

FLAGSTAFF AREA NATIONAL MONUMENTS
6400 N HWY 89
FLAGSTAFF, AZ 86004

Vf-2669 e.2
FLAG LIBRARY

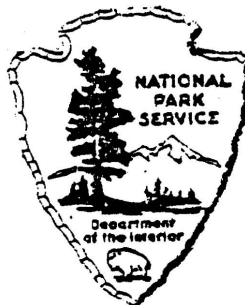
WATER RESOURCE

REPORT 80-7

SUNSET CRATER WELL NO. 2

SUNSET CRATER NATIONAL MONUMENT, ARIZONA

Paul K. Christensen
National Park Service
Southwest Region
May 16, 1980



CONTENTS

	<u>PAGE</u>
ABSTRACT	1
INTRODUCTION	2
DRILLING AND CONSTRUCTION HISTORY	2
HYDROGEOLOGY	6
WELL DESIGN	7
AQUIFER TEST	10
WATER CHEMISTRY	16
CONCLUSION	18
REFERENCES CITED	19

FIGURES

FIGURE 1. Location map	3
FIGURE 2. Time-drawdown curve	12
FIGURE 3. Calculated recovery curve.....	13
FIGURE 4. Residual drawdown curve	14
FIGURE 5. Predicted drawdown determination.....	15

TABLES

TABLE 1. Sunset Crater well no. 2 and drinking water standards	17
--	----

APPENDIX

DRILLER'S LOG	21
SCREEN DATA	28
SCREEN AND 6" DIAMETER CASING TALLY	29
PUMP PIPE TALLY	32
SIEVE ANALYSIS OF SAND USED AS ARTIFICIAL PACKING	34
PERMEABILITY TEST OF ARTIFICIAL PACK	35
AQUIFER TEST DATA	36

ABSTRACT

Sunset Crater well no. 2 was constructed next to Sunset Crater no. 1 well to replace the no. 1 well which failed. The well is located in Bonito Park just off the west boundary of the Sunset Crater National Monument. Drilling problems plagued the project and dragged out the completion of the well. Total depth of the well is 2211 feet BSL. Static water level is 1960 feet below surface well. The aquifer is the Supai group which is composed of red fine-grained sandstones and siltstones. Porosity and permeability in the aquifer are mostly due to fractures and poor cementation of the aquifer rock. The saturated and penetrated portion of the aquifer is 250 feet thick. Unconfined groundwater conditions exist.

The screened-portion sits 14 feet off total depth and is 80 feet long. The well was packed with a coarse-grained beach sand to bar the entrance of the fines from the Supai group rocks.

A 73-hour aquifer test at a discharge rate of 22.3 gpm, using the abandoned no. 1 well as an observation well, gave a transmissivity value of 4800 gpd/ft and a storage coefficient (specific yield) value of 0.0090. Predicted drawdown in the production well was 6.0 feet. A total drawdown of 2.0 feet occurred in the observation well. The static water level in the observation well recovered 90 per cent in 3 hours after pumping ceased. Specific capacity of the well is 3.7 gpm/ft drawdown.

The water from the well has a total dissolved solid content of 565 mg/l. The water bears an unpalatable taste, probably due to iron and manganese, but is potable.

INTRODUCTION

Sunset Crater well no. 2 is located in Bonito Park in Coconino National Forest about one half mile from the west boundary of Sunset Crater National Monument along the Sunset Crater-Wupatki loop road (figure 1). Bonito Park is a basin filled with alluvium, volcanics and glacial wash and is surrounded by various volcanic mountains and hills.

Sunset Crater no. 2 well was drilled to replace Sunset Crater well no. 1 which failed. This report is intended to cover the drilling and construction history, well design, the hydrogeology of the rocks encountered in drilling, the aquifer test and the water chemistry of the Sunset Crater no. 2 well.

DRILLING AND CONSTRUCTION HISTORY

Perry Brothers Drilling of Flagstaff, Arizona moved to the location and set up an air rotary rig for drilling June 5, 1979. Drilling began June 6, with a 14-inch diameter hole. Instability of the unconsolidated volcanic cinders required cementation of the hole walls. The air rotary method proved ineffective in the cinders. The driller then rigged down the air rotary rig and set up a cable tool rig. Fourteen-inch diameter casing was emplaced to a depth of 90 BSL, and the hole was cleaned out. Drilling commenced again June 13. Water and mud were mixed to a consistency suitable to remove the cuttings with the bailer.

At about 110 feet BSL, the 14-inch diameter casing could not be driven further. Drilling continued, utilizing cement to stabilize the walls, until the depth of 705 feet BSL was completed July 3. Approximately 15 feet of Kaibab formation was penetrated at this point. Next, the 12 3/4-inch

diameter casing, intended to keep the unconsolidated volcanics out of the hole, was inserted into the hole. Some irregularities existed in the hole walls to hinder the penetration of the 12 3/4-inch diameter casing past a point 110 feet BSL to rest on the Kaibab rocks 705 feet BSL. The driller considered this obstruction to be due to cement and mud build up on the walls of the hole.

The air rotary rig was again set up to ream out the hole and remove the irregularities. The reaming operation was completed to total depth July 17. Again an obstruction 110 feet BSL was encountered during the emplacement of the 12 3/4-inch diameter casing. The driller then decided to ream the hole out to a 16-inch diameter. The 14-inch diameter casing was removed and 80 feet of 16-inch diameter casing was emplaced into the hole. The cable tool rig was once more set over the hole on July 21 to ream the hole out to the 16-inch diameter size. At a depth of 125 feet BSL, the tools were bound in the hole, and the jars locked. During an attempt to knock the tools loose with the bailer, the bailer valve broke off on top of the tools in the hole. Fishing for the bailer valve from July 24 to July 30 failed. The driller then decided to "side-drill" past the tools. This was completed August 8 and the tools were pulled out of the hole. The tools had been bound in the hole by blocks of lava rock. The completion of the enlargement and straightening of the hole occurred August 23. The hole was then deepened to 724 feet BSL and 726 feet of 12 3/4-inch diameter casing was set in the hole on the Kaibab.

A 12-inch diameter bit was attached to the drill string of the cable tool rig and drilling continued to a depth of 745 feet. Steel from the bailer valve

and broken pieces of fishing equipment, used in the attempts to remove the bailer valve, were encountered. Fishing procedures for this metal failed.

September 5, the 16-inch diameter casing was removed and a cement grout emplaced from a depth of 20 feet BSL to the surface. The rotary rig was then set up over the hole. A mill to grind the steel was set into the hole on the drill string. Milling continued until September 10 when one large piece of steel was removed. Drilling began again on September 11 with rotary rig. Within 3 days, the bit wore out due to metal still in hole. The bit was replaced and drilling continued until September 18. Circulation problems were also encountered because of fractures and a large annular space coupled with inadequate pressure to lift the cuttings out of the hole.

A total depth of 1245 feet was reached by September 24. The driller decided to remove the rotary rig and set the cable tool rig up, since the metal still in the hole was detrimental to air rotary use. Water was encountered at a depth of 1967 feet BSL, but did not occur in quantities sufficient enough to drill with. Much water was lost in the saturated zone above the water table. Drilling continued fairly unheeded to a depth of 2000 BSL by October 16, when the tools became stuck in the hole. The next day the tools were jarred loose and drilling continued. At approximately a depth of 2000 feet, water was encountered in sufficient quantities to no longer require hauling water to the site for use as drilling fluids. Caving and fracturing became very prominent from about 1930 feet BSL to final total depth. The driller set 15 sacks of cement in the hole above the major water producing zone to stabilize the hole. October 30, drilling was completed to a total depth of 2200 feet BSL according to the drilling log. See the appendix for the driller's log.

October 31, Welex from Farmington, New Mexico arrived and ran borehole geophysical logs down the hole. The tests performed are gamma ray, spontaneous potential, resistance, temperature, and caliper. Welex reported a total depth of 2213 BTC. Moss-Weber Company from Chandler, Arizona ran a movie camera down the hole and reported a static water level of 1961 BTC. The geophysical logs and camera film are stored at the Regional Office in Santa Fe.

The screens and 6 5/8-inch diameter casing were emplaced November 19 through 21. Afterwards, the sand pack from California was carefully placed into the annulus between the 6 5/8-inch diameter and hole walls until expended. Local sand was then utilized to finish filling the annular space. The hole was bailed during sand emplacement.

November 26 and 27, the pitless adapter and plastic discharge pipe from the adapter to the control shed were installed beneath ground level. On November 28 and 29, the pump and discharge pipe were lowered into the screen and casing. Layman Weisman, a representative from the pump suppliers in Huntington Beach, California, was at the site to insure the proper installation of the pump and of the electrical wiring down the hole to the pump. Shaum and Son, electrical contractors from Flagstaff, completed electrical work on the control panel in the control shed November 30. Electricity was turned on the next day by Arizona Public Service Company. The pump and discharge pipe were lowered another pipe length and the pump tested, yielding 21 gpm.

HYDROGEOLOGY

Five major lithologic units were encountered during drilling: Quaternary

and/or Tertiary volcanic, Quaternary sedimentary, Permian Kaibab, Permian Toroweap and Coconino, and Pennsylvanian-Permian Supai rocks. The upper 685 feet of the drill cuttings are composed of pyroclastic and flow volcanics with stream and glacial wash deposits. Pumice units occur near the base of this upper section.

The Kaibab formation occurs in the interval between 685 feet and 990 feet BSL. The Kaibab is a tan sandy dolomite which is cherty in parts. The Toroweap and Coconino sandstones underlie the Kaibab formation. These sandstones are very pale-orange to grayish-orange and are composed of very fine- to fine-grained well-rounded quartz grains. The Toroweap and Coconino sandstones are about 770 feet thick.

The Supai group occupies the lower section of the hole from 1760 feet to total depth. These rocks are brownish-red fine-grained sandstone and siltstone. About 450 feet of Supai group rock was penetrated. The volcanics and associated stream deposits, Kaibab, Toroweap, and Coconino rocks are dry. The first minor occurrence of water occurred at a depth of about 1965 feet BSL in the Supai group. Other minor occurrences appeared until substantial amounts of water were encountered at a depth below 2000 feet BSL. The down-hole camera film taken of the hole showed that the water saturated zone is well-fractured. The drillers complained of caving problems in the Supai group in the water-saturated zone, which indicates poor cementation and fracturing. The water-saturated and penetrated portion of the Supai group is about 250 feet thick. Static water level lies 1960 BSL.

WELL DESIGN

To insure the entrance of no unconsolidated volcanics or Quaternary

sedimentary deposits into the well, 726 feet of 12 3/4-inch diameter casing was emplaced in the upper 724 feet of the hole. This pipe section rests on the Kaibab. A grout was emplaced to a depth of 20 feet BSL. To install the pitless adapter, about 6 feet of the grout and 8 feet of the 12 3/4-inch diameter casing were removed. The pitless adapter sits 3.3 feet BSL.

The screened interval in the saturated zone consists of 80 feet of size 6 screen in 4•20-foot pieces. The screens were supplied by the Houston Well Screen Company, Houston, Texas, and has the brand name, New Bar Lug Plus. Screen data is entered in the appendix. Total entrance area of the screens is 1,934 square inches. The 4 screens were emplaced end to end on 14.1 feet of 6 5/8-inch casing, which was sealed with a 2-foot cement plug at the bottom of the joint. The footage of 6 5/8-inch casing connecting the top of the screen to the pitless adapter is 2112 feet. The top of the screen sits 94.1 feet off bottom and 2107 feet BSL. The hole has a diameter of at least 11 inches in the area of the screen. Irregularity of the hole in this zone, however, produces a much larger diameter.

The submergible pump assembly in well no. 2 is the assembly used in well no. 1. The pump is rated at 25 gpm. The pump assembly is 20.3 feet long and lies at the end of 2,135 feet of 2-inch diameter steel discharge pipe and 2 check valves. The pump has an outer diameter of 5 1/8 inches. Tallies for both the 6 5/8-inch casing and 2-inch diameter discharge pipe appear in the appendix. The pump intake is located 2,149 feet BSL, 32.6 feet below the top of the screen, 61.3 feet off the bottom of the hole and 200 feet below static water level.

The screen entrance velocity can be determined by the following equation:

$$V_c = \frac{Q}{7.48 A_o S_L} \quad (\text{Walton, 1962})$$

where S_L = optimum length of screen, in feet

Q = discharge of production well, in gpm

A_o = effective open area per foot of screen, in square feet

V_o = screen entrance velocity, in fpm

In this case, the effective open area per foot of screen is assumed to be 50 per cent of the designed open area. The knowns are $S_L = 72.2$ ft. $Q = 22.3$ gpm, and $A_o = 0.09306 \text{ ft}^2$. With these conditions, the entrance velocity is 3.3 fpm or 0.5 fps. Recommended optimum entrance velocity for the transmissivity of 4800 gpd/ft belonging to the aquifer is 11 fpm. Entrance velocities are then well below the optimum recommended screen entrance velocity in theory.

This does not occur because the pump intake sits in the screen. Placement of the pump in the screen increases entrance velocities through the screen near the pump intake, which increases the precipitation rates of minerals and clogging of the screen around the pump intake, thus decreasing well efficiency.

The area between the pump and casing amounts to 0.0740 ft^2 . In the case of the pump emplaced above the screen, flow velocities between the pump and the casing at a pumping rate of 19.7 gpm would be in the neighborhood of 0.6 fps or 35 fpm. Such turbulent flow is unavoidable well loss. Flow velocity inside the casing below the pump is 0.2 fps or 13 fpm at 19.7 gpm. If the pump sits above the screen, water will enter the screen over a much

larger surface area. Thus lower entrance velocities below the optimum recommended values will result, increasing well efficiency.

A beach-type sand supplied by the Monterrey Sand Company Inc., Monterrey, California was used as artificial pack to bar the entrance of fines from Supai group into the pump. The beach sand filled up most of the annular space. About 50 c.y. of this sand was used. About 5 c.y. of local sand was used to bring the sand pack to the surface level. Ideally about 45 c.y. of sand would have been used. However, the hole, particularly in the Supai group rocks, is characterized by irregularities due to caving and fracturing.

The Monterrey Beach sand is coarse-grained, well-rounded, and well-sorted. A permeater test of the sand showed a hydraulic conductivity value of 46.4 ft/day. The appendix contains the permeater test and grain size distribution data of the sand.

AQUIFER TEST

A 73-hour aquifer test was performed on the well, December 4, 5, 6, and 7, using the old well as an observation well. The two wells are separated by 25 feet. Attempts to lower an electrical water level detector down the hole of the new well failed. One method included strapping 1-inch diameter PCV pipe onto the discharge pipe as the pump assembly and discharge pipe were lowered into the hole. Too much friction was encountered in lowering the detector wire down the hole to reach water level, to allow for the safe retrieval of the detector line.

A total drawdown of 2.0 feet occurred in the observation well at a pumping rate of 22.3 gpm. Assuming ideal artesian aquifer conditions, no

satisfactory match could be made using the Theis method due to unconfined groundwater conditions. The time-drawdown, calculated recovery, and residual drawdown curves give an average transmissivity value of 4800 gpd/ft (642 ft²/day) and an average storage coefficient (specific yield) value of 0.0090 (see figures 2, 3, and 4). The hydraulic conductivity is 19.2 gpd/ft² (2.6 ft/day).

Maximum theoretical drawdown in the sand pack at the end of the test is 6.0 feet, assuming 100 per cent well efficiency, and 12.0 feet at 50 per cent well efficiency. Figure 5 demonstrates the method used to predict the drawdown in the production well. The method is described in Ground Water and Wells (1976). The Citadel Ruin well at Wupatki National Monument, which is located about 13 miles NNE from the Sunset Crater well also draws water from the Supai group rocks. An aquifer test of this well showed a total drawdown of 5.0 feet in the well after pumping over 48 hours at an average discharge rate of 17.6 gpm. The performance of this well tends to suggest that the 6.0 feet value for the Sunset Crater well no. 2 is reasonable. After turning on the pump, water is first removed from inside the casing. The pump then gradually produces more water from the aquifer until the effects of casing storage become negligible. Depth to water inside the casing will be deeper than that in the sand pack.

Specific capacity is 3.7 gpm/ft drawdown at 100 per cent well efficiency and 1.9 gpm/ft drawdown at 50 per cent. Recovery data showed 90 per cent recovery within 3 hours after cessation of pumping. The aquifer is neither isotropic or homogeneous.

The discharge rate through the pumphouse was 22.3 gpm before hook-up with the underground line to the storage tank. After hook-up following the

aquifer test, the water flowed at a rate of 19.7 gpm. See appendix for aquifer test data.

WATER CHEMISTRY

Table 1 shows a comparison of constituent concentrations of water from Sunset Crater well no. 2 and concentration limits set by the EPA. Recommended concentration limits are intended to provide acceptable aesthetic and taste characteristics. Maximum permissible limits are set according to health criteria. The analysis was performed January 17, 1980.

The iron content of 38 mg/l appears incorrect and is probably due to laboratory error. Iron content from previously tested samples of the no. 1 well show values of 0.76, 0.72, 0.22, and 0.11 ppm. The water from the no. 2 well is clear and has an iron and manganese taste. The water is somewhat unpalatable, but potable, and lies within the limits of health criteria.

Table 1. Sunset Crater no. 2 Well Water and Drinking Water Standards

<u>Constituent</u>	Sunset Crater no. 2 well (mg/l)	Recommended Concentration Limit (mg/l)
Inorganic		
Total dissolved solids	545	500
Chloride	16	250
Sulfate	5	250
Nitrate	0.1	45
Iron	38 sic	0.3
Manganese	1.1	0.05
Zinc	0.68	5.0
		Maximum permissible Concentration
Arsenic	0.02	0.05
Barium	0.05	1.0
Cadmium	0.005	0.01
Chromium	0.02	0.05
Selenium	0.01	0.01
Lead	0.02	0.05
Mercury	0.001	0.002
Silver	0.02	0.05
Fluoride	0.34	1.4-2.4
Organic		
Cyanide	0.1	0.05

CONCLUSIONS

The Sunset Crater well no. 2 withdraws groundwater from fractured red sandstones and siltstones of the Supai Group. A 200-foot column of water lies above the pump intake. Considering the well to operate at near 100 per cent efficiency, with the present 6-inch diameter casing and screen, up to 100 gpm may be withdrawn from the well with a drawdown of 27 feet. For larger pumping rates, the 6-inch casing and screen ought to be replaced with wider diameter types. For pumpage rates less than 100 gpm screen velocities are well below optimum if the pump lies above the top of the screen. If the well operates at 50 per cent efficiency, drawdown at 100 gpm amounts to 54 feet. It is very probable the well operates at efficiency levels between 75 and 100 per cent.

The aquifer itself can supply more water than the present design allows. With improved design, which includes widening the hole diameter, probably as much as 300 gpm can be expected.

Ideally, the pump intake should be above the screened zone in an unconfined aquifer. Placement of the pump in the screen will increase entrance velocities around the pump intake and encourage precipitation of minerals and clogging of the screen. In the future when well efficiency diminishes, the screen should be cleaned and the pump placed above the screen.

During a rehab of the well, a pressure gauge with an electronic readout should be installed just above the pump to allow for more accurate measurements of the static water level in the well. After the installment of this equipment, it is recommended that an aquifer test be conducted, utilizing the Sunset Crater no. 1 well as an observation well. An electric probe will suit for measurements of water levels in the observation well.

REFERENCES CITED

_____, 1976, Ground water and wells, Johnson Division, UOP Inc.
Sain Paul, Minnesota, 440p.

Walton, W. C., 1962, Selected analytical methods for well and aquifer
determination: Illinois State Water Survey Bulletin 49.

APPENDIX

DRILLING LOG
SUNSET CRATER WELL NO. 2
(June 5 - December 1, 1979)

DRILLER: PERRY BROTHERS, FLAGSTAFF

<u>Date</u>	<u>Feet Drilled</u>	<u>Total Depth (Ft.)</u>	<u>Approximate Drilling Rate (Ft./Hr.)</u>	<u>Cutting Description</u>	<u>Remarks</u>
6/5	0	0			Ingersoll-Rand T-5 Rotary rig moved to location
6/6	85	85	?	Soft black cinders	Drill pipe and tools moved to location; started drilling
6/7	0	85			Hole backfilled to 50 ft.; mixed 15 sacks of cement in hole and let set
6/8	0	85			Cement drilled out; hole still caved; BE 36-L cable tool rig moved to location; Ingersoll-Rand T-5 rotary rig rigged down; BE 36-L set over hole
6/9	0	85			Driller went to Winslow to pick up cable tools
6/11	0	85			200 feet of 14 inch casing loaded up and hauled to location; cable tool rig rigged up and drive shoe welded on; drill tools rigged up and 14 inch casing set to 80 feet; cleaned hole out to 60 feet. Hauled 2000 gallons water.
6/12	0	85			Cleaned hole out to 80 feet
6/13	15	100	1.9	Medium black cinders	10 more feet 14 inch casing welded on, 90 feet total; cleaned hole out to 85 feet; began drilling; built up bit
6/14	25	125	2.2	do	
6/15	40	165	3.6	Medium brown cinders	Cinders falling in hole at 165'; mixed 6 sacks of cement and let set over night in hole

6/16	25	190	2.7	do	Mixed 6 sacks cement and let set in hole
6/18	50	240	5.6	do	
6/19	50	290	4.3?	do	Pulled off cable; cutoff cable on sand line
6/20	45	335	5.0	do	Ran rope socket, mixed up 5 sacks cement and let set over night in hole
6/21	35	370	3.2	do	Mixed 5 sacks cement and let set in hole over night
6/22	55	425	5.5	do	Hauled 2000 gallons water and built up bit
6/23	30	455	3.8	do	Mixed 8 sacks of cement and let set in hole over night
6/25	25	480	2.5	Medium brown cinders	Mixed 5 sacks cement and let set in hole over night
6/26	28(15) (8)	508	2.5	Medium brown cinders Hard black basalt	
6/27	22	530	1.9	do	
6/28	5	535	0.5	do	
6/29	60(10) (50)	595	6.0	do Medium reddish brown cinders	Hauled 2000 gallons water; ran rope socket; mixed 5 sacks cement and allowed to set over night in hole
6/30	55(10) (45)	650	6.1	do Medium beige cinders	
7/2	30	680	2.6	do	
7/3	25(20) (5)	705	5.0	do Medium yellow lime-stone (Kaibab)	Rigged up to run 12.75 in casing
7/5	0	705			Ran 105 feet 12.75 inch casing and pulled casing back out of hole (too much mud build-up on walls of hole for casing to go in hole)
7/6	0	705			Went to Phoenix and Winslow for tools and pulled 2.5 feet 14 inch casing out of the hole
7/7	0	705			Welded centralizers on drill collar and bit and set in hole; moved 36-L ahead and set-up IR T-5; cleaned out hole to 105 feet

7/9	0	705	{	Work on rig and order new hydraulic pump
7/10	0	705		
7/11	0	705		
7/12	0	705		
7/13	0	705		Put new hydraulic pump on T-5; cleaned out hole to 175 feet
7/14	0	705		Problems with hydraulic pump on T-5
7/16	0	705		Cleaned hole out down to 570 feet
7/17	0	705		Cleaned hole out down to 635 feet; hole filled in to 605 feet
				Waiting for new pump
				Foam to aid cleaning of hole injected; hole cleaned out to 705 feet; pull drill pipe out of hole; rig down T-5 and move 36-L over hole; prepared to run casing
7/18	0	705		Ran 110 feet 12.75 inch casing hole; casing stopped at 110 feet; pulled casing out of hole; started to pull 14 inch casing out of hole
7/19	0	705		Went to Winslow for tools and to Phoenix for 16 inch casing
7/20	0	705		Set 80 feet 16 inch casing; set plug in hole at 100 feet; rigged up 15.5 in bit
7/21	0	705		Cleaned hole out to 125 feet; welded 10 feet 16 inches casing to string; tools bound in hole; jars locked; tried to free tools
7/23	0	705		Knocked tools free with bailer; bailer valve broke off on top of tools in the hole
7/24	0	705		Tried to fish out valve with hook; no luck
7/25	0	705		Went to Winslow for fishing tools; welded on fishing tools at location
7/26	0	705		Ran wall hook on drill pipe; no luck
7/27	0	705		Ran 1/2 jar hook on drill pipe; no luck
7/28	0	705		Ran spud iron hook on drill pipe; no luck
7/30	0	705		Ran spud iron hook on drill pipe; no luck
7/31	0	705		Rigged up for side drill tools

8/1	0	705			Side drilled past 16 inch tools 4 feet
8/2	0	705			Side drilled past 16 inch tools from 4 to 14 feet
8/3	0	705			Side drilled past 16 inch tools another 2 feet
8/4	0	705			Side drilled past 16 inch tools another 1 foot
8/6	0	705			do
8/7	0	705			do
8/8	0	705			Side drilled past 16 inch tools; strung up drill line for tools and pulled 16 inch tools out of hole
8/9	0	705			Cut off 130 feet drill line and rigged down 14 inch tools
8/10	0	705			Straightened hole from 100 to 130 feet
8/11	0	705			Straightened hole from 130 to 205 feet
8/13	0	705			Straightened hole from 205 to 455 feet
8/14	0	705			Pulled off 650 feet drill line and started to string up new drill line
8/15	0	705			Moved cable divider on rig and spooled on 3200 feet of 7/8 inch drill line; reamed hole from 455 to 490 feet
8/16	0	705			Reamed hole from 490 to 505 feet; hauled 2000 gallons water
8/17	0	705			Reamed hole from 505 to 575 feet
8/18	0	705			Reamed hole from 575 to 585 feet
8/20	0	705			Reamed hole from 585 to 695 feet; put 2000 feet 9/16 inch sand line on rig
8/21	0	705			Reamed hole from 695 to 696 feet; encountered steel on bottom of hole
8/22	0	705			Reamed hole from 696 to 700 feet
8/23	0	705			Reamed hole from 700 to 705 feet
8/24	21	726	1.8	Medium yellow Kaibab lime	Reamed hole from 705 to 719 feet; ran 480 feet 12.75 inch casing
8/25	0	726			Set 12.75 inch casing to 726 feet; strung up 12 inch bit

8/27	14	740	1.4	do	Encountered steel in hole
8/28	5	745	0.5	do	do
8/29	1	746	0.3	do	Fished for steel; cut off 15 feet drill line and ran new rope socket
8/30	2	748	0.4	do	Fished for steel; no luck
8/31	7	755	0.7	do	
9/1	5	760	1.0	do	
9/4	10	770	1.0	do	
9/5	0	770			Pulled 16 inch surface casing; placed packer 20 feet below ground level and cement back to surface
9/6	?	?	?		Broke down 12 inch bit and moved 36-L away from hole; rigged up T-5 and ran 770 feet of 5.5 inch drill pipe with a mill to grind to steel in the hole
9/7	?	?	?		Milled steel piece
9/10	?	780	?	do	Milled steel piece; recovered one piece of steel in mill
9/11	20	800	2.2	do	Ran 780 feet 4.5 in drill pipe and 12 inch bit
9/12	40	840	2.4	do	
9/13	40	880	1.7	do	
9/14	20	900	1.9	do	Bit worn out; pulled pipe out of ground; put new 11 inch bit on with 3/8 inch collars; ran pipe into hole
9/15	30	930	2.1	do	
9/16	70(65) (5)	1000	5.9 5.0	do	
				Medium yellow sandstone (Coconino)	
9/17	180	1180	7.5	do	
9/18	50	1230	8.3	do	Ran out of drilling foam
9/19	15	1245	1.3	do	Picked up drilling foam at freight office
9/20	0	1245			Pulled drill pipe and drill collars out of the hole; waiting for a new bit; piece of metal still in hole

9/24	0	1245			Rigged down T-5 and moved drill pipe; moved 36-L back over hole and rigged up to drill; went to Winslow for 11 inch bits
9/25	10	1255	1.4	do	Strung up 11 inch bit and cleaned out hole
9/26	10	1265	1.0	do	
9/27	35	1300	3.7	do	
9/28	20	1320	2.7	Medium white Coconino sandstone	Ran new rope socket
9/29	40	1360	5.7	do	
10/1	60	1420	4.3	Medium yellow Coco- nino sandstone	
10/2	70	1490	4.5	do	
10/3	100	1590	4.2	do	
10/4	90	1680	3.8	do	
10/5	75	1755	3.1	do	
10/9	100	1855	5.6	Medium red Supai	
10/10	15	1870	3.0	do	Spliced 600 feet 9/16 inch cable on sand line
10/11	30	1900	7.5	do	Finished splicing 600 feet 9/16 inch cable on sand line; ran rope socket
10/12	30	1930	3.8	do	Cut off 260 feet 7/8 inch drill line
10/15	35	1965	2.2	do	
10/16	43	2008	3.7	do	Tools stuck in hole; jarred tools loose
10/17	0	2008			Jarred tools loose
10/18	17	2025	2.1	do	
10/19	0	2025			Cleaned out loose sand after hole caved in over drill tools; jarred tools loose
10/20	0	2025			Set 15 sacks of cement in fracture zone and rigged up lighter drill string
10/22	0	2025			Cleaned out hole, found crack in drill stem; took off stem; went to Winslow after another stem
10/23	10	2035	1.1	do	Rigged up drill stem; cleaned out hole to 2025 feet

10/24	30	2065	1.9	do	
10/25	45	2110	2.8	do	
10/26	20	2130	1.2	do	
10/27	15	2145	2.1	do	Cut off 30 feet drill line and ran rope socket
10/29	25	2170	2.9	do	
10/30	30	2200	8.6	do	Total depth - 2200 drilling log

Date	Activities following completion of drilling in log
10/31	1.75 hours bailing; 6.5 hours standby time for E-log (Welex Company)
11/1	2.5 hours standby for down-hole photography (Moss-Weber Co.); rigged down and loaded tools in trailer; static water level 1961 feet
11/19	1 hour bailing development; ran 6-5/8 inch casing 14'1" blank joint on bottom with 80 feet Houston bar lug plus screen (.010 in slot) into hole
11/20	Ran 6-5/8 inch casing from 300 to 800 feet
11/21	Ran 6-5/8 inch casing from 1100 to 2213 feet TD 2213 feet
11/23	Developed well with bailer (6 hours), while placing sand pack; total sand to date 150,410 lbs.
11/26	Developed with bailer (1.5 hours); finished filling hole with local sand (16,000 lbs); installed pitless adapter
11/27	Finished installing pitless adaptor and discharge pipe
11/28	Rigged up pump to run in hole; ran pump in hole
11/29	Finished running pump into hole; loaded casing on trailer and hauled to town
11/30	Shaum and Son hooked up electrical in pumphouse; cleaned up around well site
12/1	Went to Winslow and picked up 100 KW generator to take to location; lowered pump on other 31 feet. Pumping 21 gpm.

Sunset Crater Well No. 2

ESSENTIAL DATA FOR SCREENS

Brand: Bar-Lug Plus Screen

Manufacturer: Houston Well Screen Company
Houston, Texas

Number of pieces: 4 (20 ft. long each)

Screen size: 6

Pipe O.D.: 6.625 in.

Coupling O.D.: 7.025 in.

Screen O.D.: 7.125 in.

Pipe I.D.: 6.053 in.

Number of holes per ft.: 204

Number of ribs: 30

Hole size: 0.50 in.

Open area of holes: 40.1 sq. in./ft.

Slot size: 0.010 in.

Screen surface open area: 26.8 sq. in./ft.

Coupling length: 2.50 in.

Metal construction: 6.625 in Schedule 40
Stainless steel type 304

Length of screened and holed area per joint: 18.04 ft.

Total screen surface open area per joint: 483.5 sq. in.

Total open area of holes per joint: 723.4 sq. in.

Total entrance area: 1,934 sq. in.

November 19, 20, 1979

Sunset Crater Well No. 2

Screen and 6" Diameter Casing Tally

(Pipe and screen measured from top of threads on male end to end of pipe at female end.)

<u>Pipe Number</u>	<u>Length (feet and inches)</u>
1	14-1
2	20- $\frac{1}{2}$ (screen)
3	20- $\frac{1}{2}$ (screen)
4	20- $\frac{1}{2}$ (screen)
5	20- $\frac{1}{2}$ (screen)
6	19-2
7	19-0
8	20-7
9	20-8
10	20-0
11	20-6
12	20-0
13	20-3
14	20-2
15	14-9
16	20-0
17	20-0
18	19-10
19	14-8
20	20-0
21	20-6
22	20-4
23	20-8
24	20-8
25	20-2
26	20-8
27	20-1
28	20-0
29	19-9
30	20-9
31	20-0
32	20-8
33	20-9
34	20-0
35	20-0
36	19-5
37	20-0
38	20-0
39	20-9
40	20-8
41	20-6
42	20-0
43	20-0
44	20-6

45	20-10
46	19-3
47	20-4
48	20-0
49	19-2
50	20-0
51	20-0
52	20-8
53	20-0
54	20-8
55	20-10
56	20-11
57	20-0
58	20-0
59	20-0
60	20-6
61	20-0
62	20-7
63	20-3
64	14-10
65	20-8
66	20-0
67	14-10
68	20-1
69	20-1
70	20-1
71	20-0
72	20-0
73	20-10
74	20-7
75	20-0
76	20-0
77	20-6
78	20-2
79	14-1
80	20-8
81	17-11
82	20-0
83	18-3
84	20-0
85	20-8
86	20-7
87	19-7
88	20-1
89	20-0
90	20-0
91	20-0
92	20-7
93	20-0
94	20-0
95	20-0

96	19-8
97	20-0
98	18-1
99	20-8
100	20-0
101	20-10
102	20-8
103	20-0
104	25-6
105	20-1
106	26-2
107	19-10
108	20-0
109	26-3
110	21-1
111	20-0

10.75' of 6" diameter casing removed for pitless adapter emplacement.

Total 6" diameter steel casing and screen	2217.42 feet
less removed section	10.75 feet
Total in hole	2206.67 feet

