposits, near Fort Quitman they are better preserved, and there appears to be a rather well-developed surface on the Mexican side of the river about 200 to 250 feet above the river level.

MOUNTAINS

Organ Mountains.—The Organ Mountains form a part of the long chain of tilted mountains that extends from the southern end of the Rocky Mountain chain in North Central New Mexico to the Rio Grande. From San Augustine Pass, which has an altitude of 6,500 feet these mountains extend southward for about 17 miles to Fillmore Pass, altitude 4,250 feet.[33] The maximum width is about 9 miles. The range is composed largely of crystalline intrusive and extrusive igneous rocks with smaller amounts of limestones, shales, and sandstones.[34] Most of the sedimentary rocks are on the west side of the range dipping westward. The east side is more precipitous than the west side and is composed dominantly of igneous rock, suggesting that the topographic form is due to faulting accompanied by tilting. Although the lower slopes of the Organs are almost barren of vegetation, the upper slopes support a more or less scattered growth of pines and juniper, presumably because the mountain tops, having an altitude of about 9,000 feet, receive more precipitation than do the lower slopes.

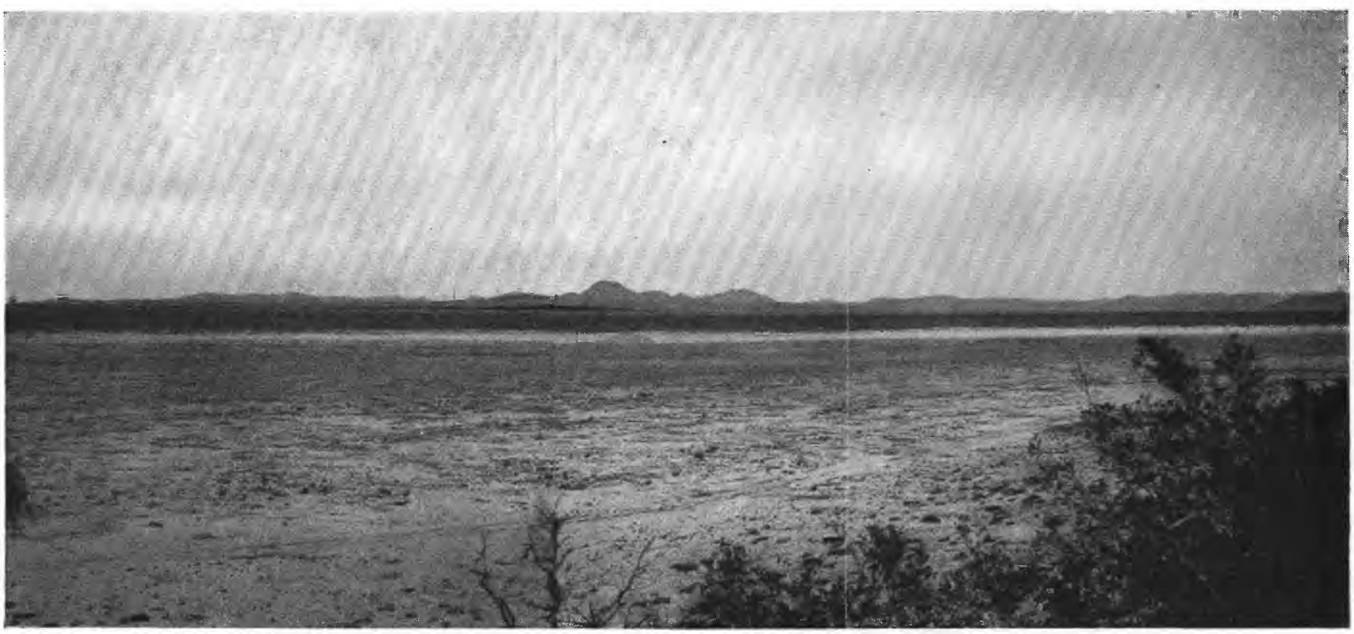
Franklin Mountains.—The Franklin Mountains are a narrow range of faulted and tilted sedimentary and igneous rocks, extending in a line

[32] Bryan, Kirk, op. cit., pp. 45–46.
[33] Meinzer, O. E., and Hare, R. G., Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, pp. 30–31, 1915.
[34] Lindgren, W., The ore deposits of New Mexico: U. S. Geol. Survey, Professional Paper 68, pp. 208–209, 1910. Dunham, K. C., op. cit., pp. 28–110.



GENERAL MAP OF THE EL PASO AREA

A. SAND DUNE FORMED BY ACCUMULATION OF WIND-BLOWN SAND AROUND BRUSHY MESQUITE TREE, HUECO BOLSON



B. PANORAMA LOOKING EAST FROM NEAR GUZMAN STATION, CHIHUAHUA, MEXICO.
View across dry floor of Lake Guzman. Sierra de San Blas in the background.

slightly east of south from Fillmore Pass, at the south end of the Organ Mountains a few miles north of the New Mexico State line, to the Río Grande at El Paso.

The highest peak in the Franklin range is Mount Franklin, which has an altitude of 7,149 feet. The range is about 3 miles wide and 15 miles long and is asymmetrical, having a steep east slope and a somewhat gentler west slope. The east slope is formed by the eroded edges of the formations composing the mountains, whereas the west slope is essentially a dip slope, the formations formerly present having been stripped off rather than incised. On the other hand, erosion has carved long deep canyons, partly gravel filled, into the east slope separating it into a series of transverse ridges, and in the northern part this process has gone so far as to cut nearly through the range, forming the comparatively low pass known as Anthony Gap. Along the east slope the formations composing the mountains are well exposed, giving a banded appearance that is accentuated in the southern part of the range by a 5-foot bed of white argillaceous quartzite, which is visible for several miles. Practically no soil is present on the mountains except in joint cracks, and vegetation is limited to scattered growths of sotol, yucca, lechuguilla, and several varieties of cactus.

Cerro de Muleros.—Cerro de Muleros is a more or less circular group of hills, the highest peak of which is called Rodadero Peak or Sierra del Cristo Rey, about eight hundred feet high. This group is about 4 miles west of the south end of the Franklin Mountains and about 3 miles north of the Sierra del Paso del Norte. The international boundary passes near the center of the hills, which are composed of a central core of monzonite or diorite porphyry,[35] surrounded by Cretaceous limestones and shales dipping away from the flanks of the igneous core. These hills are separated from the Franklins by an area of andesite porphyry and a rather narrow belt of high-level, unconsolidated sediments and from the Sierro del Paso del Norte by a high pass about 3 miles wide underlain by unconsolidated sediments. They were described by Bose[36] who ascribed their formation to the intrusion of the igneous rocks into the sedimentary rocks, forming a dome-shaped hill, which has been reduced by erosion to a series of concentric hills.

Sierra del Paso del Norte.—Sierra del Paso del Norte, southwest of Ciudad Juarez, consists of three parallel ranges of closely folded Cretaceous rocks, mostly dense limestones of Trinity age. The folding occurs along a northwest-southeast axis that cuts rather sharply across the trend of the Franklin and Organ ranges. The highest peak is about 5,500 feet above sea level. The mountains are separated from the Cerro de Muleros by a debris-filled pass about 3 miles wide, which has an altitude of about 4,250 feet near the Sierra del Paso del Norte but which is somewhat lower near Cerro de Muleros. They are separated from Sierra del Presidio on the south by a debris-filled pass perhaps 5 miles wide, which also has an altitude of about 4,250 feet, and, like the Franklins, they are bare of vegetation.

Sierra del Presidio and Sierra de Guadalupe.—Sierra del Presidio, a long, narrow range of folded Lower Cretaceous limestones trending northwest-southeast, is formed near its northwestern end by the southwestern limb of a plunging anticline, the northeastern limb having been

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[35] Dunham, K. C., op. cit. (New Mexico School of Mines Bull. 11), p. 172.

[36] Bose, Emil, Monografia Geologica y paleontologica del Cerro de Muleros: Inst. Geol. de México Bol. 25, p. 15, 1910.

destroyed by erosion or displaced by faulting. Toward the southeast the northeast limb of the anticline is more prominent and is entirely present near Sierra de Guadalupe, from which it is separated by a syncline. Sierra de Guadalupe is another anticlinal structure, apparently genetically closely related to the Sierra del Presidio, which appears slightly higher than the Sierra del Paso del Norte and higher than the Sierra de Guadalupe.

Sierra de San Ignacio.—The Sierra de San Ignacio, at the south end of the El Paso Valley on the Mexican side of the river, is separated from Sierra de Guadalupe by a rather narrow debris-filled pass, which has an altitude of about 4,250 feet. Like the mountains discussed above it is folded narrowly along a northwest-southeast axis and is almost entirely barren of vegetation.

Quitman and Malone Mountains.—On the Texas side of the Rio Grande the Quitman Mountains rise from the north side of a narrow gorge through which the Rio Grande flows out of the El Paso Valley. The Quitman and the Malone Mountains, like the above-mentioned mountains in Mexico, are a part of the western branch of the Sierra Madre Oriental[37] which, in general, have a northwesterly trend. The mountains are closely folded, of moderate height and barren of vegetation. The Quitmans are composed largely of Cretaceous rock with a large area of Tertiary intrusive rocks at the northwestern end of the range, and the Malones consist largely of Jurassic rocks.

Finlay and Hueco Mountains.—A line of broad arches extends northwestward from the end of the Quitman Mountains into New Mexico. North of the Texas Pacific R.R. this arch has been dissected into a group of hills known as the Finlay Mountains, which form the western boundary of the Diablo Plateau in this area. North of the Finlay Mountains a 500-foot west-facing escarpment of Cretaceous rocks forms the western boundary of the plateau for a distance of 20 miles,[38] and still farther north the Hueco Mountains form the boundary. The Huecos are 5 to 8 miles wide and about 25 miles long. They consist of a more or less regular, west-facing escarpment, 1,000 feet or more in height, which forms the western boundary of the Diablo Plateau, and a group of outlying hills, which are in part the dissected remnants of the anticline mentioned above. The Finlay Mountains are composed principally of Lower Cretaceous and Upper Carboniferous rocks. The northern part of the Huecos is composed chiefly of Carboniferous limestones, the southern part is composed of older Paleozoic rocks and pre-Cambrian rocks. The areas between the main escarpment of the mountains and the outlying hills are partly filled with unconsolidated debris from the mountains. Local intrusive masses, such as the body of syenite porphyry at Hueco Tanks, are intruded into sediments or rise out of the flat surface of the debris-filled basins. Cerro Alto, which rises above the general level of the top of the Hueco Mountains is an excellent example of such an igneous mass.

Jarilla Mountains.—The Jarilla Mountains, a group of low hills about 3 miles north of the north end of the Hueco Mountains, rise directly from the bolson to a height of about 600 feet and are surrounded on all sides by unconsolidated deposits of sand and clay. They are composed of Carboniferous limestones domed upward by the intru-

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[37] King, P. B., Outline of the structural development of Trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., vol. 19, p. 244, 1935.

[38] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (no. 166), p. 1, 1909.

sion of a mass of monzonite porphyry.[39] The flat debris-filled pass that separates them from the Huecos has an altitude of about 4,100 feet.

GEOLOGY

For the purpose of this report the rocks of the El Paso area may be divided into two general groups differentiated by their water-bearing capacity. These are the unconsolidated deposits of the intermontane areas, including bolson deposits and river alluvium, and the consolidated rocks, both sedimentary and igneous, of the mountain and upland areas. The unconsolidated deposits are the more important in relation to water supplies, because they contain beds of sand and gravel that supply water to wells. The consolidated rocks are in general too firmly cemented to contain much water, and in the few instances in which they supply water to wells the water is highly mineralized. However, since the products of the weathering and erosion of the consolidated rocks have been redeposited as unconsolidated rocks, the character and distribution of the consolidated rocks have a direct bearing upon the occurrence of ground water in the area.

In 1909 Richardson[40] published an excellent description of the geology of the El Paso quadrangle, which includes much of the Hueco Mountains, the Hueco bolson and the Franklin Mountains south of the State boundary. In 1915, Meinzer[41] published a report on the water supply of the Tularosa Basin, including brief descriptions of the geology. More recently, Dunham[42] published a monumental treatise on the geology of the Organ Mountains and the geology and mineral resources of Dona Ana County, and Nelson[43] has made important additions to our knowledge of the stratigraphy of the Franklin Mountains. These reports, and brief discussions of the area contained in other papers, supplemented by the writer's observations, have served as the chief sources of material for the following statement on the geology of the consolidated rocks. These rocks consist of granites, porphyries, quartzites, limestones, shales, and sandstones.

GRANITES

The term granite is here used not in the strictly petrographic sense, but more broadly, more inclusively, to include all plutonic intrusive rocks low in ferromagnesian minerals. Granitic rocks are exposed in relatively large areas in the Franklin Mountains, in most of the Organ Mountains, and in isolated areas in the southern part of the Hueco Mountains.

In the Franklin Mountains the largest area of granite is near the middle of the range, but relatively narrow outcrops occur along most of the east flank of the mountains, in general near the base. The granite is predominantly red in color and consists chiefly of coarse grains of quartz and feldspar. Richardson[44] states that the granite

[39] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., Ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 185, 1910.

[40] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (no. 166), 1908.

[41] Meinzer, O. E., and Hare, R. F., Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, 1915.

[42] Dunham, K. C., Geology of the Organ Mountains: New Mexico School of Mines, Bur. Mines and Mineral Resources, Bull. 11, 1935 (1936).

[43] Nelson, L. A., Paleozoic stratigraphy of Franklin Mountains, West Texas: Am. Assoc. Petroleum Geologists Bull., vol. 24, pp. 157–172, 1940.

[44] Richardson, G. B., op. cit. (Geol. Atlas, no. 166), pp. 6–7.

cuts through all the Paleozoic strata and that it is therefore, in part at least, of post-Carboniferous age. He suggests, however, that a part of it may be pre-Cambrian. Near the southern limit of the granite outcrop the writer found Ordovician (Bliss) sandstone, which contained pebbles of granite, lying on an eroded granite surface. According to King,[45] J. G. Barry reported that the granites in the northern part of the range are post-Carboniferous while those in the southern part are pre-Cambrian. By analogy it seems likely that the post-Carboniferous granite was probably intruded at the same time in the Franklins as in the Organs and therefore is mid-Tertiary in age.

In the Organ Mountains coarse-grained red granite with large phenocrysts of feldspar occurs in comparatively small areas on the east side of the range near its south end, again near the middle, and in a large area just north of San Augustine Pass at the south end of the San Andreas range. A complex mass of granitic rocks, chiefly quartz monzonite, underlies the central part of the range and comprises a considerable part of the bedrock there. Several of the early writers considered the granites in the Organs pre-Cambrian in age, but Lindgren[46] demonstrated that some of them were intruded into limestones and shales of Carboniferous age and are therefore post-Carboniferous.

Dunham[47] has demonstrated that the red coarse-grained, porphyritic granite that occurs near the southern end of the Organs is pre-Cambrian in age, whereas the complex of granitic rocks, monzonites, composing the central part of the range is Tertiary, probably middle Tertiary, in age.

At the south end of the Huecos, red granite lies unconformably below the Bliss sandstone.[48] Therefore the granite is pre-Cambrian.

Granite weathers readily into clay and grains of quartz, in proportion depending upon the composition of the granite, but when eroded so rapidly that weathering is not complete, it breaks down into arkosic sands and gravels. Because the granites of the Franklins and the Organs cover large areas and have been subjected to considerable erosion, it seems likely that they have contributed largely to the sands, gravels, and clays of the bolson deposits.

PORPHYRIES

The porphyries, like the granites, are solidified molten magma, but whereas the granite solidified at great depth, forming coarsely crystalline rocks, the porphyries solidified near or at the surface, forming a dense groundmass of microscopic or nearly microscopic crystals in which are embedded some crystals of large size, called phenocrysts.

Four types of porphyries occur in the El Paso area. Rhyolite porphyry, which occupies a large area in the central part of the Franklin Range, outcrops in the lower part of the east flank of the mountains and also forms the highest peak of the range. This porphyry is a pink to maroon, in places black, rock consisting of phenocrysts of feldspar and quartz up to 15 millimeters in diameter set in a dense, fine-grained

[45] King, P. B., Outline of the structural development of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull. vol. 19, no. 2, p. 227, 1935.
[46] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., Ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 205–207, 1910.
[47] Dunham, K. C., op. cit., pp. 28–39, 60–89.
[48] King, P. B., Outline of the structural development of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 2, p. 227, 1935.

matrix. Near the base of the porphyry is a variable thickness of agglomerate containing pebbles of quartzite and rhyolite, and throughout the rest of the formation the matrix and phenocrysts make up about equal percentages of the rock. The rhyolite porphyry was extruded as great lava flows during pre-Cambrian time and has a total thickness of about 1,500 feet.

The andesite porphyry, which crops out in the area west of the south end of the Franklin Mountains in the vicinity of the smelter and the College of Mines, is yellowish gray and consists of phenocrysts of feldspar and biotite mica, in size up to 5 millimeters in diameter, embedded in a microcrystalline groundmass consisting chiefly of feldspar, biotite, and some quartz. It is one of the youngest igneous rocks in the area and was intruded presumably during the time of mountain-building activity in Middle Tertiary time before the bolson deposits were formed. The Cretaceous sediments into which it was intruded are tilted to a nearly vertical position in places, while the surrounding bolson deposits are undisturbed.

Diorite porphyry, which occurs in Cerro de Muleros about a mile southwest of the smelter and forms the central part of those hills, is probably also of Middle Tertiary age.[49]

Syenite porphyry occurs in several hills near the base of the Hueco Mountains in the vicinity of Hueco Tanks, the two largest masses of the rock having a combined area of less than 2 square miles. Cerro Alto on the crest of the Huecos and the Cornudas mountains to the east of the area also are composed principally of this rock. This porphyry consists principally of white to light-colored feldspar with subordinate amounts of biotite and augite and contains phenocrysts of feldspar and biotite, in size up to 5 millimeters in diameter, in a granular groundmass of feldspar, biotite, and augite. The rock is light gray on fresh surfaces but weathers to brownish. It weathers readily and breaks down into clay so completely that even at the base of the syenite masses there are only small areas of rock fragments. Weathering proceeds at irregular rates (pl. 4, *B*) resulting at Hueco Tanks in deep hollows in the rock that hold rain water. For this reason Hueco Tanks has been a watering place for travelers since time immemorial as is attested by the hieroglyphics left by the Indians and the dates and initials left by early white travelers. Some of these basins have been artificially enlarged by white settlers who constructed dams across the outlets. (See pl. 5, *A*.) The syenite porphyry is known to be post-Carboniferous. Since similar rocks in the Cornudas Mountains are intruded into Cretaceous beds and are therefore post-Cretaceous, it is believed that the rocks in question are probably post-Cretaceous.

OTHER IGNEOUS ROCKS

Dunham[50] described a thick series of feldspathic lava flows, tuffs, agglomerates, and associated shallow intrusives of Tertiary age in the Organ Mountains and in other parts of Dona Ana County. The thickest and best known series occurs in the Organ Mountains, but thick flows of feldspathic lava and intrusions of syenite porphyry occur in the Dona Ana Mountains, and lava flows occur in the Mount Riley section and in the Sierra de las Uvas. These are correlated with Tertiary

[49] Dunham, K. C., op. cit. (New Mexico School of Mines Bull. 11), p. 172.
[50] Dunham, K. C., op. cit. pp. 51–60, 169–174.

volcanic activity in other parts of New Mexico. Basaltic lavas cover large areas in the West Potrillo Mountains and in the Sierra de las Uvas. In the vicinity of Afton these are clearly seen to overlie the thick series of unconsolidated sediments filling the La Mesa Basin, and their extrusion is therefore believed to be quite recent. There also are several volcanic cones. (See pl. 5, *B*.)

The basalts and the porphyries, with the exception of the syenite porphyry, do not weather readily but are likely to fracture and break down into angular pebbles and boulders suitable for transportation by storm waters. Therefore, they serve as excellent source materials for the coarse sand and gravel deposits of the bolsons. Since each of the porphyries has a characteristic appearance, it is easily recognized even when reduced to rounded pebbles and cobbles. The porphyries constitute a sizable proportion of the clastic sediments in the Hueco bolson and are among the most common constituents of the beds of sand and gravel. Basalt fragments are a prominent constituent of the sands in the La Mesa Basin, but are found only occasionally in the sands of the Hueco bolson.

CONSOLIDATED SEDIMENTARY ROCKS

PRE-CAMBRIAN SYSTEM

Lanoria quartzite.—The oldest rock in the El Paso area, with the possible exception of schists and gneisses reported by Dunham,[51] is the Lanoria quartzite,[52] which crops out along the east flank of the Franklin Mountains near the center of the range, the most extensive exposures being found near Fusselman Canyon. This quartzite, which is 1,800 feet thick, is a dense, thoroughly indurated, fine-grained, light- to dark-colored, but in general grayish quartzite occurring in alternately thick-bedded and thin-bedded layers. Because of its indurated character it weathers into pebbles and boulders, in general not so large as those from the rhyolite porphyry, but sufficiently large to furnish material for the sand and gravel beds of the bolson deposits.

ORDOVICIAN SYSTEM

Bliss sandstone.—The Bliss sandstone extends along the east flank of the Franklin Mountains, where usually it lies above the granite but in some places is found overlying the rhyolite porphyry. It also crops out in small areas in the southern part of the Hueco Mountains and along the east side of the Organ Mountains, where it overlies pre-Cambrian granite. Most authors have classed the Bliss sandstone as Upper Cambrian in age. However, the recent work of Dake Bridge and others indicates on paleontologic evidence that the formation should properly be classed as Lower Ordovician.[53] The Bliss, which varies in thickness from that of a knife edge to 300 feet, consists of more or less massive beds of fine-grained sand imbedded in a matrix sericite or kaolin. Near the base it is usually conglomeratic, and where it is in contact with the rhyolite porphyry it contains pebbles of that rock; near the top it is very fine-grained. In the northern part of the Franklin Mountains, where it has been intruded by post-Carboniferous granite, the sandstone

[51] Dunham, K. C., op. cit. (New Mexico School of Mines Bull. 11), pp. 28–39.
[52] Richardson, G. B., op. cit. (Geol. Atlas No. 166), p. 9.
[53] King, P. B., Older rocks of Van Horn Region, Tex.: Am. Assoc. Petroleum Geologists Bull. vol 24, pp. 153–156, 1940.

is quartzitic near the contact, but a few feet away it is only moderately indurated. In the extreme southern part of the range, where the sandstone overlies the pre-Cambrian granite, it is only moderately indurated throughout. The Bliss weathers into rather fine sand.

El Paso limestone.—Above the Bliss sandstone is a thick series of limestones ranging in age from Ordovician to Cretaceous. At the base of the section the El Paso limestone, consisting of 1,000 feet of dense blue magnesian limestone, massive in most places, but locally thin-bedded, overlies the Bliss apparently conformably. It crops out in the southern part of the Hueco Mountains; in the upper part of the east flank of the Franklin Mountains, except near the middle of the range, where it occupies the crest for a considerable distance; and along the east flank of the Organs near the south end of the range.

Montoya limestone.—Overlying the El Paso limestone disconformably is the Montoya limestone, which varies in thickness from about 200 to 400 feet. It is a dark to light-gray limestone, massive in most places and in part characterized by the presence of bands of chert a few inches thick. This limestone has a distribution similar to that of the El Paso limestone.

SILURIAN SYSTEM

Fusselman limestone.—The Fusselman limestone disconformably overlies the Montoya limestone. It is a massive-bedded, whitish to light-gray magnesian limestone, which caps the Franklin Mountains from near the State boundary and for about 5 miles southward and occurs near the top of the range at several places farther south. It also occurs in the southern part of the Hueco Mountains and along the east flank of the Organs near the south end. It has a total thickness of approximately 1,000 feet.

DEVONIAN SYSTEM

Canutillo formation.—Immediately overlying the Fusselman limestone in the Franklin Mountains is about 175 feet of sediments consisting of "Cherty limestone, light brown in color, * * * a thin bed of fossiliferous gray limestone, a thin bed of dense, almost black sandstone, which weathers brown; and about 40 feet of black fissile shale" to which Nelson[54] has given the name Canutillo formation. Beds of Devonian age were first reported in the Franklin Mountains by Darton,[55] who considered them to be Upper Devonian (Percha) in age, but Kirk has recently identified fossils from these beds as Middle Devonian.[56]

CARBONIFEROUS SYSTEM

The thick series of limestones with interbedded shales and sandstones having an aggregate thickness of more than 3,000 feet, which forms the upper part of the Paleozoic in the El Paso area, was considered by Richardson[57] to be of Pennsylvanian age and was called by him the Hueco limestone. In 1920 Beede[58] pointed out that the rocks originally

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[54] Nelson, L. A., Paleozoic stratigraphy of Franklin Mountains, West Texas: Am. Assoc Petroleum Geologists Bull., vol. 24, p. 164, 1940.

[55] Darton, N. H., Devonian strata in west Texas: Geol. Soc. America Bull. 40, pp. 116–117, 253, 1929.

[56] Nelson, L. A., Paleozoic stratigraphy of Franklin Mountains, West Texas: Am. Assoc. Petroleum Geologists Bull., vol. 24, pp. 157–172, 1940.

[57] Richardson, G. B., op. cit., p. 4.

[58] Beede, J. W., Notes on the geology and oil possibilities of the northern Diablo Plateau in Texas: Texas Univ. Bull. 1852, pp. 6–22, 1920.

mapped as Hueco in the Hueco Mountains actually included three divisions of different ages: A thick series of dark limestones of Permian age, which comprises the bedrock in the northern part of the mountains, a middle group of limestones and shales about 100 feet thick, which belongs to the Magdalena group of Pennsylvanian age, and a series called the Helms formation of Mississippian age, consisting of drab to buff platy limestone overlying clayey shale and totaling 400 to 600 feet in thickness. This conclusion was later supported by King and King.[59]

MISSISSIPPIAN SERIES

Helms formation.—This formation was named by Beede in 1920 for a peak in the Hueco Mountains, where it consists of about 500 feet of limestones and sandstones. In the Franklin Mountains, as reported by King,[60] the Helms formation has a thickness of about 500 feet and consists chiefly of thin-bedded, dark-colored limestone with an upper shale member.

PENNSYLVANIAN SERIES

Magdalena group.—The middle part of the Hueco limestone, as originally defined by Richardson, consists of about 1,600 to 1,800 feet of thin-bedded, dark-gray to black limestone with a few partings of shale and a few thin beds of conglomerate and sandstone. Nelson[61] has divided the group, from top to bottom, into the Bishop's Cap, the Berino, and the La Tuna members.

PERMIAN SYSTEM

Hueco limestone.—In 1934 King[62] restricted the term Hueco limestone to the upper part of the series so designated by Richardson, that is, to the rocks of Permian age. In the Franklin Mountains the exposed part of the Hueco consists of about 650 feet of dense, fine-grained, light-colored limestones. In the northern part of these mountains, the writers found chunks of gypsum, which may have originated in the Hueco. In the Hueco Mountains this formation consists of about 1,600 feet of dark-colored limestone.

CRETACEOUS SYSTEM

Above the Hueco limestone is a thick series of hard, dense, cherty, blue to gray, massive limestones of Lower Cretaceous (Trinity) age, which do not crop out in the Franklins but comprise most of the Finlay Mountains and underlie the Diablo Plateau to the east as well as a small area in the extreme southern part of the Huecos. These rocks make up practically the entire ranges of Sierra del Paso del Norte, Sierra del Presidio, and Sierra de Guadalupe in Mexico, where their thickness is not known but probably is measured in thousands of feet.

In the vicinity of the smelter, around the flanks of Cerro de Muleros, near the Union Station, at Stanton and Nevada Streets, and in scattered patches near the western base of the Franklins occurs a series of comparatively thin limestones and fissile to indurated shales of middle

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[59] King, P. B., and King, R. E., Stratigraphy of outcropping Carboniferous and Permian rocks of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., 13, no. 6, pp. 907–926, 1929.
[60] King, P. B., Notes on the Upper Mississippian Rocks in trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull. Vol. 18, pp. 1537–1543, 1934.
[61] Nelson, L. A., op. cit., pl. 166.
[62] King P. B., Permian stratigraphy of Texas: Geol. Soc. America Bull., vol. 45, pp. 697–798, 1934.

Lower Cretaceous to Upper Cretaceous age entirely surrounded by bolson deposits. Beyond the general statement that these beds overlie the massive limestones of Trinity age, no information is available regarding their relation to the older rocks. The paleontology of these strata has been described by Bose[63] and Stanton[64] and Darton.[65]

In general, limestones and shales weather to clay rather easily. When, as sometimes happens, limestone boulders are formed by rapid erosion they are quickly reduced to small fragments by the attrition incidental to transportation from the site of formation to the site of deposition. For this reason it is not to be expected that pebbles of limestone would form a considerable part of the bolson deposits, and, in fact, they are only occasionally found in the gravels and sands. The chert that occurs in the limestone is resistant both to weathering and erosion, and pebbles of chert are fairly common in the bolson deposits. The limestones have doubtless contributed materially to the clay beds of the bolson.

UNCONSOLIDATED SEDIMENTS

The unconsolidated deposits of the El Paso area include older slightly consolidated bolson deposits, which make up the great bulk of the clay, sand, and gravel partially filling the deep troughs between the various mountains; younger outwash deposits, which form a mantle over the older bolson deposits, probably mainly near the mountains; and river alluvium, which has been deposited within the valleys during successive periods of scour and fill. It seems likely that with sufficient study it would be possible to distinguish these different groups of sediments, but such a study has not been attempted during the present investigation. The unconsolidated deposits therefore will be considered as a unit in this report. However, the following descriptions of the unconsolidated materials apply mainly to the bolson deposits, because they are better exposed in the area and are the materials penetrated by the wells. In the El Paso Valley most of the wells probably penetrate river alluvium, but the depth of the alluvium is not known.

In general appearance the bolson deposits of the various basins are quite similar, but in detail there are important differences. Over a large part of the Tularosa Basin the sediments contain a considerable amount of gypsiferous and other soluble mineral matter and in most places the ground water is highly mineralized. In the Hueco bolson the sediments in many places contain nearly as much sand as clay, and the sand is composed of fragments of chert, granite and porphyry. In the La Mesa area the beds of sand contain a considerable proportion of basaltic fragments but little or no porphyritic material.

CHARACTER

As they are displayed in the walls of the valley of the Rio Grande and in well cuttings and cores, the bolson deposits consist of alternating layers of clay and sand or gravel ranging in thickness from that of a knife edge to nearly a hundred feet. Their lateral extent is not known,

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[63] Bose, Emil, Monografia Geologica y Paleontoligica del Cerro de Muleros: Inst. Geol. de México Bol. 25, 1910.

[64] Stanton, T. W. and Vaughan, T. W., Sections of the Cretaceous at El Paso, Tex. Am. Jour. Sci., 4th ser., vol. 1, pp. 21-26, 1896.

[65] Darton, N. H., Guidebook of the western United States: U. S. Geol. Survey Bull. 845, pp. 162-163, 1933.

but they probably extend from a few feet to several miles. In the Old Mesa field about 45 wells were drilled at intervals of 300 feet along two lines about 300 feet apart. (See inset, pl. 1.) Individual beds could not be correlated between more than two or three adjacent wells in this group. Plate 6 is a graphic representation of the logs of five wells in a line that starts in the Mesa field and ends in the Montana field. The lack of continuity of the sediments is clearly shown in this figure. On the other hand several of the beds encountered in the Montana field seem to be traceable for about half a mile, that is, entirely across the field.

Not only do the individual beds thicken and thin and pinch out from place to place, but the whole section may change within a short distance, and the percentage of sand and gravel may vary within wide limits. In well 78 (El Paso city well 11), 603 feet of sand and gravel was reported in a total depth of 758 feet. (See log, p. 102.) Thus the sand constituted about 79 percent of the total sediments penetrated by the drill. Although there is reason to question the accuracy of part of the log, it is apparent from the characteristics of the well that there was a considerable thickness of sand. In 1937 the city of El Paso had three wells, 78a, 78b, and 78c (test wells 4, 5, and 6), drilled about half a mile, three-quarters of a mile, and 1 mile north of well 78, respectively. In well 78a, which was 830 feet deep, there was 166 feet of sand, including pack sand, or 20 percent of the total thickness of sediments penetrated. (See log, p. 103.) In well 78b, which was 698 feet deep, there was 269 feet, or 38 percent of sand, and in well 78c, which was 800 feet deep, there was 217 feet of sand, or about 27 percent. The wells could have been developed to yield several hundred gallons a minute, but since yields comparable to that of well 78 (1,170 gallons a minute) were desired, it was not considered desirable to finish them as water wells. Since the above was written, another test well drilled 0.4 mile west of well 78a encountered 335 feet of sand from the surface to a depth of 800 feet, or 42 percent.

Caliche.—The presence of caliche nearly everywhere beneath the surface of the bolsons is of importance both geologically and economically. It provides excellent road material, within easy reach of the highways, and because of its resistance to erosion it forms the cap rock of the sharp wall-like side of the valley. It also may have a considerable effect upon the quantity of rainfall that percolates below the reach of the roots of plants. The caliche is a nearly continuous layer of hard, white calcium carbonate—with varying quantities of impurities—found commonly 2 to 4 feet beneath the surface of the bolsons (pls. 7, *B* and 7, *C*), but in places at the surface. It ranges in thickness commonly from 2 to 4 feet, but in some places it is absent and in others it is as much as 7 or 8 feet thick. The upper surface of the caliche is commonly undulating, and the contact between it and the overlying material, usually sandy silt, is sharp, but in places the caliche grades upward into the overlying material. The upper foot or two of caliche is commonly massive and nearly pure, but it grades downward into the underlying material, the lower contact in most places being quite indefinite. Most good exposures of the caliche show one or more pipelike columns of sand, which pass completely through and contain no nodules of caliche. (See pl. 8, *A*.) In the depressions of the bolson surface the caliche is commonly disturbed, fractured, and partly to completely absent, suggesting that the rain water concentrated in the depressions has caused the solution of that material. Because the caliche follows the surface more or less faithfully without regard to the bedding, it is apparent that it was deposited as a secondary deposit after the sand and clay.

No caliche was observed in the valleys. Near the mountains along the alluvial slopes, there is no continuous layer of caliche, but in places, as near the mouth of McKilligan Canyon, fairly large, lenticular masses of gravel are firmly cemented with calcium carbonate. In most places, however, calcium carbonate forms only a thin film over the pebbles and boulders.

Clay.—In the La Mesa area the clay is usually buff to gray and is commonly reported to contain more or less sand. In the Hueco bolson the beds of clay are, in general reddish to chocolate brown. Many of them apparently are quite pure and free from grit, others contain considerable sand, and some contain enough boulders and pebbles to cause the drill to "chatter" as it would in gravel; these have been mistaken for gravel beds by well drillers.

Sand and gravel.—The gravels for the most part are restricted to beds within a few hundred feet of the surface. In general, they do not extend far laterally and are not thick. Like the sands they are usually gray to salt-and-pepper colored, except where there is sufficient clay to impart to them a red color. Both the sands and the gravels generally are clean and free from cementing material, and in wells and banks they readily cave. In the Hueco bolson the sands and gravels are made up principally of quartz grains with fragments of quartzite, porphyry, and granite, but only rarely is basaltic lava observed. In La Mesa sediments the sands are made up chiefly of quartz grains and contain considerable amounts of scoriaceous basaltic lava.

In the Hueco bolson the sand and gravel appear to be thickest and coarsest along the west side near the Franklin Mountains. Toward the east they become thinner and in general finer, and near the eastern side of the bolson the fineness of the sands causes considerable trouble in wells. In 26 wells in the western part of the bolson, most of which were drilled between 1937 and 1939, beds of sand and gravel comprised 48 percent of the sediments penetrated by the wells.

Physical characteristics of sands.—During the course of the investigation test wells 64, 76, and 136 were drilled to determine the nature of the bolson deposits in specific areas. The logs of these wells are reproduced on pages 101 and 104. The mechanical analyses of the samples collected from the wells are shown on page 30.

One of the three test wells is 2 miles east of the Mesa field, another is 3½ miles southeast, and the third is 4 miles north of the Mesa field. The average specific yield of five samples collected from these wells was 36.9 percent. Assuming that 35 percent represents an average for the sands, that on the average the sands constitute about 50 percent of the sediments, and that the clays have a specific yield of practically zero percent, then the average specific yield of all of the sediments is about 17½ percent. The weighted average permeability, as determined from laboratory tests, of the entire section below the water table, including the clay, is 245 in test well 1; 302 in test well 2; and 345 in test well 3. The average permeability of all of the sediments below the water table in the three wells is computed to be about 300. (See p. 30.)

Physical properties of samples collected from well 64, El Paso City (Geological Survey test well 1)

Depth below land surface (feet)	Mechanical composition (percent of dry weight)							Coefficient of permeability	Specific yield[1] (percent)
	More than 2.0 mm.	2.0 to 1.0 mm.	1.0 to 0.50 mm.	0.50 to 0.25 mm.	0.25 to 0.125 mm.	0.125 to 0.062 mm.	Less than 0.062 mm.		
35–36 (core)	41.6	0.8	2.4	25.7	23.3	3.2	2.8		
72–82	45.3	10.0	11.4	19.6	11.1	.9	1.7		
92–102	98.2	.6	.2	.2	.1	.02	.9		
132–135 (core)	2.2	1.5	14.5	48.4	18.5	7.4	7.2		
222	1.2	2.8	13.7	25.8	13.0	7.1	36.5		
266–272	13.8	5.5	12.0	35.5	21.8	5.0	6.5	300	
280–290	.8	7.7	20.9	47.2	19.2	3.1	1.1	1,500	
335–337		.4	11.5	59.8	22.9	4.1	1.5	1,000	
356–358 (core)		1.0	.4	10.0	46.4	41.0	1.0	220	37.7
408–413			.5	13.5	33.0	38.5	14.5	220	
467–474	5.5	4.0	8.0	26.4	23.7	8.8	24.2	70	
514–523		.7	7.1	38.2	34.3	12.1	7.9	430	
556–566	2.9	2.9	10.9	42.5	29.3	7.4	4.1	770	
567–577			1.0	9.3	23.6	15.5	50.5		

[1] Specific yield was determined by subtracting moisture equivalent from porosity, although strictly speaking it is equal to porosity minus specific retention. The percent of error in this determination, however, is quite small.

Physical properties of samples collected from well 76, El Paso City (Geological Survey test well 2)

Depth below land surface (feet)	Mechanical composition (percent of dry weight)							Coefficient of permeability	Specific yield (percent)
	More than 2.0 mm.	2.0 to 1.0 mm.	1.0 to 0.50 mm.	0.50 to 0.25 mm.	0.25 to 0.125 mm.	0.125 to 0.062 mm.	Less than 0.062 mm.		
27–37		7.1	31.1	35.0	12.5	3.9	10.4		
76–83	19.0	26.0	31.3	19.0	4.4	.3	.1		
104–111	39.3	24.8	18.5	13.7	3.3	.4	.4		
242–243 (core)		.3	.6	10.9	65.6	20.1	2.9	210	
244–250	14.6	6.6	32.1	30.6	3.0	2.7	11.1		
273–280		.4	8.8	55.2	30.7	3.3	1.6	1,650	
314–317		.3	5.5	36.5	44.5	12.2	1.1	680	
320–330 (core)			2.4	17.8	46.5	27.9	5.9	250	
358–370		1.7	10.8	43.0	34.3	8.3	1.9	1,040	36.4
407–412		.2	5.6	45.0	37.9	9.5	1.6	580	
412–414 (core)			.5	8.5	72.6	15.3	3.0	280	
420–422 (core)			.9	15.2	55.2	23.6	5.0	230	
480–482 (core)			1.1	52.1	40.0	5.5	2.3	440	
486–493		.9	5.7	52.2	30.9	5.0	5.2		
523–533		4.4	15.3	47.7	23.4	4.7	4.5	350	
553–560			2.6	45.0	21.2	8.7	22.4	25	
598–599				5.4	22.8	48.1	23.7	50	36.4

Physical properties of samples collected from well 136, El Paso City (Geological Survey test well 3)

Depth below land surface (feet)	Mechanical composition (percent of dry weight)							Coefficient of permeability	Specific yield (percent)
	More than 2.0 mm.	2.0 to 1.0 mm.	1.0 to 0.50 mm.	0.50 to 0.25 mm.	0.25 to 0.125 mm.	0.125 to 0.062 mm.	Less than 0.062 mm.		
20–30		14.0	56.0	23.2	4.7	0.6	1.4		
56	78.7	13.1	5.0	1.8	.4	.1	.9		
104–110		24.8	34.8	34.0	4.8	.5	1.2		
148–161	5.0	11.9	29.9	37.9	13.1	2.0	.3		
194–204	9.7	12.0	23.0	33.1	14.6	2.5	5.1		
298–299 (core)		.4	2.4	30.9	54.6	10.0	2.3	420	38.0
303–313		1.0	6.5	51.6	32.0	7.0	1.9	1,040	
323–333	.6	8.2	17.0	49.5	21.8	2.0	1.0	1,290	
381–382 (core)		1.9	3.9	44.9	40.7	6.5	2.5	420	
383–388		1.0	3.7	32.6	40.8	11.2	11.2	150	
392–393 (core)		1.3	6.6	44.4	34.6	9.9	3.1	380	
423–433	.8	1.6	4.9	34.2	37.4	6.2	3.8	880	
444–447 (core)	.6	1.1	8.8	58.5	23.9	5.4	2.2	370	
481–490	1.1	2.2	17.1	43.6	19.1	5.2	13.1	610	
492–493 (core)	.8	2.3	10.6	55.7	22.3	6.6	2.4	500	35.8
498–500 (core)	53.7	2.1	17.4	19.2	5.8	1.1	.6	1,600	

The permeability of the deposits also was determined by a pumping test. Although the conditions of the test were not entirely satisfactory, it is of some value in indicating the permeability. Computations based on this test, which is described on p. 61, indicate a coefficient of permeability of about 200, which as explained on p. 29, is probably lower than the actual permeability.

SECTIONS OF THE UNCONSOLIDATED SEDIMENTS

The following measured sections will serve to show the character of the bolson deposits where they are exposed in banks. Their character as recorded in well logs is shown on pp. 100–106.

HUECO BOLSON

Section at south entrance to Fort Bliss

	Feet
Mesa surface is nearly flat and is underlain by sand containing some silt and widely scattered pebbles of material derived from rocks in the Franklin Mountains. In many places this material has been removed by wind erosion	0–4
Hard, dense, white caliche that consists of grains of sand disseminated through calcium carbonate. The upper surface is extremely irregular and is in most places the hardest part of the layer, but in some places the upper part consists of numerous pebbles of caliche embedded in the sand. The lower surface is also irregular, and the layer tends to grade downward through soft caliche into sand containing pebbles of that material with no sharp line of demarcation. The mass of the caliche is fractured and broken, being interrupted by many tiny cracks. A faint stratification is apparent, which is parallel to the upper surface of the bed	3.6
Coarse salt-and-pepper-colored sand with numerous gravel pebbles. The sand is quartz sand, and the pebbles vary from the size of peas to that of walnuts or larger. They consist of dark-red to black rhyolite porphyry, quartzite, and some andesite porphyry and limestone. All are derived from the rocks in the Franklins	4
Chocolate-brown clay, very irregular, pinching out toward the southeast	.5–1
Coarse yellow sand at top grading into clayey sand then sandy gravel. Gravel pebbles were derived from the Franklins	2.5
Chocolate-brown, fine-grained sand containing stringers of caliche	.5
Chocolate-brown clay, massive-bedded and containing disseminated sand grains	3.5
Buff clayey sand	2
Salt-and-pepper-colored to yellowish-gray sand, cross-bedded and very clean	4
Brown clayey sand, covered.	

Section about one-quarter mile north of the preceding section and near well 56

[This section shows that the beds in the area have no great lateral extent. The section begins at the same level as the last]

	Feet
Reddish-buff sandy soil intermixed with clay	1–3
Hard white caliche with sand and gravel embedded in it	2–4
Soft gray gravelly sand, indurated to sandstone in places	0–3.5
Fine, silty, brown sand. Interbedded with layers of clay and coarser sand. Becomes harder near the base and contains irregular brown concentrations	11
Chocolate-brown clay	.5
Brown silty sand containing in places white calcareous concretions	5.5
Soft coarse clean sand, partly covered but apparently becoming gravelly toward the base	(?)
Hard, brown, silty sand, partly covered	10 ±

Section toward the southeast near the Carlsbad road, 1.5 miles east of the city limits

[This section is similar but much coarser. Most of the caliche has been removed for road material]

	Feet
Fine, reddish-brown sand containing silt and some rounded pebbles of caliche	2.7
Fine-grained clean, brownish-buff sand	1.5
Coarse, clean gravel, consisting largely of pebbles of quartzite and rhyolite porphyry, but with some andesite porphyry and some black, basic igneous pebbles	1.5
Clean, buff, cross-bedded sand, becoming white on exposure to the sun. Contains in places beds of gravel and numerous hollow tubes of sand, cemented by calcium carbonate, which are evidently the casts of roots	3+

Section in trench 3 miles northeast of Ysleta, Tex.

[Trench begins at the top of the Mesa rim]

	Feet
Surface soil; reddish-brown, silty sand	0.5
Hard, dense, white caliche grading downward into sandy clay containing caliche fragments	3.5
Sandy, calcareous, light-gray clay	1.6
Fine-grained, brownish, clayey sand, grading downward to slightly coarser sand. Contains widely scattered caliche nodules	6
Coarse gravel, ranging in size from ½ inch to 3 inches. Mostly subangular in shape. Pebbles consist largely of porphyries with minor amounts of quartzite	3
Salt-and-pepper-colored quartz and porphyry sand, containing some pebbles up to the size of hazelnuts. Covered.	

Section along east side of San Felipe draw 6 miles northeast of Fabens, Tex.

[See pl. 7, *A*]

	Feet
White hard caliche, containing disseminated sand grains	2.7
Medium-grained, gray sand, containing pebbles or porphyry, quartzite, some chert, and a few fragments of scoriaceous lava	12
Chocolate-brown clay with layers of gray silt	10
Gray silty sand with layers of chocolate-brown clay	15
Chocolate-brown clay with some sand	10
Fine-grained, soft, gray sand with thin layers of clay and some thin beds of iron-stained sand cemented with calcium carbonate	20
Reddish-chocolate clay with a few thin layers of gray sand	10
Soft buff-colored sand	6
Red clay	30
Gray sand with large, flat concretions of iron carbonate and thin beds of iron-stained sandstone composed of grains or quartz, plagioclase, brown and green hornblende, biotite, and augite with a carbonate matrix; also lenticular beds of calcareous sandstone	15
	130.7

LA MESA

Section in railroad cut one-half mile west of Anapra, Dona Ana County, N. Mex.

	Feet
Reddish-buff, very sandy soil. Partly removed.	
Hard, dense, white caliche at top grading downward into very fine gray sand	7
Light gray, moderately fine sand, uncemented and containing some layers of gravel with igneous rock pebbles mostly derived from lava flows	5
Brown sandy clay	1
Medium-grained quartz sand mixed with white pellets of calcium carbonate	.5
Medium- to coarse-grained salt-and-pepper-colored sand	6
Brown to gray sandy clay	2

	Feet
Cross-bedded, light-gray, medium- to coarse-grained sand containing some coarse gravel	45
Light-buff, fine-grained, massive clayey sand containing irregular lenses of clean sand. Near the base are numerous tubes of sand cemented with calcium carbonate	9
Extremely fine-grained, gray sand with layer of coarse sand near middle	14
Gray clay, much disturbed and broken	1.3
Medium-grained, gray sand containing near the base laminated layers of alternating black and white sand	30
Light-buff, clayey sand; cross-bedded	1.5
Medium-grained, loose gray sand	6
Buff to gray, fine-grained sand; cross-bedded; containing pellets of clay and caliche on the bedding planes	2.5
Covered, mostly sand	25
Light buff clay and sandy clay	6
Fine-grained, light gray, cross-bedded sand	5
Laminated light-buff clay and sandy clay	2.5
Fine-grained, gray, cross-bedded sand	3
Light-buff massive clay	2.5
Massive, fine-grained, cemented yellowish-buff sand, grading into less-cemented gray sand near base and partly covered	30
Chocolate-brown clay and light-buff massive sandstone interbedded	11
Brown, cross-bedded sand, partly covered	10
Buff to chocolate-brown, silty clay	9
	274.8

Two fragments of fossil bones were found about 50 feet below the mesa rim at this place. The fragments could not, however, be specifically identified.

THICKNESS

The maximum thickness of the bolson deposits is not known. The deepest well in the area is reported by King[66] to be one of a group of wells drilled about 2 miles south of Newman, N. Mex., during search for oil. It is reported to have penetrated unconsolidated deposits to a depth of 4,920 feet. The log of this well is not available, the exact location not being known, but the log of a well in the same general vicinity, drilled by Cinco Minas Co. to a depth of 4,010 feet, is given on page 105. Although the terminology used by the driller is not in every case readily understandable, it is evident that massive Cretaceous limestones similar to those cropping out at the surface east and south of the Hueco bolson were not encountered in the well, and it seems probable that all the material penetrated by the well belonged to the unconsolidated bolson deposits. The International Water Co. drilled a well 2,285 feet deep north of Fort Bliss, near the intersection of the Southern Pacific R.R. with Wilson road. Richardson[67] states that the formations encountered by this well, at least to a depth of 1,561 feet, were certainly consolidated deposits although "not too much reliance can be placed on well records of this character." Mr. Monroe Fenley of Uvalde, Tex., one of the drillers of this well, informed the writer in November 1938 that bedrock was encountered between 1,500 and 1,600 feet. A large number of wells in the area have been drilled in unconsolidated deposits to depths ranging up to 1,467 feet. Along the east

[66] King, P. B., Outline of structural development of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 2, p. 253, 1935.
[67] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), p. 5, 1908.

side of the bolson several wells are known to have passed through the bolson deposits into the underlying bedrock. (See records of wells 154a, 156, 175, 176, and 178 on pp. 144–147.) These wells were drilled many years ago; little information is available concerning them, except that no water was encountered in the unconsolidated deposits and it was necessary to penetrate a considerable thickness of bedrock before water in sufficient quantities for stock and domestic use was found.

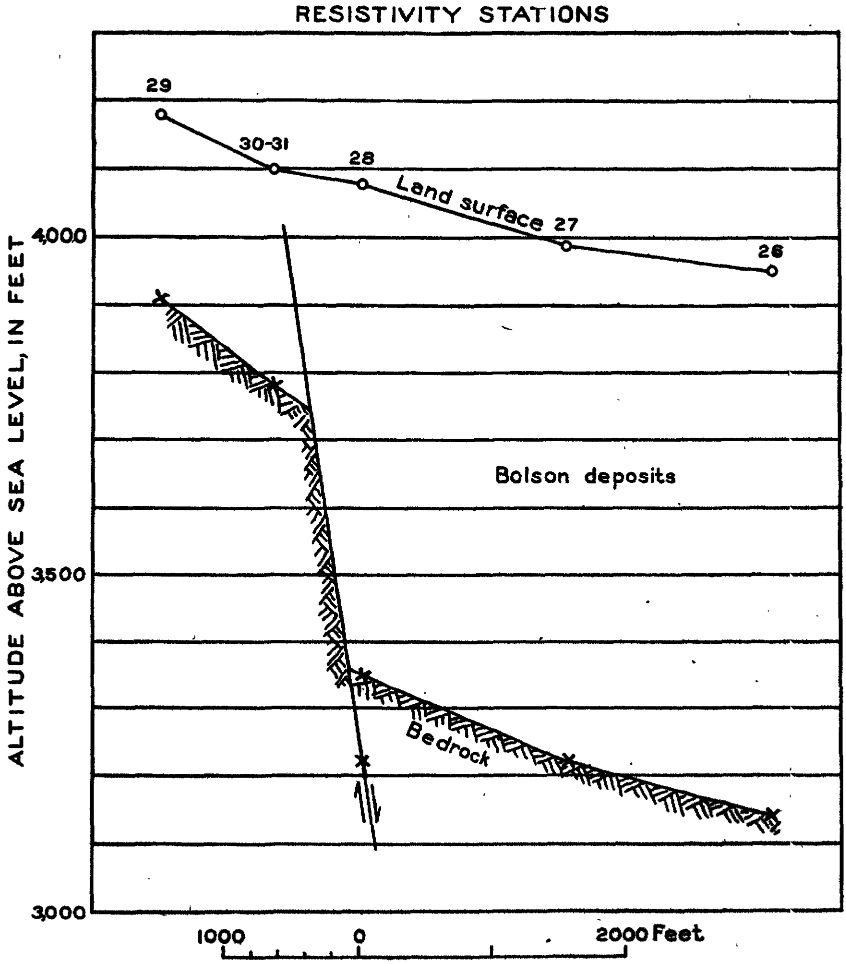


FIGURE 2.—Sketch showing position of bedrock along Franklin Mountains.

Some information regarding the thickness of the bolson deposits was supplied by resistivity measurements made by Stephenson and Swartz, which are discussed more fully on p. 46. Plate 9, prepared by Swartz, shows the locations of the resistivity stations and the areas (R) in which bedrock is believed to be less than 1,000 feet beneath the surface. Near the Franklin Mountains bedrock crops out within a few hundred feet of Station 29, about ¼ mile north of the Baptist Sanatorium. At Station 29 bedrock appears to be 250 feet below the

A. VIEW OF LAKE GUZMAN 2 MILES NORTH OF GUZMAN STATION.
Shows recent strand line (boulder-covered area) and old shore line (wave-cut terrace and cliff on hill in right middle distance).

B. IRREGULAR WEATHERING OF SYENITE PORPHYRY AT HUECO TANKS.

A. RESERVOIR FORMED BY WEATHERING IN SYENITE PORPHYRY AT HUECO TANKS.
Note small concrete dam in background.

B. LOW VOLCANIC CONE SOUTHWEST OF AFTON, N. MEX.

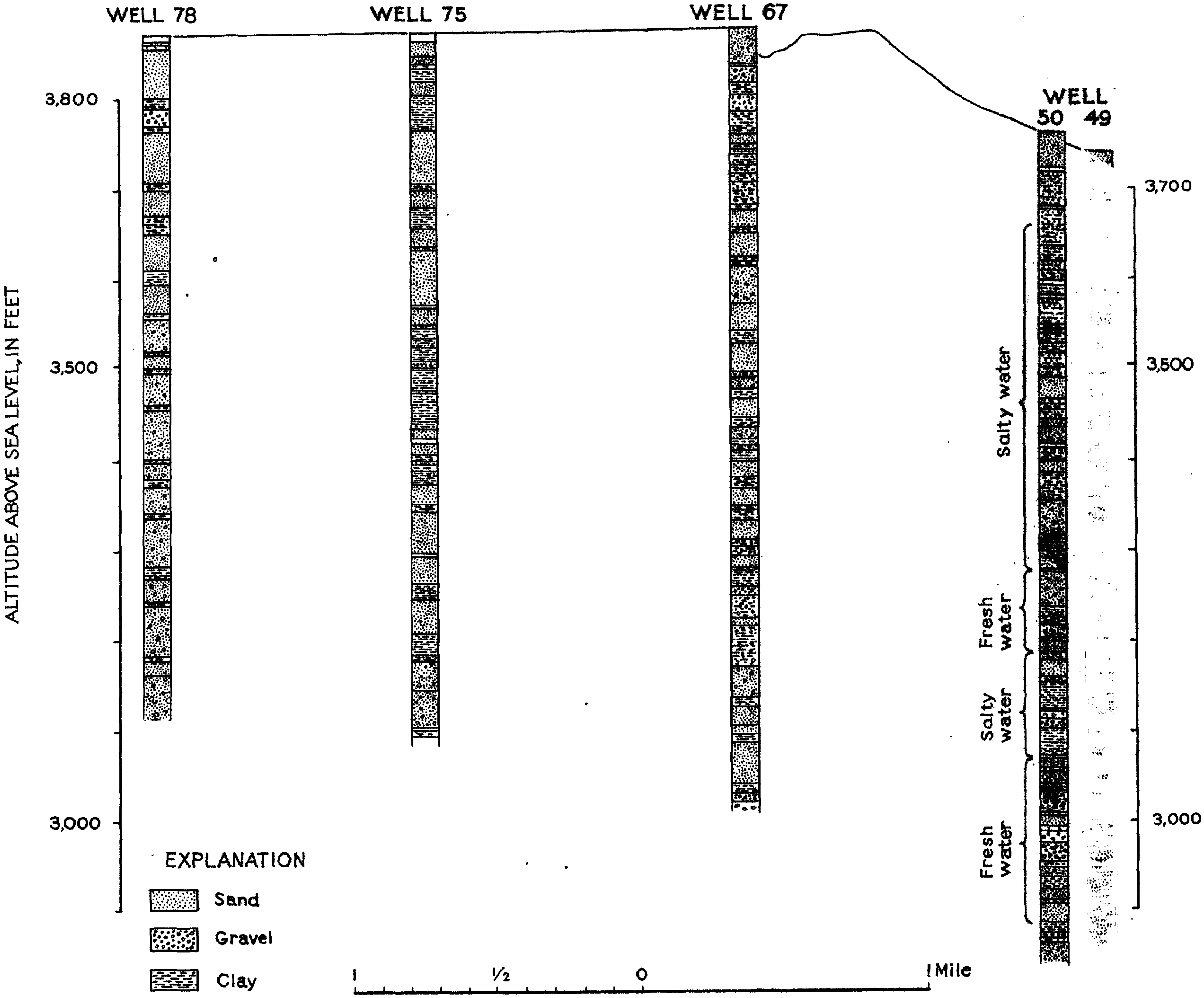
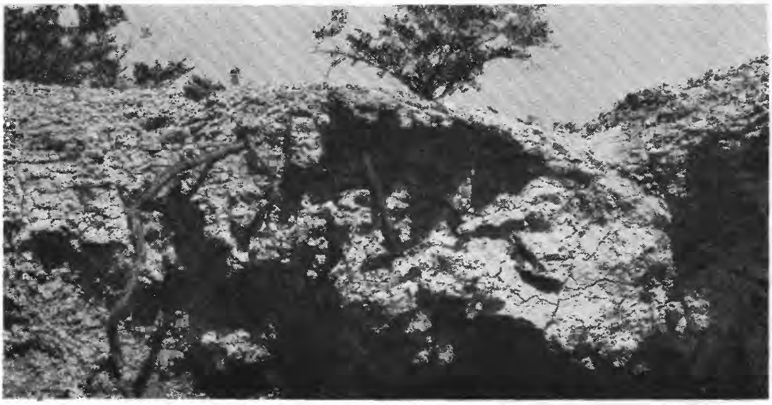


FIGURE SHOWING GRAPHIC LOGS OF 5 WELLS FROM MESA FIELD TO MONTANA FIELD

A. CLIFFS ALONG SAN FELIPE DRAW NEAR FABENS, TEX.
Formed by bolson deposits capped by caliche.

B. CALICHE OVERLYING GRAVEL BED IN PIT 1 MILE NORTH OF AMERICAN AIRWAYS FIELD.
Note sharp contact between overlying sand and caliche.



C. CALICHE BED EXPOSED ALONG VALLEY WALL ON CREWES RANCH, 4 MILES EAST OF YSLETA.

A. CALICHE PENETRATED BY PIPES.
Caliche pit 12 miles east of El Paso on Carlsbad highway.

B. SLIGHT FOLDING AND FRACTURING OF CALICHE.
Near depression 5 miles east of El Paso on Carlsbad road.

surface. Stations 30 and 31 are at the point where the line of the east-facing escarpment (see p. 46) crosses the canyon in which the traverse is located and are measured one parallel to and the other normal to the line of the escarpment. On the west side of the escarpment bedrock is indicated at 320 feet below the surface, on the east side at 720 feet—confirming the supposition that the escarpment results from faulting. At Station 28 the bedrock is indicated to be about 730 feet below the surface, at Station 27 about 770 feet, and at Station 26 about 800 feet. (See fig. 2.) At Station 25 there appears to be some evidence of bedrock at about 900 feet, but the evidence is not conclusive.

Near the Hueco Mountains the bedrock appears to be 130 feet beneath the surface at Station 128, 160 feet at Station 127, 80 feet at Station 126, and crops out a short distance west of Station 126. There apparently is a fault between Stations 126 and 125, as the bedrock is indicated to be nearly 400 feet below the surface at Station 125. The bedrock surface appears to slope rapidly to the west, and at Station 124 it is indicated to be about 850 to 900 feet below the surface.

There are comparatively few wells in the La Mesa area. The Southern Pacific Co. well at Strauss, N. Mex., was drilled to a depth of 1,330 feet entirely through unconsolidated deposits. The Lippincott well in the Mesilla Valley is reported to have encountered "lime" at 822 feet, and sandy limestone at 951 feet below the surface.

In the gorge of the Rio Grande above El Paso, Slichter[68] has shown that the maximum depth of the valley fill at the site of the proposed Mexican-American International Dam was 86 feet. In the El Paso Valley and the Mesilla Valley Bryan[69] believes that there may be from 100 to 250 feet of relatively recent deposits of the flood-plain type above the older unconsolidated sediments that make up the main mass of the deposits in the bolsons.

STRUCTURAL DEFORMATION OF THE BOLSON DEPOSITS

At the close of the Cretaceous period the El Paso area was apparently covered by shallow seas or was a low-lying land area. The structural deformations that have occurred since that time have been described by several writers. Richardson[70] concluded that the Franklin and Hueco Mountains were uplifted in Tertiary time and that their subsequent history has been one of continued erosion, involving the removal of a great mass of Cretaceous sediments and accompanied by minor uplift.

King[71] in discussing the area east and southeast of El Paso, concluded that there were considerable mountain-building movements prior to the early Tertiary movement, but that "most of the folding and faulting of the rocks of southern Trans-Pecos Texas occurred in the first half of the Tertiary period." He added, however, that many of the normal faults in the region are a later feature than the folding and suggested that the earliest movement along them occurred in the late Tertiary. He believes that movements on the normal faults have occurred several times, the latest movement being of recent date.

[68] Slichter, C. S., Observations on the ground waters of the Rio Grande Valley: Geol. Survey Water-Supply Paper 141, p. 1, 1905.
[69] Bryan, Kirk, The geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Regional planning, pt. 6, vol. 1, pt. 2, sec. 1, p. 218, Nat. Resources Comm., 1938.
[70] Richardson, G. B., op. cit., pp. 8–9.
[71] King, P. B., op. cit., pp. 221–261.

Dunham[72] concluded from his studies in the Organ Mountains that the Early Tertiary was a period of folding and uplift and intensive vulcanism and that by the end of the Oligocene the Organ Mountain region "was highly elevated above sea level." The erosion of these uplifted areas during this period caused the accumulation of thousands of feet of fanglomerate and gravel west of the mountains. About the close of the Tertiary period the Franklin and Organ Mountains, having been worn down to areas of low relief, were uplifted in their present form.

Bryan[73] states that "most of the existing mountains and highlands areas (near the Rio Grande depression) were also mountainous in Santa Fe time (Miocene-Pliocene). They were reduced during Pliocene time and were rejuvenated to form the present ranges," probably by block faulting.

The deformation that has occurred since the close of the Tertiary has been on a much-reduced scale. It has consisted almost entirely of faulting and tilting of the unconsolidated deposits, possibly along fractures that existed prior to the faulting. Near the mountains dips as high as 30° have been observed in the bolson deposits, but throughout much of the area dips so gentle as to escape notice are the rule. Richardson[74] called attention to the "disconnected line of high level benches [that] extends along the eastern base of the Franklin Range" and suggests that it represents a fault scarp, which extends also along the foot of the Organ Mountains.[75] The topography strongly suggests a faulted pediment, which, dissected by numerous canyons, slopes down from the mountain to an east-facing escarpment 10 to 50 feet high. East of the escarpment an alluvial slope descends somewhat more steeply to the Hueco bolson. Although the fault plane is not exposed the escarpment is undoubtedly a fault scarp. There is no similar scarp on the opposite side of the bolson as there should be if the cliff were wave-cut. The resistivity measurements indicate that a fault underlies the escarpment and that the movement along the fault plane was about 400 feet. The surface of the Hueco bolson has a slope toward the west of about 17 feet to the mile. King[76] tentatively suggested that the gentle westward slope of the surface of the Hueco bolson may have been caused by gentle tilting, resulting from movement along a fault plane near the base of the Franklin Mountains. By projecting the surface of the bolson westward to the fault plane a figure of 350 feet is obtained for the amount of the throw. Immediately after the faulting, erosional and depositional processes began, canyons were cut above the scarp and the materials eroded from above were deposited below the scarp as alluvial fans. Thus about 300 feet of outwash material has been piled against the base of the escarpment, reducing its height to about 50 feet or less.

Richardson described two faults of small throw near the head of Virginia Street in El Paso. Since he visited the area the sand and gravel has been removed from two large pits, exposing a fault having a throw of at least 50 feet about 200 feet north of the exposure he mentioned. The fault plane is exposed (pl. 10, *B*) along the north side of the old

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[72] Dunham, K. C., Geology of the Organ Mountains: New Mexico School of Mines, Bur. Mines and Mineral Resources, Bull. 11, pp. 148–152, 173–174, 1935 (1936).
[73] Bryan, Kirk, op. cit., p. 209.
[74] Richardson, G. B., U. S. Geol. Survey, Geol. Atlas, El Paso folio (no. 166), p. 9, 1908.
[75] Meinzer, O. E., op. cit. (Water-Supply Paper 343), p. 41.
[76] King, P. B., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 19), p. 254.

sand pits for a distance of over two city blocks. The strike of the fault plane is N. 22° E., the dip is about 75°, and the downthrow is toward the southeast. On the southeast side the beds dip steeply away from the fault because of drag folding, but at a distance of about 200 feet to the east they dip toward the fault at a rate of about 30°. The floor and the north side of each pit are composed of fairly consolidated, fine-grained, buff to reddish sand and gravel. The remnants of the material that was removed show that it was loosely consolidated sand and gravel and that it was involved in the faulting, which, therefore, is recent.

An exposure at Alabama and Tremont streets, described on page 38, gives evidence that deforming movements were recurrent. The lower beds dip northwest at about 11°, the upper beds northwest at about 6°. From El Paso eastward the Carlsbad highway crosses six north-south trending asymmetrical depressions. (See plate 10, *A*.) Faults having throws of 10 to 30 feet have been found at the points where most of these depressions intersect the valley wall. Also, the resistivity measurements reveal clearly the existence of faults along the western sides of the depressions on the Carlsbad road. Therefore the depressions probably are due to minor tilting of the bolson sediments on axes near the east sides of the depressions, as a result of movements along faults bordering the west sides of the depressions. All the sediments, including the caliche, are involved in the faulting.

The resistivity work indicates two faults of unknown throw that pass from near the point where the Carlsbad road descends into the El Paso Valley northward to the east side of Biggs field. There are, however, no surface indications of these faults and the well logs have failed to show their existence.

Faulting in the La Mesa area is inferred from the presence of asymmetrical depressions similar to those of the Hueco bolson.

GEOLOGIC AGE

A large part of the surficial material in the Hueco bolson and on La Mesa was deposited during the Quaternary period. Numerous vertebrate fossils referred to the Pleistocene epoch have been reported from these sediments, and deposition has continued even up to the present time. However, it is believed that the Pleistocene and Recent deposits form only a thin mantle over a thick series of sediments deposited during the Tertiary period and probably during the Pliocene epoch of that period. These conclusions are based on the facts that the deposits occurring along the sides of the mountains and near the tops of the valley walls are uncemented, are practically undeformed, and have yielded numerous Pleistocene fossils, whereas the sediments occurring in the lower parts of the valley walls and in wells are slightly cemented, usually deformed by normal faults, and have yielded, in one place, Pliocene fossils.

Richardson[77] reported the finding of well-preserved fossils of unquestionable Pleistocene age in Rous' gravel pit at the head of Virginia Street in El Paso. This pit has long since been worked out and the city has been built up around it. However, it apparently is the pit that is now bounded by Virginia, St. Vrain, California and River Streets. It appears that the gravel that was excavated rested in an asymmetric, broadly V-shaped trough formed by a tilted fault block. The north

[77] Richardson, G. B., op. cit., pp. 5–6.

side is bounded by a fault with the downthrow on the south and the south side is also bounded by a fault. The bottom of the trough, which is formed by slightly cemented clay and sand, slopes toward the north. Some loose gravel remains at the top of the north wall of the pit, and the material that was excavated from the pit and that contained the fossils was evidently similar to this loose gravel. Another pit, 500 to 600 feet north of the Rous pit and bounded by Ange, Octavia, River and Cliff Streets, is similar, except that the north wall is cut by a small fault. The following section, which was measured on the north side of this pit, on the downthrown side of the fault, is about 3,800 feet above sea level, or about 200 feet below the high-level bench at this place. The beds dip southwest at about 30°.

Section at Octavia and Cliff Streets, El Paso, Tex.

	Feet
1. Limestone pebbles ranging from about ½ inch to 6 inches in diameter.	
2. Massive-bedded, fine-grained friable, bedded brown sand containing masses of light-gray to white cemented sand	40
3. Massive- to thin-bedded, fine-grained, buff, clayey sandstone, contains some gravel and numerous nodules of caliche near the base	5
4. Chocolate-brown clay grading downward into layers of clay, sand, and gravel	2.5
5. Clean, loose sand, grading downward into gravel	8
6. Light buff, moderately cemented, cross-bedded sandstone, covered	10+

As bed 6 is somewhat indurated and tilted more than the overlying beds, it probably represents the top of the Tertiary sediments in this section.

Another section showing an angular unconformity between unconsolidated deposits and slightly consolidated deposits is at Alabama and Tremont Streets, about 1¼ miles northeast of the Rous gravel pit. (See pl. 10, *A*.) The section at this locality is as follows:

Section at Alabama and Tremont Streets, El Paso, Tex.

[Elevation 3,770 feet above sea level]

	Feet
1. Coarse gravel containing limestone boulders up to 1 foot in diameter	15
2. Brown sandy clay	1.2
3. Alternating beds of loose gravel and sand with clay. Beds 1 to 3 dip N. 60° W. at an angle of 6°	3
4. Gray to chocolate-brown sandy clay grading downward into gray laminated sand	2.5
5. Gray sand grading downward into light chocolate-brown clay	4.2
6. Massive-bedded, fine-grained, friable, buff micaceous sand	3
7. Chocolate-brown clay	1.5
8. Fine-grained, buff sand containing some thin beds of chocolate-brown clay	10
Covered.	

Beds 4 to 8 dip N. 60° W. at an angle of 11°. Bed 4 is more indurated and more deformed than the overlying beds and is tentatively regarded as the top of the Tertiary deposits.

Professor H. E. Quinn[78] reports several Pleistocene fossils from the gravels at Austin Terrace near the eastern limits of El Paso. These fossils occur at about 3,880 feet above sea level and slightly below the

[78] Quinn, H. E., Oral communication, 1937.

level of the Hueco bolson. Thus, unless these gravels have been lowered by slumping or faulting, the sediments near the surface of the bolson are at about the same level and may be assumed to be of the same age.

In the La Mesa area, Darton[79] reports the finding of part of the jaw of a Pleistocene horse at a depth of 70 feet in a well drilled in Kilbourne Hole "possibly in material that had caved from the sides of the hole." He also reports[80] that Mastodon, N. Mex., is so named because the remains of a mastodon were excavated from the slope on the northeast. It is therefore evident that the deposits near the surface of La Mesa are of Quaternary age. Like the near-surface deposits of the Hueco bolson they are uncemented.

However, the deeper, unconsolidated deposits of La Mesa are of Pliocene age. Bryan[81] reports the finding of part of a mastodon skull 1½ miles west of La Union, N. Mex., in the sand hills on the west side of the Rio Grande Valley, just below the Mesa rim and at least 300 feet above the valley floor. This skull fragment was obtained from Mr. Walter L. Kohlbert of El Paso and was sent to Harvard University where it was identified as definitely of Pliocene age although the species could not be determined. This find demonstrates with reasonable clearness that both Pleistocene and Pliocene sediments occur in the La Mesa basin and that since the Pliocene fossils are near the surface of the basin, the Pleistocene constitutes a thin mantle over the bulk of the unconsolidated deposits. Hence, as the deposits and the geologic histories of the two basins are similar, the Pliocene age of the slightly cemented, deformed beds that make up the major part of the sediments in both basins may be regarded as fairly definitely established.

Bryan,[82] who has spent many years in geologic studies in the southwest, refers the main body of the basin deposits to a single period of deposition on the basis of four general criteria: (1) Slight cementation of the beds, (2) deformity in all the deposits, mostly by normal faults, (3) diversity of lithologic types, and (4) conformity of arrangement to a geographic pattern consistent with the laws of deposition in basins. He concludes that "The main body of sedimentary deposits of the Rio Grande depression, from the north end of the San Luis Valley to and beyond El Paso, is considered to be of the same general age and to belong to the Santa Fe formation (Pliocene)."

ORIGIN OF THE BOLSON DEPOSITS

The broad outlines of the history of the unconsolidated deposits of the Upper Rio Grande depression are fairly clear, due largely to the work of Kirk Bryan and his students in central and northern New Mexico. Bryan's[83] interpretation of the Tertiary and Quaternary history of the upper Rio Grande depression may be summarized as follows:

1. In mid-Tertiary (Miocene) time volcanic activity and uplift on a large scale formed highlands and basins in essentially their present locations.

2. Streams eroded the highlands and deposited the eroded materials in the basins, some of which were drained—the deposits of a through-flowing stream lie near the axis of the basins—while others were undrained. The ancestral Rio Grande can

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[79] Darton, N. H., Guidebook of the western United States: Geol. Survey Bull. 845, p. 134, 1933.
[80] Darton, N. H., op. cit., p. 163.
[81] Bryan, Kirk, correspondence, Sept. 14, 1936, and Jan. 4, 1937.
[82] Bryan, Kirk, The geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Regional Planning, pt. 6, vol. 1, pt. 2, sec. 1, p. 205, Nat. Resources Comm., 1938.
[83] Bryan, Kirk, op. cit., pp. 204–219.

be traced through consecutive basins, at least as far south as the mouth of the Rio Puerco, but it diverges from the present course of the Rio Grande in the vicinity of Tijeras Arroyo, and it may be traceable farther south, possibly beyond Las Cruces. The materials deposited during this time (Pliocene) are called the Santa Fe formation.

3. Most of the present-day mountains existed also during Santa Fe time. They were reduced in the Pliocene and rejuvenated at the close of that epoch to form the present ranges. Some additional mountains seem also to have been formed at that time, and these mountain-making movements were accompanied by deformation of the Santa Fe formation, chiefly by faulting.

4. The Santa Fe formation was eroded to a broad, even surface, called the Ortiz surface, which represents essentially the present surface of such areas as La Mesa. In the Albuquerque-Bellen basin this surface is about 500 feet above the river channel; downstream it is somewhat lower. By the end of the period of erosion the Rio Grande had attained essentially its present course.

5. The river lowered its channel, but remained stabilized at successive stages for considerable periods of time. During these periods of stabilization successively lower but less extensive erosion surfaces were formed. Two such pediments are well developed in the Santo Domingo Valley—the La Bajada and Pena Blanca pediments which lie about 300 feet and 175 feet above the river channel, respectively.

6. Since the pediments were formed, the present flood-plain has developed, and two types of low terraces have been formed. One type results from the deposition of fans by tributaries and subsequent lateral planation by the river. The second type is built by the river itself.

The details of the Tertiary and Quaternary history of the El Paso section of the Rio Grande depression are less clear owing partly to the fact that, except along the walls of the valley, the exposures are poor and partly to the fact that the area has been less carefully studied. There is nothing in the nature and composition of the Pliocene sediments of the Hueco bolson or in the Tularosa Basin to suggest that they have any relation, so far as source is concerned, with the Pliocene sediments of the La Mesa area.

Meinzer[84] has shown that in the Tularosa Basin the character of the bolson deposits is closely related to the rocks that make up the adjacent mountain masses. This statement is also true with regard to the sediments of the Hueco bolson. About half of the sediments observed through exposures or wells are red to chocolate-brown clays, which were probably derived in part from the limestones and dolomites that comprised the major part of the Franklin and Hueco Mountains and in part from the weathering of the feldspathic minerals of the granite. Sand and gravel comprise the remainder of the sediments. The sands were probably derived from the quartz grains of the granite and other igneous rocks, from the fragmentation of the sandstone and quartzite, and from the chert nodules that occur in several of the limestone formations. The gravels are composed chiefly of pebbles of rhyolite and andesite porphyry, quartzite, chert, and minor amounts of limestone and granite, similar to the rocks found in the Franklin Mountains. The pebbles and sand grains are angular to subangular showing that they have not been carried far from their points of origin.

A large part of the sediments of the La Mesa area are brown to buff clays. The sand, which is relatively abundant in the exposed portion of the sediments, decreases with depth. It is chiefly gray to black and contains a considerable proportion of basalt fragments and grains. Basalt is common in the La Mesa area and in the basins upstream from La Mesa but is not known in the Hueco bolson. East of the El Paso

[84] Meinzer, O. E., and Hare, R. F., Geology and water resources of Tularosa Basin, N. Mex.: U.S. Geol. Survey Water-Supply Paper 343, p. 66, 1915.

gorge the first basalt fragments that appear in the sediments are found in the alluvium of the El Paso Valley. It is therefore concluded that the through-flowing stream postulated by Bryan in Pliocene time did not flow through the Hueco bolson.

Lee[85] postulated an ancient river that flowed through the Jornada del Muerto and La Mesa into the lakes of the interior basin of Chihuahua. This hypothesis is supported by the topography of the La Mesa surface, which, excluding the Mesilla Valley and the alluvial slopes of the mountains, has a general slope to the south and shallow depressions with a general north-south trend. (See Norio and Canutillo topographic sheets.) Near Las Cruces the elevation of the surface is about 4,250 feet above sea level, near the international boundary it is about 4,100 feet, at Lake Guzman it is 3,922 feet, and at San Jose near Laguna de los Patos it is 3,900 feet. Thus the slope from north to south is about 350 feet in 100 miles or about 3.5 feet per mile. The hypothesis is also supported by the evidence that the lakes of the lake region were formerly much larger than they have been in historic times.

No such general slope is apparent in the Hueco bolson-Tularosa Basin depression. As pointed out before, the Hueco bolson and probably the Tularosa Basin have been tilted since their surfaces were formed, and the lowest parts of both basins are now along their western sides. The lowest part of the Tularosa Basin is in the vicinity of the Alkali flats near the White Sands Monument. The surface of the alkali flat has an elevation of about 3,950 feet above sea level. The land surface rises gradually from the flat toward the south, and at the State Boundary, where it has an elevation of about 4,000 feet, it forms the divide between the Hueco and Tularosa Basins. South of the divide the surface slopes, somewhat irregularly, to an elevation of about 3,875 feet at the Mesa pumping plant near the El Paso Valley. South of that valley the surface rises again into the interior valleys of Chihuahua. Thus in this depression the present topography suggests that there was no through-flowing stream connecting the Tularosa and Hueco Basins.

As pointed out by Meinzer[86] many of the clay beds in the vicinity of El Paso were obviously deposited in lakes. However, the general irregularity of the bolson deposits and the absence of ancient shore lines indicate that the deposits are predominantly not lacustrine. Hence, some of these beds were probably deposited in small lakes or playas, but most of them probably were deposited by temporary rapid streams or by sheet wash. Such deposition could have taken place with a climate and geography not far different from that which exists at the present time.

At the end of the Cretaceous period there had accumulated, over the great thickness of Paleozoics a small thickness of Jurassic sediments—El Paso was near the northern margin of the Jurassic sea[87]—several thousand feet of Lower Cretaceous limestone and sandstone such as crop out in the Sierra del Paso del Norte and numerous other mountains in Mexico, and an unknown thickness of Upper Cretaceous shales, limestones, and sandstones, such as crop out in the gorge west of El Paso and in the Cerro de Muleros. When the early Tertiary mountain

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[85] Lee, W. T., Water resources of the Rio Grande Valley in New Mexico and their development: U. S. Geol. Survey Water-Supply Paper 188, pp. 20–25, 1907.
[86] Meinzer, O. E., op. cit., p. 67.
[87] King, P. B., Outline of structural development of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 2, p. 237, 1935.

building occurred, the uplifted mountains were capped by the entire Cretaceous section. Ephemeral streams and sheet wash immediately began to erode those rocks and carry the debris from the mountains into the deep troughs between them, just as at the present time during heavy storms large quantities of sand, gravel, and clay are carried down the mountain slopes and deposited, the gravel fairly well up the slopes, the sand somewhat lower, and the clay in the adjacent lowlands. The gravel and sand also would tend to be picked up by later floods and thus gradually be worked down the slope. West of the Franklin Mountains the water may have drained by a through-flowing river into the Lake Region of Chihuahua, but east of the Franklins there was no outlet for the water to escape and it collected in the lowest parts of the area, forming lakes or playas in which fine-grained sediments were deposited. As at present, the water probably was evaporated from most of these lakes within a few days or weeks after each storm, and the dissolved mineral matter was left in the lake bed. In general, low areas would tend to remain low with respect to the surrounding areas and subject to occasional flooding unless crustal movements intervened, but there might have been occasional storms of unusual violence which would carry such quantities of detritus into the lowlands as to change the topography completely. In this manner beds that were deposited in lakes might be overlain and underlain by stream-laid deposits. If it should happen that an undrained depression remained at the same site for a considerable period, the concentration of mineral matter resulting from evaporation of flood water would doubtless cause considerable amounts of soluble mineral salts to be included in the clays of the lake beds and occasionally in sand beds that were deposited in the lakes during heavy rainstorms.

In this way may have originated the parts of the bolson deposits that contain highly mineralized water, such as the western side of the Tularosa Basin near Alkali Flat, which was probably almost continuously the bed of an ephemeral lake; the El Paso Valley area, parts of which contain only highly mineralized water; part of Mesilla Valley; and the area around Lake Guzman and the Barreal. At first the sediments would probably accumulate most rapidly near the sides of the basins, but as the adjoining mountains were worn down there would be a tendency for the streams to erode the detrital material along the margins of the basins and deposit it in the center, thus gradually leveling the surfaces of the bolsons.

During this period of erosion and sedimentation all of the Cretaceous was stripped from the Franklin, the Organ, and the Hueco Mountains and from most of the adjoining mountains; all of the Paleozoic sediments were stripped from the central part of the Franklins and from a large part of the Organs; and the Carboniferous sediments were eroded from the southern part of the Organs and the southern part of the Franklins. However, in the mountains south of El Paso in Chihuahua only the Upper Cretaceous has been widely eroded away, because those mountains were of later origin than those in the United States, or because they were not so highly elevated, or because the Lower Cretaceous limestones there were much thicker than those to the north and therefore would not have been eroded as quickly.

Most of the erosion here postulated is believed to have occurred in middle to late Tertiary time; the structural basins were nearly filled with sediments and erosion had nearly ceased by the end of that period. In his paper on the origin of the Colorado River Blackwelder[88] states his conclusion that uplift of the Colorado mountains and consequent increase in rainfall as well as the previous filling of the basins aided in establishing through drainage of that river. Similar occurrences probably aided in establishing the Rio Grande in its present course. At the end of the Pliocene, as indicated by Bryan, the mountain areas were again elevated, and with the consequent increase in rainfall, erosion and sedimentation were renewed and Pleistocene sediments were deposited on the Tertiary sediments. As the basins were by this time nearly filled with sediments, the lowest parts were flooded during exceptionally heavy storms and became ephemeral lakes, which overflowed into the adjacent basins. This process was repeated until a continuous valley was established from La Mesa across the site of the El Paso gorge, through the Hueco bolson and across the mountains of the Big Bend. At about this time the headwaters area of the Rio Grande was elevated, and precipitation there became sufficient to support a through-flowing stream. However, until the flow was regulated by the construction of dams there were considerable periods during which the streams carried no water. In the Tularosa Basin, however, the rainfall was not sufficient to fill the lowest part to overflowing. Likewise, in the Lake Region of Chihuahua, although it contained large lakes fed by three rather large rivers, the supply of water was not sufficient to establish a channel to the Rio Grande.

RESISTIVITY MEASUREMENTS

Some information concerning the bolson deposits may be inferred from resistivity measurements made at more than 200 stations, most of them on the Mesa, a few in the El Paso Valley. A voluminous literature has sprung up on the methods of making resistivity measurements and the interpretation of the results. Some of the more important papers selected by F. W. Lee are listed below.

Ambronn, Richard, Elements of geophysics, 372 pp., McGraw-Hill Book Co., New York, 1928. (translated by Margaret C. Cobb)

Broughton Edge, A. B., and Laby, T. H., The principles and practice of geophysical prospecting, 372 pp., Cambridge University Press (American agents, the Macmillan Book Co., 60 Fifth Ave., New York City), 1931.

Eve, A. S., and Keys, D. A., Applied geophysics in the search for minerals, 2d ed., 296 pp., Cambridge University Press (American agents, the Macmillan Book Co., 60 Fifth Ave., New York City), 1933.

Eve, A. S., Keys, D. A., and Lee, F. W., Depth attainable by electrical methods in applied geophysics: U. S. Bur. Mines Tech. Paper 463, 1929.

Gish, O. H., Preliminary earth-resistivity measurements on the site of the Department of Terrestrial Magnetism, D. C.: Carnegie Inst. Washington, Year Book 23, 1924.

Gish, O. H., Improved equipment for measuring earth-current potentials and earth resistivity: Nat. Res. Council Bull. 11, 1926.

Heiland, C. A., Geophysical methods of prospecting: Colorado School of Mines, Quart., vol. 24, no. 1, March, 1929.

Lee, F. W., Joyce, J. W., and Boyer, Phil, Some earth-resistivity measurements: U. S. Bur. Mines Information Circular 6171 (10 pages), 1929.

McCullum, Barton, Measurement of earth-currents: Elec. Ry. Jour., Nov. 5, 1931.

McCullum, Barton, and Logan, K. H., Practical application of the earth-current meter: U. S. Bur. of Standards Tech. Paper 321, 47 pp., 1927.

[88] Blackwelder, Eliot, Origin of the Colorado River: Geol. Soc. America, Bull., vol. 45, pp. 551–566, 1934.

Rooney, W. J., Earth-resistivity measurements in the copper country of Michigan: Terrestrial Magnetism and Atmospheric electricity, vol. 32, 1927.
Rooney, W. J., and Gish, O. H., Measurement of the resistivity of large volumes of undisturbed earth: Carnegie Inst. Washington, Year Book 24, 1925.
Swartz, J. H., Oil prospecting in Kentucky by resistivity methods: U. S. Bur. Mines Tech. Paper 521, 1932.
Weaver, Warren, Certain applications of the surface potential method: Geophysical prospecting, Am. Inst. Min. & Met. Eng. Trans. 81, pp. 68–86, 1929.
Wenner, Frank, A method of measuring earth resistivity: U. S. Bur. Standards Sci. Paper 258, pp. 469–478, Oct. 11, 1915.

In the present report no attempt is made to describe completely the resistivity work or the results accomplished.

The method used in the El Paso investigation was the Lee[89] partitioning method, which consists very briefly of passing a current through two iron stakes driven into the ground and measuring between two potential electrodes the potential difference caused by the flow of the current in the ground. All electrodes are placed in a straight line. The current electrodes are driven into the ground at a distance $1\frac{1}{2}$ a from, and on opposite sides of, the center where a is the effective depth of the measurement. There are three potential electrodes, one at the center and two at a distance of $\frac{a}{2}$ on each side of the center. At each value of a the potential differences are usually measured successively, first between the center potential-electrode and the first one and then between the other lateral potential-electrodes. The interval a and the amount of current used are carefully controlled, so that any differences in voltage measured are due to differences in the conductivity of the materials measured. In the El Paso investigation the interval a was initially 1,000 feet at each station and was decreased in steps of 20 feet until all of the electrodes were near the center. The measurements at each station were then plotted on coordinate paper using the interval a, representing the depth in feet, as the abscissa and the resistivity in ohm-centimeters as the ordinate. The interpretation of the results was based in large part on these curves.

It should be clearly understood that the interpretation of geological conditions from resistivity measurements is still in the experimental stage and fraught with great difficulties. The applicability of resistivity methods to the search for water-bearing materials is based chiefly on the fact that coarse-grained sands and gravels, which permit rapid movement of water through them, are in general poor conductors of electrical current and have high resistivity, whereas fine-grained sediments through which water moves with difficulty, are usually good conductors and have low resistivity. It is known from field experience that the depth to which the current penetrates is approximately equal to the interval a. The resistivity that is measured is the weighted average of the resistivity of the entire column of sediments from the surface to the depth a, and although the resistivity of a given thickness of material at the depth a largely affects the resistivity measured, its effect on the average resistivity decreases with depth. Hence, the interpretations of resistivity data at shallow depths are simpler than interpretations at greater depths.

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[89] Lee, F. W., and Swartz, J. H., Resistivity measurements of oilbearing beds: U. S. Bur. Mines. Tech. Paper 488, 1930.

The resistivity investigation indicates that the Hueco bolson, so far as it was covered by these investigations, may be divided into five areas (pl. 9), based on the configurations of the resistivity curves. (See

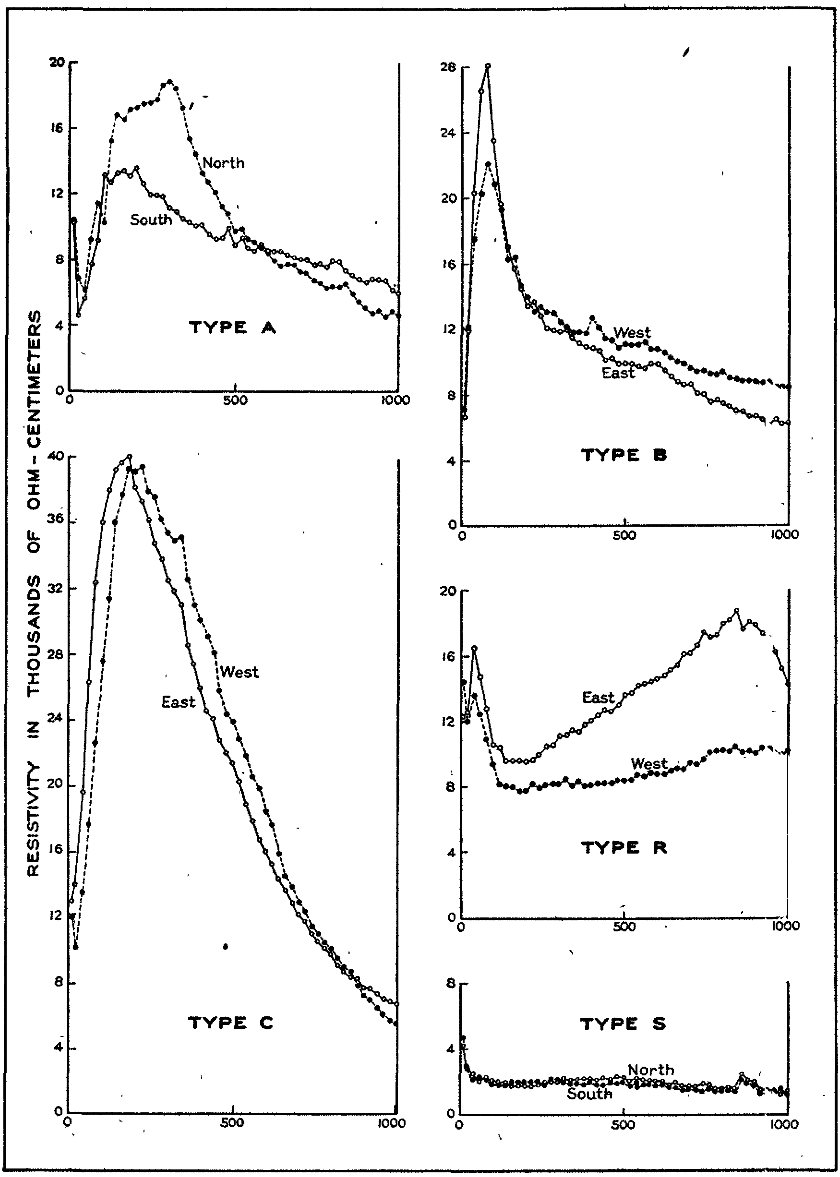


FIGURE 3.—Characteristic types of resistivity curves in the El Paso area.

fig. 3.) The salt-water area S is discussed on pages 49, 52, and in a recent paper by Sayre and Stephenson.[90] The section R is the area in

[90] Sayre, A. N. and Stephenson, E. L. The use of resistivity methods in the location of salt-water bodies in the El Paso, Texas, area. Am. Geophys. Union Trans., 18th Ann. Mtg., pt. 2, pp. 393–399, 1937.

which bedrock is believed to underlie the surface at a depth of less than 1,000 feet, namely, beneath stations 26 to 31 near the Franklin Mountains and stations 124 to 128 near the Hueco Mountains. The stations near the Franklin Mountains were occupied along a traverse extending eastward for a distance of about 3 miles from a point a short distance west of the mouth of a small canyon about ¼ mile north of the Baptist Sanitarium. The other stations lie along a line extending westward along the Carlsbad road from the first outliers of the Hueco Mountains. In both cases the bedrock is exposed nearby and is known to be within a short distance of the surface at the station. The slope of the bedrock surface near the Franklins is shown in figure 2, prepared by J. H. Swartz. At station 29 the bedrock appears to be about 250 feet below the surface. At stations 30 and 31, which are located where the projection of the east-facing escarpment (see p. 35) crosses the canyon, the bedrock appears to lie at a depth of 320 feet on the west side and 730 feet on the east side, thus confirming the supposition that the escarpment results from faulting. At stations 27 and 26 the bedrock appears to lie at 750 and 810 feet beneath the surface. There is some evidence that the bedrock is indicated at station 25, but it is not sufficiently clear to warrant positive identification. It seems likely that east of the station the bedrock becomes rapidly deeper. Along the Hueco Mountains at stations 128, 127, and 126 the bedrock appears to be 130, 160, and 80 feet, respectively, beneath the surface. West of station 126 bedrock crops out near the surface, but at station 125 it appears to be nearly 400 feet beneath the surface, indicating a fault with the downthrow toward the west. Although there is practically no surface evidence for inferring a fault at station 125, west of there the bedrock appears to become rapidly deeper.

The areas A, B, and C (pl. 9) as differentiated by E. L. Stephenson on the basis of the curve types obtained in these areas, are believed to represent areas in which the prospects for obtaining water are different. These areas doubtless overlap and intergrade and their boundaries are arbitrarily selected. The A area is believed to offer the poorest chances of obtaining large quantities of water. The curves in this area show the smallest number of variations from the normal. The B area offers somewhat better prospects for water and the C area offers the best prospects. Variations from the normal curves are somewhat more common in the B area than in the A and are most common in the C area. One of the three test wells drilled during the investigation in 193? was located in each of the three curve type areas. (See fig. 3 and logs of wells 64, 76, and 136.) These indicate that in the A area the fineness of the sand would be likely to limit the yields of wells considerably. In the western part of this area there might be sufficient sand to supply fairly large yields to wells. The B area was somewhat more favorable, and the coarsest sand was found in the well drilled in the C area.

In 1937 and 1938 the city of El Paso drilled several more test wells. The data from those wells seem to substantiate the general conclusions regarding the water possibilities of those areas, but it has also emphasized the fact that especially in the C area there is considerable variation in the percentage of sand from well to well and that although these variations appear to be shown by the resistivity curves, it may be very difficult to detect them in advance of drilling. On plate 9 the areas that appear to offer greatest possibilities for developing large yields in the C area are indicated.

OCCURRENCE OF GROUND WATER IN THE AREA

GENERAL FEATURES

The principal water-bearing beds of the area are the unconsolidated deposits of Tertiary and Quaternary age underlying the Hueco bolson and the El Paso Valley. However, the bedrock may provide small amounts of water in wells, such as Nos. 156 and 175, which pass through the bolson deposits and enter the limestones underlying them. The McElroy packing company also has had drilled in New Mexico east of the Hueco Mountains two wells that penetrate the underlying bedrock. The Lippincott well in the Mesilla Valley, drilled by the city of El Paso, also penetrated the bedrock. The water from all these wells, however, is too highly mineralized to be acceptable for most purposes, and the supply is rather small. Data regarding the wells visited during the ground-water investigation at El Paso are given in the well tables on pp. 122–147, and the location of each well is shown on plate 2.

Water of good quality occurs nearly everywhere in the deposits underlying the Mesa area of the Hueco bolson, except in the extreme northeastern part. The yield of the wells and the depth to the water level vary widely from place to place. Near the east side of the bolson the water level is encountered at 300 to 400 feet beneath the surface; on the west side it is encountered at about 200 feet near Fort Bliss and at about 300 feet near the State boundary. The difference in the water level is partly because the bolson surface rises toward the east and partly because the water table slopes toward the southeast. In general the water is not artesian, since it does not rise appreciably above the level at which it is encountered in wells. However, in a number of wells impermeable material was encountered at the water level, and when water-bearing sand was encountered at somewhat greater depth, the water rose to the static level and appeared to be under artesian pressure. An example of wells of this class is well 140, Southern Pacific Co. at Newman, where water was encountered at 328 feet and rose to 280 feet beneath the surface. All the water-bearing beds of the bolson deposits appear to be more or less interconnected so that the water from the deeper beds will rise to about the same height in a well as does the water of the shallower beds.

In the El Paso Valley water occurs in the water-bearing sands and gravels at all depths from about 10 to 1,276 feet, which is the deepest well drilled in the valley in the vicinity of El Paso. However, not all of this water is potable. In the valley downstream from El Paso most wells are relatively shallow and the water is in general more or less highly mineralized. The deeper strata have not been explored, but some of them may contain potable water for a short distance below El Paso. At Clint, however, a well drilled to a depth of 1,100 feet is reported to have encountered only briny water.

On La Mesa and along the Mesilla Valley water of satisfactory quality is encountered in a number of ranch wells and in railroad wells. The water-bearing beds are, however, not as thick or as permeable as are those in the Hueco bolson. The water stands at varying depths depending to some extent upon the altitude of the surface—at Strauss it is 342 feet; at Afton, 385 feet; at Lanark, 365 feet; and at Noria, 321 feet. In most of these wells the water rises a considerable distance above the bed in which it is encountered.

QUALITY OF WATER

By Margaret D. Foster

Analyses of waters from 78 supply wells in the El Paso area are given in the tables on pages 116–120. Several analyses are given for some of the more heavily pumped wells which were sampled periodically in order to determine whether these waters are changing in composition as a result of pumping or for some other reason. Most of the analyses were made by Margaret D. Foster in the Water Resources Laboratory of the Geological Survey. A few were made by other analysts, as noted in the table.

The partial analyses given on pages 156–158 represent waters from 215 test wells, ranging in depth from 5 to 20 feet, which were sunk in and near the eastern limits of the city in connection with the investigation of shallow ground water in El Paso Valley. The locations of these wells are shown on plate 14, and their descriptions are given on pages 148–155. The wells were sunk under the supervision of Robert Colvin by labor supplied by the Works Progress Administration, and the analyses were made by chemists employed by that agency working under the supervision of Prof. E. P. Schoch of the University of Texas.

The analyses given in the tables below indicate that the ground waters in the El Paso area differ greatly in the content and character of the dissolved mineral matter. The extremes of mineralization found were 196 and 18,268 parts per million (wells 148 and 172, respectively). In most of the waters, however, the mineral content was between 400 and 800 parts per million. Bicarbonate and/or chloride are the predominant acidic constituents in most of the waters; sulfate is usually subordinate except in some of the more highly mineralized waters, in which it may predominate, as in the water from well 10. (See diagram B, pl. 11.) The bicarbonate content of the waters is fairly uniform and whether a particular water is characterized by bicarbonate or chloride or is of mixed character depends on the chloride content, which differs greatly in different waters. Chloride is also significant with reference to the use of a water for industrial or municipal purposes. Most of the waters in which chloride is high are sodium-chloride waters; in those in which it is low or moderate the predominant basic constituent may be either sodium or calcium or both in approximately equivalent amounts. The calcium and magnesium content of a water determines its hardness; waters low in calcium and magnesium are soft, those high in these elements are hard. Hardness is the characteristic of water that receives the most attention in industrial or municipal use. In the discussion of the kind of waters found at different depths in different parts of the area particular emphasis has been placed, therefore, on chloride content and hardness. The distribution, based on chloride content and hardness, of the waters in different parts of the area is shown in the tables on pages 50, 51, 52, and 54.

Analyses of representative waters are shown graphically in plate 11, and figures 4 to 6. The heights of the several sections of the diagrams correspond to the quantities of the constituents reported in the table of analyses expressed in terms of equivalents per million rather than in parts per million. One unit of height corresponds to 20 parts per million of calcium, 12 of magnesium, 23 of sodium, 61 of bicarbonate, 48 of sulfate, 35.5 parts of chloride and 50 parts of hardness as calcium carbonate. The total hardness is measured to the top of the magnesium;

the carbonate hardness to the top of the bicarbonate, if this is lower than the top of the magnesium. If the top of the bicarbonate area extends above the top of the magnesium area all the hardness is carbonate hardness.

MONTANA WELL FIELD AND REFINERY AREA

Analyses were made of waters from nine wells (San Antonio dairy, no number; Nos. 49, 50, 52, 55, 57, 58, 59, and 61) in the Montana well

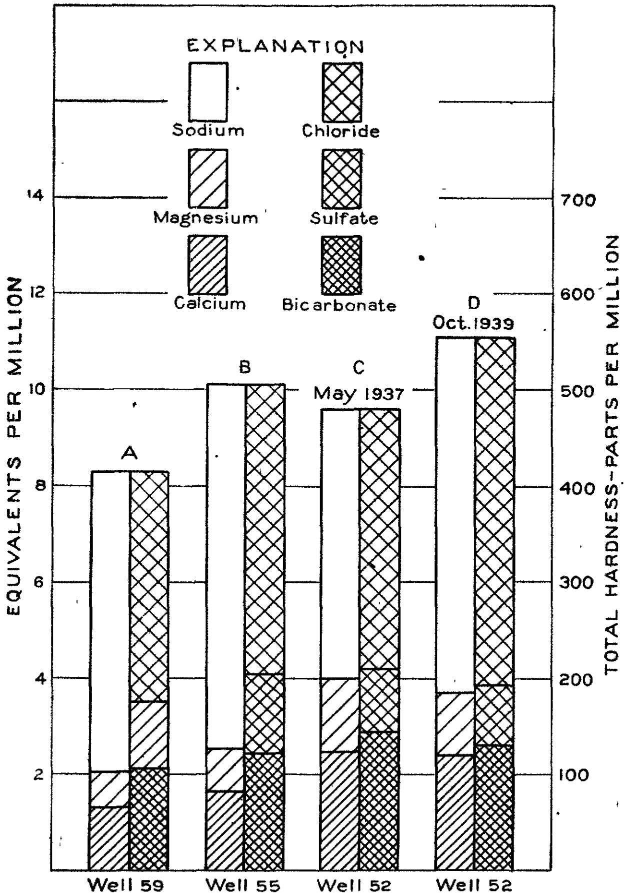


Figure 4.—Type of deep waters found in the Montana well field.

field. The distribution of these waters with reference to total hardness and chloride is shown in the table on page 50. The waters analyzed fall into two groups—those from wells 150 to 350 feet deep and those from wells more than 600 feet deep. The waters of the first group differ greatly in hardness, in chloride, and in total mineral content; those in the second group are quite uniform in those respects. Analyses of typical waters from wells 600 to 900 feet deep are shown diagrammatically in figure 4. These deeper waters are moderately hard waters in which sodium and chloride are the predominant basic and acidic constituents, respectively. Periodic analyses were made of most of the deep waters in order to determine whether they were changing in composition. The greatest change was in the water from well 52 (city well 3). The chloride content of this water is apparently lowest at the beginning of the pumping season. For example, 48 hours after pumping was begun in May, 1937, the chloride content was 18[illegible] parts per million. Within 2 months (June 25, 1937) the chloride had increased to 252 parts, but with continued pumping there was apparently no further increase, for on October 29 the chloride content was 246 parts. The hardness of the water did not change appreciably. The analyses for May 1937 and October 1937 are shown graphically in figure 4, *C* and *D*. Other wells show similar but somewhat smaller changes in mineralization. The water below 900 feet is reported to be highly mineralized.

Distribution of the waters in the Montana well field and refinery area with respect to hardness and chloride

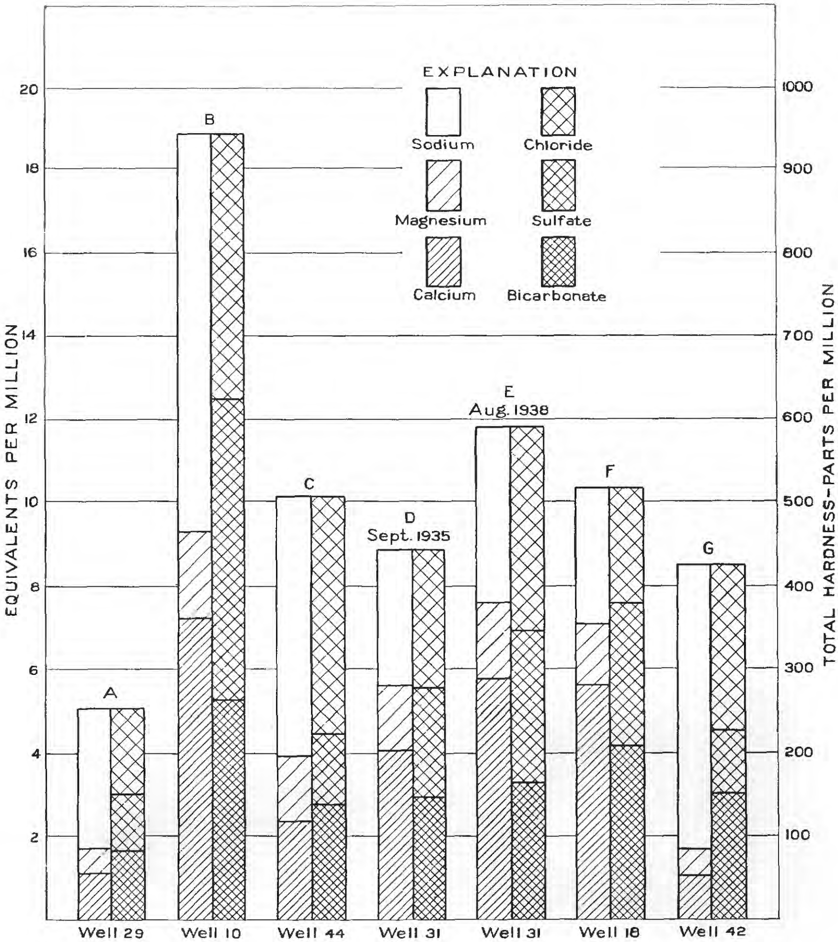
Depth below land surface (feet)	Number of wells	Total hardness (parts per million)				Chloride (parts per million)			
		Less than 100	100–200	201–400	More than 400	Less than 100	100–250	251–500	More than 500
50–150	0	0	0	0	0	0	0	0	0
151–350	3	0	1	1	1	1	0	0	2
351–600	0	0	0	0	0	0	0	0	0
More than 600	6	0	6	0	0	0	5	1	0
Total	9	0	7	1	1	1	5	1	2

DOWNTOWN AREA

Analyses of water from wells 8–14, 18, 19, 21, 22, 25, 28, 29, 31, 32, 34–37, 39, 42–44, 46, and 47 in the downtown area are given on pages 116 and 117. For a number of wells there are several analyses. The analyses show that the waters differ greatly in mineral content and in chemical character, ranging from soft waters that are moderately low in dissolved mineral matter to very hard, highly mineralized waters. Extreme types of waters found are shown graphically in plate 11, *A* and *B*. The table on page 51, giving the distribution of the waters with reference to hardness and chloride, shows that this wide variation in mineral composition is particularly characteristic of waters from wells less than 350 feet deep. The waters from wells 350 to 600 feet deep also show wide differences in chloride content and in hardness but are generally rather low in chloride and are hard. Analyses of typical waters from wells 350 to 600 feet deep are shown in plate 11, diagrams *C* and *F*. High chloride in a few of these waters may be due to faulty well construction, which permits water from shallow beds to enter the well. Water from wells 600 to 900 feet deep, on the other hand, generally is somewhat higher in chloride content but much softer. A typical water is shown in plate 11, diagram *G*. Periodic sampling and analysis shows that in some of the wells the waters are changing in composition, particularly in chloride content. For example, the water from well 44 gradually increased from 158 to 203 parts per million between January 1935 and October 1937. A year later, however, there had been no further increase in chloride. The change in the composition of the water from well 31

A. SECTION SHOWING ANGULAR UNCONFORMITY IN THE BOLSON DEPOSITS.
Alabama and Tremont Streets El Paso.

B. FAULT PLANE IN THE BOLSON DEPOSITS.
At head of Octavia Street, El Paso.



TYPE OF WATERS FOUND IN THE DOWNTOWN AREA OF EL PASO.

between September 1935 and August 1938 is shown graphically in plate 11, diagrams *D* and *E*. The change in composition in this water was general and involved, to a greater or less degree, the calcium, sodium, and sulfate as well as the chloride. Highly mineralized water is reported to have been encountered at about 725 to 750 feet in several wells recently drilled in this area. Well 21 was plugged back from 807 to 650 feet to seal off highly mineralized water.

Distribution of the waters from wells of different depths in the downtown area with respect to hardness and chloride

Depth below land surface (feet)	Number of wells	Total hardness (parts per million)				Chloride (parts per million)			
		Less than 100	100–200	201–400	More than 400	Less than 100	100–250	251–500	More than 500
50–150	6	1	1	3	1	0	4	1	1
151–350	3	0	2	0	1	1	2	0	0
351–600	13	1	2	8	2	9	2	1	1
More than 600	7	6	1	0	0	1	6	0	0
Totals	29	8	6	11	4	11	14	2	2

EL PASO VALLEY, NEAR EASTERN CITY LIMITS

The character and mineral content of very shallow waters in El Paso Valley is shown by the partial analyses (pp. 156–158) of samples from 215 test wells 5 to 20 feet deep which were sunk in and near the eastern limits of the city by Works Progress Administration labor under Mr. Colvin's direction. The distribution of the waters with respect to total mineral content, total hardness, and chloride content is shown in the

Number and percent of samples according to ranges (in parts per million) of total solids, hardness, and chloride in waters from shallow test wells in El Paso Valley near the eastern city limits

Parts per million	Samples	
	Number	Percent
Total solids		
Less than 500	1	0.6
500–1,000	40	22.4
1,001–3,000	108	60.7
3,001–5,000	14	7.9
More then 5,000	15	8.4
Total hardness		
Less than 100	3	1.8
100–200	5	3.0
201–400	37	22.0
401–600	57	33.9
More than 600	66	39.3
Chloride		
Less than 100	3	1.4
100–250	67	31.1
251–500	84	39.0
501–750	21	9.8
751–1,000	7	3.8
More than 1,000	33	15.4

table on page 51. These very shallow waters differ greatly in content of dissolved mineral matter but are generally highly mineralized. About 60 percent of the waters had between 1,000 and 3,000 parts per million total mineral content. The waters are generally very hard; more than 70 percent having a hardness of over 400 parts. In many of the waters bicarbonate, sulfate, and chloride are present in about equal amounts, although some of the waters are characterized by a predominance of one of these constituents. In well 110, for example, the predominant acidic constituent is chloride, in wells 11 and 108 it is sulfate, and in well 211 it is bicarbonate.

Analyses of waters from 6 wells 75 to 191 feet deep (wells 161–165, 172) in El Paso Valley indicate that the deeper waters in the valley, like the very shallow waters, differ greatly in mineral content and chemical character. Waters of good quality may be found (well 162), but in general the waters are highly mineralized, hard, and relatively high in chloride. No analyses are at hand of waters from a depth of more than 200 feet in this part of the area.

MESA WELL FIELD AND VICINITY

Analyses of waters from 14 wells in the Mesa well field and vicinity are given in the table on pages 118 and 119 (wells 64, 65, 67, 68, 70, 73, 75, 75a, 76, 77, 78, 79, 128 and 129a). For some of the wells several analyses are given. Most of the waters for which analyses were made are from wells more than 600 feet deep. The few analyses of waters from wells less than 600 feet deep indicate that these waters as well as those from wells more than 600 feet deep are for the most part relatively low in chloride and moderately hard. The distribution of the waters with respect to chloride content and hardness is shown in the table on this page. Analyses of typical waters are shown graphically in figure 5, diagrams *A*, *B*, and *C*. Wells near the rim of the Mesa, particularly if heavily pumped, yield somewhat more highly mineralized water than

Distribution of ground waters from wells of different depths in the Mesa well field and vicinity with respect to hardness and chloride

Depth below land surface (feet)	Number of wells	Total hardness (parts per million)				Chloride (parts per million)			
		Less than 100	100–200	201–400	More than 400	Less than 100	100–250	251–500	More than 500
50–150	0	0	0	0	0	0	0	0	0
151–350	1	0	1	0	0	1	0	0	0
351–600	2	0	2	0	0	1	1	0	0
More than 600	13	2	8	2	1	9	2	2	0
Totals	16	2	11	2	1	11	3	2	0

wells some distance from the rim. (See p. 118.) For example, well 68, near the rim and heavily pumped, yields more highly mineralized water than well 75, also heavily pumped but situated away from the rim. This difference is shown graphically in figure 5, diagrams *B*, *D*, and *E*. Moreover, the mineral content of the water from well 68 increased during the period of observation (January 1935 to October 1936) whereas that of the water from well 75 remained constant over a longer period (January 1935 to September 1938). The change in mineralization of the water from well 68 between April 1936 and October 1936 is shown graphically in diagrams *D* and *E*, figure 5. The chemical character of the water from well 68 is unusual in comparison with that of most of the other waters in the El Paso area in that calcium and magnesium are present far in excess of bicarbonate and sulfate. It is a very hard calcium-magnesium-chloride water. The water from other wells away from the rim is comparable in chloride content and

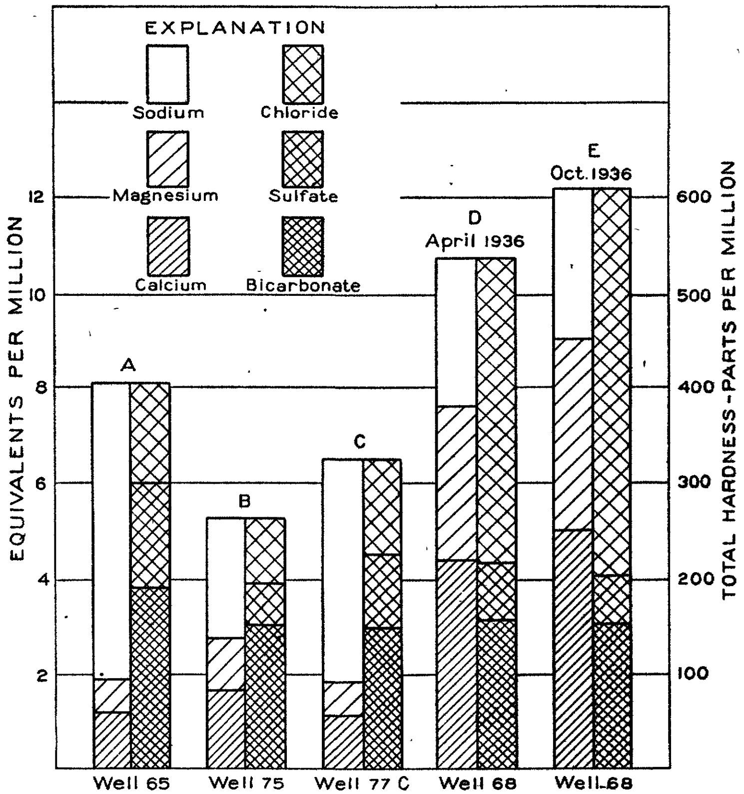


FIGURE 5.—Types of deep waters found in the Mesa well field and vicinity.

hardness with that from well 75. In those waters the predominant constituents are usually sodium, bicarbonate, and chloride. Like the water from well 75 they showed no change in composition with pumping.

HUECO BOLSON IN NEW MEXICO AND TEXAS

Analyses were made of 19 wells (wells 136, 137, 138, 141, 143, 144, 147, 148, 149, 151, 153, 155, 158, 160, 166, 174, 177, 178, and 179) in the Hueco bolson in New Mexico and Texas, or the Mesa, as it is called locally. The distribution of the waters with respect to hardness and chloride content is shown in the table on page 54. On the whole, the waters in the Hueco bolson appear to be among the best in the El Paso area. At all depths they are characterized by low to moderate hardness and by relatively low chloride content. Analyses of typical waters from different depths are shown diagrammatically in figure 6, diagrams *A* to *D*. Diagram *E*, figure 6, represents one of the few more highly mineralized waters from the bolson deposits (well 141). In this water, as in that from well 68, in the Mesa well field, calcium and magnesium are present in excess of bicarbonate and sulfate. Two wells in the area

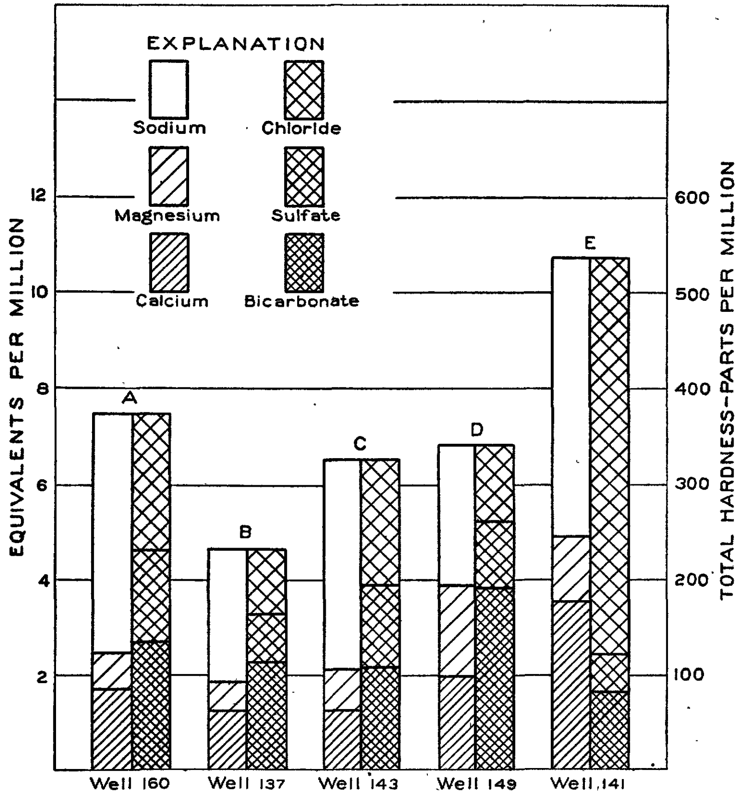


FIGURE 6.—Types of waters found in the Hueco bolson in New Mexico and Texas.

(wells 178 and 179) draw from limestone and not from the bolson deposits. The waters from both wells are highly mineralized and hard; sodium chloride is the predominant constituent although both waters are also high in sulfate.

Distribution of water from wells of different depths in the Hueco bolson in New Mexico and Texas with respect to hardness and chloride

Depth below land surface (feet)	Number of wells	Total hardness (parts per million)				Chloride (parts per million)			
		Less than 100	100–200	201–400	More than 400	Less than 100	100–250	251–500	More than 500
50–150	1	0	1	0	0	1	0	0	0
151–350	8	3	4	1	0	5	1	1	0
351–600	7	1	5	0	1	4	2	1	1
More than 600	3	1	1	1	0	2	0	0	1
Totals	19	5	11	2	1	12	3	2	2

LA MESA, N. MEX.

Analyses were made of waters from wells 1 to 3 in La Mesa, N. Mex. The shallow-well water (well 3) was comparable in mineral content and in chemical character to the water represented in diagram *A*, figure 6 (Hueco bolson figure). The other two waters, from deep wells were comparable in hardness with those from similar depths elsewhere in the El Paso area but were somewhat higher in bicarbonate and in total mineral content. The data, however, are not adequate to warrant any conclusions as to the kind of water available at different depths in La Mesa.

CHIHUAHUA, MEXICO

Four analyses were made of waters from wells in Chihuahua. Three waters, one from a spring and two from wells 45 and 250 feet deep, were low to moderate in chloride content and in hardness. The fourth water, from a well 900 feet deep, was high in chloride and moderately hard.

SUMMARY OF QUALITY OF WATER

It is evident that few broad generalizations can be made regarding the quality of the ground water in the El Paso area. The waters from different depths there show certain general characteristics. The very shallow waters in El Paso Valley differ greatly in mineral content but are generally highly mineralized. Waters from wells 50 to 600 feet deep differ greatly in mineral content and in chemical character. In most parts of the area, except in the El Paso Valley below El Paso, good waters may be found in some of the water-bearing beds at depths of less than 600 feet, but it is only in the Hueco bolson that the waters appear to be uniformly good. The waters from wells 600 to 900 feet deep show more uniformity in mineral content than do those from shallower wells. Most of these deeper waters are relatively low in chloride and moderately hard. The waters from depths greater than 900 feet are reported to be generally highly mineralized.

That some of the more highly mineralized waters from wells more than 600 feet deep may be entering the wells from shallow beds not properly sealed off has been the subject of extensive investigations by Mr. Livingston and is discussed in detail on pages 75–93, 167–188.

The great differences found in the mineral characteristics of the ground waters in the El Paso area, especially in the valley areas, may be attributed to differences in soluble mineral matter in the sediments with which they have been in contact. These differences are inherent in deposits that were formed as irregularly as were the bolson deposits.

QUANTITY OF WATER PUMPED FROM WELLS

Except for a little water pumped for industrial purposes from the Rio Grande above the city, all the water used for industrial and public supplies in the El Paso-Ciudad Juarez area is pumped from wells which naturally fall into two classes—shallow wells restricted to the valley and deep wells both in the valley and on the Mesa.

SHALLOW WELLS

In the valley water that occurs between the water table and a depth of about 500 feet is generally too highly mineralized to be acceptable for all purposes. However, for refrigeration and other uses where water of good quality is not required, it is an inexpensive and convenient source of water. Many shallow wells, most of them less than 50 feet deep, have been sunk in the business section of El Paso to obtain water for refrigerating and air-conditioning hotels and office buildings. For several miles down the valley from the city, shallow wells are used to supply water for stock and domestic use. The water table in the business section of the city is near the surface and it has been necessary to pump water from sumps or pits in many of the basements to keep the water table below the floors of the basements. For many years the El Paso Electric Co. pumped a number of shallow wells at a combined rate of nearly 8,500,000 gallons a day to supply the plant on Santa Fe Street with water for cooling. As a result of this heavy draft the water table was kept low enough so that little trouble was experienced with water in the basements of the business section of the city. However, when the Electric Company plant was shut down the water table is reported to have risen substantially, and in 1933 the city put down a drainage well about 50 feet deep near Oregon and Fourth Streets and installed a pump capable of discharging about 1,000 gallons per minute. This pump has been operated almost continuously since that date and the water table in a considerable area has been lowered. No attempt has been made to find all of the shallow wells, but a few were found and data on them are given in the well tables at the back of this report. No estimates were made of the total volume of shallow water pumped by various wells, but it is apparent that in the aggregate the total pumpage from shallow wells is large.

DEEP WELLS

Within the city limits of El Paso and Ciudad Juarez there are many wells more than 500 feet deep that are in use at the present time. On the Mesa, northeast, east, and southeast of El Paso there are a number of widely scattered deep wells. In the valley, southeast of El Paso and within 30 miles of the city, there are only a few deep wells. In 1936 the city of El Paso was supplied by 13 deep wells of which 4 were within the city limits, 3 were in the Montana well field at the eastern limits of the city and 3 were in the Mesa well field, on Wilson Road, north of Fort Bliss. The 4 wells within the city discharged into small surface reservoirs from which the water was pumped directly into the mains by centrifugal pumps. The wells in the Montana field and in the Mesa field also discharged into small reservoirs from which the water was repumped. Other large users of deep well water for public supplies are the city of Ciudad Juarez, with wells located in the El Paso Valley in Mexico, and Fort Bliss near the Mesa well field on the Mesa. The largest part of the water used for industrial purposes is pumped from a group of wells in the valley east of the city limits, for the Texas Co. refinery, the Pasotex Petroleum Co. refinery, and the Nichols Copper Co. refinery. It is estimated that the average daily water use by these three companies in 1935 amounted to 1,600,000 gallons.

Computations have been made of the total quantity of water pumped from each deep well in the area and of the total amount of water pumped each year from all of the wells in the area, including those in Ciudad Juarez, from 1906 to 1937.

PUMPAGE BY CITY OF EL PASO

The amount of water pumped each year by the city water department from 1906 to 1941 as shown by their records is given in the following table:

Water pumped by the El Paso water department 1906–1941, in million gallons a day

Year	Quantity	Year	Quantity	Year	Quantity
1906	1.0	1918	5.8	1930	8.5
1907	1.2	1919	5.6	1931	7.9
1908	1.8	1920	6.3	1932	7.3
1909	1.8	1921	6.7	1933	7.0
1910	1.7	1922	6.4	1934	7.5
1911	2.0	1923	6.3	1935	7.4
1912	3.2	1924	6.5	1936	7.8
1913	3.6	1925	6.8	1937	8.4
1914	3.8	1926	6.4	1938	13.2
1915	4.2	1927	7.3	1939	16.8
1916	5.3	1928	7.4	1940	18.4
1917	6.4	1929	7.5	1941	19.5

The table below shows the year in which each city well was placed in service, the location of the well, its estimated capacity, and the total water pumped from it, including that pumped in 1937. The figures for 1906 to 1935 were compiled by Mr. F. H. Todd from pumpage records in the office of the city water department:

Pumpage from each of the city of El Paso water wells to 1937

Wells		Location	Year placed in service	Estimated capacity		Pumpage (mil. gal.)	
City No.	Report No.			1936 (mil. gal.)	Total including 1935 (mil. gal.)	1936	1937
[1]1–44	83–124	Mesa well field	1904–17	Not used	22,052		
1	50	Montana well field at Montana and Madison Streets.	1918	1.7	9,244	465.3	297.2
[2]5	41	Grama and Morenci Streets.	1921	1.1	2,179		
[3]3	52	Montana well field	1922	1.7	6,927	274.2	251.4
2	51	Montana well field	1923	1.0	3,091		
4	49	Montana well field	1924	1.7	7,138	442.5	577.5
[4]6	22	2d and Cotton Sts.	1925	1.5	2,275	44.3	
7	31	Lee & Magoffin Sts.	1927	1.8	2,282	533.6	416.7
8	79	Mesa well field 200	1928	1.3	590	336.4	401.4
9	42	Luna and Pera Sts.	1929	1.6	1,232	118.3	193.2
11	78	Mesa well field 300 yards east of Mesa plant.	1931	2.0	701	431.3	278.9
10	21	Campbell and 6th Streets	1932	1.0	62	61.4	7.4
12	77	Mesa well field 800 yards east of well 11.	1935	1.5	104	158.4	146.4
16	30a	San Antonio and Walnut Streets.	1937	2.0			283.8
Total				19.9	58,180	2,865.7	3,053.9

[1] Old Mesa well field 1–44; discontinued in 1926.
[2] Pump removed in 1936.
[3] Abandoned in 1934; repaired in 1926.
[4] Repaired in 1926 to reduce hardness.

PUMPAGE BY CIUDAD JUAREZ

Ciudad Juarez pumped very little water until 1925, when the first of the three wells now in use was drilled. The second well was drilled in 1926 and the third in 1935. During 1935 in Ciudad Juarez much

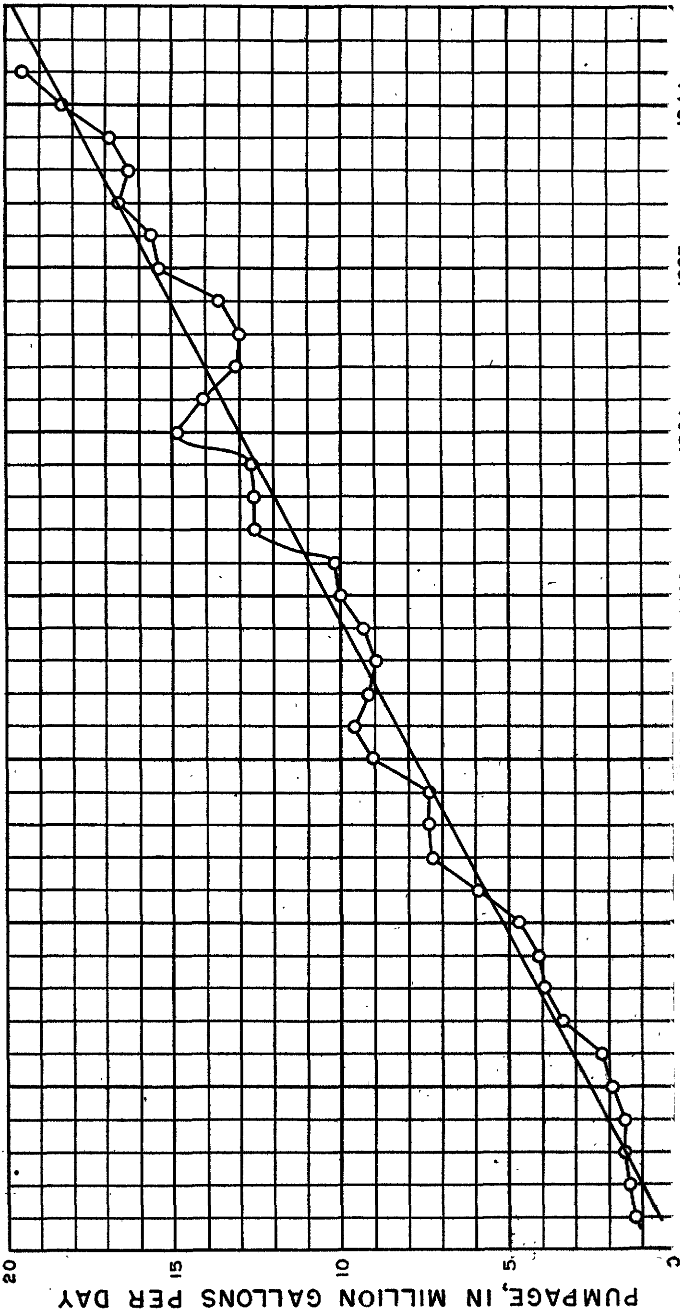


FIGURE 7.—Chart showing estimated average daily pumpage from all deep wells in the El Paso and Ciudad Juarez areas, 1906-41.

work was done in extending pipe lines to areas not previously supplied with water and in replacing old lines with larger pipe. As a result the water supplied in 1935 was estimated to be about twice that supplied in 1934. The following table has been prepared from rather meager data pertaining to the amount of water pumped by Ciudad Juarez from 1925 to 1937.

Estimated amount of water pumped by the Juarez water department, 1925–37, in million gallons a day

Year	Quantity	Year	Quantity
1925	0.1	1932	1.7
1926	1.0	1933	1.5
1927	2.3	1934	1.4
1928	2.2	1935	2.9
1929	2.1	1936	2.9
1930	1.9	1937	2.9
1931	1.8		

TOTAL PUMPAGE

The estimated total pumpage from deep wells in the El Paso-Ciudad Juarez area amounted to 15.4 million gallons a day in 1935 and 16.7 million gallons a day in 1937. Of the amount pumped in 1935 7.4 million gallons a day were pumped by the El Paso water department, 2.9 by the Ciudad Juarez water department, 3.6 from private wells for industrial purposes, 1.3 at Fort Bliss, and 0.2 from miscellaneous private and ranch wells.

The average daily pumpage from all wells in the area for each year is shown in graphic form in figure 7 and is also given in the table following.

Estimated average daily pumpage from all deep wells in the El Paso-Juarez area, 1906–41, in million gallons a day

Year	Quantity	Year	Quantity	Year	Quantity
1906	1.2	1918	7.4	1930	14.9
1907	1.4	1919	7.4	1931	14.1
1908	1.6	1920	9.0	1932	13.1
1909	1.6	1921	9.6	1933	13.0
1910	1.9	1922	9.2	1934	13.6
1911	2.2	1923	9.0	1935	15.4
1912	3.4	1924	9.3	1936	15.7
1913	3.9	1925	10.0	1937	16.7
1914	4.1	1926	10.2	1938	16.2
1915	4.7	1927	12.6	1939	16.8
1916	5.9	1928	12.6	1940	18.4
1917	7.3	1929	12.6	1941	19.6

For the past 30 years, with few exceptions, the average daily pumpage has increased about half a million gallons each year.

GROUND-WATER LEVELS AND THEIR SIGNIFICANCE

During the course of the investigation measurements of depth to water level were made on all deep wells that could be measured. These measurements are given on pages 107–115 and 122–147. In the immediate vicinity of El Paso the altitudes of the measuring points of the wells that could be measured were determined. From these data the altitude of the water level in each well was computed, and a map was prepared showing by contours the elevation of the ground water and the conformation of the ground-water surface. (See pl. 2.)

Measurements of water levels in the shallow wells bored in the El Paso Valley by Works Progress Administration labor were also made, the altitudes of the measuring points of the test wells were determined, and a map was prepared showing the altitude and conformation of the water table in that area. (See pl. 14.) Measurements of the depths to water in a number of selected wells in and near El Paso were made at monthly intervals, and the results of these measurements appear at the back of this report in the table of water-level measurements in observation wells. The fluctuations in several of the wells are shown graphically on pl. 12. Water-stage recorders were maintained on several wells to obtain a continuous record of fluctuations of the water level.

As will be shown in the succeeding pages, these data are highly significant with regard to the occurrence of ground water in the area. They show the direction of movement of the ground water, the areas of probable discharge and recharge to the ground-water reservoirs, the effect of pumping on the reservoir, and, when studied with reference to pumping data, the safe yield of the ground-water reservoir. They show also that in the valley the shallow beds yielding highly mineralized water are separated from the deeper fresh-water-bearing beds by rather effective barriers to ground-water movement, but that the mineralized water is free to migrate laterally into the fresh water-bearing beds beneath the rim of the mesa, and it is possible that by following a circuitous path it may eventually contaminate the fresh water-bearing beds in the valley.

WATER LEVELS IN 1936

The contour map of the ground-water surface is based on measurements of the depth to water in all the deeper wells that could be measured in 1936. (See pl. 2.) The measurements in the wells on the Mesa some distance from the city were made at different times during the course of the investigation. The fluctuation of the water level in these wells from time to time is small. The measurements in wells near the city were made from June 10 to 14, 1936. In general, the water level in heavily pumped areas in El Paso was considerably lower in July than it was in June 1936 and a map based on these figures would have shown the water surface at nearly its low point for the year. The pumpage was shifted among city wells during the time the measurements were taken and since the water levels probably were changing rather rapidly, they have little value for map purposes, and the June measurements were used in preference because no shifting of pumpage had occurred for several days before they were taken. No water level determinations were made on the Mexican side of the Rio Grande during June 1936, but contours have been extended into that area based upon measurements made in December 1935.

The altitudes of the measuring points of the wells in and near the city were determined by spirit leveling and are referred to the United States Coast and Geodetic Survey datum. The altitudes of the measuring points of the wells some distance from the city were determined chiefly by altimeter, although some of the more distant wells close to permanent bench marks, the altitudes of which were known, were run in by spirit level.

The map shows that the surface of the ground water slopes eastward from the Franklin and the Organ Mountains and apparently slopes northeastward from the Sierra del Paso del Norte for a distance of several miles. In the United States the slope changes a few miles from the mountains to a southerly direction and it continues south at the rate of about 3 feet to the mile in the eastern part of the bolson until near the El Paso Valley, where it tends to parallel the valley. On the west side of the bolson there are two depressions, one centering in and near the mesa well field (wells 71–75 and 77–79) and the other centering in wells 49 and 50 in the Montana well field. The cone centering in the Mesa field is nearly circular, extends about 8 miles east and northeast of the Mesa field, and is about 45 feet deep (altitude at bottom, 3,655 feet above sea level). The one centering in the Montana field is elongated toward the wells at the refineries (wells 55, etc.) and is also about 45 feet deep.

Since water moves at right angles to its hydraulic gradient, the contours indicate that water enters the ground-water reservoirs along the east side of the Franklin and Organ Mountains, moves eastward and then southward toward the El Paso Valley. Some of it is diverted into the depressions and is discharged through wells, but some of it moves on past these depressions and eventually is discharged as small seeps or by transpiration of plants along the valley. Water probably also moves northeastward from the flanks of the Sierra del Paso del Norte and the Sierra del Presidio, part of it seeping out or being transpired along the El Paso Valley and part of it being discharged by wells.

PUMPING TEST

In December 1935 a pumping test in the vicinity of the Mesa well field was made to determine the permeability by the Thiem pumping method,[91] and on December 16, 1935, the water levels were measured in five wells in that field. Well 78 (El Paso well 11) was pumped at a uniform rate, and the water levels were determined in the observation wells at intervals during the test. Well 112 (old Mesa well 32) is 1,330 feet west of the pumped well; well 114 (old Mesa well 34) is 1,008 feet west; well 120 (old Mesa well 40) is 474 feet west; well 119 (old Mesa well 39) is 150 feet west; and well 77 (El Paso well 12) is 2,332 feet east. The pump in well 78 was started at 10 a.m., December 16, and was operated continuously at a rate of 2,200,000 gallons a day, or 1,530 gallons a minute, until December 25. On the first day the water levels were measured in the observation wells, at 10- to 20-minute intervals for several hours and at about 30-minute intervals for the rest of the day.

On succeeding days the water levels were measured one or more times each day until December 25. The measurements are listed in the table of depth to water measurements at the back of this report. The draw-down in well 77 was 1.2 feet in 7 hours. The value of the test was considerably decreased by the fact that lack of adequate storage facilities at Fort Bliss made it necessary to start pumping well 75 (Fort Bliss

[91] Wenzel, L. K., The Thiem method for determining permeability of water-bearing materials and its application to the determination of specific yield, results of investigations in the Platte River Valley, Nebr.: U. S. Geol. Survey Water-Supply Paper 679-A, pp. 53–57, 1936.

well 5), 1.25 miles southwest of well 77, on the seventh hour of the test. Well 75 was pumped at the rate of 1.6 million gallons a day. The combined pumpage of well 78 and well 75 lowered the water level in well 77, 5.08 feet in 171½ hours. From these data the average coefficient of permeability of the saturated portion of the formation was computed to be about 200—that is, about 200 gallons of water a day will flow through a cross section 1 foot high and 1 mile long under a gradient of 1 foot to the mile.

FLUCTUATION OF WATER LEVEL FROM DECEMBER 1935 TO JUNE 1936

Plate 13 shows the difference in the water levels as determined December 10 to 13, 1935, and June 10 to 14, 1936. In December the pumpage had decreased nearly to a minimum for the year. The Mesa well field had not been pumped for 14 days, the city being supplied about 3.5 million gallons of water a day from wells 49 and 50 in the Montana well field. In June the demand was nearly at its peak, nearly all private wells, all three wells in the Mesa well field, wells 49 and 50 in the Montana field, and wells 31 and 42 belonging to the city in the downtown area were being pumped. The shape of the area of influence around the Montana field was about the same in June as it was in December, but the water levels were about 5 feet lower. In the area within the city, west of the Montana field, the water levels were also about 5 feet lower. The area of influence of the Mesa well field and the Fort Bliss wells extended about 3 miles farther to the north and northeast and nearly as far south as the area affected by the Montana field. The water levels were about 25 feet lower in the vicinity of heavy withdrawal on the Mesa than in December 1935. The pumpage from all wells in the Mesa well field, the Fort Bliss wells, and other small wells nearby was about 7½ million gallons a day when the June measurements were made.

RECORDS OF WATER-STAGE RECORDERS

Water-stage recorders provide valuable information regarding the fluctuations of the water level in response to pumpage or possible recharge. Wells on which recorders are installed should be at least 8 inches in diameter to allow for free movement of the float; they should be properly situated with respect to other wells, and they must not have pumping equipment in them. A water-stage recorder was installed in well 37, at the Southern Pacific shops on Piedras Street, on September 10, 1935. This well was reported to have several strings of overlapping casing, which was slotted only from a depth of 854 to 884 feet. The static water level in this well was more than 10 feet higher than that in other deep wells in the area and was comparable with the water level in nearby shallow wells. Well 37 was filled to the brim when a water main in the yard broke on November 24, 1935, and the water remained at the surface until January 11, 1936, when the recorder was removed. Therefore it is evident that the well was partly obstructed. Nevertheless there were significant fluctuations of the water level prior to that time. The water rose steadily from September 10 until about 11 p.m. on September 13, when the rate of rise decreased. At about 5 a.m., September 14, the level began to decline and the decline continued until

6 p.m. on September 15 after which it became less rapid and by noon on September 17 it had ceased entirely. From that time until November 24 the water level rose steadily. The records of the water department show that well 22 (city well 6) was pumped from September 13 to 21, well 42 (city well 9) was pumped on September 13, 14, and 15, and well 31 (city well 7) was pumped September 9 to 22 and October 15 to 25. It appears from these data that the water level in well 37 declined as a result of the pumping of well 42—at this particular time about 0.7 foot with 3 days pumping—but that it was not noticeably affected by pumping of the other city wells.

The deep-well pump was removed from well 41 (city well 5) and a water-stage recorder installed on March 3, 1936. The altitude of the floor of the pump house is 3,779.74 feet and the altitude of the water level was 3,669.93 feet above sea level when the recorder was installed. From March 11 the water level rose steadily, except for the daily fluctuations of less than 0.1 foot that occurred throughout the entire period of record, reaching an altitude of 3,671.27 feet at 5 a.m. on April 1. At that time it began to decline, reaching an altitude of about 3,670.5 feet by April 10 and remaining there until April 29. The water level then began to decline more rapidly, reaching 3,668 feet by May 9, 3,665.12 feet on June 16, and 3,663.75 feet on July 3. From then until the morning of July 11 the water level rose to about 3,663.91 feet; by July 14 it had reached 3,666.77 feet, and on the afternoon of July 26 it was 3,668.84 feet. The level had declined to 3,667.34 feet by August 2 and had risen to 3,672.75 on September 14. It declined again to 3,671.94 on September 19 and continued at about that level until September 27 when it began to rise abruptly, reaching 3,675.07 feet on October 5. It declined to 3,673.09 feet above sea level on October 14 and remained there until October 21, when it started to decline again. On October 23 it was at 3,671.78 feet.

Pumpage from wells in the Montana field for 1936, in thousand gallons

Month	Well 50	Well 49	Well 52	Total
January	53,272	55,750	----------	108,972
February	49,538	49,200	----------	98,738
March	51,714	54,500	----------	106,214
April	50,200	52,243	----------	102,443
May	52,007	52,100	----------	104,107
June	50,378	50,378	1,600	102,356
July	48,500	26,600	43,039	118,139
August	48,601	3,575	52,766	104,942
September	32,709	----------	49,779	82,488
October	28,386	17,900	55,800	102,086
November	----------	29,001	52,200	81,201
December	----------	51,261	18,980	70,241

The major fluctuations in the water level in well 41 are doubtless due to the combined effect of the pumpage of all the wells in the vicinity, but as the pumpage in the Montana field is much larger than that in any other nearby area, it would be reasonable to suppose that the pumpage in this field would exert a greater influence on the water levels. Unfortunately, the data relative to the periods when the various wells were pumped are not complete, but a few pertinent data are available. The preceding table gives the pumpage from each of the wells of the Montana field. Wells 49 and 50 (city wells 4 and 1) are 1,000 feet apart, and well 52 (city well 3) is 0.7 mile farther east.

From March until July the pumpage in the Montana field was nearly constant and was all taken from two wells that were nearly the same distance from well 41. The pumpage in the remaining wells in the vicinity was increasing, however, and reached a maximum in June. On July 3 the water level in well 41 reached its minimum and started gradually to rise. At 7 p.m. on July 10 the wells in the Montana field were shut down and at 3 a.m. July 11, the water level in well 41, which had risen 0.16 foot in 8 days, began to rise more rapidly. The wells in the Montana field were pumped again at 9 a.m. July 13, and at 8 a.m. on July 14 the water level in well 41 was 2.86 feet higher than it had been 3 days earlier, but at this time the rate of rise decreased, and during the next 12 days a rise of only 2.07 feet was recorded. An interesting feature of these data is the length of time that elapsed between the change in the pumping in the Montana field and the change in water levels in well 41 only 1¼ miles distant. Precise information as to the pumping for the remainder of the year is not available. However, the above conclusion that the rate of pumping in the Montana field affects the water level in well 41 is indicated by the pumping record from the wells. In spite of the cessation of pumping for 3 days in July the total pumpage reached a maximum during that month, and by August 2 a slight decline had occurred in well 41. In the succeeding months both the pumpage and the water level were somewhat variable, but the general water level was higher than previously. During this period about half of the water pumped from the field was from the most distant well, which would affect the water level less than closer pumpage, and the combined monthly pumpage from the two closer wells was less than half of the combined monthly pumpage from these two wells during the first 6 months of the year. It seems probable, therefore, that if further records were available a closer relationship could be established.

A water-stage recorder was maintained on well 52 (city well 3) from September 11, 1935, to April 28, 1936, and from June 12 to 24, 1936. From September to April the well below a depth of 375 feet was filled with sand, and the record obtained showed the fluctuation of the water table in that vicinity. Shallow water had access to the well through a hole in the casing. The altitude of the floor of the pump house is 3,783.20, and the depth to water fluctuated between 98.9 and 99.3 feet, making the altitude of the shallow water table 3,684.3 to 3,683.9 feet. The charts show a regular daily fluctuation of the water surface amounting to 0.04 to 0.08 foot, the low stages occurring about 10 a.m. and the high stages about 4 p.m. Local pumpage is suggested as the cause of the daily fluctuation, but no evidence is available to support such a suggestion. The recorder was installed for a short time in June after the well had been cleaned out to its original depth. The depth to water then was about 118.9 feet, but the daily fluctuations were similar and of about the same magnitude as in the shallow-water horizon. On June 18, when wells 49 and 50 were shut off for about 10 hours, the water level in well 52 rose 1.8 feet. On June 22 well 51 (city well 2) was pumped at the rate of 1.0 million gallons per day for 4 hours and the water level in well 52 fell 1.4 feet.

A water-stage recorder was installed in well 51 on June 24, 1936. The same daily fluctuations were found on these charts as were present on the recorder charts from well 52. On July 10, wells 49, 50, and 52, pumping a total of about 5 million gallons a day, were shut down, and the water level in well 51 rose from an altitude of 3,651.57 feet at 7 p.m., July 10, to 3,667.29 feet at 9 a.m., July 13, and would doubtless have risen much higher if the pumps had not been started at that time. Other abrupt changes in the water level during the remainder of the year have been registered each time the pumping of a well in the field began or ceased.

ORIGINAL GROUND-WATER LEVELS AND THEIR RELATION TO WATER LEVELS IN 1936

Few data are available on the original water levels in deep water-bearing beds in the El Paso area. Slichter[92] discussed the depth, water levels, and other data of a number of wells in the El Paso Valley and on the Mesa. Most of these wells have been destroyed, and their exact locations are not known. However, the location of some of the wells is known, and the approximate altitude of the original water level in these wells can be determined and compared with the present water levels in wells at or near their sites. Slichter used a depth to the water level of 179 feet at the International Water Co. plant (old Mesa plant) in drawing a section showing the water table as of August 30, 1904. Meinzer,[93] in writing about the wells in the Mesa well field in his report on the Tularosa Basin in 1911, stated, "It appears that in 1905, when the first wells were sunk, the water level was about 177 feet below the surface, but it now (1911) stands about 193 feet below the surface in the new wells before they are pumped." By 1911, however, about 15,000 acre-feet of water had been pumped from the wells in the Mesa well field and about 2,500 acre-feet from other wells near the field; probably a substantial cone of depression had been developed. The water level in well 83 was reported to have been 177 feet below the land surface, probably in 1904.[94] The altitude of this well is about 3,871 feet; therefore, the altitude of the water surface in 1904 was about 3,694 feet. Some draw-down had doubtless occurred by 1904. In well 80,[95] near the intersection of Wilson Road and the Southern Pacific Railroad, the water level was reported to have been 190 feet below the land surface in 1901. As the altitude of the ground at this point is about 3,886 feet, that of the water surface was, therefore, about 3,696 feet. In well 81,[96] about half a mile northeast of well 80, the water level was reported to have been 169 feet below the surface in 1901. The altitude of the ground at this point is about 3,876 feet, thus the altitude of the water surface was about 3,707 feet. The exact altitude of the measuring points on these wells is not known, but evidently it would not be far wrong to say that the original water level at the Mesa plant was about 3,700 feet above sea level, or about 170 feet below the surface of the land. The wells on the Mesa that are outside of the cone of influence of the wells near El Paso have been pumped chiefly for watering stock. The water levels in them have shown very little fluctuation during the period in which they have been measured. It seems reasonable, therefore, to assume that they have not changed much in the past. If the contours are extended from the areas where

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[92] Slichter, C. S., Observations on the ground waters of Rio Grande Valley: U. S. Geol. Survey Water-Supply Paper 141, p. 16, 1905.

[93] Meinzer, O. E., Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, p. 117, 1915.

[94] Record supplied by F. H. Todd.

[95] Slichter, op. cit., p. 78.

[96] Slichter, op. cit., p. 78.

there has been little change across the areas where heavy pumping has modified the water table, the extended lines should approximate the early water surface. The map (pl. 2) shows that if the 3,700-foot water-table contour were extended in a straight line from the eastern part of the bolson westward toward the foot of the Franklin Mountains, as it may have been before the pumpage occurred, it would pass through the old Mesa well field and cross the Southern Pacific Railroad near Wilson Road. Thus, the original depth to the water level at the Mesa plant would appear to have been about 170 feet below the land surface before pumping began. The present water level is, therefore, about 45 feet lower than the original level in the vicinity of the Mesa well field.

Although there were wells on the Mesa near Fort Bliss as early as 1901, not much water was pumped from that area until after the development of the old Mesa well field was begun in 1904. During the period from 1904 to 1917 the pumpage in this field increased to an average of 6.4 million gallons a day, and the water level probably declined progressively. After 1917 the pumpage gradually decreased to practically nothing by 1926, and the water level rose again. Wells 79, 78, and 77 (city wells 8, 11, and 12) have been drilled in the Mesa well field since 1928, but little water was pumped from them until 1935, when the average pumpage amounted to 2.0 million gallons a day. Pumpage at Fort Bliss has been increasing since the first wells were drilled, about 1900, to an average of 1.3 million gallons a day during 1935.

On December 16, 1935, the static water level in well 112 (old Mesa field No. 32) was 193.2 feet below the land surface when all three of the pumped wells in the Mesa well field had been shut down for 14 days. If the altitude of the ground at the shaft between wells 89 and 95 (old Mesa field Nos. 9 and 15) referred to in Meinzer's[97] report is about the same as at well 112, the water level in December 1935 was about 4 feet higher than that reported by Meinzer about 1912. However, in that year the wells had been shut down only 19 hours when the measurement was made, so it is probable that the water level would have risen a few feet more at that time if the wells had been allowed to stand idle for as long as they had before the measurement in 1935 was made. When pumping was resumed following the rest period in December 1935, the water level declined.

As explained on p. 61, the cone of depression formed by the pumping in and near the Mesa well field from 1904 to 1936 was about 45 feet deep and extended toward the east and northeast for a distance of about 8 miles. The volume of material in this cone of depression is calculated to be about 125,000 acre-feet. The specific yield of the sands that were tested from test wells 64, 76, and 136 was about 35 percent. The bedded material below the water table is about half sand and about half clay. For practical purposes the clay may be assumed to have a specific yield of zero percent and the average specific yield of the section below the water table is therefore about 17 percent. Thus, the material in the cone of depression would yield from storage during the formation of the cone about 22,000 acre-feet of water. However, the amount of water pumped during the formation of the cone of depression from the beginning of the pumping to June 1936 is estimated to have been about 90,000 acre-feet, and, therefore, only about one-fourth of the water pumped was taken from storage. The remainder must have come from

[97] Meinzer, op. cit., p. 117.

recharge. During the same period about 210,000 acre-feet of water was pumped from the cone of depression in the El Paso Valley in and near El Paso. The volume of this cone can not be determined because water in the valley is under artesian conditions.

WATER LEVELS IN SHALLOW WELLS IN EL PASO VALLEY

The comparatively shallow water-bearing beds, which contain moderately to highly mineralized water in the valley both in the city and for several miles below it, are apparently more or less completely separated by impervious beds from the deeper beds that contain fresh water, since the water level is higher in the shallow beds than in the deeper beds. However, these shallow water-bearing beds occur at about the same level as the upper fresh water-bearing beds of the Mesa, and under proper conditions highly mineralized water could move from the beds in the valley into the beds beneath the Mesa. To determine the relation between the shallow and the deeper water, about 250 shallow wells were dug with hand augers in the valley from Cotton Avenue eastward to below the city limits. This work was carried on as Project 1669 of the Works Progress Administration under the supervision of Robert H. Colvin. Test holes were sunk north of the river within the area where the water table was generally 25 feet or less beneath the surface, and samples were obtained of the material penetrated and of the water. Water levels were measured, and levels were run to nearly all the test holes. (See pp. 148–155.) Data were also furnished by the city engineer's office on shallow wells dug for the same purpose many years earlier in the area west of Cotton Avenue. A round of measurements of depths to water was made April 27 to 29, 1936, and these water levels were used to compile a map showing the altitude and configuration of the water table. (See pl. 14.) This map shows that throughout most of the area the hydraulic gradient is away from the river and that in the area west of Hammett Avenue it is much steeper than in the area downstream. Therefore water is seeping from the river throughout the stretch mapped, and probably the seepage is much greater in the stretch from Hammett Avenue westward. The high water table near wells 90 and 99 on Franklin Canal east of Valverde Avenue suggests that water seeps from the canal, notably near the northwest point of Cordova Island, near the crossing of United States Highway 80, and east of the city limits between Glenwood Drive and First Avenue. The water in the marsh on the east side of Highway 80, just south of Ascarate, probably also seeps from the canal.

The data obtained from the test wells indicated that water seeping from the river and canal was moving in a general northeasterly direction. A part of it may be intercepted by a shallow well at Pasotex Refinery, which yields considerable water at times, and a part by a few scattered shallow wells between Cotton Avenue and Ascarate, but as the total pumpage from these wells is small, the shallow water may move beyond them and contaminate the upper water-bearing beds beneath the Mesa. Evidence that there has been some contamination of the beds beneath the edge of the Mesa is seen in the analyses of water samples from wells 67 and 68 owned by the Southern Pacific Co., from well 65 at the American Airways station, and well 77 at Fort Bliss. (See table of water analyses, p. 118.) During the summer of 1936 the altitude of the water level in the wells of the Southern Pacific Co. was about 3,666 feet, and the altitude of the shallow water in the Montana well field was about 3,685 feet, a hydraulic gradient of 19 feet in a distance of about a mile. The data are illustrated in figure 8.

In the Montana well field beds that contain highly mineralized water occur overlying, interbedded with, and underlying the beds containing fresh water. As these highly mineralized waters are cased off in most wells there is little draft on them, and the water levels remain the same. In the fresh water-bearing beds, however, the water levels decline as a result of pumping; hence, if corrosion or faulty well construction leaves an opening in the casing that will permit the highly mineralized water to enter the well, it will do so freely because it has a higher static head than the fresh water, and it may even enter the fresh-water sands through the well. Furthermore, where the formation dividing the two types of water is thin, or not continuous, heavy pumping may cause the formations to collapse, and water may pass directly from one bed to the other when the pressure is greater in the bed containing salt water. For several years water levels in the Montana well field have been too low for safety. In this field city well 1 was placed in service in 1918, well 3 in 1922, well 2 in 1923, and well 4 in 1924. Records of the water department show that 80,500 acre-feet of water had been pumped from these four wells by the end of 1935. During the 10-year period ending with the summer of 1934, 43 percent of all the water pumped in the El Paso-Ciudad Juarez area was pumped from these wells. Seventy-five percent of all the water pumped by the city water department during the same period was taken from the Montana well field, 21 percent of which came from well 52 (city well 3). The chloride content of the water pumped from these wells was gradually increasing, and in 1934 the chloride content of well 52 increased suddenly to 400 parts per million. The exploration and repair of this well is discussed on pages 81–83. The increase in chloride was found to be due to corrosion of the casing, but the danger of contamination of the fresh-water beds by salt water, because of large differences in water level, should be guarded against by substantially reducing the pumpage from this field.

RECHARGE TO THE WATER-BEARING FORMATIONS

GENERAL FEATURES

Water that falls on an area or crosses it in surface streams or canals flows from the area as surface runoff, is lost by evaporation, or sinks into the ground. This report is especially concerned with the water that sinks into the ground. The part of the water that is held within a few feet of the surface by molecular attraction is called soil moisture. It is subject to losses by evaporation and the transpiration of plants. Part of the water may percolate downward under the pull of gravity to the water table, which is the upper surface of the saturated part of the formation, and there it becomes subject to withdrawal by springs, seeps, and wells. The water that reaches the water table is called ground-water recharge, and the area in which such recharge occurs is known as the intake area. It is usually the outcrop area of the formation, but where a formation is composed of alternating and irregular beds of sand, gravel, and clay, the intake area may be restricted to those parts of the outcrop area beneath which impermeable beds are absent or discontinuous. The intake area and all the other areas that contribute surface water to it are called the catchment area. Thus, the intake area may be only a narrow belt, but the catchment area includes the entire drainage area that discharges across this belt.

The amount of water that may be pumped from a ground-water reservoir is limited by the amount of water that is in storage and the amount of recharge to the reservoir.

If ground water is taken largely from storage the supply will be depleted, and water levels in the reservoir will decline until it will be no longer economically feasible to lift the water to the surface, or until the formation in the vicinity of the wells has been pumped dry. This depletion might occur rather rapidly in a small reservoir but would occur slowly in a large reservoir, and many years of pumping might be required to lower the water levels in the well fields to a point where further pumpage would not be economically feasible. On the other hand, if the withdrawal in the pumped area is approximately equal to the recharge, the water levels in the ground-water reservoir will decline, rather rapidly at first and then more slowly, until finally they will remain nearly constant. In the meantime, water levels in the surrounding area will decline, but to a less extent, thus establishing a gradient of the ground-water surface toward the pumped area. If this condition were stable it would be said that the reservoir was being pumped at its safe yield. Actually the pumpage and the recharge are never maintained at a constant rate; consequently there are always minor fluctuations in water levels.

The ideal procedure in determining the safe yield of an underground reservoir would be to map the intake area and make observations to determine the percentage of the total precipitation that enters the ground, passes through the belt of soil moisture, and moves downward to the underground reservoir. From these data and the precipitation records the average total annual recharge could be estimated. The figure thus reached could then be checked by a careful analysis of the records of pumpage from the reservoir and fluctuations in the water levels in wells. In practice, however, many factors beyond the control of the investigators render such a complete program impossible and it is usually necessary to base the estimates of safe yield on the effect of a known amount of pumping on the water levels during a period of years.

The contour map (pl. 1) indicates that the chief recharge area of the El Paso reservoir of fresh ground water is on the coalescing alluvial fans and in the gravel-floored canyons at the heads of the fans along the east side of the Franklin Range and the Organ Range, in the United States. Recharge also occurs in similar areas along the northeast side of the Sierra del Paso del Norte and the Sierra del Presidio. Some water may enter the area from La Mesa through the pass between Cerro de Muleros and Sierra del Paso del Norte, and some probably enters the area from the south from the Valley of Samalayuca through the water-bearing beds in the pass between Sierra del Paso del Norte and Sierra del Presidio, although the amount of water entering the area by underflow from other basins is believed to be rather small. There is considerable recharge to the shallow water-bearing beds of the Rio Grande Valley from the Rio Grande and from the canal system and irrigation ditches in the valley. This water is moderately to highly mineralized and is more or less completely separated from the deeper beds of the valley, which yield water of better quality by impermeable beds, although it is believed that there is a direct connection laterally between the shallow beds of the valley and the upper water-bearing beds of the Mesa.

RECHARGE TO FRESH WATER-BEARING BEDS

At first glance the Hueco bolson appears excellent for recharge—its large sandy areas are flat and have no well-defined drainage except near the margins of the Rio Grande Valley. Part of the water that falls on the bolson is lost by evaporation or transpiration, and part percolates downward, but detailed study shows that very little of this water reaches the water table as recharge. Underlying the entire area, with the exception of the depressions, is a bed of caliche from 1 to 4 feet thick, which appears to prevent almost entirely the ready downward movement of water. This is indicated by the root pattern of the mesquite and other desert vegetation, which radiates in all directions from the plant. The roots of the mesquite, in particular, extend 40 feet or more along the top of the caliche, but only here and there do they penetrate it. This widely extended root pattern suggests that water is more readily available to the plants on the top of the caliche than beneath it. A considerable number of holes and trenches were dug in different parts of the bolson under an allocation of funds by the Works Progress Administration under the supervision of J. F. Heuser, in order to study conditions affecting the penetration of moisture into the soil and subsoil of the valley floor. Logs of the holes were kept, and samples of the material obtained at various depths were tested for moisture content. Records of 35 of these holes are given on pages 159–164. These data show that in most places the water content was less beneath the caliche than above it; however, in a few of the test holes and trenches that were put down, chiefly in depressions where the caliche was absent or highly fractured, varying moisture contents were found, suggesting that some recharge may occur in those areas. In some places there are pipelike openings in the caliche through which some water may percolate downward into the deeper beds; in general, however, the recharge in the sandy areas probably is small, and the rain that falls on the floor of the bolson is either evaporated or transpired.

In the area near the Hueco Mountains wells are so few that the evidence of ground-water movement and recharge is not conclusive; however, the ground-water contours are nearly normal to the mountain front, indicating that the recharge from the Huecos is small in comparison with the recharge on the west side of the Hueco bolson.

In the area south of Ciudad Juarez, in Mexico, there is only one well, No. 18A. The water level in this well is about 150 feet higher than that in the city. There is thus a gradient toward the north that may cause the ground water to move in that direction. Farther south, in the Valley of Samalayuca, the water issues at the surface in several springs, and in the railroad well at Samalayuca the water level is about 500 feet above that in Ciudad Juarez. These facts may indicate that there is underflow through the pass between the Sierra del Paso del Norte and the Sierra del Presidio of ground water from the Valley of Samalayuca. There is probably also a considerable amount of recharge from the northeast slope of the Sierra del Paso del Norte and the Sierra del Presidio, where there are relatively large areas of gravel that would form excellent recharge areas. The fact that the water level in Ciudad Juarez is higher than it is in El Paso indicates that some recharge occurs southwest of the former city. No attempt was made to determine the amount of recharge on these alluvial slopes, but it seems probable that it is considerably less than that on the east side of the Franklin and Organ Mountains.

Slichter[98] has shown that the maximum thickness of the sediments in the gorge above El Paso is 86 feet. He concluded that the underflow through these beds amounted to not more than 50 gallons a minute. The thickness of the sands and gravels in the area between the river and the Sierra del Paso del Norte is not known; however, the Cerro de Muleros lies on the south side of the river, and the Cretaceous sediments on the south side of Cerro de Muleros dip southward toward the Sierra del Paso del Norte, about 3 miles distant, at such a low angle that the thickness of the unconsolidated deposits below the water table probably is not great enough to permit any large amount of ground water to enter the Hueco bolson in this area, although some water may enter from La Mesa.

In general, the slope of the water table beneath the Hueco bolson is from the northwest to the southeast. (See pl. 2.) Locally, of course, the slope of the water table is modified by pumpage as in the vicinity of El Paso. Since ground water moves in the direction of the hydraulic gradient, it is evident that the main recharge in Texas and New Mexico comes from the east side of the Franklin and Organ Ranges.

There is abundant opportunity for recharge in this area. Plate 2 shows the area of gravel (the recharge area) along the east side of the mountains as mapped in the field by reconnaissance. The western margin of the gravel is easily mapped because there is an abrupt change from gravel to rock. The eastern margin, however, is gradational from gravel to sand to clay and is therefore less easily mapped. The total area of the gravel was determined to be about 71 square miles, but the area in which rain falling on the surface must drain over the gravel (the catchment area) is 127 square miles. Actual measurements of the proportion of the rainfall that ran off, sank into the ground, or was lost by evaporation were not possible, partly because the rains occurred as thunder storms, and it was difficult to reach the area of precipitation in time to make observations on the runoff, and partly because the terrain and nature of the runoff was such that seepage measurements were not practicable. Also, during the period of the investigation the precipitation was considerably less than normal although such observations as were made, however, were significant. The gravels were so permeable that light rains were completely absorbed and no runoff occurred. Heavy rains, on the other hand, caused rapid runoff, forming torrents that flowed from the canyons down the alluvial slopes, losing water along the way and finally running into one of the slight depressions situated 2 or 3 miles from the mountains. Near the south end of the Franklin Mountains a large number of small reservoirs have been formed by the construction of a series of dams in each of the canyons. These dams held all of the water flowing from the mountains during the course of the investigation, but the runoff from the alluvial slopes below the dams was sufficient, in several cases, to move great quantities of gravel ranging upward to boulders 6 inches or more in diameter, and to deposit them in the city streets, in yards, and on lawns. Most of the runoff from this

[98] Slichter, C. S., Observations on the ground waters of Rio Grande Valley: U. S. Geol. Survey Water-Supply Paper 141, pp. 9–13, 1905.

part of the area is carried to the Rio Grande, through the draw heading near Fort Bliss.

The dams in the canyons form effective recharge reservoirs. The high-water mark of the lowermost reservoir in McKilligan Canyon (pl. 15) indicates that about 4 feet of water collected in the reservoir during the storm of the afternoon and evening of July 10, during which 0.35 inch of rainfall was reported in El Paso, but the rain is believed to have been heavier in the mountains north of the city, all of this water being lost into the gravels in less than 12 hours. The other dams in McKilligan Canyon and the canyons south of it acted in the same way. On July 30 the Weather Bureau in El Paso reported a rainfall of 0.22 inch. This rainfall is also believed to have been somewhat heavier in the mountains north of the city. One stream north of the Baptist Sanatorium, at the point of its emergence from the canyon, had a flow of less than 10 second-feet. About one-third of the discharge was lost by seepage in the quarter of a mile below the mouth of the canyon. Similar losses doubtless occur on all of the streams along the east sides of the Franklin and Organ Ranges. The water that crosses the gravel flows into the depressions and forms temporary lakes, except in the southern part of the area, and these lakes, with one or two exceptions, dry up in a short time, so that all of the water falling in the area either evaporates, is transpired by the plants, or sinks into the ground.

Because a large part of the total annual rainfall occurs in the summer when the surfaces of rocks and gravel are quite hot, a great deal of water is lost by evaporation. Presumably, in the gravel areas, after surface evaporation is satisfied, the principal part of the water entering the gravel sinks downward to the water table, but certain amounts are held by molecular attraction and lost by transpiration. Of the water that crosses the gravel areas and flows into temporary lakes only a small part may reach the water table, because the floors of these lakes are usually clayey, and evidence that considerable transpiration takes place from them is given by the fact that the vegetation on them is heavier than that in most other parts of the Hueco bolson. No direct evidence of the amount of water reaching the water table is available.

It is assumed that 25 percent of the water that falls in the catchment area in and near the Franklin and the Organ Mountains above the lower limit of the gravel becomes recharge. The total area is 127 square miles, and the average rainfall, as reported by the Weather Bureau at El Paso for the period of 51 years prior to 1931, is 9.16 inches. The annual recharge would be approximately 15,000 acre-feet per year, or about 13,000,000 gallons a day. If it is assumed that recharge is now occurring at the average rate, two-thirds of the average daily pumpage of 15,000,000 gallons, or 10,000,000 gallons is supplied by recharge to wells near El Paso.

It is probable that there are years or even periods of several years in which almost no recharge occurs. On the other hand, much more than the average recharge may occur in a single year when precipitation is above normal. Many factors, such as the intensity of the rain, the condition of the soil and vegetation, and the frequency of the rains affect the amount of recharge that may be expected from a single rain of a given quantity. Thus, a larger proportion of water will enter the ground if the rain is slow than if it is torrential, because the permeability of the soil is limited and thus the rain may fall at a rate greater than the rate at which it can be absorbed. Likewise, there will be more recharge if the rain follows a period of wet weather, because at such a time the soil moisture requirements are satisfied and most of the water that enters the ground goes downward to the water table; whereas after a long dry period the soil is depleted of moisture, and this deficiency must be made up before any water can move downward to the water table.

In the El Paso area, the precipitation as reported by the United States Weather Bureau is extremely variable. (See pp. 8, 9.) Figure 1 shows graphically the annual precipitation for the period from 1879 to 1937, inclusive, and the cumulative departure from normal precipitation. Since 1915 the precipitation has been less than average, except in 1919, 1926, 1929, 1931, and 1932, when it was only slightly more than normal. From 1911 to 1915, with the exception of 1913, the precipitation was excessive; from 1907 to 1910 it was less than normal; and from 1902 to 1906 it was much above normal, as would be expected from the fact that it followed a period of excessive precipitation. In the first measurement of depth to water in wells in the Mesa field, 177 feet in 1905, the level is relatively high. In 1911 the water level in that field was reported to be 193 feet below the surface, a decline of 16 feet since 1905, which does not appear excessive in view of the volume of the pumpage from 1905 to 1911 and of the 4 dry years, 1907 to 1910. The next recorded measurement is in 1935, when the water level had declined to 200 feet. For several years before 1935 there had been almost no pumping from the Mesa field. Although the pumpage at Fort Bliss had been increasing, the total pumpage in the area was less than in 1911. There was also a considerable cumulative deficiency in precipitation. From the amount of pumpage preceding the measurement, therefore, we should expect a higher level in 1935 than in 1911, but from recharge the level should be lower. It is unfortunate that annual records of the water levels in the Mesa field have not been kept from the time the first well was drilled so that comparisons could be made between water levels, pumpage, and precipitation, and so that the effect of periods of heavy precipitation, such as the 1911–1916 period, could be determined and the amount of recharge more closely estimated. However, a large amount of recharge must have occurred from time to time because the water level in the Mesa field in 1935 was only 23 feet below the level in 1905 in spite of the pumping that had occurred in the area.

RECHARGE TO MINERALIZED WATER-BEARING BEDS

The shallow water-bearing beds of the valley receive practically all of their recharge from the river and from the irrigation canals. No attempt was made to determine the amount of the recharge. As pointed out on page 56, the El Paso Electric Co. pumped a number of shallow wells at a rate of 8,500,000 gallons a day for several years, during which time no difficulty was experienced in the city with high ground-water levels, but when the company stopped pumping the level rose so that water stood in many basements in the business section. The city put down a drainage well 50 feet deep, which has been pumped almost continuously at a rate of about 1,000 gallons a minute since 1933, and this pumping has been fairly successful in keeping the ground water out of the basements. In addition, several of the basements have sumps with small pumps to keep the water level below the basement floors. The recharge to the shallow water in the section from El Paso to the gorge is therefore at least 1,000 gallons a minute (1,440,000 gallons a day) and may be as much as 8,500,000 gallons a day.

The rectification of the Rio Grande is reported to have lowered the bed of the stream at El Paso by several feet and will probably eventually result in lowering the water table in the downtown area by several feet.

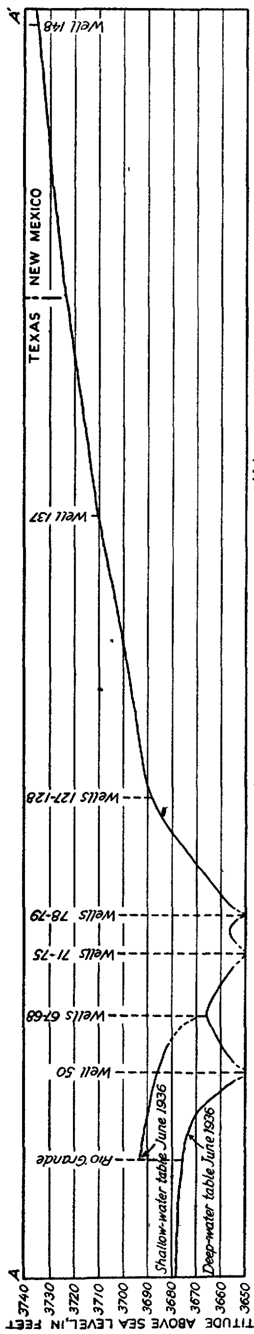


FIGURE 8.—Diagram showing profiles of water table and piezometric surface along line A-A' on plate 2.

The hydraulic gradient is sufficient to cause the water entering the shallow beds as seepage at the surface near El Paso to move northward. There is some evidence that such movement has already begun. (See fig. 8.) The shallow water in the vicinity of the Montana well field, and probably for some distance north of it, is very highly mineralized, containing in some places from 2,000 to 10,000 parts per million of dissolved solids. (See table of analyses of water from hand-dug wells pp. 156–158.) The resistivity investigations indicate that the northern boundary of this shallow salt-water area is almost coincidental with the Mesa rim.[99] The clay beds intervening between the salt-water-bearing beds and the underlying beds that bear fresh water may extend over large enough areas to prohibit the direct downward movement from the salt water to the fresh water-bearing beds, but there is apparently no barrier to lateral movement and hydraulic gradient is sufficient to cause the shallow water to move northward into the upper fresh-water beds under the Mesa, which lie at the same level as the salt-water beds beneath the valley. For this reason it is important to reduce this gradient if possible, or at least to avoid increasing it, by locating any large new well fields as far north of the valley as is practicable, by reducing the draft on the wells near the edge of the valley, and by pumping the shallow water for cooling and other purposes for which water of good quality is not required.

QUANTITY OF POTABLE GROUND WATER AVAILABLE IN STORAGE

In determining the quantity of water available from a ground-water reservoir and the rate at which it can be pumped, the rate

[99] Sayre, A. N., and Stephenson, E. L., The use of resistivity methods in the location of salt-water bodies in the El Paso, Texas, area: Am. Geophys. Union Trans., 1937, pt. 2, pp. 393–399, 1937.

of recharge, amount of water that is in storage, and permeability of the water-bearing formations must be considered. If water is removed from the reservoir faster than it is replenished, the water levels will decline eventually reaching a level at which it will no longer be economical to pump the water from wells. However, if the reservoir is large and has considerable storage capacity, a very considerable period may elapse before the water levels become so low that it is necessary to seek other sources of supply. In addition to the problem of the amount of ground water available, El Paso is faced with the danger of contamination of the beds of fresh water in and near the valley by the highly mineralized water from certain other beds. The solution of these problems is of utmost importance to the citizens of the area.

From the foregoing it is evident that ground water is being taken from storage at El Paso—the ground-water reservoir is being depleted. The rate of this depletion will depend chiefly upon the rate of recharge, and the life of the reservoir will be limited by the amount and availability of the ground water in storage. The data available are not yet sufficient to determine these quantities accurately, but a preliminary estimate has been made, and it is hoped that the collection of data may continue until accurate estimates can be made.

The significance of the cone of depression in the water surface on the Mesa in and near the Mesa field has already been discussed. If, for the purpose of computation, it is assumed that wells were drilled and pumped so that this cone of depression was elongated toward the north a distance of 10 miles and was of a depth equivalent to that in the existing cone, the depression would then be a trough 10 miles long, 45 feet deep at the middle, and about 8 miles wide. The volume of this trough of depression would be about 768,000 acre-feet and if 17 percent of this volume represents water that can be recovered by wells, the amount of water released from storage would be about 130,000 acre-feet, which at the rate of pumpage in 1935 would equal all of the pumpage from deep wells in the El Paso area for a period of about 7.5 years. More than 20 years would be required to reduce the static water level in these wells an amount equal to the amount of decline in the Mesa well field, if the pumping rate were 15,000,000 gallons a day, because only about one-third of the water is taken from storage, two-thirds coming from recharge. Of course, the amount of water that could be withdrawn from storage could be greatly increased by lowering the static level of the pumped wells to a greater depth than that postulated, but such a lowering would require greater pumping lifts, which would increase the cost of pumping.

MINERAL CONTAMINATION OF WELLS

Some wells in the El Paso area yield water higher in mineral content than normally would be expected in comparison with other wells near them. In some areas, as in the Montana well field, the mineral content of the water from wells has been increasing for quite a number of years. To determine the source of the contamination certain tests[1] have been made. Contamination tests were made on most of the city wells by collecting water samples at short intervals, beginning when the pumping

[1] Livingston, Penn, and Lynch, W. A., Methods of locating salt-water leaks in water wells: U. S. Geol. Survey Water-Supply Paper 796-A, 1937.

was started, and by testing them for chloride or hardness in the field. Since under favorable conditions the approximate depth from which a sample was taken can be calculated if the diameter of the well, the rate of pumping, and the elapsed time are known, the changes in the mineralization gave a clue as to the character of the water entering the well at various depths. The chloride values, determined by the field tests may be as much as 5 percent from the true values, but a difference of not more than 2 percent was found when two or more tests were made from the same sample. The hardness determined may be somewhat lower or higher than the true hardness, but since the tests were all made by exactly the same method, the hardnesses determined should be comparable.

One test consisted of taking water samples at desired depths with a deep-well water-sampler and testing for chloride and hardness. The water sampler used for these tests consisted of a short length of 1½-inch pipe with a leather flap valve set in each end. With this device a sample could be obtained at any desired depth by giving the cable a few jerks thus flushing the sampler and trapping a sample of water between the valves.

Another test consisted of determining the electrical conductivity of the water in a well at various depths by means of a pair of electrodes separated by a fixed distance and lowered into the well attached to a double conductor cable. At regular intervals the amount of current was measured that flowed through the water between the electrodes when a fixed low voltage was applied. Since the conductivity of water increases roughly as the amount of dissolved mineral matter in it, the conductivity is an indication of the mineralization, and the relative mineralization of the water at any depth in a well can be compared with that at any other depth. Because it is desirable to make this test as quickly as possible after pumping ceases, a small set of electrodes was designed to use while the pump was still in place. Unfortunately the pump columns in the El Paso city wells have flange couplings that nearly fill the space between the casing and the pump columns, making it impossible to work the electrodes down between the flanges and the well casing. Therefore, explorations with the electrodes as well as with the water sampler were made only in wells from which the pump had been removed. The data obtained by these tests and a discussion of the condition of each well is given below. During the test all depths were measured from the floor of the pump house.

WELLS IN THE MONTANA WELL FIELD

CITY WELL 1 (WELL 50)

On September 27, 1935, a contamination test was made after this well had been standing idle for 91 hours. The depth to water was 102.15 feet before pumping began and 185.0 feet after 5½ hours of pumping at the rate of about 1,200 gallons a minute. The pump was set with the suction at a depth of 190 feet. The curve in figure 9 shows the results of this test and is typical of curves obtained from plotting the results of tests made in wells in which highly mineralized water has leaked into the well a considerable distance above the bottom and has moved downward and replaced the fresh water below the leak. For the first minute of pumping, the water discharged contained about 250 parts per million of chloride and by the end of the third minute it contained 750 parts per million. From the third to the thirteenth minute the chloride content dropped gradually to 270 parts per million and after 3¼ hours of pumping to 260 parts per million. The water in the pump column evidently was of the same mineralization as the water

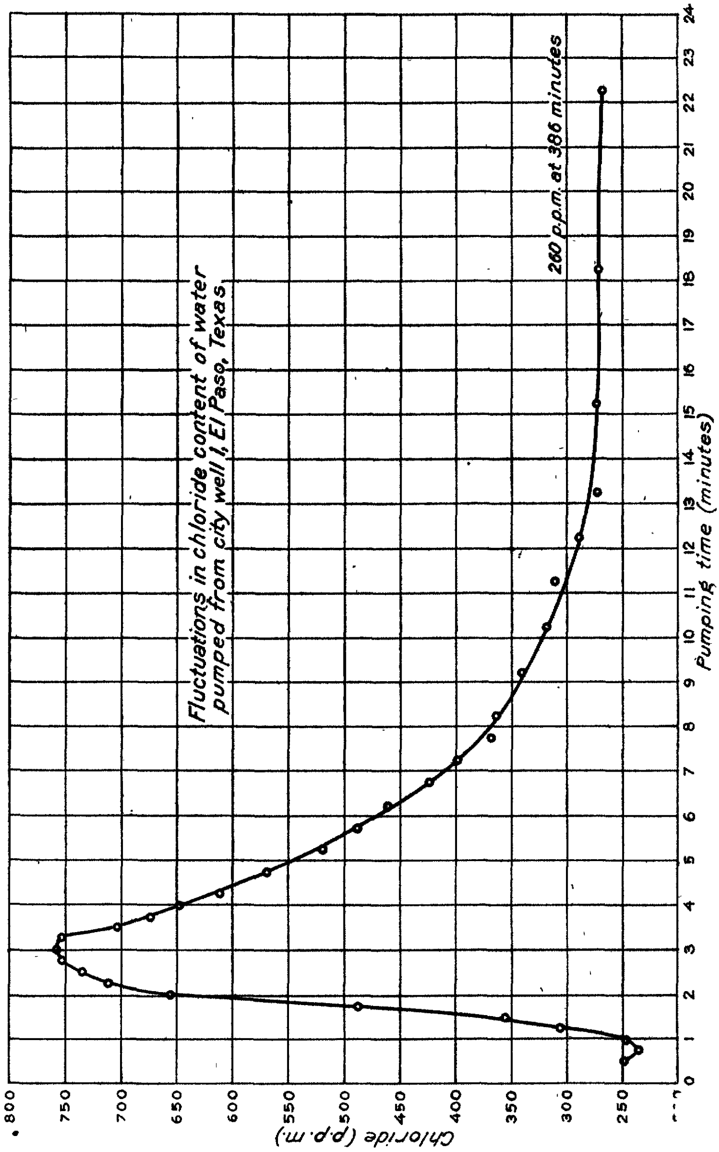


FIGURE 9.—Chart showing fluctuations in chloride content of water pumped from El Paso well 1.

pumped from the well when it was last operated. Almost immediately after this water was expelled the chloride content began to increase. It is believed, therefore, that the contaminating water probably was entering the well just below the end of the suction, probably at the bottom of the pit where the casings overlap at a depth of 225 feet.

When the well is standing idle the pressure in the salt-water horizon is apparently great enough to force water containing about 800 parts per million of chloride into the well at a very slow rate, perhaps at one gallon per minute. While the well is being pumped, however, the salt-water horizon yields a greater amount of water to the well. Although contamination from this source is not serious at present, the opening through which the leakage occurs may suddenly become enlarged, and a large leak may develop, as happened in city well 3 during the summer of 1934. Explorations and tests on the other three wells in the Montana well field indicated that this well probably draws heavily from a sand yielding water relatively high in chloride at a depth of about 600 feet. The exact location of the sand yielding the highly mineralized water can probably be determined by further explorations and, unless the well is of gravel-wall construction throughout, a liner can be grouted opposite the sand and the quality of the water improved. Placing the liner will of course reduce the capacity of the well.

During the period from 1935 to 1939 the mineral content of the water yielded by well 1 increased. Very thorough tests made in August 1939 to determine the source of the contamination showed that the statements made in 1935 concerning this well were substantially correct. (See Appendix.)

The well was found to be about 790 feet deep instead of 860 feet as reported. During the tests the parts of the well between the following depths were isolated by means of packers and were pumped and tested for chloride: 0 to 220 feet, 220 to 450, 447 to 590, 640 to 714 feet, and 740 to 790 feet. The pump pit was watertight, and no undesirable water was entering the well above a depth of about 220 feet. Mineralized water was found to be entering the well through holes in the casing at about 220, 261, and 392 feet below the ground, and the entire section of casing from 220 to about 485 feet probably is in poor condition and contains many small holes. Highly mineralized water containing between 2,000 and 2,500 parts per million of chloride was entering the well through these holes. It is likely that several of the holes in the casing were enlarged during the test. The part of the well between 220 and 450 feet, with only 8 feet of draw-down, yielded 26 gallons a minute of very salty water, which is more than leaked into the well while it was being pumped prior to the test. It appears, therefore, that the well probably will yield more highly mineralized water if it is again used than it did before the tests were made.

The best water, which was found between 447 and 590 feet, contained an average of about 250 parts per million of chloride and about 255 parts of hardness. However, samples obtained from various parts of this section during the test ranged from 180 to 700 parts per million of chloride. The water having the highest chloride content entered the well at a depth of approximately 570 feet. It apparently came from a bed of sand at this depth, although it might have come from sands at 600 or even 650 feet and have moved upward outside of the casing before entering the well. This section of the well yielded about 110 gallons a minute with about 14 feet of draw-down.

The section from 640 to 714 feet was pumped at the rate of 50 gallons a minute and the section from 740 to 790 feet at the rate of about 100 gallons a minute. The water from each of these sections contained about 675 parts per million of chloride and about 500 parts per million of hardness.

Apparently, most of the moderately mineralized water was entering the well through the slotted pipe between 695 to 715 feet and 775 to 790 feet—the slots from 790 to 815 feet were covered up—and a small amount of very salty water was entering the well through the holes at 392, 261, and 220 feet. The entrance of water from the section of the well below 600 feet could be prevented by plugging the well below that depth but this probably would reduce the yield by about a third. The flow from 220, 261, and 392 feet probably could be stopped by setting a liner in the well and grouting the well from about 200 to 485 feet, but this would be a difficult and expensive job. If it were done successfully, there still would be the inflow of salty water into the well at about 600 feet, which might increase markedly. The entrance of salty water at the 600-foot level probably cannot be effectively stopped since the well is reported to have been artificially gravelled on the outside of the casing.

Viewing the problem from all angles it is not considered advisable to attempt to repair this well in order to improve the quality of the water. It is recommended that the pump be reinstalled in the well and that it be pumped at a rate of not more than one million gallons a day. A careful record should be kept of the quality of water yielded by the well and when the mineral content becomes too great to be used in the city supply, the well should be abandoned and sealed.

CITY WELL 2 (WELL 51)

A contamination test was made on June 22, 1936, after the well had been standing idle for more than 2½ years. The depth to water was 114.1 feet before pumping began; the pumping level could not be determined. When the pump had been in operation for an hour, the discharge was measured with a current meter as 1.05 million gallons per day or about 730 gallons per minute. The chloride contained in the water discharged from the pump amounted to about 80 parts per million for the first 4 minutes of pumping; this jumped to more than 250 parts per million by the end of the 6th minute, after which it declined steadily to about 190 parts per million at the end of an hour, and when the pump stopped after nearly 4 hours of pumping the chloride content was less than 180 parts per million. The results of this test and of the explorations made with the electrodes on June 23 and July 10 are shown in the tables that follow.

Contamination test by the pumping method on El Paso city well 2 (well 51), June 22 1936

Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)
0:30	80	5:45	250	26:15	208
:45	76	6:15	254	36:15	210
1:15	82	7:15	246	44:15	192
1:45	74	8:15	248	48:15	194
2:15	78	9:15	246	68:15	190
3:15	78	10:15	238	88:15	184
3:45	76	11:15	236	103:15	182
4:00	76	12:15	222	123:15	184
4:15	126	14:15	228	133:15	180
4:30	204	18:15	230	163:15	178
4:45	240	21:15	218	183:15	174
5:15	246	24:15	214	226:15	176

Contamination test by the electrical conductivity method on El Paso city well 2 (well 51), June 23, 1936

Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)
115–180	23½	465–470	22−	555	22
185–335	24	475	21½	560	23
340	24−	480	21	565–570	23½
345–360	23+	485	21−	575–580	24
365–380	23½	490	20½	585–590	24½
385	23	495–500	20	595	25
390–400	23+	505	20−	600	25−
405–415	23	510–520	19½	605–630	24½
420	23−	525	20−	635–660	24
425	22½	530–535	19½	665	24½
430	22+	540–545	20	670–679	24
435–460	22	550	21		

Contamination test by the electrical conductivity method on El Paso city well 2 (well 51) July 10, 1936

Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)
124–220	20	460–480	19	595–630	22
225–245	20+	485	18½	635	22+
250–265	21	490–500	18	640	22
270–290	21−	505	18−	645	22−
295–325	20+	510–515	17½	650	21½
330–355	20	520	18	655	22
360–370	20−	525–530	18−	660–665	21½
375–385	19½	535–580	18	670	21½
390–415	20−	585	19½	675–680	21½
420–455	19½	590	21½	681	Bottom

Water samples were taken at various depths on July 10 to compare with the results with the electrodes. The chloride content was found to be 160 parts per million at 300 feet, 140 at 430 feet, 130 at 515 feet, 120 at 575 feet, 175 at 600 feet and 170 at 660 feet. The data from these explorations show that conditions in this well are very complicated. There is apparently a water-bearing horizon from about 500 to 540 feet (log of the well shows sand and gravel from 507 to 538), which yields water containing less than 100 parts per million of chloride. The hydrostatic pressure is great enough to allow this water to flow into the well while it is idle and move upward, escaping from the well near the surface of the water, at least above the end of the suction of the pump that was set at a depth of 210 feet. There is another sand at a depth of approximately 590 to 640 feet (log shows sand and gravel at 577 to 606 feet and 612 to 630 feet) that yields water containing more than 250 parts per million of chloride. The water from this bed apparently flows into the well while it is idle and escapes into a sand below. Neither leak is of serious proportions. The part of the well between 590 feet and its present bottom at 680 feet, however, probably yields water fairly high in chloride and draws from the sands that are causing most of the trouble in the Montana well field. If the well, which in its present condition is not a very good producer, were sealed from the present bottom up to 580 feet its yield probably would be too low for economical operation. It is recommended, therefore, that the sand in the well be cleaned out to the original depth of 840 feet, and if after careful study it is found that the well will yield sufficient volume, a liner should be set opposite any highly mineralized water sand. Although the chloride content of the water pumped from the well is relatively low under the present conditions, unless the highly mineralized water horizon is shut off the chloride content should be expected to rise when similar repairs are made on the other wells in the field. The yield from this well should be reduced to not over 0.75 million gallons a day. It probably can be operated with safety at that rate provided the other wells are repaired and the yield from the other three wells is reduced to not more than one million gallons a day each.

CITY WELL 3 (WELL 52)

During the summer of 1934 the chloride content of water pumped from city well 3 (well 52) was noticed to have risen rather suddenly to nearly 400 parts per million. Since this was considerably higher than the chloride content of water from the other wells in the Montana well field and much too high for general public use, the well was shut down, and in October of that year an attempt was made by the city water department to locate the source of the contamination. A liner was set from the bottom of the pump pit at 225 feet to a depth of 500 feet, packers being placed at the top and bottom of the liner to shut off any water that might enter the well between these depths. The well was then filled with sand and samples of the water taken at intervals as the depth of the well decreased, the pump being run for some time before each sample was taken. The chloride content of the water samples thus obtained ranged between 1,270 and 1,510 parts per million. The well was left filled with sand to a depth of 375 feet and abandoned.

On April 29, 1936, explorations were resumed. The static water level was 99.2 feet. Water samples taken at a depth of 105 and 360 feet showed a chloride content of 1,220 and 1,250 parts per million, respectively. An air-lift pump was installed and pumped continuously for 6½ hours at an estimated rate of 100 gallons a minute. Samples of the discharge taken at intervals showed a range from 1,100 to 1,260 parts per million of chloride. The draw-down amounted to about 21 feet. Fresh water was floated in on the surface of the water in the well at the rate of about 25 gallons per minute, and the progress of displacing the salty water was checked with the electrodes. It displaced the salty water to a depth of 127½ feet but would go down no farther. More water was then introduced through a 6-inch pipe at a depth of 374 feet, and its movement also was checked with the electrodes. The fresh water moved upward and escaped from the well at a depth of 127½ feet. Enough fresh water was then poured into the well to flush out completely all of the salty water, and the well was allowed to stand over night. It was then pumped at a rate of about 150 gallons a minute for an hour, and 59 samples of water collected at short intervals during that time showed that the chloride content increased steadily from about 250 to more than 1,100 parts per million. In the meantime the return of the salty water through the hole at a depth of 127½ feet and its movement down the well to the end of the suction of the pump was observed with the electrodes. A 10-inch casing was set from the surface of the ground to the bottom of the pump pit with a packer on the lower end to exclude any leakage into the well above a depth of 225 feet. The sand in the well was then cleaned out with the air lift pump, starting at a depth of 375 feet, the eduction pipe being lowered as the sand was removed. After each length of pipe was washed down, the pumping was continued until the water came clear, and a water sample was then taken and tested for chloride. The water that enters the suction pipe of a well pump placed above all water-bearing horizons moves to the pump through the well casing, but when the suction end is opposite a well screen a large percentage of the water can be expected to come directly through the screen from the sand at that point. Although the water is somewhat mixed with other water from the well, the samples are fairly good indications of the relative quality of the water at the various depths. The chloride content of representative samples and the approximate depth of the well at the time they were taken are shown in the following table.

Water samples taken from city well 3 (well 52) during process of cleaning out sand with air-lift pump

[Bottom of eduction pipe was at top of sand]

Depth of well (feet)	Chloride (parts per million)	Remarks	Depth of well (feet)	Chloride (parts per million)	Remarks
435–484	160	Added water to start pump.	697	164	After 1¼ hours of pumping.
504	180, 155, 162		717	162	
504–516	158		736	168	
516	152	After 2 hours of pumping.	756	164	
			758	164	After ¾ hours of pumping.
536	132, 128, 120	Samples during 3 hours of pumping.			
			773	160	After 20 minutes of pumping.
556	132				
576	130, 132	Pump throwing coarse gravel.	783	168	
			805	162	
596	220		824	190	
616	220, 225		827	192	
631	200		827	158	
634	214, 200		849	154	After 24 minutes of pumping.
656	196				
677	175				

The pump and all packers and liners were removed and a 20-inch casing set from the surface to the bottom of the pump pit at 225 feet. The annular space between the 20-inch and 26-inch casings was filled for about 5 feet with roofing gravel, then with 2 feet of sand, and above the sand with drilling clay up to a depth of about 100 feet. The deep-well pump was installed on June 27, and after three fourths of an hour of pumping it had reduced the chloride content to about 140 parts per million. The well then stood idle for about 44 hours, and on June 29 a contamination test showed a maximum of only 180 parts per million of chloride, indicating that the bad water that had been coming into the pump pit had been completely shut out. The static water level before pumping started on June 29 was 130.57 feet below the floor. After 2 hours of pumping, at the rate of 1.8 million gallons a day, the water level was 155.20 feet, after 100½ hours it was 161.26 feet, and after 273½ hours it was 161.75 feet below the floor of the pump house. The pump continued in operation, and on July 9 a sample collected showed about 265 parts per million of chloride or about the same as that from wells 49 and 50 in the Montana well field. Another contamination test was run on July 15 after the well had been shut down for about 5 days. The first water discharged contained about 290 parts per million of chloride. At the end of 4½ minutes it contained 160 parts per million after which it gradually increased to 190 parts per million in one hour and 38 minutes. (See table on page 83.) Twenty-seven hours later the chloride content had risen to 280 parts per million.

Contamination test by the pumping method on El Paso city well 3 (well 52), July 15, 1936

Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)
0:20	295	3:05	170	11:05	172
:35	278	3:20	166	14:05	172
:50	284	3:35	168	18:05	172
1:05	282	3:50		22:05	172
1:20	294	4:05	164	28:05	174
1:35	282	4:35	162	36:05	174
1:50	274	5:05	166	44:05	176
2:05	245	5:35	166	58:05	180
2:20	204	6:05	168	78:05	180
2:35	184	7:05	170	88:05	186
2:50	172	9:05	170	98:05	188

The following conclusions have been reached regarding the present condition of well 52 and the conditions leading up to the abandonment of the well in 1934. During the 10-year period ending with the summer of 1934, 43 percent of all the water pumped in the El Paso area, including all industrial and private supplies, was pumped from the Montana well field, and nearly 21 percent of all the water pumped by the city water department during that period was taken from well 52. During that time the chloride content of the water from well 52, and also of other wells in the Montana well field, was gradually increasing. The sudden increase in the chloride content in water from well 52 in 1934 was caused by a rapid development of a hole in the casing at a depth of 127½ feet that permitted more than 100 gallons per minute of water containing approximately 1,200 parts per million of chloride to enter and mix with the water pumped from this well. The increase of chloride content in a water in which it was already fairly high brought the total too high for satisfactory use. The recent repairing of well 52 has eliminated for the present the danger of contamination from the pump pit, but it will not check the steady rise of chloride in the water from this well or in the Montana well field in general. Sands from about 530 to 580 feet yield water containing less than 140 parts per million of chloride under pressure higher than the static pressure in the sands below, which probably yield water containing over 300 parts per million of chloride. When the well is idle, fresh water flows into it from the upper sands and moves downward, forcing the more highly mineralized water, which appears to be from a depth of about 590–670 feet, away from the well. No accurate computations can be made as to the volume of fresh water escaping from the well into the lower sand, but it is estimated to be about 50 gallons a minute. This fresh water is recovered by pumping, but as soon as it is pumped from the lower sand back into the well, that sand begins to yield the more highly mineralized water that it contains under normal conditions. The fact that the quality of the water from this well is better just after the well has been idle might mislead one into believing that the general quality of the water is improved by allowing the well to rest, especially if the water sample analyzed were collected from one to several hours after the pump was started following a long rest. This is not the case. Permanent improvement of the quality of the water from this well however, probably could be made by carefully locating the exact position of sands that yield the contaminating water and setting liners opposite them.

CITY WELL 4 (WELL 49)

A contamination test was run on city well 4 (well 49) on April 1, 1936, after the well had been standing idle for 45 hours. Water levels could not be determined. The pump discharged about 1,200 gallons a minute. The water pumped during the first 2½ minutes contained about 235 parts per million of chloride, then dropped steadily to 128 parts per million in 5 minutes, and increased again to about 195 parts per million in an hour. A sample collected after 6 hours and 25 minutes of pumping showed 235 parts per million, as shown in the table below.

Contamination test by the pumping method on El Paso city well 4 (well 49), April 1, 1936

Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)
00:30	234	5:30	130	17:15	168
:45	234	5:45	----------	18:15	----------
1:00	234	6:00	126	19:15	166
1:15	238	6:15	----------	20:15	----------
1:30	236	6:45	138	21:15	170
1:45	238	7:15	----------	22:15	----------
2:00	234	7:45	142	23:15	172
2:15	236	8:15	----------	24:15	----------
2:30	214	8:45	152	26:15	----------
2:45	194	9:15	----------	28:15	----------
3:00	174	9:45	154	30:15	174
3:15	166	10:15	----------	32:15	----------
3:30	146	10:45	154	34:15	178
3:45	140	11:15	----------	36:15	----------
4:00	134	11:45	158	41:15	184
4:15	----------	12:15	----------	46:15	----------
4:30	136	13:45	160	51:15	188
4:45	----------	14:15	----------	56:15	----------
5:00	128	15:15	162	61:15	196
5:15	----------	16:15	----------	385:00	235

This well apparently has no leak of consequence above a depth of 500 feet. A short distance below that depth fresh water containing less than 130 parts per million of chloride flows in when the well is idle and moves downward, replacing water higher in chloride. The volume of the fresh-water flow is about 25 to 30 gallons a minute. The pump in this well was not removed during the investigation and explorations with the electrodes and other instruments could not be made.

CONCLUSIONS REGARDING WELLS IN MONTANA WELL FIELD

The water from the various sands lying below the surface in the Montana well field varies greatly in mineral content and hydrostatic pressure, and that from each sand varies considerably in chemical content. The first water encountered, the so-called shallow water, is fairly high in chloride, containing about 1,200 parts per million at the location of well 52 and probably more than 800 parts per million at well 50. The hydrostatic pressure in each sand depends upon how completely it is shut off from other sands, upon its permeability, and upon the amount of water pumped from it for several miles around. The static water level in the shallow-water sands is about 15 or 20 feet higher than the average water pressure in sands below it. Little is known about the quality or static pressure of the water in the beds between the shallow water and a depth of nearly 500 feet. In well 50 the top of the screen is at a depth of 485 feet, in well 51 it is at 507 feet, in well 52 at 505 feet, and in well 49 at 465 feet. The quality of the water in the beds around 500 feet is good, averaging less than 200 parts per million of chloride. From approximately 550 to 670 feet there are sands that appear to yield to all wells in the field water moderately high in chloride. The gradual annual increase in the chloride content of the water from the Montana field is thought to indicate that the wells are drawing an increasingly larger proportion of water from this sand. For 200 feet or more below 670 feet the quality of the water seems fairly good, but below 870 to 900 feet very highly mineralized water has been reported.

It is believed that the gradual increase in chloride in the wells in the Montana well field, which has been in progress for several years, is chiefly due either to the gradual breaking down of a barrier between some of the less highly mineralized and more highly mineralized sands, or to the fact that highly mineralized water is being drawn in from beneath areas outside of the field. There is, of course, always danger that the casing opposite highly mineralized sands will corrode through and allow serious contamination of single wells, but the general increase in chloride content has been so slow that there seems to be no cause for alarm lest the well field should suddenly be ruined. On the other hand, undue complacence regarding the life of this field is not warranted. The sands between about 550 and 670 feet are believed to have a high permeability and to yield a large amount of moderately mineralized water, but at the same time the well explorations indicate that the static pressure in them is lower than that in the beds above and below. Those beds in their turn have a lower static water level than the beds of highly mineralized water above the 500-foot depth.

Further increases in the difference in head probably will result eventually in drawing sufficient water in from the outside to cause the mineralization of the field and may result in the breaking down of the barriers between the beds yielding fresh water and the beds above or below that yield mineralized water. If the gradual increase in chloride is due to increases in chloride in the water from the sands between 550 and 670 feet depth, it would be advisable to go into these wells and make repairs and to reduce the pumpage from them. The salt-water horizon could be shut off by first carefully locating the horizon from which the water comes and then setting and grouting a liner into place opposite it. Shutting off the highly mineralized water in any one of the wells will increase the hydrostatic pressure in the salt-water sand, thus causing the chloride content to increase in the other wells. It is necessary, therefore, to repair and put in order all the wells to be used in the field. Any well abandoned in this field must be carefully sealed. Making the explorations and repairing the wells are expensive jobs and should not be undertaken by anyone who is not an expert in this type of work. Repairs that are not accurately and completely made may be worse than no repairs at all. No additional wells should be drilled in or near the Montana well field and any drilling in the El Paso area, especially in the valley, must be done by an experienced driller, one who is not only capable of operating a drilling rig but who appreciates the importance of taking representative samples of water from each water-bearing sand and who understands the technique of shutting off undesirable water and the proper methods of gravel-walling wells.

OTHER CITY WELLS WITHIN THE CITY LIMITS

CITY WELL 5 (WELL 41)

A contamination test was run on city well 5 (well 41) on February 26, 1936, after the well had been standing idle for about 7 months. The static water level was about 109 feet. The pump discharged about 600 gallons a minute, but the pumping level could not be determined. The first water discharged contained about 220 parts per million of chloride; this rose immediately to about 250 parts per million, where it remained for nearly 5 minutes of pumping, then jumped to more than 300 parts per million with 6 minutes of pumping, and gradually increased to 340 parts per million in 14 minutes. After some minor fluctuations the water still contained 340 parts per million when the pump was shut down at the end of 38 minutes.

Contamination test by the pumping method on El Paso city well 5 (well 41), February 26, 1936

Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)
0:30	218	3:45	248	14:15	340
:45	224	4:15	246	16:15	336
1:00	256	4:45	246	18:15	340
1:15	250	5:15	286	20:15	340
1:30	254	5:45	308	22:15	336
1:45	240	6:15	304	24:15	336
2:00	242	7:15	320	26:15	340
2:15	246	8:15	312	28:15	342
2:30	250	9:15	315	30:15	346
2:45	250	10:15	320	32:15	346
3:00	246	11:15	326	34:15	342
3:15	248	12:15	334	38:00	340

The well remained idle until July 10, at which time explorations made with the electrodes indicated that the most highly mineralized water was between 655 and 680 feet. On July 14 about 20 gallons a minute of fresh water, containing about 100 parts per million of chloride, was introduced to the surface of the water in the well and its movement observed with the electrodes and the deep-well meter. The meter showed that the water was moving downward in the well and escaping between 720 and 820 feet. The well was allowed to stand idle for 40 hours and then was explored with the electrodes. Nine water samples were collected at desired depths. The results of these tests are shown in the tables on page 87.

These data are interpreted to mean that while the well is idle, water containing more than 250 parts per million of chloride enters the well at a depth of about 725 feet—the driller's log shows water sand at 719 to 728 feet—and moves upward into sands of lower hydrostatic pressure and probably lower chloride content. During the winter months the hydrostatic pressure in the sands from 575 to 719 feet was high enough to stop the flow of water to it, but in the summer of 1936 the water at a depth of about 725 feet moved upward entering the sands above. Without further investigation it is not possible to tell whether the water at a depth of 725 feet moved upward as far as the suction of the pump, or whether some small holes have developed in the pump pit permitting water of about the same chloride content to fill the well, over a long period of time, to a depth of about 575 feet. This well has been reported as having been filled by vandals with old iron to a depth of 845 feet several years ago, and efforts to clean out that section of the well probably would not be successful. The well is in a very poor place with reference to recharge and ground-water storage, as is shown by the small yield and large draw-down. Because repairs, such as placing a liner opposite the salty water, would further reduce the yield, this well probably should be carefully sealed and then abandoned. The well can be sealed effectively by introducing, through a pipe extending to the bottom of the well, drilling mud, preferably containing a small proportion of bentonite, so heavy that it will barely flow. The well should, of course, be completely filled with mud, and after allowing the mud to settle for several months, the well should be refilled to the surface with sand and capped with a concrete slab. As there is apparently considerable movement of water near the bottom of the well, introducing the mud at the surface and allowing it to sink of its own accord may thin it to such an extent that great quantities of the mud would pass out of the well into the water-bearing formations. This would be a wasteful method, and besides requiring a large amount of clay it might possibly make the water from other wells in the vicinity muddy.

Contamination test by the electrical conductivity method on El Paso city well 5 (well 41), July 17, 1936

Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)
118	26	285–295	24–25½	690–695	26½
120–125	26−	300–310	25	700	27−
130–155	26	315	25−	705	27+
160	26−	320–345	24½	710–730	28
165	25½	350–370	24+	735–755	28−
170–185	26−	375–500	24 constant	760–765	27+
190	25½	500–565	24	770–785	27
195	25	570–600	24+	790–795	27−
200	26	605–615	25−	800–810	26½
205–215	25½	620–650	25	815–820	26+
220	25+	655–660	25−	825–830	26
225–235	25–26	665	24+	835	26+
240	25+	670	25½	840	26
245–275	25	675	26	845	26
280	25−	680–685	26+		

Chloride content of water samples taken from El Paso city well 5 (well 41)

Depth (feet)	Chloride (parts per million)	Depth (feet)	Chloride (parts per million)	Depth (feet)	Chloride (parts per million)
116	110	300	114	710	276
150	112	400	110	725	2[illegible]4
195	114	600	136	800	158

CITY WELL 6 (WELL 22)

A contamination test on city well 6 (well 22) was made on February 27, 1936, after the well had been standing idle for about 5 months. The static water level was 14.4 feet before pumping began, but the pumping level could not be determined. The pump discharged about 1,100 gallons a minute. The first water discharged contained about 105 parts per million of chloride, and this amount jumped to nearly 160 parts per million in the first half minute of pumping, after which the decline was very rapid, reaching less than 110 parts per million at the end of the first 3 minutes. The chloride content fluctuated between about 104 and 110 parts per million for 50 minutes, and a sample taken after 18 hours showed 110 parts per million. On July 20 a second contamination test was made, and the samples of water were tested for soap hardness in addition to the usual chloride tests. The chloride content of these samples showed the same general trend as in the first test. A maximum of 174 parts per million of chloride was reached in the first half minute, and that had declined to 108 parts per million in 3½ minutes. The hardness as determined with a standardized soap solution was 400 parts per million at first and increased to about 600 parts per million in 2 minutes, then it gradually declined to about 460 parts per million in about 6 minutes and remained nearly constant until the pump was shut down at the end of an hour. (See table below.)

Contamination test by the pumping method on El Paso city well 6 (well 22), July 20, 1936

Pumping time (minutes, seconds)	Chloride (parts per million)	Hardness (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Hardness (parts per million)
0:00	102	416	3:00	118	521
:10	112		3:10	114	
:20	114	480	3:20	108	505
:30	174		3:40	108	489
:40	174	577	4:00	108	481
:50	156		5:40	108	457
:60	155	577	7:40	108	465
1:10	144		10:30	110	457
1:20	148	593	13:30	112	457
1:30	144		19:30	112	473
1:40	146	609	25:30	110	481
1:50	140		37:30	110	473
2:00	138	609	47:30	110	465
2:20	130	585	61:30	108	465
2:40	122	545			

The pump was removed and explorations were made with the electrodes supplemented by water samples obtained at desired depths. The chloride content and hardness of samples are shown below.

Chloride content and hardness of water collected with the deep well sampler from El Paso city well 6 (well 22), July 21, 1936

Depth (feet)	Chloride (parts per million)	Hardness (parts per million)	Depth (feet)	Chloride (parts per million)	Hardness (parts per million)
20	116		165	160	589
60	120		195	164	640
80	114	440	250	132	540
90	112	529	325	110	469
130	108	425	400	114	469

The data for this well were interpreted as showing that hard water was entering the well at the lower end of a liner that had been set several years previously from 88 feet to 190 feet below the surface in an effort to improve the quality of the water. The water from this section of the well flows into the well while it is idle, moves downward, and escapes into the lower sands. The liner was removed on July 23, 1936, because it was found that the packer that had been attached to the lower end of the liner had been lost either when it was set or when the liner was removed from the well. To obtain another check on the location of the contaminating water a device was used consisting of two packers, about 14.5 feet apart, mounted on a 2-inch pipe in such a way that when a pump was attached to the pipe it would draw water only from the section between the packers. The packers were first set at 140 to 155 feet below the surface. The water was pumped from above the packers to see if there was a leak in the pump pit or if the packers would leak. The data obtained from this test are shown in the table below.

Contamination test of El Paso city well 6 (well 22), made with the use of two packers, 1936

Depth of packers (feet below floor level)		Water level between packers at beginning of test (feet below floor level)	Pumping time (minutes)	Chloride (parts per million)	Hardness (parts per million)
Upper	Lower				
145½	160	13.94	3	180	----------
			9	180	----------
			15	180	690
			21	178	690
			27	180	690
			33	182	690
172½	187	12.65	3	160	
			6	165	705
			18	148	625
			24	150	640
			30	144	625
			36	146	617
187	201	15.58	15	104	450
			24	96	417
			36	88	417
			60	----------	410
			72	88	393
			96	84	385
			108	88	393
			123	86	377
213½	228	13.60	3	92	433
			9	100	----------
			15	104	----------
			21	108	513
			27	108	----------
			36	110	513
			63	108	497
			78	102	465
			90	108	473
			108	110	473
			114	----------	473
			120	----------	473
			126	----------	465
			138	104	465
252	266	13.55	3	86	----------
			18	78	337
			36	78	305
			60	72	305
265	279	13.53	9	72	305
			18	72	305
			39	72	290
296	310	14.70	6	80	----------
			18	86	250
			39	86	257
			57	84	257
378	392		No water could be pumped.		
384	398		No water could be pumped.		

This test showed that the water from 145 to 187 feet contains about 180 parts per million of chloride and about 700 parts per million of hardness. The yield from this sand is great enough to raise the average hardness to about 425 to 450 parts per million. The hardness of the water from the lower sands ranges down from about 450 to 250 parts per million. The chloride of the water in the sands below 187 feet ranges from about 100 to 70 parts per million. A temporary liner should be placed in this well from the bottom of the pump pit to a depth of 190 feet with packers at the upper and lower ends. If the well then yields water of satisfactory mineral content, the portion of the well from 405 to 503 feet should be cleaned out and the water from each sand carefully analyzed. If no further trouble is found, the liner from 100 to 190 feet should be permanently grouted in place.

CITY WELL 7 (WELL 31)

A contamination test was made on city well 7 (well 31) on February 27, 1936, after the well had been standing idle for about 4 months. Water levels could not be determined. The pump discharged about 1,250 gallons a minute. The results of this test are shown herewith.

Contamination test by the pumping method on El Paso city well 7 (well 31), February 27 1936

Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)
00:15	102	4:00	58	15:30	64
:30	74	4:30	58	17:30	62
:45	72	5:00	60	19:30	64
1:00	70	5:30	62	21:30	64
1:15	64	6:30	62	23:30	66
1:30	62	7:30	62	25:30	66
1:45	62	8:30	62	30:30	68
2:00	60	9:30	62	33:30	70
2:15	56	10:30	62	38:30	70
2:30	56	11:30	64	43:30	72
3:00	56	12:30	64	48:30	72
3:30	58	13:30	52	20 hours	100

The first water discharged contained about 100 parts per million of chloride, but this amount dropped to 56 parts per million with 2 minutes of pumping. The chloride content then rose to 74 parts per million with 44 minutes of pumping and finally showed about 100 parts per million after 20 hours of pumping. This well apparently taps a sand yielding water that contains less than 55 parts per million of chloride and that has sufficient hydrostatic pressure to cause water from this sand to flow into other sands while the well is idle. Movement of fresh water from one sand to another does not represent a defect, and the well was in excellent condition at the time the test was made.

The mineralization of the water, particularly the hardness, increased soon after the above test was made, and by 1938 the water was unsatisfactory for public use, especially for laundry use. More elaborate tests on this well were made in August and September 1939. The well was reported to have been 525 feet deep originally, but to have been finished to a depth of 430 feet. The casing was said to be slotted from 160 to 450 feet. The tests showed that the pump pit and the well casing down to a depth of 130 feet are practically watertight, and the increase in mineral content during the past years is therefore not due to leakage in this section. The well was found to be 320 feet deep, indicating that it had filled up to that depth with sand. It was cleaned out to a depth of 500 feet and swabbed and agitated between 320 and 430 feet, but no appreciable increase in the yield of the well was noted. Therefore, the water pumped from this well must enter it mainly between the depths of 160 and 320 feet, and it is believed that part of all of the water-bearing formations between 160 and 320 feet have become more highly mineralized during recent years either by lateral movement of highly mineralized water through the water-bearing beds from distant sources, or by downward movement of mineralized water from overlying sands. It seems likely that the bad water has seeped down from above and perhaps only the upper part of the sands that yield water to the well contains highly mineralized water. However, the determination of the exact point of entrance of the highly mineralized water into the well was not considered of sufficient value to warrant the cost of the work to determine it since it does not seem practicable to repair the well. Any attempt to seal off a part of the slotted portion of the casing would not be practicable and since the original casing was set with considerable difficulty, it would probably not be advisable to attempt to deepen the well. Therefore, this well probably should be abandoned and sealed as soon as it is no longer needed as a standby well.

CITY WELL 9 (WELL 42)

A contamination test was made on city well 9 (well 42) on September 16, 1935, after this well had been standing idle for 5½ hours. The static level before pumping began was about 25.0 feet. The pumping level could not be determined. The pump discharged about 1,100 gallons a minute. The results of the test are as follows:

Contamination test by the pumping method on El Paso city well 9 (well 42), September 16 1935

Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)
0:00	146	3:00	340	8:00	152
:15	145	3:15	324	9:00	150
:30	140	3:12	310	10:00	145
:45	138	3:34	302	11:00	144
1:00	135	4:00	276	12:00	138
1:15	142	4:30	245	13:00	138
1:30	148	5:00	218	14:00	140
1:45	192	5:30	202	15:00	138
2:00	340	6:00	185	16:00	138
2:15	505	6:30	176	17:00	138
2:30	410	7:00	160	18:00	138
2:45	366	7:30	158	19:00	140

For the first 1½ minutes the water discharged contained a little less than 150 parts per million of chloride, but this rose suddenly to more than 500 parts per million with 2¼ minutes of pumping. The chloride content then dropped to 300 parts per million in 3¾ minutes, 150 parts per million in 8 minutes, and continued at about 140 parts per million until the pump was stopped at the end of 19 minutes. These data are interpreted as follows: There is apparently a sand at a depth about 250 or 300 feet that contains water with more than 500 parts per million of chloride. Water from this sand flows into the well at the rate of about 10 gallons a minute while the well is standing idle. The flow probably is not much larger while the well is being pumped because the average chloride content of the water from the well is only about 150 parts per million. The chloride content could be decreased by repairing this well but the repairs are not recommended until the other wells have been repaired. The mineralization of the water from this well should be determined at regular intervals however.

CITY WELL 10 (WELL 21)

A contamination test was made on city well 10 (well 21) on June 15, 1936, after this well had been standing idle for about 4 years. The static water level was 20.88 feet before the pump was started, but the pumping level could not be determined. The pump discharged about 725 gallons a minute. The chloride content of the first water discharged was about 120 parts per million; it was only 65 parts per million after 5 minutes and less than 60 parts per million after the pump had been running about 19 hours. According to old records of analyses of water from this well, the chloride content was 100 parts per million June 9, 1931; 674 parts per million September 3, 1931; 198 parts per million October 2, 1931; 114 parts per million April 6, 1932; 175 parts per million May 11, 1932; and 191 parts per million August 19, 1932. It seems, therefore, that the normal chloride content of this water should be nearly 200 parts per million when it is idle. The fact that the chloride content was less than 60 parts per million after 19 hours of pumping probably indicates that when the well is idle one or more sands contribute a large amount of water containing less than 60 parts per million of chloride to the well, and that this water forces more highly mineralized water in other sands away from the well. The fact that the first water discharged during the pumping test contained only 120 parts per million indicates that the well was pumped for only a few hours the last time it was in service. Engineers of the city water department believed that highly mineralized water was entering the well near the bottom, and in September 1931 the well was filled up from 802 to 650 feet. The fact that the chloride content decreased from 674 parts per million on September 3, 1931, to 198 parts per million on October 2 indicates that highly mineralized water probably was entering the well between 650 and 802 feet, but no data on tests or analyses of water below a depth of 650 feet are on record, and it seems desirable to determine by further testing where the highly mineralized water was entering this well. If the quality of water from 650 to 802 feet is satisfactory it would be desirable to clean out that portion of the well to increase the yield and decrease the pumping lift.

WELLS IN AND NEAR THE MESA FIELD

CITY WELL 8 (WELL 79)

No tests were made on this well during the investigation. There has been no evidence of contamination in it. The well is in the mesa well field not far from city well 11, and conditions in the two wells are probably very nearly the same.

CITY WELL 11 (WELL 78)

A contamination test was made on December 16, 1935, after the well had been standing idle for 14 days. Water levels could not be determined. The pump discharged about 1,300 gallons a minute. The chloride content of the water pumped ranged from 90 to 100 parts per million throughout the test for 19 minutes. There is no contamination from highly mineralized water in this well, and it is considered in excellent condition.

CITY WELL 12 (WELL 77)

No test was made on this well during the investigation, but the well is in the mesa well field about half a mile east of well 78. No evidence of contamination was seen.

SOUTHERN PACIFIC CO. WELL AT FORT BLISS (WELL 67)

A contamination test was run on the southeast well at the pumping plant on July 21, 1936, after the well had been standing idle for 10½ hours. The pump discharged about 600 gallons a minute. Tests for chloride content and soap hardness were run on the samples collected. The chloride content of the first water pumped was about 225 parts per million. It gradually rose to over 360 parts per million in about 2 minutes of pumping, then dropped to 300 parts per million during the next 2½ minutes of pumping. There was a gradual decrease to 276 parts per million of chloride after 72 minutes of pumping. The hardness showed similar fluctuations starting with 430 parts per million, increasing to a maximum of over 700 parts per million, and ending with a little over 550 parts per million. The results of the tests are shown in the following table.

Contamination test by the pumping method on T. & N.O. Railroad well at the Fort Bliss pumping plant, El Paso, July 21, 1936 (southeast well)

Pumping time (minutes, seconds)	Chloride (parts per million)	Hardness (parts per million)	Pumping time (minutes, seconds)	Chloride (parts per million)	Hardness (parts per million)
0:15	222	428	5:15	292	616
:45	224	472	6:00	302	608
1:15	242	520	9:00	294	600
1:45	274	584	12:00	292	600
2:00	362	696	18:00	286	592
2:15	342	680	24:00	282	568
2:45	308	632	36:00	280	568
3:15	322	632	48:00	280	560
3:45	306	624	60:00	274	568
4:15	312	624	72:00	276	552
4:45	298	624			

The two wells, about 500 feet apart at the pumping plant, were drilled in 1921 and have slotted casings from 274 to 864 feet, and 269 to 869 feet, respectively. The casing and slotted pipe were set in one string, and no seals or packers were used. The normal static level was 221.6 feet below the ground on July 15, 1936. The analyses of water reported by Slichter,[2] from four wells, each 270 feet deep, belonging to the Southern Pacific R. R. at the Fort Bliss plant about 1904, show the quality of the water to be very good. At the time the present wells were drilled no bad water was reported from these wells (p. 118), and water analyses showed the quality to be very good. During more recent years, however, there has been a steady increase in the mineral content of the water pumped from each of these wells. (See wells 66, 67, and 68 in table of water analyses.) In 1930 the city of El Paso drilled a well 660 feet deep, at the corner of Leeds and Crockett Streets, about 0.6 mile southwest of the railroad wells (100 feet lower), and found water unfit for public use. They reported "bad water" from 246 to 291 feet, water containing 264 parts per million of chloride at 500 feet, 202 parts per million at 509 feet, and 204 parts per million at 550 feet. It is

[2] Slichter, C. S., Observations on the ground waters of Rio Grande valley: U. S. Geol. Survey Water-Supply Paper 141, p. 20, 1905.

evident from this that water containing a moderate amount of chloride was present in the neighborhood in 1930. Probably heavy pumping of the railroad wells in recent years has brought in more highly mineralized water from a short distance away. The source of contamination is probably near the water table, but it may be near the bottom of the well.

WELL CONSTRUCTION

METHODS OF DRILLING WELLS

Numerous methods are used for drilling wells, each of which was developed to meet certain particular requirements as to the character of material to be penetrated, and the depth and size of wells desired. Various methods are rather fully described by Bowman.[3] The chief methods for drilling wells in the El Paso area are the cable tool percussion method, the hydraulic rotary method, and the jetting method.

The cable tool percussion method, commonly called the cable tool method, consists of striking a succession of sharp blows against the bottom of the hole with a bit to loosen the material, which with water added from time to time forms a thin mud that is removed at intervals by running a bailer into the hole. In exceptionally loose material the well may be sunk entirely by use of the bailer. The drill bit is the lower part of a string of tools attached to a cable. The rig for manipulating the cable and tools may be portable or nonportable, depending upon the size and depth of the well to be drilled. The cable tool method is usually the most effective in drilling in hard rocks. It is not so effective in drilling in soft, caving rocks or through loose sand and gravel because it is necessary to case the hole as fast as drilling proceeds to prevent caving. In drilling through material that caves the casing rests on or near the bottom of the hole and is forced down, if necessary, by driving. When, owing to caving of the material, the casing becomes locked, a string of smaller casing is placed inside the larger casing and the hole continued smaller in size. Several reductions in diameter may be necessary in drilling a deep well. Where it is necessary to shut off highly mineralized water, the annular space between two strings of casing is commonly closed by inserting a ring of lead, which is then tapped into place. The resulting seal is not generally satisfactory, because if the lead is tapped too lightly it does not expand sufficiently to close the opening, or if it is tapped too hard it causes the outer casing to split. Swedged nipples would be more satisfactory to join casings of different sizes, thus forming a continuous string of casing. The cable tool method is used largely for drilling wells for stock on the Mesa and for drilling shallow stock and domestic wells in the valley. Because of its portability this method of drilling has considerable advantage over other methods in the Mesa area. It is not satisfactory, however, for drilling large-diameter, deep wells in the El Paso area.

The hydraulic rotary method consists of rotating continuously a cutting tool or bit screwed to the lower end of a string of hollow drill rods, which serve as a drive shaft to force the bit to rotate and also to conduct drilling mud to the bottom of the hole under pressure. The drilling mud returns to the surface through the annular space between the wall of the well and the drill pipe and carries the cuttings with it. The cuttings settle out in a settling basin from which the mud

[3] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, 1911.

is recirculated. The mud also enters the walls of the well and prevents their collapsing, so that with this method it is usually not necessary to case the well, except near the surface, until the drilling is completed. The standard rig for manipulating the drill bit and drill pipe for drilling large-diameter holes is not portable, but a portable rig that may be used for drilling small-diameter shallow holes is now on the market.

The jetting method combines the percussion features of the cable tool method with the hydraulic features of the hydraulic rotary method. The cutting tool or bit is attached to hollow rods and is designed so that the mud emerging from it under pressure acts as a hydraulic jet in loosening material at the bottom of the hole. When harder formations are encountered the bit is raised and lowered so that it strikes a succession of sharp blows against the bottom of the hole, thus loosening material. The cuttings are carried to the surface in the drilling mud. The bit and rods are rotated by hand. The jetting rig is portable and is therefore adapted to drilling small shallow wells. It drills wells in unconsolidated material in a remarkably short time, but is not adapted to drilling deep, large-diameter wells or to drilling through hard rocks or beds of gravel.

CASING AND SCREENING WELLS

All wells in the El Paso area must be cased either during or immediately after drilling; otherwise the walls of the well would cave. Likewise, screen or perforated pipe must be placed at the level of the water-bearing sands to let the water in and to prevent caving. In areas such as the Mesa, where all of the water is potable, the casing is used only to keep the walls from caving, but in areas where the water is highly mineralized the casing serves also to shut off the mineralized water. Since this water is corrosive, special precautions must be taken to prevent the corrosion of the casing at the level of the highly mineralized water. Therefore, before a permanent well is drilled, a test well should be drilled and a careful log kept of the formations encountered. True samples of the water from each water-bearing bed should be obtained and analyzed. If the log and the analyses show that it is practicable to develop a well at the desired locality, but that highly mineralized water occurs in the upper part of the well only, the hole should be drilled large enough to permit the insertion of casing without dragging against the sides of the well, and casing should be set opposite the sands containing highly mineralized water. The casing should be coated with coal-tar pitch or bituminous mixture and wrapped in heavy paper or light canvas to protect the coating from scratches while it is being lowered into the hole, or better still, three or four thicknesses of paper or inorganic fabric should be wrapped around the casing with a coating of coal-tar pitch or bituminous mixture on the casing and between layers. For a full discussion of this subject see some of the recent treatises on corrosion by Speller[4] and others. Each joint should be coated and wrapped after it has been made up and the pipe tongs have been removed.[5] Before the casing is lowered, the hole should be filled with mud as thick as the pumps can handle. If the well is properly cemented, protection against corrosion is afforded by the use of cement

[4] Speller, F. N., Corrosion, causes and prevention, McGraw-Hill, 1935.
[5] Livingston, Penn, and Bridges, T. W., Ground-water resources of Kleberg County Tex.: U. S. Geol. Survey Water-Supply Paper, 773-D, p. 219, 1936.

around the outside of the well casing. In the El Paso area, however, cementing has not been entirely satisfactory, partly because settling causes the cement to crack and allows water to reach the casing, and partly because of the difficulty of surrounding the casing with enough cement.

If a bed containing highly mineralized water is found between beds containing fresh water, the well must be drilled much larger and a large-diameter casing cemented in place opposite the bed of mineralized water to effectively exclude it.

Screening or perforated pipe is made up in a variety of ways, in brass, iron, and other metals. Common practice in the El Paso area has been to burn slots about 1/4 of an inch by 6 inches in ordinary casing with a blow torch. Much of the finer sand cannot be held out by such wide slots and the mill scale left by burning with the torch corrodes easily, thus enlarging the opening still further. By using special care slots as narrow as 1/8 inch can be cut with a torch.[6] A metal-cutting saw would cut slots narrower but much closer together and would result in a more satisfactory job. Wire-wrapped screen and slotted-brass screen has apparently not proved particularly satisfactory, partly because the small openings are rather quickly filled with mineral deposits from the water and partly because of rather rapid corrosion between the iron casing and the brass screen, due to galvanic action. Shutter screen has been used somewhat more successfully. In view of the experience in the El Paso area, only screens made of corrosion resistant metals should be used.

The principal purpose of the screen, aside from permitting water to enter the well, is to keep the sand out of the well. Screens should therefore be selected with reference to the size of slot that will keep out the major part of the sand and still permit water to enter. Consequently, since very few beds of sand are exactly alike, the size of sand in each bed should be determined before the screen for that bed is selected.

GRAVEL PACKING

After the casing and screen are set, the well is developed, that is, it is pumped to maximum capacity and surged to draw as much of the fine material as possible from the sands. The coarser material collects around the screen where the velocity of the water entering the well is highest, and the sand is graded, becoming finer away from the well and finally merging with the undisturbed sand. After the development is completed the well should not be pumped at a rate greater than about two-thirds of the developed capacity. This rearrangement of the sand is called natural gravel packing. It is very successful when screen slots of the proper size are used and where the sands are moderately coarse or contain a considerable percentage of coarse material. It is generally not satisfactory where the sands are composed largely of fine, uniform material, because in order to hold out the sand, the slots must be excessively fine and therefore permit only small amounts of water to enter. If larger slots are used, too much sand enters the well, causing wear of pumps and equipment, and eventually so much sand may be drawn into the well that the walls collapse. All of the city wells are

[6] Livingston, Penn, and Bennett, R. R., Ground-water resources in the Big Spring area, Tex.: U. S. Geol. Survey Water Supply Paper 913, (in press).

reported to pump large amounts of sand. The older wells at Fort Bliss also pumped considerable sand and have apparently collapsed; at least their yield has been suddenly and very materially decreased. It is therefore believed that where relatively large yields of water are required the sands at El Paso are not of the proper texture to form effective natural gravel-pack wells. This belief is supported by the fact that in the three test wells drilled during the investigation no sand was encountered below the water table that contained sufficient coarse material to build up a natural gravel pack around a well screen containing slots of the size used in the El Paso city wells. Probably, however, if smaller slots were used, an effective natural gravel pack would be formed, but it is likely that the yield of the wells would be materially reduced.

Artificial gravel packing consists of introducing around the screen gravel, usually carefully graded to a size determined by the mechanical analysis of the sand. The gravel commonly used is of pea to buckwheat size. After the surface or pump-pit casing has been set in place and the hole drilled to the final depth, the screen with attached casing is lowered into place and centered in the well. Gravel is then fed into the annular space between the well screen and the wall of the hole while the well is pumped slowly. After the well has been filled with gravel above the point at which the outer casing is set, pumping is increased, and the development of the well proceeds in the usual manner. After the development is complete a permanent pump is installed, which should have a capacity of not more than about two-thirds of the developed capacity of the well.

Well 50 (city well 1) is reported to be of artificial gravel-wall construction. It is said to yield as much sand as any of the other city wells. However, this well was sunk in 1917 when the technique of gravel-wall construction was in the early stages of development. Facts are not available to determine if the sand pumping is due to defective construction or to pumping the well at an excessive rate. On the other hand, well 18 (Ciudad Juarez well 3), drilled and gravel packed in 1934, yields 1,800 to 2,000 gallons a minute with a negligible amount of sand. Well 75 (Fort Bliss well 5), drilled and gravel packed in 1931, yields about 1,100 gallons a minute and according to Mr. Halverson, the plant engineer, yields practically no sand. Both of these wells were drilled by the same company that drilled well 50.

Artificial gravel packing probably will largely correct the excessive pumping of sand from the El Paso wells. It should also increase the yield of individual wells, and as the gravel acts as a support to the walls of the well, it will prevent the caving, with the consequent decrease in yield attendant upon it. It is recommended therefore that new city wells be of artificial gravel-wall construction. It may be mentioned that satisfactory gravel-wall construction requires considerable skill and long experience in drilling, and work of this character should therefore be done only by thoroughly qualified men.

CONCLUSIONS

Assuming that the average thickness and specific yield of sands in several wells widely spaced would approximate the actual average thickness and specific yield of sands in that part of the Mesa area, computations were made of the amount of water that would be recovered from storage if, for a distance of 10 miles north of the Mesa field, the water level in a series of wells were drawn down the same amount as the water level has been lowered in the Mesa field. It was found that 768,000 acre-feet of material would be unwatered, and if the material had a specific yield of 17 percent, 130,000 acre-feet, or 42 billion gallons, of water would be recovered, which would be equal to about 11.5 million gallons a day for a period of 10 years. This water would supplement water that is supplied to the reservoir by recharge, which is believed to average about 10 to 15 million gallons a day. A comparison of the total pumpage in the Mesa area since 1906 with the volume of the cone of depression formed by the pumpage indicates that between a third and a fourth of the total pumpage has been taken from storage and that the remainder has come from recharge.

In considering the problem of developing new well fields or increasing the pumpage from the old fields, consideration must be given to the probable thickness and permeability of water-bearing material, the relation of the fields to recharge areas, the possibility of contamination from adjacent areas, the static water level, and the cost of pipe-line connections.

The La Mesa area west of the Franklin Mountains does not appear to be a promising source for large ground-water supplies. The water-bearing materials are, in general, rather fine, and pumping lifts would be greater than on the Hueco bolson.

Because of the possibility of salt-water contamination in the El Paso valley, new developments there are not advisable except when absolutely necessary.

It is not advisable to extend the Montana field toward the east, partly because of finer materials there and partly because any extension of the field in that direction would necessitate drilling near the Mesa rim in an area in which salt water exists and which is already over-pumped. In fact, the pumpage from the Montana field should be decreased, and plans should be made that will permit the abandonment of the field, if this should become necessary.

In the El Paso Valley, beds yielding somewhat highly mineralized water overlie the beds that contain fresh water. This constitutes a source of possible contamination that must be carefully considered in making plans for pumping existing wells and in developing new ones. Most of the wells within the valley are drawing chiefly from fresh-water-bearing beds and also from one or more of the beds containing highly mineralized water, but there does not appear to be a general contamination of the fresh-water beds. However, contamination may occur either by interchange of water through wells that have leaky casings opposite the highly mineralized beds, or it may occur by transfer of water by circuitous routes around the ends of impermeable beds as a result of large differences in hydraulic head between the beds.

No heavy pumping of the upper, highly mineralized water is being done at the present time, except from the El Paso drainage well (well 10), but in order to keep the head of this water as low as possible, the construction of shallow wells for pumping this water for all purposes that do not require water of good quality should be encouraged. All abandoned wells should be effectively sealed from top to bottom. The program for rectifying the Rio Grande below El Paso has and will undoubtedly further lower the bed of the river at El Paso. This lowering will also lower the level of the shallow ground water.

The beds yielding highly mineralized water in the valley are at the same level as the beds yielding fresh water beneath the Mesa, and are presumably connected with them. It is likely that excessive lowering of the water level beneath the Mesa near the Mesa Rim will cause the highly mineralized water to move under the Mesa. In fact, this appears to have occurred to some extent in the Texas and New Orleans Railroad Co. wells at the edge of the Mesa.

Developments to the east of the Mesa field are not promising partly because the area contains somewhat finer sands, partly because the depth to water, and therefore the pumping lift is greater, and partly because the formation of a cone of depression in that area will tend to cut off a part of the recharge that is moving southwestward toward the heavily pumped areas south of the Mesa field and in the El Paso Valley, thus further increasing the difference in head between the fresh-water and the salt-water beds. The area north of the Mesa field is more promising because it should contain the coarsest, thickest, and most permeable sands, because it is close to the area of recharge along the Franklin Mountains, and because since it is the lowest part of the Mesa area, the static water level should be closest to the surface in this area. It is not possible to predict the thickness of the sand at any one site, or the yield of a well drilled at the site, but it is believed that sufficient water-bearing material for developing a yield of several hundred gallons a minute will be encountered in wells drilled in this area. It may be necessary to be satisfied with yields that are less copious than those of wells that are producing at present.

The small dams which have recently been built in the canyons in the southern part of the Franklin Mountains probably will serve to increase the amount of recharge, and additional dams in the canyons north of McKilligan Canyon probably would serve a similar purpose.

Since the completion of the main ground-water investigation at El Paso a continuing program of observations is being carried on jointly by the Federal Survey and the city. Each city well and each private well in the danger zone, which has been sampled for analysis during the investigation, is being sampled twice annually, and the successive analyses are being compared to determine whether the mineralization has changed. Data on water-level fluctuations in all the city wells and in all the observation wells that have been measured during this investigation, as well as data on pumpage from all wells of large yield in the area, are being obtained at monthly intervals. All the city wells, both new and old, are equipped with a ½-inch pipe extending from the surface to a considerable distance below the pumping level so that water levels may be measured at any time with a steel tape. The records thus obtained are being studied to determine the amount of recharge and the life of the reservoir. It is expected that reports on the results of these studies will be issued from time to time.

WELL LOGS

18. Ciudad Juarez well 3, near Hipodromo

[A concrete plug was placed from 505 feet to 656 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	2	2	Gravel	18	252
Fine sand	20	22	Sand and clay	21	273
White sand	51	73	Clay	21	294
Fine sand	24	97	Sand	201	495
Sand and gravel	21	118	Clayey sand	68	563
Sand	23	141	Sand	22	585
Sand and gravel	22	163	Shale and limestone	31	616
Sand	20	183	Sand	21	637
Sand and gravel	23	206	Sand and coarse gravel	19	656
Sand and clay	28	234			

21. El Paso well 10, South Campbell and 6th Streets

[Depth of well in use, 650 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface sand	50	50	Sand	54	522
Sand, rock, and gravel	16	66	Sand and rock	1	523
Clay	6	72	Sand	13	536
Loose fine sand	152	224	Clay	4	540
Clay	5	229	Coarse sand and boulders	24	564
Loose sand and boulders	108	337	Sand and rock	1	565
Clay	6	343	Clay	3	568
Loose sand	44	387	Coarse sand and boulders	60	626
Clay	6	393	Sand and rock	1	627
Sand and rock	1	394	Clay 8″	2	629
Sand	6	400	Clay	2	631
Sandy shell	1	401	Sand, coarse	22	653
Sand and gravel	15	416	Clay	4	657
Clay	4	420	Sand and gravel	10	667
Coarse sand and rocks, caliche	33	453	Hard sand and rock	1	668
Clay	5	453	Clay	4	672
Coarse sand	6	464	Coarse sand and boulders	37	709
Clay	4	468	Sand	98	807

50. El Paso well 1, Montana and Madison Streets

[Cement plug placed 680 feet to 1,023 feet. 13½-inch screen set at 485–605 feet, 695–715 feet, and 775–815 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface sand	38	38	Tough clay	3	563
Fine gravel and clay	5	43	Sand and boulders	13	576
Sandy clay	38	81	Tough clay	8	584
Hard clay	3	84	Sand	20	604
Sandy clay	41	125	Soft clay and gumbo	6	610
Hard clay	18	143	Hard gumbo	16	626
Sandy clay	9	152	Rock and shale	13	639
Clay and gravel	8	164	Rock	2	641
Hard clay	4	168	Clay and boulders	9	650
Sandy clay	12	180	Gravel and boulders	11	661
Clay and boulders	3	183	Gumbo and clay	30	691
Sandy clay	30	213	Gumbo and clay	2	693
Hard clay	4	217	Sand, gravel and boulders	11	704
Sandy clay	6	223	Hard shale	4	708
Gumbo	4	227	Boulders	13	721
Clay and gumbo	7	234	Sandy clay	3	724
Clay	10	244	Clay and boulders	4	728
Sandy clay	14	258	Gumbo	3	731
Clay and gumbo	10	268	Boulders and clay	15	746
Packed sand	27	295	Hard gumbo	7	753
Rock and boulders	4	299	Rock	3	756
Clay	6	305	Sand and sand rock	14	770
Sandy clay	12	317	Rock	5	775
Boulders and sand rock	2	319	Sand and gravel	14	789
Sandy clay	5	324	Gravel and boulders	21	810
Sand and boulders	20	344	Clay and gumbo	5	815
Rock	4	348	Sand, gravel and boulders	12	827
Hard clay	7	355	Clay and gumbo	12	839
Sandy clay	8	363	Gravel and boulders	12	851
Sand	13	376	Gumbo	4	855
Clay	3	379	Gravel and boulders	22	877
Gumbo	21	400	Clay and boulders	9	886
Clay	7	407	Sand and gravel	8	894
Sand and gravel	38	445	Clay and gumbo	3	897
Clay	5	450	Sand, gravel and boulders	26	923
Sand	4	454	Dry gumbo	4	927
Sandy clay	3	457	Sand and sand rock	15	942
Rock	2	459	Gumbo	19	961
Sandy clay	2	461	Sand and sand rock	12	973
Sand and clay	22	483	Gumbo	14	987
Clay rock and boulders	2	485	Gravel and boulders	10	997
Sand and gravel	40	525	Rock	1	998
Clay and gumbo	21	546	Sand, gravel and boulders	25	1,023
Sand, gravel, and boulders	14	560			

56. Pasotex Petroleum Co. water well 1, 0.4 mile northeast of Ascarate

	Thickness Ft.	Thickness in.	Depth Ft.	Depth in.		Thickness Ft.	Thickness in.	Depth Ft.	Depth in.
Dry surface material	96	5	96	5	Clay	22	7	398	3
Clay	15		111	5	Water sand	13		411	3
Water sand	88	4	199	9	Clay	5		416	3
Clay	20		219	9	Water sand	33	8	449	11
Water sand	65	6	285	3	Clay	7		456	11
Clay	3		288	3	Water sand	10		466	11
Water sand	12	4	300	7	Clay	7	9	474	8
Clay	11	7	312	2	Water sand	38	9	513	5
Water sand	10		322	2	Clay	27	9	541	2
Clay	25	9	347	11	Water sand	45	2	586	4
Water sand	27	9	375	8	Clay, bottom of well	3	8	590	

64. El Paso and U. S. Geological Survey test well 1, on Carlsbad road, 3.1 miles east of city limits

	Thickness	Depth		Thickness	Depth
Sand	2½	2½	Sand	4	350
Caliche	7½	10	Clay	6	356
Clay	24	34	Fine sand	3	359
Fine sand	28	62	Clay	4	363
Sand	15	77	Gravel	1	364
Sand and gravel with clay breaks	55	132	Clay	4	368
Sand and gravel	10	142	Sand	3	371
Sandy clay	15	157	Clay	37	408
Sand	9	166	Sand	20	428
Sandy clay	5	171	Sandy clay	7	435
Sand	13	184	Sand	6	441
Sand and coarse gravel	10	194	Clay	16	457
Clay	15	209	Gravel	1	458
Coarse gravel	1	210	Clay	9	467
Clay	10	220	Sand	13	480
Sand	20	240	Sandstone	3	483
Sandy clay	2	242	Sandy clay	11	494
Clay and gravel	12	254	Fine sand and clay	6	500
Sandy clay	12	266	Sandy clay and gravel	10	510
Coarse sand	28	294	Clay	4	514
Gravel	½	294½	Sand	26	540
Fine sand	16½	311	Clay	2	542
Sandy clay	10	321	Sand	6	548
Fine sand	5	326	Clay	2	550
Sandy clay	9	335	Sand (water test)	16	566
Coarse sand and gravel	2	337	Sandy clay	11	577
Clay	9	346	Sand	12	589
			Clay	11	600

76. El Paso and U. S. Geological Survey test well 2, Biggs Field, near southeast corner

	Thickness	Depth		Thickness	Depth
Sand and caliche	19	19	Clay and sandy clay	13	312
Coarse sand and gravel	23	42	Medium sand grading downward into sandy clay	15	327
Sand	5	47	Clay	24	351
Coarse sand and gravel	6	53	Fine sand	2	353
Clay	23	76	Clay	2	355
Gravel	20	96	Fine sand	15	370
Clay	8	104	Clayey sand	1	371
Coarse sand and gravel	37	141	Coarse sand	6	377
Clay	29	170	Clay	6	383
Fine sand grading into sandy clay	7	177	Sand	1	384
Clay	25	202	Clay	23	407
Gravel and clay	1	203	Medium sand	9	416
Clay	2	205	Clay and sandy clay	23	439
Fine sand	2	207	Sand	23	462
Clay	18	225	Clay	11	473
Fine sand with some small gravel	25	250	Sand	33	506
Coarse sand	6	256	Clay	10	516
White chalky clay	14	270	Sandy clay	7	523
Fine sand	10	280	Sand	59	582
Clay	6	286	Clay	11	593
Sand	13	299	Very fine sand	7	600

76b. El Paso test well 8 (finished as El Paso test well 15), about 200 feet southwest of intersection of Wilson Road and Pistol Range Road

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sandy soil	2	2	Sand	23	573
Caliche	6	8	Clay	27	600
Coarse sand and gravel	70	78	Sand	24	624
Clay	20	98	Clay	3	627
Sand	20	118	Sand	24	651
Layers of sand and clay	100	218	Clay	16	667
Clay	8	226	Rock	1	668
Sand	18	244	Sand	8	676
Clay	14	258	Clay	12	688
Sandy clay	12	270	Sandy clay	15	703
Clay	17	287	Sand	27	730
Sand (water sample)	25	312	Clay	8	738
Clay	15	327	Sandy clay	10	748
Sand	17	344	Sand	10	758
Hard sand	6	350	Sandy clay	44	802
Clay	82	432	Sand	12	814
Sand	15	447	Clay (water sample)	21	835
Clay	4	451	Sand (static head 226 feet)	28	863
Sand	10	461	Clay	15	878
Sandy clay	54	515	Sandy clay	50	928
Sand	18	533	Sand	10	938
Clay	6	539	Clay and boulders	60	998
Sand (water sample)	9	548	Sand	25	1,023
Clay	2	550	Sandy clay	55	1,078

77. El Paso well 12, Wilson Road near Biggs Field

Surface sand, etc.	35	35	Sand, gravel, boulders	35	535
Coarse gravel	5	40	Clay	3	538
Sand, gravel	80	120	Sand, boulders	21	559
Sand, clay	25	145	Clay	6	565
Sand, boulders	70	215	Sand, gravel, boulders	36	601
Clay	7	222	Clay	4	605
Fine sand, boulders	38	260	Sand, gravel, boulders	13	618
Clay	5	265	Clay	4	622
Fine sand	36	301	Sand, gravel, boulders	11	633
Clay	23	324	Clay	3	636
Boulders	3	327	Sand, gravel, boulders	6	642
Fine sand, boulders	22	349	Clay	3	645
Clay, sand	13	362	Sand, gravel, etc.	10	655
Coarse sand, gravel	22	384	Clay	3	658
Clay	5	389	Sand, gravel, boulders	17	675
Boulders, sand, gravel	23	412	Sand, rock	1	676
Sand, rock	1	413	Sand, gravel	22	698
Clay, sand, boulders	17	430	Clay	3	701
Clay	6	436	Sand, gravel	14	715
Sand and boulders	19	455	Clay	3	718
Sand, gravel, boulders	15	470	Sand, gravel	14	732
Clay	5	475	Clay	4	736
Sand, gravel, boulders	7	482	Sand, gravel	29	765
Clay	3	485	Clay	2	767
Sand, gravel, boulders	7	492	Sand, rock	1	768
Sand, rock	1	493	Sand, gravel, boulders	5	773
Boulders and sand	2	495	Clay, bottom	7	780
Clay	5	500			

78. El Paso well 11, Wilson Road

Soil	4	4	Clay	4	414
Caliche	11	15	Sand, gravel, and boulders	54	468
Sand	55	70	Clay	3	471
Clay	10	80	Rock	1	472
Gravel	20	100	Sand, gravel, and boulders	22	494
Clay	6	106	Clay	5	499
Sand	58	164	Sand, gravel, and boulders	29	528
Clay	6	170	Clay	5	533
Sand	30	200	Sand, gravel, and boulders	57	590
Clay	20	220	Clay	12	602
Sand	40	260	Sand, gravel, and boulders	26	628
Clay	15	275	Clay	3	631
Sand	33	308	Sand, gravel, and boulders	57	688
Clay	4	312	Clay	4	692
Sand and boulders	38	350	Sand	16	708
Rock	1	351	Sand, gravel, and boulders	50	758
Sand	17	368			
Clay	4	372			
Sand and boulders	38	410			

78a. El Paso test well 6, ½ mile north of well 78 on Wilson Road

	Thickness (feet)	Depth (feet)
Soil	14	14
Sand and caliche	4	18
Sand	34	52
Clay and gravel	6	58
Clay	13	71
Pack sand	71	142
Layers of clay and coarse sand	37	179
Clay	25	204
Sand	16	220
Clay	4	224
Layers of clay and sand	30	254
Sandy clay	51	305
Sand	14	319
Clay	19	334
Sand	18	352
Clay and boulders	13	365
Sand	5	370
Clay and boulders	17	389
Sandy clay	56	445
Clay	6	451
Sandy clay	14	465
Clay and boulders	18	483
Sand	3	486
Hard sand and shale	19	505
Sandy shale	27	532
Hard shale	62	594
Sandy shale and boulders	9	605
Packed sand	5	610
Packed sand and shale	5	615
Boulders	2	617
Rock	1	618
Hard shale and sand	40	658
Hard shale	41	699
Sandy shale	61	760
Shale	70	830

85. El Paso, Old Mesa field, well 5

	Thickness (feet)	Depth (feet)
Caliche	10	10
Fine sand	28	38
Caliche, clay	4	42
Fine sand	8	50
Caliche, clay	2	52
Fine sand	12	64
Red clay	42	106
Sandy gravel (dry) with clay kidneys	44	150
Clay	30	180
Tough clay	50	230
Fine sand and water	8	238
Water sand and water	8	246
Yellow clay	8	254
Sand	8	262
Yellow clay	56	318
Fine quicksand (probably water)	14	332
Hard yellow clay	44	376
Sand and kidneys of clay (probably water)	14	390
Quicksand and water	18	408
Sediment clay	39	447
Sandy clay	3	450
Clay	40	490
Hard clay	118	608
Joint clay	22	630
Hard clay (sandy)	46	676
Sediment clay	44	720
Stratified clay	148	868
Sandy clay	2	870
Clay	42	912
Stratified clay	41	953
Stratified clay (hard)	37	990
Clay, fine sand	10	1,000
Stratified clay	30	1,030
Brown sediment clay (hard)	42	1,072
Soft sand, rock	4	1,076
Brown clay (very hard)	83	1,159
Sandy clay (very hard)	30	1,189
Sandy clay (very hard)	109	1,298
Dry gravel	12	1,310
Clay	251	1,561
Rock	57	1,618
Soft rock	54	1,672
Rock	86	1,758
Hard and soft seams of rock	33	1,791
Rock	49	1,840
Clay (very hard)	13	1,853
Sandstone (supposed)	30	1,883
Hard formation—(conglomerate)	23	1,906
Rock	39	1,945
Hard formation—(conglomerate)	35	1,980
Hard formation (hard clay, supposed)	28	2,008
Clay	120	2,128
Sand, rock	27	2,155
Clay	130	2,285

106. El Paso, Old Mesa field, well 26

	Thickness (feet)	Depth (feet)
Soil	3	3
Caliche	4	7
Soil	4	11
Coarse sand	10	21
Fine sand	7	28
Clay	13	41
Fine sand	10	51
Clay	25	76
Sand	5	81
Clay	10	91
Coarse sand	10	101
Clay	8	109
Sand	10	119
Clay	12	131
Sand	20	151
Sand and gravel	14	165
Clay	11	176
Sand	10	186
Clay	19	205
Hard clay	6	211
Sand and water	5	216
Sand, gravel, and water	8	224
Clay	12	236
Sand and water	10	246
Clay	15	261
Water, sand	15	276
Clay	35	311
Sand and water	13	324
Clay	12	336
Sand and water	20	356
Clay	15	371
Water, sand	10	381
Clay	5	386
Sand, gravel and water	15	401
Clay	7	408
Water, sand	15	423
Hard clay	9	432
Water, sand	6	438
Clay	13	451
Sand, gravel, and water	10	461
Clay	5	466
Sand, water	8	474
Clay	42	516
Hard clay	50	566
Rock	10	576
Sand	5	581
Sand and boulders	13	594
Rock	2	596
Water, sand	15	611
Hard clay	2	613

136. El Paso and U. S. Geological Survey test well 3, 5.6 miles north of Wilson Road

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	4	4	Clayey, silty sand	39.5	293
Sandy clay	6	10	Fine sand	30	323
Sand, coarser toward bottom	36	46	Coarse sand	13	336
Clay	2	48	Clay with thin beds of sand	24	360
Gravel	24	72	Fine sand	23	383
Clay	11	83	Sand	5	388
Sand	3	86	Clay and sand	3	391
Coarse sand and gravel	24	110	Sand	8	399
Clay	9	119	Sandy clay	15	414
Sand and gravel	23	142	Clay	7	421
Clay	6	148	Sand, medium-grained	11	432
Sand and gravel	23	171	Clay	7	439
Clay	19	190	Sandy clay	5	444
Sand	14	204	Sand	3	447
Sand and gravel	13	217	Sandy clay	13	460
Clay	3	220	Sand and gravel	4	464
Sand and gravel	3.5	223.5	Sandy clay	17	481
Clay	15.5	239	Sand	9	490
Sand	3	242	Clay	2	492
Sandy clay	6	248	Coarse sand	8	500
Clay	5	253			
Gravel	0.5	253.5			

140. Southern Pacific Lines well 3, pump house at Newman, N. Mex.

Sand	10	10	Sand	55	300
Caliche	5	15	Clay	4	304
Sand	135	150	Sand	4	308
Clay	5	155	Clay	4	312
Sand	20	175	Sand (water)	38	350
Clay	4	179	Clay	10	360
Sand	8	187	Sandstone	20	380
Clay	3	190	Sand (water)	17	397
Sand	43	233	Clay	2	399
Clay	4	237	White Rock	1	400
Sand	7	244			
Rock	1	245			

145. U. S. Army, Dona Ana target range well, Dona Ana Co., N. Mex.

Adobe	6	6	Sand and boulders	40	470
Caliche	2	8	Clay	6	476
Sand	73	81	Sand and boulders	24	500
Clay	39	120	Sand and gravel	9	509
Gravel	14	134	Sandy clay	5	514
Clay	9	143	Sand, gravel, and boulders	15	529
Sand and boulders	57	200	Sandy clay	12	541
Clay	8	208	Sand	32	573
Sand and gravel	22	230	Sandy clay (water)	16	589
Sand	34	264	Sand and boulders	18	607
Sand and gravel	17	281	Sandy clay	12	619
Clay	4	285	Sand and gravel (water)	11	630
Sand and boulders	11	296	Sand and clay	6	636
Sand and rock	3	299	Sand and boulders	26	662
Sand and boulders	20	319	Sand and gravel	11	673
Sand (water sand)	10	329	Sedimentary rock	2	675
Clay	3	332	Sand and clay	6	681
Sand and boulders	13	345	Sand and boulders	12	693
Clay	30	375	Sandy clay	9	702
Sand and boulders (water)	28	403	Sand, rock	5	707
Sand and clay	7	410	Sand and boulders	67	774
Sand and boulders	11	421	Sand (water)	20	794
Clay	9	430	Sand, rock	4	798

Cinco Minas Co. well 1, SW¼ sec. 24, block 80, Township 1, 1.6 miles south of Newman, N. Mex.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface sand	100	100	Lime	5	1,820
Packed sand	65	165	Red shale	35	1,855
Conglomerate	165	330	Lime	15	1,870
Clay	20	350	Gumbo	60	1,930
Hard packed sand	16	366	Lime	5	1,935
Gumbo	19	385	Shale	165	2,100
Conglomerate	35	420	Lime	5	2,105
Clay	46	466	Shale	68	2,173
Conglomerate	13	479	Sandy lime	12	2,185
Hard sand and gravel	5	484	Shale	15	2,200
Clay	6	490	Sand	15	2,215
Conglomerate	18	508	Shale	35	2,250
Hard packed sand	16	524	Sand and boulders	50	2,300
Gumbo	8	532	Shale	49	2,349
Hard packed sand	13	545	Shale	51	2,400
Broken lime	26	571	Sand	28	2,428
Shale and boulders	60	631	Shale	52	2,480
Clay	11	642	Sand	8	2,488
Clay and boulders	13	655	Red shale	68	2,556
Lime	20	675	Blue shale	40	2,596
Clay and boulders	26	701	Red shale	34	2,630
Rock	16	717	Blue shale	6	2,636
Clay and boulders	14	731	Red shale	10	2,646
Rock	14	745	Lime	12	2,658
Shale	5	750	Red shale	40	2,698
Conglomerate	12	762	Lime	12	2,710
Rock	3	765	Shale	14	2,724
Shale	7	772	Sand	10	2,734
Limestone	12	784	Red shale	31	2,765
Clay and boulders	36	820	Blue shale	13	2,778
Packed sand	23	843	Red shale	25	2,803
Rock	14	857	Blue shale	20	2,823
Lime	11	868	Sand and boulders	5	2,828
Clay and boulders	30	898	Blue shale	7	2,835
Sandy lime	2	900	Sandy shale	8	2,843
Shale and boulders	82	982	Sticky shale	30	2,873
Broken lime	20	1,002	Sandy shale	37	2,910
Clay and boulders	4	1,006	Sticky shale	20	2,930
Hard lime	21	1,027	Sandy shale	5	2,935
Shale and boulders	51	1,078	Lime shells	4	2,939
Rock	5	1,083	Sandy lime	27	2,966
Shale and boulders	27	1,110	Shale	108	3,074
Lime	6	1,116	White shale	6	3,080
Shale and boulders	11	1,127	Shale	22	3,102
Broken lime	19	1,146	Shale	5	3,107
Gumbo	14	1,160	Shell rock	2	3,109
Gravel	7	1,167	Shale	31	3,140
Broken lime	33	1,200	White shale	5	3,145
Shale and boulders	53	1,253	Red shale	97	3,242
Shale and shells	20	1,273	Shell rock	1	3,243
Shale	63	1,336	Shale	16	3,259
Sticky shale	4	1,340	Hard sand oil	2	3,261
Shale	75	1,415	Shale	2	3,263
Lime	50	1,465	Shells	4	3,267
Wash rock	4	1,469	Shale	51	3,318
Red sticky shale	108	1,577	Lime sand	6	3,324
Lime rock	3	1,580	Shale	6	3,330
Red shale	32	1,612	Shells	1	3,331
Lime	8	1,620	Shale	47	3,378
Shale	50	1,670	Shells	3	3,381
Packed sand	5	1,675	Shale	91	3,472
Shale	85	1,760	Shell rock	3	3,475
Lime	10	1,770	Sand, salt core	2	3,477
Shale	45	1,815	Shale and gumbo	533	4,010

Southern Pacific Co. well at Afton, Dona Ana County, N. Mex.

Caliche	25	25	Red clay	25	540
Sand and gravel	75	100	Yellow clay	45	585
Fine sand	150	250	Fine sand	43	628
Sand and caliche	20	270	Coarse sand and clay	27	655
Fine sand	26	296	Red clay	47	702
Red clay with fine sand	31	327			
Fine sand (water)	188	515			

Southern Pacific Lines old well 1, at Strauss, Dona Ana County, N. Mex.
[Well later plugged back to 950 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand	3	3	Sand	5	523
Sandy soil	3	6	Yellow clay	4	527
Caliche	6	12	Sand	3	530
Sand	8	20	Yellow and blue clay	10	540
Yellow clay	85	105	Black sand	70	610
Cemented sand	15	120	Blue clay	20	630
Yellow clay	50	170	Black sand	20	650
Sand	15	185	Blue and red clay	120	770
Red clay	25	210	Black sand	60	830
Sand	5	215	Yellow clay	40	870
Red clay	22	237	Black sand	25	895
Cemented sand	13	250	Red clay	45	940
Yellow clay	5	255	Black sand	10	950
Sand	10	265	Red clay	30	980
Sandy clay	30	295	Sand	10	990
Sand	2	297	Red clay	20	1,010
Red clay	23	320	Sand	5	1,015
Sand	10	330	Red clay	20	1,035
Red clay	20	350	Sand	5	1,040
Sand	5	355	Red clay	40	1,080
Yellow clay	5	360	Sand	10	1,090
Sand (water)	52	412	Clay	35	1,125
Yellow clay	38	450	Sand and gravel (water)	15	1,140
Sand	25	475	Clay	10	1,150
Blue clay	3	478	Sand	125	1,275
Sand	7	485	Sandy clay	50	1,325
Yellow clay	3	488	Sandstone	2	1,327
Sand	10	498	Sand	3	1,330
Yellow clay	20	518			

Lippincott well, El Paso test well in Mesilla Valley, at Country Club, 1.6 miles west of Borderland Inn

Sand	49	49	Hard gray lime	11	951
Gravel	5	54	Sandy limestone, some water	3	954
Sand	7	61	Blue lime	3	957
Sand	24	85	Blue lime with sand seam	6	963
Gravel	5	90	Solidified lime (very hard)	1	964
Sand	9	99	Sandy limestone	1	965
Broken gravel and sand	190	289	Blue lime	2	967
Coarse gravel and sand	21	310	Silicious lime	3	970
Very coarse gravel and sand (water test)	23	333	Blue lime	4	974
			Silicious lime	3	977
Gravel, broken shale and sand	12	345	Blue lime with sand seam	9	986
Gravel, sand and lime	6	351	Hard quartz	3	989
Gravel, sand and lime	4	355	Blue lime with sand seam	8	997
Coarse sand (brown)	13	368	Cemented sand	7	1,004
Fine sand (brown)	42	410	Blue lime with sand seam	3	1,007
Sandy shale (blue)	43	453	Yellow clay and sand seam—(small flow water)	10	1,017
Gumbo	17	470			
Fine sand	10	480	Soft yellow sandstone	9	1,026
Shell lime	2	482	Blue limestone	1	1,027
Gumbo	65	547	Clay, soft sandstone	7	1,034
Sandy shale	57	604	Clay and yellow sand	3	1,037
Gumbo and sand	218	822	Soft sandstone	20	1,057
Sandy lime (hard)	3	825	Quicksand	5	1,062
Gumbo	40	865	Blue clay, sand	2	1,064
Sandy lime (hard)	3	868	Quicksand	10	1,074
Black lime (very hard)	1	869			
Lime broken with coarse gravel	71	940			

RECORDS OF WATER LEVELS IN OBSERVATION WELLS IN EL PASO AREA

[Depths to water levels are referred to the measuring points described; altitudes of the water levels are referred to mean sea level U. S. Coast and Geodetic Survey datum]

6. El Paso Electric Co. well 2, Santa Fe and 4th Streets

[Measuring point, bottom of steel pump base, 0.6 foot below ground level and 3,708.69 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 20	6.73	3,701.96	Nov. 9	8.11	3,700.58	Oct. 13	8.55	3,700.14
Dec. 11	7.72	3,700.97	Dec. 17	13.28	3,695.41	Nov. 12	9.00	3,699.69
1936			*1937*			Dec. 20	9.16	3,699.53
Jan. 13	7.86	3,700.83	Jan. 18	12.35	3,696.34	*1938*		
Feb. 13	7.73	3,700.96	Feb. 22	13.36	3,695.33	Jan. 13	9.05	3,699.64
Mar. 16	13.07	3,695.62	Mar. 15	14.06	3,694.63	Feb. 14	13.44	3,695.25
Apr. 8	12.35	3,696.34	Apr. 14	8.87	3,699.82	18	11.85	3,696.84
May 15	9.09	3,699.60	May 13	8.35	3,700.34	21	9.85	3,698.84
June 11	8.08	3,700.61	June 14	7.87	3,700.82	Mar. 15	9.69	3,699.00
July 13	8.81	3,699.88	July 7	8.60	3,700.09	Apr. 13	8.85	3,699.84
Aug. 17	8.06	3,700.63	Aug. 12	8.84	3,699.85	May 16	8.49	3,700.20
Sept. 14	8.22	3,700.47	Sept. 15	8.35	3,700.34	June 19	11.56	3,697.13
Oct. 19	7.96	3,700.73						

7. El Paso Electric Co. well 1, Santa Fe and 4th Streets

[Measuring point, top of steel pump base, 0.5 feet above ground level and 3,710.09 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 20	8.26	3,701.83	Nov. 9	10.02	3,700.07	Oct. 13	10.32	3,699.77
Dec. 11	9.26	3,700.83	Dec. 17	[1]	----------	Nov. 12	10.65	3,699.44
1936			*1937*			Dec. 20	10.70	3,699.39
Jan. 13	9.40	3,700.69	Jan. 18	[1]	----------	*1938*		
Feb. 13	9.38	3,700.71	Feb. 22	[1]	----------	Jan. 13	10.64	3,699.45
Mar. 16	15.02	3,695.07	Mar. 17	12.27	3,697.82	Feb. 14	14.14	3,695.65
Apr. 8	14.48	3,695.61	Apr. 14	10.62	3,699.47	18	14.50	3,695.59
May 15	10.69	3,699.40	May 13	10.32	3,699.77	21	11.64	3,698.45
June 11	9.77	3,700.32	June 14	9.87	3,700.22	Mar. 15	11.34	3,698.75
July 13	11.09	3,699.00	July 7	10.58	3,699.51	Apr. 13	10.44	3,699.65
Aug. 17	10.41	3,699.68	Aug. 12	10.78	3,699.31	May 16	10.04	3,700.05
Sept. 14	11.05	3,699.04	Sept. 15	10.18	3,699.91	June 19	13.55	3,696.54
Oct. 19	9.91	3,700.18						

[1] Pump in operation. No measurements taken.

8. El Paso Electric Co. well 4, Santa Fe and 4th Streets

[Measuring point, top of 8-inch casing, 7.69 feet above ground level and 3,716.31 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 20	20.28	3,696.03	Dec. 17	27.06	3,689.25	Nov. 12	20.56	3,695.75
Dec. 11	21.79	3,694.52	*1937*			Dec. 20	20.58	3,695.73
1936			Jan. 18	23.78	3,692.53	*1938*		
Jan. 13	21.71	3,694.60	Feb. 22	24.22	3,692.09	Jan. 13	19.04	3,695.78
Feb. 13	22.23	3,694.08	Mar. 15	23.23	3,693.08	Feb. 14	21.61	3,693.21
Mar. 16	26.30	3,690.01	Apr. 14	20.77	3,695.54	18	20.78	3,694.04
Apr. 18	23.91	3,692.40	May 13	20.11	3,696.20	21	19.73	3,695.09
May 15	21.17	3,695.14	June 14	19.58	3,696.73	Mar. 15	19.50	3,695.32
June 11	20.98	3,695.33	July 7	20.55	3,695.76	Apr. 13	19.27	3,695.55
July 13	23.41	3,692.90	Aug. 12	20.46	3,695.85	May 16	19.46	3,695.36
Aug. 17	19.74	3,696.57	Sept. 15	20.54	3,695.77	June 13	23.18	3,691.64
Sept. 14	21.06	3,695.25	Oct. 13	20.52	3,695.79	19	21.11	3,693.71

9. El Paso Electric Co. well 3, Santa Fe and 4th Streets

Measuring point, top of steel pump base, 0.2 foot above ground level and 3,710.06 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 20	9.77	3,700.29	Nov. 9	11.05	3,699.01	Oct. 13	11.68	3,698.38
Dec. 11	10.65	3,699.41	Dec. 17	13.08	3,696.98	Nov. 12	12.12	3,697.94
1936			*1937*			Dec. 20	12.16	3,697.90
Jan. 13	10.83	3,699.23	Jan. 18	12.54	3,697.52	*1938*		
Feb. 13	10.77	3,699.29	Feb. 22	14.58	3,695.48	Jan. 13	11.96	3,698.10
Mar. 16	16.03	3,694.03	Mar. 17	13.25	3,696.81	Feb. 18	15.49	3,694.57
Apr. 8	16.23	3,693.83	Apr. 14	11.71	3,698.35	21	12.96	3,697.10
May 15	12.05	3,698.01	May 13	11.17	3,698.89	Mar. 15	12.67	3,697.39
June 11	10.77	3,699.29	June 14	10.70	3,699.36	Apr. 13	11.60	3,698.46
July 13	12.41	3,697.65	July 7	11.85	3,698.21	May 16	11.12	3,698.94
Aug. 17	12.19	3,697.87	Aug. 12	11.66	3,698.40	June 19	15.29	3,694.77
Oct. 19	11.35	3,698.71	Sept. 15	11.27	3,698.79			

10. El Paso drainage well, 4th and Oregon Streets

[Diameter 20 inches, depth 52.5 feet. Measuring point, top of casing, 0.5 foot above ground level and 3,708.35 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1933			*1938*			*1939*		
Apr.	8		Aug. 17	11.56	3,696.79	[1]Jan. 24	25.44	3,682.91
1938			Sept. 15	10.74	3,697.61	Feb. 20	10.82	3,697.53
Apr. 16	10.13	3,698.22	Oct. 24	10.29	3,698.06	Mar. 21	12.19	3,696.16
May 20	9.84	3,698.51	Nov. 18	10.31	3,698.04			
July 17	12.85	3,695.50						

[1] Pump in operation.

13. Ciudad Juarez well 2, Mariscal and Primera Streets

[Measuring point, top of steel pump base, 0.6 foot above ground level and 3,755.83 feet above mean sea level]

1935			*1935*			*1937*		
Aug. 27	62.39	3,693.44	Dec. 11	62.76	3,693.07	Apr. 12	64.34	3,691.49

19. El Paso Milling Co., Kansas and 11th Streets.

[Measuring point, top of casing, 14.6 feet above ground level and 3,721.67 feet above mean sea level]

1935			*1936*			*1937*		
Aug. 23	27.19	3,694.48	Sept. 14	28.79	3,692.88	Aug. 12	28.60	3,693.07
Oct. 25	28.75	3,692.92	Oct. 19	27.81	3,693.86	Sept. 15	27.78	3,693.89
Dec. 13	27.08	3,694.59	Nov. 9	27.72	3,693.95	Oct. 13	27.56	3,694.11
1936			*1937*			Nov. 12	27.37	3,694.30
Jan. 13	26.92	3,694.75	Jan. 18	(1)	----------	Dec. 20	27.32	3,694.35
Feb. 13	28.58	3,693.09	Feb. 22	28.61	3,693.06	*1938*		
Mar. 16	28.50	3,693.17	Mar. 17	28.80	3,692.87	Jan. 13	27.62	3,694.05
Apr. 8	28.49	3,693.18	Apr. 15	29.93	3,691.74	Feb. 14	28.05	3,693.62
May 18	30.10	3,691.57	May 13	28.70	3,692.97	Mar. 15	27.53	3,694.14
June 12	28.81	3,692.86	June 14	28.15	3,693.52	Apr. 15	27.60	3,694.07
July 14	39.76	3,681.91	July 7	29.03	3,692.64	May 16	27.96	3,693.71
Aug. 17	37.78	3,683.89				June 13	29.14	3,692.53

[1] Pump in operation. No measurements taken.

21. El Paso well 10, Campbell and 6th Streets

[Measuring point, floor of pump house, 2.6 feet above ground level and 3,707.45 feet above mean sea level]

1934			*1936*			*1937*		
Dec. 22	18.17	3,689.28	Oct. 20	21.74	3,685.71	Aug. 12	21.70	3,685.75
1935			Nov. 9	21.11	3,686.34	Sept. 15	21.13	3,686.42
Sept. 11	18.90	3,688.55	Dec. 17	21.38	3,686.07	Oct. 13	20.58	3,686.87
Dec. 11	19.30	3,688.15	*1937*			Nov. 12	20.32	3,687.13
1936			Jan. 18	20.14	3,687.31	Dec. 20	19.91	3,687.54
Jan. 13	18.48	3,688.97	Feb. 22	20.38	3,687.07	*1938*		
Feb. 13	18.72	3,688.73	Mar. 16	20.94	3,686.51	Jan. 13	19.87	3,687.58
Mar. 16	19.46	3,687.99	Apr. 14	20.64	3,686.81	Feb. 14	20.02	3,687.43
Apr. 8	19.65	3,687.80	May 13	20.62	3,686.83	Mar. 15	19.39	3,688.06
May 15	20.14	3,687.31	June 14	20.30	3,687.15	Apr. 15	19.90	3,687.55
June 10	20.45	3,687.00	July 7	22.49	3,684.96	May 16	20.09	3,687.36
Aug. 17	(1)	----------	----------	----------	----------	June 13	21.10	3,686.35
Sept. 14	25.74	3,681.71						

[1] Pump in operation. No measurements taken.

22. El Paso well 6, 2d and Cotton Streets

Measuring point, top of brass coupling 0.06 foot above steel pump base, 0.16 foot above ground level and 3704.53 feet above mean sea level]

1934			*1936*			*1937*		
Dec. 22	16.36	3,688.17	Sept. 14	17.38	3,687.15	Aug. 12	21.17	3,683.36
1935			Nov. 9	16.21	3,688.26	Sept. 15	17.80	3,686.73
Aug. 19	19.13	3,685.40	Dec. 14	16.24	3,688.23	Oct. 13	17.33	3,687.20
Sept. 11	16.65	3,687.88	*1937*			Nov. 12	17.07	3,687.46
Nov. 5	14.98	3,689.55	Jan. 18	16.54	3,687.99	Dec. 20	17.01	3,687.52
Dec. 11	14.61	3,689.92	Feb. 23	16.58	3,687.95	*1938*		
1936			Mar. 15	16.72	3,687.81	Jan. 14	16.96	3,687.57
Jan. 13	14.45	3,690.08	Apr. 15	17.35	3,687.18	Feb. 14	16.86	3,687.67
Feb. 13	14.47	3,690.06	16	17.72	3,686.81	Mar. 15	16.63	3,687.90
Mar. 16	17.17	3,687.36	17	18.64	3,685.89	Apr. 15	17.25	3,687.28
Apr. 8	16.68	3,687.85	May 13	18.15	3,686.38	May 16	19.48	3,685.05
June 11	18.04	3,686.49	June 15	18.46	3,686.07	June 13	20.20	3,684.33
July 13	18.83	3,685.70	July 7	18.13	3,686.40			

28. Acme Laundry, 905 East Missouri Street

[Measuring point, top of steel pump base, 2.0 feet above ground level and 3,725.62 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 17	50.50	3,675.12	Oct. 18	54.59	3,671.03	Aug. 15	53.05	3,672.57
1936			Nov. 8	53.83	3,671.79	Sept. 10	52.56	3,673.06
Feb. 16	51.22	3,674.40	Dec. 13	51.77	3,673.85	Oct. 10	52.27	3,673.35
Mar. 15	52.48	3,673.14	*1937*			Nov. 14	51.28	3,674.34
Apr. 19	52.18	3,673.44	Jan. 20	51.33	3,674.29	Dec. 19	50.92	3,674.70
May 17	52.86	3,672.76	Feb. 24	51.40	3,674.22	*1938*		
June 14	53.07	3,672.55	Mar. 14	51.04	3,674.58	Jan. 16	50.25	3,675.37
July 12	76.81	3,648.81	Apr. 18	51.84	3,673.78	Feb. 13	50.08	3,675.54
14	76.75	3,648.87	May 16	51.53	3,674.09	Mar. 20	49.00	3,676.62
Aug. 16	78.41	3,647.21	June 20	55.76	3,669.86	Apr. 17	50.37	3,675.25
Sept. 13	63.62	3,662.00	July 4	56.92	3,668.70	June 12	50.91	3,674.71

33. El Paso Foundry & Machine Co., Williams Street at International Boundary

[Measuring point, top of airline, 5.0 feet above ground level and 3704.72 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Oct. 25	14.40	3,690.32	Sept. 14	15.10	3,689.62	Sept. 17	12.60	3,692.12
Dec. 11	9.89	3,694.83	Oct. 19	15.03	3,689.69	Oct. 13	12.17	3,692.55
1936			*1937*			Nov. 15	12.16	3,692.56
Jan. 13	9.75	3,694.97	Jan. 18	15.60	3,689.12	*1938*		
Feb. 13	9.75	3,694.97	Feb. 23	15.29	3,689.43	Jan. 14	12.21	3,692.51
Mar. 16	14.15	3,690.57	Mar. 16	15.08	3,689.64	Feb. 14	11.76	3,692.96
Apr. 8	13.96	3,690.76	Apr. 15	15.89	3,688.83	Mar. 15	12.20	3,692.52
May 18	14.64	3,690.08	Apr. 17	15.83	3,688.89	Apr. 18	13.61	3,691.11
June 11	14.77	3,689.95	June 14	16.30	3,688.42	May 20	15.69	3,689.03
July 17	15.01	3,689.71	July 7	16.34	3,688.38	June 18	16.45	3,688.27
Aug. 17	15.87	3,688.85	Aug. 13	16.69	3,688.03			

36. Southern Pacific Lines, Piedras Street shops

[Measuring point, floor of pump house, 0.5 foot above ground level and 3,703.95 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 17	16.50	3,687.45	Oct. 19	15.60	3,688.35	Sept. 17	19.74	3,684.21
Dec. 12	12.60	3,691.35	Nov. 9	15.65	3,688.30	Oct. 13	18.78	3,685.17
1936			Dec. 14	15.37	3,688.58	Nov. 15	18.45	3,685.15
Jan. 13	12.50	3,691.45	*1937*			Dec. 20	18.31	3,685.64
Feb. 13	12.48	3,691.47	Jan. 18	15.57	3,688.38	*1938*		
Mar. 16	14.69	3,689.26	Feb. 23	16.18	3,687.77	Jan. 17	18.00	3,685.95
Apr. 8	14.90	3,689.05	Mar. 16	15.87	3,688.08	Feb. 14	18.06	3,685.89
May 15	15.58	3,688.37	Apr. 15	17.93	3,686.02	Mar. 15	17.91	3,686.04
June 12	16.20	3,687.75	May 13	18.55	3,685.40	Apr. 15	18.40	3,685.55
July 13	16.62	3,687.33	June 15	19.00	3,684.95	May 16	20.71	3,683.24
Aug. 17	16.87	3,687.08	July 6	18.93	3,685.02	June 13	21.84	3,682.11
Sept. 14	15.82	3,688.13	Aug. 12	22.27	3,681.68			

37. Southern Pacific Lines, Piedras Street shops

[Measuring point, floor of pump house, at ground level and 3,703.95 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1935*			*1935*		
Aug. 17	34.59	3,669.36	Sept. 17	21.22	3,682.73	Oct. 19	16.98	3,686.97
Sept. 10	21.38	3,682.57	28	19.73	3,684.22	26	16.83	3,687.12
12	20.86	3,683.09	Oct. 5	18.45	3,685.50	Nov. 9	16.30	3,687.65
14	20.53	3,683.42	Oct. 12	17.58	3,686.37	23	16.00	3,687.95

39. Midwest Dairies Inc., Piedras and Oro Streets

[Measuring point, top of steel pump base, 1.0 foot above ground level and 3,710.24 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 26	35.71	3,674.53	Sept. 14	34.41	3,675.83	Aug. 12	50.23	3,660.01
Oct. 10	34.34	3,675.90	Oct. 19	34.46	3,675.78	Sept. 15	44.59	3,665.65
Dec. 12	34.08	3,676.16	Nov. 9	33.68	3,676.56	Oct. 13	43.28	3,666.96
1936			Dec. 14	32.68	3,677.56	Nov. 16	43.56	3,666.68
Jan. 13	34.32	3,675.92	*1937*			Dec. 20	42.33	3,667.91
Feb. 13	34.82	3,675.42	Jan. 18	33.83	3,676.41	*1938*		
Mar. 16	36.10	3,674.14	Feb. 22	35.88	3,674.36	Jan. 17	40.82	3,669.42
Apr. 8	35.45	3,674.79	Mar. 16	36.13	3,674.11	Feb. 14	41.32	3,668.92
May 14	37.77	3,672.47	Apr. 15	39.08	3,671.16	Mar. 15	40.46	3,669.78
June 11	39.83	3,670.41	May 13	40.54	3,669.70	Apr. 15	43.68	3,666.56
July 13	38.87	3,671.37	June 14	41.37	3,668.87	May 16	47.69	3,662.55
Aug. 18	38.80	3,671.44	July 6	39.89	3,670.35	June 20	49.13	3,661.11

40. El Paso well, Piedras and Hamilton Streets

[Measuring point, top of casing, 1.5 feet above ground level and 3,997.29 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1936*		
Nov. 20	305.22	3,692.07	Jan. 14	304.34	3,692.95	Apr. 9	305.46	3,691.83
Dec. 12	304.51	3,692.78	Feb. 14	304.29	3,693.00	*1938*		
			Mar. 16	305.33	3,691.96	Feb. 14	305.71	3,691.58

41. El Paso well 5, Morenci and Grama Streets

[Measuring point, floor of pump house, 3 feet above ground and 3,779.74 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Sept. 11	--------	3,670.22	July 14	112.97	3,666.77	Mar. 14	109.40	3,670.34
Dec. 12	107.97	3,671.77	July 26	110.90	3,668.84	Apr. 14	109.30	3,670.44
1936			Aug. 2	112.40	3,667.34	May 13	114.35	3,665.39
Jan. 2	108.17	3,671.57	15	110.85	3,668.89	June 15	114.68	3,665.06
14	108.50	3,671.24	22	110.12	3,669.62	July 10	113.87	3,665.87
Feb. 13	108.78	3,670.96	Sept. 14	106.99	3,672.75	Aug. 12	121.55	3,658.19
Mar. 3	109.81	3,669.93	19	107.80	3,671.94	Sept. 20	115.53	3,664.21
11	110.54	3,669.20	27	107.85	3,671.89	Oct. 8	115.07	3,664.76
14	110.31	3,669.43	Oct. 5	104.67	3,675.07	Nov. 16	112.38	3,666.36
26	109.59	3,670.15	14	106.65	3,673.09	Dec. 13	112.74	3,667.00
1936			19	106.85	3,672.89	*1938*		
Apr. 1	108.47	3,671.27	21	107.00	3,672.74	Jan. 15	110.32	3,669.42
10	109.20	3,670.54	23	107.96	3,671.78	Feb. 8	109.95	3,669.79
29	109.30	3,670.44	Nov. 9	107.67	3,672.07	Mar. 10	108.94	3,670.80
May 9	111.64	3,688.10	Dec. 14	104.79	3,674.95	22	111.26	3,668.48
28	113.56	3,666.18	*1937*			Apr. 15	113.15	3,666.59
June 16	114.62	3,665.12	Jan. 19	107.04	3,672.70	May 16	117.42	3,662.32
July 3	115.99	3,663.75	Feb. 23	109.43	3,670.31	June 14	120.47	3,659.27
11	115.83	3,663.91						

42. El Paso well 9, Luna and Pera Streets

[Measuring point, brass coupling 0.79 foot above floor of pump house, at ground level and 3,701.06 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1934			*1936*			*1937*		
Dec. 22	21.90	3,679.16	Sept. 14	23.54	3,677.52	Sept. 15	34.50	3,666.56
1935			Oct. 19	23.50	3,677.56	Oct. 13	32.65	3,668.41
Sept. 11	25.73	3,675.33	Nov. 9	25.19	3,675.87	Nov. 16	31.82	3,669.24
Nov. 6	24.65	3,676.41	Dec. 14	24.13	3,676.93	Dec. 20	31.76	3,669.30
Dec. 11	24.36	3,676.70	*1937*			*1938*		
1936			Jan. 18	24.11	3,676.95	Jan. 14	30.85	3,670.21
Jan. 13	24.82	3,676.24	Feb. 22	25.82	3,675.24	Feb. 14	31.06	3,670.00
Feb. 13	25.17	3,675.89	Mar. 16	25.97	3,675.09	Mar. 15	29.64	3,671.42
Mar. 16	26.73	3,674.33	May 13	74.40	3,626.66	Apr. 15	32.80	3,668.26
Apr. 8	25.37	3,675.69	Aug. 23	37.12	3,663.94	May 16	35.05	3,666.01
Aug. 17	26.17	3,674.89						

43. Camp Grande, Stevens Avenue and Frutas Street

[Measuring point, top of casing, 9.0 feet below ground level and 3,694.10 feet above mean sea level. Well sealed on August 17]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1936*		
Aug. 27	5.55	3,688.55	Feb. 13	4.48	3,689.62	May 18	5.07	3,689.03
Dec. 12	4.43	3,689.67	Mar. 16	4.63	3,689.47	June 11	5.01	3,869.09
1936			Apr. 8	4.83	3,689.27	July 13	5.49	3,688.61
Jan. 13	4.61	3,689.49						

44. Harry Mitchell Brewing Co., Travis and Frutas Streets

[Measuring point, top of steel pump base, 0.2 foot above ground level and 3,701.44 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Dec. 13	25.42	3,676.02	Nov. 10	26.03	3,675.41	Sept. 16	33.10	3,668.34
1936			Dec. 15	21.94	3,679.50	Oct. 15	30.85	3,670.59
Feb. 14	26.34	3,675.10	*1937*			Nov. 14	29.71	3,671.73
Mar. 17	27.15	3,674.29	Jan. 19	21.48	3,679.96	*1938*		
Apr. 9	26.92	3,674.52	Feb. 23	23.28	3,678.16	Jan. 5	29.41	3,672.03
May 16	29.40	3,672.04	Mar. 18	27.62	3,673.82	14	28.80	3,672.56
June 12	29.21	3,672.23	Apr. 16	29.89	3,671.55	Feb. 13	26.19	3,675.25
July 15	30.58	3,670.86	May 14	29.32	3,672.12	Mar. 13	25.19	3,676.25
Aug. 18	29.31	3,672.13	June 15	30.18	3,671.26	Apr. 17	26.47	3,674.97
Sept. 15	26.98	3,674.46	July 9	27.94	3,673.50	June 12	36.25	3,665.19
Oct. 20	26.95	3,674.49	Aug. 13	38.80	3,662.64			

51. El Paso well 2, Montana well field

[Measuring point, floor of pump house, 1 foot above ground level and 3,772.37 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1936			*1936*			*1937*		
June 13	113.80	3,658.57	Oct. 15	108.05	3,664.32	July 6	115.67	3,656.70
22	114.10	3,658.27	20	108.95	3,663.42	Aug. 12	122.82	3,649.55
29	114.26	3,658.11	21	109.06	3,663.31	Sept. 15	116.04	3,656.33
July 3	120.40	3,651.97	23	113.52	3,658.85	Oct. 13	109.09	3,663.28
10	120.80	3,651.57	31	111.16	3,661.21	Nov. 15	112.96	3,659.41
13	105.08	3,667.29	Nov. 9	111.23	3,661.14	Dec. 20	112.60	3,659.77
18	112.24	3,660.13	Dec. 14	104.04	3,668.33	*1938*		
28	116.80	3,655.57	*1937*			Jan. 14	105.52	3,666.85
Aug. 1	118.45	3,653.92	Jan. 19	107.78	3,664.34	Feb. 14	111.45	3,660.92
7	111.82	3,660.55	Feb. 22	109.59	3,662.78	Mar. 15	107.93	3,664.44
22	108.23	3,664.14	Mar. 16	109.60	3,662.77	Apr. 16	113.39	3,658.33
24	106.31	3,666.06	Apr. 15	110.03	3,662.34	May 6	118.82	3,653.55
29	109.39	3,662.98	20	111.71	3,660.66	16	119.44	3,652.93
Sept. 15	109.29	3,663.08	May 12	118.23	3,654.14	June 14	119.24	3,653.13
27	109.35	3,663.02	June 14	120.21	3,652.16			
Oct. 5	102.89	3,669.48						

52. El Paso well 3, Montana well field

[Measuring point, top of brass pipe 0.33 foot above floor of pump house, 3 feet above ground level and 3,783.43 feet above mean sea level]

1935			*1936*			*1937*		
Sept. 12	99.23	3,684.20	June 16	119.29	3,664.14	June 16	157.60	3,625.83
Oct. 12	99.25	3,684.18	20	118.50	3,664.93	June 25	158.80	3,624.63
Nov. 9	99.25	3,684.18	June 24	119.64	3,663.79	Oct. 8	154.29	3,629.24
Dec. 14	99.26	3,684.17	29	120.80	3,662.63	23	149.15	3,634.38
1936			Dec. 14	112.92	3,670.51	29	148.77	3,634.75
Jan. 11	99.30	3,684.13	*1937*			*1938*		
Feb. 15	99.42	3,684.01	Jan. 19	115.55	3,667.88	Jan. 14	114.27	3,669.26
Mar. 14	99.54	3,683.89	Feb. 22	116.97	3,666.46	Feb. 14	151.08	3,632.45
Apr. 11	99.56	3,683.87	Mar. 16	116.70	3,666.73	Mar. 15	146.19	3,637.34
25	99.47	3,683.96	Apr. 12	117.25	3,666.18	Apr. 16	152.20	3,631.33
June 12	119.13	3,664.30	May 6	153.58	3,629.85	May 16	155.53	3,628.00
13	119.21	3,664.22	12	155.88	3,627.55	June 14	155.41	3,628.12

53. Loretto College, Clifton and Raynolds Streets

[Measuring point, top of eduction pipe, 3 feet above ground level and 3,811.25 feet above mean sea level]

1935			*1936*			*1937*		
Nov. 11	149.91	3,661.34	Oct. 20	151.04	3,660.21	Sept. 15	149.90	3,661.35
Dec. 12	149.50	3,661.75	Nov. 9	141.61	3,669.64	Oct. 15	144.87	3,666.38
1936			Dec. 19	139.35	3,671.90	Nov. 15	146.80	3,664.45
Jan. 14	149.80	3,661.45	*1937*			Dec. 23	143.54	3,667.71
Feb. 13	150.53	3,660.72	Jan. 19	149.35	3,661.90	*1938*		
Mar. 16	151.72	3,659.53	Feb. 22	151.12	3,660.13	Jan. 14	142.30	3,668.95
Apr. 18	151.18	3,660.07	Mar. 16	150.83	3,660.42	Feb. 14	145.59	3,665.66
May 14	152.51	3,658.74	Apr. 15	151.48	3,659.77	Mar. 15	143.38	3,667.87
June 12	154.34	3,656.91	May 13	156.83	3,654.42	Apr. 16	147.33	3,663.92
July 14	151.00	3,660.25	June 14	158.18	3,653.07	May 16	158.65	3,652.60
Aug. 17	154.19	3,657.06	July 6	149.51	3,661.74	June 14	153.95	3,657.30
Sept. 14	151.46	3,659.79	Aug. 12	160.72	3,650.53			

55. Texas Co., 0.6 mile northeast of Ascarate

[Measuring point, top of steel pump base, 2 feet above ground level and 3,717.87 feet above mean sea level]

1935			*1936*			*1937*		
Aug. 29	45.28	3,672.59	Nov. 10	47.53	3,670.34	Oct. 15	48.65	3,669.22
Dec. 13	44.41	3,673.46	Dec. 10	46.02	3,671.85	Nov. 15	47.90	3,669.97
1936			*1937*			*1938*		
Feb. 14	45.90	3,671.97	Jan. 19	46.13	3,671.74	Jan. 5	46.22	3,671.65
Mar. 17	44.93	3,672.94	Feb. 23	46.23	3,671.64	16	78.14	3,639.73
Apr. 9	44.16	3,673.71	Mar. 17	47.00	3,670.87	17	46.26	3,671.61
May 16	46.01	3,671.86	Apr. 16	47.07	3,670.80	Feb. 12	46.18	3,671.69
June 12	47.59	3,670.28	May 14	49.38	3,668.49	Mar. 12	45.35	3,672.52
July 15	47.84	3,670.03	June 15	50.13	3,667.74	Apr. 16	49.25	3,668.62
Aug. 18	47.45	3,670.42	July 9	49.71	3,668.16	May 16	52.29	3,665.58
Sept. 15	46.92	3,670.95	Aug. 13	51.63	3,666.24	17	50.01	3,667.86
Oct. 20	46.86	3,671.01	Sept. 16	51.10	3,666.77	June 11	51.62	3,666.27

60. Sambrano Waterworks, Ascarate

[Measuring point, top of casing, at ground level and 3,691.37 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 29	5.35	3,686.02	Sept. 14	6.61	3,684.76	Aug. 12	6.86	3,684.51
Nov. 6	6.04	3,685.33	Oct. 19	6.60	3,684.77	Sept. 15	6.91	3,684.46
Dec. 12	6.30	3,685.07	Nov. 9	6.51	3,684.86	Oct. 13	6.93	3,684.44
1936			Dec. 14	6.53	3,684.84	Nov. 16	7.12	3,684.25
Jan. 14	6.50	3,684.87	*1937*			Dec. 24	7.36	3,684.01
Feb. 13	6.56	3,684.81	Jan. 19	6.66	3,684.71	*1938*		
Mar. 16	6.31	3,685.06	Feb. 23	6.35	3,685.02	Jan. 13	7.27	3,684.10
Apr. 8	6.33	3,685.04	Mar. 16	6.30	3,685.07	Feb. 14	7.11	3,684.26
May 14	6.32	3,685.05	Apr. 15	6.09	3,685.28	Mar. 16	7.00	3,684.37
June 11	6.33	3,685.04	May 13	6.32	3,685.05	Apr. 16	6.98	3,684.39
July 13	6.53	3,684.84	June 19	6.56	3,684.81	May 16	6.70	3,684.67
Aug. 15	6.68	3,684.69	July 6	6.75	3,684.62	June 18	7.10	3,684.27

64. El Paso and U. S. Geological Survey test well 1, Carlsbad highway

[Measuring point, top of pipe, at ground level and 3,942.88 feet above mean sea level]

1936			*1937*			*1937*		
July 17	260.56	3,682.32	Feb. 22	260.66	3,682.22	Nov. 16	261.00	3,681.88
24	260.54	3,682.34	Mar. 17	260.47	3,682.41	Dec. 27	261.09	3,681.79
Aug. 15	260.54	3,682.34	Apr. 20	260.58	3,682.30	*1938*		
Sept. 15	260.21	3,682.67	May 14	260.83	3,682.05	Jan. 15	261.10	3,681.78
Oct. 20	260.47	3,682.41	June 16	260.77	3,682.11	Feb. 16	260.74	3,682.14
Nov. 10	260.82	3,682.06	July 8	260.84	3,682.04	Mar. 16	260.95	3,681.93
Dec. 20	260.76	3,682.12	Aug. 12	260.88	3,682.00	Apr. 18	261.09	3,681.79
1937			Sept. 16	260.94	3,681.94	May 19	261.00	3,681.88
Jan. 19	260.22	3,682.66	Oct. 15	261.02	3,681.86	June 17	261.13	3,681.75

67. Southern Pacific Lines, near south entrance to Fort Bliss

[Measuring point, top of eduction pipe, 10 feet above ground level and 3,897.41 feet above mean sea level]

1935			*1937*			*1937*		
Nov. 20	227.51	3,669.90	Mar. 22	227.73	3,669.68	Nov. 15	229.36	3,668.05
Dec. 13	226.26	3,671.15	Apr. 15	231.82	3,665.59	Dec. 23	228.56	3,668.55
1936			May 14	231.11	3,666.30	*1938*		
May 16	229.90	3,667.51	June 18	233.97	3,663.44	Jan. 17	229.38	3,668.03
June 13	230.88	3,666.53	July 8	232.67	3,664.74	Feb. 16	228.60	3,668.81
July 15	231.60	3,665.81	Aug. 13	234.90	3,662.51	Mar. 16	230.08	3,667.33
Aug. 18	233.16	3,664.25	Sept. 17	230.00	3,667.41	Apr. 18	229.53	3,667.88
Sept. 15	229.51	3,667.90	Oct. 15	228.73	3,668.68	May 17	231.74	3,665.67
Nov. 10	227.37	3,670.04						

72. U. S. War Department, Fort Bliss well 2

[Measuring point, top of tank, 14 feet above ground level and 3,898.14 feet above mean sea level]

1935			*1936*			*1937*		
Nov. 20	230.65	3,667.49	Nov. 10	229.79	3,668.35	Sept. 17	242.98	3,655.16
Dec. 13	226.96	3,671.18	Dec. 19	232.30	3,665.84	Oct. 15	236.88	3,661.26
1936			*1937*			Nov. 15	236.02	3,662.12
Jan. 14	227.29	3,670.85	Jan. 19	228.38	3,669.76	Dec. 23	229.10	3,669.04
Mar. 16	231.04	3,667.10	Feb. 23	229.06	3,669.08	*1938*		
Apr. 8	229.83	3,668.31	Mar. 17	228.02	3,670.12	Jan. 17	228.73	3,669.41
May 15	238.15	3,659.99	Apr. 17	232.25	3,665.89	Feb. 16	228.55	3,669.59
June 12	244.26	3,653.88	May 14	234.89	3,663.25	Mar. 16	230.35	3,667.79
July 19	240.47	3,657.67	June 16	250.25	3,647.89	Apr. 18	235.71	3,662.43
Aug. 18	243.44	3,654.70	July 8	244.99	3,653.15	May 17	241.65	3,656.49
Oct. 20	230.56	3,667.58	Aug. 13	245.18	3,652.96	June 15	244.77	3,653.37

76. El Paso and U. S. Geological Survey test well 2, Southeast corner Biggs Field

[Measuring point, top of pipe, at ground level and 3,919.40 feet above mean sea level]

1936			*1937*			*1937*		
July 17	244.12	3,675.28	Feb. 22	238.83	3,680.57	Nov. 16	235.62	3,683.78
24	243.89	3,675.51	Mar. 17	238.64	3,680.76	Dec. 27	236.18	3,683.22
Aug. 17	242.89	3,676.51	Apr. 20	238.39	3,681.01	*1938*		
Sept. 15	241.44	3,677.96	May 14	238.21	3,681.19	Jan. 15	236.10	3,683.30
Oct. 20	240.54	3,678.86	June 16	238.12	3,681.28	Feb. 16	235.99	3,683.41
Nov. 10	240.05	3,679.35	July 8	237.87	3,681.53	Mar. 16	235.84	3,683.56
Dec. 20	239.47	3,679.93	Aug. 13	237.71	3,681.69	Apr. 18	235.88	3,683.52
1937			Sept. 16	236.48	3,682.92	May 19	235.70	3,683.70
Jan. 20	239.16	3,680.24	Oct. 14	236.42	3,682.98	June 17	235.74	3,683.66

77. El Paso well 12, Mesa well field

[Measuring point, brass coupling 0.26 foot above floor of pump house, 3 feet above ground level and 3,882.78 feet above mean sea level]

Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)
1935				*1936*				*1937*			
Dec. 14	------	201.77	3,681.01	Feb. 14	------	207.48	3,675.30	July 8	------	213.87	3,668.91
Dec. 16	9:21	201.72	3,681.06	Mar. 16	------	210.84	3,671.94	Aug. 12	------	213.52	3,669.26
	10:40	201.78	3,681.00	Apr. 9	------	210.36	3,672.42	Sept. 16	------	212.85	3,669.93
	11:42	201.93	3,680.85	May 15	------	211.75	3,671.03	Oct. 14	------	210.24	3,672.54
	12:22	202.06	3,680.72	June 10	------	249.46	3,633.32	Nov. 15	------	209.00	3,673.78
	1:06	202.23	3,680.55	Nov. 10	------	205.98	3,676.80	Dec. 27	------	256.5	3,626.28
	2:10	202.41	3,680.37	Dec. 20	------	205.36	3,677.42	*1938*			
	3:23	202.65	3,680.13	*1937*				Feb. 10	------	206.20	3,676.58
	4:54	202.87	3,679.91	Jan. 19	------	205.31	3,677.47	16	------	264.23	3,618.55
	5:13	202.92	3,679.86	Feb. 22	------	205.32	3,677.46	16	------	206.20	3,696.58
Dec. 17	10:55	204.50	3,678.28	Mar. 17	------	205.61	3,677.17	Mar. 16	------	213.87	3,676.41
12-19	1:30	206.13	3,676.65	Apr. 5	------	205.69	3,677.09	Apr. 18	------	206.37	3,671.91
23	1:30	206.80	3,675.98	7	------	249.22	3,633.56	May 4	------	208.61	3,674.17
26	4:35	204.50	3,678.28	June 16	------	247.60	3,635.18	17	------	211.65	3,671.13

112. El Paso, old Mesa well field, well 32

[Measuring point, center of flange coupling, 1.5 feet above ground level and 3,871.27 feet above mean sea level]

Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)
1935				*1935*				*1936*			
Aug. 6	------	200.74	3,670.53	Dec. 16	1:40	195.40	3,675.87	Oct. 20	------	204.80	3,666.47
Sept. 11	------	203.92	3,667.35		2:10	195.55	3,675.72	Nov. 10	------	204.26	3,667.01
Dec. 12	------	194.70	3,676.57		2:43	195.68	3,675.59	Dec. 19	------	204.61	3,666.66
16	8:36	194.30	3,676.97		3:10	195.80	3,675.47	*1937*			
	8:40	194.25	3,677.02		3:35	195.95	3,675.32	Jan. 20	------	204.08	3,667.19
	9:18	194.28	3,676.99		4:17	196.10	3,675.17	Feb. 23	------	203.76	3,667.51
	9:55	194.24	3,677.03		4:38	196.18	3,675.09	Mar. 16	------	203.75	3,667.52
	10:00	194.24	3,677.03		4:57	196.26	3,675.01	May 14	------	207.48	3,663.79
	10:11	194.24	3,677.03	17	9:15	198.32	3,672.95	June 16	------	214.41	3,656.86
	10:25	194.29	3,676.98	18	5:00	199.54	3,671.73	July 7	------	213.50	3,657.77
	10:30	194.31	3,676.96	19	2:15	200.00	3,671.27	Aug. 13	------	213.50	3,657.77
	10:40	194.40	3,676.87	23	1:30	200.61	3,670.66	Sept. 16	------	212.96	3,658.31
	11:02	194.54	3,676.73	24	2:30	200.75	3,670.52	Oct. 15	------	204.42	3,666.85
	11:05	194.57	3,676.70	25	12:00	200.90	3,670.37	Nov. 16	------	203.39	3,667.88
	11:21	194.65	3,676.62	*1936*				Dec. 27	------	204.54	3,666.73
	11:25	194.67	3,676.60	Feb. 14	------	201.34	3,669.93	*1938*			
	11:35	194.74	3,676.53	Mar. 16	------	210.34	3,660.93	Jan. 13	------	198.21	3,673.06
	11:38	194.76	3,676.51	Apr. 9	------	207.44	3,663.83	29	------	204.16	3,667.11
	12:05	194.97	3,676.30	May 15	------	211.94	3,659.33	Feb. 16	------	197.94	3,673.33
	12:13	194.97	3,676.30	June 12	------	213.50	3,657.77	Mar. 16	------	204.32	3,666.95
	12:38	195.08	3,676.19	July 14	------	204.45	3,666.82	Apr. 18	------	210.00	3,661.27
	12:41	195.10	3,676.17	Aug. 18	------	206.08	3,665.19	May 19	------	210.59	3,660.68
	1:10	195.25	3,676.02	Sept. 14	------	204.96	3,666.31	June 17	------	207.06	3,664.21

114. El Paso, old Mesa well field, well 34

[Measuring point, top of air line, 3 feet above ground level and 3,871.98 feet above mean sea level]

Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)
1935				*1935*				*1935*			
Dec. 16	9:50	194.45	3,677.53	Dec. 16	11:57	195.66	3,676.32	Dec. 16	5:04	197.63	3,674.35
	10:04	194.45	3,677.53		12:30	195.97	3,676.01	Dec. 17	9:10	200.00	3,671.98
	10:06	194.45	3,677.53		12:59	196.20	3,675.78		4:55	200.47	3,671.51
	10:18	194.55	3,677.43		1:04	196.22	3,675.76	18	5:00	201.25	3,670.73
	10:20	194.58	3,677.40		1:33	196.45	3,675.53	19	2:05	201.91	3,670.07
	10:33	194.64	3,677.34		2:04	196.64	3,675.34	23	1:30	202.68	3,669.30
	10:35	194.66	3,677.32		2:37	196.82	3,675.16	24	2:30	202.82	3,669.16
	10:53	195.09	3,676.89		3:03	196.95	3,675.03	25	12:00	202.96	3,669.02
	11:14	195.25	3,676.73		3:29	197.13	3,674.85	*1936*			
	11:16	195.28	3,676.70		4:25	197.46	3,674.52	Jan. 14	------	219.52	3,652.46
	11:28	195.40	3,676.58		4:35	197.45	3,674.53	*1938*			
	11:31	195.42	3,676.56		4:49	197.58	3,674.40	Jan. 29	------	212.93	3,659.05
	11:55	195.67	3,676.31		4:52	197.60	3,674.38				

119. El Paso, old Mesa well field, well 39

[Measuring point, top of air line, 1 foot above ground level and 3,871.35 feet above mean sea level]

Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)
1935				*1935*				*1935*			
Dec. 14	------	193.12	3,678.23	Dec. 16	12:02	210.35	3,661.00	Dec. 16	4:10	213.17	3,658.18
16	8:13	192.95	3,678.40		12:15	210.58	3,660.77		5:02	213.60	3,657.75
	8:28	192.95	3,678.40		12:31	210.87	3,660.48		5:19	213.76	3,657.59
	9:03	192.93	3,678.42		12:49	211.13	3,660.22		5:30	213.86	3,657.49
	9:55	192.97	3,678.38		1:10	211.40	3,659.95	Dec. 17	9:35	217.05	3,654.30
	10:17	204.50	3,666.85		1:26	211.55	3,659.80		4:46	217.24	3,654.11
	10:20	206.20	3,665.15		1:41	211.77	3,659.58	18	5:00	218.50	3,652.85
	10:38	206.94	3,664.41		1:59	212.00	3,659.35	19	1:45	219.10	3,652.25
	10:50	207.81	3,663.54		2:14	212.20	3,659.15	23	1:30	219.63	3,651.72
	10:59	208.30	3,663.05		2:29	212.35	3,659.00	24	2:30	220.00	3,651.35
	11:16	209.04	3,662.31		2:44	212.52	3,658.83	25	12:00	220.10	3,651.25
	11:26	209.40	3,661.95		3:15	212.79	3,658.56	*1936*			
	11:37	209.70	3,661.65		3:30	212.88	3,658.47	Jan. 14	------	201.23	3,670.12
	11:46	209.93	3,661.42		3:51	213.04	3,658.31				

120. El Paso, Old Mesa well field, well 40

[Measuring point, top of air line, 1 foot above ground level and 3,871.99 feet above mean sea level]

Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)	Date	Hour	Depth to water level (feet)	Altitude of water level (feet)
1935				*1935*				*1935*			
Dec. 14	------	194.02	3,677.97	Dec. 16	12:18	198.43	3,673.56	Dec. 16	4:13	200.62	3,671.37
16	8:22	194.14	3,677.85		12:28	198.64	3,673.35		5:05	200.92	3,671.07
	8:43	194.16	3,677.83		12:52	198.93	3,673.06		5:15	201.04	3,670.95
	9:17	194.16	3,677.83		1:09	199.08	3,672.91	Dec. 17	9:25	203.83	3,668.16
	9:45	194.15	3,677.84		1:22	199.25	3,672.74		4:50	204.26	3,667.73
	10:21	195.53	3,676.46		1:44	199.46	3,672.53	18	5:00	205.27	3,666.72
	10:31	196.05	3,675.94		1:54	199.57	3,672.42	19	1:55	205.80	3,666.19
	10:42	196.56	3,675.43		2:07	199.68	3,672.31	21	3:30	206.31	3,665.68
	10:55	196.64	3,675.35		2:20	199.80	3,672.19	23	1:30	206.55	3,665.44
	11:10	197.42	3,674.57		2:35	199.92	3,672.07	24	2:30	206.68	3,665.31
	11:20	197.65	3,674.34		2:50	200.05	3,671.94	25	12:00	206.82	3,665.17
	11:33	197.86	3,674.13		3:20	200.26	3,672.73	*1936*			
	11:41	198.07	3,673.92		3:48	200.46	3,671.53	Jan. 14	------	204.30	3,667.69
	11:58	198.35	3,673.64								

126. McElroy Packing Co., 3.3 miles north of Wilson Road, near Southern Pacific Ry.

Measuring point, top of pipe clamp, 0.4 foot above ground level and 3,902.63 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 1	210.75	3,691.88	Dec. 20	211.24	3,691.39	Nov. 16	211.67	3,691.96
Dec. 14	209.35	3,693.28	*1937*			Dec. 27	211.57	3,691.06
1936			Feb. 22	211.14	3,691.49	*1938*		
Feb. 14	210.81	3,691.82	Mar. 16	211.31	3,691.32	Jan. 15	211.66	3,690.97
Mar. 16	211.09	3,691.54	Apr. 21	211.23	3,691.40	Feb. 16	215.85	3,686.18
Apr. 9	211.16	3,691.47	May 14	211.88	3,690.75	18	211.56	3,691.07
May 18	211.01	3,691.62	June 16	211.72	3,690.91	Mar. 16	211.65	3,690.98
June 12	211.09	3,691.54	July 8	211.44	3,691.19	Apr. 18	211.75	3,690.88
July 18	211.16	3,691.47	Aug. 13	211.50	3,691.13	May 19	211.65	3,690.98
Nov. 10	211.35	3,991.28	Sept. 16	211.57	3,691.06	June 17	211.70	3,690.93
			Oct. 14	211.66	3,691.97			

127. Western Gas Co., 2.6 miles north of Wilson Road, near Southern Pacific Ry.

[Measuring point, top of casing, 0.4 foot above ground level and 3,882.34 feet above mean sea level]

1935			*1935*			*1936*		
Aug. 7	192.21	3,690.13	Dec. 14	192.00	3,690.34	Feb. 14	192.57	3,690.36

129. Edgar Parks, 1.9 miles north of Wilson Road on U. S. Highway 70

[Measuring point, top of casing, 0.5 foot above ground level and 3,942.70 feet above mean sea level]

1935			*1936*			*1936*		
Aug. 6	254.90	3,687.80	Mar. 16	255.34	3,687.36	Oct. 20	256.06	3,686.64
Dec. 13	254.62	3,688.08	Apr. 9	255.43	3,687.27	Nov. 10	256.49	3,686.21
1936			May 18	255.82	3,686.88	*1937*		
Feb. 14	254.80	3,687.90	Sept. 14	256.94	3,685.76	July 8	256.45	3,686.25

132. H. T. Ankerson, 2.9 miles north of Wilson Road on U. S. Highway 70

[Measuring point, top of pipe clamp, 1.5 feet above ground level and 3,904.16 feet above mean sea level]

1935			*1936*			*1937*		
Aug. 7	213.62	3,690.54	Oct. 20	228.68	3,675.48	Sept. 16	214.59	3,689.57
Dec. 13	213.31	3,690.85	Nov. 10	214.33	3,689.83	Oct. 14	224.47	3,679.67
1936			Dec. 20	214.17	3,689.99	Nov. 16	214.52	3,689.64
Jan. 14	213.63	3,690.53	*1937*			Dec. 27	214.49	3,689.67
Mar. 16	213.98	3,690.18	Feb. 22	214.04	3,690.12	*1938*		
Apr. 8	214.00	3,690.16	Mar. 16	221.95	3,682.21	Jan. 15	214.54	3,689.62
May 18	213.91	3,690.25	Apr. 21	214.13	3,690.03	Feb. 18	214.45	3,689.71
June 12	214.09	3,690.07	May 14	226.20	3,677.96	Mar. 16	224.76	3,679.40
July 14	225.60	3,678.56	June 16	225.05	3,679.11	16	218.41	3,685.75
Aug. 18	219.62	3,684.54	July 8	213.46	3,690.70	Apr. 18	215.41	3,688.75
Sept. 14	223.14	3,681.02	Aug. 13	214.39	3,689.77	June 17	223.35	3,680.81

135. McElroy Packing Co., 4.2 miles north of Wilson Road

[Measuring point, top of casing, 0.4 foot above ground level and 3,938.24 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1935			*1936*			*1937*		
Aug. 7	243.42	3,694.82	Sept. 14	243.64	3,694.60	June 16	244.32	3,699.79
Dec. 12	243.40	3,694.84	Oct. 20	243.58	3,694.66	July 8	244.34	3,699.77
1936			Nov. 10	243.86	3,694.48	Aug. 13	244.28	3,699.83
Jan. 14	243.43	3,694.81	Dec. 20	243.76	3,694.48	Sept. 16	244.35	3,699.76
Feb. 14	243.31	3,694.93	*1937*			Oct. 14	244.35	3,699.76
Mar. 16	243.58	3,694.76	Jan. 20	242.95	3,695.29	Nov. 16	244.32	3,699.79
Apr. 9	243.63	3,694.61	Feb. 22	244.18	3,699.93	Dec. 27	244.38	3,699.73
May 18	243.63	3,694.61	Mar. 16	244.24	3,699.87	*1938*		
June 12	243.71	3,694.53	Apr. 20	244.20	3,699.91	Jan. 15	244.43	3,699.68
July 14	243.75	3,694.49	May 14	244.22	3,699.89	Feb. 16	244.32	3,699.79
Aug. 18	243.75	3,694.49						

136. El Paso and U. S. Geological Survey test well 3, 6.9 miles north of Wilson Road

[Measuring point, top of pipe, at ground level and 3,944.11 feet above mean sea level]

Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)	Date	Depth to water level (feet)	Altitude of water level (feet)
1936			*1937*			*1937*		
July 24	244.45	3,699.66	Mar. 16	244.24	3,699.87	Dec. 27	244.38	3,699.73
Aug. 18	244.25	3,699.86	Apr. 20	244.20	3,699.91	*1938*		
Sept. 14	244.17	3,699.94	May 14	244.22	3,699.89	Jan. 15	244.43	3,699.68
Oct. 20	244.19	3,699.92	June 16	244.32	3,699.79	Feb. 16	244.32	3,699.79
Nov. 10	244.25	3,699.86	July 8	244.34	3,699.77	Mar. 16	244.31	3,699.80
Dec. 20	244.21	3,699.90	Aug. 13	244.28	3,699.83	Apr. 18	244.42	3,699.69
1937			Sept. 16	244.35	3,699.76	May 19	244.32	3,699.79
Jan. 20	244.11	3,700.00	Oct. 14	244.35	3,699.76	June 17	244.49	3,699.62
Feb. 22	244.18	3,699.93	Nov. 16	244.32	3,699.79			

DEEP WELLS, ANALYSES OF WATER

Analyses of ground waters in the El Paso area, Texas

[Parts per million. Well numbers correspond to numbers in table of records of wells]

No.	Owner	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$	Analyst
8	El Paso Electric Co. well 0.	Aug. 20, 1935							132		99		222	Margaret D. Foster.
9	El Paso Electric Co. well 3.	Feb. 28, 1936	933			123	23	178	277	281	190	0.91	402	Do.
10	City of El Paso	Sept. 28, 1937	1,172	28	0.45	146	25	Na 211 K 14	328	348	217	2.9	468	Do.
11	El Paso Laundry	Aug. 17, 1935							160		74		204	Do.
12	Ciudad Juarez well 1	Jan. 5, 1935							211	120	118		237	Do.
12	do	Aug. 22, 1935							174		77		243	Do.
12	do	May 4, 1936	444			78	14	64	195	106	86		252	E. P. Schoch.
12	do	Apr. 12, 1937	526	26	.03	86	14	Na 64.0 K 5.0	189	140	80	.20	272	Margaret D. Foster.
12	do	Nov. 1, 1937				87	16		192	140	82	.0	283	Do.
13	Ciudad Juarez well 2	Aug. 22, 1935							111		98		144	Margaret D. Foster.
14	Blanco Ice Plant	Jan. 1, 1930	606	23		118	11	77	280	155	84		340	International Filter Co.
18	Ciudad Juarez well 3	Sept. 23, 1935	562			108	17	71	257	148	91	.20	340	Margaret D. Foster.
18	do	Dec. 22, 1935	626	12		112	9.2	82	259	148	92		318	
18	do	Oct. 28, 1936	528			84	15	86	208	142	99	.0	272	Margaret D. Foster.
18	do	Nov. 2, 1937				110	18		254	140	92	.0	349	Do.
19	El Paso Milling Co	Aug. 23, 1935							145		64		190	Do.
21	El Paso well 10	June 25, 1937	499	29	.22	30	10	Na 130.0 K 7.0	180	97	111	.05	116	Do.
22	El Paso well 6	Jan. 1, 1935							273	200	98		444	Do.
22	do	Sept. 16, 1935	720			124	23	99	268	227	115	.33	404	Do.
22	do	Feb. 25, 1936	733		.18	130	26	92	272	238	113	.28	432	Do.
25	El Paso Ice & Refrigeration Co. well 4.	Jan. 7, 1935							173	112	319		234	Do.
25	do	Aug. 23, 1935							164		316		165	Do.
25	do	Apr. 22, 1936	796			49	16	230	170	107	310	.0	188	Do.
25	do	Oct. 28, 1936	842			56	17	240	170	97	348	.0	210	Do.
25	do	Apr. 19, 1937	904	31	.06	57	17	Na 239.0 K 8.6	169	105	352	.10	212	Do.
25	do	Nov. 2, 1937				56	17		174	104	331	.0	210	Do.
28	Acme Laundry Co. well 2.	Aug. 17, 1935							301		230		40	Do.
29	Consumers Ice & Fuel well 2.	Aug. 26, 1919	402	37		23	3.4	77	103	35	71		34	F. C. Lamb, city chemist, El Paso.
30a	El Paso well 14	Apr. 20, 1937	450	26	.12	23	8.6	Na 120.0 K 6.6	172	69	108	.0	93	Margaret D. Foster.
31	El Paso well 7	Jan. 5, 1935							177	112	94		260	Do.

31	do	Sept. 11, 1935	506			84	17	75	180	122	119	.28	280	Do.
31	do	Feb. 28, 1936	496			85	19	66	181	130	106	.12	290	Do.
31	do	Apr. 22, 1936							180		120		330	Do.
31	do	Oct. 28, 1936	556			95	22	74	186	133	140	.0	328	Do.
31	do	June 25, 1937	706	28	.78	105	21	Na 91.0, K 5.4	191	154	165	.05	349	Do.
32	Texas & Pacific R.R.	Aug. 23, 1935							148		61		130	Do.
34	El Paso Union Stockyards.	Aug. 26, 1935							176		164		284	Do.
35	Peyton Packing Co	do							221		51		26	Do.
36	Southern Pacific Co. well 1.	Jan. 10, 1919		34		13	3.1	164	165	82	129		45	F. H. Seamon.
37	Southern Pacific Co. well 2.	do	679	30		20	3.8	216	177	74	223		66	Do.
39	Midwest Dairies well 2	Aug. 26, 1935							170		630		555	Margaret D. Foster.
42	El Paso well 9	Sept. 1, 1933	538	16		25	5.2	161	191	66	147		84	El Paso Testing Laboratories.
42	do	Aug. 19, 1935							172		138		72	Margaret D. Foster.
42	do	Sept. 16, 1935	490			21	8.0	156	183	76	139	.10	85	Do.
42	do	Mar. 17, 1937	611	31	.06	30	10	Na 178.0, K 5.8	174	78	202	.05	116	Do.
43	Camp Grande	Aug. 27, 1935							250		181		291	Do.
44	Mitchell Brewing Co	Jan. 5, 1935							176	68	158		189	Do.
44	do	Aug. 27, 1935							150		175		165	Do.
44	do	Apr. 22, 1936	533			47	18	129	168	71	185	.0	191	Do.
44	do	Oct. 28, 1936	562			50	19	136	180	70	198	.0	203	Do.
44	do	Mar. 19, 1937	592	29	.06	49	19	Na 131, K 6.6	167	73	200	.05	200	Do.
44	do	Oct. 29, 1937				48	20		170	64	203	.25	202	Do.
46	McElroy Packing Co	Aug. 27, 1935							257		482		149	Do.
47	Evergreen Cemetery	—— 1899	1,160			151	35	197	334	181	368		521.	A. Goss.
49	El Paso well 4	Jan. 5, 1935							153	60	256		204	Margaret D. Foster.
49	do	Sept. 11, 1935	616			45	15	170	164	54	250	1.1	174	Do.
49	do	Apr. 22, 1936							160		249		210	Do.
49	do	Oct. 28, 1936	593			42	14	166	166	53	235	.75	162	Do.
49	do	May 26, 1937	491	36	.11	57	20	Na 76, K 7.2	198	85	100	6.5	224	Do.
50	El Paso Water Dept. well 1.	Aug. 16, 1935							140		236		170	Margaret D. Foster.
50	do	Sept. 11, 1935	589			46	16	157	167	51	235	1.7	181	Do.
50	do	Apr. 22, 1936							164		235		225	Do.
50	do	May 6, 1937				51	19	158	166	57	249	2.5	205	Do.
50	do	June 25, 1937	646	32	.24	50	17	Na 158.0, K 8.0	166	51	250	5.0	195	Do.
52	El Paso Water Dept. well 3.	June 29, 1936	499			43	18	120	184	72	152	3.0	181	Do.
52	do	Oct. 28, 1936	635			50	17	168	162	66	253	1.2	195	Do.
52	do	May 6, 1937				49	19	128	174	66	188	3.3	200	Do.
52	do	June 25, 1937	672	33	.12	48	16	Na 166.0, K 9.6	158	65	252	1.7	186	Do.
52	do	Oct. 29, 1937				50	18		162	66	246	1.4	199	Do.
55	Texas Petroleum Co	Jan. 5, 1935							154	80	206		144	Do.

Analyses of ground waters in the El Paso area, Texas—Continued

No.	Owner	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$	Analyst
55	do.	Aug. 28, 1935							140		212		117	Margaret D. Foster.
55	do.	Apr. 22, 1936	581			33	11	172	148	81	210	.75	128	Do.
56	Pasotex Petroleum Co. well 1.	Aug. 30, 1929	546	23		27	9.2	152	136	83	168		105	
57	Pasotex Petroleum Co. well 2.	Mar. 13, 1936	4,743			339	143	1,226	284	579	2,310	5.8	1,434	Do.
58	Pasotex Petroleum Co. well 3.	Aug. 28, 1935							133		174		102	Do.
59	Nichols Copper Co.	Aug. 29, 1935							133		169		106	Do.
59	do.	Sept. 23, 1935	483			27	8.4	145	130	68	170	.15	102	Do.
61	L. L. Estrada.	Sept. 9, 1935							126		505		212	Do.
64	El Paso and U. S. Geological Survey test well 1.	June 1, 1936	622			47	18	165	160	63	250	.50	191	Do.
64	do.	do.	684			42	17	195	166	75	273	.25	175	Do.
64	do.	June 25, 1936	729			38	15	220	176	84	285	.25	156	Do.
65	American Airways.	Jan. 7, 1935							214	80	74		117	Do.
65	do.	Mar. 13, 1936	460			25	9.9	135	228	100	68	8.2	103	Do.
65	do.	Oct. 28, 1936	463			24	9.4	138	236	101	66	8.0	99	Do.
65	do.	May 3, 1937				24	8.7	141	236	106	65	7.5	96	Do.
65	do.	Oct. 29, 1937				24	9.2		238	112	66	7.4	98	Do.
67	Southern Pacific Lines well 1.	Oct. 25, 1921	309	24		32	11	66	225	27	38		125	
67	do.	June 12, 1929	434			55	24	62	223	37	102	8.9	236	Southern Pacific Laboratories.
67	do.	Aug. 22, 1933	578	32		90	40	54	201	49	200	8.7	389	Do.
67	do.	Jan. 12, 1934	576	41		83	40	58	204	38	202	8.9	372	Do.
67	do.	Feb. 19, 1934	589	35		88	29	76	186	53	204	8.9	339	Do.
67	do.	July 25, 1934	585	22		87	43	60	202	50	212	8.7	394	Do.
67	do.	May 27, 1935	666	35		96	48	68	198	53	255	8.7	437	Do.
67	do.	June 4, 1936	702	36		102	49	75	217	53	268	11	456	Do.
67	do.	May 6, 1937				107	47	90	228	56	288	5.5	460	Margaret D. Foster.
68	Texas & New Orleans RR well 7.	—— 1922(?)	330	36		34	14	43	174	32	42		142	F. C. Lamb, city chemist.
68	do.	June 12, 1929	384			55	19	52	211	40	76	5.8	215	Southern Pacific Laboratories.
68	do.	July 11, 1932	479	26		65	26	71	192	43	153	6.2	272	Do.
68	do.	Aug. 22, 1933	566	24		76	41	66	182	47	209	8.7	358	Do.
68	do.	Jan. 12, 1934	606	35		82	33	56	180	25	198	8.9	340	Do.
68	do.	Feb. 19, 1934	522	19		84	31	57	172	46	188	8.9	337	Do.
68	do.	July 25, 1934	514	21		75	31	63	178	44	180	8.7	315	Do.
68	do.	Jan. 5, 1935							199	48	202		218	Margaret D. Foster.
68	do.	May 27, 1935	612	33		88	36	75	182	44	232	8.7	368	Southern Pacific Laboratories.

68	....do....	Apr. 23, 1936	580			88	39	73	194	48	230	6.3	380	Margaret D. Foster.
68	....do....	Oct. 28, 1936	651			100	49	72	188	48	282	7.3	451	Do.
70	U. S. Army well 0	—— 1908 (?)	316			33	14	55	244	53	13		140	A. Goss.
73	U. S. Army well 1	Jan. 12, 1934	320	40		39	16	26	186	24	26	8.9	163	Southern Pacific Laboratories.
75	U. S. Army well 5	Jan. 12, 1934	261	23		32	10	44	173	15	40		121	Do.
75	....do....	Jan. 5, 1935							183	40	38		147	Margaret D. Foster.
75	....do....	Apr. 23, 1936	271			32	13	53	178	39	41	5.0	133	Do.
75	....do....	Oct. 28, 1936	266			34	13	49	178	36	39	7.0	138	Do.
75	....do....	Apr. 17, 1937	297	32	.03	33	12	Na 51.0 K 5.4	178	36	40	7.5	132	Do.
75a	U. S. Army well 6	Sept. 17, 1937	316			43	16	53	176	49	62	5.5	173	Do.
76	El Paso and U. S. Geological Survey test well 2.	July 14, 1936	329			22	8.1	91	178	73	42	5.6	88	Do.
77	El Paso well 12	Sept. 11, 1935	526			51	21	114	195	106	134	3.6	214	Do.
77	....do....	Apr. 7, 1937	570	41	.03	49	21	Na 113.0 K 7.8	195	108	129	7.5	209	Do.
78	El Paso well 11	Sept. 11, 1935	430			56	21	73	193	84	96	4.5	226	Do.
78	....do....	Apr. 22, 1936							193		88		264	Do.
78	....do....	June 25, 1937	477	36	.13	56	20	Na 71.0 K 7.4	195	83	94	6.7	222	Do.
79	El Paso well 8	Jan. 5, 1935							190	60	52		196	Do.
79	....do....	Sept. 16, 1935	311			44	16	49	184	59	46	6.7	176	Do.
79	....do....	Apr. 22, 1936							182		42		206	Do.
79	....do....	Oct. 28, 1936	298			44	16	44	182	54	42	8.8	176	Do.
79	....do....	Apr. 25, 1937				45	17	50	184	64	47	9.4	182	Do.
79	....do....	Oct. 29, 1937				43	16		188	46	41	8.3	173	Do.
128	Western Gas Co. well 3	Jan. 7, 1935							201	120	208		220	Do.
128	....do....	Sept. 23, 1935	563			45	20	137	200	106	152	4.5	194	Do.
128	....do....	Apr. 22, 1936							199		144		222	Do.
128	....do....	Oct. 28, 1936	502		2.6	32	17	129	110	112	158	.0	150	Do.
128	....do....	Apr. 22, 1937				42	20	150	196	128	152	7.1	187	Do.
128	....do....	Oct. 29, 1937				46	21		190	110	140	6.7	201	Do.
129a	Restlawn Cemetery	May 4, 1937				36	14	33	172	50	14	8.3	147	Do.
136	El Paso and U. S. Geological Survey test well 3.	July 23, 1936	525			36	13	140	200	130	102	5.2	143	Margaret D. Foster.
137	Newman Investment Co.	Apr. 3, 1936	266			25	7.2	65	136	48	48	5.5	92	Do.
138	McElroy Packing Co.	Apr. 3, 1936	430			35	8.8	116	146	54	139	5.0	124	Do.
141	Southern Pacific Co.	Sept. 23, 1935	602			70	17	133	98	38	290	5.2	245	Do.
143	Vick Reeves	Apr. 23, 1936	376		2.2	25	11	99	131	83	90	3.3	108	Do.
144	James Blythe	Apr. 17, 1936	202		7.4	24	6.7	41	104	44	28	7.0	87	Do.
147	A. M. Greenwood	Apr. 16, 1936	334			34	9.8	77	182	72	45	6.7	125	Do.
148	....do....	Apr. 3, 1936	196		27	30	4.4	37	98	30	39	7.5	93	Do.
149	U. S. Army	Apr. 17, 1936	871			39	23	68	232	67	54	5.7	192	Do.
151	Mrs. Belvins	Apr. 23, 1936	207			41	5.3	23	86	68	18	9.1	124	Do.
153	McElroy Packing Co.	Aug. 10, 1935							175		90		92	Do.
155	Adelberto Navar	Aug. 17, 1935							131		280		158	Do.
158	J. K. Shearman	Mar. 13, 1936	471		5.1	28	11	130	171	125	88	4.6	115	Do.

Analyses of ground waters in the El Paso area, Texas—Continued

No.	Owner	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$	Analyst
160	Ysleta College	Apr. 29, 1936	434			34	8.7	116	164	92	100	2.3	121	Margaret D. Foster
161	Fred W. Miller	Apr. 7, 1931	1,657	18		35	16	567	281	167	695		153	El Paso Testing Laboratories.
161	do	Sept. 13, 1935							266		712		153	Margaret D. Foster.
162	C. L. Wicker	Sept. 13, 1935							229		129		62	Do.
163	V. S. Bowden	Sept. 11, 1935							191		602		363	Do.
164	G. H. Munro	Sept. 13, 1935							411		345		201	Do.
165	Sam Shannon	Sept. 11, 1935							105		895		446	Do.
166	U. S. Government	Apr. 22, 1936	586			38	15	160	138	102	202	1.4	156	Do.
172	Clint School Board	Apr. 21, 1936	18,268			1,660	381	4,567	164	2,222	9,350	7.5	5,712	Do.
174	Lee Crews Estate	Aug. 20, 1935							141		44		4.5	Do.
174	do	Apr. 10, 1936	234		.40	7.5	2.3	74	60	80	40	1.0	28	Do.
177	S. O. Roberts	Apr. 2, 1936	508		1.0	29	15	134	195	132	75	27	134	Do.
178	do	Apr. 2, 1936	2,967		3.1	136	45	905	237	478	1,262	24	524	Do.
179	do	Apr. 2, 1936	2,419			66	27	778	246	668	758	1.2	276	Do.

Analyses of water from wells on the Mesa in Dona Ana County, N. Mex.

[Analyzed by Margaret D. Foster. Parts per million]

No.	Date of collection (1936)	Total dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K) (calculated)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$
1	Apr. 22	729	20	9.0	247	407	180	72	0.75	87
2	do	1,120	47	18.0	355	423	210	282	.0	191
3	July 17	479	33	6.2	132	188	156	50	9.1	108

1. Southern Pacific railroad well at Strauss, N. Mex.; 950 feet deep.
2. Southern Pacific railroad well at Afton, N. Mex.; 702 feet deep.
3. Dr. J. E. Laws' well, 1 mile west of Cerro de Muleros, N. Mex.

RECORDS OF WELLS IN THE EL PASO AREA

[Unless otherwise noted, all wells draw from sand or gravel]

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed		Height of measuring point above land surface[1] (feet)	Water level	
								Depth to top of bed (feet)	Thickness (feet)		Depth below measuring point (feet)	Date of measurement
1	Union station, east end of roundhouse.	Santa Fe R.R.		1903	3,710.9	388						
2	Santa Fe R.R. yards, near coal chute.	do.		1882±		60						
3	Franklin Canal, near extension of 3d St.	El Paso	Sylvester Watts	1892±	3,711.2	61	156	60	60		5.26	May 9, 1923
4	W. San Antonio and S. El Paso Sts.	Hotel Paso del Norte				152+	6				13	1935
5	do.	Knickerbocker Club		1934		32	6				12	1935
6	S. Santa Fe and 4th Sts.	El Paso Electric Co. well 2.	Layne Texas Co.	1924	3,708.69	252	18	55		−0.6	[4]11	1924
7	do.	El Paso Electric Co. well 1.	do.	1924	3,710.09	229		98		.5	[4]23.6	May 1924
8	do.	El Paso Electric Co. well 0.	do.	1914	3,708.62	394	10	254		.3	[4]18	1914
9	do.	El Paso Electric Co. well 3.	do.	1924	3,710.06	304	10	30		.2	[4]9.4	1924
10	Oregon and 4th Sts.	El Paso City	P. D. Wynne	1933		52	20	8			[4]8	April 1933
11	S. Santa Fe and 7th Sts.	El Paso Laundry	Chris Deitert	1935		452+	8				6	When drilled
12	Ciudad Juarez, at Municipal Market.	Ciudad Juarez well 1	A. Strout	1925	3,726.70	499	24	245			37	1925
13	Ciudad Juarez, at Mariscal and Primera Sts.	Ciudad Juarez well 2	do.	1926	3,755.83	480	24	203			[4]65.6	1926
14	Ciudad Juarez, 700 feet SW of railway station.	Blanco Ice Co.	Chris Deitert			415					13.7	Oct. 1933
15	Ciudad Juarez, 2,000 feet SE of railway station.	Mexican National Ry.	P. D. Wynne	1935	3,707.57	564	10				16.74 15.96 18.98 18.52	April 23, 1937 Dec. 11, 1936 Apr. 12, 1937 Nov. 5, 1937
16	Ciudad Juarez, 3,300 feet SE of railway station.	Waterfill & Frazier	Chris Deitert	1925+		400+	8					
17	Ciudad Juarez, near Hipodromo.	Ciudad Juarez Brewing Assn.	do.		3,701	652	8				14	

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
1					None		Abandoned. Water too highly mineralized for locomotive use.
2					None		Abandoned. Water too highly mineralized for locomotive use.
3			2,000	23.6	None		Abandoned. First well to supply city with water.
4	T, 7 hp	75			Ind		
5	C, 5 hp	50			Ind		
6	T, 125 hp				Ind	67.5	Well has some shutter strainer, slotted pipe, and wire-wrapped screen. Reduced to 16 inches. Measuring point, bottom of pump base.
7	T, 100 hp				Ind	67	Measuring point, top of pump base.
8	Al; steam				Ind		Well has 100 feet of 10-inch perforated casing. Measuring point, top of casing.
9	T, 150 hp		3,000	28.2	Ind	67	Well has some shutter strainer and perforated pipe. Total length of screen is 293 feet. Measuring point at pump base.
10	C	1,000			None		City drainage well. Pumped to hold water table below basement floors in business district.
11	T, 20 hp	300			Ind		The laundry used water from a 60-foot well until 1927, when well caved in, and from a 400-foot well since 1927.
12	T, 100 hp		1,100	19.0	P		10-inch casing slotted (1/4 by 6 inches) below 245 feet. Reduced to 10 inches. Measuring point at pump base.
13	T, 100 hp	1,500	1,500	10.5	P		12-inch casing slotted (1/4-inch) below 203 feet. Reduced to 12 inches. Measuring point at pump base.
14	C, 5 hp				Ind		
15	None				None		Well first yielded water of poor quality. After well was repaired, the quality was reported as better. Reducing to 8 inches. Measuring point at top of casing.
16	C, 5 hp				Ind		
17	C, 10 hp		125	25.0	Ind		Another well, 480 feet deep, is used for cooling and a third well, 300 feet deep, is used to fill the swimming pool.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Height of measuring point above land surface[1] (feet)	Water level: Depth below measuring point (feet)	Water level: Date of measurement
18	Ciudad Juarez, near Hipodromo.	Ciudad Juarez well 3	Mr. Wilson	1934	3,703.36	660				.5	15	
18a	Ciudad Juarez, 8½ miles south of.	Alvina Ochoa		1913	4,000	475	8			−13.7	199.3	Sept. 29, 1935
19	El Paso, S. Kansas and 11th Sts.	El Paso Milling Co.			3,721.67	400±	10			14.6	[4]27.19	Aug. 23, 1935
20	S. Kansas and 10th Sts.	do		1912	3,702	398		180			12	June 1913
21	S. Campbell and 6th Sts.	El Paso well 10	V. Chesney	1930	3,707.35	807	20	358		1.5	[4]25.5	1931
21a	3d and Oregon Sts.	Elite Laundry Co.	Campbell	1937		200	10	125			25	1937
22	Cotton and 2d Sts.	El Paso well 6	A. Strout	1925	3,704.47	646	24	140		.1	15 [4]16 17	May 1925 1928 1932
23	Ochoa and Mill Sts.	El Paso Ice & Refrigeration Co.		1904+	3,708	400						
24	do	El Paso Ice & Refrigeration Co. well 3.	Layne-Texas Co.	1917		1,276						
25	do	El Paso Ice & Refrigeration Co. well 4.	P. D. Wynne	1920		509	12	428			29.41 27.13 27.47	May 3, 1937 Nov. 2, 1937 Jan. 31, 1939
26	Mill and Octavia Sts.	Southern Pacific Co.	MacLees	1902	3,708	265	6	255				
27	905 E. Missouri St.	Acme Laundry well 1.	G. Morewood	1927		649	12					
28	do	Acme Laundry wells 2 and 3.	Layne-Texas Co.—E. H. Wynne.	1928	3,725.62	645	10	534		2.0	[4]42	Nov. 7, 1928
29	Texas and Dallas Sts.	Consumers Ice & Fuel Co. well 2.	P. D. Wynne, Layne-Texas Co.	1920	3,704	496						
30	do	Consumers Ice & Fuel Co. well 1.		Old		802						
30a	San Antonio and Walnut Sts.	El Paso well 14	Layne-Texas Co.	1937	3,703.91	703	36			2.0	32.78	July 7, 1937
31	Lee and Magoffin Sts.	El Paso well 7	A. Strout	1927	3,704.56	525	22	160		.0	15 11 10	1928 1932 1934

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
18	T, 100 hp		2,000 ±	18.0	P		Artificial gravel-pack construction. Yielded 2,000 ± gallons a minute August 22, 1935, and 1,770 gallons a minute when drilled in 1934.
18a	None				None		Under repair. Measuring point at top of casing.
19	AL	500			Ind		Measuring point at top of casing.
20	None	200	150	36.2	None		Abandoned.
21	T, 50 hp	725			P	66	Well has 210 feet of 20-inch and 148 feet of 16-inch casing, and 221 feet of 16-inch and 71 feet of 12½-inch slotted pipe. Slots are ¼ by 6 inches. Depth in use 650 feet. Measuring point at floor.
21a	T, 10 hp				Ind		
22	T, 50 hp	1,100			P	66	Well has 88.67 feet of 24-inch and 80.33 feet of 15-inch casing, and 320.83 feet of 15-inch slotted pipe. Depth in use 405 feet. Measuring point at pump base.
23	None				None		Abandoned. Two other abandoned wells, 80 and 300 feet deep, reported at this location.
24	None				None	96	Abandoned. Never produced potable water.
25	AL				Ind	72	Well has 428 feet of 12-inch pipe and 81 feet of 12-inch slotted pipe with slots ¼ by 2½ inches.
26	None		55		None		Abandoned. Well has 255 feet of 6-inch casing and 12 feet of Cook strainer.
27	None		60		None		Abandoned because of insufficient yield.
28	T, 25 hp	195	212		Ind	77	Well has 504 feet of 10-inch and 84 feet of 6-inch casing, and 88 feet of 6-inch slotted pipe. Yielded 212 gallons per minute when drilled. Measuring point at pump base.
29	C, 5 hp				Ind	72	
30	None				None		Abandoned.
30a	T, 100 hp	1,500	1,500	31.77	P		Artificial gravel-pack construction. Test well was drilled to depth of 905 feet, plugged back to 703 feet. Well contains 24-inch casing, 0 to 243 feet; 13-inch casing blank, 243 to [illegible] feet.
31	T, 50 hp	1,250	1,250	60.0	P	66–68	Well has 86 feet of 22-inch and 74 feet of 12-inch casing, and 270 feet of 13-inch slotted pipe. Slots are ¼ by 7 inches. Yielded 1,250 gallons per minute in 1929. Measuring point at floor.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Height of measuring point above land surface[1] (feet)	Water level: Depth below measuring point (feet)	Water level: Date of measurement
32	Roundhouse near Overland and Cotton Sts.	Texas & Pacific Ry.	P. D. Wynne, Layne-Texas Co.	1923	3,705.0	556	12	428			24	1923
32a	San Antonio and Tornillo Sts.	El Paso well 17	C. R. Jensen	1938	3,704.14	750	12.5				30.08	Nov. 20, 1939.
33	Williams St. and International Boundary.	El Paso Foundry & Machine Co.		Old	3,704.72	650	8	300+		5.0	[4]30	1931
34	11th St. east of Cotton St.	El Paso Union Stockyards.	Burdick & Burdick			90	8				12	1914
35	11th St. and International Boundary.	Peyton Packing Co.		Old		860±	8					
36	Piedras St. and Southern Pacific tracks.	Southern Pacific Lines well 1.	Layne-Texas Co.	1916	3,703.95	896	13	875		.5	[4]16.5	Aug. 17, 1935
37	do	Southern Pacific Lines well 2.	do	1917	3,703.95	887	14	854		.0	[4]21.38	Sept. 10, 1935.
38	Piedras and White Oaks Sts.	Midwest Dairies Inc. well 1.	P. D. Wynne, Layne-Texas Co.			743						
39	Piedras and Oro Sts.	Midwest Dairies, Inc., well 2.	do	1934	3,710.24	542				1.0	[4]35.71	Aug. 26, 1935.
40	Piedras and Hamilton Sts.	El Paso		Old	3,997.29	500±	5			1.5	[4]305.22	Nov. 20, 1935.
41	Morenci and Grama Sts.	El Paso well 5	P. D. Wynne	1919	3,779.74	954	18	575		3.0	[4]99 100	May 19, 1919. May, 1931
42	Luna and Pera Sts.	El Paso well 9	V. Chesney	1928	3,700.27	802	24	235+		.0	[4]20 26 25	1928 1931 1932
43	Stevens Ave. and Frutas St.	Camp Grande	P. D. Wynne	1934	3,694.10	90+	6			−9.0	[4]5.55	Aug. 27, 1935.
44	Travis and Frutas Sts.	Harry Mitchell Brewing Co.	Layne-Texas Co.	1934	3,701.44	353	12	320+		.2	[4]25	1934
45	do	do	Campbell	1933		396					26	Dec. 31, 1933.
46	Durazno and Stevens Sts.	McElroy Packing Co.	do	1934		120+	6	18	90			

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of drawdown (feet)	Use of water[3]	Temperature (°F.)	Remarks
32	T	240	240	25.0	R		Well has 430 feet of 12-inch casing and 128 feet of 8-inch slotted pipe. Slots are ¼ by 6 inches.
32a	T				P		Artificial gravel-pack construction. Brackish water was encountered in test well from 770 to 820 feet. Highly mineralized water from 820 feet to 851 feet. According to Schlumberger electrical log.
33	AL	75	75	100.0	P	65	Deepened from 355 to 650 in 1930. 60 feet of screen in old part of well. Measuring point at top of air line.
34	C, 3 and 10 hp.	700			S		Well has 74 feet of 8-inch casing, recased with 74 feet of 6-inch casing, and 16 feet of 6-inch slotted pipe. Slots are ⅛ by 1¼ inches.
35	AL	220			Ind		
36	T		250		None		Abandoned. Well has 285 feet of 13-inch, 310 feet of 10-inch, 475 feet of 8-inch 94 feet of 6-inch casing, and 21 feet of 6-inch screen. Bad water 474 to 515 feet. Yielded 250 gallons per minute May 15, 1917. Measuring point at floor.
37	None		300		None		Abandoned. Well has 332 feet of 14-inch, 515 feet of 10-inch, and 56 feet of 8-inch casing, and 30 feet of 8-inch screen. Water-stage recorder maintained Sept. 10 to Dec. 31, 1935. Measuring point at floor.
38	None				None		Abandoned. Bad water at depths of 312 and 517 feet.
39	T, 25 hp				Ind		Measuring point at pump base.
40	None				None		Abandoned. Measuring point at top of casing.
41	None		1,000	53	None	82	Well has 214 feet of 18-inch and 361 feet of 12-inch casing, and 3½ feet of 12-inch, 193 feet of 12½-inch and 146 feet of 11½-inch slotted casing. Present depth 845 feet. Water-stage recorder installed March 4, 1936. Yielded 1,000 gallons per minute in 1919. Measuring point at floor.
42	T, 50 hp	1,100	700	50	P	66 79	Well has 118 feet of 24-inch and 116 feet of 15-inch casing, and 256 feet of 15-inch and 356 feet of 12½-inch slotted casing. Deepened from 446 to 802 feet in 1930. Yielded 700 gallons per minute in 1929. Measuring point at floor.
43	C, 7½ hp				P		Measuring point at top of casing.
44	T, 15 hp	140			Ind	72	Well has 205 feet of 12-inch and 120 feet of 10-inch casing, and 33 feet of 10-inch wire wrapped screen.
45	None				None		Drilled as test hole.
46	C	120			Ind		Well 100 feet deep for watering stock 200 yards north of this well.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Height of measuring point above land surface[1] (feet)	Water level: Depth below measuring point (feet)	Water level: Date of measurement
47	East Alameda Ave.	Evergreen Cemetery		Old		67						
48	Hadlock Pl. and Franklin Canal.	E. J. Hadlock		Old	3,700.0	30+				.0	8.8	Aug. 27, 1935
48a	Hadlock Addition	El Paso test well 14	C. R. Jensen	1938	3,699.0	902						
49	Madison and White Oak Sts.	El Paso well 4	P. D. Wynne	1924	3,743.73	882	24	465		.3	82	1924
											80	1928
											77	Nov. 19, 1934
											81.15	Aug. 19, 1935
50	Montana and Madison Sts.	El Paso well 1	Layne-Texas Co.	1918	3,766.96	860	24	485		3.0	101	Nov. 15, 1934
											106	Nov. 23, 1932
											114	May 13, 1932
											110	May 1, 1931
											106	1932
											95	1928
											79	1929
											77	1918
											101.41	Sept. 27, 1935
51	Montana St. at city limits.	El Paso well 2	City Waterworks	1922	3,772.37	840	20	507		1.0	[4]114	Apr. 1, 1926
											116	Mar. 22, 1933
52	Montana and Chelsea Sts.	El Paso well 3	P. D. Wynne	1922	3,783.20	862	26	505		3.0	[4]112	1928
											115	Oct. 19, 1934
53	Clifton and Raynolds Sts.	Loretto College			3,811.25		7			3.0	[4]149.91	Nov. 11, 1935
54	Ascarate, 0.6 mile NW. of.	Texas Co.			3,748.0	85+					65	
55	Ascarate, 0.3 mile N. of.	do.	P. D. Wynne	1929	3,717.87	694		444		2.0	[4]47.75	Mar. 20, 1929
56	Ascarate, 0.4 mile NE. of.	Pasotex Petroleum Co. well 1.	Layne-Texas Co.	1928	3,750.03	590	10	478			76	1931
											31.50	Aug. 23, 1935
											80.86	July 1, 1938

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
47							
48	None				None		Abandoned. Described at length in U. S. Geol. Survey Water-Supply Paper 141. Measuring point at ground.
48a							According to Schlumberger, water below 725 feet was highly mineralized. There was 106 feet of sand and gravel between the surface and 221 feet, 334 feet between 221 and 727 feet, and 127 feet between 727 and 902 feet.
49	T, 100 hp	1,200	1,360	75	P		Well has 200 feet of 24-inch and 279 feet of 13-inch casing and 417 feet of 13-inch slotted casing. Yielded 1,360 gallons per minute in 1928. Measuring point at floor.
50	T, 250 hp	1,200	1,200+	83.0	P		Well has 224 feet of 24-inch and 280 feet of 13½-inch casing; 120 feet of 13½-inch screen; 90 feet of 13½-inch casing; 20 feet of 13½-inch screen; 40 feet of 13½-inch casing; 60 feet of 13½-inch screen; 70 feet of 13½-inch casing. Depth drilled 1,023 feet. Yielded 1,200+ gallons per minute Sept. 27, 1935. Measuring point at floor.
51	None	730	730+	75	P	82	Well has 200 feet of 20-inch, 282 feet of 15½-inch, and 18 feet of 12-inch casing; and 340 feet of 12-inch screen. Abandoned well about 50 feet north. Installed water-stage recorder June 24, 1936. Yielded 730+ gallons per minute April 1, 1926. Measuring point at floor.
52	T, 100 hp	1,250	1,250	34.63 40.69 41.18	P		Well recased with 225 feet of 20-inch casing. Present depth 850 feet. Water-stage recorder maintained Sept. 11, 1935 to April 28, 1936, and June 20–24, 1936. Draw-down in feet, in 2-hour test, June 29, 1936, 34.63 feet; in 100½-hours, July 3, 1936, 40.69 feet; in 273½ hours, July 10, 1936, 41.18 feet. Measuring point, floor.
53	AL				None		Measuring point at top of eduction pipe.
54					None	67	Abandoned.
55	T, 50 hp	830+	830+	25	Ind	82 83.5	Length of screen 250 feet, slots ¼ by 8 inches. Yielded 830+ gallons per minute Aug. 29, 1935. Measuring point, pump base.
56	T				Ind	82	Well has 457 feet of 10-inch and 21 feet of 8-inch casing, and 37 feet of 8-in. screen; 31 feet of 8-inch casing; 42 feet of 8-inch screen. Screen is wire-wrapped. Measuring point at pump base.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Height of measuring point above land surface[1] (feet)	Water level: Depth below measuring point (feet)	Water level: Date of measurement
57	Ascarate, 0.4 mile NE. of.	Pasotex Petroleum Co. well 2.	Layne-Texas Co.	1928+	3,744.31	299	24	174			59.50 59.65 58.60 59.53	Aug. 28, 1935 Mar. 22, 1937 Nov. 8, 1937 July 6, 1938
58	Ascarate, 0.4 mile E. of.	Pasotex Petroleum Co. well 3.	do.	1930	3,729.72	606	12	445		−3.0	65 62.11 62.05	June 6, 1930 Mar. 2, 1936 Nov. 8, 1937
59	Ascarate, 0.7 mile E. of.	Nichols Copper Co.	do.	1929	3,739.75	640	20	500		.0	64 63 68.12	Jan. 2, 1931 Feb. 21, 1935 Aug. 29, 1935
60	Ascarate	Sambrano Water Works.		1915+	3,691.37	140+	6			.0	[4]5.35	Aug. 29, 1935
61	Ascarate, 1.7 miles SE. of.	L. L. Estrada	Paul Wuerchmeider.	1923	3,685	320	6				9.38	Sept. 10, 1935
62	Ascarate, 1.9 miles SE. of.	Deacon & Son			3,689		6			.8	9.70	Sept. 11, 1935
63	Carlsbad highway, 3.7 miles from city limits.	U. S. Dept. of Commerce.	W. L. Cass		3,959.03	320	6	314		.6	276.17	May 15, 1936
64	Carlsbad highway, 3.1 miles east of city limits.	El Paso and U. S. Geol. Survey test well 1.	H. M. Stanley	1936	3,942.88	600	6			.0	[4]260.56	July 17, 1936
65	Airport, SW. corner of.	American Airways	Burdick & Burdick		3,911.73	418	6			.2	231.03 232.03	Aug. 20, 1935 Mar. 26, 1938
65a	American Airways	El Paso	C. R. Jensen	1938		530	8			.0	233.08	Apr. 27, 1938
66	Fort Bliss, near south entrance to.	Southern Pacific Lines.		Prior to 1904		270	8					
67	do.	Southern Pacific Line well 1.	Semple & Wynne	1922	3,897.41	869	12	269		10.0	[4]213	1922
67a	Fort Bliss, near south entrance to.	Texas & New Orleans R.R. well 4.	Layne-Texas Co.	1937		860	12				219.30	Jan. 25, 1939
67b	do.	Texas & New Orleans R.R. well 3.	do.	1937		860	12				221.48	Feb. 24, 1939
68	do.	Texas & New Orleans R.R. well 2.	Semple & Wynne	1921		864	12	274			213	Aug. 30, 1921
69	Leeds & Crockett Sts.	El Paso No. 11A	City Waterworks	1930	3,791	660						

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
57	T, 75 hp	1,000			Ind	75	Well has 140 feet of 24-inch and 24 feet of 13-inch casing, and 125 feet of 13-inch screen. Screen is gravelled in 20-inch hole below 140 feet. Measuring point, floor.
58	T	500	500		Ind	82	Well has 445 feet of 12-inch and 42 feet of 10-inch casing, and 120 feet of 10-inch screen. Yielded 500 gallons per minute Mar. 2, 1936. Measuring point at base plate.
59	T, 75 hp		800	59	Ind	83 81	Well has 498 feet of 20-inch casing; 80 feet of 12-inch screen; 20 feet of 12-inch casing; 40 feet of 12-inch screen. Drilled to depth of 706 feet. Yielded 800 gallons per minute Jan. 2, 1931. Measuring point at floor.
60	C, 7½ hp				P		Well supplies about 65 houses. Measuring point at top of casing.
61	AL, 3 hp				S, D		Measuring point at ground.
62	DW				S, D		Measuring point at pipe clamp.
63	DW	3			None		Measuring point at top of concrete base.
64	None				None		441 feet of 2-inch pipe left in well. Measuring point at top of pipe.
65	DW				P		Abandoned 1938. Measuring point at top of casing.
65a	T, 7.5 hp	50			P		Cased with 8-inch casing to 243 feet. Alternate 8-inch screen and casing 243 to 397 feet, 6-inch casing 397 to 520 feet.
66	None		100		None		Four abandoned wells of same construction. Data from U. S. Geol. Survey Water-Supply Paper 141, p. 17, 1904. Yielded 100 gallons per minute from 4 wells prior to 1904.
67	AL	600+	650	9	P	76	Water is treated for use in boilers. Well has 269 feet of 12-inch casing and 600 feet of 12-inch slotted pipe. Slots are ¼ by 14 inches. Yielded 650 gallons per minute in 1922. Measuring point at top of eduction pipe.
67a	AL	700					
67b	AL	624					
68	AL	300+	660	9	P	77	Well has 274 feet of 12-inch casing and 590 feet of slotted pipe. Water is treated for use in boilers.
69	None				None		Abandoned. Never used, because of lack of water of good quality.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed		Height of measuring point above land surface[1] (feet)	Water level	
								Depth to top of bed (feet)	Thickness (feet)		Depth below measuring point (feet)	Date of measurement
70	Fort Bliss, beside elevated tank at.	U. S. Army well 0		Prior to 1904		313–319	8					
71	Fort Bliss pumping plant.	U. S. Army well 4			3,887.86	600+					221	Feb. 11, 1931
72	do	U. S. Army well 2	T. F. Hawkins	1913	3,898.14	652	10			14.0	[4]198.34 209 208 206	1913 1917 1919 1933
73	do	U. S. Army well 1	do	1913		657	12				200.75 212 221 217	July 27, 1913 1917 1919 1931
74	do	U. S. Army well 3				600						
75	do	U. S. Army well 5	R. A. Taylor, Layne-Texas Co.	1931	3,876.97	770	24	295			204	Mar. 24, 1932
75a	do	U. S. Army well 6	Layne-Texas Co.	1937	3,876.95	785	12			2.0	211.82	Sept. 16, 1937
75b	Mesa pumping plant, 0.75 mile southeast of.	El Paso test well 10.	C. R. Jensen	1938	3,879.32	1,117					209.77	Aug. 24, 1938
75c	Mesa pumping plant, 0.9 mile southeast of.	El Paso test well 9	do	1938	3,885.65	1,292						
75d	Mesa pumping plant, 1.3 miles ESE. of.	El Paso test well 12.	do	1938	3,905.81	1,187						
76	Biggs Field, near SE. corner of.	El Paso and U. S. Geol. Survey test well 2.	H. M. Stanley	1936	3,919.40	600	6			.0	[4]244.12	July 17, 1936
76a	Mesa pumping plant, 2.6 miles east of.	El Paso test well 18.	C. R. Jensen	Feb. 1939	3,928	1,117						
76b	Mesa pumping plant, 3.25 miles east of.	El Paso test well 15.	do	Dec. 1938	3,940	1,131						
76c	Mesa pumping plant, 3.75 miles east of.	El Paso test well 17.	do	Jan. 19[illegible]	3,948	1,072						

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
70	None				None		Abandoned. U. S. Geol. Survey data from Water-Supply Paper 141, p. 17, 1904.
71	T				P	76	Measuring point at floor.
72	AL				P	76	Measuring point at top of tank.
73	AL		405	16	P	76	Well has 204 feet of 12-inch and 658 feet of 10-inch casing.
74	AL				P	76	
75	T		1,100	66	P	80	Well has 295 feet of 24-inch casing; 24 feet of 24-inch shutter screen; and 485 feet of pipe and screen of which 225 feet is shutter screen. Measuring point, floor.
75a	T	1,140		69.51	P		Artificial gravel pack construction. 24-inch casing 0 to 345 feet, 12-inch silicon bronze shutter screen 311 to 785 feet. Total thickness of sand is about 385 feet, thickness of sand below 200 feet is 245 feet.
75b					None		Total thickness of sand about 410 feet, thickness of sand below 200 feet is 286 feet. Equipped with recorder.
75c					None		Total thickness of sand about 599 feet, thickness of sand below 200 feet, 446 feet.
75d					None		Total thickness of sand 459 feet, thickness of sand below 200 feet, 363 feet.
76	None				None		Observation well. 416 feet of 2-inch pipe left in well. Measuring point at top of 2″ pipe.
76a							According to Schlumberger, water was "fresh" from water table to 815 feet, brackish from 815 to 925 feet, and salty from 925 to bottom. There was 106 feet of sand and gravel from 227 to 813 feet and 128 feet from 813 to 1,117 feet.
76b							According to Schlumberger, water was fresh from water table to 780 feet, brackish from 780 to 1,095 feet, and salty from 1,095 feet to bottom. There was 48 feet of sand between surface and 233 feet, 303 feet of sand between 233 and 785 feet, and 138 feet between 785 and 1,131 feet.
76c							According to Schlumberger, water was fresh from water table to 680 feet, slightly brackish from 680 to 850 feet, and very brackish from 850 to the bottom, where it is salty. There was 98 feet of sand and gravel between the surface and 243 feet, 374 feet of sand between 243 and 842 feet, and 116 feet between 837 and 1,072 feet.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Height of measuring point above land surface[1] (feet)	Water level: Depth below measuring point (feet)	Water level: Date of measurement
76d	Mesa pumping plant, 4.25 miles east of.	El Paso test well 16.	C. R. Jensen	Jan. 1939	3,926	1,072						
76e	Mesa pumping plant, 5.2 miles east of.	El Paso test well 19.	do	March 1939	3,964	957						
77	Mesa well field	El Paso well 12	V. Chesney	1935	3,882.52	776	20	288		3.0	[4]204	June 5, 1935
77a	do	El Paso test well 7	C. R. Jensen	1938	3,900.52	902						
77b	Mesa pumping plant, 1.1 miles east of.	El Paso test well 15.	Layne-Texas Co	1938	3,900.35	1,055	24			.5	222.28	May 4, 1938
77c	Mesa pumping plant, 1.7 miles east of.	El Paso well 16	C. R. Jensen	1938	3,912.78	1,211					227.82	Apr. 3, 1939
78	do	El Paso well 11	do	1930	3,872.63	736	20	245			195 195 206.03	Oct. 1, 1931 October 1934 May 1, 1939
78a	Mesa pumping plant, 0.5 mile north of.	El Paso test well 6	do	1937	3,868	830						
78b	Mesa pumping plant, .75 mile north of.	El Paso test well 5	do	1937	3,861.48	698						
78c	Mesa pumping plant, .9 mile north of.	El Paso test well 4	do	1937	3,874.14	800	6			4.8	193.25	Aug. 24, 1938
79	do	El Paso test well 8	L. Jensen	1928	3,871.12	715	20	242			199.16	Jan. 13, 1938
80	Wilson Rd. and Southern Pacific railroad tracks.	Southern Pacific Lines		1901		410	6				190	1902
81	Wilson Rd. ½ mile N. of.	Southern Pacific Lines.	William McLease	1901		249	6				169	
92	Municipal Golf Course, near Southern Pacific railroad tracks.	El Paso well 13	V. Chesney	1935	3,879	340					199	July 30, 1936

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
76d							According to Schlumberger, water was fresh from water table to 680 feet, brackish from 680 to 872 feet, and salty below 872 feet. There was 135 feet of sand between the surface and 247 feet, 325 feet of sand between 247 and 857 feet, and 157 feet of sand between 857 and 1,077 feet.
76e							According to Schlumberger, water was fresh from water table to 565 feet, brackish from 565 to 780 feet, and salty from 780 feet to the bottom. There was 167 feet of sand between 250 and 565 feet, 169 feet of sand between 565 and 777 feet, and 97 feet of sand between 777 and the bottom.
77	T, 150 hp			45	P		Well has 300 feet of 20-inch casing, 10 feet of 12-inch casing, and 486 feet of 12-inch slotted pipe. Slots are ¼ by 8 inches. 45 feet of draw-down during 48-hour test June 10, 1936. Measuring point, floor.
77a					None		Total thickness of sand 397 feet, thickness of sand below 200 feet, 326 feet.
77b	T	1,800	1,800	42.39	P		Artificial gravel-pack construction. Drilled as test well 8. 24-inch casing 0 to 279 feet, 16-inch casing 254 to 279 feet, 16-inch screen 279 to 358 feet, 12½-inch screen 359 to 1,030 feet, 12½-inch casing 1,030 to 1,045 feet. Total thickness of sand 400 feet, thickness of sand below 200 feet, 310 feet. See log.
77c					None		Originally drilled as test well 11. Total thickness of sand about 490 feet, thickness of sand below 200 feet, 398 feet.
78	T, 150 hp		1,170		P		Well has 245 feet of 20-inch casing; 61 feet of 20-inch, 276 feet of 15½-inch, and 185 feet of 12½-inch slotted pipe. Yielded 1,170 gallons per minute in 1931. Measuring point, floor.
78a					None		Total thickness of sand, 167 feet, thickness of sand below 200 feet, 66 feet.
78b					None		Total thickness of sand 269 feet, thickness of sand below 200 feet, 108 feet.
78c	None				None		Observation well. Total thickness of sand, 227 feet, thickness of sand below 200 feet, 136 feet.
79	T, 150 hp				P	82	Well has 242 feet of 20-inch casing; 60 feet of 20-inch, 322 feet of 15-inch and 97 feet of 12-inch slotted pipe. Measuring point, floor.
80	None		20		None		Abandoned. Data from U. S. Geol. Survey Water-Supply Paper 141, p. 78, 1904. Yielded 20 gallons per minute prior to 1904.
81	None		55		None		Abandoned. Data from U. S. Geol. Survey Water-Supply Paper 141, p. 78, 1904.
82	None				None		Abandoned. Never used because it was believed uneconomical to develop.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed		Height of measuring point above land surface[1] (feet)	Water level	
								Depth to top of bed (feet)	Thickness (feet)		Depth below measuring point (feet)	Date of measurement
82a	Mesa pumping plant, 1 mile north of.	El Paso test well 20	C. R. Jensen	Mar. 1939	3,874	1,467						
83	Mesa well field	El Paso (old Mesa field): well 3.	Beck & Lewis	Old		520		236	32		177	
84	do	well 4	D. A. Beck	1904 1904	3,870	696	14	230				
85	do	well 5	Beck & American Well and Prospecting Co.	Old	3,870	2,285	14	230 318 376	30 14 32			
86	do	well 6	W. D. Lewis	1904	3,870	505	12	200	67			
87	do	well 7		1905	3,870	510	12	240 290	20 25			
88	do	well 8		1905	3,870	520	12					
89	do	well 9		1905	3,870	553	12	254 332.	32 14			
90	do	well 10		1905	3,870	520	12					
91	do	well 11		1905	3,870	550	12	190	50			
92	do	well 12	International W. Co.	1905	3,871	538	12	200	65			
93	do	well 13	do	Old	3,870	550	12	240	64			
94	do	well 14	do	Old	3,871	510						
95	do	well 15	Lou Gasser	1910	3,869							
96	do	well 16	City Waterworks	1910	3,869	620					180	1910
97	do	well 17	City Waterworks	1910	3,870	426					181	1910
98	do	well 18	do	1910	3,871	610					182 230 234	1910 July 1916 April 1917
99	do	well 19	do	1910	3,870	425					202 226.6 228	June 1911 Oct. 30, 1915 July 18, 1916
100	do	well 20										
101	do	well 21										
102	do	well 22										

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
82a							According to Schlumberger, the water from the water table to 820 feet is fresh, that from 920 to 1,365 is brackish, and that below 1,365 is fairly salty. There was 74 feet of sand and gravel between the surface and 200 feet, 308 feet of sand between 200 and 967 feet, and 118 feet of sand between 967 feet and the bottom.
83	None				None		Abandoned. No location or data are available for old Mesa wells 1 and 2.
84	None				None		Abandoned. Well has 72 feet of 14-inch casing; 364 feet of 12-inch casing perforated from 230 to 260 feet; 462 feet of 10-inch casing; recased with 696 feet of 8-inch casing.
85	None				None		Abandoned. Well still has 912 feet of 14-inch casing and 312 feet of 8-inch casing.
86	None				None		Abandoned. Exact location is not known.
87	None				None		Abandoned. Well has 490 feet of 12-inch casing, perforated from 290 feet to 315 feet and from 240 to 260 feet, and 141 feet of 8-inch casing.
88	None				None		Abandoned.
89	None				None		Do.
90	None				None		Do.
91	None				None		Abandoned. Well has 550 feet of 12-inch casing, perforated from 190 to 240 feet. Exact location is not known.
92	None				None		Abandoned. Well has 532 feet of 12-inch casing, perforated from 200 to 265 feet.
93	None				None		Abandoned. Well has 550 feet of 12-inch casing, perforated from 240 to 304 feet.
94	None				None		Abandoned.
95	None				None		Do.
96	None				None		Do.
97	None				None		Do.
98	None				None		Do.
99	None		215	15	None		Abandoned. Yielded 215 gallons per minute July 8, 1916.
100	None				None		Abandoned.
101	None				None		Do.
102	None				None		Do.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Height of measuring point above land surface[1] (feet)	Water level: Depth below measuring point (feet)	Water level: Date of measurement
103	Mesa well field	well 23	City Waterworks		3,870	609					196 216.8	When drilled July 18, 1916
104	do	well 24										
105	do	well 25	City Waterworks		3,871	611					186	Date drilled
106	do	well 26	do		3,871	613					211	Date drilled
107	do	well 27										
108	do	well 28										
109	do	well 29	City Waterworks	1913	3,871	594					212	December, 1912
110	do	well 30	do		3,871	610					198	Date drilled
111	do	well 31	do	1913	3,871	604					197	1913
112	do	well 32	do		3,871.27	606	8			1.5	[4]202	Date drilled
113	do	well 33	do		3,869	610						
114	do	well 34	do	1915	3,871.98	598	10	195		3.0	[4]195	Oct. 20, 1915
115	do	well 35	do	1916	3,871	599	10				210	January 1915
116	do	well 36	City Waterworks	1916		595	10	203			223	Jan. 6, 1920
117	do	well 37	do	1916	3,871	600	10	89			196	April 1916
118	do	well 38	do	1916		559	10	218				
119	do	well 39		1916	3,871.35	590				1.0	[4]193.12	Dec. 14, 1935
120	do	well 40		1917	3,871.99	595				1.0	[4]194.02	Dec. 14, 1935
121	do	well 41		1917		592						
122	do	well 42		1917		596						
123	do	well 43		1917	3,871	895	12				202.6	Nov. 24, 1917
124	do	well 44			3,871	1,106		209			221	Sept. 8, 1918
125	Biggs Field, 2 miles NE. of.	Baker		Old	3,942+		8					
126	Near Southern Pacific railroad tracks, 3.3 miles N. of Wilson Rd.	McElroy Packing Co.		Old	3,902.63	400	10			.4	[4]210.75	Aug. 7, 1935
127	Near Southern Pacific railroad tracks, 2.6 miles N. of Wilson Rd.	Western Gas Co. well 2.		1931	3,882.34	362				.4	[4]192.21	Aug. 7, 1935
128	do	Western Gas Co. well 3.					6				193.63	May 8, 1937

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
103	None				None		Abandoned.
104	None				None		Do.
105	None				None		Do.
106	None				None		Do.
107	None				None		Do.
108	None				None		Do.
109	None				None		Do.
110	None				None		Do.
111	None				None		Do.
112	None				None		Abandoned. Measuring point at coupling.
113	None				None		Abandoned.
114	None				None		Abandoned. Well has 195 feet of 10-inch pipe and 403 feet of 10⅝ ID slotted pipe. Measuring point at top of air line.
115	None				None		Abandoned. Well has 195 feet of 10-inch and 403 feet of 10½-inch casing.
116	None		500	46+	None		Abandoned. Well has 203 feet of 10-inch casing and 392 feet of 10½-inch slotted pipe. Yielded 500 gallons per minute July 8, 1916.
117	None				None		Abandoned. Well has 89 feet of 10-inch pipe and 407 feet of slotted pipe.
118	None				None		Abandoned. Well has 78 feet of 9½-inch pipe and 481 feet of 8-inch pipe slotted from a depth of 218 to bottom. Exact location not known.
119	None				None		Abandoned. Measuring point at top of air line.
120	None				None		Do.
121	None				None		Abandoned.
122	None				None		Do.
123	None				None		Abandoned. Well has 209 feet of 12-inch pipe; 131 feet of 12-inch slotted pipe and 504 feet of 11⅝ inch slotted pipe.
124	None				None		Abandoned.
125	None				None		Do.
126	DW				S		Measuring point at pipe clamp.
127	AL				Ind., D		Measuring point at top of casing.
128	T				do		

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Height of measuring point above land surface[1] (feet)	Water level: Depth below measuring point (feet)	Water level: Date of measurement
128a	Mesa pumping plant, 1½ miles N. of.	El Paso test well 21	C. R. Jensen	Apr. 1939	3,875	1,137						
128b	Mesa pumping plant, 2 miles N. of.	El Paso test well 22	do	Apr. 1939	3,879	1,237						
128c	Mesa pumping plant, 2½ miles N. of.	El Paso test well 23	do	May 1939	3,882	1,257	6				193.33	June 20, 1939
128d	Mesa pumping plant, 3 miles N. of.	El Paso test well 24	do	May 1939	3,885	1,217						
129	On U. S. Highway 70, 1.9 miles N. of Wilson Rd.	Edgar Parks	W. L. Cass		3,942.70	311	6	274	37	.5	[4]254.90	Aug. 6, 1935
129a	Mesa pumping plant, 2 miles north of.	Restlawn Cemetery		1910?		640				−2.7	209.40	Apr. 26, 1938
129b	do	do		1910?		630						
130	Wilson Rd., 2.9 miles north of.	G. L. Cook	W. L. Cass		3,937.77	293	6	240	60	1.6	246.59	Apr. 14, 1936
131	do	C. T. Mathis		1929		312						
132	On U. S. Highway 70, 2.7 miles N. of Wilson Rd.	H. T. Ankerson	W. L. Cass	1935	3,904.16	257	6	237			[4]213.62	Aug. 7, 1935
133	On U. S. Highway 70, 2.8 miles N. of Wilson Rd.	Bascom-Lawson	P. D. Wynne	1935		263	6	239	24			
134	On U. S. Highway 70, 3 miles N. of Wilson Rd.	W. S. Friar		1900	3,889.38	219	6			2.0	197.5	Aug. 7, 1935
135	Wilson Rd., 4.2 miles N. of.	McElroy Packing Co.		Old	3,938.24	350±	10			.4	[4]243.42	Aug. 7, 1935
135a	Mesa pumping plant, 3½ miles N. of.	El Paso test well 25	C. R. Jensen	June 1939	3,890	1,217						

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
128							According to Schlumberger the water above 838 feet is good, that below 838 feet is brackish. There was 55 feet of sand and gravel between the surface and 209 feet, 331 feet of sand between 209 and 1,017 feet, and 29 feet between 1,017 and 1,137 feet.
128b							According to Schlumberger the water above 855 feet is fresh, that below that depth is brackish. There was 143 feet of sand and gravel between the surface and 200 feet, 348 feet of sand between 200 and 1,000 feet, and 74 feet of sand between 1,000 and 1,237 feet.
128c	None						According to Schlumberger the water below 1,158 feet is brackish. There was 157 feet of sand and gravel between the surface and 217 feet, 315 feet of sand between 217 and 1,000 feet, and 83 feet of sand between 1,000 and 1,257 feet. Cased to 385 feet for an observation well.
128d							According to Schlumberger no brackish water was encountered in this hole.
129	DW				D		Formerly supplied Sunrise Addition. Measuring point at top of casing.
129a	AL	150	150	30	S		Used to irrigate lawn.
129b	AL				S		Do.
130	None				None		Measuring point, top of casing.
131	DW	10			S		
132	DW				D		Measuring point at top of pipe clamp.
133	DW				D		Well has 263 feet of 6-inch casing, the lower 24 feet of which are slotted.
134	DW				D, S		Measuring point at bottom of outlet pipe.
135	None				None		Measuring point at top of casing.
135a							According to Schlumberger no brackish water was encountered in this well. There was 105 feet of sand and gravel between the surface and 200 feet, 446 feet of sand between 200 and 1,000 feet, and 89 feet of sand between 1,000 and 1,217 feet.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed		Height of measuring point above land surface[1] (feet)	Water level	
								Depth to top of bed (feet)	Thickness (feet)		Depth below measuring point (feet)	Date of measurement
135b	Mesa pumping plant, 4 miles N. of.	El Paso test well 26	C. R. Jensen	June 1939	3,908	1,357						
135c	Mesa pumping plant, 5 miles N. of.	El Paso test well 27	do	July 1939	3,942	1,206						
136	Wilson Rd., 5.6 miles N. of.	El Paso City and U. S. Geological Survey Test well 3.	H. M. Stanley	1936	3,944.11	500	6			.0	[4]244.45	July 24, 1936
136a	Mesa pumping plant, 6 miles N. of.	El Paso test well 28	C. R. Jensen	July 1939	3,972	1,177						
137	Newman, N. Mex., 5.8 miles SW. of.	Newman Investment Co.	Chris Deitert	1929	3,971+	323	8	273	20		273	1929
138	Newman, 4.0 miles S. of.	McElroy Packing Co.			3,975.08					.0	267.24 268.22	Apr. 3, 1936 July 6, 1937
139	Newman 5.4 miles SW. of.	J. F. Reeves		Old	4,013.65	360	5	340		5.0	296.6 297.46	Aug. 9, 1935 July 17, 1938
140	Newman	Southern Pacific Lines well 3.		1917	3,999.83	400	18	328		.66	284.25 284.17 283.93	June 1, 1936 June 22, 1937 July 11, 1938
141	do	Southern Pacific Lines well 1.		1902		332	6	328				
142	do	F. M. Reeves		Old	4,016.73	320	6			.5	293.07	Feb. 8, 1937
143	Newman, 5.9 miles W. of.	Reeves and Brashear		Old	4,040.62	350+	8	320		.7	318.77 314.05	May 11, 1936 June 24, 1937
144	Newman, 6.5 miles W. of.	James Blythe		1933	4,047+	340	6				310	1933
145	Newman, 9 miles W. of.	A. M. Greenwood		Old	4,174	520	6	90	430		380.74	June 23, 1937
146	Newman, 9.3 miles NW. of.	James Trueblood			4,090±	400	6	335	65		350	1935
147	Newman, 10 miles NW. of.	A. M. Greenwood		Old	4,086±	462	6			.5	336.75 337.13 337.10	Apr. 25, 1936
148	Newman, 7.4 miles NW. of.	do		Old	4,064	350		320	30		325.59 325.65	June 23, 1937 July 12, 1938
149	Newman, 14.5 miles NW. of.	U. S. Army (Target range).		1931	4,104	798	8			4.0	334.85 334.70 334.69	Apr. 17, 1936 June 23, 1937 July 12, 1938

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
135b							According to Schlumberger no brackish water was encountered in this hole. There was 139 feet of sand between the surface and 206 feet, 447 feet of sand between 206 and 1,000 feet, and 35 feet of sand between 1,000 and 1,357 feet.
135c							According to Schlumberger there is an indication of slightly brackish water below 1,130 feet. There was 170 feet of sand and gravel between the surface and 213 feet, 471 feet of sand between 213 and 1,000 feet, and 119 feet of sand between 1,000 feet and 1,206 feet.
136	None				None		335 feet of 2-inch pipe left in well. Used as observation well. Measuring point at top of 2-inch pipe.
136a							According to Schlumberger the best water in this well is found above 860 feet, and salt water occurs in the bottom of the well. There was 195 feet of sand and gravel between the surface and 257 feet, 317 feet of sand between 257 and 1,000 feet, and 28 feet of sand between 1,000 and 1,177 feet.
137	DW				D, S		
138	DW	15			D, S		First drilled as an oil test. Measuring point at top of pipe clamp.
139	DW						Abandoned. Measuring point at lift pipe.
140	DW				R		Measuring point at pump base.
141	DW				R		
142	DW				None		Abandoned. Measuring point at lift pipe.
143	DW				D, S		Measuring point at top of casing.
144	DW				D, S		Do.
145	DW				S		Well draws from limestone.
146	DW				D, S		
147	DW	15			S		Measuring point at pipe clamp.
148	DW				S		
149	AL	90	94	12	P		

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed		Height of measuring point above land surface[1] (feet)	Water level	
								Depth to top of bed (feet)	Thickness (feet)		Depth below measuring point (feet)	Date of measurement
150	Newman, 13.6 miles NW. of.	------	------	Old	4,038	------	8	------	------	.7	268.4 268.44 268.51	Apr. 17, 1936 June 23, 1937 July 12, 1938
151	Newman, 18 miles NW. of.	Mrs. Belvins	------	Old	3,946	181	5	------	------	.0	152.83	Apr. 23, 1936
152	Newman, 6.8 miles E. of.	E. Y. McCracken	------	1930	4,072	450	------	300	------	------	350 325.59	1930 June 23, 1937
153	Newman, 7 miles E. of.	McElroy Packing Co. (joint well).	------	Old	4,077	400	5	------	------	.0	363.62 363.44 363.70	Apr. 9, 1936 June 24, 1937 July 19, 1938
154	Newman, 11 miles E. of.	Adelberto Navar	O'Niel	Old	4,096	300	------	------	------	.0	176.00	Aug. 9, 1935
154a	Newman, 11 miles E. of.	Adelberto Navar (hot well).	------	Old	4,097	------	------	------	------	------	452.90	July 19, 1938
155	Emergency landing field, 5 miles NNW. of.	Adelberto Navar	------	------	4,060	410	5	------	------	------	360.03	Mar. 30, 1936
156	Emergency landing field, 1.7 miles E. of.	------	------	------	4,078	1,100	------	------	------	------	600	------
157	Emergency landing field, 2.5 miles W. of.	Nation's south well.	------	Old	4,012	------	8	------	------	------	------	------
158	Emergency landing field, 8.8 miles W. of.	J. K. Shearman	Gibson	1933	4,010.63	390	------	------	------	.8	322.85 323.65 322.88	June 13, 1936 July 15, 1937 July 13, 1938
159	Ysleta Station 3.2 miles NW. of.	El Paso Dairy	Seidel & Wicker	1935	------	65	2.5	------	------	------	4.8	Sept. 13, 1935
160	Ysleta Station, 2.6 miles NW. of.	Ysleta College	------	------	3,736	75	5	------	------	------	62.00 64.20	Apr. 29, 1936 June 30, 1937
161	Ysleta Station, 2.8 miles NW. of.	F. W. Miller	Burdick & Burdick	1929	------	191	4	------	------	------	------	------
162	Ysleta Station, 1.2 miles NW. of.	C. L. Wicker	E. L. Forgason	1933	------	130	2.5	------	------	------	------	------
163	Ysleta Station, 1.1 miles W. of.	V. S. Bowden	Seidel & Wicker	1935	------	75	2	------	------	------	4.95	Sept. 13, 1935
164	Ysleta Station, 0.6 miles W. of.	G. H. Munro	E. L. Forgason	1935	3,668	121	2.5	------	------	------	12.0	Sept. 13, 1935
165	Ysleta Station, 0.8 miles N. of.	Sam Shannon	Burdick & Burdick	1935	------	82	2	------	------	------	------	------
166	Ysleta Station, 1.5 miles NE. of.	U. S. Government, C.C.C.	------	------	3,734.3	200	8	76	49	.9	76.62 76.05	Apr. 30, 1936 June 30, 1937

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
150	DW				None		Abandoned. Measuring point at pipe clamp.
151	DW				D, S		Measuring point at pipe clamp.
152	DW				D, S		
153	DW				S		Measuring point at top of casing.
154	DW	18			D, S		
154a							This water was reported to be hot and highly mineralized.
155	DW				S		
156	DW				S		Highly mineralized water. Well draws from limestone.
157	None				S		Abandoned. Two wells, one plugged at 248 feet and the other at 10 feet. Drilled into limestone.
158	DW	15			D, S		Measuring point at top of concrete base.
159	DW				D, S		Measuring point at ground.
160					P		Measuring point at floor.
161					D, S		
162	DW	25			D, S		
163							
164					D, S		
165	DW				D, S		
166	DW				P		Three wells drilled on this site. Measuring point at pump base.

See footnotes at end of table.

No.	Location	Owner or name	Driller	Year completed	Altitude of measuring point above sea level (feet)	Depth (feet)	Diameter (inches)	Principal water-bearing bed		Height of measuring point above land surface[1] (feet)	Water level	
								Depth to top of bed (feet)	Thickness (feet)		Depth below measuring point (feet)	Date of measurement
167	Ysleta Station, 4.8 miles SE. of.	R. C. Sparks				150	3					
168	Ysleta Station, 4.7 miles SE. of.	Rio Vista Camp	Burdick & Burdick			160	4					
169	Ysleta Station, 2.5 miles SE. of.	Lee Crews Estate					5.75				12	
170	Ysleta Station, 8 miles E. of.	C. A. Campbell	C. A. Campbell			600	6			3.0	368.6	Apr. 10, 1936
171	Clint Station, 3 miles N. of.	E. R. Ardoin			3,648	16	2				14	Apr. 24, 1936
172	Clint Station, 1.2 miles NE. of.	Town of Clint	Burdick & Burdick	1936		190						
173	Clint Station, 7.4 miles NNE. of.			Old	4,015	400+	6			.0	349.70 351.64	Apr. 10, 1936 June 30, 1937
174	Clint Station, 12.4 miles NE. of.	Lee Crews Estate			4,056	600	6	425	25		383.38	Apr. 10, 1936
175	Clint Station, 16.7 miles NE. of.	John Helms									700	
176	Clint Station, 14.2 miles NE. of.	S. O. Roberts										
177	Clint Station, 9.5 miles NE. of.	do			4,018	400	5				362	
178	Clint Station, 13.7 miles NE. of.	do			4,082	500					470	
179	Clint Station, 12.6 miles E. of.	do		1915	4,028	638	8			.0	399.97 400.92 399.61	Apr. 2, 1936 June 29, 1937 July 20, 1938
180	Clint Station, 8.5 miles SE. of.	San Felipe Ranch			3,789.5	241+	5.5			.0	162.46	July 11, 1936
181	Fabens	Fabens Water Co. well 1.	Burdick & Burdick	1933		218	6				26.24	July 8, 1938
182	do	Fabens Water Co. well 2.	do	1938		218	6					

No.	Method of lift[2]	Capacity of pump (gallons per minute)	Yield under test (gallons per minute)	Amount of draw-down (feet)	Use of water[3]	Temperature (°F.)	Remarks
167	DW, 3 hp						
168							
169	C				D, S		
170	None				None		Originally drilled as an oil test. Measuring point at top of casing.
171					D		
172	None				None		Abandoned. Drilled as a test well for town supply. Highly mineralized.
173	None				D, S		Measuring point at top of casing. A new well 50 feet N. of old well was measured in 1937. Measuring point was top of casing, 2 inches above measuring point on old well.
174	DW				None		Measuring point at pump support.
175	DW				S		Well draws from limestone.
176	None				None		Abandoned. Well draws from limestone.
177	DW	12			D, S		
178	DW				S		Measuring point at ground. Well draws from limestone.
179	DW				S		Measuring point at top of casing.
180	None				None		Do.
181	T, 15 hp	260			P		
182	T, 15 hp	260			P		

[1] Measuring points designated are those used after July 1935.
[2] AL, air lift; C, centrifugal pump; DW, deep well cylinder operated by steam, wind, gasoline engine, electric motor, or hand; T, deep-well turbine; hp., horsepower.
[3] D, domestic; Ind, industrial; P, public supply; R, railroad; S, stock.
[4] See table of depth-to-water measurements.

HAND-BORED TEST WELLS

Records of wells in Rio Grande Valley near El Paso

[Data obtained by Works Progress Administration, Project 1669 under the supervision of Robert H. Colvin]

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
1	Hills-Sutton Co., 51.5 feet north of, 67.4 feet south of south rail of spur.	3,701.24	Jan. 14 Apr. 27	6.00 5.45	3,695.24 3,695.79	Yes.
2	First St., 4.3 feet south of second pole south of; 66 feet west of railroad to El Paso Cotton Mill.	3,702.97	Jan. 14 Apr. 27	6.85 7.56	3,696.12 3,695.41	Yes.
3	Bowie High School, at bend in railroad northeast of school, 11 feet west of first pole west of fence.	3,704.31	Jan. 14 Apr. 27	6.86 7.49	3,697.45 3,696.82	Yes.
4	Bowie High School, southeast corner of grounds of, 39 feet north of Franklin Canal.	3,705.11	Jan. 14 Apr. 27	6.81 7.23	3,698.30 3,697.88	Yes.
5	El Paso Cotton Mills, 3.4 feet south of fence west of.	3,705.64	Jan. 14 Apr. 27	5.10 5.36	3,700.54 3,700.28	Yes.
6	Road to Peyton Packing Co., 100 feet south of, 3.7 feet east of first power-line pole west of railroad.	3,703.02	Jan. 14 Apr. 27	2.62 2.77	3,700.40 3,700.25	Yes.
[2]7	Road to north at well 6, on west side, 9 feet north of fifth pole on east side railroad embankment.	3,702.89	Jan. 15 Apr. 27	4.49 4.65	3,698.40 3,698.24	Yes.
8	Fourth St., southwest corner at railroad to El Paso Cotton Mills, 4 feet east of fence line.	3,703.75	Jan. 16 Apr. 27	6.97 7.57	3,696.78 3,696.18	Yes.
9	International boundary marker	3,697.97	Jan. 16 Apr. 27	2.15 2.31	3,695.82 3,695.66	Yes.
10	West side of canal, 5 feet east of first pole south of railroad bridge on track to Texas & Pacific R.R. shops.	3,703.97	Apr. 27	8.02	3,695.95	Yes.
11	Texas & Pacific R.R. shops, 3 feet west of first pole east of, on south side of tracks.	3,703.72	Apr. 27	7.52	3,696.20	Yes.
12	International boundary marker 2	3,701.23	Jan. 17 Apr. 27	5.18 5.63	3,696.05 3,695.60	Yes.
[3]13	Peyton Packing Co., north corner of	3,700.50	Jan. 17	3.57	3,696.93	Yes.
14	Southeast corner of Peyton Packing Co., outside of fence and on boundary.	3,698.93	Feb. 17 Apr. 27	2.16 1.72	3,696.77 3,697.21	Yes.
15	0.2 mile north of well 8 on east side of railroad and on west side of road.	3,702.85	Apr. 27	5.81	3,697.04	
16	San Antonio St., first pole east of Heafield St., on south side.	3,701.87	Feb. 17 Apr. 27	6.36 6.38	3,695.51 3,695.49	Yes.
17	Southeast corner Cotton and San Antonio Sts., 16 feet west of first pole east of Cotton St.	3,704.40	Feb. 17 Apr. 27	8.95 9.38	8,695.45 3,695.02	Yes.
18	Southeast corner, Myrtle and Dallas Sts.	3,702.45	Apr. 27	7.43	3,695.02	Yes.
19	Cotton St., 3 feet north of first pole north of Bassett St.	3,704.07	Feb. 17 Apr. 27	8.88 9.15	3,695.19 3,694.92	Yes.
20	Williams St., east side, south of Southern Pacific tracks, 3 feet east of fire plug.	3,703.05	Feb. 17 Apr. 27	8.15 8.04	3,694.90 3,695.01	Yes.
21	Cotton St., east side, south of Southern Pacific tracks, opposite elevator, 25 feet east of street.	3,703.80	Apr. 27	8.67	3,695.13	Yes.
22	Williams St., at loading platform, midway between two poles on east.	3,703.67	Apr. 27	8.62	3,695.05	Yes.
23	Wyoming St., north side, 50 feet west of Walnut St.	3,703.33	Apr. 27	9.01	3,694.32	Yes.
24	International boundary, 500 feet north of monument 2.	3,700.41	Apr. 27	4.95	3,695.46	No.
25	International boundary, 3 feet west of Marker 6.	3,697.62	Feb. 17 Apr. 27	2.20 2.96	3,695.42 3,694.66	Yes.
26	Northeast corner Eucalyptus and Cyprus Sts., 3 feet north of first pole.	3,701.04	Feb. 17 Apr. 27	6.38 7.29	3,694.66 3,693.75	Yes.
27	Laurel St., at southwest corner of alley between San Antonio and Olive Sts.	3,701.59	Feb. 17	6.50	3,695.09	Yes.
28	Southeast corner of Magoffin and Eucalyptus Sts., 3 feet south of pole.	3,701.95	Apr. 27	7.82	3,694.13	Yes.
29	Alley between Texas and Myrtle Sts., 3 feet east of first pole east of Eucalyptus St.	3,702.79	Feb. 17 Apr. 27	8.20 8.33	3,694.59 3,694.46	Yes.

See footnotes at end of table.

Records of wells in Rio Grande Valley near El Paso—Continued

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
30	Eucalyptus St., in hole about 100 feet south of Southern Pacific tracks.	3,701.79	Apr. 27	7.11	3,694.68	Yes.
31	Southern Pacific tracks, south side, 3 feet west of first pole east of block signal 8273.	3,701.61	Apr. 27	7.40	3,694.21	Yes.
32	Palm St., west side, at first pole north of Myrtle St.	3,702.77	Apr. 30	9.35	3,693.42	Yes.
33	International boundary marker 2, 500 feet south of.	3,699.07	Apr. 27	3.04	3,696.03	No.
34	Northwest corner of Olive and Palm Sts.	3,700.23	Apr. 27	7.05	3,693.18	Yes.
35	South corner of Piedras and Central Sts.	3,700.44	Filled	-------	----------	Yes.
36	On international boundary, 440 feet east of Texas Co., 3 feet east of customs warning sign.	3,696.89	Feb. 19 Apr. 27	2.25 3.52	3,694.64 3,693.37	Yes.
[4]37	International boundary marker 7, 3 feet west of.	3,695.49	Feb. 17	1.83	3,693.66	Yes.
38	San Marcial St., west side, 2.5 feet south of first pole north of San Antonio St.	3,701.03	Apr. 28	8.47	3,692.56	Yes.
39	San Marcial St., west side, 3 feet south of pole south of alley.	3,701.07	Apr. 28	8.80	3,692.27	Yes.
40	San Marcial St., west side, 2.5 feet south of first pole south of Durazno St.	3,699.53	Apr. 28	8.37	3,691.16	Yes.
41	San Marcial St., west side, at southwest corner of alley between Oro and Madera Sts.	3,701.02	Apr. 28	10.30	3,690.72	Yes.
42	Alley between Madera and Manzana Sts., south side, 3 feet south of first pole west of Luna.	3,699.57	Apr. 28	9.22	3,690.35	No.
43	Luna St., southwest corner at Southern Pacific tracks.	3,699.20	Apr. 28	8.61	3,690.59	Yes.
[4]44	International boundary marker 8, 4 feet south of.	3,695.25	Feb. 17 Mar. 4	2.90 3.75	3,692.35 3,691.50	Yes.
[4]45	International boundary marker 9, 3 feet west of.	3,695.28	Mar. 4	3.30	3,691.98	Yes.
46	Southwest corner Copia and Alameda Sts., 75 feet south of Alameda. 2.5 ft., south of tree.	3,699.86	Feb. 17 Apr. 28	9.03 9.46	3,690.83 3,690.39	Yes.
47	Northwest corner Copia St. at Southern Pacific tracks.	3,697.59	Apr. 28	7.31	3,690.28	Yes.
48	Middle of vacant lot next to 3826 Manzana St.	3,698.60	Apr. 28	8.37	3,690.23	Yes.
49	Alley between Alameda and Pera Sts., on west side of Travis St.	3,699.02	Mar. 4 Apr. 28	8.65 9.03	3,690.37 3,689.99	Yes.
50	International boundary, at marker 12	----------	----------	-------	----------	Yes.
51	Latta St., west side, at canal	3,700.61	Mar. 4 Apr. 28	10.79 9.74	3,689.82 3,690.87	Yes.
52	Hammett St., east side, 300 feet north of levee.	3,699.42	Mar. 4 Apr. 28	4.83 5.14	3,694.59 3,694.28	Yes.
[4]53	International boundary marker 10, 3 feet west of.	3,695.21	Mar. 4	3.81	3,691.40	Yes.
[5]54	In old river channel, at second new monument.	----------	----------	-------	----------	Yes.
[5]55	In old river channel, at third new monument (stamped 1130.659).	----------	----------	-------	----------	Yes.
56	On east side Hammett Blvd. in cut on north side of old levee.	3,696.42	Mar. 4 Apr. 28	3.93 3.54	3,692.49 3,692.88	Yes.
[4]57	East side Hammett Blvd., 2 feet south of drainage ditch.	3,696.81	Mar. 4	4.96	3,691.85	Yes.
58	East side Hammett Blvd., 1,800 feet north of No. 56, 2 feet north of first pole.	3,699.80	Mar. 4 Apr. 28	8.38 8.52	3,691.42 3,691.28	Yes.
59	Southeast corner Hammett Blvd. and Rivera St.	3,697.97	Mar. 4 Apr. 28	7.55 7.65	3,690.42 3,690.32	Yes.
60	Hammett Blvd., at first pole north of Frutas St., between pole and fence.	3,698.40	Mar. 4 Apr. 28	8.95 9.01	3,689.45 3,689.39	Yes.
[5]61	At International Boundary Commission right-of-way marker 81+27.04, 2 feet east of pipe.	----------	----------	-------	----------	Yes.
[5]62	City Disposal plant, at first pole north of.	----------	----------	-------	----------	Yes.
[5]63	In park, at southwest corner of buffalo pen.	----------	----------	-------	----------	Yes.
64	At west entrance to park, on south side of road.	3,699.27	Apr. 28	8.45	3,690.82	Yes.

See footnotes at end of table.

Records of wells in Rio Grande Valley near El Paso—Continued

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
65	East side Boone Ave., 25 feet east of streetcar tracks, 6 feet south of alley between Alameda and Pera Sts.	3,697.71	Apr. 28	8.44	3,689.27	Yes.
66	Northeast corner Rosa and Boone Sts., 2.5 feet east of first pole.	3,696.93	Mar. 4 Apr. 27	7.82 7.94	3,689.11 3,688.99	Yes.
67	Northwest corner Rosa and Roosevelt Sts., 2.5 feet north of first pole on north-south power line.	3,696.47	Mar. 4 Apr. 27	7.94 8.14	3,688.53 3,688.33	Yes.
68	At northeast gate to park, 2.5 feet west of west gate post.	3,698.75	Apr. 27	9.57	3,689.18	Yes.
69	In Park, 81 feet west of East Park Rd., 57 feet south of Dunne Blvd., 2.5 feet south of light pole.	3,697.95	Apr. 27	7.51	3,690.44	Yes.
[6]70	On east side of park, 67 feet east of road, 40 feet south of canal.	3,696.80	Apr. 27	2.56	3,694.24	Yes.
[7]71	In park, on west side of East Park Rd., 6 feet south of line of trees at south side of lake.	3,699.43	Apr. 27	5.25	3,694.18	Yes.
72	Disposal plant, 72 feet south of, on north side of embankment, 30 feet east of metal culvert.	3,694.91	Apr. 27	3.61	3,691.30	Yes.
[5]73	Southeast of city dump, northeast of intersection of old and new levees.	----------	----------	-------	----------	Yes.
74	West side of Hadlock Place, at first pole south of Alameda.	3,697.37	Apr. 27	8.25	3,689.12	Yes.
75	In front of Burleson School, between first and second trees (from west).	3,696.79	Apr. 27	7.79	3,689.00	Yes.
76	Southwest corner Alameda and Val Verde Sts., at pole.	3,697.70	Apr. 27	8.25	3,689.45	Yes.
77	West side of Hadlock Pl., 3 feet south of last pole.	3,699.93	Apr. 27	8.77	3,691.16	Yes.
78	Hadlock Place, two blocks south of canal, at T-road on northeast corner.	3,697.31	Apr. 27	5.72	3,691.59	Yes.
79	Street two blocks west of Val Verde Ave., 3 feet south of last pole on west side of street.	3,695.83	Apr. 27	4.5	3,691.28	Yes.
80	Southwest corner of Blanco St. and the street two blocks west of Val Verde Ave.	3,696.75	Apr. 27	6.02	3,690.73	Yes.
81	Val Verde Ave., east side, 2.5 feet south of last pole.	3,695.51	Apr. 27	4.70	3,690.81	Yes.
82	Val Verde Ave., east side, 0.2 mile south of well 81.	3,695.05	Apr. 27	4.70	3,690.35	Yes.
83	Val Verde Ave., east side, 2.5 feet south of pole opposite No. 419.	3,695.06	Apr. 27	4.56	3,690.50	Yes.
84	Val Verde Ave., east side, at first pole south of Blanco St.	3,695.72	Apr. 27	5.54	3,690.18	Yes.
85	Val Verde Ave., east side, 2.5 feet south of second pole south of canal.	3,698.98	Apr. 27	8.31	3,690.67	Yes.
86	At northeast corner of Hawkins Dairy on Southern Pacific right-of-way.	3,693.20	Apr. 27	5.58	3,687.62	No.
87	On grounds of El Paso City-County Hospital, south of Southern Pacific tracks, 2.5 feet west of first pole on north end of street east.	3,694.22	Apr. 27	6.35	3,687.87	Yes.
88	In rear of Evergreen Cemetery.	3,694.23	Apr. 27	6.45	3,687.78	Yes.
[8]89	At first pole east of northeast corner of City-County Hospital on Loose Blvd.	3,696.17	Apr. 27	-------	----------	Yes.
90	At first "Pick no Flowers" sign on U S 80, east of El Paso city limits.	3,696.50	Apr. 28	4.74	3,691.76	Yes.
91	Northeast corner Fourth St. and Texas & Pacific tracks west of canal, inside fence.	3,704.16	Feb. 17 Apr. 27	7.12 8.15	3,697.04 3,696.01	Yes.
92	Southeast corner of old Texaco refinery, 2 feet south of last post.	3,706.55	Feb. 17 Apr. 27	4.11 4.07	3,702.44 3,702.48	Yes.
93	West side of stockyards, about 50 feet northwest of southwest corner.	3,703.76	Feb. 17 Apr. 30	2.52 2.01	3,701.24 3,701.75	No.
[8]94	Southeast corner of El Paso Milling Co., 3 feet east of last post.	3,709.60	Feb. 17 Apr. 30	7.69 -------	3,701.91 ----------	Yes.
95	Southwest corner of Piedras and Magoffin Sts.	3,701.28	Feb. 17 Apr. 30	7.99 8.49	3,693.29 3,692.79	Yes.
96	Southwest corner Texas and Magnolia Sts., in rear of sign-board.	3,700.41	Feb. 17 Apr. 27	7.38 7.74	3,693.03 3,692.67	No.
[4]97	Cebado St., west side at first pole south of alley between Alameda and Frutas Sts.	3,699.49	----------	-------	----------	No.

See footnotes at end of table.

Records of wells in Rio Grande Valley near El Paso—Continued

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
98	West side of vacant lot on north side of 3200 block Rivera Street, 10 feet south of alley.	3,700.44	Apr. 30	8.63	3,691.81	No.
[6]99	South side of canal, at pole on city limits line.	3,699.84	Apr. 27	8.68	3,691.16	Yes.
100	At fence on east end of Blanco Street, in middle of street.	3,695.47	Apr. 27	5.17	3,690.30	Yes.
101	Three feet west right-of-way sta. 20+00 on south side U S 80.	3,694.79	Apr. 28	5.95	3,688.84	Yes.
102	At right-of-way Sta. 30+00 on south side U S 80.	3,693.31	Apr. 28	5.35	3,687.95	Yes.
103	At right-of-way Sta. 40+00 on south side U S 80.	3,692.69	Feb. 10 Apr. 28	5.95 4.98	3,686.74 3,687.71	Yes.
104	At right-of-way Sta. 50+00 on south side U S 80.	3,692.60	Apr. 28	5.22	3,687.38	Yes.
105	At right-of-way Sta. 61+12 on north side U S 80.	3,692.45	Feb. 10 Apr. 27	6.08 7.30	3,686.37 3,685.15	Yes.
106	At right-of-way Sta. 70+00 on south side U S 80.	3,691.94	Feb. 7 Apr. 27	5.60 5.05	3,686.34 3,686.89	Yes.
[6]107	At right-of-way Sta. 80+00 on south side U S 80.	3,689.74	Feb. 7 Apr. 27	4.43	3,685.31	Yes.
108	Mile post 825 on south side of Southern Pacific tracks, 2.5 feet east of.	3,692.98	Apr. 27	5.36	3,687.62	Yes.
109	135 feet east of Southern Pacific oil tank 2, 140 feet south of southeast corner adobe house on hill.	3,694.84	Apr. 27	8.18	3,686.66	Yes.
110	630 feet east of well 109, 85 feet west of southwest corner of board fence.	3,693.91	Apr. 27	7.54	3,686.37	Yes.
111	South side of Southern Pacific tracks, 3 feet east of first pole west of road to Air Prod. Co.	3,692.33	Apr. 27	4.99	3,687.34	Yes.
112	South end of Chelsa Dr., 2.5 feet east of first pole west of, on south side of road.	3,695.05	Apr. 27	6.89	3,688.16	Yes.
113	Colfax St., west side, 2.5 feet south of first pole north of old U S 80.	3,695.20	Apr. 27	5.35	3,689.85	Yes.
114	Southwest corner of intersection of Southern Pacific tracks and Aubrey Rd.	3,691.01	Feb. 10 Apr. 27	4.26 3.91	3,686.75 3,687.10	Yes.
115	Peyton Packing Co., south side gate, behind large bush (first gate at stockyards).	3,704.39	Apr. 27	5.29	3,699.10	No.
116	At crossing sign on railroad east of Glenwood Dr., in ditch south of tracks.	3,693.14	Feb. 6 Apr. 27	6.51 6.15	3,686.63 3,686.99	Yes.
117	Old U S 80, south side, at first pole west of intersection of Maryland Rd (?).	3,692.67	Apr. 27	4.26	3,688.41	Yes.
118	Old U S 80, south side, 0.2 mile east of well 117, at first pole on east side of curve.	3,694.18	Apr. 27	5.95	3,688.23	Yes.
[6]119	Old U S 80, south side, 0.2 mile east of well 118, 3 feet east of pole.	3,695.27	Apr. 27	3.75	3,691.52	Yes.
120	Southwest corner Second Ave., and old U S 80, 2.5 feet west of pole.	3,695.96	Apr. 27	10.12	3,685.84	Yes.
121	4th Ave. and U S 80					Yes.
122	On city limits, 75 feet south of Stephenson St.	3,694.92	Apr. 27	7.58	3,687.34	Yes.
123	0.2 mile northwest of well 122, 3 feet east of third pole in depression on northernmost city line.	3,696.82	Apr. 27	10.28	3,686.54	Yes.
124	East end Durazno St., 3 feet north of "Dump no trash" sign on north side of street.	3,695.41	Apr. 27	7.74	3,687.67	Yes.
125	West side Madison Street, 2 feet west of pole below rim.	3,700.34	Apr. 27	13.31	3,687.03	Yes.
126	Manzana Ave., at third pole west of Madison St.	3,698.13	Apr. 27	10.45	3,687.68	Yes.
127	Southeast corner Crockett St. and Manzana Ave., 1.5 feet west of Crockett St., 17 feet from fence.	3,702.78	Mar. 4 Apr. 27	13.96 13.98	3,688.82 3,688.80	Yes.
128	On U S 80, at Ascarate, 3 feet east of first pole in second section of parking.	3,693.50	Feb. 7 Feb. 10 Apr. 27	7.26 7.10 7.67	3,686.24 3,686.40 3,685.83	Yes.
[6]129	North side of old U S 80, 50 feet east of Cottonwood St., 25 feet northeast of road.	3,691.27	Feb. 7 Apr. 27	4.65 3.67	3,686.62 3,687.60	Yes.

See footnotes at end of table.

Records of wells in Rio Grande Valley near El Paso—Continued

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
130	Alley 160 feet west of Fivemile Bridge, 3 feet west of first pole west of.	3,694.23	Feb. 7 Apr. 27	7.63 8.44	3,686.60 3,685.79	Yes.
131	2 feet west of pole on southwest corner of intersection, Second Ave. and the second street south of Old U S 80.	3,691.72	Feb. 10 Apr. 27	6.00 5.10	3,685.72 3,686.62	Yes.
132	On Glenwood Drive between old and new U S 80, 3 feet north of pole in front of yellow house.	3,693.43	Feb. 6 Apr. 28	6.58 5.86	3,686.85 3,687.57	Yes.
133	West side Glenwood Drive, 3 feet north of fifth pole, south of U S 80.	3,692.85	Feb. 6 Apr. 28	5.80 4.86	3,687.05 3,687.99	Yes.
134	West side Glenwood Drive, 3 feet south of 13th pole south of U S 80.	3,692.33	Feb. 6 Apr. 28	5.18 3.20	3,687.15 3,689.13	Yes.
135	West side Glenwood Drive 2.5 feet south of pole 120 feet north of Model Dairy sign.	3,691.42	Feb. 6 Apr. 28	4.21 4.22	3,687.21 3,687.20	Yes.
136	West side Glenwood Drive, 2.5 feet south of fifth from last pole.	3,692.47	Feb. 6 Apr. 28	4.90 3.88	3,687.57 3,688.59	Yes.
137	West side Glenwood Drive 3 feet south of last pole.	3,691.69	Feb. 6 Apr. 28	4.27 3.55	3,687.42 3,688.14	Yes.
138	South end Pendell St. Southeast corner seepage ditch and levee.	3,690.49	Feb. 6 Apr. 27	4.27 2.14	3,686.22 3,688.35	Yes.
139	0.2 mile north of new levee, at intersection east of Glenwood Drive on west side old levee at T-road east.	3,691.16	Feb. 6 Apr. 27	4.25 4.05	3,686.91 3,687.11	Yes.
140	0.2 mile north of well 139, 30 feet east of old levee.	3,690.40	Feb. 6 Apr. 27	3.68 4.74	3,686.72 3,685.66	Yes.
[4]141	0.2 mile north of well 140 on west side of old levee, 270 feet north of T-road east.	3,688.98	Feb. 7 Apr. 27	2.27	3,686.71	Yes.
142	0.4 mile north of well 140, 75 feet east of old levee.	3,687.93	Feb. 7 Apr. 27	1.61 Dry	3,686.32	Yes.
143	West side of First Ave., 0.2 mile south of U S 80, 1.5 feet east of fence.	3,691.44	Feb. 7 Apr. 28	6.00 5.24	3,695.44 3,686.20	Yes.
144	West side of First Ave., 0.4 mile south U S 80, 1 foot east of fence.	3,690.90	Apr. 28	5.69	3,685.21	Yes.
145	South end First Ave., 1.5 feet north of International Boundary Commission monument 14, in old channel.	3,690.88	Apr. 28	6.59	3,684.29	Yes.
146	West side of Aubrey Rd., 0.2 mile south of U S 80.	3,692.70	Feb. 10 Apr. 28	5.77 4.34	3,686.93 3,688.36	Yes.
147	In center of Aubrey Rd., at south end.	3,691.87	Feb. 10 Apr. 28	4.90 3.12	3,686.97 3,688.75	Yes.
148	0.2 mile south of well 147 under fence.	3,691.13	Feb. 10 Apr. 28	4.45 2.69	3,686.68 3,688.44	Yes.
149	0.4 mile south of well 147, in field, 25 feet south of east west irrigation ditch.	3,691.26	Feb. 10 Apr. 28	4.24 3.96	3,687.02 3,687.30	Yes.
150	Maryland Rd., south end, 0.2 mile south U S 80.	----------	Feb. 10 Apr. 27	5.34 3.85	----------	Yes.
151	South end Collingsworth Rd., on northwest corner.	3,690.60	Feb. 10 Apr. 28	3.86 2.48	3,686.74 3,688.12	Yes.
152	Pendell St., south end ----------	3,692.91	Apr. 27	5.51	3,687.40	Yes.
153	Walker St., south end ----------	3,688.07	Feb. 10 Apr. 27	0.86 1.57	3,687.21 3,686.50	Yes.
154	First Ave., north of levee, on north property line of last house on west side.	3,691.68	Feb. 10 Apr. 27	5.72 5.67	3,685.96 3,686.01	Yes.
155	Fourth Ave., west side, 0.2 mile north of U S 80.	3,692.13	Feb. 10 Apr. 27	4.97 4.09	3,687.16 3,688.04	Yes.
156	Northeast corner El Paso Natural Gas Co. on U S 80.	3,692.98	Feb. 10 Apr. 27	8.47 8.06	3,684.51 3,684.92	Yes.
157	South side U S 80, 10 feet south of 2d pole, east Gateway Coffee Shop sign.	3,688.05	Feb. 10 Apr. 27	4.26 3.85	3,683.79 3,684.20	Yes.
158	On north side of new levee, 0.2 mile east of well 73.	3,696.07	Apr. 28	6.41	3,689.66	Yes.
159	On north side of new levee, 0.4 mile east of well 73.	3,693.82	Apr. 28	5.02	3,688.80	Yes.
160	On north side of new levee, 0.6 mile east of well 73, at International Boundary Commission Sta., 98-47.66.	3,695.63	Apr. 28	6.98	3,688.65	Yes.
161	East of Glenwood Dr., in fence corner in middle of old channel north of new levee.	3,692.14	Feb. 14 Apr. 27	2.77 4.09	3,689.37 3,688.05	Yes.
[5]162	On Maryland Rd., 0.2 mile north of U S 80.	----------	----------	----------	----------	Yes.
163	On Aubrey Rd., 0.2 mile north of U S 80.	3,692.81	Apr. 28	5.31	3,687.50	Yes.

See footnotes at end of table.

Records of wells in Rio Grande Valley near El Paso—Continued

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
164	(No well)					
165	0.2 mile south of U S 80, on road through field, 15 feet north of first tree on west. (Road south at ROW Sta. 10+5.)	3,693.57	Apr. 28	4.47	3,689.10	Yes.
166	0.4 mile south of U S 80 on above road, across bridge, in hole west of road.	3,692.15	Apr. 28	3.24	3,688.91	Yes.
167	0.6 mile south U S 80 on west side of above road, on side of ditch.	3,695.71	Apr. 28	6.38	3,689.33	Yes.
168	0.8 mile south of U S 80, west of above road, 20 feet south of large tree.	3,693.84	Apr. 28	4.24	3,689.60	Yes.
[4]169	East of intersection of levees south of city dump.	3,694.51	Apr. 28	------	----------	Yes.
170	In embankment south of city dump, at middle of curve on north side.	3,694.87	Apr. 30	3.38	3,691.49	Yes.
[4]171	Northeast of intersection of levee and sewer line southwest of city dump.	3,695.33	Apr. 30	------	----------	Yes.
172	0.2 mile east of intersection of new levee and old Mexican Railroad embankment, east of well 161, on south side of new levee.	3,692.13	Feb. 14 Apr. 28	4.73 3.73	3,687.40 3,688.40	Yes.
173	On south side new levee, 0.2 mile east of well 172.	3,690.03	Feb. 14 Apr. 28	3.64 2.68	3,686.39 3,687.35	Yes.
[4]174	On south side new levee, 0.4 mile east of well 172.	3,689.32	Feb. 14 Apr. 28	3.92	3,685.40	No.
175	Northwest of intersection of Ascarate spillway and slough north of new levee.	3,686.19	Feb. 14 Apr. 28	4.97 4.42	3,681.22 3,681.77	Yes.
176	In open field 1,000 feet east of well 144 (First Ave.).	3,690.75	Apr. 28	6.02	3,684.73	Yes.
177	1.5 feet east of, International Boundary Commission marker 11, in river channel west of First Ave.	3,691.52	Apr. 28	6.12	3,685.40	Yes.
178	On south side of old railroad embankment, 0.35 mile west of east end.	3,690.41	Feb. 14 Apr. 28	5.46 5.59	3,684.95 3,684.82	Yes.
179	0.4 mile north of old railroad embankment, along dirt road north at well 180, on west side.	3,691.67	Apr. 28	6.59	3,685.08	Yes.
180	On north side of railroad embankment, 0.15 mile west of east end.	3,689.10	Feb. 14 Apr. 28	5.22 5.33	3,683.88 3,683.77	Yes.
181	At east end of old railroad embankment.	3,687.30	Feb. 14 Apr. 28	4.53 4.13	3,682.77 3,683.17	Yes.
182	On east side of old railroad embankment, 0.2 mile north of new levee.	3,692.46	Apr. 27	5.91	3,686.55	Yes.
183	On south side of old railroad embankment, 0.4 mile north of new levee.	3,691.85	Apr. 27 Apr. 28	6.10 6.14	3,685.75 3,685.71	Yes.
184	About 1,000 feet (paced) east of well 182, on line parallel to new levee.	3,691.13	Apr. 27	4.58	3,686.55	
185	About 1,000 feet (paced) from well 183 on line parallel to new levee.	3,691.42	Apr. 28	6.36	3,685.06	Yes.
186	About 1,000 feet (paced) from well 184, on line parallel to new levee.	3,690.34	Apr. 27	5.69	3,684.65	Yes.
187	From midpoint between wells 178 and 180, south 500 feet along a line at right angle to embankment.	3,690.15	Apr. 27	5.99	3,684.16	Yes.
188	About 1,000 feet from levee, south at right angle at well 181.	3,688.51	Apr. 29	3.27	3,685.24	Yes.
189	From midpoint between wells 180 and 181, south 6.3 feet, 1,000 feet along a line at right angle to embankment.	3,688.20	Apr. 27	4.32	3,683.88	Yes.
190	On T-road north at well 180, 0.2 mile north of embankment in fork of road.	3,689.67	Apr. 28	6.12	3,683.55	Yes.
[5]191	(No well)					
192	On east side of fence in old channel, 280 feet north of International Boundary Commission monument 50.	3,685.85	Apr. 28	3.47	3,682.38	Yes.
193	On east side old channel, on west side of indistinct road, 170 feet west of west embankment of Ascarate spillway.	3,696.93	Apr. 28	5.66	3,691.27	Yes.
194	On west side old channel, 10 feet east of International Boundary Commission bench mark stamped 3647.09.	3,687.27	Apr. 28	4.65	3,682.62	Yes.
195	800 feet east of west end of railroad embankment.	3,687.72	Apr. 28	5.24	3,682.48	Yes.

See footnotes at end of table.

Records of wells in Rio Grande Valley near El Paso—Continued

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
196	750 feet north of well 174, at right angle to new levee.	3,687.35	Apr. 27	4.39	3,682.96	Yes.
197	150 feet east of old channel, 150 feet north of T-road east, (road leads to customs sign) on west side of indistinct road.	3,688.91	Apr. 28	7.31	3,681.60	Yes.
198	Northeast corner of Piedras and Durazno Sts.	3,701.89	Apr. 28	9.42	3,692.47	Yes.
199	Southeast corner of Manzana and Raynor Sts.	3,700.66	Apr. 28	8.87	3,691.79	Yes.
200	Southeast corner of Piedras and Madera Sts.	3,702.05	Apr. 28	9.62	3,692.43	No.
201	1.5 feet west of first pole in alley between Oro and Madera Sts., east of Raynor.	3,701.67	Apr. 28	10.58	3,691.09	Yes.
202	Southwest corner of Cebada and Oro Sts., 3 feet south of pole.	3,701.04	Apr. 28	10.59	3,690.45	No.
203	Southeast corner of White Oaks and Estrella Sts.	3,705.16	Apr. 27	15.02	3,690.14	No.
204	Northeast corner of White Oaks and Luna Sts.	3,703.97	Apr. 28	13.97	3,690.00	Yes.
205	Southwest corner of Willow and Wyoming Sts.	3,704.67	Apr. 27	10.05	3,694.62	Yes.
[10]206	Missouri St., at second pole east of railroad crossing (pole 23330).	3,702.78	Apr. 27	-------	---------	Yes.
207	Missouri St., 1.5 feet west of first pole east of Walnut St.	3,701.78	Apr. 27	7.60	3,694.18	Yes.
208	Southeast corner of Palm and Wyoming Sts.	3,702.72	Apr. 27	8.67	3,694.05	No.
209	Northwest corner of Poplar and Wyoming Sts.	3,704.37	Apr. 27	[11]6.92	3,697.45	No.
210	Missouri St. at first pole east of Magnolia St.	3,703.33	Apr. 28	9.75	3,693.58	Yes.
211	Missouri St. at first pole west of Maple St.	3,704.96	Apr. 27	12.38	3,692.58	Yes.
212	50 feet north of second side embankment from east end of old railroad embankment.	3,690.40	Apr. 28	5.55	3,684.85	No.
213	50 feet north of third side embankment from east end of old railroad embankment.	3,691.25	Apr. 27	[11]5.93	3,685.32	Yes.
[12]214	750 feet east of well 177 by fence in middle of old river channel.	3,692.41	Apr. 27	-------	---------	Yes.
215	250 feet east of well 177 by fence in middle of old river channel.	3,691.14	Apr. 28	5.91	3,685.23	Yes.
216	500 feet east of well 177, by fence in middle of old river channel.	3,691.35	Apr. 28	6.32	3,685.03	Yes.
217	250 feet east of well 145, by fence in middle of old river channel.	3,690.99	Apr. 28	6.52	3,684.47	Yes.
218	At base of rim in arroyo, 200 feet east of Chelsa Drive.	3,698.57	Apr. 27	12.71	3,685.86	No.
219	At base of rim in arroyo, 0.2 mile east of Chelsa Drive.	3,708.48	Apr. 27	22.89	3,685.59	No.
220	At fence in old pit on north side of railroad at Fivemile Bridge (north side of pit).	3,714.76	Apr. 27	27.53	3,687.23	No.
221	East of Southern Pacific oil tanks, at southeast corner of dairy property.	3,698.77	Apr. 27	12.42	3,686.35	No.
222	North side of North Loop Rd. at base of rim, 0.2 mile east of Ascarate.	3,698.85	Apr. 28	12.35	3,686.50	No.
223	On south side of North Loop Rd., 0.6 mile east of Ascarate.	3,696.77	Apr. 28	10.89	3,685.88	No.
224	Southwest corner of North Loop Road and T-road south.	3,690.22	Apr. 28	3.83	3,686.39	Yes.
225	Northwest corner of Copia and Rivera Sts.	3,697.79	Mar. 4 Apr. 28	6.57 6.60	3,691.22 3,691.19	
226	(No well.)	---------	---------	-------	---------	
[13]227	200 feet north of North Loop Rd. in fence corner, 1.25 mile east Ascarate.	3,695.19	Apr. 28	11.10	3,684.09	No.
[13]228	On west side T-road north, 1.45 miles east of Ascarate, 2 feet east of pole.	3,690.34	Apr. 28	7.40	3,682.94	No.
229	(No well.)	---------	---------	-------	---------	
[13]230	On east side of road to El Paso Dairy, 3 feet south of first pole.	3,690.35	Apr. 28	8.70	3,681.65	No.
231	(No well.)	---------	---------	-------	---------	
232	In field on west side Glenwood Drive, 800 feet west and 700 feet north of well 140.	3,694.06	Apr. 28	5.79	3,688.27	Yes.

See footnotes at end of table.

Records of wells in Rio Grande Valley near El Paso—Continued

No.	Location	Altitude[1] of measuring point (feet above sea level)	Date of measurement (1936)	Depth to water level (feet)	Altitude of water level (feet above sea level)	Water sampler
233	About 1,000 feet north of well 232, in same field and 30 feet east of tree.	3,694.16	Apr. 28	6.03	3,688.13	Yes.
234	About 1,000 feet north of well 233, in same field and 30 feet east of tree.	3,694.29	Apr. 28	5.32	3,688.97	Yes.
235	(No well.)					
236	On east side of Ascarate spillway, 60 feet north of south end of concreted ditch.	3,689.43	Apr. 27	6.79	3,682.64	Yes.
237	On east side of Ascarate spillway, 700 feet south of well 236.	3,688.62	Apr. 27	5.87	3,682.75	Yes.
238	On east side Ascarate spillway, 925 feet south of well 237 at Mexican house.	3,687.54	Apr. 27	5.61	3,681.93	Yes.
239	On east side Ascarate spillway, 1,190 feet south of well 238.	3,686.60	Apr. 27	5.45	3,681.15	Yes.
240	On east side Ascarate spillway at wooden ditch-gate, 1,220 feet south of well 239.	3,687.26	Apr. 27	5.94	3,681.32	Yes.
241	Along lateral, 750 feet east of well 240, 7.5 feet east of last tree.	3,686.00	Apr. 27	4.61	3,681.39	Yes.
242	Northeast corner of Wyoming and Cotton Sts.	3,705.11	Apr. 27	9.91	3,695.20	No.
243	In northern part of gravel pit west of Highway Dept. Building.	3,701.37	Apr. 27	15.55	3,685.82	No.
[5]244	On International boundary south of Peyton Packing Co., on north side of slough.					Yes.
[5]245	Southeast corner of Poplar and Missouri Sts.					Yes.
[5]246	South side of Southern Pacific R.R. tracks at Poplar St.					Yes.
[5]247	South side of old U S 80 at second pole west of Prati store.					Yes.

[1] Measuring point was top of 1-inch casing at ground level.
[2] Pipe stolen June 17, 1936.
[3] Pipe stolen. Depth to water probably in error.
[4] Pipe stolen.
[5] Pipe stolen before levels were run.
[6] Water level high because of canal.
[7] Water level high because of lake.
[8] Filled with sand.
[9] Covered in grading river bank.
[10] Hole dry.
[11] Depth to water probably in error
[12] Dry at 6.2 feet.
[13] Beyond east limit of map.

Analyses of water from hand-bored test wells in Rio Grande Valley near El Paso

[Parts per million. Well numbers correspond to numbers in table of hand-bored test wells. Analyzed under direction of E. P. Schoch, University of Texas (W.P.A. Project 1669)]

No.	Date of collection (1936)	Total dissolved solids (calculated)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K) (calculated)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
	January								
1	6				310	240	40	440	200
2	6				230	310	430	180	440
3	3				320	1,100	430	230	450
4	6				520	500	560	390	410
5	3				360	540	260	320	370
6	6				370	280	430	400	430
7	6				250	270	360	280	460
8	6				430	650	630	380	790
9	6				220	290	260	180	420
10	6				230	490	270	180	430
11	3				600	400	1,000	400	670
12	3				430	590	590	480	840
13	3				290	470	290	580	870
14	3				180	220	280	210	360
16	3				420	400	1,100	1,200	2,200
17	6				160	370	210	110	290
18	6				400	460	0	600	340
19	6				370	370	500	360	510
20	6				270	410	120	150	78
21	6				400	520	280	220	160
22	6				110	510	100	78	410
23	6				220	420	480	380	600
25	8				490	390	810	550	870
26	8				260	450	150	190	230
27	8				3,100	750	1,000	3,900	410
28	8				960	560	1,100	3,000	3,700
29	8				610	810	320	240	160
30	8				720	650	190	880	390
31	8				1,400	440	610	1,600	130
32	8				840	600	470	1,000	600
34	10				440	440	620	490	740
35	10				1,100	320	270	1,600	390
36	10				240	320	590	240	700
37	10	1,500	240	43	220	390	480	310	790
38	10	3,400	100	110	970	740	990	860	720
39	10	2,600	340	55	510	560	640	760	1,100
40	10	900	37	56	110	660	0	370	320
41	10	9,800	480	180	3,000	640	950	4,900	1,900
43	10	2,500	200	43	660	480	580	800	680
44	10	3,400	380	65	740	620	890	980	1,200
45	10	2,700	390	100	420	580	940	590	1,400
46	10	1,800	68	28	580	560	370	490	280
47	10	3,400	320	67	820	680	1,000	880	1,100
48	10						1,600	2,600	
49	13	1,400	150	28	340	470	370	320	480
50	13	1,600	200	43	300	350	480	380	680
51	13	2,200	260	75	420	410	800	500	960
52	13	1,000	140	24	20	340	140	500	460
53	13	14,000	960	690	3,000	1,200	3,200	5,300	5,300
54	13	1,600	160	21	370	320	420	420	490
55	13	1,000	120	14	230	290	360	160	360
56	14	820	76	14	200	270	250	140	240
57	14	940	110	21	210	320	230	210	360
58	14	7,600	440	160	4,700	400	1,100	970	1,800
59	14	850	130	21	140	160	300	190	400
60	14	1,200	130	16	320	490	330	240	400
61	14	1,000	230	16	120	430	230	220	650
62	14	1,300	150	26	300	440	240	360	480
63	14	1,300	120	33	300	210	440	330	440
64	14	990	110	21	210	130	360	230	360
65	15	1,100	120	21	240	300	340	220	400
66	15	5,400	150	110	1,700	580	1,300	1,900	840
67	15	3,800	280	70	1,000	550	890	1,200	1,000
68	15	720	72	11	200	170	76	270	220
69	30	1,100	130	31	240	510	240	210	440
70	30	1,400	100	21	370	390	400	290	400
71	30	960	54	23	250	150	360	190	230
72	16	1,400	140	18	330	410	430	260	430
73	16	990	140	26	190	320	190	290	460
74	16	6,800	780	270	1,400	780	700	3,400	3,200
75	30	1,600	170	36	370	430	520	340	560
76	30	2,200	230	74	460	500	800	440	880
77	30	2,700	360	74	500	600	730	730	1,200
78	30	1,700	240	48	300	500	560	340	800

Analyses of water from hand-bored test wells in Rio Grande Valley near El Paso—Con.

No.	Date of collection (1936)	Total dissolved solids (calculated)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K) (calculated)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
79	30	2,600	310	65	520	610	900	520	1,000
80	30	1,400	150	33	320	350	360	380	520
81	16	1,900	240	43	340	390	520	440	760
82	16	1,300	120	19	400	470	380	190	380
83	16	2,100	130	23	570	420	960	220	420
84	30	2,100	270	74	430	420	550	590	980
85	30	1,600	130	33	400	430	480	340	460
87	30	2,300	340	70	360	370	600	700	1,100
88	30	2,500	240	48	610	520	710	670	780
89	30	2,400	220	38	590	610	800	460	720
90	30	970	120	14	160	230	400	160	340
91	30	1,700	170	28	430	490	400	460	530
92	30	1,100	120	33	250	380	320	230	440
94	30	980	110	35	200	350	270	200	420
95	30	3,800	310	50	1,000	800	830	1,200	980
99	21	1,200	190	33	200	200	410	260	620
100	21	2,100	160	31	580	670	550	430	540
101	21	5,500	200	51	1,900	360	540	2,600	720
102	21	2,100	220	51	500	340	690	510	780
103	21	1,200	100	26	310	270	350	250	380
104	21	690	60	19	200	250	140	150	230
105	21	1,000	140	16	180	180	370	220	420
106	21	1,400	180	28	350	340	400	320	560
107	13	1,200	120	16	300	180	350	300	370
108	22	2,900	330	100	590	490	1,200	500	1,200
109	22	10,000	200	62	3,500	850	2,600	3,400	760
110	22	28,000	1,800	590	8,200	530	1,800	16,000	6,900
111	22	4,500	160	38	1,500	300	710	2,000	560
112	22	1,700	88	9	520	350	540	380	260
113	22	2,300	83	27	760	580	400	760	320
114	22	1,600	48	36	480	460	420	350	260
116	23	1,100	120	26	250	380	300	240	420
117	23	2,200	370	77	330	380	710	530	1,200
118	23	2,100	28	21	730	660	590	420	160
119	23	1,100	110	21	260	240	340	240	360
120	23	1,000	100	23	230	350	280	200	360
	February								
121	3	6,200	760	320	1,200	890	650	3,100	3,200
122	3	4,300	160	55	1,400	540	920	1,600	630
123	3	5 200	69	35	1,800	570	920	2,100	320
124	3	2,800	410	70	490	500	710	860	1,300
125	3	11,000	140	62	3,700	990	3,100	3,400	610
126	3	7,100	360	200	1,900	840	2,200	2,000	1,800
127	4	6,300	250	120	1,900	440	1,000	2,800	1,100
128	4	1,200	-------	-------	370	260	300	220	36
129	4	1,400	150	50	300	380	360	320	480
130	4	1,100	140	26	250	300	360	230	440
131	4	1,400	72	15	410	400	340	320	240
132	4	3,900	250	94	1,000	790	1,200	990	1,000
133	4	1,100	170	25	120	300	340	280	530
134	4	1,000	80	20	250	280	360	160	280
135	4	2,300	210	59	510	300	860	520	770
136	4	2,700	320	66	540	790	790	550	1,100
137	4	1,100	150	28	210	350	280	260	490
138	5	1,200	140	37	270	540	190	330	500
139	5	1,200	140	30	240	280	340	280	460
140	5	1,500	140	30	370	450	330	400	480
141	5	1,200	130	30	250	280	360	280	450
142	5	1,300	190	36	260	570	320	280	620
143	5	2,000	220	42	440	680	540	400	720
144	5	1,500	130	23	390	450	320	400	420
145	6	1,400	200	42	240	350	360	380	670
146	6	2,300	400	52	380	430	780	440	960
147	6	2,300	210	52	560	620	700	500	730
148	6	2,600	140	33	730	540	900	500	490
149	6	960	54	6	300	400	210	190	160
150	6	2,000	140	25	540	540	640	380	460
151	6	3,500	180	42	1,100	1,000	460	1,200	640
152	6	3,700	390	86	790	740	940	1,100	1,300
153	6	1,200	150	25	230	300	320	280	480
154	6	2,400	260	71	480	580	790	480	930
155	6	2,700	280	100	890	740	940	1,000	1,100
156	7	1,500	160	25	340	460	440	290	490
157	7	1,000	120	28	190	220	330	220	420
158	7	1,100	150	23	220	290	270	290	460
159	7	940	97	23	240	550	84	220	340
160	7	1,800	220	40	340	380	630	360	720

Analyses of water from hand-bored test wells in Rio Grande Valley near El Paso—Con.

No.	Date of collection (1936)	Total dissolved solids (calculated)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K) (calculated)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
161	10	1,300	120	33	250	230	420	150	280
162	10	2,900	340	69	580	730	950	580	1,100
163	10	3,100	180	37	900	820	940	650	620
165	11	3,100	670	79	590	650	890	580	600
166	11	2,600	320	74	510	600	880	560	1,100
167	11	1,400	140	20	370	730	270	230	420
168	11	1,000	140	23	210	350	280	230	440
169	11	2,300	290	52	400	370	980	340	940
170	11	1,400	180	37	270	300	430	360	610
171	11	1,300	130	28	310	160	300	480	440
172	11	920	120	30	180	330	160	260	410
173	11	2,100	230	47	440	560	670	400	760
175	11	1,400	76	20	410	340	370	340	270
	March								
165	19	2,400	----	----	----	580	840	480	----
166	13	2,300	----	----	----	560	760	480	----
167	19	1,100	----	----	----	380	340	180	----
168	19	960	----	----	----	350	230	220	----
178	10	830	----	----	----	370	200	150	----
179	10	1,000	----	----	----	300	270	240	----
180	10	1,200	----	----	----	260	310	360	----
181	10	1,400	----	----	----	380	360	360	----
182	10	870	----	----	----	270	260	180	----
183	10	810	----	----	----	310	180	200	----
185	10	1,400	----	----	----	380	500	270	----
186	10	940	----	----	----	260	250	240	----
187	10	870	----	----	----	300	270	150	----
188	10	2,100	190	56	490	460	630	510	700
189	10	1,100	----	----	410	370	300	220	33
190	10	970	----	----	----	350	230	220	----
192	10	1,100	----	----	----	210	370	290	----
193	11	3,400	----	----	----	700	1,000	930	----
194	10	1,200	----	----	----	430	310	240	----
195	10	910	----	----	----	270	300	160	----
196	10	810	----	----	----	300	190	180	----
197	11	840	----	----	----	270	280	140	----
198	13	1,400	----	----	----	680	310	280	----
199	13	2,900	----	----	----	830	560	920	----
201	13	8,200	----	----	----	710	1,700	3,300	----
204	13	3,700	----	----	----	810	410	1,600	----
205	13	5,300	----	----	----	380	730	4,100	----
206	13	560	----	----	----	260	150	86	----
207	13	440	----	----	----	300	69	58	----
210	11	1,100	----	----	----	800	180	110	----
211	11	1,800	----	----	----	1,300	850	130	----
213	11	720	----	----	----	400	23	180	----
214	16	1,000	----	----	----	230	330	220	----
215	16	1,700	----	----	----	290	910	140	----
216	16	1,200	----	----	----	600	220	240	----
217	16	1,500	----	----	----	460	610	150	----
222	16	1,800	----	----	----	530	450	450	----
224	16	2,000	----	----	----	740	350	540	----
230	16	2,900	----	----	----	680	980	640	----
232	19	920	----	----	----	150	360	180	----
233	19	1,400	----	----	----	110	600	290	----
234	19	2,500	----	----	----	510	960	440	----
236	11	930	----	----	----	280	310	170	----
237	11	820	----	----	----	180	280	170	----
238	11	1,300	----	----	----	540	350	220	----
239	11	1,200	----	----	----	350	260	360	----
240	11	1,400	----	----	----	580	390	200	----
241	11	1,700	----	----	----	570	540	290	----
	January								
244	6	----	----	----	210	240	310	170	300
245	6	----	----	----	580	580	140	500	70
246	6	----	----	----	190	390	290	300	640
247	23	1,300	160	26	280	200	390	270	520

RECORDS OF SHALLOW TEST HOLES ON THE MESA

1. 5 miles east of El Paso in first depression on Carlsbad road, 10 feet north of right-of-way marker 290 + 00 on north side of Carlsbad road

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	1.9	0	Sand, very little caliche	6.55	8
Very fine sand	3.7	1	Do	5.73	9
Sandy clay	8.6	2	Coarse sand and gravel	6.92	10
Do	5.81	3	Do	2.62	11
Sandy caliche	5.27	4	Do	3.08	12
Sandy clay	6.12	5	Fine sand and gravel	3.37	13
Do	5.25	6	Do	3.49	14
Sand, very little caliche	7.04	7	Do	1.57	15

2. 160 feet south of well 1

Surface sand	2.09	0	Sandy clay	5.04	5
Sandy clay	10.19	1	Do	5.25	6
Do	6.96	2	Do	5.80	7
Do	5.68	3	Sandy caliche	5.88	8
Do	5.13	4			

3. 9 miles east of El Paso in second depression on Carlsbad road, opposite right-of-way marker 530 + 00 on south side of road

Surface sand	1.61	0	Sandy caliche	7.39	4
Sandy caliche	8.69	1	Do	6.21	5
Do	9.08	2	Do	6.07	6
Do	7.89	3	Do	6.35	7

4. 200 feet east of hole 3

Surface soil	1.350	0	Sandy caliche	7.07	8
Sandy caliche	10.5	1	Do	7.04	9
Caliche	7.88	2	Do	6.07	10
Do	13.3	3	Fine sand and caliche	4.71	11
Do	12.1	4	Do	4.02	12
Do	9.85	5	Do	3.29	13
Do	8.99	6	Very fine sand	2.93	14
Do	8.33	7			

5. 300 feet south of hole 2

Surface sand (fine)	0.88	0	Fine sand	2.36	6
Sandy clay	6.23	1	Do	1.76	7
Do	6.55	2	Sand and gravel	1.47	8
Fine caliche	5.84	3	Coarse sand and gravel	1.41	9
Do	5.94	4	Sand	2.04	10
Fine sand	2.96	5	Do	4.28	11

6. 300 feet south of hole 5

Surface sand	0.509	0	Sand, clay and caliche	5.01	6
Sand and clay	5.90	1	Sand, clay and gravel	3.76	7
Caliche	6.99	2	Sand and gravel	2.66	8
Do	6.21	3	Do	2.20	10
Sandy caliche	5.29	4	Do	2.22	10
Do	4.62	5	Coarse sand and gravel	2.49	11

7. 300 feet south of hole 6

Surface sand	0.504	0	Sand and clay	17.1(?)	7
Sand and clay	11.9	1	Fine sand	4.76	8
Sand, clay and caliche	10.7	2	Very fine sand	2.27	9
Do	9.07	3	Do	3.31	10
Do	9.70	4	Do	1.92	11
Sand and clay	6.40	5	Do	1.81	12
Do	6.00	6			

8. 300 feet south of hole 7

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.893	0	Sand	3.30	6
Sandy clay	7.40	1	Do	1.468	7
Sand and caliche	6.30	2	Fine sand	1.71	8
Sand, clay and caliche	7.83	3	Do	2.21	9
Do	7.10	4	Sand and gravel	2.39	10
Sand	4.26	5			

9. 300 feet south of hole 8

Surface sand	0.985	0	Sand and caliche	7.34	5
Clay	10.01	1	Sand	4.01	6
Do	9.78	2	Fine sand	1.93	7
Clay and caliche	10.30	3	Very fine sand	0.96	8
Sand and caliche	6.68	4			

10. 300 feet south of hole 9

Surface sand	0.696	0	Sand and caliche	4.14	6
Sand and clay	5.92	1	Do	5.05	7
Do	6.54	2	Caliche	6.82	8
Do	5.31	3	Do	5.42	9
Do	6.03	4	Very fine sand	3.82	10
Sand	4.51	5			

11. 300 feet south of hole 10 on the rim of first depression east of El Paso

Surface sand	0.636	0	Sand and caliche	3.77	6
Sand and clay	4.40	1	Do	5.08	7
Do	4.98	2	Do	4.16	8
Sand and gravel	3.95	3	Very fine sand	2.66	9
Sand and caliche	4.38	4	Do	1.55	10
Do	5.67	5			

12. 300 feet north of hole 1

Surface sand	0.83	0	Sandy caliche	3.74	5
Sand	6.50	1	Very fine sand	5.05	6
Fine sand	5.15	2	Do	2.67	7
Do	3.99	3	Do	1.33	8
Sandy caliche	7.04	4			

13. 300 feet north of hole 12

Surface sand	0.828	0	Clay and caliche	7.29	8
Sand	3.26	1	Sandy caliche	8.46	9
Do	5.19	2	Very fine sand	8.36	10
Sand and little caliche	4.28	3	Sandy caliche	9.93	11
Do	5.54	4	Clay and caliche	15.60	12
Sand and caliche	11.76	5	Do	14.32	13
Clay and caliche	15.30	6	Clay	17.20	14
Do	16.62	7			

14. 300 feet north of hole 13

Surface sand	0.572	0	Sandy caliche	4.33	5
Sand	6.76	1	Do	7.68	6
Do	6.77	2	Caliche, sand and gravel	6.87	7
Do	4.56	3	Very fine sand	2.74	8
Sandy caliche	4.76	4	Do	2.04	9

15. 300 feet north of hole 14

Surface sand	0.812	0	Very fine sand	2.61	6
Sandy caliche	6.06	1	Do	2.84	7
Caliche	13.20	2	Do	2.70	8
Do	9.05	3	Do	2.98	9
Caliche and sand	4.59	4	Sand and caliche	3.97	10
Sand and caliche	3.14	5	Do	3.03	11

16. South side of Carlsbad road, opposite right-of-way marker 310 + 00

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.171	0	Sand, very little caliche	3.14	4
Sand and clay	4.54	1	Do	2.37	5
Do	5.23	2	Caliche, very little sand	6.73	6
Do	4.64	3			

17. 300 feet west of hole 16
[No sample taken below a depth of 8 feet]

Surface sand	0.322	0	Sand	4.63	5
Sandy clay	8.13	1	Do	4.59	6
Sand	6.65	2	Sand, very little caliche	4.65	7
Do	6.25	3	Do	4.77	8
Do	5.20	4	Do	----------	9

18. 300 feet west of hole 17

Surface sand	0.270	0	Sand, little caliche	11.45	10
Sand and clay	3.31	1	Fine sand	5.27	11
Do	6.45	2	Very fine sand	2.69	12
Do	5.41	3	Sand, little gravel	1.73	13
Sand	5.58	4	Very coarse sand	2.99	14
Do	5.73	5	Sand	4.27	15
Sand and little caliche	7.04	6	Sand, very little gravel	1.875	16
Do	8.54	7	Gravel and coarse sand	1.29	17
Clay, little caliche	11.10	8	Do	1.35	18
Caliche, little clay	10.1	9	Sand and fine gravel	1.587	19

19. 300 feet west of hole 18
[No sample of hard caliche taken]

Surface sand	0.565	0	Caliche and sand	6.27	4
Sand, little caliche	3.73	1	Sand and caliche	6.84	5
Do	4.11	2	Hard caliche	----------	6
Sand, very little caliche	6.90	3			

20. North side of Carlsbad road, opposite row marker 300 + 00

Surface sand	0.846	0	Sand and little caliche	10.21	6
Clay and sand	10.75	1	Do	5.16	7
Clay and little caliche	12.72	2	Sand and gravel	4.92	8
Clay and caliche	11.80	3	Do	1.83	9
Sand, clay and caliche	9.65	4	Coarse sand	1.085	10
Sand and caliche	8.05	5			

21. 330 feet west of hole 20

Surface sand	1.38	0	Fine sand	2.63	5
Sand	6.56	1	Do	2.14	6
Fine sand	3.98	2	Very fine sand	1.16	7
Sand, little caliche	5.35	3	Do	1.37	8
Fine sand	4.63	4	Sand, very little gravel	1.03	9

22. 300 feet west of hole 21

Surface sand	0.54	0	Very coarse clean sand	1.44	10
Sand and caliche	5.03	1	Do	1.70	11
Sand and little caliche	3.64	2	Do	1.53	12
Do	4.16	3	Clean sand	2.00	13
Fine sand	2.78	4	Do	1.53	14
Very coarse clean sand	2.82	5	Do	1.49	15
Do	1.535	6	Do	9.20	16
Do	1.36	7	Sandy clay	5.60	17
Do	1.63	8	Do	3.27	18
Do	1.77	9	Clean fine sand	3.31	19

23. On Carlsbad road, in first depression 500 feet west of right-of-way marker 290 + 00

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.333	0	Fine sand	4.67	7
Sand	3.51	1	Fine sand and caliche	6.85	8
Do	5.15	2	Do	7.11	9
Do	5.86	3	Do	5.06	10
Do	6.33	4	Fine sand	6.41	11
Do	6.25	5	Do	7.18	12
Fine sand	4.66	6			

24. 50 feet east of right-of-way marker 280 + 00

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand and gravel	1.06	0	Clean fine sand	3.07	10
Sand, clay and caliche	8.86	1	Sand and caliche	5.59	11
Clay	16.01	2	Do	8.96	12
Sandy clay	11.31	3	Clay and caliche	13.52	13
Clay	17.20	4	Sandy clay	9.44	14
Clay and caliche	17.11	5	Clay and caliche	14.09	15
Do	14.42	6	Clay and sandy caliche	10.80	16
Sand and caliche	11.01	7	Clay	18.30	17
Sand, clay and caliche	6.79	8	Clay and caliche	15.85	18
Clean fine sand	3.02	9	Clay and sandy caliche	10.18	19

25. 250 feet west of right-of-way marker 370 + 00. In second depression east of El Paso

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	5.46	0	Sand and gravel	5.96	7
Sand	5.97	1	Do	8.72	8
Sandy caliche	6.82	2	Sandy caliche and gravel	14.43	9
Fine sand	4.28	3	Do	12.21	10
Sandy caliche	5.48	4	Sand and hard clay	13.90	11
Do	5.72	5	Do	12.88	12
Sand and gravel	6.34	6			

26. Opposite right-of-way marker 370 + 00

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.88	0	Sand and silt	7.15	9
Sand	6.88	1	Sand, caliche and clay	7.52	10
Sand and hard caliche	6.35	2	Fine clean sand	3.90	11
Very hard caliche	9.15	3	Coarse sand (clean)	3.32	12
Sand and hard caliche	6.48	4	Do	2.11	13
Do	6.17	5	Do	2.60	14
Do	8.33	6	Coarse sand (silt)	2.14	15
Do	5.28	7	Do	2.14	16
Do	12.22	8			

27. 250 feet east of right-of-way marker 370 + 00 on Carlsbad road in second depression east of El Paso

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.97	0	Caliche	0.88	6
Sand and gravel	4.08	1	Sandy caliche	0.79	7
Sand and caliche	3.70	2	Do	0.59	8
Do	3.39	3	Sand and gravel	6.46	9
Do	0.91	4	Do	4.74	10
Caliche	0.93	5	Fine sand and gravel	5.16	11

28. 250 feet east of hole 27

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.94	0	Sandy caliche	7.89	8
Sand	5.58	1	Sand and caliche	8.50	9
Do	4.16	2	Sand and clay	6.85	10
Fine sand	3.25	3	Sand and gravel	7.96	11
Do	3.56	4	Sandy clay	12.03	12
Sand	3.32	5	Fine sand	4.39	13
Do	8.58	6	Do	4.67	14
Sandy caliche	8.15	7	Do	2.44	15

29. 250 feet west of hole 25

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.51	0	Sandy caliche	3.98	6
Sandy clay	6.57	1	Do	7.97	7
Sandy caliche	9.38	2	Do	9.10	8
Sand	7.59	3	Do	10.07	9
Fine clean sand	3.82	4	Do	6.17	10
Do	3.36	5	Very hard rock	----------	11

30. 3.2 miles east of Wilson Rd. on old Hueco Tanks road, in first depression east of El Paso

Surface sand	1.04	0	Sandy caliche	9.49	9
Sand	5.16	1	Do	11.66	10
Do	5.48	2	Do	9.20	11
Do	4.88	3	Do	6.65	12
Do	5.07	4	Sand	5.03	13
Do	5.60	5	Sand and gravel	2.40	14
Sandy clay	4.70	6	Do	2.28	15
Clayey caliche	12.08	7	Do	2.03	16
Do	11.02	8	Do	2.15	17

31. 250 feet east of hole 30

Surface sand	1.66	0	Sand and caliche	5.97	7
Sandy caliche	8.50	1	Do	7.16	8
Do	8.24	2	Clayey caliche	12.42	9
Sand	5.76	3	Sandy caliche	8.33	10
Sand and gravel	5.78	4	Sandy clay	5.72	11
Do	5.78	5	Sand and gravel	3.26	12
Sand and caliche	7.30	6			

32. 250 feet west of hole 30

Surface sand	1.14	0	Sandy caliche	9.05	6
Sandy clay	7.98	1	Sand and hard caliche	9.02	7
Sandy caliche	8.16	2	Do	5.65	8
Do	8.12	3	Sand	3.89	9
Caliche	7.36	4	Sand and fine gravel	2.26	10
Sandy caliche	7.85	5	Coarse gravel[1]		

[1] Gravel about 2″ in size. Since auger would not raise it, no sample was taken.

166. 300 feet east of hole 165

Surface sand	1.54	Surface	Clay	8.06	10
Medium sand	5.12	1	Do	7.48	11
Do	5.15	2	Sand and clay	6.85	12
Do	6.58	3	Do	5.85	13
Sand and caliche	6.68	4	Sand and gravel	1.44	14
Do	7.37	5	Do	1.12	15
Clay and caliche	13.23	6	Do	1.24	16
Clay	9.09	7	Fine sand	1.22	17
Do	11.23	8	Do	0.93	18
Do	9.30	9			

167. 300 feet east of hole 166

Surface sand	5.58	0	Sand and caliche	5.98	3
Coarse sand	7.90	1	Do	8.56	4
Sand and clay[1]	----------	2	Very hard caliche		

[1] Spilled sample.

168. 300 feet east of hole 167

Surface sand	4.84	0	Fine sand	4.82	5
Medium sand	5.28	1	Caliche and sand	6.61	6
Fine sand	4.63	2	Do	6.20	7
Medium sand	4.46	3	Caliche and fine sand	4.96	8
Fine sand	5.16	4			

169. 300 feet east of hole 168

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.84	0	Sand and clay	4.16	2
Medium sand	4.61	1	Sand and caliche	4.77	3

170. 300 feet east of hole 169

	Moisture (percent by weight)	Depth (feet)		Moisture (percent by weight)	Depth (feet)
Surface sand	0.316	0	Sand and caliche	5.85	8
Medium sand	5.81	1	Do	5.72	9
Do	7.52	2	Sand and small amount of caliche.	5.71	10
Do	6.52	3	Sand	5.08	11
Clay and caliche	9.00	4	Fine sand	3.99	12
Do	8.60	5	Do	1.63	13
Sand and caliche	7.45	6			
Do	5.83	7			

APPENDIX

WELL EXPLORATIONS IN EL PASO, TEX., IN 1939

INTRODUCTION

If salt water has access to an idle well through a screen or defective casing and the pressure in the salt-water bed is greater than that in the fresh-water bed, salt water will enter the well bore and in time penetrate a considerable distance into the fresh-water bed. If the pressure in the two beds is about the same and the salt-water bed is above the one containing fresh water some water may enter and sink into the well bore because of its higher specific gravity. If the pressure in the fresh-water bed is higher, fresh water will tend to flow through the well bore into the salt-water bed.

In making explorations to determine the source of contamination of a well it is necessary to do more than determine the chemical character of the water in the bore of the hole, because with unequal pressures in the various beds supplying water to the well, part of the water in the bore of the well probably has been replaced by the water having the highest pressure, as it flows from one bed to another. If the contamination is from a single source the problem is relatively simple, but if it comes from more than one source a complete understanding of the problem requires a large number of different tests. The only sure way of determining the character of the water at the different horizons is to isolate each water-bearing bed and pump it until all contaminating water has been retrieved from it, before making a chemical analysis.

Finding the source of the contamination is a different problem with each well. Certain tests or combinations of tests may show positive results in one well but negative results in another. However, by carefully studying the results of each operation as the investigation progresses, the plan for each succeeding operation can be made. The first test of a contaminated well should be the pumping test, in which the well is pumped and a sample collected at frequent intervals during a pumping period of at least an hour, preferably longer. If the well is contaminated with salt water a simple field test for chloride is usually sufficient to determine the general changes in the chemical character of the water as pumping progresses. The well should stand idle for several hours or days before the test is made, depending upon the degree of contamination. This gives the salt water an opportunity to accumulate in the well and establish itself at definite horizons. The pumping test will usually show not only whether salt water is leaking into the well but also the comparative magnitude of the leak and possibly its approximate position. After the pumping test is completed, the other exploratory steps can be taken up as the occasion requires.

In 1935 and 1936, during the ground-water investigation in the El Paso area, some study was given to the problem of the increasing mineralization of certain El Paso wells, and the results then obtained are given on pages 75–93.

In August 1939 Mr. Livingston began making tests in city wells 7 and 1 to determine the cause of the increase in mineralization in those wells. The wells were pumped, and samples of the water were collected and analyzed at frequent intervals to determine the changes in mineral content as pumping progressed. Electrodes[7] were lowered into the wells to find the contact between fresh and salty water. Fresh water was turned into the wells at different depths to flush out the water there and assist in finding holes in the casing. Water samples were taken at various depths, two sizes of samplers being used, the larger 3 inches and the smaller 1½ inches in diameter. Separate pumping tests were made on each important water-bearing sand. This was accomplished by filling up the well with sand and clay to the bottom of the sand to be tested, inserting a water-tight packer above the sand, and pumping the section between the packer and top of the fill with an air-lift pump. A deep-well meter[8] was used from time to time to observe whether water was flowing vertically through the well from one sand to another or was leaking around the packers. A record of all water levels was kept and changes were made in methods and equipment during the test until satisfactory results were obtained. Mr. Livingston was assisted during the tests by Robert Colvin, engineer; J. N. Hinyard, chemist; and Clifford Jensen, driller, of the El Paso Water and Sewer Department. For the most part the chloride, hardness, and pH determinations were made by Messrs. Hinyard and Colvin. The soap solution was mixed with the water sample by a small electric-power mixing machine. Determinations of pH were made with a small portable electrical apparatus. The test on El Paso well 7 covered the period from August 22 to September 23, and the test on El Paso well 1 from August 28 to November 9, 1939.

EL PASO WELL 7

EXPLORATIONS AND CONTAMINATION TESTS

El Paso well 7 was drilled in 1927 by the El Paso Water Department. The records are a little confusing, but evidently the well was drilled to a depth of at least 525 feet. Some trouble was experienced in setting the casing, and the lower part of the well was lost. The well, which was reported as having 86 feet of 22-inch and 74 feet of 12-inch casing and 270 feet of 13-inch slotted pipe, was said to have yielded 1,250 gallons a minute in 1929.

In the vicinity of well 7 the first water occurs just below the surface of the ground. Below this shallow horizon and above the fresh-water sands tapped by the city wells is an intermediate zone, which generally yields undesirable water. The water level in this zone is about 15 feet lower than the shallow-water level and about 15 feet higher than the water level in the nonleaking wells that tap the fresh-water beds. In well 7, however, the water level corresponds to that in the intermediate zone.

Several wells in the vicinity are known to have penetrated sands containing highly mineralized water. El Paso well 6, about 800 feet

[7] Livingston, Penn and Lynch, W. A., Locating salt-water leaks in water wells, U. S. Geol. Survey, Water-Supply Paper 796-A, 1937.

[8] Livingston, Penn, Op. Cit.
McCombs, John and Fiedler, A. G., Methods of exploring and repairing leaky artesian wells, U. S. Geol. Survey, Water-Supply Paper 596-A, 1927.

away, was abandoned because the water was too hard. Test well 14, drilled in 1937 about 0.6 mile to the northeast, struck highly mineralized water at a depth of 90 to 100 feet. Test well 17, drilled in 1939 about 0.3 mile to the southwest of well 7, encountered water containing about 470 parts per million of chloride and about 990 parts per million of hardness in a sand at a depth of 134 feet.

PUMPING METHOD

The first test for contamination in well 7 was made by Mr. Livingston on February 27, 1936, by the pumping method. When the pump was started, the chloride content of the water was about 55 parts per million, and it rose to about 100 parts per million with extended pumping, indicating that a small quantity of water, fresher than the normal discharge, was leaking into the well while it was standing idle. In general, however, the well was in excellent condition. During the next 2 years the water from the well gradually became more highly mineralized, and by 1938 it was unsatisfactory for city use, especially so for laundry use, because of its high degree of hardness. The table on this page gives the chemical analyses of water from well 7 during the period 1935–39.

The pumping method was again tried in 1939. The well was pumped from 9:22 a.m. on August 22 until noon on August 24, at an estimated rate of 450 to 500 gallons a minute. Samples of water were collected at frequent intervals and tested for chloride, hardness, and pH. Part of the water discharged was passed through a set of electrodes, and its conductance was measured by means of a milliammeter. The electrodes were damaged and the milliammeter readings discontinued after the first 15 minutes of pumping, and the pH determinations were discontinued after about 7 hours, because of the difficulties in making them with sufficient promptness after collection. For comparison, a few determi-

Analyses of water from El Paso well 7, 1935–39

[Parts per million]

Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst
Jan. 5, 1935								177	112	94		260	M. D. Foster.
Sept. 11, 1935	506			84	17	75		180	122	119	0.3	280	Do.
Feb. 28, 1936	496			85	19	66		181	130	106	.1	290	Do.
Apr. 22, 1936								180		120		330	Do.
Oct. 28, 1936	556	28	0.78	95	22	74		186	133	140		328	Do.
June 25, 1937	706	38	.03	105	21	91	5.4	191	154	165	.05	349	Do.
Aug. 15, 1938	761	12	.5	115	23	33	7	199	172	173	.3	332	Do.
Aug. 23, 1939	820			126	25	111		216	260	149		417	J. N. Hinyard.
Aug. 23, 1939	792			133	28	88		216	236	153		447	E. W. Lohr.
Sept. 23, 1939	828	27	trace	120	25	129		216	260	170		[1]404	J. N. Hinyard.

[1] Hardness by soap method 410.

Chloride content, soap hardness, conductance, and pH of water from El Paso well 7 during tests on August 22–24, 1939

Sample No.	Date	Time (hr. min. sec.)	Current (milli-amperes)	Chloride content (parts per million)	Soap hardness (parts per million)	pH
[1]1	Aug. 22	9:22:00 a.m.		180	254	7.80
2		10	28	192	207	7.81
3		20	28	184	153	8.04
4		30	28	184	100	8.97
5		40	28	184	97	9.18
6		50	28	180	100	9.20
7		9:23:00	28	192	93	9.25
8		10	32	180	93	9.21
9		20	31	184	107	9.13
10		30	31	144	120	9.09
11		40	31	140	133	9.05
12		50	32	136	133	8.53
13		9:24:00	32	136	133	8.40
14		10	32	132	133	8.48
15		20	32½	140	133	8.48
16		30	34	132	133	8.48
17		40	38	136	142	8.48
18		50	42	136	145	8.39
19		9:25:00	46	132	170	8.35
20		20	47	144	247	7.87
21		40	49	156	294	7.70
22		9:26:00	49½	162	297	7.50
23		20	49½	162	307	7.60
24		40	49½	164	314	7.50
25		9:27:00	50½	180	314	7.72
26		20	49½	170	302	7.81
27		40	49½	172	320	7.72
28		9:28:00	49½	166	330	7.81
29		30	49			7.72
30		9:29:00	49	168	337	7.83
31		30	48			7.70
32		9:30:00	48	166	354	7.81
33		30	48			7.72
34		9:31:00	48	166	380	7.80
35		30	48			7.73
36		9:32:00	48	166	367	7.70
37		9:33:00	47	168		7.62
		9:33:30	48			
38		9:34:00	47	152	324	7.60
39		9:35:00	52	156		7.50
40		9:36:00	50	148	336	7.58
41		9:37:00	48	152		7.58
42		9:38:00		152	336	7.65
43		9:39:00		152		7.60
44		9:40:00		152	334	7.50
45		9:41:00		148		7.60
46		9:42:00		148	336	7.51
47		9:47:00		148		7.42
48		9:52:00		144	347	7.42
49		9:57:00		152		7.58
[2]50		10:02:00		150	330	7.48
51		10:07:00		150		7.49
52		10:12:00		148	327	7.50
53		10:17:00		148		7.50
54		10:22:00		148	340	7.45
55		10:32:00		144		7.53
56		10:42:00		148	347	7.49
57		10:52:00		146		7.57
58		11:02:00		144	357	7.49
59		11:12:00		144		7.48
60		11:22:00		144	337	7.65
62		11:42:00		150	359	7.63
63		11:52:00		156		7.60
64		12:02:00 p.m.		156		7.64
65		12:22:00		156		7.60
66		12:42:00		156	347	7.59
67		1:02:00		154		7.60
[3]68		1:22:00		156		7.61
69		1:42:00		154		7.61
70		2:02:00		154	354	7.61
71		2:22:00		152		7.60
72		2:42:00		156	348	7.68
73		3:02:00		162		7.68
74		3:22:00		160	394	7.68
76		4:02:00		156	413	7.68
[4]77		4:32:00		162	350	7.69
78		5:00:00		144	367	

Chloride content, soap hardness, conductance, and pH of water from El Paso well 7 during tests on August 22–24, 1939—Continued

Sample No.	Date	Time (hr. min. sec.)	Current (milli-amperes)	Chloride content (parts per million)	Soap hardness (parts per million)	pH
79		6:00:00	------------	146	----------	--------
80		7:55:00	------------	144	----------	--------
81		8:00:00	------------	142	----------	--------
[5]82		8:30:00	------------	142	372	--------
83		9:00:00	------------	138	----------	--------
84		9:30:00	------------	140	----------	--------
85		10:00:00	------------	142	----------	--------
[6]86		10:30:00	------------	142	342	--------
87		11:00:00	------------	142	----------	--------
88		12:00:00	------------	142	----------	--------
89	Aug. 23	1:00:00 a.m.	------------	140	----------	--------
90		2:00:00	------------	146	287	--------
91		3:45:00	------------	144	----------	--------
92		4:00:00	------------	142	314	--------
93		5:00:00	------------	142	----------	--------
94		6:00:00	------------	146	----------	--------
95		7:00:00	------------	146	287	--------
96		8:00:00	------------	148	280	--------
97		9:00:00	------------	148	319	--------
98		10:00:00	------------	150	----------	--------
99		11:10:00	------------	150	290	--------
100		12:00:00	------------	150	----------	--------
101		1:00:00 p.m.	------------	150	326	--------
[7]102		2:00:00	------------	150	----------	--------
103		3:00:00	------------	152	300	7.05
104		4:00:00	------------	------------	346	7.04
105		7:10:00	------------	150	300	--------
106		9:10:00	------------	------------	----------	--------
107		11:05:00	------------	152	277	--------
108	Aug. 24	7:00:00 a.m.	------------	------------	----------	--------
[8]109		8:10:00	------------	154	300	7.05

[1] Pumping began 9:22 a.m. at 450–500 gallons a minute.
[2] Depth to water 46.57 feet at 10 a.m.
[3] Depth to water 47.07 feet at 1:22 p.m.
[4] Depth to water 47.39 feet at 4:40 p.m. Opened to full capacity at 4:41 p.m. Discharge 1,000 gallons a minute.
[5] Hardness 375 parts per million by dropping bottle.
[6] Hardness 355 parts per million by dropping bottle.
[7] Discharge 1,040 gallons a minute.
[8] Two water samples collected for complete analyses. Pump shut down at 12 m. Depth to water 14.71 feet at 3 p.m.

nations of hardness were made by using dropping bottles and soap solutions prepared by the Division of Quality of Water, of the Federal Geological Survey. The results are shown in the table above.

The figures show that there was not much change in the chloride content as pumping progressed and that the maximum was not very high. The hardness dropped from about 250 parts per million as pumping began to less than 100 parts at the end of the first minute. It rose to 300 parts per million after about 4 minutes and reached about 400 parts after 7 hours of pumping. It then dropped somewhat and during the remainder of the test ranged from about 370 to 280 parts, averaging about 315—a hardness of 300 to 400 parts per million is considered too high for general city use and especially objectionable for laundry or boiler use. Although the results of the test, especially the wide range in the hardness of the water, pointed to the probability that highly mineralized water was entering the well through a leak, they did not indicate the position of the leak or leaks, which was determined by the tests described below.

PRELIMINARY TESTS WITH ELECTRODES AND DEEP-WELL METER

First the pump was removed. The electrodes were then lowered into the well, but no differences in the conductance of the water indicative of the source of the leak were discovered. Next the deep-well current meter was lowered into the well, but no movement of the water was found. This proved that if any exchange of water was occurring from one sand to another it was very small. During these tests the well was found to have a depth of only 320 feet, instead of the reported depth of 455 feet, indicating that more than 100 feet of it had filled up with sand.

TESTING PUMP PIT AND BLANK CASING

An attempt was then made with a canvas packer to shut off the water at the bottom of the pump pit. The packer was about 12 inches in diameter and was made by wrapping cement sacks over a piece of 4½-inch pipe. It was lowered down through the 22-inch pump pit into the upper end of the 12-inch casing, extra weight being supplied by a string of 4½-inch pipe extending below the packer to the bottom of the well. After the packer was set the pit was pumped at a rate of about 30 gallons a minute, but it was found that the water level could not be lowered by more than about 15 feet, indicating that the packer was ineffective. The deep-well meter was let down into the 12-inch pipe above the packer, and velocities were registered showing a flow of about 30 gallons a minute coming up through it.

An arrangement of two packers was made consisting of a packer at each end of a 14-foot piece of 4½-inch pipe, which had been perforated with several ½-inch holes. The 4½-inch pipe was open at the top and plugged at the bottom. Each packer consisted of a disk of 6-ply conveyor belting slipped over the pipe and supported on each side by a disk of ¼-inch iron plate about 11 inches in diameter. The disks of conveyor belting were cut to a little larger diameter than the inside diameter of the well casing. An arrangement of this type previously has been used with success in other wells in which it was desired to test successively short sections of the well casing to find the position of a salt-water leak. The method is to lower the double packer a distance equal to its length, or about 14 feet at a time, and pump the section of the well between the packers by means of an air line placed inside the 4½-inch pipe. The packers were set by a slight upward pull, which tended to curl the belting under and make a fairly tight seal.

For some unknown reason, a tight seal was not obtained in well 7 until the packers had been lowered to a depth of 130 to 144 feet. After they had been set at that position, the well was filled with tap water to the floor of the pump house and allowed to stand while the water level was observed. This level, it was found, fell at a rate of about 0.3 foot per hour, amounting to about 0.1 gallon a minute. The test indicated that the 22-inch pump pit and the 12-inch cased section were practically watertight down to a depth of 130 feet.

TESTING SCREENED PART OF WELL

According to the well log the well casing is slotted from a depth of about 160 feet to below 430 feet. Since the well had filled with sand to 320 feet it was clear from the test described above that practically all of the water pumped from the well was entering it between 130 and 320 feet, and probably between 160 and 320 feet.

Next the well was cleaned out to a depth of 500 feet and again pumped but the yield, it was found, was not materially greater than it had been before. During the time the well was being cleaned out the electrodes were run into it, and the conductance of the water in the screened section from 160 to 420 feet was tested. As expected, it was found that in general there was very little difference in the conductance of the water entering the well in different parts of the section. Conductance depends largely upon the ionization[9] of the minerals in solution and usually varies more closely with the chloride content than with the hardness. Therefore, a conductivity survey has little value in cases like this where water of high hardness is the cause of the contamination. The usual formula $\frac{E}{R} = I$ is also applicable to this electrical circuit in which E is the applied voltage, R is the resistance of the water gap, wire, and connections, and I is the current. In this case the applied voltage was constant, amounting to about 4½ volts. For convenience, readings were recorded in milliamperes, as shown in the table on page 170, and not in reciprocal ohms.

The temporary pumping equipment was removed from the well and another inspection made with the deep-well meter. A slight indication of moving water was found between 380 and 410 feet, but the velocity was so low that it was not possible to determine whether the movement was up or down. Water then was turned into the well at the ground surface at the rate of 10 gallons a minute, and when this was done, the meter indicated clearly that the water moved downward, part of it leaving the well at a depth of about 130 feet, part at about 150 to 160 feet, and the remainder before it reached a depth of 255 feet. This was an indication that there might be some small holes in the casing from about 130 to 160 feet.

Chloride content and soap hardness of water from El Paso well 7 during tests on September 11–23, 1939

Sample No.	Date	Time (hr. min.)	Chloride (parts per million)	Soap hardness (parts per million)
[1]1	Sept. 11	10:35 a.m.	149	525
2		10:50	144	477
3		11:05	144	431
4		11:35	142	406
5		12:35 p.m.	136	423
6		1:35	138	381
7		2:35	134	391
8		4:25	136	377
9		[2]8:30	140	377
[3]10	Sept. 18	8:10 a.m.	132	376
11		11:20	147	452
12		4:45 p.m.	153	452
13	Sept. 19	9:50 a.m.	157	425
14		5:00 p.m.	161	437
15	Sept. 20	11:40 a.m.	165	437
16		9:45 p.m.	167	438
17	Sept. 21	5:00	171	446
18		9:45	171	413
19	Sept. 22	11:45 a.m.	171	432
20		1:45 p.m.	171	413
21	Sept. 23	[4]10:00 a.m.	159	410

[1] Began pumping 10:35 a.m. at about 1,000 gallons a minute.
[2] Pump stopped at 9:15 p.m. because it had been discharging too much mud and sand into reservoir.
[3] Pump started again at 8:10 a.m. Pumped continuously into bypass.
[4] Pump shut down at 1:15 p.m. after large water sample had been collected for analysis.

FINAL CONTAMINATION TEST

The deep-well pump was reset and the well was pumped at the rate of about 1,000 gallons a minute from 10:35 a.m. to 9:15 p.m. on September 11, and from 8:10 a.m. September 18 to 1:15 p.m. September 23.

[9] MacInnes, Duncan A. The principles of electrochemistry: Reinhold Publishing Corporation, pp. 40, 322, 1939.

During the pumping period samples of water were collected from time to time and tested for chloride and hardness. The results of the tests are given in the table on page 173. When these figures are compared with those in the table on pages 170–171, it is plain not only that there was no improvement in the hardness of the water discharged from this well after it had been cleaned out and deepened but also that the hardness actually had increased somewhat.

SUMMARY OF INVESTIGATION OF WELL 7

The tests on well 7 showed that the pump pit and the well casing down to a depth of 130 feet were practically watertight and that the increase in the mineral content of the water during the past few years has, therefore, not been due to leakage in that section. The well could be sounded only to the depth of 320 feet, indicating that it had been filled to that level with sand. It was cleaned out to a depth of 500 feet and was swabbed and agitated between 320 and 430 feet but these operations produced no appreciable increase in the yield of the well. It is, therefore, concluded that the water pumped from the well must enter it mainly between the depths of 130 to 160 feet. Apparently there are small holes in the casing from 130 to 160 feet, which allow some leakage into the well from beds containing highly mineralized water. These beds apparently are separated by only a short distance vertically from the principal producing beds, and it seems probable that at least the upper part of the latter has become contaminated by leakage downward through the formation. The exact position of the leaks between 130 and 160 feet was not determined.

EL PASO WELL 1

EXPLORATIONS AND CONTAMINATION TESTS

El Paso well 1 (United States Geological Survey well 50) the first well in the Montana well field, was drilled in 1918 by the Layne and Bowler Well Drilling Company to a depth of about 1,023 feet, but because bad water was found in the lower part of the well it was sealed back to 860 feet. The well log gives the casing, from the surface downward, as follows: 224 feet of 24-inch blank, 280 feet of 13½-inch blank, 120 feet of 12½-inch screen, 90 feet of 13½-inch blank; 20 feet of 13½-inch blank, 60 feet of 13½-inch screen; and 70 feet of 13½-inch blank. The yield was about 1,200 gallons a minute when the well was drilled. All screen and casing was of built-up and riveted construction. The position of the water-bearing sands and screens are shown graphically in figure 10.

The work on well 1 was begun with a pumping test. The pump was then removed and the conductance of the water in the bore of the well was measured. After that the meter was lowered into the well to determine the rate, if any, of the exchange of water from one bed to another. The pump pit and blank pipe at the upper part of the well were tested for leaks, and later each water-bearing bed was isolated and pumped to obtain water samples from the different horizons.

PUMPING METHOD

A contamination test by the pumping method was made on this well on September 27, 1935. The results indicated that a small flow of salt

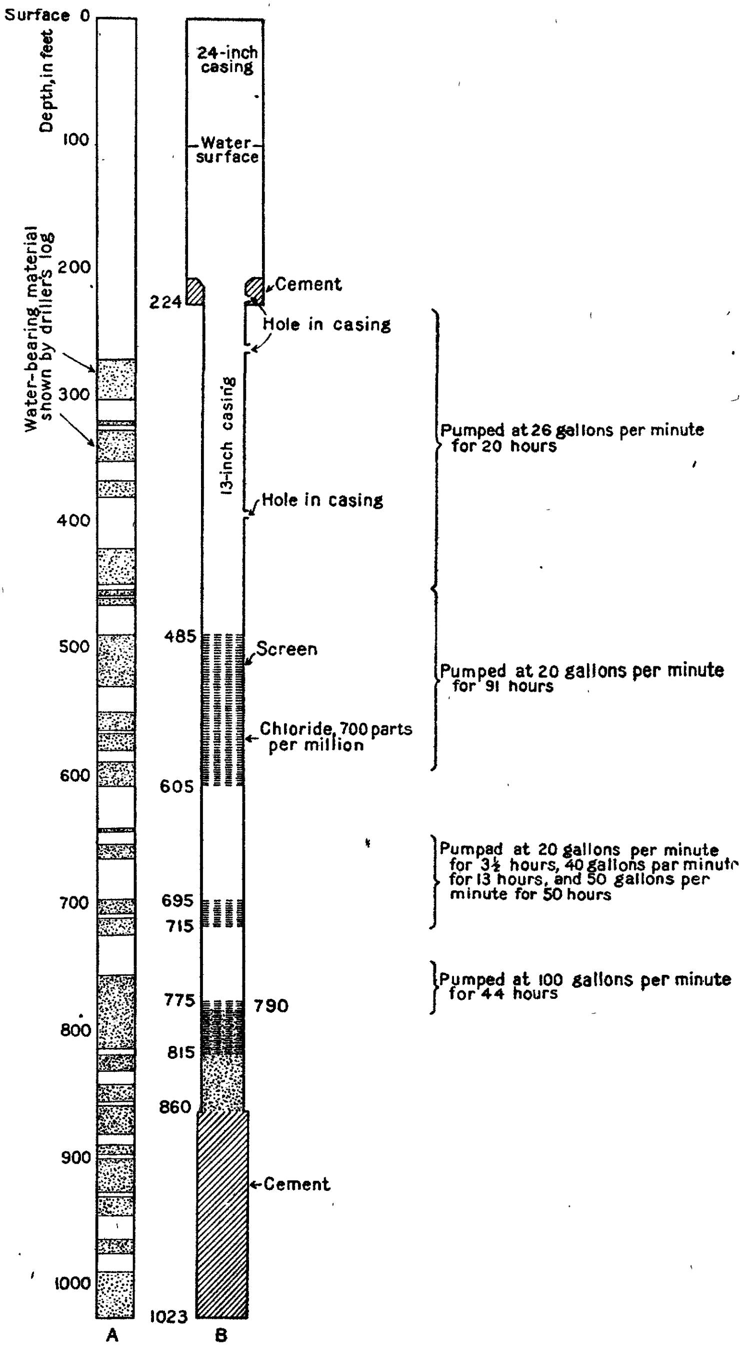


FIGURE 10.—El Paso well 1: *A*, Driller's log of water-bearing sands; *B*, Casing and screen settings and positions of salt-water leaks.

Analyses of water from El Paso well 1, 1935–39

[Parts per million]

Date of collection	Depth (feet)	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst
Aug. 16, 1935	860	--	--	--	--	--	--	--	140	--	236	--	170	M. D. Foster.
Sept. 11, 1935	860	589	--	--	46	16		157	167	51	235	1.7	181	Do.
Apr. 22, 1936	860	--	--	--	--	--	--	--	164	--	235	--	225	Do.
May 6, 1937	860	--	--	--	51	19		158	166	57	249	2.5	205	Do.
June 25, 1937	860	646	32	0.24	50	17	158	8.0	166	51	250	5.0	195	Do.
Sept. 11, 1939	860	811	30	trace	64	23		169	178	66	290	--	255	J. N. Hinyard.
Sept. 11, 1939	860	757	--	--	64	23		175	174	58	305	2.6	254	E. W. Lohr.
Oct. 19, 1939	740–790	1,594	28	.5	122	47		324	157	110	679	--	497	J. N. Hinyard.
Oct. 26, 1939	640–714	1,587	--	--	112	43		347	173	111	676	--	457	Do.
Nov. 3, 1939	447–590	710	--	--	59	28		143	189	69	248	--	264	Do.
Nov. 4, 1939	447–590	600	--	--	54	20		102	190	53	198	--	219	Do.
Nov. 9, 1939	392	4,671	--	--	274	110		1,087	186	334	2,125	--	1,134	Do.
Nov. 9, 1939	261	4,990	--	--	292	124		1,188	199	357	2,330	--	1,238	Do.

water containing not less than 800 parts per million of chloride was leaking into the well just below the suction of the pump, probably at the point where the casing was reduced in size at a depth of about 225 feet. It was pointed out on page 78 that the main reason the water had increased in mineral content was because the pump was drawing highly mineralized water from a sand in the main water-bearing horizons, probably below 600 feet.

From 1935 to 1938 there was an increase in the mineral content of the water showing either that the well was drawing in more of the highly mineralized water than formerly, through leaks in the casing, or that some of the fresh water-producing horizons were becoming contaminated. (See table on this page showing results of chloride tests from 1935 to 1939.) Encroachment of highly mineralized water upon the Montana well field, in which well 1 is situated, is of vital importance, and tests were begun in August 1939 to determine the source of the contamination. The well had been in more or less continuous service until August 15, 1938. It had been operated again for 12 hours on September 27, 1938, after which it had remained idle until August 1939.

The pump was started at 9 a.m. on August 28, 1939, discharging about 900 gallons a minute. The depth-to-water at 8:30 a.m. was 103.60 feet below the floor of the pump house. (All depths are measured from the floor of the pump house, which is about 1½ feet above the general ground level.) Samples from the pump discharge were collected at frequent intervals and tested for chloride, hardness, and pH using the same procedure as for well 7. Conductance readings also were made. These data are shown in the following table. The results of this pumping test confirm the statements made in regard to the test

Chloride content, soap hardness, conductance, and pH of water from El Paso well 1 during tests on August 28 to September 12, 1939

Sample No.	Date	Time (hr. min. sec.)	Current (milliamperes)	Chloride content (parts per million)	Soap hardness (parts per million)	pH
[1]1	Aug. 28	9:00:00 a.m.	30	320	127	6.79
2		10	31	324	128	7.16
3		20	32	340	144	7.22
4		30	40	458	171	6.83
5		40	41	466	177	6.83
6		50	45	558	210	6.75
7		9:1:00	50	614	238	6.75
8		10	55	654	252	6.71
9		20	58	682	265	6.70
10		30	68	860	344	6.73
11		40	70	875	396	6.73
12		50	79	1,050	443	6.76
13		9:2:00	80	1,145	475	6.73
14		10	83	1,130	468	6.75
15		20	86	1,180	485	6.76
16		30	90	1,305	542	6.77
17		40	92	1,330	528	6.78
18		50	94	1,305	522	6.79
19		9:3:00	94	1,310	570	6.80
20		10	92	1,295	590	6.80
21		20	93	1,295	722	6.81
22		30	93	1,300	650	6.82
23		40	93	1,300	690	6.82
24		50	93	1,295	675	6.83
25		9:4:00	93	1,300	624	6.84
26		20	93	1,285	675	6.85
27		40	93	1,290	695	6.88
28		9:5:00	92	1,290	682	6.90
29		20	91	1,290	695	6.90
30		40	91	1,270	675	6.91
31		9:6:00	90	1,290	708	6.92
32		20	91	1,290	695	6.92
33		40	90	1,283	702	6.97
34		9:7:00	90	1,277	702	6.97
35		20	90	1,283	702	6.98
36		40	89	1,267	706	7.00
37		9:8:00	89	1,260	----------	7.03
38		20	89	1,275	695	7.05
39		40	89	1,270	----------	7.05
40		9:9:00	88	1,283	722	7.05
41		20	88	1,263	----------	7.09
42		40	88	1,260	735	7.09
43		9:10:00	88	1,267	----------	7.10
44		20	87	1,260	722	7.10
45		40	87	1,265	----------	7.10
46		9:11:00	86	1,265	735	7.10
47		20	85	1,275	----------	7.10
48		40	85	1,270	748	7.11
49		9:12:00	85	1,275	----------	7.13
50		30	84	1,275	742	7.13
51		9:13:00	84	1,260	----------	7.13
52		30	83	1,275	----------	7.15
53		9:14:00	82	1,270	----------	7.16
54		30	81	1,270	748	7.16
55		9:15:00	81	1,280	----------	7.17
56		30	80	1,270	----------	7.17
57		9:16:00	80	1,250	----------	7.17
58		30	79	1,260	748	7.18
59		9:17:00	79	1,255	----------	7.18
60		30	79	1,235	735	7.19
61		9:18:00	78	1,230	----------	7.19
62		9:19:00	79	1,240	755	7.19
63		9:20:00	78	1,225	----------	7.19
64		9:21:00	77	1,215	767	7.19
65		9:22:00	76	1,190	----------	7.19
66		9:23:00	75	1,190	761	7.19
67		9:24:00	74	1,190	----------	7.19
68		9:26:00	72	1,160	735	7.21
69		9:28:00	72	1,150	----------	7.21
70		9:30:00	71	1,065	728	7.25
71		9:35:00	67	1,050	----------	7.25
[2]72		9:40:00	65	1,025	767	7.28
73		9:45:00	62	935	----------	--------
74		9:50:00	60	880	683	--------
75		10:00:00	55	735	----------	--------
76		10:10:00	50	635	656	--------
[3]77		10:20:00	48	590	----------	--------
78		10:30:00	46	560	590	--------

Chloride content, soap hardness, conductance, and pH of water from El Paso well 1 during tests on August 28 to September 12, 1939—Continued

Sample No.	Date	Time (hr. min. sec.)	Current (milli-amperes)	Chloride content (parts per million)	Soap hardness (parts per million)	pH
79		11:00:00	48	520	-----	-----
80		11:30:00	47	510	486	-----
81		12:00:00 m.	48	510	-----	-----
82		12:30:00 p.m.	53	503	453	-----
83		1:00:00	52	497	-----	-----
84		1:30:00	51	480	440	-----
85		2:00:00	50	485	-----	-----
86		2:45:00	49	475	-----	-----
87		3:45:00	48	470	428	-----
88		4:45:00	48	445	-----	-----
89		5:45:00	50	435	377	-----
90		6:45:00	46	430	-----	-----
91		7:45:00	45	425	394	-----
92		8:45:00	44	425	-----	-----
93		9:45:00	42	425	381	-----
94		10:45:00	40	415	-----	-----
95		11:45:00	38	415	394	-----
[4]96	Aug. 29	7:45:00 a.m.	37	390	-----	-----
97		9:15:00	38	395	433	-----
98		10:15:00	38	400	-----	-----
99		11:15:00	38	385	383	-----
100		1:45:00 p.m.	37	390	-----	-----
101		5:15:00	38	380	407	-----
102		9:15:00	38	375	-----	-----
103	Aug. 30	7:15:00 a.m.	38	380	352	-----
104		12:15:00 p.m.	36	325	243	-----
105		7:15:00	36	375	322	-----
106	Aug. 31	2:15:00 a.m.	36	375	-----	-----
107		9:15:00	34	370	-----	-----
108		5:55:00 p.m.	34	375	-----	-----
109	Sept. 1	12:15:00 a.m.	-----	370	-----	-----
110		7:15:00	36	360	322	-----
111		7:45:00 p.m.	38	360	340	-----
112	2	10:00:00 a.m.	37	360	322	-----
113		7:00:00 p.m.	-----	340	289	-----
114	3	11:45:00 a.m.	39	355	327	-----
115		2:05:00 p.m.	38	355	297	-----
116		5:05:00	36	355	282	-----
117		10:20:00	36	355	317	-----
118	4	7:45:00 a.m.	34	355	315	-----
119		1:35:00 p.m.	35	350	302	-----
120		7:55:00	36	360	315	-----
121	5	1:15:00 a.m.	34	350	326	-----
122		12:30:00 p.m.	32	340	300	-----
123		5:30:00	30	-----	-----	-----
124	6	7:35:00 a.m.	30	340	295	-----
125		12:30:00	32	340	295	-----
126	7	9:30:00	32	333	314	-----
127		1:15:00 p.m.	(5)	314	305	-----
128	8	12:00:00 m.	-----	309	-----	-----
129		7:45:00 p.m.	-----	308	-----	-----
130	9	8:00:00 a.m.	-----	302	-----	-----
131	10	2:30:00 p.m.	-----	295	302	-----
132	11	9:35:00 a.m.	-----	299	292	-----
[6]133	12	10:10:00	-----	297	305	-----
-----	[7]12	10:15:00	-----	-----	-----	-----
-----	[8]13	10:10:00	-----	-----	-----	-----

[1] Pump started at 9 a.m. Estimated discharge 1.2 gallons a minute. Depth to water below concrete floor 103.60 feet at 8:30 a.m.
[2] Readings for pH discontinued.
[3] Depth to water 175.42 feet.
[4] Depth to water 177.41 feet.
[5] Current readings discontinued.
[6] Two water samples collected for complete analysis. Depth to water 182.40 feet.
[7] Pump shut down.
[8] Depth to water 112.40 feet.

of September 27, 1935. (See p. 79.) A much longer time was required to clear the well of salt water on August 28, 1939, than on September 27, 1935, but this is accounted for by the fact that the well had stood idle nearly a year before the 1939 test but only 91 hours before the one in 1935. A continuous inflow of salt water for a year, amounting to less than a gallon a minute, into the bore of the well and thence out into

RESERVOIR AT MOUTH OF McKILLIGAN CANYON.

Band of refuse (dark band extending across side of reservoir from right to left) shows height of water during storm of July 10, 1936. This picture taken 12 hours after storm ceased shows the reservoir dry.

A. EL PASO WELL 1 WITH TESTING EQUIPMENT.

B. POWER-DRIVEN WINCH, ELECTRODES, AND TWO WATER SAMPLERS.

the fresh water-bearing sands, would account for this difference. Tests for hardness and chloride could not be made as fast as the samples were collected, so in order to have available a quick and ready indicator of the general changes in mineral content of the water, readings of conductance were made in the continuous flow of the water being discharged from the pump. The conductance readings were higher than those recorded for well 7, but this may have been due to mechanical differences in the apparatus as set up in each case.

PRELIMINARY TESTS WITH ELECTRODES

The pump was shut down at 10:15 a.m. on September 12 and removed from the well by 11 a.m. on September 13. At 11 a.m. a set of electrodes was lowered into the well, and conductance measurements were made of the water at varying depths from the surface to the bottom of the well. The depths with corresponding conductance, recorded in milliamperes instead of reciprocal ohms are given in the table below. Plate 16, *A* is a view of city well 1 with a part of the testing equipment in the foreground. Plate 16, *B* gives a nearer view of the equipment.

Conductance measurements made in well 1 on September 13, 1939, 27 hours after the deep-well pump was stopped

Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)
122	18	241	23	418	20	612	20
143	18	255	22½	439	20	632	20
163	18	265	22	459	20	653	20
179	18	286	22½	479	20	673	20
186	18	306	22½	500	20	694	20
204	18	316	22	512	19½	714	20
215	19	337	22	514	19	719	21
217	20	357	22	520	19½	734	21
222	21	377	22	541	19½	755	21
229	21½	392	22	561	19½	775	21
232	22	395	21	581	19½	793	22
238	23	401	20	602	20		

The conductance readings indicated a salty zone in the column of water in the well at about 238 to 255 feet, but they did not show definitely the position of the leak, which probably was due to the mixing of the water caused by the withdrawal of the pump.

TESTING PUMP-PIT AND BLANK CASING

After this preliminary test with the electrodes had been completed, a canvas packer was made on a 13-inch outside diameter nipple and lowered on a string of 12-inch pipe to the top of the 13½-inch casing in order to shut off the water at the bottom of the pump pit. After the packer had been set, another test was made with the electrodes, which indicated a salt-water leak not far below 225 feet, but the contact between the fresh and salt water in the well was not well enough defined to show the exact position of the leak.

With the packer in place, an attempt was made to empty the pump pit by means of an air-lift pump but it was not successful. Evidently, the pump pit was not completely shut off and a test with the deep-well meter showed that most of this water was coming up past the packer. The lower end of the pump suction was at about 210 feet and samples taken from the water discharged from the pump showed chloride in excess of 1,800 parts per million, which indicated a leak of highly mineralized water near the lower part of the pump pit. The canvas packer was removed from the well and another double-packer arrangement made out of conveyor belting. The double-packers were a little too large to work properly, but a fairly tight seal in the top of the 13½-inch casing was obtained by driving the packers into the casing. With the 13½-inch casing shut off by the packer the water level in the pump pit was finally lowered to a depth of 181 feet. The pit was inspected for leaks by lighting the casing with a 100-watt bulb lowered on an extension cable. No leak was found. Since it was known that there were several feet of salty water at the bottom of the pump pit, it was necessary to flush out this salty water in order to find the place where it was coming into the well. With the packer still in the top of the 13½-inch casing, fresh tap water was turned into the well until the pump pit was filled to the ground surface. Theoretically when this was done the fresh water should have driven the salty water in the well down to the leak, and thence out through the hole. The contact between the fresh and salty water near the bottom of the pump pit was checked from time to time with the electrodes but it moved downward so slowly that after about 24 hours it was decided that it would take too long to wait for all the salty water to escape from the pit. The rate of decline of the water level in the pit was observed as about 2½ feet an hour, less than one gallon a minute. The packer was pulled out, and the water level in the pit dropped rapidly to its normal level. A test with the electrodes about 2 hours after the packer had been pulled showed that a very satisfactory flushing action had resulted in the pump pit and casing when the fresh water rushed down the well. No evidence of a salt-water leak was found in the pump pit down to a depth of about 220 feet. However, by means of the electrodes a very definite salt-water leak was found 261 feet below the surface. The results obtained are shown in the table on page 181. The well continued to stand idle for about 40 hours longer, at which time another test with the electrodes was made. The salt-water leak again showed very definitely at 261 feet, and another leak was found at about 220 feet. The results of these observations are given in the table on page 181.

ISOLATING SECTIONS OF THE WELL

BETWEEN 220 AND 485 FEET

Since the lower packer could not be driven down below 219 feet the packers were cut down and tried again. From September 25 to October 17 everything possible was done to make the packers watertight in order to obtain a true sample of the salty water entering the well in the section between 220 and 485 feet, but every attempt failed. One of the pieces of apparatus was made up with an industrial pneumatic tire for each packer. Tires were selected of such size that when not inflated they would just slip inside the casing. The tires were mounted about 18½ feet apart on a 3-inch pipe. They were filled with water and connected to a ½-inch pipe extending to the surface of the ground in such a way that the desired pressure on the tires could be controlled by applying air pressure. A special valve was also provided so that the inside and outside pressure on the tires could be equalized when the packers were moved. This also failed to work. The upper end of the 13½-inch well casing evidently was very sharp and jagged and the sharp points caught in the tires and tore them. Although the apparatus did not work successfully in this well, it probably would work successfully in a well that was reasonably free of sharp, jagged edges.

Conductance measurements made in well 1, 2 hours after the well had been flushed out with fresh water, September 23, 1939

Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)
102	26	228	27½	281	38	557	31
112	25	232	27	301	38	563	32
143	25–26	235	26	311	39	571	33
163	26	240	26	312	39	576	34
164	26½	241	27	347	38	586	35
199	26½	242	27	369	37	589	36
204	26½	249	27	375	36	600	36½
209	27	250	27½	388	35	610	37
212	26	251	28	392	34	619	38
213	26	253	27½	396	32	630	38½
214	26–27	256	27½	403	31	644	39
214½	26–28½	258	28	419	30	718	39
215	29	259	28	454	29½	719	38
216	28	[1]261	28–36	520	29½	729	37
217	28	262	37	532	30	739	37
219	26	263	37	549	30½	792	37
222	28	264	38				

[1] Depth to hole in casing 261 feet.

Conductance measurements made in well 1, 45 hours after the well had been flushed out with fresh water, September 24, 1939

Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)
102	30	220	30½	262	41	390	39½
173	30	220	33	268	40½	391	39
189	30	222	33	278	40+	395	38
201	30	240	33½	282	40	397	37
210	31	259	34	296	40+	398	37
214	29½	259½	39	302	41	400–786	37±
215	30½	260	40	358	40+		

BETWEEN 741 AND 790 FEET

A successful method of shutting off the water in the 13½-inch casing was finally worked out by using a single packer made of 10 disks cut from 8-ply conveyor belting. This packer was first set at a depth of 740 feet, and sand 15 feet thick was placed on top of it. After the sand had settled on the packer two sacks of drilling clay were placed on the sand by means of a 2-inch pipe reaching from the ground to the top of the sand. The portion of the well between the packer and the bottom of the well was then pumped continuously for about 44 hours at about 100 gallons a minute. A list of chloride determinations from samples of water obtained as pumping progressed is shown in the table on page 182, and a complete chemical analysis of a sample taken at the close of the test is given in the table on page 176. It appears from these data that the chemical content of the water had declined to a minimum, so that the water sample collected at the end of the period was a true sample of the water entering the well through the screen between 775 and 815 feet. It will be noted that the water from this sand is much more highly mineralized than that discharged from the pump when it is drawing from all sands. During the pumping period a very careful watch was kept on the depth of the well, the sand and clay on the packer, and the water levels, in order to be sure that the pump was drawing water only from the isolated part of the well.

Chloride content of water pumped from well 1 (depth 741 to 790 feet) October 17–19, 1939

[Chloride in parts per million]

Date and time	Chloride	Date and time	Chloride	Date and time	Chloride	Date and time	Chloride
Oct. 17		*Oct. 17*—Con.		*Oct. 18*—Con.		*Oct. 18*—Con.	
[1]12:45 p.m.	1,030	5:00	1,228	5:00	703	8:00	720
12:55	1,732	6:00	1,108	6:00	703	9:00	728
1:05	1,668	7:00	974	7:00 a.m.	703	10:00	728
1:15	1,650	8:00	913	8:00	703	11:00	728
1:25	1,632	9:00	870	9:00	695	12:00 p.m.	720
1:35	1,622	10:00	852	10:00	684	*Oct. 19*	
1:45	1,632	11:00	843	11:00	692	1:00 a.m.	728
1:55	1,578	12:00 p.m.	825	12:00 m.	692	3:00	728
2:10	1,570	*Oct. 18*		1:00 p.m.	692	5:00	728
2:30	1,508	1:00 a.m.	807	4:00	692	7:00	728
3:00	1,508	2:00	772	5:00	703	8:00	720
3:30	1,412	3:00	745	6:00	720	[2]8:30	720
4:15	1,323	4:00	728	7:00	720		

[1] Pumping began at 100 gallons a minute.
[2] Pump shut down.

BETWEEN 640 AND 714 FEET

The sand and clay in the packer were removed by means of a 2-inch air-lift pump. The packer was then pulled up to 640 feet and sealed with sand and clay in the same manner as for the preceding setting, after which the well was filled with sand and clay up to a depth of 714 feet. When filling the well it was important to be sure that about two sacks of drilling clay were placed opposite blank casing and that at least 20 feet of sand were placed on the clay to hold it down, otherwise water would filter up through the sand inside of the casing and lift the sand into suspension where it would be pumped out with the water. The portion of the well between depths of 640 and 714 feet was pumped at the rate of 20 to 50 gallons a minute for about 66 hours. During this part of the test the chloride content reached a high of about 1,800 parts per million a few hours after pumping began, but with extended pumping it finally decreased to about 700 parts. Changes in chloride content are shown in the table on page 183. Since the chemical character of the water did not improve during the last 2 days of pumping, a sample collected at the end of the pumping period was considered representative of the water entering the well through the screen at 695 to 715 feet. The chemical analysis of this water, as is shown in the table on page 176, is very similar to the water obtained from the lower sand.

BETWEEN 447 AND 590 FEET

The well was filled to a depth of 590 feet with sand and clay, the packer was set at about 447 feet below the surface, and pumping from between these depths was begun at the rate of about 120 gallons a minute. As on previous tests samples of water were collected at intervals from the water discharged from the pump and tested for chloride, with the results shown in the table on page 183. It was found that the chloride content reached a high of nearly 2,500 parts per million, but that with extended pumping it decreased gradually to about 280 parts, at which time a water sample was collected for complete chemical analysis. After pumping continuously for about 91 hours the pump was shut down for about 3 hours and then was operated again while samples were collected. The water contained about 260 parts per million of chloride at the start of pumping but only about 180 parts per million at the end of 7 minutes. This was evidence that water was leaking into the well from some other horizon. Conductance readings were made through this part of the well, and water samples were collected at desired depths with the water sampler.

Chloride content of water pumped from well 1 (depth 640 to 714 feet) October 23–26, 1939

[Chloride in parts per million]

Date and time	Chloride	Date and time	Chloride	Date and time	Chloride	Date and time	Chloride
Oct. 23		*Oct. 24*		*Oct. 24*—Con.		*Oct. 25*—Con.	
[1]2:47 p.m.	161	1:00 a.m.	1,043	4:00	670	4:00	780
2:57	1,008	3:00	861	7:00	715	7:00	772
3:07	1,035	5:00	774	10:00	705	10:00	743
3:17	1,192	7:00	722	12:00 p.m.	743	*Oct. 26*	
3:27	1,328	[4]8:00	696	*Oct. 25*		1:00 a.m.	724
3:37	1,443	9:00	687	1:00 a.m.	742	2:00	715
3:47	1,470	9:52	678	4:00	762	4:00	715
[2]6:30	--------	11:00	670	11:00	780	6:00	686
[3]7:05	1,765	12:00 m.	652	12:00 m.	789	8:00	686
8:05	1,820	1:00 p.m.	660	1:00 p.m.	798	9:00	666
9:30	1,540	2:00	670	2:00	782	[5]10:05	705
11:00	1,330	3:00	670				

[1] Pumping began at 20 gallons a minute.
[2] Pump shut down.
[3] Pumping began at 40 gallons a minute.
[4] Discharge increased to 50 gallons a minute.
[5] Pump shut down.

Chloride content of water pumped from well 1 (depth 447 to 590 feet) October 30 to November 3, 1939

[Chloride in parts per million]

Date and time	Chloride	Date and time	Chloride	Date and time	Chloride	Date and time	Chloride
Oct. 30		*Oct. 31*—Con.		*Nov. 1*—Con.		*Nov. 2*—Con.	
[1]3:40 p.m.	220	2:00	865	3:00	310	1:00 p.m.	272
4:00	2,110	3:00	780	4:00	301	2:00	272
5:00	2,425	4:00	715	5:00	296	3:00	272
6:00	2,460	5:00	648	6:00	296	4:00	272
7:00	2,460	6:00	611	7:00	292	5:00	272
8:00	2,400	7:00	573	8:00	292	6:00	272
9:00	2,315	8:00	540	9:00	296	7:00	272
10:00	2,250	9:00	503	10:00	282	8:00	268
11:00	2,150	10:00	485	11:00	292	9:00	272
12:00 p.m.	2,107	11:00	455	12:00 p.m.	282	10:00	272
Oct. 31		12:00 p.m.	433	*Nov. 2*		11:00	268
1:00 a.m.	2,060	*Nov. 1*		1:00 a.m.	292	12:00 p.m.	263
2:00	2,050	1:00 a.m.	423	2:00	292	*Nov. 3*	
3:00	1,990	2:00	410	3:00	277	1:00 a.m.	268
4:00	1,925	3:00	400	4:00	275	2:00	263
5:00	1,840	4:00	385	5:00	272	3:00	268
6:00	1,740	5:00	376	6:00	272	4:00	263
7:00	1,660	6:00	366	7:00	272	5:00	258
8:00	1,550	7:00	357	8:00	282	6:00	258
9:00	1,410	8:00	338	9:00	277	7:00	258
10:00	1,317	9:00	328	10:00	282	8:00	262
11:00	1,160	12:00 m.	319	11:00	272	9:00	256
12:00 m.	1,080	1:00 p.m.	319	12:00 m.	268	[2]10:15	252
1:00 p.m.	980	2:00	310				

[1] Pumping began at about 120 gallons a minute.
[2] Water sample collected for complete analysis. Pump shut down.

Samples from this section, obtained with the sampler, ranged from 180 to 700 parts per million of chloride. The water having the highest chloride content, which entered the well at a depth of approximately

570 feet, apparently came from a bed of sand at that depth, although it might have come from sands at 600 or even 650 feet and moved upward outside of the casing before entering the well. This section of the well yielded about 110 gallons a minute with about 14 feet of draw-down.

Chloride content of water pumped from well 1 (depth 226 to 450 feet) November 7–8, 1939
[Chloride in parts per million]

Date and time	Chloride	Date and time	Chloride	Date and time	Chloride	Date and time	Chloride
Nov. 7		*Nov. 7*—Con.		*Nov. 7*—Con.		*Nov. 8*—Con.	
[1]11:10 p.m.	2,350	5:00	2,260	11:00	2,490	4:00	2,400
1:40	2,440	6:00	2,260	12:00 p.m.	2,490	5:00	2,445
2:10	2,495	7:00	2,300	*Nov. 8*		6:00	2,390
2:40	2,440	8:00	2,350	1:00 a.m.	2,520	7:00	2,445
3:06	2,400	9:00	2,400	2:00	2,445	8:00	2,390
3:30	2,350	10:00	2,445	3:00	2,400	[2]9:00	2,445
4:10	2,260						

[1] Pumping began at 26 gallons a minute.
[2] Pump shut down.

BLANK CASING BETWEEN 226 AND 450 FEET

During this test 26 gallons a minute was pumped from a section of the well not provided with well screen, so the amount pumped must have entered the well through holes formed by corrosion of the casing. The isolated section was between the upper packer at 226 feet and the top of the sand and clay plug at 450 feet. The chloride content of samples of water discharged by the pump is given in the table on this page. The chloride content of the water discharged remained at 2,400 to 2,500 parts per million throughout the 20 hours of pumping and showed no evidence that it could be lowered with further pumping. One way of finding the salt-water leaks in this section of blank pipe was to flush out the salt water with fresh water and determine with the electrodes the contacts between the salt and fresh water. These contacts should be nearly opposite the leaks. Therefore the pump was shut down, and about 10 gallons per minute of fresh tap water was poured into the well through a 2-inch pipe extending from the surface to a depth of 243 feet. During this time the contact between the fresh and salty water, as checked with the electrodes, moved downward until it reached a depth of about 261 feet, below which it could not be driven—conclusive evidence of a salt-water leak at 261 feet. The stream of fresh water at 243 feet was then cut off and introduced to the bottom of the well through 442 feet of ½-inch pipe. The contact between the fresh water on the bottom and the salty water above moved upwards to about 392 feet and remained nearly stationary—good evidence of a salt-water leak at 392 feet. Thus, the part of the well from 261 and 392 feet was filled with salty water, while above and below those depths the salty water had been flushed out. The stream of fresh water was then changed from the bottom of the well to a depth of about 337 feet. After it had run in for several hours at this depth, the fresh water had replaced the salty water from 337 to 392 feet and also had replaced a large part of the salty water between 337 and 262 feet. It was believed from these data that sufficient evidence had been obtained to show that the two main holes in the casing were at 261 and 392 feet. Probably there were also several other small holes between those depths that were not well defined. The conductance readings for the tests are given in the table on page 185.

Conductance measurements made in well 1, Nov. 8 and 9, 1939

[Packer at 226 feet, depth of well 450 feet]

Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)	Depth (feet)	Current (milli-amperes)
[1]229	30	276	29	412	26	285	33
244	34	281	29	416	25	295	33
254	35	286	29	421	24	305	33
249	30–34	291	29	426	23	315	33
229	21	292	30	432	22½	322	33½
235	22	295	30	[10]437	22½	325	33½
243	23	300	30			336	33
244	24	305	30	[11]243	23	346	33½
246	25	315	29½	254	23	356	33
249	26	325	30	257	24	366	33
253	27	335	30	259	25	376	33
254	27	346	30	260½	26	387	33
261	28	356	30	261	27	392	33
263	29	366	30	261½	32	393½	31
266	30	376	30	262	33	397	30
267	31	386	30	269	33½	398	29
268	32	396	30	274	33½	402	27
270	32	398	31–32	285	33½	403	26
273	33	399	33	292	34	404	25
275	33	407	33	295	33	405	24
279	33½	417	33	297	34	407	23
285	33½	427	33	300	33	410	22
287	34	[6]437	33	305	33	417	22
295	34			315	32½	427	21½
[2]305	34	[7]243	22½	317	33	[14]437	21½
		245	23	325	33		
244	24	254	23	336	33	[15]243	23
254	25	259	23	346	33	254	23
260	25½	262	23	356	33	259	23
262	26	263	23½	363	32	260	24
266	26	264	24	376	32	261	27
267	29	265	24	387	31	261½	32
268	30	265½	26½	392	30	264	32
285	30	266	27	397	29½	274	32
289	31	267	29	400	27	285	32
292	32	268	30	401	26	295	32
295	31	269	30	404	25	305	31½
300	32	274	30	405	24	315	31½
[3]305	32	282	30	407	23	325	32
315	31	285	29½	410	22	335	32
320	32	295	30	417	22	345	32
325	33	297	30½	427	22	355	32
336	34	305	30	[12]437	21½	365	32
346	34	315	30			375	32
356	34	325	30	243	23	385	32
366	33½	335–397	30	254	23	390	31
376	33½	398½	30	259½	23	393	30
386	33½	399	32	260	24–25	397	30
397	33	399½	33	261	32	398	29
407	33	407	33	264	32	400	27
417	33	417	33	274	32½	401	26
427	33	427	32	285	32½	404	25
438	33	[8]438	32	290	33	405	23
				295	32½	407	22
[4]243	22	[9]243	23	305	32½	410	21
254	22	254	23	315	32	412	21
263	23	257	24	325	32½	417	21
264	23	259	25	336	32½	[16]427	21
265	24	261	31	346–387	33		
265½	25	265	33	393	32	[17]243	23
266	26	274	33	397	30	254	23
266½	27	285	32½	399	28	259	23
267	28	287	33	404	26	260½	24
268	29	295	32½	407	25	261	30
275	29	297	33	409	24	264	30
285	29	305	32½	412	23	274	30
292	30	309	32	414	22	286	30
305	30	315	32	418	21	295	30
315	30	325	32	427	21	305	29½
325	31	336	31	[13]437	21	315	29
[5]336	31	346	31			325	29½
		356	30½	243	24	335	29
243	22	361	30	249	24	340	29
254	22	366	30	254	24	343	24½
263	22	376	30	259	24	345	25½
264	23	386	30	259½	25	347	25
266	27	397	30	260½	26	356	25
267	28	401	29	261	33	366	25
267½	29	405	28	264	33	376	25½
269	29	408	27	275	33½	378	26

Conductance measurements made in well 1, Nov. 8 and 9, 1939—Continued

Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)	Depth (feet)	Current (milliamperes)
387	25½	344	24	376	29	371	30½
395	26	346	25	387	28½	376	30
399	27	348	25½	389	28	381	30
409	26½	356	25½	397	28½	387	30
417	26	360–387	25	404	28	397	30
422	25	393	26	407	27	401	29½
427	24	394	25½	417	27	405	29
433	23	399	25	421	26	413	29
[18]437	23	402	25½	425	27	416	28½
		404	26	427	27	419	28½
244	23	405	26	429	26	422	28
254	23	407–419	25	438	25	427	28½
260	23½	425	24	[21]444	25½	432	28
261	28	[19]432	23			[23]438	27½
262	29			[22]244	26	[24]443	27½
263	29	[20]244	24	254	26		
274	29	249	24	259	26	[25]244	24
285	29	254	24	261	26–30	254	24
290	29½	259	24	262	31	261	24
295	29	262	24	269	31	262	26
305	29	262½	29½	274	31	263	28
315	28½	264	30	285	30½	264	28
317	29	274	29½	295	30½	274	28
322	29½	285	29½	305	30½	276	28
324	29½	295	29½	315	30	285	28
327	29	305	29½	325	30½	295	28
330	29	315	29	336	30½	303	28
334	28	325	29½	342	30	305	27½
336	28	336	29½	346	30½	315	27
338	27	346	29	356	30½	320	26
342	27	356	29	361	30	323	27
343	25	366	29	366	30	[26]325	28

[1] Began running 10 gallons a minute of fresh water into the well at 243 feet.
[2] 10:06 a.m.
[3] 10:25 a.m.
[4] 10:45 a.m.
[5] 11:30 a.m.
[6] 11:45 a.m.
[7] 12:30 p.m.
[8] Water shut off at 12:50 p.m. Began running 10 gallons a minute of fresh water into the well at 442 feet (1:20 p.m.).
[9] 2:30 p.m.
[10] 2:45 p.m.
[11] 3:45 p.m.
[12] 4 p.m.
[13] 6:50 p.m.
[14] 8:25 p.m.
[15] 9:05 p.m.
[16] Water shut off at 9:20 p.m. Began running 10 gallons a minute of fresh water into the well at 337 feet (10:50 p.m.).
[17] 10:50 p.m.
[18] 11:15 p.m.
[19] 12:30 a.m. Pumping begun 1 a.m. at 27 gallons a minute at 337 feet. Pumped continuously until 1:55 p.m.
[20] 10:30 a.m.
[21] 10:45 a.m.
[22] 1:40 p.m.
[23] 1:55 p.m.
[24] Suction of pump moved from 337 to 262 feet and pumping continued.
[25] 3:45 p.m.
[26] End of test.

The well was pumped several hours with the intake at 337 feet, and when the mineral content had reached its maximum a water sample was collected for complete analysis, the assumption being that the sample probably would contain, for the most part, water that entered the well through the hole in the casing at 392 feet. After the sample was collected, the suction of the pump was pulled up to 262 feet, nearly opposite the hole in the casing, and after several hours of pumping another water sample was collected. These water analyses are given in the table on page 176, opposite the listed depths of 392 and 261 feet. The hole in the casing at 220 feet probably is very small, and no attempt was made to isolate it to obtain a sample of the water leaking into the well at that point. The water there probably is similar to that at 392 and 261 feet, possibly with a little higher nonpumping level. Figure 10 shows the position of the leaks, the casing and screen setting, and the driller's log.

COMPARISON OF NONPUMPING WATER LEVELS IN VARIOUS SANDS IN WELL 1

During the test on well 1 other wells in the Montana well field were pumped at irregular intervals and consequently there was a wide fluctuation of the water level in the field. The interference of one well

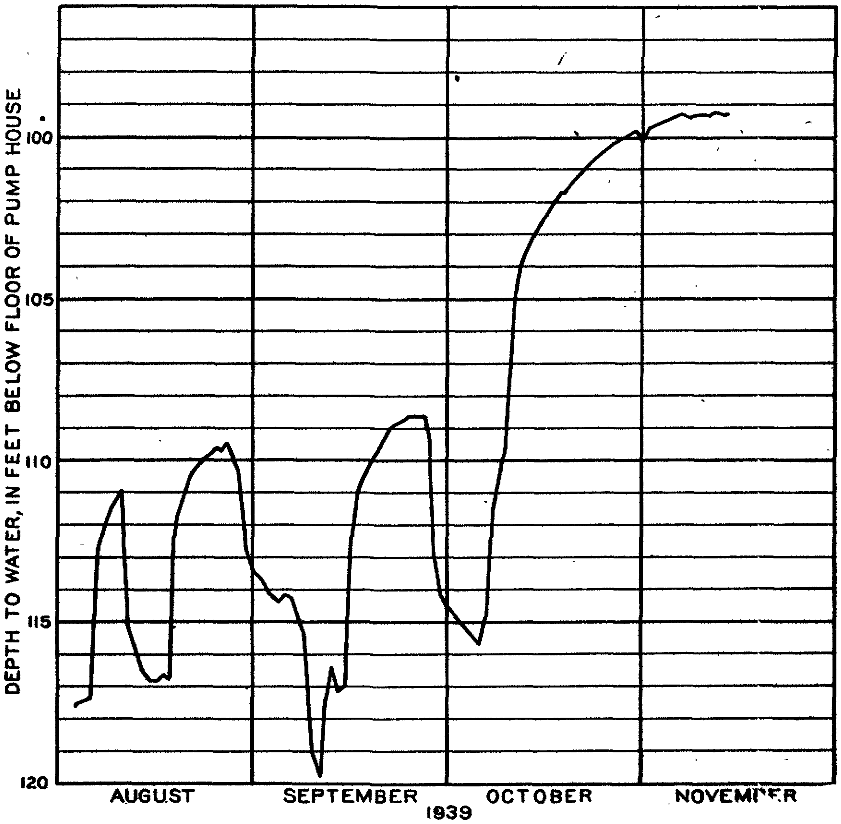


FIGURE 11.—Fluctuation of water level in El Paso well 2.

with another is great, and comparison of the nonpumping water level in various sands in well 1 could not be made when the readings were taken several days apart. However, about October 5 all wells in the Montana field were shut down, and a general rise in the water level in the whole field followed. By the latter part of October the water level in the Montana well field probably had nearly recovered from the direct effect of pumping, as is shown by the graph of the water level in well 2, which was recorded during the test by a continuous water-stage recorder. (See fig. 11.) The depth to the water level for each section of well 1 that was isolated during the test was measured under nonpumping conditions. When the section between 640 and 714 feet was isolated, the water level on October 27 was 95.8 feet below the level of the pump house; when the section between 447 and 590 feet was isolated the water level on November 6 was 95.2 feet; and when the section between 226 and 450 feet, the salt-bearing beds, was isolated, the water level on November 7 was 92.6 feet. Thus, the level of water from the salt-water aquifer was nearly 3 feet higher than that in the fresh water-bearing sands. This confirms the statement made on page 78 that the non-pumping water level of the salty water was higher than that of the fresh water, resulting in a movement of a small amount of salty water into the well while it was standing idle.

SUMMARY OF INVESTIGATION OF WELL 1

Apparently most of the moderately mineralized water was entering the well through the slotted pipe between 695 and 715 feet and between 775 and 790 feet. (The slots from 790 to 815 feet were covered.) A small amount of very salty water was entering the well through holes at 220, 261, and 392 feet. The entrance of salty water to the well in the section below 600 feet could be prevented by plugging the well below that depth, but this probably would reduce the yield by about one-third. The flow from 220, 261, and 392 feet probably could be stopped by setting a liner in the well, and grouting the well from about 200 to 485 feet, but this would be difficult and expensive. If it were done successfully, there still would be the inflow of salty water into the well at about 600 feet, which may increase markedly. The entrance of salty water at the 600-foot level probably cannot be stopped effectively at a reasonable cost, because the well is reported to have been artificially gravelled on the outside of the casing.

MONTANA WELL FIELD

Tests made on well 3 in 1936 indicate that conditions were about the same in that well as they were in well 1. It does not necessarily follow that the other wells in the Montana field—wells 2 and 4—have the same characteristics pertaining to contamination, but it seems likely that such is the case. To determine this definitely would require exhaustive tests on wells 2 and 4 similar to those made in well 1, and probably further tests on well 3. It is impossible to predict, with the data at hand, how soon the wells in the Montana field will yield water too highly mineralized for city use. However, all the evidence now available indicated that the conclusions set forth on pages 84–85 are substantially correct and that less and less dependence should be placed on the Montana field as a source of water supply for El Paso.

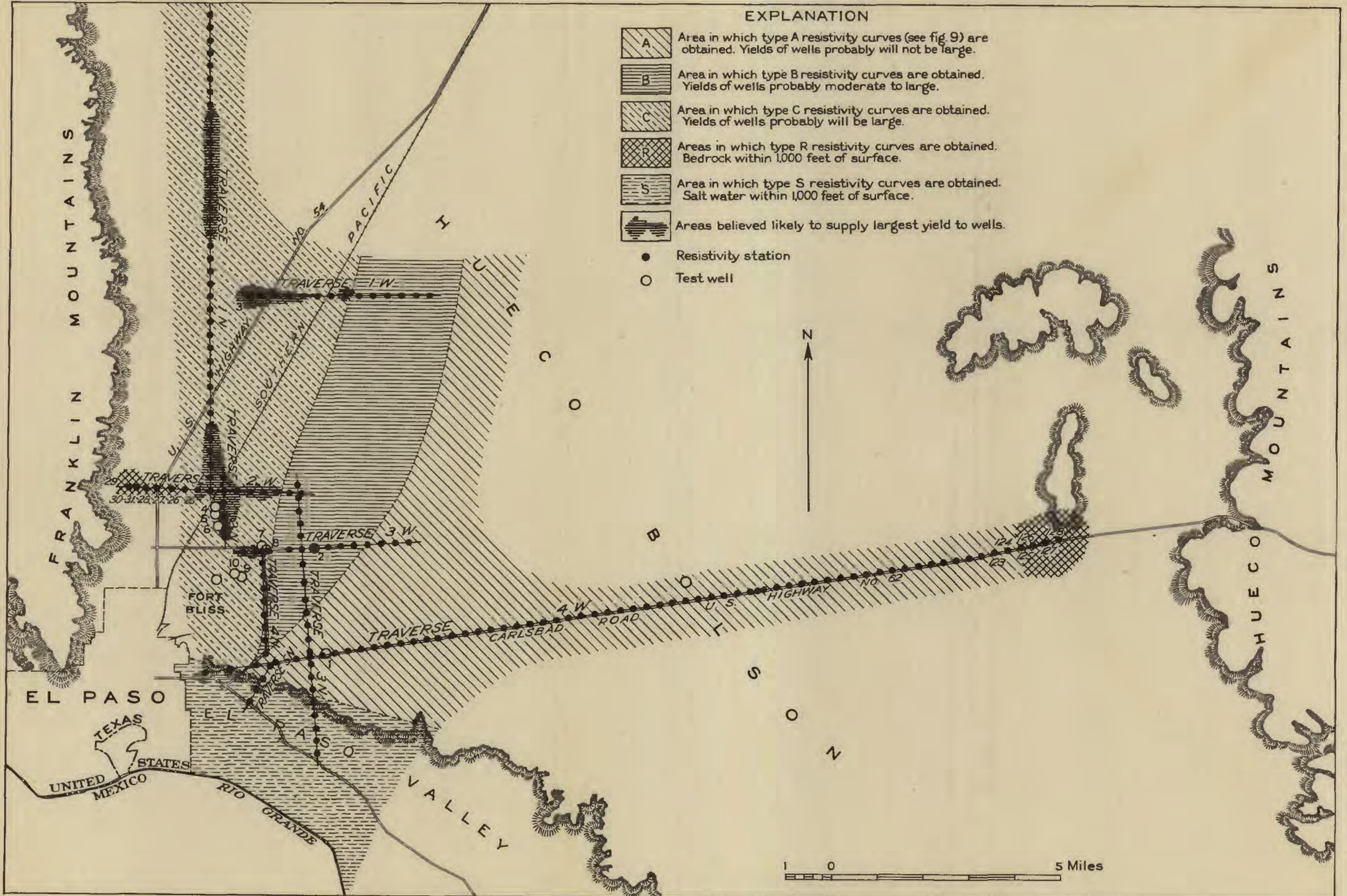
INDEX

MAP OF THE EL PASO AREA SHOWING CONTOURS ON THE WATER TABLE IN JUNE 1936 AND LOCATION OF WELLS

Scale $\frac{1}{125,000}$

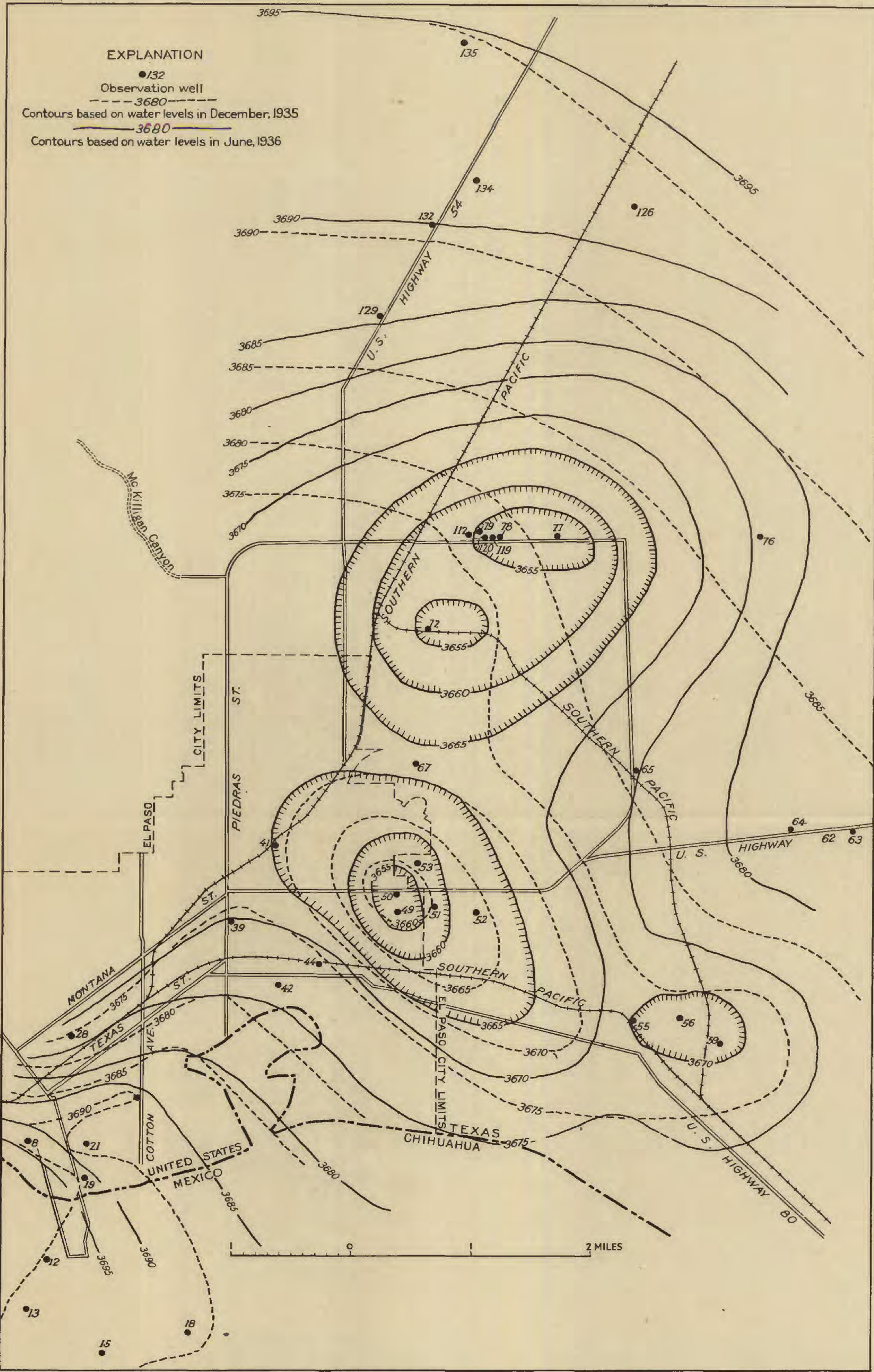
1 0 1 5 Miles

1944

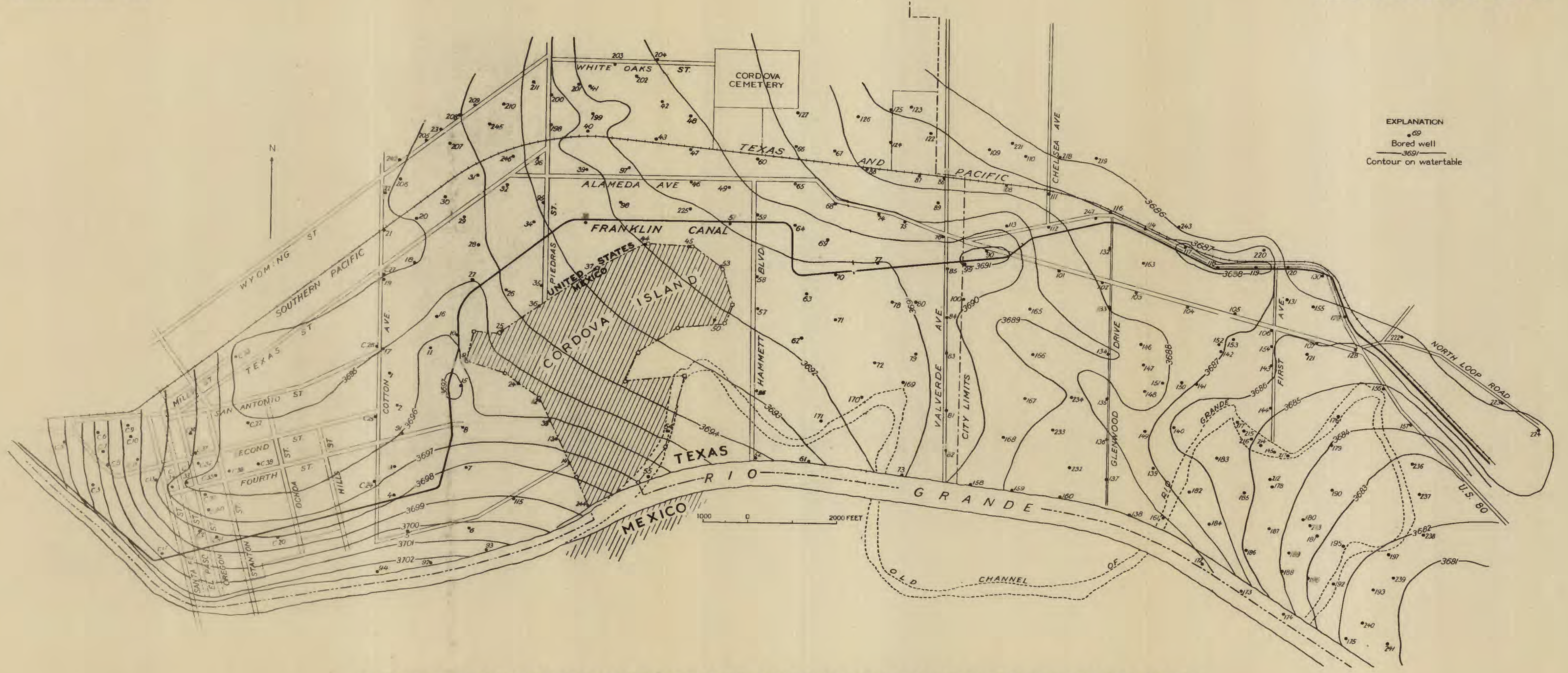


MAP SHOWING AREAS CHARACTERIZED BY DISTINCT TYPES OF RESISTIVITY CURVES

FLUCTUATIONS IN THE WATER LEVELS IN WELLS 22, 53, 55, 64, 112, AND 130



MAP OF THE EL PASO AND CIUDAD JUAREZ AREAS SHOWING BY CONTOURS THE ALTITUDE OF THE WATER LEVEL IN DEEP WELLS IN DECEMBER 1935 AND IN JUNE 1936



MAP OF THE RIO GRANDE VALLEY NEAR EL PASO SHOWING CONTOURS ON THE WATER TABLE
APRIL 27–29, 1936