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GEOLOGY AND GROUND-WATER RESOURCES OF THE LAS CRUCES AREA, NEW MEXICO

by

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This report is a brief review of the geology and ground-water resources of a 550 sq mi area surrounding Las Cruces, Dona Ana County, New Mexico.

The area includes the southern and northern ends, respectively, of the Jornada del Muerto Basin and the Mesilla Bolson, which are crossed by the entrenched Mesilla Valley of the Rio Grande (Fig. 1). Mountains flanking the basin and valley areas are the San Andres-Organ range on the east, the Dona Ana Mountains to the north, and the Robledo-Picacho uplifts to the northwest (Fig. 1).

Much of the text material and hydrology is extracted from Hydrologic Report 1 of the New Mexico Bureau of Mines and Mineral Resources by King and others (1971). Sections on the hydrology of the Las Cruces well field and on the quality of water include much new information derived from recent U.S. Geological Survey investigations under the direction of Clyde A. Wilson. These studies are done in cooperation with the City of Las Cruces, Elephant Butte Irrigation District, State Engineer Office, Water Resources Research Institute of New Mexico, and the Bureau of Reclamation. New U.S.G.S. data on aquifer transmissivity and well yields are also included. Geological names used in this paper are not necessarily those recognized by the Stratigraphic Names Committee of the U.S. Geological Survey.

CONSOLIDATED ROCKS

The primary hydrologic role played by consolidated rocks in the area of study is that of a barrier to the movement of water. The consolidated rocks also serve as the source of many of the dissolved solids found in the ground surface waters of the area. The geohydrologic properties of various bedrock units that occur in the area have been summarized by Dinwiddie (1967) and Titus (1967). On the geologic map (Fig. 1) the consolidated rocks are represented by four groups: (1) Precambrian and Tertiary metamorphic and igneous intrusive rocks; (2) Paleozoic, Cretaceous, and early Tertiary sedimentary rocks; (3) middle Tertiary volcanic rocks and associated sedimentary rocks; and (4) Quaternary basalt and volcanic cones. Groups 1, 2 and 3 comprise the bedrock exposed in the mountain uplifts and buried by fills of variable thicknesses in the intermontane basins.

Igneous Intrusive and Metamorphic Rocks

Deep-seated igneous intrusive bodies of granitic to porphyritic texture and of Precambrian and Tertiary age make up the cores of the San Andres-Organ Mountain chain and the Dona Ana Mountains. Smaller uplifts with igneous intrusive centers include Goat Mountain and Picacho Mountain. The Precambrian units are intimately associated with complexes of metamorphic rocks.

All the rocks in the intrusive-metamorphic group may be effective barriers to ground-water movement and yield only

small quantities of water in local weathered or fractured zones. Quality of water derived from intrusive-metamorphic terrains is usually good, but may be exceptionally poor in mineralized areas such as occurs near the community of Organ.

Sedimentary Rocks of Paleozoic, Cretaceous, and Early Tertiary Age

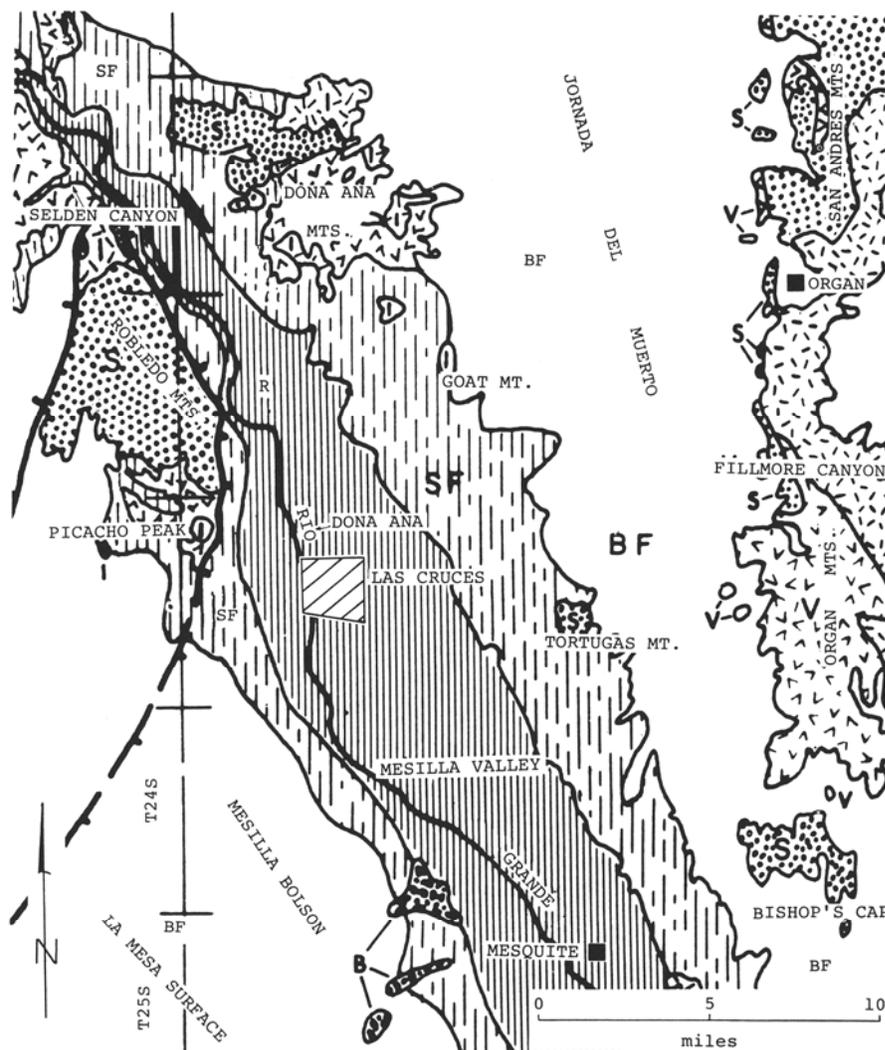
For the purposes of this report, sedimentary rocks of Paleozoic, Cretaceous, and early Tertiary age are discussed as one hydrogeologic unit. All these rocks are well consolidated and have been locally subjected to tectonic deformation. The rocks of Paleozoic age are dominantly limestone and dolomite, with the exception of a basal Cambrian-Ordovician quartzite to quartzite conglomerate, a Devonian shale sequence, and intertonguing bodies of gypsum and redbed sandstone to siltstone in the Upper Pennsylvanian to Permian part of the section. Paleozoic rocks make up the bulk of the bedrock in the San Andres and Robledo Mountains. Relatively complete stratigraphic sections ranging from Cambrian-Ordovician to Permian in age are exposed in each of the uplifts. (cf. First Day's road log, this guidebook). The lower Tertiary sedimentary rocks consist of conglomerate, sandstone, and shale that crop out in a few areas along the south flank of the Robledo Mountains and the west flanks of the San Andres and Organ Mountains.

Primary porosity is low in all the rock units. The major effective porosity and permeability is from joints, fissures, and faults. Solution cavities in carbonate and gypsiferous rocks appear to be uncommon in this area. Yields from the few wells penetrating the sedimentary rocks are low, rarely exceeding a few gallons per minute (gpm). At the Apollo Project, located about 4 mi north of Organ, two test wells (Doty, 1963, p. 8 and 9, wells D and G; King and others, 1971, p. 26, wells 20.3 E, 12.332, 20.3E, 15.442) penetrated about 1,150 and 350 ft respectively of rocks below the water table that are interpreted as Cretaceous and lower Tertiary shale, sandstone, and conglomerate. Although the wells were regarded as "dry" holes, enough water for stock or domestic purposes might be available. Large water yields have been reported from the Torpedo-Bennett fault zone along the northwest base of the Organ Mountains (Dunham, 1935). Water produced from the sedimentary-rock group often has a high content of dissolved solids, particularly in areas of hydrothermal mineralization or where gypsum is present.

Tertiary Volcanic and Sedimentary Rocks

The third major bedrock group comprises middle Tertiary volcanic and thick sequences of interbedded clastic sedimentary rocks. These rocks are mainly of Eocene to Miocene age and comprise the major bedrock units in the Dona Ana and southern Organ Mountains.

There is a great variation in the amount of consolidation of



EXPLANATION

- Valley-fill alluvium; late Quaternary; clay to gravel, less than 80 ft thick.
- Olivine basalt flows and volcanic cones; Quaternary, generally post date the Santa Fe Group.
- Basin-fill surface. Santa Fe Group, with discontinuous overlay (generally less than 25 ft thick) of younger alluvial, eolian and minor lacustrine deposits.
- Santa Fe Group basin fill; Miocene to middle Pleistocene; clay to gravel; locally as much as 4,000 ft thick. Also discontinuous overlay (generally less than 100 ft thick) of younger valley slope deposits.
- Volcanic rocks, and associated clastic sedimentary rocks, undifferentiated; early and middle Tertiary.
- Sedimentary rocks, undifferentiated; Paleozoic, Cretaceous and early Tertiary.
- Intrusive rocks, undifferentiated, and associated metamorphics; Precambrian and Tertiary.
- Faults involving significant displacements of basin fill.

Figure 1. Generalized geology of the Las Cruces, New Mexico area (modified from King and others, 1971).

these materials. Rhyolite, andesite-latite, and basaltic andesite flows and rhyolitic welded tuffs are generally hard and dense; on the other hand, unwelded tuffs of rhyolitic to andesitic composition and the interbedded sedimentary rocks are moderately well to very poorly consolidated. These rocks generally have low permeability. Even the poorly consolidated

volcanic and associated sedimentary rocks consist of well-graded mixtures including a wide range of particle sizes (from boulders to clay); thus, the primary porosity of these materials is very low. As in the older rocks, effective porosity is provided by fractures. Since the joints, faults, and fissures in the bedrock tend to be sites of mineralization, water in zones of

intense fracturing at many places has a high content of dissolved solids and commonly is nonpotable. Two other Apollo Project test wells were drilled into Tertiary volcanic rocks (Doty, 1963, p. 6, 7, and 10, wells C and H; King and others, 1971, p. 26, wells 21.3E.4.211, 20.3E16.233). Well C, which penetrated about 550 ft of rhyolite and interbedded sedimentary rock below the water table, produced less than 50 gpm; well H, which penetrated about 1,150 ft of andesitic rocks, was regarded as a "dry (damp) hole."

Discussion

An important point that should be considered here is the influence of the various bedrock units exposed in the mountain uplifts upon the textural and geochemical characteristics of the basin fills. The basin fills are described in the next section, but it should be noted here that types of material deposited in the basins, particularly in the piedmont-slope areas, directly reflect the way different bedrock lithologies behave as they are affected by various agents of weathering, entrainment, and transport. For example, monzonite and other granitic-textured rocks generally break down into fragments ranging in size from very coarse sand to clay during weathering and transportation. Limestone and calcareous sandstone and siltstone (such as those cropping out in the San Andres and Robledo Mountains) tend to break down either into gravel or fine sand to silt-sized particles. The more massive, very hard rocks, such as metaquartzite and some rhyolite (e.g., the Soledad Rhyolite in the southern Organ Mountains) tend to break down into gravel-sized particles. The shape and the size of the gravel is, in great part, controlled by spacing of fractures in the bedrock. Poorly-consolidated tuff and tuffaceous sedimentary rocks of middle Tertiary age, older shale and mudstone, and the clayey horizons of some upland soils have been the source of much of the fine-grained material in the basin fills. Gypsite beds in the Upper Pennsylvanian and/or Permian section in parts of the San Andres Mountains are important to the geochemistry of ground water. These rocks have been the source beds for locally thick secondary gypsum deposits in the fills of adjacent basin areas.

UNCONSOLIDATED TO MODERATELY CONSOLIDATED DEPOSITS

This category of geologic materials includes the two major water-bearing units in the region: The Santa Fe Group basin fill of Miocene to middle Pleistocene age, and the Rio Grande floodplain alluvium and tributary arroyo valley fills of late Quaternary age. The stratigraphy and general composition of these units has been described by Hawley and others (1969) and Seager and others (1971). This section of the report will emphasize the hydrogeology of the basin and valley fills at places where semiquantitative information is available from well data. The report by King and others (1971) contains a number of sample and drillers' logs that include specific notations on the stratigraphic and lithologic units penetrated by water wells and oil tests.

Basin Fill-The Santa Fe Group

The Santa Fe Group is the major ground-water reservoir in the region. Aquifers in the Santa Fe produce most of the water used in metropolitan and industrial centers, as well as a significant proportion of ground water used to supplement surface

irrigation surplus (King and others, 1971). From the preceding discussion, however, it can be seen that the group is not a single hydrologic unit. Water-bearing properties of the basin fill and quality of the ground water reflect the variety of depositional environments in both open- and closed-basin systems. Thus the Santa Fe Group includes a number of aquifers as well as major zones that are relatively impermeable. Obviously, the quantity of water needed for a particular purpose at a certain place determines an individual's concept of what an aquifer is. Highly productive domestic and stock wells are often referred to as "dry holes" when considered as producers of water for irrigation or industrial uses.

Closed intermontane basin (bolson) environments prevailed during early stages of basin filling whereas later stages were marked by coalescence of the floors of contiguous basins and development of a regional system of through drainage (the ancestral Rio Grande). Locally derived piedmont-slope alluvium, characterized by wide textural variation and including alluvial-fan, coalescent-fan, and pediment deposits, is a typical facies in both closed and open basin settings. In closed basins, piedmont-slope alluvium grades into or intertongues with fine-grained, lacustrine and alluvial basin-floor deposits. In open systems, the basin-floor facies consists mainly of medium, to coarse-grained fluvial deposits, with fine-grained materials making up a relatively small proportion of the basin-fill sequence.

The Santa Fe Group in the Southern Jornada del Muerto Basin and Selden Canyon

The main part of the structural basin that forms the southern Jornada del Muerto lies east of a line extending through the crests of the Dona Ana Mountains, Goat Mountain, and Tortugas Mountain (Fig. 1). A line extending from Tortugas Mountain to the Fillmore Canyon area of the central Organ Mountains forms the approximate southern boundary of the Jornada basin system.

The broad piedmont slope rising to the San Andres-Organ Mountains chain and the narrower slopes rising to the Dona Ana Mountains consist mainly of coalescent alluvial-fan surfaces, with minor post-Santa Fe deposition in middle to late Quaternary time. The underlying fan alluvium of the upper Santa Fe Group (locally called the Camp Rice Formation) forms the upper several hundred feet of basin fill and appears to intertongue with pebbly sand to clay of the fluvial facies. The fluvial facies is partly impregnated with gypsum. The zone of facies change occurs approximately below the break in slope at the piedmont slope-basin floor juncture. Still older fan deposits definitely predate the fluvial facies and appear to interfinger, below the present basin floors, with extensive fine-grained deposits that may be partly of lacustrine origin.

The only large ground-water development in the southern Jornada del Muerto Basin is in the southeast corner of T. 20 S., R. 2 E., and the southwest corner, T. 20 S., R. 3 E. (Fig. 1) on the lower slopes of the large alluvial fan spreading out from the mouth of a canyon in the San Andres Mountains. Four water wells in the area are capable of producing from 500 to 1,500 gpm. The western two wells are used for irrigation, and the eastern two are production wells for the Apollo Project Test Site, located 5 mi to the east. Basin fill geology of this area is illustrated in the First Day's road log in this guidebook. The two Apollo wells each penetrate more than 1,000 ft of

unconsolidated Santa Fe Group fan alluvium that contains thick, very gravelly zones (limestone, sandstone, chert, and some rhyolite clasts). The static water level in the area ranges from 300 to 350 ft below the ground surface, and the coefficient of transmissibility for the 400 to 500 ft of saturated sediments tested ranges from 48,000 to 80,000 gallons per day per foot (gpd/ft).

Moderate amounts of ground water are produced at the southern end of the Jornada Basin along U.S. Highway 70 between Interstate Highway 25 and Organ (Fig. 2). Subsurface hydrogeologic information available for this area (including drillers' logs, notes on well cuttings, geophysical data, and water-table configuration) is summarized in Figure 3, a cross-section extending from the La Mesa surface, west of the Mesilla Valley, to 1 mi east of Organ.

Ground water production in the U.S. Highway 70 area is again from the alluvial-fan facies of the Santa Fe Group. Basin fill in the area was deposited in an environment of coalescing alluvial fans that spread out from several canyons in the central and northern Organ Mountains. The fan deposits are fine textured in comparison with the coarse fan gravels that were penetrated by the Apollo wells. Intergranular spaces between coarser clasts are largely plugged with compact, well-graded mixtures of fine sand, silt, and clay. Common lithologic types noted in well cuttings include (1) primarily monzonite-derived sand and very fine-grained pebble gravel, originally from the northern Organ Mountains, (2) andesite pebble gravel derived from outcrops on the flanks of the northern Organs and (3) mixed pebbles of rhyolite and andesite derived from the Fillmore Canyon area of the central part of the mountains (Dunham, 1935). The Fillmore Canyon watershed was the primary source for much of the fan alluvium in the Santa Fe Group in a 45-sq mi area, including the southwest part of T. 22 S., R. 3 E., the southeast part of T. 22 S., R. 2 E., the northeast part of T. 23 S., R. 2 E., and the northwest part of T. 23 S., R. 3 E. (Fig. 2).

South of the Dona Ana Mountains there is no distinct surface divide between the southernmost part of the Jornada del Muerto Basin and the northeastern Mesilla Bolson. Surface and subsurface studies between the Dona Anas and Tortugas Mountain demonstrate that the two basins aggraded as a single unit during the deposition of at least the final 200 to 300 ft of basin filling. However, subsurface information from wells and gravity surveys (American Metals Climax, Inc., Bear Creek Exploration Company, Kerr-McGee Corporation, and Mobil Oil Company officials, personal communications) indicates that the southern Jornada is a well-defined structural basin separated from the Mesilla Bolson by a buried bedrock high extending from the Dona Ana Mountains to Tortugas Mountain. The hydrogeologic cross section along U.S. Highway 70 (Fig. 3) shows the general position of this barrier and illustrates the marked effect it has on the water-table configuration. East of the bedrock high, the basin fill thickens markedly, and a gravity survey by Bear Creek Exploration company indicates that the depth-to-bedrock is about 2,500 ft along a belt beginning about 2.5 mi west of Organ and extending several miles northward (Robert Stuart, personal communication, 1964). Two test holes in the south-central part of T. 21 S., R. 3 E., indicate that the Santa Fe Group basin fill is about 1,900 ft thick in those areas.

Wells in the southern Jornada Basin area along Highway 70, have much lower yields than wells discussed previously. Most

wells are for domestic use and yield a few gallons per minute. Some larger wells used for public supply or irrigation yield a few hundred gallons per minute. The saturated part of the Santa Fe Group present in the Jornada is not nearly as permeable as the Santa Fe beds beneath the Mesilla Valley. This reflects the mainly bolson (piedmont-slope to playa) origin of the Jornada Basin fill versus the fluvial (ancestral Rio Grande) origin of the saturated upper Santa Fe Group deposits in the Mesilla Valley-La Mesa surface areas.

No wells have been drilled on the main part of the Fillmore Canyon alluvial fan area, between Tortugas Mountain and U.S. Highway 70. A test well drilled in 1966, half-way between Tortugas Mountain and the Organ Mountain front (King and others, 1971, p. 20) possibly penetrated dense volcanic rock at 285 ft after penetrating about 10 ft of younger basin alluvium and 275 ft of Santa Fe Group fan gravel. This "rock" could be a large rhyolite boulder. However, if bedrock was actually encountered, the deep basin shown in Fig. 3 ends rather abruptly within a distance of no more than 6 mi south of U.S. Highway 70.

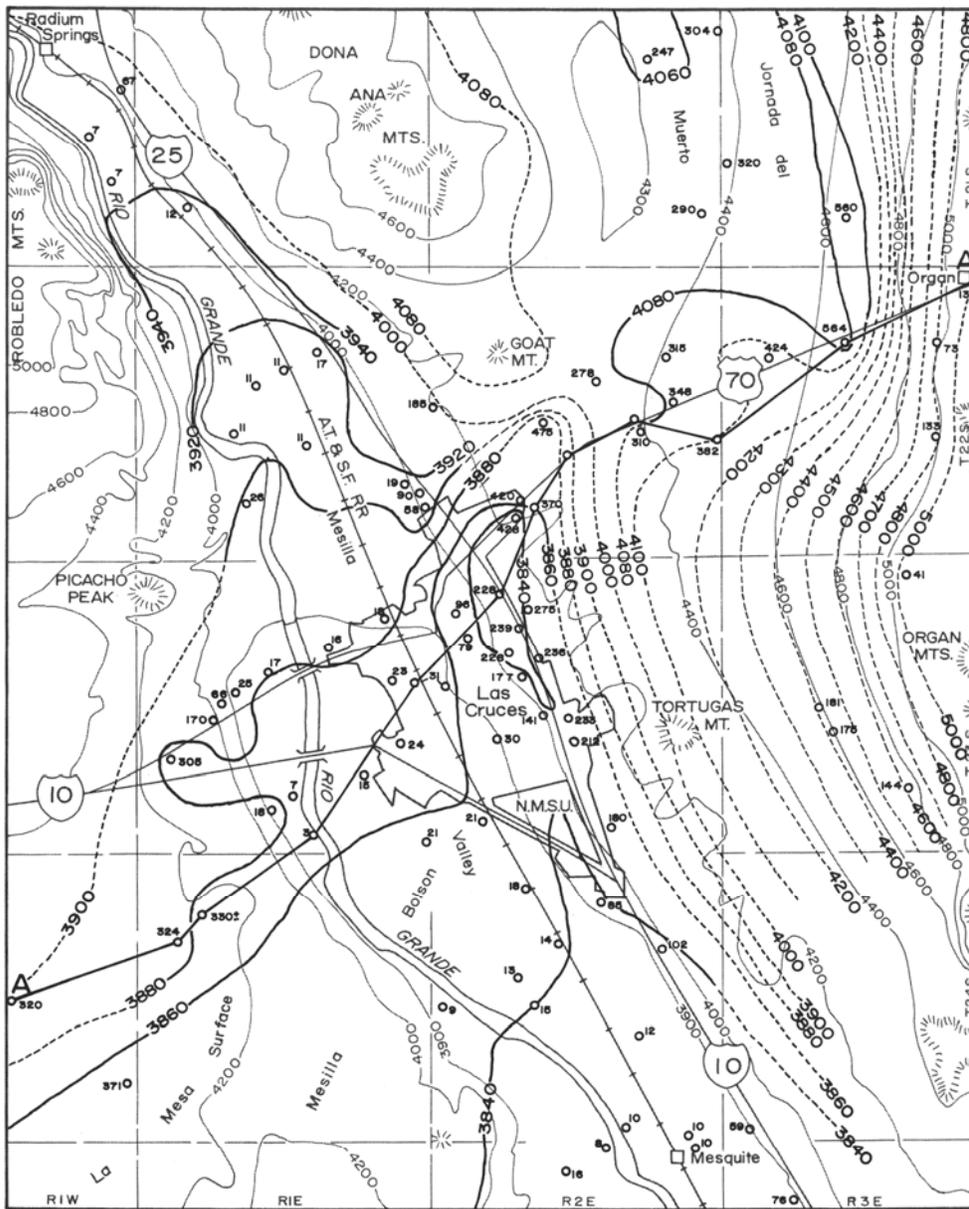
The Santa Fe Group in the Mesilla Bolson

The quantity of water produced from the Santa Fe Group basin fill in the Mesilla Bolson is many times greater than the combined production from all other basins discussed. Wells drilled in the Santa Fe Group are primarily concentrated in the area of the bolson occupied by the Mesilla Valley.

The Santa Fe Group exposed in side slopes of the Mesilla Valley consist of two facies that in various places intertongue or are gradational with each other. In the northern part of the valley opposite the Dona Ana and Robledo Mountains, the alluvial-fan facies intertongues with fluvial sands on mountain foot slopes. Essentially continuous outcrops of the fluvial sand and gravel occur in two valley-border areas: (1) the east valley slope, between the communities of Dona Ana and Mesquite; and (2) the west valley slope, south of Picacho Mountain. Due to the general unconsolidated nature of the upper Santa Fe beds, exposures are poor, particularly on the lower slopes.

Intertonguing of the two facies can be observed locally in the walls of several deep arroyos that extend from the Organ Mountains across the northeastern part of the bolson and into the Mesilla Valley (Hawley and others, 1969, fig. 2). Figure 3 shows diagrammatically the intertonguing relationships between the fluvial facies and the alluvial-fan facies along U.S. Highway 70, east of Las Cruces. The results of surface mapping along Alameda Arroyo (located along the northern edge of Las Cruces) and the sample and drillers' logs of four key wells (King and others, 1971, p. 20) were used in construction of the part of the cross section extending from the crest of the buried bedrock high to the Mesilla Valley floor.

Distinct lithologic differences between the rounded siliceous gravels of the fluvial facies and the more angular, locally-derived gravels of the fan facies enabled Taylor (1967, p. 20 and 21) to distinguish the two facies in basin fill penetrated by Las Cruces city wells 23 and 24, located along Interstate 25, on the east side of Las Cruces. The distinctive suite of volcanic rock clasts derived from Fillmore Canyon in the Organ Mountains, mentioned in Taylor previously, appeared in the fan facies in both city wells at depths considerably below the top of the intervening buried bedrock high shown in Figure 3 of this report. This observation indicates that the buried uplift is



410 O Well. Number indicates depth to water (feet) below land surface.

— 3880 — Water table contour showing elevation of water table. Contour interval is 100 feet with supplementary 20 foot contours as needed. Dashed where approximate, Datum plane is mean sea level. Water levels for Rio Grande valley and within Las Cruces city limits were measured during period Dec. 1973 to June 1974; for uplands period was May 1965 to Jan. 1975.

— 4000 — Land surface contour. Contour interval is 200 feet with supplementary 100 foot contours. Datum plane is mean sea level.



Figure 2. Water table contour map for Las Cruces, New Mexico area (modified from King and others, 1971).

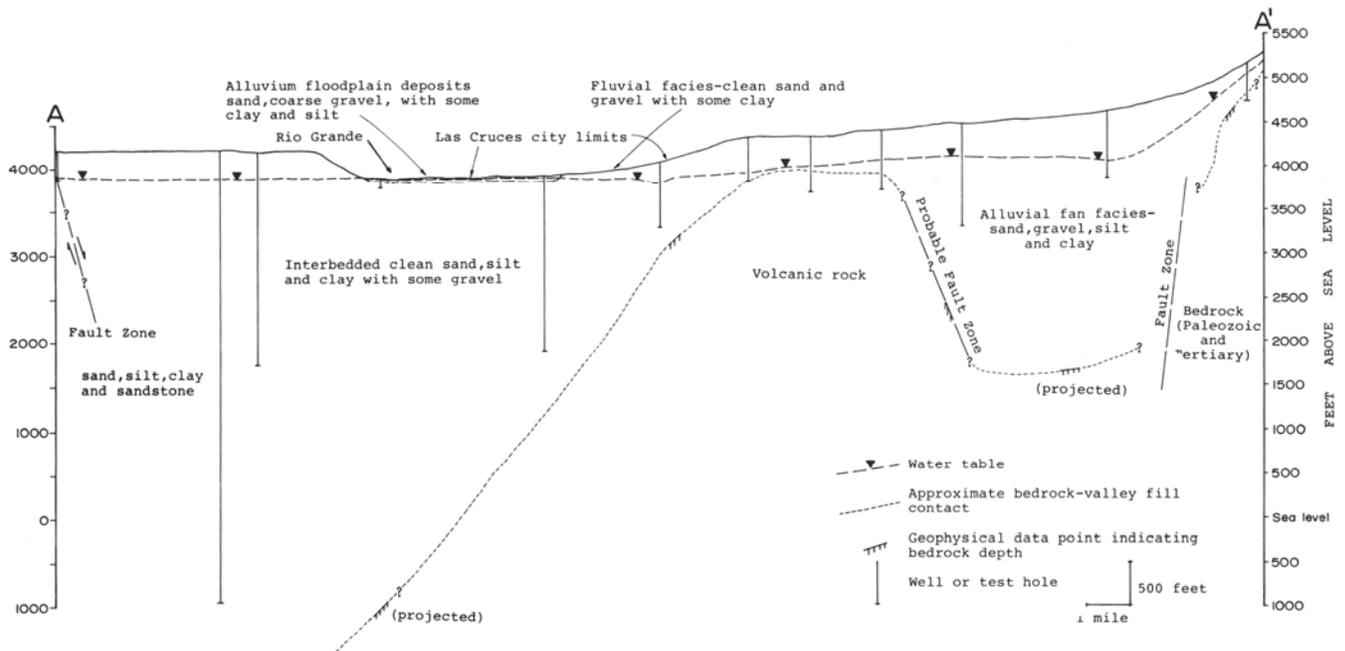


Figure 3. Hydrogeologic cross-section, Las Cruces, New Mexico area (modified from King and others, 1971). See Figure 2 for location.

locally breached in the area east of Interstate Highway 25, between U.S. Highway 70 and Tortugas Mountain, and that it is not a continuous barrier to water movement in the Santa Fe Group basin fill. Taylor's detailed studies of the gravel lithologies in cuttings from city wells 23 and 24 also enabled the writers to determine that ground-water production of the east Las Cruces well field comes from a zone of the Santa Fe Group characterized by intertonguing of sand and gravel (with only minor amounts of silt and clay) of the alluvial-fan and fluvial facies. Wells are capable of producing large quantities of good quality water.

At present, sixteen wells supply Las Cruces with its water. The city wells, all located along Interstate 25, between Highway 70 and Tortugas Mountain, range in depth from 360 to 751 ft and all produce water from the Santa Fe Group. Depth to static-water level ranged from 79 to 239 ft in 1974; pumping levels may exceed 330 ft in some wells located in the center of the field and during periods of continuous well pumpage. Well yields vary from about 300 to over 1,250 gpm. In 1974 the city used 3.3 billion gallons of water (10,000 acre-feet). Average daily consumption was 9 million gallons or about 192 gallons per person per day.

Preliminary results of aquifer tests in the city well field indicate transmissivities ranging from 12,000 to over 200,000 gpd/ft. The southeast end of the well field seems to be the most permeable area; most of the field has a transmissivity below 50,000 gpd/ft. Specific capacities range from 7.5 to 65.6 gpm/ft of drawdown.

Figure 4 shows the typical hydrographs of wells within the Las Cruces well field. City well 21 is located in the center of the field while well 10 is located on the westward outer fringe of the field, and is not pumped as much.

Average decline for all wells in the field is about 1.5 ft per year. The resulting cone-of-depression is shown in the central part of the water-table contour map, Figure 2. Due to the igneous-intrusive barrier to ground-water flow in the subsurface east of the city well field, some declines averaging 3 ft per

year have occurred in domestic wells along Highway 70 immediately northeast of the city well field. The decline of the water table around the city field is not unusual in aquifers in arid regions where recharge is very limited. At present, Las Cruces personnel are considering new areas for additional well fields.

The comments of the previous paragraphs also generally apply to the New Mexico State University campus area. The University has an independent water-supply system tapping both the fan facies and the fluvial facies. The well near the University Golf Course (center area of T. 23 S., R. 2 E.) is one of the few wells in the area near Tortugas Mountain that has had its hydraulic capabilities adequately tested. Records of a step-drawdown well-performance test (Stuart Meerscheidt, Butte Pump Co., June, 1962, personal communication) show a relatively low coefficient of transmissibility of about 6,000 gpd/ft (about 150 ft of saturated basin fill tested). The well was recently abandoned due to poor quality of the water produced.

A small area of domestic ground-water production from the alluvial-fan facies, 2 mi southeast of the university and immediately southwest of Tortugas Mountain is of particular interest because of the high temperature of water (90 to 110°F) produced from a zone about 350 to 450 ft below the surface. A high geothermal gradient associated with a fault zone bounding the Tortugas Mountain block may be the cause of this temperature anomaly (see paper by Swanberg, this guidebook).

In the part of the Mesilla Bolson occupied by the Mesilla Valley, subsurface information on the nature of the Santa Fe Group below the Rio Grande flood plain is incomplete because the majority of the wells have been drilled to depths less than 300 ft. Deep drilling in the New Mexico part of the valley area has been confined to a few scattered test holes.

The late Quaternary river-valley fill (flood plain alluvium),

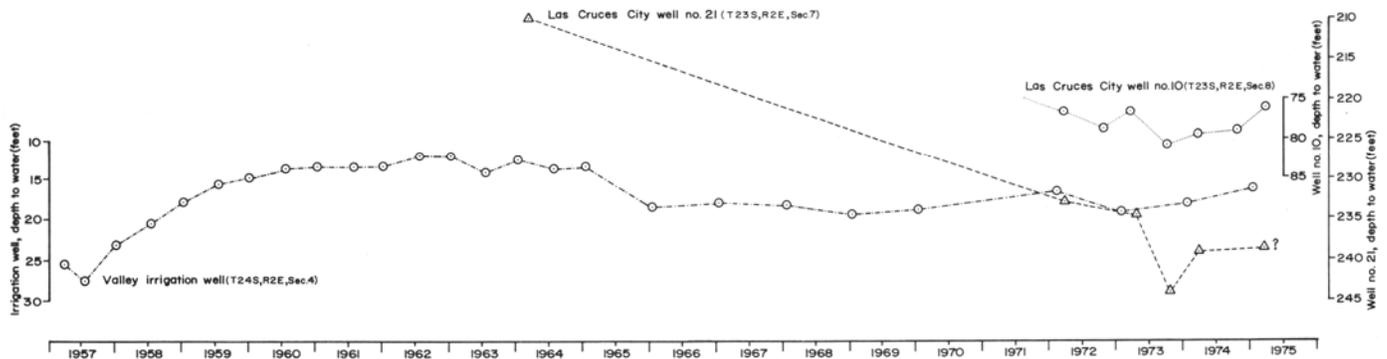


Figure 4. Hydrographs showing water level fluctuations for three wells in the Las Cruces, New Mexico area.

which is discussed in a later section, appears to be no more than 80 ft thick. Many shallow irrigation wells extend through the valley fill and into the uppermost beds of the underlying Santa Fe Group basin fill. Because there is no legal requirement in this part of New Mexico for submission of well logs or well construction data to the State Engineer, it has been impossible to determine from the information available the relative amounts of water produced from the two units.

Major use of ground water in the Mesilla Valley is for supplemental irrigation of crops. The amount of ground water pumped varies yearly and depends on the amount of surface water available from the Rio Grande Irrigation Project and current precipitation. The maximum surface-water allotment which may be available in "good" years of run-off into Elephant Butte Reservoir is 3 acre feet of water per acre of crop land. Ground water is then pumped for irrigation before or after the normal surface water release dates (March-October) and to supplement surface water during years of low allotment.

Water levels fluctuate continuously in the flood plain alluvium aquifer as shown in Figure 4 for a well located in the north-central part of T. 24 S., R. 2 E. (Fig. 2). Recharge comes mostly from surface water applied for irrigation. The lowest water levels in the later 1950's were due to a series of years of very limited surface water allotment and heavy pumpage from the aquifer. Water levels rose in 1973 and 1974 because in these two years the maximum 3 acre-feet per acre surface-water allotment was available.

A series of aquifer tests were conducted on a deep (686 ft) irrigation well located in the center part of T. 24 S., R. 2 E. This well is only perforated in the Santa Fe Group. The tests gave an average transmissivity of 150,000 gpd/ft. About 270 ft of sand were included in the perforated segment of the well casing. Hydraulic conductivity was 560 gallons per day per square foot (gpd/ft²) and the specific capacity was 40 gpm/ft of drawdown. The well is designed to produce 3,500 gpm.

Santa Fe strata penetrated below the valley fill in the southern part of the valley, south of Mesquite, (Fig. 2) generally consist of alternating layers of fine to coarse sand, and clay to sandy clay (King and others, 1971). However, wells on the east side of the valley near Las Cruces also encounter some beds of gravel in the upper 200 to 300 ft of basin fill (King and others, 1971, p. 21). Earlier workers assumed that the Santa Fe Group below the Mesilla Valley floor was non-gravelly and erroneously attributed some deep gravel-bearing strata to post-Santa Fe valley-fill deposits (Conover, 1954; Leggat and others, 1962).

The basin-fill facies classification used up to this point does not adequately characterize the sequence of alternating sand and clay units extending 30 to 40 mi southward into Texas, where Leggat and others (1962) referred to it as the "medium (Santa Fe Group) aquifer." Well cuttings from the sand to sand and gravel zones are identical to cuttings from the fluvial facies elsewhere in the area.

Strain (1966, 1969) postulated that a large lake, Lake Cabeza de Vaca, periodically occupied the floor of Hueco Bolson (not shown on maps, located east of Organ Mountains) in early Pleistocene time, prior to the extension of ancestral Rio Grande deposits into that basin. He also considered it likely that higher stands of this lake extended into the Mesilla Bolson via basins located in northern Chihuahua, the "narrows" near El Paso, 40 mi south, and possibly Fillmore Pass south of the Organ Mountains. He also believed clayey beds exposed in the lower parts of the valley walls near El Paso might represent lacustrine strata. With this hypothesis in mind, it appears quite possible that the alternating clay and sand sequence represents basin-fill deposition in a deltaic area near the mouth of the ancestral Rio Grande, with the lithologic variation being controlled by rising and falling levels of ancient Lake Cabeza de Vaca. These deposits are correlated with Strain's (1966) Fort Hancock Formation.

The Santa Fe Group appears to extend westward under the floor of the Mesilla Bolson (La Mesa surface) without any appreciable decrease in thickness between the Las Cruces Municipal Airport area west of Las Cruces and north of U.S. Highway 70, and the International Boundary some 40 mi to the south. The general textural trend for the upper 1,330 ft of bolson fill, revealed from study of well logs by King and others (1971), is one of progressive decrease in average grain size from north to south. Coarse gravelly zones are uncommon even beneath the northern part of the Mesilla Bolson floor. However, the area appears to have great potential for development of good quality ground water. A deep water test (ASARCO Well) a short distance southwest of the report area is discussed in the Second Day's road log of this guidebook.

Rio Grande Valley-Fill Deposits

Three major alluvial-fill sequences that postdate deposition of the Santa Fe Group basin fill are present in the Rio Grande Valley. The youngest of the three, comprising the late Quaternary flood-plain and channel alluvium of the Rio Grande as well as interfingering alluvial-fan deposits of tributary arroyos, is the only group of valley-fill deposits that makes up an im-

portant aquifer unit. This is due to the fact that the older valley fills, associated with constructional parts of the Tortugas and Picacho geomorphic surfaces (Hawley and others, 1969), appear in all cases to be above the water table.

In latest Pleistocene time, probably during the last major Wisconsin glacial-pluvial substage (between 22,000 and 13,000 years ago), when the discharge of the ancestral Rio Grande was considerably greater than present, the floor of the river valley was eroded down to a level about 80 ft below the present flood-plain surface (Hawley and others, 1969). Subsequent to the time of maximum degradation, a thick channel gravel and sand deposit was laid down on the erosion surface, which appears in most cases to have been cut into ancient basin-fill of the Santa Fe Group, or, in the case of the Selden Canyon area, locally into older rocks. Carbon-14 dating of Holocene valley fills (Hawley and others, 1969) in the Mesilla Valley indicates that early back filling of the inner valley was relatively fast, with aggradation of the valley floor being essentially completed by 7,000 years B.P. (A. L. Metcalf, U.T.E.P. Biology Dept., personal communication, October, 1968.) The upper group of flood-plain deposits are finer grained than the basal gravelly unit and consist mainly of sand to clay.

As mentioned in the section of the Santa Fe Group in the Mesilla Valley, the shallower wells in valley-floor areas (generally less than 200 ft deep) are commonly finished in both the younger valley fill and the underlying Santa Fe beds. A good example of this practice is the "shallow aquifer" of Leggat and others (1962) in the southern Mesilla Valley near El Paso, Texas. This aquifer designation includes both late Quaternary flood-plain deposits and middle Pleistocene and older basin fill.

In general, the quantity of water production from wells penetrating the shallow-valley and basin-fill deposits is not a problem. Irrigation wells with larger pumps and tapping the very permeable flood-plain alluvium usually produce between 1,000 and 2,000 gpm and occasionally over 2,500 gpm. Specific capacities usually range from 20 to 60 gpm/ft of draw-down. Aquifer transmissibility tests are difficult to analyze in the Mesilla Valley because most irrigation wells penetrate both the alluvium and the Santa Fe. Preliminary studies indicate that the transmissivity of a 60-foot saturated thickness of the floodplain alluvium would average at least 75,000 gpd/ft, giving a hydraulic conductivity of 1,250 gpd/ft².

Quality of ground water in the shallow deposits varies greatly from place to place, and at a single location it often varies greatly with depth. It appears that two major geologic features associated with flood-plain depositional environments are important in influencing the quality of water stored and moving through the valley-fill deposits. First, the late Quaternary valley fill contains local lenses of concentrated organic matter ranging in size from microscopic particles to large fragments of rotten wood. Such materials probably represent deposition in ancient ox-bow lake and slough environments. Besides organic compounds, hydrogen sulphide and iron concentrations are common features of these zones and have a deleterious effect on ground-water quality. Second, concentrations of soluble salts were locally built up in poorly drained, fine-textured, flood-plain sediments. Although this phenomenon is particularly noticeable at the present time due to irrigation practices since inception of the Elephant Butte Irrigation Project, it is also a natural geologic process that has taken place during the progressive filling of the valley in latest

Quaternary time. With local exceptions, the salt problem seems to increase progressively southward in the Mesilla Valley. In Selden Canyon at the north end of the valley, the late Quaternary valley fill for all practical purposes is the only source for reliable supplies of ground water of relatively good quality. The Santa Fe Group in this area is clayey or otherwise compact and impermeable. The same can be said for the older Tertiary volcanic and sedimentary rocks that underlie the valley-fill alluvium in Selden Canyon. As in the Mesilla Valley, the late Quaternary fill generally grades upward from very gravelly at the base to sandy at the top, and it rarely exceeds 80 ft in thickness.

CHEMICAL QUALITY OF GROUND WATER

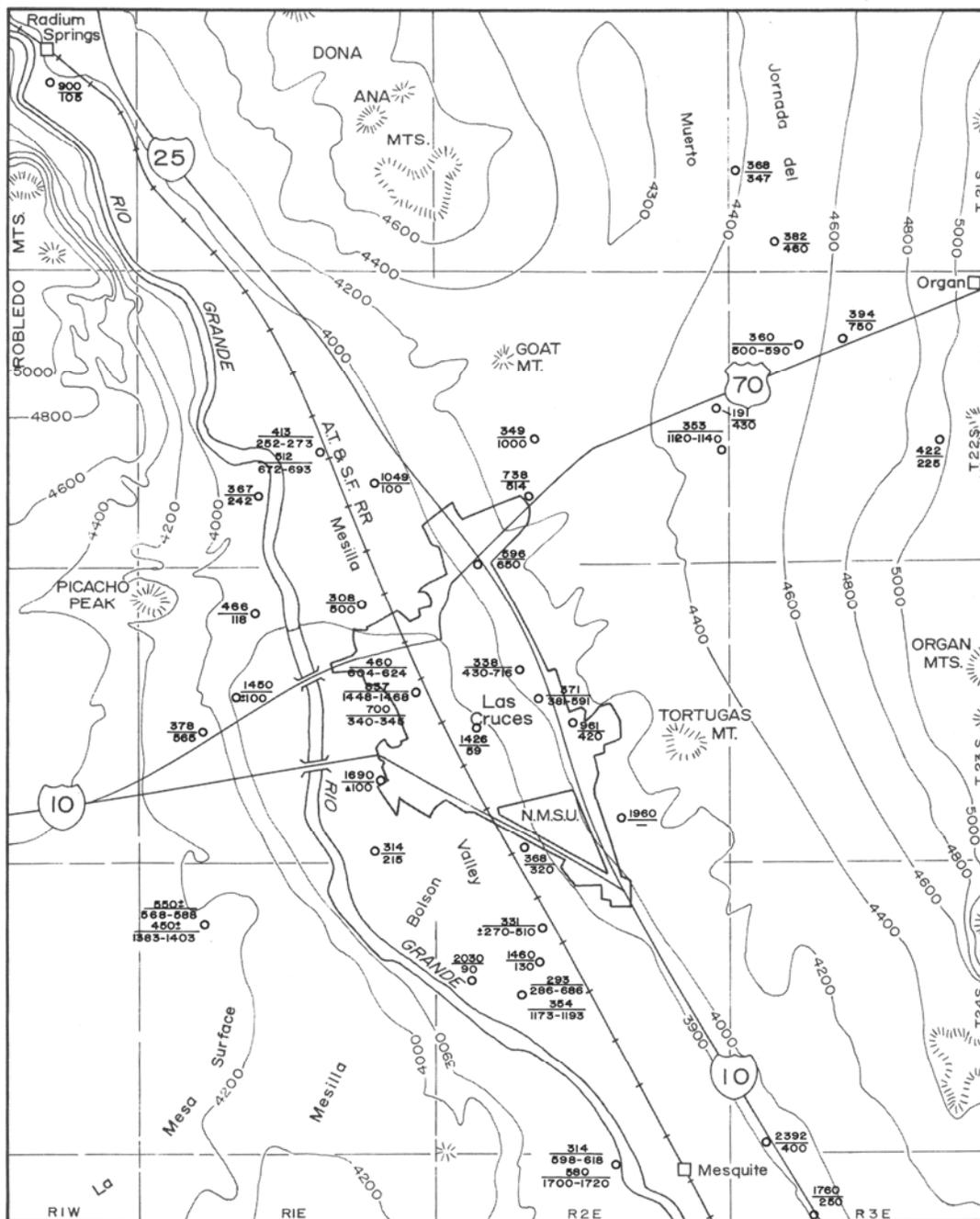
Chemically, ground water in the Las Cruces area may be classified as fresh (less than 1,000 milligrams per liter (mg/l) total dissolved solids) or slightly saline (between 1,000 and 3,000 mg/l total solids). Table 1 lists chemical analysis of ground water from selected wells in the area. Figure 5 is a map showing the total dissolved solids content and depth of water from wells. Generally, fresh ground water occurs in the areas northeast of Las Cruces (Jornada del Muerto), in the city well field along the east edge of Las Cruces, and in the deeper wells throughout the area which produce water only from the Santa Fe Group. Slightly saline water occurs in the shallow wells which tap the flood-plain alluvium of the Rio Grande and in some deeper wells located southeast of Las Cruces along the eastern edge of the Mesilla Valley. The latter wells produce water from either the Santa Fe Group or the flood-plain alluvium or both.

The greatest depth from which a ground water sample has been taken was 1,700 to 1,720 ft, in a test hole near Mesquite (Fig. 5). Total solids were 580 mg/l; the water was of a sodium-sulfate type. Water samples from below 1,000 ft have been obtained in four other test holes in the Las Cruces area.

The average total solids content of water from the Las Cruces city well field is about 530 mg/l (daily averages vary, depending on which wells are pumped). The total solids content in the sixteen city wells ranged from 305 mg/l to 961 mg/l during the 1972-1974 period. Ground water in the city well field is of sodium-calcium-bicarbonate type, with some wells also producing water with considerable sulfate and chloride content. A chemical analysis of water from a typical city well is given in Table 1.

Ground water in the flood-plain alluvium is usually more mineralized than water in the bordering Santa Fe Group. Most valley irrigation wells range in depth from 70 to 200 ft and obtain water from both the alluvium and the underlying Santa Fe. The quality of the irrigation water varies greatly in constituents; total solids may range from less than 500 mg/l to over 3,000 mg/l. Total solids of water in the Rio Grande averages about 600 mg/l during the irrigation season (March-October).

Recently the Elephant Butte Irrigation District drilled five deep (about 400 to 686 ft) irrigation wells in the Mesilla Valley southwest of Las Cruces, and cemented off the upper ground water horizons in order to improve quality of the produced water. Domestic wells in the Mesilla Valley are usually deeper than irrigation wells and produce the better quality water from the Santa Fe Group.



$\frac{440}{810}$ Well. Top figure is the Total Dissolved Solids concentration in milligrams/liter. Bottom figure is depth of well or perforated interval, in feet. + denotes approximate value.

—4000— Land surface contour. Contour interval is 200 feet with supplementary 100 foot contours. Datum plane is mean sea level.



Figure 5. Map showing total dissolved solids concentrations of ground water, and well depths for the Las Cruces, New Mexico area.

TABLE 1
 SELECTED CHEMICAL ANALYSES OF WATER FROM WELLS IN THE LAS CRUCES AREA, NEW MEXICO
 (ANALYSES BY U.S. GEOLOGICAL SURVEY, CHEMICAL CONSTITUENTS ARE IN MILLIGRAMS PER LITER
 WHICH ARE APPROXIMATELY EQUIVALENT TO PARTS PER MILLION WHEN DISSOLVED SOLIDS
 IS LESS THAN 7000 PARTS PER MILLION)

LOCATION BY SECTION, TOWNSHIP, RANGE	OWNER	DEPTH OF WELL (FEET)	STRATIGRAPHIC UNIT	DATE COLLECTED	TEMPERATURE °C	SILICA(SiO ₂)	IRON(Fe)	TOTAL CALCIUM (Ca)	MAGNESIUM(Mg)	SODIUM(Na)	POTASSIUM(K)	BICARBONATE (HCO ₃)	CARBONATE (CO ₃)	SULFATE(SO ₄)	CHLORIDE(Cl)	FLUORIDE(F)	NITRATE(NO ₃)	DISSOLVED SOLIDS	TOTAL HARDNESS	PERCENT SODIUM	SODIUM ABSORPTION RATIO	SPECIFIC CONDUCTANCE (MICROMHMS AT 25°C)
T.22 S., R.3E, SEC. 8	H. WOODBURN	590	STA. FE GP. 1	8-2-73	25.5	33	--	69	13	21	2.2	171	0	120	13	0.2	0.96	360	230	17	0.6	533
T.23S., R.1E, SEC. 25	F. PAPAN	100	ALLUVIUM STA. FE GP.	6-9-72	18	31	--	290	41	200	9.3	343	0	770	180	0.5	0.38	1690	890	32	2.9	2050
T.23S., R.2E, SEC. 17	CITY OF LAS CRUCES WELL #27	730	STA. FE GP.	5-24-72	24	27	--	37	12	56	6.3	140	0	76	53	0.9	0.22	338	140	45	2.0	544
T.24S., R.2E, SEC. 17	ELEPHANT BUTTE IRRIGATION DISTRICT	686	STA. FE GP.	7-25-73	18.5	24	--	46	7.1	40	2.7	162	0	54	39	0.1	.00	293	140	37	1.5	477
T.24S., R.2E, SEC. 18	J. SALOPEK	90	ALLUVIUM	10-3-72	18	29	--	310	44	300	10	418	0	880	250	0.4	0.96	2030	950	40	4.2	2760
T.25S., R.3E, SEC. 8	DOMINGUEZ BROTHERS	250	STA. FE GP.	2-26-73	31.5	53	--	170	30	420	40	612	--	270	470	1.4	1.7	1760	550	60	7.8	2870
RECOMMENDED LIMIT BY U.S. PUBLIC HEALTH SERVICE (1962)								0.3						250	250	0.7 TO 1.0	45	500				

1) SANTA FE GROUP (STA. FE. GP.)

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