Availability of Ground Water in Parts of the Acoma and Laguna Indian Reservations New Mexico

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1576-E

Prepared in cooperation with the U.S. Public Health Service and the U.S. Bureau of Indian Affairs

Availability of Ground Water in Parts of the Acoma and Laguna Indian Reservations New Mexico

By GEORGE A. DINWIDDIE *and* WARD S. MOTTS

WATER SUPPLY OF INDIAN RESERVATIONS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1576–E

Prepared in cooperation with the U.S. Public Health Service and the U.S. Bureau of Indian Affairs

---

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

	Page
Abstract	E1
Introduction	2
System of numbering wells in New Mexico	5
Geography	5
Geology	6
Geologic formations and their water-bearing properties	7
Chinle Formation	9
Entrada Sandstone	9
Todilto Limestone	10
Summerville Formation	10
Bluff Sandstone	10
Morrison Formation	11
Dakota Sandstone	11
Mancos Shale	12
Mesaverde Group	12
Basalt and dikes of Tertiary age	12
Alluvium	13
Basalt of Quaternary age	14
Test-well drilling	15
Test drilling in the Anzac-McCartys area	16
Well 10.9.25.330 (irrigation test well 1)	16
Well 10.9.25.441 (irrigation test well 2)	17
Well 10.8.28.314 (irrigation test well 3)	18
Well 10.8.27.224 (irrigation test well 4)	20
Well 9.8.2.110 (irrigation test well 5)	22
Test drilling in the Acomita area	22
Well 10.7.29.214 (pueblo test well 4)	23
Well 10.7.35.210 (irrigation test well 6)	26
Well 10.6.31.443 (irrigation test well 7)	28
Test drilling near the mouth of Encinal Creek	30
Well 10.6.35.322 (pueblo test well 1)	31
Well 10.6.35.342 (pueblo test well 2)	34
Test drilling in the Paguate area	37
Well 11.5.30.422 (pueblo test well 3)	37
Well 11.5.32.234 (pueblo test well 5)	40
Well 10.5.26.223 (irrigation test well 8)	41
Surface water	42
Ground water	44
Quality of water	47
Domestic use	48
Agricultural use	49
Conclusions	51
Selected references	61
Index	63

ILLUSTRATIONS

[Plates are in pocket]

PLATE 1. Reconnaissance geologic map.
2. Map showing altitudes of water levels, depths to water, and aquifers.
3. Quality of water map.

		Page
FIGURE	1. Index map showing the area described in this report	E4
	2. Diagram showing the system of numbering wells in New Mexico	5
	3–6. Recovery curves from tests of wells:	
	3. Well 10.8.28.314	18
	4. Well 10.7.29.214	25
	5. Well 10.7.35.210	27
	6. Well 10.6.31.443	28
	7. Drawdown curve from test of well 10.6.35.322	32
	8–10. Recovery curves from tests of wells:	
	8. Well 10.6.35.322	34
	9. Well 10.6.35.342	36
	10. Well 11.5.30.422	38
	11. Drawdown curve from test of well 11.5.32.234	40
	12. Classification of irrigation water	50

TABLES

		Page
TABLE	1. Generalized stratigraphic section and water-bearing characteristics of geologic formations in parts of the Acoma and Laguna Indian Reservations, N. Mex	E8
	2. Streamflow at stations in the Acoma and Laguna Indian Reservations, N. Mex	43
	3. Records of selected wells in the Acoma and Laguna Indian Reservations, N. Mex	56
	4. Chemical analyses of water from selected wells in the Acoma and Laguna Indian Reservations, N. Mex	60
	5. Records of selected springs in the Acoma and Laguna Indian Reservations, N. Mex	61

AVAILABILITY OF GROUND WATER IN PARTS OF THE ACOMA AND LAGUNA INDIAN RESERVATIONS NEW MEXICO

By George A. Dinwiddie and Ward S. Motts

ABSTRACT

The need for additional water has increased in recent years on the Acoma and Laguna Indian Reservations in west-central New Mexico because the population and per capita use of water have increased; the tribes also desire water for light industry, for more modern schools, and to increase their irrigation program. Many wells have been drilled in the area, but most have been disappointing because of small yields and poor chemical quality of the water.

The topography in the Acoma and Laguna Indian Reservations is controlled primarily by the regional and local dip of alternating beds of sandstone and shale and by the igneous complex of Mount Taylor. The entrenched alluvial valley along the Rio San Jose, which traverses the area, ranges in width from about 0.4 mile to about 2 miles.

The climate is characterized by scant rainfall, which occurs mainly in summer, low relative humidity, and large daily fluctuations of temperature.

Most of the surface water enters the area through the Rio San Jose. The average annual streamflow past the gaging station Rio San Jose near Grants, N. Mex. is about 4,000 acre-feet. Tributaries to the Rio San Jose within the area probably contribute about 1,000 acre-feet per year. At the present time, most of the surface water is used for irrigation.

Ground water is obtained from consolidated sedimentary rocks that range in age from Triassic to Cretaceous, and from unconsolidated alluvium of Quaternary age. The principal aquifers are the Dakota Sandstone, the Tres Hermanos Sandstone Member of the Mancos Shale, and the alluvium. The Dakota Sandstone yields 5 to 50 gpm (gallons per minute) of water to domestic and stock wells. The Tres Hermanos Sandstone Member generally yields 5 to 20 gpm of water to domestic and stock wells. Locally, beds of sandstone in the Chinle and Morrison Formations, the Entrada Sandstone, and the Bluff Sandstone also yield small supplies of water to domestic and stock wells. The alluvium yields from 2 gpm to as much as 150 gpm of water to domestic and stock wells.

Thirteen test wells were drilled in a search for usable supplies of ground water for pueblo and irrigation supply and to determine the geologic and hydrologic characteristics of the water-bearing material. The performance of six of the test wells suggests that the sites are favorable for pueblo or irrigation supply wells. The yield of the other seven wells was too small or the quality of the water was too poor for development of pueblo or irrigation supply to be feasible. However,

the water from one of the seven wells was good in chemical quality, and the yield was large enough to supply a few homes with water.

The tests suggest that the water in the alluvium of the Rio San Jose valley is closely related to the streamflow and that it might be possible to withdraw from the alluvium in summer and replenish it in winter. The surface flow in summer might be decreased by extensive pumpage of ground water, but on the other hand, more of the winter flow could be retained in the area by storage in the ground-water reservoir. Wells could be drilled along the axis of the valley, and the water could be pumped into systems for distribution to irrigated farms.

The chemical quality of ground water in the area varies widely from one stratigraphic unit to another and laterally within each unit and commonly the water contains undesirably large amounts of sulfate. However, potable water has been obtained locally from all the aquifers. The water of best quality seemingly is in the Tres Hermanos Sandstone Member of the Mancos Shale and in the alluvium north of the Rio San Jose. The largest quantity of water that is suitable for irrigation is in the valley fill along the Rio San Jose.

Intensive pumping of ground water from aquifers containing water of good quality may draw water of inferior chemical quality into the wells.

INTRODUCTION

Demands for potable water have increased as the population and the per capita use of water have increased. The per capita use of water in the pueblos is expected to increase from about 10 gpd (gallons per day), the present rate (1961), to about 60 gpd in a few years, according to the U.S. Public Health Service. The tribes also would appreciate having water for light industry and for schools. Many of the communities on the reservations have been using water of inferior quality, due to a high mineral content, because water of good chemical quality has not been found in adequate quantities. Many wells have been drilled on the reservations in the last 30 years, but most have been disappointing because of the poor quality of the water.

The U.S. Public Health Service was assigned the responsibility for development and improvement of community water supplies and sanitation on these and other Indian reservations. In 1960, the Public Health Service requested the U.S. Geological Survey to investigate the availability of potable ground water at selected sites on the Acoma and Laguna Indian Reservations to aid in the water-development phase of the program on these reservations. This part of the investigation was financed by the U.S. Public Health Service, Division of Indian Health, as one phase of Public Law 86–121 Project AL–60–1E.

The Acoma and Laguna Indians have been interested for many years in irrigating more of the land on their reservations. In the fall of 1958, the All Pueblo Council passed a resolution that requested an investigation of the possibilities of irrigation on Pueblo Indian lands. Because of the keen interest of the Acoma and Laguna Indians in this project, funds were made available to the U.S. Bureau of Indian

Affairs for an investigation on their reservations. The Bureau of Indian Affairs requested the Geological Survey to investigate the general availability of ground water for irrigation in the Rio San Jose valley on the reservations, as a part of that program.

Both of the investigations were concerned primarily with an appraisal of existing supplies, the selection of test-well sites, the observation of test drilling, and the analysis of test-well data. Neither study, in scope, was more than a beginning of the appraisal of the ground-water resources of the two reservations.

This report was prepared from information obtained during the course of these two investigations and from previous studies made in the area. Emphasis is placed on the results of the test drilling.

The area studied is in Tps. 9–11 N., Rs. 4–9 W., in the east-central part of Valencia County, N. Mex. (fig. 1). The area is mainly within the Acoma and Laguna Reservations, but a small area outside of the reservations was studied to better evaluate the availability of ground water in the reservations.

The general geology of the area had been mapped previously, and the geology in relation to the occurrence of uranium had been studied intensively in some localities; however, none of the previous geologic work had been directed toward an evaluation of the water resources. Several reports on the geology of the region are listed in the selected references at the back of this report. Several local ground-water investigations, which involved the selection of sites for domestic and stock wells, have been made on the reservations by the Geological Survey. The general ground-water conditions in the Rio San Jose valley of the Acoma and Laguna Indian Reservations were investigated in 1952 (W. L. Champion, written communication). J. R. Rapp investigated the possible sources of ground water for irrigation in the Acoma Creek valley and in the vicinity of Anzac on the Acoma Indian Reservation in 1959.

The present investigation was made by W. S. Motts and G. A. Dinwiddie, assisted intermittently by S. W. West, J. R. Rapp, and B. W. Maxwell. Records of wells, chemical data, and other useful hydrologic information were furnished by the United Pueblos Agency, U.S. Bureau of Indian Affairs, and by the Albuquerque Field Office, U.S. Public Health Service, Division of Indian Health. Additional information on wells was obtained in the field, and the specific conductance of many water samples was checked with a field conductance meter. A geologic reconnaissance was made to improve understanding of the hydrology of the area and to provide a basis for the selection of sites for test wells. The general geology was mapped on U.S. Geological Survey 7.5-minute topographic quadrangle maps. The Geological Survey men observed most of the test drilling, prepared

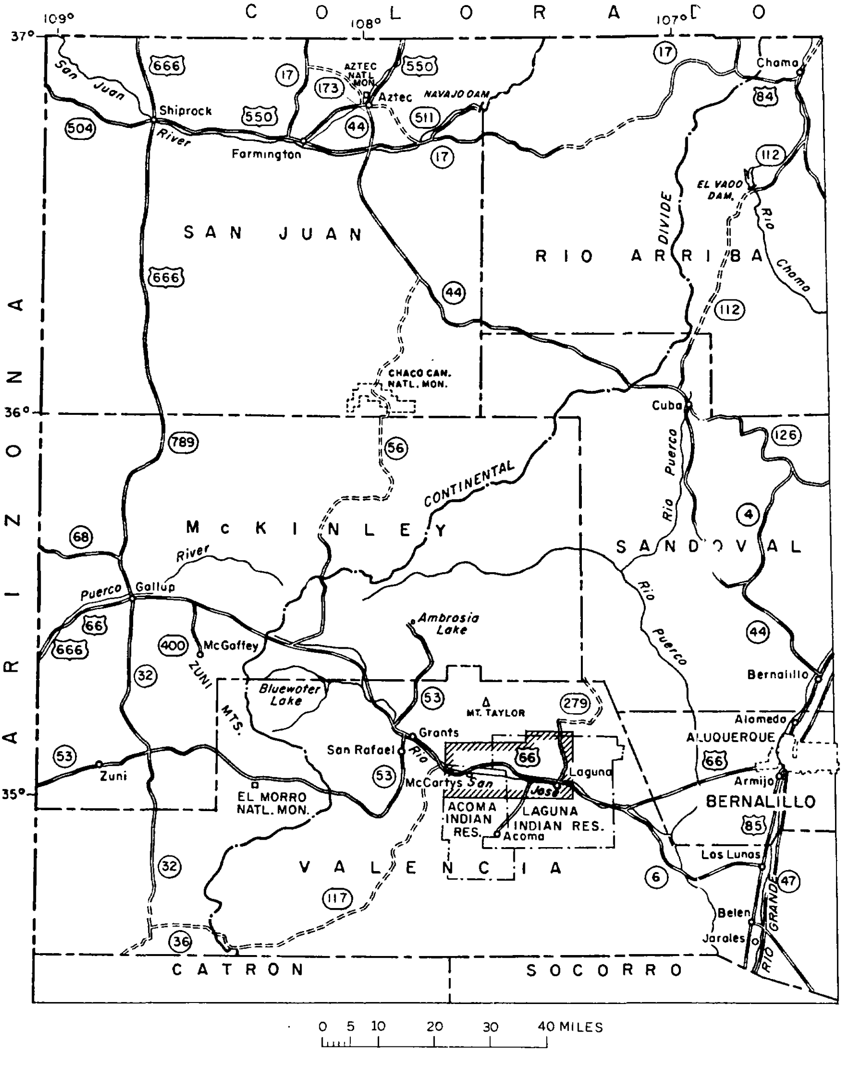


FIGURE 1.—Map of northwestern New Mexico showing Acoma and Laguna Indian Reservations and area (within shaded outline) described in this report.

lithologic logs of the test wells from the drill cuttings, collected and analyzed samples of water from most of the test wells, measured the discharge rate and the water-level drawdown during pumping tests, and measured the water-level recovery after the pumping was completed.

The authors are especially grateful for the cooperation of Lester E. Blaschke and George Quist, of the U.S. Public Health Service; Joe A. Brannon and A. J. Kennedy, of the U.S. Bureau of Indian Affairs;

and several individuals in the Acoma and Laguna Indian tribes, who supplied information and showed keen interest in the projects.

SYSTEM OF NUMBERING WELLS IN NEW MEXICO

All wells referred to in this report are identified by a location number used by the Geological Survey and the State Engineer for numbering water wells in New Mexico. The location number is a description of the geographic location of the well, based on the system of public land surveys. It indicates the location of the well to the nearest 10-acre tract, when the well can be located so accurately. The location number consists of a series of numbers corresponding to the township, range, section, and tract within a section, in that order, as illustrated below. If a well has not been located closely enough to be placed within a particular section or tract, a zero is used for that part of the number. Springs are numbered in the same manner, except that the letter "S" precedes the number.

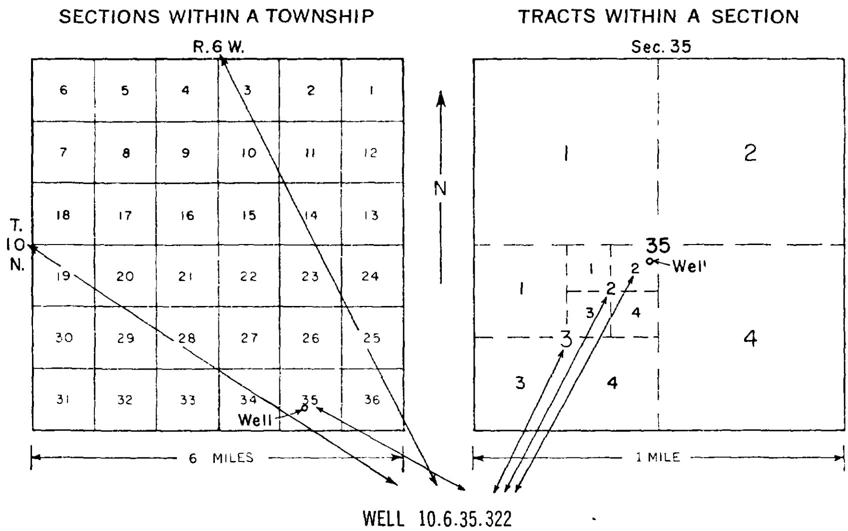


FIGURE 2.—Diagram showing the system of numbering wells in New Mexico.

GEOGRAPHY

The project area is in the Colorado Plateaus physiographic province (Fenneman, 1931, p. 274) and in the Montana-Arizona plateaus ground-water province (Meinzer, 1923, p. 313). The topography is controlled primarily by the igneous rocks of Mount Taylor, by the regional and local dip of the rocks, and by interstratified sandstone and shale. Broad mesas south of the Rio San Jose are capped by beds of sandstone, which form gentle dip slopes. The igneous rocks of Mount Taylor, rising 11,301 feet above sea level north of the Rio San Jose, dominate the topography. Mount Taylor is flanked by broad, gently sloping mesas, which are capped with basalt. The basalt spread over an old erosional surface that now stands high above the nearby lowlands of the Rio San Jose. The Rio San Jose and its tributaries eroded through the high-level basalt and deep into the underlying sedimentary rocks.

The Rio San Jose has undergone alternate periods of cutting and filling, which were influenced somewhat by flows of basaltic lava down its valley. The river at present is downcutting through a basalt lava flow of Recent age, lakebeds formed in part by the lava, and older alluvium of the river. The Rio San Jose valley ranges in width from about 0.4 mile to about 2 miles.

The climate of the area is typical of the semiarid parts of the Southwest. It is characterized by scant precipitation, low relative humidity, and large daily fluctuations in temperature. The annual precipitation at San Fidel from 1921 to 1946 was about 11 inches. About 70 percent of the annual precipitation is in the summer.

Many of the Indians on the Acoma and Laguna Reservations live in villages along the Rio San Jose. Some of the villages along the river are Acomita and McCartys, on the Acoma Reservation, and Mesita, Laguna, New Laguna, and Seama, on the Laguna Reservation. The village of Acoma is on a prominent mesa a few miles south of the Rio San Jose, and the villages of Paguate and Encinal are on the Rio Paguate and Encinal Creek, respectively, north of the Rio San Jose.

GEOLOGY

Geologic formations compose the framework for underground storage and movement of water. Coarse well-sorted sediments and fractured rocks store and transmit water readily. Fine, poorly sorted sediments and dense, unfractured rocks generally do not store and transmit much water. The mineral content of the rocks and the extent of ground-water circulation affect the chemical quality of the water. Geologic structural features, such as folds and faults, affect the accessibility of ground water. Geomorphic processes also have had a strong influence on the occurrence of ground water. In order to explain the availability and quality of ground water in the Acoma and Laguna Reservations, the general geology is summarized below.

The area is in the southern part of the San Juan basin, a broad structural depression in northwestern New Mexico and adjacent parts of Colorado and Utah. The major structural feature in the area is the McCartys syncline, which plunges northward beneath the village of McCartys and the Mount Taylor volcanic field. The regional dip of beds in the area is northward to northwestward at low angles (about 2°); however, many minor faults and gentle folds influence the dips locally.

Several collapse structures in the Morrison Formation, the Bluff Sandstone, and the Summerville Formation in the eastern part of the area have been observed. The collapse structures are roughly circular in plan, and they flare outward toward the top. Downwarped beds and concentric faults are prevalent in the border zones of the collapse structures.

The principal geomorphic processes controlling the thickness of alluvium in the area are cut and fill. The drainage system of the Rio San Jose has eroded a broad valley as much as 700 feet lower than the level of an earlier erosional plain that developed in early Tertiary time (Hunt, 1937). Locally, the inner canyon of the Rio San Jose was cut at least 150 feet below the present floor of the valley. Some of the tributary canyons were at grade with the Rio San Jose. The inner canyon of the Rio San Jose and its principal tributaries have been partly refilled with alluvium and volcanic flow rocks. Two broad alluvial areas, in addition to the typical channel cut and fill, have formed north of the Rio San Jose in part of T. 10 N., Rs. 7 and 8 W. and in the central part of T. 10 N., R. 6 W. The configuration of the bedrock surface and the thickness of alluvium in these areas have not been determined. The distribution of the geologic formations that crop out in the area are shown on plate 1.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Rocks that range in age from Pennsylvanian to Recent crop out in or near the area, but only the rocks that range in age from Late Triassic to Recent yield water to wells in the area. Therefore, the rocks that are older than Late Triassic age are not described in this report. The only one of the older formations that might be a potential source of large supplies of water is the San Andres Limestone of Permian age. The San Andres Limestone is the principal aquifer in the vicinity of Grants and Bluewater, 10 to 20 miles northwest of this area. However, in the reservations, the San Andres lies at depths of 1,500 to possibly as much as 3,500 feet. The water in the San Andres is probably impotable, but the chances are good that it would be suitable for irrigation and some types of industrial use. The general stratigraphic succession and water-bearing properties of the formations tapped by water wells in the area are summarized in table 1 and the formations are described chronologically in more detail on the following pages. The thicknesses of the formations were obtained from Rapp (1960) and Champion (written communication, 1952).

TABLE 1.—*Generalized stratigraphic section and water-bearing characteristics of geologic formations in parts of the Acoma and Laguna Indian Reservations, N. Mex.*

System	Series	Formation	Estimated thickness (feet)	Character	Water-bearing characteristics
Quaternary	Recent and Pleistocene	Interbedded alluvium and basalt	0–150	Fluvial deposits of gravel, sand, and silt; generally, very fine to medium sand interbedded with coarse sand and gravel. Individual particles predominantly quartz, chert, and volcanic material. Windblown sand deposited at many places.	Yields from 2 to more than 150 gpm of water to domestic, stock, and irrigation wells.
			0–50	Alluvium interbedded with basalt flows; in valley of Rio San Jose.	Yield of water to domestic and stock wells is reported to range from 50 to 100 gpm.
Tertiary	Pliocene and Miocene	Basalt and Dikes	0–100	Basalt flows; cap high mesas north of Rio San Jose. Northward-trending dikes throughout.	Not tapped by wells in the Acoma-Laguna Reservations.
Cretaceous	Upper	Mesaverde Group	About 400	Alternating beds of sandstone, shale, and coal. Sandstone units generally massive and cliff forming.	Not tapped by wells in the Acoma-Laguna Reservations.
		Mancos Shale	About 1,000	Dark-gray shale. Resistant massive sandstone in lower part.	Sandstone yields from 5 to 20 gpm of water to domestic and stock wells.
	Upper and Lower(?)	Dakota Sandstone	0–75	Light-colored fine- to medium-grained quartzose sandstone; in places contains basal conglomerate.	Yields from 5 to 50 gpm of water to domestic and stock wells.
Jurassic	Upper	Morrison Formation	300–500	Variegated shale and claystone containing interbedded sandstone.	The beds of sandstone yield from 5 to 10 gpm of water to domestic and stock wells.
		Bluff Sandstone	75–150	Light-colored fine- to medium-grained, cross-bedded sandstone; cliff forming.	Generally yields from 2 to 10 gpm.
		Summerville Formation	Abont 100	Red-siltstone and fine- to medium-grained sandstone; forms prominent cliffs.	Unused.
		Todilto Limestone	0–100	Upper bed of gypsum and basal bed of fissile limestone.	Unused.
		Entrada Sandstone	150–250	Light-colored, fine- to medium-grained cross-bedded sandstone in upper part; red sandstone in lower part.	Well 10.6.33.140 (table 3) reportedly yields 8 gpm. Well 10.7.33.234 (table 3) flowed 12 gpm, but was abandoned due to poor chemical quality of water.
Triassic	Upper	Chinle Formation	1,500±	Red and maroon shale and siltstone; some interbedded sandstone.	Reportedly yields from 5 to 300 gpm of water to irrigation and stock wells.

CHINLE FORMATION

The Chinle Formation of Late Triassic age overlies the San Andres Limestone of Permian age. The formation crops out a short distance east and southeast of Mesita and lies at depths of 0 to 2,700 feet below the land surface in the area. The formation consists primarily of red, maroon, purple, chocolate-brown, and greenish-gray shale, siltstone, and shaly siltstone. The Chinle also includes interbedded limestone, limestone conglomerate, and very fine to very coarse grained sandstone. Most wells in the area penetrate only the upper part of the formation. The beds of limestone and sandstone in the upper part generally are thin (less than 20 ft thick), and many of the beds have a small areal distribution.

The Chinle Formation generally yields small amounts of water (5–10 gpm) to wells in and adjacent to the project area. Larger yields have been obtained locally; well 10.9.26.433 (table 3), for example, reportedly yields 300 gpm. Yields of more than a few gallons per minute should not be expected, however, because the larger yields are caused by localized geologic conditions, such as fracture zones. Most of the yield of well 10.9.26.433 probably is from sandstone in the lower half of the formation.

The quality of the water in the Chinle is variable. The specific conductance, a measure of the ability of the water to conduct an electric current and an index to the dissolved-solids content, of the water ranged from 668 to 3,870 micromhos. Water having higher specific conductance may be expected at places, as indicated by well 10.4.26.400 (table 3), which was abandoned because the water was too salty to use.

The Chinle Formation is the principal source of potable water in the vicinity of Mesita in the eastern part of the area, where water is found at depths of 55 to 60 feet. The formation has not been utilized as a source of ground water in the area west of Mesita, because it is overlain by other units that are as permeable as the Chinle.

ENTRADA SANDSTONE

The Entrada Sandstone of Late Jurassic age overlies the Chinle Formation and crops out only in the extreme southeastern part of the area in a narrow belt between Mesita and Laguna and north of Mesita (pl. 1). The formation underlies most of the area at depths of 0 to 2,400 feet. The Entrada is a fine- to medium-grained cross-bedded sandstone that ranges in thickness from 150 to 250 feet and varies in color from pale reddish brown and salmon pink in the lower part to grayish pink and yellowish gray in the upper 30 feet.

The Entrada has been little utilized as a source of potable water in the area, because the yield has been small and the quality of water has been poor in adjacent areas. Also, the Entrada is overlain by other units that are as permeable or more permeable in much of the area.

TODILTO LIMESTONE

The Todilto Limestone of Late Jurassic age overlies the Entrada Sandstone and crops out in the southeastern part of the area in a narrow band between Mesita and Laguna and north of Mesita (pl. 1). The formation underlies most of the area, at depths of 0 to 2,300 feet. The basal part of the Todilto is a thin, gray, fissile limestone which ranges in thickness from 5 to 25 feet.

A bed of massive slope-forming gypsum overlies the basal limestone and ranges in thickness from 0 to 90 feet. The gypsum thins southward. The Todilto Limestone has not been utilized as a source of water, largely because the water from this source contains high concentrations of calcium sulfate. The bed of gypsum is a major source of chemical contamination of ground water in several other units in the area.

SUMMERVILLE FORMATION

The Summerville Formation of Late Jurassic age overlies the Todilto Limestone and crops out in the southeastern part of the area in a belt about a mile wide between Mesita and Laguna and north of Mesita (pl. 1). The formation underlies most of the area at depths of 0 to 2,200 feet, and is about 100 feet thick. The Summerville generally is a light- to moderate-red siltstone and fine- to medium-grained sandstone that forms distinctive cliffs along the Rio San Jose in T. 9 N., R. 5 W. (pl. 1). The Summerville Formation has not been utilized as a source of water in the area because of its small yield.

BLUFF SANDSTONE

The Bluff Sandstone of Late Jurassic age overlies the Summerville Formation and is exposed in narrow to wide belts and in small patches in the southeastern part of the area (pl. 1). The village of Laguna was built on an outcrop of the Bluff Sandstone. The formation underlies most of the area at depths of 0 to 2,100 feet, and ranges in thickness from 75 to 150 feet. The Bluff is a light-colored fine- to medium-grained crossbedded quartzose sandstone. It commonly forms prominent cliffs.

The Bluff Sandstone generally yields from 2 to 10 gpm of water to domestic and stock wells. Larger yields have been obtained locally—well 10.5.32.200 (table 3), for example. This well reportedly was tested at 75 gpm, and an undetermined but possibly large part of the yield was from the Bluff Sandstone. Yields of more than 10 gpm are rare, however.

The Bluff Sandstone has not been widely utilized as a source of potable water in the area because of the generally small yield of wells and the reportedly poor chemical quality of its contained water. The Bluff is overlain by more permeable units in much of the area.

MORRISON FORMATION

The Morrison Formation of Late Jurassic age overlies the Bluff Sandstone and crops out along the Rio San Jose and its tributaries in the eastern and central parts of the area (pl. 1). The formation underlies the northern and western parts of the area at depths of 0 to 1,600 feet. The Morrison is composed of variegated shale, claystone, and discontinuous, interbedded sandstone. The Morrison ranges in thickness from 300 to 500 feet in this area. The lowest member of the Morrison Formation in this area, the Recapture Member, consists of red, maroon, and greenish-gray shale, claystone, and sandy claystone. The Westwater Canyon Member overlies the Recapture Member and consists of a light-colored fine- to coarse-grained sandstone that is discontinuous. The Westwater Canyon Member probably interfingers with the overlying Brushy Basin Member and the underlying Recapture Member. The Brushy Basin Member consists primarily of greenish-gray shale, claystone, sandy claystone, and interbedded sandstone. The Brushy Basin Member thins abruptly to the south and wedges out a short distance south of the Rio San Jose. The upper part of the Brushy Basin Member consists of a light-colored fine- to coarse-grained sandstone that is exposed in the vicinity of Paguate. This sandstone, locally called the Jackpile sandstone, is variable in thickness and has a very small areal extent. Locally, it contains extensive deposits of uranium ore. The sandstone beds of the Morrison Formation generally range in thickness from 0 to 120 feet. The Morrison Formation yields from 5 to 10 gpm of water to domestic and stock wells in the area. This yield is mainly from the Recapture and Westwater Canyon Members.

The Morrison Formation has not been widely utilized as a source of water, because of generally small yields. The formation is overlain by more permeable units in much of the northern and western parts of the area.

DAKOTA SANDSTONE

The Dakota Sandstone of Early(?) and Late Cretaceous age overlies the Morrison Formation and is exposed in high escarpments along the Rio San Jose and its tributaries in the central and eastern parts of the area (pl. 1). The Dakota Sandstone consists of light-colored fine- to medium-grained quartzose sandstone and dark-gray to black carbonaceous shale. The unit contains a basal conglomerate at some places.

The Dakota Sandstone yields from 5 to 50 gpm of water to domestic and stock wells in the area. Larger yields have been obtained locally—well 10.8.13.241 (table 3) for example. This well was reportedly pumped at 800 gpm for 5 hours, and a large part of the yield was probably from the Dakota Sandstone; however, such a large yield is exceptional and should not be expected at most places. The large yield of well 10.8.13.241 is probably related to a local, intensely fractured zone.

The Dakota Sandstone has not been widely utilized as a source of water in the area because of generally small yields. The Dakota is overlain by other units that are as permeable in much of the northern and western parts of the area.

MANCOS SHALE

The Mancos Shale of Late Cretaceous age overlies the Dakota Sandstone and crops out in a large part of the area (pl. 1). The Mancos consists primarily of medium- to dark-gray shale and contains three beds of pale-yellowish-brown fine- to medium-grained massive sandstone in the lower part. The three beds of sandstone and the intervening beds of shale in the lower part of the Mancos, the Tres Hermanos Sandstone Member, cap many of the mesas in the area.

The beds of sandstone in the Tres Hermanos Sandstone Member are the only units in the Mancos Shale that yield potable water. The yield from the Tres Hermanos generally ranges from 5 to 20 gpm; however, larger yields have been obtained locally; well 10.9.25.324 (table 3), for example, reportedly yields 100 gpm. The specific conductance of the water from the Tres Hermanos ranged from 670 to about 3,000 micromhos (table 4). Several springs in the project area discharge from 1 to 10 gpm of water from the sandstone beds of the Tres Hermanos. The water from the springs is used for domestic supply (table 5).

MESAVERDE GROUP

The Mesaverde Group of Late Cretaceous age overlies the Mancos Shale and crops out in the high mesas in the northern part of the area. The Mesaverde consists of alternating beds of shale, sandstone, and coal. The beds of sandstone are exposed as massive weather-resistant units. The Mesaverde Group is not utilized as an aquifier in the area, because the unit is present only on the high mesas in the northwestern part of the area.

BASALT AND DIKES OF TERTIARY AGE

Basaltic lava flows of Tertiary age cap most of the high mesas in the northern part of the area (Hunt, 1937). The basalt lies on an old erosion surface which truncates the Mesaverde Group in the western part of the area and the Mancos Shale in the eastern part (pl. 1). The basalt ranges in thickness from 0 to 100 feet.

Wells have not been drilled in these basalt flows in the area; however, a well that taps the basalt just north of the area reportedly yields water at a rate of about 200 gpm. Springs discharge potable water from the base of the basalt in the headwater areas of Encinal Creek and Rio Paguate, which the springs feed. The discharge of the west fork of Encinal Creek was gaged at 50 gpm on September 11, 1956, and the discharge of the east fork was estimated to be about the same. This discharge rate probably was about minimum, according to other measurements that have been made by the Geological Survey. The discharge of Rio Paguate, about 3 miles above the village of Paguate, was 180 gpm on September 14, 1956. At the upper diversion dam, a point that is closer to Paguate, the flow at that time was 120 gpm. This discharge rate probably was near a minimum, according to other measurements by the Geological Survey at the same place. Shale of the Mesaverde Group and the Mancos Shale, which underlie the basalt, restrict the downward movement of water that percolates through the fractures in the basalt to the springs. The basalt flowed into and filled many former topographic depressions, and usable supplies of water may be stored in the basalt where it fills the former depressions.

Several dikes, which trend northward to northwestward, are exposed in escarpments and as ridges throughout the area (pl. 1). These dikes appear to have low permeabilities and may impede the movement of ground water. A dike near McCartys (pl. 1) is probably an example of such an impediment. Water was reportedly found in beds of sandstone in the Mancos Shale west of the dike but was not found immediately east of the dike. The dikes do not restrict the movement of ground water in the alluvium because the dikes do not penetrate the alluvium. The effects of the dikes on the lateral movement of ground water and the chemical quality of the ground water has not been clearly defined. The relation of the dikes to ground water should be thoroughly investigated, if further studies of the hydrology of the area are made.

ALLUVIUM

Alluvium of Quaternary age is exposed along the Rio San Jose and its tributaries (pl. 1) and is interbedded with lava flows of Quaternary age in the Rio San Jose valley. Some gravel deposits are exposed on the gently sloping plains in the area between San Fidel and the mesa to the north. The plains slope southward toward the Rio San Jose, and the gravel deposits are elongated in the same southerly direction. The alluvium consists mainly of silt, clay, very fine to medium sand, and interbedded very coarse sand and gravel. The sand and gravel consist mostly of quartz, chert, and volcanic debris. The alluvium in the area ranges in thickness from 0 to at least 150 feet. The alluvium is thickest adjacent to the axis of the Rio San Jose.

712-186—64——2

The alluvium in the tributaries north of the Rio San Jose contain larger and better sorted sediments than the alluvium south of the river. Much of the alluvium from the north side consists of sand and gravel derived from the hard, dense volcanic rocks of the Mount Taylor volcanic complex and the surrounding high mesas that are capped mainly by basalt and andesite (Hunt, 1937, pl. 7). A smaller part of the Mount Taylor area is underlain by rhyolite, trachyte, and latite. Gravel and sand derived from the hard volcanic rocks generally are fairly well rounded and sorted. Therefore, beds of gravel and sand derived from the volcanic rocks have relatively high permeabilities and yield water readily to wells. On the other hand, alluvium deposited by tributaries south of the Rio San Jose is derived largely from soft sandstone and shale, which tend to disintegrate into small particles during erosion and transportation. Therefore, this alluvium generally consists of fine material. Such alluvium has low permeability and yields water slowly to wells.

Most of the large-capacity wells in the area obtain water from discontinuous beds of channel gravel, which are interbedded with flood-plain silt.

The alluvium is the principal aquifer in the area (table 3 and pl. 2). The yields of wells that tap the alluvium range from 2 to more than 150 gpm. The yields of most of the old wells range from 2 to 15 gpm.

Water in the fine alluvium south of the Rio San Jose is more highly mineralized than water in the coarse alluvium north of the Rio San Jose because the fine alluvium contains a greater proportion of readily soluble minerals. The concentration of dissolved solids in the analyzed samples of water from the alluvium ranged from 375 to 8,440 ppm (parts per million). The concentration of sulfate in the samples of water from the alluvium ranged from 53 to 4,020 ppm (table 4 and pl. 3). The coefficient of transmissibility (the rate of flow of water at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent) of the alluvium ranges from 560 to 130,000 gpd per ft, where tested.

Precipitation, streamflow, and, locally, discharge from the underlying rocks are all sources of recharge to the alluvium. The alluvium discharges water to the Rio San Jose in the western part of the area, where its channel intercepts the water table, and by evapotranspiration where the water table is within a few feet of the land surface.

BASALT OF QUATERNARY AGE

Two or more lava flows of Quaternary age (Hunt, 1937), which consist mainly of olivine basalt, are present in the valley of the Rio San Jose (pl. 1), interbedded with alluvium of Quaternary age.

Fractures and depressions that were formed by the collapse of lava tubes are numerous in outcrops of the basalt, and many of the depressions contain water, the upper surface of which coincides with the water table in the basalt. Individual basalt flows range in thickness from 0 to 50 feet.

The basalt reportedly yields water at rates of 50 to 100 gpm to domestic and stock wells; however, most, if not all, of the wells that tap the basalt also tap one or more beds of alluvium, so that the yield of the basalt cannot be segregated. In some places, the basalt is a confining bed. The water in the alluvium beneath the basalt in well 10.8.28.314 (irrigation test well 3) was under artesian pressure when the well was drilled in 1960.

Several springs discharge from the lava flows. The largest is Horace Springs, in the SE¼ sec. 23, T. 10 N., R. 9 W., just west of the Acoma Reservation, which discharges about 2,000 gpm.

TEST-WELL DRILLING

Thirteen test wells were drilled by the Public Health Service and the Bureau of Indian Affairs to obtain geologic and hydrologic information in the Rio San Jose drainage basin. The Geological Survey advised on technical aspects of the program, observed the drilling and testing, and collected and analyzed the data. Five wells were drilled in search of domestic supplies and eight were drilled to test for irrigation supplies. All the wells were drilled with cable-tool drills, and drill cuttings were collected at 5-foot intervals. From examination of these cuttings, lithologic logs of most of the test wells were prepared. The location of the water-bearing strata, the altitude of the water levels, and the chemical character of the ground water were determined.

The testing procedure for each well was as follows. When a strong inflow of water was indicated during drilling, the test well was cleaned by bailing and a sample of water was taken for chemical analysis. The test well was bailed as rapidly as practicable in order to estimate its capacity to yield water. Drilling was stopped when the principal water-bearing strata had been penetrated, and 6-inch casing was installed. The casing was perforated with torch-cut slots opposite the water-bearing zones. The well was cleaned by bailing, and if a large yield of usable water was indicated, a test pump was installed. The well was surged with the test pump until clean, sand-free water was pumped. The water level was allowed to stabilize after completion of the development. Then each well was pumped for either 12 or 24 hours, during which time the water level in the well and the discharge of the pump were measured. When the pump was stopped, the recovery of the water level was measured for about 24 hours. The test wells were pumped in order to observe the performance of the wells and to determine the coefficient of transmissibility of the aquifers. The performance of the wells is reported as specific capacity (the yield per foot of drawdown) and the coefficient of transmissibility of the aquifers (defined as the rate of flow of water, in gallons per day, at the prevailing water temperature, through each vertical strip of the aquifer 1 foot wide having a height equal to the thickness of the aquifer and under a unit hydraulic gradient).

The selection of the test sites was influenced principally by two factors: (1) the need for water for domestic and irrigation use at specific localities, and (2) the assumption, on the basis of geologic and hydrologic principles, that the most water and the water of best chemical quality moves through the alluvium of the northern tributaries to the valley fill in the Rio San Jose valley.

The test sites and the results of drilling and testing are described on the following pages in order down the valley (west to east). The locations of these test wells and other selected wells in the area are shown on plates 2 and 3.

TEST DRILLING IN THE ANZAC-McCARTYS AREA

Test wells were drilled in the Anzac-McCartys area in an attempt to locate a sufficient amount of water of satisfactory chemical quality for additional irrigation. The Anzac-McCartys area includes the valley of the Rio San Jose in the western part of the Acoma Reservation. The main water-bearing formations in this area are the alluvium and the lava flows of Quaternary age in the Rio San Jose valley. The water that is discharged by springs, Horace Springs in particular, makes the Rio San Jose a perennial stream in the Anzac-McCartys area. For this reason, relatively large quantities of water were anticipated in the alluvium and basalt flows in the valley.

WELL 10.9.25.330 (IRRIGATION TEST WELL 1)

Well 10.9.25.330 (irrigation test well 1) was drilled in the valley of a southern tributary to the Rio San Jose about 1½ miles southwest of Anzac. (See pl. 2.) The well penetrated 82 feet of alluvium and 10 feet of Mancos Shale. The alluvium consists of an upper unit of sandy silt 54 feet thick, a middle unit of sand and gravel 16 feet thick, and a lower unit of sandy silt 12 feet thick.

The prepumping water level in the well was 33 feet below the land surface, and the saturated thickness of the alluvium was 49 feet. The well was test pumped at 10 gpm, and the water level was lowered 35 feet in 7 minutes to the level of the pump intake; the specific capacity (the yield per foot of drawdown) of the well was 0.1 gpm per foot of drawdown. The coefficient of transmissibility of the alluvium at this site, as computed from the water-level recovery curve, was 200 gpd per ft. The water from the well was good in chemical quality for all the ordinary uses. The specific conductance of the water was 900 micromhos.

The small yield of well 10.9.25.330 indicates that the site is not favorable for a production well (for other than a supply for a few houses) or for a stock well.

WELL 10.9.25.441 (IRRIGATION TEST WELL 2)

Well 10.9.25.441 (irrigation test well 2) was drilled on the flood plain of a southern tributary to the Rio San Jose, a mile southwest of Anzac. (See pl. 2.) The well penetrated 78 feet of alluvium and 1 foot of Mancos Shale. (See log of well.) All the alluvium was fine to very fine sand and silt. The prebailing water level was 13 feet below the land surface. Bailing the well at 30 gpm for 30 minutes did not lower the water level appreciably. However, water from the well contained 8,440 ppm of dissolved solids, including 4,020 ppm of sulfate and 1,260 ppm of chloride. Because the water from the well was not suitable chemically for ordinary uses, the well was not test pumped.

Log of well 10.9.25.441 (irrigation test well 2)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Sand, silty, grayish-orange (10*YR* 7/4) when dry, very fine, subangular, well-sorted; contains silt and calcareous material; coherent, friable	5	5
Sand, similar to that in the interval 0–5 ft, but pale yellowish brown (10*YR* 6/2) when dry	20	25
Sand, similar to that in the interval 0–5 ft, but contains a small amount of fine quartz sand	5	30
Sand, similar to that in the interval 0–5 ft, but contains a small amount of fine quartz sand and very little calcareous material	5	35
Sand, similar to that in the interval 0–5 ft, but pale yellowish brown (10*YR* 6/2) when dry	35	70
Sand, similar to that in the interval 0–5 ft, but pale yellowish brown (10*YR* 6/2) when dry; contains some very coarse sand and fine gravel, patches of ironstone, and a little calcareous material	8	78
Cretaceous:		
Mancos Shale:		
Shale, moderately calcareous, medium-gray (when dry); friable	1	79

WELL 10.8.28.314 (IRRIGATION TEST WELL 3)

Well 10.8.28.314 (irrigation test well 3) was drilled in the valley of the Rio San Jose a little more than a mile west of McCartys. (See pl. 2.) The well penetrated 115 feet of alluvium and basalt and 10 feet of Mancos Shale. Water-bearing materials that were penetrated from top to bottom consisted of 30 feet of sand, 45 feet of interbedded basalt and sand, 10 feet of gravel, and 30 feet of silt. (See log of well.) The yield of the well increased and the quality of the water became better as drilling proceeded below the basalt.

The prepumping water level was 4.8 feet below the land surface; the saturated thickness of alluvium and basalt was 110 feet. The well was pumped at 100 gpm for 24 hours, and the water level was lowered 11.5 feet; the specific capacity of the well was 8.7 gpm per ft of drawdown.

The coefficient of transmissibility, as computed from the water-level recovery curve, was 16,000 gpd per ft (fig. 3). The abrupt steepening of the water-level recovery curve indicates hydrologic boundaries, which are probably the walls of an old, buried canyon. Recharge effects from the Rio San Jose were not evident on the curve, although the river was flowing only a few hundred feet from the test well.

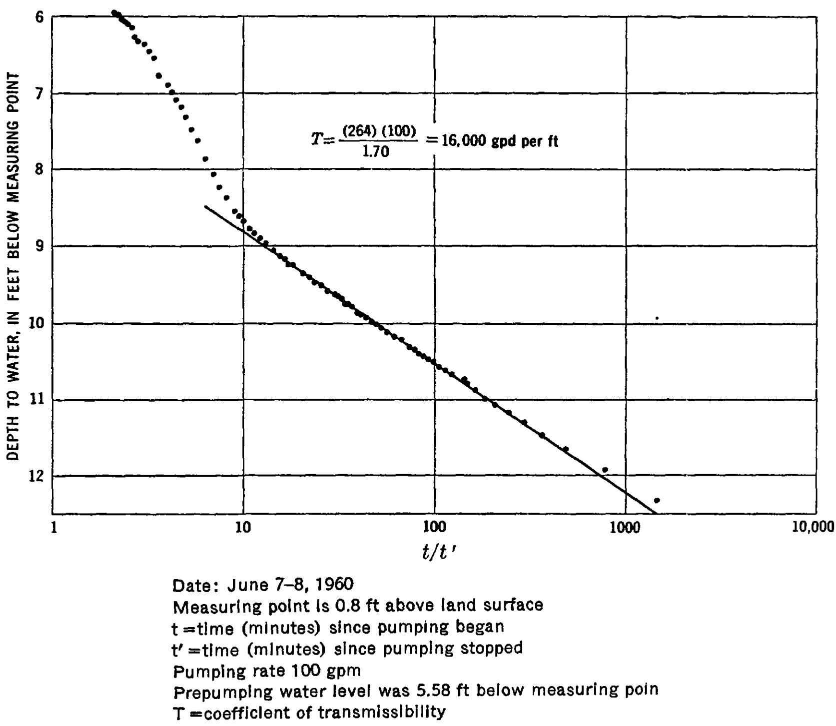


FIGURE 3.—Curve of water-level recovery from test of well 10.8.28.314 (irrigation test well 3).

Log of well 10.8.28.314 (irrigation test well 3)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium and basalt:		
Clay, silty, olive-gray (5*Y* 4/1) when wet; contains chert grains, quartzose grains, calcareous nodules as much as 1 inch along the longest axis, organic material, and calcareous material; unconsolidated	5	5
Sand, silty, dark-yellowish-brown (10*YR* 4/2) when wet, moderately well sorted; consists of silt, very fine sand, and calcareous material; unconsolidated	5	10
Sand, silty, dark-yellowish-brown (10*YR* 4/2) when wet, subrounded to subangular, moderately well sorted; consists of silt, fine sand, quartzose and chert grains, and calcareous material; unconsolidated	5	15
Sand and silt, pale-yellowish-brown (10*YR* 6/2) when dry; consists of silt and fine sand, subrounded to subangular and moderately well sorted; consists predominantly of quartzose grains, chert, and calcareous material; moderately coherent and slightly friable. The interval 20–25 ft is dark yellowish brown (10*YR* 4/2) when wet and contains some small calcium carbonate nodules. The material 25–30 ft is grayish brown (5*YR* 3/2) when wet	15	30
Basalt, medium-dark-gray (*N* 4) when dry; interbedded with small nodules of ironstone and fine-grained quartzose sandstone cemented with calcium carbonate	5	35
Sand, slightly silty, light-olive-gray (5*Y* 5/2) when wet, very fine to medium, subangular, moderately well sorted; consists of quartzose grains, basalt grains, and patches of ironstone; contains calcareous material; unconsolidated	5	40
Basalt, grayish-black (*N* 2) with some lighter areas when wet; fine-grained	10	50
Sand, brownish-gray (5*YR* 4/1), very fine to medium, moderately well sorted; consists predominantly of quartz grains; unconsolidated	10	60
Olivine basalt, medium-dark-gray (*N* 4) when dry. The interval 65–70 ft contains some very fine to fine well-sorted unconsolidated quartz sand; the interval 70–75 ft contains fine to coarse, poorly sorted, friable quartz sand. The sand is probably caved material from some section above this interval 60–75 ft	15	75
Gravel and sand, light-brown (5*YR* 6/4) when dry; fine to very coarse sand and gravel as much as one half inch in diameter, subrounded to subangular, poorly sorted; contains sandstone, chert, and dark volcanic material	10	85
Silt, light-brown (5*YR* 6/4) when dry; contains some sand grains, moderately well sorted; the dry breaking strength is high. The interval 100–105 ft contains sand of all sizes and a small amount of gravel	30	115

Log of well 10.8.28.314 (irrigation test well 3)—Continued

Material	Thickness (ft)	Depth (ft)
Cretaceous:		
Mancos Shale:		
Shale, moderately calcareous, medium-gray when dry; friable	10	125

The water from the well became more mineralized during the 24-hour pumping test. Samples of water tested during the pumping test had the following specific conductances: 1,150 micromhos, after 30 minutes; 1,300 micromhos, after 450 minutes; and 1,400 micromhos, after 1,440 minutes. A sample of water from the well, which was collected near the end of the test, contained 887 ppm of dissolved solids, including 361 ppm of sulfate, and had an SAR of 4.7. The water is probably suitable for domestic and stock use and for irrigation of well-drained soils. The water level declined about 11.5 feet after 24 hours of pumping at a rate of 100 gpm. At the pumping rate of 100 gpm, the drawdown curve indicated that the pumping level would be 19 feet after 7 days and 21½ feet after 70 days, but hydrologic boundaries would effect the drawdown in the well.

WELL 10.8.27.224 (IRRIGATION TEST WELL 4)

Well 10.8.27.224 (irrigation test well 4) was drilled in the valley of an unnamed south tributary to the Rio San Jose a little less than 1 mile northeast of McCartys. (See pl. 2.) The well penetrated 90 feet of alluvium and 8 feet of shale in the Brushy Basin Member of the Morrison Formation. The alluvium consisted of 77 feet of poorly sorted to well-sorted sand, underlain by 13 feet of interbedded sand and gravel. (See log of well.) The water level in the well was 45 feet below the land surface. The specific conductance of the water, as checked by a field conductance meter, was 4,800 micromhos. Because the water from the well was probably too saline for most uses, the well was not tested for yield.

Log of well 10.8.27.224 (irrigation test well 4)

The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Sand, silty, dark-yellowish-brown (10*YR* 4/2) when wet, subangular to angular, well-sorted; contains silt and very fine sand, consisting of quartz grains; contains calcareous material; unconsolidated. The interval 10–15 ft contains more silt and a small amount of basalt gravel. The interval 15–20 ft contains about 5–10 percent basalt gravel	20	20

Log of well 10.8.27.224 (irrigation test well 4)—Continued

Material	Thickness (ft)	Depth (ft)
Quarternary—Continued		
Alluvium—Continued		
Sand, gravelly, dark-yellowish-brown (10*YR* 4/2) when wet; very fine to very coarse sand and gravel as much as one-fourth inch in diameter; very coarse sand and gravel are rounded to well rounded; very fine to fine sand is subangular to angular; poorly sorted; consists of basalt and quartz; contains small amount of calcareous material; unconsolidated	5	25
Sand, similar to that in the interval 0–20 ft, but contains about 5–10 percent basalt gravel	5	30
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine, subangular to angular, well-sorted; consists of quartz grains; contains calcareous material; unconsolidated	10	40
Sand, similar to that in the interval 30–40 ft but contains a small amount of well-rounded basalt gravel	15	55
Sand, similar to that in the interval 30–40 ft but contains about 10–15 percent very coarse sand and gravel as much as one-fourth inch in diameter; composed of basalt	5	60
Sand, similar to that in the interval 30–40 ft but contains about 5 percent very coarse sand and gravel as much as one-fourth inch in diameter; composed of basalt	5	65
Sand, similar to that in the interval 30–40 ft but contains less than 5 percent very coarse sand and gravel as much as one-fourth inch in diameter; composed of basalt	5	70
Sand, similar to that in the interval 30–40 ft but contains about 10–15 percent silt	5	75
Sand, similar to that in the interval 30–40 ft but contains about 10–15 percent well-rounded, coarse sand and gravel as much as one-fourth inch in diameter; composed of basalt	2	77
Gravel, dusky-yellowish-brown (10*YR* 2/2); 1/16–3/8 inch in diameter, well-rounded to subangular, poorly sorted; consists of basalt and quartz sandstone; contains a small amount of calcareous material; unconsolidated	3	80
Sand, similar to that in the interval 30–40 ft but contains about 20 percent coarse sand and gravel as much as one-fourth inch in diameter; composed of basalt and about 10 percent silt	5	85
Gravel, similar to that in the interval 77–80 ft	5	90
Jurassic:		
Morrison Formation:		
Brushy Basin Member:		
Shale, calcareous, light-bluish-gray (5*B* 7/1) when dry; friable	8	98

WELL 9.8.2.110 (IRRIGATION TEST WELL 5)

Well 9.8.2.110 (irrigation test well 5) was drilled near the mouth of Canon Largo 1½ miles southeast of McCartys. (See pl. 2.) The well penetrated 60 feet of alluvium and 20 feet of Mancos Shale. The alluvium consists of silty very fine to fine well-sorted sand and poorly sorted gravel. (See log of well.) The depth to water was 38 feet below the land surface. The water level was lowered 40 feet by bailing 60 gallons of water from the well, and it took 6 hours for the water level to recover to the prebailing level. The well was not test pumped because of the apparent low permeability of the water-bearing material.

Log of well 9.8.2.110 (irrigation test well 5)

The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Sand, silty, grayish-orange (10*YR* 7/4) to pale-yellowish-brown (10*YR* 6/2) when dry, very fine to fine, subangular to angular, well-sorted; contains calcareous material; unconsolidated	43	43
Gravel, sandy, pale-yellowish-brown (10*YR* 6/2) when dry, fine sand and gravel one-eighth in. in minimum diameter, subrounded to angular and poorly sorted; gravel consists of volcanic material and sandstone; contains calcareous material; unconsolidated	4	47
Sand, silty, pale-yellowish-brown (10*YR* 6/2) when dry, well-sorted; consists of silt and very fine sand containing calcareous material; unconsolidated	13	60
Cretaceous:		
Mancos Shale:		
Shale, slightly calcareous, medium- to medium-dark-gray (*N* 4) when dry, friable	20	80

TEST DRILLING IN THE ACOMITA AREA

The village of Acomita on the Acoma Reservation needs more water and water of better chemical quality. The water now used for municipal supply (1960), from wells that tap the consolidated sedimentary rocks, contains 1,740 ppm of dissolved solids, including 520 ppm of sulfate, according to U.S. Public Health Service records. Rural residents north of the Rio San Jose and west of Acomita, in secs. 31–33, T. 10 N., R. 7 W., haul or carry water to their homes from Canipa Spring, in the NW¼ sec. 12, T. 9 N., R. 8 W. (See pl. 2.)

Water from wells that tap the alluvium near the village of Acomita generally has high concentrations of dissolved solids. (See pl. 3 and table 4.) Several wells that tap the Dakota Sandstone north of Acomita yield water that is too saline for domestic use. The well that furnishes water for the Acomita school reportedly yields potable water, but the yield is barely sufficient to supply the school. A well that was drilled by the Bureau of Indian Affairs near Acomita penetrated 1,000 feet of consolidated sedimentary rocks without obtaining potable water, and the well was bottomed in a zone of highly mineralized water.

An attempt was made to locate a well as close as possible to Acomita. All the wells near Acomita were visited, and the conductance of the water from the wells was tested with a field conductance meter. The water of lowest conductance was found in the valley that drains into Acomita reservoir, between the reservoir and San Fidel. The valley has a large drainage area, much of which is on the south flank of Mount Taylor and adjacent high mesas. Therefore, the site for a well was chosen just above the Acomita reservoir because of the possibility that substantial amounts of potable water move through the alluvium in the valley and because of the relatively low specific conductance of water in the Acomita reservoir and in a nearby well that taps the alluvium. Water in the reservoir had a specific conductance of 1,400 to 1,600 micromhos in the winter of 1960. Water from a well (10.7.29.120) just west of the reservoir had a specific conductance of 770 micromhos. (See table 3.)

WELL 10.7.29.214 (PUEBLO TEST WELL 4)

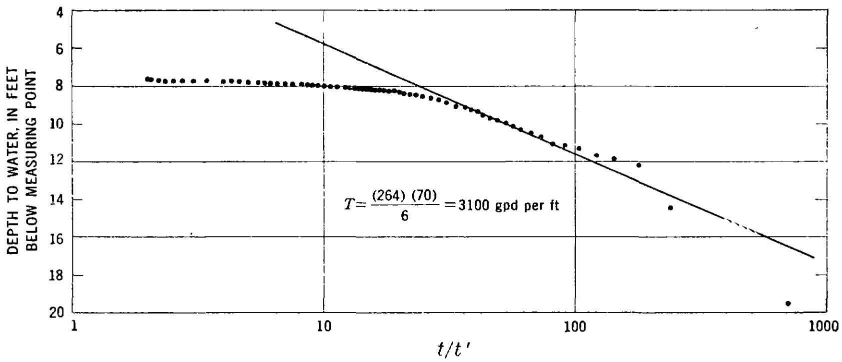
Well 10.7.29.214 (pueblo test well 4) was drilled a few hundred feet north of Acomita reservoir and about 2 miles west of Acomita. (See pl. 2.) The well penetrated 95 feet of alluvium and 141 feet of consolidated sedimentary rocks consisting of the Mancos Shale, the Dakota Sandstone, and the Morrison Formation. The alluvium consists of interbedded silt, sand, and gravel. The basal part of the alluvium consists of 45 feet of very fine well-sorted sand. The consolidated sedimentary rocks that were penetrated consist primarily of shale having a low permeability. (See log of well.)

Log of well 10.7.29.214 (pueblo test well 4)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Silt, sandy, pale-yellowish-brown (10*YR* 6/2) when dry; consists of silt and very fine well-sorted sand; contains calcareous material; unconsolidated	5	5
Sand and gravel, silty, grayish-orange (10*YR* 7/4) when dry; consists of silt, very fine to very coarse sand, and gravel which is as much as one-half inch in diameter, subrounded, and very poorly sorted; consists of quartz sand, and basalt and sandstone gravel; contains calcareous material; unconsolidated	5	10
Sand and gravel, silty, pale-yellowish-brown (10*YR* 6/2) when dry; consists of silt, very fine to very coarse sand, and gravel, which is as much as one-half inch in diameter, subrounded, and very poorly sorted; consists of quartz sand, and basalt and sandstone gravel; contains calcareous material; unconsolidated	25	35
Sand and gravel, silty, light-olive-gray (5*Y* 5/2) when dry; consists of silt, very fine to very coarse sand, and gravel, which is as much as one-fourth inch in diameter, subrounded, and very poorly sorted; consists of quartz sand, and basalt and sandstone gravel; contains calcareous material; unconsolidated	10	45
Gravel, sandy, pale-yellowish-brown (10*YR* 6/2) when dry; consists of fine to very coarse sand, and gravel, as much as one-eighth inch in diameter; subrounded to subangular, and poorly sorted; consists of quartz grains, basalt, and quartz sandstone; contains calcareous material; unconsolidated	5	50
Sand, slightly silty, pale-yellowish-brown (10*YR* 6/2) when dry; consists of silt and very fine sand, which is subangular to angular and well sorted; contains calcareous material; unconsolidated	45	95
Cretaceous:		
Mancos Shale:		
Shale, medium-gray when dry, friable	25	120
Dakota Sandstone:		
Shale, carbonaceous, medium-dark-gray when dry, friable	25	145
Jurassic:		
Morrison Formation:		
Brushy Basin Member:		
Shale, calcareous, light-greenish-gray (5*GY* 8/1) when dry, friable	55	200
Shale, calcareous, pale-red (5*R* 6/2) when dry, friable	5	205
Shale, calcareous, light-greenish-gray (5*GY* 8/1) when dry, friable	31	236

The prepumping water level in the well was 6.6 feet below the land surface. Most of the water was obtained from the alluvium, which had a saturated thickness of 88 feet. The well was pumped for 12 hours at 70 gpm, and during this time the water level in the well declined 12.8 feet; the specific capacity of the well was 5.5 gpm per ft of drawdown. The coefficient of transmissibility of the aquifer, as computed from the recovery curve (fig. 4), is 3,100 gpd per ft. The



Date: April 14–15, 1960
Measuring point is 1.0 ft above land surface
t = time (minutes) since pumping began
t′ = time (minutes) since pumping stopped
Pumping rate 70 gpm
Prepumping water level was 7.63 ft below measuring point
T = coefficient of transmissibility

FIGURE 4.—Curve of water-level recovery from test of well 10.7.29.214 (pueblo test well 4)

slope of the curve decreases abruptly where *t/t′* is about 30, which was about 25 minutes after the pump was stopped. The flattening of the curve probably was caused by a recharge boundary—perhaps the infiltration of water from Acomita reservoir into the aquifer—which would limit the spread of the cone of depression in that direction. The well is up the water-table gradient from the reservoir and the movement of the ground water is very slow. Therefore, it would take several years, if ever, for the water level at the well to be lowered enough to cause water to move from the reservoir to the well, even though pumping was continuous.

Water obtained from the well near the end of the 12-hour pumping test contained 729 ppm of dissolved solids including 180 ppm of sulfate. (See pl. 3.) Water from this well is less mineralized than the water that the village of Acomita is using, which contains about 1,750 ppm of dissolved solids. Even if continuous pumping of a well at this site might eventually draw in water from the Acomita reservoir, the water from the reservoir would be diluted by the water of better quality upgradient in the aquifer.

WELL 10.7.35.210 (IRRIGATION TEST WELL 6)

Well 10.7.35.210 (irrigation test well 6) was drilled in an area where the alluvium of the Rio San Jose narrows 1½ miles east of Acomita. (See pl. 2.) The well penetrated 122 feet of alluvium and basalt and 10 feet of the Brushy Basin Member of the Morrison Formation. The materials that were penetrated, from the surface down, consisted of 20 feet of sand, silt, and clay; 55 feet of basalt; 5 feet of clay; 42 feet of gravel; and 10 feet of shale. (See log of well.) The gravel was fine to very coarse, poorly sorted, and sandy, and it appeared to be fairly permeable.

Log of well 10.7.35.210 (irrigation test well 6)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	*Thickness (ft)*	*Depth (ft)*
Quaternary:		
Alluvium and basalt:		
Silt and clay, light-olive-gray (5*Y* 5/2) when dry, well-sorted; contains calcareous material; unconsolidated	6	6
Sand, silty, grayish-orange (10*YR* 7/4) when dry; silt and very fine sand, subangular and well sorted; consists of quartz sand; contains calcareous material; unconsolidated	9	15
Sand, slightly silty, grayish-orange (10*YR* 7/4) when dry, fine to very coarse, subrounded to subangular, poorly sorted; consists of basalt, quartz, and quartz sandstone; contains calcareous material; unconsolidated	5	20
Basalt, light-olive-gray (5*YR* 5/2) when dry, gravel as much as one-fourth inch in diameter, subangular to very angular, poorly sorted; contains some medium sand and calcareous material, which is probably caved material from previously drilled part of the hole. The sand in interval 30–75 ft contains variable amounts of white, clear, and pink chert	55	75
Clay, silty, brownish-gray (5*YR* 4/1) when dry, well-sorted; contains calcareous material; unconsolidated	5	80
Gravel, slightly sandy, pale-yellowish-brown (10*YR* 6/2) when dry; medium to very coarse sand and gravel which is as much as three-eighths inch in diameter, subrounded to angular, and poorly sorted; consists of basalt, quartz sandstone, granite, and chert; contains calcareous material; unconsolidated	5	85
Gravel, sandy, grayish-orange (10*YR* 7/4) when dry; fine to very coarse sand and gravel, which is as much as three-eighths inch in diameter, rounded to subangular, and poorly sorted; consists of basalt, quartz grains, and chert; contains calcareous material; unconsolidated	37	122
Jurassic:		
Morrison Formation:		
Brushy Basin Member:		
Shale, pale-olive (10*Y* 6/2) when dry, friable	10	132

The prepumping water level was 9.8 feet below the land surface, and the saturated thickness of the alluvium and basalt was 112 feet. The well was tested by pumping for 20 hours at 100 gpm which lowered the water level 17.5 feet; the specific capacity of the well was 5.7 gpm per foot of drawdown. The coefficient of transmissibility of the aquifer was 8,000 gpd per ft, as computed from the water-level recovery curve (fig. 5). The water-level recovery curve indicates one or two hydrologic boundaries.

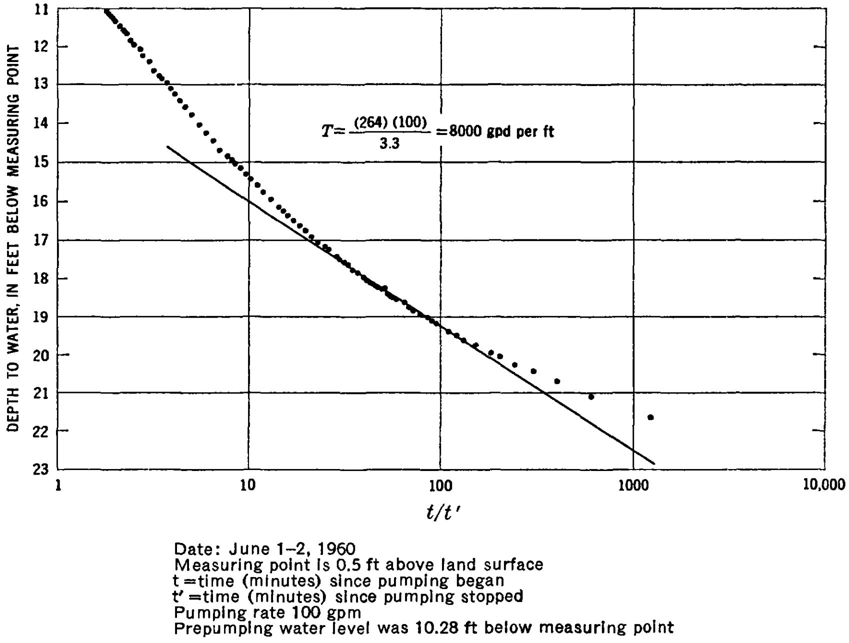


FIGURE 5.—Curve of water-level recovery from test of well 10.7.35.210 (irrigation test well 6)

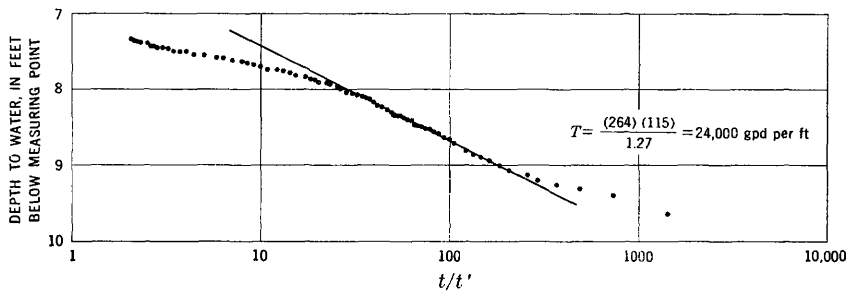
A sample of water from well 10.7.35.210 contained 2,310 ppm of dissolved solids, including 1,090 ppm of sulfate and 195 ppm of chloride. The SAR (sodium-adsorption ratio, a ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil) of the water was 10, so the water is classified for irrigation as C4–S3 (Wilcox, 1955), which is considered poor for irrigation use.

The water from well 10.7.35.210 does not appear to be chemically suitable for irrigation, but it probably could be used as a supplemental supply by mixing it with water of better quality.

WELL 10.6.31.443 (IRRIGATION TEST WELL 7)

Well 10.6.31.443 (irrigation test well 7) was drilled in the valley of the Rio San Jose 1 mile northeast of Seama and nearly 4 miles east of Acomita. (See pl. 2). The site is just below the confluence of two major tributaries of the Rio San Jose, where subsurface inflows of usable ground water seem possible.

The well penetrated 145 feet of alluvium and interbedded basalt; bedrock was not reached. The alluvium consists of silt, sand, and gravel. (See log of well.) The prepumping water level in the well was 6.8 feet below land surface. The aquifer had a minimum saturated thickness of 138 feet. The well was test pumped for 24 hours at 115 gpm, and the water level was lowered 8.5 feet; the specific capacity of the well was 13.5 gpm per ft of drawdown. The coefficient of transmissibility of the aquifer in the vicinity of the well, as computed from the recovery curve, is 24,000 gpd per ft (fig. 6).



Date: May 25–26, 1960
Measuring point is 0.4 ft above land surface
t = time (minutes) since pumping began
t' = time (minutes) since pumping stopped
Pumping rate 115 gpm
Prepumping water level was 7.25 ft below measuring point
T = coefficient of transmissibility

FIGURE 6.—Curve of water-level recovery from test of well 10.6.31.443 (irrigation test well 7).

The slope of the recovery curve decreases from the point at which t/t' is 25 (60 minutes after pumping stopped). The flattening of the curve is interpreted to be the result of recharge to the aquifer along the bed of the Rio San Jose.

A sample of water that was collected from the well near the end of the pumping test contained 1,040 ppm of dissolved solids, including 422 ppm of sulfate. The water had an SAR of 3.8 and was classified as C3–S1 water. The water is probably suitable for irrigation of soils having good drainage.

Log of well 10.6.31.443 (irrigation test well 7)

[The color of material is keyed to the National Research Council color chart, (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium and basalt:		
Sand and silt, gravelly, grayish-orange (10*YR* 7/4) when dry; silt, very fine to coarse sand, and gravel which is as much as one-half inch in diameter, subrounded to subangular, and poorly sorted; gravel consists of gray crystalline rock, basalt, and sandstone; contains calcareous material; moderately friable	12	12
Gravel, sandy, grayish-orange (10*YR* 7/4) when dry; coarse sand and gravel, which is as much as one-half inch in diameter and subrounded to subangular; moderately well sorted; very friable. The gravel consists of dark volcanic rocks, fine-grained sandstone, light-colored volcanic rocks, and green and white chert	5	17
Sand, gravelly, medium-dark-gray (*N* 4) when dry; predominantly very coarse sand and granules, partly of fine sand and gravel, which is as much as three-fourths inch in diameter, subangular to angular, and some rounded particles; moderately well sorted; derived from dark volcanic rocks; unconsolidated. The material in the interval 20–27 ft is well sorted and contains less gravel and more very fine to fine sand. The interval 25–27 ft contains only a very small amount of gravel	10	27
Basalt, medium-gray to medium-dark-gray (*N* 3½) when dry, fine-grained, very angular; contains an abundance of olivine	18	45
Sand, medium-gray (*N* 5) when dry, fine to very coarse, but predominantly coarse to very coarse, subrounded to subangular, moderately well sorted; consists of volcanic material; unconsolidated	5	50
Sand, medium-dark-gray (*N* 4) when dry, fine to very coarse, but predominantly medium to coarse, subrounded to subangular, moderately well sorted; consists of volcanic material and variously colored chert grains; unconsolidated	10	60
Sand, gravelly, medium-light-gray (*N* 6) when dry, fine to very coarse sand and gravel, as much as one-fourth inch in diameter, subrounded to subangular, and poorly sorted; consists of volcanic material and chert; unconsolidated	5	65
Sand, light-brown (5*YR* 6/4) when dry, fine to very coarse sand and gravel as much as one-fourth inch in diameter, but predominantly medium to very coarse sand, subrounded to subangular, moderately well sorted; consists of light-colored grains, gray, brown, and orange chert, pink granite, light and dark volcanic material, and sandstone; unconsolidated	5	70

712-186—64——3

Log of well 10.6.31.443 (irrigation test well 7)—Continued

Material	Thickness (ft)	Depth (ft)
Quaternary—Continued		
Alluvium and basalt—Continued		
Sand and gravel, light-brown (5*YR* 6/4) when dry, very fine to very coarse sand and gravel as much as one-fourth inch in diameter, subrounded to subangular, and poorly sorted; consists of dark volcanic material; unconsolidated to very friable	10	80
Sand and gravel, pale-brown (5*YR* 5/2) to light-brown (5*YR* 6/4) when dry, fine to very coarse sand and gravel as much as ⅜ of an inch in diameter, subrounded to subangular, poorly sorted; consists of light and dark volcanic material, quartz grains, and pink and orange chert; contains calcareous material; unconsolidated. The material in the interval 125–140 ft is pale yellowish brown (10*YR* 6/2) when dry, and additionally contains some fragments of light-colored very fine- to fine-grained well-cemented quartz sandstone. Material in the interval 140–145 ft is also pale yellowish brown (10*YR* 6/2) when dry, and additionally contains some well-rounded pebbles ¾–1¼ inches in diameter	65	145

TEST DRILLING NEAR THE MOUTH OF ENCINAL CREEK

Wells 10.6.35.322 and 10.6.35.342 (pueblo test wells 1 and 2, respectively) were drilled near the mouth of Encinal Creek, a northern tributary to the Rio San Jose, a mile northwest of New Laguna in an attempt to find potable water for individual dwellings in the area, for Paraje and Casa Blanca west of Encinal Creek, and for New Laguna and Laguna east of Encinal Creek. The following factors were considered in selecting this location for preliminary testing. Laguna is on an outcrop of Bluff Sandstone, which generally yields less than 10 gpm of water of inferior chemical quality to wells. The water in the formations underlying the Bluff Sandstone is not any better in quality. New Laguna and Paraje were built on thin alluvium overlying the Morrison Formation. The alluvium at these places is above the water table, and the Morrison Formation generally yields less than 10 gpm of water of inferior chemical quality to wells. The water in the formations below the Morrison is neither more plentiful nor better in chemical quality. Casa Blanca is on thick deposits of alluvium, but water of good chemical quality generally has not been obtained from the alluvium at Casa Blanca.

The physiographic and geologic features of the area indicated that potable water probably moves through the alluvium of Encinal Creek into the alluvium of the Rio San Jose valley. Much of the alluvium in the vicinity of the test wells consists of sand and gravel, which were derived from the hard, dense volcanic rocks on Mount Taylor and the surrounding high mesas. These beds of sorted sand and gravel were expected to be highly permeable and to yield water readily to wells. A well field near the mouth of Encinal Creek would be favorably located for the distribution of water to the four villages.

Water for Casa Blanca and Paraje is now (1960) obtained from a spring in the NW¼ sec. 10, T. 9 N., R. 6 W. Water from the spring is delivered to Casa Blanca through a 2½-inch pipe and from Casa Blanca to Paraje through a 2-inch pipe. The yield of the spring is not always adequate, especially in summer. The spring was dry in June 1960, and the residents were hauling water from surrounding areas. Laguna and New Laguna get water from wells northwest of Laguna, which are owned by the Atchison, Topeka, and Santa Fe Railway Co. The water supply for New Laguna and Laguna is sufficient for the present (1961) per capita use of about 10 gpd, but the present supply will not be adequate when the per capita use increases to an expected 60 gpd. Potable water also will be needed for a proposed Indian school west of Encinal Creek in the SW¼ sec. 35, T. 10 N., R. 6 W.

WELL 10.6.35.322 (PUEBLO TEST WELL 1)

Well 10.6.35.322 (pueblo test well 1) was drilled about halfway between New Laguna and Paraje. (See fig. 3.) The well penetrated 105 feet of alluvium and 15 feet of sandstone. The alluvium consisted of 80 feet of predominantly very fine and fine sand underlain by 25 feet of poorly sorted gravel. (See log of well.) The prepumping water level was 65 feet below the land surface; however, most of the water entered the well below 70 feet. The test well was bailed for 1 hour at 24 gpm and the water level declined about 39 feet. The water level had recovered to 68.6 feet below the land surface within 30 minutes after the bailing stopped. The well was pumped twice. The second test was made to check the results of the first, because the drawdown curve of the first test was somewhat erratic. The second test verified the first; therefore, only the drawdown and recovery curves of the first, and longer, test are herein included. During the first pumping test, the well was pumped for approximately 12 hours at 23 gpm and the water level declined 23.1 feet (fig. 7); the specific capacity of the well was 1 gpm per foot of drawdown. The coefficient of transmissibility of the aquifer, as computed from the recovery curve, is about 3,000 gpd per foot (fig. 8). This figure agrees fairly well with the coefficient of transmissibility of 3,500 gpd per ft, which was computed from the recovery curve of the second test.

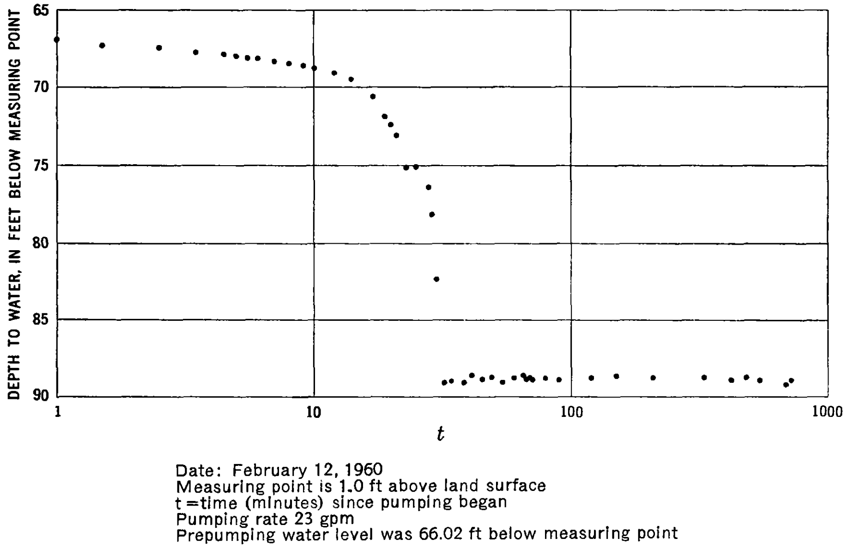


FIGURE 7.—Curve of water-level drawdown from test of well 10.6.35.322 (pueblo test well 1).

Log of well 10.6.35.322 (pueblo test well 1)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	*Thickness (ft)*	*Depth (ft)*
Quaternary:		
Alluvium:		
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine to fine, subrounded, well-sorted; consists primarily of white and amber quartz grains; contains calcareous material; friable	5	5
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine to fine, subrounded to subangular, well-sorted; consists primarily of white and amber quartz grains; contains calcareous material; unconsolidated	5	10
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine, subangular, well-sorted; consists primarily of white, yellow, and amber quartz grains; contains calcareous material; unconsolidated	10	20
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine to fine, subangular, well-sorted; consists primarily of white and amber quartz grains with about 5 percent basalt; contains some calcareous material; unconsolidated	5	25
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine to fine, some very coarse sand, subangular to angular; groundmass well sorted and consists primarily of white and amber quartz grains, but very coarse sand is basalt; contains some calcareous material; unconsolidated	10	35

Log of well 10.6.35.322 (pueblo test well 1)—Continued

Material	Thickness (ft)	Depth (ft)
Quaternary—Continued		
Alluvium—Continued		
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, about 90 percent very fine to fine and about 10 percent very coarse, subangular to angular, moderately well sorted; consists of primarily white and amber quartz grains but very coarse sand is basalt; contains some calcareous material; unconsolidated	5	40
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine to very coarse, subangular to angular, poorly sorted; consists of about 80 percent white and amber quartz grains and about 20 percent basalt; contains calcareous material; unconsolidated	30	70
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine to very coarse, some gravel, subrounded to angular, poorly sorted; consists of 65 percent quartz sand, 20 percent basalt sand, and 15 percent basalt gravel; contains calcareous material; unconsolidated	5	75
Sand, slightly silty, dark-yellowish-brown (10*YR* 4/2) when wet, very fine to fine, some gravel, subangular, poorly sorted; consists of 75 percent quartz sand, 15 percent basalt sand, and 10 percent basalt gravel; contains calcareous material; unconsolidated	5	80
Gravel, dusky-yellowish-brown (10*YR* 2/2), 1/16–1/2 inch in diameter, well-rounded to subangular, poorly sorted; consists of 75 percent basalt and 25 percent sandstone, unconsolidated	5	85
Gravel, olive-gray (5*Y* 3/2) when wet, very coarse sand and gravel as much as three-eighths inch in diameter, subrounded to angular, poorly sorted; consists of 95 percent basalt and 5 percent sandstone; unconsolidated	20	105
Jurassic:		
Bluff Sandstone:		
Sandstone, slightly calcareous, light-olive-brown (5*Y* 5/6) when wet, fine- to medium-grained, subangular, well-sorted; consists of white and amber quartz sand; moderately well cemented	15	120

An unusual feature of the drawdown curve is an abrupt steepening after 11 minutes of pumping and an abrupt flattening after 30 minutes of pumping. The unusual steepening and flattening cannot be explained with certainty, because not enough could be learned of the physical setting, which must be complex. The visible features and the cuttings from the well show that the aquifer tapped by pueblo test well 1 lacks homogeneity, and it is not areally extensive, except in one direction. Normally the slope of a drawdown curve increases by a factor of two, where a single hydrologic boundary is intercepted

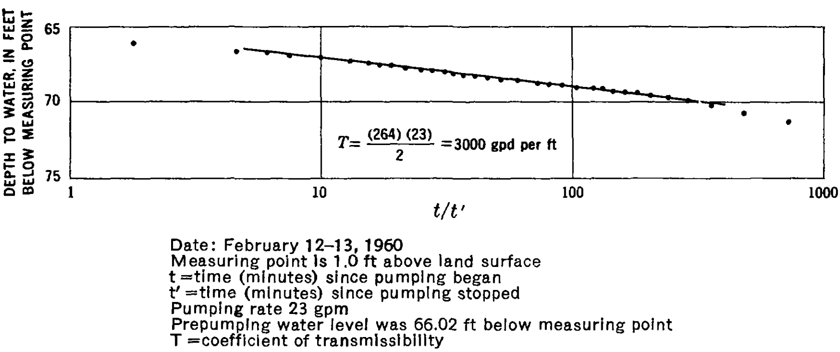


FIGURE 8.—Curve of water-level recovery from test of well 10.6.35.322 (pueblo test well 1).

by the cone of depression in the water level around a well; the slope of this curve increases much more than by a factor of two suggesting more than one boundary, as in a permeable channel deposit. The flattening of the curve suggests a connection nearby with a more permeable or more extensive water-bearing zone. Such a zone is known to occur a short distance to the south.

Water, which was tested by a field-conductance meter, did not show appreciable changes of specific conductance during the test pumping. Also, the specific conductance did not vary appreciably from top to bottom of the water-bearing zone. The water from pueblo test well 1 contained 1,040 ppm of dissolved solids, including 520 ppm of sulfate. (See table 4.) The water from the well is considered to be usable for pueblo supply, inasmuch as water of better chemical quality is not available.

WELL 10.6.35.342 (PUEBLO TEST WELL 2)

Because of the desirability of a well field near the mouth of Encinal Creek and the small yield of well 10.6.35.322, a second well was drilled 1,600 feet south of well 10.6.35.322 (pl. 2). The site for well 10.6.35.342 was selected within an area where potable water had been obtained and at a place where hydrologic boundaries would have less affect on production. The site is in the Rio San Jose valley, out from the mouth of Encinal Canyon.

Well 10.6.35.342 penetrated 110 feet of alluvium and 12 feet of sandstone. The upper 75 feet of alluvium consisted of very fine and fine sand and a 10-foot zone of poorly sorted gravel; the lower 35 feet consisted of 15 feet of poorly sorted gravel interbedded with 20 feet of well-sorted sand. (See log of well.) The prepumping water level in the well was 54 feet below the land surface; the saturated thickness of alluvium was 56 feet. The lower bed of gravel and sand appears to be the major water-yielding zone in the vicinity of the well.

Log of well 10.6.35.342 (pueblo test well 2)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Sand, silty, dark-yellowish-brown (10*YR* 4/2) when wet, subangular to angular, well-sorted; contains silt and very fine sand; consists of quartz grains with some calcareous material; unconsolidated	5	5
Sand, slightly silty, moderate-brown (5*YR* 3/4) when wet, very fine to fine, subangular to angular, well-sorted to moderately well sorted; consists of quartz grains; contains calcareous material; unconsolidated	15	20
Sand, slightly silty, moderate-yellowish-brown (10*YR* 5/4) when wet, very fine to fine, subangualr to angular, well-sorted to moderately well sorted; consists of quartz grains and a small amount of basalt sand; contains calcareous material; unconsolidated	10	30
Gravel, sandy, moderate-yellowish-brown (10*YR* 5/4) when dry; very fine sand and gravel, which is one-sixteenth inch in medium diameter, subangular to angular and poorly sorted; consists of 30 percent quartz sand and 70 percent basalt gravel; contains calcareous material; unconsolidated	10	40
Sand, slightly silty, moderate-yellowish-brown (10*YR* 5/4) when dry, very fine, subangular to angular, well-sorted; consists of quartz grains; contains calcareous material; unconsolidated	5	45
Sand, slightly silty, moderate-yellowish-brown (10*YR* 5/4) when wet, very fine to coarse, subrounded to angular, moderately well sorted; consists of quartz and basalt sand; contains calcareous material; unconsolidated	5	50
Sand, silty, moderate-yellowish-brown (10*YR* 5/4) when dry, very fine, subrounded to subangular, well-sorted; consists of quartz grains; contains calcareous material; unconsolidated	5	55
Sand, silty, moderate-yellowish-brown (10*YR* 5/4) when dry, very fine to medium, subrounded to subangular, moderately well sorted; consists of quartz and basalt sand; contains calcareous material; unconsolidated	20	75
Sand, gravelly, pale-yellowish-brown (10*YR* 6/2) when dry, fine to very fine, subangular, well-sorted; consists of quartz grains and some basalt gravel; contains calcareous material; unconsolidated	5	80
Gravel, sandy, pale-yellowish-brown (10*YR* 6/2) when dry, medium to very coarse sand and small gravel, subrounded to rounded, poorly sorted; consists of quartz grains, basalt, and quartz sandstone; contains calcareous material; unconsolidated	10	90
Sand, slightly silty, pale-yellowish-orange (10*YR* 8/6) when dry, very fine, subangular, well-sorted; consists of quartz grains; contains calcareous material; unconsolidated	15	105

Log of well 10.6.35.342 (pueblo test well 2)—Continued

Material	Thickness (ft)	Depth (ft)
Quaternary—Continued		
Alluvium—Continued		
Gravel, sandy, pale-yellowish-brown (10*YR* 6/2) when dry, subangular to subrounded; consists of basalt, quartz, quartz sandstone, gravel, and fine to very coarse, subrounded to well-rounded, poorly sorted quartz and basalt sand; unconsolidated	5	110
Jurassic:		
Bluff Sandstone:		
Sandstone, slightly calcareous, light-olive-brown (5*Y* 5/6) when wet, fine-grained, subangular, well-sorted; consists of quartz sand; moderately well cemented	12	122

The well was bailed for 1 hour at 30 to 35 gpm, and the drawdown was 2 feet. The well was later pumped for 12 hours at 90 gpm, and the water level was lowered 4 feet; the specific capacity of the well was 22 gpm per foot of drawdown during the test. The recovery curve indicates that the transmissibility of the aquifer is 130,000 gpd per ft (fig. 9).

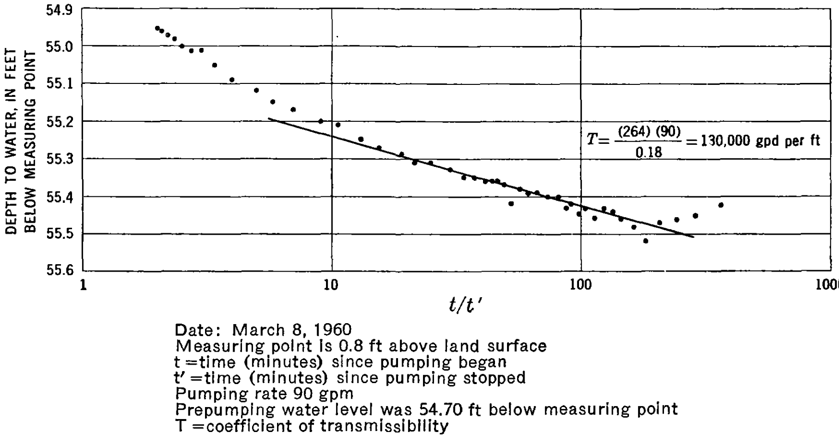


FIGURE 9.—Curve of water-level recovery from test of well 10.6.35.342 (pueblo test well 2).

A sample of water was taken for chemical analysis near the end of the pumping test. The water contained 1,110 ppm of dissolved solids, including 556 ppm of sulfate. (See table 4.) The water is considered to be usable for pueblo supply, inasmuch as water of better chemical quality is not available.

TEST DRILLING IN THE PAGUATE AREA

The village of Paguate obtains its water from a shallow infiltration gallery adjacent to the Rio Paguate. The flow of the Rio Paguate is adequate for the village and is of good chemical quality, but it is subject to bacterial contamination. Therefore, ground water was sought for the village supply, because ground water is purified naturally of most types of bacteria as it moves through the materials underground.

The alluvium in the vicinity of Paguate is too thin in most places to store and transmit large quantities of water. The Tres Hermanos Sandstone Member of the Mancos Shale, which underlies the village, is very fine to fine grained and is firmly cemented with calcium carbonate. It yields only small amounts of water (generally 5–20 gpm) to wells. Formations beneath the Tres Hermanos Sandstone Member yield even less water of poorer chemical quality. The outcrops of the individual beds of sandstone in the Tres Hermanos Sandstone Member were mapped in the vicinity of Paguate so the beds could be identified in the subsurface. The upper and middle units of the Tres Hermanos crop out in the vicinity of Paguate, and the lower unit crops out to the east. The underlying Dakota Sandstone also crops out east of Paguate. The beds of sandstone dip about 2° NW., and all the units are present in the subsurface a short distance northwest of Paguate. The test wells were located downdip from outcrops of sandstone in the Tres Hermanos Sandstone Member in order to obtain water from the sandstone if the yield of the alluvium was inadequate.

The Rio Paguate is a perennial stream above the village, and it was hoped that enough water would percolate from the Rio Paguate into the alluvium and the Tres Hermanos Sandstone Member to replenish water withdrawn by pumping from wells. On April 7, 1960, the flow of the Rio Paguate in the NW¼SW¼NW¼ sec. 30, T. 11 N., R. 5 W., was 480 gpm, and the flow of the stream in the SE¼SE¼NW¼ sec. 30, T. 11 N., R. 5 W., was 420 gpm, a loss in flow of 60 gpm to ground infiltration between the two points. Nearly all the water in the Rio Paguate is diverted in the SE¼NE¼ sec. 30, T. 11 N., R. 5 W., below the second gaging point, for irrigation.

WELL 11.5.30.422 (PUEBLO TEST WELL 3)

Well 11.5.30.422 (pueblo test well 3) was drilled to a depth of 466 feet, in the NE¼SE¼ sec. 30, T. 11 N., R 5 W., 1½ miles northwest of Paguate, near the Rio Paguate. (See pl. 2.) The well penetrated

712–186—64——4

35 feet of alluvium consisting of poorly sorted sand and gravel, the middle and lower sandstone units of the Tres Hermanos Sandstone Member of the Mancos Shale, the Dakota Sandstone, and part of the Morrison Formation. (See log of well.) Perched water from the alluvium cascaded down the well to the level of water in the Tres Hermanos Sandstone Member. The alluvium and the lower sandstone unit of the Tres Hermanos Sandstone Member yielded most of the water to the well.

The prepumping water level was 75 feet below the land surface. The well was pumped at an initial rate of about 15 gpm; however, the water level was lowered to the pump intake in a short time at this pumping rate. The discharge was decreased, and the well was pumped for 12 hours at about 10 gpm, and the water level declined 192 feet. The specific capacity of the well was 0.05 gpm per ft of drawdown. Because of variations in discharge during pumping, the recovery curve was used to compute the coefficient of transmissibility of the aquifer

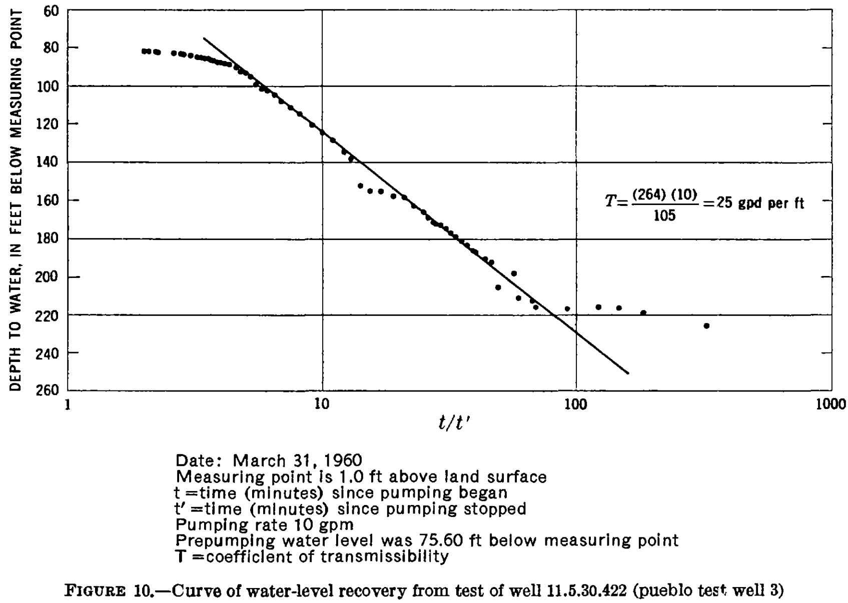


FIGURE 10.—Curve of water-level recovery from test of well 11.5.30.422 (pueblo test well 3)

(fig. 10), which was 25 gpd per ft. The water from the well contained 423 ppm of dissolved solids, including 124 ppm of sulfate, and it is suitable for pueblo supply. (See table 4.)

Log of well 11.5.30.422 (pueblo test well 3)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)

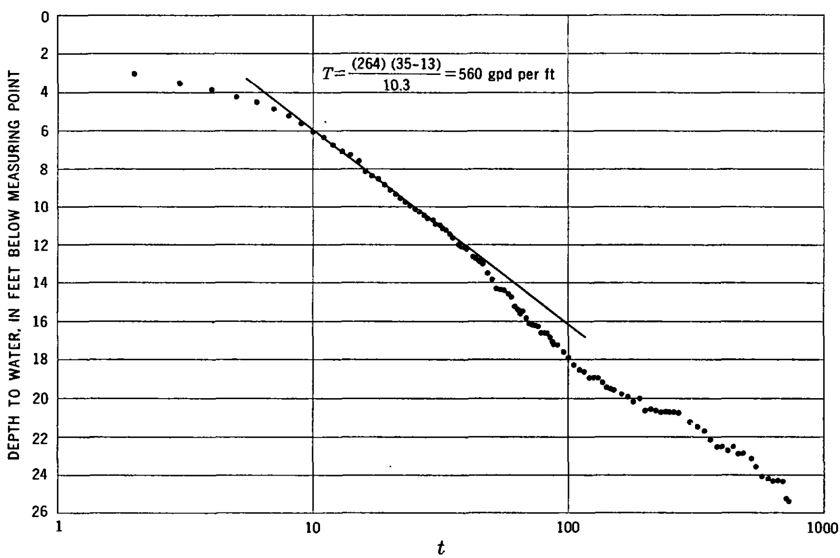
Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Sand and gravel, slightly silty, pale-yellowish-brown (10*YR* 6/2) when dry; very fine to very coarse sand and gravel, which is well rounded to subangular and poorly sorted; consists of quartz and basalt; contains calcareous material; unconsolidated. Interval 15–35 ft contains a slightly larger percentage of well-rounded gravel	35	35
Cretaceous:		
Mancos Shale:		
Shale, calcareous, greenish-gray (5*GY* 6/1) when dry, friable. Interval 70–161 ft contains some very fine sand	126	161
Tres Hermanos Sandstone Member:		
Sandstone, very slightly calcareous, light-olive-gray (5*Y* 6/1) when wet, fine-grained, subangular to angular, well-sorted; consists of moderately well cemented quartz grains. Interval 180–230 ft contains some very fine sand	69	230
Shale, calcareous, sandy, dark-greenish-gray (5*GY* 4/1) when wet; contains some silt and very fine sand, which is angular and well sorted; friable	10	240
Shale, slightly calcareous, silty, dark-gray (*N* 3) when wet, very well sorted; friable	32	272
Sandstone, very slightly calcareous, light-olive-gray (5*Y* 6/1) when dry, very fine to fine-grained; consists of subangular to angular well-sorted quartz sand	43	315
Sandstone, silty, olive-gray (5*Y* 4/1) when dry; silt and very fine sand, which consists of angular well-sorted quartz grains	10	325
Shale, sandy, olive-gray (5*Y* 4/1) when dry; silt and very fine sand, which consists of angular well-sorted quartz grains	15	340
Shale, very slightly calcareous, dark-gray (*N* 3) when wet; silt and very fine sand, which is angular and well sorted; friable	49	389
Dakota Sandstone:		
Sandstone, light-olive-gray (5*Y* 6/1) when wet, medium-grained; consists of subangular well-sorted quartz sand	20	409
Jurassic:		
Morrison Formation:		
Westwater Canyon Member:		
Sandstone, clayey, light-olive-gray (5*Y* 6/1) when wet, very fine to fine-grained; consists of subangular, well-sorted quartz sand	57	466

NOTE.—This log is a composite of the sample log and an electric log that was run by The Anaconda Co.

WELL 11.5.32.234 (PUEBLO TEST WELL 5)

Well 11.5.32.234 (pueblo test well 5) was drilled about 2,000 feet west of the village of Paguate and about 1,000 feet west of the Rio Paguate. (See pl. 2.) The well was near the west side of Paguate valley, where previous drilling had indicated that the alluvium was thickest. The greatest volume of saturated alluvium was expected to be at this site because it is in a wide part of the valley just above a narrow constriction. Fieldwork indicated that the alluvium was thin near the east side of the valley, along the present channel of the Rio Paguate. Adequate supplies of water were expected from the thicker alluvium and the middle sandstone unit of the Tres Hermanos Sandstone Member of the Mancos Shale, which underlies the site.

The well penetrated 60 feet of alluvium and was bottomed in the Mancos Shale at a depth of 79 feet. It did not seem feasible to test drill the Tres Hermanos Sandstone Member at the time, especially after it had been tested in well 11.5.30.422. The alluvium consists primarily of moderately well sorted sand with increasing amounts of gravel in the lower part. (See log of well.) Water in the lower part of the alluvium was under artesian pressure, and the well flowed at a rate of 13 gpm. The well was pumped for 12 hours at about 35 gpm, and the water level was lowered to 25 feet below the land



Date: April 22, 1960
Measuring point is at land surface
t = time (minutes) since pumping began
Pumping rate 35 gpm
Water flowed from around the casing at a rate of 13 gpm before pumping began
T = coefficient of transmissibility

FIGURE 11.—Curve of water-level drawdown from test of well 11.5.32.234 (pueblo test well 5).

surface. The water level recovered rapidly after the pump was stopped, and the well started flowing again within 9 minutes. The specific capacity of the well was about 1 gpm per foot of drawdown. The drawdown curve was used for computing the coefficient of transmissibility (fig. 11). The transmissibility was 560 gpd per ft. Water from the well contained 375 ppm of dissolved solids, including 53 ppm of sulfate. (See table 4.) The water is suitable for pueblo use.

Log of well 11.5.32.234 (pueblo test well 5)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Sand, silty, light-olive-gray (5*Y* 6/1) when dry; mostly silt, very fine sand, and some very coarse sand, subrounded to subangular, moderately well sorted; consists of volcanic material and a small amount of calcareous material; unconsolidated	10	10
Sand, similar to that in interval 0–10 ft but contains slightly more calcareous material	10	20
Sand, similar to that in interval 0–10 ft but contains no calcareous material and a very small amount of coarse sand	25	45
Sand, similar to that in interval 0–10 ft but contains some fine gravel and some calcareous particles	15	60
Cretaceous:		
Mancos Shale:		
Shale, moderately calcareous, medium-gray (*N* 5) when dry, friable	19	79

Extrapolation of the drawdown curve indicates that if well 11.5.32.234 was pumped at 35 gpm, the water level would be lowered to 31 feet in 7 days and to 70 feet in 35 days. Hydrologic boundaries, however, would likely increase the water-level drawdown, and some of the shallow water-bearing beds might be dewatered in a short time, further affecting the drawdown. It probably would not be possible to pump the well continuously at 35 gpm. Therefore, a production well in the alluvium would be likely to yield more than 13 gpm, which is the artesian flow, and less than 35 gpm. If a well at this site were drilled to the base of the Tres Hermanos Sandstone Member, at a depth of about 300 feet, an additional 10 gpm could probably be obtained; however, it should be emphasized that this figure is based on inference.

WELL 10.5.26.223 (IRRIGATION TEST WELL 8)

Well 10.5.26.223 (irrigation test well 8) was drilled just below the dam at Paguate reservoir, 3½ miles northeast of Laguna. (See pl. 2.) It was assumed that seepage from the Paguate reservoir would be a source of ground-water recharge near the site. The well penetrated 25 feet of alluvium and 10 feet of Bluff sandstone. The alluvium consists of moderately well sorted to poorly sorted sand and gravel. (See log of well.) The water level was 7 feet below the land surface.

The specific conductance of water from Paguate reservoir, as determined in the field several times early in 1960, ranged from 2,000 to 2,500 micromhos. In contrast, water from well 10.5.26.223 had a specific conductance of 10,000 micromhos, which indicates that it is unsuitable for any ordinary use.

The well was bailed for a short time at 25 gpm, but further tests of yield were not made because of the poor chemical quality of the water.

Log of well 10.5.26.223 (irrigation test well 8)

[The color of material is keyed to the National Research Council color chart (Goddard, 1948)]

Material	Thickness (ft)	Depth (ft)
Quaternary:		
Alluvium:		
Sand, silty, pale-yellowish-brown (10*YR* 6/2) when dry; consists of silt and fine sand, subangular and moderately well sorted, primarily of quartz grains; contains calcareous material; coherent and friable	17	17
Sand, moderate-yellowish-brown (10*YR* 5/4) when dry; consists of very fine to coarse sand of quartz grains, and some fine gravel, subrounded to subangular and poorly sorted, of volcanic material; contains carbonate material; unconsolidated	3	20
Sand and gravel, pale-yellowish-brown (10*YR* 6/2) when dry; consists of very fine to very coarse sand and gravel as much as ¼ inch in diameter, well rounded to subangular and poorly sorted, of quartz and volcanic material; contains calcareous material; unconsolidated. Also present are pebbles and cobbles of grayish-orange (10*YR* 7/4), very fine- to fine-grained, subangular, well-sorted, calcareous, well-cemented quartz sandstone	5	25
Jurassic:		
Bluff Sandstone:		
Sandstone, pale-yellowish-orange (10*YR* 8/6) when dry, very fine- to fine-grained, subrounded to subangular, well-sorted; consists primarily of quartz grains; moderately well cemented	10	35

SURFACE WATER

Surface-water inflow to the Acoma and Laguna Indian Reservations is mainly in the Rio San Jose, a stream which is perennial in the western part of the area, and two of its tributaries, Encinal Creek and Rio Paguate. Several other tributaries contribute an unknown quantity of water from storm runoff. Streamflow is seasonal and only partly controlled.

The average annual flow past the gaging station Rio San Jose near Grants, N. Mex., just inside the west boundary of the Acoma Indian Reservation, was 5,120 acre-feet for the water years 1937–58 (table 2). The flow past this gaging station is partly controlled by Bluewater Lake, which has a storage capacity of 38,500 acre-feet at the crest of the uncontrolled siphon spillway. Part of the flow in the Rio San Jose is diverted at a point about 2 miles west of the village of McCartys for irrigation of land south of the river. Most of the remainder of flow in the Rio San Jose is diverted at a point about 1 mile west of McCartys for irrigation of land north of the river. The Rio San Jose becomes dry somewhere between McCartys and San Fidel. The water that is diverted to the south is used entirely for irrigation and enters into the alluvium. The water that is diverted to the north is used partly for irrigation and partly to replenish the storage supply in Acomita reservoir, which has a storage capacity of 850 acre-feet.

The average annual flow past the gaging station Encinal Creek near Casa Blanca, N. Mex., in the NW¼ sec. 34, T. 11 N., R. 6 W., 150 feet above the diversion for the Encinal and Pueblo ditches, was 144 acre-feet for the 2 years of record, water years 1938–39 (table 2).

TABLE 2.—*Streamflow, in acre-feet, at stations in the Acoma and Laguna Indian Reservations, N. Mex.*

Water year	Rio San Jose near Grants, N. Mex., (SW¼ sec 24, T. 10 N., R. 9 W.)	Encinal Creek near Casa Blanca, N. Mex. (NW¼ sec. 34, T. 11 N., R. 6 W.)	Paguate Creek near Laguna, N. Mex. (NE¼ sec. 30, T. 11 N., R. 5 W.)
1937	3, 790		
1938	4, 080	165	720
1939	4, 070	122	738
1940	4, 650		741
1941	13, 960		2, 750
1942	4, 900		
1943	4, 250		
1944	5, 040		
1945	5, 020		
1946	5, 500		
1947	4, 520		
1948	4, 340		
1949	4, 200		
1950	3, 720		
1951	4, 300		
1952	3, 820		
1953	4, 320		
1954	5, 360		
1955	6, 970		
1956	4, 150		
1957	7, 830		
1958	3, 880		
Average (rounded)	5, 120		

Encinal Creek is perennial above the village of Encinal. The water is used for irrigation and domestic supply.

The average annual flow past the gaging station Paguate Creek near Laguna, N. Mex., in the NE¼ sec. 30, T. 11 N., R. 5 W., 300 feet above the diversion for the Paguate Pueblo ditches, was 1,240 acre-feet for the 4 years of record, water years 1938–41 (table 2). The stream is perennial above the village of Paguate, and some of the water is diverted into a small reservoir. The water is used for irrigation and domestic supply. The average flows given above for the Rio San Jose and Paguate Creek are somewhat high due to the inclusion of the unusually large amount of runoff in 1941.

GROUND WATER

Potable water is scarce in the Acoma and Laguna Indian Reservations, and more potable water than has been developed is needed for pueblo, domestic, and stock supplies. Water in excess of these needs would be desirable to supplement the present surface-water irrigation in the valley of the Rio San Jose. Any increase in the overall supply must come from ground water.

Ground water in the area occurs in consolidated sedimentary rocks, in unconsolidated alluvium, and in basalt flows. The principal aquifers in the consolidated sedimentary rocks are the Bluff Sandstone, some of the beds of sandstone in the Morrison Formation, the Dakota Sandstone, and the Tres Hermanos Sandstone Member of the Mancos Shale. The consolidated sedimentary rocks are utilized only for small supplies because they are too tight to transmit much water. The alluvium and the basalt flows in the valley along the Rio San Jose generally are the best aquifers in the area because they transmit relatively large quantities of usable water.

Ground water in the alluvium of the tributaries of the Rio San Jose moves down the valleys and into the valley fill along the Rio San Jose. The ground water in the valley fill of the Rio San Jose moves downstream, from west to east, out of the area.

Some of the test wells that were drilled in the alluvium of the Rio San Jose valley indicated sufficient quantities of water of usable chemical quality to warrant consideration as sites for production wells for irrigation and domestic supply. Well 10.8.28.314 (irrigation test well 3) indicated a site for a production well that could yield more than 100 gpm—perhaps as much as 600 gpm. A production well at the site of well 10.7.35.210 (irrigation test well 6) might yield as much as 350 gpm for supplemental irrigation. Well 10.6.31.443 (irrigation test well 7) was test pumped at a rate of 115 gpm, and from all indications a production well at this site perhaps could be pumped at 500 gpm or more. A properly constructed well at the site of well

10.6.35.342 (pueblo test well 2) probably could be pumped indefinitely at about 90 gpm, and a higher rate of pumping probably could be sustained—perhaps as much as 400 gpm. Well 10.7.29.214 (pueblo test well 4) indicated a site for a production well which probably would have a sustained yield of about 75 gpm and perhaps as much as 200 gpm of water that is considered to be usable for domestic supply.

The problem of obtaining water from the ground involves not only the amount of water that is available but also the ability of the water to move through the aquifer to the well. The coefficient of transmissibility is a measure of the ease with which water may be transmitted through an aquifer. It is obvious that the higher the coefficient of transmissibility of an aquifer the faster water may be taken from that aquifer. The coefficients of transmissibility have limited applicability because of the restricted areal extent and the variability of the alluvium. A common method of expressing the performance of a well, termed the specific capacity, relates the yield in gallons per minute to the drawdown in feet for a given interval of time. The specific capacity is affected by the efficiency of the well in addition to the character of the aquifer. The coefficients of transmissibility and the specific capacities that were determined at several test-well sites are given in the section of this report on test-well drilling. The depths to water in wells drilled in the alluvium near the Rio San Jose range from 2 to about 34 feet below the land surface. The altitudes of the water levels in these wells range from about 5,600 feet near the east side of the area to about 6,300 feet near the west side of the area (pl. 2). The thickness of saturated alluvium in the Rio San Jose valley is as much as 140 feet at some places, and there is no evidence of thinning of the alluvium in the valley due to bedrock highs. The thickness of alluvium, the coefficient of transmissibility, and the specific capacity are all significantly greater in the alluvium along the Rio San Jose; therefore, the most water will be obtained from this alluvium.

For the specific capacity of a well to be significant, pumping must be continuous until all of the influences of hydrologic boundaries, if any exist, have been observed. Recharge boundaries, such as a stream losing water to infiltration, generally result in less drawdown, a more stable pumping level, and a higher specific capacity. Discharge boundaries, such as a lateral contact of an aquifer with impermeable materials, generally result in greater drawdown and a lower specific capacity because there is a resultant decrease of water available to the pumping system.

The first use of ground water in the area was for small domestic and stock supplies, and the water was obtained from shallow dug wells in the alluvium and from springs. As the demand for water increased and became more widespread, wells were drilled deeper and some bedrock aquifers were used. Future development of ground-water supplies must keep pace with increasing demands; therefore, much thought and care should be exercised in future water use and well construction and treatment. Aquifers that contain water of usable quality should be guarded against contamination by water of bad quality. Supplies of good water can be protected to a large extent by proper construction of wells. Wells should be properly developed to assure a long life of high productivity. Most of the wells for pueblo and domestic supply in this area will be drilled into the alluvium, which contains a large amount of fine material. In order to assure that this fine material will not decrease the productivity of the well, the well should be developed fully by surging in conjunction with the use of a dispersing agent, such as sodium hexametaphosphate, to remove as much of the fine material as possible. Treatment with sodium hexametaphosphate tends to disperse the clay particles and facilitate their removal.

Ground water is exhaustible; therefore, ground-water recharge, movement, and discharge are important factors of the ground-water supply of the area. The ground-water reservoir is recharged in small part by precipitation directly on outcrops of permeable strata and to a greater extent by streams that flow across outcrops of permeable rock. Recharge water moves downward through permeable strata to the zone of saturation, and downdip or down the valleys to points of discharge. In this area, consolidated sedimentary rocks generally dip northward to northwestward; therefore, recharge water in the permeable zones of the consolidated sedimentary rocks moves generally northward to northwestward. Locally, the water moves directly from recharge areas on the ridges and mesas to points of discharge in adjoining valleys.

Precipitation is greatest north of the Rio San Jose, owing to the high altitudes of Mount Taylor and the adjacent mesas; consequently, ground water is most abundant in the alluvium of the tributaries flowing from the north to the Rio San Jose. Where ground water in the alluvium moves over permeable bedrock above the zone of saturation, part of the water may enter the permeable bedrock. At other places where streams have cut through water-bearing, permeable bedrock, it is possible for ground water to move from the bedrock into the alluvium. Water discharged from the bedrock through springs and seeps recharges the alluvium in many parts of the area, particularly in the northern and western parts. (See table 5 and pl. 2.) Most of the springs and seeps in the area discharge water from the Tres Hermanos Sandstone Member of the Mancos Shale and from the basalt flows of Tertiary and Quaternary age.

Ground water occurs under artesian conditions in some of the permeable units of the consolidated sedimentary rocks—generally beds of sandstone—where they are overlain by confining beds of nearly impermeable shale. Artesian conditions also exist in the alluvium at some places where it is overlain by basalt flows in the Rio San Jose valley.

A comparison of the altitudes of water levels and the altitudes of streambeds reveals that the water in storage in the alluvium is in equilibrium with the streams in much of the area. The water level in well 10.6.35.342 (pueblo test well 2) indicates an exception. The altitude of the water level in this well is lower than the altitude of the bed of the Rio San Jose; therefore, the stream has a potential to contribute to ground-water recharge in the vicinity of the well. This is a local situation, and it may be due to pumping from well 9.6.2.120, which is used for irrigation.

Lowering of the water level a few feet by the pumping of wells in the alluvium in the Rio San Jose valley would be advantageous at most places. Lowering of water levels would partly dewater the zone of root growth of plants with a resultant decrease in the loss of water by evapotranspiration. Lowering of water levels also would allow more recharge of water from the Rio San Jose to the alluvium with the resultant conservation and utilization of Rio San Jose water in the area.

QUALITY OF WATER

The major problem of water supply in the project area is the scarcity and erratic occurrence of potable water.

The Rio San Jose appears to be entrenched in consolidated sedimentary rocks, some of which contain highly mineralized water under artesian pressure. The erratic difference in the chemical quality of water in the alluvium may be caused, in large part, by the discharge of this highly mineralized water into the alluvium. For example, water from irrigation test well 1 had a specific conductance of 900 micromhos, whereas, about three-quarters of a mile to the east, the water from irrigation test well 2 had a specific conductance of 10,100 micromhos and contained 8,440 ppm of dissolved solids. (See table 4 and pl. 3.) Both wells tap alluvium. Water in the fill north of the Rio San Jose is generally less mineralized than that south of the river. This difference in mineralization probably is the result of a greater amount of ground-water recharge from the north and by the difference in the composition of the sediments with which the water comes in contact.

In many places, water in the consolidated sedimentary rocks is potable. In the northeastern part of the area, wells that penetrate the Tres Hermanos Sandstone Member of the Mancos Shale, such as pueblo test well 3 (well 11.5.30.422) 1½ miles northwest of Paguate, yield potable water for domestic and stock use. However, the greatest amount of potable water is in the sand and gravel of the alluvium in the valley of the Rio San Jose and its tributaries. Unfortunately, the basic data are inadequate to define the sediment distribution and types of material. All the waters that were analyzed are suitable for use by livestock.

DOMESTIC USE

The maximum concentrations of the common chemical constituents in drinking water for interstate carriers, as set by the U.S. Public Health Service (1946), are listed below.

Constituent	*Maximum limits (ppm)*
Chloride (Cl)	250
Sulfate (SO_4)	250
Magnesium (Mg)	125
Iron and Manganese (Fe+Mn)	.3
Fluoride (F)	1.5

In addition, the total solids should not exceed 500 ppm for a water of good chemical quality. However, if such water is not available, a total solids content of as much as 1,000 ppm is permitted.

Water in this area generally does not meet the standards set by the U.S. Public Health Service; locally, however, the water is acceptable. In general, water in the area contains more than 1,000 ppm of dissolved solids; however, the water is being used because water of better chemical quality has not been available.

The sulfate ion most commonly exceeds the recommended limit. The principal sources of sulfate ion are the gypsum in the Todilto Limestone and the gypsum and selenite in some of the beds of shale, mainly the Mancos Shale.

The fluoride content in the ground water of the area generally is close to the recommended upper limit of 1.5 ppm, but analyses indicate that some of the water contains more than 1.5 ppm of fluoride. (See table 4.) An excess of fluoride content in the water may be a cause for rejecting some water, or restricting its use, for domestic supply. A discussion of the significance of the different chemical constituents in water is not necessary to this report since this information can be obtained from many published reports, such as "Study and Interpretation of the Chemical Characteristics of Natural Water" (Hem, 1959).

AGRICULTURAL USE

The suitability of water for irrigation is dependent mainly on (1) the concentration of boron, (2) the concentration of dissolved solids, and (3) the SAR (sodium-adsorption-ratio). $SAR=\frac{Na^{+}}{\sqrt{(Ca^{++}+Mg^{++})/2}}$, where the ionic concentrations are expressed in milliequivalents per liter. The SAR is used to express the relative activity of sodium ions in exchange reactions with soil.

In general, irrigation waters may be classified by use of a diagram that was prepared for that purpose (Wilcox, 1955). The diagram is based on electrical conductivity in micromhos per centimeter, an index of salinity, and on the SAR, an index of the sodium hazard.

Selected analyses of water from wells in the area were plotted on the diagram. (See fig. 12.) In general, the water is in the group classifications of high salinity hazard and low to medium sodium hazard.

Water of medium to high salinity generally can be used on soils with good drainage. Plants with salt tolerance should be selected, and some salinity control may be necessary.

The sodium hazard generally increases as the salinity increases (fig. 12). Therefore, because the water in the area generally has a high salinity hazard, the sodium hazard is especially critical. Low-sodium water can be used on most soils, but sodium-sensitive plants might still be harmed. Use of medium-sodium water may require some soil management but generally may be used on coarse-textured soil with good drainage.

Boron analyses were not run because the problem of an excessive boron concentration is not generally considered critical in New Mexico. This conclusion is based on studies made in surrounding areas and throughout the State.

The water in the alluvium and basalt probably is usable for irrigation in the Rio San Jose valley where good drainage, relatively high permeability, and medium to high leaching conditions are present.

High-sodium water produces harmful levels of exchangeable sodium in most soils; however, gypsiferous soils may not develop these harmful levels. Therefore, the sodium status of high-sodium water may be improved by the addition of gypsum to the water and to the soil.

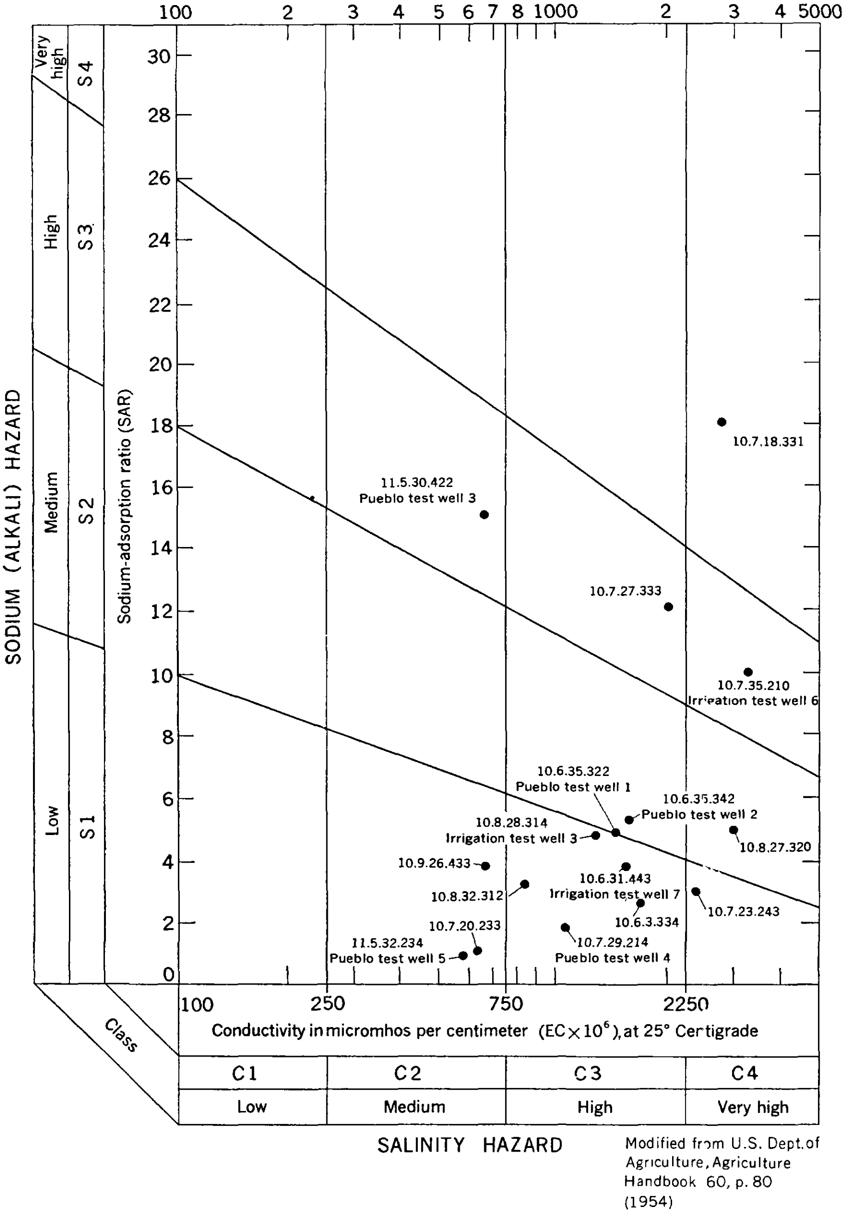


FIGURE 12.—Classification of irrigation water from selected wells in the Acoma and Laguna Indian Reservations, N. Mex.

CONCLUSIONS

Ground water in sufficient quantities for pueblo or irrigation supplies is available at places in the alluvium and basalt in the Rio San Jose valley and its tributaries. Wells 10.9.25.330, 9.8.2.110, 10.6.35.322, and 11.5.30.422 (irrigation test wells 1 and 5 and pueblo test wells 1 and 3, respectively) did not yield enough water for either irrigation or pueblo supply. However, the water from wells 10.9.25.330, 10.6.35.322, and 11.5.30.422 was potable, and wells to serve a few families could be developed at each of the sites.

Wells 10.9.25.441, 10.8.27.224, and 10.5.26.223 (irrigation test wells 2, 4, and 8, respectively) yielded water of unsuitable chemical quality for pueblo or irrigation supply, so the wells were not tested for yield. Well 10.9.25.441 contained 8,440 ppm of dissolved solids, including 4,020 ppm of sulfate and 1,260 ppm of chloride. Water from wells 10.8.27.224 and 10.5.26.223 was not analyzed, but the specific conductance was 4,800 and 10,000 micromhos, respectively.

Well 10.8.28.314 (irrigation test well 3) was pumped at an average rate of 100 gpm for 24 hours, and the water level was lowered 11.5 feet. A longer test would be needed to determine the rate at which the well could be pumped continuously, or for the duration of an irrigation season. However, a comparison of the specific capacity of the well with the log indicates that a properly constructed well at this site could yield more than 100 gpm—perhaps as much as 600 gpm. Water from the well contained 887 ppm of dissolved solids, including 361 ppm sulfate, and had an SAR of 4.7. This water is considered to be satisfactory for irrigation and acceptable for domestic supply if water of better quality is not available in the area.

Well 10.7.35.210 (irrigation test well 6) was pumped at 100 gpm for 20 hours, and the water level was lowered 17.5 feet. A production well at this site might yield as much as 350 gpm, but further tests would be necessary to determine accurately the maximum sustained yield. Water from the well contained 2,310 ppm of dissolved solids, including 1,090 ppm of sulfate, and had an SAR of 10. This water is not satisfactory for human consumption, but it could be used as a supplemental supply for irrigation after dilution with water of better chemical quality.

Well 10.6.31.443 (irrigation test well 7) was pumped at 115 gpm for 24 hours, and the water level was lowered 8.5 feet. The small drawdown relative to the pumping rate suggests that a production well at this site could be pumped at a rate greater than 115 gpm—perhaps 500 gpm or more. Further tests would be necessary to determine the maximum yield that could be sustained and the effects of recharge from the Rio San Jose on the chemical quality of the ground water.

Water from the well contained 1,040 ppm of dissolved solids, including 422 ppm of sulfate, and had an SAR of 3.8. This water is considered to be satisfactory for irrigation and usable for pueblo supply.

A properly constructed well at the site of well 10.6.35.342 (pueblo test well 2) probably could be pumped indefinitely at about 90 gpm, and a higher rate of pumping probably could be sustained—perhaps as much as 400 gpm. Water from the well contained 1,110 ppm of dissolved solids, including 556 ppm of sulfate, and is considered to be usable for pueblo supply inasmuch as water of better quality is not available. The water would probably be satisfactory for irrigation on well-drained soil.

A properly constructed well at the site of well 10.7.29.214 (pueblo test well 4) probably would have a sustained yield of about 75 gpm and perhaps as much as 200 gpm. The alluvium is the only aquifer that should be considered at this site. Water from the well contained 729 ppm of dissolved solids, including 180 ppm of sulfate, and the water is considered to be usable for pueblo supply.

A properly constructed well at the site of well 11.5.32.234 (pueblo test well 5) probably could sustain a yield of about 25 gpm of potable water. The yield of a well at this site that penetrated the Tres Hermanos Sandstone Member of the Mancos Shale would have a slightly larger yield than one that penetrated only the alluvium. Water from the well contained 375 ppm of dissolved solids, including 53 ppm of sulfate, and the water is acceptable for pueblo supply.

A well field in the vicinity of well 10.6.35.342 (pueblo test well 2) would furnish an ample supply of water to the villages of Laguna, New Laguna, Paraje, and Casa Blanca and to the proposed school in sec. 35, T. 10 N., R. 6W. Development and use of irrigation wells within a mile of the pueblo-supply well field would endanger the supply of potable water for the pueblos. A production well or two near the site of well 10.7.29.214 (pueblo test well 4) should furnish an ample supply of water to Acomita and to many homes in the surrounding area. Development of wells nearby for other uses would endanger the pueblo supply in a relatively short time. A production well or two in the vicinity of well 11.5.32.234 (pueblo test well 5) should furnish an ample supply of water to Paguate. The information on well 10.6.31.443 (irrigation test well 7), a mile northeast of Seama, suggests that the site would be favorable for a well to supply Seama and other settlements nearby. A production well at the site of well 10.8.28.314 (irrigation test well 3), about 1½ miles west of McCartys, would supply McCartys and other settlements nearby. Additional test drilling in the area might disclose a supply of potable water nearer to McCartys.

Information on wells in the vicinity of Mesita indicate that the shallow water in the alluvium near Mesita is chemically unfit for domestic use according to drinking water standards as recommended by the U.S. Public Health Service (1946). Water of marginal quality has been obtained from a bed of sandstone in the upper part of the Chinle Formation, which underlies Mesita at a depth of about 60 feet. This bed of sandstone yields water to a well at the former highway construction camp, a mile south of Mesita, and to wells at the El Paso Natural Gas Co. compressor station, 2 miles south of Mesita. Test drilling will be necessary to locate a supply of potable water for Mesita. The shallow saline water must be cased out of pueblo supply wells that are drilled near the village.

A site was selected for test drilling a mile west of Encinal, in the SW¼ sec. 4, T. 10 N., R. 6 W., but time and budget limitations prevented the drilling. The aquifer at this site is the Tres Hermanos Sandstone Member of the Mancos Shale. The depth of a test well might need to be about 500 feet to penetrate this aquifer, and a yield of 10–30 gpm of potable water would be expected.

The tests suggest that the water in the alluvium of the Rio San Jose valley is closely related to the streamflow and that it might be feasible to withdraw water from the alluvium along the Rio San Jose in summer and replenish it in winter. Lowering of the water table in summer would reduce the loss of water by transpiration of plants, by evaporation from the capillary fringe of the water table, and by direct evaporation from ponds, such as in the collapse depressions in basalt. Much water is now lost from the valley by evapotranspiration, and the dissolved solids are concentrated in the remaining water. The surface flow in summer might be decreased, however, by extensive pumpage of ground water. On the other hand, more of the winter flow could be retained in the area by storage in the ground-water reservoir.

The reach of the Rio San Jose valley between McCartys and the west boundary of the Acoma Reservation seems to be the most favorable place for development of large supplies of ground water from the alluvium and basalt. In this reach of the valley, the Rio San Jose is a perennial stream, which is fed by Horace Springs just west of the Acoma Reservation. Part of the surface flow in the reach is diverted for irrigation during several months each year. In winter, the surface water is not used, except that part of the water is diverted downstream into the Acomita reservoir for later irrigation use. The perennial streamflow would assure a supply of water for ground-water recharge. The depth to the water table generally is less than 10 feet in the reach, so that loss of ground water by evapotranspiration is higher than in

712-186—64——5

most parts of the valley. Some of the land is waterlogged and would be benefited by the lowering of the water table. Ground water could be recharged from surplus streamflow in other reaches of the valley, some of which would also be benefited by the lowering of the water table.

In some parts of the valley, the alluvium and basalt appear to have relatively high transmissibilities and would yield a few hundred gallons per minute of water to wells. This suggests that heavy pumping in summer would be possible. Wells could be drilled along the axis of the valley, and the water could be pumped into canal systems for distribution to irrigated farms. Production wells near wells 10.8.28.314 and 10.6.31.443 (irrigation test wells 3 and 7) and possibly well 10.7.35.210 (irrigation test well 6) could feed the canals. Water from the Rio San Jose could be used in winter, with proper control of suspended matter, bacteria, and algae, to recharge the aquifer through the same wells that are pumped during the summer. However, a program of artificial recharge through wells would require study and experimentation to appraise its practicality. The cost of removing suspended sediment from the surface water before injection might make such a program infeasible.

Unfortunately, the amount of ground water in storage and the amount of recharge to the aquifers underlying the area are small. The withdrawal of more water from the aquifers than is replenished by recharge will partly dewater the aquifers and locally draw in highly mineralized water. At many places, the alluvium contains highly mineralized water, which could move readily into areas of intensive pumping. Likewise, lowering the head of water in the alluvium may at some places increase the upward migration of highly mineralized artesian water from the underlying consolidated sedimentary rocks. Long-range plans for water use in the area must recognize this situation and establish safeguards to protect adequate supplies of potable water for human consumption.

A comprehensive study of the water resources of the Acoma and Laguna Indian Reservations would be desirable. Such a study should be planned to determine the amount of water in storage in the aquifers, the interrelation of ground and surface water, and the quality of water in relation to the aquifers. Test drilling would be necessary to obtain adequate hydrologic and geologic data. The geologic phase of the program should include a study of the distribution and thickness of all the stratigraphic units. Information on the yield of the San Andres Limestone and the quality of its contained water would be very useful in planning. Methods of increasing ground-water recharge, especially during periods of storm runoff, also should be investigated.

A quantitative study, as suggested above, could be used to plan an optimum program of water development and use.

The San Andres Limestone of Permian age, which is the principal aquifer in the vicinity of Grants and Bluewater 10 to 20 miles northwest of the report area, has not been tested in either of the reservations. Throughout the region the San Andres was exposed to erosion, fractured, and subjected to solution by percolating ground water before the overlying formations were deposited. At many places, such as in the Grants-Bluewater area (Gordon, 1961), well developed solution channels impart a very high transmissibility to the limestone.

The San Andres Limestone lies at depths of about 1,500 feet near Mesita to possibly as much as 3,500 feet in the Rio San Jose valley near McCartys. The San Andres should be considered in future studies of the reservations, because it possibly contains a much larger supply of ground water than any other unit in the reservations, and because at many places the water in it may be under sufficient artesian pressure to flow from wells or to rise within a few feet of the surface. The water in the San Andres is probably impotable, but the chances are good that it would be suitable for irrigation.

TABLE 3.—*Records of selected wells in the Acoma and Laguna Indian Reservations, N. Mex.*

Location No.: See page 5 of text for explanation.
Depth: Depths measured by Geological Survey to nearest tenth of a foot; reported depths to nearest foot.
Water level: Depths measured by Geological Survey to nearest tenth of a foot; reported depths to nearest foot.
Principal aquifer: Determined by field observation, by examination of well cuttings, or by interpretation of geologic maps. "Material" generally is that indicated by the driller.
Stratigraphic unit: Qal, alluvium of Quaternary age; Qb, basalt of Quaternary age; Km, Mancos Shale; Kd, Dakota Sandstone; Jm, Morrison Formation; Jb, Bluff Sandstone; Je, Entrada Sandstone; and T̄c, Chinle Formation.
Use of water: D, domestic; I, irrigation; N, none; Ps, public supply; S, stock; T, test well.
Remarks: Gpm, gallons per minute; 50° F, temperature of water in degrees Fahrenheit.

Location No.	Year completed	Depth (ft)	Altitude (ft)	Water level		Principal aquifer		Use of water	Remarks
				Depth below land surface (ft)	Date	Stratigraphic unit	Material		
7.8.33.320	1935	541		500	4-10-35	Km	Sandstone	S	Bailed at 12 gpm (reported). Water reported as good.
36.100	1935	754		572	4-10-35	Km(?)	do	S	Bailed at 14 gpm (reported). Water reported as good.
8.4.15.200	1935	186		144	1-22-35		Basalt		Bailed at 4 gpm (reported). Water reported as good.
9.3.15.313		16.1	5,700	14.8	10-21-58	Qal		S	Dug well. Wooden cribbing to 16.1 ft.
9.4.8.400	1935	76	5,000	42	1-24-35	Qal	Sand and gravel		Bailed at 6 gpm (reported). Water reported as good.
16.324	1959	123		57	5-1-59	T̄c	do	S	Pumped at 5 gpm (reported) for 6 hours.
18.000	1913	70				Qal	do		Specific conductance is 3,870 micromhos. Hole abandoned.
19.000	1913	48		28	3-24-13	Qal(?)	Sand	S	Perforated from 46 to 48 ft. Pumped at 7 gpm (reported).
9.6.2.120		57.8	5,900	42.2	1-27-60	Qal	Sand and gravel	I	Specific conductance is 1,550 micromhos. 57°F.
3.100	1913	70		16	7-8-13	Qal	Sand and gravel(?)		Quality reported as fair.
4.222			5,930	19.1	12-19-50	Qal	do	D, S	
6.144	1913	48	5,955	26.7	12-7-50	Qal, Jm	Sand, gravel, and sandstone.	S, D(?)	Pumped at 10 gpm for 4 hours with no perceptible drawdown (reported).
9.200	1941	45				Jb	Sandstone		Bailed at 2½ gpm (reported).
10.132		15	5,910			Jm	do	D	Dug. Supplies water to Casa Blanca and Paraje.
10.132a		10	5,910			Jm	do	D	Do.
31.130	1934	41		22	12-12-34	Jm	do	S	Bailed at 10 gpm (reported). Water reported as good.
9.7.1.000	1913	58		45	7-26-13	Qal(?)	Sand and clay		Perforated from 48 to 58 ft.
1.200	1938	356				Jb(?)	Sandstone		Perforated from 105 to 128 ft, from 196 to 220 ft, and from 309 to 333 ft. Bailed at 3½ gpm (reported).
15.200	1935	599		299	2-5-35	Jb(?)	do	S	Bailed at 10 gpm (reported). Water reported as good.
9.8.2.110	1960	80	6,170	38.0	3-28-60	Qal	Sand and gravel	T	Irrigation test well 5. Bailed dry. Specific conductance is 2,500 micromhos. 57° F.
18.200	1935	410	7,500	298	3-13-35	Km	do	S	Bailed at 15 gpm (reported). Water reported as good.
9.9.3.330	1946	650		350		Km(?)	do	S	Yields 20 gpm (reported).
10.4.8.400	1935	388	6,000	264	2-26-35	Qal(?)	Gravel		Bailed at 5 gpm (reported). Water reported as good.
26.400	1935	515				T̄c	Sandstone		Water reported as salty. Abandoned.

10. 5. 26. 223	1960	35	5, 730	7. 0	2- 5-60	Qal	Gravel	T	Irrigation test well 8. Specific conductance (field) is 10,000 micromhos. 59° F. Abandoned.
32. 200	1913	60				Jb(?)	Sandstone(?)	D	Pumped at 75 gpm (reported). Water reported as excellent.
32. 444		34	5, 736	32. 3	12-20-50	Jm	Sandstone		
33. 000	1914	87				Qal(?)	Sand		Pumped at 8 gpm (reported) for 8 hours with no perceptible drawdown. Water reported as good.
10. 6. 3. 000	1914	30				Km(?)	Sandstone(?)		Dug. Casing perforated from 28 to 30 ft. Pumped at ⅛ gpm (reported). Water reported as very good.
3. 334		20	6, 376	17. 0	12- 6-50	Km	Sandstone	D, S	Dug.
4. 222	1952	360	6, 440	305	9-10-52	Km	do		Pumped at 12 gpm for 29 hours (reported).
18. 313	About 1900	15	6, 190	5. 2	12-19-50	Qal		D	Water reported as good.
18. 313a	1940	97	6, 190			Qal	Clay	D	Do.
28. 000	1913	45				Qal(?)			Do.
31. 443	1960	145	5, 940	6. 8	5-24-60	Qal	Sand and gravel	T	Irrigation test well 7. Cased and perforated to 145 ft. Pumped at 115 gpm for 24 hours with 8 ft. of drawdown. Specific conductance is 1,510 micromhos. 58° F.
33. 000	1960	71		12	6- -13	Qal	Boulders		
33. 000a	1960	127				Qal	Sand and gravel		Pumped at 6 gpm (reported).
33. 140	1936	581				Je	Sandstone	D	Perforated from 453 to 581 ft. Pumped at 8 gpm for 6 hours. Water reported as good.
33. 142		36	5, 962	32. 0	12-20-50	Qal, Jm	Sandstone and alluvium.	D	
34. 422	1955	100		38	1-14-60	Qal	Gravel	D	
35. 314	1957	102	5, 935	54. 5	do	Qal	do	N	Perforated from 94 to 102 ft. Specific conductance is 2,500 micromhos. 56° F.
35.322	1960	120	5, 945	65. 0	2- 5-60	Qal	Sand and gravel	T	Pueblo test well 1. Casing perforated to 97 ft. Pumped at 25 gpm for 12 hours with 23 ft of drawdown. Specific conductance is 1,460 micromhos. 59° F.
35.342	1960	122	5, 920	53. 9	3- 7-60	Qal	do	T	Pueblo test well 2. Casing perforated to 91 ft. Pumped at 90 gpm for 12 hours with 4.14 ft of drawdown. Specific conductance is 1,570 micromhos. 61° F.
10.7.18.331	1947	430	6, 227	79. 0	10- 3-47	Km(?)		S	Water reported as good. 60° F (reported).
18.444			6, 160	48. 9	4-27-51	Km(?)		S	
20.233		15	6, 150	13		Qal	Gravel	D	Dug. Yields 20 gpm (reported). Water reported as good.
23.243	1936	160		39. 3		Kd(?)	Sandstone	D	Pumped at 50 gpm (reported). Water reported as poor.
23.243a		160	6, 165	38. 0	12-22-50	Kd	do	D	Yields 5 gpm (reported). Water unfit for use without treatment.
25.444		84		42. 0	12- 7-50	Qal	Sand and gravel	Ps	
27.000	1913	42				Qal(?)		N	Water reported as very bad. Abandoned.
27.222		97	6, 088	50. 5	12-14-50	Km, Kd(?)	Sandstone	S	Water reported as fair.
27.300	1914	100		20	1-19-14	Km(?)	Soft rock		Casing perforated from 97 to 100 ft. Yields 20 gpm (reported). Water reported as good.
27.322	1932	12	6, 040	11. 4	12-14-50	Qal	Sand and gravel	D	Dug. Good water, but the supply is not permanent.
27.330	1950							Ps	

TABLE 3.—*Records of selected wells in the Acoma and Laguna Indian Reservations, N. Mex.*—Continued

Location No.	Year completed	Depth (ft)	Altitude (ft)	Water level: Depth below land surface (ft)	Water level: Date	Principal aquifer: Stratigraphic unit	Principal aquifer: Material	Use of water	Remarks
10.7.27.330 a	About 1900		6,070	1.5	3-28-60	Km	Sandstone	S	Dug. Specific conductance is 2,000 micromhos. 53° F.
27.330 b	do		6,020	8.1	do	Km	do	S	Dug. Specific conductance is 2,200 micromhos. 59° F.
27.333	1914	100		20		Qal	Soft rock	Ps	
27.441	1953	101				Qal	Sand	Ps	Bailed at 20-30 gpm for 9 hours. Water reported as average for area. Water level reported above 63 ft.
28.330	1941	78	6,100	15	3-28-60	Km	Sandstone	I, S	Yields 5 gpm (reported). Specific conductance is 3,000 micromhos. 57° F.
28.334		10	6,050	2.0	1-25-60	Qal		D, S	Dug. Specific conductance is 1,750 micromhos. 42° F. Water reported as poor.
29.120		20	6,120	5.0	1-26-60	Qal		D, S	Dug. Specific conductance is 770 micromhos. 48° F. Water reported as good.
29.214	1960	236	6,090	6.6	4-14-60	Qal	Sand and gravel	T	Pueblo test well 4. Casing perforated to 95 ft. Pumped at 75 gpm for 12 hours with 13.8 ft drawdown. Specific conductance is 1,030 micromhos. 56° F.
31.300	1939	310				Qal(?)	do	N	Abandoned. Sulfur water.
33.000	1914	28				Qal	Clay		Casing perforated from 25 to 28 ft. Pumped at 20 gpm (reported). Water reported as fair.
33.234	1937	1,000		Flowing	5- -57	Je	Sandstone	N	Abandoned. Flowed 12 gpm (reported). Water reported as bad.
34.000	1914	48				Qal(?)	Sand		Casing perforated from 42 to 48 ft. Pumped at 17 gpm (reported). Water reported as fair.
34.000 a	1913	93				Qal(?)	Clay		Casing perforated from 85 to 93 ft. Pumped at 2 gpm (reported). Water reported as very good.
34.000 b	1913	45				Qal(?)	Sand		Casing perforated from 35 to 45 ft and gravel packed. Yields 3 gpm (reported). Water reported as fair.
34.000 c	1914	55				Qal	Sand and gravel	N	Abandoned. Salt water.
35.210	1960	132	5,990	9.8	5-31-60	Qal	do	T	Irrigation test well 6. Casing perforated to 122 ft. Pumped at 100 gpm for 20 hours with 17 ft of drawdown. Specific conductance is 3,250 micromhos. 60° F.
36.000	1913	84		34	9-17-13	Qal	do		Water reported as very good. Reported that water level rose 7½ ft in 3 years.
36.000 a	1913	45				Qal		N	Boulders too extensive, abandoned well for more favorable drilling conditions.
36.221	1913	66		49	12- 7-50	Qal	Clay	D, S	Pumped at 2 gpm (reported). Reported as very good water.

10.8.7.000	1949	1,040				Km(?)		S	Water reported as good.
13.241	1947	415	6,267	115.2	10- 5-48	Km, Kd	Sandstone	I	Pumped at 800 gpm for 5 hours (reported). Water reported as very good.
13.433	1949	123	6,225	40		Km(?)	Sandstone(?)	D, S	Water reported as fair.
26.324		178	6,150	21.5	2-19-52	Qal, Qb	Gravel and basalt	N	Casing perforated from 45 to 110 ft. Pumped at 310 gpm for 24 hours with 15 ft of drawdown (reported). Abandoned.
27.224	1960	98	6,180	45.2	2-23-60	Qal	Sand and gravel	T	Irrigation test well 4. Specific conductance is 4,800 micromhos.
27.320		240				Km	Sandstone		Yields 10 to 12 gpm (reported).
27.324	1914	55				Qal(?)	Clay		Casing perforated from 47 to 55 ft. Pumped at 17 gpm for 4 hours with no perceptible drawdown (reported).
28.314	1960	125	6,170	4.8	6- 6-60	Qal, Qb	Sand, gravel and basalt.	T	Irrigation test well 3. Pumped at 100 gpm for 24 hours with 12 ft of drawdown. Specific conductance is 1,320 micromhos. 59° F.
28.444	1953	167		83.6		Km	Sandstone	Ps	Bailed at 20-30 gpm. Specific conductance is 900 micromhos.
32.312	1938	373	6,575	141(?)		Km	do	S	
10.9.17.113	1945	76	6,432	44.2	12- 8-50	Qal	Gravel	S	Yields 5 gpm (reported).
21.222	1949	70		48.5	do	Qal	do	S	
21.444	1949	80		44.2	do	Qal	do	S	
23.130	1948	70	6,330	38.8	6-14-49	Qal	do	N	Abandoned.
23.133	1950	1,035	6,332	Flowing	1- -51	R̄c	Sandstone	I	Yields 150 gpm (reported).
23.443	1948	30	6,280	8.3	6-14-49	Qb	Basalt	D, S	Yields 50 gpm (reported).
23.443 a	1951	33	6,280	9		Qal, Qb	Basalt and sand	D	Casing perforated from 23 to 33 ft. Yields 50 gpm (reported). Water reported as good.
25.324	1958	147		54	1- -58	Km	Sandstone		Yields 100 gpm (reported).
25.330	1960	90	6,290	33.4	3-21-60	Qal	Sand	T	Irrigation test well 1. Casing perforated to 90 ft. Pumped dry at 10 gpm. Specific conductance is 900 micromhos. 77°F.
25.441	1960	78	6,285	13.4	3-21-60	Qal	do	T	Irrigation test well 2. Casing perforated to 78 ft. Specific conductance is 10,100 micromhos. 58° F.
26.224	1936(?)	100	6,275	8.8	12-12-50	Qb	Basalt	S	Yields 50 gpm (reported).
26.433	1947	965	6,347	21.7	1- 4-51	R̄c (?)	Sandstone	I, S	Yields 300 gpm (reported). Specific conductance is 668 micromhos. 67°F.
29.120	1944	80	6,455	60.8	6-14-49	Qal	Gravel	S	
31.144		165		71.8	6-14-49	Qal		S	
11.5.30.422	1960	466	6,265	74.6	3-30-60	Qal, Km	Sand, gravel and sandstone.	T	Pueblo test well 3. Casing perforated from 161 to 220, from 272 to 325, and from 389 to 466 ft. Pumped at 15 gpm for 1.6 hours. Inadequate supply of water. Specific conductance is 670 micromhos. 66°F.
32.234	1960	79	6,150	Flowing	4-22-60	Qal	Sand and gravel	T	Pueblo test well 5. Pumped at 33 gpm for 12 hours and the pumping level was 25 ft below land surface. Flows 13 gpm. Head estimated to be 15 feet above land surface. Specific conductance is 583 micromhos. 56° F. Abandoned because the site is unfavorable to the local residents.

TABLE 4.—*Chemical analyses of water, in parts per million, from selected wells in the Acoma and Laguna Indian Reservations, N. Mex.*

[Analyses by U.S. Geol. Survey]

Location No.: See page 5 of text for explanation.
Stratigraphic units: Qal, alluvium of Quaternary age; Qb, basalt of Quaternary age; Km, Mancos Shale; Kd, Dakota Sandstone; ₹c, Chinle Formation.
Dissolved solids: Values calculated from determined constituents.

Location No.	Date collected	Stratigraphic unit	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and Potassium (K) as Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio (SAR)	Specific conductance (micromhos at 25° C)	pH
Recommended maximum concentrations in drinking water.[1]	--	--	--	--	(2)	--	125	--	--	--	250	250	1.5	--	500–1,000	--	--	--	--	--	--
10.6.3.334	1-20-51	Km	--	50	--	132	67	156	304	0	558	80	.5	0.9	1,190	605	356	36	2.8	1,650	--
4.222	9-10-52	Km							298	0		19								1,200	
31.443 (irrigation test well 7).	5-25-60	Qal	58	36	0.26	100	47	183	364	0	422	70	1.3	2.1	1,040	444	146	47	3.8	1,510	7.7
35.322 (pueblo test well 1).	2-12-60	Qal	59	29	.42	62	50	208	257	0	520	38	1.9	1.9	1,040	360	150	56	4.8	1,460	8.1
35.342 (pueblo test well 2).	3-8-60	Qal	61	24	8.1	73	44	234	276	0	556	43	2.1	1.6	1,110	364	138	58	5.3	1,570	7.8
10.7.18.331	10-5-48	Km(?)	60	--	--	36	27	566	572	0	924	43	2.1	16	1,910	201	0	87	18	2,750	--
20.233	2-20-51	Qal	--	49	--	71	21	35	274	0	78	15	.3	14	418	264	39	22	.9	626	--
23.243	12-15-50	Kd(?)	--	20	--	183	108	229	303	0	1,020	57	1.2	5.9	1,770	900	652	36	3.3	2,310	--
27.333	8-16-51	Qal	--	14	--	51	24	404	516	0	555	64	4.3	2.0	1,370	226	0	80	12	2,040	--
29.214 (pueblo test well 4).	4-14-60	Qal	56	60	--	92	49	84	467	0	180	26	1.0	6.9	729	432	50	30	1.8	1,070	7.8
35.210 (irrigation test well 6).	5-1-60	Qal	60	27	--	99	81	570	492	0	1,090	195	1.9	1.3	2,310	580	177	68	10	3,250	7.6
10.8.27.320	12-18-53	Km	--	19	--	202	127	360	353	0	1,130	239	.8	5.3	2,260	1,030	736	43	4.9	2,980	--
28.314 (irrigation test well 3).	6-7-60	Qal, Qb	59	21	.60	73	31	189	346	0	361	41	.8	.0	887	308	24	57	4.7	1,320	7.7
32.312	10-2-52	Km	--	15	--	47	23	112	324	0	174	6	.6	.0	538	212	0	54	3.4	833	--
10.9.17.113	12-8-50	Qal	57	30	--	330	380	931	469	0	2,840	754	.7	3.1	5,500	2,390	2,000	46	8.3	6,840	--
25.324	1-11-58	Km	--	--	--	--	--	--	330	0	--	185	--	--	--	1,030	760	--	--	2,[illegible]	--
25.441 (irrigation test well 2).	3-21-60	Qal	58	18	--	439	393	1,850	935	0	4,020	1,260	1.3	1.4	8,440	2,710	1,940	60	15	10,100	7.6
26.433	12-8-50	₹c (?)	67	18	--	30	14	104	290	0	100	9.0	.4	4.9	423	132	0	63	3.9	668	--
11.5.30.422 (pueblo test well 3).	3-31-60	Qal, Km	66	15	--	5.5	1.1	149	235	5	124	7.3	.8	.2	423	18	0	95	15	670	8.4
32.234 (pueblo test well 5).	4-22-60	Qal	56	42	.81	69	20	30	309	0	53	7.6	.3	.8	375	254	1	21	.8	583	7.3

[1] U.S. Public Health Service drinking water standards, 1946.

[2] Iron and manganese together not to exceed 0.3 ppm.

TABLE 5.—*Records of selected springs in the Acoma and Laguna Indian Reservations, N. Mex.*

Location no: See page 5 of text for explanation.
Altitude: Altitude interpolated from topographic maps of the U.S. Geol. Survey.
Principal aquifer and material: Determined by field observation or by interpretation of geologic maps.
Stratigraphic unit: Qal, alluvium of Quaternary age; Qb, basalt of Quaternary age; Km, Mancos Shale; Jm, Morrison Formation.
Yield: E, estimated; R, reported.
Use of water: D, domestic; I, irrigation; N, none; S, stock.

Location No.	Name	Altitude (feet)	Principal aquifer		Yield (gpm)	Use
			Stratigraphic unit	Material		
S9. 8. 3. 300	Largo Spring		Km	Sandstone		D, S
12. 130	Sheep Dip Spring		Km	do		D
S10. 5. 28. 300		5, 800±	Jm	Shale		S
S10. 6. 15. 134	Kose Spring	6, 175	Km	Sandstone	10 E	N
S10. 7. 20. 410		6, 134	Qal		10 E	S
28. 300	Paytiamo Spring		Km	Sandstone		D
28. 400	Shourlte Spring		Km	do		D
S10. 8. 28. 400	Star Spring		Km	do		D
S10. 9. 23. 400	Horace Spring	6, 281	Qb	Basalt	2, 000 E	I

SELECTED REFERENCES

Dane, C. H., and Bachman, G. O., 1957, Preliminary geologic map of the northwestern part of New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map I–224.

Fenneman, N. M., 1931, Physiography of Western United States: New York, McGraw-Hill Book Co., p. 274.

Freeman, V. L., and Hilpert, L. S., 1956, Stratigraphy of the Morrison formation in part of northwestern New Mexico: U.S. Geol. Survey Bull. 1030–J, p. 309–334.

Goddard, E. N., Chm., and others, 1948, Rock color chart: Washington, D.C., Natl. Research Council; repub., 1951, Geol. Soc. America.

Gordon, E. D., 1961, Geology and ground-water resources of the Grants-Bluewater area, Valencia County, New Mexico: New Mexico State Engineer Tech. rept. 20, 109 p., 14 figs., 2 pls.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473. (Reprinted 1962.)

Hilpert, L. S., and Moench, R. H., 1960, Uranium deposits of the southern part of the San Juan Basin, New Mexico: Econ. Geology v. 55, no. 3, p. 429–464.

Hunt, C. B., 1937, Igneous geology and structure of the Mount Taylor volcanic field, New Mexico: U.S. Geol. Survey Prof. Paper 189–B, p. 299–302 [1938].

Meinzer, O. E., 1923, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p.

New Mexico Geological Society, 1950, Guidebook of the north and east sides of the San Juan basin, New Mexico, New Mexico Geol. Soc. 1st Field Conf., 1950: 153 p.

——— 1959, Guidebook of west-central New Mexico, New Mexico Geol. Soc. 10th Field Conf., 1959: 162 p.

Rapp, J. R., 1960, Reconnaissance of ground water for irrigation, Acoma Indian Reservation, Valencia County, New Mexico: U.S. Geol. Survey open-file rept., 28 p.

Thornbury, W. D., 1958, Principles of geomorphology: New York, John Wiley & Sons, 618 p.

U.S. Department of Health, Education, and Welfare, 1946, Public Health Service drinking water standards: v. 61, no. 11.

Wilcox, L. V., 1955, Classification and use of irrigation waters: U.S. Dept. Agriculture Circ. 969, 19 p.

INDEX

[Major references are in italic]

A

Page

Abstract — E1
Acknowledgments — 3
Acomita area, test drilling — *22*
Agricultural use of water — *49*
Alluvium, aquifer attributes — 45
  coefficient of transmissibility, Anzac-McCartys area — 16
  description and water-bearing characteristics — 13
  geomorphic controls of thickness — 7
  well logs — 17, 19, 20, 22, 24, 26, 29, 32, 35, 39, 41, 42
Anzac-McCartys area, test drilling — *16*
Aquifers, Anzac-McCartys area — 16
  Encinal Creek area — 30
  Grants and Bluewater area — 7
  Paguate area — 37
  sedimentary rock — 44
Artesian water — *47*

B

Bacterial contamination — 37
Basalt, Quaternary, description and water-bearing characteristics — *14*
  well logs — 19, 26, 29
Basalt, Tertiary, description and water-bearing characteristics — *12*
Bluff Sandstone, collapse structures — 7
  description and water-bearing characteristics — *10*
  well logs — 33, 36, 42
Brushy Basin Member of Morrison Formation, description — 11

C

Calcium sulfate, in water from Todilto Limestone — 10
Chinle Formation, description and water-bearing characteristics — *9*
Chloride, well 10.7.35.210 — 27
  well 10.9.25.441 — 17
Climate — 6
Coefficient of transmissibility, defined — 14, 16, 45
  well 10.6.31.443 — 28
  well 10.6.35.322 — 31
  well 10.7.29.214 — 25
  well 10.7.35.210 — 27
  well 10.9.25.330 — 16
  well 11.5.32.234 — 41
Collapse structures — 7
Conclusions — *51*

Page

Contamination of ground water — 10

D

Dakota Sandstone, description and water-bearing characteristics — *11*
  well logs — 24, 39
Dikes, Tertiary, description and water-bearing characteristics — *13*
Dissolved solids, alluvium — 14
  Chinle Formation — 9
  well 10.6.31.443 — 28
  well 10.6.35.322 — 34
  well 10.6.35.342 — 36
  well 10.7.29.214 — 25
  well 10.7.35.210 — 27
  well 10.9.25.441 — 17
  well 11.5.30.422 — 38
  well 11.5.32.234 — 41
Domestic use of water — *48*
Drainage of Rio San Jose — 7
Drilling, test-well — *15*

E

Encinal Creek, discharge — 13
  test drilling near mouth — *30*
Entrada Sandstone, description and water-bearing characteristics — *9*

F

Faults, associated with collapse structures — 7
Field methods, test wells — 15
Fluoride content of water — *48*

G

Geography — *5*
Geologic formations and their water-bearing characteristics — *7*
Geology — *6*
Geomorphic controls on alluvium thickness — 7
Grants and Bluewater area, principal aquifer — 7
Gravel deposits. *See* Alluvium.
Ground water — *44*
  movement, effect of dikes — 13

H

Horace Springs, discharge — 15

I

Igneous rocks, topographic controls — 5

	Page
Introduction	*2*
Irrigation test well 1, description	*16*
Irrigation test well 2, description	*17*
Irrigation test well 3, description	*18*
Irrigation test well 4, description	*20*
Irrigation test well 5, description	*22*
Irrigation test well 6, description	*26*
Irrigation test well 7, description	*28*
Irrigation test well 8, description	*41*

J

Jackpile sandstone	11

L

Lithology, alluvium	*13*, 17, 19, 20, 22, 24, 26, 32, 35, 39, 41, 42
Bluff Sandstone	*10*, 33, 36, 42
Chinle Formation	*9*
Dakota Sandstone	*11*, 24, 39
Entrada Sandstone	*9*
Mancos Shale	*12*, 17, 20, 22, 24, 39, 41
Mesaverde Group	*12*
Morrison Formation	*11*, 21, 24, 26, 39
Summerville Formation	*10*
Todilto Limestone	*10*
Location of study area	3
Log of well 9.8.2.110	22
10.5.26.223	42
10.6.31.443	29
10.6.35.322	32
10.6.35.342	35
10.7.29.214	24
10.8.27.224	20
10.8.28.314	19
10.9.25.441	17
11.5.30.422	39
11.5.32.234	41

M

Mancos Shale, description and water-bearing characteristics	*12*
source of sulfate	48
well logs	17, 20, 22, 24, 39, 41
McCartys syncline	6
Mesaverde Group, description and water-bearing characteristics	*12*
Morrison Formation, collapse structures	7
description and water-bearing characteristics	*11*
well logs	21, 24, 26, 39
Mount Taylor volcanic field	6
Movement of water	*46*
effect of dikes	13

P

Paguate area, test drilling	*37*
Perched water	38
Physiographic provinces	5
Precipitation, annual	6
Previous investigations	3
Pueblo test well 1, description	*31*
Pueblo test well 2, description	*34*
Pueblo test well 3, description	*37*
Pueblo test well 4, description	*23*
Pueblo test well 5, description	*40*
Purpose and scope of report	3

Q

Quality of water, Acomita area	*22*
alluvium	*14*
Bluff Sandstone	11, 30
Chinle Formation	*9*
Entrada Sandstone	*9*
general	*47*
Mancos Shale	*12*
Morrison Formation	30
Paguate area	37
San Andres Limestone	7
Todilto Limestone	*10*
well 10.4.26.400	9
well 10.5.26.223	42
well 10.6.31.443	28
well 10.6.35.322	34
well 10.6.35.342	36
well 10.7.29.214	25
well 10.7.35.210	27
well 10.8.27.224	20
well 10.8.28.314	18
well 10.9.25.330	17
well 10.9.25.441	17
well 11.5.30 422	38
well 11.5.32.234	41

R

Recapture Member of Morrison Formation, description	*11*
Recharge	*46*
alluvium	14
Regional dip	6
Rio Paguate, discharge	13
Rio San Jose, average annual flow	43

S

Salinity and sodium hazard	*49*
San Andres Limestone, water-bearing characteristics	7
Sedimentary rocks, topographic controls	5
Specific capacity, defined	16, 45
well 10.6.35.322	31
well 10.7.29.214	25
well 10.7.35.210	27
well 10.9.25.330	16
well 11.5.30.422	38
well 11.5.32.234	41
Specific conductance, Acomita reservoir	23
Chinle Formation	9
Mancos Shale	12
well 10.5.26.223	42
well 10.6.35.322	34
well 10.7.29.120	23
well 10.8.27.224	20
Springs, basalt, Quaternary	15
basalt, Tertiary	13
Mancos Shale	12
near Casa Blanca	31
Stratigraphic section	8

	Page
Structural features	6
Sulfate, alluvium	14
well 10.6.31.443	28
well 10.6.35.322	34
well 10.6.35.342	36
well 10.7.29.214	25
well 10.7.35.210	27
well 10.9.25.441	17
well 11.5.30.422	38
well 11.5.32.234	41
Summerville Formation collapse structures	7
description and water-bearing characteristics	*10*
Surface water	*42*

T

Testing procedure	*15*
Test sites, selection	*16*
Test-well drilling	*15*
Todilto Limestone, description and water-bearing characteristics	*10*
source of sulfate	48
Topography	5
Transmissibility, alluvium	14
Tres Hermanos Sandstone Member of Mancos Shale, description	*12*

U

Uranium ore	11

V

Volcanic fields	6

W

Water-bearing characteristics of formations	*7*
Well, description, 9.8.2.110	*22*
10.5.26.223	*41*
10.6.31.443	*28*
10.6.35.322	*31*

Well, description—Continued	Page
10.6.35.342	*34*
10.7.29.214	*23*
10.7.35.210	*26*
10.8.27.224	*20*
10.8.28.314	*18*
10.9.25.330	*16*
10.9.25.441	*17*
11.5.30.422	*37*
11.5.32.234	*40*
Well-numbering system	*5*
Well sites, favorable	44
Westwater Canyon Member of Morrison Formation, description	*11*

Y

Yields of wells, alluvium	*14*
basalt, Quaternary	*15*
basalt, Tertiary	*12*
Bluff Sandstone	*10*, 30
Chinle Formation	*9*
Dakota Sandstone	*11*
Entrada Sandstone	*9*
Mancos Shale	*12*, 37
Morrison Formation	*11*, 30
Summerville Formation	*10*
well 10.5.32.200	10
well 10.6.31.443	28
well 10.6.35.322	31
well 10.6.35.342	36
well 10.7.29.214	25
well 10.7.35.210	27
well 10.8.13.241	12
well 10.8.27.224	20
well 10.8.28.314	18, 20
well 10.9.25.324	12
well 10.9.25.330	17
well 10.9.26.433	9
well 11.5.30.422	38
well 11.5.32.234	40

O