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INJECTION OF ACIDIC INDUSTRIAL WASTE INTO THE FLORIDAN AQUIFER NEAR BELLE GLADE, FLORIDA: UPWARD MIGRATION AND GEOCHEMICAL INTERACTIONS

1973-75

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CONTENTS

Page

Abstract 1
Introduction 2
Regional geohydrology 5
Description of injection system. 7
    Construction of wells 7
    Plant operated monitoring system. 9
Operating history. 10
    1966 - 72 10
    1973 - 75 12
Results 14
    Chemistry of waste. 14
    Chemistry of native fluids and composition of aquifer rock. . . 14
    Geochemical effects 29
        Deep monitor well. 29
        Shallow monitor well 37
            Changes in sulfate/chloride ratios. 45
            Observations, 1969-73 46
            Observations, 1973-75 48
            Chemical oxygen demand data and waste migration . . . 49
Summary and discussion. 51
Selected references. 53

ILLUSTRATIONS

Figure 1.--Map of Belle Glade area and potentiometric surface of Floridan aquifer in south Florida. 3
2.--Generalized geohydrologic section of the Belle Glade injection site and industrial waste injection and monitor-system after deepening the injection well, January 1972. 6
3.--Graph showing volume of waste injected, December 1966-March 1975 13
4.--Graph showing sulfate reduction in shallow monitor well fluid, 1966-75 47
5.--Graph showing chemical oxygen demand for shallow monitor well fluid 50

TABLES

Table 1.--Chronology of waste injection showing duration of injection, depth interval of waste emplacement and well used for injection. 11
2.--Chemical analyses of industrial waste. 15
3.--Chemical analyses of water from well at University of Florida Experiment Station 22
4.--Chemical analyses of water from deep monitor well. 30
5.--Chemical analyses of water from shallow monitor well . . . 38

INJECTION OF ACIDIC INDUSTRIAL WASTE INTO THE FLORIDAN AQUIFER NEAR BELLE GLADE, FLORIDA: UPWARD MIGRATION AND GEOCHEMICAL INTERACTIONS, 1973-75.

By

Donald J. McKenzie

ABSTRACT

In 1966, a furfural plant at Belle Glade, Florida, began injecting hot, acidic liquid waste into the saline, water-filled lower part of the Floridan aquifer, between the depths of 1,495-1,939 feet. The beds above and below the injection zone were subjected to attack by the acid waste. By 1969, effects of the waste were detected in the water of the well monitoring the upper part of the Floridan aquifer at 1,400 feet. The disposal well was deepened late in 1971 to 2,242 feet in an attempt to stop the upward migration of waste.

The results of research investigations by the U.S. Geological Survey during 1966-73 indicated that the waste continued to move upward and laterally. This was indicated by observations of water-quality changes in the monitor wells. Subtle decreases in the sulfate/chloride ratios, concomitant with increases in the hydrogen sulfide concentrations, were reported to be sensitive indicators of waste migration.

This investigation, continued by the U.S. Geological Survey in 1973-75, shows that the remedial actions of repairing the disposal well liner and injecting periodically into the deep monitor well at 2,060 feet failed to contain the wastes within the lower part of the Floridan aquifer. This investigation tends to confirm the earlier conclusions. The data collected by the Survey are supported by the owner's chemical-oxygen-demand and pH determinations. A hydraulic connection between the injection zone and the overlying monitoring zone is implied. Plans call for injecting into deeper strata.

INTRODUCTION

The U.S. Geological Survey is engaged in a nationwide research program to evaluate the effects of underground waste disposal on the subsurface environment. Part of that investigation has been the collection of hydraulic and geochemical data at an industrial deep-well injection system near Belle Glade, Florida (fig. 1). Injection of hot, acidic, liquid waste into the lower part of the Floridan aquifer at the Belle Glade site began in 1966. By 1975, more than 1.5 billion gallons ($5.68 \times 10^6 m^3$) of waste had been injected.

Objectives of the Survey's investigation in Belle Glade are to understand subsurface interactions of injected liquid wastes with the native fluids and aquifer rock and to determine the ultimate fate of waste injected in a saline and highly permeable carbonate rock aquifer.

The waste, natural Floridan aquifer water, and fluids from the injection zone and upper Floridan aquifer were sampled periodically for comprehensive chemical analyses. Correlations of specific chemical characteristics were made between the waste and the fluids in the shallow and deep monitor wells.

Results of this investigation have been reported by Kaufman, Goolsby, and Faulkner (1973), and by Kaufman and McKenzie (1975). The purpose of this report is to present all the data collected through 1975, and to evaluate that data not covered by the earlier two reports. This report updates and emphasizes the developments that have occurred since 1973.

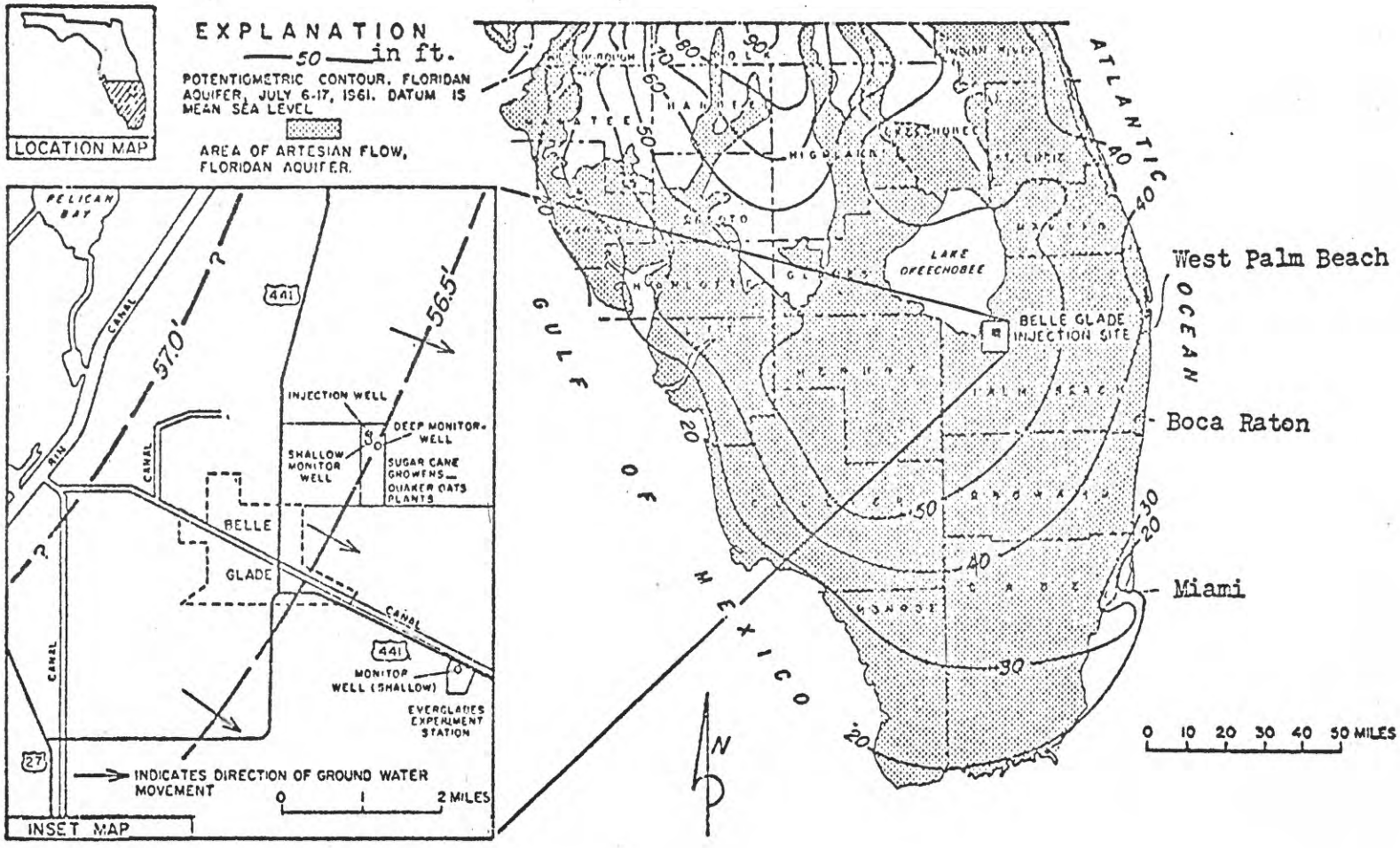


Figure 1.--Belle Glade area and potentiometric-surface of Floridan aquifer in south Florida. (After Healy, 1962 and Kaufman, 1973).

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	By	To obtain SI units
inches (in)	2.54	centimeters (cm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
gallons (gal)	3.785×10^{-3}	cubic meters (m^3)
million gallons (Mgal)	3785	cubic meters (m^3)
gallons per minute (gal/min)	6.309×10^{-5}	cubic meters per second (m^3/s)
million gallons per day (Mgal/d)	.04381	cubic meters per second (m^3/s)

REGIONAL GEOHYDROLOGY

The shallow aquifer in the vicinity of Belle Glade, in the north central part of Palm Beach County, extends from land surface to about 150 ft (46 m). In the southeast corner of the county it reaches a depth of over 400 ft (122 m) and forms the north terminus of the Biscayne aquifer which serves Broward and Dade Counties. The shallow aquifer is underlain by several hundred feet of dense marl and carbonate strata which overlie the Floridan aquifer.

The Floridan aquifer is mostly limestone and dolomite of middle Eocene to middle Miocene age (Parker and others, 1955, p. 188-189). The data obtained from test wells in southern Florida suggest that the Floridan aquifer is composed of several artesian zones within the formations that make up the overall system (Meyer, 1971, p. 69).

Figure 2 shows the general sequence of permeable and confining beds at the injection site, as well as a schematic of the injection system and monitoring wells. In this report, the Floridan aquifer has been divided into an "upper" and a "lower" part. The upper part lies above a stratum, about 150 ft (46 m) thick, reportedly of dense carbonate rock, that serves as the confining layer over the injection zone. The lower part lies below this confining layer. Fluid waste is injected into the lower part of the Floridan aquifer, within the approximate depth range of 1,500 to 2,250 ft (460 to 690 m) below land surface. In both the upper and lower parts of the Floridan at this location, ground water is brackish or saline.

At Belle Glade, land surface is about 15 ft above mean sea level. The altitude of the potentiometric surface in both the lower and upper

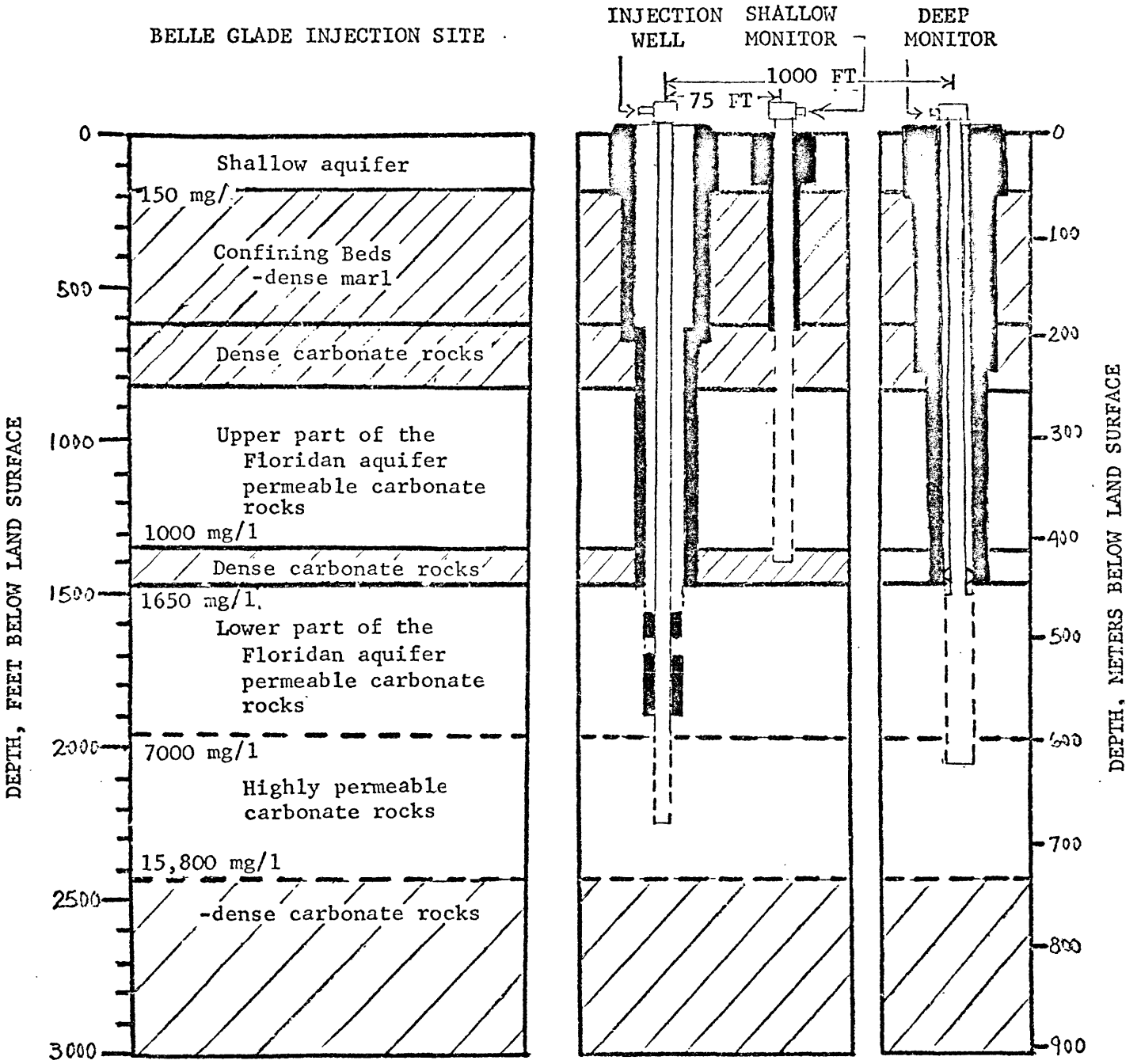


Figure 2.--Generalized geohydrological section at Belle Glade showing the industrial waste injection and monitoring system as of January 1972, after deepening the injection well.
(Partial data sources include Garcia-Bengochea and Vernon, 1970; Kaufman, 1973).

parts of the Floridan aquifer is about 57 ft (Healy, 1962). The slope of the potentiometric surface indicates that regional ground-water flow in the Floridan aquifer is southeastward toward the Atlantic Ocean.

DESCRIPTION OF INJECTION SYSTEM

Construction of Wells

The injection system consists of one disposal well, one shallow monitor well, and one deep monitor well that is also used as a standby disposal well. The waste from the furfural plant is injected into the lower part of the Floridan aquifer (fig. 2).

The disposal well was originally drilled to a depth of 1,939 ft (591 m) and cased with 12-inch (30-cm) diameter pipe to 1,494 ft (456 m). Injection was through an 8 inch (20-cm) diameter stainless steel liner that was run to the bottom of the casing and set with a packer. The well was open from 1,495 to 1,939 ft (456 - 591 m) in the lower part of the Floridan aquifer.

The deep monitor well (fig. 2) is 1,000 ft (305 m) southeast of the disposal well in the downgradient direction of ground-water flow. Because the well is used to assess hydraulic and geochemical effects of waste disposal within the injection zone, the well was made similar in depth and construction to the disposal well. It has a total depth of 2,060 ft (628 m) and a 12-inch (30-cm) steel casing to 1,495 ft (456 m). This well also has an 8-inch (20-cm) stainless steel liner from the surface to the bottom of the casing. This permits the well to be used for waste injection when the disposal well is shut down.

DEPTH, METERS BELOW LAND SURFACE

The shallow monitor well (fig. 2) is 75 ft (23 m) south of the injection well. It monitors hydraulic and geochemical effects within the upper part of the Floridan aquifer. The well is cased to a depth of 648 ft (198 m) and completed open-hole through the upper part of the Floridan aquifer to a depth of 1,400 ft (427 m). The well bottom is about 50 feet (15 m) into the 150-foot (46-m) thick zone of reportedly dense carbonate rock that serves as the confining layer over the injection zone.

A well which taps the upper part of the Floridan aquifer at the University of Florida Everglades Experiment Station, 3 mi (5 km) southeast of the Belle Glade site, was used to represent the chemical character of the upper part of the Floridan aquifer. This well is cased to 957 ft (292 m) and completed open hole to 1,332 ft (406 m).

Plant Operated Monitoring System

Continuous monitoring of the system was planned to detect changes in the quality of water in the upper and lower parts of the aquifer. The shallow monitor well was allowed to backflow continuously at 2-3 gal/min (0.01-0.02 m^3/s) to facilitate the recovery of representative samples from the upper part of the Floridan aquifer. The annulus between the liner and 12-inch (30-cm) casing in the disposal and deep-monitor wells contains water that is circulated constantly under pressure. Any appreciable change in pressure in the closed circuit would indicate a leak in the casing-liner system. In addition, since injection began; a daily record of the following as information has been kept by the plant operators.

Volume of injected waste

Average injection pressure

In late 1969, the plant operators began additional monitoring, as follows:

Shallow monitoring well and deep monitoring well

Chemical oxygen demand and pH: Weekly

Biochemical oxygen demand: Biweekly

Specific conductance: Continuously

Disposal well and waste

Injection rate, pressure and temperature: Continuously

Suspended solids, biochemical oxygen demand: Biweekly

Chemical oxygen demand, pH: Weekly

OPERATING HISTORY

1966 - 72

Beginning in December 1966, waste was injected in the lower part of the Floridan aquifer, between the depths of 1,495 ft (456 m) and 1,939 ft (591 m). Injection was seasonal; production operations were usually suspended 2 - 3 months in late summer.

In the fall of 1969, company staff detected an increase in COD (chemical-oxygen-demand) and BOD (biological-oxygen-demand) and a decrease in pH (hydrogen ion activity) in water from the shallow monitor well. These were indications that waste was migrating upward from the injection zone. In an attempt to seal off the upper Floridan aquifer, the disposal well was deepened to 2,242 ft (683 m) and the liner extended to 1,939 ft (591 m) and grouted (fig. 2). The casing was not extended, but remained at 1,495 ft.

While the disposal well was being deepened, from October 1971 through January 1972, the deep monitor well was used for waste disposal (Table 1). More than 75 Mgal (2.84×10^5 m^3) of waste were injected during this 4-month span. Since the disposal well was returned to service, the deep monitor well has been allowed to backflow continuously at 2-3 gal/min (.01-0.2 m^3s). The backflow was sampled periodically for information about the ultimate fate of waste in the aquifer.

In October 1972, about 9 months after waste injection had been resumed in the deepened disposal well, a mechanical caliper log indicated that the well was open to the aquifer from 1,923 - 1,945 ft (586 - 593 m) and apparently bridged or plugged below 1,945 ft (593 m).

Table 1.--Chronology of waste injection, showing duration of injection, depth interval of waste emplacement and well used for injection.

TIME:	WASTE INJECTION ZONE:
December 17, 1966 to October 8, 1971	Disposal Well (1500 - 1900 ft.) (457 - 579 m)
October 9, 1971 to January 12, 1972	Deep Monitor Well (1495 - 2060 ft.) (456 - 628 m)
January 13, 1972 to June 17, 1973	Disposal Well (1938 - 2242 ft.) (591 - 683 m)
June 18, 1973 to June 1974	Deep Monitor Well (1495 - 2060 ft.) (456 - 628 m)
July 1974 to Present April 1975	Disposal Well (1938 - 2242 ft.) (591 - 683 m)

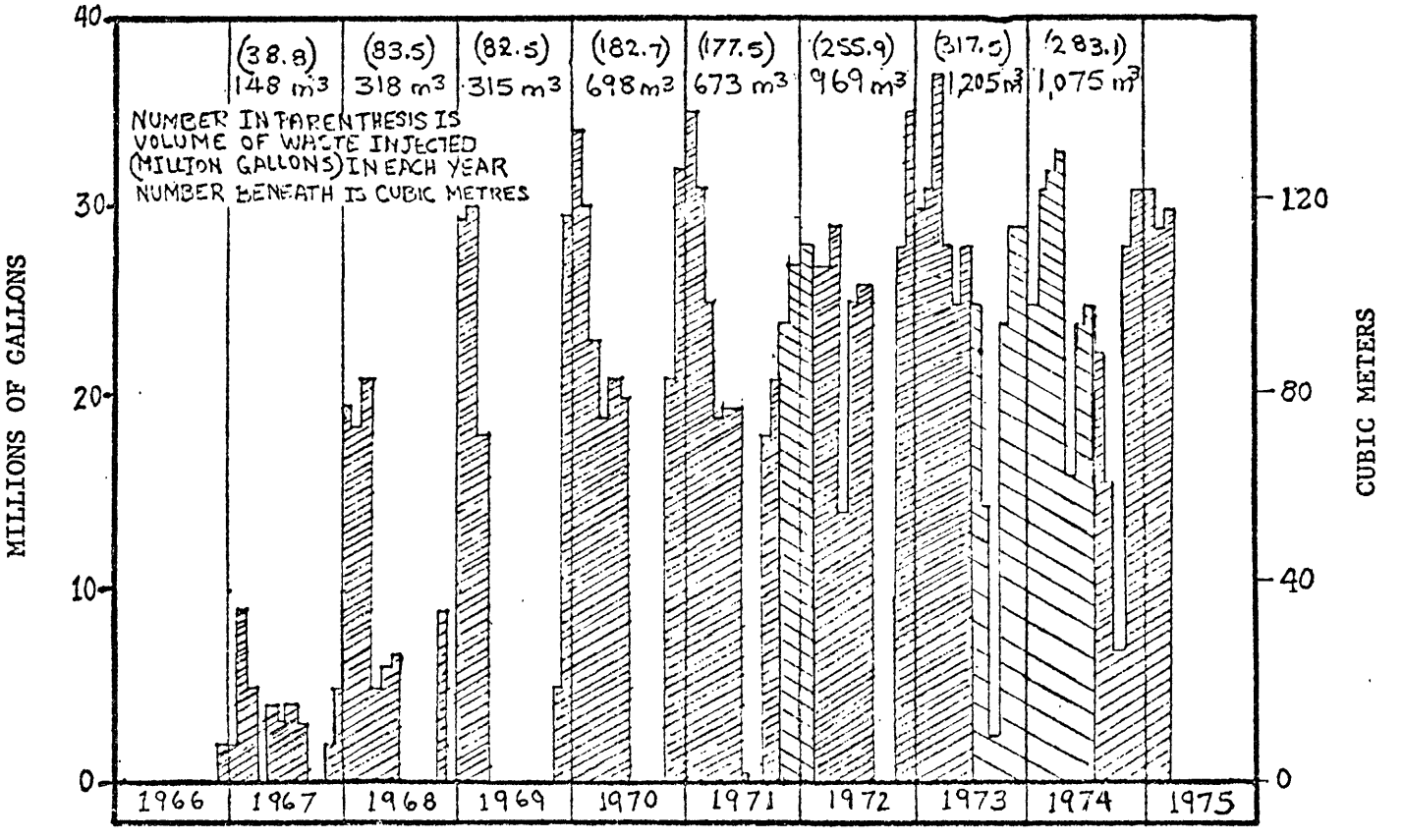
It was discovered that about 15 ft (4.6 m) of the mild-steel bottom section of the liner had been destroyed by corrosion.

Since November 1972, plant operations and injection have been constant except for intervals of a few days when the plant has been closed for routine maintenance (fig. 3).

History from 1973 to 1975

In June 1973, the disposal well was shut down for repairs to the liner. The work was completed about 1 year later, in June 1974. The total depth of hole and bottom of liner remained unchanged at 2,242 ft (683 m) and 1,939 ft (591 m), respectively. Present (1975) construction is shown in figure 2. The disposal well was returned to service in July 1974, and has remained constinuously in operation except for 30 days in September - October 1974.

In 1974, shortly before the disposal well was returned to service, it was discovered that water was being lost from the deep monitor well annulus circulatory system. Investigation showed that the bottom 16 ft of the inner stainless steel liner had been damaged. Repairs were completed in January 1975. To prevent further problems, the teflon packer was replaced with acid-proof cement.



▨ Waste discharged into injection well.
▧ Waste discharged into deep monitor well.
□ No injection.

Figure 3.--Volume of waste injected, December 1966 - March 1975.
(Data furnished by Quaker Oats Co.)

RESULTS

Chemistry of Waste

The waste is hot, acidic and highly organic. The average pH is 3.2, and it contains high concentrations of nitrogen, carbon, and phosphorus (table 2). The total organic carbon concentrations ranged from 540 to 12,000 mg/l (milligrams per litre). The suspended solids exceeded 1,110 mg/l. The chloride concentrations ranged from 80 to 300 mg/l. The specific gravity of the waste ranged from about 1.000 to 1.006 at 20°C. Owing largely to the high temperature of the waste, it is less dense than the native ground-water. Based on the relative density of water, the estimated density of the waste at 80°C is about 0.98 g/ml (grams per millilitre); the density of native brackish or saline fluids within the depth range investigated is greater than 1.003 g/ml.

Chemistry of Native Fluids and Composition of Aquifer Rock

Water analyses (table 3) from the Experiment Station well, 3 miles southeast of the injection site, were collected from 1971-75. The analyses show the chemical character of the native brackish-saline fluid from the upper part of the Floridan aquifer. Comparison of recent (1975) analyses of water from this well with a partial chemical analysis reported by Stringfield (1933) indicates that the chemical quality of native fluid in the upper part of the Floridan aquifer at the well has not changed significantly in the last 40 years. The chloride concentration in 1933 was 1,650 mg/l. In 1975 it was 1,600 mg/l.

Table 2.— ANALYSES OF INDUSTRIAL WASTE

DATE	TIME	DEPTH (FT)	TEMPERATURE (DEG C)	TURBIDITY (JTU)	COLOR (PLATINUM-COBALT UNITS)	SPECIFIC CONDUCTANCE (MICROMHOS)	CHEMICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L)	PH (UNITS)	CARBON DIOXIDE (CO2) (MG/L)	ALKALINITY AS CACO3 (MG/L)	TOTAL ACIDITY AS CACO3 (MG/L)	BICARBONATE (HCO3) (MG/L)
264227080390700 - BELLE GLADES QUAKER OATS INDUST WASTE (LAT 26 42 27 LONG 080 39 07)												
JULY, 1973												
06...	1130	--	--	280	3200	1890	25300	3.0	.0	0	12500	0
06...	1130	--	--	--	--	2200	--	2.9	.0	0	--	0
OCT.												
18...	1130	--	76.0	540	2100	3100	26300	3.1	.0	0	9430	0
FEB., 1974												
01...	1200	--	--	--	900	1640	--	2.9	.0	0	5460	0
JULY												
09...	1130	--	75.0	450	2300	2400	29000	2.9	.0	0	10300	0
OCT.												
18...	1130	--	76.0	540	--	3100	26300	3.1	.0	0	--	0
NOV.												
05...	1200	--	65.0	--	8000	3150	--	3.0	.0	0	9380	0
FEB., 1975												
04...	1100	--	65.0	420	1500	3800	25000	3.3	.0	0	5160	0
APR.												
11...	1100	--		320	2400	2980	28000	4.0	.0	0	2280	0

Table 2.— ANALYSES OF INDUSTRIAL WASTE con't

DATE	DIS-SOLVED SODIUM (NA) (MG/L)	SODIUM AD-SORP-TION RATIO	PERCENT SODIUM	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)
264227080390700 - BELLE GLADES QUAKER OATS INDUST WASTE (LAT 26 42 27 LONG 080 39 07)										
JULY, 1973										
06...	33	.7	10	170	80	180	17	28	--	5
06...	--	--	--	--	--	--	--	--	--	--
OCT.										
18...	150	2.5	25	230	210	250	1.8	70	--	14
FEB., 1974										
01...	190	6.9	61	99	84	120	.5	21	--	14
JULY										
09...	110	1.9	19	310	160	290	22	35	--	0
OCT.										
16...	--	--	--	--	--	--	--	70	--	--
NOV.										
05...	150	2.0	18	340	280	410	1.5	44	--	4
FEB., 1975										
04...	430	8.2	50	330	300	360	13	38	--	13
APR.										
11...	400	7.9	55	180	270	200	3.5	29	--	4

Table 2.— ANALYSES OF INDUSTRIAL WASTE con't

DATE	DIS-SOLVED ORTHO PHOS-PHATE (PO4) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	DIS-SOLVED ORTHO. PHOS-PHORUS (P) (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	DIS-SOL-VED ORGANIC CARBON (C) (MG/L)	TOTAL IN-ORGANIC CARBON (C) (MG/L)	TOTAL CARBON (C) (MG/L)	TOTAL SUL-FIDE (S) (MG/L)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)
264227080390700 - BELLE GLADES QUAKER OATS INDUST WASTE (LAT 26 42 27 LONG 080 39 07)												
JULY, 1973												
06...	--	27	--	7000	--	--	--	--	460	460	110	45
06...	--	--	--	--	--	--	--	43	--	--	--	--
OCT.												
18...	--	.00	--	12000	--	--	--	--	690	690	160	70
FEB., 1974												
01...	--	--	--	--	--	--	--	--	140	140	50	4.2
JULY												
09...	--	47	--	7500	--	--	--	--	610	610	140	63
OCT.												
18...	--	28	--	12000	--	--	--	--	--	--	--	--
NOV.												
05...	--	--	--	--	--	--	--	--	1000	1000	260	95
FEB., 1975												
04...	--	22	--	9000	--	--	--	--	520	520	130	48
APR.												
11...	27	12	8.9	540	--	--	--	--	490	490	120	45

Table 2.— ANALYSES OF INDUSTRIAL WASTE con't

DATE	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	SUS-PENDED SOLIDS (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	TOTAL ORTHO PHOS-PHORUS (P) (MG/L)	DENSITY (GM/ML AT 20 C)	TOTAL ACIDITY AS H+ (MG/L)
264227080390700 - BELLE GLADES QUAKER OATS INDUST WASTE (LAT 26 42 27 LONG 080 39 07)										
JULY, 1973										
06...	--	470	--	8750	--	916	--	23	--	251
06...	--	--	--	--	--	--	--	--	--	--
OCT.										
18...	--	800	--	2400	8650	1340	12.0	.00	--	194
FEB., 1974										
01...	--	80	--	1150	414	679	.56	--	--	110
JULY										
09...	--	800	--	1500	9720	1340	13.2	35	--	208
OCT.										
16...	--	--	--	--	--	--	--	28	--	--
NOV.										
05...	--	1100	--	1110	13900	1770	18.9	--	--	189
FEB., 1975										
04...	--	350	--	1700	12600	1750	17.4	17	--	104
APR.										
11...	--	930	--	1930	5000	1290	6.80	--	--	46

Table 2.-- ANALYSES OF INDUSTRIAL WASTE con't

DATE	CARBONATE (CO3) (MG/L)	TOTAL NITROGEN (N) (MG/L)	TOTAL ORGANIC NITROGEN (N) (MG/L)	DISSOLVED AMMONIA NITROGEN (N) (MG/L)	AMMONIA NITROGEN (N) (MG/L)	DISSOLVED NITRITE (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	DISSOLVED NITRATE (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL KJELDAHL NITROGEN (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)
264227080390700 - BELLE GLADES QUAKER OATS INDUST WASTE (LAT 26 42 27 LONG 080 39 07)												
JULY 1973												
06...	0	94	73	--	21	--	.06	--	.00	--	--	--
06...	0	--	--	--	--	--	--	--	--	--	--	--
OCT.												
18...	0	138	124	--	14	--	.00	--	.05	--	--	--
FEB. 1974												
01...	0	--	--	--	--	--	--	--	--	--	--	--
JULY												
09...	--	138	119	--	19	--	.14	--	.00	138	.14	--
OCT.												
16...	--	138	124	--	14	--	.00	--	.05	--	--	--
NOV.												
05...	--	--	--	--	--	--	--	--	--	--	--	--
FEB. 1975												
04...	--	146	140	--	6.8	--	.05	--	.00	146	.05	--
APR.												
11...	0	--	75	--	4.4	.12	--	.19	--	79	--	.31

Table 2.--ANALYSES OF INDUSTRIAL WASTE con't

DATE	DIS_ SOLVED NITRATE (NO3) (MG/L)	DIS_ SOLVED NITRITE (NO2) (MG/L)	MAN- GANESE (MN) (UG/L)	IRON (FE) (UG/L)	TOTAL NITRO- GEN (NO3) (MG/L)	DEPTH TO TOP OF WATER- BEARING ZONE (FT)	SAMPLE SOURCE	TOTAL DEPTH OF WELL (FT)	SPE- CIFIC GRAVITY
264227080390700 - BELLE GLADES QUAKER OATS INDUST WASTE (LAT 26 42 27 LONG 080 39									
JULY, 1973									
06...	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--
OCT.									
16...	--	--	--	--	--	--	--	--	--
FEB., 1974									
01...	--	--	--	--	--	--	--	--	--
JULY									
09...	--	--	--	--	612	--	0	--	1.0
OCT.									
16...	--	--	--	--	--	--	--	--	--
NOV.									
05...	--	--	--	--	--	--	42	--	--
FEB., 1975									
04...	--	--	--	--	647	--	43	--	1.0
APR.									
11...	.80	.39	--	--	--	--	41	--	1.0

Table 2.-- ANALYSES OF INDUSTRIAL WASTE con't

DATE	TOTAL CADMIUM (CD) (UG/L)	HEXAVALENT CHROMIUM (CR6) (UG/L)	TOTAL CHROMIUM (CR) (UG/L)	DISSOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MANGANESE (MN) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED STRONTIUM (SR) (UG/L)
264227080390700 - BELLE GLADES QUAKER OATS INDUST WASTE (LAT 26 42 27 LONG 080 39 07)												
JULY, 1973												
06...	1	--	30	--	100	--	--	--	230	--	--	1600
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT.												
18...	2	--	0	--	100	--	--	--	31	--	--	2
FEB., 1974												
01...	1	0	--	--	120	--	--	--	7	--	--	--
JULY												
09...	2	--	35	--	58	--	--	--	7	--	--	3700
OCT.												
18...	--	--	--	--	--	--	--	--	--	--	--	--
NOV.												
05...	17	0	<10	--	110	--	--	--	--	--	--	--
FEB., 1975												
04...	0	4	900	--	1200	--	--	--	240	--	--	--
APR.												
11...	0	0	1700	--	1100	--	--	--	680	--	--	--

Table 3.--Analyses of well water at University of Florida Experimental Station.

DATE	TIME	DEPTH (FT)	TEMPERATURE (DEG C)	TURBIDITY (JTU)	COLOR (PLATINUM-COBALT UNITS)	SPECIFIC CONDUCTANCE (MICROMHOS)	CHEMICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L)	PH (UNITS)	CARBON DIOXIDE (CO2) (MG/L)	ALKALINITY AS CACO3 (MG/L)	TOTAL ACIDITY AS CACO3 (MG/L)	BICARBONATE (HCO3) (MG/L)
264000080375001 - PH 203 (LAT 26 40 00 LONG 080 37 50.01)												
JUNE, 1971												
14...	--	--	22.0	--	5	5160	--	6.3	--	26	--	32
OCT.												
19...	--	--	--	--	0	6200	--	8.1	--	125	--	152
19...	1400	--	--	--	--	--	--	--	--	--	--	--
MAR., 1972												
28...	1300	--	24.5	15	10	6100	5	7.0	--	131	--	160
28...	1300	--	24.5	--	--	5100	--	8.0	2.7	136	--	166
DEC.												
15...	1600	--	26.0	1	5	6240	36	8.3	1.2	124	.0	151
15...	1600	--	26.0	--	--	--	--	7.2	--	--	--	--
APR., 1973												
19...	1700	--	23.5	1	5	6000	33	7.8	4.0	128	5.0	156
19...	1700	--	23.5	--	--	4450	--	8.0	2.7	139	--	170
JUL,												
06...	1400	--	26.0	2	10	6000	118	8.1	1.9	121	.0	148
06...	1400	--	26.0	--	--	5800	--	7.6	6.3	129	--	157
FEB., 1974												
01...	1400	--	24.5	8	4	6030	78	8.1	2.0	126	5.0	154
JULY												
09...	1400	1332	24.0	2	3	5800	69	7.8	4.9	157	--	192
FEB., 1975												
11...	1100	--	--	1	--	--	62	--	--	--	--	--
MAY												
14...	0915	--	--	--	--	5700	--	--	--	--	--	--

Table 3.--Analyses of well water at University of Florida Experimental Station--Cont.

DATE	DIS-SOLVED SODIUM (NA) (MG/L)	SODIUM AD-SORP-TION RATIO	PERCENT SODIUM	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)
264000080375001 - PH 203 (LAT 26 40 00 LONG 080 37 50.01)												
JUNE 1971												
14...	900	--	--	26	1580	456	.4	.5	0	--	--	--
OCT.												
19...	960	--	--	35	1620	522	.9	19	10	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
MAR. 1972												
28...	920	13	67	34	1600	510	1.2	12	0	--	--	0
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	950	14	68	31	1700	540	1.0	8.7	10	--	--	0
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR. 1973												
19...	980	14	70	32	--	520	.9	12	--	1	--	0
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	1000	15	71	40	1700	500	1.0	13	4	--	--	1
06...	--	--	--	--	--	--	--	--	--	--	--	--
FEB. 1974												
01...	1100	18	76	36	1700	530	.9	13	--	0	--	--
JULY												
09...	900	13	67	35	1600	520	1.0	13	--	2	--	--
FEB. 1975												
11...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
14...	--	--	--	--	1600	--	--	--	--	--	--	--

Table 3.--Analyses of well water at University of Florida Experimental Station--cont.

DATE	DIS-SOLVED ORTHO PHOS-PHATE (PO4) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	DIS-SOLVED ORTHO. PHOS-PHORUS (P) (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	DIS-SOL-VED ORGANIC CARBON (C) (MG/L)	TOTAL IN-ORGANIC CARBON (C) (MG/L)	TOTAL CARBON (C) (MG/L)	TOTAL SUL-FIDE (S) (MG/L)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)
			264000080375001 -		PB 203 (LAT 26 40 00 LONG 080 37 50.01)							
JUNE, 1971												
14...	.02	--	--	--	--	--	--	--	692	666	62	126
OCT.												
19...	.03	--	--	--	--	--	--	--	922	797	130	140
19...	--	--	--	2.0	--	--	--	--	--	--	--	--
MAR., 1972												
28...	--	.02	--	.0	.0	31	31	--	950	820	140	140
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	--	.00	--	--	--	--	29	--	950	820	140	140
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR., 1973												
19...	--	.00	--	10.	--	34	44	4.0	910	780	140	130
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	--	.00	--	2.0	--	32	34	--	820	700	130	120
06...	--	--	--	--	--	--	--	4.5	--	--	--	--
FEB., 1974												
01...	--	.02	--	1.0	--	31	32	--	700	580	150	80
JULY												
09...	--	.02	--	.0	--	30	30	--	930	770	140	140
FEB., 1975												
11...	--	.00	--	33.	--	--	--	--	--	--	--	--
MAY												
14...	--	--	--	--	--	--	--	--	--	--	--	--

Table 3.--Analyses of well water at University of Florida Experimental Station--cont.

DATE	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	SUS-PENDED SOLIDS (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	TOTAL ORTHO PHOS-PHORUS (P) (MG/L)	DENSITY (GM/ML AT 20 C)	TOTAL ACIDITY AS H+ (MG/L)	DIS-SOLVED AMMONIA (NH4) (MG/L)	TOTAL NITRATE (NO3) (MG/L)
		264000080375001 -			P8 203 (LAT 26 40 00 LONG 080 37 50.01)							
JUNE, 1971												
14...	30	--	--	--	--	3170	--	--	--	--	--	--
OCT.												
19...	80	--	--	--	--	3500	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
MAR., 1972												
28...	80	20	--	--	--	3400	--	--	1.004	--	--	.00
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	--	--	--	2	--	3600	--	.00	--	.0	--	--
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR., 1973												
19...	0	20	--	1.	--	--	--	.00	--	.1	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	0	--	--	2	--	3580	--	.00	--	.0	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
FEB., 1974												
01...	--	30	--	41	3680	3690	5.00	.01	--	.1	--	--
JULY												
09...	--	10	--	--	3800	3450	5.17	.01	--	--	--	--
FEB., 1975												
11...	--	--	--	--	--	--	--	.00	--	--	--	--
MAY												
14...	--	--	--	--	--	--	--	--	--	--	--	--

Table 3.--Analyses of well water at University of Florida Experimental Station--cont.

DATE	CARBONATE (CO3) (MG/L)	TOTAL NITROGEN (N) (MG/L)	TOTAL ORGANIC NITROGEN (N) (MG/L)	DISSOLVED AMMONIA NITROGEN (N) (MG/L)	AMMONIA NITROGEN (N) (MG/L)	DISSOLVED NITRITE (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	DISSOLVED NITRATE (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL KJELDAHL NITROGEN (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)
264000080375001 - PR 203 (LAT 26 40 00 LONG 080 37 50.01)											
JUNE, 1971											
14...	0	--	--	--	--	.00	--	--	--	--	--
OCT.											
19...	0	--	--	--	--	.00	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
MAR., 1972											
28...	0	--	.05	--	.86	--	.00	.00	.00	--	--
28...	0	--	--	--	--	--	--	--	--	--	--
DEC.											
15...	0	--	04	--	.65	--		--	.02	--	--
15...	--	--	--	--	--	--	--	--	--	--	--
APR., 1973											
19...	0	--	.18	--	.70	--	.00	--	.00	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
JULY											
06...	0	.78	.16	--	.62	--	.00	--	.00	--	--
06...	--	--	--	--	--	--	--	--	--	--	--
FEB., 1974											
01...	0	--	.31	--	.69	.00	--	.00	--	--	--
JULY											
09...	0	.60	.01	--	.60	--	.00	--	.00	.61	.00
FEB., 1975											
11...	--	--	.00	--	.64	--	.00	--	.00	--	--
MAY											
14...	--	--	--	--	--	--	--	--	--	--	--

Table 3.--Analyses of well water at University of Florida Experimental Station--cont.

DATE	DIS_ SOLVED NITRATE (NO3) (MG/L)	DIS_ SOLVED NITRITE (NO2) (MG/L)	MAN- GANESE (MN) (UG/L)	IRON (FE) (UG/L)	TOTAL NITRO- GEN (NO3) (MG/L)	DEPTH TO TOP OF WATER- BEARING ZONE (FT)	SAMPLE SOURCE	TOTAL DEPTH OF WELL (FT)	SPE- CIFIC GRAVITY	DEPTH TO BOT- TOM OF SAMPLE INTER- VAL (FT)	SUS- PENDED SEDI- MENT (MG/L)
		264000080375001 -			PH 203 (LAT 26 40 00 LONG 080 37 50.01)						
JUNE, 1971											
14...	.00	.01	10	40	--	--	--	1332	--	--	--
OCT.											
19...	.00	.00	0	70	--	--	--	1332	--	1332	--
19...	--	--	--	--	--	--	--	--	--	--	--
MAR., 1972											
28...	.00	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--
DEC.											
15...	--	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--	--
APR., 1973											
19...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
JULY											
06...	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--
FEB., 1974											
01...	.00	.00	--	--	--	--	--	--	--	--	--
JULY											
09...	--	--	--	--	2.7	--	--	--	1.0	--	--
FEB., 1975											
11...	--	--	--	--	--	--	--	--	1.0	--	--
MAY											
14...	--	--	--	--	--	--	--	--	--	--	--

Table 3.--Analyses of well water at University of Florida Experimental Station--cont.

DATE	TOTAL CADMIUM (CD) (UG/L)	HEXAVALENT CHROMIUM (CR6) (UG/L)	TOTAL CHROMIUM (CR) (UG/L)	DISSOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MANGANESE (MN) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED STRONTIUM (SR) (UG/L)
			264000080375001 -		Pb 203 (LAT 26 40 00 LONG 080 37 50.01)							
JUNE, 1971												
14...	--	0	--	0	--	--	--	0	--	--	--	--
OCT.												
19...	--	0	--	0	--	--	--	0	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
MAR., 1972												
28...	0	0	--	10	10	140	70	0	0	10	10	18000
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	--	0	--	10	--	--	--	0	--	--	--	18000
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR., 1973												
19...	0	0	0	10	--	--	--	1	--	--	--	18000
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	--	0	--	10	--	--	--	1	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
FEB., 1974												
01...	1	0	--	--	6	--	--	--	0	--	--	--
JULY												
09...	1	--	<10	--	3	--	--	--	3	--	--	3900
FEB., 1975												
11...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
14...	--	--	--	--	--	--	--	--	--	--	--	--

Analysis of native fluid samples collected from the lower part of the Floridan are given in Table 4, for March 1971. Analyses following that date were made after waste injection into the deep monitor well had occurred. All the analytical data show that the native fluids are basically of the sodium-chloride type, but include appreciable quantities of sulfate, magnesium and calcium. The chemistry and potential uses of these brackish to saline artesian waters in southern Florida are discussed by Vernon (1970) and Meyer (1971).

In November 1971, the U.S. Geological Survey performed an X-ray diffraction analysis of the rocks of the injection zone and confining beds to determine their mineralogical composition. The interval from 1,495 to 1,600 ft is predominantly calcite, with about 2 percent quartz. The zone from 1,885 to 1,925 contains considerable dolomite and about 2 percent quartz. From 1,985 to 2,080 ft. the rock is 55 percent calcite and 35 percent dolomite. There are no analyses for the intervening zones.

Geochemical Effects

Deep Monitor Well

As mentioned earlier, the deep monitor well was used for waste injection from October 1971 to January 1972, while the disposal well was being deepened. When the disposal well was put back in service, waste that had been injected into the deep monitor well was allowed to backflow continuously at 2 - 3 gal/min (0.01-0.02 m^3/s). This backflow was periodically sampled to provide information on geochemical interactions and ultimate fate of the waste in the aquifer, including anaerobic decomposition.

The first pH determinations of the backflow fluid, made by the company, showed that the injected waste was partly neutralized almost imme-

Table 4.--Analyses of water from deep monitor well--cont.

DATE	TIME	DEPTH (FT)	TEMPERATURE (DEG C)	TURBIDITY (JTU)	COLOR (PLATINUM-COBALT UNITS)	SPECIFIC CONDUCTANCE (MICROMHOS)	CHEMICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L)	PH (UNITS)	CARBON DIOXIDE (CO2) (MG/L)	ALKALINITY AS CACO3 (MG/L)	TOTAL ACIDITY AS CACO3 (MG/L)	BICARBONATE (HCO3) (MG/L)
264200080390002 - 43S37E28 2 DEEP (LAT 26 42 00 LONG 080 39 00.02)												
MAR.. 1971												
18...	--	--		--	10		--		--		--	
18...	1200	--	24.6	--	0	3700	--	8.2	1.5	125	--	152
MAR.. 1972												
27...	1400	--	40.0	65	900	10300	--	7.6	199	4070	--	4960
27...	1400	--	40.0	--	--	--	--	6.2	--	--	--	--
SEP.												
28...	1230	--	32.0	100	1000	12500	--	6.9	1100	4490	--	5480
28...	1230	--	32.0	--	--	10300	--	5.9	--	--	--	--
DEC.												
15...	1230	--	26.0	300	520	8740	16000	7.4	214	2760	199	3360
15...	1230	--	28.0	--	--	6200	--	6.2	--	--	--	--
APR.. 1973												
19...	1200	--	30.0	300	600	9000	3500	6.8	1390	4460	1140	5460
19...	1200	--	30.0	--	--	5000	--	6.8	1420	4590	--	5600
FEB.. 1975												
04...	1200	--	29.0	6	30	780	40	--	--	59	.0	72
APR.												
11...	1030	1495	31.5	70	1400	3140	23000	3.6	.0	0	7150	0

Table 4.--Analyses of water from deep monitor well--cont.

DATE	DIS-SOLVED SODIUM (NA) (MG/L)	SODIUM AD-SORP-TION RATIO	PERCENT SODIUM	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)
264200080390002 - 43S37E28 2 DEEP (LAT 26 42 00 LONG 080 39 00.0?)												
MAR.. 1971												
18...	5070	--	--	--						--		--
18...	492	8.5	62	18	920	340	1.5	14	--	--	--	--
MAR.. 1972												
27...	800	4.6	23	140	1300	228	3.3	58	--	10	--	?
27...	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	880	5.3	27	130	--	--	2.9	12	--	10	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	820	5.1	26	130	1300	11	1.4	75	--	15	--	0
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR.. 1973												
19...	680	4.3	24	100	870	4.0	.6	65	--	1	--	0
19...	--	--	--	--	--	--	--	--	--	--	--	--
FEB.. 1975												
04...	70	2.5	50	4.5	120	85	.7	11	--	3	--	--
APR.												
11...	210	2.9	27	210	220	260	11	75	--	11	--	--

Table 4.--Analyses of water from deep monitor well--cont.

DATE	DIS-SOLVED ORTHO PHOS-PHATE (PO4) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	DIS-SOLVED ORTHO. PHOS-PHORUS (P) (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	DIS-SOL-VED ORGANIC CARBON (C) (MG/L)	TOTAL IN-ORGANIC CARBON (C) (MG/L)	TOTAL CARBON (C) (MG/L)	TOTAL SUL-FIDE (S) (MG/L)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)
264200080390002 - 43S37E28 2 DEEP (LAT 26 42 00 LONG 080 39 00.02)												
MAR.. 1971												
18...		--	--	--	--	--	--					
18...	.00	--	--	--	--	--	--	--	666	541	97	94
MAR.. 1972												
27...	24	8.0	--	3870	3725	330	4200	--	6100	2100	1100	700
27...	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	--	9.9	--	3800	--	120	3900	--	5200	670	1400	400
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	--	2.2	--	1460	--	900	2360	--	4900	2100	1200	450
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR.. 1973												
19...	--	3.2	--	1370	--	780	2150	87	4700	190	1200	400
19...	--	--	--	--	--	--	--	--	--	--	--	--
FEB.. 1975												
04...	--	.02	--	17	--	--	--	--	150.	87	53	3.3
APR.												
11...	40	17	13	760	--	--	--	--	990	990	240	94

Table 4.--Analyses of water from deep monitor well--cont.

DATE	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	SUS-PENDED SOLIDS (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	TOTAL ORTHO PHOS-PHORUS (P) (MG/L)	DENSITY (GM/ML AT 20 C)	TOTAL ACIDITY AS H+ (MG/L)	DIS-SOLVED AMMONIA (NH4) (MG/L)	TOTAL NITRATE (NO3) (MG/L)
264200080390002 - 43S37E28 2 DEEP (LAT 26 42 00 LONG 080 39 00.0?)												
MAR.. 1971												
18...	50	--	60	--	--		--	--	--	--	--	--
18...	--	--	--	--	--	2040	--	--	--	--	--	--
MAR.. 1972												
27...	20	--	--	--	--	6800	--	7.9	1.007	--	--	.10
27...	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	--	--	--	372	--	7500	--	8.1	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	--	--	--	532	--	5670	--	62	--	4.0	--	--
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR.. 1973												
19...	10	20	--	64	--	6060	--	2.1	--	23	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
FEB.. 1975												
04...	--	10	--	6	412	383	.56	.02	--	.0	--	--
APR.												
11...	--	360	--	1000	8300	1460	11.3	--	--	144	--	--

Table 4.--Analyses of water from deep monitor well--cont.

DATE	CARBONATE (CO3) (MG/L)	TOTAL NITROGEN (N) (MG/L)	TOTAL ORGANIC NITROGEN (N) (MG/L)	DISSOLVED AMMONIA NITROGEN (N) (MG/L)	AMMONIA NITROGEN (N) (MG/L)	DISSOLVED NITRITE (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	DISSOLVED NITRATE (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL KJELDAHL NITROGEN (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)
264200080390002 - 43S37E28 2.DEEP (LAT 26 42 00 LONG 080 39 00.02)												
MAR., 1971												
18...	0	--	--	--	--		--	--	--	--	--	--
18...	0	--	--	--	--	--	--	.00	--	--	--	--
MAR., 1972												
27...	0	--	7.9	--	11		--	.15	.02	.03	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	0	--	3.2	--	22		--	.15	--	.41	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	0	--	5.6	--	12		--	.05	--	.00	--	--	--
15...	--	--	--	--	--	--	--	--	--	--	--	--	--
APR., 1973												
19...	0	--	8.5	--	9.5		--	.28	--	.00	--	--	--
19...	0	--	--	--	--	--	--	--	--	--	--	--	--
FEB., 1975												
04...	--	.94	.89	--	.02	--	--	.01	--	.02	.91	.03	--
APR.												
11...	0	--	86	--	8.7	.09	--	.03	--	94	--	--	.12

Table 4.--Analyses of water from deep monitor well--cont.

DATE	DIS_ SOLVED NITRATE (NO3) (MG/L)	DIS_ SOLVED NITRITE (NO2) (MG/L)	MAN- GANESE (MN) (UG/L)	IRON (FE) (UG/L)	TOTAL NITRO- GEN (NO3) (MG/L)	DEPTH TO TOP OF WATER- BEARING ZONE (FT)	SAMPLE SOURCE	TOTAL DEPTH OF WELL (FT)	SPE- CIFIC GRAVITY
264200080390002 - 43S37E28 2 DEEP (LAT 26 42 00 LONG 080 39 00.02)									
MAR., 1971									
18...					--		--		--
18...	.00	--	--	--	--	--	--	--	--
MAR., 1972									
27...	.10	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--
SEP.									
28...	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--
DEC.									
15...	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--
APR., 1973									
19...	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--
FEB., 1975									
04...	--	--	--	--	4.2	--	--	--	1.0
APR.									
11...	.10	.30	--	--	--	--	--	--	1.0

Table 4.--Analyses of water from deep monitor well--cont.

DATE	TOTAL CADMIUM (CD) (UG/L)	HEXAVALENT CHROMIUM (CR6) (UG/L)	TOTAL CHROMIUM (CR) (UG/L)	DISSOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MANGANESE (MN) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED STRONTIUM (SR) (UG/L)
264200080390002 - 43S37E28 2 DEEP (LAT 26 42 00 LONG 080 39 00.02)												
MAR.. 1971												
18...	--	0	--	0	--	--	--	--	--	--	--	--
18...	--	--	--	--	--	--	--	--	--	--	--	--
MAR.. 1972												
27...	--	0	--	20	--	--	2600	4	--	--	200	15000
27...	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	--	--	--	20	--	--	--	--	--	--	--	20000
28...	--	--	--	--	--	--	--	--	--	--	--	--
DEC.												
15...	--	0	--	20	--	--	--	3	--	--	--	24000
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR.. 1973												
19...	3	0	20	30	30	--	--	3	4	--	--	23000
19...	--	--	--	--	--	--	--	--	--	--	--	--
FEB.. 1975												
04...	0	1	70	--	61	--	--	--	22	--	--	--
APR.												
11...	3	0	270	--	16	--	--	--	190	--	--	--

diately, increasing in pH from 3.2 to 5.5. The Survey's analyses of the fluid made after 75 and 160 days residence time, in a report by Kaufman and others (1973), showed that the pH of the waste fluid continued to increase. In 75 days the pH was 6.2 and in 160 days it was 6.6.

Analyses of the fluid after 160 days residence time showed increases in calcium, magnesium, and silica owing to the dissolution of limestone. The acidic waste had developed an alkalinity (as $CaCO_3$) of 3,500 mg/1. Hydrogen sulfide increased sharply, presumably due to sulfate reduction by anaerobic bacteria. Kaufman and others (1973) showed the existence of sulfate reducing bacteria in backflow from the deep monitor well. No chemical analyses are available for fluids from the deep monitor well for April 1973 - February 1975. During this time the well either was used for waste injection or was being repaired.

Shallow Monitor Well

Geochemical effects associated with the upward migration of the waste are shown especially well by the chemical analyses of water from the shallow monitor well. Table 5 shows that calcium, magnesium and alkalinity concentrations increased; there was a reduction in sulfate concentrations; and generation of as much as 107 mg/1 of hydrogen sulfide. Dissolution of the carbonate rocks, anaerobic decomposition, and sulfate reduction within the subsurface environment is indicated. Also, dissolved-gas analyses indicate the presence of methane, nitrogen, and carbon dioxide.

Table 5.--Analyses of water from shallow monitor well.

DATE	TIME	DEPTH (FT)	TEMPERATURE (DEG C)	TURBIDITY (JTU)	COLOR (PLATINUM-COBALT UNITS)	SPECIFIC CONDUCTANCE (MICROMHOS)	CHEMICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L)	PH (UNITS)	CARBON DIOXIDE (CO2) (MG/L)	ALKALINITY AS CACO3 (MG/L)	TOTAL ACIDITY AS CACO3 (MG/L)	BICARBONATE (HCO3) (MG/L)
264200080390001 - 43S37E28 1 SHALLOW (LAT 26 42 00 LONG 080 39 00.01)												
MAR.. 1971												
18...	--	--	27.0	--	50	4550	--	8.1	--	902	--	1100
OCT.												
20...	--	--	--	--	60	4500	--	8.0	--	910	--	1110
20...	0900	--	--	--	--	--	--	--	--	--	--	--
MAR.. 1972												
28...	1000	--	25.0	20	20	4500	--	6.6	410	837	--	1020
28...	1000	--	25.0	--	--	4320	--	6.4	596	902	--	1100
SEP.												
28...	1200	--	35.0	30	40	4300	--	5.7	3290	845	10	1030
DEC.												
15...	1200	--	27.0	110	120	4680	1100	8.2	10	820	50	1000
15...	1200	--	27.0	--	--	3700	--	6.5	--	--	--	--
APR.. 1973												
19...	1000	--	32.0	100	40	4500	1100	6.6	418	853	194	1040
19...	1000	--	32.0	--	--	3600	--	6.6	442	902	--	1100
JULY												
06...	1200	--		120	60	4270	320	7.1	127	817	.0	996
06...	1200	--		--	--	4200	--	6.4	589	759	--	925
OCT.												
18...	1200	--	31.0	550	100	4460	1220	7.0	158	808	35	985
FEB.. 1974												
01...	1100	1400	--	200	100	4610	2600	6.6	422	861	20	1050
MAY												
03...	1030	1400	28.0	320	100	4400	57	--	--	1020	30	1240
JULY												
09...	1200	1400	34.5	270	50	4400	1400	6.5	640	1040	--	1264
NOV.												
05...	1230	1400	26.0	--	100	3300	--		1200	1090	--	1324
FEB.. 1975												
04...	1130	1400	27.0	140	300	5300	1300	6.5	709	1150	--	1400
APR.												
11...	1000	650	26.0	170	110	4700	1500	6.6	522	1070	--	1300

Table 5.--Analyses of water from shallow monitor well--cont.

DATE	DIS-SOLVED SODIUM (NA) (MG/L)	SODIUM AD-SORP-TION RATIO	PERCENT SODIUM	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)
264200080390001 - 43S37E28 1 SHALLOW (LAT 26 42 00 LONG 080 39 00.01)												
MAR., 1971												
18...	478	--	--	24	830	186	1.2	21	0	--	690	--
OCT.												
20...	500	--	--	30	870	218	.9	20	--	--	--	--
20...	--	--	--	--	--	--	--	--	--	--	--	--
MAR., 1972												
28...	480	5.7	43	27	940	210	.9	23	--	100	--	0
28...	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	500	5.7	42	44	860	310	1.0	20	--	0	--	0
DEC.												
15...	500	5.9	44	26	900	180	--	18	3	--	--	0
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR., 1973												
19...	540	6.2	44	30	400	240	1.0	24	--	4	--	0
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	500	6.2	47	25	860	170	1.1	20	4	4	--	1
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT.												
18...	550	6.5	46	50	920	160	1.0	21	9	--	--	--
FEB., 1974												
01...	520	6.0	43	32	880	170	1.0	22	--	12	--	--
MAY												
03...	550	7.0	50	31	850	130	1.2	23	--	5	--	--
JULY												
09...	500	5.6	41	35	900	250	.3	24	--	6	--	--
NOV.												
05...	480	5.4	40	35	880	190	1.2	23	--	4	--	--
FEB., 1975												
04...	500	5.6	41	58	960	50	1.0	24	--	4	--	--
APR.												
11...	500	5.5	40	32	960	110	.9	24	--	2	--	--

Table 5.--Analyses of water from shallow monitor well--cont.

DATE	DIS-SOLVED ORTHO PHOS-PHATE (PO4) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	DIS-SOLVED ORTHO. PHOS-PHORUS (P) (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	DIS-SOL-VED ORGANIC CARBON (C) (MG/L)	TOTAL IN-ORGANIC CARBON (C) (MG/L)	TOTAL CARBON (C) (MG/L)	TOTAL SUL-FIDE (S) (MG/L)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)
264200080390001 - 43S37E28 1 SHALLOW (LAT 26 42 00 LONG 080 39 00.01)												
MAR., 1971												
18...	.00	--	--	--	--	--	--		1450	549	258	186
OCT.												
20...	.23	--	--	--	--	--	--	--	1420	510	252	182
20...	--	--	--	380	--	--	--	--	--	--	--	--
MAR., 1972												
28...	--	.14	--	365	340	135	500	--	1400	570	250	180
28...	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	--	.22	--	280	--	70	350	--	1500	660	270	190
DEC.												
15...	--	.02	--	334	--	194	528	--	1400	570	260	170
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR., 1973												
19...	--	.20	--	274	--	146	420	72	1500	630	280	180
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	--	.02	--	237	--	--	--	40	1300	440	240	150
06...	--	--	--	--	--	--	--	40	--	--	--	--
OCT.												
18...	--	.06	--	310	--	--	--	--	1300	530	240	180
FEB., 1974												
01...	--	.03	--	300	--	--	--	--	1400	580	280	180
MAY												
03...	--	.14	--	330	--	140	470	--	1200	150	220	150
JULY												
09...	--	.06	--	310	--	--	--	--	1500	470	290	190
NOV.												
05...	--	--	--	--	--	--	--	--	1500	430	310	180
FEB., 1975												
04...	--	.08	--	330	--	--	--	--	1500	370	260	200
APR.												
11...	.40	.15	.13	600	--	--	--	--	1600	510	300	200

Table 5.—Analyses of water from shallow monitor well--cont.

DATE	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	SUS-PENDED SOLIDS (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	TOTAL ORTHO PHOS-PHORUS (P) (MG/L)	DENSITY (GM/ML AT 20 C)	TOTAL ACIDITY AS H+ (MG/L)	DIS-SOLVED AMMONIA (NH4) (MG/L)	TOTAL NITRATE (NO3) (MG/L)
264200080390001 - 43S37E28 1 SHALLOW (LAT 26 42 00 LONG 080 39 00.01)												
MAR.. 1971												
18...	30	--	0	--	--	2530	--	--	--	--	--	--
OCT.												
20...	20	--	--	--	--	2660	--	--	--	--	--	--
20...	--	--	--	--	--	--	--	--	--	--	--	--
MAR.. 1972												
28...	10	0	--	--	--	2600	--	--	1.003	--	--	.00
28...	--	--	--	--	--	--	--	--	--	--	--	--
SEP.												
28...	--	--	--	14	--	2700	--	--	--	.2	--	--
DEC.												
15...	--	--	--	126	--	2580	--	.00	--	1.0	--	--
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR.. 1973												
19...	10	170	--	28	--	2250	--	.15	--	3.9	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	0	--	--	14	--	2490	--	.02	--	.0	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT.												
18...	10	--	--	0	3160	2610	4.30	.03	--	--	--	--
FEB.. 1974												
01...	--	50	--	16	325	2600	.44	--	--	.4	1.3	--
MAY												
03...	--	70	--	0	3450	2570	4.69	.08	--	.6	--	--
JULY												
09...	--	50	--	5	3540	2810	4.81	.06	--	--	--	--
NOV.												
05...	--	0	--	8	3310	2750	4.50	--	--	--	--	--
FEB.. 1975												
04...	--	20	--	13	3360	2760	4.57	.08	--	--	--	--
APR.												
11...	--	30	--	36	3630	2770	4.94	--	--	--	--	--

Table 5.--Analyses of water from shallow monitor well--cont.

DATE	CARBONATE (CO3) (MG/L)	TOTAL NITROGEN (N) (MG/L)	TOTAL ORGANIC NITROGEN (N) (MG/L)	DISSOLVED AMMONIA NITROGEN (N) (MG/L)	AMMONIA NITROGEN (N) (MG/L)	DISSOLVED NITRITE (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	DISSOLVED NITRATE (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL KJELDAHL NITROGEN (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)
264200080390001 - 43S37E28 1 SHALLOW (LAT 26 42 00 LONG 080 39 00.01)												
MAR.. 1971												
18...	0	--	--	--	--	.00	--	--	--	--	--	--
OCT.												
20...	0	--	--	--	--	.00	--	--	--	--	--	--
20...	--	--	--	--	--	--	--	--	--	--	--	--
MAR.. 1972												
28...	0	--	1.0	--	1.0	--	.02	.00	.00	--	--	--
28...	0	--	--	--	--	--	--	--	--	--	--	--
SEP.												
26...	0	--	1.2	--	.78	--	1.9	--	.00	--	--	--
DEC.												
15...	0	--	1.0	--	1.1	--	.00	--	.00	--	--	--
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR.. 1973												
19...	0	--	1.8	--	.98	--	.03	--	.00	--	--	--
19...	0	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	0	2.2	1.3	--	.90	--	.00	--	.00	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT.												
18...	0	--	1.2	--	1.1	.01	--	.04	--	--	--	--
FEB.. 1974												
01...	0	--	1.9	1.0	--	.02	--	.04	--	--	--	--
MAY												
03...	--	2.7	1.3	--	1.4	--	.04	--	.00	--	--	--
JULY												
09...	--	2.6	1.2	--	1.4	--	.00	--	.00	2.6	.00	--
NOV.												
05...	--	--	--	--	--	--	--	--	--	--	--	--
FEB.. 1975												
04...	--	3.0	.90	--	2.1	--	.02	--	.06	3.0	.08	--
APR.												
11...	0	--	1.4	--	2.0	.08	--	.02	--	3.4	--	.10

Table 5.--Analyses of water from shallow monitor well--cont.

DATE	DIS_ SOLVED NITRATE (NO3) (MG/L)	DIS_ SOLVED NITRITE (NO2) (MG/L)	MAN- GANESE (MN) (UG/L)	IRON (FE) (UG/L)	TOTAL NITRO- GEN (NO3) (MG/L)	DEPTH TO TOP OF WATER- BEARING ZONE (FT)	SAMPLE SOURCE	TOTAL DEPTH OF WELL (FT)	SPE- CIFIC GRAVITY
264200080390001 - 43S37E28 1 SHALLOW (LAT 26 42 00 LONG 080 39 00.01)									
MAR., 1971									
18...	.00	.01	20	40	--	650	--	1400	--
OCT.									
20...	.00	.02	10	50	--	650	--	1400	--
20...	--	--	--	--	--	--	--	--	--
MAR., 1972									
28...	.00	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--
SEP.									
28...	--	--	--	--	--	--	--	--	--
DEC.									
15...	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--
APR., 1973									
19...	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--
JULY									
06...	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	1.0
OCT.									
18...	.20	.04	--	--	--	--	--	--	--
FEB., 1974									
01...	.20	.07	--	--	--	--	--	--	--
MAY									
03...	--	--	--	--	--	--	--	--	1.0
JULY									
09...	--	--	--	--	12	--	--	--	1.0
NOV.									
05...	--	--	--	--	--	--	--	--	--
FEB., 1975									
04...	--	--	--	--	14	--	--	--	1.0
APR.									
11...	.10	.26	--	--	--	--	--	--	1.0

Table 5.--Analyses of water from shallow monitor well--cont.

DATE	TOTAL CADMIUM (CD) (UG/L)	HEXAVALENT CHROMIUM (CR6) (UG/L)	TOTAL CHROMIUM (CR) (UG/L)	DISSOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MANGANESE (MN) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED STRONTIUM (SR) (UG/L)
264200080390001 - 43S37E28 1 SHALLOW (LAT 26 42 00 LONG 080 39 00.01)												
MAR.. 1971												
18...	--	0	--	0	--	--	--	0	--	--	--	--
OCT.												
20...	--	0	--	0	--	--	--	10	--	--	--	--
20...	--	--	--	--	--	--	--	--	--	--	--	--
MAR.. 1972												
28...	1	0	--	0	0	30	30	0	6	10	10	36000
28...	--	--	--	--	--	--	--	--	--	--	--	--
SEP..												
28...	--	0	--	0	--	--	--	5	--	--	--	39000
DEC.												
15...	--	0	--	10	--	--	--	6	--	--	--	36000
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR.. 1973												
19...	5	0	0	2	10	--	--	--	--	--	--	36000
19...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
06...	--	0	--	0	--	--	--	1	--	--	--	33000
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT.												
18...	--	0	--	0	--	--	--	23	--	--	--	30
FEB.. 1974												
01...	1	0	--	--	5	--	--	--	8	--	--	--
MAY												
03...	1	0	0	--	4	--	--	--	5	--	--	--
JULY												
09...	1	0	<10	--	4	--	--	--	10	--	--	--
NOV.												
05...	8	0	<10	--	0	--	--	--	0	--	--	--
FEB.. 1975												
04...	0	1	<10	--	0	--	--	--	3	--	--	--
APR.												
1...	0	0	<10	--	0	--	--	--	2	--	--	--

To discriminate between changes in the ground-water chemistry due to (1) waste migration and (2) dilution and mixing of various waters, use is made of the sulfate/chloride ratio. The chloride concentration indicates the extent of mixing with underlying more saline waters.

According to Kaufman and McKenzie (1975), "Changes in sulfate/chloride ratios in the monitor well fluids were evaluated and compared with operational changes in the injection system. Emphasis was placed on interpreting observed changes in this ratio with respect to waste migration." That is, a decrease in the ratio suggests the arrival of the nutrient-rich waste.

The lack of comprehensive chemical analyses of natural fluids from several zones at the injection site prior to waste injection places a constraint on any interpretations concerning the chemical character of the natural water. However, water from the Experimental Station well, about 3 miles (4.8 km) from the injection well, is considered to represent the natural subsurface background in the upper part of the Floridan aquifer. As already stated, the chemical quality of the water from the well has not changed significantly in more than 40 years. Water from the well has a sulfate/chloride ratio usually greater than 510/1,600 (1:3.1) and a hydrogen sulfide concentration of about 4.0 mg/l.

Changes in sulfate/chloride Ratio

According to Kaufman and others (1973) and Kaufman and McKenzie (1975), oxidation (decomposition) of organic waste by sulfate-reducing bacteria was taking place within the saline subsurface environment by means of anaerobic bacterial processes in which sulfate (and perhaps CO_2)

serves as the source of oxygen. In this system, as the organic material is oxidized, sulfate concentrations decreased also and the decrease in sulfate is quantitatively equal to the increase in hydrogen sulfide.

Observations: 1969-73

Subtle chemical changes, indicated by slight increases in calcium concentration and alkalinity and by a slight decrease in the sulfate/chloride ratio (fig. 4) suggest that the waste front arrived at the shallow monitor well in February-March 1969, about 27 months after waste injection began. By March 1971 the sulfate/chloride ratio had declined from 0.42 to 0.22. The slight increase in the ratio (fig. 4) late in 1970, is correlated with a plant shutdown.

Waste injection into the deepened disposal well began in January 1972. By March 1972, the sulfate/chloride ratio in fluid from the shallow monitor well had decreased slightly from 0.25 to 0.22. From 0.22 in March 1972 the ratio increased to 0.36 in September, then to 0.42 in December. This increase is attributed to a plant shutdown from early August through October 1972. Waste injection resumed in November 1972, and the sulfate/chloride ratio again decreased, from 0.42 in December 1972 to 0.27 in April 1973.

From December 1972 to July 1973, sulfate concentration and the sulfate/chloride ratio changed considerably, apparently reflecting the greater sensitivity of these indicators to renewed waste migration and consequent bacterial action.

Information on this system for the first 3 years of operation (1967-69) has been reported by Garcia-Bengochea and Vernon, 1970.

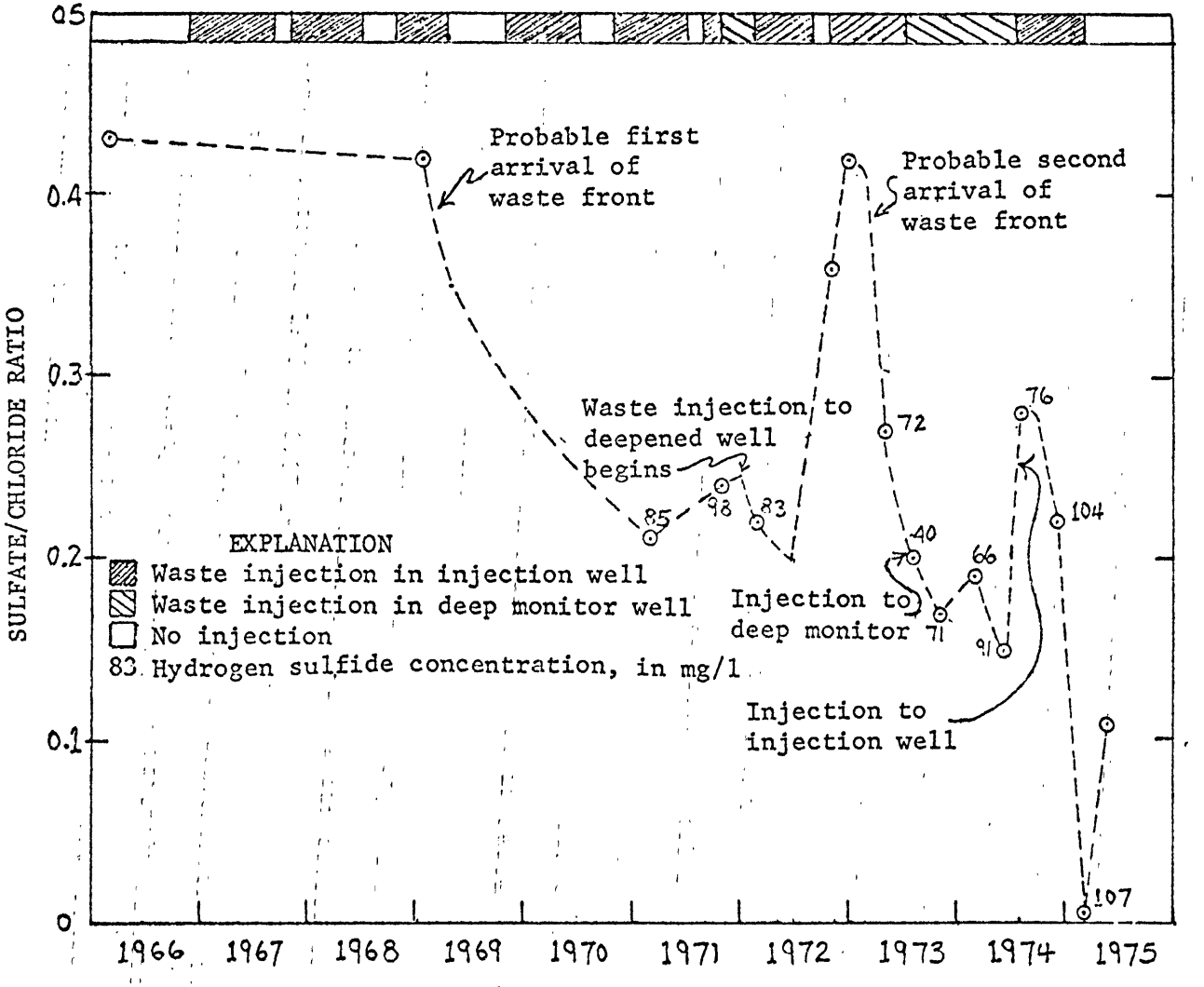


Figure 4.--Sulfate reduction in shallow monitor well fluid, 1966-75. (Pre 1971 data from Garcia-Bengochea and Vernon, 1970)

Observations: 1973-75

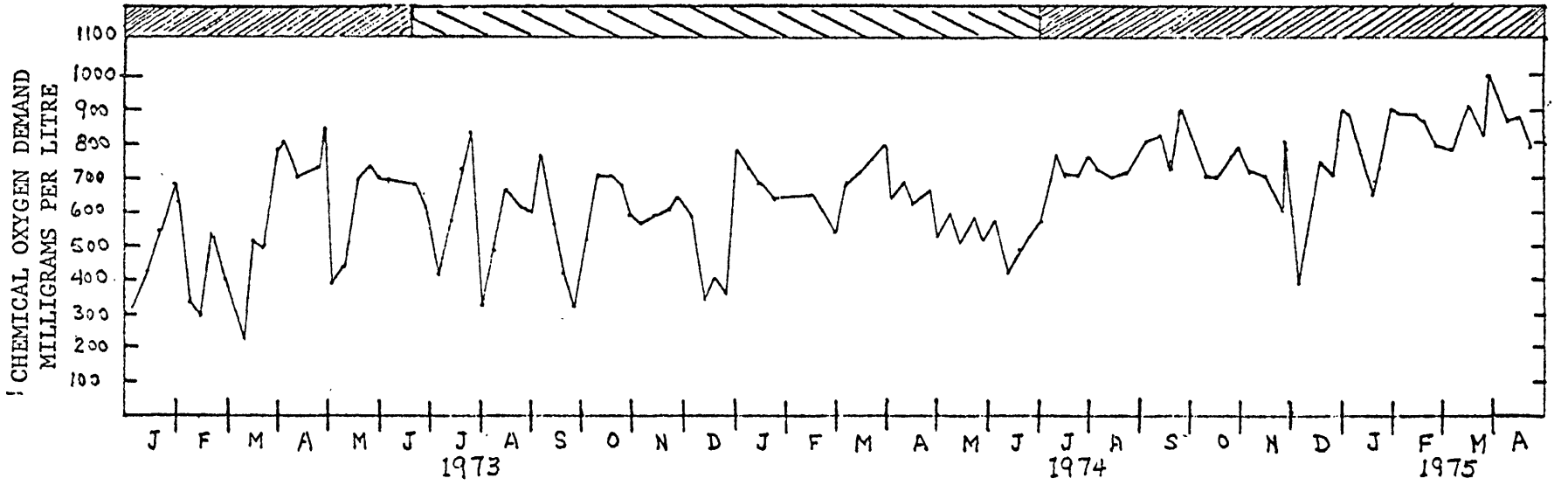
In June 1973 the disposal well was shut down by the operators and waste was diverted to the deep monitor well. In water from the shallow monitor well, the sulfate/chloride ratio decreased from 0.27 in April 1973 to 0.20 in July and to 0.15 in May 1974 (fig. 4). During this time span, hydrogen sulfide increased in concentration from 40 mg/l to 91 mg/l. This suggests that waste injection into the deep monitor well also resulted in upward leakage from the injection zone to the shallow monitor well although the site of the deep monitor well is about 1,000 ft (305 m) from the shallow monitor, compared to only 75 ft (25 m) between the disposal well and the shallow monitor. During April 1973-May 1974, calcium, magnesium, sodium, and silica remained approximately unchanged in concentration (table 5). However, there was a gradual but constant increase in alkalinity. The slight increase in the sulfate/chloride ratio that occurred from November 1973 to February 1974 may be due to a lag effect from shifting waste injection away from the injection well or possibly to the exceptionally low volume of waste that was injected in August and September (fig. 3).

Waste was redirected to the disposal well in June 1974 after repairs to the liner were completed. In July the sulfate/chloride ratio in water from the shallow monitor well increased substantially from the previous value (fig. 4), reflecting, perhaps, a lag between resumption of waste injection into the disposal well and the arrival of waste at the shallow monitor. The sulfate/chloride ratio decreased to 0.05 in February 1975, an indication that leakage of waste fluid to the upper part of the Floridan aquifer was continuing.

During the period of injection, July 1974 to April 1975, concentrations of calcium, magnesium, sodium and silica remained constant and pH did not change significantly. Alkalinity, on the other hand, continued its regular increasing trend since October 1973, following the diverting of waste from the disposal well into the deep monitor well (808 to 1,070 mg/1). There was an attendant constant drop in non-carbonate hardness. The COD and TOC (total organic carbon) also increased slightly. Color increased from 100 to 110 units. Conductivity increased from 4,400 to 4,700 micromhos.

Chemical-Oxygen-Demand Data and Waste Migration

Kaufman and others (1973) showed that changes in COD and pH in water in the shallow monitor also are closely related to waste injection schedules. COD increased and pH decreased in the water from the shallow monitor well when the injected waste arrived at the shallow monitor. Both a seasonal plant shutdown and, for a time, diversion of waste injection to the deep monitor well resulted in COD and pH becoming relatively stable in the shallow monitor. However, as illustrated by the graph of COD values in figure 5, from January 1973 through December of that year, the COD of the fluid from the shallow monitor fluctuated widely, from 220 to 840 mg/1. By December end, waste had been injected into the deeper monitor well for 7 months. From December 1973 to July 1974, when waste injection into the disposal well resumed, the COD concentration fluctuated less widely on a short-term basis. Since July 1974, fluctuation has, in general, not been great but the concentration had, by March end 1975, increased nearly to 1,000 mg/1. On the



▨ Indicates waste injection in injection well.
▧ Indicates waste injection in deep monitor.

Figure 5.--Chemical-oxygen-demand for shallow monitor well fluid.
(Data furnished by Quaker Oats Co.)

basis of information available to the author, the change in the character of the fluctuations since December 1973 cannot be explained. However, the long-term increase to 1,000 mg/l in 1975 is interpreted to mean that increasing quantities of the injected waste are moving into the upper part of the Floridan aquifer.

SUMMARY AND DISCUSSION

In 1966 a furfural plant at Belle Glade, Florida, began injecting hot, acidic liquid waste into the saline, water-filled lower part of the Floridan aquifer between the depths of 1,495-1,939 ft. By February-March 1969 or within a time span of about 27 months, effects of the waste injection were detected in the water of the shallow monitor well, which samples the upper part of the Floridan aquifer, above the so-called "confining" layer.

In an attempt to stop the upward migration of waste, the disposal well was deepened to 2,242 ft (683 m) during October 1971 to January 1972. During the construction, the deep monitor well was used for waste injection. Within 15 months after waste injection into the deepened disposal well was resumed, effects of the waste were again detected in the shallow monitor well water.

In June 1973, the disposal well was again shut down to repair a portion of the bottom section of the injection liner destroyed by corrosion. Waste was again diverted to the deep monitor well. A report by Kaufman and McKenzie (1975) documents the time span for early 1966 through July 1973.

Repairs on the deep disposal well were completed and injection was redirected to the well in July 1974. By February 1975, effects of the

renewed injection into the disposal well were very significant in the shallow monitor well, only 7 months after the resumption of injection. Leakage into the upper part of the Floridan aquifer was continuing at a faster rate than noted earlier.

From the information contained in the earlier report by Kaufman and McKenzie (1975) it was evident that the receiving carbonate aquifer could not contain the hot, acidic wastes, even when the injection well was deepened to 2,242 ft.

This report gives information showing that remedial actions of repairing the disposal well liner and injecting into the deep monitor well still had no significant effect for containing wastes within the lower part of the Floridan aquifer.

Though data indicate continued movement of the waste into the upper part of the Floridan aquifer, the areal extent of the zone of contamination is still unknown. Only additional monitor wells in the injection zone and upper part of the Floridan aquifer, upgradient and farther downgradient, could determine how far and lateral the waste has moved.

In a new attempt to contain the wastes, construction of a test injection well to a depth of about 3,000 ft (914 m) was begun in September 1975. A program to monitor the effectiveness of the new disposal well when it becomes operational is planned.

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