CORRELATION OF GROUND-WATER QUALITY WITH DIFFERENT SEDIMENT TYPES, LOWER SANTA CRUZ BASIN, ARIZONA

By

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The quality of the ground water in the alluvial basins of southern Arizona is extremely varied and is greatly influenced by the geologic characteristics of the sediments in the aquifers. The concentrations of the dissolved solids differ both areally and with depth in the basins. These differences in water quality undoubtedly are related closely to the mineralogy and texture of the sediments, but little quantitative information is available to define these relationships.

Most of the data on the quality of the ground water in these basins have been obtained from chemical analyses of samples pumped from wells that penetrate several water-bearing horizons. The depth of the wells ranges from less than 100 feet to more than 1,000 feet, and casings usually are perforated from the water level to the bottom of the hole. The water obtained by pumping the well is a composite or mixed sample from several horizons, and this masks even large differences in the water-quality characteristics of the different water-bearing zones. The depth-quality relation is more complex in the deep wells because many different water-bearing zones are penetrated.

Useful information regarding differences and correlations requires subsurface geologic control—such as drillers' logs, electric logs, and complete analyses of well cuttings—and detailed water-quality information obtained from water samples collected in such a way as to define quality in the various water-bearing horizons.

Probably the best way of getting information on water quality in the valley fill is to collect water samples at the time of drilling, either by means of a bailer on cable-tool rigs or by packers on the drill stems of rotary rigs. Until the practice of collecting water samples for the purpose of ground-water exploration becomes an accepted part of a drilling operation, the hydrologist must rely on substitute methods of sampling. Two methods that can be used in lieu of the above are: (1) a water-conductivity traverse within the well bore by means of a conductance probe, and (2) collection of samples at various depths by means of a sampler designed to take point samples.

Water-quality data and geologic data obtained while drilling at a few sites near Phoenix in Maricopa County indicated that chemical-quality differences could be detected and correlated with differences in lithology and particle-size distribution of the sediments. Water quality was determined in terms of specific conductance (expressed in micromhos per centimeter at 25°C) and of concentrations of the sulfate and chloride ions. Specific conductance is a measure of the ability of the water to conduct an electric current and is a rough measure of the amount of salts dissolved in the water.

These results encouraged the writers to attempt to collect chemical-quality data from wells in the alluvial aquifers in other areas. It was expected that samples collected at different depths in the well bore would show results similar to those obtained during drilling. Small differences in water quality might be obscured by mixing of the water in the well bore; nevertheless, it seemed worthwhile to obtain water-quality measurements and to determine their usefulness, when correlated with geology, in the analysis of the hydrology of a study area. Equipment for collecting water samples from any depth was obtained recently by the Tucson office of the Quality of Water Branch, U. S. Geological Survey.

The sampler (Fig. 1) is about 2 inches in diameter and about 3 feet in length and holds about 1 quart of water. The sampler is lowered into the well by means of a steel cable fastened to a reel. Each end of the sampler contains a ball valve that traps the water in the sampler when it is raised and lowered several times in rapid succession at the desired depth. Field specific conductance and temperature of the water are measured immediately upon removing the sampler from the well. If more complete data are needed, samples are analyzed in the laboratory.

Through the cooperation of Mr. Carl Anderson and Mr. Marvin Young—manager, San Carlos Irrigation and Drainage District, and project engineer, Bureau of Indian Affairs, San Carlos Irrigation Project, respectively—the Geological Survey was permitted to make detailed quality-of-water investigations in wells belonging to the San Carlos Irrigation Project. During April 1961 about 15 wells were sampled, ranging in depth from 300 to 1,400 feet. Water samples in these wells were collected from zones 100 to 1,000 feet below the land surface. The wells were selected because the pumps were temporarily removed for repair, thus allowing entrance of the sampler, and because complete records of the wells were available. The wells are in the Casa Grande-Coolidge area in the lower Santa Cruz basin, Pinal County. The results of this fieldwork were most encouraging, as the field specific conductances of the water samples collected at various depths revealed differences in water quality in a small part of the basin.

The most striking and previously unknown quality-of-water situation was discovered in 3 wells about 8 miles east of Casa Grande and about 10 miles southwest of Coolidge in T. 6 S., R. 7 E. These wells are spaced from 1-1/2 to 2 miles apart and range in depth from 810 to 1,385 feet. The well casings are perforated from near the water table to the bottom. The results of the chemical analyses are as follows:

Depth of sample (feet below land surface)	Temperature (^{o}F)	Hardness as $CaCO_3$ (ppm)	Sulfate (SO_4) (ppm)	Chloride (Cl) (ppm)	Specific conductance (micromhos at 25°C)
		Well 83			
300	75	404	-	-	1,480
350	75	522	187	248	1,460
375	77	1,610	528	6,580	19,300
400	76	1,600	-	-	20,500
550	80	2,230	817	10,400	29,400

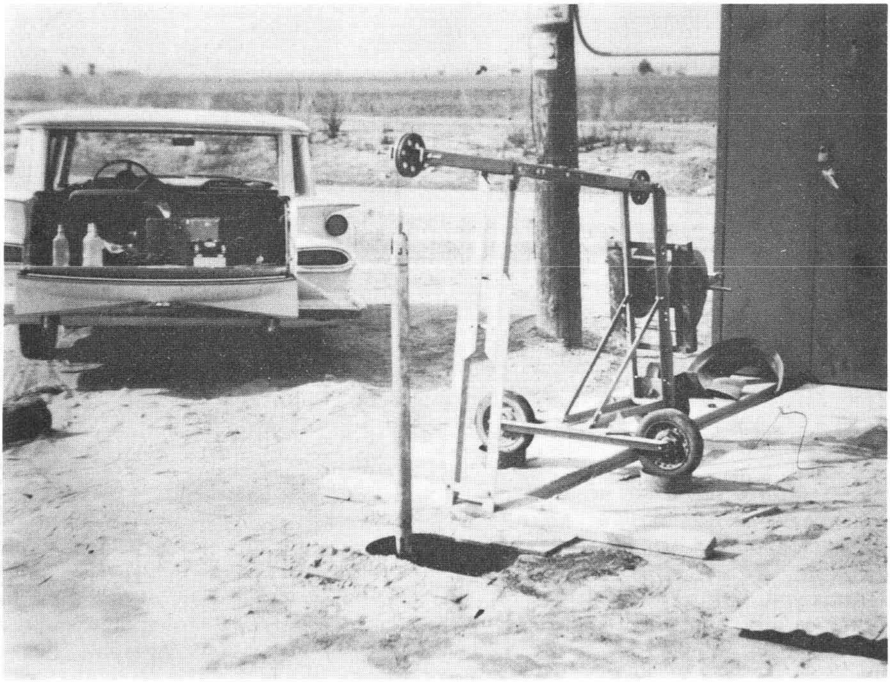

Figure 1.--Sampler for collection of water at any depth in a well.

Depth of sample (feet below land surface)	Temperature (^{o}F)	Hardness as $CaCO_3$ (ppm)	Sulfate (SO_4) (ppm)	Chloride (Cl) (ppm)	Specific conductance (micromhos at $25^{o}C$)
		Well 85			
250	71	545	-	-	1,460
500	77	1,770	1,140	2,950	10,400
1,000	77	1,230	742	1,780	6,730
		Well 115			
200	76	-	-	-	1,450
350	76	-	-	-	1,020
500	77	274	81	194	1,010
940	78	-	-	-	1,030

Differences in specific conductance and temperature of the water from these wells at various depths are accompanied by corresponding differences in hardness, sulfate, and chloride. This observed change in quality with depth is significant because it suggests the possibility of changes in lithology of the sediments penetrated by the wells.

In the lower Santa Cruz basin the major rock unit yielding ground water is the valley fill or alluvial deposits. These terms are applied to all the unconsolidated and semiconsolidated rocks that occupy the basin floor. These sediments may be a thousand or more feet thick and underlain by indurated sediments yielding little or no water to wells. The process of deposition, including movement and sorting of rock material either from through-flowing streams or from adjacent mountains, is common in the basins of southern Arizona. The deposition of the valley-fill deposits has been divided into subunits indicative of different lithologic characteristics that largely determine the hydrologic properties and water quality.

To correlate water quality with sediment types, a geologic section (Fig. 2) was prepared from drillers' logs and examination of drill cuttings. The section is in T. 6 S., R. 7 E., and extends 3-1/2 miles eastward from well 115 to well 83. The section (Fig. 2) shows a permeable zone of sand and gravel and some clay at the land surface to a depth of 260 to 375 feet below the land surface. This shallow zone yields moderate to large amounts of water to wells. In the spring of 1934, the static water level along the profile was about 35 to 50 feet below the land surface. With little recharge of water to the aquifer and continued pumping for irrigation, the water level declined markedly. In the spring of 1961, the static water level along the profile was about 185 to 260 feet below the land surface. Wells were deepened because of the declining water table, and a thick layer of silty clay was found below the permeable sediments. This silty clay is less permeable and finer grained than the overlying sediments, and water yield per foot of drawdown is small. The silty clay probably was deposited in a body of standing water—where a body of water lacks an outlet, evaporation causes the formation of gypsum and other salts as indicated in the geologic section. If the lake is ephemeral there may be different horizons of gypsum and salt deposition. Thus, other gypsum and salt zones may be found elsewhere in the basin.

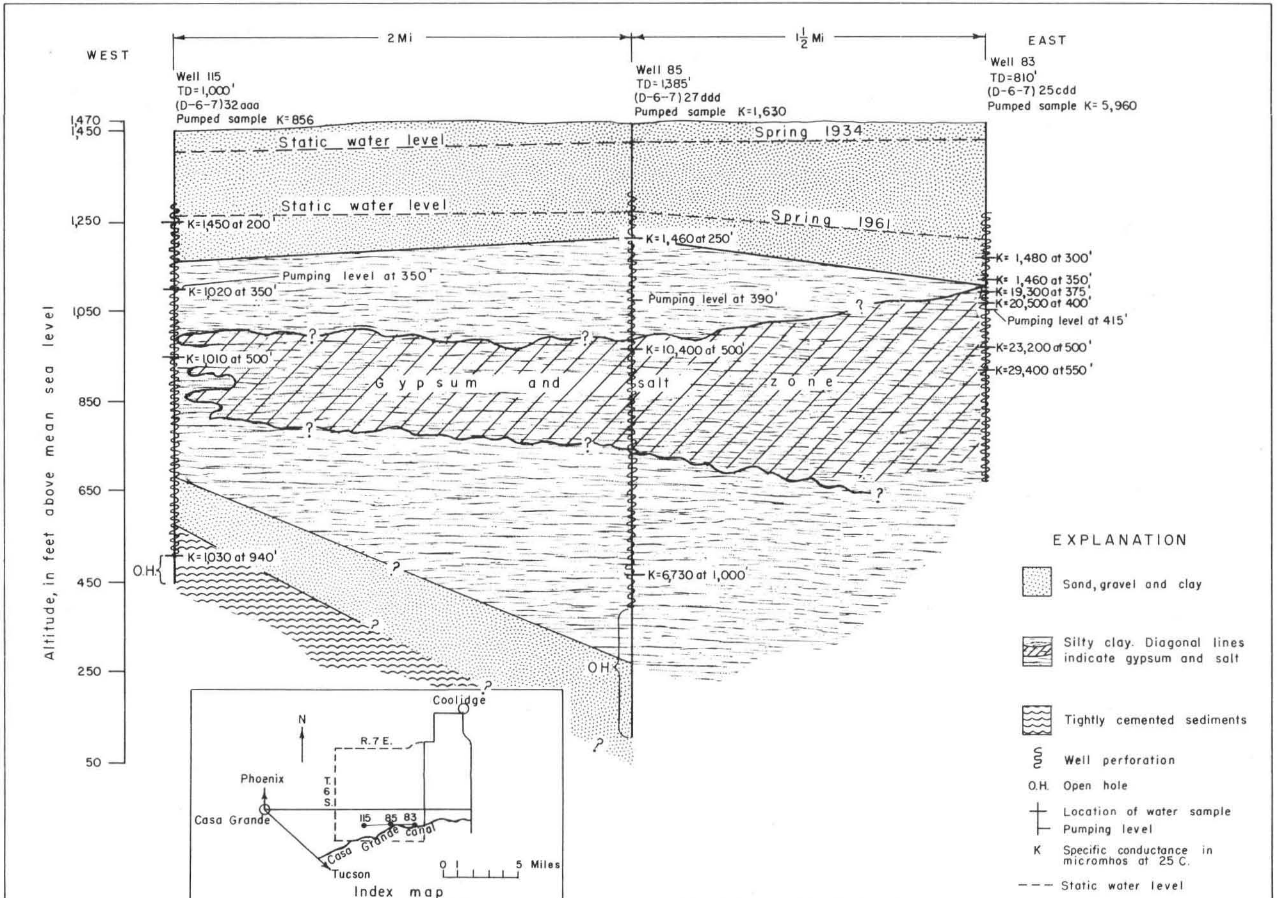

Figure 2. —Geologic section across T. 6 S., R. 7 E., lower Santa Cruz basin, Ariz., showing changes in conductance of water with depth.

Explanation of the apparent water-quality anomalies at wells 83, 85, and 115 was greatly simplified when the values for specific conductance were added to the section illustrated in Figure 2 at appropriate depths. The specific conductance of the water in well 83 ranged from 1,480 micromhos at 300 feet to 29,400 micromhos at 550 feet below the land surface. The well was reported to be 810 feet deep, but owing to caving it was not possible to collect samples below 550 feet. The conductivity changed markedly between 350 and 375 feet, near the contact of the upper sandy horizon with the gypsum and salt zone in the silty clay layer. A conductivity traverse made at a later date showed that the conductivity changed at 360 feet below the land surface.

When well 83 was pumped, the specific conductance of the composite sample collected at the discharge pipe was 5,960 micromhos. The pump setting was at 440 feet. In 1960 the well yielded 675 gpm (gallons per minute) with 214 feet of drawdown for a specific capacity of 3.2 gpm per foot of drawdown. The pumping level in May 1961 was at 415 feet, which is in the gypsum and salt zone in the silty clay bed. Most of the water pumped from the well probably came from the more permeable zone above 360 feet, because the conductivity of the pumped sample was only about one-fourth as great as the conductivity of the water in the gypsum and salt zone of the less permeable silty clay beds.

Simple laboratory tests were made to determine what proportion of mixing of the waters of different conductivities would be required to produce a composite sample with a conductivity of 5,960. It was assumed that the water from the gypsum and salt zone in the lower silty clay bed had an average conductivity of 24,000 micromhos. When 186 parts of water with a conductivity of 24,000 was combined with 1,000 parts of water with a conductivity of 1,480, the resultant conductivity of the water mixture was 5,960 micromhos. This is a ratio of about 1 to 5.

Similar data were collected from well 85, about 1-1/2 miles west of well 83. The conductivity of the water was 1,460 micromhos at 250 feet and 10,400 micromhos at 500 feet below the land surface. The quality of the water improved at depths between 500 and 1,000 feet. The conductivity of the water at 1,000 feet was 6,730 micromhos, and it is possible that the water at this depth is better than indicated. The presence of water of good quality in the more permeable sands from 1,000 to 1,385 feet below the land surface at this well may be obscured by mixing in the well bore owing to settling of the more dense water from above. Closer correlation with the diffusion zone of well 83 might have been possible if more samples had been collected. Unfortunately, a pump was installed in the well before additional samples could be collected.

The specific conductance of the water from well 85 was 607 micromhos in 1941 at its original depth of 250 feet. Subsequent lowering of the water table in the area made it necessary to deepen the well to 400 feet in 1947. At this depth, the well yielded water with a specific conductance of 1,400 micromhos. In 1959 the well was deepened to its present depth of 1,385 feet. The conductivity of the water from the pumped well, in the spring of 1961, was 1,630 micromhos. The pump was set at 500 feet and the well yielded 950 gpm with 220 feet of drawdown for a specific capacity of 4.3 gpm per foot of drawdown in 1960. The pumping level was at 390 feet, which is above the gypsum and salt zone in the silty clay bed.

Assuming that the average conductivity of the water from the gypsum and salt zone in the silty clay layer at well 85 is 8,500 micromhos—the average specific conductance of samples collected at 500 and 1,000 feet—only about 2 percent of the water pumped came from the gypsum and salt zone. The remaining 98 percent came from the more permeable sandy zone above 260 feet and (or) from the more permeable zone below 1, 200 feet.

The specific conductance of the sample at the discharge pipe of well 115 was 856 micromhos, and the specific conductance of the point samples ranged from 1, 010 to 1, 030 in the silty clay and tightly cemented sediments. The tightly cemented sediments probably yield little or no water, so water of excellent quality under artesian pressure must be coming from the permeable sand, gravel, and clay zone at 770 to 870 feet below the land surface. Unfortunately no water sample was collected from this zone. Undoubtedly water of high conductivity is in the silty clay layer penetrated by the well, but it is masked in the well bore by the upward flow of good water. Analyses of drill cuttings indicate that silty clay contains gypsum at about 450 feet below the land surface.

The pump in well 115 was set at 350 feet below the land surface, and the well yielded 1, 750 gpm with 164 feet of drawdown for a specific capacity of 10. 7 gpm per foot of drawdown. The specific capacity of this well is about three times greater than the specific capacities of wells 83 and 85, probably because well 115 completely penetrates the more permeable zone below the silty clay. The pumping level was below the contact of the upper sandy horizon and the silty clay layer but above the gypsum and salt zone.

The pumping levels of wells 83, 85, and 115 are in different lithologic horizons, and the hydrologic conditions at each well are different. This explains the difference in the quality of the water at the discharge pipes. As the water levels continue to decline because of extensive pumping for irrigation, less water of good quality will be available from the shallow sand, gravel, and clay zone. The gypsum and salt zone in the silty clay may cause deterioration of water quality in the future at wells 83 and 85. If a pump is set near the gypsum and salt zone in well 115, the conductivity of the water at the discharge pipe probably will increase. However, if the lower sand, gravel, and clay zone contributes moderate amounts of water of good quality, the change in the quality of the water yielded by the well probably will not be great.

The results of this study are directly applicable only to the area investigated, but the quality-of-water conditions may be typical of other parts of the alluvial basins of southern Arizona. It is evident from the data presented that water samples collected at the discharge pipe of a pumping well are not necessarily indicative of the quality of the water in the valley fill where more than one water-bearing bed is tapped by the well. Quality-of-water data collected at time of drilling or from point samples under static conditions and correlated with sediment types, as described in this paper, are essential to an accurate understanding of the ground-water system and the changes imposed upon it by mans' manipulations.