

GEOLOGICAL SURVEY CIRCULAR 360



GEOLOGY AND GROUND-WATER SUPPLIES
OF THE FORT WINGATE INDIAN SCHOOL
AREA, MCKINLEY COUNTY, NEW MEXICO

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By J. T. Callahan and R. L. Cushman

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ABSTRACT

A study of the local geology in relation to ground-water occurrence was made in the vicinity of the Fort Wingate Indian School which lies in McKinley County, N. Mex., just east of the town of Gallup.

The geologic formations studied range in age from Permian to Triassic. The San Andres formation of Permian age is composed of the Glorieta sandstone member and an overlying limestone member. The formation, which contains water under artesian conditions, is a single aquifer because water occurs in both the sandstone and the limestone members and no impermeable strata separate them.

Other formations present in the area, all of Triassic age, are the Moenkopi formation, the Shinarump conglomerate, and the Chinle formation. These three relatively impermeable formations confine the water in the

underlying San Andres formation. Three water-bearing sandstones are present in the Chinle formation. The authors believe that the production of large amounts of water from these sandstone beds is impractical.

The recharge area for the San Andres formation lies higher in the Zuni Mountains, immediately south of the Fort Wingate Indian School, and includes some 80 square miles. The recharge area for the Chinle formation consists of narrow bands of sandstone in and near the school lands. These sandstones are recharged by relatively small amounts of water.

Water from the San Andres formation differs in chemical constituents from that of the Chinle formation. Water from the San Andres formation is very hard and contains several hundred parts per million of sulfate. Water from sandstone of the Chinle formation is only moderately hard, but it contains increasingly greater amounts of dissolved solids downdip from the recharge areas.

Probable reasons are given for the wide range in the amount of flow from the several wells that penetrate the San Andres formation, and suggestions are given to guide future ground-water development from the San Andres formation.

INTRODUCTION

At the request of the Navajo Service, Bureau of Indian Affairs, a ground-water investigation was made in the vicinity of the Fort Wingate Indian School in McKinley County, N. Mex. (fig. 1), to learn more about the water-bearing characteristics of the aquifers in the area, particularly the San Andres formation.

This investigation is a part of the study of the ground-water resources of the Navajo and Hopi Indian Reservations now being made by the U. S. Geological Survey. The results of this study precede a complete report on the ground-water resources of the Navajo country. The work was financed by, and was in cooperation with, the Navajo Service, Bureau of Indian Affairs.

Fieldwork in this area was begun in October 1950 and continued intermittently until October 1953. The work was under the direct supervision of J. W. Harshbarger, Navajo Project geologist, and under the general supervision of L. C. Halpenny, district engineer of the Ground Water Branch of the Geological Survey for Arizona. The fieldwork was begun by H. A. Whitcomb and R. L. Jackson and completed by the authors. The investigation consisted of a geologic reconnaissance, measurement of the discharge of springs and wells, and collection and chemical analysis of water samples.

of the Zuni Mountains and form a southward-trending hogback. The land surface south of the area slopes upward to the crest of the Zuni Mountains.

Drainage in the area is controlled by the geologic structure and topography. Surface water drains northward down the dip slope of the strata and through breaches in the cuestas to the Rio Puerco just south of U. S. Highway 66, and then westward to the Little Colorado River. Springs at the Fort Wingate Indian School, the Navajo Service Sheep Laboratory (about 2 miles southwest of the school), and in the canyons to the south maintain perennial streamflow in the upper reaches of the washes. Surface-water runoff reaches the Rio Puerco only after heavy rainfall. Washes not fed by springs are dry throughout most of the year and carry surface flow only after rains or during periods of melting snow.

GEOLOGY AND GROUND-WATER RESOURCES

Geologic Formations and their Water-Bearing Properties

The rocks of importance to an investigation of the ground-water resources in the Fort Wingate Indian School area range in age from Permian to Late Triassic. The formations concerned are listed in the stratigraphic column below, together with the probable maximum thickness and the water-bearing character of each. A more detailed stratigraphic section is given on page 10. Rocks of Jurassic and Cretaceous ages are exposed on the western and northern edges of this area but are not a source of water for the area. Thus, they have no influence on the water problems of the area and are not discussed further in this report.

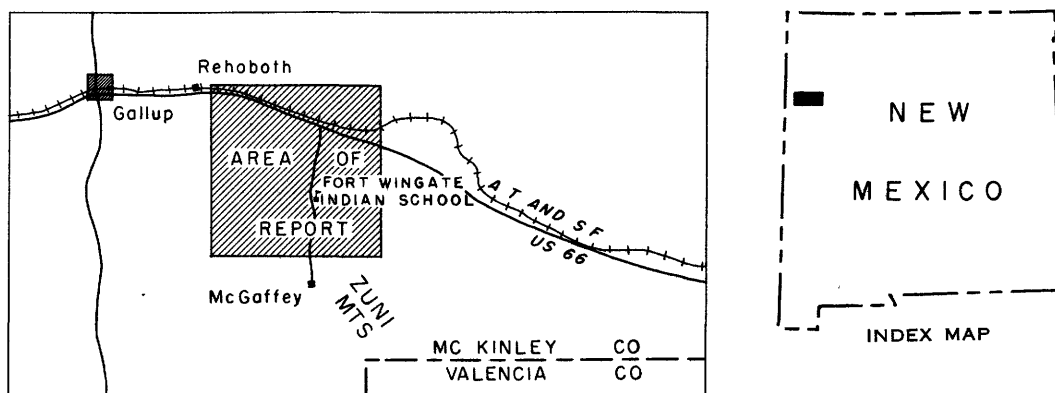
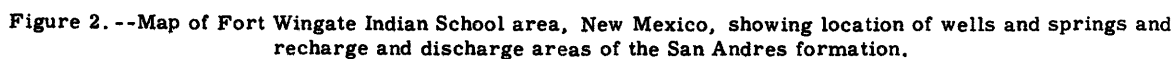


Figure 1.--Map of Navajo country showing location of Fort Wingate Indian School area.

LOCATION, TOPOGRAPHY, AND DRAINAGE

The Fort Wingate Indian School is located on Government-allotted land in McKinley County, N. Mex., about 12 miles east of Gallup, N. Mex., and 3 miles south of U. S. Highway 66 (fig. 2). The area is in a broad valley cut into the northern slope of the Zuni Mountains. To the north the valley is rimmed by the high escarpment of a cuesta formed by erosion of northward-dipping strata. A series of lower cuestas parallel the cuesta of the high escarpment. West of the area these cuestas merge around the north flank

Formation	Age	Character	Thickness (feet)
Chinle formation.....	Triassic	Water bearing in part	1,600
Shinarump conglomerate.....	do	do	50
Moenkopi formation.....	do	Nonwater bearing	34
San Andres formation:			
Limestone member.....	Permian	Water bearing	100
Glorieta sandstone member.	do	do	200



Permian System

San Andres formation

The San Andres formation (Lee and Girty, 1909), composed of the Glorieta sandstone member and an overlying limestone member, is considered a single aquifer because no impermeable bed separates these members. In this area the limestone member is about 100 feet thick and the Glorieta sandstone member is about 200 feet thick. The wells at Rehoboth Mission and the Navajo housing project and a well northeast of the Rehoboth Mission identified as well 3 all partly penetrate the San Andres formation (fig. 2).

Glorieta sandstone member. --The color of the Glorieta sandstone member ranges from a very light gray to a moderate orange pink. The sandstone is composed almost entirely of subrounded to rounded quartz grains that are very fine to medium grained and are well sorted. The amount of cementation of the sandstone varies. Well-cemented zones are intercalated with loosely cemented zones. Neither the horizontal nor vertical position of these zones within the sandstone can be predicted.

Limestone member. --The limestone member is grayish orange pink to light brown in color and aphanitic to finely crystalline in grain; it contains varying amounts of silt and dolomite near its base. It is thick (2 to 4 feet) to very thick bedded (more than 4 feet), and has well-developed joint systems and solution channels. The upper surface of the limestone was subjected to postdepositional erosion; thus the thickness of the limestone is not uniform.

The movement of water within the San Andres formation is controlled by the following factors: The size and extent of the joints and solution channels within the limestone; the permeability of the underlying sandstone; and the direction of the dip of the beds. Water can move freely through the larger open solution channels and joints in the limestone. The permeability of the sandstone varies with the size and shape of the connected pore spaces, the grain sorting, and the amount of cement deposited in the pore spaces between the sand grains. It is possible that well-cemented impermeable zones occur as isolated irregularly shaped masses, and that ground water moves down dip around them much like water in a stream moves around obstructions. Water tends to move along bedding planes and joints but neither are well developed in the sandstone. Consequently the lateral velocity of water within the sandstone is comparatively slow because the pore spaces are smaller in size than the individual grains. The velocity is probably of the magnitude of hundreds of feet per year.

Triassic System

Moenkopi formation

The Moenkopi formation (Ward, 1901) of the Triassic system unconformably overlies the San Andres formation, as it was deposited on the eroded surface of the Permian rocks. The formation consists of reddish-brown sandy siltstone and claystone, and near the Navajo Service Sheep Laboratory it is 34 feet thick.

This formation is not everywhere present; it is absent in some places probably because of nondeposition and in others because of postdepositional erosion. The area described in this report probably is near the eastern margin of deposition of the Moenkopi formation. Wherever present, the siltstone and claystone of the Moenkopi formation form a barrier to the upward or downward movement of ground water and thereby form a part of the confining bed that causes artesian conditions to exist in the San Andres formation.

Shinarump conglomerate

The Shinarump conglomerate (Powell, 1876) overlies the Moenkopi formation. Where the Moenkopi formation is absent, the Shinarump lies directly on the limestone member of the San Andres formation. The Shinarump conglomerate consists of irregular lenses of conglomeratic sandstone interbedded with grayish-purple and light-brown mudstone. At one place, near the Navajo Service Sheep Laboratory, the formation consists of 12 feet of mudstone overlain by 13 feet of conglomerate. This is about the average thickness for the formation in this area. The mudstone acts as a barrier to the movement of water, and, where it lies directly on the limestone member of the San Andres formation, it forms a part of the confining beds that cause artesian conditions in that formation. At places, water is found in small quantities in the sandstone and conglomerate of the Shinarump conglomerate. The water moves down dip to the north. Where the sandstone and conglomerate lie in direct contact with the San Andres formation, they could be recharged by water moving upward under artesian pressure from that formation.

Chinle formation

The Chinle formation (Gregory, 1916), of Late Triassic age, overlies the Shinarump conglomerate. Rocks of the Chinle formation crop out in nearly all the Fort Wingate Indian School area. The Chinle formation has a total thickness of about 1,600 feet in this vicinity. The formation consists mostly of claystone and siltstone and, in lesser amounts, of sandstone and limestone. The outcropping resistant limestone and sandstone of the Chinle formation form parallel ridges, and the less resistant claystone and siltstone are exposed in the intervening subsequent valleys. The relatively impervious beds of the Chinle formation are the confining layers for all water-bearing rocks beneath them.

For the most part, the Chinle formation is not water bearing. However, there are three sandstones in the Chinle formation in which water has been encountered: (1) a lower sandstone at the base of the formation, (2) a middle sandstone between 400 and 500 feet above the base of the formation, and (3) an upper sandstone between 800 and 850 feet above the base of the formation. (See fig. 3.) The lower sandstone is the source of a part of the water for the well at the Fort Wingate Indian School. The middle sandstone, which occurs between 400 and 500 feet above the base of the formation, is the source of water for a well supplying the trading post at Perea (fig. 2). This same sandstone yielded water in a well drilled at the Iyanbito Day School (table 1). Claystone of the Chinle formation confines the water in the sandstone and conglomerate of the Shinarump conglomerate, and, at any place where

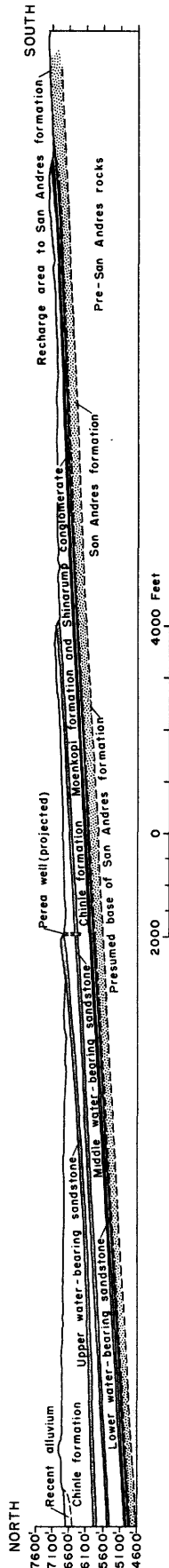


Figure 3. --Generalized geologic cross section of the Fort Wingate Indian School area, showing aquifers.

both the Moenkopi formation and the Shinarump conglomerate are missing, the claystone forms the confining bed on top of the San Andres formation.

Geologic Structures

Folded Rocks

Structurally, the area investigated lies on the nose of a broad asymmetric anticline which plunges in a north-northwest direction. The west limb of the anticline dips steeply to the west at angles as high as 85°. The east limb of the anticline dips at angles of 5° to 10°. This structure, together with the confining beds, controls artesian conditions in the aquifers. Artesian pressure is present to some degree in all the water-bearing rocks in the area. The most striking example is the pressure exerted by water in the San Andres formation. Wells tapping this aquifer usually flow at the land surface, the rate of flow depending on the altitude at the well location and the depth of penetration of the aquifer. Open-flow rates as much as a few hundred gallons per minute have been measured. One well flowed less than 1 gpm (gallon per minute) at the land surface, yet the hydrostatic pressure causing the flow was sufficient to force a column of water to a height of about 180 feet above the land surface. Apparently the well bottomed in a relatively impermeable part of the aquifer.

Faults

High-angle faults were observed in the vicinity of the Navajo Service Sheep Laboratory and the Fort Wingate Indian School, and in the mountains to the south. A fault just west of the Sheep Laboratory is of the scissor type, hinged at the north end, with the maximum displacement to the south. The west side of this fault is the upthrown side, with the limestone member of the San Andres formation abutting against rocks of the Chinle formation. It is likely that the Santa Fe spring (fig. 2) issues along this fault. The fault is covered by alluvium in the vicinity of the spring.

GROUND WATER

San Andres Formation

The San Andres formation is the most reliable aquifer in this area. There is a great difference in the amount of flow from wells that are situated a few miles from each other, ranging from one to several hundred gallons per minute. This variation in flow may be due to any of several reasons. One of these is the local variation in permeability of the San Andres formation. A well that penetrates large solution channels, highly jointed rocks, or loosely cemented sandstones will yield water more rapidly than one that does not intersect these permeable zones. Most of the wells in the area investigated do not completely penetrate the San Andres formation. Thus they do not expose the aquifer completely and so cannot take advantage of all the water that would be available.

Recharge Conditions

The recharge area of the San Andres formation extends into the Zuni Mountains for some 10 miles to the

south of the Fort Wingate Indian School. This area is up dip from the school, where the formation is exposed at the surface. Much of the recharge area is forested. The recharge occurs by infiltration from precipitation or runoff. The average annual precipitation at the Fort Wingate Indian School is 14.45 inches and at the McGaffey Ranger Station in the mountains to the south, 17.26 inches. Because the recharge area lies between these two points, the precipitation on the area is considered to be between about 14 and 17 inches per year. The amount of water that is available for recharge of the aquifer after transpiration, evaporation, and runoff takes place is an unknown quantity. Recharge possibilities should be good, because only a thin soil covers the much-jointed permeable limestone in the mountains.

Discharge Conditions

On the basis of measurements made during the summer of 1952, the existing wells in the Fort Wingate Indian School area, including those at the Navajo housing project, the Rehoboth Mission, and the Iyanbito Day School, discharge from the San Andres formation a total of several hundred gallons per minute (table 1).

Many springs issue from the rocks of the San Andres formation in the Zuni Mountains south of the school. Most of those observed were discharging from 1 to 5 gpm. The discharge from these springs flows only short distances down the canyons and disappears in the alluvium.

Chinle Formation

Three separate sandstone units in the Chinle formation carry water in this area. Beds of siltstone and claystone cause the water in the sandstone to be under artesian pressure. The Perea well (fig. 3), which penetrates the sandstone to about 500 feet above the base of the formation, does not flow. The trader at the Perea Trading Post reports the well to be capable of yielding no more than 10 gpm, which is sufficient only to satisfy local requirements for both domestic and stock use. The Fort Wingate Indian School well obtained flowing water from the lower sandstones of the formation and also from the Glorieta sandstone member. The combined flow from both formations was 45 gpm. No volumetric test or measurement of flow was made while the drilling was confined to the Chinle formation. No data are available as to the total amount of water that could be obtained from sandstones of the Chinle formation in this area.

Recharge Conditions

The recharge area for the sandstones of the Chinle formation is within, and in the vicinity of, the Fort Wingate Indian School area. The areal extent of the sandstone outcrops is very small and precipitation is less than 15 inches per year. Thus, recharge to the Chinle formation must necessarily be comparatively small. The movement of water within these sandstones is down dip in a northerly direction. Because of the extensive and impervious layers of siltstone and claystone interbedded with the sandstone units of the Chinle

formation, probably little or no circulation of water takes place between these sandstone units.

Discharge Conditions

Two wells yield water from the Chinle formation in the area of this report. The well at the Perea Trading Post yields water from the middle sandstone, and the well at Fort Wingate School yields some water from the lower sandstone. The well at the Perea Trading Post is approximately 1 mile down dip from the recharge area of the sandstone that it penetrates. If any substantial additional amount of water is to be produced from this sandstone, a pumping test should be made to determine its hydrologic potentialities. Because of the proximity of the well to the recharge area and hence the small volume of water in storage, it is probable that sustained pumping of large amounts of water might cause a large reduction in the quantity stored. The water that was obtained from this same sandstone bed in the Iyanbito Day School well at a depth between 900 and 935 feet below the surface was considered unsuitable for domestic use (table 2). The water sample was obtained at the time the well was being drilled. The sandstone was cemented off and drilling was continued into the San Andres formation. The Iyanbito well is about 3 miles down dip from the recharge area of this sandstone.

The well at the Fort Wingate Indian School is within a mile of the outcrop area of the lower sandstone that it penetrates, and within one-fourth of a mile of a spring that issues from this sandstone.

The springs near the Navajo Service Sheep Laboratory and Fort Wingate Indian School yield a total of 230 gpm (table 1). These springs are in the area where the high-angle faults occur. All the springs discharge water from the basal zone of the Chinle formation. It is possible that some of this water is moving upward along the fault zones under artesian pressure from the San Andres formation. A comparison of chemical analyses (table 2) of waters from these springs and from the Fort Wingate Indian School well shows these waters to be similar; the latter well receives a flow from both the Chinle and the San Andres formations.

Hydrologic Character of San Andres Formation

The amount of water that the San Andres formation will transmit each day is a function of the hydraulic gradient and the transmissibility. On the basis of unpublished information the transmissibility is estimated to be less than 25,000 gpd per foot; and possibly, but not probably, less than half that figure. The hydraulic gradient as determined from existing wells is about 150 feet per mile. The amount of water in gallons per day that will move through each mile-wide section of the aquifer, measured at right angles to the hydraulic gradient, is calculated as the product of the coefficient of transmissibility and the hydraulic gradient.

Therefore, something less than 3,750,000 gallons of water per day, or 2,600 gpm, moves through each mile-wide segment of the aquifer. Assuming a 1,000-foot spacing of wells along the strike of the beds, the 5 wells drilled in a mile-wide zone could each safely

yield an amount less than 400 gpm, depending on the true value of the coefficient of transmissibility.

Future Development

New wells developed in this area should be carefully planned and systematically carried out. Sites for them should be carefully chosen as to direction and distance from existing wells. The suggested figure of 1,000 feet for the spacing of wells is arbitrary, but it seems as reasonable as any figure that can be given until additional data have been obtained. After the completion of each new well, an extensive pumping test should be made to help in obtaining a more reliable value for the coefficient of transmissibility.

Well sites should be located perpendicular to the direction of dip of the strata, and hence perpendicular to the direction of movement of water within the aquifer. A well drilled updip and near an existing well might interfere with the movement of water toward the existing well, and thereby lessen its production. A well drilled downdip from an existing well might not receive all the water that could otherwise be available to it, as the existing well would intercept some of the water.

At the present time nearly all water obtained from wells in the San Andres formation is by natural flow. If only the natural flow is used, additional wells probably can be spaced more closely than if the wells are to be pumped, as their average yield would be less than the amount that could be pumped. If increased water requirements necessitated pumping the wells, then the cone of pressure relief surrounding each well would be greater, the well would draw water from a greater horizontal distance, and the spacing between wells would have to be greater. Wide spacing would prevent the cones of pressure relief of the individual wells from seriously overlapping and causing a decrease in production.

QUALITY OF WATER

Water from the middle sandstone of the Chinle formation shows an increase in dissolved solids in a downdip direction from the recharge area. This is manifested by the increase in dissolved solids between the Perea well and the Iyanbito School well (table 2). The water from the Iyanbito School well, which was subsequently cemented off, had the highest observed concentration of dissolved solids and the greatest concentration of bicarbonate, chloride, and fluoride. Waters from the Santa Fe, Navajo Sheep Laboratory, and Fort Wingate Indian School springs all issue from the basal part of the Chinle formation. These waters are hard and contain mostly calcium, bicarbonate, and sulfate, and small amounts of sodium and chloride. The water from the Perea well contains the largest amount of sodium and sulfate of any of the waters sampled. This well obtains water from the middle sandstone of the Chinle formation. Because of the high percentage of sodium and the high dissolved solids, this water is considered undesirable for domestic, industrial, or irrigation use.

The dissolved-solids concentration of the waters yielded by the San Andres and Chinle formations in this

area has a rather wide range (table 2). Water from most of the wells that penetrate the San Andres formation is very hard and contains mostly calcium, magnesium, and sulfate, and minor amounts of chloride. Water from some of the wells contains perceptible amounts of hydrogen sulfide gas. The water is utilized as a public supply, and for cooling and other purposes after treatment. The hardness of the water in the San Andres formation may be explained as being the result of solution of the limestone member and removal of calcium carbonate cement from the sandstone member as ground water moves through the formation. Large amounts of sulfate in this water indicate the presence of gypsum in the formation, but no beds of gypsum were observed in the top 200 feet of the formation. Gypsum may be disseminated throughout the formation, however.

Water from the Rehoboth well, which is reported to tap the San Andres formation, is only moderately hard and contains considerable sodium and chloride. The rather high concentration of sodium and chloride in this water may be the result of a mixing of waters from the Chinle and the San Andres formations.

CONCLUSIONS

Two formations in the Fort Wingate Indian School area yield water to wells, the Chinle formation and the San Andres formation. The sandstones in the Chinle formation are recharged locally, and the recharge area is narrow. Therefore, only a limited amount of water may be available to wells drilled into the sandstones of the Chinle. For the most part, water from the middle sandstone of the Chinle formation is undesirable for domestic uses. However, water from the Perea well is used. Water from the lower sandstone unit of the Chinle formation is suitable for domestic and irrigation use in the vicinity of the school.

Flows of water from several wells that penetrate the San Andres formation are listed in table 1. The total of these flows shows that the annual discharge from the aquifer in this area is not less than about 750 acre-feet. In addition, about 380 acre-feet of water per year is discharged from the Chinle formation, much of it perhaps indirectly from the San Andres formation. Precise data for average annual recharge to the aquifers are unavailable.

The San Andres formation is potentially the most productive aquifer in the area. The recharge area for this aquifer is rather extensive and is located at a higher altitude and in an area of greater precipitation than the area occupied by the school. Structural and lithologic conditions are favorable for the accumulation of water in the aquifer under hydrostatic pressure. The fine-grained rocks of the Chinle formation form most of the overlying confining beds. Wells tapping the San Andres formation produce as much as a few hundred gallons of water per minute. Higher rates of withdrawal are considered feasible, up to the limit of the aquifer to transmit water, but no exact limiting figure can yet be stated.

Full penetration of the aquifer is an important factor governing well productivity. It is probable that existing wells would have larger yields if they completely penetrated the aquifer. Proper spacing of wells as to dis-

tance and direction from one another, proper setting and perforating of casing, and proper development following drilling are considered to be highly desirable in future wells. These would give better wells for less overall cost. On the basis of the field data collected, spacing flowing wells 1,000 feet apart along the strike of the formation is not likely to cause serious overdevelopment of the aquifer. Future development plans should take into account the hazard of overproduction from the San Andres formation. Overproduction would progressively lower the artesian pressure, causing the flow of water from wells to diminish and ultimately to cease. This eventuality is not anticipated as a result of production at the present rate.

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Table 1. --Well and spring discharge, depth of wells, and aquifers in the Fort Wingate Indian School area

Well or spring	Flow (gpm)	Total depth (feet)	Aquifer
16B-12.....	8.0	.....	San Andres formation.
16B-40.....	70.5	1,675	Do.
Iyanbito Day School well.....	4.0	1,510	Do.
Well 3.....	1	1,950	Do.
Rehoboth Mission well.....	10	1,569	Do.
Wingate railroad station well.....	60	1,305	Do.
Fort Wingate Indian School well.....	45	348	Chinle and San Andres formations.
Fort Wingate spring.....	180	.....	Do.
Navajo Service Sheep Laboratory spring.....	33.4	.....	Do.
Santa Fe spring.....	19.2	.....	Do.
Perea well.....	None	490	Chinle formation.
Iyanbito Day School well ¹	None	1,510	Do.

¹Water sample obtained from sandstone in Chinle formation, 900 to 935 feet below surface, when the well was being drilled.

Table 2. --Analyses of water from wells and springs in the Fort Wingate Indian School area and vicinity

[Analyses by Geological Survey. Parts per million except specific conductance, temperature, and percent sodium]

Well or spring	Date of collection	Temperature (°F)	Specific conductance (micro-mhos at 25° C)	Silica (SiO ₂)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Dissolved solids	Hardness as CaCO ₃	Percent sodium
16B-12.....	5- 3-50	67	1, 350	11	169	87	24	247	596	5	0.2	0.3	1, 010	779	6
16B-40.....	5- 9-50	85	1, 340	13	116	61	112	218	571	7	.1	.1	987	540	31
Iyanbito Day School well.....	2-27-52	.....	1, 170	.....	.....	.....	.....	219	.....	6	.4	.....	.....	540	.....
Rehoboth Mission well.....	6-12-52	81	1, 510	13	29	12	306	284	463	50	.6	.2	1, 010	122	84
Fort Wingate Indian School well.....	12-10-53	60	1, 010	13	160	45	9.2	260	365	7	.2	.4	728	584	3
Fort Wingate spring.....	8- 9-50	54	913	13	141	40	7.6	276	283	8	.2	.9	630	516	3
Navajo Service Sheep Laboratory spring.....	8- 9-50	56	703	8.9	103	33	5.8	328	118	8	.1	1.2	440	392	3
Santa Fe spring.....	8- 4-50	55	730	.....	.....	.....	.....	325	.....	7	.....	.....	.....	.....	.....
Perea well.....	8- 4-50	.....	3, 030	9.5	8.0	3.7	684	350	625	412	.5	1.3	1, 920	35	98
Iyanbito Day School well ¹	3-31-51	.....	3, 780	.....	.....	.....	.....	488	.....	443	2.2	.....	.....	49	.....

¹Water sample obtained from sandstone from Chinle formation, 900 to 935 feet below surface, when well was being drilled.

GROUND WATER OF THE FORT WINGATE INDIAN SCHOOL AREA, N. MEX.

Stratigraphic section, Permian and Triassic, Fort Wingate Indian School area

[Measured by R. L. Jackson and S. R. Johnson November 1950. The descriptive terminology used in this stratigraphic section is generally similar to that proposed by McKee and Weir (1953) in a paper on descriptive terms applied to stratification in sedimentary rocks]

	Feet
Triassic:	
Wingate sandstone (Undescribed, not present along line of geologic cross section).....	355
Unconformity:	
Chinle formation:	
"B" member:	
36. Mudstone, variegated grayish-red and light-greenish-gray, banded; composed of silt and clay; poorly cemented; flat, irregularly bedded; forms a slope. Base is irregular.....	8
35. Limestone, pale-reddish-purple; silty; contains some medium-crystalline calcite; flat, irregularly bedded; weathers hackly; forms a ledge slope.....	10
34. Limestone, mottled very light gray and pale-reddish-purple; medium crystalline with rare rounded quartz grains; flat, thin, irregularly bedded; weathers hackly; forms an irregular ledge.	6
33. Limestone, light-brownish-gray; finely crystalline; flat, irregularly bedded; forms a prominent ledge. Base is irregular.....	6
32. Mudstone, same as unit 26.....	9
31. Limestone, mottled pale-reddish-purple and light-gray; aphanitic; flat, irregularly bedded; weathers knobby; forms a weak ledge. Base is flat.....	2
Total "B" member.....	41
"C" member:	
30. Mudstone, same as unit 26.....	440
29. Limestone, sandy, same as unit 27.....	2
28. Mudstone, same as unit 26.....	38
27. Limestone, sandy, pale-red-purple; silty and finely crystalline; flat-bedded; weathers blocky; forms an irregular ledge. Base is flat.....	2
26. Mudstone, mottled dark-reddish-brown and light-greenish-gray; very thick gnarly bedded; weathers hackly; forms an irregular slope. Base is flat.....	11
25. Sandstone, grayish-red-purple, very fine grained, poorly sorted; composed of subangular stained quartz with rare mica, rare black accessory minerals, and rare argillaceous material; firmly cemented, weakly calcareous; trough crossbedding, low-angle, medium-scale crossbeds; weathers blocky; forms a weak ledge. Base is flat.....	10
24. Covered interval.....	45
23. Sandstone, light-olive-gray, fine to very fine grained, fair-sorted; composed of subrounded to subangular frosted quartz with abundant black accessory minerals, common argillaceous material and rare red accessory minerals; firmly cemented, weakly calcareous; trough crossbedding, low-angle medium-scale crossbeds; weathers blocky; forms an irregular slope. Beds contain siltstone and claystone granules at base. Unit becomes more calcareous towards the top. Base is gradational.....	20
22. Siltstone conglomerate:	
Matrix, light-greenish-gray, medium- to fine-grained, poorly sorted; composed of subangular frosted quartz with common black and red accessory minerals and argillaceous material; firmly cemented, calcareous;	
Gravel, angular to subangular siltstone and claystone pebbles (1/8 to 1/2 in. across), reddish-brown to dark-reddish-brown; flat, irregularly bedded; weathers rounded and pitted. Base is gradational.....	2
21. Claystone, forms a niche.....	1
20. Claystone, same as unit 18.....	54
19. Mudstone, grayish-red; composed of amber and white quartz with common mica and rare green accessory minerals; poorly cemented; flat, very thin bedded; weathers smooth; forms a slope. Base is irregular.....	1
18. Claystone, mottled grayish-red-purple and light-greenish-gray; very thin, irregularly bedded; weathers hackly; forms an irregular slope. Contains rare very fine grained quartz inclusions. Base is gradational.....	54
17. Mudstone, mottled grayish-red-purple and light-greenish-gray; composed of silt and clay; crossbedded, low-angle small-scale crossbeds; weathers hackly; forms an irregular slope. Base is gradational.....	18

Stratigraphic section, Permian and Triassic, Fort Wingate Indian School area--Continued

Unconformity--Continued

Feet

Chinle formation--Continued

"C" member--Continued

16. Conglomerate:

Matrix, sandstone, light-greenish-gray, fine-grained, poorly sorted; composed of subangular amber, white, and clear quartz with rare black accessory minerals and abundant argillaceous material; poorly cemented, weakly calcareous; very thick bedded; weathers gnarly; forms an irregular slope. Base is irregular.

Pebbles, siltstone, limestone and quartz pebbles (1/8 to 1 in. across), angular to subangular; siltstone and limestone pebbles predominate.....	5
15. Claystone, mottled moderate-reddish-brown and light-greenish-gray; very thin, irregularly bedded; weathers hackly; forms an irregular slope. Contains common subangular quartz granule inclusions. Base is irregular and gradational.....	19
14. Claystone, variegated grayish-red-purple and greenish-gray; very thin, irregularly bedded; weathers hackly; forms an irregular slope. Base is irregular.....	30
13. Sandstone, calcareous, variegated pale-reddish-purple and light-greenish-gray, very fine grained, poorly sorted; composed of subangular to angular white and amber quartz grains with common black detrital and argillaceous material; firmly cemented, highly calcareous; flat, irregularly bedded; weathers blocky; forms a weak ledge. Base is irregular.....	25
12. Claystone, grayish-red-purple; irregularly bedded; weathers hackly; forms an irregular slope. Base is concealed.....	6
11. Covered.....	8
10. Sandstone, pale-red-purple (weathering light brown), fine to very fine grained, poorly sorted; composed of subangular amber, clear and smoky quartz with abundant black accessory minerals, rare green accessory minerals and common argillaceous material; well-cemented, noncalcareous; flat, thin, irregularly bedded; weathers blocky; forms an irregular ledge. Base is gradational.....	6
9. Mudstone, grayish-red-purple; composed of silt and clay with common mica accessories, highly argillaceous; firmly cemented; very thin, irregularly bedded; weathers hackly; forms a ledge-slope. Base is irregular.....	18
8. Sandstone, grayish-orange-pink, fine-grained, well-sorted; composed of rounded to subrounded clear and frosted quartz with rare green accessory minerals and argillaceous material; trough crossbedding; low-angle medium to large-scale crossbeds; weathers blocky; forms a vertical cliff. Granules of quartz occur along base of crossbeds. Base is irregular.....	29
7. Limestone, pale-olive, medium-crystalline; thin (1/2 to 1 in.), flat-bedded; weathers blocky; forms a blocky ledge. Base is flat.....	18
6. Sandstone, argillaceous, pinkish-gray, very fine to coarse-grained, poorly sorted; composed of subangular to angular clear and frosted quartz grains with abundant argillaceous material; poorly cemented; very thick bedded; weathers smooth to rounded; forms a weak ledge. Contains abundant quartz granules. Conglomerate at base (basal 2 ft) contains quartz pebbles (1/4 to 1 in. across) which grade upward into argillaceous sandstone. Base is gradational..	11
5. Claystone, dusky red-purple and light-gray; very thick bedded; weathers hackly, forms a rolling steep slope. Grades upward into unit 6. Base is sharp.....	98
4. Mudstone, mottled grayish-green and pale-reddish-purple; composed of silt and clay; very thin, irregularly bedded; forms a rolling steep slope. Contains pale-greenish-gray siltstone ledge-forming units: a 1 1/4-ft ledge at the base, and a 1-ft ledge 15 ft above the base. Base is sharp and flat.....	31
3. Claystone, mottled grayish-yellow-green and dark-reddish-brown, very thin, flat, irregularly bedded; weathers hackly; forms a steep slope. Base is flat.....	89
2. Siltstone, argillaceous, yellowish-gray, poorly sorted; composed of subangular quartz with rare red accessory minerals, common black accessory minerals, and common to abundant argillaceous material; very flat, thin, irregularly bedded; forms a weak ledge. Base is concealed.....	3
1. Covered, irregular, flat slope.....	70
Total "C" member.....	1,164

"D" member:

12. Sandstone, grayish-orange-pink (weathers light brown), very fine grained, fair-sorted; composed of subrounded clear quartz with common black accessory minerals; firmly cemented, siliceous; trough crossbedding, high-angle medium-scale crossbeds; weathers smooth to rounded; forms a rounded ledge. Base is irregular.....	33
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GROUND WATER OF THE FORT WINGATE INDIAN SCHOOL AREA, N. MEX.

Stratigraphic section, Permian and Triassic, Fort Wingate Indian School area--Continued

	Feet
Unconformity--Continued	
Chinle formation--Continued	
"D" member--Continued	
11. Conglomerate:	
Matrix, grayish-red-purple, medium to very fine grained, poorly sorted; composed of sub-angular clear and frosted quartz with common black accessory minerals.	
Gravel, pale-olive-gray to reddish-brown; limestone and siltstone pebbles ($\frac{1}{4}$ to 1 in.), subangular and pitted; very thick bedded; weathers knobby; forms an irregular ledge.	
Base is irregular.....	7
10. Claystone, dark-reddish-brown; very thin flat bedded; weathers hackly; forms a rolling slope.	
Base is gradational.....	35
9. Claystone, reddish-brown-purple; flat, very thin bedded; weathers hackly; forms a rolling slope. Base is concealed.....	41
8. Covered, long low irregular slope.....	83
Total "D" member.....	199
Shinarump conglomerate:	
7. Conglomerate:	
Matrix, very pale orange (weathers dark reddish brown), very coarse to very fine grained, poorly sorted; composed of subangular clear, frosted, and stained quartz with rare red accessory minerals and feldspar detritals; firmly cemented.	
Gravel, quartz, jasper, chalcedony and feldspar pebbles, subangular ($\frac{1}{2}$ to $2\frac{1}{2}$ in. across), very thick irregularly bedded. Base is irregular.....	13
6. Mudstone, mottled grayish-purple and light-brown; composed of claystone and siltstone; firmly cemented; very thick, irregularly bedded; weathers hackly; forms a ledge slope. Base is irregular.....	12
Total Shinarump conglomerate.....	25
Moenkopi formation:	
5. Sandstone, yellowish-gray (weathers reddish brown), very fine grained, poorly sorted; composed of subrounded to subangular clear quartz grains with rare red accessory minerals, common black accessory minerals and abundant argillaceous material; firmly cemented, planar crossbedding, low-angle small-scale crossbeds; weathers smooth to rounded; forms a weak ledge. Base is sharp and irregular.....	27
4. Claystone, dark-reddish-brown; very flat, thin bedded; weathers hackly; forms an irregular slope. Base is irregular.....	5
Total Moenkopi formation.....	32
Permian:	
San Andres formation:	
Limestone member:	
3. Limestone, grayish-orange-pink (weathering gray), finely crystalline; thick to very thick bedded; weathers pitted; forms a vertical cliff. Manganese detritals are common. Rare mollusoid fauna, preservation poor. Jointing well developed. Base is flat.....	86
2. Dolomitic limestone, silty, light-brown, aphanitic; composed of dolomite and silt; very thick bedded; weathers blocky; forms a vertical irregular cliff. Contains rare calcite geodes ($\frac{1}{2}$ in. across). Base is irregular.....	11
Total limestone member.....	97
Glorieta sandstone member (Incomplete):	
1. Sandstone, moderate orange-pink (weathering moderate brown), very fine grained, poorly sorted; composed of rounded to subrounded clear quartz with rare black accessory minerals; well cemented, siliceous; thin to thick bedded; weathers blocky; forms a vertical cliff. Base is concealed.....	100

