United States

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U.S. Geological Survey

Water-supply investigation at Chinle, Navajo Indian Reservation, Arizona

by

L. C. Halpenny and S. C. Brown

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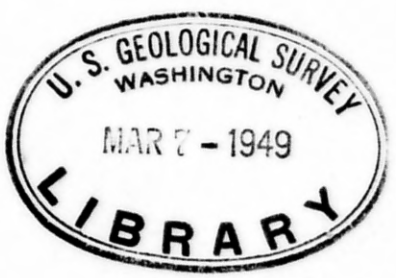

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TABLES

ILLUSTRATIONS

In late January 1948 the Geological Survey was requested to investigate the possibilities of obtaining additional water supplies at four sites on the Navajo Indian Reservation. Each site was given a priority, and the site at Chinle was designated as second of the four in importance. Field work was to be completed and reports submitted to the Navajo Service by April 9, 1948.

Location

Chinle is situated in Beautiful Valley, about 42 miles north of Ganado and about 40 miles northwest of Window Rock. Beautiful Valley is wide and flat, as it has been cut into the gently-dipping, easily eroded Chinle formation. The community of Chinle is located near the mouth of Canyon de Chelly, about 2 miles upstream from the confluence of Chinle Wash and de Chelly Wash. The mouth of Canyon de Chelly is about 1 mile east of Chinle, and east of this point the canyon is narrow and deep, being cut into massive sandstone.

Problem

The existing water supply consists of a dug and drilled well, 176 feet deep, in the alluvial fill of Canyon de Chelly. The well was reported to produce about 85 gallons per minute. Additional water is needed for a possible increase in population to a total of 1,200 people. At a daily rate of 150 gallons per person, a continuous supply of about 125 gallons per minute of water would be needed. If the water is produced in an 8-hour period each day, a supply of about 375 gallons per minute would be needed. The most probable source of additional water was reported to be the alluvial fill of Canyon de Chelly.

Field work

The work was under the general supervision of S. F. Turner, District Engineer (Ground Water). L. C. Halpenny, engineer, and S. C. Brown, geologist, began work in the Chinle area January 26, 1948, and completed the field reconnaissance February 3. The work was hampered by heavy snows which covered the land surface and made field work difficult.

GEOLOGY OF THE CHINLE AREA

There are two principal stratigraphic units cropping out in the immediate vicinity of Chinle. The Chinle formation, of Triassic age, lies unconformably upon the DeChelly sandstone member of the Cutler formation, of Permian age. About 6 miles west of Chinle, the Chinle formation is overlain by the Glen Canyon group. Gregory[1] shows the Shinarump conglomerate, of Triassic age, lying between the DeChelly sandstone member of the Cutler formation and the Chinle formation to the south of Canyon de Chelly. However, the authors did not observe any exposures of the Shinarump conglomerate south of the canyon along the Chinle-Sawmill road. The Shinarump is also absent on the north side of the canyon.

1/ Gregory, H. E., Geology of the Navajo country; a reconnaissance of parts of Arizona, New Mexico, and Utah: U. S. Geol. Survey Prof. Paper 93, pl. 2, 1917.

At the mouth of Canyon de Chelly, the DeChelly sandstone member of the Cutler formation dips westward under the Chinle formation. The overlying Chinle formation has a strike of N. 15° W. and a dip of 2°45'W., based on computations by the three-point method from a plane-table survey.

The Chinle formation, of Triassic age, is estimated to be about 1,100 feet thick in the Chinle area. It lies unconformably on the DeChelly sandstone member of the Cutler formation and underlies the Glen Canyon group. The Chinle-Glen Canyon contact apparently is locally unconformable.

The upper part of the Chinle formation is about 350 feet thick. It consists of alternating beds of red sandy shale, variegated marly shale, and red to brown sandstone. The shales range up to 20 feet in thickness, and the sandstone beds range between 3 and 5 feet in thickness. The section is somewhat calcareous throughout. The middle part of the Chinle formation is about 700 feet thick and is predominantly variegated shales of pink, red, ashy gray, lavender, and dark gray. Petrified wood in chunks and logs is abundant in the gray-colored zones. Thin beds and lenses of sandstone and impure limestone are present throughout the middle section. The lower part of the Chinle formation is about 150 feet thick and consists of gray and brown sandstone beds ranging in thickness from 5 to 25 feet and separated by beds of red to brown arenaceous shale. The sandstone beds are thin-bedded to massive, lenticular, ripple-marked, and contain fragments of petrified wood.

About 40 feet of nonstratified, poorly sorted boulder gravel lies unconformably upon the DeChelly sandstone member of the Cutler formation and the Chinle formation at two places immediately south of the canyon mouth. The boulders are predominantly of sandstone and range up to 1 foot in diameter. These gravels are considered Quaternary or Tertiary (?) in age. They were deposited on a high-level bench formed by an ancient meander of the stream. After the bench was formed on the sandstone and shale, the gravels were deposited. Later the stream channel was deepened to its present position, leaving the gravel remnants high above the present channel.

DeChelly Wash is partially filled with quicksand, scattered boulders, and gravel lenses to a depth of at least 220 feet. The fill is considered as of Quaternary age in this report. The log of well 10R-156 shows 78 feet of gravel between 98 and 176 feet. A test well about 350 feet north of well 10R-156 was drilled to a depth of 222 feet, and was reported to have encountered 220 feet of quicksand overlying 2 feet of shale. A second well is now being drilled 20 feet from well 10R-156, and the last report showed that no gravel was encountered above 140 feet. The logs of the three wells indicate that the gravel beds are very spotty and lenticular.

No faults were observed in the area. The westward dip of the beds represents the west side of the Defiance uplift.

GROUND WATER

Occurrence of ground water

The DeChelly sandstone member of the Cutler formation is not generally recognized as an aquifer in the area, but an examination of the outcrops indicates that where it is below the water table it should produce water. The possibilities for obtaining water from this formation will be discussed later in the report. The sand members in the Chinle formation yield water to stock wells in Beautiful Valley and at Many Farms, which is 16 miles north of Chinle. At Chinle, the formation is probably not water bearing, as only one thin bed of sandstone occurs in that part of the formation underlying the community. The Quaternary or Tertiary (?) alluvium is not water bearing, as it lies above the water table.

The water table is near the surface in the Quaternary alluvial fill of Canyon de Chelly. The depth below the land surface ranges from a few inches near the stream to about 4 feet near the outer edge of the flood plain. Nothing is known of the seasonal and annual range of fluctuation of the water table. Movement of the ground water is downstream, at about the same gradient as that of the surface flow. Three wells produce water from the alluvial fill to the east of Chinle: wells C-2, 10R-156, and 250. Records of these wells are given in tables 1, 2, and 3, and the locations are shown on plate 1. Of the three wells, the most productive is well 10R-156, which is used to supply water for the school and community at Chinle. Well 250 is equipped with a windmill and furnishes water for stock and domestic use for the nearby Indians. Well C-2 supplies water to the headquarters of Canyon de Chelly National Monument and to Thunderbird Ranch.

The log of well 10R-156 shows that water-bearing beds of gravel and sand were encountered at a depth of 98 to 176 feet, with the most productive horizon reported at 152 to 174 feet. The well was dug and sealed to a depth of 42 feet. Below this depth a drilled hole extends to a depth of 176 feet. This was cased with 4-inch pipe, with 20 feet of 3½-inch, 80-gage, button screen set at 135 to 155 feet. The 4-inch pipe was sealed at the bottom of the well and extends a foot or two into the bottom of the dug caisson. The well is reported to be producing from the screened zone. Two turbine pumps are installed in the dug portion of the well, one a gasoline-powered, standby pump and the other an electric-powered pump that is controlled by a float and automatic switch on the storage tank. Both pumps have the suction pipe installed about 2 feet above the bottom of the dug caisson.

Pumping test

A pumping test was made on well 10R-156 from January 28 to January 31. Observations of water level were also made in well 250 during the period of the test. Prior to the pumping test, the automatic electric turbine pump was operating nearly 24 hours a day. The discharge into the storage tank was unknown, and could not be measured because of the arrangement of water lines. However, the specific capacity of the well was computed as 5 gallons per minute per foot of drawdown, based on a drawdown of 26 feet with a discharge of 130 gallons per minute. Under normal operation, with the electric turbine pumping into the storage tank, the drawdown was about 16 feet. Based on the specific capacity of the well, the normal discharge was approximately 80 gallons per minute.

On the morning of January 29, an attempt was made to shut off the electric pump long enough to determine the static water level, but the first attempt failed due to the necessity for refilling the water tank. At 4:24 p. m. the pump was again shut off until 10:03 a. m. January 30. The water level recovered to a position of approximate equilibrium, 6.93 feet below the rim of the manhole in the top of the caisson. Both pumps were then turned on for 3½ hours in order to fill the storage tank. The automatic electric pump was then shut off, and an attempt was made to operate the gasoline pump at a constant discharge for a length of time sufficient for the water level in the well to attain equilibrium. At a discharge of 131 gallons per minute the water level in the well approached equilibrium at about 33 feet below the measuring point. A greater discharge could not be used for fear of lowering the water level to such an extent that oil on the surface of the water would enter the pump intake. However, about 11 p. m., January 30, the storage tank again became empty, and water had to be pumped into the tank. The pump was then shut down to obtain the recovery of the water level, but the valves on the line to the tank failed, allowing the tank of water to drain back into the well. The test was discontinued at this stage, and the automatic electric pump was turned on. The Theis[2/] recovery method was applied to the data collected, using the recovery curve obtained the night of January 29-30 and the discharge and drawdown obtained the night of January 30-31. The transmissibility of the aquifer was computed to be about 2,100. The specific capacity of the well was computed as 5 gallons per minute per foot of drawdown, from the steady discharge of 131 gallons per minute and the resulting drawdown of 26 feet. On the basis of the data obtained from well 10R-156 and well 250, the extent of the cone of depression of well 10R-156 was computed. For instance, with a steady discharge of 130 gallons per minute, the drawdown at a distance of 133 feet would be 1 foot.

During the pumping test it was noted that consumption of water at Chinle was abnormally high. The water storage tank, which is situated on an 80-foot hill between the well and the school, has a reported capacity of 20,000 gallons. During the test period the tank would usually be emptied in about 8 hours, and on one occasion the tank of water was used up in 6 hours. Based on an estimated population of 300 at Chinle, the use of water was at least 200 gallons and may have been as much as 250 gallons per person per day.

QUALITY OF WATER

Three samples of water from wells in the Chinle area were analyzed in the Geological Survey laboratory in Albuquerque. The analyses are given in table 3. The waters are hard but are otherwise suitable for domestic use.

Table 2 indicates that wells C-2 and 250 were drilled 41 feet and 28 feet, respectively, into the DeChelly sandstone member of the Cutler formation. The waters from these wells are higher in calcium, sulfate, and chloride, and lower in bicarbonate, than the water from well 10R-156, which did not penetrate the DeChelly sandstone member. This difference in chemical character indicates that at least some water is being produced from the DeChelly sandstone member in wells C-2 and 250.

2/ Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: Am. Geophys. Union Trans., p. 520, 1935.

POSSIBILITIES OF OBTAINING ADDITIONAL WATER

On the basis of the pumping test, a well for a supplemental water supply would have to be at least 500 feet from well 10R-156 to prevent serious overlapping of the two cones of depression. At a distance of 450 feet between wells, the lowering of the water table midway between the two wells would be about 2 feet. However, it was impossible to place a new well farther than about 350 feet downstream from well 10R-156 and keep the new well out of the stream channel. Therefore, a site for a test well was selected 350 feet north of well 10R-156. The location was placed about the same distance from the outer edge of the fill as well 10R-156, in an effort to strike the same lens of gravel that was found in that well. Later developments indicated that well 10R-156 would be abandoned when the new well was completed, and therefore a second site was selected about 20 feet northeast of well 10R-156.

It is probable that water can be obtained from the DeChelly sandstone member of the Cutler formation, especially where it underlies the alluvial fill in Canyon de Chelly. At Chinle the beds dip under shales of the Chinle formation and farther west the conditions are such that any water in the DeChelly will be under artesian pressure. The chemical analyses indicate that the two wells which were drilled into the DeChelly (C-2 and 250) produce water whose quality is different from that of the water from well 10R-156. This indicates that at least some water is being produced from the DeChelly in these two wells.

The log of well 10R-156 shows that no sandstone was encountered in the well, which is 176 feet deep. A plane-table traverse indicated that the top of the DeChelly sandstone member of the Cutler formation, uneroded, would have been encountered at 85 feet below the surface. The fact that sandstone was not encountered indicates that the canyon was scoured out at this point. It was calculated that at well 250 the DeChelly, if uneroded, would be 88 feet from the top of the well casing, and the log shows that sandstone was encountered at 87 feet. Thus, well 250 was drilled on the rim of the buried canyon, and well 10R-156, 60 feet farther east, was drilled in a part of the canyon which is now partly filled with alluvium.

RECOMMENDATIONS

On the basis of the driller's log of well 10R-156 it was believed that water-bearing gravels should occur at a depth of about 100 feet within a radius of a few hundred feet from the well. Accordingly, a location was selected for a test well at a distance of about 350 feet north from well 10R-156. A recommendation was made to drill into the DeChelly sandstone member of the Cutler formation in order to determine its water-bearing possibilities. The test well was drilled to a depth of 222 feet and the driller reported that the only material encountered was quicksand. The well was abandoned after drilling 2 feet in hard material reported as shale. This hard material may have been a boulder from the canyon rim or may have been the DeChelly sandstone member, but the penetration was inadequate for identification.

A site for a second test well was selected, about 20 feet northeast of well 10R-156. It is reported that, if the new well is a success, well 10R-156 will not be used except for emergency operation in the event of a temporary shut-down of the new well. It is strongly recommended that the water-bearing possibilities of the DeChelly member of the Cutler formation be tested by drilling at least 50 feet into the formation and making a bailing test with the overlying alluvium cased off. The pumping test showed that the alluvial fill would produce sufficient water for the presently planned expansion of the community of Chinle, but water for any further expansion would probably need to be produced from the DeChelly sandstone member. Therefore, it is highly desirable that the water-bearing properties of the sandstone be determined.

In order to obtain the maximum amount of information from the test well, samples of the well cuttings should be collected at intervals of 10 feet and for every formation change. Each sample should be at least 5 pounds. A sample of any water produced from the DeChelly sandstone member should be collected for analysis.

Table 1. - Records of wells in Chinle area, Apache County, Arizona.
(All wells are drilled unless otherwise noted in "Remarks" column)
(Locations of wells are shown on Plate 1)

No.	Owner	Driller	Date completed	Altitude above sea level	Depth of well (feet)	Diameter of well (in.)
d/ C-2	National Park Service	Burt Cravath	1936	-	100	8
d/ 10R-156	Navajo Service	do.	1934	-	176	4
d/ 250	do.	do.	1934	-	115	6
C-1	Chinle Catholic Mission	-	-	-	21	120
10R-155	Navajo Service	-	-	-	144	3

a/ Measuring point was top of casing or top of well curb.
b/ C, cylinder; T, turbine; G, gasoline; E, electric; W, windmill; number indicates horsepower.

Records obtained by L. C. Halpenny and S. C. Brown

No.	Water level: Depth below measuring point (feet)	Water level: Date of measurement a/	Pump and power b/	Use of water c/	Temp. °F.	Remarks
C-2	3.61	Feb. 3, 1948	C,G 3	D,S	-	Furnishes water for headquarters of Canyon de Chelly National Monument and for Thunderbird Ranch. See log.
10R-156	6.93	Jan. 30, 1948	T,E 10	P	57	Dug to 42 feet; drilled to total depth. Dug portion is 10 feet in diameter. Standby turbine pump in well powered with gasoline engine. Furnishes water for community and school at Chinle. See log.
250	11.39	Jan. 29, 1948	C,W	D,S	-	Furnishes water for stock trough and for itinerant Indians. See log.
C-1	15.98	Feb. 3, 1948	None	N	-	Dug well. Reported abandoned because of poor quality of water.
10R-155	11.10	Feb. 2, 1948	None	N	-	Abandoned stock well near Chinle Wash.

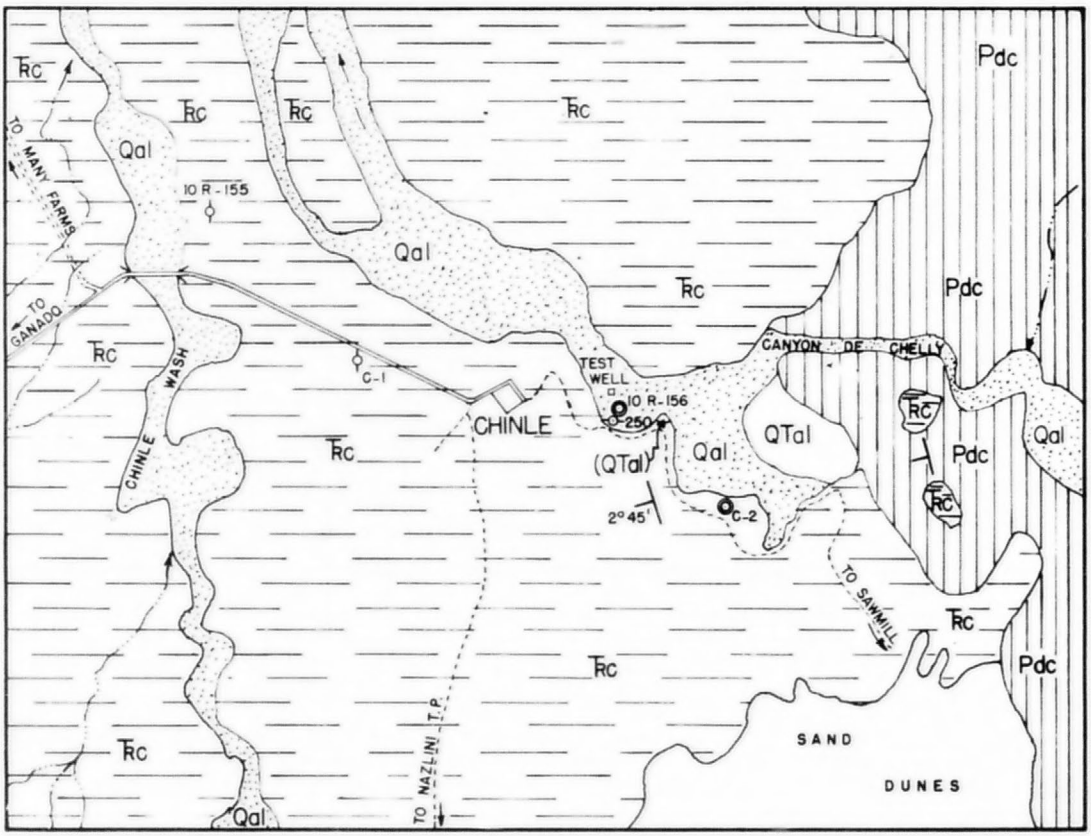
c/ D, domestic; S, stock; P, public supply; N, not used.
d/ See table 3 for analysis of water sample.

Table 2. - Logs of wells in Chinle area, Apache County, Arizona.
(Locations of wells are shown on Plate 1)

	Thickness (feet)	Depth (feet)
Log of well C-2.		
National Park Service, owner.		
Sand - - - - - - - - -	8	8
Sand and silt, water	38	46
Sand, gravel, water	4	50
Sand - - - - - - - - -	9	59
de Chelly sandstone?		
Red sandstone - - -	41	100
TOTAL DEPTH - - - - -		100
Cased to total depth; McEvoy button screen 53-61 feet.		
Log of well 10R-156.		
Navajo Service, owner.		
Caisson (measured depth, 42 feet, Jan. 30, 1948)	51	51
Clay and rock, saturated with water	47	98
Sand and gravel, very coarse- - - - - - -	78	176
Very soft red shale		176
TOTAL DEPTH - - - - -		176
Driller reports: "Producing horizon from 153 to 174 feet; best gravel in territory." Caisson is sealed off. Casing extends from about 41 feet to total depth. Perforated button screen, 135-155 feet.		
Log of well 250		
Navajo Service, owner.		
Clay and rock - - -	20	20
Sand, water - - -	2	22
Clay and rock - - -	33	55
Clay, sand, and gravel, water - - - - - -	10	65
Clay and rock - - -	22	87
de Chelly sandstone		
Sandstone - - - - -	28	115
TOTAL DEPTH - - - - -		115
Casing perforated, 84-86 feet.		

Table 3. - Analyses of water from wells in Chinle area, Apache County, Arizona.
Numbers correspond to those in tables 1 and 2 on plate 1.
Analyses by Geological Survey
(Parts per million except specific conductance)

Well No.	Date of collection 1948	Depth (feet)	Specific conductance (Micromhos 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 $CaCO_3$
C-2	Feb. 3	100	658	94	24	24	307	105	16	0.5	0.3	429	333
10R-156	Jan. 30	176	510	71	18	21	312	26	10	0.4	0.3	319	251
250	do.	115	674	78	25	39	302	91	26	0.5	4.0	428	298



UNITED STATES DEPARTMENT OF THE INTERIOR
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PLATE I. MAP OF CHINLE AREA, ARIZONA

SHOWING GEOLOGY AND LOCATIONS OF WELLS.

EXPLANATION

MATERIAL	WATER-BEARING PROPERTIES
ALLUVIUM (QUATERNARY)	YIELDS WATER TO WELLS FROM GRAVEL LENSES.
ALLUVIUM (QUATERNARY OR TERTIARY ?)	ABOVE WATER TABLE IN AREA.
CHINLE FORMATION (TRIASSIC)	YIELDS SMALL AMOUNTS OF WATER TO WELLS FROM SAND MEMBERS.
DE CHELLY SANDSTONE (PERMIAN ?)	MAY BE WATER BEARING IN AREA.

2°45' DIP AND STRIKE
WELL WITH POWER PUMP
WELL WITH WINDMILL
UNUSED WELL

GRADED ROAD
UNIMPROVED ROAD
TRAIL

GEOLOGY BY S. C. BROWN AND WELL LOCATIONS BY L. C. HALPENNY.

SCALE: 0 1 2 MILES

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