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CONSTRUCTION AND TESTING OF TWO WASTE-INJECTION MONITOR WELLS IN NORTHWEST FLORIDA

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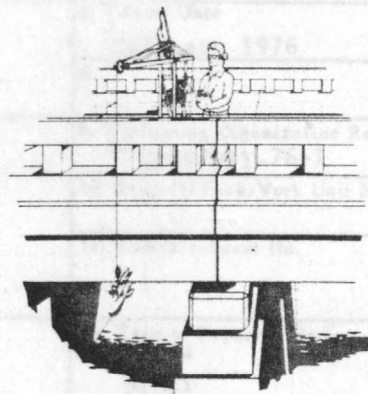
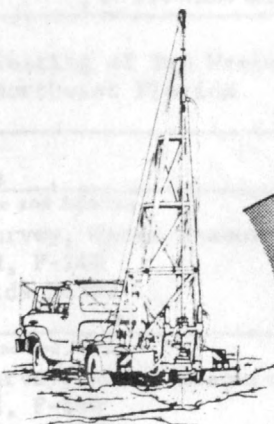
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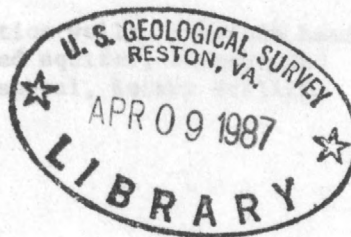
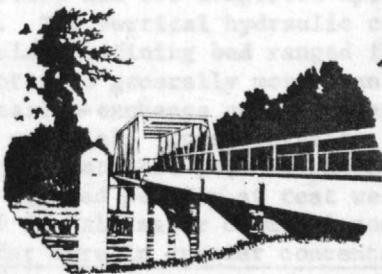
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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-1



Prepared in cooperation with the
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WRI 76-1 Construction and testing of two waste-injection monitor wells in Northwest Florida

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16. Abstracts Two test wells were constructed by the U. S. Geological Survey into an injection zone at sites 35 kilometres east and 27 kilometres northeast of an active injection system to monitor the injection zone and to provide additional data for evaluating the regional effects of deep-well waste injection. Test wells 1 and 2 are cased to a depth of 372 metres and 300 metres below land surface and are completed open hole in limestone to 457 metres and 393 metres, respectively. The vertical hydraulic conductivity of core samples taken at the test wells in the clay confining bed ranged from 8.8×10^{-7} to 7.9×10^{-8} metres per day. The clay contained generally more than 40 percent montmorillonite and mixed clay minerals and its cation-exchange capacity ranged from 43 to 47 milliequivalents per 100 grams of solid material. Total porosity of the lower limestone was 21 percent at test well 1 and 18 percent at test well 2. Calculated values of transmissivity ranged from 328 to 468 metres squared per day at test well 1 and from 21.6 to 48.2 metres squared per day at test well 2. All major chemical constituents of water in the lower limestone of the Florida aquifer were in greater concentrations in test well 1.					
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CONSTRUCTION AND TESTING OF TWO

WASTE-INJECTION MONITOR WELLS

IN NORTHWEST FLORIDA

By C.A. Pascale

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-1

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FLORIDA DEPARTMENT OF ENVIRONMENTAL

REGULATION

For additional information write to:

U.S. Geological Survey

15 John Knox Road, Suite F-240

Gainesville, Florida 32603

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UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

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Vincent E. McKelvey, Director

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U.S. Geological Survey
325 John Knox Road, Suite F-240
Tallahassee, Florida 32303

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English units		SI units
<u>Length</u>		
inches (in)	25.4	millimetres (mm)
feet (ft)	0.3048	metres (m)
miles (mi)	1.609	kilometres (km)
<u>Volume</u>		
gallons (gal)	3.785	litres (l)
	3.785×10^{-3}	cubic metres (m ³)
cubic yards (yd ³)	0.7646	cubic metres (m ³)
<u>Flow</u>		
gallons per minute (gal/min)	0.06309	litres per second (l/s)
<u>Transmissivity</u>		
feet squared per day (ft ² /d)	0.0929	metres squared per day (m ² /d)
<u>Pressure</u>		
pounds per square inch (psi)	0.07031	kilograms per square centimetre (kg/cm ²)
<u>Weight per Unit Length</u>		
pounds per foot (lb/ft)	1.4892	kilograms per metre (kg/m)

Metric Conversion Table

The following factors may be used to convert the English units published herein to SI units.

Multiply English units	By	To obtain SI units
<u>Length</u>		
inches (in)	25.4	millimetres (mm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
<u>Volume</u>		
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<u>Transmissivity</u>		
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<u>Pressure</u>		
pounds per square inch (lb/in ²)	.07031	kilograms per square centimetre (kg/cm ²)
<u>Weight per Unit Length</u>		
pounds per foot (lb/ft)	1.4882	kilograms per metre (kg/m)
<u>Hydraulic Conductivity</u>		
feet per day (ft/d)	.3048	inches per day (in/d)

CONSTRUCTION AND TESTING OF TWO
WASTE-INJECTION MONITOR WELLS IN NORTHWEST FLORIDA

By Charles A. Pascale

ABSTRACT

Two test wells were constructed by the U.S. Geological Survey into an injection zone at sites 22 miles (35 kilometres) east and 17 miles (27 kilometres) northeast of an active injection system to monitor the injection zone and to provide additional data for evaluating the regional effects of deep-well waste injection. Test wells 1 and 2 are cased to a depth of 1,220 feet (372 metres) and 985 feet (300 metres) below land surface and are completed open hole in limestone to 1,500 feet (457 metres) and 1,290 feet (393 metres), respectively.

The vertical hydraulic conductivity of core samples taken at the test wells in the Bucatunna Clay Member of the Byram Formation, confining bed, ranged from 2.9×10^{-6} to 2.6×10^{-7} feet per day (0.88×10^{-6} to 0.79×10^{-7} metres per day). The clay contained generally more than 40 percent montmorillonite and mixed clay minerals and its cation-exchange capacity ranged from 43 to 47 milliequivalents per 100 grams of solid material. Total porosity of the lower limestone was 21 percent at test well 1 and 18 percent at test well 2; effective porosity was 13 and 14 percent, respectively.

Calculated values of transmissivity ranged from 3,530 to 5,040 feet squared per day (328 to 468 metres squared per day) at test well 1 and from 232 to 519 feet squared per day (21.6 to 48.2 metres squared per day) at test well 2. All major chemical constituents of water in the lower limestone of the Floridan aquifer were in greater concentrations in test well 1. Water at test well 2 was fresh and contains dissolved solids and chloride in concentrations of less than 1,000 and 330 milligrams per litre, respectively. Water level was 65 feet (20 metres) above sea level in test well 1, and 118 feet (36.0 metres) in test well 2.

Top that waste has moved upward through the Bucatunna Clay Member of the Byram Formation, a confining bed, into the upper limestone of the Floridan aquifer. A generalized geologic section is shown in fig. 2.

As a part of the U.S. Geological Survey statewide subsurface
waste storage research program in Florida, two deep test-monitor
wells were drilled specifically to monitor, on a regional basis, the
effects of high pressure injection of acidic industrial waste into
limestone aquifers of low to moderate permeability. New hydrogeologic
data collected at these wells will be used in conjunction with available
data already collected and analyzed from other observation
wells and injection wells in northwest Florida to evaluate

INTRODUCTION

Background

Since 1963 more than 10 billion gal (3.8 million m³) of acidic industrial waste has been injected through two wells into the confined, saline-water-filled lower limestone of the Floridan aquifer near Pensacola, in northwest Florida. This system is the only active deep-well waste disposal system in northwest Florida; a similar disposal system will be completed in the same aquifer near Milton, 8.5 mi (13.7 km) east of the active system in 1975 as shown in figure 1. As of 1974, injection at the active system is continuous at about 2,400 gal/min (150 l/s) and wellhead pressure at the two injection wells averages 180 lb/in² (12.7 kg/cm²). Wellhead pressure is increasing in two monitor wells tapping the injection zone, one 1.9 mi (3.1 km) north and the other 1.5 mi (2.4 km) south of the injection site. In mid-1974 the pressure averaged 117 lb/in² (8.2 kg/cm²). The head in the lower limestone at the injection site is about 280 ft (85 m) higher than in the upper limestone. This results not only in a significant upward pressure against the confining bed, but also in a tendency for the fresh-water-salt-water interface in the lower limestone to move updip. Under normal circumstances the interface is about 20 mi (32 km) northeast of (updip from) the injection site. Monitoring in the upper limestone above the confining bed at the injection site does not indicate any pressure changes in the upper limestone of the Floridan aquifer. But within the injection zone, pressure effects theoretically extend outward from the injection site more than 40 mi (64 km). By 1973, traces of waste were found in water from the lower limestone at the south monitor well, but so far none have been observed at the north monitor well, nor is there any indication that waste has moved upward through the Bucatunna Clay Member of the Byram Formation, a confining bed, into the upper limestone of the Floridan aquifer. A generalized geologic section is shown in figure 2.

As a part of the U.S. Geological Survey statewide subsurface liquid-waste storage research program in Florida, two deep test-monitor wells were drilled specifically to monitor, on a regional basis, the effects of high pressure injection of acidic industrial waste into limestone aquifers of low to moderate permeability. New hydrogeologic data collected at these wells will be used in conjunction with sizeable quantities of data already collected and analyzed from other observation wells and injection wells in northwest Florida to evaluate:

The long-term regional distribution and magnitude of pressure changes due to injection of acidic liquid waste into the lower zone of the Floridan aquifer.

The effects of pressure changes in the injection zone on the position of the fresh-saline water interface in the injection zone several miles updip.

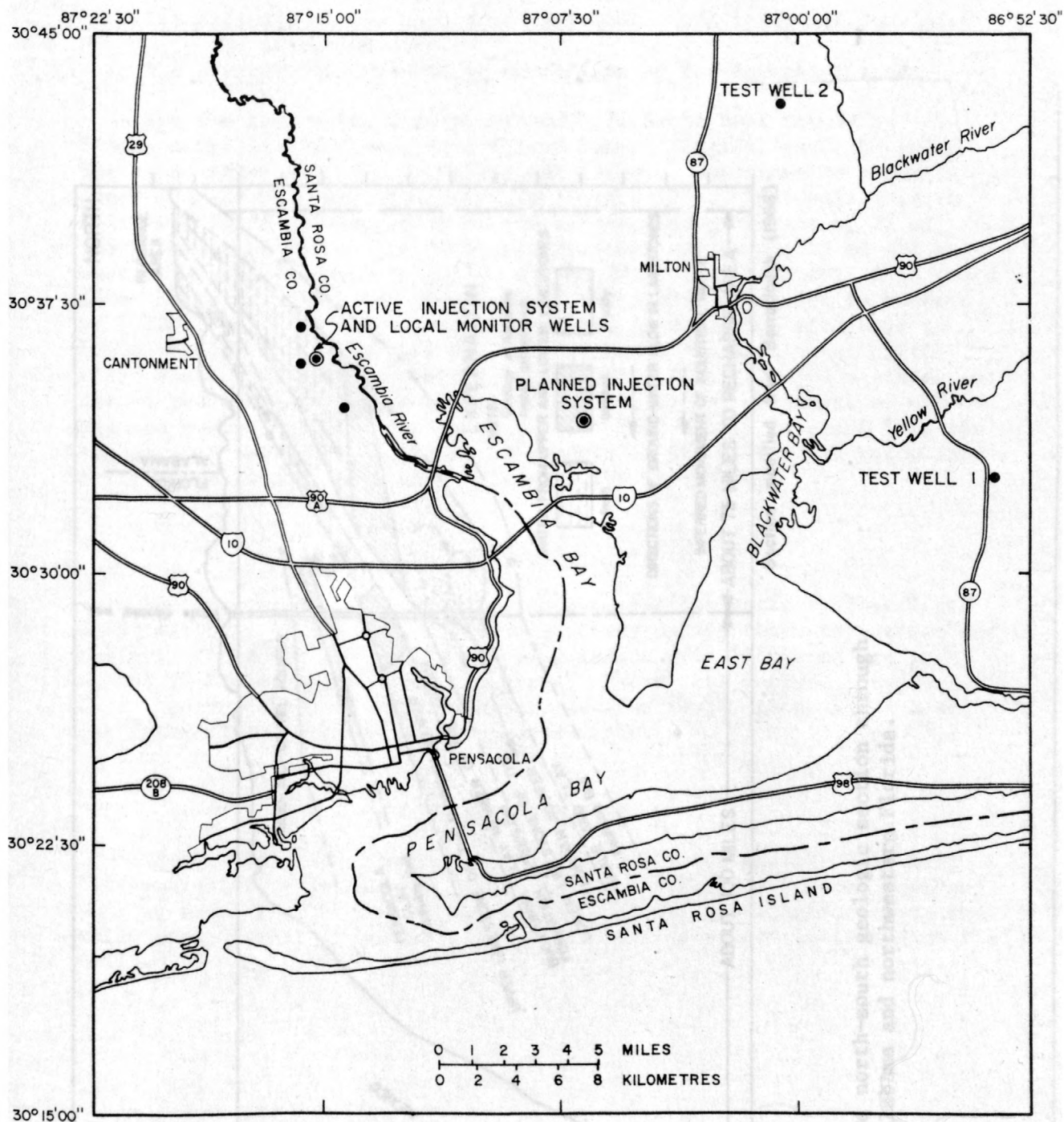


Figure 1.--Map showing location of test wells and active and planned injection system.

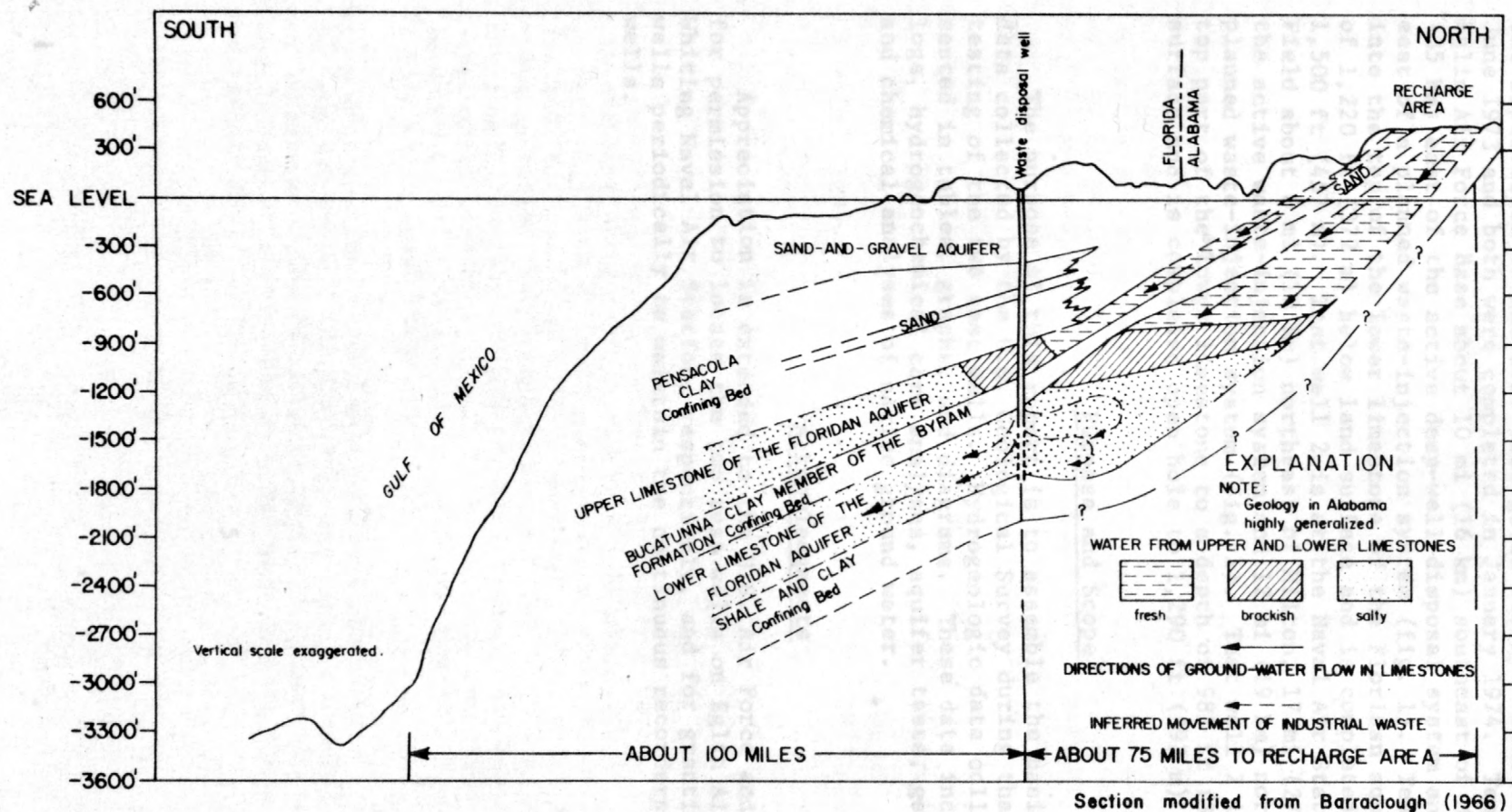


Figure 2.--Generalized north-south geologic section through southern Alabama and northwestern Florida.

The efficacy of the Bucatunna Clay Member confining bed overlying the injection zone.

The pressure and volumetric capacities of the injection zone.

The two test wells were constructed in Santa Rosa County by Thomason Drilling Company, Fort Walton Beach, Florida, for, and under the supervision of the U.S. Geological Survey. Construction began in June 1973 and both were completed in January 1974. Test well 1 is on Eglin Air Force Base about 10 mi (16 km) southeast of Milton, 22 mi (35 km) east of the active deep-well disposal system and 13 mi (21 km) east of a planned waste-injection system (fig. 1). Test well 1 is cased into the top of the lower limestone of the Floridan aquifer to a depth of 1,220 ft (372 m) below land surface and is completed open hole to 1,500 ft (457 m). Test well 2 is at the Naval Air Station at Whiting Field about 6 mi (10 km) northeast of Milton, 17 mi (27 km) northeast of the active waste-injection system and 12 mi (19 km) northeast of the planned waste-injection system (fig. 1). Test well 2 is cased into the top part of the lower limestone to a depth of 985 ft (300 m) below land surface and is completed open hole to 1,290 ft (393 m).

Purpose and Scope

The purpose of this report is to assemble the basic hydrogeologic data collected by the U.S. Geological Survey during the construction and testing of the two test wells. Hydrogeologic data collected are presented in tables, graphs, and diagrams. These data include lithologic logs, hydrogeochemical core analyses, aquifer tests, geophysical logs, and chemical analyses of native ground water.

Acknowledgments

Appreciation is extended to the U.S. Air Force and the U.S. Navy for permission to locate the two test wells on Eglin Air Force Base and Whiting Naval Air Station, respectively, and for granting access to the wells periodically to maintain the continuous recorders installed on the wells.

WELL CONSTRUCTION

Drilling and Casing Procedures

The two test wells were drilled with a hydraulic-rotary drilling machine. Bentonite-base mud mixed in fresh water was used as the circulating fluid.

Test well 1.--At test well 1, a 4 3/4-in (121-mm) diameter pilot hole was drilled to 570 ft (174 m) using a soft-formation bit. All depths in this report are referenced to land surface as the zero datum. Surface altitude at test well 1 is 125.4 ft (38.2 m). The hole was then reamed to 14 in (360 mm) to a depth of 316 ft (96.3 m) and 10 3/4-in (273-mm) casing was landed at that depth to prevent caving and loss of mud to the unconsolidated sand section. Specification of casings used at both test wells are shown in the following table:

Casing diameter, outside		Wall thickness		Weight per unit length	
(in)	(mm)	(in)	(mm)	(lb/ft)	(kg/m)
10 3/4	273	0.307	7.80	34.24	50.96
6 5/8	168	.280	7.11	18.97	28.23
5 1/2	140	.258	6.55	14.62	21.76

Graphic lithologic logs are in figures 3 and 4. From the bottom of the 10 3/4-in (273-mm) casing, a 9-in (230-mm) diameter hole was drilled through clay, sand, and limestone using either a soft-formation bit or a rock bit, as required, to 1,225 ft (373 m), 35 ft (10.7 m) into the top of the lower limestone of the Floridan aquifer. Cores, 2 1/8-in (54-mm) in diameter, were cut at intervals 1,080 to 1,085 ft (329 to 331 m) in clay; 1,120 to 1,125 ft (341 to 343 m) also in clay, and 1,225 to 1,230 ft (373 to 375 m) in limestone. Casing 6 5/8 in in diameter was installed from land surface to 1,220 ft (372 m) into the top of the lower limestone and grouted with cement. All casing joints in both test wells were butt-welded. The well was completed in the lower limestone by drilling a 4 3/4-in (120-mm) open hole from 1,220 ft (372 m) to 1,500 ft (457 m).

During construction of test well 1, fluid circulation was lost at depths 864 and 930 ft (263 and 283 m) in two highly permeable zones in the upper limestone of the Floridan aquifer. More than 100 bags of cement and 25 bags of vermiculite were required to seal these permeable zones and restore fluid circulation.

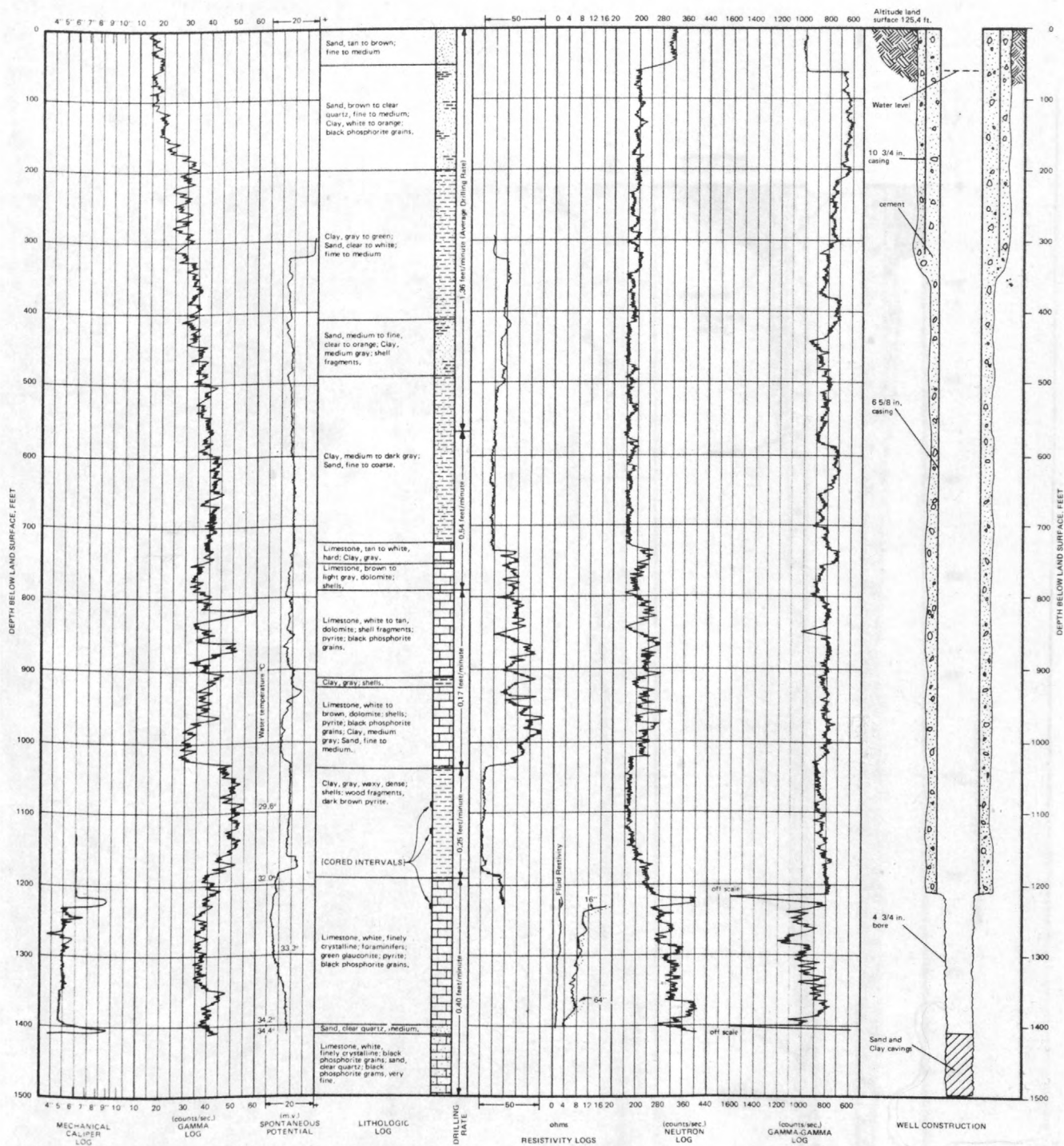


Figure 3.--Geophysical logs, graphic lithologic logs, and construction diagram of test well 1 (303241N0865404.1).

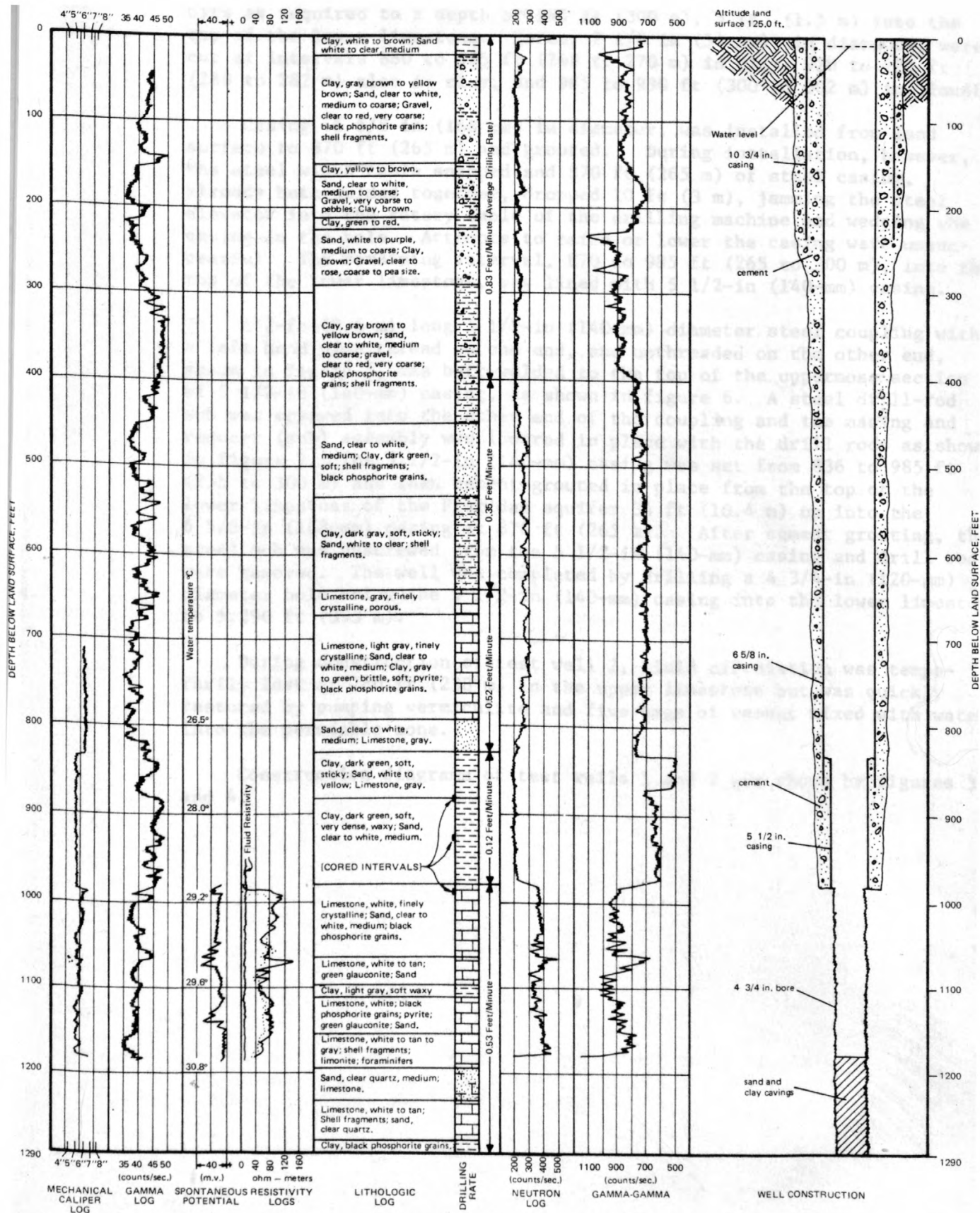


Figure 4.--Geophysical logs, graphic lithologic logs, and construction diagram of test well 2 (304252N0870022.1).

Test well 2.--At test well 2, a 4 3/4-in (12-mm) diameter pilot hole was drilled from land surface to 400 ft (122 m). Surface altitude at test well 2 is 125.0 ft (38.1 m). The hole was then reamed to 14 in (360 mm) to 230 ft (70 m) and 10 3/4-in (273-mm) casing was installed to that depth. A 9-in (230-mm) diameter hole was then drilled below the 10 3/4-in (273-mm) casing, alternating with soft-formation and rock bits as required to a depth of 985 ft (300 m), 5 ft (1.5 m) into the top of the lower limestone. Cores, 2 1/8 in (54 mm) in diameter, were cut at intervals 880 to 885 ft (268 to 270 m) in clay, 920 to 925 ft (280 to 282 m) also in clay, and 985 to 990 ft (300 to 302 m) in limestone.

Casing, 6 5/8 in (168 mm) in diameter, was installed from land surface to 870 ft (265 m) and grouted. During installation, however, the steel winch cable snapped and 870 ft (265 m) of steel casing, already butt-welded together, dropped 10 ft (3 m), jamming the steel elevator into the rotary table of the drilling machine and wedging the casing in the hole. Attempts to raise or lower the casing were unsuccessful. The remaining interval, 870 to 985 ft (265 to 300 m), into the top of the lower limestone, was lined with 5 1/2-in (140-mm) casing.

A 2-ft (0.6-m) long 5 1/2-in (140-mm) diameter steel coupling with a left hand pipe thread on one end, and unthreaded on the other end, shown in figure 5, was butt-welded to the top of the uppermost section of 5 1/2-in (140-mm) casing, as shown in figure 6. A steel drill-rod sub was screwed into the other end of the coupling and the casing and reducer (sub) assembly was lowered in place with the drill rods as shown in figure 7. The 5 1/2-in (140-mm) casing was set from 836 to 985 ft (255 to 300 m) and then cement-grouted in place from the top of the lower limestone of the Floridan aquifer 34 ft (10.4 m) up into the 6 5/8-in (168-mm) casing at 870 ft (265 m). After cement grouting, the steel sub was unscrewed from the 5 1/2-in (140-mm) casing and drill rods were removed. The well was completed by drilling a 4 3/4-in (120-mm) diameter hole below the 5 1/2-in (140-mm) casing into the lower limestone to 1,290 ft (393 m).

During construction of test well 2, fluid circulation was temporarily lost at 780 ft (238 m) in the upper limestone but was quickly restored by pumping vermiculite and five bags of cement mixed with water into the permeable zone.

Construction diagrams of test wells 1 and 2 are shown by figures 3 and 4.

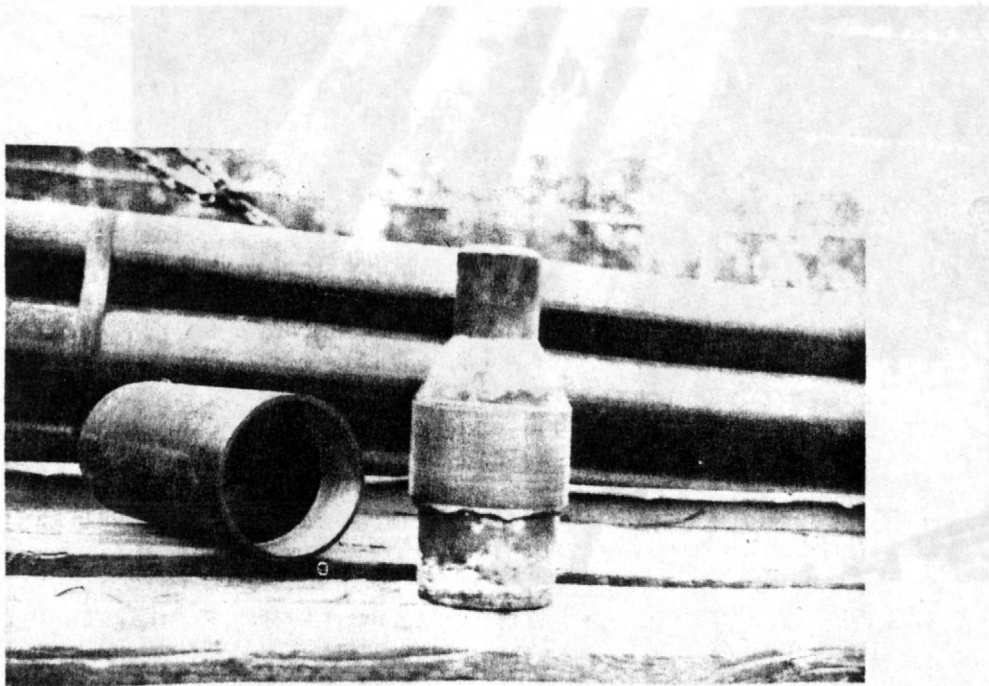


Figure 6.--Drill-rod sub screwed in coupling butt-welded to joint of
5 1/2-in (140-mm) steel casing.

Figure 5.-- A 5 1/2-in x 2-ft (140-mm x 0.6-m) steel coupling (left)
with left hand thread and a steel 5 1/2-in x 2 7/8-in
(140-mm x 73-mm) drill-rod sub (right).

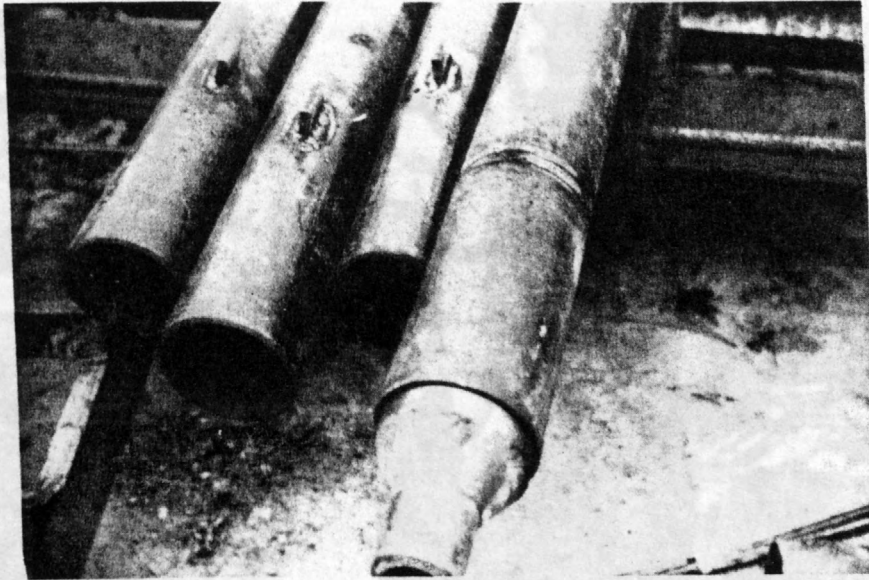


Figure 6.--Drill-rod sub screwed in coupling butt-welded to joint of 5 1/2-in (140-mm) steel casing.

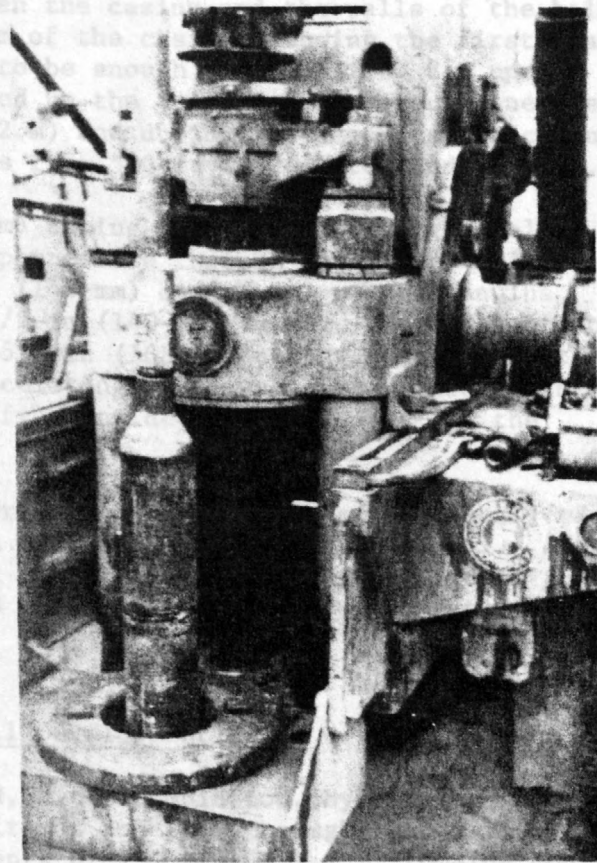
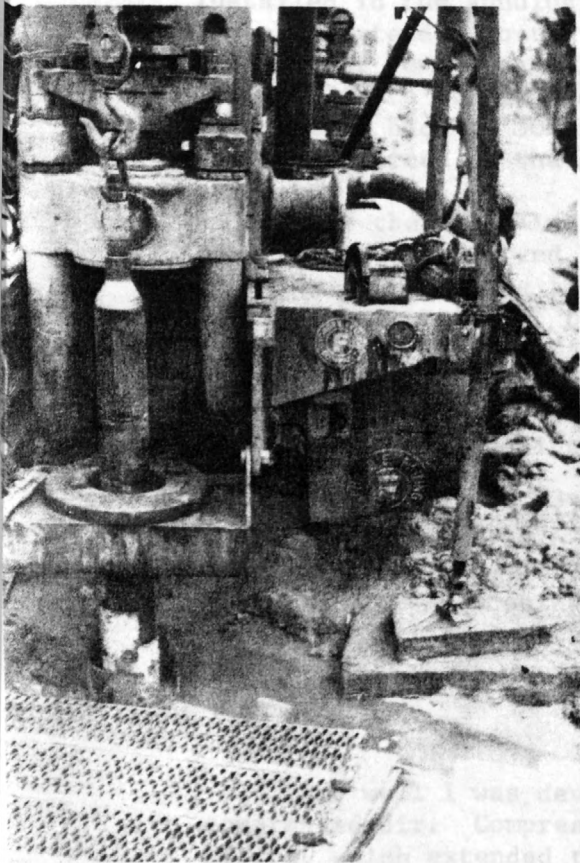


Figure 7.--The 5 1/2-in (140-mm) steel casing attached to drill pipe
 about to be lowered into 6 5/8-in (168-mm) casing.

Cement Grouting

The 6 5/8-in (168-mm) and 5 1/2-in (140-mm) diameter casings were cement-grouted in place using standard portland cement with no additives. At test well 1, a 1 1/2-in (38-mm) grout line was installed inside and to the bottom of the 6 5/8-in (168-mm) casing and sealed at the top of the casing with a Dresser coupling welded in the top of the bradenhead as shown in figure 8. After the casing was pumped full of drilling fluid, cement grout was forced by pump pressure through the grout line and up the annular space between the casing and the walls of the hole. The grouting process continued until the grout displaced all the drilling fluid in the annular space and flowed freely at the surface.

At test well 2, the 870-ft (265-m) string of 6 5/8-in (168-mm) casing was grouted in two stages by pumping cement through a pipe installed in the annulus between the casing and the walls of the hole. The pipe extended to the bottom of the casing. During the first stage, a volume of cement calculated to be enough to grout from 870 up to 500 ft (265 to 152 m) was forced up the annulus. The grout line was then pulled back to 500 ft (152 m) and during the second stage cement grout was forced up the annulus from 500 ft (152 m) to land surface.

After the 5 1/2-in (140-mm) casing was installed in the hole, cement grout was forced by pump pressure through the 2 7/8-in (73-mm) steel drill rods, the 5 1/2-in (140-mm) casing and up the annulus between the outside of the 5 1/2-in (140-mm) casing, the walls of the hole, and the inside of the 6 5/8-in (168-mm) casing. After grouting, about 500 gal (1,900 l) of circulating fluid was pumped through the drill rods to flush the grout from inside the drill rods and the 5 1/2-in (140-mm) casing.

About 12 yd³ (9 m³) of portland cement (250 bags of cement) was required to grout the 6 5/8-in (168-mm) casing at test well 1. At test well 2, 8 yd³ (6 m³) (170 bags of cement) was required to grout the 6 5/8-in (168-mm) casing and 3 yd³ (2 m³) (60 bags of cement) to grout the 5 1/2-in (140-mm) casing.

Well Development

Test well 1 was developed, after completion, by pumping with compressed air. Compressed air was injected through the drill-rod string, which extended to a depth of 250 ft (76.2 m). Pumping continued intermittently for 2 hours until the water removed from the well contained very little suspended material. Development removed the drilling mud and cuttings that had penetrated into the walls of the open-hole section of the limestone formation. A considerable amount of medium sand composed of clear quartz grains was removed from the well. The

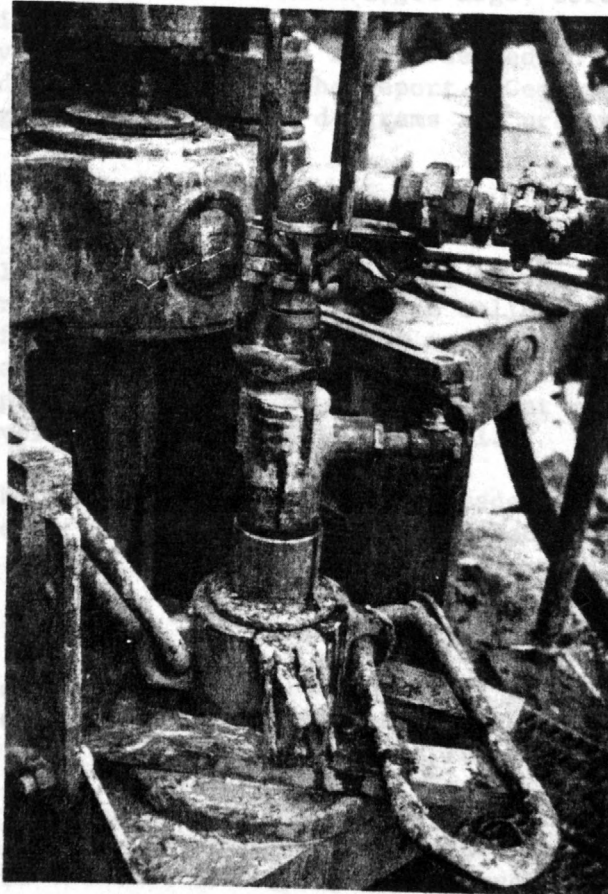


Figure 8.--Hookup of bradenhead and grout line used to grout well casing.

level of the fluid in the well before development was 100 ft (30 m) below land surface. After development, the water level stabilized at 60 ft (18.3 m) below land surface.

Test well 2 was pumped with compressed air more than 3 hours before the water removed was free of suspended clay particles. The level of the fluid in the well before development was 80 ft (24 m) below land surface. After development, the water level stabilized at 7 ft (2.1 m) below land surface. No. 303241N0865404.1)

(Lithologic description by C. A. Pascala)

HYDROGEOLOGIC DATA

U.S. Geological Survey
Hydrogeologic data collected during the construction of the two observation wells include lithologic logs, core descriptions and related hydrologic core analyses, aquifer test results, water analyses and water-level hydrographs that are presented in tables 1-5 and figures 11-14 and 17 at the end of the report. Geophysical logs, graphic lithologic logs and construction diagrams are presented in figures 3 and 4.

Thomson Drilling Company, James E. Thomson, Fort Walton Beach,

Drill Cuttings

Drill cuttings were collected from every 10-ft (3-m) interval during drilling. The cuttings were collected from a wooden trough leading from the drill hole to the mud-settling pit. After each sample was collected, all cuttings were removed from the trough so that the next sample to be collected would represent material from the next successively deeper section of the well.

Lithologic logs of the cuttings made in the field for each well are presented in tables 1 and 2 and summarized in part on figures 3 and 4.

Open hole, 280 ft (85.3 m) from 1,220 to 1,500 ft (372 to

457 m)

Cores

Cores were obtained from each well as follows: For each selected coring depth the drill bit was replaced with a 2 1/8-in (54-mm) inside diameter 5-ft (1.52-m) long core barrel as shown in figure 9, and a 5-ft (1.52-m) interval was cored. Sections of core were then removed from the core barrel as shown in figure 10 and covered with plastic and aluminum foil to maintain their moisture content. They were then shipped to the U.S. Geological Survey hydrologic laboratory in Denver, Colorado, for determination of porosity, cation-exchange capacity, mineral identification, and carbonate content. These data are used to help evaluate the integrity of the Bucatunna Clay Member as a confining bed and the lower limestone of the Floridan aquifer as a receiving zone for acidic industrial waste.

100 gal/min (6.3 l/s) (pumped)

specificity: 5,040 ft²/d (468 m²/d)

Table 1.--Lithologic log of test well 1.

(USGS No. 303241N0865404.1)

(Lithologic description by C. A. Pascale)

Owner: U.S. Geological Survey

Location: NW $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T. 1 N., R. 27 W., 2.5 miles (4.0 km)
south of Yellow River on highway 87, 100 yds (90 m) east
of highway

Driller: Thomason Drilling Company, James E. Thomason, Fort Walton Beach,
Florida

Date drilled: December 1973

Total depth: 1,500 ft (457 m)

Depth of casing: 1,220 ft (372 m)

Casing diameter: 6 5/8-in O.D. (168-mm)

Well finish: Open hole, 280 ft (85.3 m) from 1,220 to 1,500 ft (372 to
457 m)

Method of drilling: Hydraulic rotary

Aquifer: Floridan, lower limestone

Altitude (land surface): 125.4 ft (38.2 m) (Measuring point is
top of 6 5/8-in (168-mm) welded flange 2.60 ft
(0.79 m) above lsd.)

Water level: 60.5 ft (18.4 m) below land surface 01/15/74

Yield: 100 gal/min (6.3 l/s) (pumped)

Transmissivity: 5,040 ft²/d (468 m²/d)

Chloride concentration: 3,300 mg/l 12/20/73

Temperature: 33.0°C 12/20/73

Table 1.--Continued.

Lithology	Thickness (feet)	Depth (feet)
Sand, tan to brown, quartz, fine to medium, subrounded.	20	20
Sand, tan to orange, quartz, fine to medium.	30	50
Sand, light brown, quartz, fine to medium, subangular; clay, orange to white; black phosphorite grains.	60	110
Sand, orange to clear quartz, fine to medium, subangular; clay, white to orange; black phosphorite grains.	90	200
Clay, medium gray; sand, clear to white quartz, fine to medium; black phosphorite grains.	60	260
Clay, gray to green; sand, clear to gray, medium; shell fragments; black phosphorite grains.	70	330
Clay, light to medium gray; sand, clear to white, fine to medium; black phosphorite grains; shell fragments less abundant.	40	370
Clay, light to medium gray; sand, clear to white, fine to medium; black phosphorite; shell fragments abundant.	40	410
Sand, medium to fine quartz, subangular, clear to orange; clay, medium gray; shell fragments.	80	490

Table 1.--Continued.

Lithology	Thickness (feet)	Depth (feet)
Clay, gray with traces of orange; sand, fine to medium, frosted to clear; shell fragments, black phosphorite grains.	90	580
Clay, medium to dark gray; sand, coarse; shell fragments; black phosphorite grains.	145	725
Limestone, tan to light gray, hard dolomitic; clay, gray; sand, fine to medium; black phosphorite grains.	5	730
Limestone, cream to white; black phosphorite grains; pyrite; shells.	20	750
Limestone, brown to light gray, dolomitic; black phosphorite grains; pyrite; shells.	40	790
Limestone, cream to tan, dolomitic, rough texture; shell fragments; pyrite; black phosphorite grains.	40	830
Limestone, white to gray, fine texture; pyrite; black phosphorite grains.	70	900
Limestone, white to tan; shells; clay, gray to light gray.	10	910
Clay, gray; shells; limestone, tan.	10	920

Table 1.--Continued.

Lithology	Thickness (feet)	Depth (feet)
Limestone, white to tan to gray, dolomitic; shells; clay, gray; black phosphorite grains.	50	970
Limestone, brown to tan, dolomitic; shell fragments; clay, medium gray; pyrite.	40	1010
Limestone, white to gray; shells and shell fragments; pyrite; clay, medium gray; sand, fine to medium, clear to orange.	30	1040
Clay, gray, waxy; shells; limestone fragments, white; sand, fine to medium; black phos- phorite grains.	20	1060
Clay, gray, waxy, sticky; shells; wood fragments; dark brown.	30	1090
Clay, dark to medium gray, dense, waxy, sticky; shells, cream; wood fragments, light to dark brown.	90	1180
Clay, gray, dense, waxy; pyrite; limestone fragments.	10	1190
Limestone, white, finely crystalline; clay, gray; sand, clear quartz; shells; black phosphorite grains.	40	1230

Table 1.--Continued.

Location: SW 1/4, sec. 1, T. 2 N., R. 28 W., Whiting Field, Mil Florida		Thickness (feet)	Depth (feet)
Limestone, white to tan, finely crystalline; foraminifers; shells; pyrite; black phosphorite grains. January 1974		30	1260
Limestone, white; finely crystalline; green glauconite; pyrite; black phosphorite grains.		110	1370
Limestone, white, finely crystalline; forami- nifers; black phosphorite grains; sand, clear, quartz, fine. on hole, 305 ft (93.0 m) from 98'		30	1400
Sand, clear, quartz, medium; limestone, white, finely crystalline; black phosphorite grains; green glauconite. ridge, lower limestone		10	1410
Limestone, white, finely crystalline; sand, clear, quartz; black phosphorite grains.		40	1450
Limestone, white, finely crystalline; sand, clear, quartz, medium (50% sand); black phosphorite grains, very fine.		50	1500

Transmissivity: 519 ft²/d (48.2 m²/d)

Chloride concentration: 330 mg/l 01/14/74

Temperature: 30.0°C 01/14/74

Table 2.--Lithologic log of test well 2.

(USGS No. 304252N0870022.1)

(Lithologic description by C. A. Pascale and J. R. Wagner)

Owner: U.S. Geological Survey

Location: SW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 1, T. 2 N., R. 28 W., Whiting Field, Milton,
Florida

Driller: Thomason Drilling Company, James E. Thomason, Fort Walton
Beach, Florida

Date Drilled: January 1974

Total depth: 1,290 ft (393 m)

Depth of casing: 985 ft (300 m)

Casing diameter: 6 5/8-in O.D. (168-mm) to 870 ft (265 m), 5 1/2-in
(140-mm) O.D. to 985 ft (300 m)

Well finish: Open hole, 305 ft (93.0 m) from 985 to 1,290 ft (300 to
393 m)

Method of drilling: Hydraulic rotary

Aquifer: Floridan, lower limestone

Altitude (land surface): 125.0 ft (38.1 m) (Measuring point is top
of 6 5/8-in (168-mm) O.D. casing 4.00 ft
(1.22 m) above lsd.)

Water level: 7.17 ft (2.19 m) below land surface 02/01/74

Yield: 50 gal/min (3.2 l/s) (pumped)

Transmissivity: 519 ft²/d (48.2 m²/d)

Chloride concentration: 330 mg/l 01/14/74

Temperature: 30.0°C 01/14/74

Table 2.--Continued.

Lithology	Thickness (feet)	Depth (feet)
Clay, white to brown, sticky; sand, white to clear quartz, medium.	20	20
Sand, clear to white quartz, medium; clay, brown to red.	20	40
Sand, clear to white, medium to coarse; gravel, white to yellow, very coarse to pea size; clay, brown.	20	60
Sand, clear to white, medium to coarse, sub- rounded to rounded; gravel, clear to white, very coarse; clay, light brown.	90	150
Clay, yellow to brown, sticky; gravel, very coarse to small pebbles; sand, medium, clear to white.	10	160
Sand, clear to white, medium to coarse, sub- rounded to angular; gravel--very coarse to pebble; clay, light brown.	50	210
Clay, green-gray to red, sticky; gravel, very coarse to pea size; sand, clear to white medium.	10	220
Sand, white to clear, medium to coarse; gravel, white to clear, very coarse to pebbles; clay, yellow brown to green, sticky.	30	250

Table 2.--Continued.

Lithology	Thickness (feet)	Depth (feet)
Sand, clear to purple, medium to coarse, sub- rounded to subangular; clay, brown; gravel, clear to rose, very coarse to pea size.	40	290
Clay, gray brown to yellow brown; sand, clear to white, medium to coarse; gravel, clear to red, very coarse; black phosphorite grains. white, medium; limestone, gray.	40	330
Clay, dark green, sticky; sand, clear to white, subangular to subrounded; shell fragments; black phosphorite grains. sand, white to	120	450
Sand, clear to white, medium; clay, dark green, soft; shell fragments; black phosphorite grains. soft, very dense, waxy; sand.	80	530
Clay, dark gray, soft, sticky; sand, white to clear, angular to subangular; shell fragments. medium; black phosphorite	110	640
Limestone, gray, finely crystalline, porous; sand, clear to white, medium; clay, dark gray, soft, sticky; black phosphorite grains; pyrite; shell fragments.	30	670
stone, white to tan, limonite stains on limestone, finely crystalline; green glauco- dite; sand, clear quartz.	30	1090

Table 2.--Continued.

Lithology	Thickness (feet)	Depth (feet)
Limestone, light gray, fine; sand, clear to white, medium; clay, gray to green, brittle, soft; black phosphorite grains; pyrite; shell fragments.	120	790
Sand, clear to white, medium; limestone, gray, fine; shell fragments; black phosphorite grains.	40	830
Clay, dark green, soft, sticky; sand, white to yellow, angular to subangular; limestone, gray, fine; shell fragments.	50	880
Clay, dark green, soft, very dense, waxy; sand, clear to white, medium.	100	980
Limestone, white, finely crystalline; sand, clear to white, medium; black phosphorite grains.	30	1010
Limestone, white, finely crystalline; pyrite; green glauconite; black phosphorite grains; shell fragments.	50	1060
Limestone, white to tan, limonite stains on limestone, finely crystalline; green glauconite; sand, clear quartz.	30	1090
Clay, light gray, soft, waxy; limestone, white to tan, finely crystalline.	20	1110

Table 2.--Continued.

Lithology	Thickness (feet)	Depth (feet)
Limestone, white, finely crystalline; black phosphorite grains; pyrite; trace of clay.	20	1130
Limestone, white, finely crystalline; shell fragments; phosphorite; green glauconite; sand, clear quartz, medium.	20	1150
Limestone, white to tan to gray; shell fragments; foraminifers; limonite clay, white; clay, gray, silty.	40	1190
Sand, clear quartz; medium, subangular; limestone, white to tan, crystalline.	40	1230
Limestone, white to tan, finely crystalline; shell fragments; sand, clear quartz, medium; limonite clay.	30	1260
Limestone, white to tan; sand, clear quartz, medium; shell fragments; clay, light gray, soft; black phosphorite, black.	20	1280
Clay, gray, soft; black phosphorite grains, abundant; sand, clear quartz, medium; limestone fragments.	10	1290



Figure 9.--Core barrel used in test wells.



Figure 10.--Section of the Bucatunna Clay Member of the Byram Formation cored at 1,120-1,125 ft (341-343 m) in test well 1.

Mineralogy, cation-exchange capacity, and carbonate content.--The mineralogy of the Bucatunna Clay Member of the Byram Formation confining bed was determined by subjecting the core samples to x-ray diffraction analyses. The samples appeared to contain only quartz and clay minerals (table 3). The low total percentage mineral content may be due to the presence of organic matter. All the samples contain a relatively high percentage of montmorillonite and mixed layer clay minerals, generally more than 40 percent. The cation-exchange capacity ranged from 43 to 47 meq/100g (milliequivalents per 100 grams) of solid material. The amount of exchangeable cations normally ranges from 0.5 to 5 meq/100g for finely ground igneous rock, from 3 to 15 meq/100g for kaolinite and more than 100 meq/100g for vermiculite and some montmorillonites (Davis and DeWiest, 1966, p. 91-92). Any movement of liquid through this clay would measurably alter the proportions of cations in the liquid.

The carbonate content of core samples taken in the lower limestone of the Floridan aquifer at 1,225 ft (373 m) at test well 1 and 985 ft (300 m) at test well 2 is about 54 percent by weight CO_3 (carbonate) and 90 percent by weight CaCO_3 equivalent (calcite).

Vertical hydraulic conductivity and porosity.--The vertical hydraulic conductivity of the core samples taken at 1,080 and 1,120 ft (329 and 341 m) at test well 1 and at 880 and 920 ft (268 and 280 m) at test well 2 in the Bucatunna Clay Member confining bed ranged from 2.9×10^{-6} to 2.6×10^{-7} ft/d (0.88×10^{-6} to 0.79×10^{-7} m/d).

Total porosity of core samples taken at 1,225 ft (373 m) at test well 1 and at 985 ft (300 m) at test well 2 in the lower limestone of the Floridan aquifer was 21 and 18 percent, respectively; effective porosity was 13 and 14 percent, respectively.

Table 3. Mineralogy, cation-exchange capacity, and carbonate content of core samples from the Byram Formation, Mississippi River Valley, Louisiana.

Test well no.	Date of collection	Mineralogy (%)	Cation-exchange capacity (meq/100g)	Carbonate content (%)
1	08-16-73	45	43	54
	08-20-73	45	43	54
2	09-27-73	45	43	54
	09-28-73	45	43	54

Refer to metric conversion table for units.

Table 3.--Mineralogy and cation-exchange capacity of cored samples taken from the Bucatunna Clay Member of the Byram Formation, a confining bed overlying the lower limestone of the Floridan aquifer.

Test well no.	Date of collection	Depth (feet below land surface)	WEIGHT PERCENT								Cation-exchange capacity (milliequivalents per 100 grams)
			Quartz	Calcite	Chlorite	Kaolinite	Illite	Montmorillonite	Mixed-layer clay minerals	Total	
1	08-16-73	1,084	12	0	0	11	4	25	24	76	46
	08-20-73	1,120	14	0	0	11	5	31	28	89	47
2	09-27-73	880	13	2	0	12	4	20	27	78	43
	09-28-73	920	8	7	0	7	3	16	20	61	46

Refer to metric conversion table to convert English units to SI units.

Aquifer Tests

Drawdown and recovery tests were made at both wells to determine the transmissivity of the lower limestone of the Floridan aquifer. During the drawdown tests, discharge rates--100 gal/min (6.3 l/s) at test well 1 and 50 gal/min (3.2 l/s) at test well 2--were determined by using a 3-in (76-mm) diameter circular orifice in a 4-in (102-mm) diameter discharge pipe. Initially, test well 2 was pumped at 100 gal/min (6.3 l/s) but drawdown was so great that the turbine pump broke suction. An electric tape was used to measure the drawdown. The maximum drawdown after 8 hours was 8.88 ft (2.71 m) in test well 1 and 50.65 ft (15.44 m) in test well 2. During the recovery test, which began when pumping stopped at the end of the drawdown test, the water-level recovery also was measured with an electric tape. Calculated values of transmissivity ranged from 3,530 to 5,040 ft²/d (328 to 468 m²/d) at test well 1 and from 232 to 519 ft²/d (21.6 to 48.2 m²/d) at test well 2; the test results are given in figures 11-14. The values at test well 2 are of the same order of magnitude as transmissivities determined by pumping tests at the active and proposed deep-well disposal systems located 17 and 12 mi (27 and 19 km) southwest of test well 2, respectively.

Geophysical Logs

Mechanical-caliper, temperature, spontaneous-potential, and electrical-resistivity logs were made of the open-hole section of the lower limestone of the Floridan aquifer for each of the two wells. Spontaneous-potential and resistivity logs at test well 1 were also run from 316 to 1,225 ft (96 to 373 m) in a mud-filled hole before the 6 5/8-in (168-mm) casing was installed. The other logs were run with native water in the hole. The gamma, neutron, and gamma-gamma logs were run in the cased and open-hole sections of both wells. These logs are reproduced in figures 3 and 4. Water temperatures, determined from the temperature logs, are shown on the spontaneous-potential log of each well every 100 ft (30 m) for the intervals 1,100 to 1,410 ft (335 to 430 m) at test well 1 and 800 to 1,180 ft (244 to 360 m) at test well 2. Geophysical logging equipment was operated by personnel of the U.S. Geological Survey and the Florida Bureau of Geology. Figure 15 shows U.S. Geological Survey vehicle and equipment used to log the test wells.

Water Samples

Water samples were collected from the lower limestone of the Floridan aquifer after well construction was completed. The samples were collected at each well during the aquifer test after pumping 1, 4, and 8 hours at rates of 100 gal/min (6.3 l/s) at test well 1 and 50 gal/min (3.2 l/s) at test well 2.

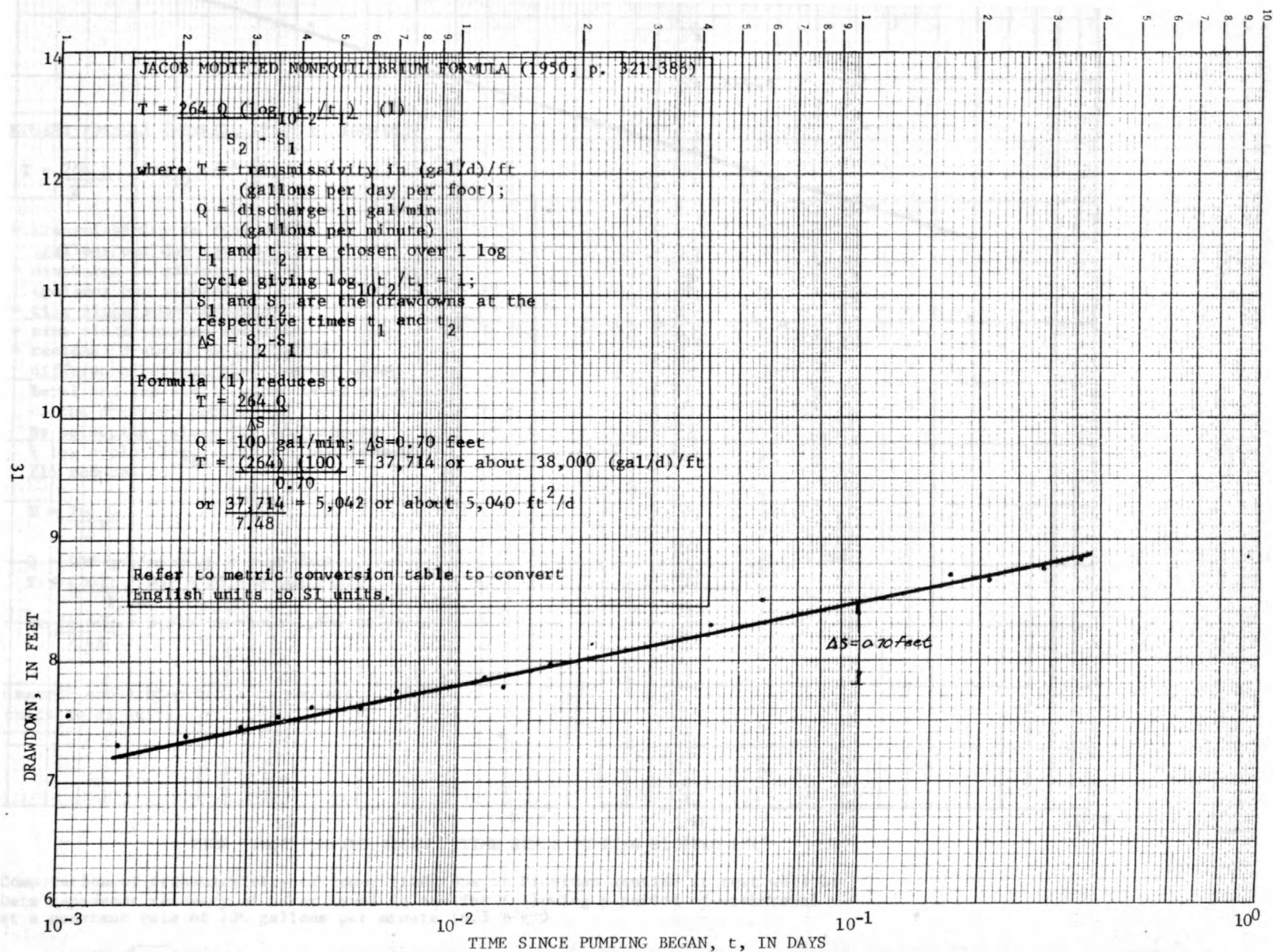


Figure 11. Computation of transmissivity of lower limestone of Floridan aquifer at test well 1. Data represent decline of water level in aquifer during period that well was pumped at constant rate of 100 gallons per minute (6.3 l/s).

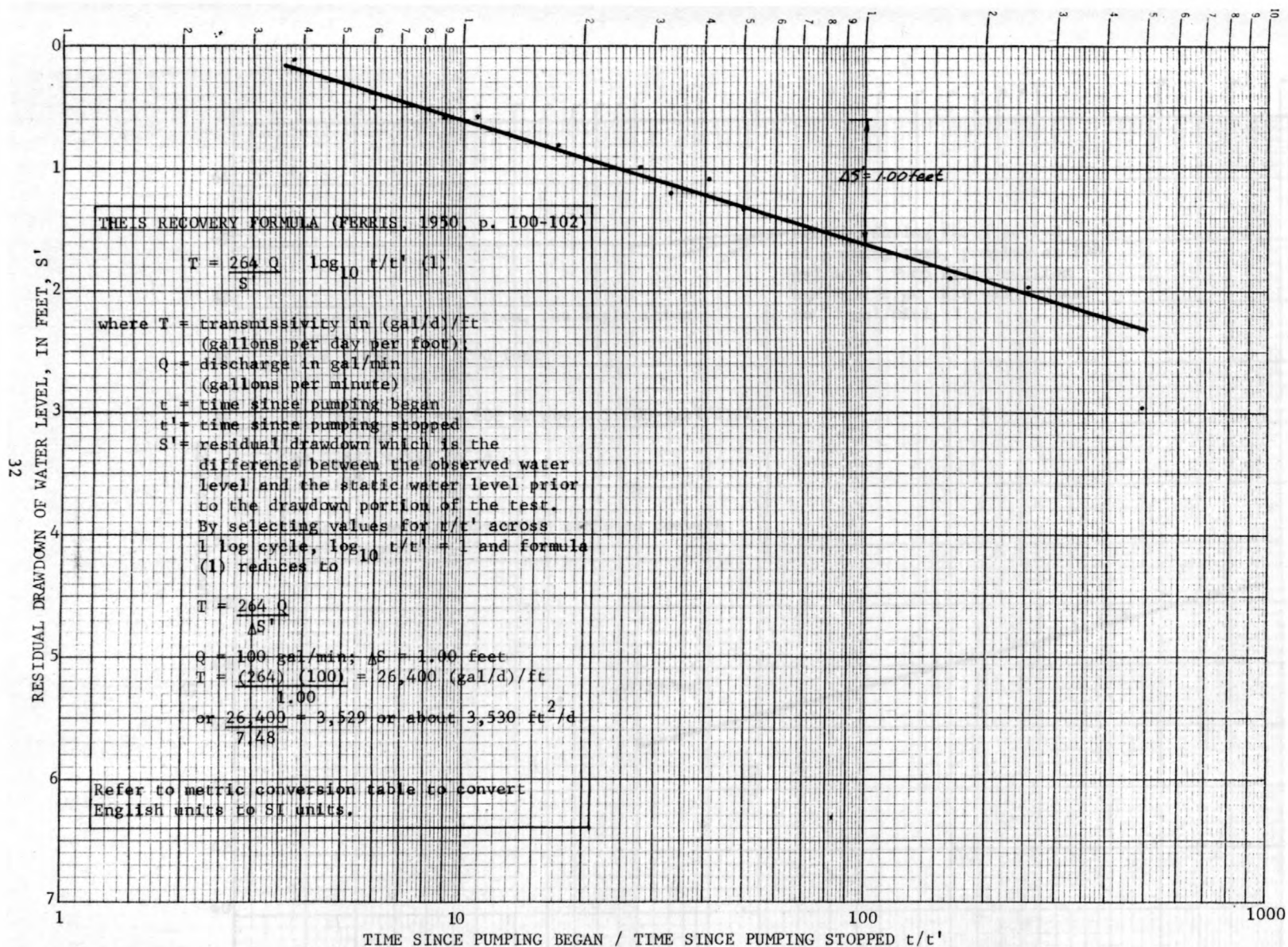


Figure 12. Computation of transmissivity of lower limestone of Floridan aquifer at test well 1. Data represent recovery of water level in aquifer following a period of withdrawal at a constant rate of 100 gallons per minute (6.3 l/s).

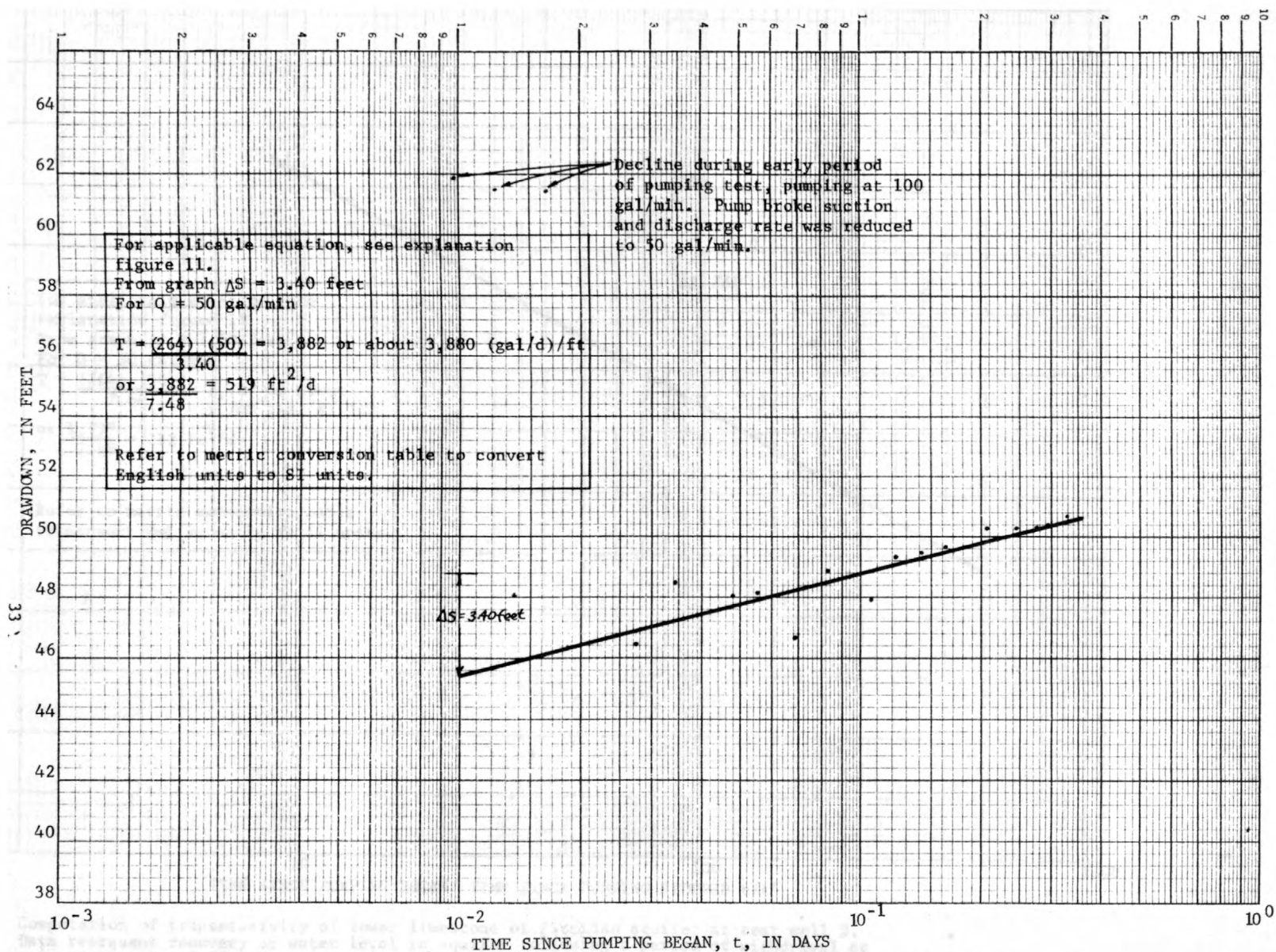


Figure 13. Computation of transmissivity of lower limestone of Floridan aquifer at test well 2. Data represent decline of water level in aquifer during period that well was pumped at constant rate of 50 gallons per minute (3.2 l/s).

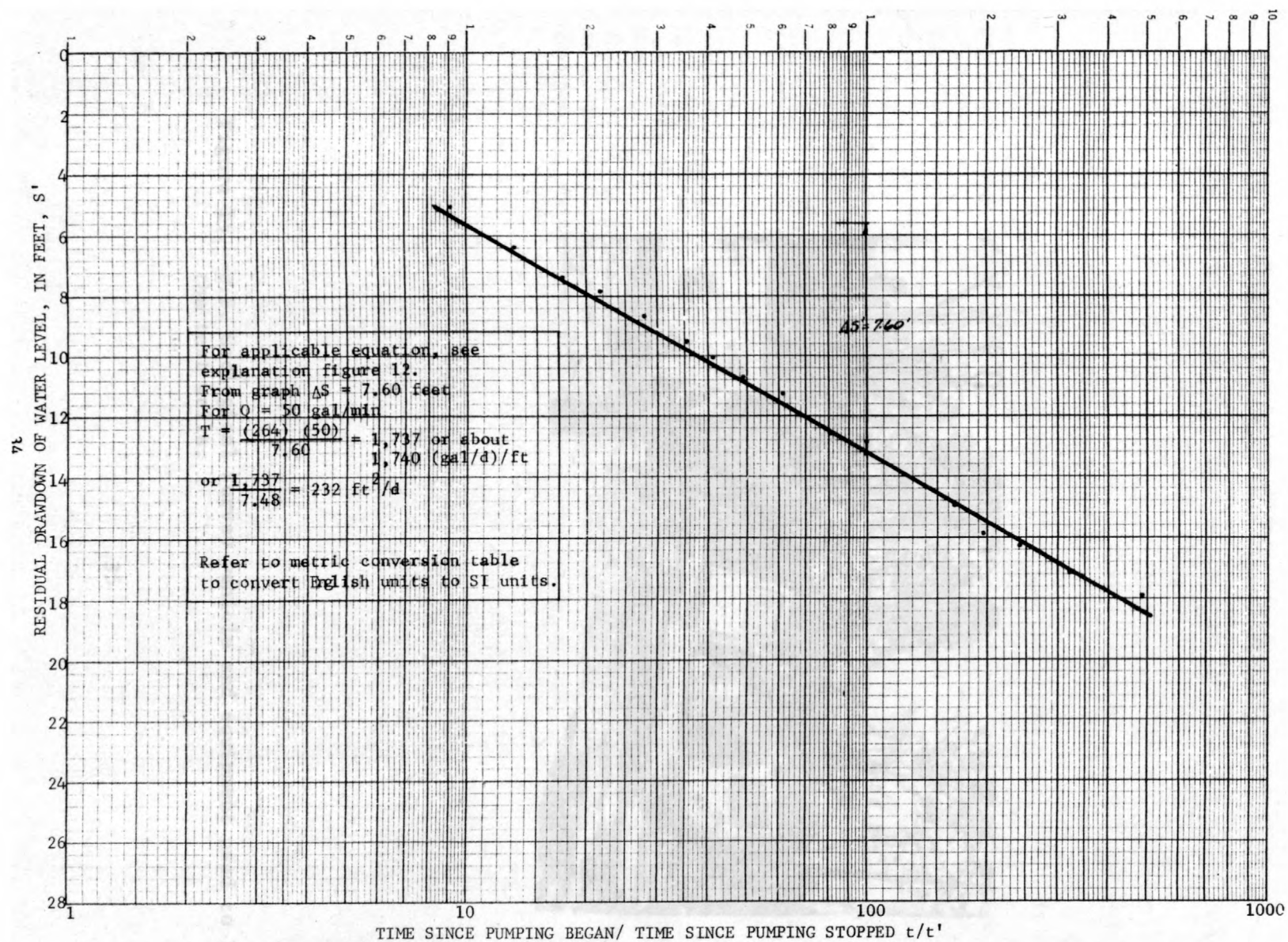


Figure 14. Computation of transmissivity of lower limestone of Floridan aquifer at test well 2. Data represent recovery of water level in aquifer following a period of withdrawal at a constant rate of 50 gallons per minute (3.2 l/s).



Figure 15.--U.S. Geological Survey vehicle and equipment used to log the test wells.

Chemical Analyses of Water Samples

Water samples collected from both wells were analyzed for major and minor chemical constituents by the U.S. Geological Survey Central Laboratory in Atlanta, Georgia, and by the Florida District Service Laboratory in Ocala, Florida. Analytical methods used at both facilities are given in table 4. Analyses of 6 water samples, 3 from each of the two test wells, are listed in table 5.

Chemical analyses of water taken from the two wells show that concentrations of all major chemical constituents in water from the lower limestone of the Floridan aquifer are greater in test well 1. The dissolved solids (residue at 180°C) are about 5,700 and 900 mg/l (milligrams per litre) at test well 1 and 2, respectively; chloride is about 3,300 and 330 mg/l. Although the water in test well 2 is not considered potable on the basis of U.S. Environmental Protection Agency standards (1972)--dissolved-solids concentration (residue at 180°C) is greater than 500 mg/l--residents in some areas of Florida, for lack of better water, use water whose dissolved-solids concentration is more than 900 mg/l.

Water-Level Recorders

Water-level recorders were installed after construction and testing. Water level was 65 ft (19.8 m) above sea level at test well 1 and 118 ft (36.0 m) above at test well 2. Rising trends in water levels considered to be in response to waste injection have been evident ever since well completion, as shown in figure 16.

Table 4.--Laboratory methods used to analyze water samples from
test wells 1 and 2.

<u>Constituent</u>	<u>Method</u>
Alkalinity as CaCO ₃	Potentiometric calculation
Aluminum, dissolved	Atomic-absorption spectrophotometry
Arsenic, dissolved	Atomic Silver diethyldithiocarbamate
Bicarbonate	Atomic Electrometric titration
Boron, dissolved	Atomic Dianthrimide spectrophotometry
Cadmium, dissolved	Atomic Atomic-absorption spectrophotometry
Calcium, dissolved	Atomic Atomic-absorption spectrophotometry
Carbon, total organic	Flame Combustion-infrared spectrophotometry
Carbon dioxide	phot Nomographic calculation
Carbonate	Atomic Electrometric titration
Chemical oxygen demand	Atomic Dichromate oxidation-titration
Chloride, dissolved	Cadmium Mercurimetric titration
Chromium, dissolved	Diazot Atomic-absorption spectrophotometry
Chromium, hexavalent	Automa Atomic-absorption spectrophotometry
Cobalt, dissolved	Kjelds Atomic-absorption spectrophotometry
Color	Calcula Color comparator
Conductivity	pH Meter Wheatstone bridge
Copper, dissolved	Digesti Atomic-absorption spectrophotometry
Fluoride, dissolved	autoa Zirconium-eriochrome cyanine R
Hardness, non-carbonate	Atomic Calculated
Hardness, total	Calcula Calculated from calcium, magnesium,
Hardness, dissolved, 180°C	Ignition and strontium

Table 4.--Continued.

<u>Constituent</u>	<u>Method</u>
Iron, dissolved	Atomic-absorption spectrophotometry
Lead, dissolved	Atomic-absorption spectrophotometry
Lithium, dissolved	Atomic-absorption spectrophotometry
Magnesium, dissolved	Atomic-absorption spectrophotometry
Manganese, dissolved	Atomic-absorption spectrophotometry
Mercury, dissolved	Flameless-atomic-absorption spectro- photometry
Molybdenum, dissolved	Atomic-absorption spectrophotometry
Nickel, dissolved	Atomic-absorption spectrophotometry
Nitrate	Cadmium reduction autoanalyzer
Nitrite	Diazotization autoanalyzer
Nitrogen, ammonia	Automated indophenol blue
Nitrogen, organic	Kjeldahl digestion-distillation titration
Nitrogen, total	Calculated
pH	pH Meter (potentiometric)
Phosphorus, total	Digestion-automated single reagent autoanalyzer
Potassium, dissolved	Atomic-absorption spectrophotometry
Residue, dissolved, sum	Calculated
Residue, dissolved, 180°C	Ignition gravimetric
Silica, dissolved	Automated molybdate blue
Sodium, dissolved	Atomic-absorption spectrophotometry
Strontium, dissolved	Atomic-absorption spectrophotometry

Table 4.--Continued.

Constituent	Method
Sulfate, dissolved	Thorin titration
Turbidity	Nephelometric
Vanadium, dissolved	Catalytic oxidation-colorimetric
Zinc, dissolved	Atomic-absorption spectrophotometry

Table 5.--Chemical analyses of water samples from test wells. Constituents in milligrams per litre, except where noted.

Constituent	Test Well 1 (Sampled December 20, 1973)			Test Well 2 (Sampled January 14, 1974)		
	10:25 am	1:25 pm	5:25 pm	12:55 pm	3:55 pm	6:55 pm
Time						
Alkalinity as CaCO ₃ , total	292	290	290	328	324	323
*Aluminum, dissolved	20	20	60	70	60	50
*Arsenic, dissolved	0	0	2	0	0	0
Bicarbonate	356	353	353	355	367	370
*Boron, dissolved	--	2,500	2,200	650	500	600
*Cadmium, dissolved	4	5	4	3	3	0
Calcium, dissolved	46	67	53	5.0	5.0	5.0
Carbon, organic total	24	39	--	5.0	2.0	2.0
Carbon dioxide	9.0	7.1	9.0	0.8	1.0	1.3
Carbonate	0	0	0	22	14	12
Chemical oxygen demand	152	93	--	54	12	12
Chloride, dissolved	3,200	3,300	3,200	310	310	330
*Chromium, dissolved	0	0	0	1	0	0
*Chromium, hexavalent	0	5	5	0	0	0
*Cobalt, dissolved	3	3	3	1	1	1
Color (platinum cobalt scale)	5	5	7	5	10	8
*Copper, dissolved	4	4	4	0	0	1
Density at 20°C	1.006	1.005	--	1.002	1.000	1.002
Dissolved solids, calculated sum	5,760	5,720	5,600	892	902	904
Dissolved solids, residue at 180°C	5,620	5,670	5,690	868	872	870
Fluoride, dissolved	3.3	2.9	2.4	3.0	2.0	3.0
Hardness as CaCO ₃ (Ca, Mg)	140	450	380	19	21	21
Hardness, noncarbonate as CaCO ₃	0	160	90	0	0	0
*Iron, dissolved	1,600	1,400	1,400	50	100	100
*Lead, dissolved	5	24	3	8	5	0
*Lithium, dissolved	190	190	190	0	0	0
Magnesium, dissolved	5.1	69	60	1.7	2.0	2.0
*Manganese, dissolved	14	14	29	17	17	17
*Mercury, dissolved	0.4	0.0	0.5	0.0	0.0	0.0
*Molybdenum, dissolved	1	0	1	0	0	0
*Nickel, dissolved	3	0	0	3	0	0
Nitrate, NO ₃ as N	.00	.00	--	.00	.00	.00
Nitrite, NO ₂ as N	.00	.00	--	.00	.01	.01
Nitrogen, NH ₃ as N	3.5	3.5	--	3.5	.74	.74
Nitrogen, total organic as N	.25	.05	--	.25	.40	.30
Nitrogen, total as N	3.7	3.5	--	3.7	1.1	1.0
pH	7.8	7.9	7.8	8.9	8.8	8.7
Phosphorus, total ortho as P	.01	.01	--	.02	.03	.03
Phosphorus, total as P	.03	.03	--	.03	.04	.03
Potassium, dissolved	54	74	79	11	11	9.7
Silica, dissolved	23	23	23	33	33	34
Sodium, dissolved	2,200	2,000	2,000	320	330	320
Specific conductance (umhos at 25°C)	10,100	10,200	10,200	1,550	1,560	1,560
*Strontium, dissolved	10	10	10	0	0	0
Sulfate, dissolved	50	8.9	9.4	10	13	5.4
Turbidity	15	15	--	15	10	8
*Vanadium, dissolved	85	85	54	4.0	3.0	2.0
Water temperature (°C)	32.2	33.0	33.0	29.5	29.5	30.0
*Zinc, dissolved	10	40	7	5	10	10

*Micrograms per litre

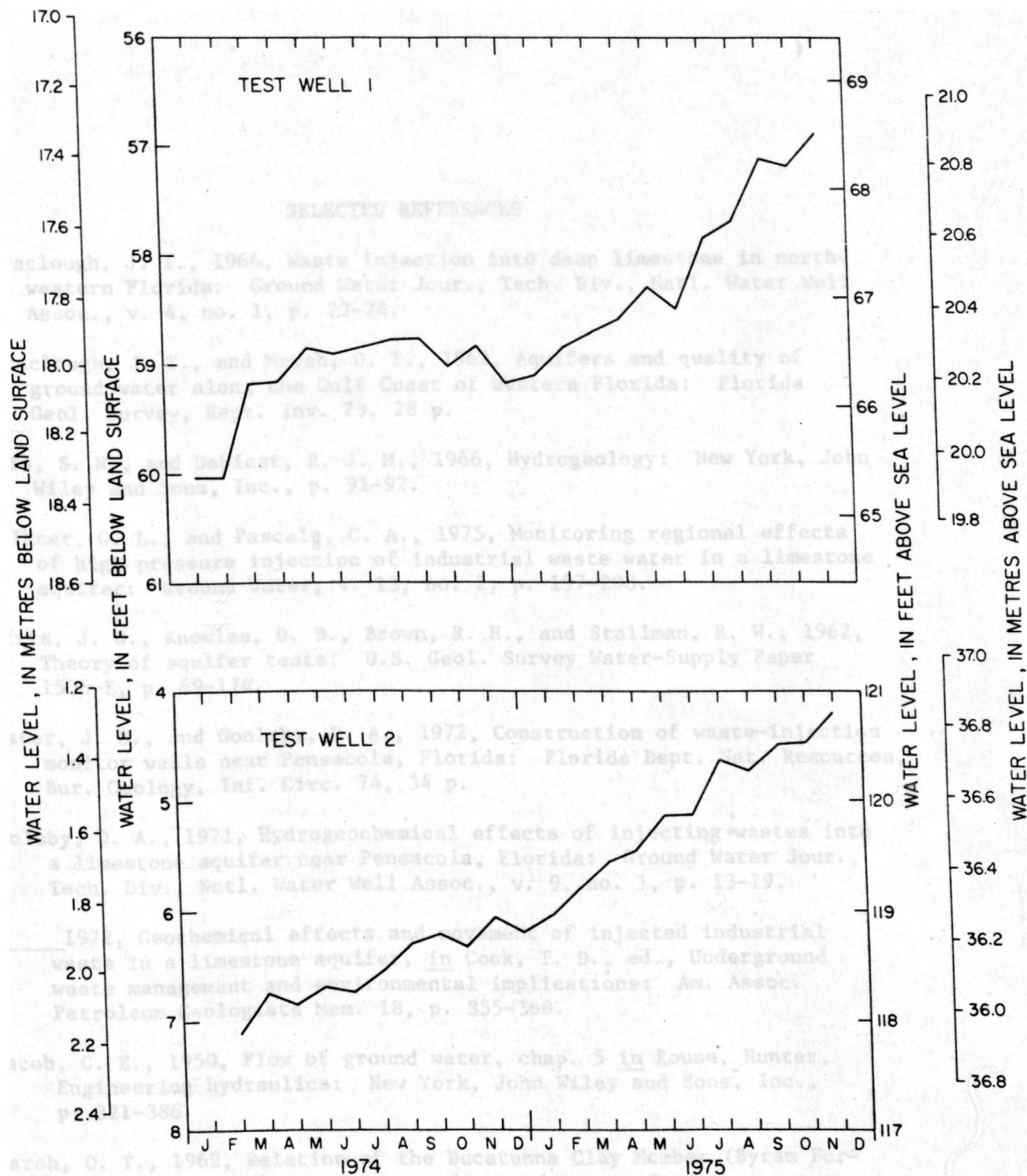


Figure 16.--Hydrographs of water levels in test well 1 and test well 2.

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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
325 John Knox Rd--Suite F240
Tallahassee, Florida 32303

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