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Geological Survey

Geology and ground-water resources of Paradise Valley Maricopa County, Arizona

By

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and

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INTRODUCTION

Purpose and cooperation

The ground-water resources of Paradise Valley, Maricopa County, Arizona, have been studied by the Geological Survey, United States Department of the Interior, in response to requests from the City of Phoenix and the State of Arizona. The City desired information in regard to the availability of ground water in Paradise Valley as a possible source of municipal supply. The Arizona State Legislature desired basic data for use in drafting legislation providing for the equitable distribution of existing ground-water supplies.

The work was done with funds furnished on a cooperative basis by the City of Phoenix, the Arizona State Land Department, and the Federal Geological Survey. S. F. Turner, District Engineer (Ground Water), of the Geological Survey, supervised the work.

Location

Paradise Valley lies in Maricopa County, north of the community of Scottsdale, between the Phoenix and McDowell mountain ranges. The northern limit of Paradise Valley is indefinite and in this report the valley is considered to be limited on the north by a line passing through the center of T. 6 N. Paradise Valley merges on the south with the valley of the Salt River. In this report the southern boundary of Paradise Valley is arbitrarily assumed to be along the Arizona Canal, from the SE cor. sec. 17, T. 2 N., R. 6 E. to the sharp bend in the canal in sec. 11, T. 2 N., R. 4 E., thence west to the nearest point of the Phoenix Mountains, near the common corner of secs. 3, 4, 9, and 10, T. 2 N., R. 4 E.

Maps and surveys

Most of Paradise Valley is shown on topographic maps of the Federal Geological Survey. The Camelsback quadrangle covers most of the valley on a scale of 1 mile to the inch and has a contour interval of 50 feet. The Cave Creek quadrangle covers the northern part of the valley on a scale of 2 miles to the inch and has a contour interval of 100 feet. The entire valley and the adjoining mountains are covered by a county map made by the Arizona State Highway Planning Survey. This map shows township and section lines, roads, and the principal drainageways on a scale of 1 mile to the inch. Aerial photographs were available for the western part of the valley, which was not covered by the topographic maps. The topographic maps, the county highway map, and the aerial photographs were all used in plotting field data and in compiling the base map (pl. 1).

Climate

Paradise Valley has a climate characterized by hot, dry summers and mild winters. The temperature frequently reaches 110 degrees in the summer and occasionally is even higher, but the relative humidity is low. In contrast to the high summer daytime temperatures, the summer nights are usually cool and comfortable.

Tables 1 and 2 show a summary of the climatological data for the Weather Bureau stations at Bartlett Dam and at Phoenix. These stations are the only ones now operated near Paradise Valley. The precipitation and temperature records for Bartlett Dam most nearly represent average conditions in Paradise Valley. The elevation at Bartlett Dam is about 1,800 feet above sea level and the elevation in Paradise Valley ranges from about 1,300 feet at the Arizona Canal to 2,200 feet above sea level at Cave Creek.

A comparison of the climatological data from Bartlett Dam with those from Phoenix shows that the temperatures are approximately the same, although it is probable that a longer period of record would indicate that the mean minimum temperature at Bartlett Dam would be somewhat lower than that at Phoenix. The comparison of the data shows that the precipitation at Bartlett Dam is greater than at Phoenix. The average precipitation at Bartlett Dam during the 5-year period from 1940 to 1944, inclusive, was 13.90 inches. The average precipitation at Phoenix during the same period was 9.68 inches. The 49-year average for Phoenix is 7.78 inches. Tables 1 and 2 show that the annual precipitation is concentrated principally in two periods, one during July, August, and September, the other during December, January, and February.

Vegetation

The vegetation of Paradise Valley is described by Meinzer[1] as follows:

> "The soil over most of the valley is a brownish loam, generally containing a few pebbles and small fragments of such rocks as those surrounding the valley. It is of good physical constituency and would no doubt make fertile soil for agriculture. Adjacent to the mountains there is a narrow belt of coarse gravelly soil which is not sufficiently disintegrated to be suitable for cultivation.
>
> "Mesquite, creosote bush, and palo verde make up in large part the flora on the loamy soil, and the cacti of various species, including the giant cactus and the cholla, occupy the gravelly soils at the margins of the valley and on the adjacent uplands. Except for the cacti the mountains support only very sparse vegetation. In general mesquite and palo verde grow in this valley to heights of only 5 or 6 feet, but some of them in the vicinity of stream courses reach heights of nearly 20 feet, having trunks over 4 feet in circumference near the base. The largest measurements of circumference obtained were 4.5 feet for mesquite and 4.7 feet for palo verde, with estimated heights of 15 feet and 18 feet respectively. The specimens having these dimensions were growing in the bed of the Verde canal, where flood waters accumulate, and they were therefore exceptionally well watered but not more than about 20 years old."

1/ Meinzer, O. E., and Ellis, A. J., Ground water in Paradise Valley, Arizona: U. S. Geol. Survey Water-Supply Paper 375, pp. 56-57, 1915.

History of development

About 1895 the Rio Verde Canal Company constructed the Verde Canal (see pl. 1), which was intended to irrigate approximately 50,000 acres of land in Paradise Valley. Water was to be stored behind a dam to be built at the Horseshoe reservoir site on the Verde River in T. 8 N., R. 6 E. This water was to be diverted into the canal at a small dam about 18 miles downstream. The canal was practically finished when the canal company became involved in litigation over water rights and the work was discontinued. Later, the Salt River Valley Water Users' Association made borings at the Horseshoe damsite, although the dam was not built until the winter of 1944-45. Bartlett Dam, about 20 miles below the Horseshoe site, was completed in 1939 and both Horseshoe and Bartlett Reservoirs are now used to store Verde River flood water for irrigation use on the project of the Salt River Valley Water Users' Association.

Paradise Valley was opened to homestead settlers prior to 1914, and many families attempted to settle there. The lack of a surface-water supply and the high pumping lift necessary to obtain ground water discouraged the settlers and caused the eventual abandonment of most of the places. Since that time the principal industry of the valley has been stock ranching. Ground water has been used for irrigation only during the last few years, and this use has been confined to small areas with the lowest pumping lifts.

Agriculture

Land that is suitable for farming is abundant in the central and lower parts of Paradise Valley. Precipitation is insufficient for dry farming, and there is little likelihood that surface-water supplies will ever be made available for a substantial part of the irrigable land.

For many years, stock raising has been the principal agricultural development of Paradise Valley. In recent years, under the stimulus of high prices, several irrigation wells have been drilled in the lower part of Paradise Valley, north of the Arizona Canal. At the present time (1946) 1,000 to 1,500 acres is irrigated with water pumped from wells. The principal crops are citrus fruits, cotton, alfalfa, and barley.

Previous investigations

In 1914, O. E. Meinzer and A. J. Ellis[2] made a reconnaissance survey of the geology and ground-water resources of Paradise Valley. As the publication describing their work is now out of print, data from it were used freely in preparation of the present report.

LAND FORMS

Paradise Valley is a gently-sloping alluvial plain formed by the filling of the trough between the Phoenix and McDowell mountain ranges. The valley comprises an irregularly-shaped area of about 245 square miles, with a length of about 20 miles and a width of about 10 miles.

2/ Meinzer, O. E., and Ellis, A. J., Ground water in Paradise Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 375, 1915.

Meinzer and Ellis[3] believed that the drainage basin of Cave Creek is important with respect to Paradise Valley. They state:

> "...Cave Creek, an intermittent stream that drains about 225 square miles of mountainous country north of Paradise Valley, formerly no doubt flowed southward through Paradise Valley but now flows across only the northwest corner of this valley...Paradise Valley is closely related to Cave Creek in both its physiographic history and its ground-water supply,..."

The valley floor slopes generally southward and the axial draw lies near the Phoenix Mountains. The surface gradient in the central and lower parts of the valley ranges from 25 to 30 feet to the mile. The surface gradient increases to well over 100 feet to the mile in the northern part of the valley and along the McDowell Mountains on the northeast side.

The McDowell Mountains on the northeast side of the valley have a maximum altitude of 4,022 feet above sea level. They form an unbroken chain from the outlet of Paradise Valley northward to the granitic plateau that extends toward the headwaters of Cave Creek. The Phoenix Mountains on the west side of the valley have a maximum altitude of about 2,700 feet above sea level. The Phoenix Mountains are partly buried in alluvial fill, which extends through some of the lower saddles. Both mountain ranges are rugged. Their slopes are precipitous and have little or no soil.

GEOLOGY

The descriptions of all rocks of greater age than Quaternary are grouped under the heading "pre-Quaternary rocks" in this report, because only the Quaternary rocks are of hydrologic importance.

Pre-Quaternary rocks

Pre-Cambrian rocks

Igneous and metamorphic rocks of pre-Cambrian age form the major part of the Phoenix and McDowell mountain ranges. In the order of their abundance, these rocks include schists, granites, quartzites, gneisses, and slates.

The pre-Cambrian schists that constitute a major part of the Phoenix Mountains and a large part of the McDowell Mountains are of varying composition. Pods and lenses of massive quartz are of frequent occurrence and both jasper and epidote are usually abundant. Slate commonly occurs with the schist in the Black Mountain area directly south of Cave Creek Station.

In both the Phoenix and the McDowell Mountains the schists are cut by intrusions of porphyritic and fine-grained granitic rocks. None of the intrusive rocks observed are of great size nor have they caused marked effects upon the attitude of the enclosing rocks. The intrusive rocks have produced some metallic mineralization of the schist at various places in both mountain ranges, but in no place thus far observed has the mineralization been of sufficient extent to be of commercial importance. Narrow pegmatite dikes cutting the dark gray

[3] Meinzer, O. E., and Ellis, A. J., op. cit. p. 51.

sericite and mica schists are exposed along the south face of the hills in sec. 4, T. 2 N., R. 4 E. These dikes are deeply weathered and disintegrate rapidly at the surface.

The schists have a predominantly northeast strike and have a generally steep southeast dip, apparently as a result of block tilting. Folding is slight or absent in the schists, and although faulting has probably been extensive it is largely obscured.

The outcrops of steeply-tilted schists appear to be conducive to the downward percolation of surface moisture. However, exposures in numerous mine shafts and prospect pits indicate that the schists are extremely hard and compact more than a few feet below the surface. Therefore, the effectiveness of the schists as a medium for the storage or transmission of ground water is slight.

Granites of at least three varieties have been observed in the Phoenix and McDowell Mountains. The most common and most widely distributed variety is a medium-coarse to very coarse-grained, light gray rock composed of orthoclase feldspar, quartz, and biotite mica, and it contains many inclusions of a darker porphyritic rock. This granite forms the northern end of the McDowell Mountains and the plateau that extends to the headwaters of Cave Creek. The granite weathers readily into large, rounded boulders. This granite is the source of the arkosic material that covers most of the upper part of the valley.

The same variety of granite is found in the Phoenix Mountains near Cave Creek (secs. 22 and 27, T. 4 N., R. 3 E.). In this locality the granite is of smaller grain size than that in the McDowell Mountains. A fine-grained biotite occurs in the same locality as an intrusion into the older granite. This intrusive granite is not as highly altered as the older enclosing rock. It is exposed on the surface and in the underground workings of the Jack White mine (SW cor. sec. 15, T. 4 N., R. 3 E.).

The third variety of granite observed is a coarse-grained, pink rock, heavily chloritized and kaolinized, which forms the eastern portion of Camelback Mountain, sec. 16, T. 2 N., R. 4 E.

Gneiss is exposed in a small area on the west side of the Phoenix Mountains, outside the limits of Paradise Valley (pl. 1, sec. 19, T. 3 N., R. 3 E.).

Small areas of fine-grained quartzite associated with schist are exposed in the McDowell and Phoenix mountain ranges (pl. 1). The quartzites are not water-bearing.

Older sedimentary rocks

No sedimentary rocks older than Quaternary were found within the limits of Paradise Valley but an outcrop of such rocks was found on the western end of Camelback Mountain (secs.17 and 18, T. 2 N., R. 4 E.) and is shown on plate 1 as "older sedimentary rock".

Older volcanic rocks

Volcanic rocks, most of which are of Cretaceous or early Tertiary age are widely distributed. They consist of rhyolite, dacite, andesite, diabase, and basalt, and occur in numerous places in the hills and mountains that border Paradise Valley. In the hills extending northwest from Cave Creek Dam and in a parallel range of hills 3 miles farther north the volcanic rocks have been extensively metamorphosed. Definite schistosity (platy structure) has been developed in some areas, but metamorphism has not progressed sufficiently to obscure the original rock constituents.

In general, the pre-Quaternary volcanic rocks are impermeable except along faults or fracture zones. A notable exception is in sec. 16, T. 5 N., R. 5 E., where a well drilled on the Brown Ranch obtained a good supply of water in these rocks.

Quaternary formations

Vesicular basalt and the alluvial fill that appears at the surface in Paradise Valley are the only formations that can definitely be assigned to the Quaternary system.

Basalt

Rather thin flows of dark gray and reddish-brown vesicular basalt cover small areas on both sides of Paradise Valley. Wells have been drilled through this rock into the underlying alluvium, thereby definitely establishing the age of the basalt as Quaternary. Weathering causes a rapid surface disintegration of the basalt into rounded boulders and clay. The clay effectively limits the depth to which the weathering may penetrate. For this reason the basalt cannot be considered of importance for the storage or transmission of water.

Alluvial fill

The great mass of alluvial fill that has been deposited within the rock trough of Paradise Valley is, so far as can be determined from exposures and well logs, similar in character to the materials found in the other basins of this region. The lower and central portions of the floor of Paradise Valley are covered with a brownish-colored silt. Toward the northern end of the valley this grades into a sandy silt, which in turn grades into a coarse, arkosic sand where the valley approaches the granitic borders on the northeast and north. Layers of caliche occur at or near the surface in many localities around the edges of the valley. Beneath the surficial materials there extends downward, to undertermined depths, a succession of sediments derived from adjacent highlands to the north, east, and west. These sediments are clays, silts, caliche, sands, and gravels. Beds of any one type of material are not continuous, either vertically or laterally, for any great distance, nor are they in any definite order of succession. The logs of two wells drilled in close proximity generally differ from top to bottom, so that the logs of wells cannot be used to predict the depth at which any particular material may be anticipated.

Source of alluvial fill.-The presence of large boulders and the subangular form of the gravels in the alluvial fill of Paradise Valley indicate that this material has not been transported a great distance. A part of the fill in Paradise Valley was deposited by Cave Creek, although it is possible that some of the material was brought into the valley by streams that formerly drained the New River-Agua Fria area. The series of hills extending northwest along the axis of the Phoenix Mountains, from Cave Creek Dam to the high country west of the Agua Fria River, form a chain in which the gaps are the outlets for Skunk Creek, New River, and the Agua Fria River. Remnants of Tertiary or younger lava flows occur at many places along this line of hills. It is possible that these lava flows obstructed the channels of the above-named streams, forcing them to follow temporary southeasterly courses into Paradise Valley. Large quantities of material have been required to fill the structural trough of Paradise Valley and its continuation between the north end of the Phoenix Mountains and the main mountain mass to the north, and it is difficult to attribute the source of this debris to the comparatively small drainage areas of Cave Creek and the adjacent washes. A logical assumption would be that at least a substantial portion of this debris came from the much greater drainage areas of New River and the Agua Fria River.

The filling of Paradise Valley probably occurred during several different stages of deposition. The character of the deepest deposits is unknown, but wells in the valley have penetrated stream-laid material to depths of more than 800 feet. The alluvial fill near the surface in Paradise Valley is Quaternary in age, but some of the deeper fill is possibly Tertiary. As no fossils have been found in the fill, no definite statement can be made as to the age of the alluvial fill, except that the upper part is Quaternary.

The maximum thickness of alluvial fill in Paradise Valley is not known, although several wells have been drilled to 800 feet and one well (No. 1782) has been drilled to 972 feet. Not one of these wells is known to have encountered bedrock, and for this reason the depth of fill is assumed to be at least 1,000 feet. The alluvial fill in the Mesa-Tempe area immediately south of Paradise Valley is known to be more than 1,300 feet in thickness[4].

A series of stream terraces such as occur in some other valleys was not observed in Paradise Valley, although stream terraces are prominent along the Salt, Agua Fria, and Verde Rivers. If a series of terraces existed in Paradise Valley they have been completely obliterated. The floor of Paradise Valley and its continuation to the northwest corresponds to the third or highest terrace of the Agua Fria River. The absence of terracing throughout the northwest continuation of Paradise Valley, as well as in the valley itself, suggests that some factor in addition to changing climatic conditions was responsible for the formation of terraces along the Agua Fria River. Climatic changes alone presumably would have produced similar results over the entire area. The terraces on the Agua Fria River might have been formed as the stream cut its way downward through successive barriers of Tertiary or later lava flows. There has been no erosion in Paradise Valley similar to that which has exposed a rather extensive area of conglomerate along the upper Agua Fria River.

It is probable that a similar conglomerate also underlies the upper portion of the alluvial fill in parts of Paradise Valley. A similar formation in other parts of Arizona is known as the Gila conglomerate. It is possible that some of the cemented sand and gravel reported in the logs of wells in Paradise Valley may be Gila conglomerate. No surface exposure of this formation has been found in the valley.

4/ Lee, W. T., Underground waters of Salt River valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 136, p. 115, 1905.

Water-bearing beds of sand and gravel occur throughout Paradise Valley. The most productive aquifers in the valley are the coarse sand and gravel strata which, presumably, mark the old buried channels of Cave Creek, New River, and Agua Fria River. These aquifers are widely and irregularly distributed in the southern part of the valley, owing probably to the meandering of the streams as their gradient diminished. In the northern part of the valley two wells (Nos. 1782 and 1787) have standing water levels 670 and 626 feet below the surface, respectively. Wells 1781 and 1783 were dry. The failure to find water in these wells does not necessarily indicate the absence of aquifers but may indicate that the wells did not penetrate to sufficient depths to enter saturated beds. Deeper drilling in this part of the valley will probably show the presence of water in quantities sufficient for domestic and stock use, but the high pumping lift required would make it uneconomical to use the water for most agricultural purposes. The writers found no structural features in the valley or in the bordering mountains that would indicate the presence of artesian water in Paradise Valley. In the northeast part of T. 5 N., R. 4 E., seven wells have standing water levels less than 150 feet below the surface (table 3, pl. 1), showing the presence of a zone of saturation above the underlying granite pediment. The ground water is much nearer the surface on the granite pediment than in the part of the valley to the southwest.

GROUND WATER

Occurrence

Ground water occupies the pore spaces of the lower part of the alluvial fill of Paradise Valley. The alluvial fill is comprised of alternating, relatively discontinuous lenses of clay, silt, caliche, sand, and gravel. Tables 3 and 6 list records of wells in the valley. Table 4 gives logs of wells in the valley, and tables 5 and 7 give analyses of water samples. In the southern part of the valley, recently-drilled wells have penetrated aquifers of relatively high permeability and are reported to produce as much as 1,800 gallons a minute with drawdowns of 30 to 50 feet. It is reported that wells located in secs. 11 and 12, T. 2 N., R. 4 E., penetrate the principal aquifers at depths of 100 to 150 feet and that a well about 1 mile farther south, drilled to a depth of 450 feet, failed to penetrate any highly productive aquifer below a depth of approximately 150 feet. The depth to water in this area is about 100 feet. The depth to water increases rapidly to the north, and therefore the pumping of water for irrigation is uneconomical more than 2 or 3 miles north of the Arizona Canal. Farther north (NW¼ sec. 14, T. 3 N., R. 4 E.), at the U. S. Army Cadet Training School (Thunderbird No. 2), the wells are not as productive, each well yielding less than 200 gallons a minute with a drawdown of about 160 feet, according to reports. It is possible that wells of larger yield might be obtained in this area if the deposits representing the buried channels of Cave Creek could be located. North of Thunderbird Field there is ground water in sufficient quantity for domestic and stock use. However, because the slope of the water table is less than the slope of the land surface, the depth to water in the deep alluvial fill increases rapidly, both northward along the axis of the valley and toward the mountains on each side. Ground water is found within 150 feet of the land surface in the area underlain by shallow bedrock in the northeastern part of T. 5 N., R. 4 E., as stated previously, and in the western part of T. 5 N., R. 5 E.

Measurements of water level could not be obtained in enough wells during the present investigation of Paradise Valley to determine ground-water contours. Most of the old wells have been destroyed, or they have caved because the casings have disintegrated. A pumping test was made on an irrigation well near the Arizona Canal, (well 1618, pl. 1 and tables 3 and 4), to determine the water-bearing characteristics of the principal aquifer. This well is owned by the Salt River Valley Water Users' Association. As the pumping did not measurably affect the water levels in other wells during the test, the recovery method described by Theis5/ was used to compute permeability. The well was not pumped for several days prior to the test, so that the cone of depression caused by previous pumping from the well had almost disappeared. The well was then pumped continuously for 7 days and shut down. The recovery of the water level was then measured for 5 days. An unused well about 1 mile distant was measured periodically to determine regional changes in water levels during the test. The transmissibility was computed to be 116,000 gallons per day per foot, that is, 116,000 gallons per day through a section of the complete aquifer a mile wide under a gradient of 1 foot per mile.

Recharge

The channel of Cave Creek throughout its length is underlain by gravelly material, and the seepage from stream-flow upon this material constitutes the principal source of recharge to the ground-water reservoir. The stream-bed material is poorly sorted and unconsolidated and the particles range in size from fine sand up to boulders several feet in diameter. The material appears to be highly permeable.

Recharge to the ground-water reservoir of Paradise Valley may be attributed to four sources: perennial flow in the upper reaches of the channel of Cave Creek, flash floods caused by violent summer storms in the drainage basin of Cave Creek, flash floods in the sandy beds of the larger washes that drain the Phoenix and McDowell mountains, and seepage into materials that underlie the Arizona Canal. It has been found in tests on Queen Creek6/ and on the Santa Cruz River and Rillito Creek7/ that clear water from slow winter rains percolates into the material underlying the stream channel up to 15 times faster than does silty water from flash floods. Several springs near the sources of Cave Creek, the most important being Seven Springs, flow throughout the year.

5/ Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pp. 519-524, 1935.

6/ Babcock, H. M., and Cushing, E. M., Recharge to ground-water from floods in a typical desert wash, Pinal County, Ariz.: Am. Geophys. Union Trans., Reports and papers, Hydrology, pp. 49-56, 1942.

7/ Turner, S. F., and others, Ground-water resources of the Santa Cruz Basin, Ariz.: U. S. Geol. Survey (mimeographed), pp. 45-53, 1943.

There is considerable evidence that the major portion of the underflow of Cave Creek follows some of the old buried stream channels. The water table slopes downward from north to south through the valley, indicating that the source of supply is near the upper end of the valley. The foundation of Cave Creek Dam probably rests upon impermeable bedrock and any underflow of Cave Creek at this place presumably would be forced to the surface. Inasmuch as no underflow has been observed it is probable that the underflow of Cave Creek follows some ancient channel to the east of the dam. Furthermore, at the place where Cave Creek flows west through the Phoenix Mountains, 2½ miles south of the dam, impermeable schist lies very near the surface, and this rock constricts the stream passage to an opening not more than 100 yards in width. This barrier should bring any remaining underflow of Cave Creek to the surface, but no surface flow appears at this place. In addition, the vegetation in this constriction does not differ in character or size from that elsewhere along the channel, as it would if ground water were forced near the surface.

There is a possibility that some of the underflow of Cave Creek may move westward into the basin of Skunk Creek, in Deer Valley, from some point north of Cave Creek Dam. The surface divide between the two streams is low and indefinite and no evidence of a buried hard-rock barrier has been observed. As there are very few wells in the vicinity, there are no data to indicate the slope of the water table through this area.

Throughout the entire length of Paradise Valley there is no indication of the presence of any rock barrier across the valley, nor is there any appreciable constriction at the lower end where it merges with the Salt River Valley. There are, undoubtedly, buried ridges that extend some distance laterally into the valley from both the Phoenix and the McDowell ranges, but it is unlikely that any of these go far enough to constitute an obstruction to the flow of ground water.

Recharge from runoff in small washes and drainage channels that originate in the McDowell and Phoenix mountains is probably less than that from runoff in Cave Creek. These mountains receive less precipitation than those near the headwaters of Cave Creek because of their lower altitude. Runoff from washes that drain the Phoenix and McDowell mountains probably flows over permeable materials for a short distance near the edges of the mountains. The runoff that does not seep into these materials flows onto areas underlain by almost impermeable layers of silt and caliche and is evaporated and transpired.

Recharge to the ground-water reservoir from direct rainfall upon the silt-covered valley floor is probably slight. Tests in the Eloy area of the lower Santa Cruz River[8/] [9/] and in the Queen Creek area of Pinal County show that practically no recharge occurred from rainfall on the desert.

8/ Smith, G. E. P., The ground-water supply of the Eloy District in Pinal County, Ariz.: Univ. of Ariz. Tech Bull. 87, pp. 12-13, 1940.

9/ Turner, S. F., and others, Ground-water resources of the Santa Cruz River Basin, Ariz.: U. S. Geol. Survey (mimeographed), pp. 53-55, 1943.

Recharge from water in the Arizona Canal and from irrigation south of the canal has contributed to the ground-water reservoir of Paradise Valley. Before the canal was built the water table in the valley sloped downward to the south. After the canal was built, recharge from it caused a ground-water ridge to develop under the canal, and in 1914 the effects of this ridge extended about 5 miles to the north (see fig. 1). Pumpage since 1914 has reduced this ridge and reestablished the profile that existed prior to the building of the canal. Samples of well water from the north side of the canal are lower in chloride and hardness than samples from the south side, indicating that most of the water that seeps from the canal, which is relatively salty, now moves southward to the heavily-pumped Salt River Valley.

Discharge and annual safe yield

Both natural and artificial discharge, or pumping, occur from the Paradise Valley ground-water reservoir. It is possible that some natural discharge occurs through the gap in the Phoenix Mountains north of Cave Creek Dam. Probably the greatest quantity of natural discharge from Paradise Valley occurs at the entrance to the Salt River Valley. This discharge was probably large before the Arizona Canal was built. The underground flow was then dammed by the ground-water ridge that formed beneath the canal. This ridge apparently reached its maximum height about 1920. As stated previously, it has since been reduced by pumping. Figure 1 shows that in 1945 the water table near the Arizona Canal was 40 feet lower than in 1914, and that there was a discharge of ground water from Paradise Valley to the Salt River Valley.

There was very little pumping in the central and lower parts of Paradise Valley until about 1940, when the first land was irrigated by water pumped from wells. During 1944 about 5,000 acre-feet of water was pumped in this area for irrigation.

The annual safe yield of Paradise Valley as a whole is approximately equal to the underflow out of the valley. As computed from the following factors, the underflow out of the valley is estimated to be about 6,700 acre-feet a year:

(1) the transmissibility of the aquifer;

(2) the slope of the water table;

(3) the width of the section through which underflow occurs.

The average transmissibility of the aquifer is assumed to be roughly equal to that determined by the pumping test previously described, although additional pumping tests would be desirable to obtain a more reliable figure. A round figure for transmissibility of 100,000 gallons per day per foot is assumed. The slope of the water table was determined from figure 1 to be about 10 feet per mile, and the width of the section through which underflow occurs is estimated to be 6 miles. The underflow may then be computed as 100,000 times 10 x 6 or 6,000,000 gallons per day. This is equal to 9.3 second-feet or 6,700 acre-feet per year.

QUALITY OF WATER

By J. D. Hem

Chemical character of the ground water

The chemical character of ground water in Paradise Valley was determined from the analyses of 16 samples of water from the valley. These analyses show that most of the ground waters of the valley contain small to moderate amounts of dissolved mineral matter. Ground water in most of the alluvial fill of the valley contained from 175 to 350 parts per million of dissolved solids. Near the Phoenix Mountains a few samples were obtained that were more highly mineralized, containing 500 to 1,000 parts per million of dissolved matter. At the lower end of the valley, near the Arizona Canal, some samples were collected that contained 1,000 to 1,800 parts per million.

The more dilute waters of the alluvial fill in Paradise Valley contain mainly calcium, magnesium, and bicarbonate. The more highly-mineralized waters near the Phoenix Mountains contain mainly calcium, magnesium, and sulfate. The ground waters near the Arizona Canal contain mainly sodium and chloride. The analyses are included in table 5.

Chemical character of the surface water

The surface streams in the valley are all ephemeral, and no samples of their waters were collected. However, waters of ephemeral streams in the Santa Cruz River Basin are not highly mineralized[10], and it is probable that waters of ephemeral streams in Paradise Valley contain relatively small amounts of dissolved matter. The surface flow of the Arizona Canal is composed mainly of water diverted from the Salt River at Granite Reef Dam. The water of the Salt River at Granite Reef is generally moderately mineralized, containing mostly sodium and chloride.

Relation of quality of water to use

Nearly all of the waters of Paradise Valley may be considered "excellent to good"[11] for use in irrigation. The more highly mineralized waters near the Arizona Canal contain more chloride and have a higher percentage of sodium and are classed as "good to injurious" for use in irrigation.

The waters of Paradise Valley are hard, and some of them may contain enough dissolved matter to impart a slight taste. In some parts of the valley the ground waters contain sufficient concentrations of fluoride to cause mottling of the tooth enamel in children who drink the waters. The highest concentration of fluoride found in the valley was 3.2 parts per million. The water sample containing this quantity of fluoride came from well 1776, in the granite pediment area in the northeast corner of the valley. Two of the more highly mineralized water samples from Paradise Valley were collected near the Phoenix Mountains and they contained between 2.0 and 3.0 parts per million of fluoride.

10/ Turner, S. F., and others, Ground-water resources of the Santa Cruz Basin, Ariz.: U. S. Geol. Survey (mimeographed), p. 76, 1941.

11/ Wilcox, L. V., and Magistad, O. C., Interpretation of analyses of irrigation waters and the relative tolerance of crop plants: U. S. Dept. Agr., Bur. Plant Industry, Soil and Agr. Research Admin.; Riverside, Calif. (mimeographed), 8 pp., May 1943.

Relation of quality of water to recharge

The low mineral content of most ground waters in Paradise Valley indicates that the principal source of these waters is infiltration from ephemeral streams. The ground water near the Arizona Canal is similar in chemical character to the water of the Salt River. This similarity indicates that the canal supplies a considerable amount of recharge to the southern part of Paradise Valley. The extent of the area affected by recharge from the canal cannot be determined from the available analyses.

The report by Meinzer and Ellis[12] on Paradise Valley in 1914 included analyses of a few ground-water samples. Comparison of these analyses with analyses made in 1946 indicates that the mineral content of ground waters north of Scottsdale, along the Arizona Canal, has increased. This increase probably is a result of recharge from the canal since 1914.

The comparatively high mineral content of a few samples from wells near the Phoenix Mountains may be due to recharge from deep-seated inflows, possibly through fault openings, or to the presence of sediments containing soluble matter in the alluvial fill of these areas. Recharge to the alluvial fill from fault springs in the valley is probably insignificant in amount, because the areas where waters of higher concentration were found are small.

Discharge of dissolved solids

The only means by which significant quantities of soluble matter can be discharged from Paradise Valley is through ground-water underflow into the Salt River Valley to the south.

Excessive pumpage in the southern part of Paradise Valley might stop underflow from the valley and cause more highly-mineralized water to enter from the Salt River Valley. This would result in an increase in the mineral content of ground water in the pumped areas to approximately the same concentration as that of waters in the neighboring part of the Salt River Valley. It is likely that if all underflow from Paradise Valley were prevented, salts would accumulate in the ground water in the valley because of return flow from irrigation.

SUMMARY AND CONCLUSIONS

The alluvial fill of Paradise Valley is the principal ground-water reservoir. This reservoir is recharged mainly from flows in Cave Creek. Some recharge probably occurs along slopes near the mountains and from washes and other drainage channels on the desert. Recharge from the Arizona Canal and from irrigation with canal water in the area to the south has contributed to the ground-water reservoir of Paradise Valley. Before the canal was built the water table in the valley sloped toward the south. After the canal was built, recharge from it caused a ground-water ridge to develop under the canal, and in 1914 the effect of this ridge in damming underflow from the north extended about 5 miles north (see fig. 1).

12/ Meinzer, O. E., and Ellis, A. J., Ground water in Paradise Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 375, 1915.

Wells in the southern part of Paradise Valley produce as much as 1,800 gallons a minute from aquifers of relatively high permeability. Farther north wells have not been as productive but wells of larger yield might be obtained if the deposits representing the buried channels of Cave Creek could be located.

Nearly all of the waters of Paradise Valley may be considered "excellent to good" for irrigation use. The more highly mineralized waters near the Arizona Canal contain enough chloride and sodium to be classed as "good to injurious" for irrigation use.

For domestic use the ground waters of Paradise Valley are generally satisfactory although somewhat hard. In some parts of the valley the ground waters contain concentrations of fluoride sufficient to cause mottling of the tooth enamel in small children.

The safe yield of the ground-water reservoir in Paradise Valley is estimated to be about 6,700 acre-feet, but an intensive investigation might show a somewhat different value. Because the withdrawal of ground water in Paradise Valley now appears to be at or near the safe yield, it is believed that additional large-scale developments either by private enterprise or by the City of Phoenix will cause a depletion of storage and eventual encroachment of highly mineralized water. Therefore, any development of ground water in Paradise Valley by the City of Phoenix should be considered only a temporary expedient.

Table 1. Summary of climatological data, 1940-44, Bartlett Dam, Maricopa County, Arizona.
(From records of U. S. Weather Bureau)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean max. temp., °F.	64.5	67.2	70.5	78.9	90.8	98.7	105.3	101.9	98.1	86.6	76.5	67.0	84.7
Mean min. temp., °F.	41.5	43.0	45.1	50.4	58.6	65.5	75.2	74.0	68.7	58.6	48.5	42.5	55.9
Mean temp., °F.	53.1	55.1	57.8	65.4	74.7	83.7	89.8	88.5	83.6	72.9	62.0	55.2	70.0
Extreme max. temp., °F.	80	89	92	100	105	112	115	115	109	102	87	84	115
Extreme min. temp., °F.	26	29	33	39	43	50	60	58	56	43	35	29	26
Mean precipitation, in.	1.39	1.59	1.55	.95	.38	.06	.79	1.14	1.22	.98	.94	2.76	13.9
Greatest monthly precip., in.	2.51	3.61	4.15	3.20	1.02	.28	1.54	2.43	1.72	2.32	2.28	6.49	24.31
Year of occurrence	1941	1941	1941	1941	1941	1940	1941	1943	1941	1940	1941	1940	1941

Table 2. Summary of climatological data, 1896-1944, Phoenix, Maricopa County, Arizona
(From records of U. S. Weather Bureau)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean max. temp., °F.	65.1	68.9	74.6	82.4	91.1	101.1	103.5	101.4	97.2	86.4	74.8	65.7	84.4
Mean min. temp., °F.	38.9	42.7	47.0	53.0	60.3	69.2	77.2	76.0	69.2	56.3	45.4	39.6	56.2
Mean temp., °F.	52.0	55.7	60.8	67.7	75.7	85.1	90.4	88.7	83.2	71.4	60.1	52.6	70.3
Extreme max. temp., °F.	84	92	95	103	114	118	118	115	112	105	96	84	118
Extreme min. temp., °F.	16	24	30	35	39	49	63	58	49	36	27	22	16
Mean precipitation, in.	0.80	0.86	0.71	0.43	0.13	0.07	1.02	0.98	0.88	0.44	0.68	0.94	7.94
Greatest monthly precip., in.	3.67	4.64	4.82	3.36	1.31	0.75	6.47	4.92	5.41	2.30	3.61	3.75	19.73
Year of occurrence	1897	1905	1941	1926	1930	1899	1911	1943	1939	1914	1905	1940	1904

Table 3. Records of domestic and irrigation wells in Paradise Valley, Maricopa County, Arizona

No.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (in.)
	T.5 N.,R.5 E.					
1036	NE¼ sec. 16	E. E. Brown	-	1945	800	8
1037	NE¼ sec. 17	-	-	-	39	6
1038	NE¼ sec. 31	K. T. Palmer	-	-	120	-
1039	SW¼ sec. 33	Reginald Phillips	-	-	-	8
1040	SE¼ sec. 33	do.	-	1941	110	8
1041	SW¼ sec. 33	do.	-	-	58	8
	T.3 N.,R.5 E.					
1061	NW¼NW¼ sec. 29	W. L. Brooks	-	-	-	6
	T.2 N.,R.4 E.					
1601	SW¼SW¼ sec. 2	McCormack	C.W.Freelove	1940	405	20
1602	NE¼ sec. 2	do.	Roscoe Moss	1944	450	20
1603	NE¼SE¼ sec. 3	do.	-	1944	-	6
1604	NE¼SE¼ sec. 3	Van Ben Schuter	-	-	248	6
1605	NE¼NW¼ sec. 10	Wick and Fields	-	-	210	6
1606	SE¼SE¼ sec. 10	Ruth S. Melin	-	-	-	-
1607	do.	Mollie J. Smith	-	-	265	-
1608	SW¼NW¼ sec. 11	R. D. Searles	-	1945	215	12
1609	SE¼NE¼ sec. 11	Salt River Valley Water Users' Assn.	E. N. Brown	1925	283	24
1610	NW¼SW¼ sec. 15	Martin	Fred Beaucamp	1927	202	20

a/ Measuring point was usually top of casing, top of pump base, top of water pipe clamp, or top of well curb.

b/ C, cylinder; T, turbine; G, gasoline; E, electric motor; W, windmill; H, hand.

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Remarks
1036	-	-	C,G	D,S	Reported discharge 30 gallons a minute. See log.
1037	28.0	June 7, 1946	C,G	D,S	-
1038	-	-	C,G	D,S	-
1039	50 e/	June 1946	C,G	D	Reported depth to water 22 feet in Aug. 1943.
1040	37.5 e/	Feb. 1946	None	N	-
1041	50 e/	do.	C,G	D	-
1061	180.4	Nov.10, 1944	C	N	-
1601	116	Oct.10, 1944	T,E	I	-
1602	119.2	do.	T,E	I	-
1603	113.5	do.	None	N	-
1604	210 e/	Apr. 1946	C,E	D	-
1605	-	-	T,E	P	-
1606	-	-	C,E	D	-
1607	-	-	C,E	D	Reported to produce 2 to 3 gallons a minute.
1608	122 e/	Jan. 1946	None	N	See log.
1609	100.5 e/	Dec. 1945	T,E	I	Do.
1610	125 e/	July 1945	T,E	I	Do.

c/ D, domestic; S, stock; I, irrigation; P, public supply; N, none.
d/ See table of analyses for analysis of water from this well.
e/ Water level reported.

Table 3. Records of domestic and irrigation wells in Paradise Valley-Cont.

No.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (in.)
1611	NE¼ sec. 15	Ellis	-	1944	176	10
d/1612	NE¼NW¼ sec. 24	Salt River Valley Water User's Assn.	E. N. Brown	1925	161	20
d/1613	NE¼NE¼ sec. 25	City of Phoenix	Aubrey Lyons	1941	300	20
d/1614	NW¼NE¼ sec. 25	do.	do.	1941	800	20
d/1615	NE¼NW¼ sec. 25	do.	do.	1941	455	20
d/1616	SE¼SW¼ sec. 25	Salt River Valley Water User's Assn.	Scott Coburn	1929	197	20
d/1617	NW¼ sec. 35	do.	Roscoe Moss	1941	250	20
1618	SE¼NW¼ sec. 12	do.	-	1925	165	24
	T.3 N.,R.4 E.					
1701	NW¼SW¼ sec. 15	F. Caswell	-	Prior to 1914	176	60
1702	NE¼NW¼ sec. 1	E. E. Brown	-	-	600	-
1704	NE¼NE¼ sec. 6	Harvey Bell	-	-	300	6
1705	SW¼SE¼ sec. 6	Stanley Yori	W. L. Brooks	1930	318	6
1706	SW¼SW¼ sec. 8	H. E. McLain	-	1910	200	6
1707	do.	do.	W. L. Brooks	1929	300	12
1708	SW¼SW¼ sec. 9	C. A. Anderson	-	-	200	-
1709	NW¼NW¼ sec. 14	Defense Plant Corp.	Hayward and Connelly	1942	800	12
1710	NW¼NW¼ sec. 14	do.	do.	1942	507	12
1711	SE¼SE¼ sec. 15	-	-	-	194	6
1712	SE¼SE¼ sec. 17	-	-	-	168	6
d/1713	NE¼ sec. 24	Thomas	-	-	365	6
1714	NW¼NW¼ sec. 34	Doubletree Ranch	-	-	150	6

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Remarks
1611	130e/	Apr. 1944	T,E	I	-
1612	81.5	Jan. 1946	T,E	I	See log.
1613	75e/	Feb. 1941	T,E	P	Do.
1614	61e/	1941	T,E	P	Do.
1615	68e/	1941	T,E	P	Do.
1616	62e/	Dec. 1945	T,E	I	Do.
1617	58e/	do.	T,E	I	Do.
1618	106.8	Dec. 20, 1945	T,E	I	Discharge about 550 gallons a minute.
1701	172.85	Oct. 24, 1945	C,W	S	See well 19, table 6.
1702	400e/	Mar. 1946	C,G	D,S	-
1704	240e/	Sept. 1945	C,G	D	See well 8, table 6.
1705	210e/	Apr. 1946	C,G	D	-
1706	185e/	do.	None	N	-
1707	187e/	do.	C	N	-
1708	184e/	Mar. 1946	C,W	D	-
1709	208	Apr. 24, 1945	T,E	P	See log.
1710	210	Oct. 14, 1944	T,E	P	Do.
1711	166.32	Mar. 24, 1946	None	N	-
1712	162.52	Apr. 26, 1946	None	N	-
1713	-	-	C,G	S	-
1714	-	-	C,E	D,S	See well 35, table 6.

Table 3. Records of domestic and irrigation wells in Paradise Valley-Cont.

No.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (in.)
d/ 1715	SW¼NW¼ sec. 35	Cheney	-	-	-	20
1716	NE¼SE¼ sec. 36	Fowler McCormack	-	1944	300	20
	T.4 N.,R.4 E.					
d/ 1751	NE¼NE¼ sec. 29	D. Vondracek	Houck	-	355	6
d/ 1752	NW¼SW¼ sec. 30	do.	do.	-	300	6
1753	SW¼SW¼ sec. 31	S. E. Fezell	-	1928	300	6
1754	do.	Fred Disera	W. L. Brooks	-	300	6
1755	do.	Decker	do.	-	300	6
1756	SE¼SE¼ sec. 35	Christiansen	-	-	-	8
	T.5 N.,R.4 E.					
d/ 1776	SW¼ sec. 1	S. M. Wiley	-	-	277	-
1777	cen. sec. 1	-	-	-	176	-
1778	SE¼ sec. 3	F. W. Donars	-	-	160	-
d/ 1779	SW¼ sec. 3	Joe Marta	-	-	142	-
1780	SE¼ sec. 3	Ruby Howard	-	-	97	-
1781	NW¼ sec. 5	Josephine Stewart	-	-	254	-
d/ 1782	NE¼ sec. 7	Walter F. Salyer	-	-	972	-
1783	SW¼ sec. 9	-	-	-	375	-
1784	NE¼ sec. 14	-	-	-	104	-
1785	SE¼ sec. 15	-	-	-	807	-
1786	NW¼ sec. 24	-	-	-	100	-
1787	SE¼ sec. 29	Milton D. Smith	-	-	686	-

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Remarks
1715	-	-	T,E	I	-
1716	166	Oct. 14, 1944	T,E	I	Reported discharge 1,300 gallons a minute.
1751	330e/	Nov. 1945	C,G	S	-
1752	266e/	do.	C,G	D,S	See well 5, table 6.
1753	235e/	Oct. 1945	C,G	D	-
1754	-	-	C,W	D	-
1755	-	-	C,W	D	-
1756	302.6	Apr. 26, 1946	C,G	D,S	-
1776	-	-	C,G	D,S	-
1777	85e/	June 1946	C,G	D,S	-
1778	133e/	do.	C,G	D,S	-
1779	130e/	do.	C,G	D,S	-
1780	31.0	do.	C,G	D,S	-
1781	dry	do.	None	N	-
1782	670e/	do.	C,W	D,S	-
1783	dry	June 1946	None	N	-
1784	44.0	June 4, 1946	C,G	D,S	-
1785	dry	June 6, 1946	None	N	-
1786	51.0	June 4, 1946	C,G	D,S	-
1787	626e/	June 1946	C,G	D,S	-

Table 3. Records of domestic and irrigation wells in Paradise Valley-Cont.

No.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (in.)
	T.5 N.,R.3 E.					
1866	SE¼SE¼ sec. 33	J. J. Hendricks	-	-	31	4
1867	SW¼SW¼ sec. 34	do.	-	1945	-	8
	T.4 N., R.3 E.					
1886	NW¼SE¼ sec. 34	A. D. Hendricks	-	1945	219	8
1887	NE¼SW¼ sec. 3	James Seeley	-	-	36	48
1888	SW¼NW¼ sec. 15	Paul Versluis	-	-	-	6
1889	SE¼SE¼ sec. 22	Shumway	-	-	250	6
d/ 1890	NW¼SE¼ sec. 27	H. E. Myers	-	1938	152	2½
1891	SE¼SE¼ sec. 27	-	-	-	264	6
1892	NE¼NE¼ sec. 34	C. F. Boyer	-	-	230	6
1893	NW¼NE¼ sec. 34	C. V. Dent	Joe Yousko	1946	-	-
1894	SW¼SE¼ sec. 34	Wheeler	-Stewart	-	218	6
d/ 1895	SW¼SW¼ sec. 35	A. J. Norris	A. H. Vaughn	-	203	6
1896	do.	do.	Joe Yousko	-	242	8
	T.3 N.,R.3 E.					
1906	SW¼SW¼ sec. 1	- Maxwell	- Kinney	-	300	8
d/ 1907	SW¼NW¼ sec. 2	H. J. Love	Wm. Hinton	-	246	8
1908	NE¼NW¼ sec. 2	J. M. Roeder	R. M. Holmes	-	226	8
1909	SW¼SE¼ sec. 2	Rudy Sanders	do.	-	237	6
1910	SW¼NE¼ sec. 3	J. O. Shipp	do.	-	202	-
1911	NW¼NE¼ sec. 3	Dave Holmes	do.	-	194	-

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Remarks
1866	30	Apr. 24, 1946	C,W	D,S	-
1867	-	-	C,W	S	-
1886	185.2	Nov. 7, 1945	C,G	D	-
1887	33.25	Apr. 24, 1946	C,H	S	-
1888	-	-	C,G	D,S	-
1889	-	-	C,G	D,S	-
1890	98e/	Apr. 1946	C,W	D	Reported unfit for drinking.
1891	214.43	Mar. 22, 1946	None	N	-
1892	223e/	Apr. 1946	C,G	D	-
1893	-	-	C,G	D	-
1894	181.69	Mar. 22, 1946	C,H	D	-
1895	180	Nov. 1945	C,W	D	-
1896	187.84	Mar. 22, 1946	None	N	-
1906	182.80	Mar. 24, 1946	None	N	See well 7, table 6.
1907	180e/	-	C,W	D	-
1908	193.72	Apr. 24, 1946	None	N	-
1909	190e/	-	C,E	D	-
1910	172e/	-	C,W	D	-
1911	172e/	-	C,W	D	-

Table 3. Records of domestic and irrigation wells in Paradise Valley-Cont.

No.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (in.)
1912	NW¼NE¼ sec. 3	W. H. Carter	Joe Yousko	-	276	-
d/ 1913	do.	Freda Nation	do.	-	297	8
1914	do.	R. H. Brewer	R. M. Holmes	-	193	-
1915	SE¼NE¼ sec. 3	W. F. Tevlin	A. J. Stewart	-	270	-
1916	NE¼NE¼ sec. 11	Thos. H. Hobbs	Higgins	-	218	-
1917	NW¼NE¼ sec. 11	Sunnyside School	A. H. Vaughn	-	250	6
1918	do.	E. A. Nesbit	Coke	-	206	6
1919	SE¼SE¼ sec. 12	Harvey Bell	-	-	183	-
1920	SW¼ sec. 14	Arizona Aero Corp.	A. J. Stewart	-	342	8
1921	do.	do.	Hyatt	-	250	4
1922	NW¼ sec. 23	Seventh Ave. Bible Church	-	-	285	6
1923	NW¼NE¼ sec. 31	Davidson	-	-	300	-

a/ Measuring point was usually top of casing, top of pump base, top of water pipe clamp, or top of well curb.

b/ C, cylinder; T, turbine; G, gasoline; E, electric motor; W, windmill; H, hand.

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Remarks
1912	177 e/	-	C,W	D	-
1913	187 e/	Apr. 1946	C,G	D	-
1914	192 e/	-	C,E	D	-
1915	180 e/	Apr. 1946	C,E	D	-
1916	185 e/	-	C	D	-
1917	190 e/	1933	C,G	P	-
1918	190 e/	1913	C,G	D	See well 11, table 6.
1919	140 e/	Apr. 1946	None	N	-
1920	196.02	Mar. 22, 1946	None	N	-
1921	190	-	C,G	D	See well 15, table 6.
1922	-	-	C,G	D	-
1923	-	-	C,E	D,S	-

c/ D, domestic; S, stock; I, irrigation; P, public supply; N, none.
d/ See table of analyses for analysis of water from this well.
e/ Water level reported.

Table 4. Logs of wells in Paradise Valley, Maricopa County, Arizona.

	Thickness (feet)	Depth (feet)
Driller's log of well 1036.		
E. E. Brown, owner.		
NE¼ sec. 16, T. 5 N., R. 5 E.		
Alluvium - - - - - - - -	20	20
Tuff and lava - - - -	280	300
Angular granite, moderately consolidated	500	800
TOTAL DEPTH - - - - -		800
Driller's log of well 1608.		
R. D. Searles, owner.		
SW¼NW¼ sec. 11, T. 2 N., R. 4 E.		
Caliche - - - - - - - -	112	112
Sand and boulders - -	16	128
Clay - - - - - - - - - -	8	136
Sand and boulders - -	8	144
Clay - - - - - - - - - -	71	215
TOTAL DEPTH - - - - -		215
Driller's log of well 1609.		
Salt River Valley Water Users' Ass'n., owner.		
NE¼ sec. 11, T. 2 N., R. 4 E.		
Clay - - - - - - - - - -	10	10
Dry gravel - - - - - -	15	25
Clay (water 69 feet) -	55	80
Water-bearing gravel -	22	102
Clay and caliche - - -	181	283
TOTAL DEPTH - - - - -		283
Driller's log of well 1610.		
- Martin, owner.		
NW¼SW¼ sec. 15, T. 2 N., R. 4 E.		
Top soil - - - - - - - -	3	3
Clay - - - - - - - - - -	110	113
Gravel and boulders -	67	180
Clay - - - - - - - - - -	22	202
TOTAL DEPTH - - - - -		202

	Thickness (feet)	Depth (feet)
Driller's log of well 1612.		
Salt River Valley Water Users' Ass'n., owner.		
NW¼ sec. 24, T. 2 N., R. 4 E.		
Top soil - - - - - - -	2	2
Caliche - - - - - - -	8	10
Clay - - - - - - - - -	8	18
Caliche - - - - - - -	16	34
Boulders - - - - - - -	70	104
Clay - - - - - - - - -	22	126
Gravel - - - - - - - -	9	135
Caliche - - - - - - -	15	150
Clay - - - - - - - - -	11	161
TOTAL DEPTH - - - -		161
Driller's log of well 1613.		
City of Phoenix, owner.		
NE¼NE¼ sec. 25, T. 2 N., R. 4 E.		
Top soil - - - - - - -	2	2
Clay and caliche - -	4	6
Clay and sand - - -	6	12
Hard caliche - - - -	2	14
Gravel and boulders	31	45
Cemented gravel and boulders - - - - - - -	97	142
Sandy clay - - - - -	10	152
Hard cemented sand -	7	159
Clay - - - - - - - - -	10	169
Hard sandy clay - -	54	213
Sticky clay - - - -	6	219
Cemented sand and clay	81	300
TOTAL DEPTH - - - -		300

Table 4. Logs of wells in Paradise Valley, Maricopa County, Arizona-Cont.

Driller's log of well 1614.
City of Phoenix, owner.
NW¼NE¼ sec. 25, T. 2 N., R. 4 E.

	Thickness (feet)	Depth (feet)
Top soil	2	2
Hard caliche	10	12
Cemented sand and gravel	4	16
Gravel and boulders	127	143
Sandy clay and cemented sand	28	171
Sandy clay and some gravel	26	197
Cemented sand and gravel	60	257
Cemented sand, some silt	65	322
Sandy clay, some gravel	75	397
Hard clay	66	463
Cemented sand, layers of clay	337	800
TOTAL DEPTH		800

Driller's log of well 1615.
City of Phoenix, owner.
NE¼NW¼ sec. 25, T. 2 N., R. 5 E.

	Thickness (feet)	Depth (feet)
Caliche and clay	10	10
Cemented sand and gravel	5	15
Hard caliche	4	19
Cemented sand and boulders	4	23
Gravel, sand and boulders	140	163
Hard sandy clay	75	238
Cemented sand and some gravel	5	243
Hard sandy clay	26	269
Hard sandy clay, some gravel	186	455
TOTAL DEPTH		455

Driller's log of well 1616.
Salt River Valley Water Users' Ass'n., owner.
SE¼SW¼ sec. 25, T. 2 N., R. 4 E.

	Thickness (feet)	Depth (feet)
Top soil	4	4
Caliche and sand	3	7
Hard caliche	3	10
Sand	1	11
Hard caliche	7	18
Sand and clay	2	20
Hard caliche	3	23
Packed sand	80	103
Fine sand	5	108
Gravel	4	112
Sand and gravel	31	143
Clay	5	148
Caliche	5	153
Sand and gravel	5	158
Caliche	3	161
Clay	36	197
TOTAL DEPTH		197

Driller's log of well 1617.
Salt River Valley Water Users' Ass'n., owner.
NW¼ sec. 35, T. 2 N., R. 4 E.

	Thickness (feet)	Depth (feet)
Top soil	3	3
Clay	5	8
Caliche	22	30
Hard clay	11	41
Gravel	3	44
Clay	8	52
Gravel	86	138
Clay and gravel	5	143
Gravel, up to 6 inches diam.	35	178
Hard clay	72	250
TOTAL DEPTH		250

Table 5. Analyses of water from wells in Paradise and Salt River Valleys, Maricopa County, Arizona
Well numbers correspond to numbers in table of well records
(Parts per million except specific conductance)

Well No.	Date sampled	Depth (feet)	Specific conductance $K \times 10^5$ at 25°C.	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Total Hardness (as $CaCO_3$)
a/ 1601	Apr. 24, 1945	405	68.6	34	32	69	230	35	78	0.8	36	398	216
b/ 1609	July 1943	283	-	24	23	123	209	45	137	-	10	570	-
b/ 1612	July 1943	161	-	47	21	230	311	88	238	-	17	953	-
c/ 1613	Aug. 12, 1943	300	-	68	30	201	266	110	280	-	-	955	292
c/ 1614	do.	800	-	60	34	254	332	130	306	-	-	1116	289
b/ 1617	July 1943	250	-	122	70	345	462	365	376	-	62	1802	-
a/ 1713	Apr. 24, 1945	365	40.0	20	18	49	232	14	10	1.2	9.6	236	124
a/ 1751	Apr. 25, 1946	355	43.6	-	-	-	268	-	12	-	-	-	-
a/ 1752	do.	300	36.6	18	23	29	213	8.2	9	0.4	6.4	199	140
a/ 1776	June 4, 1946	277	48.5	34	4.9	75	287	9.1	9	3.2	3.2	280	105
a/ 1779	do.	142	83.1	102	30	42	441	31	44	2.2	10	478	378
a/ 1782	June 5, 1946	972	60.0	49	23	54	321	26	27	1.0	3.9	342	217

Table 5. Analyses of water from wells in Paradise and Salt River Valleys, Maricopa County, Arizona-Cont.

Well No.	Date sampled	Depth (feet)	Specific conductance $K \times 10^5$ at 25°C.	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total Hardness (as $CaCO_3$)
a/ 1890	Apr. 24, 1946	152	151	127	62	124	349	325	140	3.0	15	968	572
a/ 1895	do.	203	133	112	61	73	97	309	145	1.4	100	849	530
a/ 1907	do.	250	33.0	24	16	26	184	11	7	0.4	10	185	126
a/ 1913	do.	297	38.5	28	19	29	188	29	16	0.4	5.8	220	148

a/ Analyzed by U. S. Geological Survey.
b/ Analyzed by Salt River Valley Water Users' Association.
c/ Analyzed by University of Arizona, Agr. Expt. Sta.

Table 6. Records of wells in Paradise Valley, Maricopa County, Arizona (1914).
(From U. S. Geol. Survey Water-Supply Paper 375-B, pp. 70-71, 1915.
Records obtained by O. E. Meinzer.).

Number on Map	Owner	Location: Quarter	Location: Section	Location: Township north	Location: Range east	Kind of well	Depth of well	Depth to water level	Diameter or cross section	Yield per minute
							Feet	Feet		Gallons
1a	J. D. Houck	SE....	29	6	4	Dug	16	12	5 by 5 feet	....
1b	do.	SE....	29	6	4	do.	6	4	4 by 4 feet	....
2	E. A. Howard	SW....	28	6	4	do.	(a)	..	....	....
3	W. H. Rheimer	SE....	28	6	4	do.	23	22	....	....
5	C. B. Williams	SW....	30	4	4	Drilled	310	272	6 inches	5
6	- Tymack	NE....	5	3	3	do.	200+	...	....	Low
7	George O'Clair	SW....	1	3	3	do.	300	195	6 inches	20
8	Harvey Bell	NE....	6	3	4	do.	251	237	do.	....
9	- Lyman	NE....	8	3	3	......	280	...	....	....
10	- Hall	SE....	9	3	3	......	160	...	....	....
11	- Nesbit	NE....	11	3	3	Drilled	235	200	....	....
13	J. Lammers	SE....	11	3	4	do.	...	...	....	....
14	- Langley	NW....	12	3	4	......	273	232	....	....
15	S. L. Montgomery	SW....	14	3	3	Drilled	225	196	6 inches	18
16	- Allee	NW....	13	3	3	......	198	75	....	....
17	....	(b)	13	3	3	......	400+	...	....	....
18	- Engel	Center	13	3	3	......	163	...	....	....
19	- Lynn	SW....	15	3	4	Dug	176	173	....	....
20	- Pepper	NE....	15	3	4	......	200	185	....	....
21	....	NW....	14	3	4	Drilled	...	184	....	....
23	....	NW....	22	3	4	Dug	c100	...	....	....
24	J. R. Brock	......	22	3	4	Drilled	532	157	....	....
25	....	NE....	23	3	4	do.	...	...	....	....
26	....	NW....	24	3	4	Dug	c 60	....	4 feet	....
27	Jasper Morgan	(d)	24	3	4	.....	200	180+	....	....
28	J. N. Green	SW....	27	3	4	Drilled	175	145	....	....
29	Miss Green	NE....	27	3	4	do.	160	130	....	....
30	- Hover	NW....	26	3	4	do.	257	145	....	....
31	Henry Crowe	(e)	26	3	4	Dug 146, drilled 100	246	145	....	f 40
32	H. E. Pierce	NW....	30	3	5	Drilled	...	150	6 inches	....
33	S. A. Allen	NE....	30	3	5	......	198	180	....	....
34	J. W. Smith	SE....	33	3	4	Drilled	141	102	6 inches	f 10-12
35	R. W. Gowey	NW....	34	3	4	do.	147	111	....	....
36	Kelley Wright	SW....	35	3	4	......	205	...	....	....
37	A. Showers	NE....	35	3	4	Dug 120, drilled 180	300	108	....	....

a Shallow.
b Middle of north margin.
c Well not completed.
d East central part.
e North central part.
f Reported by the drillers.

Table 6. Records of wells in Paradise Valley, Maricopa County, Arizona (1914)-Cont.

Number on Map	Owner	Location				Kind of well	Depth of well	Depth to water level	Diameter or cross section	Yield per minute
		Quarter	Section	Township north	Range east					
							Feet	Feet		Gallons
39	Dr. La Rue	SE....	3	2	4	......	116	85	....	....
40	Fred T. Weaver	SW....	2	2	4	Drilled	121	75	....	a 13
41	....	SE....	2	2	4	Dug	...	57	....	....
42	J. T. Holmes	NE....	2	2	4	Drilled	160	80	....	....
43	J. D. Bowers	NE....	1	2	4	Dug	120	88	....	....
44a	Mrs. A. J. Montgomery	SE....	1	2	4	Drilled	103	70	8 inches	a 50
44b	do.	SE....	1	2	4	do.	103	70	do.	a 50
45	....	NE....	10	2	4	....	115	90	....	a Good
46	Hans Weaver Sanatorium	SE....	10	2	4	Drilled	145	90	6 inches	a 20
47	Hattie Weaver	NW....	11	2	4	do.	116	75	....	....
48	Mrs. Larsen	SW....	11	2	4	do.	100	..	....	....
49	....	SE....	15	2	4	do.	...	..	....	....
50	R. G. Hawkins	SW....	22	2	4	Dug and Drilled	168	69	8 inches	a 750-900
51	....	SW....	23	2	4	......	60	..	....	....
52	Store at Scottsdale	NW....	26	2	4	Drilled	...	..	....	....

a Reported by the drillers.

5. Penetrated loam containing several beds of caliche and at a depth of 272 feet reached a bed of water-bearing sand 7 feet thick, underlain by a layer of yellow clay, beneath which it entered a bed of coarse gravel that extends below the bottom of the well. Pumping plant consists of a single-acting cylinder pump, the cylinder being set 293 feet below the surface of the ground; a 4-horsepower gasoline engine; and a concrete reservoir 18.5 feet square and 3 feet deep. Cost of drilling well was $315; cost of pumping plant (not including well), $435. Well has been pumped continuously for 10 hours without noticeably affecting the supply. In test made August 30, 1914, 107 gallons was pumped in 21.5 minutes, making the rate of pumping about 5 gallons per minute.

7. Pumping plant consists of single-acting cylinder pump, cylinder with 8-foot suction pipe set 270 feet below surface of ground; an International 4-horsepower gasoline engine; and an elevated tank. Irrigates a small garden and about 30 peach trees. In test made August 28, 1914, almost exactly 20 gallons per minute was pumped.

Table 6. Records of wells in Paradise Valley, Maricopa County, Arizona (1914)-Cont.

8. Penetrated bed of caliche at 12 feet below surface. Water lifted by means of rope and bucket. Temperature of water, 79°F. Cost of well, $262.

15. Penetrated valley fill containing a bed of caliche, 10 feet below the surface and two layers of gravel; the lower one, at a depth of 196 feet, yields water. Well ended in coarse cemented rock talus. Pumping plant consists of a single-acting cylinder pump (cylinder set 215 feet below surface), a 3-horsepower Fairbanks-Morse gasoline engine, and a 750 gallon elevated tank. Irrigated 6 acres of maize and melons in 1913. In test made August 27, 1914, 18 gallons per minute were pumped.

31. Well ends in conglomerate containing bowlders several feet in diameter. Yield of well reported to be 40 gallons per minute. Temperature of water 79°F.

37. Penetrated three strata of gravel; ended in fourth stratum. No casing used. Water reached at 118 feet below surface; rose rapidly within 108 feet of surface.

40. Well ends in water-bearing gravel. Pumping plant consists of a single-acting cylinder pump (cylinder with 15-foot suction pipe set 80 feet below surface), a 12-horsepower gasoline engine, and a 1,275-gallon elevated tank.

44. Two wells 10 feet apart. At depth of 103 feet reached bed of uncemented bowlders and sand, which could not be penetrated without casing. In one well this bed consisted almost entirely of bowlders, some of which required to be broken in order to be removed; in the other it consisted of sand and some bowlders 1 or 2 inches in diameter. Pumping plant consists of single-acting cylinder pump in each well, both operated by gasoline engine. The two wells are said to have been pumped continuously for 5 hours, during which a combined yield of 100 gallons per minute was obtained.

46. Well ends in water-bearing conglomerate. Pumping plant consists of a single-acting cylinder pump (cylinder with 20-foot suction pipe set 120 feet below surface), a 4-horsepower gasoline engine, and a 1,275-gallon elevated tank.

48. Well ends in water-bearing conglomerate.

50. Dug to 69 feet; drilled to bottom. Penetrated alternating beds of clay and gravel, including four beds of water-bearing gravel. Pumping plant consists of a No. 5 vertical centrifugal pump with a rated capacity of 750 gallons per minute, set 69 feet below surface, and a 30 horsepower crude-oil engine. Drilled portion of well is cased, the upper 10 feet and lower 45 feet being perforated. Said to have been pumped at the rate of 900 gallons per minute for several hours without apparent effect on yield.

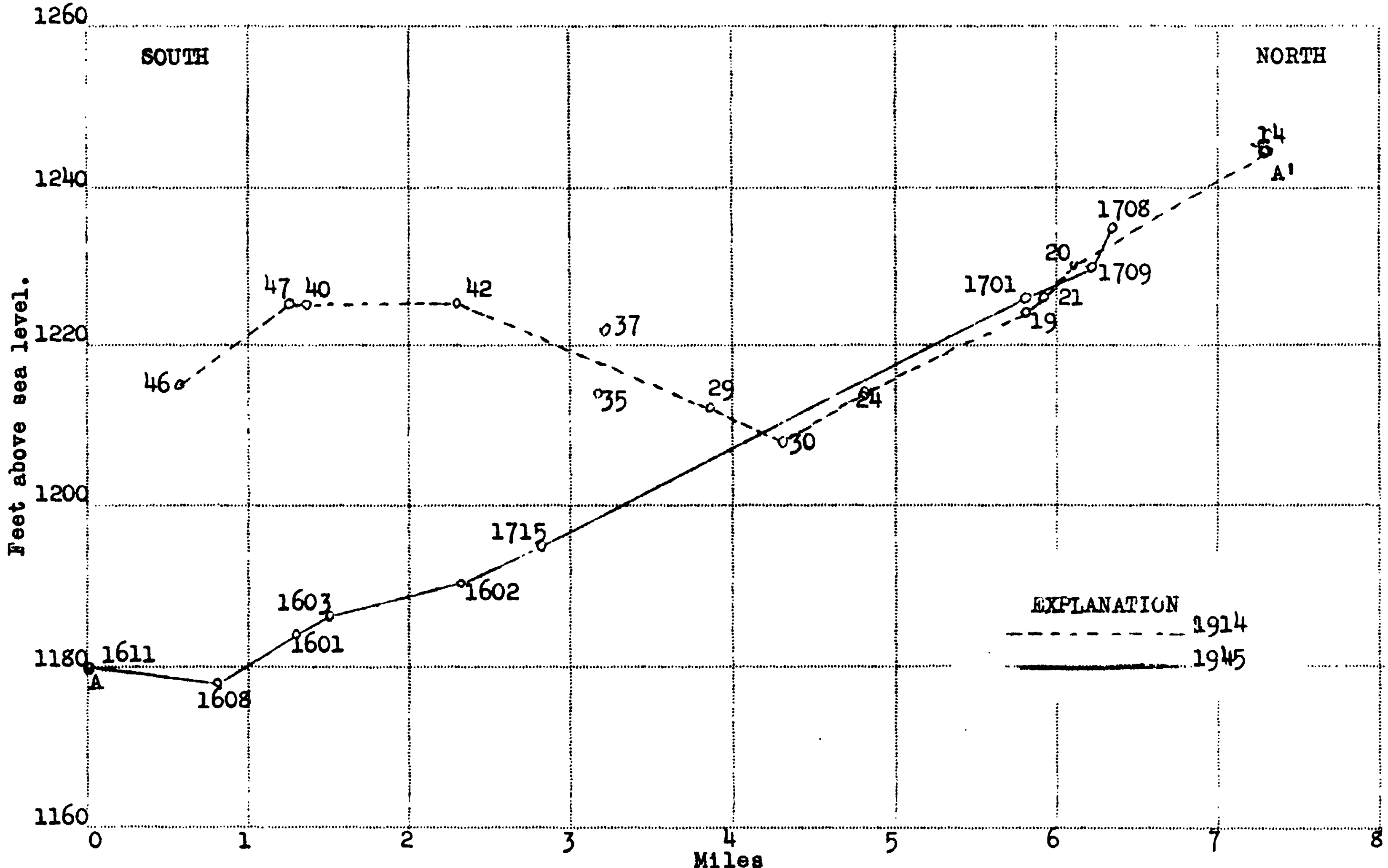
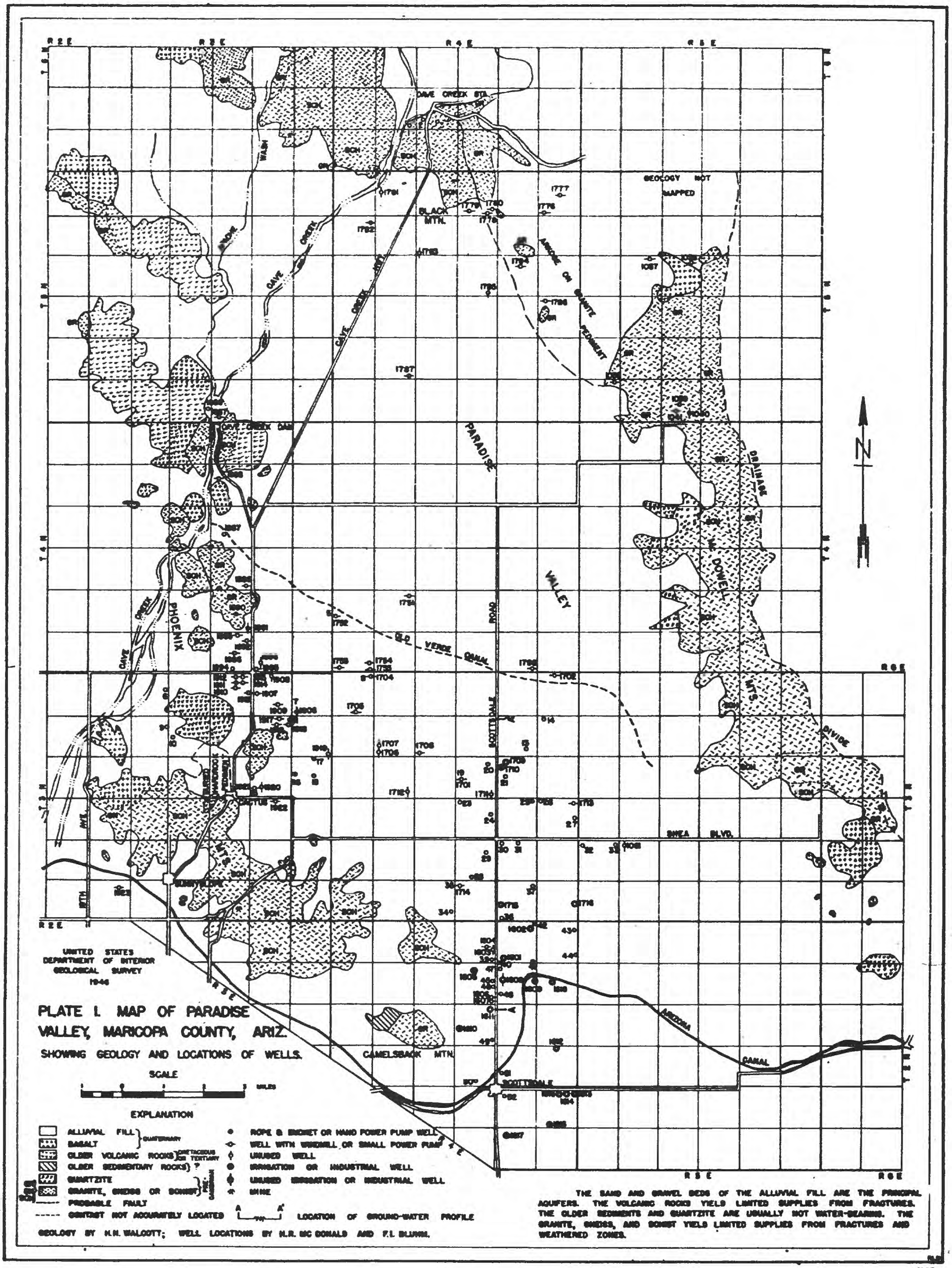


Figure 1. GROUND-WATER PROFILES IN PARADISE VALLEY FOR 1914 AND 1945, extending north from a point two miles north of Scottsdale. Numbers refer to wells listed in tables 3 and 5.



UNITED STATES
DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY
1946
PLATE I. MAP OF PARADISE VALLEY, MARICOPA COUNTY, ARIZ.
SHOWING GEOLOGY AND LOCATIONS OF WELLS.
SCALE
MILES
EXPLANATION
ALLUVIAL FILL
BASALT
QUATERNARY
OLDER VOLCANIC ROCKS
CRETACEOUS OR TERTIARY
OLDER SEDIMENTARY ROCKS ?
QUARTZITE
GRANITE, GNEISS OR SCHIST
PRE-CAMBRIAN
PROBABLE FAULT
CONTACT NOT ACCURATELY LOCATED
ROPE & BUCKET OR HAND POWER PUMP WELL
WELL WITH WINDMILL OR SMALL POWER PUMP
UNUSED WELL
IRRIGATION OR INDUSTRIAL WELL
UNUSED IRRIGATION OR INDUSTRIAL WELL
MINE
LOCATION OF GROUND-WATER PROFILE
GEOLOGY BY H.N. WALCOTT; WELL LOCATIONS BY H.R. MC DONALD AND F.L. BLUHM.
THE SAND AND GRAVEL BEDS OF THE ALLUVIAL FILL ARE THE PRINCIPAL AQUIFERS. THE VOLCANIC ROCKS YIELD LIMITED SUPPLIES FROM FRACTURES. THE OLDER SEDIMENTS AND QUARTZITE ARE USUALLY NOT WATER-BEARING. THE GRANITE, GNEISS, AND SCHIST YIELD LIMITED SUPPLIES FROM FRACTURES AND WEATHERED ZONES.
CAVE CREEK STA.
BLACK MTN.
GEOLOGY NOT MAPPED
PARADISE
VALLEY
CAVE CREEK DAM
McDOWELL MTS.
PHOENIX
CAMELSBACK MTN.
SCOTTSDALE
SUNNYSLOPE
CACTUS
SHEA BLVD.
ARIZONA CANAL
OLD VERDE CANAL
SCOTTSDALE ROAD
DRAINAGE DIVIDE
R 2 E
R 3 E
R 4 E
R 5 E
R 6 E
N

98298