EFFECTS OF HYDRAULIC BOREHOLE MINING ON GROUND WATER AT A TEST SITE IN NORTHEAST ST. JOHNS COUNTY, FLORIDA

By Paul S. Hampson

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CONVERSION FACTORS

For those readers who may prefer to use International System of Units (SI) rather than inch-pound units, the conversion factors for terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	0.00006309	cubic meter per second (m^3/s)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

An experimental mining project was conducted in northeast St. Johns County, Florida, to determine the feasibility of extracting deeply buried phosphate ore by hydraulic borehole mining techniques. The phosphate zone is 18 feet thick, between 232 and 250 feet below land surface, and consists of approximately equal proportions of fine-grained phosphate, sand, and clay.

Six wells were constructed at the test site to monitor the effects of the mining operation on the ground-water resources of the area. One well penetrated the Floridan aquifer beneath the phosphate zone, another was completed in the phosphate zone, and the other four were finished in water-bearing zones above the phosphate zone. The mining project consisted of three separate tests during which different mining methods were used.

Changes in water levels, other than in the mined zone, were detected only in the overlying monitored zone. These changes occurred in the water-bearing zone immediately above the phosphate zone during the first two tests and were caused by roof failures in the cavities formed by the mining operation. Water-quality changes were observed only in the mined zone and were a natural consequence of the injection of water from the deeper Floridan aquifer as part of the mining operation.

INTRODUCTION

From April 17 to August 30, 1980, an experimental mining project was conducted in northeast St. Johns County, Florida, by Agrico Mining Company (fig. 1). The U.S. Geological Survey, in cooperation with the U.S. Bureau of Mines, assisted in evaluating the effects of the mining project on the ground-water resources. The project utilized hydraulic borehole mining equipment and techniques developed by the U.S. Bureau of Mines. In the past, hydraulic borehole mining has been used for the extraction of coal, uranium, and oil sand that could not be mined feasibly using conventional methods (U.S. Bureau of Mines, 1978). The purpose of the project was to develop and test hydraulic borehole methods for the extraction of deeply buried phosphate ore and to study the economic feasibility and environmental impact of such an operation. The phosphate ore was contained in a zone 18 feet thick located between 232 and 250 feet below land surface.

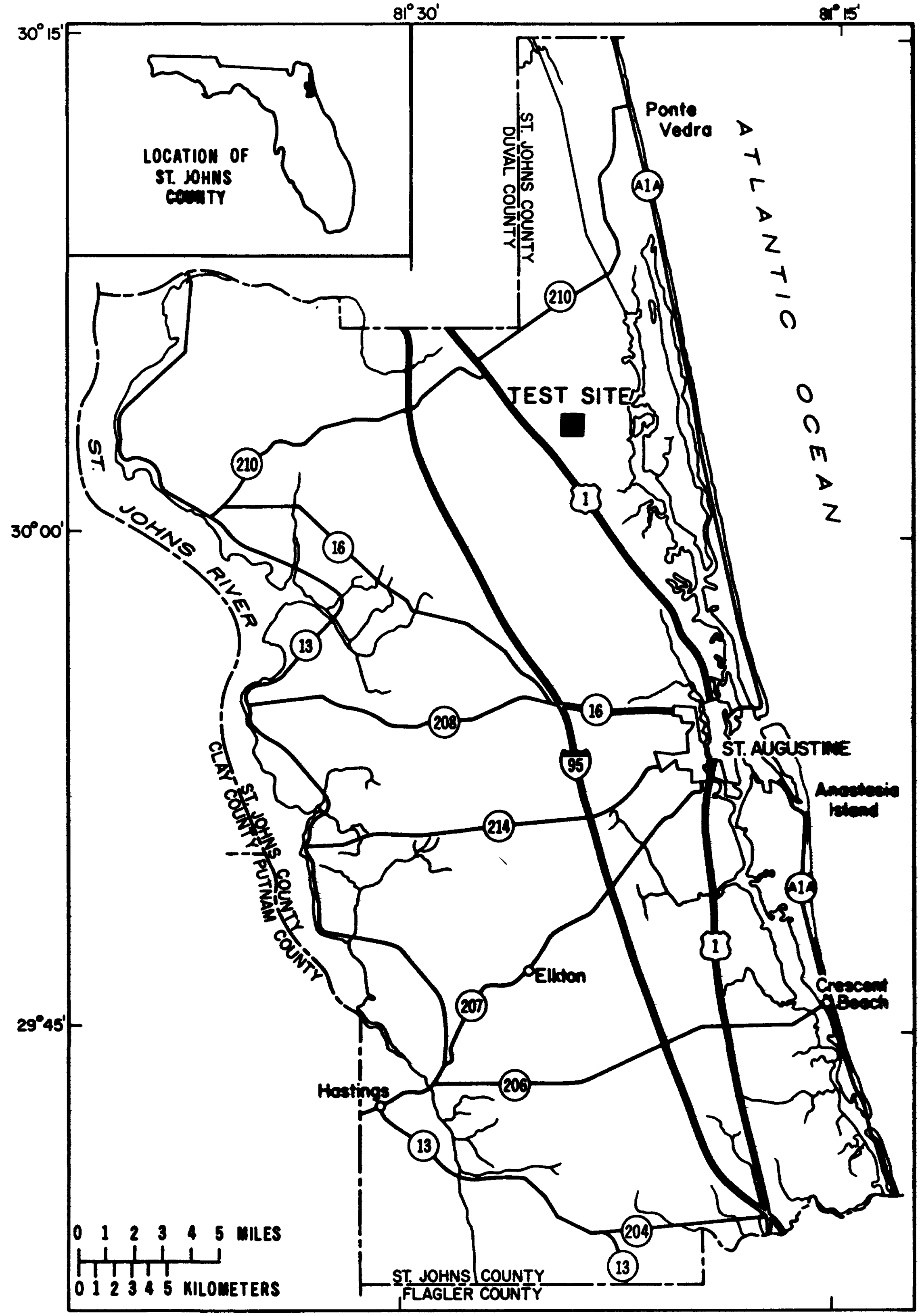

Figure 1.--Location of St. Johns County and the test site.

The U.S. Geological Survey, in cooperation with the U.S. Bureau of Mines, designed and implemented a hydrologic data collection network to monitor the effects of the mining operation on the ground-water resources of the area.

Purpose and Scope

The purpose of this report is to present hydrologic data collected during the hydraulic borehole mining operation and briefly discuss the effects of the mining on ground water. Data are presented in tables and illustrations showing the hydrogeology of the test site, well construction diagrams, gamma ray logs, water-level hydrographs, and chemical analyses of water from wells and ponds at the site.

Six monitor wells were constructed at various depths above, in, and below the phosphate zone. Water-level measurements and water-quality samples were collected before, during, and after the mining operation. Continuous pressure recorders were installed to monitor the water levels in the Floridan aquifer below the phosphate zone and in the zone immediately above the phosphate zone.

Acknowledgments

The author expresses his appreciation to George A. Savanick of the U.S. Bureau of Mines and C. K. Brown of Agrico Mining Company for their suggestions and help during the study. The author also thanks Richard Johnson of the St. Johns River Water Management District for furnishing the gamma radiation logging equipment and for logging the monitor wells.

Hydraulic Borehole Mining Technique

The hydraulic borehole mining procedure is the remote extraction of ore through a single borehole. A large diameter borehole is drilled through the ore deposit and 16-inch casing cemented from land surface to the top of the deposit. The mining tool is then inserted into the borehole and high pressure water jets are used to cut and slurry the ore, thus creating a cavity. The slurry is drawn into an eductor pump near the bottom of the mining tool and is pumped out into holding ponds at the surface. The eduction rate can be varied to create either an air or a water environment in the cavity. If the eduction rate greatly exceeds the injection rate and the water yield of the formation being mined, the formation can be dewatered, creating an air pocket in the cavity. This is usually desirable because the water jets can cover a greater distance in air than through water. If the eduction and injection rates are balanced, hydrostatic pressure is maintained and the cavity remains filled with water.

The mining tool consists of a mining section about 5 feet in length which is connected to a string of 12-inch diameter pipe. A single cutting nozzle is located near the top of the mining section and four slurry pump intake ports are near the bottom. The tool and pipe are connected to a rotatable kelly at the surface which allows the cutting nozzle to rotate 360 degrees, and to a crane which allows the tool to be raised and lowered.

After being brought to the surface, the ore is allowed to settle to the bottom of a holding pond and the clarified water is drained into a second holding pond for reuse in the mining operation. In this mining operation, water from a well tapping the Floridan aquifer supplied the initial and replacement demand for water. The generalized configuration of the test site including the locations of the wells and slurry ponds is shown in figure 2. More detailed information on well locations relative to each other is shown in figure 3.

GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

A detailed discussion of the hydrogeology of St. Johns County can be found in Bermes and others (1963). A summary of the principal hydrogeologic units of concern to the mining operation is given in table 1.

Deposits of Holocene and Pleistocene age comprise the surficial aquifer in St. Johns County. This aquifer consist primarily of interbedded lenses of sand, shell, and clay, and may yield as much as 40 gal/min from 2-inch wells. In general, water in the surficial aquifer is unconfined but semiconfined conditions occur in some areas.

The Hawthorn Formation of Miocene age underlies the surficial aquifer and consists of phosphatic sandy clay and marl interbedded with lenses of phosphorite pebbles, phosphatic sand, and phosphatic sandy limestone. The sand and limestone lenses of the Hawthorn Formation may also yield as much as 40 gal/min from 2-inch wells. These water-bearing lenses in the Hawthorn Formation are confined and under artesian pressure. The clays and marls of the Hawthorn Formation separate the surficial aquifer from the deeper Floridan aquifer and confine the water in the Floridan aquifer under artesian pressure.

The Ocala Limestone, the uppermost unit of the Floridan aquifer at the test site, is the principal source of ground water in most of northeast Florida and is the deepest geologic unit penetrated by wells at the test site. It consists of chalky, granular limestone and generally yields hundreds of gallons of water per minute.

Figure 4 shows the generalized hydrogeology of the test site and the water-bearing zones that were monitored. The lithology and gamma radiation log of well B1, the deepest well constructed at the site, is shown in figure 5. Figure 6 shows the gamma radiation logs of the other monitor wells.

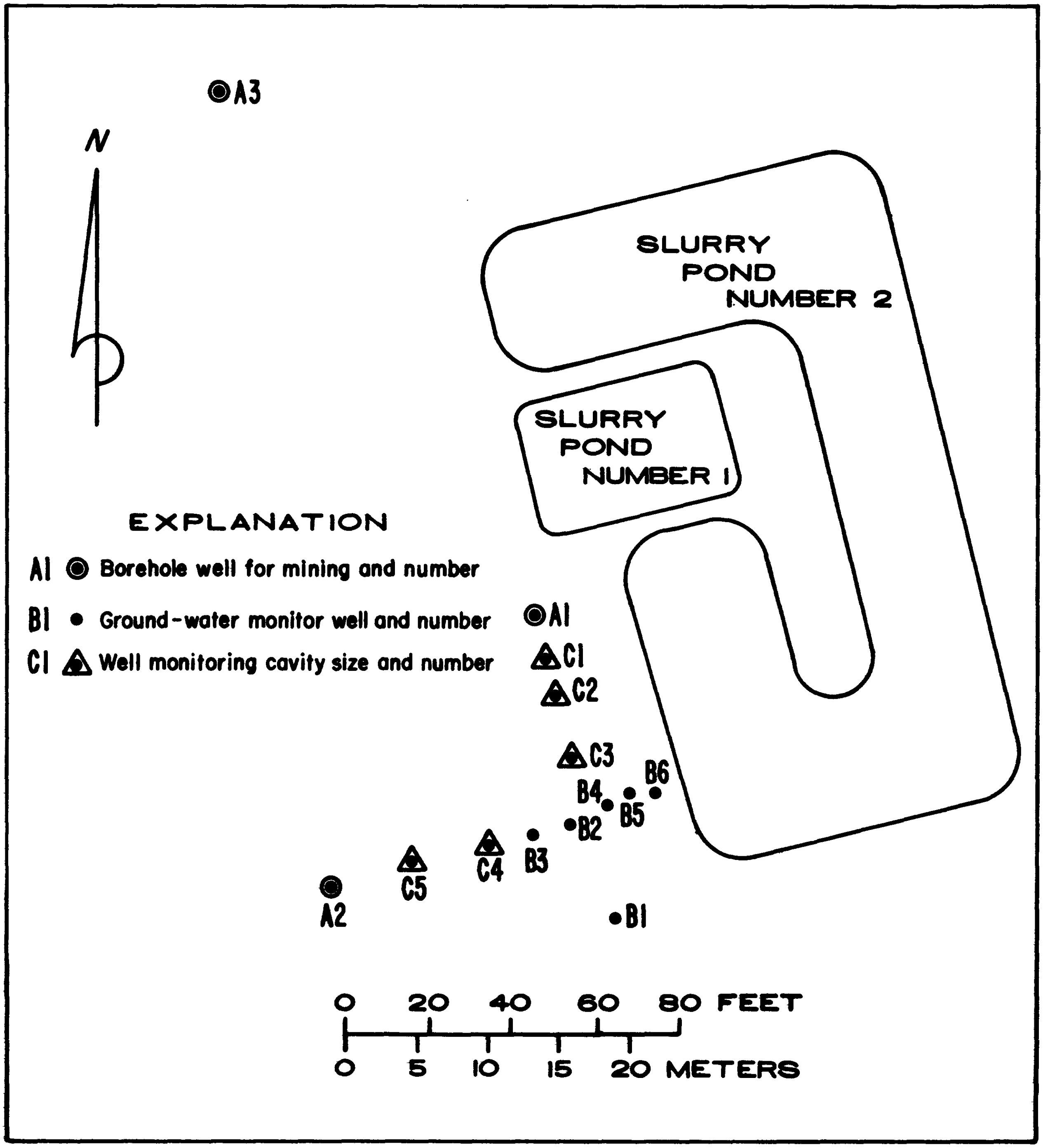

Figure 2.--Generalized configuration of the test site.

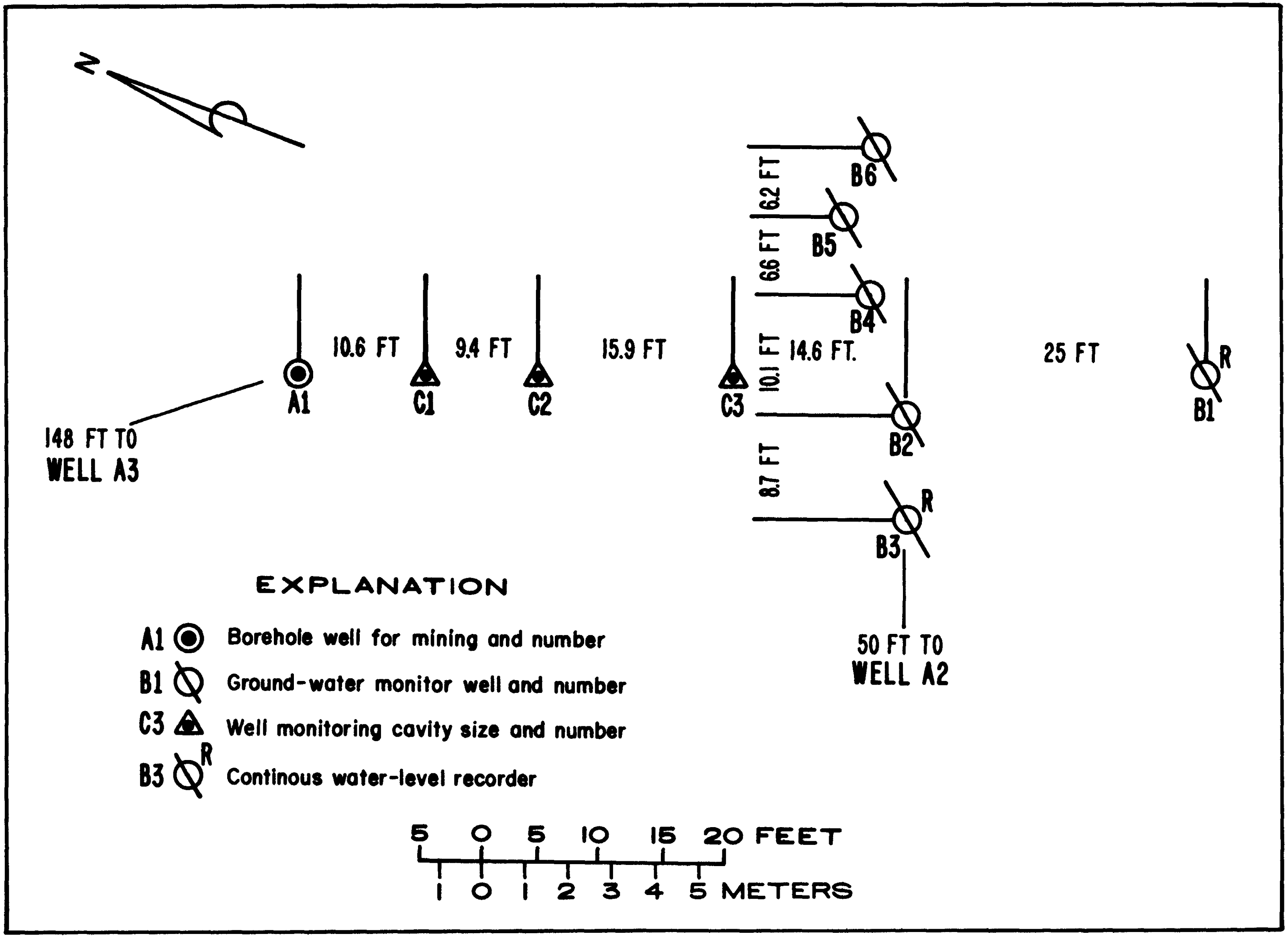

Figure 3.--Monitor well locations relative to borehole well A1.

Table 1.--Stratigraphic and hydrogeologic units of St. Johns County

[Modified from Bermes and others, 1963, table 2]

Geologic age		Stratigraphic unit	Thickness (ft)	Hydrogeologic unit
Period	Epoch			
Quaternary	Holocene and Pleistocene	Surficial deposits	20-120	Surficial aquifer
Tertiary	Miocene	Hawthorn Formation	50-115	Confining unit
	Late Eocene	Ocala Limestone	120-200	Upper part of the Floridan aquifer

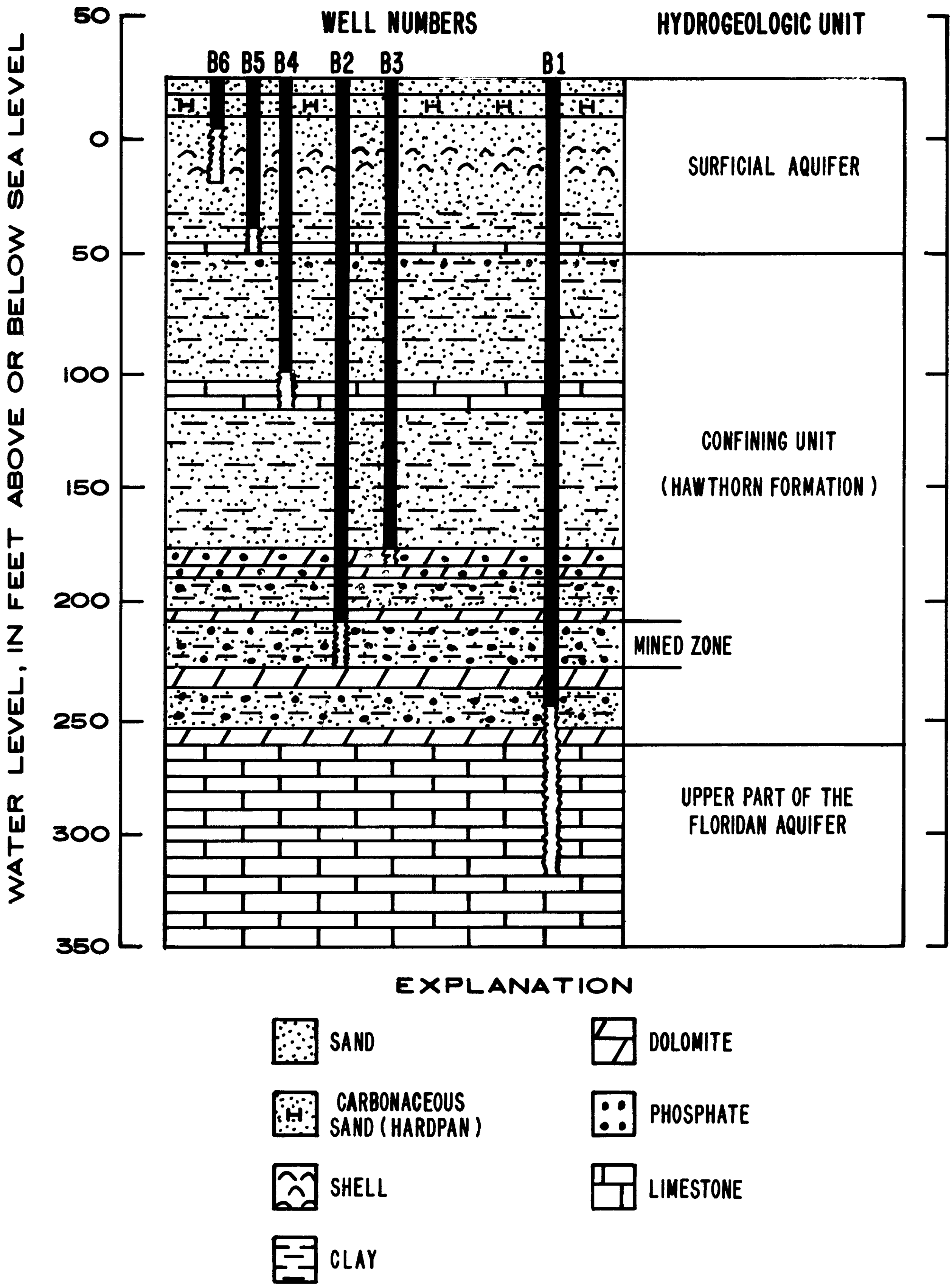

Figure 4.--Generalized columnar section showing the monitored zones and hydrogeologic units.

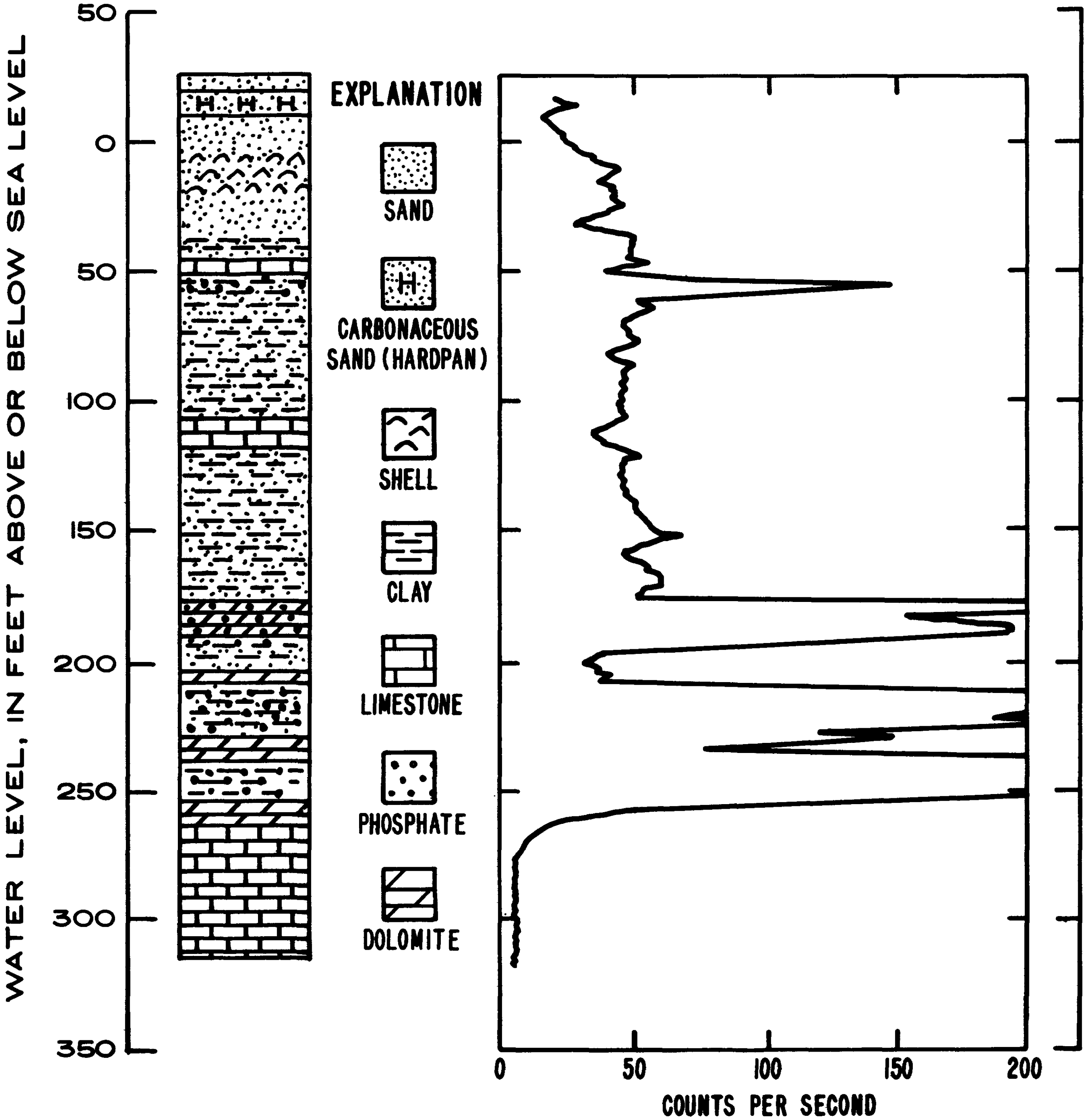

Figure 5.--Columnar geologic section and gamma ray log of well B1.

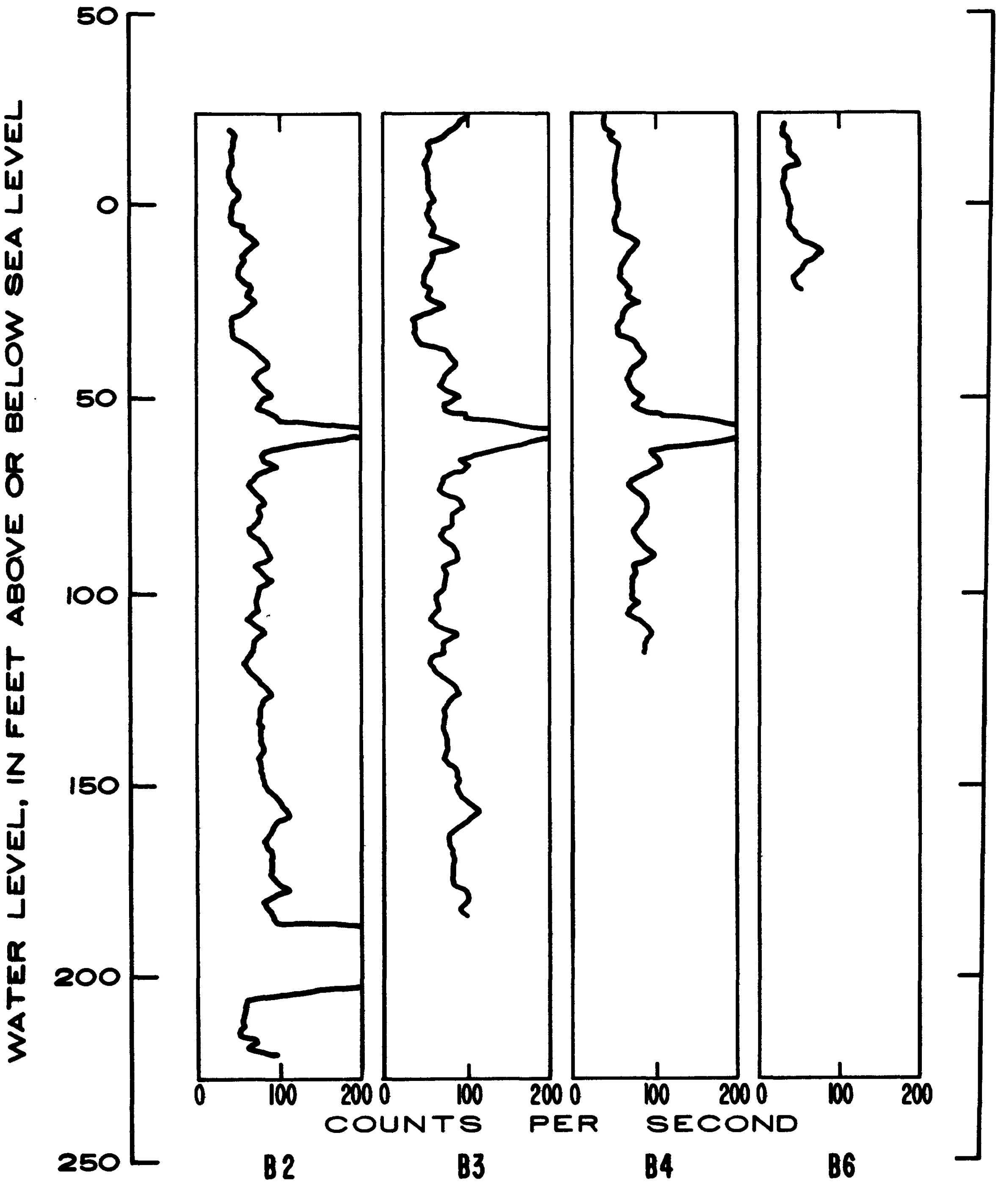

Figure 6.--Natural gamma ray logs of wells B2, B3, B4, and B6.

Table 2 presents well construction information, well functions, and the approximate yields of the monitoring wells. Three types of wells were constructed: (1) borehole wells for ore extraction numbered with the letter A, (2) monitoring wells for water-level measurement and water-quality sampling numbered with the letter B, and (3) wells drilled to monitor cavity size as the operation progressed numbered with the letter C.

HYDROLOGIC DATA

Water-Level Fluctuations

Three successive mining tests were performed at the site, each utilizing a different borehole well and modified mining techniques. During the respective tests, mining was conducted Monday through Friday, usually between the hours of 9 a.m. and 4 p.m.

The first test began on April 17, 1980, and was performed in borehole A1 (fig. 2). During the first week of operation, eduction and injection rates were held about equal at approximately 800 gpm to maintain hydrostatic pressure in the cavity, the entire 18-foot mined zone between 232 and 250 feet below land surface was mined, and the mining tool was rotated through a full 360-degree arc to form an approximately circular cavity. The final cavity extended beyond well C1, but not as far as well C2 (see fig. 3 for distances). On April 28, 1980, the eduction rate was increased to about 1,100 gpm in an attempt to dewater the cavity and test the effectiveness of the cutting jet in an air environment. This operation was discontinued following a sudden drop in the water level at well B3, which monitored the zone immediately above the mined zone. Figure 7 shows the hydrograph of well B3 during the mining operation and the water-level decline of April 28. Figure 8 shows the water-level decline during the period of heavy pumping in more detail and the recovery after mining ceased. This drop in water level was accompanied by a large increase in water inflow to the cavity that exceeded the capacity of the eduction pumps. In addition, the composition of the extracted material changed to more closely resemble material present in the zone monitored by well B3. This indicated that the dewatering operation had caused failure of the dolomitic roof of the cavity allowing the overlying material to enter and hydraulically connecting the two zones. Also at this time, wells B2 and C3 became plugged with material similar to that found in the ore body between 232 and 250 feet below land surface. Well B2 was plugged to a depth of 32 feet below land surface and well C3 was plugged to 65 feet below land surface. Well C3 was cleared by additional pumpage from the cavity; however, well B2 was not reopened until October 1980.

The second test began on July 14, 1980, in borehole well A2 (fig. 2). Because of the failure of the first test, a new mining technique was used. In this test, the cavity was dewatered; however, the mining tool was rotated only through a 30-degree arc in the general direction of well B3 and only the upper 5 feet of the mining zone was extracted. This test was discontinued on July 17, following a water-level decline in well B3 similar to that which occurred during the first test. Figure 9 shows the water-level fluctuations in well B3 during the second test and the water-level decline of July 17. As in the first test, inflow to the cavity increased and a change in the composition of the extracted material was observed indicating roof failure in the cavity. Following this operation, the water level in well B3 never fully recovered until the well was reopened in October 1980.

Table 2.--Well construction, function, and approximate yields

Well No.	Casing	Total depth (ft)	Casing depth (ft)	Screen	Function	Approximate yield (gal/min)
A1	16-in. dia. steel.	253	231	None	Mining	Not applicable.
A2	16-in. dia. steel.	251	229	do.	do.	Do.
A3	16-in. dia. steel.	250	230	do.	do.	Do.
C1	3-in. dia. PVC.	251	231	do.	Cavity size monitor.	Do.
C2	3-in. dia. PVC.	251	231	do.	do.	Do.
C3	3-in. dia. PVC.	251	231	do.	do.	Do.
C4	3-in. dia. steel.	251	230	do.	do.	Do.
C5	3-in. dia. steel.	250	230	do.	do.	Do.
B1	256 ft, 4-in. 9 ft, 3-in. dia. steel.	341	265	do.	Ground-water monitor.	150 gal/min by natural flow.
B2	3-in. dia. PVC.	251	231	do.	do.	Flows less than 1 gal/min.[1/]
B3	3-in. dia. PVC.	209	202	do.	do.	Flows less than 5 gal/min.
B4	2-in. dia. steel.	147	126	do.	do.	10 gal/min.
B5	2-in. dia. steel.	73	63	8 ft,. 1.25-in. PVC.	do.	5 gal/min.
B6	2-in. dia. steel.	45	21	None	Ground-water monitor	5 gal/min.

[1/] Well partially plugged from time drilled. Did not flow until cleared in October, 1980.

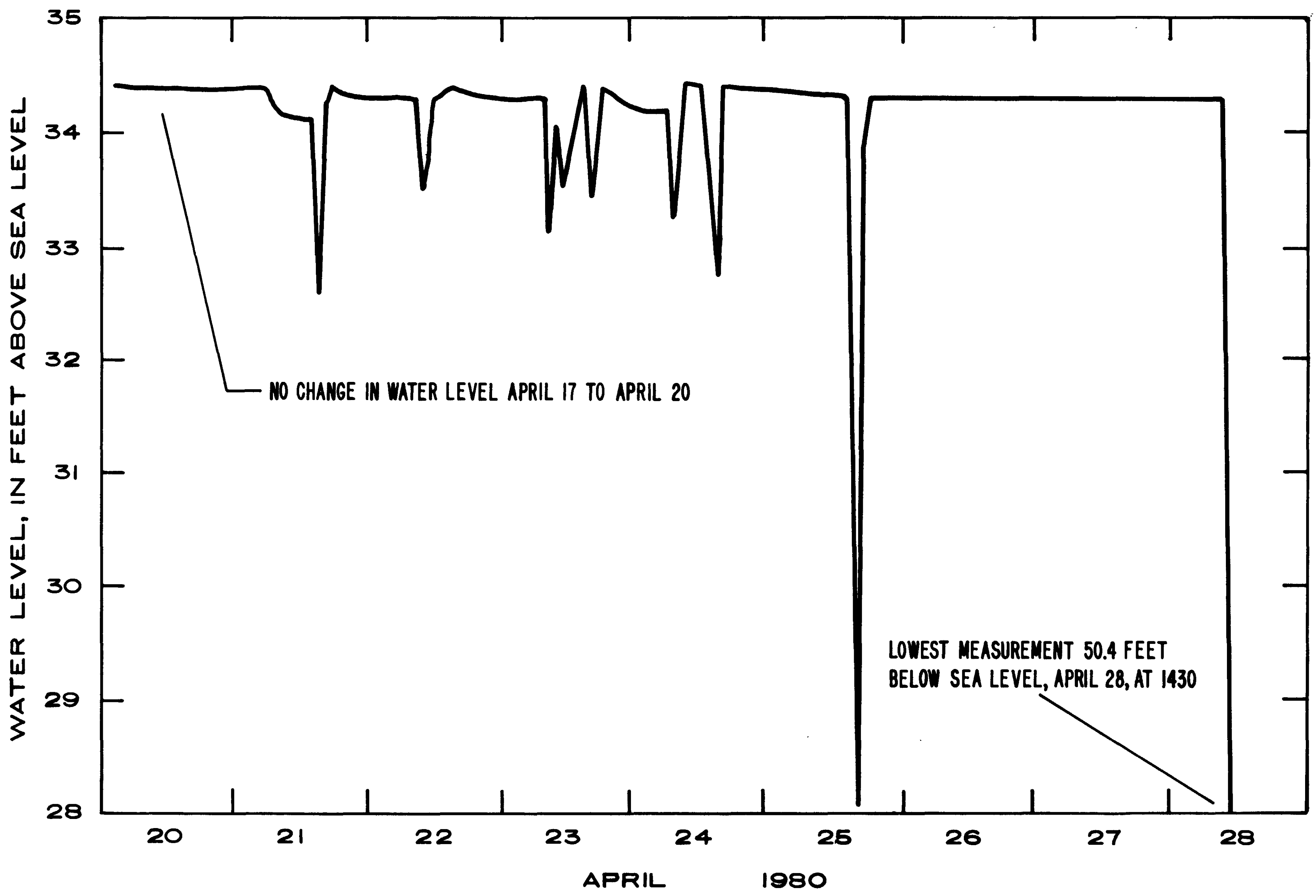

Figure 7.--Water-level fluctuations in well B3 during first mining test.

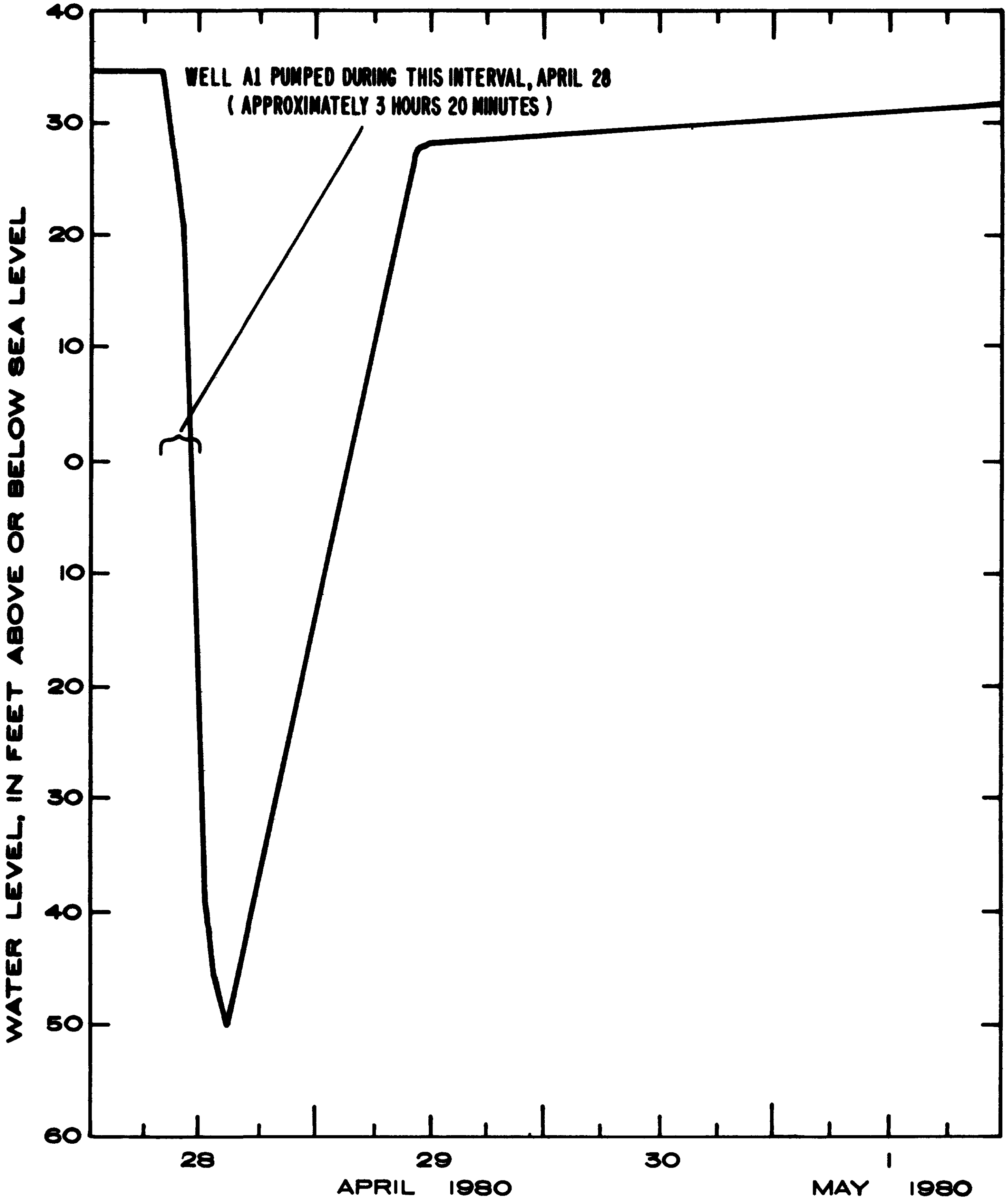

Figure 8.--Water-level fluctuations in well B3 during first mining test.

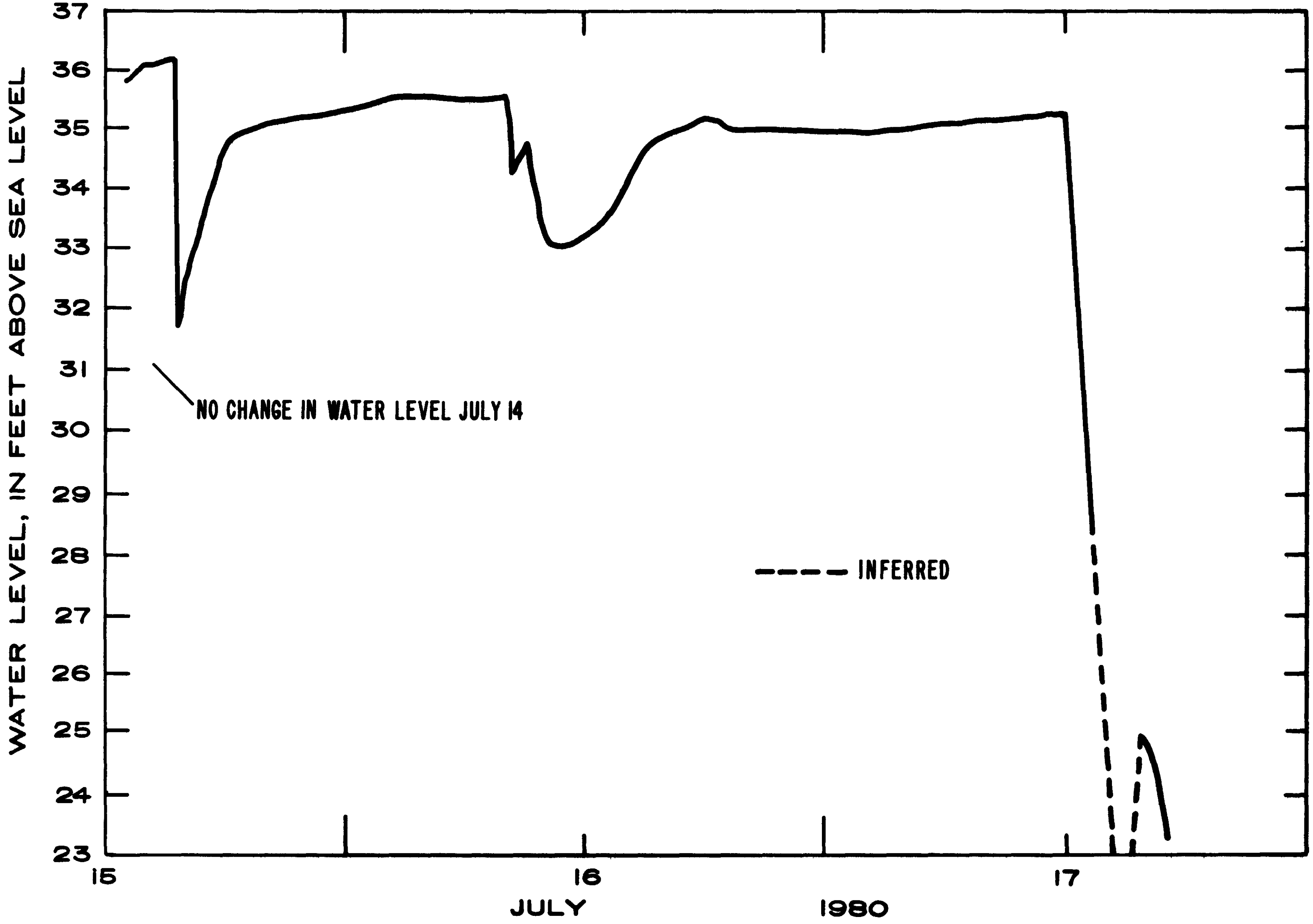

Figure 9.--Water-level fluctuations in well B3 during second mining test.

The third test was performed in borehole well A3 (fig. 2) from August 27 through August 30, 1980. Because of the failure of the two previous tests, no attempt was made to dewater the cavity in this test. The mining tool was rotated 360 degrees to form a circular cavity and a modified injection technique was used to increase the effectiveness of the cutting jet while submerged. The final radius of the cavity was estimated to be 20 feet. Water levels in well B3 were not continuously recorded during this test because of being plugged during the second test. However, no large increase in inflow to the cavity or change in extracted material composition was observed.

From October 16 through October 23, 1980, the three boreholes were backfilled and sealed. During this time, the collapsed and plugged monitor wells (wells B2 and B3) were reopened for further observation.

During the first two tests, large and sudden water-level fluctuations were observed only in well B3, completed in the zone immediately above the mining zone, and in wells monitoring the mining zone. Figure 10 shows the hydrograph of well B3 before and during the first and second tests. Water-level changes resulting from the dewatering operations were observed in the mining zone; however, because of the low permeability of the material in this zone and the sporadic nature of the dewatering operations, it was not possible to obtain meaningful measurements.

Figure 11 shows the hydrographs of wells B4, B5, and B6, which monitored other zones above the mining zone, and rainfall at the Big Davis Creek station near Bayard, approximately 6 miles northwest of the test site. These hydrographs show a general water-level decline which is probably because of reduced rainfall during the monitoring period. Water levels in these wells were not noticeably affected by the short periods of mining.

Figure 12 shows hydrographs of well B1, which monitored the Floridan aquifer at the test site, and the Meadowbrick well, which monitors the Floridan aquifer in southern St. Johns County about 40 miles distant. The hydrographs show a fairly sharp decline in water levels from late March to early May. This is considered to be the usual seasonal decline reported by Bermes and others (1963) that occurs during April and May. The hydrograph of well B1 shows no noticeable water-level variations resulting from the short periods of mining.

Water-Quality Analyses

Chemical analyses of water collected from wells and slurry pond 2 at the test site are given in tables 3 through 10. Samples from wells were collected 2 months prior to mining, at approximately biweekly intervals during mining, and 2 months after mining had stopped. The samples were analyzed for total hardness, calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, and silica. Determination of alkalinity, strontium, uranium, and radium-226 were also performed on selected samples.

Table 3 shows the analytical results for water collected from well B1 which monitored the Floridan aquifer at the test site. All variations in the data are within the range of analytical and sampling error. No water-quality changes which may have resulted from the mining activity are indicated by the data.

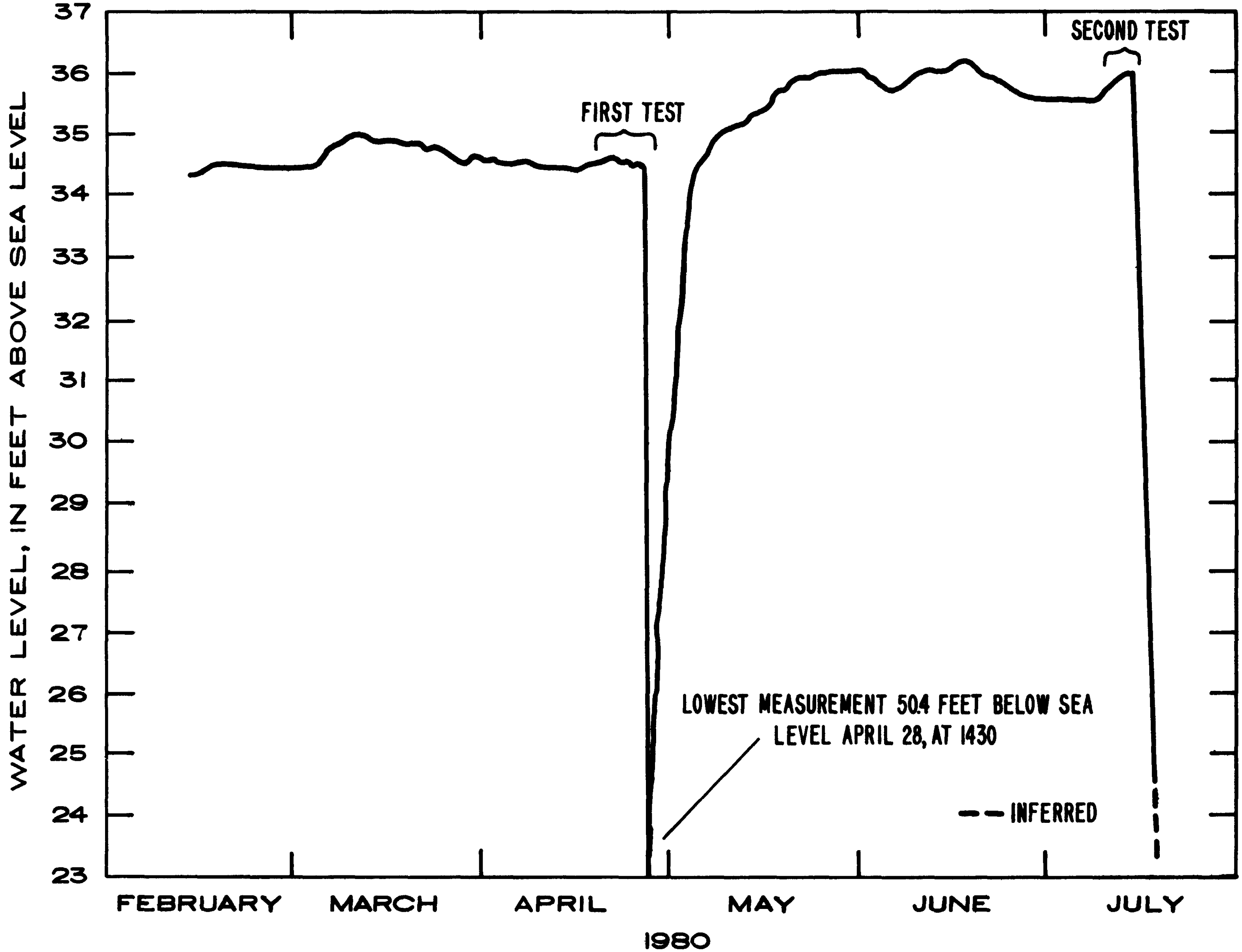

Figure 10.--Water-level fluctuations in well B3 during the first and second mining tests.

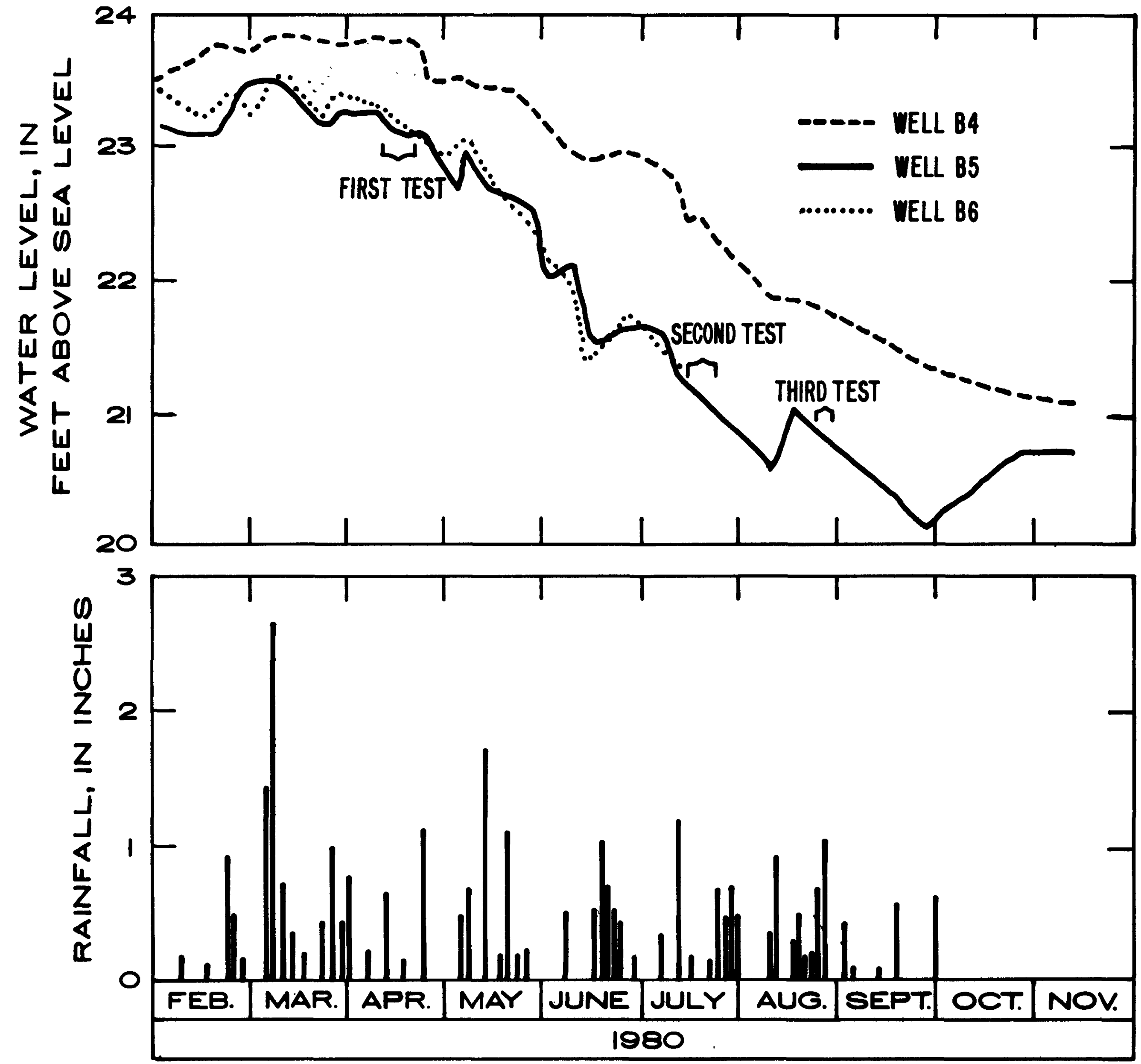

Figure 11.--Water-level fluctuations in wells B4, B5, and B6 and daily rainfall at Big Davis Creek near Bayard.

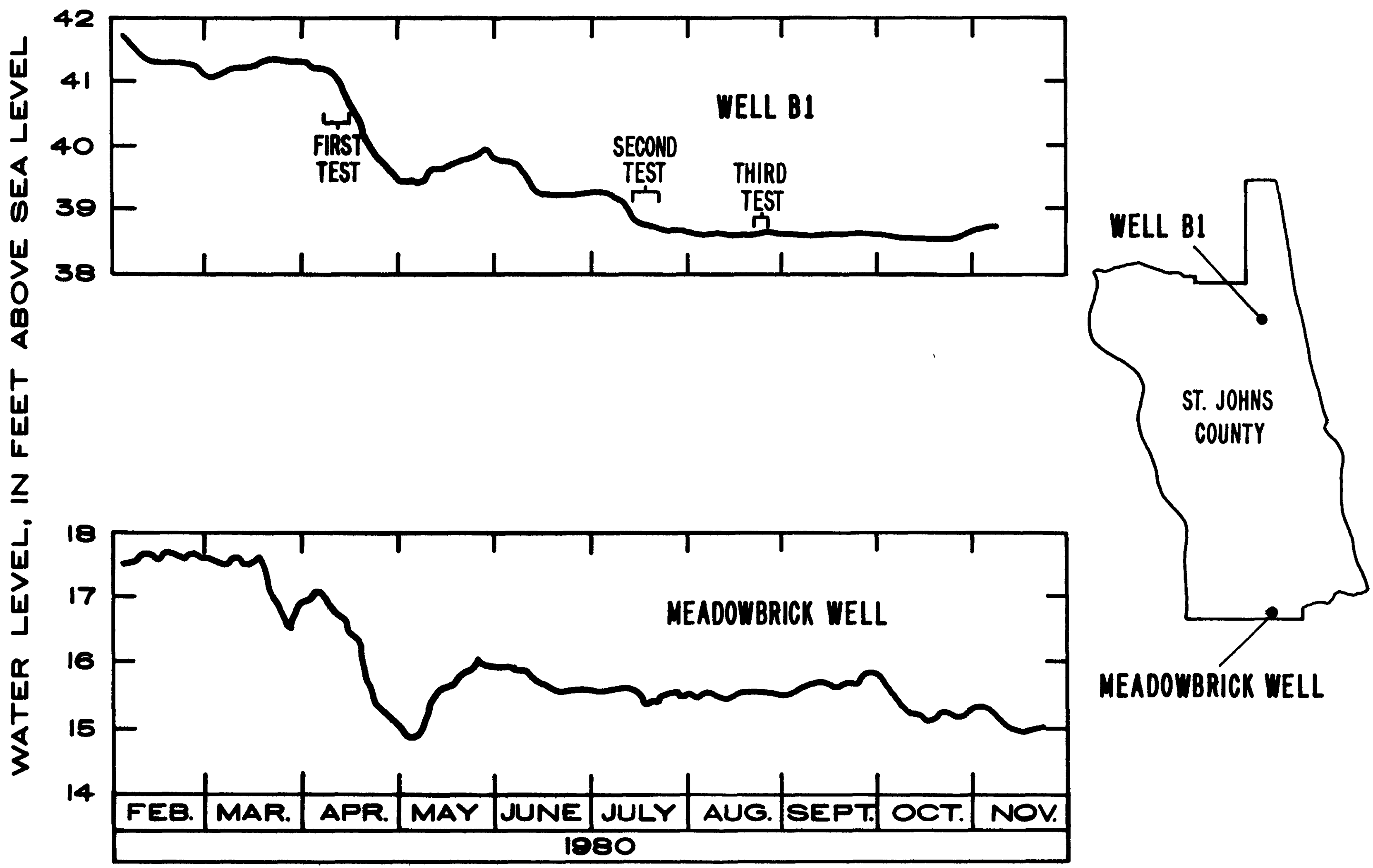

Figure 12.--Water-level fluctuations in well B1 and Meadowbrick in St. Johns County.

Table 3.--Chemical analyses of water from well B1 in St. Johns County

[Total depth of well is 341 feet; mg/L, milligrams per liter; ug/L, micrograms per liter; pCi/L, picocuries per liter]

DATE OF ANALYSIS	PH	ALKA-LINITY FIELD (mg/L as CaCO3)	HARD-NESS (mg/L as CaCO3)	CALCIUM DIS-SOLVED (mg/L as Ca)	MAGNE-SIUM, DIS-SOLVED (mg/L as Mg)	SODIUM, DIS-SOLVED (mg/L as Na)	POTAS-SIUM, DIS-SOLVED (mg/L as K)
FEB, 1980							
12...	-----	150	320	75	31	55	3.6
APR							
23...	6.6	150	330	76	35	62	3.6
MAY							
12...	-----	---	310	71	32	61	2.5
30...	5.8	---	310	70	32	61	2.7
JUNE							
11...	7.3	---	320	72	33	63	2.9
27...	7.7	---	330	75	34	64	2.9
JULY							
11...	7.3	---	320	71	34	67	3.1
27...	-----	---	330	75	34	64	2.9
NOV							
10...	-----	140	310	69	32	61	3.0

DATE OF ANALYSIS	CHLO-RIDE, DIS-SOLVED (mg/L as Cl)	SULFATE DIS-SOLVED (mg/L as SO4)	FLUO-RIDE, DIS-SOLVED (mg/L as F)	SILICA, DIS-SOLVED (mg/L as SiO2)	STRON-TIUM, DIS-SOLVED (ug/L as Sr)	RADIUM 226, DIS-SOLVED, RADON METHOD (pCi/L)	URANIUM NATURAL TOTAL (ug/L as U)
FEB, 1980							
12...	110	160	.9	27	3000	.02	.46
APR							
23...	110	160	1.0	28	----	---	---
MAY							
12...	-----	170	.9	26	----	---	---
30...	110	160	1.0	26	----	---	---
JUNE							
11...	110	160	.9	26	----	---	---
27...	120	150	.9	27	----	---	---
JULY							
11...	110	170	.9	27	----	---	---
27...	120	160	.9	27	----	---	---
NOV							
10...	110	160	1.0	27	2900	.05	.58

Table 4 shows the analytical results for water collected from the mined zone before and after the mining operation. It was necessary to sample two different wells tapping this zone. The first analysis shown, dated February 2, 1980, is of water from well C1 (see fig. 2) before mining began and represents the original formation water. Because of insufficient yield, it was not possible to sample well B2, as originally intended, until the well was cleared with drilling equipment in October 1980. Well C1 was plugged when the cavity formed by mining through borehole well A1 was backfilled in October 1980 and was not available for sampling after the mining had ended. The second analysis shown, dated November 10, 1980, is of water collected from well B2 after the well had been cleared following the mining operations. This well was located approximately 50 feet from borehole well A1 and 40 feet from well C1 (see fig. 3). If the quality of the original formation water was uniform between wells C1 and B2 before the mining operation, the data indicate that the water quality in the mined zone at well B2 was not affected by the mining operation. Water-quality changes were localized near the borehole because the mined zone had a low permeability and the water used for mining was withdrawn at about the same or a greater rate than it was injected. Consequently, very little mining water migrated into the mined zone during the test.

Table 5 shows analytical results for water samples collected from well C1 from May 12 through July 27, 1980. Well C1 was directly connected to the cavity formed by the mining of borehole well A1. The changes in chloride concentration shown in table 5 were the result of mixing original formation water with water injected for mining. The injected water was taken from slurry pond 2 (fig. 2) which was initially filled with water from well B1 that tapped the Floridan aquifer. Water from well B1 was also used periodically to replace evaporation losses. An analysis of water collected near the reinjection pump intake in pond 2 during the operation is given in table 6. At the time of collection, this water was a mixture of water from the Floridan aquifer which was used to fill the pond initially and the original formation water in the mining zone.

Tables 7, 8, 9, and 10 show analytical results for water samples collected from wells B3, B4, B5, and B6, respectively. These data indicate that the quality of water in the monitored zones was not affected by mining activity.

SUMMARY AND CONCLUSIONS

Only two of the zones monitored during the three tests showed some effects of the mining operation. They were the mined zone between 232 and 250 feet below land surface and the zone immediately above. Water-level changes were observed in the mined zone during dewatering operations; however, it was not possible to obtain accurate measurements because of the relative impermeability of the zone and the sporadic nature of the operations. Water-quality variations were observed in the mined zone near the cavity formed by the first mining test. These variations were the natural consequence of mixing injected water with the original formation water as part of the mining process. The water quality in a well that tapped this zone, approximately 50 feet from the cavity formed by this first test, was unaffected.

Table 4.--Chemical analyses of water from the mined zone in St. Johns County

[Total depth of wells is 251 feet; mg/L, milligrams per liter; ug/L, micrograms per liter; pCi/L, picocuries per liter]

WELL NO.	DATE OF ANALYSIS	PH	ALKALINITY FIELD (mg/L as CaCO3)	HARDNESS (mg/L as CaCO3)	CALCIUM DISSOLVED (mg/L as Ca)	MAGNESIUM, DISSOLVED (mg/L as Mg)	SODIUM, DISSOLVED (mg/L as Na)	POTASSIUM, DISSOLVED (mg/L as K)
C1	FEB, 1980 2...	--	130	250	54	27	54	6.8
B2	NOV 10...	--	140	230	50	26	61	6.5

WELL NO.	DATE OF ANALYSIS	CHLORIDE, DISSOLVED (mg/L as Cl)	SULFATE DISSOLVED (mg/L as SO4)	FLUORIDE, DISSOLVED (mg/L as F)	SILICA, DISSOLVED (mg/L as SiO2)	STRONTIUM, DISSOLVED (ug/L as Sr)	RADIUM 226, DISSOLVED, RADON METHOD (pCi/L)	URANIUM NATURAL TOTAL (ug/L as U)
C1	FEB, 1980 2...	38	150	1.2	48	2300	1.2	2.2
B2	NOV 10...	39	150	1.3	49	2300	0.3	3.1

Table 5.--Chemical analyses of water from well C1 in St. Johns County

[Total depth of well is 251 feet; mg/l, milligrams per liter]

DATE OF ANALYSIS	PH	HARDNESS (mg/L as CaCO3)	CALCIUM DISSOLVED (mg/L as Ca)	MAGNESIUM, DISSOLVED (mg/L as Mg)	SODIUM, DISSOLVED (mg/L as Na)	POTASSIUM, DISSOLVED (mg/L as K)	CHLORIDE, DISSOLVED (mg/L as Cl)	SULFATE DISSOLVED (mg/L as SO4)	FLUORIDE, DISSOLVED (mg/L as F)	SILICA, DISSOLVED (mg/L as SiO2)
MAY, 1980										
12...	---	260	56	29	53	6.4	54	170	1.3	45
29...	---	270	64	30	50	6.3	55	160	1.3	44
JUNE										
11...	7.3	280	60	31	52	6.5	54	170	1.2	43
27...	---	280	61	31	53	6.3	--	160	1.3	44
JULY										
11...	7.3	280	61	31	47	6.2	55	160	1.2	43
27...	---	280	61	32	53	6.3	--	160	1.3	44

Table 6.--Chemical analysis of water in pond 2, May 2, 1980

[Concentrations are in milligrams per liter]

Constituent	Concentration	Constituent	Concentration
Chloride, dissolved	93	Potassium, dissolved	6.6
Fluoride, dissolved	1.8	Sodium, dissolved	58
Hardness, total as CaCO3	290	Sulfate, dissolved	160
Magnesium, dissolved	33	Silica, dissolved	35
Calcium, dissolved	63		

Table 7.--Chemical analyses of water from well B3 in St. Johns County

[Total depth of well is 209 feet; mg/L, milligrams per liter; ug/L, micrograms per liter; pCi/L, picocuries per liter]

DATE OF ANALYSIS	PH	ALKALINITY FIELD (mg/L as CaCO3)	HARDNESS (mg/L as CaCO3)	CALCIUM DISSOLVED (mg/L as Ca)	MAGNESIUM, DISSOLVED (mg/L as Mg)	SODIUM, DISSOLVED (mg/L as Na)	POTASSIUM, DISSOLVED (mg/L as K)
MAY, 1980							
02...	---	---	160	32	20	50	9.0
12...	---	---	160	32	20	49	6.8
30...	---	---	170	33	21	51	---
JUNE							
11...	7.2	---	170	33	22	55	7.5
27...	---	---	180	33	22	56	7.2
JULY							
11...	7.4	---	170	33	21	49	7.3
27...	---	---	180	35	22	56	7.2
NOV							
10...	---	180	150	30	19	50	7.1

DATE OF ANALYSIS	CHLORIDE, DISSOLVED (mg/L as Cl)	SULFATE DISSOLVED (mg/L as SO4)	FLUORIDE, DISSOLVED (mg/L as F)	SILICA, DISSOLVED (mg/L as SiO2)	STRONTIUM, DISSOLVED (ug/L as Sr)	RADIUM 226, DISSOLVED, RADON METHOD (pCi/L)	URANIUM NATURAL TOTAL (ug/L as U)
MAY, 1980							
02...	25	51	1.8	63	----	.40	4.8
12...	26	54	1.7	62	----	---	---
30...	23	58	1.8	63	----	---	---
JUNE							
11...	24	61	1.7	64	----	---	---
27...	32	59	1.8	65	----	---	---
JULY							
11...	24	62	1.7	63	----	---	---
27...	32	59	1.8	66	----	---	---
NOV							
10...	33	61	1.8	63	1200	.03	4.3

Table 8.--Chemical analyses of water from well B4 in St. Johns County

[Total depth of well is 147 feet; mg/L, milligrams per liter; ug/L, micrograms per liter; pCi/L, picocuries per liter]

DATE OF ANALYSIS	PH	ALKALINITY FIELD (mg/L as CaCO3)	HARDNESS (mg/L as CaCO3)	CALCIUM DISSOLVED (mg/L as Ca)	MAGNESIUM, DISSOLVED (mg/L as Mg)	SODIUM, DISSOLVED (mg/L as Na)	POTASSIUM, DISSOLVED (mg/L as K)
FEB, 1980							
12...	---	200	150	34	16	21	5.0
APR							
28...	7.9	170	140	33	16	24	4.8
MAY							
12...	---	---	150	31	17	26	4.8
JUNE							
11...	7.9	---	140	29	16	27	4.6
27...	---	---	150	31	17	26	4.9
JULY							
11...	8.3	---	130	27	16	--	5.0
27...	---	---	150	31	17	26	4.9

DATE OF ANALYSIS	CHLORIDE, DISSOLVED (mg/L as Cl)	SULFATE DISSOLVED (mg/L as SO4)	FLUORIDE, DISSOLVED (mg/L as F)	SILICA, DISSOLVED (mg/L as SiO2)	STRONTIUM, DISSOLVED (ug/L as Sr)	RADIUM 226, DISSOLVED, RADON METHOD (pCi/L)	URANIUM NATURAL TOTAL (ug/L as U)
FEB, 1980							
12...	15	1.8	.8	28	720	.01	.39
APR							
28...	14	---	.9	--	---	---	---
MAY							
12...	15	2.0	.8	21	---	---	---
JUNE							
11...	14	2.7	.8	12	---	---	---
27...	--	---	.9	--	---	---	---
JULY							
11...	14	.7	.8	--	---	---	---
27...	--	---	--	--	---	---	---

Table 9.--Chemical analyses of water from well B5 in St. Johns County

[Total depth of well is 73 feet; mg/L, milligrams per liter; ug/L, micrograms per liter; pCi/L, picocuries per liter]

DATE OF ANALYSIS	PH	ALKALINITY FIELD (mg/L as CaCO3)	HARDNESS (mg/L as CaCO3)	CALCIUM DISSOLVED (mg/L as Ca)	MAGNESIUM, DISSOLVED (mg/L as Mg)	SODIUM, DISSOLVED (mg/L as Na)	POTASSIUM, DISSOLVED (mg/L as K)
FEB, 1980							
12...	---	---	190	60	9.6	11	3.0
APR							
28...	---	190	170	54	9.7	12	3.0
MAY							
12...	---	---	160	55	10	13	2.7
28...	7.6	190	170	54	9.7	12	3.0
JUNE							
11...	7.2	---	170	53	10	14	2.9
27...	---	---	180	57	10	13	3.1
JULY							
11...	7.7	---	180	57	10	12	3.2
27...	---	---	180	57	10	13	3.1
NOV							
10...	---	210	180	55	9.8	11	3.1

DATE OF ANALYSIS	CHLORIDE, DISSOLVED (mg/L as Cl)	SULFATE DISSOLVED (mg/L as SO4)	FLUORIDE, DISSOLVED (mg/L as F)	SILICA, DISSOLVED (mg/L as SiO2)	STRONTIUM, DISSOLVED (ug/L as Sr)	RADIUM 226, DISSOLVED, RADON METHOD (pCi/L)	URANIUM NATURAL TOTAL (ug/L as U)
FEB, 1980							
12...	14	.4	.4	--	650	.02	.36
APR							
28...	13	.0	.4	12	---	---	---
MAY							
12...	14	3.0	.4	29	---	---	---
28...	13	.0	.4	12	---	---	---
JUNE							
11...	13	1.7	.4	22	---	---	---
27...	20	.3	.4	15	---	---	---
JULY							
11...	14	1.1	.4	12	---	---	---
27...	20	.3	.4	15	---	---	---
NOV							
10...	16	1.6	.4	--	620	.05	.25

Table 10.--Chemical analyses of water from well B6 in St. Johns County

[Total depth of well is 45 feet; mg/L, milligrams per liter]

DATE OF ANALYSIS	PH	ALKALINITY FIELD (mg/L as CaCO3)	HARDNESS (mg/L as CaCO3)	CALCIUM DISSOLVED (mg/L as Ca)	MAGNESIUM, DISSOLVED (mg/L as Mg)	SODIUM, DISSOLVED (mg/L as Na)	POTASSIUM, DISSOLVED (mg/L as K)	CHLORIDE, DISSOLVED (mg/L as Cl)	SULFATE DISSOLVED (mg/L as SO4)	FLUORIDE, DISSOLVED (mg/L as F)
FEB, 1980										
12...	---	230	220	83	2.7	13	.7	22	.4	.1
MAY										
12...	---	---	220	82	2.9	14	.8	22	.8	.1
JUNE										
11...	6.8	---	220	82	3.0	15	.7	22	.2	.1

In the zone immediately overlying the mined zone, sudden water-level changes were observed in conjunction with attempts to dewater the mining zone in the first and second tests. Large increases in inflow to the cavities formed in the mined zone and changes in the composition of the extracted material following the water-level changes indicated that the dolomitic roofs of these two cavities had failed. As a result, the hydraulic connection between the mined zone and the overlying zone was increased.

During the third test it was not possible to monitor water levels in the zone immediately overlying the mined zone. However, the absence of inflow increases and the absence of changes in the extracted material suggest that the zone was unaffected by this test. No water-quality changes in this zone were observed.

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