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GROUND-WATER RESOURCES OF SANTA FE COUNTRY

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INTRODUCTION

Except for one detailed study of the Santa Fe area (Spiegel and Baldwin, 1963), most of the information on ground water in Santa Fe country is site-specific, or if regional, rather generalized. Ongoing research by the U.S. Geological Survey is expected to provide a more comprehensive discussion of the regional ground-water resources within a few years (Mourant, 1979). The available information on ground water in both Santa Fe and Taos counties has been summarized in recent reports which have not been circulated widely (Wilson and others, 1978a,b). Most of this article is extracted directly from the two county reports, which collectively contain several hundred pages on water-related subjects. The extracts have been selected to highlight areas of controversy, especially related to the water supply of the city of Santa Fe and environs.

AQUIFER GROUPS

Table 1 lists the major geologic units found in Santa Fe country, and especially the County of Santa Fe. For purposes of evaluating ground-water resources, the units can be grouped into four categories or resource areas:

(1) Santa Fe Group basin: areas where Santa Fe Group has tentatively thick saturated section and/or has been studied more. Water in storage is estimated at 1,600-16,000 acre-feet/square mile (7.7 to 77 x 105 m3/km2) (Wilson and others, 1978a).

(2) Santa Fe Group fringe: areas where Santa Fe Group has thinner saturated section and/or has not been studied well. Water in storage is estimated at 320-1,600 acre-feet/square mile (1.5 to 7.7 x 105 m3/km2).

(3) Mountain area: areas of Precambrian and other rocks which provide a limited water supply.

(4) Homestead area: areas of Mesozoic and Paleozoic sediments, igneous rocks and other units which provide a limited or no water supply, and/or which have serious water-quality prOblems.

A map of the four resource areas (fig. 1) has been prepared for the County of Santa Fe. Similar patterns are found north to Taos County, except that in the Taos area, there is no pronounced basin containing Santa Fe Group sediments, and most of the poorly productive (Homestead) area is underlain by volcanic rocks which are known to be water-bearing at depths of several hundred feet or more.

The most important aquifer in the region is the Santa Fe Group. The following description applies to this Group in the vicinity of the City of Santa Fe. The Tesuque Formation, the basal unit of the Santa Fe Group, consists of "several thousand feet of pinkish-tan soft arkosic, silty sandstone and minor conglomerate and siltstone" (Spiegel and Baldwin, 1963, p. 39). It is an alluvial fan deposit created by erosion of the Precambrian and Paleozoic rocks of the mountains (Miller and others, 1963). According to Miller, abrupt changes in texture both vertically and horizontally are the rule in the Tesuque Formation and few beds can be traced for more than a mile or two. The sandstone beds are cemented by calcium carbonate, and at most places, even unconsolidated materials are highly calcareous. The beds strike generally north-south and dip westward toward the axis of the trough. Dips may be nearly 30 degrees near the mountains but flatten toward the trough axis. The Tesuque Formation underlies most of the area north of the Santa Fe River.

The Ancha Formation, which rests with angular unconformity on the Tesuque Formation, consists of gravel, sand and silt similar in appearance to the Tesuque Formation (Spiegel and Baldwin, 1963, p. 45-50). The Ancha is generally coarser, more poorly sorted and unconsolidated compared to the Tesuque Formation, yet the contrast in dip between the nearly horizontal Ancha Formation and the tilted Tesuque beds is the principle differentiating factor. The Ancha Formation covers most of the Santa Fe area south of the Santa Fe River fault, a normal fault which is near and approximately parallel to the Santa Fe River. The Ancha ranges in thickness from 100 to 200 ft (30 to 60 m) in the south-central part of the area to at least 300 ft (90 m) in the southern portion of the area.

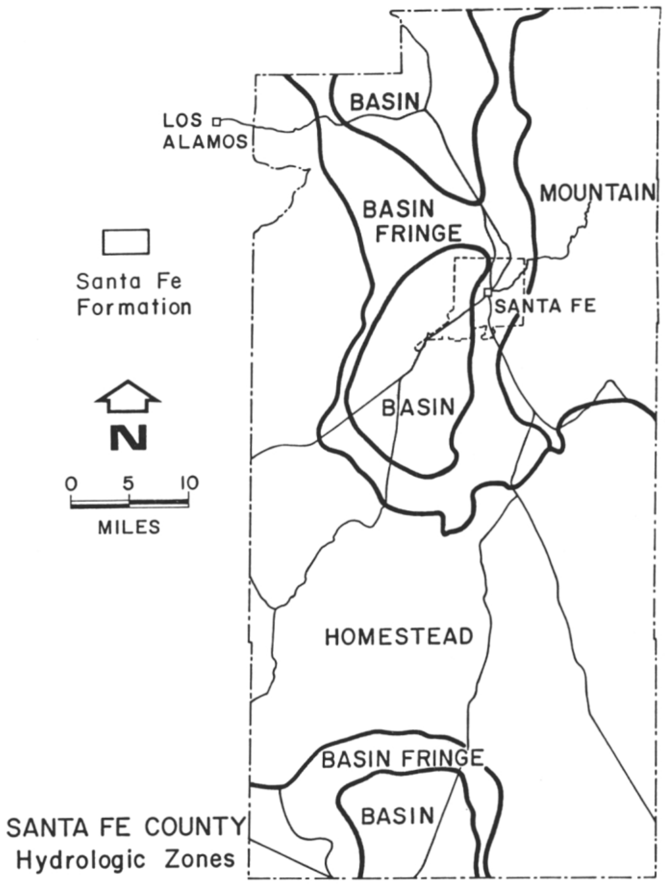

Figure 1. Map of the four resource areas, Santa Fe County.

Table 1. Major Geologic Units, Santa Fe Country (from Hagerman, 1974)

UNIT	DOMINANT LITHOLOGY	EXTENT AND LOCATION	WATER-BEARING CHARACTERISTICS
Precambrian	Complex igneous and metamorphic units, commonly broken and in many places deeply weathered.	Main unit in much of Sangre de Cristo Mountains.	Limited and unreliable supplies of water may be obtained from fractures and weathered material.
Pennsylvanian	Limestones and shales (Magdalena Formation). Some quartzite.	Narrow band, discontinuous along front of Sangre de Cristo Mountains; Cañoncito and Glorieta area; Edgewood area.	Variable; generally not favorable except for some occurrences in Edgewood area.
Permian	Limestone, shale, gypsum and other sedimentary units. (Abo, Glorieta & Yeso formations).	Near Golden; Rosario; Glorieta. Prominent along Glorieta Mesa S. of Rowe.	Glorieta area locally contains some water. Other formations yield little or no water, or have severe water-quality problems.
Triassic	Sandstone and shale.	Commonly associated with Permian (see above); in Galisteo basin.	Isolated supplies of limited extent may be available.
Jurassic	Sandstone and shale (Entrada and Morrison formations).	Limited extent. NW of Lamy; La Bajada-Rosario; N. of Golden; SE of Galisteo.	Not considered a potential aquifer.
Cretaceous	Shale with sandstone and limestone (Mancos, Mesaverde and Dakota formations).	Extensive occurrence in central parts of County (Lamy, Galisteo, La Bajada).	Supplies limited in quantity and by adverse quality, although localized favorable conditions may exist.
Lower-mid Tertiary	Sandstone and other sedimentary units (Galisteo Formation). Igneous intrusive and extrusive rocks (Espinaso Formation).	Extensive occurrence in central and west portion of Santa Fe County: South Mountain; San Pedro; Cerrillos; Cienega.	With exceptions, generally a reliable source for small quantities of water.
Upper Tertiary and Quaternary	Basin fill; sedimentary and volcanic rocks (Santa Fe Group; Bishops Lodge, Tesuque and Ancha formations); lava flows.	Major unit in almost all basin areas (except Galisteo basin). Also, lava terrain from La Bajada northward.	Principle aquifer, especially where Tesuque Formation is thick and saturated. Potential for supplies to be developed below 900 ft (275 m) is uncertain.
Recent	Alluvium	Along stream courses.	May provide good supplies where saturated, especially along major perennial streams (northern valleys).

GEOHYDROLOGY NEAR SANTA FE

The Tesuque Formation is the principle aquifer of the area. The general direction of movement of ground water is to the west, from the recharge areas near the mountains to the discharge areas along the Rio Grande. Locally, structural and drainage controls may divert ground water away from this trend. The Ancha Formation is usually unsaturated. Exceptions to this occur where the Ancha lies directly on impermeable Precambrian rocks as it does south of Seton Village, or where a bed of low transmissivity in the Tesuque Formation forces water to enter the Ancha Formation in order to pass over the barrier. The springs at Cieneguita and Agua Fria are caused by such barriers (Spiegel, 1975). Each of the major springs occupies a distinct valley eroded in the Tesuque Formation and buried by the Ancha.

The westward dip of less permeable beds in the Tesuque Formation obstructs the westward flow of ground water, forcing the water to move across the beds. Koopman (1975) estimated the average permeability of the Tesuque Formation in the Pojoaque area to be 25 times greater in the direction of bedding than across it. Similar conditions exist in the Santa Fe area. An important consequence of this fact is that aquifer transmissivity is greater in the direction parallel to the strike of the beds, that is north-south, so that the effects caused by a pumping well will tend to be elongated in a north-south direction. Many faults within the Rio Grande trough, and the boundary of the trough and mountains, also trend more or less north-south. These create barriers to ground water flow and are another reason why pumping in Santa Fe normally has greater drawdown effects in a north-south direction.

The low-transmissivity horizon in the Tesuque, noted above, is yet another north-south barrier. It is apparent that the various barriers are a major factor controlling ground-water conditions in the Santa Fe area. However, the relative significance of the different barriers is not clear, especially in the area northwest of the city (see discussion of Buckman well field, below).

AQUIFER CHARACTERISTICS

The variability of lithologic and structural conditions in the principle aquifer, the Tesuque Formation, makes the selection of hydrologic characteristics which will fit the entire Santa Fe area nearly impossible. For example, Spiegel (in Spiegel and Baldwin, 1963) listed the range of transmissivity shown in Table 2, but later (Spiegel, 1971) stated that these values "should not be referred to as correct values for the area represented by the wells analyzed." The existing situation in Santa Fe requires complex analytical methods to obtain valid hydrologic characteristics for a site. Detailed geologic mapping of the Tesuque Formation (e.g., Galusha and Blick, 1971), coupled with analysis of aquifer performance test data in the various members of the Tesuque Formation, may permit the generalization of hydrologic characteristics within the members. Presently, the needed geologic and aquifer performance data have not been gathered.

Table 2. Aquifer Characteristics Near Santa Fe

Characteristic	Formation	Value	Location	Source
Transmissivity	Tesuque	100-5000 ft^2/day	Santa Fe area	Spiegel and Baldwin, 1963
	Tesuque	360 ft^2/day	Osage well	SEO files
	Tesuque and Ancha	17-1340 ft^2/day	Sunlit Hills	Spiegel, 1973, Turner, 1973
Saturated Thickness	Tesuque	over 250 ft	Sunlit Hills	Turner, 1973
	Ancha	100 ft	Sunlit Hills	Turner, 1973
	Tesuque and Ancha	100-140 ft	Santa Fe Downs	Spiegel, 1975
Storage Coefficient	Tesuque	0.018	Alto Street well	Spiegel and Baldwin, 1963
	Unknown, but assumed to be 0.2 in Santa Fe area.			Spiegel and Baldwin, 1963
	Tesuque and Ancha	0.322×10^{-3} to 190×10^{-3} (21 different determinations)	Sunlit Hills	Turner, 1973
	Tesuque	0.05	Osage well	SEO
Water in Storage	Santa Fe	128,000 AF/ sq. mile	Santa Fe basin	Spiegel and Baldwin, 1963
		9,600-16,000 AF/ sq. mile	Santa Fe basin	Akin, 1975
		8,000 AF/sq. mile	Santa Fe basin	Wilson and others, 1975
		1,600-16,000 AF/ sq. mile	Santa Fe basin	Wilson and others, 1978a
		to 92,000 AF/ sq. mile	Pojoaque basin	Reiland and Koopman, 1974

RECHARGE PATTERNS

Streams draining the Sangre de Cristos are generally perennial, although total stream flow has declined since the 1920's because of climate and land-use factors. Prior to urbanization of Santa Fe, the surface flows from the Santa Fe River recharged the aquifer through channel and irrigation seepage, and the water table was relatively high. Well pumping was minor, and there was no tendency to lower the water table. In recent years, all or nearly all the river flow has been diverted into the municipal water system, eliminating most recharge within the city limits. In addition, pumping from wells (especially Public Service Company (PNM) wells) has withdrawn much water from the aquifer. Consequently, there has been a water-table decline in the Santa Fe area, as discussed subsequently. A sizable portion of the municipal water is collected in the city sewer system, and after treatment, is discharged to irrigated fields or the river channel southwest of the main urban area. In this vicinity, the water table has risen due to an increase in recharge compared to earlier conditions. To summarize, the pre-urban hydrologic conditions of the ground reservoir have been altered by a net decrease in recharge, a net increase in withdrawals, and a shift of the main recharge point from near the mountains to southwest of the built-up area.

THE WATER TABLE NEAR SANTA FE

The water table slopes westward in the metropolitan area. Near the major stream courses, it may be relatively shallow; elsewhere, water may occur at a depth of 150 to 200 ft (45 to 60 m) or more. Perched water bodies are common. Artesian water also occurs, as does unconfined ground water in the main aquifer of the Tesuque Formation.

As discussed above, the historic patterns of water use in Santa Fe have altered in recent years; ground-water recharge from irrigation and stream flow has declined as surface water has been diverted to municipal uses, and ground-water withdrawals have increased. About 40,000 acre-feet (50 x 106 m3) have been withdrawn from the PNM wells since 1950, or more than 1,000 acre-feet (1.2 x 106 m3) per year. In recent years, PNM has relied on the Buckman well field rather than city wells, and local pumping has been small. Data on pumping of private wells are not readily available.

The decreased recharge and increased pumping in and near Santa Fe have had the expected result of causing a lowering of the water table. Measured annual declines are in the range 0.5 to 2.8 ft (15 to 85 cm) per year. A more qualitative measure of ground-water-table declines is the fact that many springs and cienegas along the Santa Fe River have dried up over time (e.g., see discussion in Spiegel and Baldwin, 1963).

LONG-TERM AVAILABILITY OF WATER NEAR SANTA FE

Hagerman (1975) evaluated data on water-level declines and concluded that the local aquifer could be exhausted within a matter of several years. Akin (1975) indicated that this evaluation is too pessimistic. An estimate for planning purposes can be made as follows:

(1) Assume water table now lies at 200 ft (61 m) below surface (it is often much higher).

(2) Assume historic decline of 3 ft (1 m) per year will continue (this is reasonable considering PNM's current pumping policies, and in fact, may overstate the decline).

(3) Assume that the aquifer extends to 700 ft (215 m) (as indicated by Akin (1975), and as shown by records from the Osage and Santa Fe wells).

(4) Assume that well pumping beings to become noneconomic, for large-scale wells at least, when the saturated thickness is less than 200 ft (61 m).

Under these admittedly generalized (but overall conservative) assumptions, at least 300 ft (92 m) of water-table decline can be experienced without reaching a point where well pumping becomes noneconomic. This amount of decline would be expected to occur in a period of 100 years.

The above estimates should not be taken to indicate that ground-water declines are necessarily acceptable, given that existing shallow wells would be impaired by such a lowering. Further, the remaining springs and cienegas of the area would dry up from such a large-scale water-table decline. However, the estimate does indicate that a significant amount of water can be removed physically and economically from the aquifer of the Santa Fe area without leading to a regionwide dewatering of the ground-water reservoir.

It appears than an artificial recharge project has some potential for implementation in Santa Fe; if interest exists in such a project, further study would be definitely warranted.

BUCKMAN WELL FIELD

The Buckman well field was constructed by PNM as a municipal water-supply source for the City of Santa Fe. The field is located near the old town of Buckman, 15 mi (24 km) northwest of (and nearly 1,500 ft (460 m) lower than) the city; it lies about 1 to 2 mi (1.5 to 3 km) east of the Rio Grande, almost directly across the river from White Rock. The field consists of six production and two large-bore observation wells. Initial production from the well field began in 1972, and has averaged about 3,000 acre-feet (3.7 x 106 m3) per year, with an upward trend. Specific capacities average 2.5 gallons per minute per foot (31 liters/m) of drawdown.

Two major areas of concern or controversy have resulted from development of the Buckman well field. First, the long-term performance capability of the field has not been demonstrated. This is at least partly the result of the great complexity of geology in the area, and the resulting uncertainty about the source of the water which is being diverted by the well field. The second issue relates to the effects of pumping on surface-water flows in the Rio Grande and the tributary basins of Rio Pojoaque. The size of these effects determines whether the existing water rights are adequate or additional ones are needed. Again, the complexity of the area makes prediction of these effects difficult.

The principle aquifer of the Buckman area is the Tesuque Formation. Shomaker (1974) provided additional details regarding the area. The most important characteristics of the Tesuque Formation are its considerable variability and complexity, due to bedding and facies variations, and the presence of faults. These complications make evaluation of the aquifer very difficult; in many cases, geologic relationships have proven to be unpredictable where based on circumstantial evidence. For example, Shomaker and others have interpreted the existence of the Pojoaque fault, east of Buckman, to indicate that an important structural barrier exists which limits the extent to which pumping effects would be transmitted eastward. However, recent pumping tests in the area of the fault have indicated no such structural barrier. The fault, if present, is not a major factor in the hydrology of Buckman.

Shomaker (1975) indicates that the permeability within the Tesuque Formation decreases from west to east in the Buckman field, and postulates the existence of a transmissivity barrier east of the field, related to regional patterns of sedimentary facies. Subdivision studies and the configuration of the water level east of the Rio Grande provide evidence to support the existence of a low-transmissivity zone in the area.' The fact that water quality improves westward also supports this conclusion.

Shomaker tentatively has correlated the rocks encountered by some of the wells in the Buckman area. The Tesuque Formation tapped by the wells at Buckman can be divided into two water-producing units, the upper and lower aquifer zones. These are beds of permeable, relatively clean sandstones separated by a thick zone of relatively impermeable siltstone and shale. The upper aquifer zone commonly is 500 to 700 ft (150 to 215 m) below the surface, and may be nearly zero to about 150 ft (45 m) thick. Sandstones above this zone are not important water contributors. The lower aquifer zone, which occurs from 900 to 1,400 ft (275 to 425 m) from the surface, and which may be considerably thicker than the upper zone, is estimated to contribute an equal amount of water to the flow of the well. The bottom of the lower zone is identified by Shomaker at the "N" marker, which is an abrupt change from sandy clay to clay sediments. These low-permeability beds are at least 500 ft (150 m) thick, and no well has penetrated their full thickness. A considerable thickness of the Tesuque Formation remains to be explored. The variable nature of the formation makes the discovery of deeper water-bearing zones likely.

Recent drilling by PNM does not indicate that alluvium is a major prospect for large-capacity municipal water-supply wells.

Shomaker concluded that the most likely source of water being diverted at Buckman is recharge along the margin of the Jemez Mountains and near Los Alamos, as well as recharge from the Rio Grande. He indicated that recharge to the east of the field would reach the area in small quantities due to the structural and transmissivity barriers noted above. However, the elevation of the river is well below the piezometric head in the well field, indicating that river recharge may not be a major source of existing flows; rather, ground-water inflow from the area of the well field should be augmenting stream flow, via artesian leakage upward, through relatively impermeable units beneath the river. Ground-water contributions to the Rio Grande have been estimated at approximately 1 cfs/river mile (0.017m3/km) from the combined inflow east and west of the river (e.g., Griggs and Hem, 1964; Spiegel and Baldwin, 1963).

If the above inferences are grossly correct, pumping at Buckman should affect ground- and surface-water conditions to the east and west, and in the Rio Grande. Rio Grande effects involve a reduction in ground-water influx to the river. Should pumping eventually lower the water level at Buckman to an elevation below that of the river, a reversal in flow could occur, and river flow could leak into the Buckman reservoir.

Effects west of the river should be greater than to the east, because of the higher transmissivities in the former area. However, it seems likely that recharge originating in the Rio Pojoaque basin is a source of a significant proportion of the water which is withdrawn at Buckman, and that pumping impacts from the field will be transmitted eastward. This conclusion also has been reached by the State Engineer in his decision to require retirement of water rights in the Rio Pojoaque drainage in order to offset pumping effects from Buckman.

Quantitative effects, including computer modeling, have been attempted in order to determine more precisely the hydrologic conditions near Buckman (see Akin, 1975; Black and Veatch, 1976; Cushman, 1965). All such efforts have involved use of simplified interpretation of geologic characteristics, and have made many assumptions. None of the efforts has had adequate input regarding the complex geology of the area, because such information is not available. None has predicted satisfactorily phenomena which already are occurring in the area; for example, water-level declines in the two observation wells have been less than predicted by all of the mathematical models.

Some of the modeling efforts noted above have evaluated the drawdown potential of the field. For example, Akin (1975, p. 13) discusses the results of a model which assumed the aquifer to be artesian, infinite and homogeneous, with transmissivity of 6,000 gpd/ft (7.4 x 104 lpd/m) and storage coefficient of 0.0008. Comparison of his results to data provided by Shomaker indicates that after 40 years, the predicted drawdown in producing wells was still *above* the top of the upper zone of the aquifer. This indicates that well field production would be physically possible up to and subsequent to that time.

OTHER AREAS

Cerrillos Area

The hydrology of the Cerrillos Hills has been studied intensively in association with a copper mine. A full and complete understanding of the area hydrology is not yet available. It should be noted that, although there are fracture zones in the Cerrillos area which can yield substantial quantities of water (500 gpm (1890 Ipm) or more), the overall theme of many of the studies is that water supplies are not especially abundant in the area.

Pojoaque-Tesuque Area

This vicinity has been studied by Borton (1968), Koopman (1975), Miller and others (1963), Spiegel and Baldwin (1963), and Trauger (1967). Data for the Tesuque area were summarized by Wilson and others (1978a). The main aquifers are the Tesuque Formation and overlying alluvium.

The alluvium is interconnected hydraulically with both surface water and the Tesuque Formation. Permeability of the units depends on material, generally being highest in gravels and coarse sands, and lowest where clays or cemented layers are common. The coarse alluvium transmits about 40 times more water per unit thickness than the Tesuque under natural conditions (Koopman, 1975). Because of the variability in permeability, water flows preferentially along beds of relatively coarse sediment. Koopman (1975) estimated the average permeability of the Tesuque to be 25 times greater in the direction of bedding than across the beds. Transmissivity values are estimated at between 10 and 1,000 square ft (0.9 and 93 m2) per day for the Tesuque, and 1,000 to 2,000 square ft (93 to 186 m2) per day for alluvium along the major rivers. The storage coefficient for the Tesuque varies markedly, from low values below 0.001 (e.g., where artesian conditions are found) to values as high as 0.2. The latter value was reported by Koopman (1975) to be typical of the Tesuque in the Pojoaque basin, whereas Spiegel and Baldwin (1963) found a value of less than 0.02 to be typical of the formation in the Santa Fe area.

Truchas and Santa Cruz Area

Borton (1974) states that in the Truchas-Santa Cruz area, "The main aquifers ... are the Tesuque Formation and the alluvium in the major stream channels; aquifers also exist as joints, fractures, and solution openings in the Pennsylvanian and Precambrian rocks of the Sangre de Cristo and Picuris Mountains, but these sources of ground water are very limited and relatively unused. Ground water which occurs in sands and gravels of the Tesuque is usually found under water-table or unconfined conditions ... Ground-water movement is westward towards the Rio Grande from the principal area of recharge near the mountains. Configuration of the water-table contours shows mounding of the water table below many of the intermittent streams ... which indicates stream loss during times of flood or snow melt. This is probably the most important type of recharge to the ground-water reservoir."

Pehasco

Wells in the Penasco area typically penetrate a sequence of varied alluvial sediments, dominantly clay interbedded and intermixed with significant horizons of gravel and/or sand. Most wells are less than 100 ft (30 m) deep, and the water table is usually within 5 to 20 ft (1.5 to 6 m) of the ground surface. Yields are reported to be in the range of 5 to 15 gpm (19 to 57 Ipm). In the Las Trampas area, some decline of possibly artesian water levels has been reported, and at least one dry hole is known to occur. An unusual well located at 23.12.36.330 penetrates a number of good limestone aquifers and is reported to yield 125 gpm (473 Ipm).

Taos

In the Taos area, wells are generally between 40 and 200 ft (12 and 60 m) deep, with water being found in alluvial sediments at 10 to 140 ft (3 to 43 m) beneath the surface. Yields of 15 to 30 gpm (57 to 113 Ipm) are common in properly constructed wells. Several well logs report that hard rock layers have been encountered, including lava, caliche and (near the mountains) shale. There is some conflict in the data about long-term water-level trends in the area, but overall, no decline has been observed, and the water table is very shallow in much of the area, especially near streams which serve as ground-water drains.

Drilling data from the Taos area indicate that the Santa Fe Group consists of the following sequence of rocks: (1) a lower sand facies; (2) a middle facies of basaltic flows and interbedded lake and river deposits; and (3) an upper facies of alluvial deposits. The aquifer is overlain by ancient alluvial fan deposits, piedmont gravels and stream-terrace deposits. In general, this overburden has been reported as not thicker than 35 ft (11 m), although locally thicker units may occur. The overlying units are generally above the water table, and hence, are not aquifers in the Taos area. However, in places, the development of irrigation has led to perched or semiperched zones of saturation in the stream-terrace deposits.

The Taos-Valdez area has been analyzed in some detail due to Bureau of Reclamation interest in possible irrigation projects. Consequently, the nature of the aquifers in the area is established relatively well, as is the seasonal and regional pattern of ground-water recharge, flow and discharge. Certain areas where ground water is comparatively abundant have been identified, and well-test data and computer-model results are available which indicate that the main aquifer (Santa Fe Group) has the following hydrological characteristics: transmissivity of 900 to 7,000 ft2 /day (84 to 650 m2); storage of 0.001-0.04. The lower value of transmissivity and higher value of storage may be fairly typical of the aquifer over much of Taos County. It has been estimated that 1,000 acre-feet (1.2 x 106 m3) or more ground water might be withdrawn from the Taos area each year. This would tend to lower water tables, dry up cienegas and vegas, and reduce surface flows. Withdrawal of much larger quantities (e.g., 2,500 acre-feet (3.1 x 106 m3) or more) probably would lead to severe water-table lowering over a sizable area, and the drying up of many existing wells. One possible reason for the limited ground-water supply is the existence at depth of a fine-grained layer of clay lake sediments, which limits the thickness of the underground reservoir. One report suggests that artificial recharge of surface water into the aquifer might improve ground-water supplies signficantly, and also enhance surface-water flows late in the irrigation season.

Ground water is of fair to good quality in the Santa Fe Group. Wells tapping alluvial sediments often are polluted by sewage from septic tanks and cesspools. Water in formations of Mesozoic age or older are locally of poor natural quality.

REFERENCES

Akin, P. D., 1975, Memorandum concerning a review of reports done for the Santa Fe County Commission: New Mexico State Engineer Office, Memo dated September 4, 1975, 14 p.

Black and Veatch, 1976, Report on the digital modeling of the Buckman Well Field (Santa Fe County): Report to Public Service Company of New Mexico, 33 p.

Borton, R. L., 1968, General geology and hydrology of north-central Santa Fe County, New Mexico: New Mexico State Engineer Open-File Report, 21 p.

----, 1974, A listing of geohydrologic data available for 106 exploratory holes drilled by Nuclear Dynamics, Inc., in Rio Arriba, Sandoval, and Santa Fe Counties, 1970-1972: New Mexico State Engineer Open-File Report, 9 p.

Cushman, R. L., 1965, An evaluation of aquifer and well characteristics of municipal well fields in Los Alamos and Guaje Canyons, in Santa Fe County, near Los Alamos, New Mexico: U.S. Geological Survey Water-Supply Paper 1809-D, p. D1-D50.

Galusha, T. and Blick, J. C., 1971, Stratigraphy of the Santa Fe Group, New Mexico: Bulletin of the American Museum of Natural History, v. 144, art. 1, 127 p.

Griggs, R. L. and Hem, J. D., 1964, Geology and ground-water resources of the Los Alamos area, New Mexico: U.S. Geological Survey Water-Supply Paper 1753, 107 p.

Hagerman, C. de B., 1974, Geologic units and hydrologic conditions, Santa Fe County, New Mexico: Report to Board of Santa Fe County Commissioners, 29 p.

– ---, 1975, Santa Fe well field: Memorandum on Santa Fe and Buckman well fields, Consulting Professionals, Inc., Santa Fe, 7 p.

Koopman, F. C., 1975, Estimated ground water flow, volume of water in storage and potential yields of wells in the Pojoaque River drainage basin, Santa Fe County, New Mexico: U.S. Geological Survey Open-File Report 74-159, 33 p.

Miller, J. P., Montgomery, A. and Sutherland, P. K., 1963, Geology of part of the southern Sangre de Cristo Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources Memoir 11, 106 p.

Mourant, W. A., 1979, Hydrologic and geologic maps and data for Santa Fe County, New Mexico: U.S. Geological Survey open-file information, ca. 150 p.

Reiland, L. J. and Koopman, F. C., 1974, Estimated availability of surface and ground water in the Pojoaque River drainage basin, Santa Fe County, New Mexico: U.S. Geological Survey Open-File Report 74-151,35 p.

Shomaker, J. W., 1974, Interpretation of well logs in Buckman well field, and general limits of Tesuque Formation aquifer: Report prepared for Black and Veatch Consulting Engineers, 15 p.

----, 1975, Letter (6/9/75) to C. V. Hallenbeck (Black and Veatch Consulting Engineers) concerning Buckman well field, Santa Fe County, New Mexico.

Spiegel, Z., 1971, Letter to W. E. Hale, district chief, U.S. Geological Survey, Albuquerque, 29 Nov. 1971.

----, 1973, Evaluation of a report by Hydrotechnics on "The hydrology of the Sunlit Hills area, Santa Fe County, New Mexico.": Consulting report for Old Pecos Trail Association, Santa Fe, New Mexico, 2 p.

----, 1975, Preliminary report on the hydrology of the Cienega area, Santa Fe County, New Mexico: Report to Santa Fe Downs, 34 p.

Spiegel, Z. and Baldwin, B., 1963, Geology and water resources of the Santa Fe area, New Mexico: U.S. Geological Survey Water-Supply Paper 1525, 258 p.

Trauger, F. D., 1967, Hydrology and general geology of the Pojoaque area, Santa Fe County, New Mexico: U.S. Geological Survey Open-File Report, 32 p.

Turner, W., 1973, The hydrology of the Sunlit Hills area, Santa Fe County, New Mexico: Hydrotechnics, Albuquerque, 114 p.

Wilson, L. and others, 1975, Environmental report series prepared for the Santa Fe County General Plan, Santa Fe County, New Mexico, 50 p.

– ---, 1978a, Santa Fe County water plan: Report to the Interstate Streams Commission, Santa Fe, 637 p.

– 1978b, Taos County water plan: Report to the Interstate Streams Commission, Santa Fe, 273 p.