TEXAS DEPARTMENT OF WATER RESOURCES

REPORT 292

GROUND-WATER EVALUATION FROM TEST HOLE DRILLING NEAR MISSION, TEXAS

By

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ABSTRACT

During 1983 and 1984, an investigation was conducted to establish additional hydrogeological data in southwestern Hidalgo County where agricultural activities, including the widespread use of agricultural drainage wells, may be adversely affecting ground-water quality. This report of the investigation contains data on selected wells in the study area, including records of 98 wells and chemical analyses of water samples from 69 wells. Five test holes were drilled by the Department in conjunction with this study. In each test hole water samples were taken, geophysical logs were run, and lithologic samples were collected. All data indicate three distinct water-producing zones exist within the local aquifer, the Lower Rio Grande Valley aquifer. The shallow zone (50-100 ft) contains very highly mineralized water, which makes it unsuitable for most uses. In addition, high nitrate concentrations in the shallow zone may indicate pollution from agricultural sources. The middle zone (100-300 ft) and lower zone (below 300 ft) contain fresh to slightly saline water over most of the study area. These zones are generally suitable for domestic and stock watering; however, they are not suitable for irrigation water and have limited industrial applications. Approximately 4 million gallons per day or 4,500 acre-feet per year of water is available for development from the middle and lower zones of the aquifer. It is recommended that the middle and lower zones not be used as disposal zones for agricultural drainage well fluids.

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INTRODUCTION

Purpose

This project was initiated by the Underground Injection Control Section (UIC) of the Department to investigate the ground-water resources in the vicinity of Mission, Texas, in southern Hidalgo County. The main objective of the project was to drill test wells which would provide accurate ground-water quality data for the near-surface aquifer system within the study area. Secondary objectives of this investigation include: (1) determination of the geometric and hydraulic characteristics of the aquifer; (2) investigation of the impact of agricultural drainage wells (injection-type) on ground-water quality; (3) refinement of test hole drilling and sampling techniques; and (4) determination of the potential for additional ground-water development.

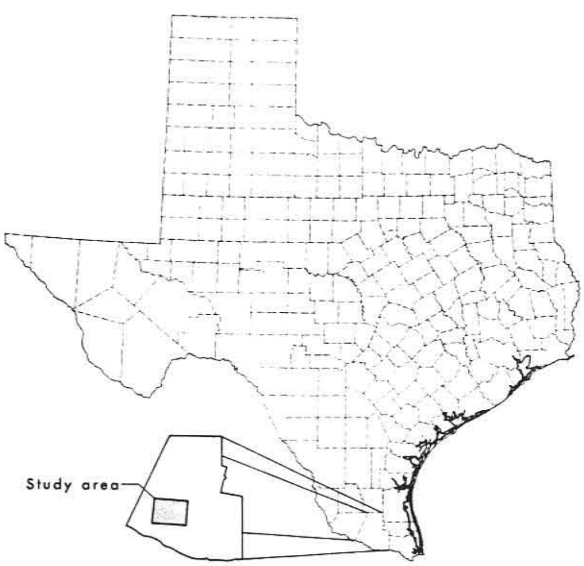

Figure 1.—Location of Study Area

Location and Extent

The study area is located as shown in Figure 1. This area defines the approximate limit of agricultural drainage well operations. Included in the study area (250 square miles) are the cities of Mission, Palmhurst, Alton, Citrus City, and western portions of McAllen and Edinburg.

Climate

The climate in the Lower Rio Grande Valley can be described as semi-tropical and semi-arid. Very high or low temperatures are uncommon. The mean annual precipitation at McAllen is approximately 23 inches. Precipitation is highest from April through September. During this time 14 inches, or 60 percent, of the total annual rainfall occurs. This time period also coincides with the growing season for most crops in the region.

Previous Investigations

The study area has been previously discussed in publications relating to geology and ground-water resources. Some of the investigations leading to these publications were conducted by the U. S. Geological Survey, Texas Board of Water Engineers, and Texas Water Development Board. Prior publications which are the principal references for this report include the following hydrogeological investigations: Lonsdale and Nye (1938), Texas Board of Water Engineers (1941), Baker and Dale (1961), Wood and others (1963), and Preston (1983).

In addition to the above, a limited hydrogeological investigation (Knape, 1984) was conducted as part of the Department's statewide assessment of all underground injection activities. This assessment addressed the use of agricultural drainage wells and their potential impact upon ground-water resources. Numerous federal, state, and local officials were contacted and a field inventory of drainage wells, including sampling of injection fluids, was conducted. Upon completion of the assessment, it was determined that further investigations of the ground-water resources in the area were needed to make regulatory decisions concerning agricultural drainage wells.

Acknowledgements

The author is indebted to the property owners within the study area for supplying information concerning their wells and permitting access to their properties; to Pursley Drilling Company, for information and valuable assistance throughout this investigation; and to the State Department of Highways and Public Transportation for assistance in constructing mud pits, providing traffic control signs, and right-of-way cleanup.

Personnel

This report was prepared during 1983-1984 under the supervision of Bill Klemt. The author was assisted in assembling the report by Pat Stratton and Robin Domel. Acknowledgements are also extended to Jimmie Russell, for his assistance in electric log interpretation; Marion Striegler, Lewis Barnes, and members of the Department's drilling crew, who coordinated test hole drilling and sampling; and Doug Crim, who logged the test holes with the Department's geophysical logging unit.

METRIC CONVERSIONS TABLE

The English units used in this report may be converted to metric units by the following conversion factors:

From English units	Multiply by	To obtain metric units
acres	0.4047	square hectometers (hm^2)
acre-feet (ac-ft)	.001233	cubic hectometers (hm^3)

From English units	Multiply by	To obtain metric units
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	.189	meters per kilometer (m/km)
gallons per minute (gal/min)	.06309	liters per second (l/s)
gallons per day per square foot [(gal/d)/ft^2]	40.74	liters per day per square meter [(l/d)/m^2]
gallons per day per foot [(gal/d)/ft]	12.418	liters per day per meter [(l/d)/m]
horsepower (electric) hp	746	watts (w)
inches (in.)	2.54	centimeters (cm)
miles (mi)	1.609	kilometers (km)
million gallons per day (million gal/d)	3.785	million liters per day (million l/d)
square miles (mi^2)	2.590	square kilometers (km^2)

To convert degrees Fahrenheit to degrees Celsius use the following formula:

$$°C = 0.556 (°F-32)$$

APPROACH AND PROCEDURES

Method of Investigation

The field work for this investigation was begun in June 1983 and ended in August 1983. The office work, including data assembly and writing the report, was accomplished from September 1983 to June 1984. The following investigation procedure is presented in chronological order.

Field work consisted of collecting drillers and electric logs of water wells, and water quality, water level, and well construction data; drilling and completing five test holes; examining sample cuttings; geophysical logging of test holes; and water sampling of test holes. Also, an inventory of selected water wells and agricultural drainage wells was conducted and elevations of wells having hydrogeological data were determined.

Office work included constructing geologic cross-sections; tabulating well records, logs, and chemical analyses; preparing well location maps; constructing hydrogeologic maps; tabulating historical pumpage; and projecting future ground water demands based on prior use, water quality, and aquifer characteristics.

Drilling Rig and Equipment

A modified Failing 1500 drilling rig operated by the Texas Department of Water Resources was used to drill five test holes. Additional equipment consisted of a 900 gallon water truck, 2¾ inch O.D. drill pipe, 3 inch O.D. steel casing, two 21 foot sections of 3 inch O.D. perforated pipe, and one inch O.D. galvanized pipe used for an air line. Drilling was accomplished using wing-type bits which are capable of drilling through unconsolidated sediments. No cores were taken during this study.

Drilling Procedures

All five test holes were drilled on highway right-of-way. The Texas Department of Highways and Public Transportation was contracted to perform the following services: digging and backfilling of mud pits for the test holes; providing and maintaining the necessary safety signs, barricades, and lights; and supplying water for drilling purposes. The Highway Department also assisted in the location of suitable drilling locations and provided facilities to store drilling equipment when not in use.

Drilling was often slow and especially difficult in unconsolidated coarse gravels. These gravels were encountered in each test hole during the first 100 feet of drilling. A special chemical mud solution made by Baroid called "E-Z Mud" was utilized to help circulate the coarse gravel. Another problem which slowed the drilling process in the first test hole drilled (Well 3) was frequent caving which occurred when circulation was suspended. This problem was minimized in later test holes by drilling continuously for longer periods and monitoring drilling fluid properties more closely.

Formation cuttings were collected at the surface at 10 foot intervals. All samples were washed and examined at the drilling site. Following examination, each sample was placed in a sample bag and marked with the depth of origin. Re-examination of samples took place in the office following field work.

A suite of geophysical logs, which included electric, gamma ray, gamma-gamma, and neutron logs, were run on each of the test holes using the Department's logging unit. These logs, along with the sample logs, were used to select the intervals to be tested for water quality.

Water Sampling Procedures

The following is a brief description of the ground-water sampling procedure used for the investigation. First, a screen or perforated pipe approximately 20 feet in length is attached to a string of 3-inch tubing and run in the mud-filled borehole until the screen is opposite the deepest zone to be sampled. A relatively fine gravel is placed in the hole above the zone to be tested. At the surface, a "T" connection is placed on the tubing and an airline is run into the tubing. Air from a compressor is forced down the airline and up the tubing which creates a suction or jetting action on the screened section. This jetting causes water to enter the tubing through the screen and is forced up the tubing to the surface as shown in Figure 2. This method proved successful in obtaining water samples for chemical analysis from the selected depth intervals listed in Table 1.

Each test hole was plugged and abandoned following water sampling.

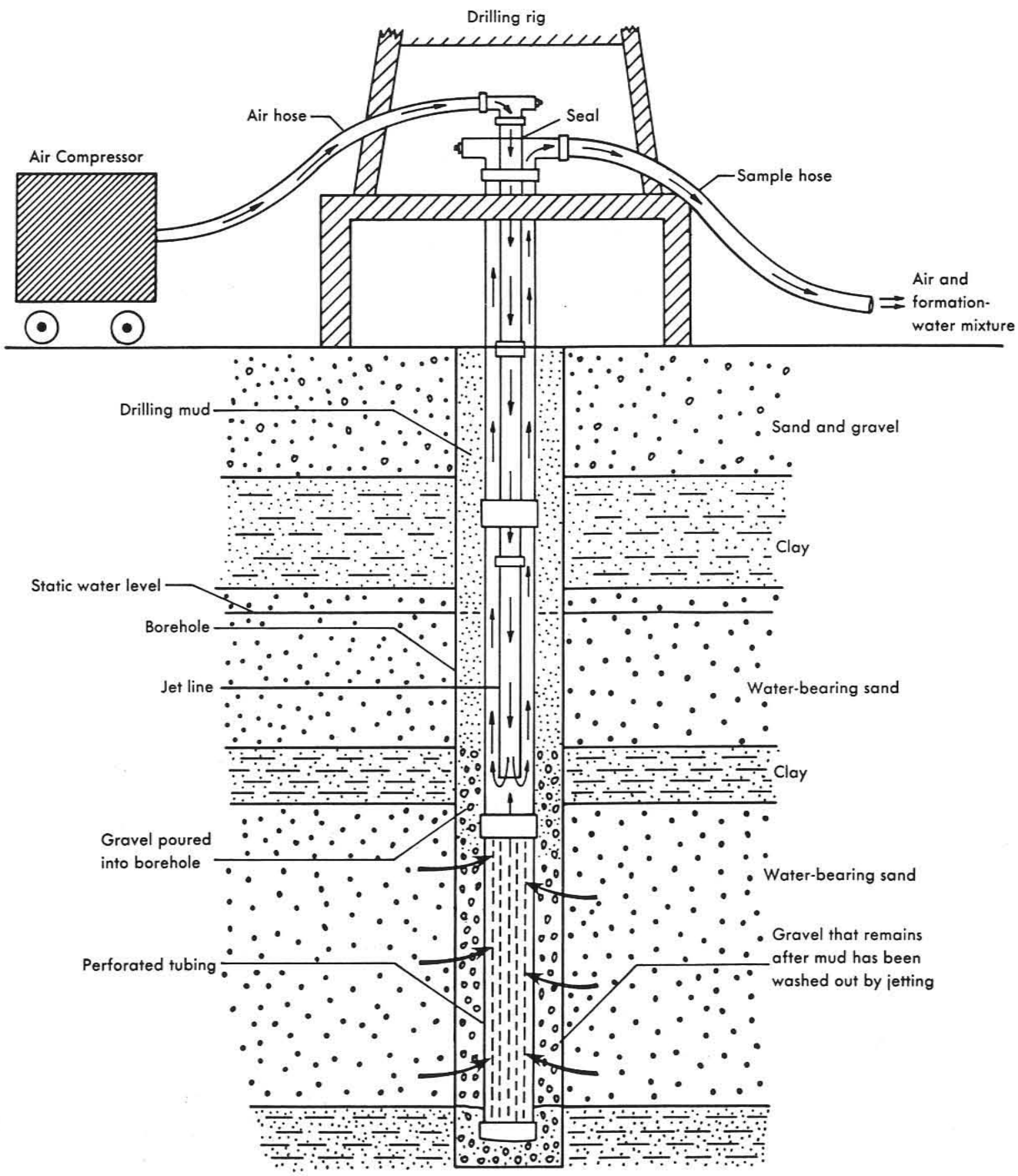

Figure 2.—Method of Water Sampling in an Open Hole

Table 1.—Test Hole Water Sampling

Well	Total depth drilled (ft)	Sampling interval (ft)	Approximate yield (gal/min)	Approximate jetting time (hours)
1	804	63-105	40-50	½
		380-410	50-70	3
2	804	60- 90	variable	½
		358-390	50-70	1
		440-462	50-70	2
3	811	60- 80	variable	1¼
		220-252	variable	½
		410-450	variable	2½
4	804	63- 84	25	½
		273-294	25	¾
		399-420	40	2
5	660	63- 84	variable	¼
		224-273	variable	1

Well Inventory

This report contains basic data on selected wells in the study area, including a well location map (Figure 3), records of wells (Table 5), and chemical analyses of water samples from 69 wells (Table 6). Also used in the study were lithologic descriptions of samples taken from the five test holes and drillers' logs of 24 selected wells in the study area (Table 7). All of the wells selected for this report provide hydrogeologic information necessary for the interpretive portions of this report.

Most of the chemical analyses presented in this report were determined in the laboratories of the Texas Department of Health. The remainder were determined by the U. S. Geological Survey and by commercial laboratories. Additional chemical analyses on certain wells may be found in the publications listed in the selected references.

Each well in this report is assigned a one or two digit number (1 to 98). Other reference well numbers from Texas Board of Water Engineers Bulletin 6014 (Baker and Dale, 1961) and State well numbers, where assigned, are included in the records of wells (Table 5).

GENERAL GEOLOGY OF WATER-BEARING ZONES

Stratigraphy

The Lower Rio Grande Valley is underlain by complex interbedded layers and lenses of clay, silt, sand, and gravel. These sediments are loosely consolidated or unconsolidated fluvial, deltaic, and shallow marine deposits, which range in age from early Tertiary to Recent. These units are not easily definable in the subsurface. In many areas, zones of montmorillonite clay are present near the surface which impede vertical percolation of surface waters and can lead to perched water tables.

Structure

The geologic formations in the study area have a regional dip to the east, toward the Gulf of Mexico. Except for the Recent deposits, the angle of dip for the top of each formation is greater than the slope of the land surface; consequently, the formations outcrop in northward trending belts which increase in age inland. The actual dip is extremely hard to determine because of the interbedded nature of the deposits.

Some folding and faulting have taken place in the region and have been identified largely at depths in which oil and gas occur, below any freshwater resources.

LOWER RIO GRANDE VALLEY AQUIFER

Occurrence of Ground Water

The Lower Rio Grande Valley aquifer is the principal aquifer in the study area. Fresh to slightly saline ground water is produced from all or part of the Goliad, Lissie, and Beaumont Formations and Recent alluvial deposits. These geologic units are characterized by complex interbedded layers and lenses of clay, silt, sand, and gravel. Hydrologic continuity occurs between the adjacent permeable beds; however, locally they are separated by layers of less permeable sediments.

Based on geophysical well data, chemical analyses, and drillers' logs, three poorly defined zones of water-bearing sands and gravels have been delineated in the study area. In some areas it is difficult to distinguish between these zones due to the complex vertical and horizontal gradations of sand, gravel, and clay units. Figures 4 and 5 are geologic sections through the study area which define the water-bearing zones.

The upper or shallow water-bearing zone occurs from approximately 50 to 100 feet below land surface in the study area, and contains layers of sand and gravel. The approximate altitude of and depth to the top of the shallow zone are shown on Figure 6. This figure shows that the top of the shallow zone has a general dip to the east of approximately 15 feet per mile.

The approximate net sand and total thickness values for the shallow zone are shown on Figure 7. Net sand thicknesses are erratic and thus could not be contoured from the relatively few data that are available for the shallow zone. The zone is probably not present throughout the entire study area.

The middle water-bearing zone occurs from approximately 100 to 300 feet below land surface and contains interbedded clay, silt, sand, and fine gravel. The approximate altitude of and depth to top of the middle zone are shown on Figure 8. The approximate net sand and total thickness of the middle zone are shown on Figure 9. Net sand thickness generally is greater in the eastern part of the study area and decreases dramatically toward the north and northwest. The zone appears to be absent in the latter area.

The lower water-bearing zone occurs from approximately 300 feet below land surface to the base of slightly saline water and is composed of sediments similar to those of the middle zone. The base of slightly saline water ranges from approximately 600 feet below land surface at the study area's west and southwest boundaries to about 1,500 feet at the northeast corner. The approximate altitude and depth to the top of the lower zone are shown on Figure 10. The approximate net sand and total thickness of the lower zone are shown on Figure 11. Net sand and total thickness increase significantly from the southwest to the northeast section of the study area.

Chemical Quality

All ground water contains minerals carried in solution, the type and concentration of which depend upon the surface and subsurface environment, rate of ground-water movement, and source of the ground water. Precipitation is relatively free of minerals until it comes in contact with the various constituents which make up the soils and component rocks of the aquifer. As a result of the solvent properties of water, minerals are dissolved and carried into solution as the water moves through the aquifer. The solute concentration depends upon the solubility of the minerals present, and the length of time water is in contact with the rocks. The amount of dissolved minerals in ground water generally increases with depth where circulation has been restricted due to various geologic conditions.

A tabulation of 69 chemical analyses from selected wells and test holes in the study area is presented in Table 6. The source, significance, and range in concentration of selected chemical constituents in ground water in the Lower Rio Grande Valley aquifer are given in Table 2. The chloride, sulfate, nitrate, and dissolved-solids concentration for the shallow, middle, and lower zones are shown in Figures 12, 13, and 14, respectively.

In addition to standard chemical analyses, each water-bearing zone of the five test holes and six other water wells (wells 14, 17, 19, 21, 22, and 23) were analyzed for 26 types of pesticides. These pesticides are listed in Table 3.

Table 2.—Source, Significance, and Concentration Range of Selected Chemical Constituents in Ground Water in the Lower Rio Grande Valley Aquifer

(Adapted from Doll and others, 1963, p. 39-43)

Only analyses which were representative of native ground water were used. Analyses are in milligrams per liter except percent sodium, specific conductance, pH, and SAR.

Constituent or Property	Source of Cause	Significance	Ranges in Concentrations: Shallow Zone	Middle Zone	Lower Zone
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 mg/l. High concentrations, as much as 100 mg/l, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.	25-108	20-52	15-31
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 mg/l stain laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. Texas Department of Health (1977) drinking water standards state that iron should not exceed 0.3 mg/l. Larger quantities cause unpleasant taste and favor growth of iron bacteria.	—	—	—
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.	(Ca) 22-836 (Mg) 9-456	(Ca) 37-470 (Mg) 13-174	(Ca) 23-179 (Mg) 13-78
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in oil-field brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.	(Na) 200-3822 (K) 3-94	(Na) 350-2363 (K) 8.3-28	(Na) 200-3822 (K) 5.2-23
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon-dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.	(HCO_3) 0-508	(HCO_3) 246-407	(HCO_3) 224-372
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Texas Department of Health (1977) drinking water standards recommended that the sulfate content should not exceed 300 mg/l.	240-2,867	78-1,050	138-706
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in oil-field brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. Texas Department of Health (1977) drinking water standards recommend that the chloride content should not exceed 300 mg/l.	212-6,328	410-3,158	238-1,831
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual (Maier, 1950, p. 1120-1132).	0.4-7.0	0.5-28	0.9-1.9
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. Texas Department of Health (1977) drinking water standards suggest a limit of 45 mg/l (as NO_3) or 10 mg/l (as N). Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding (Maxcy, 1950, p. 271). Nitrate shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.	<0.04-104.5	0.2-48.8	<0.04-26.4
Boron (B)	A minor constituent of rocks and of natural waters.	An excessive boron content will make water unsuitable for irrigation Wilcox (1955, p. 11) indicated that a boron concentration of as much as 1.0 mg/l is permissible for irrigating sensitive crops; as much as 2.0 mg/l for semitolerant crops; and as much as 3.0 mg/l for tolerant crops. Crops sensitive to boron include most deciduous fruit and nut trees and navy beans; semitolerant crops include most small grains, potatoes and some other vegetables, and cotton; and tolerant crops include alfalfa, most root vegetables, and the date palm.	1.5-25.2	0.2-3.6	2.5-3.7
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils.	Texas Department of Health (1977) drinking water standards recommends that waters containing more than 1,000 mg/l dissolved solids not be used if other less mineralized supplies are available. For many purposes the dissolved-solids content is a major limitation on the use of water.	1,220-14,674	1,214-7,004	1,160-4,262
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All of the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness up to 60 mg/l are considered soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; more than 180 mg/l, very hard.	92-3,965	265-1,983	134-767
Sodium-adsorption ratio (SAR)	Sodium in water.	A ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil (U.S. Salinity Laboratory Staff, 1954, p. 72, 156). Defined by the following equation: $SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$ where Na^{+}, Ca^{++}, and Mg^{++} represent the concentration in milliequivalents per liter (me/l) of the respective ions.	3.9-27.9	6.0-23.6	10.2-19.6
Residual sodium carbonate (RSC)	Sodium and carbonate or bicarbonate in water.	As calcium and magnesium precipitate as carbonates in the soil, the relative proportion of sodium in the water is increased (Eaton, 1590, p. 123-133). Defined by the following equation: $RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$ where CO_3^{--}, HCO_3^{-}, Ca^{++}, and Mg^{++} represent the concentrations in milliequivalents per liter (me/l) of the respective ions.	—	0-2.5	0-4.4
Specific conductance (micromhos at 25°)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.	885-32,765	1,900-7,740	1,680-4,950
Hydrogen ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals. The Texas Department of Health drinking water standards recommends a pH greater than 7.	7.4-11.5	7.0-8.3	7.5-8.5

Table 3.—Pesticides Analyzed in Selected Wells

2,4-D	DDE
2,4,5-T	Aldrin
Silvex	Chlordane
Heptachlor	Dieldrin
Heptachlor Epoxide	Endrin
Lindane	Methyl Parathion
Methoxychlor	Dibutyl Phthalate
Parathion	Diethylhexyl Phthalate
PCB	Ethion
Diazinon	Guthion
DDT	Bromacil
DDD	Simazine

Note: Wells 1-5 (test holes) and 14, 17, 19, 21, 22, and 23 were analyzed for the above pesticides by the Texas Department of Health, Austin, Texas. No pesticides were detected in any of the wells sampled.

Concentration limits recommended by the Texas Department of Health (1977) for selected chemical constituents in public and domestic water supplies are shown in the following table:

Constituent	Maximum recommended concentration (mg/l)
Chloride (Cl)	300
Nitrate (as NO_3)	45
Sulfate (SO_4)	300
Dissolved Solids	1,000

Water containing less than 1,000 mg/l of dissolved solids is regarded in this report as fresh. Water having a dissolved-solids concentration of 1,000 to 3,000 mg/l is classified as slightly saline and is used by many small communities, farms, and ranches. Water of this class has been recognized as somewhat unsatisfactory but generally not harmful. It must be recognized that in many areas of Texas the only available water supply may have a dissolved-solids concentration greatly in excess of 1,000 mg/l.

Water that is not suitable for human consumption may be acceptable for industrial use, and different standards may apply for each type of industry. Suggested water-quality tolerances for a number of industries are presented in Table 4, and the effects that most minerals have on industrial use are shown in Table 2. Ground water used by industry may be classified into four principal categories: cooling water, boiler water, process water, and water used for secondary recovery of oil by water injection.

Although cooling water is usually selected on the basis of its temperature and source of supply, its chemical quality is also significant. Any characteristic that may adversely affect the heat-exchange surfaces is undesirable. Substances such as magnesium, calcium, iron, and silica may cause the formation of scale. Another objectionable feature that may be found in cooling water is corrosiveness caused by calcium and magnesium chlorides, sodium chloride in the presence of magnesium, acids, and oxygen and carbon dioxide gases.

Boiler water used for the production of steam must meet high water quality standards, since extreme temperature and pressure conditions intensify the problems of corrosion and incrustation. Under these conditions the presence of silica is particularly undesirable as it forms a hard scale or incrustation.

Water coming in contact with, or incorporated into, manufactured products is termed "process water" and is subject to a wide range of quality requirements. Physical, biological, and chemical characteristics must be considered. Water used in the manufacturing of textiles must be low in dissolved-solids content and free of iron and manganese, which could cause staining. The beverage industry normally requires water free of iron, manganese, and organic substances. The process operations that require water in quantity for the petroleum and allied industries are storage and transportation, crude oil desalting, cracking, fractionation, molecular rearrangement, and refining. Less than 20 percent of the water required in the petroleum industries is used in these processes, while more than 70 percent is used for cooling purposes. Water quality criteria for petroleum and allied products have been published (Noyes, 1980). In general, these standards recommend that the dissolved-solids concentration of the water should be less than 3,500 mg/l and place additional water quality limitations on specific inorganic constituents.

Water used for injection in the secondary recovery of oil is generally water taken from the oil reservoir; however, this water, usually brine, generally must be supplemented in order to meet the volume requirements. Careful control must be exercised over the injected water with regard to suspended solids, dissolved gases, microbiological growths, and mineral constituents. Suspended solids in the water can cause plugging of the reservoir. Hydrogen sulfide, carbon dioxide, and oxygen all have corrosive effects on well equipment, and oxygen reacting with the metallic ions, primarily iron, will cause plugging of the reservoir. Organisms such as iron bacteria, algae, and fungi also have an effect of plugging the reservoir or pumping equipment, and the sulfate reducers have a corrosive effect. Insofar as the mineral constituents are concerned, iron and

Table 4.—Water-Quality Tolerances for Industrial Applications[1]

[Allowable Limits in Milligrams Per Liter Except as Indicated]

INDUSTRY	TURBIDITY	COLOR	COLOR $+O_2$ CONSUMED	DISSOLVED OXYGEN (ml/l)	ODOR	HARDNESS	ALKALINITY (AS $CaCO_3$)	pH	TOTAL SOLIDS	Ca	Fe	Mn	Fe+Mn	Al_2O_3	SiO_2	Cu	F	CO_3	HCO_3	OH	$CaSO_4$	Na_2SO_4 TO Na_2SO_3 RATIO	GENERAL[2]
Air Conditioning[3]	—	—	—	—	—	—	—	—	—	—	0.5	0.5	0.5	—	—	—	—	—	—	—	—	—	A,B
Baking	10	10	—	—	—	(4)	—	—	—	—	.2	.2	.2	—	—	—	—	—	—	—	—	—	C
Boiler feed:																							
0-150 psi	20	80	100	2	—	75	—	8.0+	3,000-1,000	—	—	—	—	5	40	—	—	200	50	50	—	1 to 1	—
150-250 psi	10	40	50	.2	—	40	—	8.5+	2,500-500	—	—	—	—	.5	20	—	—	100	30	40	—	2 to 1	—
250 psi and up	5	5	10	0	—	8	—	9.0+	1,500-100	—	—	—	—	.05	5	—	—	40	5	30	—	3 to 1	—
Brewing:[5]																							
Light	10	—	—	—	Low	—	75	6.5-7.0	500	100-200	.1	.1	.1	—	—	—	1	—	—	—	100-200	—	C,D
Dark	10	—	—	—	Low	—	150	7.0→	1,000	200-500	.1	.1	.1	—	—	—	1	—	—	—	200-500	—	C,D
Canning:																							
Legumes	10	—	—	—	Low	25-75	—	—	—	—	.2	.2	.2	—	—	—	—	—	—	—	—	—	C
General	10	—	—	—	Low	—	—	—	—	—	.2	.2	.2	—	—	—	1	—	—	—	—	—	C
Carbonated beverages[6]	2	10	10	—	0	250	50	—	850	—	.2	.2	.3	—	—	—	.2	—	—	—	—	—	C
Confectionary	—	—	—	—	Low	—	—	(7)	100	—	.2	.2	.2	—	—	—	—	—	—	—	—	—	—
Cooling[8]	50	—	—	—	—	50	—	—	—	—	.5	.5	.5	—	—	—	—	—	—	—	—	—	A,B
Food, general	10	—	—	—	Low	—	—	—	—	—	.2	.2	.2	—	—	—	—	—	—	—	—	—	C
Ice (raw water)[9]	1-5	5	—	—	—	—	30-50	—	300	—	.2	.2	.2	—	10	—	—	—	—	—	—	—	C
Laundering	—	—	—	—	—	50	—	—	—	—	.2	.2	.2	—	—	—	—	—	—	—	—	—	—
Plastics, clear, undercolored	2	2	—	—	—	—	—	—	200	—	.02	.02	.02	—	—	—	—	—	—	—	—	—	—
Paper and pulp:[10]																							
Groundwood	50	20	—	—	—	180	—	—	—	—	1.0	.5	1.0	—	—	—	—	—	—	—	—	—	A
Kraft pulp	25	15	—	—	—	100	—	—	300	—	.2	.1	.2	—	—	—	—	—	—	—	—	—	—
Soda and sulfite	15	10	—	—	—	100	—	—	200	—	.1	.05	.1	—	—	—	—	—	—	—	—	—	—
Light paper, HL-Grade	5	5	—	—	—	50	—	—	200	—	.1	.05	.1	—	—	—	—	—	—	—	—	—	B
Rayon (viscose) pulp:																							
Production	5	5	—	—	—	8	50	—	100	—	.05	.03	.05	<8.0	<25	<5	—	—	—	—	—	—	—
Manufacture	.3	—	—	—	—	55	—	7.8-8.3	—	—	.0	.0	.0	—	—	—	—	—	—	—	—	—	—
Tanning[11]	20	10-100	—	—	—	50-135	135	8.0	—	—	.2	.2	.2	—	—	—	—	—	—	—	—	—	—
Textiles:																							
General	5	20	—	—	—	20	—	—	—	—	.25	.25	—	—	—	—	—	—	—	—	—	—	—
Dyeing[12]	5	5-20	—	—	—	20	—	—	—	—	.25	.25	.25	—	—	—	—	—	—	—	—	—	—
Wool scouring[13]	—	70	—	—	—	20	—	—	—	—	1.0	1.0	1.0	—	—	—	—	—	—	—	—	—	—
Cotton bandage[13]	5	5	—	—	Low	20	—	—	—	—	.2	.2	.2	—	—	—	—	—	—	—	—	—	—

1 American Water Works Association, 1950.
2 A—No corrosiveness; B—No slime formation; C—Conformance to Federal drinking water standards necessary; D-NaCl, 275 mg/l.
3 Waters with algae and hydrogen sulfide odors are most unsuitable for air conditioning.
4 Some hardness desirable.
5 Water for distilling must meet the same general requirements as for brewing (gin and spirits mashing water of light-beer quality; whiskey mashing water of dark-beer quality).
6 Clear, odorless, sterile water for syrup and carbonization. Water consistent in character. Most high quality filtered municipal water not satisfactory for beverages.
7 Hard candy requires pH of 7.0 or greater, as low value favors inversion of sucrose, causing sticky product.
8 Control of corrosiveness is necessary as is also control of organisms, such as sulfur and iron bacteria, which tend to form slimes.
9 Ca $(HCO_3)_2$ particularly troublesome. Mg $(HCO_3)_2$ tends to greenish color. CO_2 assists to prevent cracking. Sulfates and chlorides of Ca, Mg, Na should each be less than 300 mg/l (white butts).
10 Uniformity of composition and temperature desirable. Iron objectionable as cellulose adsorbs iron from dilute solutions. Manganese very objectionable, clogs pipelines and is oxidized to permanganates by chlorine, causing reddish color.
11 Excessive iron, manganese, or turbidity creates spots and discoloration in tanning of hides and leather goods.
12 Constant composition; residual alumina 0.5 mg/l.
13 Calcium, magnesium, iron, manganese, suspended matter, and soluable organic matter may be objectionable.

manganese are undesirable as they cause plugging in injection wells. Water that is high in sulfate should not be mixed with water containing appreciable amounts of barium. This would result in formation of barium sulfate which has a very low solubility. The pH value is also significant when corrosion control and the solubilities of calcium carbonate and iron are considered. The higher the pH, the more difficult it is to maintain iron in solution and to keep calcium scale from forming.

Characteristics of irrigation water that seem to be most important in determining its quality are as follows: (a) total concentration of soluble salts; (b) relative proportion of sodium to other principal cations (magnesium, calcium, and potassium); (c) concentration of boron or other elements that may be toxic; and (d) under some conditions, the bicarbonate concentrations as related to the concentration of calcium plus magnesium. These have been termed, respectively, the salinity hazard, the sodium (alkali) hazard (sodium-adsorption ratio, or SAR), the boron hazard, and the bicarbonate ion hazard (residual sodium carbonate, or RSC).

For the purposes of diagnosis and classification of irrigation waters, the total concentration of soluble salts (salinity hazard) in the water can be adequately expressed in terms of specific conductance. Specific conductance is the measure of the ability of the ionized inorganic salts in solution to conduct an electrical current and is usually expressed in terms of micromhos per cubic centimeter at 25°C. In general, water having a conductance below 750 micromhos per cubic centimeter is satisfactory for irrigation; however, salt-sensitive crops, such as strawberries and green beans, may be adversely affected by irrigation water having a conductance in the range of 250 to 750 micromhos per cubic centimeter.

Percent sodium is a term used to indicate the proportion of sodium ions in solution in relation to the total cation concentration. In the past, irrigation waters were divided into the three following classes based on the percent sodium: (a) water with a percent sodium less than 60, excellent to good; (b) water with a percent sodium between 60 and 75, good to injurious, and (c) water with a percent sodium greater than 75, injurious to unsatisfactory. The percent sodium in water samples from the Lower Rio Grande Valley aquifer ranged from 12 to 93.

A better measure of the sodium hazard of water for irrigation is the sodium-adsorption ratio (SAR) which is used to express the relative activity of sodium ions in exchange reactions with soil. The SAR may be computed from the data obtained from the standard water analysis by using the following equation:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where Na^+, Ca^{++}, and Mg^{++} represent the concentrations of sodium, calcium, and magnesium ions in milliequivalents per liter (me/l). The SAR of water samples collected from the Lower Rio Grande Valley aquifer ranged from 3.9 to 28.7.

When the SAR and specific conductance of a water are known, the classification of the water for irrigation can be determined by graphically plotting these values on the diagram shown in

Figure 15. Low sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium-sodium water (S2) will present an appreciable sodium hazard in certain fine-textured soils having high cation-exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils having good permeability. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage, leaching, and addition of organic matter. Very high sodium water (S4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

Low-salinity water (C1) can be used for irrigation for most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. High salinity water (C3) cannot be used on soils with restricted drainage.

The classification of ground water from representative wells completed in the Lower Rio Grande Valley aquifer shows high (C3) to very high (C4) salinity hazard while the sodium (alkali) hazard is low (S1) through very high (S4), as illustrated in Figure 15.

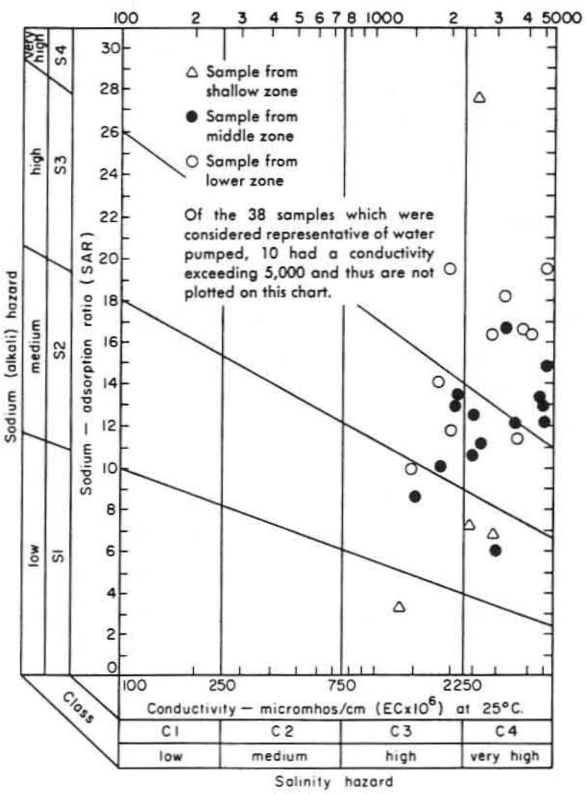

Figure 15.—Classification of Lower Rio Grande Valley Aquifer Waters for Irrigation (Method after U. S. Salinity Laboratory Staff, 1954, p. 80)

Boron is necessary for good plant growth; however, excessive boron content will render water unsuitable for irrigation. Wilcox (1955, p. 11) stated that concentrations of boron as high as 1.0 mg/l are permissible for irrigation of boron-sensitive crops, as high as 2.0 mg/l on semi-tolerant crops, and as much as 3.0 mg/l for tolerant crops. Examples of sensitive crops are deciduous fruit and nut trees and navy beans; semi-tolerant crops include most grains, cotton, potatoes, and some other vegetables; and tolerant crops are alfalfa and most root vegetables. The concentration of boron in the Lower Rio Grande Valley aquifer ranges from 0.2 to 25.2 mg/l.

The residual sodium carbonate (RSC) factor (Table 2) is used in assessing the quality of water for irrigation because excessive sodium carbonate concentrations cause soils to break down and lose their permeability, restricting the movement of air and water. Wilcox (1955, p. 11) gives the following limits for RSC for irrigation waters: above 2.6 me/l (milliequivalents per liter) is not suitable for irrigation, 1.25 to 2.6 me/l is marginal, and water containing less than 1.25 me/l probably is safe. The RSC factor in the Lower Rio Grande Valley aquifer ranges from 0.0 to 4.4 me/l.

As the data indicate (Table 2), a wide range in water quality exists within the Lower Rio Grande Valley aquifer. The shallow zone generally contains the most highly mineralized water of the three zones, which makes it unsuitable for most uses. However, in the southern portion of the study area near the Rio Grande, and in some local areas in the north-central region (Figure 12), the shallow zone does produce fresh to slightly saline water.

Nitrate levels exceed Texas Department of Health (1977) recommended concentration (45 mg/l) in five wells sampled by the Department. These excessive levels of nitrate in ground water may be attributed to the intensive use of nitrogen fertilizers in the region.

Over most of the study area, the middle zone contains fresh to slightly saline water (Figure 13), with the exception of the northern region where this zone is absent (Figure 9). Nitrate levels exceeded Texas Department of Health maximum recommended standards (45 mg/l) in 25 percent of the wells sampled by the Department. In general, the middle zone is not suitable for irrigation purposes due to its high salinity and sodium (alkali) hazards (Figure 15), and has limited industrial applications. The zone is suitable for domestic and stock watering applications; however, users should be aware of the nitrate concentrations of the waters to be consumed.

Generally, the lower zone contains the best quality water in the study area. Fresh to slightly saline water occurs over the entire study area (Figure 14), and nitrate levels were found to be within safe limits. This zone presents the best source for public supply, domestic, and stock watering; however, it is generally not suitable for irrigation due to its high salinity and sodium (alkali) hazards (Figure 15), and has limited industrial applications.

Hydraulic Properties

Hydraulic properties of the Lower Rio Grande Valley aquifer were calculated using data obtained from the sample cuttings of the test holes drilled in conjunction with this study. An aquifer's permeability depends on the shape, sorting, arrangement, and cementation of its component sediment grains. To obtain permeability and transmissivity data for the Lower Rio Grande Valley aquifer, the following procedure was used: (1) A detailed review of the test hole sample logs was made to estimate the average particle size and degree of sorting for each water-bearing zone within the aquifer; (2) permeability was estimated for each zone by consulting laboratory data which relate particle-size characteristics to permeability (Morris and Johnson, 1966); and (3) the coefficient of transmissivity was calculated by multiplying the permeability by the net sand thickness of each water-bearing zone, and then adding these values to obtain an estimate of the transmissivity for the entire aquifer.

The following table presents the permeability, net sand thickness, and transmissivity coefficients for each water-bearing zone:

Zone	Permeability [(gal/d)/ft^2]	Net sand thickness (ft)	Transmissivity [(gal/d)/ft]
Shallow	500	25	12,500
Middle	100	75	7,500
Lower	100	250	25,000
Total aquifer	130 (Average)	350	45,000

The specific yield and artesian storage coefficient of the Lower Rio Grande Valley aquifer are estimated to be approximately 20 percent and 3×10^{-4}, respectively.

It is difficult to correlate the above calculated values to actual pumping test data in the region because the pumping test results show a high degree of variability with regard to permeability and storage. However, the above values do fall within the ranges of permeability and storage of the pumping tests, and are thus considered representative of the aquifer in the study area.

Recharge, Discharge, and Movement of Ground Water

Recharge of water to the Lower Rio Grande Valley aquifer is derived from adjacent or underlying water-bearing beds, seepage of surface water from the Rio Grande and other streams, or by percolation of water from the land surface from precipitation and applied irrigation water. Discharge of water from the aquifer occurs in one or more of the following ways: by lateral or downward percolation of water into other deposits; evaporation and transpiration losses; discharge of water into the Rio Grande; or by pumping wells.

Ground water in the aquifer generally moves downward to the zone of saturation and then generally in the direction of the piezometric gradient. The piezometric surface is an imaginary surface that everywhere coincides with the static water level in the aquifer. The piezometric surface of the Lower Rio Grande Valley aquifer is illustrated in Figure 16. Calculations based on the aquifer's hydraulic properties and the slope of the piezometric surface indicate that movement of ground water is on the order of 0.3 feet per day in the shallow zone, and much less in the middle and lower zones, toward the Gulf of Mexico.

Development of Ground Water

Development of ground water from the Lower Rio Grande Valley aquifer prior to 1900 was mainly for domestic and livestock purposes. Public supply wells provided ground water for the cities of McAllen and Mission in the past, but these cities, along with all others in the study area, currently use surface water. Today, most of the water used in the study area for all purposes is obtained from Amistad and Falcon Reservoirs on the Rio Grande.

In 1979, less than 10,000 acre-feet of ground water was used in Hidalgo County for all purposes while irrigation use from surface water alone was on the order of 500,000 acre-feet.

An estimate of the amount of water available from the lower and middle zones of the Lower Rio Grande Valley aquifer in the study area was made based on the steady-state transmission capacity of the aquifer. The transmission capacity can be approximated by using the formula

$$Q = TWI$$

where

- Q = the average quantity of water in gallons per day moving through the aquifer;
- T = the average coefficient of transmissivity in gallons per day per foot of aquifer width;
- W = the width of the study area in miles, parallel to the strike of the piezometric surface; and
- I = the average hydraulic gradient in feet per mile.

The estimate of the amount of ground water available for development is based on the following conditions: (a) the effect of pumping is such that pumping levels approximate static water levels; (b) the line along which pumpage is to occur is located approximately midway between the western and eastern boundaries of the project; and (c) lowering of water levels at the project boundaries does not occur. The average coefficient of transmissivity was determined from the average net sand thickness and estimated permeability of the aquifer.

Based on the above, approximately 4 million gallons per day or 4,500 acre-feet per year can theoretically be transmitted by the lower and middle zones of the aquifer to pumping wells.

Ground-Water Problems

Problems associated with the quality of ground water from the Lower Rio Grande Valley aquifer can be related to agricultural practices in the region, including injection of fluids through agricultural drainage wells, and improper well construction.

Agricultural production is the primary economic activity of the region. Principal crops include cotton, grain, sorghum, vegetables, and citrus. Crops are irrigated by water obtained from the Rio Grande, and fertilizers and pesticides are applied as needed. During the 1950's, agricultural drainage well systems were first installed to help alleviate the problem of perched water tables in agricultural areas. As of 1982, there may be as many as 300 systems in operation in the study area. Drainage well systems act to collect surface waters and drain them into a well for disposal into a permeable subsurface formation. The shallow zone, which contains medium to coarse grain gravels, has been used extensively as a disposal zone for drainage well fluids. These fluids contain high concentrations of dissolved solids and nitrate (Table 6, samples 7-11), and in previous Department investigations (Knape, 1984), two herbicides, Bromacil and Simazine, were detected.

Water quality problems relating to improper well construction can usually be attributed to insufficient casing and lack of cement in the annulus between the casing and borehole. This is especially true where bad quality water may exist above or below a usable water interval. Without casing which has been cemented in the borehole the undesirable water is allowed to travel up or down in the space between the casing and borehole and contaminate the usable water. Flooding is also a problem where the top of the casing is below the known flood elevation. In this situation contaminated flood waters can enter the well bore and percolate into sources of drinking water.

CONCLUSIONS AND RECOMMENDATIONS

Ground water is produced from three zones within the Lower Rio Grande Valley aquifer. Hydraulic continuity occurs between the adjacent permeable beds; however, locally they are separated by layers of less permeable sediments. Over most of the study area, the shallow zone contains highly mineralized water which makes it unsuitable for most uses. Nitrate levels in the shallow zone are high which is probably due to the agricultural practices in the region. Water quality is better in the middle and lower zones. These zones are suitable for domestic and stock supplies in most areas, and could be used as a public supply source if no other water sources were available. Generally, the middle and lower water-bearing zones are not suitable for irrigation purposes due to their high salinity and sodium hazards (Figure 15), and may have limited industrial uses due to their relatively high dissolved-solids content.

Approximately 4 million gallons per day or 4,500 acre-feet per year of water is available for development from the middle and lower zones of the aquifer.

It is recommended that the middle and lower water-bearing zones not be utilized as disposal zones for agricultural drainage well fluids. These zones contain useable quality water and the introduction of drainage well fluids, which are known to contain high concentrations of dissolved solids, nitrate, and possibly small amounts of a variety of pesticides, would adversely affect water quality.

In addition, it is recommended that the Department establish observation wells in the study area to monitor water levels and water quality for the shallow, middle, and lower zones. Wells located adjacent to agricultural areas could monitor the long-term effects of agricultural practices on ground-water quality. Any additional studies in the region should include aquifer tests to refine information on the aquifer characteristics and capabilities.

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Table 5.—Records of Selected Wells and Test Holes

All wells are drilled unless otherwise noted in the remarks column.
Water Level : Reported water levels are given in feet; measured water levels are given in feet and tenths of feet.
Method of lift and type of power: C, cylinder; Cf, centrifugal; E, electric; G, gasoline, oil, butane, or diesel engine; N, none; Sub, submersible; T, turbine; W, windmill. Number indicates horsepower.
Use of water : D, domestic; Ind, industrial; Irr, irrigation; J, jet; N, none; P, public supply; S, livestock; Ag, agricultural drainage well (injection type well).
Water bearing unit : Lower Rio Grande Valley aquifer.
Altitude of land surface was determined from topographic maps.

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing		Altitude of land surface datum (ft)	Water Level		Method of lift	Use of water	Remarks	Well number from Bulletin 6014
					Diameter (in.)	Depth (ft)		Below land-surface datum (ft)	Date of measurement				
* 1	Texas Department of Highways and Public Transportation	Texas Department of Water Resources	1983	804	—	—	190	—	—	N	N	Test hole drilled for this study. Well 87-46-201. Plugged and abandoned July 25, 1983.	—
* 2	do	do	1983	804	—	—	169	—	—	N	N	Test hole drilled for this study. Well 87-46-501. Plugged and abandoned July 11, 1983.	—
* 3	do	do	1983	811	—	—	160	—	—	N	N	Test hole drilled for this study. Well 87-46-802. Plugged and abandoned June 28, 1983.	—
* 4	do	do	1983	804	—	—	224	—	—	N	N	Test hole drilled for this study. Well 87-45-601. Plugged and abandoned August 24, 1983	—
* 5	do	do	1983	659	—	—	104	—	—	N	N	Test hole drilled for this study. Well 87-47-401. Plugged and abandoned August 8, 1983.	—
* 6	Howard Kappler	H. Pursley, Jr.	1983	83	4	74	224	28	July 25, 1983	—	Ag	Casing slotted 63-74 ft. Not cemented.	—
* 7	Boyd Davis	do	1982	84	4	82	220	25	Aug. 6, 1982	—	Ag	Casing slotted 66-82 ft.	—
* 8	Smith Grove Care	do	1983	103	4	83	220	25	1983	—	Ag	Casing slotted 62-83 ft. Located at Lot 30 Blk. 24.	—
* 9	Howard Kappler	do	1982	102	4	94	200	14	1982	—	Ag	Casing slotted 73-94 ft.	—
* 10	do	do	1982	143	4	84	215	—	—	—	Ag	Casing slotted 63-84 ft.	—
* 11	J. L. Taylor	do	1983	82	4	74	141	13	July 30, 1983	—	Ag	Packer at 63 ft. Casing slotted 63-74 ft.	—
* 12	D. W. Lance	D. Killinger	1948	538	4	500	160	—	—	S,E	D,S	Well 87-46-202.	—
* 13	Howard Munal	H. Pursley	1983	82	4	82	138	9	1983	—	—	Well 87-46-301.	—
* 14	Citrus Valley Subdivision	H. Pursley, Jr.	1983	40	4	40	115	13	Aug. 5, 1983	S,E	—	Produces approx. 5 gal/min. Gravel packed 15-40 ft. Well 87-47-403.	—
* 15	do	do	1983	323	4	314	111	+1	Aug. 18, 1983	—	—	Produces 60 gal/min. Well 87-47-402.	—
* 16	Foremost and Paving Co.	do	1979	125	—	115	175	—	—	—	—	Well 87-46-702.	—
* 17	W. F. Basham	do	1980	312	4	126	175	—	—	—	P	Casing slotted 105-126 ft. Well 87-46-704.	—
* 18	Don Hartshorn	do	—	305	5	300	160	—	—	—	D	Casing slotted 200-300 ft. Well 87-54-102.	—
* 19	W. F. Basham	do	1982	287	4	273	184	—	—	—	P	Casing slotted 231-273 ft. Well 87-54-103.	—
* 20	Bob Mitchell	do	1979	293	—	—	175	50	Reported	—	D	Well 87-46-703.	—
* 21	Rio Grande Children's Home	do	1974	350	—	—	175	44	June 10, 1982	S,E	P	Well 87-46-701.	—
* 22	Frank Eckroat	—	1956	276	8	276	183	86.3	Sept. 16, 1957	—	D,Irr	Casing slotted 250-276 ft. Well 87-45-901	K-24
* 23	Maxie Lewendowski	Killinger	1977	72	4	—	180	4	Reported	S,E	N	Water salty. Well 87-46-403.	—

See footnotes at end of table.

Table 5.—Records of Selected Wells and Test Holes—Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Altitude of land surface datum (ft)	Water Level: Below land-surface datum (ft)	Water Level: Date of measurement	Method of lift	Use of water	Remarks	Well number from Bulletin 6014
• 24	Kenneth Kneblick	Charley P. Moore	1977	66	4.5	66	184	3	Dec. 17, 1980	—	Irr	Casing perforated 46-66 ft.	—
• 25	Lester Roloff	Colbath	1933	278	5	278	206	—	—	—	N	Abandoned.	K-15
• 26	A. H. Wicks	—	1925	123	4	123	160	60	1933	—	N	do	L-3
• 27	City of Mission	Pursley	1953	363	16	363	127	28.9	Sept. 24, 1953	—	N	Casing slotted 270-363 ft. Department Log Q-46.	L-116
• 28	Showers Estate	—	—	396	3	396	240	106	1933	C,W	D,S	—	F-30
• 29.	E. Salinas	Colbath	1927	205	4	125	271	—	—	C,W	D,S	—	F-28
• 30	Showers Estate	—	—	197	4	197	218	101	1933	C,W	D,S	—	F-34
• 31	Hammond Bros.	O. C. Woods	1911	750	6	—	185	49	1933	C,W	D,S	—	6-23
• 32	Showers Estate	Colbath	—	210	5	210	226	96.5	Aug. 11, 1933	C,G	D,S	—	K-12
• 33	do	—	—	161	4	—	214	88	1933	C,W	D,S	—	K-14
• 34	LaHoma Ranch	—	1945	485	8	485	179	—	—	T,E	Irr,D	Casing perforated in sand at 420 and 460 ft.	K-18
• 35	Ray Barnick	B. Killinger	1957	345	12	345	185	111	1957	T,G	Irr	Casing slotted 255-340 ft.	K-23
• 36	W. W. Woody	Gene Liberty	1956	350	12	350	175	—	—	T,G	Irr	Casing slotted 154-214, 228-252, and 256-350 ft.	K-22
• 37	Mary Fleoden	B. Killinger	1928	95	6	95	207	90	1933	C,W	D,S	Open-hole completion.	K-9
• 38	Floyd Everhart	H. Pursely	1956	335	16	335	150	40	1957	T,G	Irr	Casing slotted 176-212, 236-270, and 292-330 ft.	K-66
• 39	Showers Estate	—	—	153	5	—	153	14	1933	C,W	S	—	K-65
• 40	Everett Bell	Gene Liberty	1957	260	16	260	165	—	—	T,G	Irr	Casing slotted 130-260 ft.	K-28
• 41	J. P. Waite	B. Killinger	1957	50	16	50	163	—	—	T,B	Irr	Casing slotted 40-50 ft. Well 87-53-204.	K-60
• 42	G. Garrett	E. Newbro	1928	241	4	241	167	114	1933	C,W	D,S	—	L-1
• 43	Lee Hawkins	—	1915	175	4	—	145	58 46.5	1933 May 22, 1945	C,W	D,S	—	L-4
• 44	Shary Estate	—	—	150	4	—	150	49 39.3	1933 May 22, 1945	C,W	D,S	—	L-5
• 45	Wm. Schoening	W & W Drilling Co.	1953	242	12	242	140	33.1	Mar. 5, 1957	T,G, 72	Irr	Casing slotted 70-100 and 192-242 ft.	L-6
• 46	W. B. Beard	B. Killinger	1929	50	4	50	135	36	1933	C,W	D,S	—	L-7
• 47	C. W. McMillon	Pursley	1952	297	16	297	99	21	1957	T,G, 100	Irr	Casing slotted 243-297 ft.	L-14
• 48	I. S. Knops	do	1952	298	12	298	102	6	1952	T,G, 65	Irr	Casing slotted 223-298 ft.	L-15
• 49	Frank Brady	—	1930	90	4	—	117	25	1933	C,E	S	—	L-20
• 50	A. B. McAfee	—	1929	194	4	—	105	7	1933	C,W	D,S	—	L-21
• 51	E. M. Bradbury	—	—	38	4	38	125	—	—	E	D,S	Open-hole completion.	L-29
• 52	Francis Jensen	B. Killinger	1956	121	10	121	141	18	1956	Cf,G	Irr	—	L-31
• 53	Mrs. P. J. Sweeney	do	1925	68	4	68	135	33.4	Oct. 4, 1957	—	N	Abandoned.	L-32
• 54	Bill Hines	—	1918	98	4	98	140	27.5	May 21, 1945	E	D,S	Open-hole completion.	L-33
• 55	H. T. Klatt	Elmer Ray	1932	114	12	114	135	38	1945	T,G, 40	Irr	—	L-34
• 56	C. Knadle	—	1918	102	6	—	150	55 32.7	1933 May 21, 1945	C,W	D,S	—	L-35
• 57	Mrs. Louise Hunt	Colbath	1933	35	5	35	150	6	1933	C,W	D,S	Open-hole completion.	L-36
• 58	Mrs. J. S. Lyons	John Moore	1930	55	5	55	148	43	1933	C,G	D,S	Open-hole completion.	L-37

See footnotes at end of table.

Table 5.—Records of Selected Wells and Test Holes—Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Altitude of land surface datum (ft)	Water Level: Below land-surface datum (ft)	Water Level: Date of measurement	Method of lift	Use of water	Remarks	Well number from Bulletin 6014
• 59	F. D. McLain	Duke	1953	153	14	153	150	—	—	T,G	Irr	Casing slotted 120-150 ft.	L-41
• 60	Mrs. G. F. Gray	—	1925	265	4	265	154	49	1933	C,W	S	—	L-47
• 61	Ralph Veazey	Hugh Cole	1953	87	4	87	135	39	1953	E, 1½	D,S	Casing slotted 84-87 ft.	L-52
• 62	Davis & Gandy	Pursley	1957	486	16	486	123	292	Mar. 27, 1957	T,G	Irr	Casing slotted 266-306 and 346-486 ft.	L-55
• 63	Moore Canning Co.	A & T Drilling Co.	1946	512	12	512	125	80	1954	T,E, 75	Ind	Screen 422-512 ft.	L-58
• 64	City of McAllen	Layne-Texas Co.	1953	408	14 12	408	125	70	1954	T,G, 144	N	Screen 308-408 ft. Measured yield 1,230 gal/min.	L-59
• 65	do	Gene Liberty	1953	270	14	270	117	46	1953	T,G, 120	N	Casing slotted 180-270 ft. Measured yield 1,400 gal/min.	L-68
• 66	E. B. Richey	—	1924	86	5	86	117	19.2	May 23, 1945	C,W	D,S	—	L-87
• 67	C. E. Schwanz	Elmer Ray	1931	67	8	67	105	12	Oct. 31, 1957	T,G	Irr	Casing slotted 55-67 ft.	L-100
• 68	Willadel Citrus Groves	Elmer Ray	1930	55	12	55	110	6.2	June 1, 1945	T,G	Irr	Reported yield 1,000 gal/min.	L-102
• 69	E. Waibel	—	—	42	4	42	135	7.1	Mar. 24, 1945	C,W	D	—	L-107
70	Kingwood Oil Co.	—	1944	2,255	—	—	111	—	—	N	N	Oil test. Department log Q-4	—
71	Gato Oil Corp.	—	—	—	—	—	180	—	—	N	N	Oil test. Department log Q-10	—
72	Heep Oil Corp.	—	1953	8,520	—	—	124	—	—	N	N	Oil test. Department log Q-16	—
73	Sinclair Prairie Oil	—	1945	—	—	—	100	—	—	N	N	Oil test. Department log Q-32	—
74	Eva Reyna	Charley P. Moore	1981	67	3.5	67	138	12	Mar. 11, 1981	—	D	Casing perforated 63-67 ft.	—
75.	Continental Oil Co.	—	1949	8,501	—	—	121	—	—	N	N	Oil test. Department log Q-69	—
76	Superior Oil Co.	—	1953	—	—	—	226	—	—	N	N	Oil test. Department log Q-118	—
77	Magnolia Petroleum Co.	—	1948	—	—	—	100	—	—	N	N	Oil test. Department log Q-155	—
78	Continental Oil Co.	—	1949	—	—	—	154	—	—	N	N	Oil test. Department log Q-181	—
79	J. H. Hooker	Harrell Drilling Co.	1960	7,306	—	—	117	—	—	N	N	Oil test. Department log Q-204	—
80	Mokeen Oil Co.	—	1964	—	—	—	97	—	—	N	N	Oil test. Department log Q-255	—
81	Bel Oil Corp. & J. K. Harrell	—	1960	10,101	—	—	243	—	—	N	N	Oil test. Department log Q-669	—
82	Hamman Oil	—	1945	7,214	—	—	168	—	—	N	N	Oil test. Department log Q-741	—
83	Shell Oil Co.	—	1956	—	—	—	190	—	—	N	N	Oil test. Department log Q-742	—
84	Boyd Davis	H. Pursley, Jr.	1980	112	4.5	105	226	39	Mar. 12, 1980	N	Ag	Casing slotted 84-105 ft.	—
85	W. B. Shaw	do	1981	92	4	84	224	18	Sept. 10, 1981	—	Ag	Casing slotted 63-84 ft.	—
86	Boyd Davis	R. H. Pursley	1982	104	4	84	175	30	June 25, 1982	—	Ag	Casing perforated 63-84 ft.	—
87	Delia Barrera	Charley P. Moore	1978	59	4.5	59	175	—	—	—	D	Casing perforated 39-59 ft.	—
88	Dietex-Owens Grove	do	1980	80	4.5	80	209	6	Feb. 20, 1980	—	Ag?	Casing perforated 70-80 ft.	—
89	Bob Wellen	do	1983	58	4.5	58	190	12	Mar. 9, 1983	—	D	Casing slotted 54-58 ft.	—

See footnotes at end of table.

Table 5.—Records of Selected Wells and Test Holes—Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Altitude of land surface datum (ft)	Water Level: Below land-surface datum (ft)	Water Level: Date of measurement	Method of lift	Use of water	Remarks	Well number from Bulletin 6014
90	Compton Grove Care	Charley P. Moore	1982	83	4.5	83	170	10	June 26, 1982	—	Ag?	Casing perforated 75-83 ft.	—
91	Compton Grove Care	R. H. Pursley	1983	303	4	273	226	—	—	—	Ag	Casing slotted 231-273 ft.	—
92	do	Charley P. Moore	1982	57	4.5	57	205	17	Sept. 18, 1982	—	Ag?	Casing perforated 47-57 ft.	—
93	Thomas M. Chapman	do	1980	60	2.5	60	180	15	June 21, 1980	—	D	Casing perforated 57-60 ft.	—
94	J. N. Wilsher	H. Pursley, Jr.	1976	105	4.5	105	144	—	—	—	Ag	—	—
95	Ross L. Jenson	Charley P. Moore	1979	70	4.5	70	185	28	July 20, 1979	—	Ag?	Casing perforated 62-70 ft.	—
96	Carlos Leal	do	1980	75	2.5	75	160	20	Feb. 29, 1980	—	D	Casing perforated 71-75 ft.	—
97	Compton Grove Care	do	1976	87	4.5	87	146	—	—	—	Ag?	Casing perforated 67-87 ft.	—
98	Larry Phillips	do	1977	68	4.5	60	125	—	—	—	D	—	—

*For chemical analysis of water see Table 6.

Table 6.—Chemical Analyses of Water From Selection Wells and Test Holes

(Analyses given in milligrams per liter except percent sodium, pH, sodium adsorption ratio, specific conductance, and residual sodium carbonate)
Water-bearing unit: All wells pump from the Lower Rio Grande Valley aquifer unless noted by footnote.
Dissolved solids : The bicarbonate "reported" is converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure is used in the computation of this sum.

Well	Producing interval (ft)	Well depth (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	pH	Boron (B)	Total hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)
1	63-105	804	July 25, 1983	72	268	178	—	2,302	32	235	1,484	3,338	1.4	32.96	7,940	8.2	—	1,400	7,540	77.5	26.6	0.0
	380-410	do	do	27	179	78	—	1,249	19	321	706	1,831	1.9	13.82	4,262	8.2	—	767	4,950	77.3	19.6	.0
2	60- 90	804	July 11, 1983	96	22	9	—	615	9	223	536	487	3.7	15.51	1,876	8.0	—	92	2,400	92.7	27.9	1.8
	358-390	do	do	22	79	27	—	732	15	224	340	1,013	1.1	.22	2,310	7.9	—	309	3,100	82.8	18.1	4.4
	440-462	do	do	22	74	30	—	738	15	227	355	1,017	1.1	.04	2,364	7.9	—	311	3,100	82.9	18.2	.0
3	60- 80	800	June 28, 1983	36	384	148	—	2,033	23	317	1,296	3,192	1.2	56.53	7,320	7.5	—	1,568	6,990	74.5	22.3	.0
	220-252	do	June 23, 1983	28	442	171	—	1,803	26	246	1,050	3,158	.8	48.82	7,004	7.8	—	1,809	6,900	67.9	18.4	.0
	410-450	do	do	15	80	33	—	779	14	255	394	1,050	1.1	< .04	2,456	7.8	—	336	3,270	82.7	18.5	.0
4	63- 84	804	Aug. 24, 1983	28	224	38	—	1,378	72	0	1,279	1,607	1.3	93.65	5,016	11.5	—	717	5,380	78.7	22.4	.0
	273-294	do	do	30	100	25	—	418	20	309	152	630	1.1	31.05	1,534	8.3	—	355	2,150	70.7	13.7	.0
	399-420	do	Aug. 23, 1983	31	33	16	—	474	14	336	248	485	1.3	<0.1	1,466	8.5	—	151	2,000	87.1	19.5	2.5
5	63- 84	659	Aug. 8, 1983	50	376	158	—	1,151	26	328	896	2,128	1.1	10.45	5,138	7.7	—	1,590	5,500	60.7	12.6	.0
	244-273	do	do	32	249	106	—	1,008	21	362	706	1,641	1.8	13.87	4,032	7.9	—	1,058	4,640	66.9	13.5	.0
6	65- 83	83	July 25, 1983	67	180	52	—	1,008	15	315	862	1,193	2.1	99.05	3,620	8.0	—	666	4,150	76.3	17.0	.0
** 7	—	81	Aug. 19, 1983	48	254	68	—	478	4	294	603	742	.5	113.4	2,474	7.8	—	914	2,920	—	—	—
** 8	—	103	do	43	268	63	—	584	4	340	857	734	.4	62.86	2,798	7.7	—	931	3,140	—	—	—
** 9	—	84	do	41	300	64	—	502	2	351	890	559	.5	115.8	2,724	7.6	—	1,017	2,960	—	—	—
** 10	—	143	do	52	244	58	—	354	5	290	631	464	.9	115.4	2,104	7.6	—	850	2,410	—	—	—
** 11	—	82	do	42	462	156	—	1,372	6	349	2,212	1,596	.9	85.76	6,318	7.7	—	1,798	5,610	—	—	—
12	518-538	538	Aug. 7, 1983	17	86	33	—	703	15	271	349	964	1.3	<.04	2,256	8.3	—	352	3,100	80.6	16.3	.0
13	62- 82	82	Aug. 19, 1983	67	309	164	—	2,509	21	420	1,792	3,338	3	46.74	8,352	7.8	—	1,450	7,590	78.8	28.7	.0

See footnotes at end of table.

Table 6.—Chemical Analyses of Water From Selection Wells and Test Holes—Continued

Well	Producing interval (ft)	Well depth (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	pH	Boron (B)	Total hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)
14	28- 40	40	Aug. 6, 1983	40	456	120	—	647	7	289	1,630	795	3.1	23.74	4,050	7.9	—	1,635	3,900	46.2	7.0	.0
15	273-314	323	Aug. 19, 1983	20	95	49	—	808	15	336	370	1,128	2.2	21.4	2,652	7.8	—	439	3,390	85.7	16.8	.0
16	90-110	125	do	35	179	65	—	1,590	82	433	2,002	1,310	2	104.5	5,562	7.8	—	717	5,410	80.1	25.8	.0
17	105-126	312	June 9, 1983	37	470	174	—	2,363	18	407	1,652	3,472	1.2	87.85	8,508	7.7	—	1,893	7,740	72.9	23.6	.0
18	260-300	305	Aug. 19, 1983	23	60	28	—	381	14	333	164	478	1.1	21.13	1,314	8.0	—	265	1,900	74.6	10.2	.2
19	231-273	287	June 9, 1983	21	115	13	—	549	17	306	276	747	.9	.31	1,868	8.0	—	344	2,550	76.8	12.9	.0
20	—	293	Mar. 15, 1982	23	107	27	—	480	18.5	299	250	638	.9	21.09	1,700	7.8	2.6	378	2,420	72.2	10.7	.0
21	—	350	June 10, 1982	23	61	23	—	368	14	355	138	442	1.2	26.4	1,236	8.1	2.5	248	1,680	75.2	10.2	.9
22	250-276	276	do	25	79	26	—	350	14	324	78	496	1.3	31.98	1,214	8.0	.2	304	1,710	70.3	8.7	.0
23	—	72	do	25	836	456	—	3,822	94	508	2,867	6,328	1.1	< .04	14,674	7.7	25.2	3,965	32,767	67.1	26.4	.0
24	46- 66	66	Dec. 17, 1980	30	171	18	—	200	3	307	374	212	.4	28.8	1,070	8.2	—	500	1,400	46.3	3.9	.0
25	—	278	Sept. 5, 1939	—	128	53	—	515	—	304	340	735	—	19.0	—	—	—	537	—	—	9.6	.0
26	—	123	May 22, 1945	—	—	—	—	—	—	561	1,100	1,980	—	4.5	—	—	—	915	—	—	—	—
27	270-363	363	July 21, 1953	21	88	44	0.04	756	11	286	461	950	.9	3.0	2,480	7.5	3.7	400	4,160	79.8	16.4	.0
28	—	396	Aug. 25, 1983	—	108	53	—	723*	—	297	384	1,000	—	4.7	2,420	—	—	487	—	—	—	.0
29	—	205	do	—	91	27	—	323*	—	332	90	455	—	40	1,190	—	—	338	—	67	—	.0
30	—	197	do	—	—	—	—	—	—	537	75	715	—	4.8	—	—	—	705	—	—	—	—
31	—	750	do	—	55	23	—	521*	—	310	417	480	—	.0	1,650	—	—	232	—	—	—	.4
32	—	210	do	13	84	35	—	398	12	370	183	520	—	.0	1,430	—	—	354	—	70.1	9.4	.0
33	—	161	do	—	84	35	—	—	—	170	100	560	—	1.0	—	—	—	291	—	—	—	—
34	420-460	485	do	18	108	58	—	612	23	280	306	930	—	.5	2,200	7.5	2.8	508	3,770	71	12	.0
35	255-340	345	Aug. 1957	23	74	33	—	474	20	336	269	580	—	11	1,650	7.8	2.5	320	2,790	75	12	.0
36	—	350	Aug. 7, 1957	20	97	43	—	448	16	315	223	652	—	17	1,670	7.6	1.8	419	2,920	69	9.5	.0
37	—	106	Sept. 5, 1939	—	—	—	—	—	—	—	277	545	—	20	—	—	—	—	—	—	—	—

See footnotes at end of table.

Table 6.—Chemical Analyses of Water From Selection Wells and Test Holes—Continued

Well	Producing interval (ft)	Well depth (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	pH	Boron (B)	Total hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)
38	—	335	Aug. 12, 1957	24	118	45	—	397	—	292	101	695	—	41	1,570	8.2	1.4	480	2,780	64	7.9	0.0
39	—	153	Aug. 24, 1933	—	156	46	—	410*	—	307	240	675	—	20	1,700	—	—	579	—	—	7.4	.0
40	130-260	260	Aug. 6, 1957	24	37	20	—	397	—	368	153	410	—	2.5	1,230	7.6	1.9	174	2,130	83	13	2.5
41	40- 50	50	Aug. 24, 1933	—	156	46	—	—	—	307	240	675	—	20	1,700	—	—	579	—	—	7.4	.0
42	—	241	Sept. 5, 1939	—	107	47	—	697*	—	310	345	960	1.0	6	2,320	—	—	460	—	—	14	.0
43	—	175	May 22, 1945	—	—	—	—	—	—	396	1,400	2,140	—	11	—	—	—	1,080	—	—	—	—
44	—	150	do	—	—	—	—	—	—	321	340	1,220	—	21	—	—	—	765	—	—	—	—
45	—	242	Aug. 8, 1957	60	125	53	—	755	7.0	360	631	880	—	22	2,710	7.6	3.1	530	4,300	75	14	.0
	—	do	Oct. 31, 1957	84	131	53	—	807	—	358	630	950	—	21	2,860	8.0	3.4	530	4,540	76	15	.0
46	—	50	Aug. 27, 1933	—	—	—	—	—	—	376	100	210	—	3.6	—	—	—	123	—	—	—	—
47	243-297	297	Apr. 16, 1953	30	154	82	—	744	—	251	515	1,160	—	3.0	2,840	7.7	3.6	721	4,920	70	12.0	.0
48	223-298	298	Apr. 24, 1953	28	133	73	—	770	—	297	412	1,170	—	6.0	2,740	7.1	3.6	632	4,730	73	13	.0
49	—	90	May 18, 1945	—	147	73	—	801*	—	428	1,150	608	—	4.3	2,990	—	—	667	—	—	13	.0
50	—	194	do	—	224	88	—	684*	—	115	596	1,200	—	32	2,850	—	—	921	—	—	9.8	.0
51	—	38	May 1, 1953	72	103	41	—	357	—	371	378	280	—	152	1,570	7.5	1.5	426	2,390	65	7.5	.0
52	—	121	Aug. 15, 1956	52	157	58	0.02	864	28	377	843	980	2.8	9.9	3,180	7.0	2.2	630	4,960	74	15	.0
53	—	69	Jan. 9, 1953	108	230	74	—	1,530*	—	418	991	2,000	7.0	—	5,150	7.4	—	879	8,160	79	22	.0
54	—	98	May 21, 1945	—	—	—	—	—	—	393	900	1,460	—	14	—	—	—	810	—	—	—	—
55	—	114	do	42	124	45	.25	605*	—	366	430	740	2.0	16	2,180	7.8	—	494	3,540	12	11.8	.0
56	—	102	do	—	—	—	—	—	—	423	1,050	2,210	—	11	—	—	—	990	—	—	—	—
57	—	35	Sept. 7, 1939	—	—	—	—	—	—	—	863	2,040	.8	15	—	—	—	—	—	—	—	—
58	—	55	do	—	—	—	—	—	—	449	343	575	4.1	48	—	—	—	262	—	—	—	—
59	120-150	153	Aug. 16, 1957	25	253	109	—	801	—	301	640	1,350	.8	23	3,350	7.2	2.6	1,080	5,420	62	11	.0
60	—	265	Aug. 7, 1939	—	—	—	—	—	—	278	449	1,110	.7	6.7	—	—	—	735	—	—	—	—

See footnotes at end of table.

Table 6.—Chemical Analyses of Water From Selection Wells and Test Holes—Continued

Well	Producing interval (ft)	Well depth (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	pH	Boron (B)	Total hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)
61	84- 87	87	July 20, 1953	34	370	132	0.03	1,270*	—	393	1,030	2,010	0.9	—	5,040	7.1	3.8	1,470	7,940	65	14	0.0
62	—	486	Oct. 24, 1957	18	45	17	—	700*	—	262	339	780	1.8	2.0	2,040	7.7	6.3	182	3,530	89	23	.7
63	422-512	512	May 26, 1953	20	32	13	.04	367	5.2	372	296	238	1.5	.0	1,160	7.8	3.3	134	1,930	85	14	3.4
64	308-408	408	Aug. 24, 1953	22	44	19	.02	381	5.6	358	339	262	1.1	.2	1,250	7.7	2.9	188	2,060	81	12	.0
65	180-270	270	Sept. 1, 1953	32	187	67	.01	376	8.3	216	570	565	.5	.2	1,910	7.4	.9	742	3,040	52	6.0	.0
66	—	86	May 23, 1953	—	—	—	—	—	—	376	650	740	—	11	—	—	—	—	885	—	—	—
67	55- 67	67	—	—	105	37	—	308*	—	310	369	310	1.1	6.4	1,290	—	—	414	—	—	6.6	.0
68	—	55	Sept. 2, 1939	—	127	46	—	244*	—	269	347	318	—	7.1	1,220	—	—	506	—	—	4.7	.0
69	—	42	May 24, 1945	—	285	92	—	1,050*	—	401	1,160	1,280	—	40	4,100	—	—	1,090	—	—	14	.0

* Sodium and potassium calculated as sodium (Na).

** Agricultural drainage well. Sample is of injection fluid, not ground water.

Table 7.—Selected Drillers' Logs of Wells and Test Holes

	Thickness (feet)	Depth (feet)
Well 1		
Owner: Texas Department of Highways and Public Transportation Driller: Texas Department of Water Resources		
Clay, red-brown	10	10
Caliche, white, also interbedded sand	12	22
Clay, blue and tan, quartz 42-52 ft	30	52
Clay, brown-yellow and red-brown	16	68
Gravel, fine to medium grained, subrounded to subangular (some pieces chopped by drilling bit), assorted colors including black, tan, brown, orange, white	14	82
Sandy clay, red	40	122
Clay, blue, bluish-gray	30	152
Clay, blue, red, black	30	182
Clay, red-brown, bluish-gray (clay coming out from borehole in large chunks, approximately 3 ft or more in length)	167	349
Clay, sandy clay, red-brown, blue	23	372
Sand, fine grained, bluish-gray, brown, yellow	30	402
Sandy clay, silty, white (poor returns to surface)	28	430
Sand, fine grained, bluish-gray	20	450
Sandy clay, blue	10	460
Sandy clay, gray-black	7	467
Gravel, fine grained, subangular, black, brown, tan	9	478
Sandy clay, red, bluish-gray, black	30	508
Sand, fine grained, gray-green	7	515
Sandy clay, silty, gray-black	25	540
Sand, fine grained, gray-green	47	587
Sandy clay, silty, gray-black	23	610
Sand, fine, gray, with gravel, fine, subrounded, multicolored	57	667
Sandy clay, gray-black	24	691
Clay, gray	31	722
Sand, fine grained, bluish-gray, with sandy clay, blue	22	744
Clay, gray-black	10	754
Sand, fine grained, yellow	46	800
Well 2		
Owner: Texas Department of Highways and Public Transportation Driller: Texas Department of Water Resources		
Caliche, white, with some clay, brown	22	22
Clay, brown and blue, sticky	27	49
Sandy clay, brown	10	59

	Thickness (feet)	Depth (feet)
Well 2—Continued		
80% gravel, fine grained, well sorted, subrounded, assorted colors including black, red, orange, white, gray 20% sand, fine grained, gray	13	72
90% gravel, fine to medium grained, poorly sorted, subrounded, assorted colors including white, black, gray, brown, orange, tan, yellow 10% sand, fine grained, gold	23	95
Sandy clay, silty, gray and orange	16	111
50% clay, blue and red 50% sand, fine grained, gold	22	133
Gravel, fine grained, well sorted, subrounded to subangular (probably chewed by drill bit), assorted colors including black, white, gray, tan, orange	3	136
80% sand, fine grained, gold 10% gravel (see gravel at 136 ft) 10% clay, red	26	162
10% clay, red and gray	20	182
50% clay, red 50% sand, mostly fine grained, gray and gold	10	192
Clay, red, brown, blue, gray	75	267
70% sand, fine grained, gold 30% clay, red	25	292
70% clay, red-brown 30% sand, fine grained, brown	10	302
70% sand, fine grained, gold 30% clay, red	10	312
Clay, gray-black, red, blue	40	352
50% sand, fine grained, bluish-gray 50% clay, red	10	362
Sand, fine grained, bluish-gray	28	390
70% clay, red and brown 20% sand, fine grained, gray 10% gravel, fine grained, assorted colors	22	412
Sandy clay, bluish-gray; Sand (432-442 ft), fine grained, gold	47	459
Mostly gravel, fine, well sorted, subrounded to subangular (may be due to drill bit), assorted colors including black, gray, white, tan	37	496
Sandy clay, gold and gray	44	540
80% clay, gray and brown 20% sandy clay, bluish-gray	17	557
80% sandy clay, bluish-gray 20% clay, red-brown and gray	35	592
Clay, bluish-gray and light gray	47	639
Sand, fine grained, gold and green	18	657
Sandy clay, bluish-gray and light gray	45	702
Sandy clay, red-brown and gray	40	742

Table 7.—Selected Drillers' Logs of Wells and Test Holes—Continued

	Thickness (feet)	Depth (feet)
Well 2—Continued		
Sandy clay, bluish-gray	50	792
Clay, dark gray	10	802
Well 3		
Owner: Texas Department of Highways and Public Transportation Driller: Texas Department of Water Resources		
Clay, gray	29	29
Sand, coarse grained, gold, also clay, gray	12	41
Sandy clay, gray	14	55
Sand, coarse grained, black	10	65
Gravel, fine to medium grained, poorly sorted, subrounded, assorted colors including black, white, tan, orange, red, yellow	16	81
Gravel, coarse grained, well sorted, subrounded to subangular, assorted colors as above	6	87
Gravel, fine to medium grained, poorly sorted, subrounded, assorted colors (see 81 ft)	4	91
Gravel, fine to coarse grained, poorly sorted, subangular. Also small amount of clay, brown	9	100
Gravel, fine grained, well sorted, subangular, (may be due to drilling); assorted colors (see 81 ft)	21	121
Gravel, fine to medium grained, poorly sorted, subrounded, assorted colors (see 81 ft)	17	138
Gravel, (see 138 ft), with small amount of clay, light brown	13	151
Clay, brown	50	201
Clay, red	16	217
Mostly sand, fine grained, orange, white, and gold, with small amounts of clay, brown, red, orange, and gravel, fine, assorted colors	54	271
Greater proportion of clay, brown, with less sand and gravel (see 271 ft)	20	291
Sand, fine grained, gold, with small amount of clay, brown. Also some fine gravel at 300 ft	10	301
Clay, red and brown	31	332
Sand, coarse grained, black, brown, white, with small amount of clay, bluish-gray, and fine gravel	39	371
Clay, bluish-gray, with some coarse grained sand (see 371 ft)	20	391
Mostly clay, red, with some coarse grained sand (see 371 ft) and fine gravel, assorted colors	90	481
70% sand, fine grained, dark gray 30% clay, red	20	501
70% sand, fine grained, light brown 30% clay, red	10	511
60% sand, fine grained, gray 40% clay, red	10	521

	Thickness (feet)	Depth (feet)
Well 3—Continued		
90% sand, fine grained, gray 10% clay, red	10	531
70% sand, fine grained, gray-black 30% clay, red	10	541
60% sand, fine grained, gray-black 40% clay, red and gold	10	551
90% sand, fine grained, gray-black 10% clay, red	20	571
40% sand, fine grained, gray-black 40% clay, gray 20% gravel, fine, assorted colors	10	581
60% sand, fine grained, gray-black 30% clay, brown and red 10% gravel, fine, assorted colors	19	600
60% sand, fine grained, gray 40% clay, brown	11	611
80% clay, blue 20% sand, fine grained, gray	20	631
Clay, red, with small amount of fine gravel	20	651
Mostly clay, brown	10	661
Sand, fine grained, bluish-gray	10	671
Sandy clay, gray and brown	10	681
Sand, fine grained, bluish gray, with some fine gravel	15	696
Sandy clay, light brown, with small amount of fine gravel (poor returns to surface)	55	751
Sandy clay, gray, small amount of fine gravel. Also pyrite in fine gravel size	10	761
Mostly clay, brown and red, with small amount of fine gravel	50	811
Well 4		
Owner: Texas Department of Highways and Public Transportation Driller: Texas Department of Water Resources		
Mostly sandy clay, brown, with small amount of fine gravel and caliche	35	35
Sand, medium to coarse grained, red and white	17	52
Gravel, fine grained, well sorted, subrounded, assorted colors including blue, red, black, white, orange, brown	5	57
Sand, fine grained, gold	6	63
Mostly gravel (see 57 ft) with small amount sand, fine grained, gold	22	85
Sandy clay, light brown	17	102
Sand, fine grained, gold	13	115
Sandy clay, gray and brown, blue	25	140
50% sand, fine grained, brown 50% clay, red	18	158

Table 7.—Selected Drillers' Logs and Test Holes—Continued

	Thickness (feet)	Depth (feet)
Well 4—Continued		
Gravel, medium grained, well sorted, subangular, assorted colors including black, white, orange, brown	4	162
Sand, fine to medium grained, gray and gold	31	193
Gravel, fine to medium grained, poorly sorted angular (appears to be chopped by drill bit), assorted colors including yellow, black, tan, brown	10	203
Sandy clay, gray	7	210
Gravel, fine grained, subrounded, assorted colors	4	214
Sandy clay, gray, with small amount of gravel (see 214 ft)	10	224
Clay, sandy clay, red, gray	10	234
80% sandy clay, gray and red 20% gravel (see 214 ft)	31	265
Sandy clay, blue and gray	37	302
Sandy clay, bluish-gray, with clay, red	38	340
Sand, fine grained, gold	15	355
Clay, bluish-gray	7	362
Sand, fine grained, gold	18	380
Sandy clay, dark gray at 385 ft, light gray at 405 ft, gray at 417 ft, bluish-gray at 427 ft, dark gray at 436 ft	56	436
Clay, dark gray	24	460
Clay and sandy clay, brown, gray	17	477
Sand, fine grained, gray	13	490
Clay, dark gray	10	500
Sand, fine grained, gold and dark gray	20	520
Alternating beds of sand, fine, gray; clay, gray; and sandy clay, gray	60	580
Clay, dark gray at 584 ft, brown at 594 ft, and blue from 604 to 622 ft	42	622
Clay and sandy clay, gold (poor returns to surface)	17	639
Sandy clay, gold	15	654
Clay, bluish-gray and red	41	695
Sandy clay, dark brown (poor returns to surface)	56	751
50% sand, fine grained, blue 50% clay, brown	19	770
Sandy clay, gray	32	802
Well 5 Owner: Texas Department of Highways and Public Transportation Driller: Texas Department of Water Resources		
Clay, light brown, and caliche, white	10	10
Caliche, tan, brown, white	25	35
Well 5—Continued		
Clay, blue, red-brown with blue streaks	40	75
Gravel, fine to medium grained, subrounded to subangular, assorted colors including black, white, yellow, orange, brown	11	86
Sandy clay, gray and yellow	28	114
Sand, fine grained, yellow and brown	29	143
Clay, red and brown	19	162
Sand, fine grained, yellow and brown	17	179
Sandy clay, brown. Fine sand grains present, red and yellow	45	224
Clay, red-brown and blue	29	253
Sand, fine grained, gray; and gravel, fine to medium grained, subangular, assorted colors	8	261
Clay, blue to 293 ft, red-brown 261-304 ft	43	304
Sand, fine grained, gray and gold, and gravel, fine grained, subrounded to subangular, assorted colors	27	331
Clay, red-brown	56	387
Sand, fine grained, gray	13	400
Clay, red-brown	17	417
Gravel, fine grained, subangular, assorted colors	3	420
Sand, fine grained, gold and white	7	427
Clay, red-brown	73	500
Sand, fine grained, gold	19	519
Clay, red-brown	26	535
Sand, fine grained, gray and yellow	8	543
Clay, red-brown	9	552
Sand, fine grained, bluish-gray	8	560
Sandy clay, brown	16	576
Clay, red-brown	19	595
Sand, fine grained, dark green	12	607
Sandy clay, gray and yellow	10	617
60% sandy clay, gray and yellow 30% gravel, fine grained, subangular, assorted colors 10% clay, red-brown	10	627
Sandy clay, gray	18	645
Well 7 Owner: Boyd Davis Driller: Harold W. Pursley, Jr.		
Surface	4	4
Shale	6	10
Caliche	10	20
Shale	45	65
Gravel, coarse	19	84

Table 7.—Selected Drillers' Logs of Wells and Test Holes—Continued

	Thickness (feet)	Depth (feet)
Well 8		
Owner: Smith Grove Care Driller: Rolland H. Pursley		
Surface	4	4
Shale	58	62
Gravel	20	82
Shale	21	103
Well 22		
Owner: Frank P. Eckroat Driller: Bert Killinger		
Caliche	35	35
Caliche and clay	18	53
Sand	15	68
Gravel, cemented	2	70
Sand (water)	11	81
Gravel, cemented	9	90
Shale, hard	10	100
Shale	29	129
Sand	28	157
Shale	4	161
Sand	22	183
Shale	18	201
Sand, firm	16	217
Sand, good	33	250
Sand layers, loose and hard	26	276
Well 29		
Owner: E. Salinas Driller: Colbath		
Caliche and gravel	37	37
Gravel and clay, gray	57	94
Sand	17	111
Clay	84	195
Sand	10	205
Well 35		
Owner: Ray Barnick Driller: Bert Killinger		
Surface soil	15	15
Caliche	10	25
Clay	25	50
Sand and clay	26	76
Sand	16	92
Sand and gravel, scattered	3	95

	Thickness (feet)	Depth (feet)
Well 35—Continued)		
Gravel, cemented	2	97
Sand, firm	3	100
Gravel, cemented	1	101
Sand, loose	3	104
Gravel and cemented gravel	8	112
Sand, firm	3	115
Clay	35	150
Sand	18	168
Clay	14	182
Sand	16	198
Clay	38	236
Sand	4	240
Clay	15	255
Sand, firm	17	272
Sand, good	68	340
Clay	5	345
Well 47		
Owner: C. C. McMillon Driller: Pursley		
Topsoil	16	16
Caliche	83	99
Gravel, small and sand	100	199
Shale	32	231
Sand	12	243
Gravel, large	54	297
Well 64		
Owner: City of McAllen Driller: Layne-Texas Co.		
Soil	6	6
Clay, sandy	10	16
Gravel and clay, packed	31	47
Clay	29	76
Gravel and clay, packed	9	85
Gravel, loose	9	94
Gravel, large, loose	33	127
Clay	43	170
Caliche and clay	16	186
Sand and caliche	8	194
Sand	61	255
Shale	45	300
Sand	114	414

	Thickness (feet)	Depth (feet)
Well 64—Continued		
Shale, tough	30	444
No record	26	470
Well 67		
Owner: C. E. Schwanz Driller: E. H. Ray		
Surface soil	3	3
Clay and silt	9	12
Sand	21	33
Clay	2	35
Sand	2	37
Gravel	30	67
Well 74		
Owner: Eva Reyna Driller: Charley P. Moore		
Dark topsoil	10	10
Caliche	12	22
Clay	33	55
Sand and gravel	12	67
Well 84		
Owner: Boyd Davis Driller: Harold W. Pursley, Jr.		
Surface	4	4
Shale	4	8
Caliche	14	22
Shale	12	34
Sand	21	55
Gravel (large)	41	96
Shale	16	112
Well 85		
Owner: W. B. Shaw Driller: Harold W. Pursley, Jr.		
Surface	4	4
Shale	51	55
Hard sand	37	92
Well 86		
Owner: Boyd Davis Driller: Rolland H. Pursley		
Surface	4	4
Shale	76	80
Sand and gravel	24	104

	Thickness (feet)	Depth (feet)
Well 87		
Owner: Delia Barrera Driller: Charley P. Moore		
Sandy topsoil	8	8
Caliche	17	25
Clay, yellow	25	50
Sand & gravel	9	59
Well 88		
Owner: Dietex—Owens Grove Driller: Charley P. Moore		
Yellow clay	10	10
Caliche	12	22
Yellow clay	33	55
Sand and gravel	25	80
Well 89		
Owner: Bob Wellen Driller: Charley P. Moore		
Sandy topsoil	10	10
Caliche	12	22
Clay	23	45
Sand	13	58
Well 90		
Owner: Compton Grove Care Driller: Charley P. Moore		
Topsoil	2	2
Clay	8	10
Caliche	9	19
Clay	46	65
Sand and gravel	18	83
Well 91		
Owner: Compton Grove Care Driller: Rolland H. Pursley		
Surface	4	4
Shale	40	44
Sand	11	55
Gravel	5	60
Shale	16	76
Sand	21	97
Shale	113	210
Sand	40	250
Shale	15	265
Sand	38	303

Table 7.—Selected Drillers' Logs of Wells and Test Holes—Continued

Well 92

Owner: Compton Grove Care
Driller: Charley P. Moore

	Thickness (feet)	Depth (feet)
Topsoil	4	4
Clay, yellow and blue	36	40
Gravel	17	57

Well 93

Owner: Thomas M. Chapman
Driller: Charley P. Moore

	Thickness (feet)	Depth (feet)
Black topsoil	2	2
Yellow clay	8	10
White clay	15	25
Blue clay	25	50
Sand and gravel	10	60

Well 94

Owner: J. N. Wilsher
Driller: Harold W. Pursley, Jr.

	Thickness (feet)	Depth (feet)
Surface	5	5
Sand	15	20
Shale	40	60
Sand and gravel	45	105

Well 95

Owner: Ross L. Jenson
Driller: Charley P. Moore

	Thickness (feet)	Depth (feet)
Sandy topsoil	3	3
Clay, white	7	10
Caliche	10	20

Well 95-Continued

	Thickness (feet)	Depth (feet)
Clay, yellow	15	35
Clay, stripped with sand	5	40
Clay, yellow	15	55
Clay, stripped with sand	5	60
Gravel	10	70

Well 96

Owner: Carlos Leal
Driller: Charley P. Moore

	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay	10	12
Caliche	23	35
Clay	30	65
Sand and gravel	10	75

Well 97

Owner: Compton Grove Care
Driller: Charley P. Moore

	Thickness (feet)	Depth (feet)
Sandy topsoil	4	4
Yellow clay	63	67
Sand and gravel	20	87

Well 98

Owner: Larry Phillips
Driller: Charley P. Moore

	Thickness (feet)	Depth (feet)
Yellow clay	45	45
Sand and sandstone	20	65
Gravel	3	68