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Use of Air-Pressurized Slug Tests to Estimate Hydraulic Conductivity at Selected Piezometers Completed in the Santa Fe Group Aquifer System, Albuquerque Area, New Mexico

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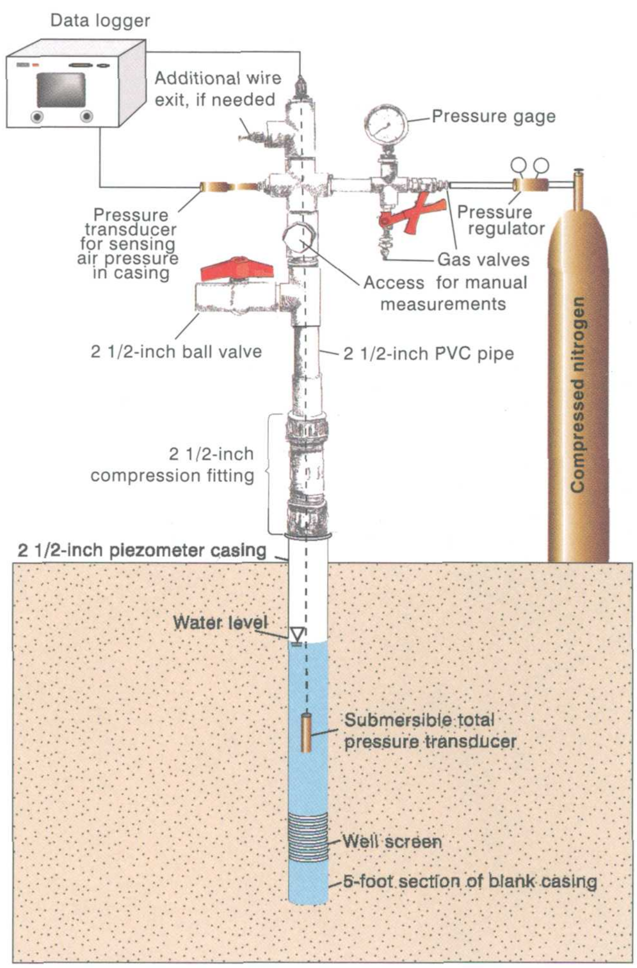
Water-Resources Investigations Report 00-4253



Prepared in cooperation with the

CITY OF ALBUQUERQUE PUBLIC WORKS DEPARTMENT, WATER RESOURCES MANAGEMENT

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Albuquerque, New Mexico
2000

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
foot squared per day	0.09290	meter squared per day
pound per square inch	2.307	feet of water

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

USE OF AIR-PRESSURIZED SLUG TESTS TO ESTIMATE HYDRAULIC CONDUCTIVITY AT SELECTED PIEZOMETERS COMPLETED IN THE SANTA FE GROUP AQUIFER SYSTEM, ALBUQUERQUE AREA, NEW MEXICO

By Carole L. Thomas and Condé R. Thorn

ABSTRACT

The City of Albuquerque Public Works Department, Water Resources Management (City), is interested in quantifying aquifer hydraulic properties in the Albuquerque, New Mexico, area to better understand and manage water resources in the Middle Rio Grande Basin. In 1998, the City and the U.S. Geological Survey entered into a cooperative program to determine hydraulic properties of aquifer material adjacent to screened intervals of piezometers in the Albuquerque area.

Investigators conducted slug tests from March 8 through April 8, 1999, to estimate hydraulic conductivity of aquifer material adjacent to the screened intervals of 25 piezometers from 11 nested-piezometer sites in the Albuquerque area. At 20 of the piezometers, slug-test responses were typical; at 2 piezometers, tests were prematurely terminated because the tests were taking too long to complete; and at 3 piezometers, test responses were oscillatory. Methods used to estimate hydraulic conductivity were the Bouwer and Rice method or the Cooper, Bredehoeft, and Papadopulos method for most tests; the Shapiro and Greene method for prematurely terminated tests; and the van der Kamp method for oscillatory tests.

Hydraulic-conductivity estimates ranged from about 0.15 to 92 feet per day. In general, the smaller estimated values are associated with fine-grained aquifer materials and the larger estimated hydraulic-conductivity values are associated with coarse-grained aquifer materials adjacent to the screened intervals of the piezometers. Hydraulic-conductivity estimates ranged from 0.15 to 8.2 feet per day for aquifer materials adjacent to the screened intervals at 12 piezometers and from 12 to 41 feet per day for aquifer materials adjacent to the screened intervals at 10 piezometers. Hydraulic-conductivity estimates at four piezometers were greater than 41 feet per day.

INTRODUCTION

Population growth and an aquifer system affected by declining water levels in wells have caused water supply concerns in and near the city of Albuquerque, New Mexico. Population in Albuquerque has more than quadrupled from 96,815 inhabitants in 1950 (U.S. Department of Commerce, Bureau of the Census, 1952-82) to 464,725 inhabitants in 1990 (U.S. Department of Commerce, 1991). Recent reports (Hawley and Haase, 1992; Thorn and others, 1993) cite declining water levels in wells and indicate that the zone of highly productive aquifer material is less extensive and thinner than hydrologists previously thought. The City of Albuquerque Public Works Department, Water Resources Management (City), is interested in quantifying aquifer hydraulic properties in the Albuquerque area to better understand and manage water supply. In 1998, the City and the U.S. Geological Survey (USGS) entered into a cooperative program to determine hydraulic properties of aquifer material adjacent to screened intervals of piezometers within the ground-water-monitoring network in the Albuquerque area.

In July 1995, the City, New Mexico Office of the State Engineer, County of Bernalillo, and USGS began a cooperative effort to develop a network of nested piezometers dedicated to monitoring ground-water quantity and quality in the Middle Rio Grande Basin with emphasis in the Albuquerque area (fig. 1). The nested piezometers (multiple piezometers completed within the same borehole) provide an opportunity to determine aquifer hydraulic properties at discrete depths within the Santa Fe Group aquifer system, the principal aquifer system in the Albuquerque area. Air-pressurized slug tests conducted in selected piezometers provide the information to calculate hydraulic-conductivity values of aquifer material adjacent to piezometer screens.

Purpose and Scope

This report presents hydraulic-conductivity estimates of aquifer material adjacent to the screened intervals of 25 selected piezometers at 11 of 14 nested-piezometer sites in the Albuquerque area. Twenty-six values of hydraulic conductivity were estimated; data from one test were used to determine two hydraulic-conductivity values because two analytical methods are applicable to the data. The selected piezometers are completed in the Santa Fe Group of Tertiary age, which is part of the Santa Fe Group aquifer system.

The scope of this report includes a discussion of the methods used to collect and analyze data. Investigators used an air-pressurized slug-test method to collect the data for estimation of hydraulic conductivity. Preliminary testing to perfect the data-collection method began in November 1998. Air-pressurized slug tests were conducted from March 8 through April 8, 1999. Analytical methods used to estimate hydraulic conductivity were the Bouwer and Rice (Bouwer, 1989) method; the Cooper, Bredehoeft, and Papadopulos (1967) method; the Shapiro and Greene (Greene and Shapiro, 1995; Shapiro and Greene, 1995) method; and the van der Kamp (1976) method.

Description of the Study Area

Hydrologically, Albuquerque and the surrounding metropolitan area are part of the Middle Rio Grande Basin (Bartolino, 1997), an area of about 3,000 square miles (fig. 1). Albuquerque is the main population center with about 89 percent of the basin's 1990 population (Thorn and others, 1993). The New Mexico Office of the State Engineer has regulatory authority over water resources in this basin and has declared it a "critical basin." Critical basin declaration means that rapid economic and population growth are expected in this basin and that technical information regarding the available water supply is less than adequate (New Mexico State Engineer Office, written commun., 1995).

Recently, Hawley and Haase (1992) and Thorn and others (1993) described the Middle Rio Grande Basin geologically and hydrologically. They considered the Santa Fe Group aquifer system to be the main geologic source of ground water in the area. They described the aquifer system to be composed of the Santa Fe Group and post-Santa Fe Group valley and basin-fill deposits, with the most productive lithologies being the axial-channel deposits of the ancestral Rio Grande and, to a lesser extent, piedmont-slope and alluvial-fan deposits of the upper and middle parts of the Santa Fe Group. Water levels have declined as much as 140 feet from 1960 to 1992 in the east Albuquerque area because of ground-water withdrawal, fault barriers, and the limited extent of the axial-channel deposits (Thorn and others, 1993, p. 1).

Ground water is the primary source of water for urban, rural, commercial, and industrial uses (other than agricultural) in the Middle Rio Grande Basin (Thorn and others, 1993, p. 53). Surface water is used primarily for agriculture in the basin; it is stored in upstream reservoirs and delivered from the Rio Grande and its associated system of canals, ditches, and laterals.

Acknowledgments

The authors acknowledge the residents of Sandia Pueblo who graciously allowed access to and testing of the piezometers at the Sandia Pueblo nested-piezometer site. The authors are especially grateful to Rhea Graham and Derrick Lente of the Pueblo of Sandia Environment Department for their assistance, under adverse weather conditions, with the installation of transducers in piezometers.

AIR-PRESSURIZED SLUG TESTS

Slug tests hydraulically stress a limited volume of the formation surrounding the open interval (screened interval) of a piezometer or well, but offer an inexpensive and rapid means of estimating aquifer hydraulic properties. For this reason, slug tests are widely used in ground-water investigations.

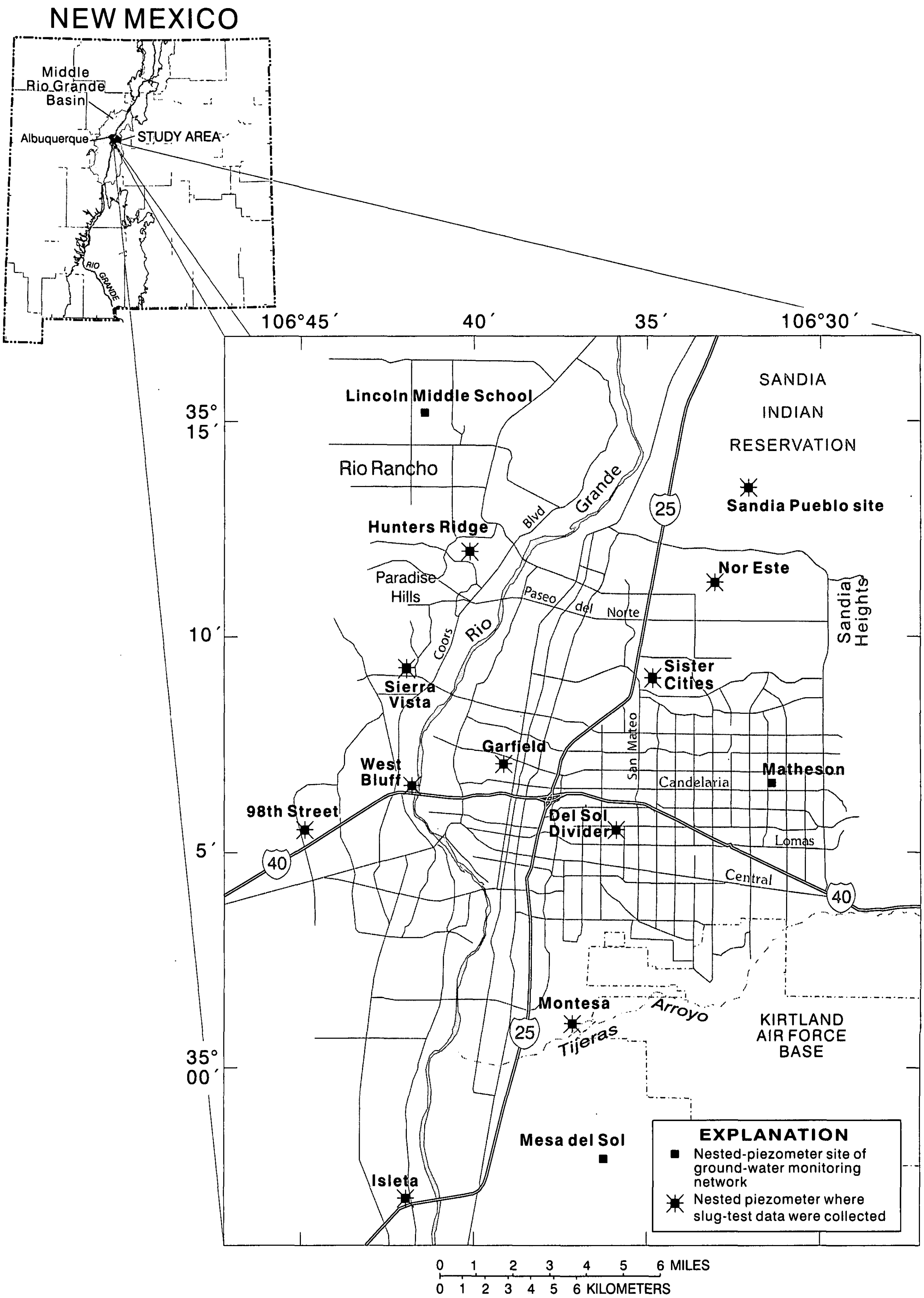


Figure 1. Location of nested-piezometer sites where slug-test data were collected.

The air-pressurized slug-test method described by Greene and Shapiro (1995) was used to estimate hydraulic-conductivity values of the aquifer material surrounding piezometer screens. This method offers a means of estimating hydraulic conductivity without extensive downhole equipment and without the need to add or remove a column of water. In this type of slug test, the column of air above the water level in the piezometer is pressurized. The pressurization causes the water level in the piezometer casing to decline as water is forced through a screened interval and into the adjacent aquifer materials until a new equilibrium, water-level position is reached. After the new equilibrium water level has been reached, the pressure is released instantaneously. Water flows from the aquifer back into the piezometer through the screened interval until the original water level is achieved. Data can be collected for determination of aquifer hydraulic properties during both the declining and rising water-level phases of the test. Three examples of water-level response during an air-pressurized slug test are shown in figure 2.

Slug tests were performed at 11 of 14 nested-piezometer sites for 25 individual piezometers (fig. 1). Slug tests were not performed for the shallowest piezometer (water-table piezometer) at each site because the upper part of the screens are above the water table, and air pressurization of these casings results in air moving through the screen and into the formation with little effect on the water level in the piezometer. The middle (middepth) and deep piezometers at each nested-piezometer site were tested.

Data-Collection Methods

Investigators used uniform procedures to conduct slug tests. Figure 3 shows the slug-test equipment and its placement over a piezometer casing. Compressed nitrogen gas was used to pressurize the column of air above the water in the piezometer because the gas does not introduce contamination to the water column. A submersible total pressure transducer located below the water level in the piezometer casing monitored the sum of pressure in the water column and air pressure in the piezometer casing. A second pressure transducer monitored only the air pressure in the piezometer casing. The air pressure in the casing subtracted from the sum of water-column pressure and air-column pressure gave the water-column pressure. The remaining equipment needed to conduct the air-pressurized slug test was assembled at the top of the piezometer casing (fig. 3).

Ideal conditions for the analysis of slug-test data would require instantaneous pressurization of the air column and instantaneous release of pressure in the air column, allowing hydraulic properties to be estimated for the declining water level and the recovering (rising) water level. Instantaneous pressurization of the air column with a constant pressure while the water level declined was not obtained. Therefore, investigators used only the recovering water-level data to calculate hydraulic properties. The pressure release to start the recovery phase of the slug test was nearly instantaneous, taking 1 to 5 seconds to go from fully pressurized to ambient air pressure in the piezometer casing. Opening the 2.5-inch ball valve (fig. 3) released the pressure in the casing and started the recovery phase of the test. The length of time to accomplish full pressure release was dependent on the casing volume above the water level. The time was shortest for piezometers with static water levels within 100 feet of land surface and was longest for piezometers with static water levels 400 to 500 feet below land surface.

The design-pressure increase for the column of air in the piezometer casing above the water level was 10.0 pounds per square inch. This caused a water-level decline of 23.1 feet below the static water level. The large change in water level improved the sensitivity of the test to differences in hydraulic conductivity. The magnitude and timing of the water-level changes during recovery defined the hydraulic conductivity of aquifer material adjacent to the piezometer screen. A data logger connected to the submersible pressure transducer recorded the water-level position every second (fig. 3). The estimated accuracy of the water-level measurements over the range of movement is plus or minus 0.06 foot (Honeywell, Inc., 1999).

Analytical Methods

Investigators used confined aquifer system solutions to analyze slug-test responses because confining and semiconfining strata are present above and below the screened intervals that were tested. The analytical method used to calculate a hydraulic-conductivity estimate was dependent on the water-level response to the slug test.

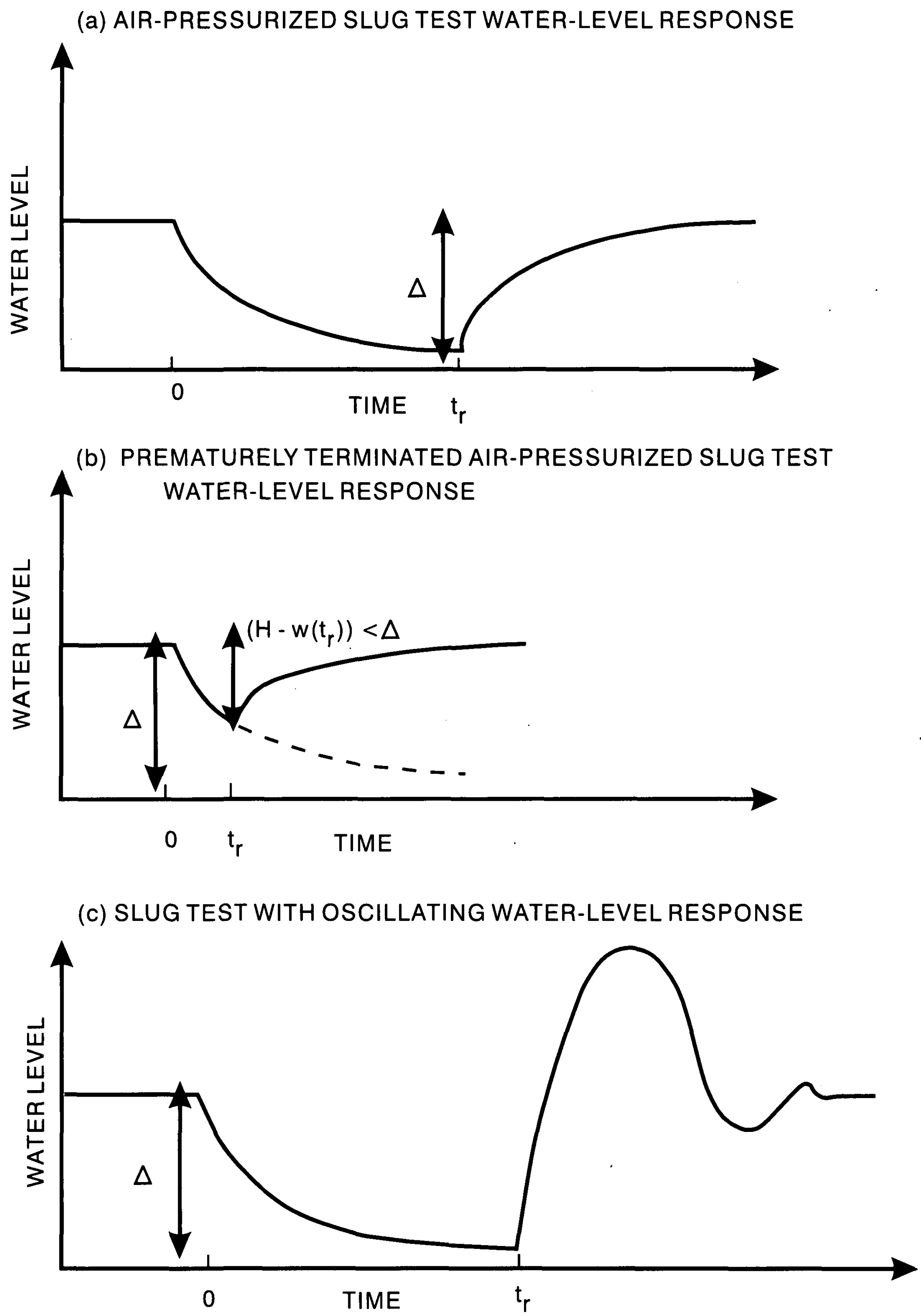


Figure 2. Time-varying water level during (a) air-pressurized slug test, (b) prematurely terminated, air-pressurized slug test, and (c) slug test with oscillation. Delta, Δ, is the maximum change in water level from applied air pressure; t_r is the time at which the pressurized part of the slug test is terminated and recovery starts; H is the initial water level at time, $t=0$; and $w(t_r)$ is the water level at time $t=t_r$ (modified from Greene and Shapiro, 1995).

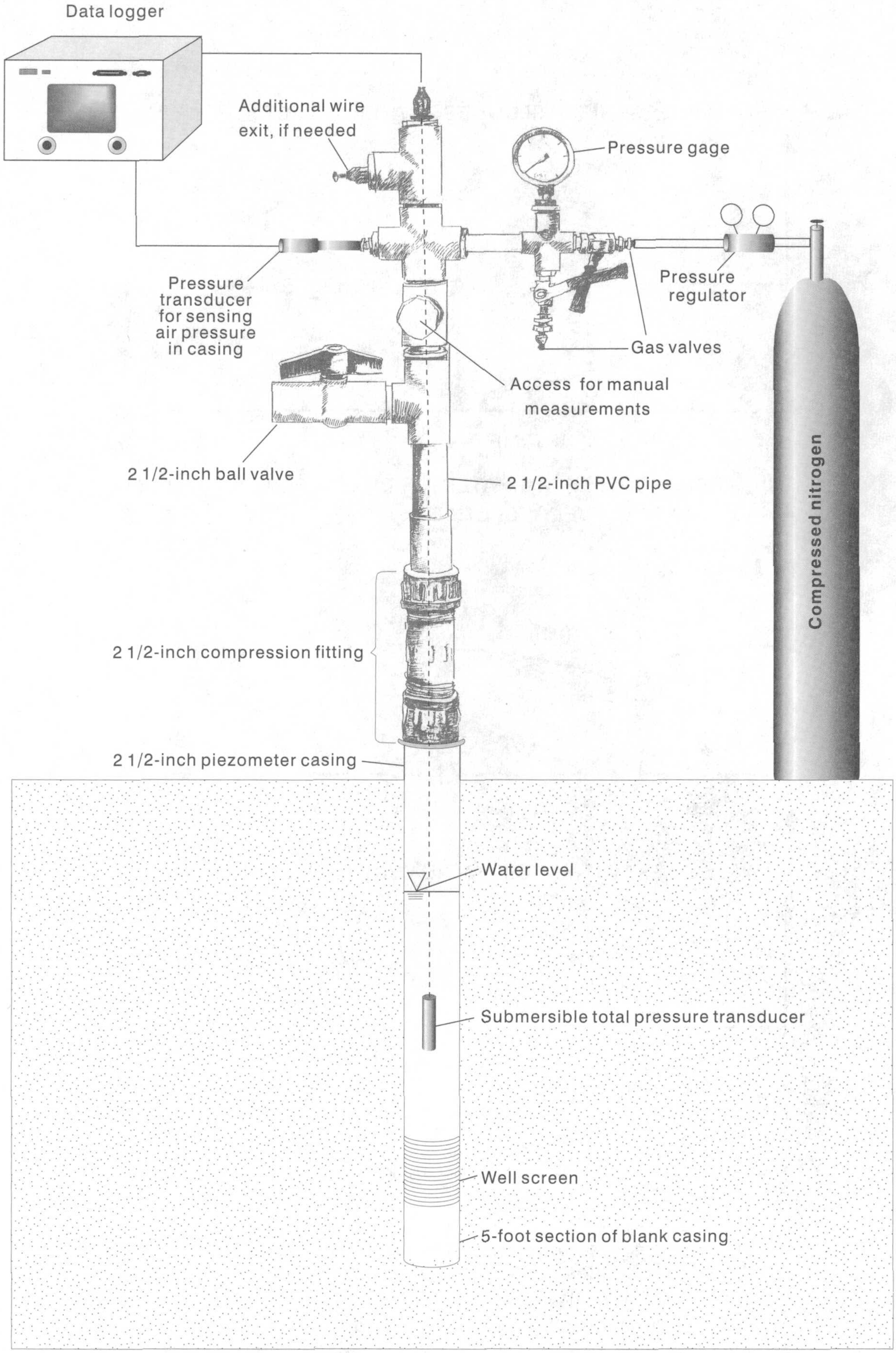


Figure 3. Equipment used to conduct air-pressurized slug tests in piezometers.

Generally, the Bouwer and Rice (Bouwer, 1989) method was used to analyze the slug-test-response data. The Cooper, Bredehoeft, and Papadopulos (1967) method often produced a poor type-curve fit and therefore was not applied to much of the slug-test-response data. Investigators judged the Cooper, Bredehoeft, and Papadopulos method suitable to analyze data for two slug tests. Both the Bouwer and Rice and the Cooper, Bredehoeft, and Papadopulos methods were used to analyze slug-test data for Isleta Piezometer 3 (table 1); the Shapiro and Greene method (Greene and Shapiro, 1995; Shapiro and Greene, 1995) was used to analyze data for the two slug tests that were prematurely terminated; and the van der Kamp (1976) method was used to analyze data for the three slug tests that had oscillatory responses. The references cited here provide detailed descriptions of the analytical methods used and their underlying assumptions.

Skin Effects

Skin effects (the alteration of permeability in the immediate vicinity of a well screen due to construction and operation of the well (Jackson, 1997)) are very important in slug-test design and analysis. The existence of a low-hydraulic-conductivity skin (for example, remnant drilling mud) will significantly misrepresent the hydraulic conductivity of the adjacent aquifer material. Conversely, the existence of a large-hydraulic-conductivity skin (sand pack, for example) does not appear to significantly affect the hydraulic conductivity of the adjacent material (Butler, 1997, p. 189). In this study, the latter applies because of the procedures used to construct and install the piezometers.

Uniform procedures were used during piezometer construction and installation at all nested-piezometer sites. The middle and deep screens at all nested-piezometer sites are located within the middle and bottom portions of the City's production zone. For this report, the production zone is defined by projecting the altitudes of the top and bottom of the screened interval from nearby City production wells (three to five wells) to the nested-piezometer site. Most nested-piezometer sites are located about 1 mile from the nearest production well. After review of the geophysical logs obtained at the nested-piezometer sites, the more permeable zones were chosen near the middle and bottom portions of the City's production zone for placement of the screens.

Twenty-four of the piezometers described in this report have 5-foot screens; one piezometer has a 15-foot screen. All screens are 2.5 inches in diameter, have a slot size of 0.020 inch, and are made of stainless steel. Below each screen is a 5-foot section of blank stainless steel casing that is capped at the bottom. Adjacent to the screen and the underlying blank casing is very well sorted, coarse-grained sand (sand pack) that extends to about 20 feet above the top of the screen. A 10-foot-thick layer of bentonite chips overlies the sand pack.

After all piezometers for a site were installed, the piezometers were developed. During development, water in the aquifer adjacent to the screened interval is drawn through the sand pack, into the piezometer, and discharged out of the piezometer at land surface. The movement of water from the aquifer through the sand pack and screen and into the piezometer removes mud introduced during drilling of the borehole. Development continued until water pumped from the piezometer was clear, indicating that drill mud in the sand pack and adjacent aquifer material had been removed. Development for each piezometer lasted about 8 to 12 hours. The development of the piezometers minimized the existence of a low-hydraulic-conductivity skin near the screened interval of each piezometer.

Partial Penetration

The 25 piezometers partially penetrate the Santa Fe Group aquifer system. To analyze slug-test data for a partially penetrating piezometer, a simplified representation of the flow system was adopted. Radial flow through the aquifer material adjacent to the piezometer screen was assumed with no vertical flow in response to the slug-induced disturbance.

For a partially penetrating piezometer, the effective screen length replaces the formation thickness for analytical purposes. The effective length of the well screen is the well-construction property most likely to introduce error into the hydraulic-conductivity estimate (Butler, 1997, p. 20). The length of the screen and the length of the filter pack are the two most common measurements used for the effective screen length. To follow Butler's (1997, p. 21) recommendation, the effective screen length was set equal to the length of the piezometer screen, which was 5 feet for all piezometers, with the exception of Garfield Piezometer 1, which was 15 feet. Therefore, a 5-foot effective screen length was used for all

Table 1. Selected construction data, lithology, and estimates of hydraulic conductivity of aquifer material from selected piezometers, Albuquerque area, New Mexico

Piezometer site	Screened interval (feet)	Borehole diameter[1] (inches)	Lithology[2] (adjacent to screened interval)	Confining unit[3] (feet below land surface)	Date of slug test	Water level on date of slug test (feet below land-surface datum)	Estimated hydraulic conductivity (feet per day)
Sandia Pueblo							
Piezometer 1	1,295-1,300	11.3	Silty clay, sand	1,050-1,600	03-10-99	486.41	3.5[b]
Piezometer 2	1,015-1,020	10.7	Sand	900-920	03-10-99	486.18	92[v]
Hunters Ridge							
Piezometer 1 (nest 1)	1,508-1,513	10.0-10.8	Sandy silt	1,496-1,506	03-31-99	163.25	4.2[b]
Piezometer 2 (nest 1)	845-850	10.0-11.0	Sand with gravel	416-422	03-31-99	159.68	20[b]
Piezometer 1 (nest 2)	349-354	11.0	Silty sand, gravel	None	03-31-99	152.68	41[b]
Piezometer 2 (nest 2)	295-300	10.8	Silty gravel, sand	None	03-31-99	150.15	13[b]
Nor Este							
Piezometer 1	1,515-1,520	11.3-11.5	Sand	1,406-1,412	03-11-99	539.44	60[v]
Sierra Vista							
Piezometer 1	1,634-1,639	10.5-11.0	Clayey sand	1,550-1,560	04-08-99	178.82	3.6[c]
Piezometer 2	918-923	10.8	Sand	908-914	04-08-99	152.83	8.2b[b]
Sister Cities							
Piezometer 1	1,298-1,303	10.5-10.8	Sand	1,270-1,286	03-15-99	348.92	17[b]
Piezometer 2	789-794	10.8	Sand, silty clay	776-782	03-15-99	347.83	6.3[b]
Garfield							
Piezometer 1	995-1,010	10.9-11.5	Sand	960-970	04-05-99	48.89	55[v]
West Bluff							
Piezometer 1 (nest 1)	1,085-1,090	10.5	Silty sand	1,030-1,040	04-01-99	170.88	7.1[b]
Piezometer 2 (nest 1)	679-684	10.8	Sand with gravel	658-664	04-01-99	166.14	12[b]
Piezometer 1 (nest 2)	318-323	11.0	Silty sand	220-250	04-01-99	155.12	6.8[b]
Piezometer 2 (nest 2)	244-249	10.2-11.4	Clayey sand, gravel	135-140	04-01-99	155.14	13[b]

Table 1. Selected construction data, lithology, and estimates of hydraulic conductivity of aquifer material from selected piezometers, Albuquerque area, New Mexico--Concluded

Piezometer site	Screened interval (feet)	Borehole diameter[1] (inches)	Lithology[2] (adjacent to screened interval)	Confining unit[3] (feet below land surface)	Date of slug test	Water level on date of slug test (feet below land-surface datum)	Estimated hydraulic conductivity (feet per day)
98th Street							
Piezometer 1	1,534-1,539	10.5	Silt, clayey sand	1,504-1,508	03-09-99	422.40	6.0[b]
Piezometer 2	1,102-1,107	10.5	Sand, clayey sand	1,054-1,058	03-09-99	423.39	27[b]
Del Sol Divider							
Piezometer 1	1,557-1,562	10.5-10.8	Silty clayey sand	1,534-1,550	03-08-99	333.99	1.5[b]
Piezometer 2	832-837	10.6-10.9	Sand, silty sand	688-738	03-08-99	345.26	1.9[b]
Montesa							
Piezometer 1	1,618-1,623	10.8	Sandy clay	1,214-1,224	03-30-99	212.72	0.15[g]
Piezometer 2	698-703	10.8	Sand	686-694	03-30-99	214.84	19[b]
Isleta							
Piezometer 1	1,315-1,320	10.5	Sandy clay	1,300-1,310	04-06-99	18.04	1.4[g]
Piezometer 2	805-810	10.5	Sand	740-750	04-06-99	8.18	18[b]
Piezometer 3	175-180	10.5	Sand, gravel	130-140	04-06-99	7.35	19[b], 68[c]

[1]Borehole diameter, in the vicinity of the screened interval, estimated from caliper log.
[2]Lithology from drillers' logs, geophysical logs, and drill cutting descriptions.
[3]Confining unit represents the nearest fine-grained interval in excess of 4 feet thick above the screened interval as displayed on geophysical logs and drill cutting descriptions.
[b]Bouwer, 1989.
[c]Cooper, Bredehoeft, and Papadopulos, 1967.
[g]Greene and Shapiro, 1995.
[v]van der Kamp, 1976.

piezometers except Garfield Piezometer 1, where a 15-foot effective screen length was used. The 5- and 15-foot screen lengths are the minimum effective screen lengths. Using minimum effective screen lengths has the effect of overestimating hydraulic conductivity. If the actual effective screen length was the length of the sandpack (about 30 feet) the overestimation would be about 30 feet divided by 5 feet or six times.

Consistent with the assumption of radial flow, the saturated thickness of the interval tested was assumed to be equal to the minimum effective screen length. Therefore, the saturated thickness was 5 feet for all analyses except Garfield Piezometer 1, for which a 15-foot saturated thickness was assumed.

Effective Radii of Piezometer Casing and Screen

The analytical methods also require estimates of the effective radii of the piezometer casing and screen. For the analyses discussed in this report, the effective screen radius was set equal to the radius of the filter pack, following the rationale discussed by Butler (1997, p. 21). The diameter of the filter pack is approximately 10 5/8 inches, which was the size of the drill bit used to drill the borehole. The borehole diameter near the screened interval for each piezometer was determined from caliper logs available for each nested-piezometer site (table 1). The diameter of the piezometer casing was set equal to the 2.323-inch inside diameter of the casing.

Bouwer and Rice Method

The Bouwer and Rice method applied to confined aquifers is a modification of their solution developed for slug tests in partially or fully penetrating wells in unconfined formations (Bouwer, 1989). The method assumes that the aquifer is homogeneous and isotropic. Duffield (1996) developed a computer program (AQTESOLV) to automate the Bouwer and Rice method for analysis of a slug test in a confined aquifer.

For example, this method was applied to Sister Cities Piezometer 2 (fig. 4). The plot starts at the beginning of the recovery period and shows water-level displacement with time. A visual, straight-line match to the early part of the plot gives a hydraulic conductivity of 6.3 feet per day (fig. 4). The early part of the plot represents the changing water level during the first 4 minutes of recovery. After about 5 minutes of recovery, the water level has come to equilibrium about 0.01 foot below the original static water level.

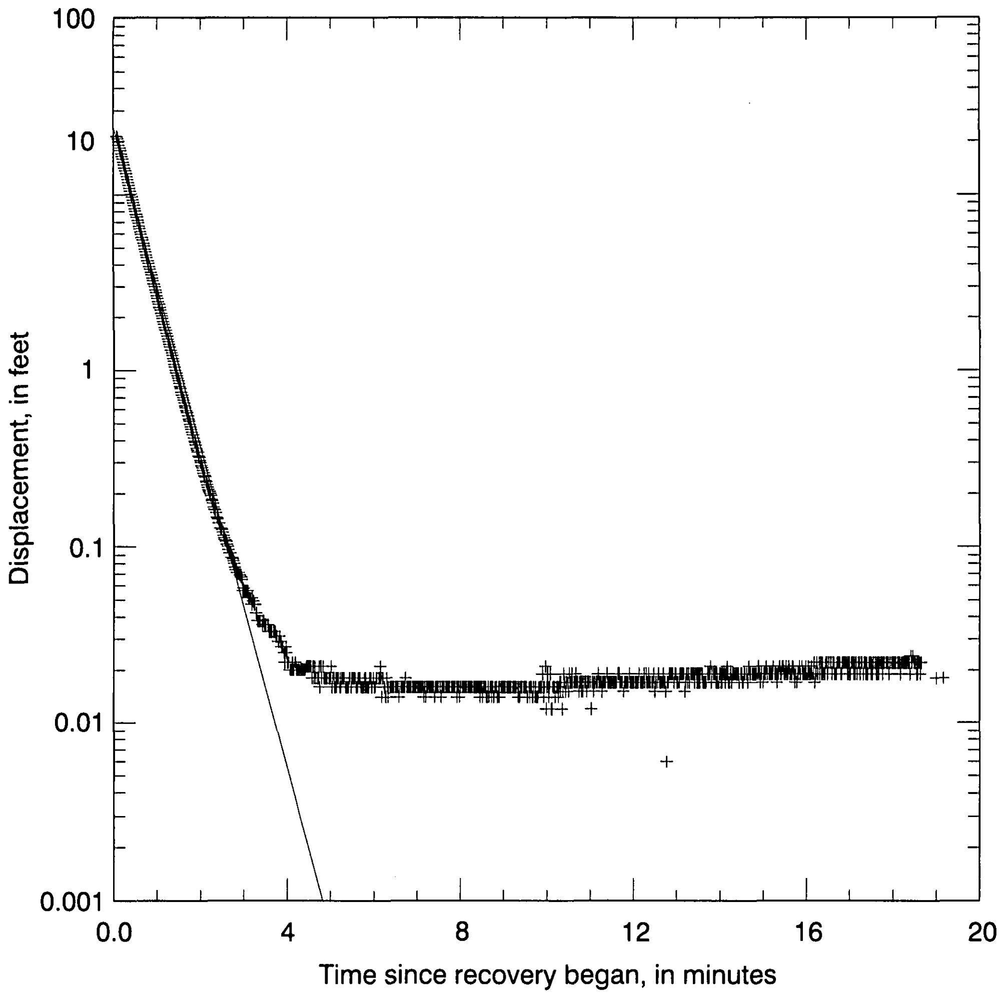
Cooper, Bredehoeft, and Papadopulos Method

Cooper, Bredehoeft, and Papadopulos (1967) discussed a type-curve solution for the analysis of a slug test in a confined aquifer. Their solution assumes a nonflowing well fully penetrating a confined aquifer of homogeneous and isotropic material. Their solution is modified for partially penetrating conditions with the assumptions discussed earlier. Duffield's (1996) computer program (AQTESOLV) automated the Cooper, Bredehoeft, and Papadopulos solution for the analysis of a slug test for partially penetrating conditions in a confined aquifer. This program was used to analyze slug-test data for Sierra Vista Piezometer 1 and Isleta Piezometer 3.

For example, the Cooper, Bredehoeft, and Papadopulos method was applied to Sierra Vista Piezometer 1 (fig. 5). The plot starts at the beginning of the recovery period and shows water-level displacement divided by initial displacement with time. In figure 5, the AQTESOLV software fits the plotted points to a match curve. The program calculated a transmissivity of 18 feet squared per day for the match curve. Transmissivity divided by saturated thickness (assumed to be screen length) gave a hydraulic conductivity of 3.6 feet per day

Shapiro and Greene Method

Shapiro and Greene developed a modification of the air-pressurized slug test suitable for low-permeability aquifer material. Their method includes a specialized application of the Cooper, Bredehoeft, and Papadopulos type-curve solution (Greene and Shapiro, 1995; Shapiro and Greene, 1995). The method, modified for partially penetrating conditions, assumes radial flow and a confined aquifer of homogeneous and isotropic material. The advantage of this method is the time saved collecting data in the field. When the time required for the pressurized water level to come to equilibrium in low-permeability aquifer material is quite long, the slug test can be stopped before the new equilibrium water level is achieved (fig. 2b). Two of the 25 piezometers tested during this study (Montesa Piezometer 1 and Isleta Piezometer 1) were prematurely terminated and analyzed using this method.



PROJECT INFORMATION

Test location: Albuquerque, N. Mex.
Test well: Sister Cities, Piezometer 2
Test date: 3/15/99

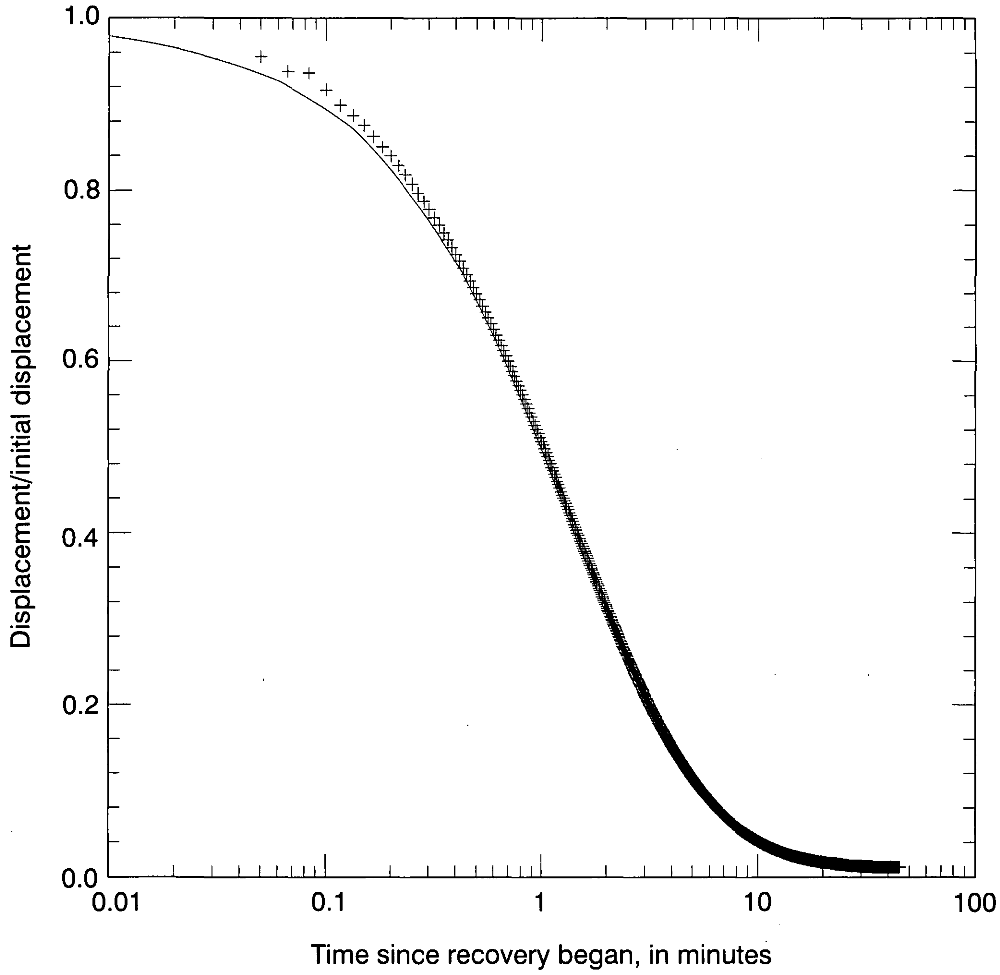
WELL DATA

Initial displacement: 22.82 feet
Casing radius: 0.0968 foot
Screen length: 5 feet
Water column height: 12 feet
Well-bore radius: 0.45 foot

SOLUTION

Aquifer model: confined
Solution method: Bouwer and Rice
Hydraulic conductivity = 6.3 feet/day

Figure 4. Bouwer and Rice straight-line match to plot of water-level displacement with time, starting at the beginning of the recovery period.



PROJECT INFORMATION

Test location: Albuquerque, N. Mex.
Test well: Sierra Vista, Piezometer 1
Test date: 4/8/99

WELL DATA

Initial displacement: 23.76 feet
Casing radius: 0.0968 foot
Screen length: 5 feet
Water column height: 79 feet
Well-bore radius: 0.4479 foot

SOLUTION

Aquifer model: confined
Solution method: Cooper, Bredehoeft, and Papadopulos
Hydraulic conductivity = 3.6 feet/day

Figure 5. Cooper, Bredehoeft, and Papadopulos type-curve match to plot of water-level displacement divided by initial displacement with time, starting at the beginning of the recovery period.

For example, the Shapiro and Greene method was applied to Montesa Piezometer 1 (fig. 6). The plot starts at the beginning of the recovery period and shows water-level displacement divided by initial displacement with time. Figure 7 is a plot of type curves generated using Shapiro and Greene's method. The two figures are overlaid and slid along the horizontal axis until a best fit of the slug-test data (fig. 6) with one of the type curves (fig. 7) is obtained. A match point is chosen so that dimensionless time of the type curve equals 1 (fig. 7) to facilitate the calculation process. Calculations yield a transmissivity of 0.75 foot squared per day and a hydraulic conductivity of 0.15 foot per day.

Van der Kamp Method

Oscillatory slug-test data sets require specialized analytical methods, such as that of van der Kamp (1976). Oscillatory response occurs because of higher transmissivities, longer water column lengths, and the initial behavior of an aquifer in an elastic manner when perturbed (Weight and Wittman, 1999). Bredehoeft and others (1966) showed that oscillatory responses to slug tests are primarily controlled by the inertia of the water column in the well. They showed that the transmissivity of the aquifer around the screened interval and the length of the water column above the top of the screen are the primary determinants of oscillation of the water column. Slug tests conducted in 3 of the 25 piezometers (Sandia Pueblo Piezometer 2, Nor Este Piezometer 1, and Garfield Piezometer 1) had oscillatory responses and were analyzed using the van der Kamp method.

The van der Kamp method requires an estimate of storativity, a dimensionless number, defined as the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Lohman, 1972, p. 8). An estimate of storativity for the sand lithology (table 1) adjacent to the screened intervals of these piezometers is 10^{-4} (Weight and Wittman, 1999; Douglas McAda, U.S. Geological Survey, oral commun., 1999). Storativity appears as a product inside the logarithmic term of one of the coefficient terms so that even a large error in magnitude will have a small effect on a hydraulic-conductivity estimate (Butler, 1997, p. 158-159).

For example, the van der Kamp method was applied to Nor Este Piezometer 1 (fig. 8). The plot starts about 13 seconds after the beginning of the recovery period and shows water-level displacement with time. The angular frequency (ω) and the damping coefficient (C) are estimated from subsequent peaks or troughs in the test data as shown in figure 8. These estimates are then used to calculate the effective column length and dimensionless damping parameter as described in Butler (1997, p. 155). Hydraulic conductivity is estimated by iteration as described in Butler (p. 155-156) and is equal to 60 feet per day.

ESTIMATES OF HYDRAULIC CONDUCTIVITY

Estimates of hydraulic conductivity presented in this report are representative of only the aquifer material (lithology) near the screened interval of each piezometer, not hydraulic conditions of the aquifer system as a whole. Overall, the estimated values of hydraulic conductivity correlate favorably with the lithology representative of the screened interval of each slug-tested piezometer. That is, the smaller hydraulic conductivities are associated with the fine-grained lithologies and the larger hydraulic conductivities are associated with the coarse-grained lithologies.

Hydraulic-conductivity estimates range from 0.15 foot per day at Montesa Piezometer 1 to 92 feet per day at Sandia Pueblo Piezometer 2 (figs. 9 and 10; table 1). Hydraulic-conductivity estimates range from 0.15 to 8.2 feet per day (table 1) for aquifer material at 12 of the 25 piezometers. The lithology near the screened intervals of these piezometers is described as clayey sand, silty clay, silt, silty sand, and sand (table 1). Estimates range from 12 to 41 feet per day (table 1) for aquifer material at 10 of the 25 piezometers. The lithology near the screened intervals of these 10 piezometers is described as silty sand, sand, and gravel (table 1). Hydraulic-conductivity estimates are greater than 41 feet per day at 4 of the 25 piezometers (two hydraulic-conductivity estimates are presented for Isleta Piezometer 3; table 1). The lithology near the screened intervals of these four piezometers is described as sand and gravel (table 1).

SUMMARY

Investigators conducted air-pressurized slug tests from March 8 through April 8, 1999, for 25 selected piezometers at 11 nested-piezometer sites within the Albuquerque area. Slug-test data were analyzed and used to estimate hydraulic conductivity at discrete depths in the Santa Fe Group aquifer system.

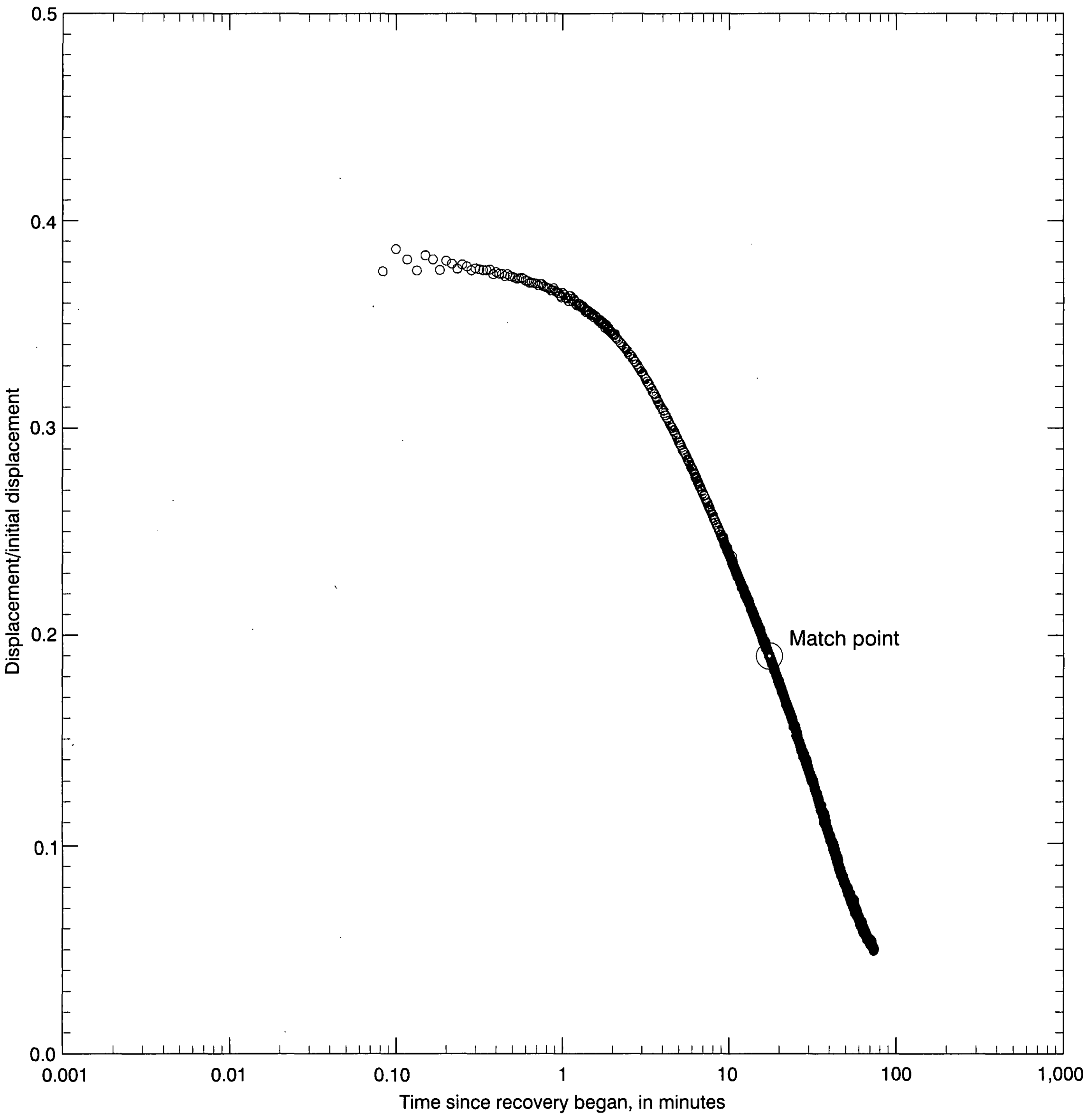


Figure 6. Water-level displacement divided by initial displacement with time, starting at the beginning of the recovery period for prematurely terminated, air-pressurized slug test, Montesa Piezometer 1, March 30, 1999.

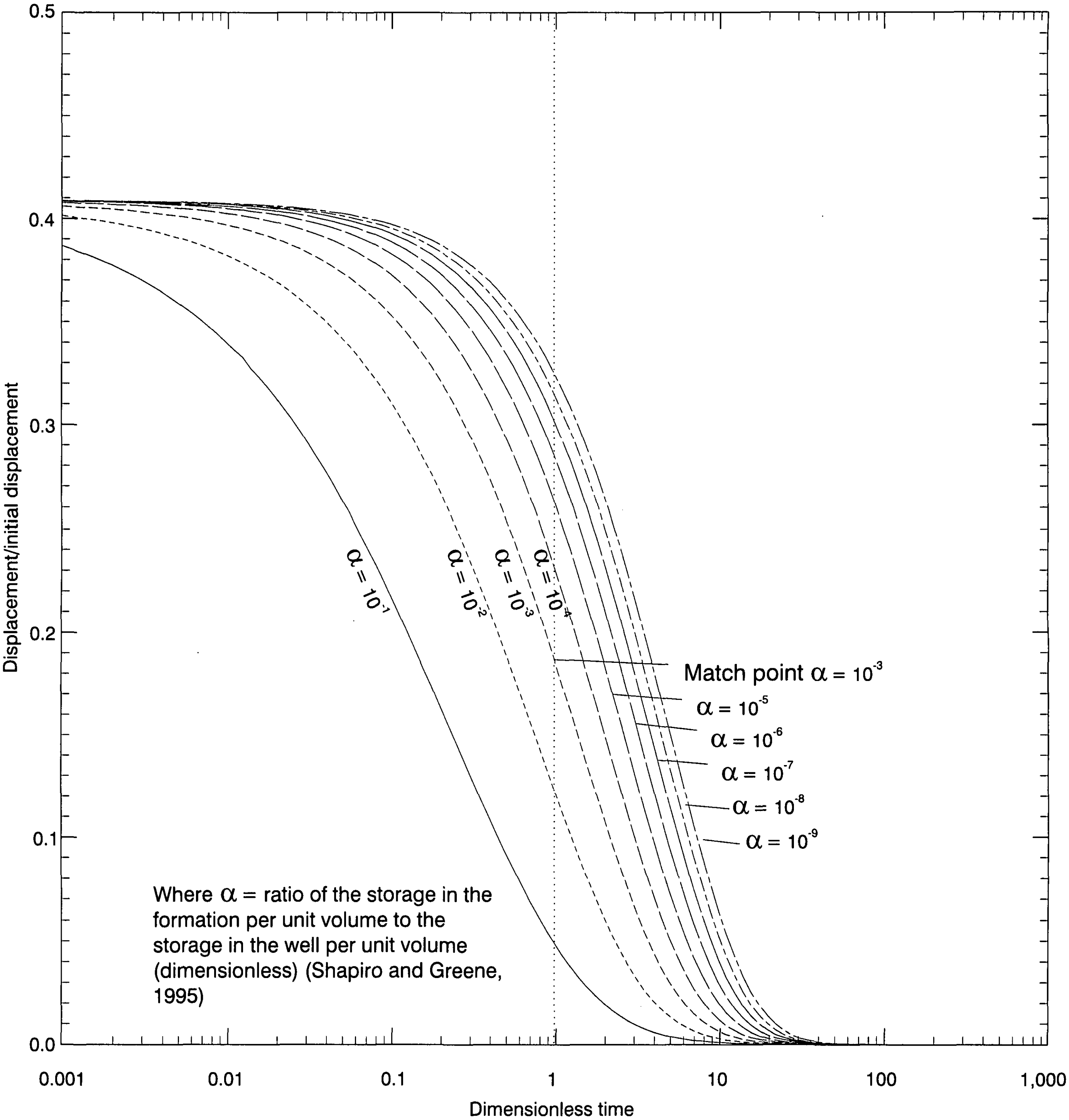


Figure 7. Type curves for prematurely terminated, air-pressurized slug test, Montesa Piezometer 1, March 30, 1999.

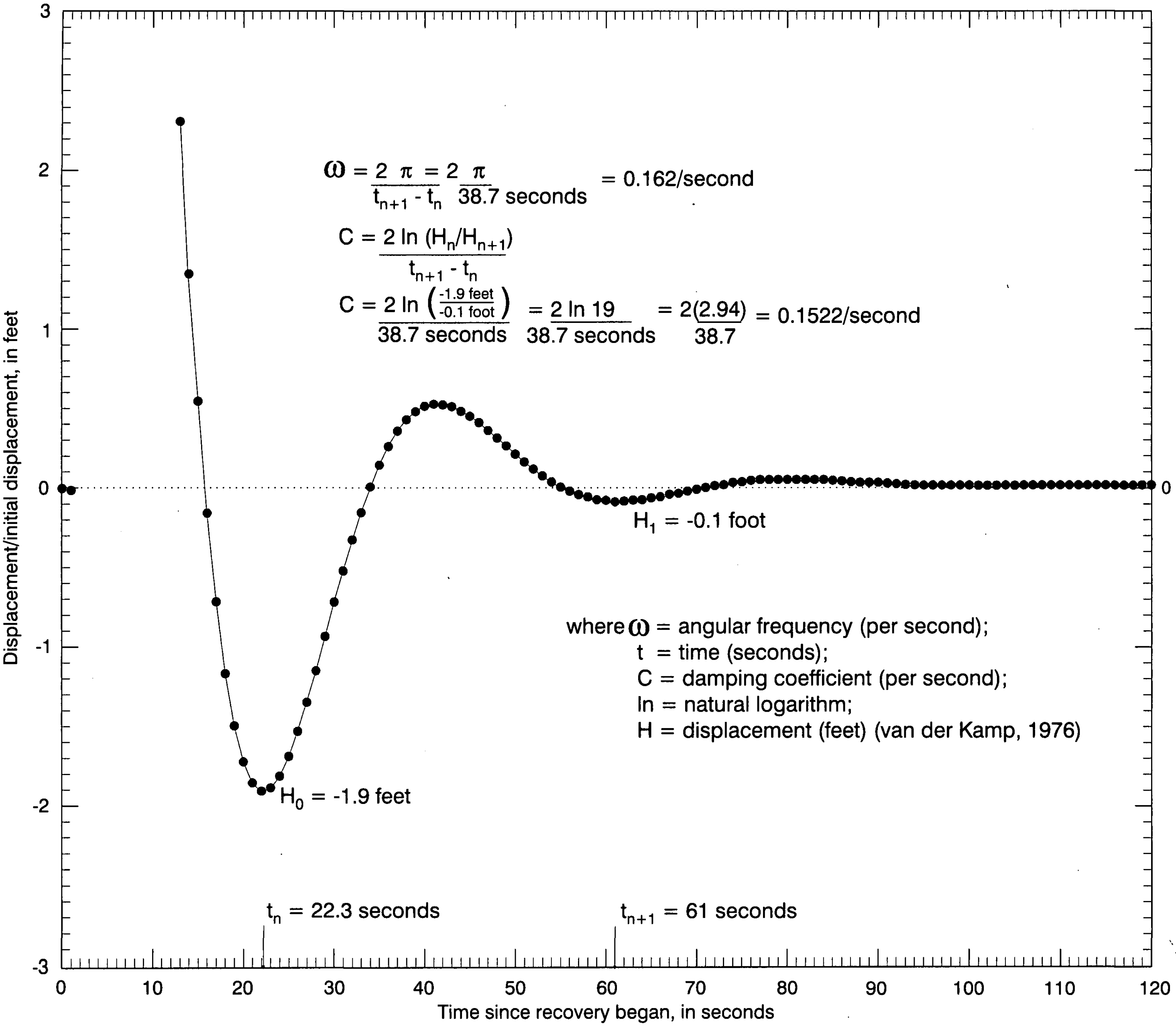


Figure 8. Water-level displacement with time, starting at the beginning of the recovery period for slug test, Nor Este Piezometer 1, March 11, 1999.

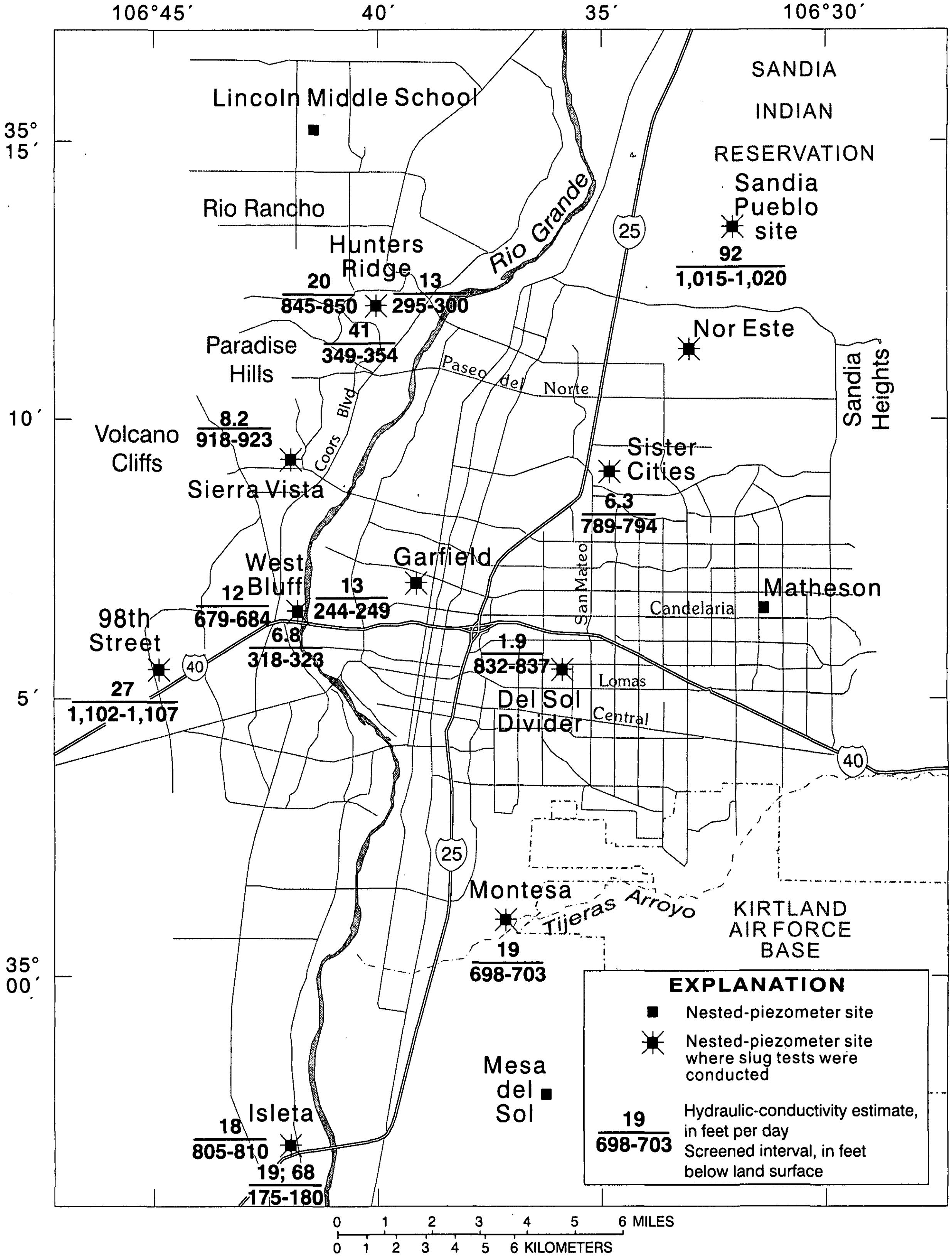


Figure 9. Hydraulic-conductivity estimates at the middepth piezometers, Albuquerque, New Mexico.

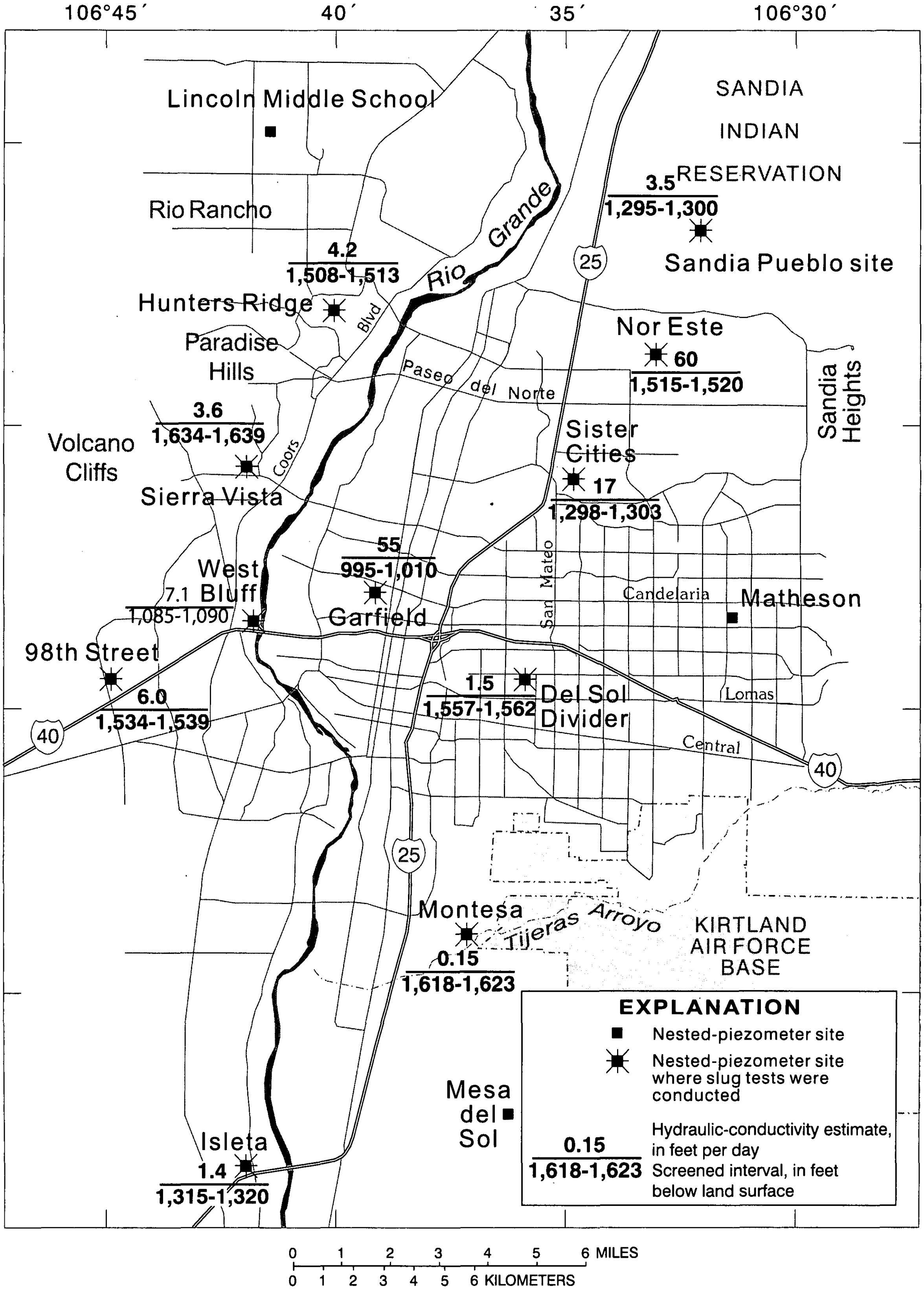


Figure 10. Hydraulic-conductivity estimates at the deepest piezometers, Albuquerque, New Mexico.

At 20 of the piezometers, slug-test responses were typical; at 2 piezometers, tests were prematurely terminated because the tests were taking too long to complete; and at 3 piezometers, test responses were oscillatory. Investigators used four analytical methods to determine aquifer-hydraulic properties. The four methods were dependent on the water-level responses to the slug tests: the Bouwer and Rice method or the Cooper, Bredehoeft, and Papadopulos method for the typical responses; the Shapiro and Greene method for the prematurely terminated responses; and the van der Kamp method for the oscillatory responses.

Hydraulic-conductivity estimates ranged from 0.15 to 92 feet per day. In general, the smaller hydraulic-conductivity estimates are associated with fine-grained aquifer materials and the larger estimates are associated with coarse-grained aquifer materials adjacent to the screened intervals of the slug-tested piezometers. Twelve hydraulic-conductivity estimates ranged from about 0.15 to 8.2 feet per day, and 10 ranged from about 12 to 41 feet per day. Four of the estimates were greater than 41 feet per day (two estimated hydraulic conductivities are presented for Piezometer 3 at the Isleta site).

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