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Groundwater resources in the Saline Valley Conservancy District, Saline and Gallatin Counties, Illinois

VICKIE L. POOLE
Geological Survey Division, INR

ELLIS W. SANDERSON
Water Survey Division, INR

This cooperative study was supported partly by funds provided through the University of Illinois by the Illinois Department of Transportation, Division of Water Resources, and partly by the Saline Valley Conservancy District.

September 1981

Illinois Institute of Natural Resources
GEOLOGICAL SURVEY and WATER SURVEY Divisions
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ILLINOIS STATE GEOLOGICAL SURVEY
Natural Resources Building
615 East Peabody Drive
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Poole and Sanderson: ISGS CONTRACT/GRANT REPORT: 1981-2

ERRATA

p. 3, 4th paragraph, beginning with line 9, should read: ...Formation. Beach and bar sands that were formed in Lake Saline and sand and gravel deposits that were formed from wave erosion of till have also been included in the Equality Formation. These coarser-grained deposits can yield small to moderate supplies of groundwater locally.

CONTENTS

ACKNOWLEDGMENTS

This study was supported in part by funds provided through the University of Illinois by the Illinois Department of Transportation, Division of Water Resources, Frank Kudrna, director, Siavash Mostoufi, and John K. Flowe, planning and research engineers, and in part by the Saline Valley Conservancy District, Shirley Ligon, manager.

Drafting: Fred Graszer

Groundwater resources in the Saline Valley Conservancy District, Saline and Gallatin Counties, Illinois

ABSTRACT

A number of communities in Saline County and western Gallatin County, Illinois, experience periodic water shortages. These communities obtain their water supplies from a variety of sources, each inadequate to supply increasing demands. A comprehensive hydrogeologic study of this region was conducted as part of a continuing program to assess public groundwater supplies and regional aquifers. This study included reevaluation of existing subsurface and geophysical data supplemented by extensive surface electrical earth resistivity surveys and a controlled drilling, sampling, and testing program. A high-capacity test well and three observation wells were constructed, and a controlled aquifer test was conducted to evaluate the production capabilities of a promising sand and gravel aquifer. Analysis of the study data shows that a 3 million gallons per day well field can be successfully completed at a location 1½ miles north of Junction, Gallatin County, Illinois.

INTRODUCTION

A number of communities in Saline and western Gallatin Counties, Illinois, experience periodic water shortages. These communities obtain their water supplies from a variety of sources, each inadequate to satisfy increasing demands. A high-priority goal of the Saline Valley Conservancy District has been to develop an adequate, reliable groundwater supply for the water-deficient communities in the District. An estimated 1.7 million gallons per day is needed to fulfill current water demands; future demands are expected to increase to 3 million gallons per day.

The Water Resources Division of the Illinois Department of Transportation and the State Geological Survey and State Water Survey Divisions of the Illinois Institute of Natural Resources are currently assessing regional aquifer systems in Illinois as part of an ongoing program. The Saline Valley Conservancy District asked these agencies for help in exploring and developing groundwater resources in the District.

The cooperative study subsequently undertaken consisted of geologic assessment by the State Geological Survey and hydrologic assessment by the State Water Survey. The geologic assessment included examination and evaluation of current subsurface and geophysical data. Additional geophysical studies (surface electrical earth resistivity and down-hole logging of test holes) were conducted in selected areas. Analyses of formation samples recovered during test drilling were used in conjunction with the geophysical logs to determine the character and distribution of potential aquifers in the study region. Hydrologic assessment, using a controlled aquifer test, included evaluation of the character and water-producing capabilities of a sand and gravel aquifer.

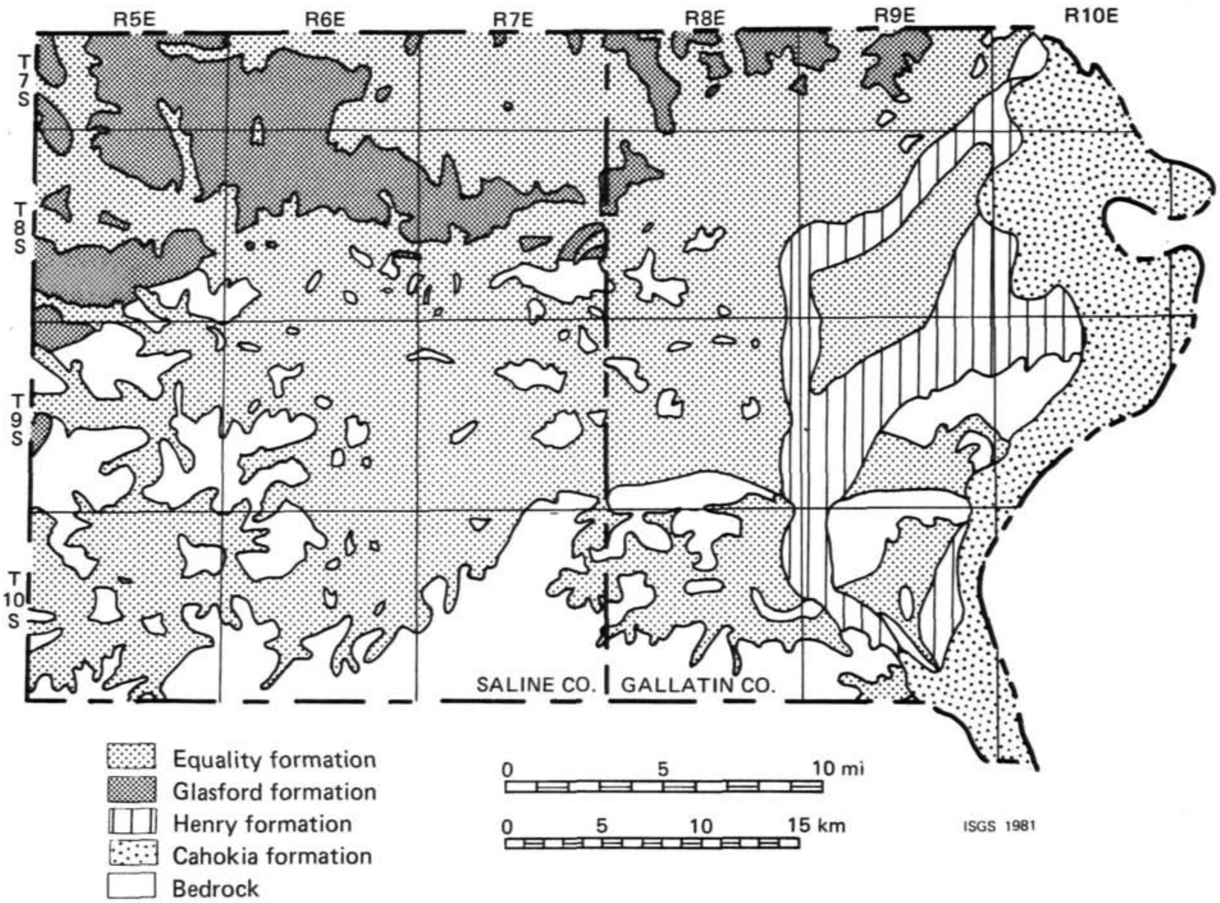


FIGURE 1. Generalized Quaternary deposits of Saline and Gallatin Counties, Illinois.

GEOLOGY

This discussion of geology is based on the work of Frye et al. (1972), Horberg (1952), Lineback and others (1979), Willman and Frye (1970), and Heinrich (1981) as well as on data gathered for this study.

The Saline Valley Conservancy District is in southeastern Illinois near the confluence of the Wabash and Ohio Rivers. The District includes the major portion of the Saline River Basin, Saline and Gallatin Counties, Illinois (exclusive of T. 7-8 S., R. 9-10 E.). The District includes divisions of two physiographic provinces: The Mount Vernon Hill Country of the Till Plains Section of the Central Lowland Province and the Shawnee Hills Section of the Interior Low Plateaus Province. Topography of the area varies from gently rolling till plains in the north-northwest and flat Pleistocene lake plains in the central portion of the District to an unglaciated, rough-surfaced area controlled by bedrock and local geologic structures in the south and southeast.

Surface drainage of the area is principally to the east and southeast toward the Ohio River via the Saline River and its tributaries. Extensive channel improvements and construction of large drainage ditches have been necessary because of poor natural drainage, especially on the Pleistocene lake plains.

The Saline Valley Conservancy District is situated at the southern margin of Pleistocene glaciation in Illinois. Unconsolidated deposits (figs. 1, 2) of the Saline Valley range from 0 to more than 160 feet (48.5 m) thick; they consist of a complex of Illinoian moraines and ridged drift, Holocene and Wisconsinan alluvium, outwash, and gravel terraces, and Wisconsinan lake deposits and loess (wind-blown silt). The blanketing loess varies in thickness from 2 feet (.6m) to 8 feet (2.4 m) in Saline County, and from 6 feet (1.8 m) to 25 feet (7.6 m) in Gallatin County.

The bedrock surface in the study area consists primarily of Pennsylvanian shales, siltstones, sandstones, limestones, and coal. A narrow band of Mississippian limestones is present along the upthrown side of the Shawneetown Fault in the southern part of the District. Where present, the sandstones, and to a lesser extent, the fractured limestones, can generally yield small supplies of water for domestic use.

The thin glacial till and intercalated outwash deposits in the northern part of the District have been assigned to the Glasford Formation of the Illinoian Stage of glaciation. They represent the southernmost limits of glaciation in Illinois. The outwash occurs as thin, discontinuous lenses and stringers and can yield only small supplies of water for domestic use.

At the beginning of the Wisconsinan Stage of glaciation, outwash from glaciers located in the upper Ohio River and Wabash River Basins filled the main valleys of the Wabash and Ohio Rivers, blocking drainage to the Ohio River from the Saline River Basin and forming Lake Saline. The silts and clays deposited in these lakes throughout most of the Wisconsinan Stage have been assigned to the Equality Formation. These coarser-grained deposits can yield small to moderate supplies of ground water locally.

Most of the sand and gravel outwash deposited during the Wisconsinan Stage of glaciation has been assigned to the Henry Formation. The Henry Formation is generally a surficial unit, but in the Saline Valley it does include outwash deposits beneath the lake deposits of the Equality Formation. Sand and gravel deposits of the Henry Formation are a major source of groundwater.

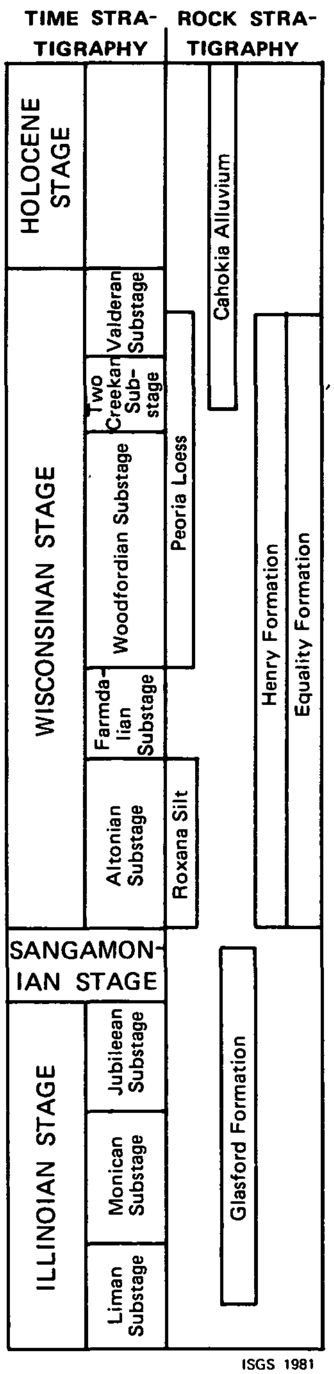


FIGURE 2. Generalized stratigraphic classification of the upper Pleistocene Series.

Water for domestic and municipal use within the Conservancy District is now obtained from four general sources: (1) Harrisburg Lake (a man-made reservoir); (2) Pennsylvanian sandstones; (3) local, thin sand and gravel deposits of the Saline River Valley (Equality Formation); and (4) thick sand and gravel deposits of the Ohio River Valley bottomlands (Henry Formation and Cahokia Alluvium, a late Wisconsinan to Holocene outwash deposit). A review of currently available information suggested that favorable conditions existed for major water-bearing sand and gravel deposits in an area near the Ohio River, just north and south of the Shawneetown Hills and just east of Ridgway, in the broad lowlands associated with the Wabash, Little Wabash, and Ohio Rivers. Exploration for a water supply for the Saline Valley Conservancy District was concentrated along the Saline River and its branches and in areas where available well data indicated considerable thicknesses of Henry and Equality Formations (glacial drift and alluvium). These areas were chosen for detailed study in the hope of minimizing the length of pipeline required to serve Harrisburg, Eldorado, and eventually other communities.

Geophysical study

Geologic assessment of the Saline Valley Conservancy District began with the collection and evaluation of available subsurface data, including well logs, auger and bridge borings, and coal and oil well records. Previous geophysical studies (primarily electrical earth resistivity surveys) in the area were reevaluated. Areas were delineated where data were lacking, where sand and gravel aquifers were currently being utilized, and where other water-bearing deposits might exist. This procedure and the decision of the Saline Valley Conservancy District to search for a large groundwater supply (approximately 3 million gallons per day) west of the Ohio River, provided guidelines for determining the profile locations for a supplemental electrical earth resistivity survey. The results of this new survey were then used in conjunction with existing geologic and geophysical data to select proposed locations of 12 test holes within the District.

An electrical earth resistivity survey is a rapid, inexpensive, and relatively reliable method of determining the possible presence or absence of coarse-grained, water-bearing deposits within the unconsolidated sediments that cover a large portion of the study area. The method is based on the fact that where fresh water is present, coarse-grained sand and gravel deposits present greater resistance to the flow of electrical current than fine-grained silts and clays.

From July to September, 1980, 191 vertical electrical sounding (VES) profiles were run in the Conservancy District (fig. 3). These profiles and 107 VES profiles located near the town of Equality in Gallatin County in 1946 were analyzed, using both qualitative and quantitative techniques. Qualitative analyses included plotting apparent resistivity values vs potential electrode spacings (VES curves) for each VES profile. Examination of maxima, minima, and inflection points of apparent resistivity on these VES curves provided a general idea of the types and distributions of the lithologies in the unconsolidated deposits. Quantitative analyses of the resistivity data were conducted using a digital computer program which inverts VES curves into a corresponding series of layering parameters—thicknesses and "true" resistivities (fig. 4). The technique, developed by Zohdy and Bisdorf (1975), uses the method of convolution (Ghosh, 1971) and modified Dar Zarrouk functions (Zohdy, 1973, 1975). Figure 3 shows the

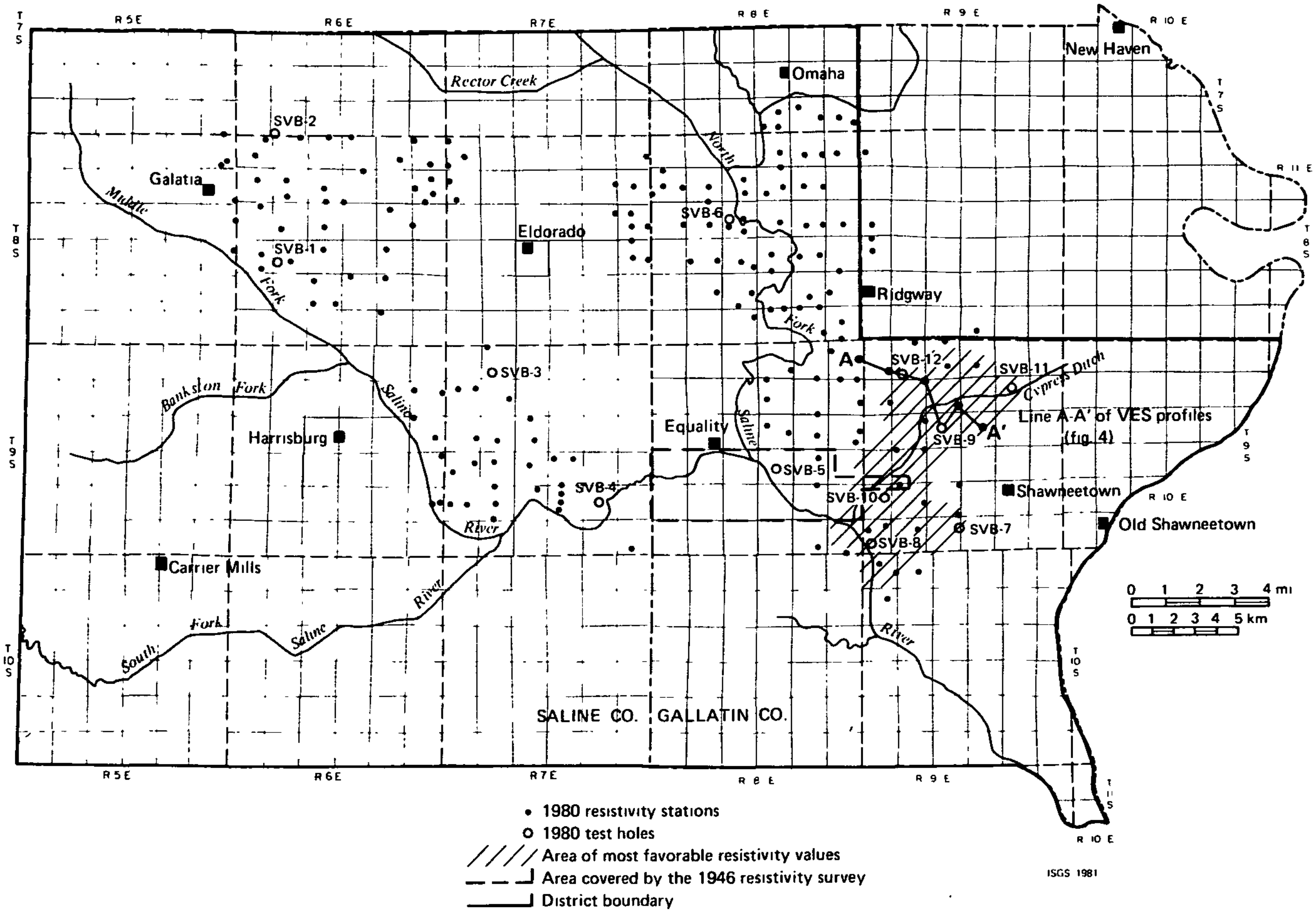


FIGURE 3. Resistivity station and test hole locations, Saline Valley Conservancy District.

location of the profiles, and figure 4 presents the inversion of a typical line (AA') of VES profiles.

The electrical earth resistivity data indicated several areas in the Saline Valley Conservancy District where water-bearing sand and gravel deposits were likely to be present. Several small areas in Saline County and a large arcuate area northwest, west, and southwest of the Shawneetown Hills in Gallatin County were considered most favorable. Test drilling sites SVB-1 through SVB-12 (fig. 3) were chosen partly on the basis of the resistivity data and partly on the lack of subsurface data in the area. Another factor in determining locations of test holes was the availability of easements. This factor ruled out the possibility of a boring site near the Ohio River.

Drilling program

On the basis of geologic and geophysical data, four test holes (SVB-1 through SVB-4) in Saline County and eight test holes (SVB-5 through SVB-12) in Gallatin County (fig. 3) were drilled. John Mathes and Associates, Inc. (Joe Simoncini, driller) were contracted to drill the test holes. Test Holes SVB-1 through SVB-11 were drilled in August and September, 1980, and Test Hole SVB-12 was drilled in November, 1980. Wash samples were collected at 5-foot (1.5 m) intervals and split-spoon samples were collected at chosen intervals at each

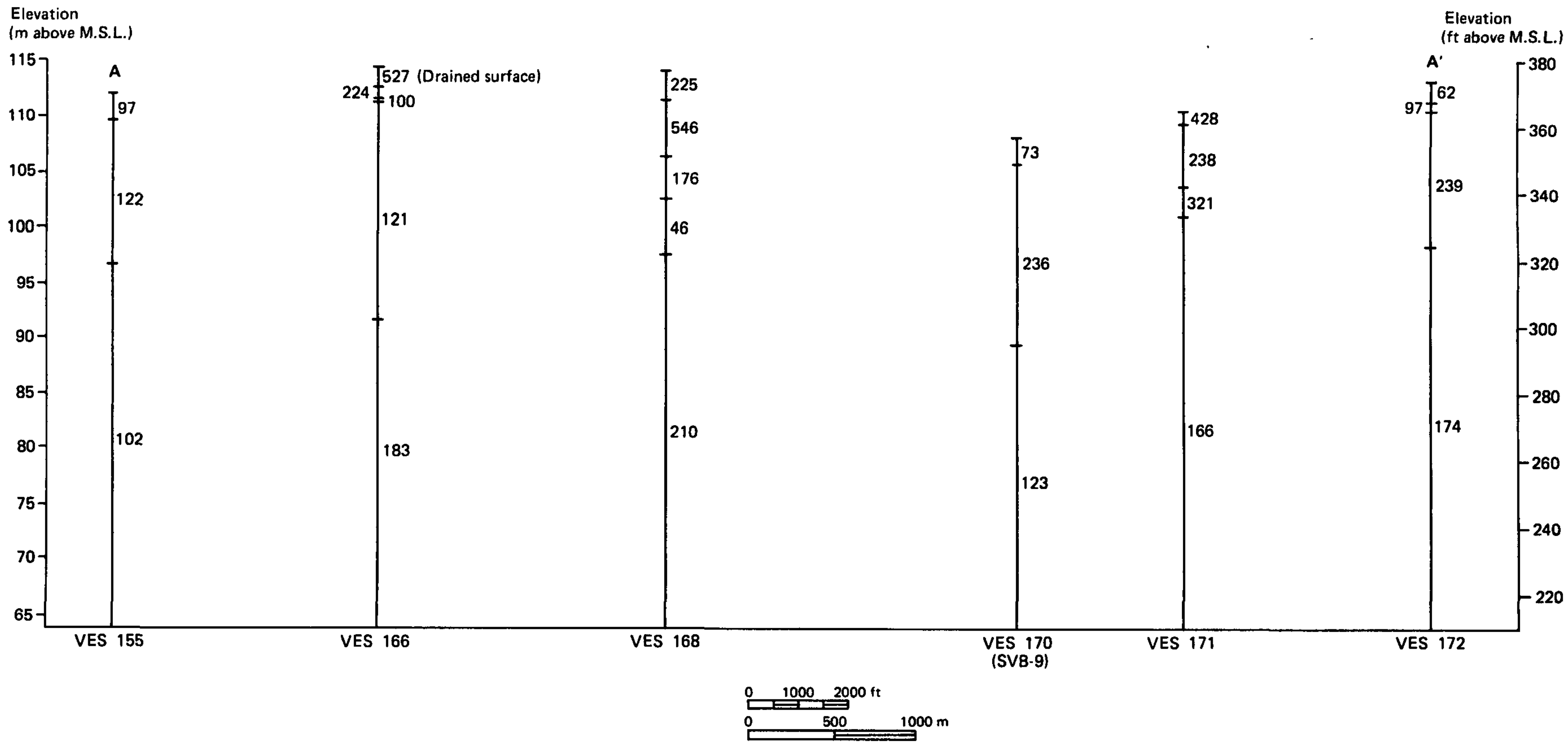


FIGURE 4. Saline Valley Conservancy District study area. Layering parameters ("true" resistivity and thicknesses) determined by inversion of vertical electrical sounding (VES) data along line A - A' (see fig. 3). "True" resistivity values are in ohm-feet. (Data collected in 1980.)

test hole. After description and lab analyses, all samples were placed in the files of the Illinois State Geological Survey samples library. Three geophysical logs (spontaneous potential, resistivity, and natural gamma radiation) were run in each test hole before it was plugged; these logs helped determine the character of the unconsolidated sediments. A simple descriptive log and trace of the natural gamma log for each test hole are included in appendix A.

HYDROLOGY

Study of the resistivity and test hole data suggested that a favorable location for developing the desired water supply existed in the vicinity of Test Hole SVB-9, about 1 1/2 miles north-northeast of the Village of Junction. A site for constructing a high capacity test well was subsequently obtained by the Conservancy District in the NE NE NE Section 17, T. 9 S., R. 9 E., Gallatin County, about 1/2 mile west of Test Hole SVB-9 (fig. 5). Groundwater in the sand and

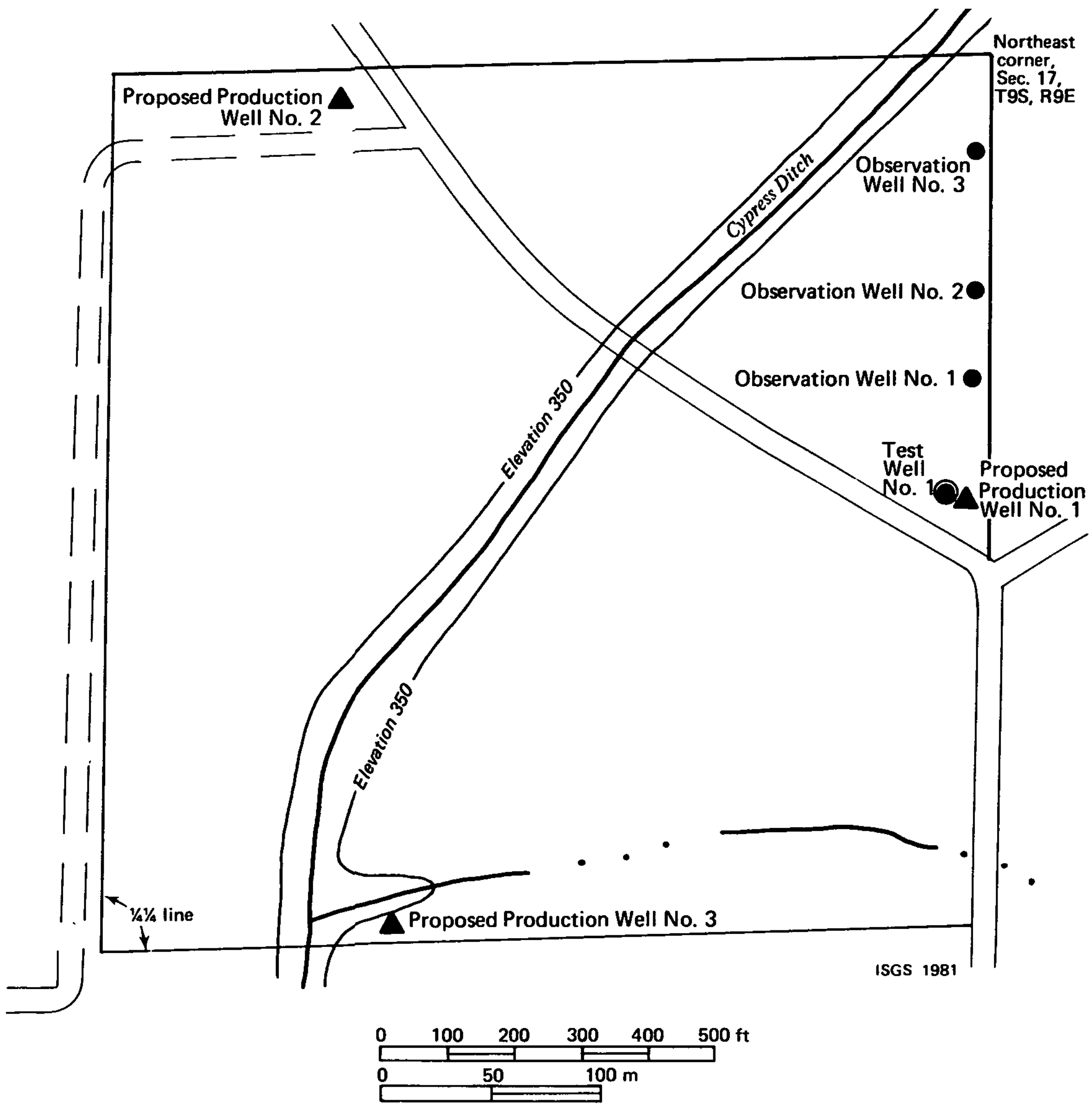


FIGURE 5. Location of aquifer test site and proposed production wells in the NE¼ NE¼, Sec. 17, T. 9 S., R. 9 E., Gallatin County.

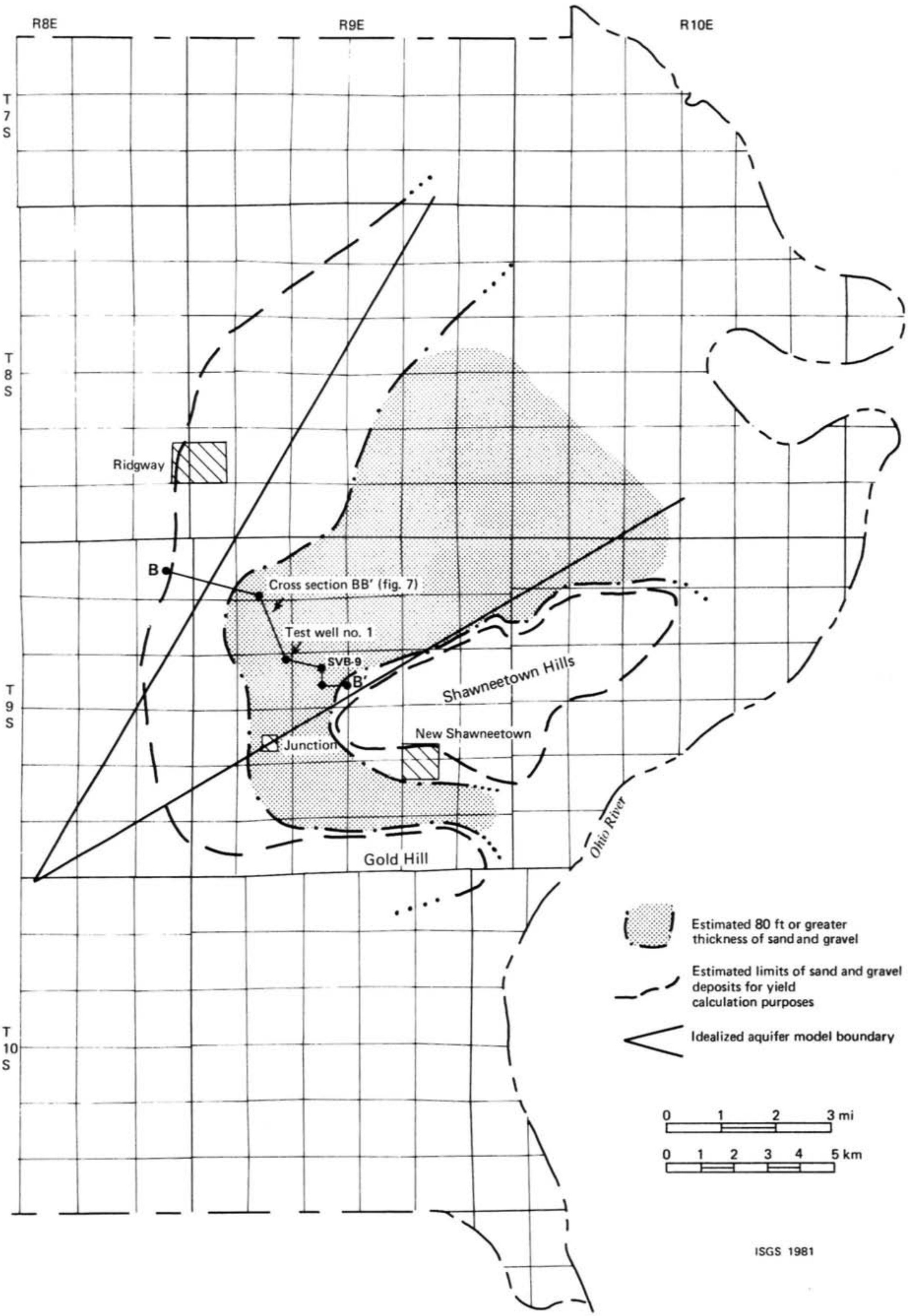


FIGURE 6. Saline Valley Conservancy District study area (Gallatin County) showing areal extent of aquifer and general estimated thickness.

gravel aquifer occurs under artesian and water table conditions. Artesian conditions exist where till or fine-grained lacustrine deposits overlie the aquifer and impede or retard the vertical movement of groundwater, thus confining the water in the aquifer under artesian pressure. Under artesian conditions, water levels in wells tapping the aquifer rise above the top of the aquifer into the overlying fine-grained clay or till deposits. Water table conditions exist at places where the water levels in wells tapping the aquifer lie within the sand and gravel aquifer.

Artesian and water table conditions were encountered in Test Well No. 1 and Test Hole SVB-9. At Test Well No. 1, the driller's log (appendix B-l) shows the clay is present from land surface to 9 feet (2.7 m) and 15 to 30 feet (4.5 to 9.1 m). These clay beds impede the vertical movement of groundwater and confine the water under artesian pressure. At Test Hole SVB-9, the log (appendix A) shows that silty sand is present from land surface to 10 feet (3.0 m). These deposits allow vertical movement of groundwater (recharge) and expose the groundwater surface to atmospheric pressure (i.e., water table'conditions).

Hydrogeology

The estimated areal extent of the sand and gravel aquifer system in the study area is shown in figure 6. The aquifer appears to extend northeast to the Ohio River and southeast between the Shawneetown Hills and Gold Hill to the Ohio River, following a preglacial bedrock channel that was possibly carved by the ancient Ohio River. The Shawneetown Hills and Gold Hill are composed of bedrock and are the impermeable limits of the aquifer; thus they act as barrier boundaries which distort the cone of depression and result in increased drawdown in the well field. To the west, and northwest, the underlying bedrock surface rises, resulting in the aquifer's pinching out. It is estimated that an effective boundary trends in a northeasterly direction near Ridgway (fig. 6). Northwest-southeast cross-section B-B' (fig. 7) shows the thickness and distribution of the sand and gravel aquifer and its relationship with the bedrock surface. The aquifer averages 80 feet (24.2 m) in thickness and consists mainly of clean, fine, light brown to olive-gray sand with some coarse sand to gravel layers. The results of a sieve analysis on formation samples collected from Test Hole SVB-9, Test Well No. 1, and Observation Well No. 2 are shown in appendix D.

Aquifer test

A controlled aquifer test of the high capacity test well was made in December 1980 to determine the hydraulic properties of the sand and gravel aquifer. The test was conducted by the State Water Survey in cooperation with the Layne-Western Company, Inc., drilling contractor, and Brown-Roffman, consulting engineers.

The hydraulic properties of an aquifer and its confining bed may be determined by analyzing data from aquifer tests in which the effects on water levels due to pumping a well at a known constant rate are measured in the pumped well and at observation wells penetrating the aquifer. Graphs of water level drawdown versus time after pumping started, and graphs of drawdown versus distance from the pumped well, are used to solve equations that express the relationship

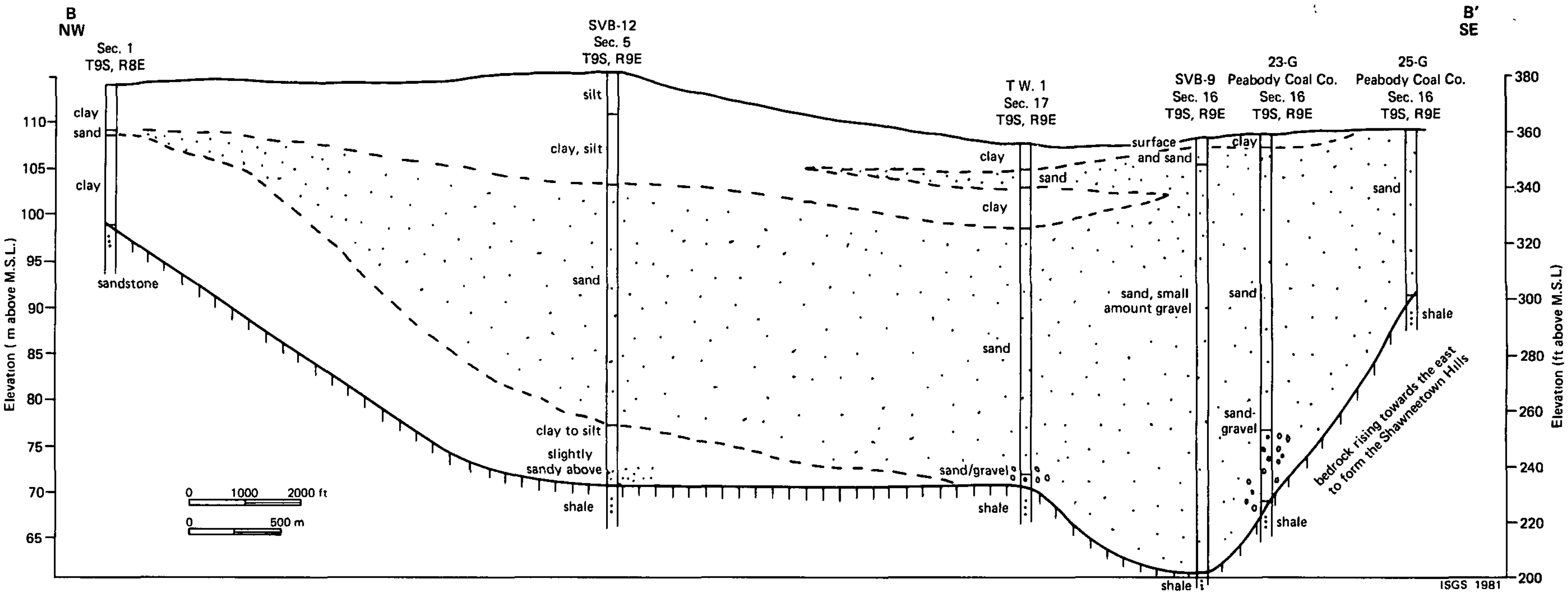


FIGURE 7. Northwest-Southeast cross section B - B' (see fig. 6) in parts of T. 9 S., R. 8 E. and T. 9 S., R. 9 E., Gallatin County, Illinois.

between transmissivity, storage, and the lowering of water levels in the vicinity of a pumped well.

During the December 1980 test, the effects of pumping Test Well No. 1 were measured in the pumped well and in three observation wells. The locations of the wells used during the test are shown in figure 5. The drillers logs of the wells are included in appendix B-l. The test well was pumped continuously for 1430 minutes at a constant rate of 1090 gpm (69 L/s). Drawdowns were determined by comparing water levels measured before pumping started with water levels measured during the pumping period. The data collected are included in appendix B-2.

During the test pumping period, several water samples were collected to determine the mineral quality of the groundwater. The samples were analyzed by the laboratories of the Illinois Environmental Protection Agency and the State Water Survey. Appendix C gives results of the analysis of the sample collected after pumping 23 hours.

The aquifer test data and the nonequilibrium formula (Walton, 1962) were used to calculate the hydraulic properties of the sand and gravel aquifer. Results of the analysis indicate that the transmissivity (T) of the aquifer averages about 80,500 gpd/ft (1.16 x 10-2 M^2/sec) anc the hydraulic conductivity (K) is about 875 gpd/ft^2 (4.13 x 10^{-4} m/sec), a reasonable value for the fine-to-medium sand encountered at the test well site. The storage coefficient (S) in the vicinity of the test well was computed to be about 0.00063, a value representative of artesian conditions. Hydraulic properties determined from the well test data analysis are summarized in table 1.

Aquifer model

The effects of a groundwater development can be simulated using aquifer models that have straight-line boundaries and an effective width, length, and thickness.

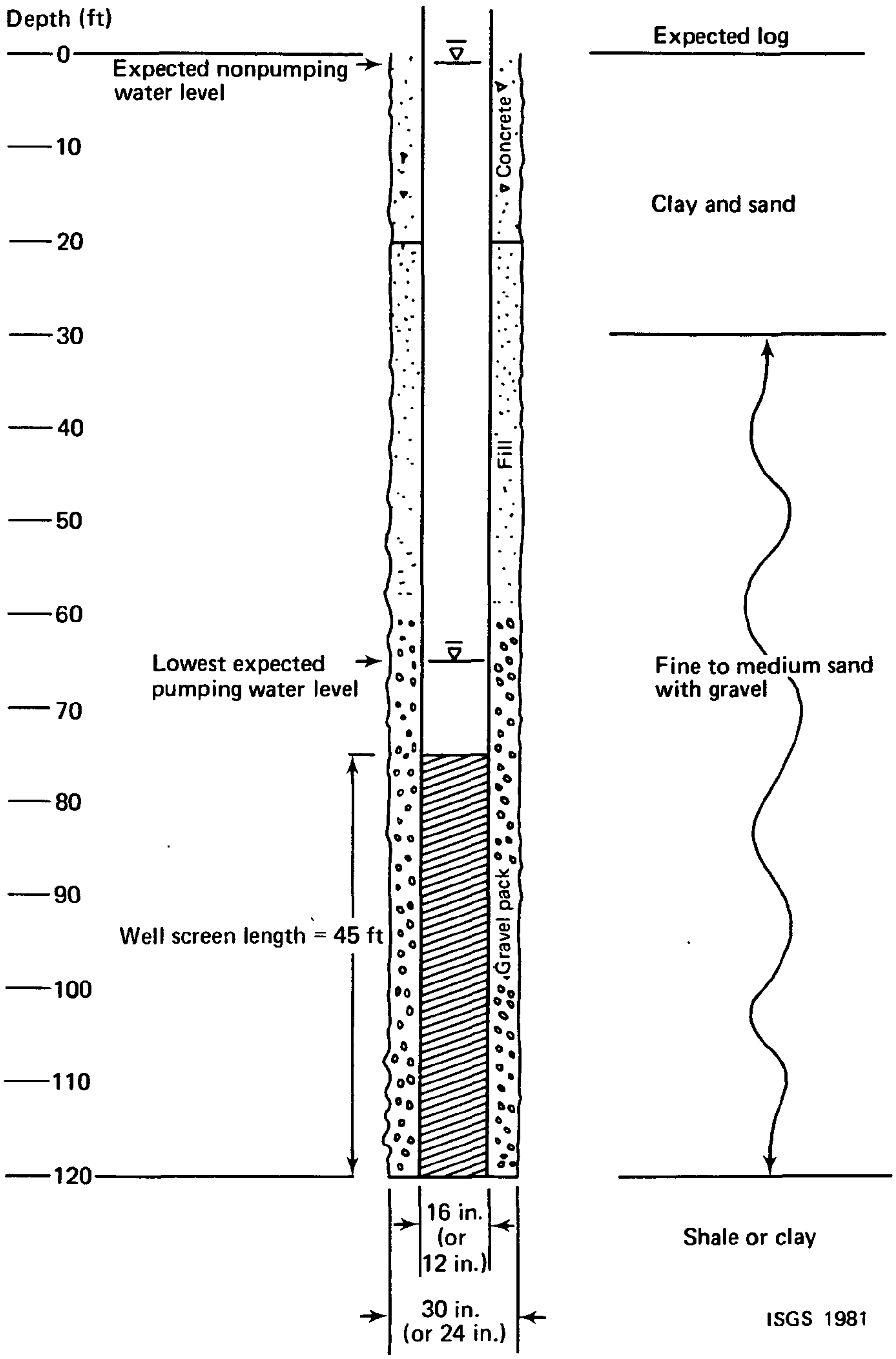
TABLE 1. Transmissivity and storage coefficient at the aquifer test site.

Well	Method of analystis	Transmissiviity(T) (gpd/ft) (x 1.438 x 10"7 = m^2/s)	Storage coefficient (S)
OW1	Time-drawdown (Theis)	73,500	.00077
	Time--drawdown (Jacob)	78,800	.00062
OW2	Time--drawdown (Theis)	78,100	.00064
	Time--drawdown (Jacob)	84,600	.00053
OW3	Time--drawdown (Theis)	78,100	.00067
	Time--drawdown (Jacob)	92,800	.00048
TW	Time--drawdown (Jacob)	80,000	—
	Distance-drawdown	78,100	.00067

T average = 80,500 gpd/ft (l.16 x 10^{-2} m^2/s)

Hydraulic conductivity (K) == 875 gpd/ft^2 (4.13 x 10^{-4} m/s)

S average == .00063



FIGURF 8. Features of typical production well for Saline Valley Water Conservancy District.

Ideal straight-line boundary conditions and uniform water-bearing characteristics rarely (if ever) are found in nature. However, these models can be used for analytical purposes, because the irregularities are small in proportion to the large areal extent of most aquifers.

On the basis of the results of the geologic and hydrologic studies, the sand and gravel aquifer system in the study area was idealized as a 30-degree wedge-shaped aquifer 80 feet (24.2 m) thick. The orientation of the aquifer model in relation to the study area is shown in figure 6.

The water level drawdown at the sites of the three proposed production wells (fig. 5) was computed using the aquifer model, calculated and estimated hydraulic properties of the aquifer, image well theory, and the nonequilibrium formula. The computed total water level drawdown that occurs in each production well at this site consists of drawdown resulting from: (1) laminar flow of water through the aquifer; (2) interference from other production wells; (3) interference from the barrier boundary or edge of an aquifer; (4) partial penetration of the aquifer; (5) decrease in the saturated thickness of the aquifer (dewatering); and (6) turbulent flow losses through the well screen and inside the well. The nonequilibrium formula (Theis, 1935) and image well theory (Ferris, 1959), and the transmissivity and storage coefficient of the aquifer determined from results of the aquifer test were used to calculate the drawdown components due to flow of water through the aquifer and drawdown due to interference from the two other production wells. An estimated long-term storage coefficient of 0.01 was substituted into the nonequilibrium formula to estimate the drawdown due to barrier boundaries and other interferences outside the immediate area of the production wells. The larger storage coefficient was used to simulate the effect of water table conditions known to be present in as much as 30 to 40 percent of the lowland area. The remaining drawdown components due to partial penetration, dewatering, and turbulent flow at the well were calculated with recognized standard techniques described by Walton (1962). These drawdown calculations showed that after 180 days of no recharge, with continuous pumping at a combined rate of 2100 gpm (700 gpm per well; 44 L/s), the water level drawdown in each proposed production well would be approximately 65 feet (19.7 m). The 180-day period was chosen to simulate the average portion of a year during which groundwater level recession usually occurs in a year of normal precipitation.

The analysis using the aquifer model indicates that 3 million gallons per day is the maximum quantity of groundwater that can be developed from the proposed well field. The estimated maximum drawdown will cause pumping water levels to be near the top of the well screens, which are designed to be 45 feet (13.7 m) long (fig. 8). To determine whether the aquifer model used in this report accurately simulates actual aquifer conditions, the District will have to monitor future withdrawals and water levels in the well field. A permanent observation well equipped with a continuous water level recorder located in the vicinity of the well field would provide valuable data in assessing the response of the aquifer to the actual withdrawals.

Theoretical effects of pumping

Pumping from a well field in the vicinity of Test Well No. 1 will affect water levels in nearby wells that tap the extensive sand and gravel aquifer. The barrier boundaries present near Junction will distort the theoretical cone of depression and increase the water level drawdown in wells. The drawdown expected as an annual maximum interference (180 days without recharge) was calculated for the estimated initial demand of 1.7 mgd (1200 gpm; 75.7 L/s) and for the future demand of 3.0 mgd (2100 gpm; 132.5 L/s).

Distance		Maximum annual interference 1.7 mgd		3.0 mgd	
ft	m	ft	m	ft	m
3,000	(909)	9.9	(3.0)	17.5	(5.3)
5,000	(1515)	7.9	(2.4)	13.9	(4.2)
10,000	(3030)	4.9	(1.5)	8.6	(2.6)
20,000	(6060)	1.9	(0.6)	3.3	(1.0)

These annual interference drawdowns were calculated for specific sites northeast of the proposed well field. Drawdowns in other locations northeast of the well field will be comparable. To the south, the annual drawdowns may be somewhat greater because of the barrier boundaries, Shawneetown Hills and Gold Hill.

Effects of groundwater development

The development of the District's well field will still allow for successful completion of irrigation wells in the area. Sufficient available drawdown will be present to allow high capacity (500-1000 gpm; 31.6-63.1 L/s) irrigation wells to be constructed where the thick, extensive sand and gravel aquifer is present. The impact of distant (>1 mile; 1.6 km) irrigation withdrawals on water levels in the District well field will be small, probably less than 2 feet (0.76 m). However, the short-term interference effects by nearby irrigation wells might necessitate changes in the operation of the District wells. Proper management of the resource will allow the anticipated total water supply needs of the region to be met.

If the District well field is operated to capacity and supplemental irrigation is widespread, then a second well field for the District may be required. On the basis of the present study, excellent potential for further development is offered by locations several miles to the northeast, where the aquifer widens to a much larger areal extent. Areas near the Ohio River at the eastern edge of Gallatin County appear to offer excellent potential for development of additional large groundwater supplies.

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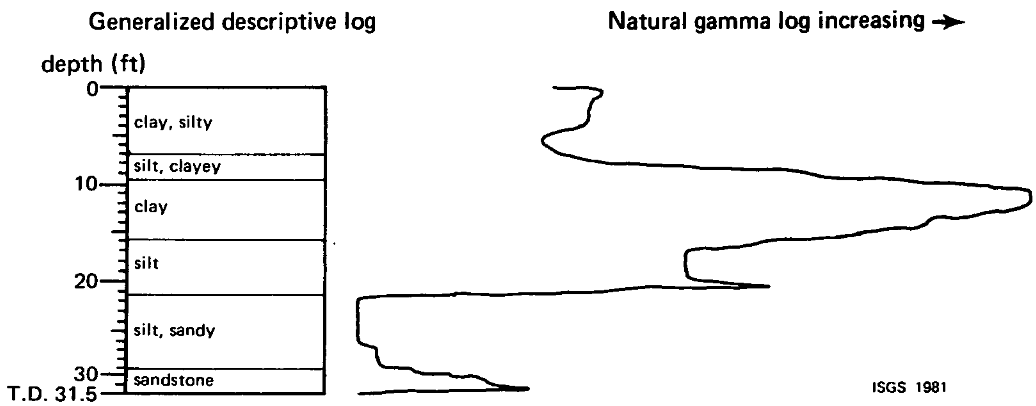
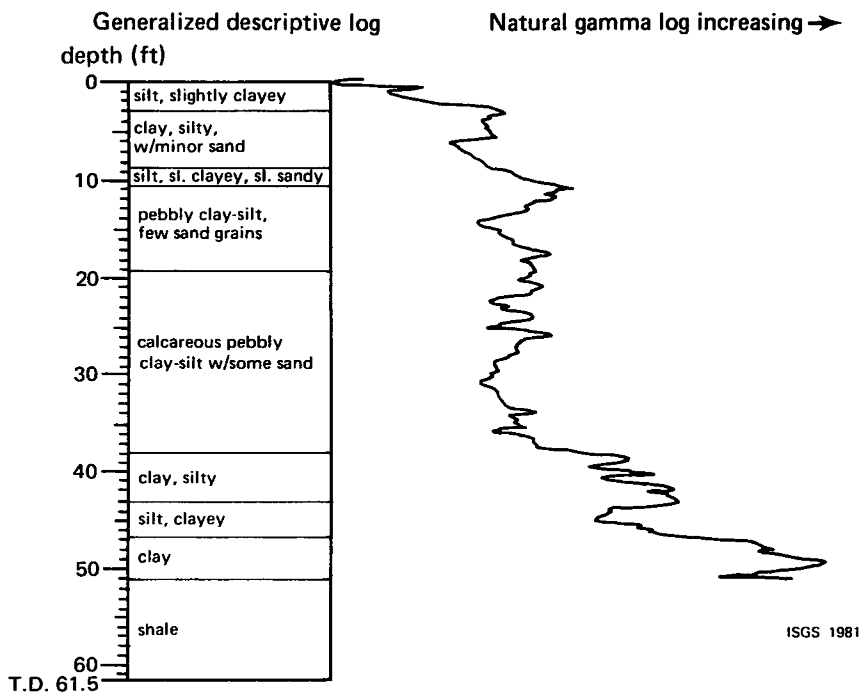
APPENDIX A . Simple descriptive and natural gamma logs for test borings in Saline and Gallatin Counties.

SVB-1 1000 ft N, 4290 ft W of SE/c, 20-8S-6E, Saline Co.

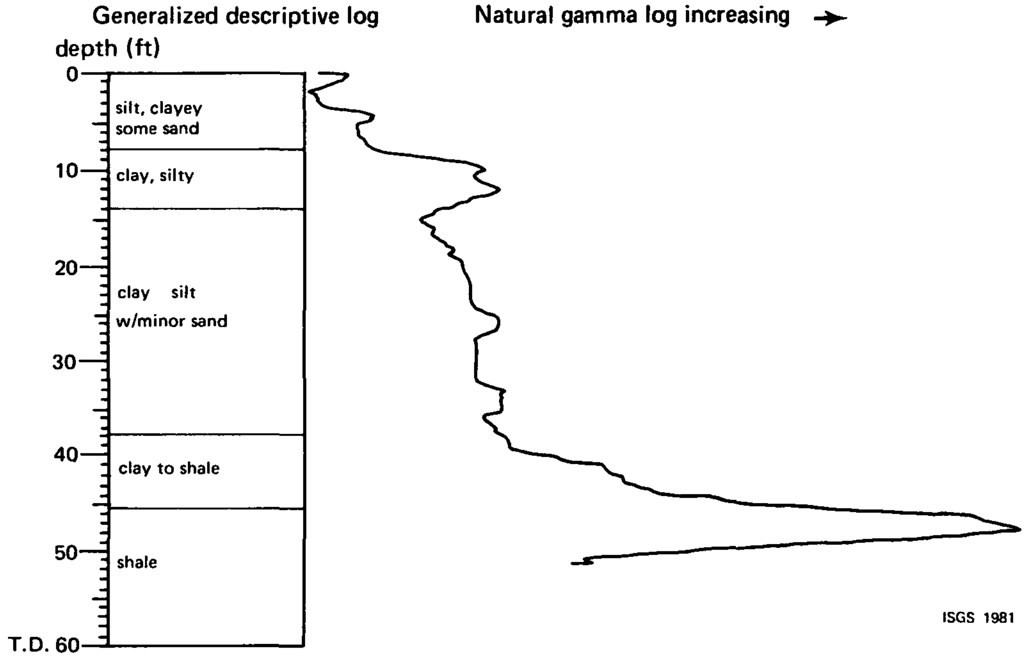


SVB-2 400 ft N, 4980 ft W of SE/c, 32-7S-6E, Saline Co.

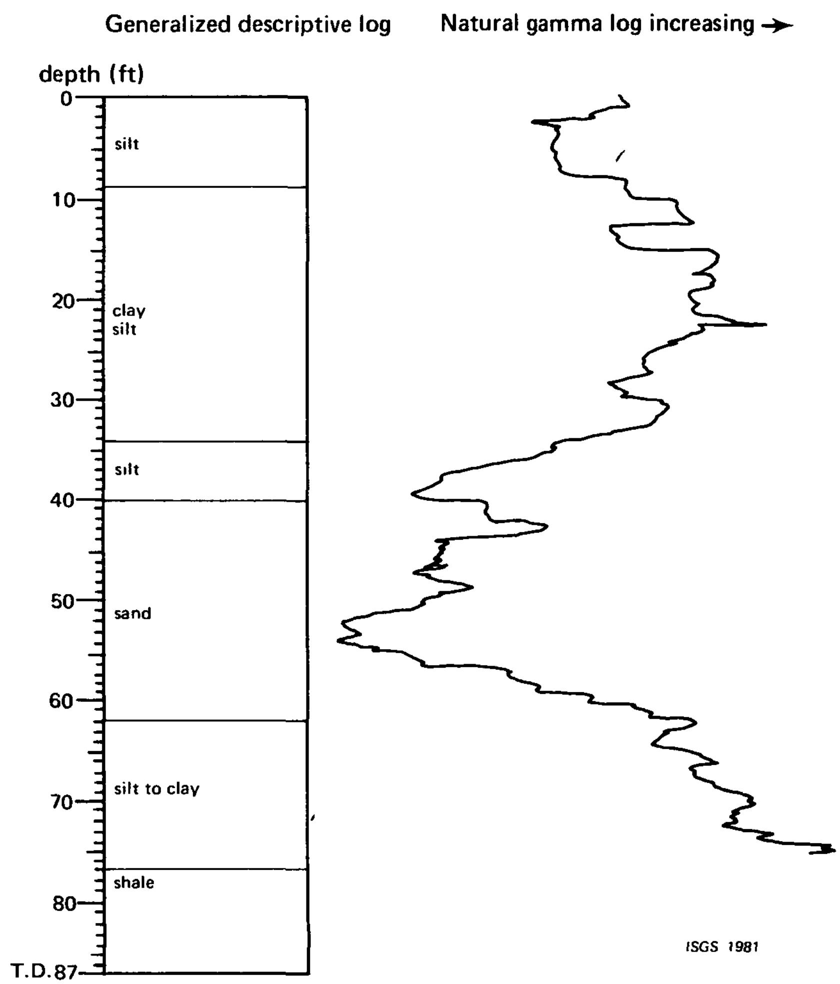


APPENDIX A. *(continued)*

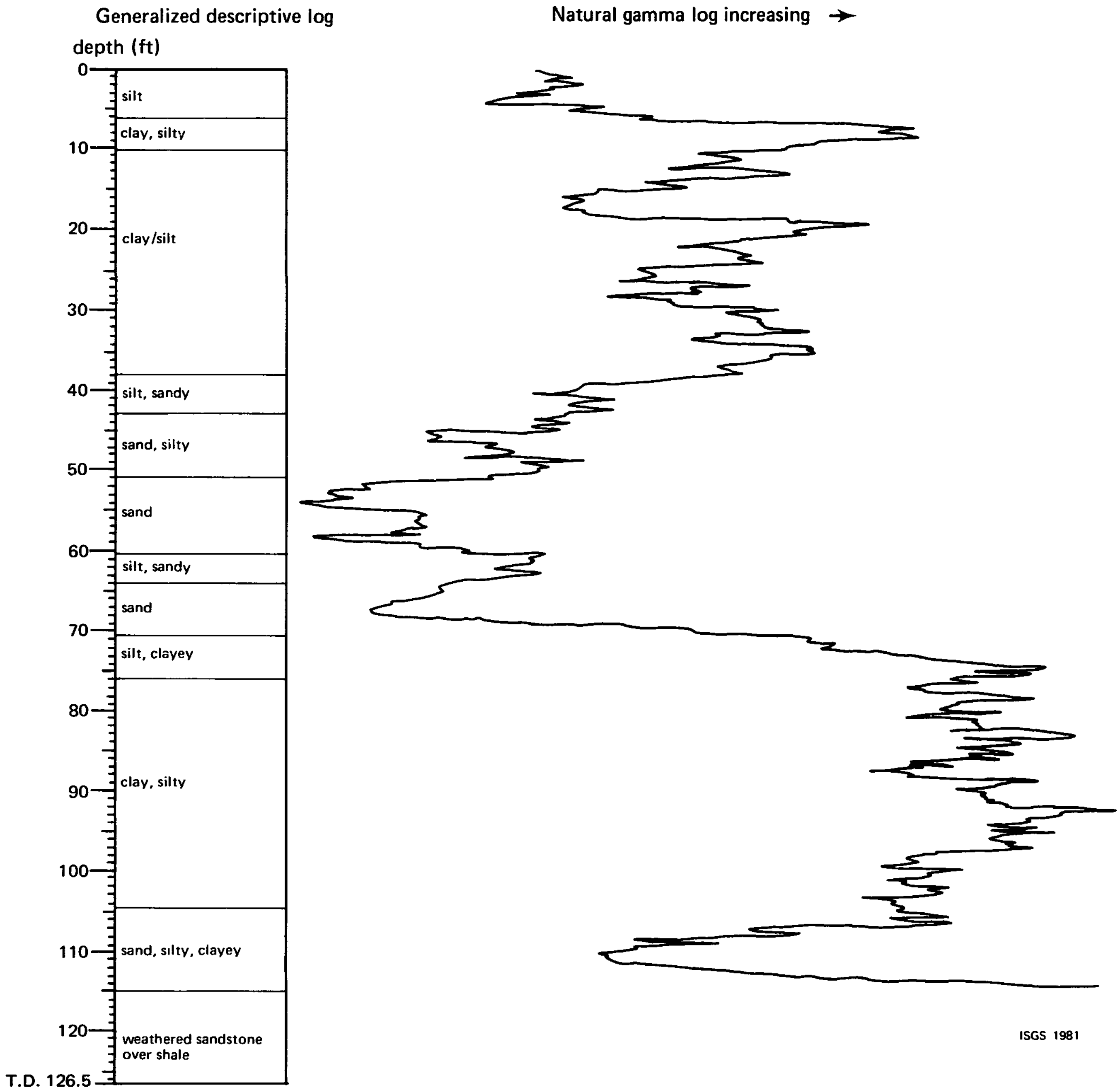
SVB-3 1320 ft N, 3960 ft W of SE/c, 5-9S-7E, Saline Co.



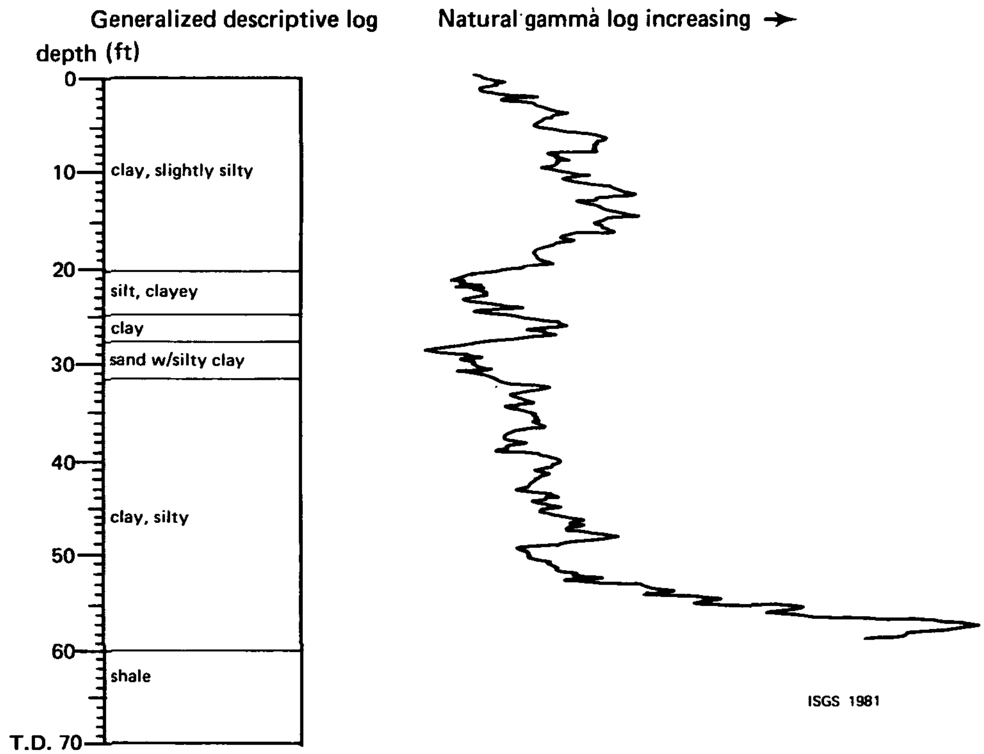
SVB-4 2640 ft N, 2640 ft W of SE/c, 26-9S-7E, Saline Co.



SVB-5 2640 ft N, 1980 ft W of SE/c, 22-9S-8E, Gallatin Co.

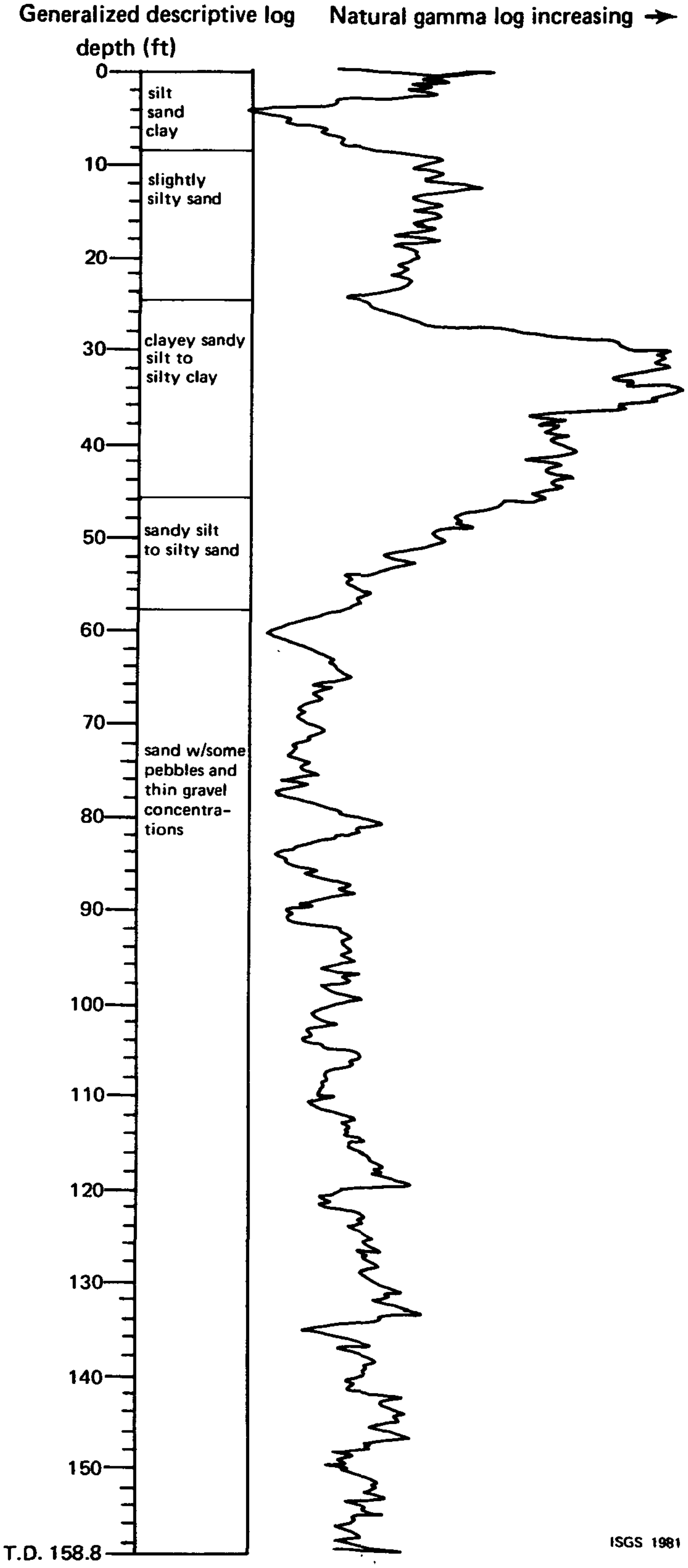


SVB-6 3465 ft N, 3630 ft W of SE/c, 16-8S-8E, Gallatin Co.



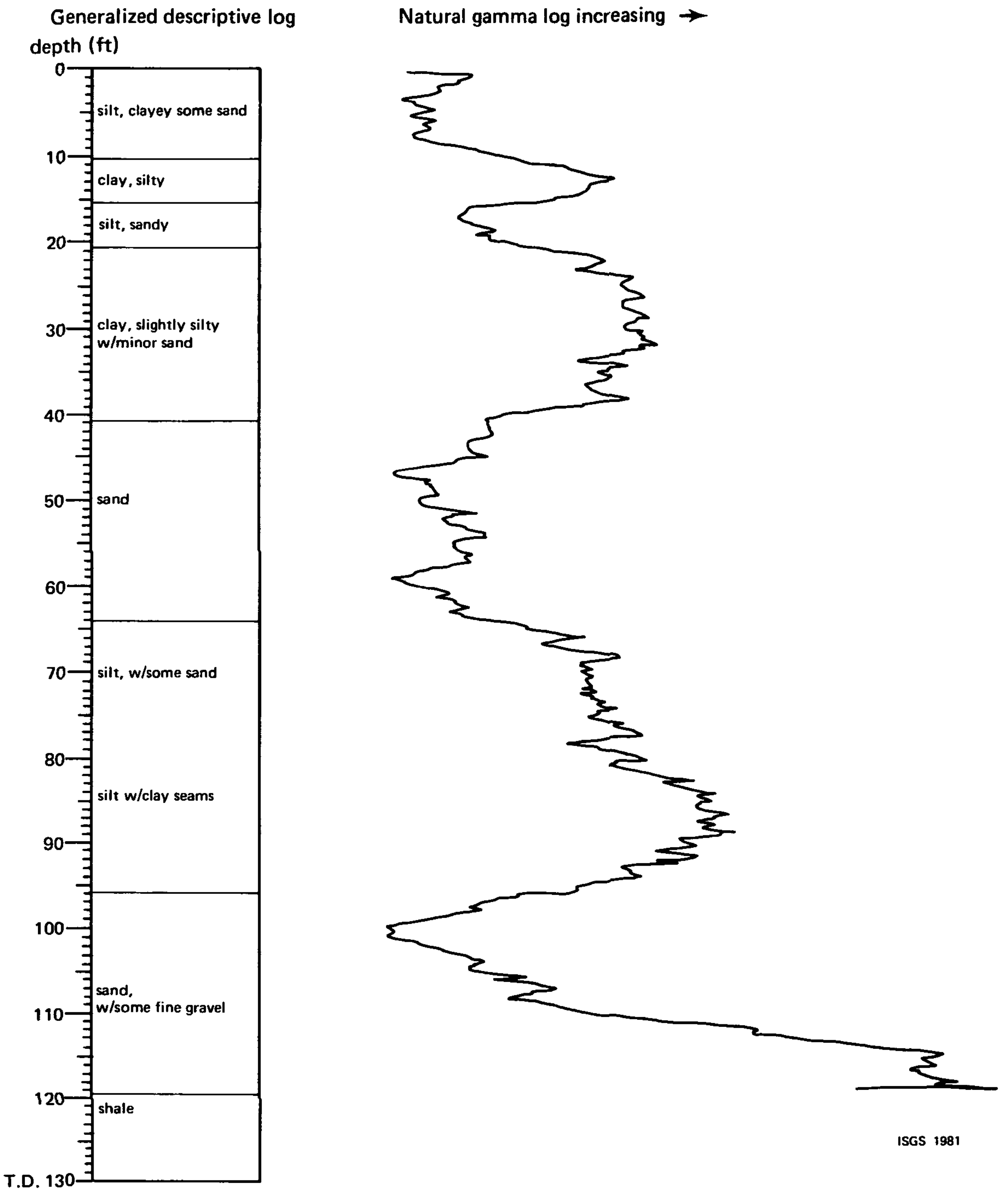
APPENDIX A. *(continued)*

SVB-7 4280 ft N, 5250 ft W of SE/c, 34-9S-9E, Gallatin Co.

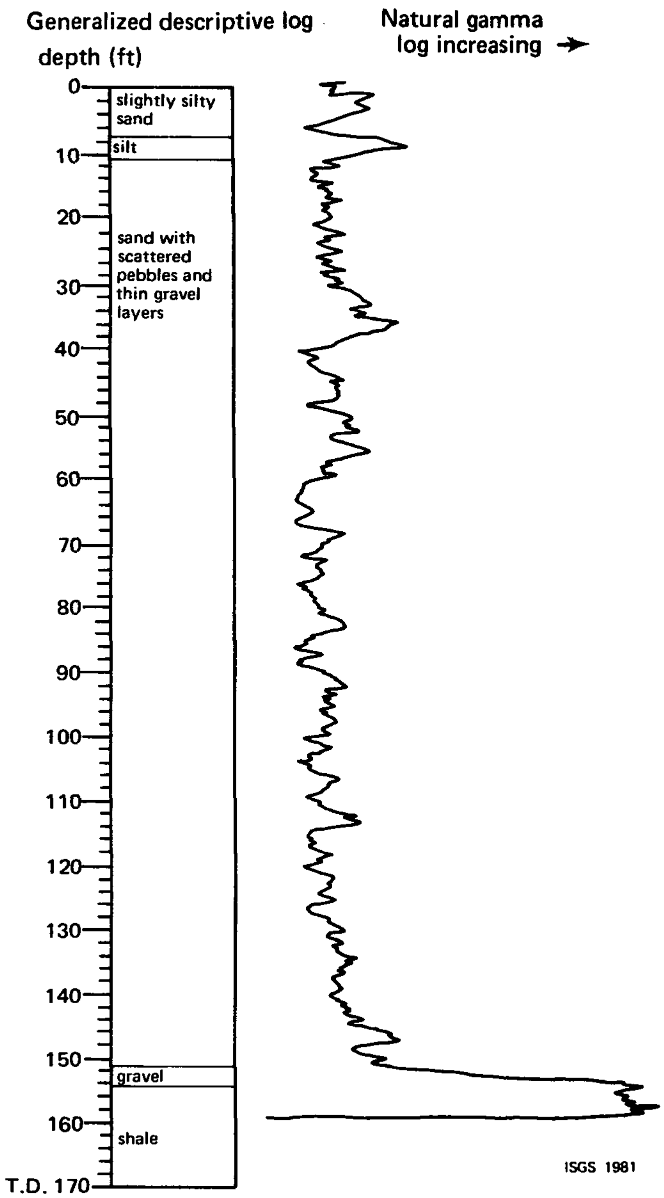


APPENDIX A. *(continued)*

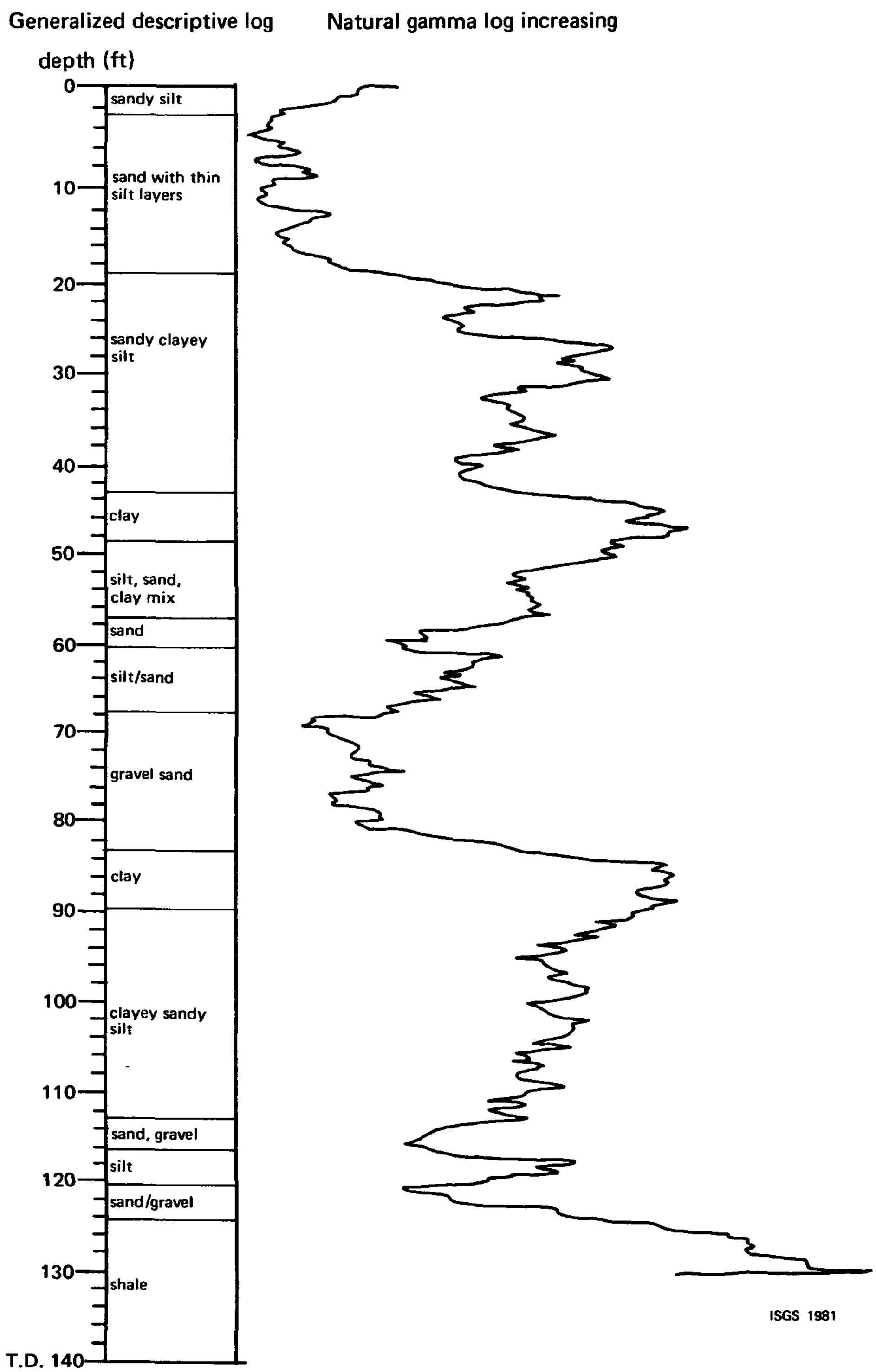
SVB-8 1320 ft N, 3795 ft W of SE/c, 31-9S-9E, Gallatin Co.



SVB-9 3980 ft N, 2640 ft W of SE/c, 16-9S-9E, Gallatin Co.

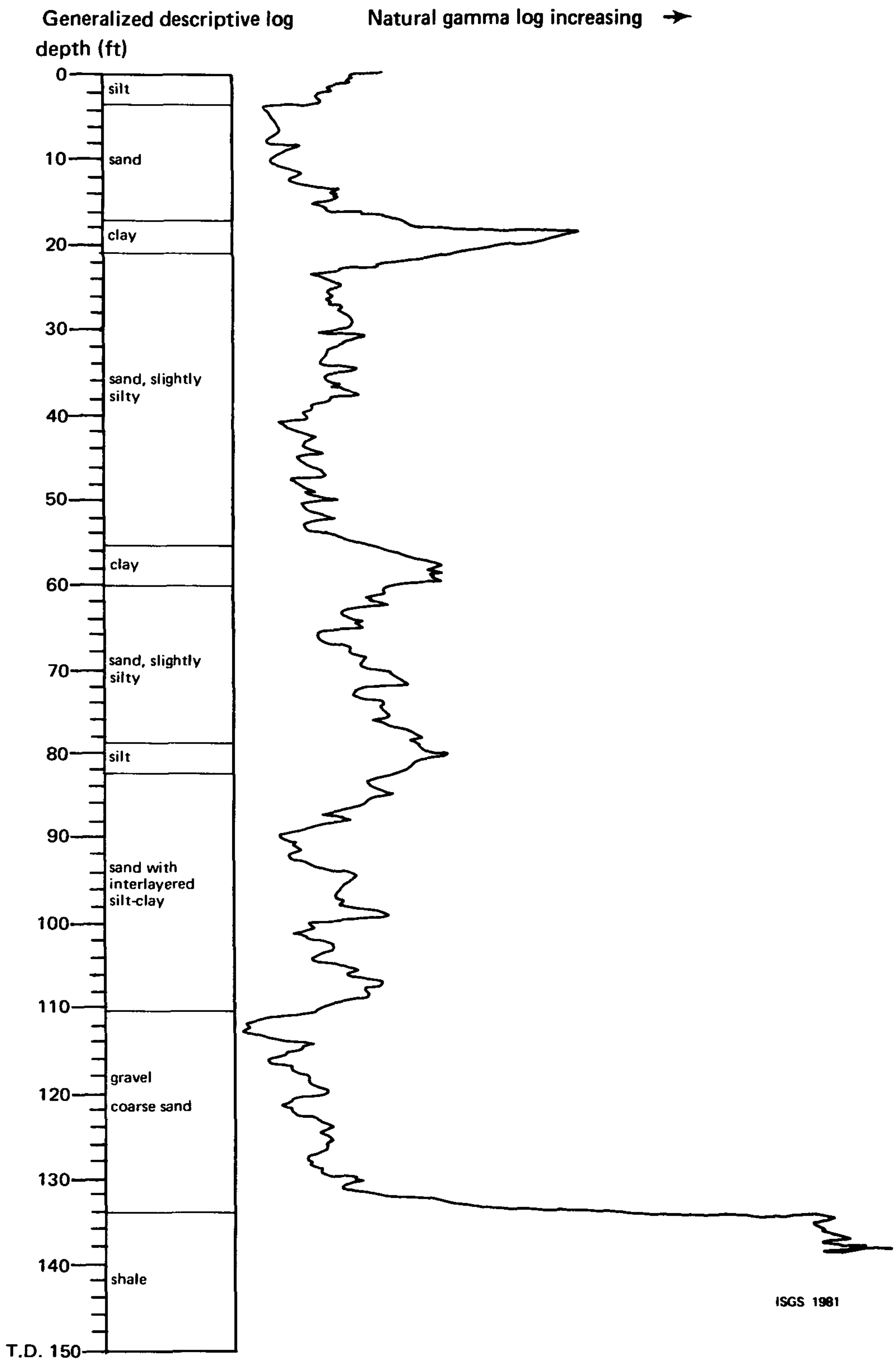


SVB-10 2640 ft N, 660 ft W of SE/c, 30-9S-9E, Gallatin Co.



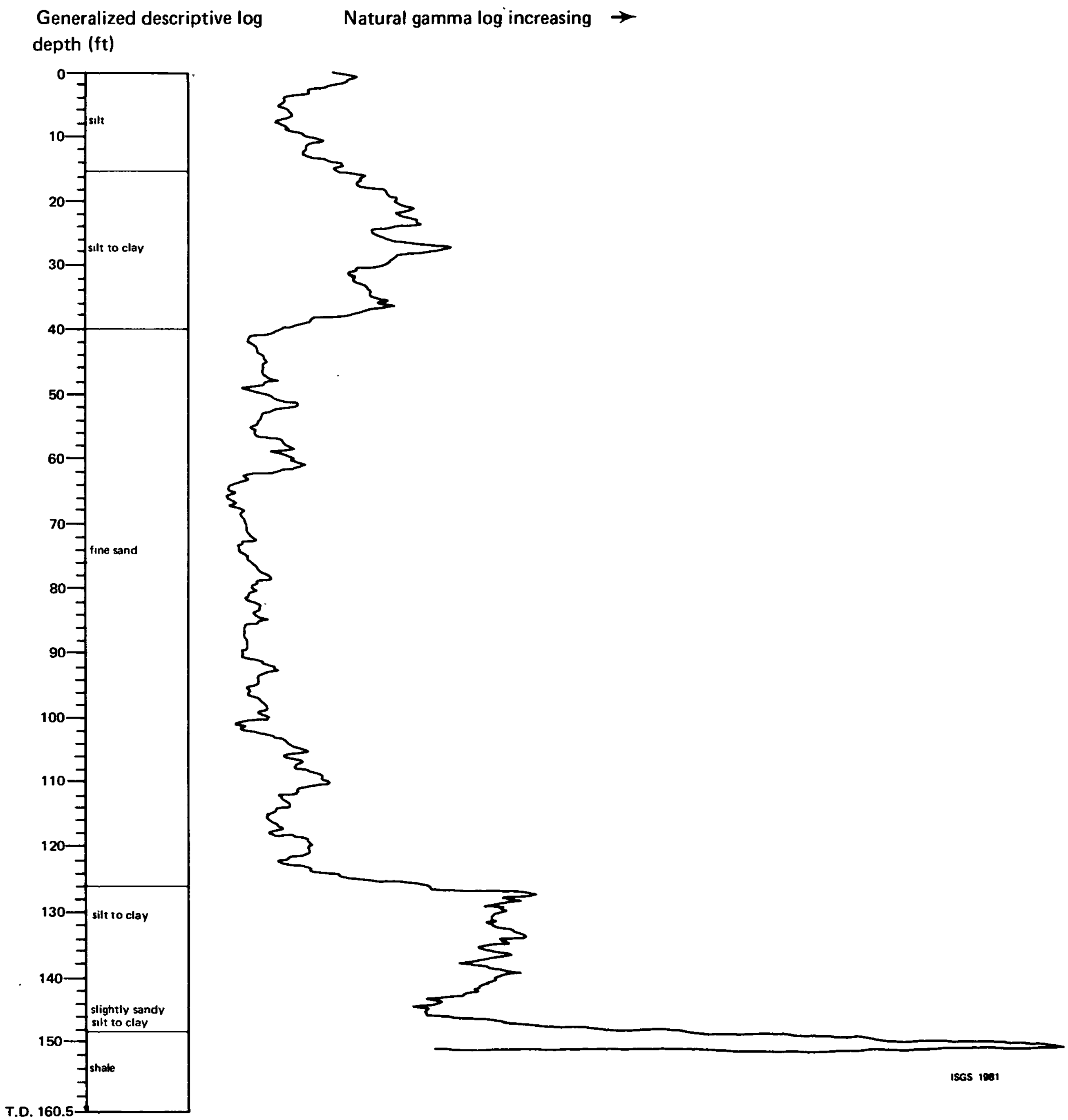
APPENDIX A. *(continued)*

SVB-11 3300 ft N, 2970 ft W of SE/c, 11-9S-9E, Gallatin Co.



APPENDIX A. *(continued)*

SVB-12 10 ft N, 3960 ft W of SE/c, 5-9S-9E, Gallatin Co.



APPENDIX B-l. Well production test, Saline Valley Conservancy District.

WELL DATA (TW-1)

Well owner:	Saline Valley Conservancy District
Consulting engineer:	Brown-Roffman Consulting Engineer, Harrisburg, IL
Well location:	Approx. 510 ft south and 10 ft west of the NE/c, Sec. 17.1h, T. 9 S., R. 9 E., Gallatin County
Date well completed:	Dec. 5, 1980
Date of production test:	Dec. 16-17, 1980
Length of production test:	23 hr. 50 min., constant rate
Aquifer:	Sand and gravel

Well no.:	TW-1
Drilling contractor:	Layne-Western, Kirkwood, M0
Drill cuttings:	To be taken to the ISGS
Drilling method:	Straight rotary
Depth:	120 ft
Hole record:	30 in. 0 to 120 ft
Casing record:	16 in. O.D. +0.5 to -75 ft
Screen record:	16 in. P.S. Layne Shutter Armco, 6 slot, 45 ft long, set 75 to 120 ft
Annulus and gravel pack record:	WB50 3 to 120 ft
Test pump and power:	Layne vertical turbine test pump, 10 in., 3 stages, powered by diesel engine
Test pump setting:	Intake set at 105 ft
Measuring equipment:	Layne-Western 10 x 7 orifice tube, electric dropline, folding ruler
Time water samples collected:	Dec. 16, 1980; 12:10 PM; 4:30 PM; 8:40 PM Dec. 17, 1980; 3:35 AM; 7:40 AM
Temperature of water:	58°F
Ground elevation at well:	+ 355 ft MSL, taken from topographic map
Measuring point:	Top of steel casing 0.5 ft above LSD
Nonpumping water level:	1.82 ft below measuring point

Driller's log for pumped well (pilot hole)

Formation	Depth (ft)
Clay	0 - 9
Fine sand	9 - 15
Clay	15 - 30
Fine sand	30 - 118
Sand and gravel	118 - 122
Shale - hard	122+

OBSERVATION WELL DATA

The line of observation wells lies to the north towards the stream. Land surface elevation is about the same for the pumped well and observation Well Nos. 1 & 2 and is about 1 to 2 feet lower for Observation Well No. 3.

OBSERVATION WELL NO. 1

Depth:	118.7 ft
Hole record:	8 in. 0 to 124 ft
Casing record:	6 in. I.D. PVC casing +1.3 to -118.7 ft
Screen record:	Bottom 40 ft of casing is slotted
Measuring equipment:	Leupold & Stevens Type F recorder
Ground elevation:	±355 ft MSL, taken from topographic map
Measuring point:	Top of PVC approx. 1.3 ft above LSD
Nonpumping water level:	2.84 ft below measuring point
Distance and direction from pumped wel1:	170.5 ft north of pumped well

APPENDIX B-I. *(continued)*

Driller's log

Formation	Depth (ft)
Clay	0 - 8
Fine clay	8 - 17
Clay	17 - 36
Fine sand	36 - 90
Fine to medium sand	90 - 115
Medium to coarse sand w/some fine gravel	115 - 124
Shale	124 - 126

OBSERVATION WELL NO. 2

Depth:	115.3 ft
Hole record:	8 in. 0 to 121 ft
Casing record:	6 in. I.D. PVC casing +1.7 to -115.3 ft
Screen record:	Bottom 40 ft slotted
Measuring equipment:	Leupold & Stevens Type F Recorder
Ground elevation:	±355 ft MSL, taken from topographic map
Measuring point:	Top of PVC casing approx. 1.7 ft above LSD
Nonpumping water level:	3.12 ft below measuring point
Distance and direction from pumped wel1:	300.7 ft north of pumped well

Driller's log

Formation	Depth (ft)
Clay	0 - 7
Sandy clay	7 - 19
Clay	19 - 45
Fine to medium sand	45 - 90
Medium to coarse sand w/some fine gravel	90 - 121
Shale	121 - 125

OBSERVATION WELL NO. 3

Depth:	114.7 ft
Hole record:	8 in. 0 to 121 ft
Casing record:	6 in. I.D. PVC casing +2.3 to -114.7 ft
Screen record:	Bottom 40 ft slotted
Measuring equipment:	Leupold & Stevens Type F recorder
Ground elevation:	±355 ft MSL, taken from topographic map
Measuring point:	Top of PVC casing approx. 2.3 ft above LSD
Nonpumping water level:	1.35 ft below measuring point
Distance and direction from pumped wel1:	502.0 ft north of pumped well

Driller's log

Formation	Depth (ft)
Clay	0 - 6
Sand and clay	6 - 14
Clay	14 - 35
Fine to medium sand	35 - 90
Medium to coarse sand w/some fine gravel	90 - 120
Shale .	120 - 125

APPENDIX B-2. Well production test, Saline Valley Conservancy District, Well No. TW-I, Gallatin County, Illinois. Aquifer test water level data.*

Date and hour	Time (min)	Test Well No. 1 Pump rate (gpm)	Test Well No. 1 Depth to water (ft)	Test Well No. 1 Draw-down (ft)	Observation Well No. 1 Depth to water (ft)	Observation Well No. 1 Draw-down (ft)	Observation Well No. 2 Depth to water (ft)	Observation Well No. 2 Draw-down (ft)	Observation Well No. 3 Depth to water (ft)	Observation Well No. 3 Draw-down (ft)	Remarks
Dec. 16											
AM 7:40			1.82		2.84		3.12		1.35	0	
8:00					2.84		3.12		1.35	0	
8:20					2.84		3.12		1.35	0	
8:40	0.0		1.82		2.84	0	3.12		1.35	0	Pump on Well No. 1
	0.1				2.85	0.01	3.12	0	1.35	0	
	0.2				2.87	0.03	3.12	0	1.35	0	
	0.3				2.94	0.10	3.12	0	1.35	0	
	0.4				2.99	0.15	3.13	0.01	1.35	0	
	0.5				3.06	0.22	3.14	0.02	1.35	0	
	0.6				3.15	0.31	3.15	0.03	1.35	0	
	0.7				3.22	0.38	3.17	0.05	1.35	0	
	0.8				Missed		3.18	0.06	1.35	0	
	0.9				3.30	0.46	3.20	0.08	1.36	0.01	
8:41	1.0		28.49	26.67	3.32?**	0.48?	3.22	0.10	1.36	0.01	
	1.2				3.51?	0.67?	3.26	0.14	1.36	0.01	
	1.4				3.66?	0.82?	3.31	0.19	1.37	0.02	
	1.6				3.79?	0.95?	3.37	0.25	1.37	0.02,	
	1.8				3.80?	0.96?	3.42	0.30	1.39	0.04	
8:42	2.0		29.32	27.50	3.92?	1.08?	3.43	0.31	1.40	0.05	
	2.2				4.05?	1.21?			1.41	0.06	
	2.4				4.15?	1.31?			1.42	0.07	
	2.6				Missed				1.43	0.08	
	2.8				Missed				1.45	0.10	
8:43	3.0		29.99	28.17	4.45	1.61	Recorder		1.46	0.11	
	3.2				4.54	1.70	float		1.48	0.13	
	3.4				4.70	1.86	hung up		1.50	0.15	
	3.6				4.79	1.95			1.51	0.16	
	3.8				4.85	2.01			1.53	0.18	
8:44	4.0		30.43	28.61	4.92	2.08			1.55	0.20	
	4.2				4.99	2.15			1.56	0.21	
	4.4				5.06	2.22			1.59	0.24	
	4.6				5.12	2.28			1.61	0.26	
	4.8				Missed		4.20	1.08	1.63	0.28	
8:45	5.0		30.80	28.98	5.24	2.40	4.24	1.12	1.65	0.30	

Hour	Time (min)	Test Well No. 1 Pump rate (gpm)	Test Well No. 1 Depth to water (ft)	Test Well No. 1 Draw-down (ft)	Observation Well No. 1 Depth to water (ft)	Observation Well No. 1 Draw-down (ft)	Observation Well No. 2 Depth to water (ft)	Observation Well No. 2 Draw-down (ft)	Observation Well No. 3 Depth to water (ft)	Observation Well No. 3 Draw-down (ft)	Remarks
	5.5				5.40	2.56	4.35	1.23	1.70	0.35	
8:46	6.0	1104	31.08	29.26	5.52	2.68	4.45	1.33	1.75	0.40	
	6.5				5.65	2.81	4.55	1.43	1.80	0.45	
8:47	7.0		31.32	29.50	5.76	2.96	4.64	1.52	1.84	0.49	
	7.5				5.87	3.03	4.72	1.60	1.89	0.54	
8:48	8.0		31.56	29.74	5.97	3.13	4.80	1.68	1.94	0.59	
	8.5				6.04	3.20	4.88	1.76	1.99	0.64	
8:49	9.0	1100	31.71	29.89	6.13	3.29	4.95	1.83	2.02	0.67	
	9.5				6.21	3.37	5.02	1.90	2.08	0.73	
8:50	10		31.90	30.08	6.29	3.45	5.09	1.97	2.13	0.78	
8:51	11				6.44	3.60	5.22	2.10	2.22	0.87	
8:52	12		32.12	30.30	6.58	3.74	5.34	2.22	2.30	0.95	
8:53	13				6.71	3.87	5.44	2.32	2.35	1.00	
8:54	14		32.35	30.53	6.84	4.00	5.55	2.43			
8:55	15				6.95	4.11	5.66	2.54			
8:56	16	1085	32.54	30.72	7.05	4.21	5.75	2.63	Recorder		
8:57	17				7.15	4.31	5.84	2.72	float		
8:58	18				7.24	4.40	5.93	2.81	hung up		
8:59	19				7.33	4.49	6.01	2.89			
9:00	20		32.86	31.04	7.41	4.57	6.08	2.96			
9:02	. 22				7.56	4.72	6.23	3.11	2.99	1.64	
9:04	24				7.70	4.86	6.35	3.23	3.10	1.75	
9:05	25	1080	33.18	31.36							
9:06	26				7.83	4.99	6.47	3.35	3.20	1.85	
9:08	28				7.94	5.10	6.58	3.46	3.30	1.95	
9:10	30		33.40	31.53	8.05	5.21	6.68	3.56	3.39	2.04	
9:12	32				8.15	5.31	6.76	3.64	Missed		
9:14	34				8.25	5.41	6.86	3.74	3.56	2.21	
9:15	35		33.56	31.74							
9:16	36				8.33	5.49	6.94	3.82	3.64	2.29	
9:18	38				8.42	5.58	7.02	3.90	3.71	2.36	
9:20	40		33.73	31.91	8.50	5.66	7.10	3.98	3.79	2.44	
9:25	45	1075	33.88	32.06	8.68	5.84	7.29	4.17	3.95	2.60	
9:30	50		34.01	32.19	8.83	5.99	7.45	4.33	4.10	2.75	
9:35	55	1070	34.12	32.30	8.98	6.14	7.60	4.48	4.25	2.90	
9:40	60	1090	34.21	32.39	9.11	6.27	7.72	4.60	4.36	3.01	Adjust rate
9:45	65		34.95	33.13	9.25	6.41	7.86	4.74	4.47	3.12	
9:50	70		35.00	33.18	9.40	6.56	7.98	4.86	4.59	3.24	
10:00	80		35.19	33.37	9.62	6.78	8.20	5.08	4.79	3.44	
10:10	90	1090	35.33	33.51	9.80	6.96	8.38	5.26	4.95	3.60	

*Leupold & Stevens Type F Recorders were installed on observations wells 17 hours prior to pumping test well. No water level trend was noted in the wells during the last six hours before pumping began.

**Questionable readings due to temporary equipment problems.

APPENDIX B-2. Well production test, Saline Valley Conservancy District, Well No. TW-I, Gallatin County, Illinois. Aquifer test water level data. *(continued)*

			Test Well No. 1		Observation Well No. 1		Observation Well No. 2		Observation Well No. 3		
Hour	Time (min)	Pump rate (gpm)	Depth to water (ft)	Draw-down (ft)	Depth to water (ft)	Draw-down (ft)	Depth to water (ft)	Draw-down (ft) .	Depth to water (ft)	Draw-down (ft)	Remarks
10:20	100		35.45	33.63	9.96	7.12	8.54	5.42	5.11	3.76	
10:40	120		35.68	33.86	10.23	7.39	8.80	5.68	5.39	4.04	
11:00	140	1080	35.83	34.01	10.43	7.59	9.02	5.90	5.59	4.24	
11:20	160		35.95	34.13	10.63	7.79	9.20	6.08	5.78	4.43	
11:40	180	1075	36.05	34.23	10.78	7.94	9.36	6.24	5.94	4.59	
PM 12:10	210	1075	36.22	34.40	10.97	8.13	9.55	6.43	6.15	4.80	
12:40	240	1070	36.35	34.53	11.11	8.27	9.72	6.60	6.32	4.97	
1:10	270	1070	36.47	34.65	11.25	8.41	9.86	6.74	6.46	5.11	
1:40	300	1070	36.57	34.75	11.37	8.53	9.99	6.87	6.59	5.24	
2:40	360	1070	36.72	34.90	11.58	8.74	10.20	7.08	6.80	5.45	
3:40	420	1066	36.86	35.04	11.75	8.91	10.37	7.25	6.97	5.62	
3:45	425	1090							6.98	5.63	Adjust rate
4:40	480	1090	37.74	35.92	12.00	9.16	10.61	7.49	7.18	5.83	
5:40	540	1095	37.82	36.00	12.14	9.30	10.76	7.64	7.31	5.96	
6:40	600	1090	37.91	36.09	12.26	9.42	10.88	7.76	7.44	6.09	
7:40	660	1090	38.01	36.19	12.35	9.51	10.97	7.85	7.53	6.18	
8:40	720	1090	38.09	36.27	12.39	9.55	11.06	7.94	7.63	6.28	
9:40	780	1090	38.05	36.23	12.53	9.69	11.12	8.00	7.70	6.35	
10:40	840	1090	38.14	36.32	12.59	9.75	11.18	8.06	7.76	6.41	
11:40	900	1090	38.15	36.33	12.65	9.81	11.23	8.11	7.82	6.47	
Dec. 17											
AM 12:40	960	1090	38.16	36.34	12.69	9.85	11.28	8.16	7.87	6.52	
1:40	1020	1090	38.18	36.36	12.74	9.90	11.32	8.20	7.92	6.57	
2:40	1080	1090	38.24	36.42	12.78	9.94	11.36	8.24	7.96	6.61	
3:40	1140	1090	38.29	36.47	12.82	9.98	11.40	8.28	8.00	6.65	
4:40	1200	1090	38.32	36.50	12.86	10.02	11.42	8.30	8.04	6.69	
5:40	1260	1090	38.34	36.52	12.90	10.06	11.48	8.36	8.07	6.72	
6:40	1320	1090	38.34	36.52	12.92	10.08	11.51	8.39	8.11	6.76	
7:40	1380	1090	38.36	36.54	12.94	10.10	11.53	8.41	8.13	6.78	
8:25	1425	1090	38.38	36.56	12.96	10.12			8.16	6.81	
8:29	1429		38.38	36.56	12.96	10.12	11.58	8.46	8.16	6.81	
8:30	1430				12.97	10.13					Pump off
	0.1	0			12.97		11.58		8.16		Recovery
	0.2				12.97		11.57		8.17		
	0.3				12.94		11.57		8.17		

		Test Well No. 1			Observation Well No. 1		Observation Well No. 2		Observation Well No. 3		
Hour	Time (min)	Pump rate (gpm)	Depth to water (ft)	Draw-down (ft)	Depth to water (ft)	Draw-down (ft)	Depth to water (ft)	Draw-down (ft)	Depth to water (ft)	Draw-down (ft)	Remarks
	0.4				12.88		11.56		8.17		
	0.5				12.80		11.55		8.17		
	0.6				12.72		11.54		8.16		
	0.7				12.63		11.52		8.16		
	0.8				12.54		11.50		8.16		
	0.9				12.43		11.48		8.15		
8:31	1.0		12.83		12.40		11.46		8.15		
	1.2				12.24		11.41		8.15		
	1.4				12.10		11.36		8.14		
	1.6				11.99		11.30		8.13		
	1.8				11.86		11.25		8.12-		
8:32.	2.0		11.60		11.75		11.20		8;n		
	2.2				11.64		11.14		8.10		
	2.4				11.54		11.08		8.08		
	2.6				11.48		11.03		8.07		
	2:8				11.35		10.98		8.05		
8:33	3.0		10.97		11.27		10.92		8.03		
	3.2				11.18		10.87		8.02		
	3.4				11.11		10.82		8.00		
	3.6				11.03		10.77		7.98		
	3.8				10.96		10.71		7.96		
8:34	4.0		10.35		10.89		10.67		7.94		
	4.2				10.82		10.62		7.92		
	4.4				10.75		10.58		7.90		
	4.6				10.68		10.53		7.89		
	4.8				10.63		10.49		7.87		
8:35	5.0		9.92		10.57		10.44		7.85		
	5.5				10.43		10.34		7.80		
8:36	6.0		9.59		10.30		10.23		7.74		
	6.5				10.18		10.14		7.70		
8:37	7.0		9.29		10.07		10.05		7.64		
	7.5				9.96		9.97		7.59		
8:38	8.0		9.05		9.86		9.89		7.54		
	8.5				9.76		9.81		7.50		
8:39	9.0		8.84		9.67		9.73		7.45		
	9.5				9.59		9.68		7.40		
8:40	10		8.64		9.50		9.61		7.35		
8:41	11				9.35		9.48		7.28		
8:42	12		8.33		9.22		9.37		7.18		
8:43	13				9.09		9.26		7.10		
8:44	14		8.06		9.00		9.16		7.03		
8:45	15				8.88		9.06		6.96		

APPENDIX B-2. Well production test, Saline Valley Conservancy District, Well No. TW-I, Gallatin County, Illinois. Aquifer test water level data. *(continued)*

Hour	Time (min)	Test Well No. 1 Pump rate (gpm)	Test Well No. 1 Depth to water (ft)	Test Well No. 1 Draw-down (ft)	Observation Well No. 1 Depth to water (ft)	Observation Well No. 1 Draw-down (ft)	Observation Well No. 2 Depth to water (ft)	Observation Well No. 2 Draw-down (ft)	Observation Well No. 3 Depth to water (ft)	Observation Well No. 3 Draw-down (ft)	Remarks
8:46	16		7.82		8.78		8.96		6.88		
8:47	17				8.68		8.87		6.82		
8:48	18				8.59		8.79		6.76		
8:49	19				8.50		8.70		6.68		
8:50	20		7.45		8.43		8.63		6.62		
8:52	22				8.27		8.49		6.51		
8:54	24				8.14		8.35		6.40		
8:55	25		7.08								
8:56	26				8.01		8.24		6.30		
8:58	28				7.89		8.13		6.20		
9:00	30		6.79		7.81		8.02		6.10		
9:02	32				7.68		7.92		6.01		
9:04	34				7.58		7.83		5.93		
9:05	35		6.54								
9:06	36				7.50		7.74		5.86		
9:08	38				7.41		7.67		5.78		
9:10	40		6.32		7.33		7.59		5.70		
9:15	45		6.12		7.14		7.41		5.54		
9:20	50		5.96		6.98		7.25		5.40		
9:25	55		5.78		6.84		7.10		5.26		
9:30	60		5.69		6.70		6.97		5.14		
9:35	65				6.58		6.85		5.02		
9:40	70		5.45		6.46		6.74		4.91		
9:50	80		5.25		6.26		6.55		4.72		
10:00	90		5.07		6.09		6.38		4.56		
10:10	100		4.93		5.94		6.23		4.41		
10:30	120		4.66		5.68		5.97		4.17		Pump on
10:31	1		21.92								Step 1
10:32	2		19.87								
10:33	3		19.90								
10:34	4	598	20.00								
10:35	5		20.18								
10:36	6		20.30								
10:37	7	598	20.39								
10:38	8		20.50								
10:39	9		20.57								
10:40	10		20.65								

Hour	Time (min)	Test Well No. 1 Pump rate (gpm)	Test Well No. 1 Depth to water (ft)	Test Well No. 1 Draw-down (ft)	Observation Well No. 1 Depth to water (ft)	Observation Well No. 1 Draw-down (ft)	Observation Well No. 2 Depth to water (ft)	Observation Well No. 2 Draw-down (ft)	Observation Well No. 3 Depth to water (ft)	Observation Well No. 3 Draw-down (ft)	Remarks
10:42	12		20.73								
10:44	14	589	20.83								
10:46	16		20.95								
10:48	18		21.00								
10:50	20		21.06								Increase rate
10:51	1		27.75								Step 2
10:52	2		27.85								
10:53	3		28.00								
10:54	4	852	28.12								
10:55	5		28.21								
10:56	6		28.31								
10:57	7		28.37								
10:58	8		28.43								
10:59	9		28.50								
11:00	10		28.53								
11:02	12	849	28.61								
11:04	14		28.68								
11:06	16		28.76								
11:08	18	849	28.82								
11:10	20		28.88								Increase rate
11:11	1		34.73								Step 3
11:12	2		Missed								
11:13	3		35.63								
11:14	4		35.72								
11:15	5	1095	35.81								
11:16	6		35.94								
11:17	7		36.04								
11:18	8		36.11								
11:19	9		36.18								
11:20	10	1095	36.24								
11:22	12		36.36								
11:24	14		36.42								
11:26	16	1095	36.50								
11:28	18		36.59								
11:30	20		36.61								End of test

APPENDIX C. Water sample analysis data.*

		mg/L	me/L			mg/L	me/L
Iron(t)	Fe	1.4		Phosphate (t.o. + a.h.)	P	0.10	
Manganese(t)	Mn	0.08					
Aluminum(t)	Al	—		Silica(d)	SiO_2	19.9	
Calcium(d)	Ca	76.4	3.81	Fluoride(d)	F	0.3	
Magnesium(d)	Mg	35.4	2,.91	Boron(d)	B	0.2	
Strontium(d)	Sr	0.18		Nitrate	NO_3	0.0	0.00
Sodium(d)	Na	12.8	0,.56	Chloride(d)	Cl	0.0	0.00
Potassium(d)	K	0.8	0..02	Sulfate(d)	SO_4	2.1	0.04
Ammonium	NH_4	0.07	0,.04	Alkalinity	(as $CaCO_3$)	356	7.12
**Arsenic	As	0.006					
Barium(t)	Ba	< 0.1		Hardness (d)	(as $CaCO_3$)	336	6.72
Cadmium(t)	Cd	< 0.005					
Chromium(t)	Cr	< 0.005		Total dissolved minerals		378	
Copper(t)	Cu	0.01					
Lead(t)	Pb	< 0.05		Temp. (reported)		58°F	
Lithium(t)	Li	0.00					
Nickel(t)	Ni	< 0.05					
**Selenium	Se	< 0.001					
Silver(t)	Ag	—					
Zinc(t)	Zn	< 0.005					

t = total
d = dissolved
o. + a.h. = ortho + acid hydrolyzable
mg/L = milligrams per liter
me/L = milliequivalents per liter
mg/L x .0583 = grains per gallon

*Sample collected at 7:40 am, December 17, 1980 from Test Well No. 1 (owned by the Saline Valley Conservancy District) after 23 hours of pumping at a rate of 1090 gpm.
**Determinations by IEPA (Lab no. B 30672).

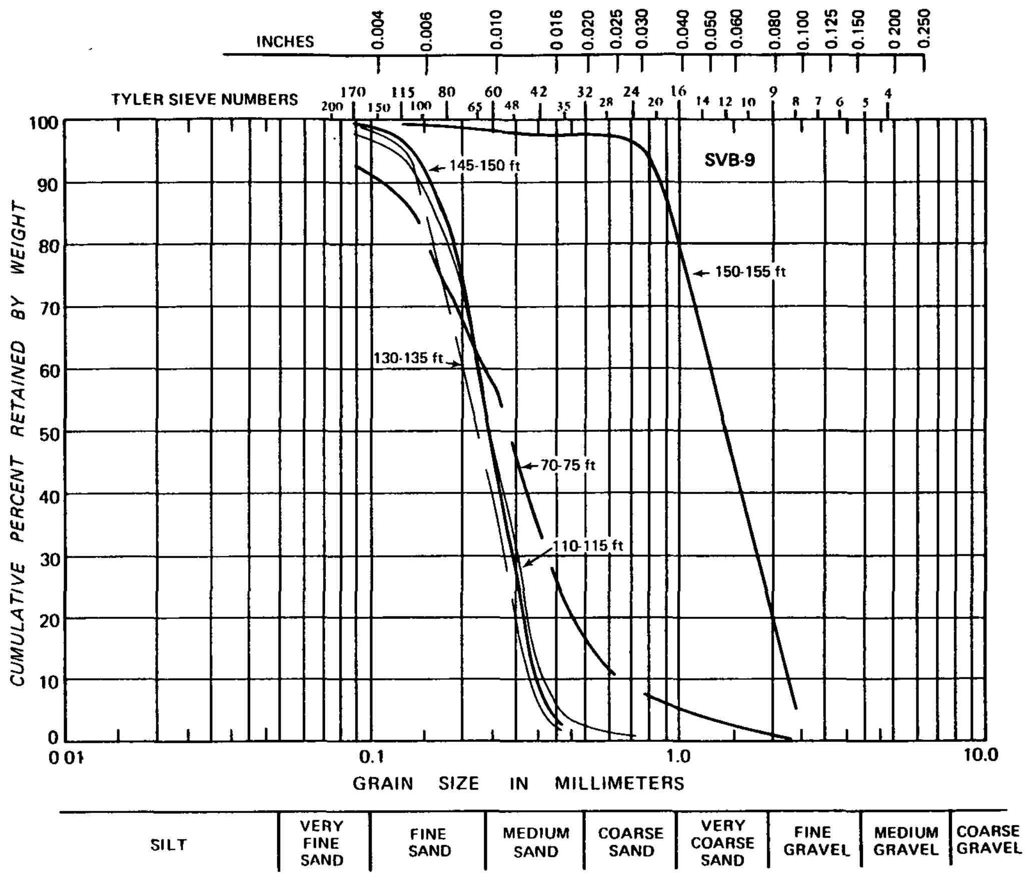
APPENDIX D. Selected sieve analysis data (cumulative percent retained by weight).

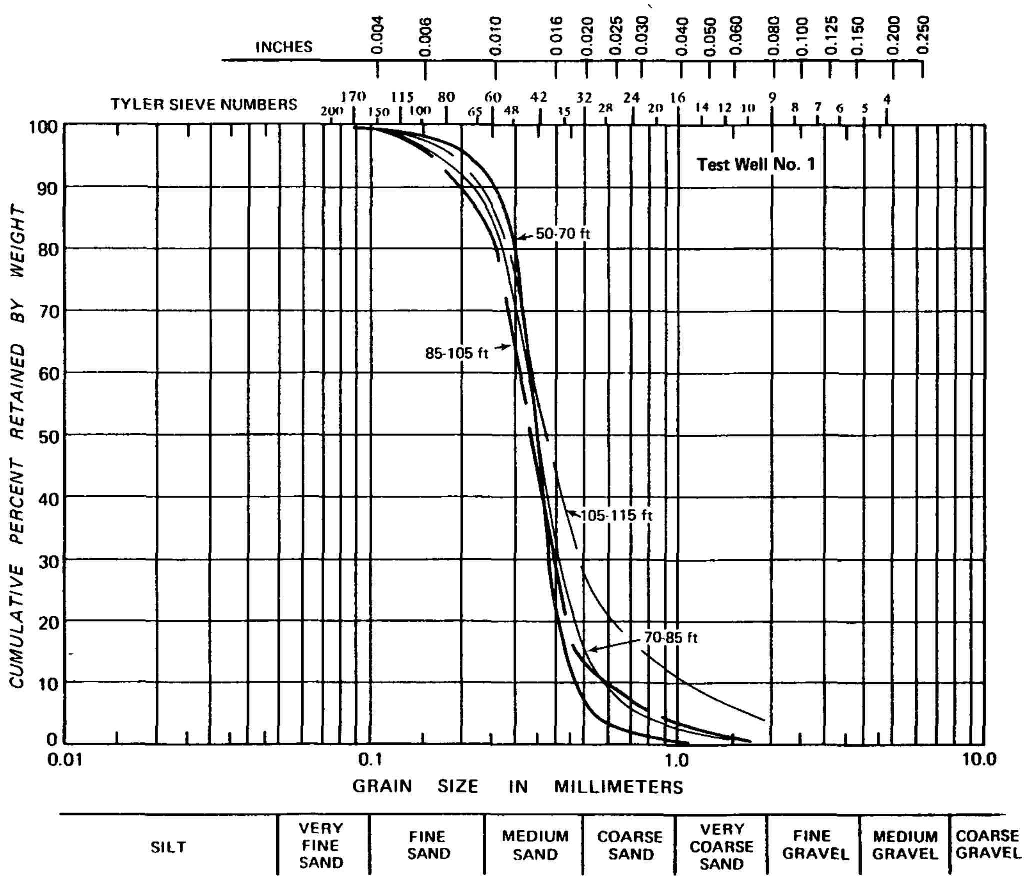
Well	Depth (ft)	Sample type	Fine gravel		Very coarse sand	Coarse sand			Medium sand		Fine sand		Very fine sand	Very fine sand silt & clay
	Sieve size (in.)		.0937	.078	.039	.0276	.0195	.0165	.0138	.0097	.0069	.0049	.0035	<.0035
	Tyler mesh		8	9	16	24	32	35	42	60	80	115	170	Pan
SVB-9	15-20	W*	—	—	—	.04	—	.9	2.2	14.8	48.0	85.6	93.6	100.0
	20-21.5	SS**	.2	—	.8	2.1	—	15.1	26.6	62.5	86.1	94.3	95.8	100.0
	30-35	W	—	—	—	3.1	—	17.9	28.5	55.4	78.5	94.4	97.6	100.0
	30-31.5	SS	.2	—	.8	1.7	—	12.7	22.7	49.3	70.9	90.3	95.6	100.0
	35-40	W	.3	—	7.3	10.1	—	25.7	36.2	60.8	78.8	92.9	97.8	100.0
	40-45	W	.2	—	7.0	10.0	—	25.1	36.4	62.1	78.0	91.3	96.7	100.0
	70-75	W	.1	—	5.3	8.4	—	22.3	32.8	57.3	73.0	87.4	93.1	100.0
	70-71.5	SS	6.8	—	11.4	14.1	—	31.1	46.0	74.9	85.4	89.7	91.6	100.0
	110-115	w	—	—	.3	.5	—	4.2	11.1	49.1	80.4	94.4	98.0	100.0
	130-135	w	—	—	.1	.1	—	1.5	5.8	40.8	70.2	96.2	99.4	100.0
	145-150	w	—	—	.1	.2	—	2.3	7.5	46.0	83.6	97.4	99.5	100.0
	150-155	w	4.7	—	77.3	96.5	—	97.5	97.8	98.4	99.0	99.4	99.5	100.0
TW No. 1	50-70	w	—	.2	1.3	2.1	7.2	—	48.1	90.7	97.7	99.0	99.3	100.0
	70-85	w	—	.5	2.9	5.7	15.2	—	48.5	85.1	94.5	98.3	99.2	100.0
	85-100	w	—	.6	3.4	6.4	13.7	—	41.3	80.6	93.2	98.5	99.4	100.0
	105-115	w	—	3.8	10.4	16.1	26.4	—	53.5	87.8	96.0	98.8	99.4	100.0
OW No. 2	55-70	w	—	.2	1.5	2.7	7.3	—	31.5	79.7	95.8	98.0	98.4	100.0
	70-80	w	—	.7	2.1	3.1	6.4	—	26.4	78.9	95.3	97.8	98.3	100.0
	80-100	w	—	.3	4.0	9.7	20.4	—	46.5	86.3	97.1	99.1	99.4	100.0
	100-115	W	—	.3	1.7	2.8	6.7	—	24.5	74.7	94.6	98.3	98.9	100.0

* W = Wash sample

**SS = Split spoon sample

APPENDIX D. *(continued)*





APPENDIX D. ***(continued)***