MEMO. ON GEOLOGIC RECONN. OF SIX SITES FOR WATER WELLS, WESTERN PART OF NAVAJO INDIAN RESERVATION

By

H. A. Whitcomb and C. A. Repenning

Mr. L. C. Halpenny, Holbrook, Arizona May 3, 1951

Chas. V. Theis, Albuquerque, N. M.

Status of report, "Memorandum on geologic reconnaissance of six sites for water wells, western part of Navajo Indian Reservation, Coconino and Navajo Counties, Arizona, by H. A. Whitcomb, and C. A. Repenning, April 1950."

The above report was sent Washington for editing and release on April 21, 1950, and we have not been advised as to its status. If you have this information, will you please advise whether it has been released to the open files or to the Indian Service only.

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CVT/rj

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April 21, 1950

Transmittal of report: "Memorandum on geologic reconnaissance of six sites for water wells, western part of Navajo Indian Reservation, Coconino and Navajo Counties, Arizona."

Enclosed is the original and one carbon copy of the above report for editing, for release first to the Office of Indian Affairs and later to the open file.

Copies of the report are being sent for review to Messrs. Theis, Howard, Hem, and Read. They have been requested to send their criticisms directly to Washington.

Harold A. Whitcomb

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cc: C. V. Theis
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United States

Department of the Interior

Geological Survey

Released to open file June 1950

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Tucson, Arizona
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Introduction

At the request of the Bureau of Indian Affairs, the Geological Survey is making an investigation of the ground-water resources of the Navajo and Hopi Indian Reservations. The program of work includes investigating the possibility of developing domestic and stock water supplies at sites selected by officials of the Navajo Service. It is anticipated that test wells will be drilled at those sites where investigations by the Geological Survey show that ground water is likely to be available. Test wells that yield water of satisfactory quality are usually completed as producing water wells.

This memorandum describes reconnaissance investigations at six localities in the western part of the Navajo Reservation and one in the western part of the Hopi Reservation. The principal community in the vicinity of the localities studied is Tuba City, which lies north of the Little Colorado River about 13 miles by road northeast of U. S. Highway 89 (see fig. 1). Tuba City is 75 miles from the nearest railroad station, at Flagstaff, Arizona.

Each of the six localities studied was assigned a number for convenience (see locations, fig. 1). The sites are discussed individually in the following sections.

Site 1

The proposed well site is on the Kaibito Plateau in a little known area between Kaibito and Navajo Canyons where surface-water supplies are impermanent or relatively inaccessible. The area is about 20 miles by truck trail northeast of Kaibito. The Kaibito Plateau is a region of light rainfall, and the mean annual precipitation probably does not exceed 7 inches. Ephemeral streams carry surface runoff northward to Navajo Creek and westward to Kaibito Wash.

The proposed location is in a broad valley which slopes northward toward the upper reaches of Navajo Canyon. The altitude is about 6,000 feet.

The Navajo sandstone of the Glen Canyon group (Jurassic), which forms much of the surface of the Kaibito Plateau, is exposed in the vicinity of the prospective well site. The presence of outcrops of the overlying Carmel formation of the San Rafael group (Jurassic), capping the Navajo sandstone a short distance to the south, indicates that practically the entire thickness of the Navajo sandstone is represented. It is estimated that the Navajo sandstone is between 800 and 1,000 feet thick in the area studied. The sandstone is characteristically buff in color, grading locally to pale orange or pink, massive, and cross-bedded on a large scale. Occasional thin lenses of cherty limestone occur locally in the upper part of the formation. As a rule, the hydrologic properties of the sandstone are excellent. The Navajo sandstone is underlain by about 125 feet of relatively impermeable shales and sandstones of the Kayenta formation. The massive Wingate sandstone, about 200 feet thick, underlies the Kayenta formation and constitutes the basal unit of the Glen Canyon group.

A reconnaissance of the region, supplemented by review of published reports of geologic investigations in adjacent areas, indicates that the site for the proposed well is on the northern flank of a broad dome. Dips range from 1° to 2° north. In the area, the Navajo sandstone has been deeply incised by two major canyons. Navajo Canyon lies along the northern and eastern margins of the dome, and the canyon of Kaibito Wash has been cut into the dome west of the area.

Several factors combine to produce conditions that are unfavorable for the accumulation of ground water in the area. South and east of the proposed well site the Navajo sandstone is overlain by a series of sandy shales and thin, interbedded sandstones that make up the lower part of the Carmel

formation. This relatively impermeable capping, up-dip from the well site, restricts the amount of recharge available to the Navajo sandstone. The dissection of the Navajo sandstone by Navajo and Kaibito canyons has progressed to the base of the formation in all but the upper reaches of Navajo Canyon, causing most of the accumulated ground water to escape down dip. There is little opportunity for recharge of the underlying Kayenta and Wingate formations. The only exposures in the region are in cliffs in the lower parts of canyon walls. The top of the Kayenta formation is made up of soft, silty shale that impedes percolation of water from the Navajo sandstone downward into the Kayenta and Wingate beds. For these reasons, it is believed that the Kayenta and Wingate formations cannot be considered as aquifers in the area here described.

Geologic conditions in the area lead the writers to conclude that drilling a well at site 1 is inadvisable. This conclusion is supported by information obtained from test wells drilled under similar geologic conditions in adjacent areas (wells 1A-125, 1A-150, and 1A-151, tables 1 and 2). It is certain that any water encountered will be at considerable depth, probably at the contact between the Navajo sandstone and the Kayenta formation.

Site 2

The prospective site is about 12 miles northwest of Kaibito. Geologic conditions in this area are comparable to those existing north of Kaibito, at site 1. Three dry holes, already drilled short distances to the south and to the west of the proposed site, make further attempts to develop a well in the area ill-advised. The holes (wells 1A-125, 1A-150, and 1A-151, tables 1 and 2) were drilled to depths of 1,268 feet, 1,420 feet, and 820 feet, respectively.

Site 3

The proposed well site is located on the Shonto Plateau about 3 miles southwest of the Shonto School. The area lies between Shonto Wash and Begashbito Wash, about half a mile west of the road that links Shonto with Reservation Highway 1. The altitude at the well site is approximately 6,300 feet. The area is drained by Shonto and Begashbito washes, which flow southwestward to Moenkopi Wash.

H. V. Peterson, geologist, Geological Survey, submitted a memorandum to the Navajo Service in 1942, in which he stated that water might be expected at this site at a depth of about 600 feet. After a brief reconnaissance of the Shonto area, the present writers are substantially in agreement with the conclusions reached by Mr. Peterson.

An undetermined thickness of Navajo sandstone underlies the site of the proposed well. The upper part of the formation has been removed by erosion. It is believed that the thickness in the Shonto area is in excess of the 400 feet of Navajo sandstone exposed in Laguna Canyon, 10 miles northeast. About 200 feet of the underlying Kayenta formation and Wingate sandstone are also exposed in Laguna Canyon. It is estimated that the thicknesses of the Kayenta formation and the Wingate sandstone in the Shonto area are 125 feet and 275 feet, respectively.

The only deep well in the vicinity (well 2A-13, tables 1, 2, and 3) is located at Inscription House, about 4 miles northwest. The well was drilled to a depth of 620 feet, and yields about 10 gallons per minute from the lower 70 feet. The well log shows an upper 500 feet of yellow sandstone and a lower 120 feet of red sandstone. The lack of detailed descriptions of the strata penetrated makes precise identification impossible. On the basis of available information, there is nothing to indicate that any formation

other than Navajo sandstone was penetrated. It is improbable that the sandy shales and sandstones of the Kayenta formation would have been passed unnoticed. If this assumption is correct, it seems likely that the top of the Kayenta formation probably is not far below the bottom of the well. It is postulated that the relatively impermeable shales at the top of the Kayenta formation retard percolation of ground water from the Navajo sandstone into the underlying beds. Under these conditions, it is believed that in the Shonto area ground water within a practicable drilling distance is confined principally to the lower part of the Navajo sandstone.

The quality of ground water in this area is indicated by the first three analyses in table 3. The water from springs in Shonto Wash issues from the Navajo sandstone and would be satisfactory for domestic use, although it is hard. Water from well 2A-13, probably also from the Navajo sandstone, is lower in dissolved solids and softer than water from the springs. Water from the dug well at Shonto is obtained in alluvium which is recharged in part by the spring flow from the Navajo sandstone. The water from this well, however, is lower in dissolved solids and hardness than water from the springs, indicating that the alluvium may be recharged in part by flood waters in the wash. Water obtained from the Navajo sandstone at the site for the proposed well probably will be of satisfactory quality.

The present investigation leads the writers to believe that the geologic conditions that occur in the vicinity of the well at Inscription House, also exist at the well site 4 miles southeast. A well drilled to a depth of 700 to 900 feet at this site should produce sufficient water to warrant the installation of a windmill.

Site 4

The fourth site investigated is at the foot of the southeastern slope of Shonto Plateau, in Klethla Valley. The site is about 13 miles northeast of Cow Springs, and about 1½ miles west of Reservation Highway 3 along the road to Betatakin. The altitude at the well site is approximately 6,300 feet.

The Navajo sandstone crops out over most of Shonto Plateau. The formation dips approximately 7°E. into Klethla Valley and disappears beneath alluvium. Eastward, the dip of the beds overlying the Navajo sandstone decreased to 5 degrees.

It is expected that a well drilled at this site would enter the Navajo sandstone near the top of the formation, after passing through 10 to 15 feet of dune sand. The thickness of the Navajo sandstone in the area is estimated to be between 600 and 800 feet, on the basis of exposures in Laguna Canyon about 10 miles to the north. A thin but apparently persistent bed of limestone was observed west of the well site, about 150 to 200 feet below the top of the Navajo sandstone. If this limestone continues eastward, it may act as a confining bed and cause ground water in the lower part of the sandstone to be under artesian pressure. No wells have been drilled in the vicinity of site 4. Quality of water in the Navajo sandstone in this area is expected to be similar to that of water in the vicinity of site 3.

If a well is drilled at site 4, it is considered advisable to drill to the base of the Navajo sandstone in order to assure maximum production. The base of the Navajo sandstone is estimated to lie at a depth of 600 to 800 feet.

Site 5

Site 5 is located on the east side of Kaibito Plateau, about 6 miles north of Red Lake (see fig. 1). The area can be reached by wagon trail from Red Lake or from the Red Lake-Navajo Mountain road. The altitude at the site is about 5,600 feet. Vegetation-covered sand dunes occupy most of the area.

The oldest formation exposed in the area is the Navajo sandstone, which crops out along the western margin. This sandstone is estimated to be 500 to 600 feet thick at the well site. The Navajo sandstone is overlain by approximately 200 feet of pink sandy shales and thin gray sandstone of the Carmel formation. An estimated 200 to 250 feet of the fine-grained, massive Entrada sandstone, the upper formation of the Jurassic San Rafael group, overlies the Carmel formation. Only the lower part of the Morrison formation, which overlies the Entrada sandstone, is present in the area. The formation is exposed at Red Lake. Northward, the formation has been thinned by erosion, and only a few feet of basal sandstone and shale may underlie the sand dunes at the well site.

A well drilled at the proposed site is expected to penetrate the following stratigraphic sequence:

	Thickness	Depth to base
Alluvium (dune sand)	15-20	15-20
Morrison formation	0-50	15-70
Entrada sandstone	200-250	215-320
Carmel formation	200-250	415-570
Navajo sandstone	500-600	915-1,170

The dip of the beds at the well site is about 1°SW. Within 5 miles southward, the dip of the strata reverses and steepens to 16°NE. West of the well site, dips ranging from 6° to 15°E. were measured. The direction and the distribution of dips indicate that the well site is on the gently dipping northeast limb of a southeast-plunging syncline.

The only existing wells in the area are three wells that have been dug in the alluvium at Red Lake. The supply of water available from the dune sand at the well site is considered negligible.

The Morrison formation is very thin or absent and the hydrologic properties of the lower unit are not favorable. The massive Entrada sandstone has favorable water-bearing properties, large storage capacity, and an extensive recharge area. The preponderance of relatively impermeable shales in the Carmel formation limit its water-bearing capacity. The formation is not considered an important aquifer in the area. The Navajo sandstone has excellent hydrologic properties, is strongly jointed where exposed, and has a large recharge area.

It is concluded that only the Entrada and the deeper-lying Navajo sandstones are likely to yield water in sufficient quantities to warrant drilling a well.

As a result of stratigraphic and structural studies it is believed, that to obtain a maximum supply of water at the site chosen, the well should be drilled a few feet below the base of the Navajo sandstone into the underlying shales of the Kayenta formation. The base of the Navajo sandstone should be reached at a depth of 900 to 1,200 feet. A quantity of water sufficient to meet the expected demand should, however, be obtained at a depth of 900 feet. It is anticipated that water encountered in the Navajo sandstone will be under artesian pressure.

Little is known of the quality of ground water in the Entrada and Navajo sandstones in this area. However, water obtained from the Navajo sandstone on the Kaibito Plateau is almost universally suitable for domestic use. There is no reason to believe that water from the Entrada sandstone will not also be satisfactory.

Site 6

Well site number 6 is located at the Tuba City coal mine, about 13 miles southeast of Tuba City and about half a mile north of Reservation Highway 3. The Coal Mine is on the Moenkopi Plateau at the rim of Coal Mine Canyon. The altitude at the mine is approximately 5,900 feet. The terrain in the vicinity of the mine is gently rolling. Drainage is northeast.

On the Moencopi Plateau, the regional dip is gentle and generally to the east. However, in the vicinity of the Coal Mine local flexing of strata has resulted in a shallow syncline with a northwest-trending axis. The Tuba Coal Mine and the site of the proposed well, are located on the southwest limb of the syncline.

Coal Mine Canyon is cut about 400 feet into vari-colored Jurassic sandstones of the Morrison formation and the underlying San Rafael group. At the Coal Mine, the Morrison formation is disconformably overlain by about 30 feet of alternating shale and coal beds which are assigned to the base of the Cretaceous Mancos shale. The Dakota (?) sandstone, which elsewhere underlies the Mancos shale, has not been recognized at the Coal Mine.

The absence of outcrops of strata underlying the Carmel formation, the lower member of the San Rafael group, makes it difficult to predict the prospects of obtaining ground water from the underlying beds.

As a result of studies along the western margin of the Moencopi Plateau it is believed that 400 to 500 feet of rocks of the San Rafael and upper Glen Canyon groups underlie the Morrison formation. Under favorable geologic conditions, the Entrada and Navajo sandstones are good aquifers, especially the Navajo sandstone. However, Moenkopi Wash, which dissects those sandstones east of Tuba City, undoubtedly drains much of the water

that percolates into them.

Three wells, ranging in depth from 358 to 752 feet, were successfully completed within a few miles south and west of the Coal Mine in 1935 and 1936 (wells 3A-27, 3A-149, and 3A-28, tables 1, 2, and 3). The depth to water in the three wells was increasingly greater northward, ranging from 150 to 490 feet. The nearest well (3A-27), located about 4 miles west-southwest of the Coal Mine, is 564 feet deep and encountered water at 490 feet. Production was recorded as 20 gallons per minute. No recent tests have been made, consequently present production is unknown. It is believed that geologic conditions at the Coal Mine are similar to those at well 3A-27, and that a well drilled at the proposed site would be equally productive. It is impossible to predict exactly at what depth water would be encountered at the Coal Mine, but it is not to be expected at a depth of less than 500 feet.

An analysis of a water sample from well 3A-149, about 6 miles southwest of the well site, indicates that ground water in the Jurassic rocks in this region is of suitable quality for domestic and stock use.

Conclusions

Geologic conditions at sites 1 and 2 are considered unfavorable, and drilling is not recommended at these localities. There is a reasonably good possibility of developing water supplies of suitable quality for domestic use at the remaining four sites.

Table 1.-Records of wells in western part of Navajo Indian Reservation, Coconino and Navajo Counties, Arizona
(All wells are drilled unless otherwise noted in "Remarks" column.)

Navajo Service Well no.	Location (miles from nearest proposed well site)	Owner	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (in.)
1A-125	Site 1 22 SW	Navajo Service	Fred Bentley	1936	6,200	1,268	-
1A-150	22 W 5 NW	do.	Art Williams	1936	-	1,420	-
1A-151	29 SW 12	do.	do.	1938	-	820	-
d/ 2A-13	Site 3 4 NW	do.	C. M. Carroll	1935	-	620	6-5/8
d/ -	5 NE 3	do.	-	-	-	20	96
3A-27	Site 6 4 W	do.	C. M. Carroll	1935	5,820	564	6-5/8
d/3A-149	5 SW 6	do.	do.	1935	-	752	6-5/8
3A-28	10 SW	do.	do.	1935	5,450	358	6-5/8

a/ Measuring point was top of casing.
b/ C, cylinder; W, windmill; G, gasoline.
c/ N, not used; D, domestic; S, stock; P, public supply.
d/ See table 3 for water analysis.
e/ Water level reported at time of drilling; cannot be measured without removing pump.

Records obtained from Water-Supply Office, Navajo Service.

Navajo Service Well no.	Water level: Depth below measuring point (feet) a/	Water level: Date of measurement	Pump and power b/	Use of water c/	Remarks
1A-125	-	-	None	N	Dry hole. Located 7½ miles south of lat. 36° 45', 9 miles west of long. 111°15'. See log.
1A-150	-	-	None	N	Dry hole. Located 3 miles south of lat. 36° 45', 13½ miles west of long. 111°15'. See log.
1A-151	-	-	None	N	Dry hole. Located 8 miles south of lat. 36° 45', 2 miles west of long. 111°30'. See log.
2A-13	550	e/	C,W	D,S	At Inscription House. Reported yield, 10 gallons per minute. See log.
-	6.8	Oct. 11, 1949	C,G	P,S	At Shonto. Dug well in alluvial fill of Shonto Wash. Flow of wash is perennial; derived from upstream springs issuing from Navajo sandstone.
3A-27	490	e/	C,W	S	Located ½ mile south of lat. 36°00', 5-3/4 miles west of long. 111°00'. Reported yield, 20 gallons per minute. See log.
3A-149	485	e/	C,W	S	Located 3½ miles south of lat. 36°00', 4-3/4 miles west of long. 111°00'. Reported yield, 20 gallons per minute. See log.
3A-28	150	e/	C,W	S	Located 6½ miles south of lat. 36°00', 8½ miles west of long. 111°00'. Reported yield, 20 gallons per minute. See log.

Table 2.-Driller's logs of wells in western part of Navajo Indian Reservation, Coconino and Navajo Counties, Ariz.

	Thickness (feet)	Depth (feet)
Driller's log of well 1A-125.		
Surface sand - - - -	5	5
Hard buff-colored sandstone - - - - - - - -	163	168
Pink sandstone - - -	107	275
Dark-pink sandstone	105	380
Buff-colored sandstone	24	404
Soft red sandstone -	42	446
Hard red sandstone -	37	483
Soft red sandstone -	40	523
Sandy red shale - -	12	535
Pink sandstone - - -	6	541
Soft, coarse-grained red sandstone - - -	49	590
Red shale - - - - -	5	595
Sharp-grained pink sandstone - - - - -	13	608
Sandy red shale - -	22	630
Red sandstone - - -	15	645
Buff-colored sandstone	5	650
Pink sandstone - - -	25	675
Pink sandy limestone	5	680
Sandy, light-red shale	15	695
Hard shale - - - - -	3	698
Sandy red shale - -	55	753
Red sandstone - - -	22	775
Buff-colored sandstone	15	790
Coarse-grained brown sandstone - - - - -	5	795
Pink sandstone - - -	30	825
Red sandstone - - -	20	845
Buff-colored sandstone	20	865
Pink sandstone - - -	5	870
Sandy red shale - -	81	951
Sandy pink shale - -	34	985
Fine-grained red sand	20	1,005
Sandy red shale - -	15	1,020
Coarse-grained red sandstone - - - - - - -	55	1,075
Soft, light-red sandstone - - - - - - -	17	1,092
Sandy red shale - -	8	1,100
Pink sandstone - - -	27	1,127
Red sandy limestone	19	1,146
Pink sandstone - - -	9	1,155
Red shale - - - - -	20	1,175
White sandstone - -	10	1,185
Red shale - - - - - -	5	1,190
Hard red sandstone -	38	1,228
Sandy red shale - - -	22	1,250
Red shale - - - - - -	8	1,258
Red sandstone - - - -	20	1,278
TOTAL DEPTH - - - - -		1,278
Driller's log of well 1A-150.		
Blow sand - - - - - -	24	24
Coarse-grained white sand - - - - - - - -	151	175
Coarse-grained light-red sand - - - - - -	105	280
Light-red sandstone -	35	315
Dark-red sandstone -	35	350
Red sandstone - - - -	80	430
Light-red sandstone -	180	610
Yellow sandstone - -	90	700
Coarse-grained red sandstone - - - - -	75	775
Hard red sandstone -	104	879
Hard limestone - - -	12	891
Light-red sandstone -	59	950
Hard red limestone -	10	960
Sandy red shale - - -	95	1,055
Pink sandstone - - -	45	1,100
Red sandstone - - - -	90	1,190
Soft, sandy red shale	70	1,260
Sandy red shale - - -	41	1,301
Sandy pink shale - -	119	1,420
TOTAL DEPTH - - - - -		1,420
Driller's log of well 1A-151.		
Blow sand - - - - - -	4	4
Red sandstone - - - -	36	40
Yellow or tan-colored sandstone - - - - -	127	167
Soft yellow sandstone	50	217
Soft gray sandstone -	213	430
Yellow or tan-colored sandstone - - - - -	145	575
Gray sandstone - - -	195	770
Soft, caving gray sandstone - - - - - - -	50	820
TOTAL DEPTH - - - - -		820

Table 2.-Driller's logs of wells in western part of Navajo Indian Reservation, Coconino and Navajo Counties, Ariz.-Cont.

	Thickness (feet)	Depth (feet)
Driller's log of well 2A-13.		
Red sand	35	35
Yellow sand	65	100
Hard yellow sand	35	135
Yellow sand	360	495
Red sand	65	560
Red water sand	60	620
TOTAL DEPTH		620
Driller's log of well 3A-27.		
Surface sand	15	15
White sand, water at 490 feet	549	564
TOTAL DEPTH		564
Driller's log of well 3A-149.		
Surface soil	5	5
Red sand	15	20
Yellow sand	52	72
White sand	103	175
Brown sand	60	235
White sand	105	340
Yellow sand	50	390
White sand	180	570
Gray sand	125	695
White water sand	37	732
Hard gray sand	20	752
TOTAL DEPTH		752
Driller's log of well 3A-28.		
White sand	60	60
Red sand	45	105
White sand, water	250	355
Red shale	3	358
TOTAL DEPTH		358

Table 3.-Analyses of water samples from western part of Navajo Indian Reservation, Coconino and Navajo Counties, Arizona. Analyses by Geological Survey. Parts per million except specific conductance.

Well no.	2A-13	-a/	-b/	3A-149
Date sampled	Mar. 21, 1950	Oct. 11, 1949	Mar. 20, 1950	Sept. 28, 1949
Temperature, degrees F.	62	52	54	61
Specific conductance, micromhos @ 25°C.	299	317	501	522
Silica (SiO_2)	14	18	27	12
Calcium (Ca)	45	44	59	29
Magnesium (Mg)	8.8	7.6	23	10
Sodium and potassium (Na+K)	3.2	9.9	17	72
Bicarbonate (HCO_3)	146	146	294	160
Sulfate (SO_4)	11	14	17	121
Chloride (Cl)	9	14	14	8
Fluoride (F)	.0	.0	.4	.5
Nitrate (NO_3)	15	11	.9	.7
Dissolved solids	178	190	303	332
Hardness as $CaCO_3$	148	141	242	114

a/ Dug well at Shonto.

b/ Shonto Wash, at Shonto. Discharge, 50 gallons per minute; combined flow of several springs that issue from Navajo sandstone.

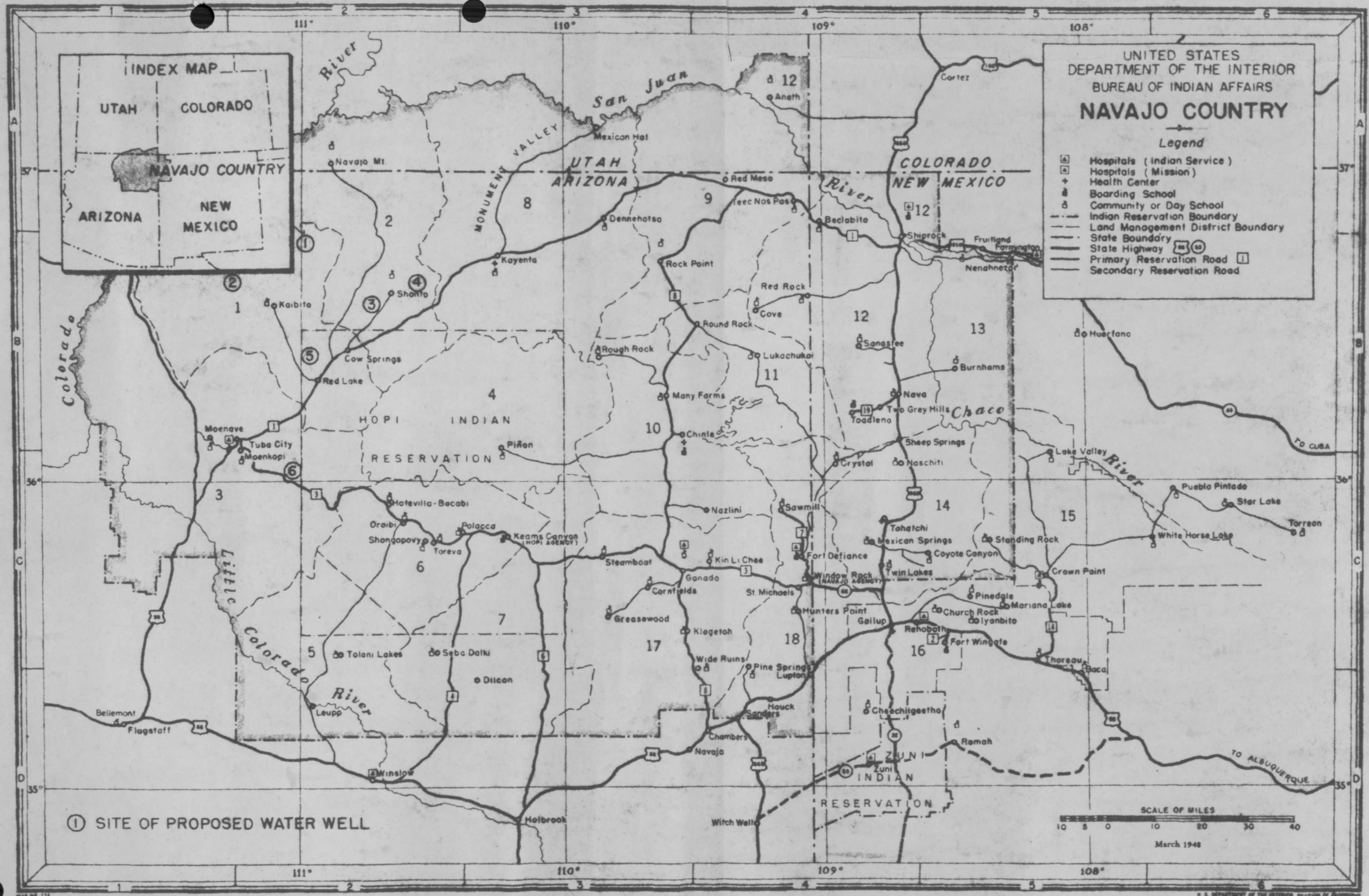

FIGURE I.– MAP OF NAVAJO INDIAN RESERVATION, SHOWING LOCATIONS OF WELL SITES.