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FORT HUACHUCA, ARIZONA
SUPPLEMENTAL REPORT

TEST WELL DRILLING
and
STUDY OF HYDROGEOLOGIC CONDITIONS

JANUARY 1974

US ARMY ENGINEER DISTRICT, SACRAMENTO
CORPS OF ENGINEERS

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PART I

Authorization. The overall Upper San Pedro River Basin ground water study was authorized by TWX dated 20 June 1972 from the Department of the Army to STRATCOM, subject: "Water Resources, Fort Huachuca." SPD letter dated 15 November 1972, subject: "Water Supply Study, Fort Huachuca, Arizona," assigns technical responsibility to the Sacramento District in all engineering-geological aspects of the study. Authorization and funding for field exploration was contained in Directive No. SPD-1 dated 21 August 1972 and SPD-4 dated 29 March 1973. Foundation and Materials Branch was requested to develop an exploration program, prepare plans and specifications and supervise and administer contract work by Sacramento District Service Requests 511.1R 73.2 dated 8 September 1972 and 511.1R 73.3 dated 16 April 1973.

Purpose and Scope. The present study, which is a continuation of a study that began in 1970, is intended to make an overall assessment of the water resources at Fort Huachuca and the long range impact of water resources on the growth and development of the Post and surrounding areas. It is a cooperative project with contributions being made by the Tucson office of the US Geological Survey and the Arizona Water Commission. The Los Angeles District has responsibility for coordination with other agencies and for putting the compiled data into a single report. Inasmuch as the Sacramento District's responsibility is limited to engineering and geological aspects, this report will be restricted to a discussion of geologic field work, test well drilling and results, updating previous reports on geohydrologic conditions and making recommendations on areas that are considered to be the most promising for future ground water development. Information on recently completed field work including construction and testing of new test wells is contained in Part II of this report.

References. The following published and unpublished reports contain information pertinent to the present San Pedro Basin ground water study.

a. Blanton and Cole, 1958, Investigation of Existing and Proposed Water System at Fort Huachuca, Arizona; prepared for Los Angeles District Corps of Engineers.

b. Blanton and Company, 1973, Investigation and Recommendations for Upgrading the Water System at Fort Huachuca, Arizona; prepared for Sacramento District Corps of Engineers.

c. Brown, S.G., Davidson, E.S., Kister, L.R., and Thomasen, B.W., 1966, Water Resources of Fort Huachuca Military Reservation, Southeastern Arizona: US Geological Survey Water Supply Paper 1819-D, 57 p.

d. Davidson, E.S., and White, N.C., 1963, San Pedro River Valley in Annual Report on Ground Water in Arizona, Spring 1962 to Spring 1963, by N.D. White, R.S. Stulik, E.K. Morse, and others: Arizona State Land Department, Water Resources Report 15, p. 68-76.

e. Fox, Robert C., 1972, Water Resources of a Portion of San Pedro River Valley, Arizona.

f. Heindl, L.A., 1952, Upper San Pedro Basin, Cochise County, in Ground Water in the Gila River Basin and Adjacent Areas, Arizona - a Summary, by L.C. Halpenny and others: US Geological Survey Open File Report, p. 69-86.

g. John Carollo Engineers, 1971, Water Supply Study, Phase I Fort Huachuca, Arizona; prepared for Sacramento District Corps of Engineers.

h. Post Engineer, Fort Huachuca, 1970, Analysis of Water Resources, Fort Huachuca, Arizona.

i. US Army Engineer District, Los Angeles Corps of Engineers, 1969, Master Plan Analysis of Existing Facilities, US Army Garrison, Fort Huachuca, Arizona.

j. US Army Engineer District, Sacramento Corps of Engineers, 1970, Summary of Ground Water Supply Conditions, Fort Huachuca, Arizona.

k. _____ 1971, Water Supply Investigation, Interim Report.

l. _____ 1972, Final Report on Test Well Drilling and Study of Hydrogeologic Conditions, Fort Huachuca, Cochise County, Arizona.

Geographic Setting. Fort Huachuca is located in Cochise County, southeastern Arizona in the Basin and Range Lowland province about 15 miles north of the Mexican Border and 75 miles southeast of Tucson. The south and southwest boundaries of the reservation follow the crest of the Huachuca Mountains, a northwest trending mountain range. The west boundary extends from the northern end of the range north to Babocomari River. To the north and northeast, the boundary extends along the Babocomari almost to the San Pedro River near Charleston. The main post area of Fort Huachuca is situated on the northeast flank of the Huachuca Mountains between elevations 4,700 feet and 4,900 feet. The ground surface slopes gently to the northeast and is cut by numerous drainage ravines. Immediately east of the main gate is the town of Sierra Vista. Private homes and ranches are scattered to the east and southeast. The main post area and the East Range are shown on the topographic map, Inclosure 1.

Place Names and Locations. The entire reservation is referred to as Fort Huachuca, and its boundaries as reservation boundaries (Inclosure 1). The town of Sierra Vista is east of the main post area adjacent to the reservation boundary and is rapidly extending eastward. The Post Well Field is between the post and Sierra Vista. The northern part of the reservation is divided by State Highway 90 running northwest from Sierra Vista. The area east of the highway is called the East Range. Garden Canyon is the largest canyon on the east side of the Huachuca Mountains; its mouth is about 5 miles south of the post living quarters area. Pre-existing wells are referred to by a numbering system used by the US Geological Survey. For example, the well about 3 miles northeast of the post, with water elevation 4,154

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(Inclosure 1) is numbered (21-20) 22bbb, which indicates that it is in T21S, R20E, Section 22. The code "bbb" places it in the northwest corner of the section (see p. 5 of reference c). This well is known as the "spatial resolution" well. Post production wells are known as Post Wells 1 through 6. The 9 test wells that have been drilled and tested to evaluate the area near Libby Field and the East Range are referred to as Test Wells 1 through 9. Using the USGS system East Range test wells are designated as follows:

Test Well 3	(21-20) 16 aac
Test Well 4	(21-20) 15 acd
Test Well 5	(21-20) 16 adb
Test Well 6	(21-20) 35 ccb
Test Well 7	(21-20) 11 bcd
Test Well 8	(21-20) 13 cbb
Test Well 9	(21-21) 17 bcc

Climate and Rainfall. The climate of the area is mild, sunny, and dry. Mean yearly temperature is 61°F. Average annual precipitation is about 15 inches at Post Headquarters and as much as 25 inches in the mountain range. Summer thundershowers fall mainly on the plains but often are accompanied by very little rainfall in the mountains. Conversely, the steady winter rains fall more heavily in the mountains than on the flat areas. Thus, in the 1964 Administrative Report of the US Geological Survey, Figure 5 shows heavy rainfall in July and August 1961 at Fort Huachuca, but practically no runoff in Garden Canyon. Figure 10 of USGS Water Supply Paper 1819-D shows that most of Garden Canyon runoff in 1959-63 occurred in the winter months.

Evaporation is a major factor during most of the year. According to the USGS, most of the summer rainfall and most of the canyon runoff is taken by evapo-transpiration before it can percolate into the alluvium and contribute to ground water recharge.

Geologic Setting.

The Huachuca Mountains on the southwestern boundary of the fort are a faulted complex of granite, carbonate rocks, conglomerate, and claystone ranging in age from Precambrian to Tertiary. The San Pedro Basin, northeast of the mountains, is filled with alluvial sediments referred to as basin fill. The basin fill is 360 to 800 feet thick. Bedding dips gently away from the mountain front toward the San Pedro River. The basin fill overlies variably cemented gravelly sediments referred to as the Pantano Formation, which is faulted and tilted to the southwest toward the mountain front. A detailed description of the geology is presented in USGS Water Supply Paper 1819-D.

A geologic description of the basin sediments follows:

Stream alluvium and terrace deposits:	Light-reddish-brown to light brown sand, gravel, and clay, locally derived, Thickness 0-100 feet.

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Upper Unit of Basin Fill:	Reddish-brown gravel, sand, and silt; some red and green clay and limy silt. Thickness 163 to 331 feet in test well area.
Lower Unit of Basin Fill:	Light-gray to brown gravel and sandstone, strong to weakly cemented, lenticular; locally derived cobbles and pebbles of quartz, granite, limestone, quartzite, and rhyolitic tuff. The gravels are poorly sorted and contain a mixture of silt, sand, cobbles, and boulders. The sandstones contain interstitial clay. Thickness 100 to 420 feet in test well area.
Pantano Formation:	Dark reddish-brown to brownish-gray gravel, sand, and silt, variably cemented; boulders as much as 4 feet in diameter; fragments composed of purple to red rhyolitic tuff, gray to pink felsitic tuff, purple to dark-green andesite, red and maroon shale and siltstone, light yellow granite, dark gray limestone, and light gray to white quartzite. Thickness is 663 feet in Test Well 8, 774 feet drilled in Test Well 2 near Libby Field.

Geology of the Test Well Area. Ground surface in the test well area is covered with terrace deposits or stream alluvium. The stream alluvium, mostly occupying the floors of dry washes that are typical of the desert, was probably derived chiefly from the terrace deposits and perhaps the upper part of the basin fill. It consists of sand or sand and gravel in various proportions with a few cobbles in some areas. In the East Range where Test Wells 3 through 9 are located, the terrace deposit ranges in thickness from 35 to 70 feet. It consists mostly of sand with varying, though generally low, amounts of reddish-brown clay. The upper few feet contain a higher percentage of clay, generally in the range of 20 to 40 percent, and in a few locations the near surface material is sandy clay. A few small gravel particles and thin streaks of caliche are present near ground surface.

The upper and lower units of basin fill, which underlie the terrace deposits, were described in detail in the previous report (Ref. 1). In the test wells just drilled, the upper unit consists of clay, fine to coarse sand and 1/4- to 1/2-inch gravel in various combinations. Some layers exhibit a high degree of sorting, some show little sorting in the size ranges between clay and small gravel. A degree of sorting is shown throughout by a distinct lack of larger gravel sizes and cobbles. The most common soil types found are sand and clayey sand followed by sandy clay and sand, or clay-sand combinations containing small gravels. Brown, reddish brown, and tan are the most common colors although light gray, greenish gray, and maroon clays are found in the eastern part of the area. The light gray clay

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is limey. Cementation is generally weak or nonexistent and the material is easily drilled. In the seven test wells drilled in the East Range area, the thickness of the upper unit ranges from 163 feet in Test Well 7 to 331 feet in Test Well 9.

The lower unit of basin fill is similar to the upper unit as far as soil types are concerned. Sand and clayey sand are the most common types except in Test Well 9, which has more clay and sandy clay. The lower unit has scattered thin zones containing cobbles and a few layers or lenses containing small gravels. Overall color is generally a lighter shade of brown than the upper unit or it is brownish gray. At some locations the lower part of the lower unit is darker in color because of the increasing number of dark brown and maroon sand grains. It appears to be reworked Pantano Formation. Cementation and hardness are highly variable, although there is generally a gradual increase in both with depth. Overall, the layer is slightly more consolidated and cemented than the upper unit. The drilled thickness of the lower unit in the East Range area ranges from 139 feet in Test Well 3, to 420 feet in Test Well 7.

The Pantano Formation, which underlies the basin fill, is a slightly cemented to moderately well cemented, dark brown to reddish brown conglomerate. It was encountered in all four test wells and was penetrated completely by Test Well 8. In Well 8 it extends to a depth of 1,295 feet and is 663 feet thick. In Test Wells 3, 4, and 5 the Pantano Formation is coarse grained, consisting chiefly of sandy gravel and gravelly sand, with a small amount of interstitial clay. In the four new test wells, the formation is either much finer grained or else the cuttings were ground up to a large extent by drilling. In Test Wells 6, 7, 8, and 9, cuttings from the Pantano are mostly fine to medium grained, angular sand containing a small amount of brown clay. Geophysical logs indicates that the formation has alternating thin layers of harder (more cemented) and softer rock with a slight increase in cementation and decrease in porosity with increasing depth.

Underlying the Pantano Formation is a hard, well cemented volcanic conglomerate which is thought to be the Bronco Volcanics. The cuttings recovered from Test Well 8 were obviously ground up by drilling. They consisted of angular to subround, fine to coarse sand, mostly dark green, dark gray, brown and maroon volcanics, with a few small grains of calcite which were probably fracture fillings in larger fragments. The geophysical logs, as well as the drilling time log, indicate that the formation is considerably harder, more cemented and tighter than the Pantano Formation. In Test Well 8, it extends from 1,295 feet to 1,501 feet, the bottom of the well.

Ground Water Conditions. The test drilling just completed was intended, in at least one location, to define the vertical limits of the aquifer; that is, to locate the bottom of the Pantano Formation and explore the formation directly beneath it. The Pantano was fully penetrated by Test Well 8; and a hard, well cemented volcanic conglomerate with low porosity and permeability was encountered at 1,295 feet. The volcanic conglomerate is not considered to be a water producer except in fracture zones, and the aquifer can therefore

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be defined as the saturated part of the upper and lower units of basin fill and the Pantano Formation.

The geohydrologic characteristics of the upper and lower units of basin fill are highly variable within short distances and are predictable only in a general way. It would be expected that the deposits would be coarser grained near their source, which is thought to be the Huachuca Mountains and the mountains to the southwest and west, and would gradually become finer grained with increasing distance from the mountains. This is only partly true, however. Boulders and cobbles apparently decrease with distance from the mountains, and gravel sizes may also decrease, but sand and silty-clay deposits do not follow a predictable pattern. In the East Range area, stream currents have apparently played a major role in determining aquifer characteristics by the sorting and deposition of the finer-grained materials. The only pattern suggested by test drilling indicates a more permeable band of deposits extending from Test Wells 3 and 5 through Test Well 7 to Test Well 6 and a less permeable area to the south and southeast where Test Wells 8 and 9 are located. There is no information concerning the area north and west of Test Wells 3, 5, 6, and 7. Test Wells 4 and 9 have the lowest specific capacity and highest proportion of fines of any of the East Range test wells. Yet Well 4 is only 1 mile southwest of Test Wells 3 and 5 and about 1 mile northwest of the spatial resolution well, which had a moderate specific capacity (16 gpm/foot). Test Well 9 is the easternmost well.

The highly variable character of the basin fill deposits is best illustrated by Test Well 8 and the associated observation well, which was drilled 100 feet to the west. The drill cuttings from the two wells had very little similarity from ground surface to 468 feet, the depth of the observation well. About 20 percent of the formation penetrated by Test Well 8 was clayey to the point of having very low permeability, but about 45 percent of the observation well had similar conditions. The observation well was extended beyond the 350-foot depth originally planned to insure that a sufficient thickness of permeable material had been penetrated to make an adequate hydraulic connection with Test Well 8. Drill cuttings and geophysical logs from Well 8 suggested that it would be a good producer, yet the specific capacity was relatively low. This suggests the liklihood of a barrier around the well that restricts inflow from the surrounding aquifer. That is consistent with the low permeability of the basin fill at the observation well.

Another indication of differing aquifer characteristics is the range of values for specific capacity of the different wells (specific capacity is a measure of well productivity. It is obtained by dividing the pumping rate in gallon per minute by the drawdown in feet and is expressed as gpm per foot of drawdown). Average figures for all the wells in the East Range area for which pumping data are available are tabulated below. For comparison, the specific capacities of the Post wells are also included.

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Well Designation	Specific Capacity
Test Well 3	22 gpm/ft.
Test Well 4	7 gpm/ft.
Test Well 5	29 gpm/ft.
Test Well 6	21 gpm/ft.
Test Well 7	23 gpm/ft.
Test Well 8	10 gpm/ft.
Test Well 9	8.6 gpm/ft.
Spatial Resolution Well	16 gpm/ft.
Post Well 1	15.4 gpm/ft. at 593 gpm
Post Well 2	17.1 gpm/ft. at 615 gpm
Post Well 3	17.7 gpm/ft. at 760 gpm
Post Well 4	40.7 gpm/ft. at 611 gpm
Post Well 5	6.2 gpm/ft. at 450 gpm
Post Well 6	37.5 gpm/ft. at 601 gpm

Information on Post Wells from Blanton and Company report, reference b. Values are for 1971 production.

Previous reports have suggested that the upper unit of basin fill is a better water producer than the lower unit. The recent test well drilling indicates that this is not necessarily true and that permeability is related more to clay content than consolidation and cementation. It also suggests that either unit can be more permeable than the other depending on local conditions of sorting and deposition. For example, Test Well 9 has 208.5 feet of upper basin fill that is saturated but has the lowest specific capacity; Well 7 has the least saturated upper basin fill, 1.8 feet, and the highest specific capacity. Test Well 7 apparently draws mostly from the lower unit of basin fill. Test Well 6, which is second to Well 7 as a good producer, has only 81 feet of saturated upper basin fill and apparently produces mainly from its 320 feet of lower basin fill.

In spite of the highly variable nature of the basin fill deposits, they are considered to be the primary water producers in the East Range area. The Pantano Formation was thought to be barren except in fractured zones prior to the first test drilling. It now appears that it produces mainly through pore space between grains. Geophysical logs as well as drill cuttings suggest that it can produce small to moderate amounts of water, although it is not nearly as permeable as the basin fill units. This conclusion is also supported by pumping tests in Test Wells 1 and 2, which produce entirely from the Pantano.

The Pantano Formation is considered to be the basal unit of the aquifer. The Bronco Volcanics, which underlie the Pantano (at least in the vicinity of Test Well 8), is a hard, well cemented formation. Well cuttings and geophysical logs indicate that it is essentially impermeable except in fracture zones.

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The four new test wells were drilled between the 4,100- and 4,150-foot ground water contours where the water table gradient is relatively flat (Inclosure 1). Water levels at the new test wells are consistent with previous measurements, and the most recent water level measurements in the East Range area indicate that the ground water surface has remained essentially stable since the previous report was issued in April 1972. Water levels for those wells in the East Range area that can be measured, are tabulated as follows:

Well Designation	Water Depth September 1973	Elevation	Water Depth February 1972	Elevation
Test Well 3	277.45	4,142.6	277.1	4,142.9
Test Well 4	275.54	4,149.5	275.05	4,150.0
Test Well 5	282.0	4,144.0	281.8	4,144.2
Spatial Resolution Well	326.02	4,154	326.3	4.153.7
Test Well 6	149.19	4,137.8		
Test Well 7	213.20	4,133.5		
Test Well 8	243.55	4,145.8		
Test Well 9	156.50	4,142.7		

Although the water level has been stable in the East Range and other areas that are not pumped appreciably, the most recent water level measurements, which were made September to November 1973, indicate that the steady decline of the water table reported previously is continuing in the areas that are heavily pumped. The best information available indicates that the decline since the last water level measurements were made ranges from 1 to 9 feet in the Post Well Field-Sierra Vista area. However, some of the previous readings went back as far as 1968. Still, the maximum rate of decline is as much as 1.8 feet per year, which is similar or slightly higher than that reported previously. Although distinct cones of depression have not formed in newly developed areas, the declining water table is following the residential and commercial development to the east and southeast and is expected to continue with further expansion of Sierra Vista. Little reliable information is available for the Huachuca City area, but it is apparent that the water table is declining, perhaps on the order of 1 foot or less per year. The cone of depression around Huachuca City does not appear to be expanding rapidly and is still separate from the cone at Sierra Vista.

A new ground water map has been prepared as part of the present investigation (Inclosure 1). The main differences between it and previous maps are slight modifications in the 4100 and 4150 contours to reflect recently determined water levels in Test Wells 6 through 9, a change in the configuration of the cone of depression surrounding the Post well field and the elimination of the ground water ridge or nose, east of Sierra Vista. The information obtained from the new test wells is reasonably consistent with previous data and the slight revisions in the ground water contours in the East Range requires no explanation. The change at the Post well field is a result of new readings that suggest previous readings from two wells were in error, probably

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due to malfunctioning air line measuring devices. The new readings, which are believed to be reliable, indicate that the lowest part of the cone is elevation 4,117 at Well 2. This eliminates the 4,100-foot contour around Well 3 as previously shown and shifts the 4,150 contour to the southwest and west. The 4,150 contour is also expanding to the east as a result of increased pumpage in that direction at residential and commercial developments. The prominent nose that appeared on previous maps about 6 miles east of the Post's main gate has disappeared as a significant feature because of new water level measurements in that area. It appears now that old measurements made in shallow stock wells represented a perched water level. Readings from recently drilled deep wells reflect entirely different water levels and water table configuration.

Although the revised ground water map represents a minimal number of new water level readings, it represents the best information available. Other water level measurements would be highly desirable, especially in some key wells; but unfortunately they are impossible to obtain. Many privately-owned wells are not designed for taking water level readings and can only be measured when the pump head has been pulled for repairs or other reasons. However, the map depicts the conditions that would be expected; namely, that the water level is continuing to decline in heavily pumped areas and that the cone of depression is gradually extending into the recently developed areas where pumpage has been increasing. In areas that are isolated and have not been developed extensively for water production such as the East Range, the water level has remained essentially stable since February 1972. It is somewhat encouraging that the cones of depression surrounding the post well field and the Huachuca City areas have not expanded more than they have.

Results of Test Well Drilling. The recent test well drilling confirms much of the information obtained from the previous investigations; namely, that the water table is very flat in the East Range, that the primary water producers are the upper and lower units of basin fill, that the Pantano Formation has low to moderate permeability, that the basin fill deposits are highly variable laterally as far as soil types and permeabilities are concerned, that the vertical boundaries between geologic units are fairly regular and predictable and that the aquifer in the East Range is sufficiently permeable to make feasible a new well field there. New information resulting from the 1973 drilling include a determination of aquifer thickness at one location (Test Well 8) and an extension of detailed knowledge of geologic conditions into a large area of the East Range. This permits a realistic well field design based on aquifer permeability. The drilling and test pumping have also made a major contribution to the digital model analysis that is being done by the Arizona Water Commission. The digital model, when verification has been completed, will be used to analyze well locations and interactions to determine the best pattern to be used in a future well field as well as the broader consideration of how the water supply is going to react basin-wide to various projected population figures.

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Location and Design of New Well Field. As the April 1972 report (ref. 1) pointed out, there are four distinct areas of Fort Huachuca that might be considered as potential locations of new wells: (1) North of the post proper and west of Highway 90 (Libby Field area and westward), where ground water is in the Pantano Formation, (2) the Post Well Field-Sierra Vista area, where the basin fill units are thick and produce most of the ground water being used, (3) the strip of alluvial apron extending southeast of the Post Well Field to the mouth of Garden Canyon, and (4) the East Range area. Area 1 was explored by Test Wells 1 and 2 in the previous test well drilling. The water table there is only a few feet higher in elevation than it is in the East Range test wells and the aquifer is the lower yielding Pantano Formation. Wells located in this area would be difficult and expensive to construct and would be low to moderate producers. A larger number of wells would, therefore, be needed for a given quantity of water and pumping costs would not be appreciably lower than from other areas. Initial costs of extra wells would partly or perhaps wholly offset the cost of pipeline to bring water in from other areas. The area is not considered feasible for the location of a well field. Area 2, the present Post Well Field, is overdrawn at the present and is too vulnerable to developments on private land in and around Sierra Vista. Area 3 is small and it too is vulnerable to private developments, such as Tenneco to the east and southeast.

The East Range area is the only one worth serious consideration. Its only real disadvantage is the distance from there to the use area in the main post. It has several advantages, which are discussed in the following paragraphs.

The East Range is an extensive area, comprising about 44 square miles. The city of Sierra Vista is developing along its southwestern boundary and Huachuca City is just outside its northwest corner. However, most of it is isolated from developments at the present and in the foreseeable future. Its size provides a great deal of isolation from private developments that might compete with the post for water and also permits sufficient spread between production wells to minimize interference of wells with each other. Of all the areas that might be considered, the East Range is least likely to be affected by city or private wells.

The testing that has been done in the East Range provides reasonable assurance that the aquifer in selected areas is permeable enough for construction of good production wells. The saturated basin fill ranges in thickness from 153 to 443 feet in the test wells; and where it consists of the coarser-grained sand or gravel facies, wells that will produce 1,000 gpm or more can probably be constructed. The upper part of the Pantano Formation will also contribute smaller but significant amounts of water.

According to the US Geological Survey (Ref. c, p. D20, plate 1), ground water in the East Range moves down gradient in a general northeast direction and is forced to the surface by a ground water barrier formed by consolidated volcanic and sedimentary rocks along the San Pedro River

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and to a lesser extent by consolidated rocks in the valley of the Babocomari River. Ground water reaching the San Pedro River maintains a short reach of perennial flow at the Charleston gaging station. Thus, these two areas act as a natural drains for excess ground water in this part of the basin. A well field as contemplated in the East Range area may intercept and make use of a large part of this overflow, which is now being lost to evapotranspiration.

One of the major objectives of the present study was to determine, through use of the digital model, the reaction of the ground water basin to different water production levels needed to support several alternate population figures and time periods. These alternates are listed in Table 1. They include post population figures ranging from 12,000 (present population) to a maximum of 50,000 and a time period from the present to 2030. Growth of Sierra Vista and surrounding communities is being estimated by the Arizona Water Commission and is taken into account in the analysis.

In order to analyze the effects of water withdrawal, it is necessary to know the location and production levels of future wells. A well field has therefore been designed for the East Range area that can meet water requirements for a post population of up to 50,000. Pertinent data on water requirements and wells required are shown in Table 1; locations of proposed wells are shown on Plate 1. The locations of the proposed wells have been reviewed by the consulting firm, Harshbarger and Associates, to insure that optimum well locations are being used. The well field location and design will be analyzed by the digital model when verification is completed, but the results are too late for discussion in this report.

The first step in designing a well field is to determine what water consumption will be for the different projected population figures. The methods used to determine water requirements are summarized in the following paragraphs.

Although some water is obtained from the collection systems in Garden and Huachuca Canyons, the flow rates vary considerably and these sources are not considered to be reliable. Peak requirements occur during the time of greatest irrigation demand and least production from Garden and Huachuca Canyons; therefore, these sources cannot be considered as contributors to the peak demand; and it is assumed that the entire water supply will be produced from wells. Irrigation water for the golf course and Chaffee Parade Ground presently is supplied by effluent from the post sewage plants after first undergoing secondary treatment and chlorination. Therefore, these two areas need not be included in determining irrigation requirements.

Much of the information on well production and water consumption was obtained from the report by Blanton and Company, reference b. According to the report, the capacity of the well field as it is presently operating is 3.49 million gallons per day (mgd) if the pumps are operated only 16 hours a day in accordance with the requirements of TM 5-813-2.

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TABLE I

Summary of Present and Future Water Requirements

	Post Population	Peak Water Requirements	Deficit *	Actual Avg Consumption Year Round	Proposed Source to Make Up Deficit
Alt I	12,000	4.613 mgd	1.123 mgd	2.676 mgd	No additional source. Pump existing wells as needed.
Alt Ia	12,000	4.613 mgd	1.123 mgd	2.676 mgd	Test Well No. 5. Pumping 16 hrs/day at 1,500 gpm= 1.44 mgd. Total Available = 4.93 mgd.
Alt II	25,000	7.5 mgd	4.01 mgd	5.2 mgd	Test Well No. 5 plus new wells, A, B, C. Total Available - 7.8 mgd.
Alt III (1980)	Same	as	Alt	II	
(2000)	50,000	15.0 mgd	11.51 mgd	10.40 mgd	Test Well No. 5 plus 10 new wells, A through K. Total available 14.53 mgd.
(2030)	Same	as	Alt	III (2000)	

*Deficit is difference between present well field capacity (3.49 mgd) and peak requirement.

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The total water required to meet domestic and fire demand for the present population (equivalent population of 12,980) is 2.453 mgd. The daily requirement for irrigation (excluding the golf course and Chaffee Field) is 2.160 mgd during the May-June season of heavy irrigation. Those figures were used to obtain a maximum per capita per day water consumption value, which was in turn used to calculate maximum water requirements for other (projected) population figures. It was assumed that irrigation needs for both public areas and residences would grow in the same ratio as at the present and in direct proportion to the increasing population. This maximum or peak water requirement was used to determine the number of wells needed. Actual average daily water consumption was calculated from well production records kept by Fort Huachuca personnel. This actual water consumption value is used to determine the reaction of the ground water basin to water withdrawal.

To determine the number of additional wells required to meet future water needs, it was assumed that each of the new wells would be capable of producing 1,000 gpm. Pumping 16 hours a day, each new well could contribute 960,000 gallons per day to the peak water requirement. In practice, however, each new well (including Test Well 5) would only be required to produce about 665,000 gpd to meet average water needs on a year 'round basis.

Of the 8 deeper wells on the East Range, five are considered to be good producers (Test Wells 3, 5, 6, 7, and Spatial Resolution Well), and three are considered to be poor or mediocre producers (Test Wells 4, 8, and 9). The low-producing wells are roughly in an east-west line from 1 to 2.5 miles north of the reservation boundary (Inclosure 1). The good producers are generally to the north and west. Completely definitive coverage of the East Range by test wells is precluded by its size and related economic and time factors. However, it is believed that adequate information is available to define a less permeable area in the southern part of the East Range and a more permeable area to the north and west. The proposed well field is laid out according to this concept. New wells are spotted near the higher producing test wells, where definitive information is available, and near the Spatial Resolution Well, which is a moderate producer. The other wells are spread out over the area in a more-or-less random pattern except that spacing is at least one mile. At that spacing, mutual interference between wells will occur if adjacent wells are pumping at the same time, but the interference will be minimal.

The proposed wells have letter designations from A through K, which suggests construction priority. If the area is developed as a well field, it is assumed that Test Well 5, which is a full size (16 inch) well, will be put on line first. Logically, the sequence of development would start in this area, which will require less pipeline, and work to the northwest.

Evaluation of Present Well Field. Although the present well field is capable of producing 3.49 mgd, it should be noted that Post Well 5 appears to be deteriorating and may be in the beginning stages of failure. Since 1958 the specific capacity of the well has decreased from 14 gpm to 6.2 gpm.

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This may reflect a deterioration of the well casing after 31 years or else the water level has declined so far that the main producing zone is now the less permeable lower part of the basin fill and/or the Pantano Formation. In either case, cleaning and renovating the well would not be worthwhile; in fact, the casing has probably corroded to the extent that acidizing or other method of cleaning may cause the casing to fail. It should be assumed that the useful life of Well 5 will soon end. Wells 1 and 2 are also questionable. According to Blanton and Company (Reference b, p.51), the pump bowls are so close to the dynamic water level that they are in danger of sucking air. The Blanton report recommends lowering the pump bowls, or, preferably, installing new pumps. Wells 1 and 2 are only about 750 feet apart, they were drilled in 1939 and 1940 and they have only about 150 feet of saturated basin fill. When a new well field in the East Range is put into production, it seems desirable to shut down one or both. This would relieve some of the pressure on the present well field and would save the expense of renovating pumps in wells whose value is questionable.

Conclusions. Since the ground water study was begun in 1970 a large amount of data has been collected and analyzed. The major contribution has been the results of test well drilling and pumping but also includes information that was available from the US Geological Survey and from the post engineer's office as well as from water companies in Sierra Vista and Huachuca City and private individuals throughout the area. The data have been updated as much as possible during the drilling and testing operations of 1971-72 and 1973. The following conclusions are based on an assessment of all data collected since the study was begun by the Sacramento District in 1970.

a. With the exception of a few small areas where perched water is present, all of the saturated materials in this part of the San Pedro Basin are part of a single aquifer, that is, they are hydraulically connected.

b. All deep wells in the area including the post wells, the Sierra Vista and Huachuca City semi-public wells and private wells draw their water from this aquifer.

c. The water level in the areas where wells are concentrated and are heavily pumped has declined for a number of years and is continuing to decline at a rate that is controlled by pumpage.

d. Cones of depression developed around the Sierra Vista-Post Well Field and Huachuca City areas are expanding slowly, and at Sierra Vista the cone is beginning to follow the new residential and commercial development to the east.

e. Recharge to the ground water basin is less than the water being withdrawn.

f. The major water producing zone of the aquifer consists of the coarser grained layers of the upper and lower basin fill units.

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g. Permeability in the basin fill units is more dependent on sorting and content of fines than on depth or cementation.

h. There are wide lateral variations in permeability within short distances in the basin fill units and these variations can be predicted only in a general way.

i. The upper part of the Pantano Formation is slightly permeable and can produce smaller but significant amounts of water, which is probably produced through interconnected pores rather than through fractures as assumed prior to test well drilling.

j. The only area within the reservation boundaries that is worth considering for large scale ground water development is the East Range

k. The Post Well Field needs to be modified for the following reasons:

(1) The wells are overpumped during periods of high water usage.

(2) The wells are spaced too close to each other and to nearby Sierra Vista City wells.

(3) Three wells (Wells 1, 2, and 5) are deteriorating because of water level decline and/or other reasons and have a limited life expectancy.

Recommendations. Inasmuch as this report is being completed prior to verification of the Arizona Water Commission's digital model, it should be understood that some modification of recommendations might be necessary to reflect conclusions reached in the computer analysis of data. Modifications, if any, would probably be minor, however, and would likely involve only changes in the configuration of the proposed well field. Questions concerning water resources required to support future population growth can be answered better when the computer analysis is completed. Recommendations contained here are intentionally restricted to considerations dealing directly with immediate post water requirements and in a general way to future ground water development.

a. The need for the East Range well field is obvious, and development should begin there as soon as design and construction funds can be obtained.

b. Development should start by putting Test Well 5 into production to relieve pressure on the Post Well Field. This is necessary for the present post population.

c. As soon as possible Post Wells 2 and 5 should be phased out and replaced by constructing and putting Well A into production.

d. In general, the priority suggested by designations of proposed Wells A through K should be followed as additional water is required unless economics of distribution system or land usage suggests a modification of priorities.

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e. Because there is considerable lateral variation in aquifer conditions, construction of a production well at any location must be preceeded by drilling a pilot hole and logging it geologically and geophysically as the initial part of the construction contract.

f. The basic design for future production wells, as suggested by test well drilling, should be as follows:

Depth: 800 feet
Well type: Nongravel packed
Drilling Method: Conventional or reverse rotary
Grout surface seal: Approximately 75 lineal feet
Casing: diameter - 16-inch I.D.
perforations - horizontal louver, $\pm$ 48 square inches of opening per foot
Development: By swabbing or bailing and pumping

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PART II

Introduction. In order to continue the investigation of the ground water supply conditions at Fort Huachuca, Arizona, another exploratory drilling program was authorized during the summer of 1972. Specifications were prepared for the drilling of four additional small test wells with a smaller observation well to be drilled 100 feet away from a designated test well. The contract for the test drilling was awarded to Keith L. Rising of Lamar, Colorado. A description of the procedures followed to drill, develop and test pump the wells is contained in this section.

Field Work. For the most part the field work consisted of technical supervision of the drilling, developing and test pumping of the wells. The test wells are all located in the East Range area of Fort Huachuca (Inclosure 1).

Notice to proceed was given on 9 May 1973 and the contractor began to move in his equipment. The contractor was requested to drill the observation well and Test Well 8 first in order to furnish information to the Arizona Water Commission at the earliest time for use in their digital model. However, due to the busy construction season in the area, the contractor was unable to hire sufficient men to do the developing and pumping concurrently with the drilling operation. He then decided to drill and case all the holes first and then go back for the developing and pumping with his own crew. This plan was followed to the completion of the contract.

Cuttings were sampled continuously during the drilling and geologic logs (Inclosure 5, sheets 1 through 16) were made on the basis of the drill samples. The US Geological Survey ran sieve analyses of the samples. Geophysical logs (Inclosure 6, Wells 6, 7, 8, 9), run after the completion of drilling of each well, correlate with the geologic logs, and the combined information was used to set up the perforation schedule for each well. The geophysical logs also define the major geologic units in the wells.

A water quality analysis of each well sample was made by the US Geological Survey and the results are in Inclosure 7, sheets 1 through 6. The Preventive Medicine Unit of the base hospital ran a bacteria analysis of each sample.

Test Well Construction. A generalized picture of the test wells can be seen graphically in Inclosure 2. Tabulated data for each well along with a graphic section through the wells are shown in Inclosures 3 & 4. The drill rig was a Joy, Model 300, that had been modified to be equivalent to a Model 350. The wells were drilled by the standard rotary method. Drilling fluid pumped from one end of a small sump by means of a National C-150 (6-3/4" x 12") mud pump passes down the inside of the drill stem and out of the bit. It lubricates the bit, stabilizes the walls of the hole and carries the cuttings up the hole to be discharged over a shaker screen. Various sized, toothed, tri-cone roller bits were used to drill the holes.

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The small observation well was drilled first using a 9-7/8-inch bit to a depth of 51 feet. A 7-7/8-inch bit was then used to advance the hole to bottom at 468 feet. The adjacent Test Well, Number 8 was advanced to 1,305 feet with a 13-3/4-inch bit. Due to the hardness of the materials encountered at this depth it was decided to reduce the bit size to 7-7/8 inch to complete the hole to 1,501 feet. This small heavy-duty tri-cone bit had chisel shaped compacts instead of teeth.

The other three Test Wells, Numbers 6, 7, and 9, were drilled to an approximate depth of 1,000 feet using 13-3/4-inch bits. The upper part of each hole was drilled with a slightly larger bit to facilitate the placement of a neat cement grout surface seal.

Upon completion of the drilling of each hole, geophysical logs were run by Welex Corporation of Santa Fe Springs, California. The logs consisted of induction electric, spontaneous potential, compensated acoustic velocity, and compensated density. These logs were used to determine formation and unit contacts, porosities and to aid in setting up the perforation schedules for the casing. The geophysical logs are included as Inclosure 6, Wells 6 through 9.

The casing for the observation well is standard 4-inch pipe with threaded collars. Perforations are 1/8 x 2-1/4-inch milled slots having four vertical rows and two horizontal rows per lineal foot to give 2-1/4 square inches of opening per lineal foot. The perforation schedule is shown in Inclosure 3. Casing for the Test Wells conforms to ASTM Spec. A36-70 and API Std. 5LX grade X52. It is 10 inches I.D. with standard 1/4-inch wall thickness. The perforations are 1/8" x 2-7/8" full flow horizontal louvre-type slots. Eight vertical rows with 12 openings per row provide 33-1/2 square inches of opening per lineal foot of perforated casing. The perforation schedules for the Test Wells are shown in Inclosure 3. The casing is collared and came in 30-foot lengths or slightly longer. The casing sections are joined by welding and the bottom sections are sealed with field-welded steel plates.

In Well 8, the 10-inch casing extends to 1,305 feet. Below this depth the 7-7/8-inch hole is open to the bottom at 1,501 feet. In Well 7, the casing extends to 810 feet, and the hole is open to the bottom at 1,002 feet. In both cases the materials encountered near the bottom were considered to be cemented enough to stand open without casing.

After casing was set in each hole, the grout surface seal was emplaced. A packer was set at the prescribed depth and neat cement grout was pumped through a 1-1/4-inch grout pipe by means of a Worthington (4-1/2" x 6") pump. Surface seal depths are shown in Inclosure 3. The extra depth of seal in Well 7 was intended to provide adequate support for the casing, which was hung in the hole.

Development. Initial development of the wells was started with the drill rig. Cuttings were pumped from the mud pits and fresh water was added to thin the

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mud. With the bit on bottom this thinned fluid was circulated in the hole to flush out all the fine cuttings and some of the remaining mud cake. After this initial development, the drill rig was moved and a bailing rig was set in place. Bailing approximately 23 hours with an 8-inch I.D. bailer 23 feet long was required for each hole. A small three-inch bailer was used in the observation well and in the smaller diameter section of Well 8.

The development stage of the contract was completed by installing a turbine pump in each well and pumping and surging each for approximately 20 hours to clean out the remaining mud and pull sand in to open up the formation. The wells were pumped at a low initial rate and were surged whenever the water cleared. As development progressed, the pumping rate was increased until the wells were producing at least 400 gallons per minute. The pump used for developing and testing had 7-1/2-inch bowls with 19 stages and was powered by a Ford 428 V8 industrial engine. Water levels were measured by means of an electric probe. Water flows were measured with a three- or four-inch orifice in a six-inch pipe and a calibrated piezometer tube.

Test Pumping. Wells 6, 7, and 9 were tested at five pumping rates varying from 175 gpm to 450 gpm. Water levels were measured at timed intervals during drawdown until the pumping level stabilized. Then the pump was shut off and water levels were measured to determine the rate of rebound. When the water level stabilized at the highest pumping rate the well was pumped for 24 hours to determine transmissivities and to see if there would be any short term boundary effects on the aquifer. Well 8 was tested at four rates varying from 175 gpm to 400 gpm. Water level measurements were taken in Well 8 and the observation well simultaneously during the various pumping tests. The final pump test was run continuously for five days. Transmissivity and the storage coefficient were calculated from the results of this test. Boundary effects were also checked. Specific capacities of the wells at various pumping rates are in Inclosure 3; the drawdown rebound curves are in Inclosure 8, sheets 1 through 5.

Following the pump tests the wells were sterilized with granular calcium hypochlorite (HTH) and let stand for 24 hours. The chlorine was then pumped to waste and water samples were taken for standard water quality analyses, which were run by the US Geological Survey. The results are in Inclosure 7, sheets 1 through 6. Bacterial analyses were done by the Preventive Medicine Unit of Fort Huachuca; the results were negative.

Upon completion of the contract the Test Wells were capped and locked.

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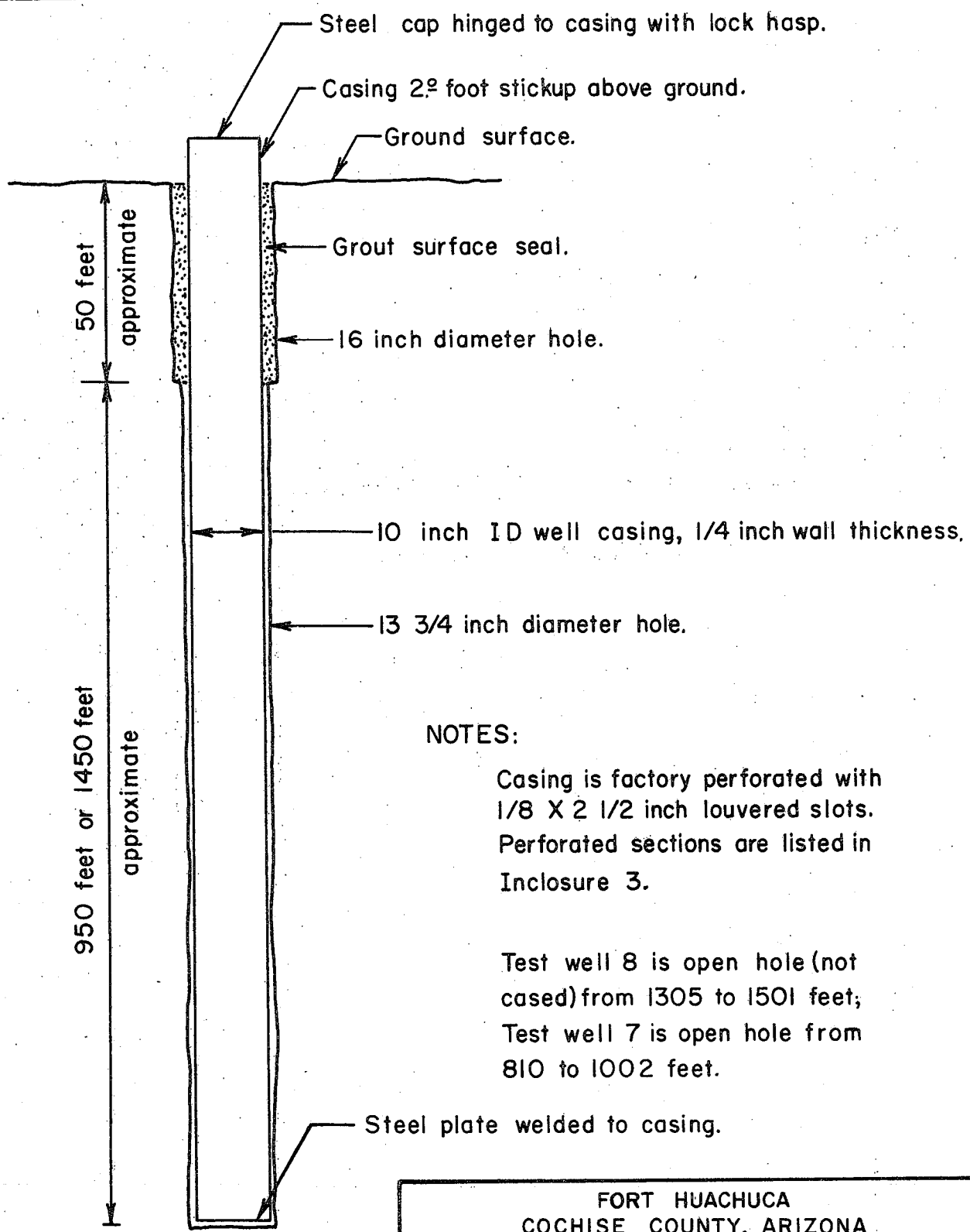


NOTES:

Casing is factory perforated with 1/8 X 2 1/2 inch louvered slots. Perforated sections are listed in Inclosure 3.

Test well 8 is open hole (not cased) from 1305 to 1501 feet; Test well 7 is open hole from 810 to 1002 feet.

FORT HUACHUCA
COCHISE COUNTY, ARIZONA

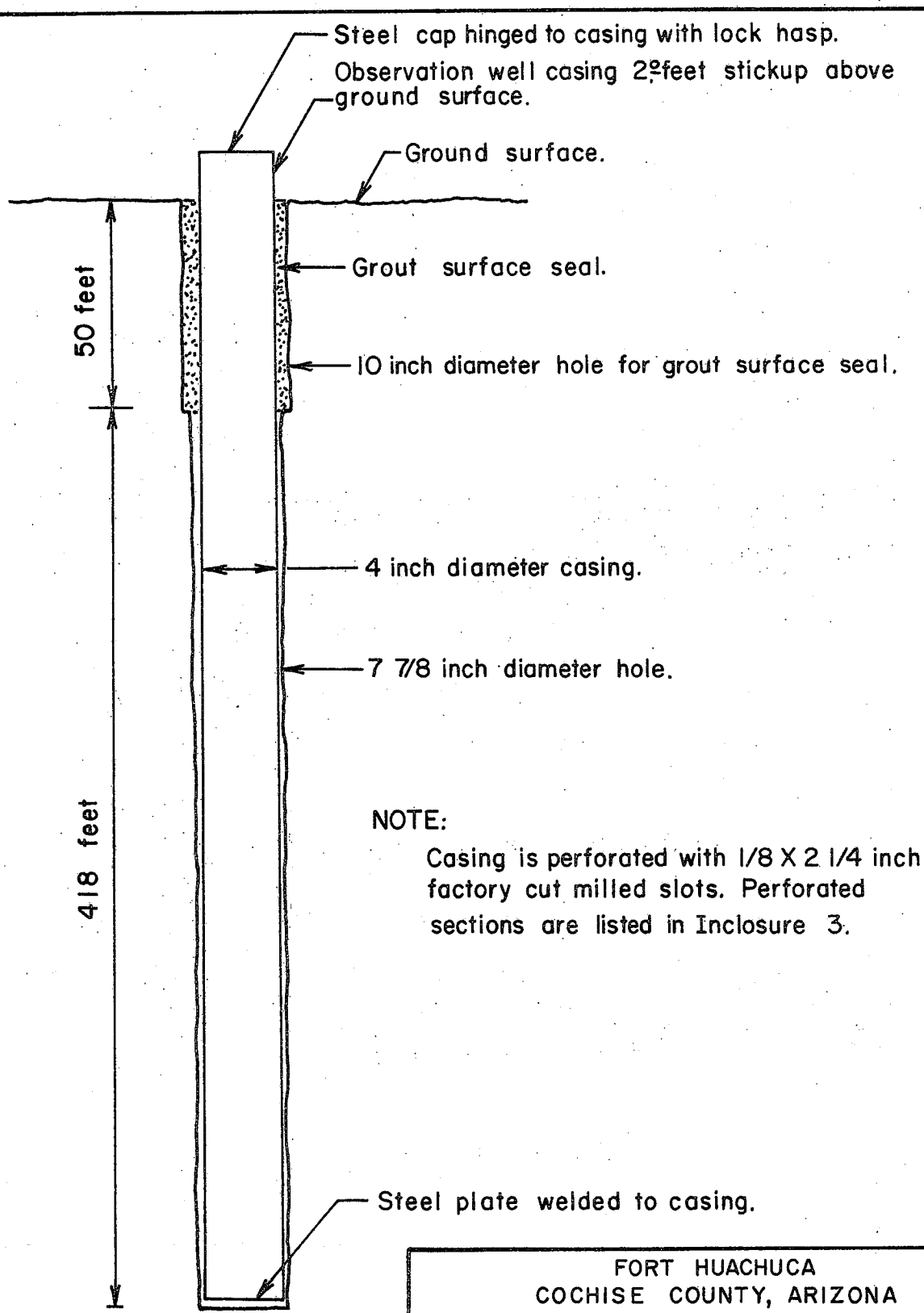
TEST WELL CONSTRUCTION

NOT TO SCALE

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

PREPARED BY:	DATE:	DRAWN BY:
R. Anderson & J. Gewerth		D.W. Paige

INCLOSURE 2 SKETCH 1



NOTE:

Casing is perforated with 1/8 X 2 1/4 inch factory cut milled slots. Perforated sections are listed in Inclosure 3.

FORT HUACHUCA
COCHISE COUNTY, ARIZONA

OBSERVATION WELL CONSTRUCTION

NOT TO SCALE

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

PREPARED BY:	DATE:	DRAWN BY:
R. Anderson & J. Gewerth		D.W. Paige

INCLOSURE 2 SKETCH 2

Fort Huachuca, Arizona
Geologic Log
Test Well No. 6

0.0 Terrace deposits
Gravelly sandy clay, reddish brown, moderately plastic, dry, sand and gravel are angular to rounded, maximum size 2-1/2 inches, sand is fine to medium, mostly fine.

1.6 Caliche with sand and gravel, reddish gray.

4.6 Sand, brown, fine grained, well sorted, clean, abundant mica.

15.0 Sand is slightly lighter brown color, angular to rounded.

30.0 Sand is light brown to gray, few medium size grains.

44.0 Sand is fine to medium grained, trace of tan clay.

62.0 Upper Unit of Basin Fill
Sand, medium brown, fine to medium grained, angular to rounded, clay content varies from 0 to 10 percent.

67.0 Sandy clay, tan, moderately plastic, about 30 percent fine to medium grained, angular to rounded sand.

70.0 Clayey sand, tan, fine to medium grained, some caliche, clay content variable, generally 30 to 40 percent, moderately plastic.

101.0 Sandy clay, tan, moderately plastic, sand content varies from 15 to 30 percent, fine to medium grained.

103.0 Clayey sand, fine to coarse, 30 to 40 percent tan moderately plastic clay.

105.0 Sandy clay as at 101.0 feet.

138.0 Sand, fine to medium grained, angular to rounded, well graded, numerous maroon colored grains, trace of tan clay.

147.0 Sandy clay, tan, moderately plastic, 20 to 35 percent fine to medium sand.

158.0 Clayey sand, fine to coarse, angular to rounded; clay is tan, moderately plastic, clay content variable from 10 to 40 percent.

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Test Well No. 6 (cont'd)

189.0 Sandy clay, tan, moderately plastic, 10 to 30 percent fine to coarse sand.

195.0 Sand, fine to medium, angular to rounded, mostly dark brown and maroon, trace of tan clay.

208.0 Sandy clay-clayey sand; about equal amounts of moderately plastic, tan clay and fine to coarse grained, angular to subrounded sand.

230.0 <u>Lower Unit of Basin Fill</u>
Clayey sand, fine to medium with few coarse grains, more volcanics than above, angular to subround, about 40 percent tan clay.

250.0 Sandy clay, similar to 230.0 feet with a predominance of tan clay, 30 to 40 percent fine to medium sand.

258.0 Sand, fine to medium grained, scattered coarse grains, angular to subround, trace of tan clay

262.0 Clayey sand, fine to coarse, angular to subround, 10 to 30 percent tan clay.

268.0 Sand, fine to coarse, trace of tan clay.

272.0 Clayey sand as at 262.0 feet.

282.0 Sand, fine to medium grained, scattered coarse grains, angular to rounded, 5 to 15 percent brown, moderately plastic clay, scattered streaks of clay.

335.0 Clayey sand, fine to medium grained, clay content varies from 15 to 30 percent.

345.0 Clayey sand as at 335.0 feet with scattered small gravel fragments.

264.0 Clay content decreases to less than 5 percent.

378.0 Clayey sand-sandy clay, about equal amounts of brown clay and fine to medium grained sand.

390.0 Clayey sand, fine to medium with few coarse grains, 10 to 15 percent moderately plastic brown clay. Thin clay streak at ± 401.

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Test Well No. 6 (cont'd)

410.0 Sand, mostly fine to medium grained, mostly angular, clay content varies from 0 to 10 percent; most of sand grains are dark brown and maroon, looks like reworked Pantano Formation.

490.0 Sand as at 410.0 feet with scattered small gravel fragments.

550.0 Pantano Formation
Sand, fine to medium with few coarse grains, angular to subround, most grains are brown, maroon, green, mostly volcanic rocks, cuttings have been ground up by drilling, slightly to moderately cemented becoming harder with depth. Little change in cuttings from 550.0 to bottom of well; drilling time increases slightly.

1004.0 Bottom of well

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Fort Huachuca, Arizona
Geologic Log
Test Well No. 7

0.0 Terrace deposits
Clayey sand, reddish brown, sand is mostly fine to medium, some coarse, angular to subround, variable amount of lean clay.

3.5 Clayey Sand as above with scattered small gravel, 10 to 20 percent reddish brown clay.

20.0 Sand, mostly fine to medium grained, few coarse grains, angular to subround, trace to 5 percent reddish brown clay.

52.0 Upper Unit of Basin Fill
Sand, mostly medium to coarse, angular to subround, trace of brown clay.

93.0 Clayey sand, fine to coarse angular to subround sand with 20 to 30 percent brown, moderately plastic clay.

105.0 Sand is fine to medium grained, 10 to 20 percent brown clay.

130.0 Clayey sand as above, 20 to 30 percent brown clay.

150.0 Clayey sand as above, 30 to 40 percent clay.

158.0 Sand, fine to medium, angular to subround, less than 5 percent clay.

164.0 Sandy clay, brown, moderately plastic, 30 to 40 percent fine to medium grained sand.

181.0 Clayey sand, fine to medium grained. Few coarse grains, 30 to 40 percent brown, moderately plastic clay.

198.0 Sandy clay-clayey sand, cuttings are mixture of fine to medium sand and brown clay in varying proportions, probably layers of sand and sandy clay.

215.0 Lower Unit of Basin Fill
Sandy clay, brown, moderately plastic, 10 to 20 percent fine to medium sand.

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Test Well No. 7 (Cont'd)

245.0 Thin layer of fine to medium sand, may be slightly clayey.

248.0 Sandy clay as at 220.0 feet.

263.0 Sand, fine to coarse, angular to subround, mostly medium to coarse, trace of brown clay.

279.0 Clayey sandy gravel, gravel is fine, subangular to rounded, sand is fine to coarse, 10 to 20 percent brown, moderately plastic clay.

284.0 Sand, fine to medium, mostly fine, angular to subrounded, trace of brown clay.

289.0 Sandy clay, brown, moderately plastic

294.0 Sand, fine to medium with few coarse grains angular to subround, variable amount of brown clay

315.0 Clayey sand, same as at 294.0 feet with 10 to 15 percent brown clay.

330.0 Sand, fine to medium, angular to subround, few coarse grains, trace to about 5 percent brown clay, may be thin layers of clay or clayey sand.

431.0 Thin streaks of clayey sand, sand is fine to medium coarse.

436.0 Sand as at 330.0 feet.

450.0 Clayey sand, fine to medium, angular to subangular few coarse grains, trace to 10 percent brown clay.

463.0 ± 15 percent light brown clay.

485.0 Clayey sand as at 450.0 feet.

510.0 Slight increase in number of dark brown and maroon sand grains, continues to increase with depth, decrease in quartz grains.

551.0 Sand, fine to medium, few coarse grains, angular to subrounded, clean, darker grains continue to increase (looks like reworked Pantano Formation).

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Test Well No. 7 (Cont'd)

590.0 Hard streaks caused by cementation, becomes more cemented with depth.

635.0 <u>Pantano Formation</u>
Sand, fine to coarse, angular to subround, scattered gravels and cobbles, mostly dark colored grains, dark green, dark gray, brown, maroon, overall brown color, slightly to moderately cemented, slight increase in cementation and hardness with increasing depth.

700.0 A few zones are softer, overall moderately cemented.

750.0 Cuttings are fine to medium grained, formation is harder, moderately well cemented, scattered softer zones.

1002.0 Bottom of hole

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Fort Huachuca, Arizona
Geologic Log
Test Well No. 8

0.0 <u>Terrace deposits</u>
Sandy clay, reddish brown, moderately plastic, small amount fine to coarse sand.

1.0 Clayey, gravelly sand, fine to coarse with small gravel, angular, 30 to 40 percent reddish brown lean clay.

3.5 Sandy clay, reddish brown lean clay as above, 15 to 20 percent, mostly fine, sand.

5.0 Clayey sand, mostly fine to medium grained, few coarse grains and scattered gravel, angular to subround, 10 to 20 percent reddish brown lean dry clay, few streaks of caliche.

13.0 Sand, fine to coarse grained, angular to subround; thin streaks of hard sandy clay 16 to 20 feet.

35.0 <u>Upper Unit of Basin Fill</u>
Sand, mostly fine to very fine, slightly cemented.

40.0 Clayey sand, fine to medium sand with 5 to 15 percent reddish brown clay.

44.0 Clayey sand, fine to medium coarse, well graded.

46.0 Sand, fine to coarse, angular to subround, trace of clay.

57.0 Gravelly sand, fine to coarse sand with about 40 percent 1/4 to 3/8-inch gravel, angular to subangular, few rounded, gravel content decreasing from 59.0 feet.

60.0 Sand, fine grained, contains scattered gravel, Coarser grained with more gravel at 70.0 feet.

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Test Well No. 8 (Cont'd)

72.0 Gravelly sand, fine to coarse angular sand with 30 to 40 percent angular to subround gravel, trace of clay.

85.0 Sand, fine to coarse, mostly angular scattered small gravel; thin streaks of sandy clay 94.0 to 97.0 feet.

97.0 Clayey sand, sand as at 85.0 feet with 5 to 10 percent brick red to brown clay. Clay content decreases below 105 feet.

107.0 Sand, fine to medium grained, finer at 116.0 feet, trace of clay. Clay content 5 to 10 percent at 118 feet

120.0 Sand as at 107 feet with thin layers of clayey sand, clay content 5 to 15 percent.

140.0 Clayey sand-sandy clay, about equal amounts of fine to medium sand and lean brown clay; more sandy from 149 feet. Grades to clean sand at 157 feet

157.0 Sand, fine to medium grained, angular to subround.

160.0 Sandy clay, brown, moderately plastic, variable amount of fine sand.

166.0 Clay, reddish brown, lean, small amount of very fine sand.

174.0 Sand, fine to coarse with a few small gravels, cuttings are angular.

182.0 Sandy clay-clayey sand, varying proportions of fine to coarse sand and brown lean clay, few small gravels.

198.0 Sand, fine to coarse with few small gravels, angular, clean.

207.0 Gravelly clayey sand, fine to coarse sand with about 25 percent gravel up to 1/2 inch size, mostly angular to subangular, 5 to 15 percent clay.

213.0 Sandy clay, light brown, lean, fine to medium sand, scattered coarse sand and small gravel.

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Test Well No. 8 (Cont'd)

230.0 Sand, fine to coarse, well graded, mostly angular.

237.0 Clayey sand grading to sandy clay, fine to coarse sand with increasing amount of light brown clay.

252.0 Sand, fine to medium grained, angular.

254.0 Clayey sand; sand as at 252 feet with 15 to 30 percent light brown clay.

258.0 Sand, fine grained, well sorted, clean.

268.0 Clayey sand, fine to medium grained angular sand with variable amounts of lean brown clay, clay content 10 to 40 percent.

300.0 Lower Unit of Basin Fill
Sandy clay, light brown, lean, 10 to 40 percent fine to medium sand.

305.0 Clayey sand, fine to medium grained sand with highly variable amounts of light brown lean clay, some thin layers of clean sand.

360.0 Sand, fine to medium grained, angular, trace to 10 percent brown clay.

405.0 Sand, mostly fine grained, slightly coarser below 422.0 feet, angular to subround.

445.0 Mostly medium grained sand, trace of clay.

497.0 Sand is fine grained, trace to 10 percent brown clay, abundant quartz and feldspar grains give overall medium gray color, slightly cemented.

570.0 Sand, fine to medium grained, angular to subround slight increase in darker colored grains, slightly to moderately cemented, cementing increases with depth.

600.00 Darker colored grains more abundant with increasing depth, probably reworked Pantano.

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Test Well No. 8 (Cont'd)

632.0 Pantano Formation
Sand, fine to medium grained, cuttings are mostly fine and angular, probably being ground up, mostly dark colors with a small amount of quartz, overall brown color, moderately cemented, hardness (cementation) continues to increase with depth.

685.0 Cuttings are mostly medium grained, angular, ±10 percent fine.

693.0 Fine to medium coarse, cementation seems to vary as reflected by drilling rate.

780.0 Mostly fine grained but probably being ground up by bit.

880.0 Cuttings are fine to coarse angular sand (less grinding with new bit). Grain size seems to vary with bit condition and hardness (cementation)

1000.0 Overall color is grayish brown, cuttings are fine to medium.

1080.0 Cuttings are fine to coarse, angular to subangular

1095.0 Gravelly Sand, fine to coarse sand and small gravel, angular to subangular, some gravel particles are fragments of soft shale (Sandy siltstone).

1104.0 Sand, fine to coarse, angular to subround, scattered gravel size fragments of light reddish brown sandy siltstone.

1220.0 Fine to medium, mostly fine, no gravel sizes.

1295.0 Volcanic Conglomerate--(Bronco Volcanics) Drilled with 7-7/8 inch bit. Hole not cased from 1304. Cuttings are fine to coarse sand, mostly medium to coarse, angular to subround, grains are almost all dark colors-dark green, dark gray, brown, maroon, few small grains of calcite, very hard, well cemented.

1501.0 Bottom of Well.

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Fort Huachuca, Arizona
Geologic Log
Observation Well - Site 8

0.0	<u>Terrace deposits</u> Sandy clay, light reddish brown, lean clay, dry, contains a large percent of fine sand.
1.0	Clayey sand, reddish brown, very fine and medium grained, angular sand (skip graded), 40 to 60 percent reddish clay.
3.0	Clayey sand, reddish brown, fine to coarse grained, but mostly medium to coarse, angular, about 10 to 15 percent lean clay.
12.0	Sand, reddish brown, mostly fine to medium grained, angular, small amount of reddish clay.
15.0	Sand is fine to coarse, angular.
24.0	<u>Upper Unit of Basin Fill</u> Sand, medium to coarse, slightly cemented.
30.0	Sand is medium grained, angular, cemented.
40.0	Sand is fine to medium grained, few rounded grains, small amount of clay.
43.0	Clayey sand, very fine to fine grained, 25 to 35 percent reddish brown clay.
46.0	Sand, very fine to fine grained, appears to be clean, partly cemented slightly.
75.0	Clayey sand, medium to coarse sand and scattered gravel up to 1/2-inch size, 10 to 15 percent clay.
84.0	Silty gravelly sand, medium to coarse sand with few small gravels and 15 to 20 percent silt or lean clay.
96.0	Sand alternating with sandy clay; mostly medium grained sand with varying percent lean clay or silt, mottled brick red and brown.
104.0	Sand, fine to medium grained, angular to subround, 5 to 10 percent reddish brown silt. Sand gets finer with depth.

USF200002548

Observation Well - Site 8 (cont'd)

115.0 Sand is very fine to fine grained, appears to be clean.

148.0 Sandy clay, brown, firm, small amount of fine to medium sand.

151.0 Sand, fine to coarse but mostly medium, few gravels up to 1/2-inch size.

160.0 Sandy gravel, subround to angular gravel up to 3/4-inch size, about 20 percent medium to coarse sand, clayey near bottom.

175.0 Sandy clay, brown, firm, small amount of fine to medium sand.

178.0 Sandy gravel, subround to angular gravel up to 3/4-inch size, about 20 percent medium to coarse sand.

187.0 Gravelly sandy clay, brown, lean clay with about 25 percent sand and gravel up to 3/4-inch size.

192.0 Clayey sandy gravel, angular to subround gravel up to 3/4-inch size with about 15 percent lean brown clay.

204.0 Sandy gravel, coarse sand and gravel up to 3/4-inch size, angular to subround.

210.0 Gravelly clay, brown, lean, sandy clay with 30 to 40 percent angular to subround gravel up to 1/2-inch size.

225.0 Clayey gravel - gravelly clay, clay and gravel as at 210.0 feet in variable proportions.

243.0 Clayey gravel as at 225.0 feet, 10 to 20 percent lean borrow clay, cobbles 243.0 to 247.0 feet.

253.0 Sandy clay, brown, firm, 10 to 15 percent fine to coarse sand, few small gravels. Gravel content increases at 255 feet, up to 40 percent.

255.0 Gravelly sandy clay, brown, firm, gravel content highly variable, sand mostly fine or coarse (gravel and coarse sand in a sandy clay matrix).

USF200002549

Observation Well - Site 8 (cont'd)

285.0 <u>Lower Unit of Basin Fill</u>
Sandy clay, brown to light gray, lean, low percent fine sand, scattered gravel and coarse sand grains.

318.0 Sandy clay as above but sand content highly variable — ± 5 to 30 percent

345.0 Sandy clay-clayey sand, about equal amounts of lean brown clay and fine to medium sand, few coarse grains.

360.0 Clayey sand, mostly medium grained, small amount is fine grained, 10 to 15 percent lean brown clay.

380.0 Sand, fine to medium grained, streaks of brown clay, overall 5 to 10 percent clay.

400.0 Clayey sand, fine and coarse sand (skip graded) with 15 to 25 percent brown clay. Clay content increase to almost 50 percent at ± 410 feet.

413.0 Sandy clay, grayish brown, 30 to 40 percent grayish brown clay.

446.0 Sand, fine to medium grained, few coarse grains, cemented.

468.0 Bottom of observation well

USF200002550

Fort Huachuca, Arizona
Geologic Log
Test Well No. 9

0.0 Terrace deposits
Gravelly clayey sand, reddish brown; sand is fine to coarse but mostly coarser sizes, angular to subround; gravel is mostly fine, angular to rounded, ± 25 to 40 percent reddish brown clay.

5.0 Clayey sand, reddish brown, sand is fine to medium grained, angular to subround, 30 t0 40 percent reddish brown clay.

16.5 Clayey sand as above but clay content is 5 to 10 percent.

24.5 Clay content estimated 30 percent.

26.5 Clay content estimated 5 to 10 percent

33.5 Sand, mostly medium grained, high percent of quartz grains, trace of clay.

34.5 Sand is clean, mostly quartz, angular to rounded.

39.0 Upper Unit of Basin Fill
Sand, fine to medium, angular to subround, overall brown color, trace of reddish brown clay.

56.5 Sand is moderately cemented, fine grained.

66.0 Sand contains 5 to 10 percent reddish brown clay.

74.0 Sand, fine to coarse, angular to rounded, gradation varies (well graded to poorly graded), clean.

85.0 Sand, mostly medium and coarse, contains a small amount of clay at 85.0 feet, increase to 10 to 15 percent at 90.0 feet.

90.0 Clayey Sand--sandy clay, probably in alternating layers, light brown and light gray sandy clay alternating with medium to coarse sand, gray clay is limey.

USF200002551

Test Well No. 9 (Cont'd)

107.0 Clay, light brown, soft, moderately plastic, small amount of fine to medium sand as thin streaks.

110.0 Color alternates from light greenish gray to light brown.

150.0 Color is mixed light gray (almost white) and light brown, no more than 5 percent fine sand.

170.0 Clayey sand, fine to medium, angular to subround, low percent brown clay at 170.0 feet, increase to ± 25 percent at 179.0 feet.

188.0 Sand, fine to medium grained, angular to subround less than 5 percent brown clay.

194.0 Clayey sand, sand as at 188.0 feet with about 25 percent brown clay at 194.0 feet; clay content varies from about 10 to 30 percent.

255.0 Sandy clay, brown, soft, moderately plastic contains about 30 to 35 percent fine to coarse sand.

265.0 Clay, brown, stiff, highly plastic, very small amount of fine sand.

308.0 Color change to dull maroon.

317.0 Thin streak is sandy, color change to brown.

340.0 Clay contains 5 to 10 percent fine sand and scattered small angular gravels.

370.0 <u>Lower Unit of Basin Fill</u>
Clayey sand, brown, sand fine to coarse, mostly medium to coarse, scattered angular pea gravel, ± 30 percent lean clay.

380.0 Thin streak of clean sand.

382.0 Clay content varies from 5 to 20 percent.

398.0 Thin streaks of clean sand from 398.0 to 400.0 feet.

400.0 Clayey sand, fine to coarse, angular to subround, clay content varies from about 10 to 30 percent.

USF200002552

Test Well No. 9 (Cont'd)

478.0 Sandy clay, brown, moderately plastic, 5 to 10 percent fine to medium grained sand.

500.0 Clay, brown, moderately plastic, contains less than 5 percent fine to medium sand.

598.0 Clayey sand, fine to coarse, mostly medium to coarse, angular to subround, about 5 percent brown clay, some evidence of cementation.

600.0 Pantano Formation
Sand, fine to coarse, angular to subround, mostly darker colors, some gray granitic rock and white quartz, slightly cemented, hardness and cementation increase with depth; contains a small amount of interstitial clay.

620.0 Sand, fine to coarse, angular to subround, less than 5 percent brown clay.

740.0 Gravelly sand, fine to coarse, angular to subangular sand and 1/4- to 3/8-inch gravel, few flat pieces of soft brown shale (claystone), 30 to 50 percent gravel, trace of brown clay.

780.0 Gravel content is no more than 15 percent

800.0 Sand, fine to coarse, mostly angular, scattered small gravels, trace of brown clay, slightly cemented.

840.0 Sand is mostly medium to coarse, scattered small gravels.

920.0 Sand is fine to medium, few coarse grains, angular to subangular, trace of brown clay, slightly to moderately cemented.

935.0 Sand is fine to coarse, angular to subangular, trace of brown clay.

964.0 Sand contains numerous fragments of brown shale.

1005.0 Bottom of hole.

USF200002553

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WRD CENTRAL QW LAB, SALT LAKE CITY, UTAH

WATER QUALITY ANALYSIS DATE: 740114

STATION I.D.313841110164701

(D-20-20 35CCB FT. HUACHUCA TW NO. 6)

STATE CODE	COUNTY	PROJECT	AGENCY	MAILING ADDRESS
LOCATION 04	CODE. 003	CODE. 02306	CODE.	TUCSON, ARIZ.

BEGIN DATE	END DATE	TIME	TYPE	NO. OF DETR	SAMPLE I.D.	RECORD NO.	SOURCE
730917			2		320012	16607	GROUND WATER

FT. HUCHUCA TEST WELL NO. 6

	MG/L		MG/L
BICARBONATE	207	BORON DISS	0.04
CALCIUM DISS	40	CARBONATE	0.0
CHLORIDE DISS	5.5	CHROMIUM HEXAVALENT	0.0
FLUORIDE DISS	0.2	COPPER DISS	
LEAD DISS		IRON DISS	0.0
MANGANESE DISS	0.01	MAGNESIUM DISS	12
POTASSIUM DISS	1.6	SILICA DISS	31
SODIUM DISS	18	SULFATE DISS	5.6
CADMIUM DISS		PHOSPHATE DISS ORTHO	0.28
SELENIUM DISS	0.004	MERCURY DISS	0.0
PHOS ORTHO DISS AS P	0.09	ALK, TOT (AS $CACO_3$)	170
NO_2 + NO_3 AS N DISS	0.79	PH	7.9
HARDNESS TOTAL	150	SODIUM PERCENT	21
HARDNESS NONCARB	0.0	RES DISS TON/AFT	0.3
RESIDUE DISS CALC SUM	220	SAR	0.6
		CONDUCTIVITY	357

MAJOR IONS

CATIONS (MG/L)		ANIONS (MG/L)	
CALCIUM DISS	40	BICARBONATE	207
MAGNESIUM DISS	12	CARBONATE	0.0
POTASIUM DISS	1.6	CHLORIDE DISS	5.5
SODIUM DISS	18	FLUORIDE DISS	0.2
		SULFATE DISS	5.6
		NO_2 + NO_3 AS N	0 79

INCLOSURE 7 SHEET

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WRD CENTRAL QW LAB, SALT LAKE CITY, UTAH

WATER QUALITY ANALYSIS DATE: 731009

STATION I.D.
313716110171601

(D-21-20 11BCD FT. HUACHUCA TW NO. 7)

STATE CODE LOCATION	COUNTY CODE	PROJECT CODE	AGENCY CODE	MAILING ADDRESS
04	003	02306		TUCSON, ARIZ.

BEGIN DATE	END DATE	TIME	TYPE	NO. OF DETR	SAMPLE I.D.	RECORD NO.	SOURCE
730828			2	35			GROUND WATER

FT. HUCHUCA TEST WELL NO. 7

	MG/L		MG/L
BICARBONATE	170	BORON DISS	0.040
CALCIUM DISS	36	CARBONATE	0
CHLORIDE DISS	3.5	CHROMIUM HEXAVALENT	0
FLUORIDE DISS	0.1	COPPER DISS	0.001
LEAD DISS	.0	IRON DISS	0
MANGANESE DISS	.010	MAGNESIUM DISS	6.6
POTASSIUM DISS	1.2	SILICA DISS	29
SODIUM DISS	16	SULFATE DISS	6.1
CADMIUM DISS	0	PHOSPHATE DISS ORTHO	0.09
SELENIUM DISS	.005	MERCURY DISS	0.0
PHOS ORTHO DISS AS P	0.03	ALK,TOT (AS $CACO_3$)	139
NO_2 + NO_3 AS N DISS	0.56	PH	7.8
HARDNESS TOTAL	120	SODIUM PERCENT	23
HARDNESS NONCARB	0.	RES DISS TON/AFT	0.25
RESIDUE DISS CALC SUM	185	SAR	0.6
		CONDUCTIVITY	281

MAJOR IONS

CATIONS (MG/L)		ANIONS (MG/L)	
CALCIUM DISS	36	BICARBONATE	170
MAGNESIUM DISS	6.6	CARBONATE	0
POTASIUM DISS	1.2	CHLORIDE DISS	3.5
SODIUM DISS	16	FLUORIDE DISS	0.1
		SULFATE DISS	6.1
		NO_2 + NO_3 AS N	0.56

INCLOSURE 7 SHEET 2

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WRD CENTRAL QW LAB, SALT LAKE CITY, UTAH

WATER QUALITY ANALYSIS DATE: 740114

STATION I.D. 313613110161901

(D-21-20 13CBB FT. HUACHUCA TW NO. 8)

STATE CODE LOCATION	COUNTY CODE	PROJECT CODE	AGENCY CODE	MAILING ADDRESS
04	003	02306		TUCSON, ARIZ.

BEGIN DATE	END DATE	TIME	TYPE	NO. OF DETR	SAMPLE I.D.	RECORD NO.	SOURCE
730903		1430	2		320009	16598	GROUND WATER

FT. HUCHUCA TEST WELL NO. 8

	MG/L		MG/L
BICARBONATE	199	BORON DISS	0.04
CALCIUM DISS	35	CARBONATE	0.0
CHLORIDE DISS	3.1	CHROMIUM HEXAVALENT	0.0
FLUORIDE DISS	0.2	COPPER DISS	0.001
LEAD DISS	0.005	IRON DISS	0.0
MANGANESE DISS	0.08	MAGNESIUM DISS	7.4
POTASSIUM DISS	1.3	SILICA DISS	33
SODIUM DISS	26	SULFATE DISS	8
CADMIUM DISS	0.0	PHOSPHATE DISS ORTHO	0.31
SELENIUM DISS	0.003	MERCURY DISS	0.0
PHOS ORTHO DISS AS P	0.1	ALK, TOT (AS $CACO_3$)	163
NO_2 + NO_3 AS N DISS	0.03	PH	8.0
HARDNESS TOTAL	120	SODIUM PERCENT	32
HARDNESS NONCARB	0.0	RES DISS TON/AFT	0.27
RESIDUE DISS CALC SUM	213	SAR	1.0
		CONDUCTIVITY	321

MAJOR IONS

CATIONS (MG/L)		ANIONS (MG/L)	
CALCIUM DISS	35	BICARBONATE	199
MAGNESIUM DISS	7.4	CARBONATE	0.0
POTASIUM DISS	1.3	CHLORIDE DISS	3.1
SODIUM DISS	26	FLUORIDE DISS	0.2
		SULFATE DISS	8.0
		NO_2 + NO_3 AS N	0.03

INCLOSURE 7 SHEET 3

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WRD CENTRAL QW LAB, SALT LAKE CITY, UTAH

WATER QUALITY ANALYSIS DATE: 740114

STATION I.D.313613110161901

(D-21-20 13CBB FT. HUACHUCA TW NO. 8)

STATE CODE LOCATION	COUNTY CODE	PROJECT CODE	AGENCY CODE	MAILING ADDRESS
04	003	02306		TUCSON, ARIZ.

BEGIN DATE	END DATE	TIME	TYPE	NO. OF DETR	SAMPLE I.D.	RECORD NO.	SOURCE
730903		0700	2		320008	16595	GROUND WATER

FT. HUCHUCA TEST WELL NO. 8

	MG/L		MG/L
BICARBONATE	200	BORON DISS	0.02
CALCIUM DISS	37	CARBONATE	0.0
CHLORIDE DISS	3.2	CHROMIUM HEXAVALENT	0.0
FLUORIDE DISS	0.2	COPPER DISS	0.001
LEAD DISS	0.002	IRON DISS	0.02
MANGANESE DISS	0.08	MAGNESIUM DISS	7.6
POTASSIUM DISS	1.2	SILICA DISS	33
SODIUM DISS	25	SULFATE DISS	7.7
CADMIUM DISS	0.001	PHOSPHATE DISS ORTHO	0.31
SELENIUM DISS	0.006	MERCURY DISS	0.0
PHOS ORTHO DISS AS P	0.1	ALK,TOT (AS $CACO_3$)	164
NO_2 + NO_3 AS N DISS	0.06	PH	7.8
HARDNESS TOTAL	120	SODIUM PERCENT	30
HARDNESS NONCARB	0.0	RES DISS TON/AFT	0.27
RESIDUE DISS CALC SUM	214	SAR	1.0
		CONDUCTIVITY	323

MAJOR IONS

CATIONS (MG/L)		ANIONS (MG/L)	
CALCIUM DISS	37	BICARBONATE	200
MAGNESIUM DISS	7.6	CARBONATE	0.0
POTASIUM DISS	1.2	CHLORIDE DISS	3.2
SODIUM DISS	25	FLUORIDE DISS	0.2
		SULFATE DISS	7.7
		NO_2 + NO_3 AS N	0.06

INCLOSURE 7 SHEET 4

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WRD CENTRAL QW LAB, SALT LAKE CITY, UTAH

WATER QUALITY ANALYSIS DATE: 740114

STATION I.D. 313613110161901

(D-21-20 13CBB FT. HUACHUCA TW NO. 8)

STATE CODE	COUNTY	PROJECT	AGENCY	MAILING ADDRESS
LOCATION 04	CODE 003	CODE 02306	CODE	TUCSON, ARIZ.

BEGIN DATE	END DATE	TIME	TYPE	NO. OF DETR	SAMPLE I.D.	RECORD NO.	SOURCE
730908		0800	2		320010	16601	GROUND WATER

FT. HUCHUCA TEST WELL NO. 8

	MG/L		MG/L
BICARBONATE	199	BORON DISS	0.03
CALCIUM DISS	36	CARBONATE	0.0
CHLORIDE DISS	3.5	CHROMIUM HEXAVALENT	0.0
FLUORIDE DISS	0.2	COPPER DISS	0.03
LEAD DISS	0.003	IRON DISS	0.0
MANGANESE DISS	0.04	MAGNESIUM DISS	7.6
POTASSIUM DISS	1.2	SILICA DISS	33
SODIUM DISS	26	SULFATE DISS	8.3
CADMIUM DISS	0.0	PHOSPHATE DISS ORTHO	0.31
SELENIUM DISS	0.003	MERCURY DISS	0.0
PHOS ORTHO DISS AS P	0.1	ALK, TOT (AS $CACO_3$)	163
NO_2 + NO_3 AS N DISS	0.06	PH	8.2
HARDNESS TOTAL	120	SODIUM PERCENT	32
HARDNESS NONCARB	0.0	RES DISS TON/AFT	0.27
RESIDUE DISS CALC SUM	215	SAR	1.0
		CONDUCTIVITY	330

MAJOR IONS

CATIONS (MG/L)		ANIONS (MG/L)	
CALCIUM DISS	36	BICARBONATE	199
MAGNESIUM DISS	7.6	CARBONATE	0.0
POTASIUM DISS	1.2	CHLORIDE DISS	3.5
SODIUM DISS	26	FLUORIDE DISS	0.2
		SULFATE DISS	8.3
		NO_2 + NO_3 AS N	0.06

INCLOSURE 7 SHEET 5

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WRD CENTRAL QW LAB, SALT LAKE CITY, UTAH

WATER QUALITY ANALYSIS DATE: 731009

STATION I.D.
313622110142001

(D-21-21 17 BCC FT. HUACHUCA TW NO. 9)

STATE CODE LOCATION	COUNTY CODE	PROJECT CODE	AGENCY CODE	MAILING ADDRESS
04	003	02306		TUCSON, ARIZ.

BEGIN DATE	END DATE	TIME	TYPE	NO. OF DETR	SAMPLE I.D.	RECORD NO.	SOURCE
730816			2	29			GROUND WATER

FT. HUCHUCA TEST WELL NO. 9

	MG/L		MG/L
BICARBONATE	190	BORON DISS	0.030
CALCIUM DISS	35	CARBONATE	0
CHLORIDE DISS	3.4	CHROMIUM HEXAVALENT	
FLUORIDE DISS	0.9	COPPER DISS	
LEAD DISS		IRON DISS	0
MANGANESE DISS	0.010	MAGNESIUM DISS	8.3
POTASSIUM DISS	1.0	SILICA DISS	32
SODIUM DISS	21	SULFATE DISS	5.7
CADMIUM DISS		PHOSPHATE DISS ORTHO	0.09
SELENIUM DISS		MERCURY DISS	
PHOS ORTHO DISS AS P	0.03	ALK,TOT (AS $CACO_3$)	156
NO_2 + NO_3 AS N DISS	0.22	PH	7.9
HARDNESS TOTAL	120	SODIUM PERCENT	27
HARDNESS NONCARB	0	RES DISS TON/AFT	0.27
RESIDUE DISS CALC SUM	202	SAR	0.8
		CONDUCTIVITY	312

MAJOR IONS

CATIONS (MG/L)		ANIONS (MG/L)	
CALCIUM DISS	35	BICARBONATE	190
MAGNESIUM DISS	8.3	CARBONATE	0
POTASIUM DISS	1.0	CHLORIDE DISS	3.4
SODIUM DISS	21	FLUORIDE DISS	0.9
		SULFATE DISS	5.7
		NO_2 + NO_3 AS N	0.22

INCLOSURE 7 SHEET 6