THE GEOLOGY AND GROUND WATER INVESTIGATION OF THE TRES ALAMOS DAM SITE AREA OF THE SAN PEDRO RIVER, COCHISE COUNTY, ARIZONA

by

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STATEMENT BY AUTHOR

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ABSTRACT

Rocks of the mountains paralleling the San Pedro River Valley in the Tres Alamos Dam Site area range in age from Precambrian to Paleozoic. Granitic rocks which occur at the dam site are similar to those in the mountains to the west and east and are mapped as Precambrian in age. The oldest Tertiary unit exposed in the San Pedro Valley is the Granitic Conglomerate of Miocene (?) age which is overlain unconformably by the Black Conglomerate of Pliocene (?) age. A period of faulting and erosion followed the consolidation of the Black Conglomerate and parts of the units were removed. Erosion was followed by deposition of the Plio-Pleistocene Benson Beds. The flat-bedded Benson Beds are generally fine grained and are reddish brown in color. The light brown Tres Alamos formation of Pleistocene age overlies the Benson Beds.

The Tres Alamos unit is flat-bedded and consists of conglomeratic facies near the mountain fronts grading into fine-grained facies near the center of the valley. The youngest unit discussed is the floodplain deposits of the San Pedro River and its tributaries.

The Tertiary conglomerates yield small to moderate amounts of unconfined water to wells penetrating those parts not overlain by Benson Beds. In the center of the valley where the conglomerates are overlain by Benson Beds, the unit contains artesian water at depths greater than 200 feet. The permeability of the Tertiary conglomerates probably ranges from 100 to 1,000 gpd/ft^2. The Tres Alamos formation yields small amounts of non-artesian water to wells penetrating the conglomeratic facies. The permeability of the coarse facies of the Tres Alamos formation is estimated to range from 10 to 1,000 gpd/ft^2. The Benson Beds do not yield water to any known well. The fine-grained beds of this unit form the confining layer for the underlying artesian system. The floodplain deposits yield moderate to large amounts of unconfined water to wells. The permeability of the floodplain deposits is believed to range from 1,000 to 5,000 gpd/ft^2.

The granitic rocks exposed at the Tres Alamos Dam Site appear to form a ground water barrier to the artesian system. If this barrier existed in the past dividing the valley into two separate basins of deposition, it is possible that the sediments containing the artesian system are not continuous through the dam site area. It is possible that the artesian water may be moving through a buried channel to the west of the dam site, through buried remnants of the Tertiary conglomerates on the sides of the granitic rocks near the dam site, or through regional faults associated with the development of the Basin and Range province.

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INTRODUCTION

Statement of Problem

Principal features of the problem were to determine the nature and principal occurrence of the confined and unconfined ground-water systems above and below the Tres Alamos Dam Site in the San Pedro River Valley. The hydraulic continuity of the confined water system depends in part on the influence of the granitic rock barrier at the Tres Alamos Dam Site. The granitic rock barrier may separate the artesian systems above and below the dam site, or there may be a permeable zone around or through the dam site that would allow the artesian systems to be hydraulically connected. The hydraulic continuity of both ground-water systems depends on the nature of the lithology of the water-bearing sediments. The facies relationships of the sediments must be differentiated to determine the ground-water flow in the unconfined and confined systems.

Location and Drainage

The Tres Alamos Dam Site area, as used in this report, lies in the San Pedro River Valley, the northwestern part of Cochise County, in southeastern Arizona. The dam

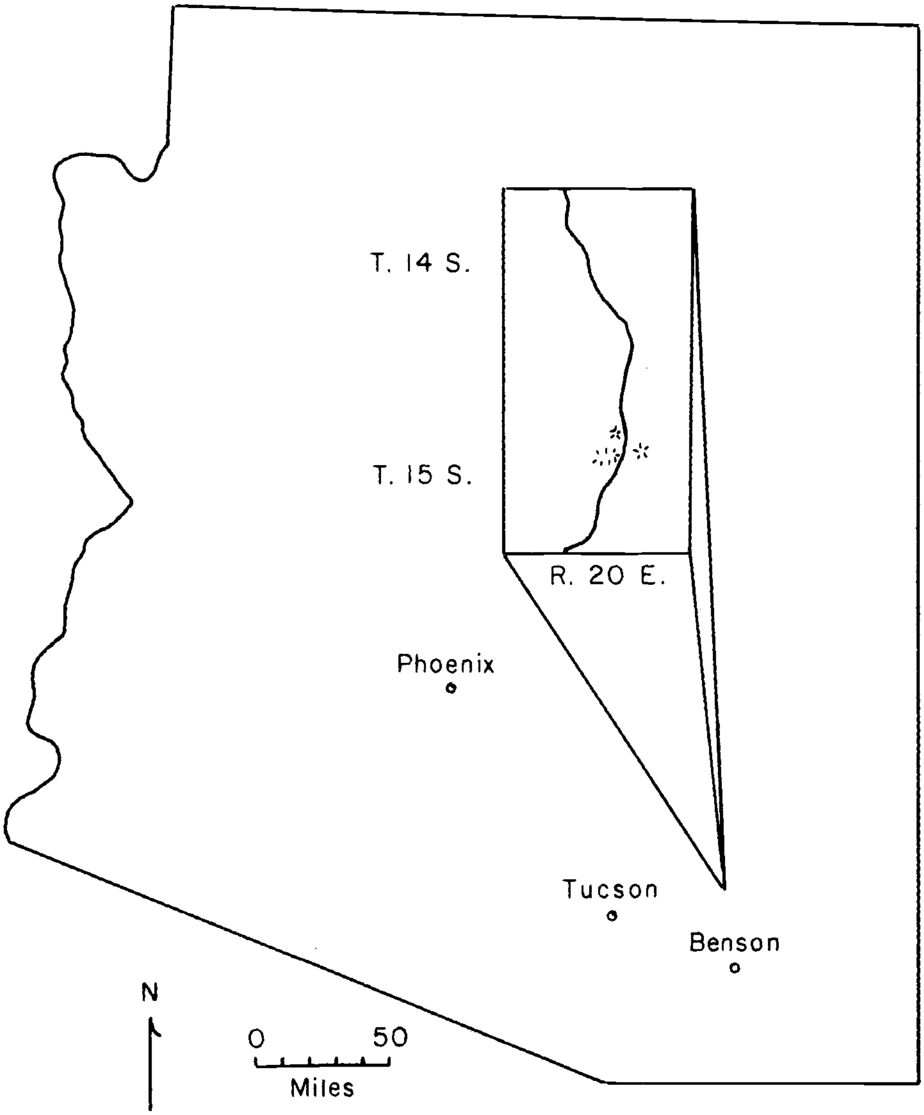

Figure I. Index Map of the Tres Alamos Dam Site Area site area has a maximum length of about 12 miles in a north-south direction and a width of about 7 miles. The Tres Alamos Dam Site lies about midway between the towns of Redington and Benson. The area discussed in this report is defined by T. 14 S., R. 20 E.; T. 15 S., R. 20 E.; sections 1, 12, 13, 24, 25, and 36, T. 14 S., R. 20 E.; and sections 1, 12, 13, 24, 25, and 36, T. 15 S., R. 20 E.

The northward flowing San Pedro River roughly bisects the mapped area into eastern and western halves. The San Pedro River is an intermittent stream, and only during periods of unusually heavy runoff does the river flow through the valley. The surface flow at the Tres Alamos Dam Site was estimated by Heindl (in Halpenny, 1952) to average about 45,000 acre-feet per year for the period 1932-41. The surface flow is probably less at present as the volume of water used for irrigation has increased since that period. The river above the Tres Alamos Dam Site drains about 2,500 square miles of which about 650 square miles are in Mexico. Below the dam site, the river flows northwest about 65 miles to where it joins the Gila River at Winkelman, Arizona, (Heindl, in Halpenny, 1952). Numerous washes draining the higher areas to the east and west join the San Pedro River.

Land Forms

The San Pedro Valley is typical of many Basin and Range valleys. These areas owe their shape to faulting of the bedrock, subsequent erosion of the uplifted areas, and deposition in the down-faulted trough.

The valley floor consists of a central floodplain and the adjoining alluvial slopes. The floodplain is a smooth and gentle surface underlain by fine-grained sediments. The alluvial slopes are characterized by gullied surfaces, gently sloping terraces, and prominent broad alluvial fans sloping toward the valley from the mountains to the east and west. The terraces were cut by the San Pedro River during its cyclic downcutting and lateral planation. The alluvial fans were built by the major tributaries to the San Pedro River. These tributaries, alternating through their various channels, have moved great amounts of sediments down from the mountain fronts toward the center of the valley. On the east and west side of the valley the alluvial slopes extend up to the bedrock exposures on the adjoining mountains.

Previous Work

The most recent geologic study in the San Pedro Valley was done by L. A. Heindl (Heindl, 1963). Heindl discusses the Cenozoic deposits of the Mammoth area and describes a sequence of Tertiary and Quaternary geologic units similar to those described in this paper.

A study of the geology and ground-water geology of the San Pedro River was published by L. A. Heindl (in Halpenny, 1952). Heindl presents a great deal of general information on the water resources and the subsurface geology of the San Pedro Valley from the Mexico border to Winkelman, Arizona, where the San Pedro River joins the Gila River. Older studies include unpublished work by Kirk Bryan, G.E.P. Smith, and G. A. Waring.

Dr. John F. Lance, Department of Geology, University of Arizona, has published several papers on fossil localities and paleontological dates near Benson, Arizona, several miles to the south of the area studied and near Redington, Arizona, several miles to the north of the area.

Acknowledgments

Grateful acknowledgment is given to Dr. John W. Harshbarger, Head, Department of Geology, University of Arizona, who supervised and reviewed this thesis.

The advice and assistance of Dr. John F. Lance, Mr. John G. Ferris, Dr. Mark A. Melton, and Dr. Joseph F. Schreiber, Jr., Department of Geology, University of

Arizona; Professor H. C. Schwalen, Department of Agricultural Engineering, University of Arizona; and Mr. Edward Davidson, U. S. Geological Survey, Tucson, Arizona, is greatly appreciated.

Special acknowledgment is made to the author's wife whose constant encouragement and help was very instrumental in making this thesis possible.

METHODOLOGY

Geologic Mapping

A geologic map of the Tres Alamos Dam Site area was made by the author during the summer and fall of 1962. The field mapping was done on a part of the Happy Valley Quadrangle area, fifteen minute, topographic map, enlarged to a scale of two inches per mile. The outcrop positions were located by preliminary traverses, and later with the use of aerial photographs by tracing the outcrop. Six distinctive lithologic units were recognized and are indicated on the map. The geologic structure was mapped, although many of the faults were covered by surface debris and must be inferred to extend beyond their points of discovery.

Gravity Survey

The gravity survey information was furnished by Dr. Mark A. Melton, Department of Geology, University of Arizona. The information has not been published and mention will be made of only a few pertinent observations. The acceleration or the force of gravity is measured with a gravity meter and commonly expressed in milligals. One milligal is equivalent to an acceleration of 0.001 cm/sec/sec or about one millionth of normal gravitation attraction. Relatively high gravity values are indicated over "hard rock" or the consolidated rocks forming the structural basin. As the gravity values become smaller, the divergence is usually interpreted to represent a greater thickness of less dense sedimentary deposits.

Well Logs and Water Level in Wells

The driller's logs and water level data used in this paper were collected from the files of the U. S. Geological Survey, Tucson, Arizona, and from the files of the Department of Agricultural Engineering, University of Arizona. Some additional information was obtained by examining the drilling mud pits of completed wells and by conversing with well owners and well drillers.

The well numbers in this paper follow the system used by the Ground Water Branch of the U. S. Geological Survey. This method is based on the Public Land Survey System. In Arizona the primary boundaries are the Gila Baseline (east-west) and the Salt River Meridian (north-south) which divide the state into four quadrants. The four areas are indicated counter-clockwise by the capital letters "A", "B", "C", and "D". The northeast quadrant is designated by "A", the northwest by "B", etc. The first digit of the well number represents the township, the second digit the range, and the third digit the section. The first lower case letter indicates the 160 acre area, the second the 40 acre area, and the third the 10 acre area. If two or more wells are located in a single 10 acre tract, the individual wells are distinguished by adding numbers in chronological order after the lower-case letters. According to this system, the second well located in the NW quarter of the SW quarter of the NE quarter of section 15, T. 15 S., R. 20 E., would be referred to as (D-15-20)15acb2.

Well Logs

The driller's logs of water wells have been recorded primarily by the well drillers, and often do not define clearly the lithology or the relative positions of the units penetrated. After becoming familiar with the area and through conversation with the driller and well owner, the nomenclature used for the various units was somewhat clarified. Considering the scarcity of well logs, the author attempted to derive significant information from even the shallowest and most general logs. The driller's logs were examined to obtain some indication of the sub-surface lithology, thickness, and location of the various units.

Water Level in Wells

Professor H. C. Schwalen, Department of Agricultural Engineering, University of Arizona, furnished the author with the water level data and also with a water-level contour map. The contour map covers parts of the area discussed in this paper. The water level data was studied to distinguish between artesian and non-artesian wells and to determine gradients of the ground-water table in areas not included in the ground water contouring. The water-level contour map was used to determine gradients of the ground-water table and the corresponding directions of ground-water movement.

Sediment Size Analyses

Rock samples of the floodplain deposits, the Tres Alamos formation, and the Benson Beds were collected in the field. In the laboratory the rock samples were divided repeatedly until a 20 to 30 gram portion representative of the entire sample could be obtained for analyses. The sample was then weighed and transferred to a beaker where water was added to form a slurry. A ten percent hydrochloric acid solution was added to dissolve the carbonate which was chiefly in the form of cement. The material remaining was then washed to remove all chloride, dried, and weighed. At this point the weight percent of carbonate and clastics was calculated. The clastics were sieved using a set of Tyler standard screen sieves. Sediment sizes retained on the screens ran from gravel through very fine sand; clay-and silt-size material was caught in the bottom pan. The various size grades obtained were then grouped and expressed as percentage clay and silt, sand, and gravel.

GEOLOGY

Stratigraphy and Water-bearing Characteristics of the Units

The oldest unit exposed in the San Pedro Valley is the granitic rocks mapped as Precambrian in age which crop out at the Tres Alamos Dam Site. These granitic rocks are similar to those cropping out in parts of the mountains to the east and west.

The oldest Tertiary unit exposed is a conglomerate of high granitic pebble content which has been given the informal name "Granitic Conglomerate" in this paper. Within this conglomerate there are many nearly vertical faults of unknown displacement. The unit dips approximately 40 degrees to the east. The Granitic Conglomerate is overlain and in fault contact with a younger Tertiary conglomerate which is given the informal name "Black Conglomerate" for its dark appearance in the cliffs where it is exposed. The Black Conglomerate is essentially horizontally bedded and is also cut by numerous near vertical faults, but these faults are generally of only a few inches displacement.

A large fault forms the eastern boundary of the Black Conglomerate, and the Benson Beds of Tertiary-Quaternary

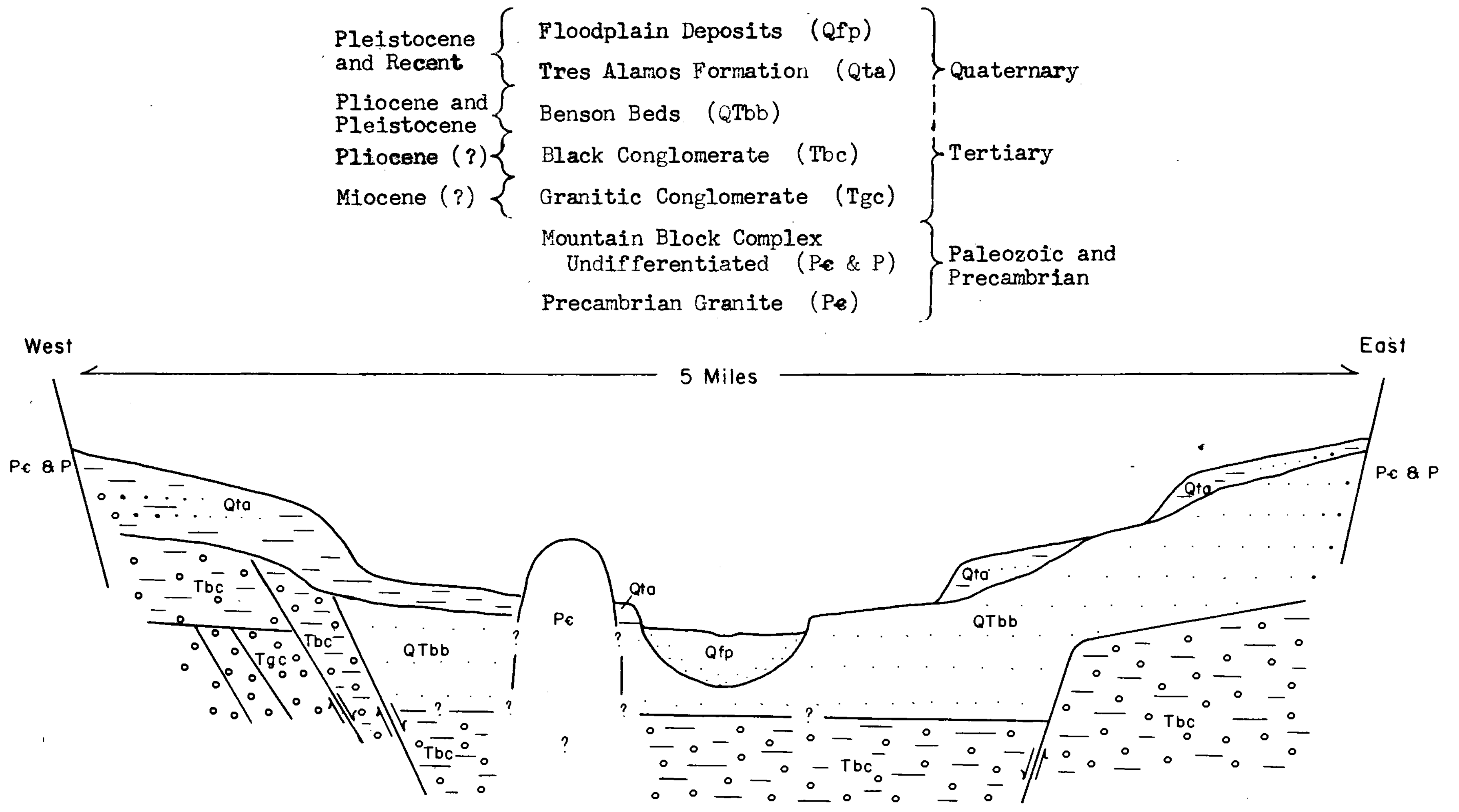

Figure 2. Schematic East-West Geologic Cross-section of the San Pedro River Valley in the Tres Alamos Dam Site Area

age (Lance, 1960) are in depositional contact with the Black Conglomerate against the eroded face of this fault. The Benson Beds are essentially horizontal and are generally fine grained in the central parts of the valley but grade laterally into coarser facies against the mountain fronts. The fine-grained material of this formation is in depositional contact with the outcrops of granitic rock forming the Tres Alamos Dam Site.

After the deposition of the Benson Beds a period of erosion occurred. The Pleistocene alluvial fan and floodplain deposits of the unit, informally named "Tres Alamos formation" were deposited disconformably on the eroded surface of the Benson Beds. The Tres Alamos formation is also in depositional contact with the granitic rocks forming the dam site, and the coarser margins of the unit are in depositional contact with the mountain blocks.

The youngest unit mapped is the Quaternary alluvium deposited in the present channels and floodplains of the San Pedro River and its tributaries.

Tertiary Deposits

Granitic Conglomerate.--The Granitic Conglomerate of Miocene (?) age is herein named informally by the author from exposures in sections 4, 19, and 30, T.14 S., R. 20 E. In the eastern half of section 30 the conglomerate overlies an erosion surface of Precambrian granite; however, the other exposures have no observable base and may rest on older Tertiary sediments.

The dips of the Granitic Conglomerate beds are generally to the east and range in magnitude from horizontal to nearly 60 degrees. The outcrop exposed in section 30 dips with an average of 40 degrees to the east and represents the most continuous exposure. This exposure was measured and a thickness of 1,200 feet was calculated. The exposure was measured by recording dips with a Brunton compass and measuring slope distance by pacing in a direction normal to the strike. The magnitude of displacement caused by faulting is unknown and would indicate that calculated thicknesses may not be reliable.

The size of the particles in the Granitic Conglomerate ranges from silt and sand to boulders greater than 10 feet in diameter. The particles from pebble to boulder size are generally sub-angular to sub-rounded. The individual beds of Granitic Conglomerate range in thickness from a few inches to several feet and are discontinuous and lense-like. Generally the individual lenses have a cobble conglomerate texture, although there are occasonally lenses, rarely exceeding two feet in thickness, of sand and pebble-size material. The carbonate cement is firm, and the unit is a well-consolidated cliff former.

After the consolidation of the conglomerate, faulting ensued which tilted the beds to approximately their present attitude. Erosion then planed the tilted surface, and the younger Tertiary Black Conglomerate was deposited on the eroded surface.

Pebble counts were completed on the Granitic Conglomerate outcrops in sections 4 and 30, T. 14 S., R. 20 E. These counts consisted of removal of pebble-sized material from a small area of the conglomerate outcrop and separating the pebbles according to composition. Three major rock types were recognized. Granitic pebbles having a light green stain were separated from granitic pebbles having a pink or red stain. The third major division of pebbles was derived from Paleozoic sediments. The percentage of total granitic pebble content or the percentage of green granite plus red granite was determined to be 60 percent and is considered to be a significant criterion for distinguishing between the Granitic Conglomerate and the younger Black Conglomerate (see table 1).

The permeability of this unit is estimated by comparison to laboratory permeability test to be in the range of 100 to 1,000 gpd/ft^2. An unknown thickness of this

Table 1. Results of Granitic Conglomerate Pebble Counts

Location No. 1: Section 4, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Total	Total Granite
No. of pebbles	56	12	34	102	68
% of total	54.9	11.8	33.3	100.0	66.7

Location No. 2: Section 4, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Total	Total Granite
No. of pebbles	54	8	34	102	62
% of total	53.5	7.8	38.6	100.0	61.4

Location No. 3: Section 4, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Total	Total Granite
No. of pebbles	57	16	52	125	73
% of total	45.6	12.8	41.6	100.0	58.4

Location No. 4: Section 30, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Total	Total Granite
No. of pebbles	123	67	144	334	190
% of total	36.8	20.1	36.4	100.0	56.9

Location No. 5: Section 30, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Total	Total Granite
No. of pebbles	136	51	107	294	187
% of total	46.3	17.3	36.4	100.0	63.6

unit probably occurs at depth in the central portions of the valley and should yield artesian water when penetrated by wells.

Black Conglomerate.--The Black Conglomerate of Pliocene age was named informally by the author from exposures in sections 18, 19, and 30, T. 14 S., R. 20 E. In the eastern half of section 30 the conglomerate overlies an erosion surface on Miocene (?) Granitic Conglomerate. The remaining exposures have no observable base but are inferred to rest on Granitic Conglomerate at depth. The outcrops are faulted, but the maximum displacement appears to be in the order of one or two feet. The fault zones, where exposed, are partially open and contain small amounts of caliche.

The exposed Black Conglomerate is essentially flat-bedded, although locally the dips may be as great as seven degrees. The outcrops were measured in several places, and the greatest exposed thickness was found to be approximately 118 feet. The author believes the true thickness of this unit to be greater than the exposed thickness.

The size of the particles in the Black Conglomerate ranges from silt and clay to boulders greater than three feet in diameter. The particles of pebble size are generally sub-rounded to sub-angular and are predominantly bladed or tabular in shape. The particles of cobble size and larger are generally sub-rounded and roughly equi-dimensional. The average particle size of this unit appears to fall in the coarse gravel or cobble division of the Wentworth size classification. The outcrops of Black Conglomerate generally appear massive, although there are infrequent granitic boulders with diameters exceeding two feet. There are also occasional lenses of predominantly pebble and sand-size material. The unit is strongly cemented with a carbonate cement. The exposures form resistant cliffs having a maximum height of approximately 70 feet.

After consolidation of the conglomerate faulting ensued. This faulting dropped the parts of the unit which now underlie the Benson Beds in the center of the vally to approximately their present position. The upper surface of the Black Conglomerate was later modified by a period of erosion that occurred before the deposition of the Plio-Pleistocene Benson Beds.

Pebble counts were made by sampling exposures in sections 18 and 30, T. 14 S., R. 20 E., using the method described in the preceding section. The average total granitic pebble content was calculated to be 22 percent (see table 2).

Table 2. Results of Black Conglomerate Pebble Counts

Location No. 1: SW 1/4, SW 1/4, NE 1/4, section 18, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Jasper	Schist	Total	Total Granite
No. of pebbles	23	26	178	0	7	234	49
% of total	9.8	11.1	76.1	0.0	3.0	100.0	20.9

Location No. 2: SW 1/4, NW 1/4, NE 1/4, section 30, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Jasper	Schist	Total	Total Granite
No. of pebbles	52	60	264	11	6	393	112
% of total	13.2	15.3	67.2	2.8	1.5	100.0	28.5

Location No. 3: SW 1/4, NW 1/4, NE 1/4, section 30, T. 14 S., R. 20 E.

	Green Granite	Red Granite	Paleozoic Sediments	Jasper	Schist	Total	Total Granite
No. of pebbles	10	13	122	1	2	148	23
% of total	6.8	8.8	82.4	0.7	1.4	100.0	15.6

The Black Conglomerate is estimated to have a permeability in the order of 100 to 1,000 gpd/ft^2. A minimum thickness of several hundred feet of this unit is believed to underlie the central portions of the basin immediately below the Benson Beds. Much of the artesian water supplied to wells is probably yielded by this conglomerate.

Tertiary - Quaternary

Benson Beds or Gila Conglomerate.--The red-brown Plio-Pleistocene beds have been referred to informally in literature as the Gila Conglomerate (Knechtel, 1936) and as the Benson Beds (Lance, 1960). To simplify terminology the unit will be referred to as the Benson Beds in this paper.

The Benson Beds are inferred to lie unconformably on the Tertiary conglomerates at depth in the center of the valley and lie unconformably on the Precambrian granitic rocks forming the Tres Alamos Dam Site. The Benson Beds are also in depositional contact on the Black Conglomerate along the fault located in sections 18, 19, and 30, T. 14 S., R. 20 E.

In the western side of the valley the Benson Beds are exposed from the southern edge of the mapped area to section 17, T. 14 S., R. 20 E., about two miles from the northern boundary. On the east side of the valley the unit is exposed at the southern edge of the area studied and continues north to the Tres Alamos Dam Site. On the east side of the valley there are no exposures of this unit north of the granitic rocks forming the Tres Alamos Dam Site. At the time of their deposition the Benson Beds were probably present throughout the valley and were later partially removed by erosion.

The Benson Beds are essentially horizontal, although maximum dips of two to three degrees have been observed. The uppermost known outcrop of the Benson Bed unit occurs at an elevation of approximately 3,650 feet, and the base of the unit seems to be greater than 200 feet below the surface of the valley. The elevation difference indicates a thickness greater than 450 feet for this unit.

Sedimentary particles in the Benson Beds range in size from silt and clay to gravel. Near the center of the valley, the material tends to be fine grained; however, the particles tend to increase in size rapidly toward the mountain fronts. Table 3 shows size analyses completed on rock samples from this unit, and figure 3 correlates the size analyses with the location of the samples. Sample no. 4 was taken about one mile west of sample no. 3 on the west side of the valley, and sample no. 4 is significantly coarser. Sample no. 1 was taken about one-half mile east of sample

Table 3. Particle Size Analyses of Benson Beds Samples

No.	Location	% CO_3	Particle Size (mm) 16	8	4	2	1	0.5	0.25	0.12	0.06	pan	Total Percent Gravel	Sand	Silt & Clay
1	NW1/4,NE1/4, NE1/4,Sec.27 T15S,R20E	6.3	0.0	0.0	0.0	0.0	0.0	0.8	8.2	35.3	27.5	26.5	0.0	71.8	26.5
2	NW1/4,NE1/4, SW1/4,Sec.22, T15S,R20E	6.1	0.0	0.0	0.0	0.1	0.1	0.9	2.2	21.4	32.8	41.7	0.1	57.4	41.7
3	NE1/4,NW1/4, NW1/4,Sec.31 T15S,R20E	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.4	14.1	31.6	52.1	0.0	47.1	52.1
4	NE1/4,SW1/4, NW1/4,Sec.36 T15S,R19E	8.8	0.0	0.0	1.8	1.7	1.2	1.6	5.0	16.4	24.1	47.9	3.5	48.3	47.9
5	NE1/4,NW1/4, NW1/4,Sec.4, T15S,R20E	12.3	0.0	0.0	0.0	0.0	0.0	0.1	1.0	10.6	27.9	60.1	0.0	39.6	60.1
6	SW1/4,NW1/4, SW1/4,Sec.33 T14S,R20E	13.0	0.0	0.0	0.0	0.0	0.1	0.4	2.3	19.0	30.6	46.6	0.0	52.4	46.6
7	SW1/4,NW1/4, NW1/4,Sec.20 T14S,R20E	9.4	0.0	0.0	0.0	0.0	0.0	0.2	0.5	2.2	7.1	89.9	0.0	9.8	89.9

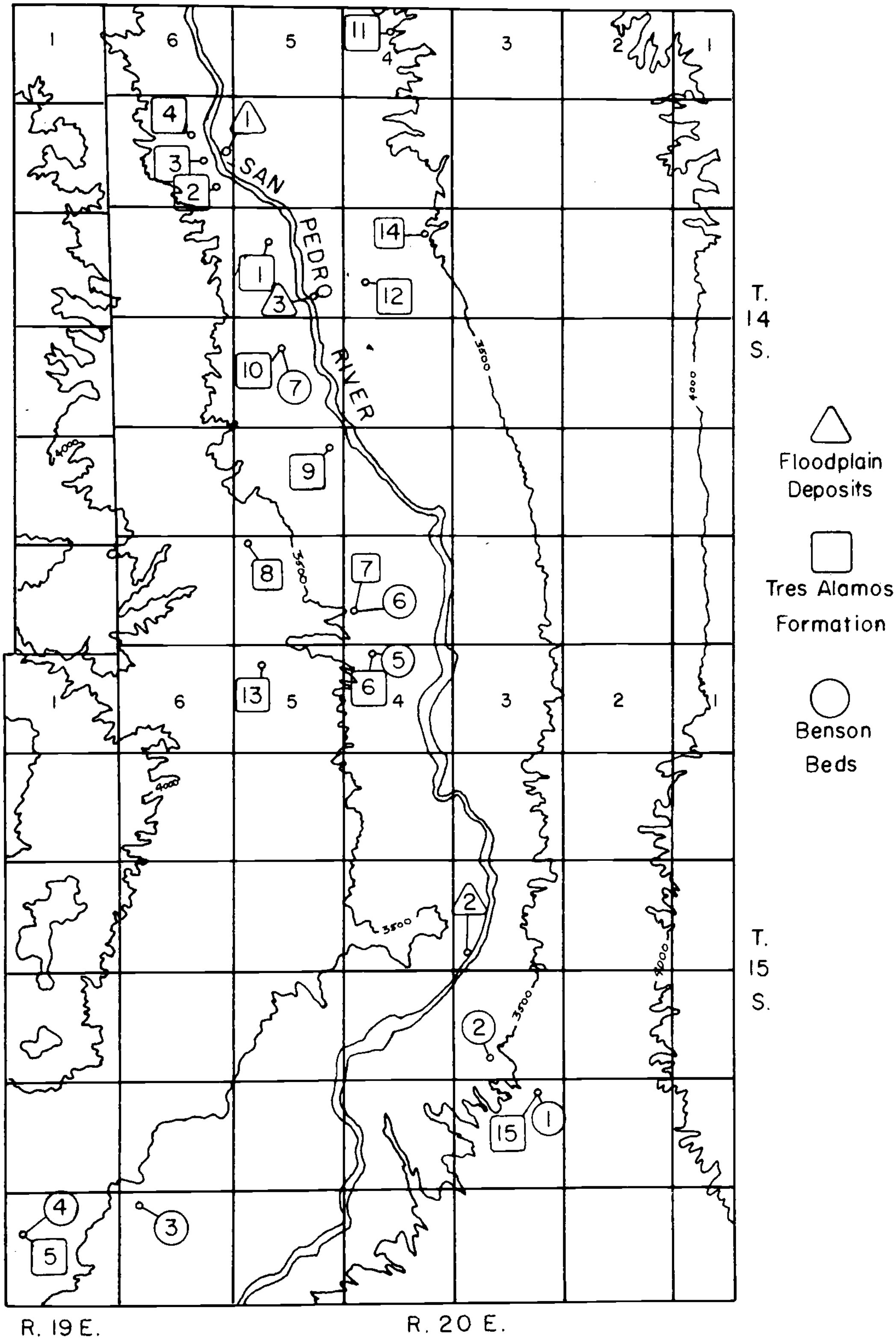

Figure 3. Index Map of Rock Samples Used in Size Analyses

no. 2 on the east side of the valley, and again the sample farther away from the center of the valley is coarse grained.

The Benson Beds are generally exposed in cliffs where they are protected by more competent overlying beds but are slope formers where most of the overlying material has been removed. In most sections near the center of the valley, there are a few thin layers of predominantly sand-size material forming small ledges on the slopes. These ledges become more abundant in exposures near the mountain fronts.

At the end of Benson Bed deposition erosion became the dominant action, and large portions of the unit were removed. The maximum relief on the eroded surface of the unit seems to be in the order of 300 feet or greater. The Pleistocene Tres Alamos formation was deposited on the eroded surface.

The Benson Beds generally do not act as an aquifer, but constitute the impermeable beds responsible for the artesian pressure in the underlying units. The fine-grained nature of the sediments would indicate the permeability in the coarse facies near the mountain fronts would rarely exceed 10. The permeability of the unit can also be seen to increase toward the mountains by noting that the carbonate or caliche content decreases in the samples taken farther away from the center of the valley (see table 3).

Quaternary

Tres Alamos Formation.--Overlying the Benson Beds in most of the Tres Alamos Dam Site area is a sequence of rocks whose relationships have not been clearly recognized heretofore. As this is a distinct mappable unit extending over large areas, it is herein defined as the Tres Alamos formation of Pleistocene age. Lateral tracing may reveal that this formation is equivalent to the Sacatan formation described by L. A. Heindl (Heindl, 1963). Descriptive sections of the Tres Alamos formation are given in that part of this paper entitled Stratigraphic Sections. The Tres Alamos formation is exposed in each section of T.14 S., R. 20 E. and R. 15 S., R. 20 E., and forms a nearly continuous belt along both sides of the San Pedro Valley. The Tres Alamos formation unconformably overlies the Benson Beds and is also in depositional contact with the Precambrian rocks making up the Tres Alamos Dam Site, the Tertiary conglomerates, and the mountain block complexes.

The Tres Alamos formation is generally light brown in color and is essentially horizontally bedded in all known locations as maximum dips do not exceed three degrees. The uppermost known outcrop of the Tres Alamos formation occurs at an elevation of about 4,200 feet, and the lowest known outcrop is exposed at an elevation of about 3,200 feet indicating an approximate relief of 1,000 feet.

Near the center of the valley the contact between the Benson Beds and the Tres Alamos formation is easily located by observing the definite change in color from the dark red-brown of the Benson unit to the light brown of the Tres Alamos. The textures of the sediments also change significantly. The underlying Benson Beds are generally fine-grained consisting of clays, silts, and the smaller sand sizes. The overlying Tres Alamos formation contains a much higher percentage of sand and often contains pebbles. Generally the Tres Alamos exposures near the center of the valley are finer grained than those exposures nearer the mountains. Table 4 indicates the size analyses completed on sediment samples from the Tres Alamos formation, and figure 3 correlates the size analyses with the locations of the rock samples. Samples no. 7, 9, and 10 are taken from exposures near the center of the valley and can be seen to consist predominantly of sand-size particles. The fine-grained facies are generally flat-bedded and would seem to indicate deposition from a less turbulent environment in or near the floodplain. The individual lenses or layers grade vertically into coarser or finer material within inches, but the horizontal extent of the single beds often exceeds the length of the outcrops.

Table 4. Particle Size Analyses of Tres Alamos Formation Samples

No.	Location	% CO_3	Particle Size (mm)										Total Percent		
			16	8	4	2	1	0.5	0.25	0.12	0.06	pan	Gravel	Sand	Silt & Clay
1	NW1/4,SE1/4, NE1/4,Sec.17 T14S,R20E	10.2	0.0	0.0	8.0	4.6	5.4	6.5	13.0	27.0	22.9	12.3	12.6	74.8	12.3
2	NE1/4,SE1/4, SE1/4,Sec.7, T14S,R20E	24.8	0.0	14.1	11.2	7.0	8.4	12.4	13.5	10.6	9.1	13.5	32.3	54.0	13.5
3	SW1/4,NE1/4, SE1/4 Sec.7, T14S,R20E	9.6	0.0	0.0	1.4	9.1	12.6	19.1	19.5	13.5	8.1	12.1	10.5	72.8	12.1
4	SE1/4,SW1/4, NE1/4,Sec.7, T14S,R20E	17.3	32.2	0.0	6.5	7.8	8.3	7.6	6.3	8.3	10.0	12.8	46.5	40.5	12.8
5	NE1/4,SW1/4, NW1/4,Sec.36 T15S,R19E	3.3	0.0	0.0	7.7	15.9	19.0	22.2	15.6	9.2	5.3	5.0	23.6	71.3	5.0
6	NE1/4,NW1/4, NW1/4,Sec.4, T15S,R20E	1.8	0.0	8.0	15.1	10.7	18.8	20.7	15.5	5.9	2.0	3.3	33.8	62.9	3.3

Table 4. Continued.

No.	Location	% CO_3	Particle Size (mm) 16	8	4	2	1	0.5	0.25	0.12	0.06	pan	Total Percent Gravel	Sand	Silt & Clay
7	SW1/4,NW1/4, SW1/4,Sec.33, T14S,R20E	9.1	0.0	0.0	0.0	0.9	2.0	5.3	15.3	23.6	22.3	30.7	0.9	68.5	30.7
8	NW1/4,NW1/4, NW1/4,Sec.32 T14S,R20E	10.3	0.0	5.0	5.6	4.5	9.1	8.8	10.8	13.3	14.3	28.4	15.1	56.3	28.4
9	SE1/4,NW1/4, NE1/4,Sec.29 T14S,R20E	11.5	0.0	0.0	0.0	0.2	0.5	1.2	5.1	14.3	18.4	60.4	0.2	39.5	60.4
10	SW1/4,NE1/4, NW1/4,Sec.20 T14S,R20E	27.8	0.0	0.0	1.0	0.5	0.5	1.8	4.1	9.3	17.5	65.3	1.5	33.2	65.3
11	NE1/4,SE1/4, NW1/4,Sec.4, T14S,R20E	1.3	0.0	29.5	7.9	6.7	11.5	11.8	10.8	7.3	3.0	11.3	44.1	44.4	11.3
12	SW1/4,NW1/4, SW1/4,Sec.16 T14S,R20E	0.4	0.0	21.3	7.6	7.0	13.6	34.5	12.0	2.3	0.4	1.1	35.9	62.8	1.1

Table 4. Continued.

No.	Location	% CO_3	Particle Size (mm) 16	8	4	2	1	0.5	0.25	0.12	0.06	pan	Total Percent Gravel	Sand	Silt & Clay
13	SE1/4,NW1/4, NW1/4,Sec. 5, T15S,R20E	8.7	0.0	4.8	19.0	14.3	21.0	14.2	7.2	5.7	5.7	8.1	38.1	53.8	8.1
14	SE1/4,NW1/4, NW1/4,Sec.16 T14S,R20E	17.5	0.0	0.0	23.6	15.8	11.8	9.4	12.4	11.4	5.8	8.7	39.4	50.8	8.7
15	NW1/4,NW1/4, NE1/4,Sec.27 T15S,R20E	1.8	0.0	0.0	0.3	1.4	3.8	6.6	10.4	12.9	16.2	48.0	1.7	49.9	48.0

Near the mountain fronts the Tres Alamos formation consists of a coarse conglomerate comprised of pebbles, cobbles, and boulders in a matrix of clay, silt, and sand; however, the boulders are not as large as those found in the Tertiary conglomerates. Rock samples no. 11, 12, and 13 were collected near the mountain fronts and contain a significantly higher percentage of coarse material. The bedding is lense-like in the coarse facies and generally grades from fine to coarse deposits within inches vertically and within feet horizontally. Cut and fill structure is common, and stream cross-bedding and pebble imbrication indicate deposition by fast moving streams.

The Tres Alamos formation generally contains a high percentage of schist pebbles which are considered to be a significant criterion for distinguishing the coarse facies of the Tres Alamos formation from the Tertiary conglomerates. The exposures of the Tres Alamos formation are often in cliffs, the most spectacular of which are located in sections 6 and 7, T. 14 S., R 20 E. The cliffs in sections 6 and 7 often exceed 100 feet in height and are essentially vertical. The sediments exposed in the high cliffs are mostly gravel with a high sand content. (See samples no. 2, 3, and 4, table 4.) In other areas the exposures consist of lower cliffs and ledgy or rounded hills.

The Tres Alamos formation contains well defined stream channel deposits in sections 30 and 31, T. 15 S., R. 20 E. These channels overlie the Benson Beds and form a resistant cap protecting the fine-grained underlying materials from erosion. The stream channel sediments consist of sand and pebbles predominantly with a calcium carbonate cement and form a competent conglomerate. The channels average about 40 feet in width and range from about 20 to 40 feet in thickness. The channel deposits are semi-continuous for a distance of about one mile in a direction roughly perpendicular to the present course of the San Pedro River.

The Tres Alamos formation is believed by the author to represent an alluvial fan and floodplain depositional environment. The coarse materials, or the conglomerate facies, near the mountains are believed to be more nearly related to alluvial fan deposition, while the finer sediments near the center of the valley were modified by the action of the ancestral San Pedro River.

The Tres Alamos formation is a source of water for several wells equipped with windmills. In these areas the unconfined ground water generally lies a few hundred feet below the surface of the ground. The permeability of the Tres Alamos unit varies with location. Near the center of the valley the values are lower corresponding to the increase in the percentage of fine material in the sediment. By comparing the size analyses of the samples from the fine-grained facies to this unit with laboratory permeability tests using similar samples (Stearns, 1927), it can be demonstrated that the permeability of the finer facies should occur in the range of 10 to 100 gpd/ft^2, although coarser lenses occurring in the sediment may raise this value. The permeability of the coarse facies near the mountain fronts should occur in the range of 10 to 1,000 gpd/ft^2 depending on the percentage of fine sand, silt, and clay present.

Floodplain Deposits.--The unit referred to in this paper as floodplain deposits occupies the present channels and floodplains of the San Pedro River and its tributaries. As defined, the floodplain deposits extend the complete length of the mapped area and roughly border the present channel of the San Pedro River. The unit overlies the Tres Alamos formation but is also in depositional contact with the Benson Beds, the Tertiary conglomerates, and the granitic rock outcrops at the Tres Alamos Dam Site.

The unit is horizontally bedded in all known outcrops except for occasional primary dips of a few degrees and is essentially undeformed. The unit varies in width from about two miles to about one-fourth mile at the Tres Alamos Dam Site and has an average thickness of approximately 120 feet and a maximum thickness of about 200 feet.

The sediments in the floodplain deposits range in size from clay to boulders. Several sections of the alluvium exposed in the river banks were examined, and some contained lenses of predominantly sand-size material varying in thickness from a few inches to several feet.

A conglomeratic facies is exposed in section 9, T. 15 S., R. 20 E., in the banks of the river. Logs of wells penetrating the floodplain deposits commonly indicate zones of much coarser material than that presently exposed in most of the outcrops. Coarse lenses are inferred to represent areas of changing stream velocity or sediments that were deposited during times of greater stream velocity and are believed to be common in the sub-surface of this unit.

Table 5 indicates the results of size analyses completed on the rock samples of floodplain deposits, and figure 3 indicates the locations of the samples. The rock samples collected for size analyses were taken from the walls of the steep banks paralleling the present channel and are believed to represent finer sediments than would be typical of this unit.

Table 5. Particle Size Analyses of Floodplain Deposits Samples

No.	Location	% CO_3	Particle Size (mm) 16	8	4	2	1	0.5	0.25	0.12	0.06	pan	Total Percent Gravel	Sand	Silt & Clay
1	SE1/4,SE1/4, NE1/4,Sec.7, T14S,R20E	20.1	0.0	0.0	0.0	1.3	1.2	4.4	9.4	18.7	18.0	46.3	1.3	51.7	46.3
2	NE1/4,SW1/4, SW1/4,Sec.15 T15S,R20E	10.5	0.0	0.0	0.4	3.2	3.8	2.2	3.6	6.5	4.6	75.5	3.6	20.7	75.5
3	NW1/4,SE1/4, SE1/4,Sec.17 T14S,R20E	21.4	0.0	0.0	0.0	0.0	0.2	0.5	1.3	4.6	10.2	83.0	0.0	16.8	83.0

Permeability estimates for the floodplain deposits must take into consideration the heterogeneity of the various beds encountered. Some of the coarse or well sorted lenses probably have permeabilities near 1,000 gpd/ft^2. As the material becomes less well sorted and fine grained, the permeability of the unit will decrease and should approach zero when material of predominantly clay and silt sizes are encountered.

Geologic Structure

The mapped area lies within the Basin and Range province which is generally accepted to have originated by faulting (Nolan, 1943). The structural basin of the San Pedro River Valley is believed to have been produced by this faulting; thus, it would be bounded by one or more major faults.

The relationships of the granitic rocks forming the Tres Alamos Dam Site to the Basin and Range development is not known. The granitic rock outcrops are closely jointed, but no evidence of faulting was found.

Parallel faults of inferred large vertical displacement are mapped in section 18, 19, and 30, T. 14 S., R. 20 E. The tilting of the Granitic Conglomerate pre-dates this faulting and may indicate deformation related to the movements forming the structural basin. The westernmost of these faults dips 43 degrees to the east and down throws the Granitic Conglomerate on the east side a sufficient distance to cause the overlying Black Conglomerate to be in contact with the Granitic Conglomerate in the exposed section. The eastern fault is not exposed in any form other than an eroded scarp, but it also seems to dip to the east and possibly at a steeper angle. The faults displace the Tertiary conglomerates, and the Plio-Pleistocene Benson Beds are in depositional contact with the eroded scarp of the eastern fault. These relations indicate that the age of the observed faulting is Tertiary, and pre-Benson Bed deposition. A fault of large vertical displacement is inferred to form the western boundary of the Granitic Conglomerate located in section 4, T. 14 S., R. 20 E. These and other unexposed faults are believed to have dropped the Tertiary conglomerates and possibly older sediments into the floor of the basin, later to be covered by the deposition of the Benson Beds. Several near vertical faults of unknown displacement offset the Granitic Conglomerate. These faults parallel the larger mapped faults and are probably related to adjustments of the unit during the time of movement on the mapped faults. The Black Conglomerate contains vertical faults of minor displacement. These faults are believed to be related to slumpage movement after consolidation of the unit.

There is evidence that the Pleistocene Tres Alamos unit has suffered minor movement. This movement is along vertical joints and is believed to be related to compaction or minor slumpage of the unit. The displacement at any one spot does not seem to exceed one or two feet.

GEOHYDROLOGY

In the San Pedro Valley ground water occurs in the floodplain deposits and in the Tertiary conglomerates, both as non-artesian and artesian water systems. The artesian water occurs below the Benson Beds in the Tertiary conglomerates, This artesian system is encountered at depths as shallow as 200 feet. The non-artesian water occurs in the floodplain deposits, the Tres Alamos formation and the Tertiary conglomerates overlying the Benson Beds.

Non-artesian Ground Water

Replenishment and Circulation

Recharge to the non-artesian aquifers is by infiltration from runoff, seepage from irrigated lands, and underflow along the San Pedro River. A primary source of replenishment to the non-artesian aquifers is seepage from runoff in channels of streams moving down from the mountain fronts and from the channel of the San Pedro River. This seepage percolates into the porous sand and gravel along washes and the floodplain of the river, and eventually reaches the ground water reservoir. An indeterminable amount of the water applied during irrigation to cultivated fields

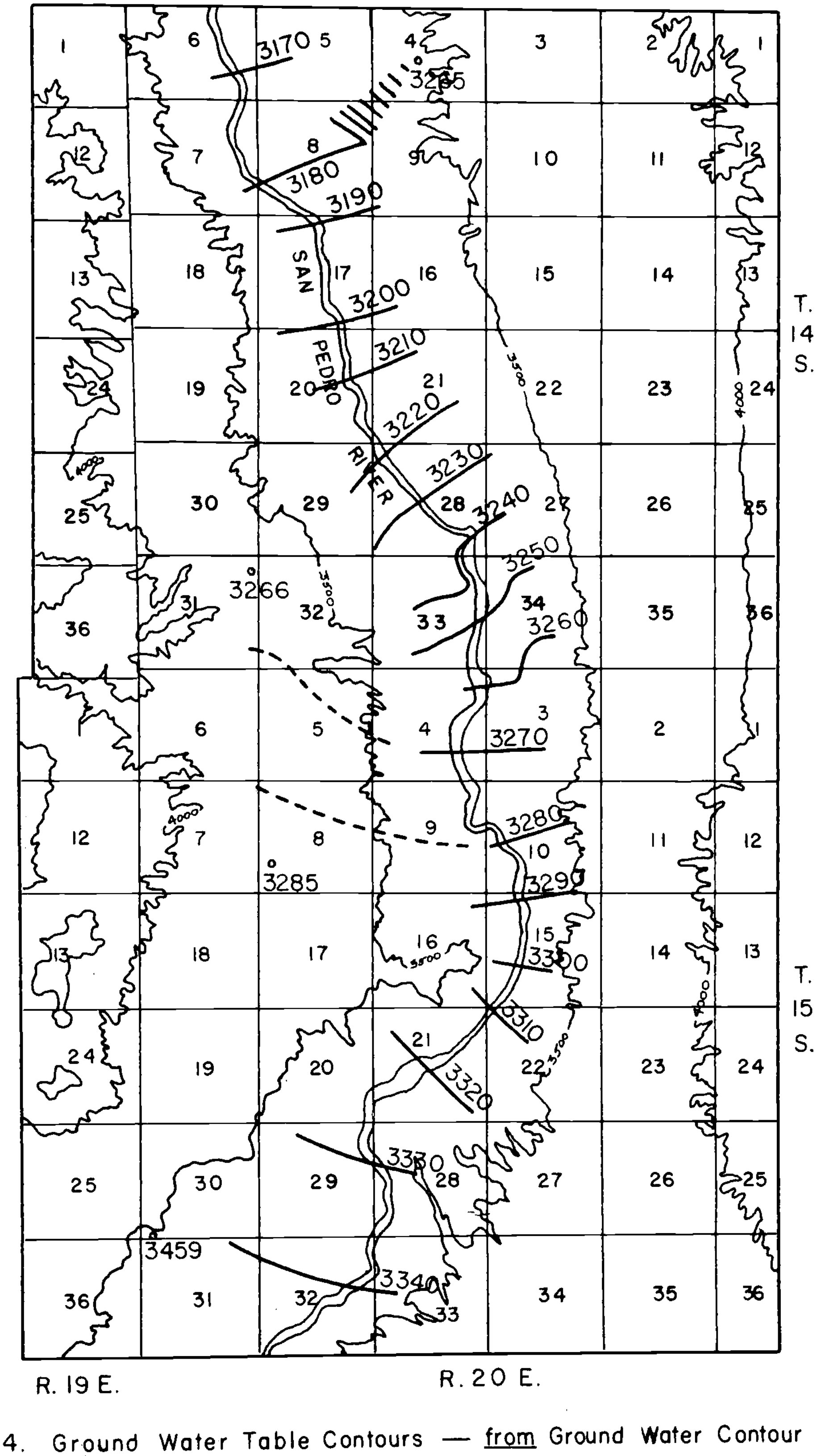

Figure 4. Ground Water Table Contours — from Ground Water Contour Map, San Pedro Valley, Dept. of Ag. Engr., U. of A. (Modified)

returns to the underlying ground water body as recharge. The amount of recharge varies with the quantity and rate of application of the irrigation water and with the permeability of the soil. Underflow is the movement of ground water in a permeable deposit which underlies a surface stream and is limited at its bottom and sides by rocks of lower permeability (Meinzer, 1960). Heindl (in Halpenny, 1952) estimated the volume of water moving downstream through the Tres Alamos Dam Site as underflow to range between 40 and 200 acre feet per year.

The natural discharge of the non-artesian aquifers partially occurs as underflow in the floodplain deposits, moving northward out of the area. Natural discharge also occurs as evapo-transpiration primarily along the channels of the San Pedro River and its tributaries. Artificial discharge is through wells that tap the non-artesian aquifers.

The unconfined ground water moves under the influence of gravity and the hydraulic gradient from the areas of recharge to the areas of discharge. The recharge originates near the mountain fronts as infiltration and from the upstream parts of the floodplain deposits as underflow. The hydraulic gradient is steep near the mountain fronts and decreases toward the axis of the valley. Near the center of the valley the slope of the water table is to the north at approximately 25 feet per mile; thus, the non-artesian ground water moves down the slopes of the valley, and north through the floodplain deposits as underflow.

Permeability and Transmissibility of the Water-bearing Units

The general distribution of several recognized units is shown on the geologic map (Plate I). The lithology of the units is described in the geology section of this paper.

The standard coefficient of permeability is defined as the flow of water at 60 degrees Fahrenheit in gallon per day (gpd) through a medium having a cross-sectional area of 1 square foot (ft^2) under a hydraulic gradient of unity or 1 foot per foot (Meinzer, 1923). The coefficient of transmissibility is the coefficient of permeability multiplied by the saturated thickness of the aquifer and is expressed as gallons per day per foot (gpd/ft). Specific capacity is a term representing the discharge of a well divided by the drawdown. The numerical value of transmissibility is approximately equal to the specific capacity of a well with entrance loss excluded multiplied by 2,000 (Ferris, 1963).

Floodplain Deposits.--The floodplain deposits average about 1 mile in width and attain a maximum thickness of about 200 feet near the San Pedro River. The lithology of the floodplain deposits was noted to be very heterogeneous

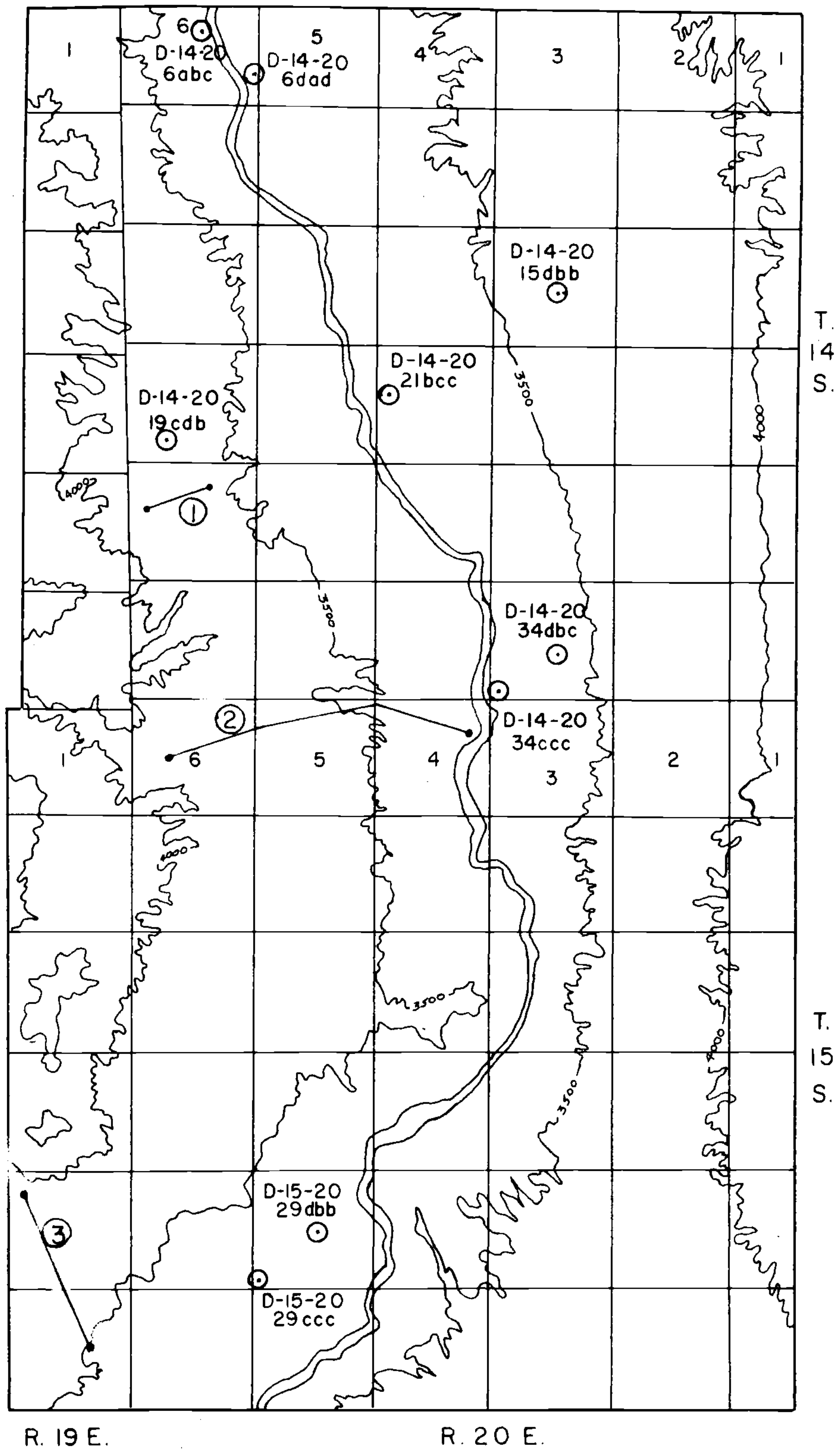

Figure 5. Index Map of Representative and Cited Wells and Measured Stratigraphic Sections

in nature. The heterogeneity indicates that the permeability would also be variable. Heindl (in Halpenny, 1952) indicates that the permeability of the floodplain deposits may range from 1,000 to 5,000 gpd/ft^2.

Well (D-14-20)34cc penetrates 60 feet of the floodplain deposits, and the lower 40 feet are indicated to be water-bearing sand and gravel. When this well is discharging 900 gpm, the drawdown is 50 feet. These data indicate a specific capacity of 18 gpm/ft of drawdown and an approximate transmissibility of 36,000 gpd/ft. The transmissibility at this point would be related to a permeability of approximately 1,000 gpd/ft^2.

The drawdown of well (D-14-20)21bcc is 10 feet corresponding to an estimated discharge of 450 gpm. The specific capacity is calculated to be approximately 45 gpm/ft of drawdown and would signify an approximate transmissibility of 90,000 gpd/ft in this area. Again about 40 feet of water-bearing strata are penetrated, indicating an approximate permeability of 2,000 gpd/ft^2. These permeabilities are representative of 40 feet of water-bearing media and should be larger where a greater thickness of aquifer is penetrated.

Tres Alamos Formation.--The Tres Alamos formation crops out in large areas between the mountain fronts and the floodplain of the San Pedro River. There are no recorded logs of wells penetrating this unit. The water level is generally greater than 200 feet below the surface, and the greatest recorded saturated thickness is in the order of 150 feet. In the geology section the permeability of the Tres Alamos formation was estimated to be in the range of 10 to 1,000 gpd/ft^2 in the coarse facies near the mountain fronts. As most of the wells drilled in this unit occur near the mountain fronts, these permeability values should be valid for transmissibility calculations. Considering only the upper 150 feet of the saturated thickness, the transmissibility should range from 1,500 to 150,000 gpd/ft. The ranchers living in the San Pedro Valley do not consider the Tres Alamos formation to be an economic source for irrigation supplies.

Tertiary Conglomerates.--The Tertiary conglomerates cropping out in the northwest corner of the mapped area are penetrated by well (D-14-20)19cdb. This well is 477 feet deep, and the lower 80 feet penetrate saturated strata. This well was tested upon completion by removing water with a bailing bucket. The well was bailed for 1 hour without going dry. The bailer removed approximatly 100 gallons of water every 2 minutes. The drawdown while bailing probably did not exceed 50 feet. If these data are accepted, the specific capacity of the well must exceed 1 gpm/ft of drawdown. The transmissibility of the aquifer appears to be greater than 2,000 gpd/ft.

The permeability of the unit was estimated to range from 100 to 1,000 gpd/ft^2. Considering only the upper 80 feet of the saturated thickness, the transmissibility is calculated to range from 8,000 to 80,000 gpd/ft. The two derivations of transmissibility then agree at least in the same order of magnitude.

Artesian Ground Water

The artesian aquifers occupy a position at depth in the center of the structural valley. Those parts penetrated by wells roughly correspond to the areas overlain by flood-plain deposits.

Replenishment and Circulation

The sand and gravel forming the permeable strata of the artesian system probably receive the greater part of their recharge from runoff. The principal recharge areas are the conglomeratic facies near the mountain fronts outside the areas underlain by the impermeable silt- and clay-rich strata. The water enters the permeable Tertiary conglomerates and the Tres Alamos formation and moves downward into the aquifers that extend beneath the confining Benson

Beds. Recharge for the artesian basin south of the Tres Alamos Dam Site probably also occurs as artesian underflow from the upstream or southern parts of the valley. Artesian underflow may or may not recharge the artesian basin north of the Tres Alamos Dam Site (see page 49).

The primary natural discharge from the northern basin probably occurs as artesian underflow moving to the north. Some natural discharge from the artesian system may occur upward into the unconfined ground water system through faults or other permeable zones. Artificial discharge is through artesian wells. If the artesian systems are not connected, the primary discharge of the southern basin may be through artesian wells and through leakage upward into the unconfined system.

Permeability and Transmissibility of the Water-bearing Units

The artesian system is believed to occur in the Tertiary conglomerates underlying the Benson Beds. Well (D-14-20)34dbc penetrates the artesian system at a depth of approximately 200 feet and terminates at a depth of 250 feet. When the drilling was completed, the water level rose to 9 feet below the top of the well. The well owner estimates the discharge to be 450 gpm, corresponding to a drawdown of approximately 50 feet. This data indicated a specific capacity of 9 gpm/ft of drawdown and corresponds to an approximate transmissibility of 18,000 gpd/ft. The permeability of the upper 50 feet of aquifer is calculated to be 360 gpd/ft^2. Earlier in this paper the permeability of the Tertiary conglomerates is estimated to range from 100 to 1,000 gpd/ft^2. The permeabilities received from both methods of calculation are essentially identical when the accuracy of the data used for calculation is considered.

The artesian aquifers probably contain thicknesses of strata greater than 200 feet. The transmissibility of the upper 200 feet of saturated media should range from 20,000 to 200,000 gpd/ft.

Influence of the Granitic Rock Barrier at the Dam Site

General Features

One of the primary objectives of the study was to determine the relationship of the ground water under artesian pressure present a few miles north of the Tres Alamos Dam Site to the artesian water in the San Pedro Valley south of the dam site. It is not definitely known whether there is any zone through which the artesian pressures are transmitted or if the artesian systems are related, This study down not provide conclusive evidence to solve this problem but several hypotheses are indicated.

The granitic rocks exposed at the Tres Alamos Dam Site appear to form a barrier extending across the valley in sections 15, 16, and 17, T.15 S., R. 20 E., in an east-west direction. There is a small gap in section 15 through which the San Pedro River passes. The minimum distance between the granitic rocks on either side of the present river channel at this location is approximately 300 feet. To the west of this crossing in the same section there is another small gap bridged by floodplain deposits. Beyond the barrier to the east and west in sections 14, 15, and 18, R. 15 S., R. 20 E., the granitic rocks are in the subsurface at an unknown depth. They are covered to the west by the Tres Alamos formation, the Benson Beds, and possibly the Tertiary conglomerates, and to the east by the Tres Alamos formation and possibly by Benson Beds and the Tertiary conglomerates.

Possible Discontinuities of Confined Water-bearing Strata

The Precambrian granitic rocks exposed at the Tres Alamos Dam Site may form an impermeable barrier separating the artesian system occurring at depth in the valley to the north and the south of the dam site. If this barrier existed in the past dividing the valley into two basins of deposition, it is possible that the sediments containing the artesian water are not continuous through the dam site area. The artesian zones are believed to exist in the Tertiary conglomerates lying at depth in the valley. There also may be artesian zones in the coarse lenses in the lower section of the Benson Beds which overlie the conglomerates. The depth to artesian water is generally greater than 200 feet. If the sediments overlying the granitic rocks at the dam site do not exceed 200 feet in depth, it would be probable that the artesian water-bearing zones do not connect.

Possible Conduits for Confined Water Transmission

Buried Channel.-- There are some indications from unpublished gravity survey data by Dr. Mark A. Melton that a significant thickness of sediments may exist to the west of the granitic rocks exposed in the Tres Alamos Dam Site. This accumulation of strata may be thick enough to contain old river channel sediments deposited in or below the Benson Beds. During Benson Bed deposition the ancestral San Pedro River must have flowed in the same general path as it presently follows, but it undoubtedly followed various channels around the granitic rocks at the dam site. The various channels would probably contain coarse sediments. As these channels were abandoned and buried by impermeable material, they would represent permeable zones around the dam site capable of transmitting water under artesian pressure. The postulated channel sediments could transmit sufficient ground water under hydraulic pressure to supply the artesian head required to the north of the dam site. It can also be postulated that the lower part of the Benson Beds may contain coarse material with a permeability great enough to transmit a significant quantity of ground water under hydraulic pressure. The base of the Benson Beds has never been recognized in an outcrop so this coarsening has not been observed, but well logs often indicate coarsening near the lower section of the Benson Beds.

Tertiary Conglomerate Remnants.--The Tertiary conglomerates exposed in section 30, T. 14 S., R. 20 E., are observed in several outcrops to lie unconformably on the older rocks composing the mountain blocks. There may be other unexposed locations where this same relationship exists, but the younger sediments of the Benson Beds or Tres Alamos formation cover the outcrops. If remnants of one or both of these conglomerates exist against the granitic rocks in the sub-surface to the east or west of the granitic barrier, it is possible that these deposits may act as a conduit for transmission of the artesian water and interconnect the systems above and below the Tres Alamos Dam Site.

Transmission Through Fault Zones.--Under structural geology it was noted that the formation of the original San Pedro Valley was probably related to the development of the Basin and Range province. This relation would indicate that large faults or fault zones exist on either side of the basin separating the valley from the various mountain block complexes. The magnitude of the movement on the faults should be in the order of several thousand feet. This large displacement indicates that the fault zones should be extensive. The faulting that dropped the Tertiary conglomerate into the central parts of the valley was probably related to Basin and Range movement and would indicate that the Tertiary conglomerates, containing the artesian groundwater system, are in intimate contact with the fault zones. If these faults were hydraulically connected with the artesian aquifers above and below the Tres Alamos Dam Site and were open at depth, they could allow the artesian water to easily circumvent the granitic barrier.

CONCLUSIONS

The principal conclusions derived from this study are as follows:

1. The principal non-artesian aquifers are the floodplain deposits, the Tres Alamos formation, and the parts of the Tertiary conglomerates not overlain by the Benson Beds. The floodplain deposits have a permeability of 1,000 to 5,000 gpd/ft^2 and yield moderate to large amounts of water to wells. The Tres Alamos formation has a permeability of 10 to 1,000 gpd/ft^2 in the conglomeratic facies and yields small amounts of water to wells. The parts of the Tertiary conglomerates not overlain by Benson Beds have a permeability from 100 to 1,000 gpd/ft^2 and yield small to moderate amounts of water to wells.

2. The principal artesian aquifers are the Tertiary conglomerates underlying the Benson Beds in the central parts of the San Pedro Valley. The permeability of the Tertiary conglomerates ranges from 100 to 1,000 gpd/ft^2. The artesian system occurring in the conglomerates is penetrated at a minimum depth of about 200 feet below the surface of the valley floor.

3. The unconfined ground-water system is recharged from runoff in the San Pedro River and its tributaries, from

from underflow moving north in the floodplain deposits, and from seepage from irrigated lands.

4. The confined ground-water system is recharged from runoff percolating through the conglomeratic facies in areas not underlain by Benson Beds and from artesian underflow moving north under the Benson Beds.

5. The artesian systems may or may not be hydraulically connected. If the systems are connected the artesian water may be transmitted through a buried channel in the Benson Beds, through sub-surface remnants of the Tertiary conglomerates, or through regional fault zones.

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APPENDIX

Table 6. Driller's Logs of Representative Wells (thickness and depth in feet)

Well	Material	Thickness	Depth
(D-14-20)6abc	Surface Sand	3	3
	Blue Clay	31	34
	Clay, pink and blue	4	38
	Sand (water)	32	70
	Clay, sandy	25	95
	Clay, sandy	25	120
(D-14-20)6dad	Surface Sand	3	3
	Clay	35	38
	Sand (water)	32	70
	Clay	10	80
	Very hard granite conglomerate	21	101
(D-14-20)15bdd	Layers of soil, sand, clay	60	60
	Fine Sand (water)	20	80
	Fine Sand, some clay	10	90
	Good Sand, Water, Coarse Sand	20	110
	Clay	5	115
(D-14-20)19cdb	Gravel and conglomerate	40	40
	Hard conglomerate	300	340
	Hard conglomerate, some sand conglomerate	137	477
(D-14-20)24dbc	Light sand, silts	20	20
	Sand and clay	130	150
	Clay, some sand	50	200
	Sand and clay cemented	46	246
(D-15-20)29dbb	Topsoil	3	3
	Clay	18	21
	Sand, gravel (water)	34	55
	Red clay	34	89
	Yellow clay	56	145
(D-15-20)29ccc	Topsoil	3	3
	Clay	38	41
	Sand, gravel	48	86
	Red clay	38	124
	Yellow clay	16	140

Table 7. Measured Stratigraphic Sections

No. 1. Location: Section 30, T. 14 S., R. 20 E.

Pliocene (?):

Black Conglomerate:	Feet
2. Conglomerate, dark grayish-brown; lenticular bedding; contains some crossbeds; weathers massive; forms competent cliffs. Base sharp and irregular. Matrix: Fine to coarse; poorly sorted; well cemented, calcareous Gravel: Contains granitic, metamorphic, and Paleozoic sedimentary pebbles, cobbles and boulders.----	48
Total Black Conglomerate ------------	48

Unconformity: Slight relief.

Miocene (?):

Granitic Conglomerate:	Feet
1. Conglomerate, light gray, slightly reddish in areas; coarse lenticular bedding; dips about 40° to the east; weathers massive; forms competent cliffs. Base sharp and irregular. Matrix: Fine to coarse grained; poorly sorted; well cemented, calcareous. Gravel: Contains primarily granitic but also metamorphic and Paleozoic sedimentary pebbles, cobbles, and boulders.-------------------------	1,200
Total Granitic Conglomerate ---------	1,200

Unconformity: Moderate relief.

Precambrian Granite: Undescribed.

No. 2. Location: Sections 4, 5, and 6, T. 15 S., R. 20 E.

Pleistocene:

Tres Alamos Formation:

5. Conglomerate, light grayish-brown, locally reddish-brown; lenticular bedding; forms competent to rough cliffs. Base gradational.

Pleistocene - Continued

Tres Alamos Formation - Continued	Feet
Matrix: Fine to coarse grained; poorly sorted; moderately cemented, calcareous. Gravel: Contains granitic, metamorphic, Paleozoic sedimentary pebbles, cobbles and boulders.----	286
4. Conglomerate, light grayish-to reddish-brown; lenticular bedding; forms rough cliffs to ledgy slopes. Base gradational. Matrix: Fine to coarse grained; poorly sorted; moderately to poorly cemented, calcareous. Gravel: Contains granitic, metamorphic, and Paleozoic sedimentary pebbles and cobbles.--------------	136
3. Sandstone, light brown to orange-brown, fine to very coarse grained, poorly sorted; poorly cemented, calcareous; unit consists of thin to thick flat beds; forms ledgy slopes. Base generally sharp and irregular.--------------------------	24
Total Tres Alamos Formation ---------	446

Unconformity: Small to large relief (1-200 ft).

Plio-Pleistocene:

Benson Beds:	
2. Mudstone, reddish-brown to dark reddish-brown, fine grained, poorly sorted; poorly to moderately cemented, calcareous; forms ledgy slopes. Contains abundant extensive lenses and stringers of coarse sandstone. Base gradational.------------------------	72
1. Mudstone, dark to light reddish-brown, fine grained, poorly sorted; poorly to moderately cemented, calcareous; forms smooth slopes. Contains rare lenses of sandstone. Base not exposed.--------------------	128
Total Benson Beds ------------------	200

Unconformity: Not exposed in most areas.

Pliocene:
Black Conglomerate: Undescribed.

No. 3. Location: Sections 25 and 26, T. 15 S., R. 19 E.
Pleistocene:
Tres Alamos Formation: Feet

5. Conglomerate, light grayish-brown; lenticular bedding; contains some crossbeds, forms rough cliffs and ledgy slopes. Base gradational.
Matrix: Fine to coarse grained; poorly sorted; moderately cemented, calcareous.
Gravel: Contains granitic, metamorphic, and Paleozoic sedimentary pebbles and cobbles.-------------- 132

4. Conglomerate, light brown; irregular and thin to thick bedded; contains crossbeds and graded beds; forms steep ledgy slopes. Base gradational.
Matrix: Fine to coarse grained; poorly sorted; moderately to poorly cemented, calcareous.
Gravel: Contains granitic, metamorphic, and Paleozoic sedimentary pebbles.-------------------------- 88

3. Sandstone, light brown, fine to very coarse grained, poorly sorted; poorly to moderately cemented, calcareous, contains thin to thick flat beds; forms ledgy slopes. Base generally sharp and irregular.----------------- 66

Total Tres Alamos Formation --------- 286

Unconformity: Slight to high relief.

Plio-Pleistocene:
Benson Beds:

2. Mudstone, dark reddish-brown, fine grained, poorly sorted; poorly to moderately cemented, calcareous; forms ledgy slopes. Contains abundant extensive lenses and stringers of pebble conglomerate and coarse sandstone. Also commonly contains calcereous nodules (1 to 6 inches). Base gradational.-------------------------------- 92

Plio-Pleistocene - Continued

Benson Beds - Continued — Feet

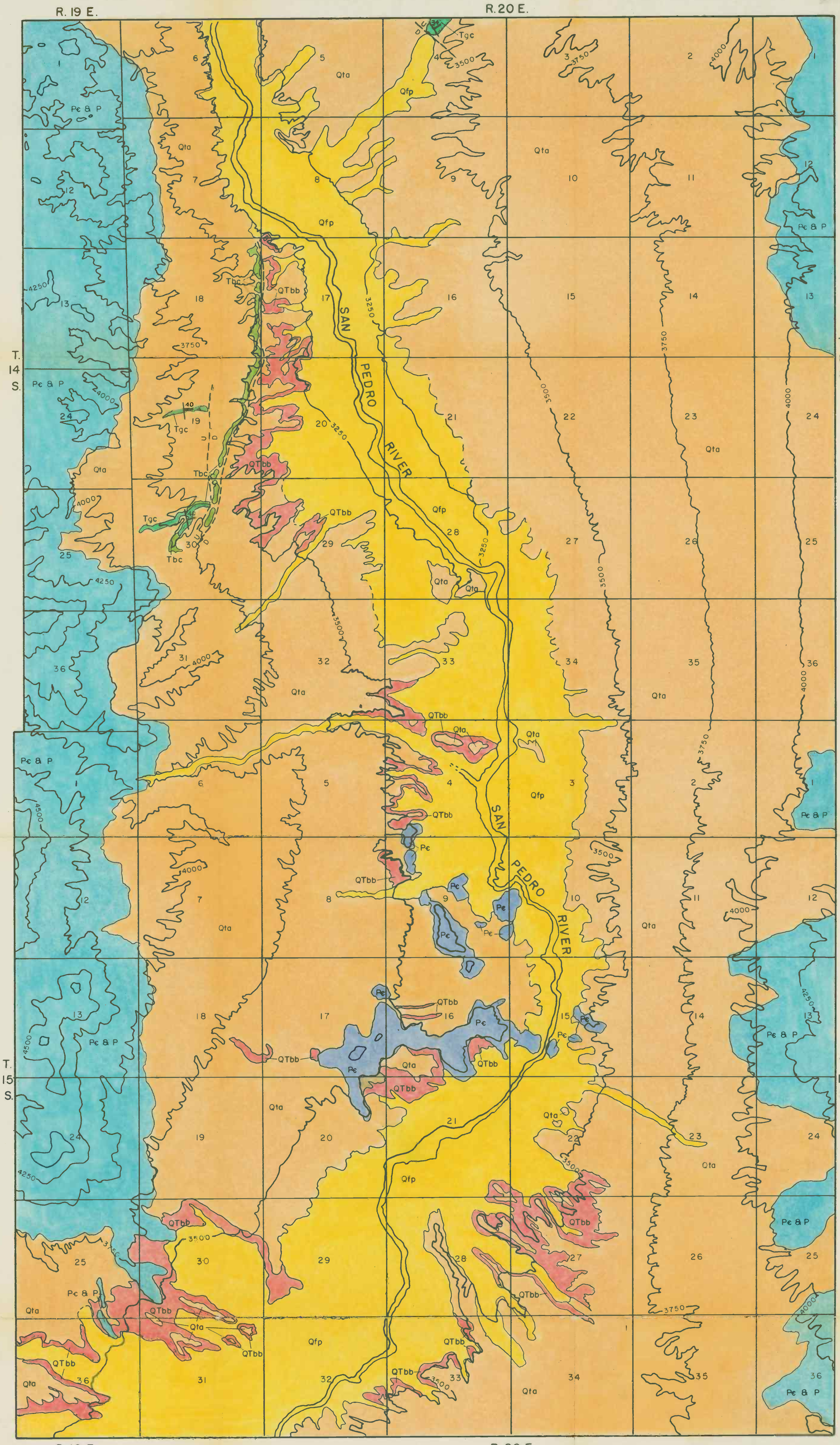
1. Mudstone, dark reddish-brown, fine grained, poorly sorted; poorly to moderately cemented, calcareous; forms smooth to ledgy slopes. Contains occasional lenses of medium to coarse sandstone. Base not exposed.-- 79

Total Benson Beds -------------------- 171

Unconformity: Not exposed in most areas.

Pliocene:

Black Conglomerate: Undescribed.



EXPLANATION

QUATERNARY

Pleistocene and Recent

Qfp

Floodplain Deposits

Unconsolidated alluvial deposits of clay, silt, sand and gravel. Average thickness is 150 feet. Coarse-grained beds yield moderate to large amounts of water to wells.

Qta

Tres Alamos Formation

Fluvial deposits of silt, sand and gravel. Known thickness exceeds 450 feet. Coarse-grained facies yield small amounts of water to wells.

Pliocene and Pleistocene

QTbb

Benson Beds

Fluvial deposits of clay, silt and sand. Known thickness exceed 400 feet. Forms confining layer for underlying artesian system.

TERTIARY

Pliocene (?)

Tbc

Black Conglomerate

Consolidated alluvial deposits of silt, sand, gravel, cobbles and boulders. Known thickness exceeds 100 feet. May form part of artesian aquifer below Benson Beds. Conglomerate yields moderate amounts of water to wells.

Miocene (?)

Tgc

Granitic Conglomerate

Consolidated alluvial deposits of silt, sand, gravel, cobbles and boulders. Known thickness exceeds 1,200 feet. May form part of artesian aquifer below Benson Beds. Conglomerate yields moderate amounts of water to wells.

UNCONFORMITY

PALEOZOIC AND PRECAMBRIAN

Pc & P

Mountain Block Complex Undifferentiated

Precambrian granite, gneissic granite, schist, and Paleozoic limestone, shale, sandstone and quartzite.

Pc

Precambrian Granite

Granitic rocks cropping out at the Tres Alamos Dam Site.

SYMBOLS

Contact

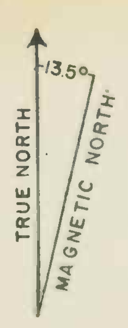
Dashed where approximately located.

Fault

Dashed where inferred. U, upthrown side; D, downthrown side.

Strike and dip of tilted beds.

Geology by
E. L. Montgomery, 1963



GEOLOGIC MAP
OF THE
TRES ALAMOS DAM SITE AREA
COCHISE COUNTY, ARIZONA

Postul Montgomery (41)

SCALE 1/31,680

0 0.5 1.0 2.0 Miles

CONTOUR INTERVAL: 250 Feet

DATUM PLANE MEAN SEA LEVEL

E9791
1963
105