TECHNICAL MEMORANDUM

HYDROGEOLOGIC INVESTIGATION ALONG EASTERN PORTIONS OF LAKE OKEECHOBEE

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#105

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HYDROGEOLOGIC INVESTIGATION ALONG EASTERN PORTIONS OF LAKE OKEECHOBEE

INTRODUCTION

Purpose and Scope

The purpose of this study was to document how changes in Lake Okeechobee stages are reflected in groundwater level changes on the landward side of the Hoover Dike and how the lake influences water quality. Two sites were considered - one in Belle Glade and one in Canal Point. At the Canal Point site close examination was made of an avocado grove where questions were raised involving the effects of increased lake stage. In order to determine the extent of hydraulic connection, seepage through the dike was calculated. These values may be compared to those of Meyer (3). The analysis of these data allowed for determination of the effect of lake stage on areas surrounding eastern portions of Lake Okeechobee.

In this report, all elevations are referred to the National Geodetic Vertical Datum (NGVD) and are reported as feet above mean sea level (msl). Duration of this study was approximately eight months - from June 1979 to January 1980. Within this period, lake stage went from 15.23 ft. (msl) to the 1979 low of 14.27 ft. (msl), then to a high of 17.58 ft. (msl). Water levels, rainfall, and water quality data were collected and used in this study. Historical data was also used when available to supplement data collected during this study.

Previous Studies

A concise, in depth report documents seepage beneath the Hoover Dike on the south shore of Lake Okeechobee in 1965 (Meyer (3)). This reference, cited often herein, supplied baseline data to which current data was compared. Since the same wells were used, the current data was directly correlated with that reported by Meyer (3).

Location of Investigation

Two sites were selected along the eastern shore of Lake Okeechobee in Palm Beach County for this study (Figure 1). The southernmost site along Levee D2 of the Herbert Hoover Dike is located approximately 3 miles north of Belle Glade. The second site is approximately one mile north of Canal Point along Levee D9.

The two sites shall be referred to as the Belle Glade site and the Canal Point site throughout this study. The Belle Glade site is located in Section 13, T43S, R36E, along Levee D2 at U. S. Army Corps of Engineer Station 980 +00 (Figure 2A). The Canal Point site in Section 27, T41S, R37E, along Levee D9 at U. S. Army Corps of Engineer Station 390 + 06 (Figure 2B).

These two locations were selected to conform with sites 4 and 5 as designated by Meyer (3) and shown here in Figures 2A and 2B, respectively. The intent in choosing these two sites was to utilize previously existing USGS monitor wells drilled specifically to study seepage beneath the Hoover Dike. At the Belle Glade location, represented by site 4 of the Meyer (3) investigation, all USGS monitor wells were destroyed. At the Canal Point site, or site 5, four of the original USGS monitor wells (one having a digital recorder installed) remained intact. All 4 of these wells were utilized for this study.

It was intended that this study should aid in determining whether a direct relationship existed between lake stage and water levels beneath the avocado grove in Canal Point. The results of this study should also be applicable to other areas adjacent to eastern portions of the lake.

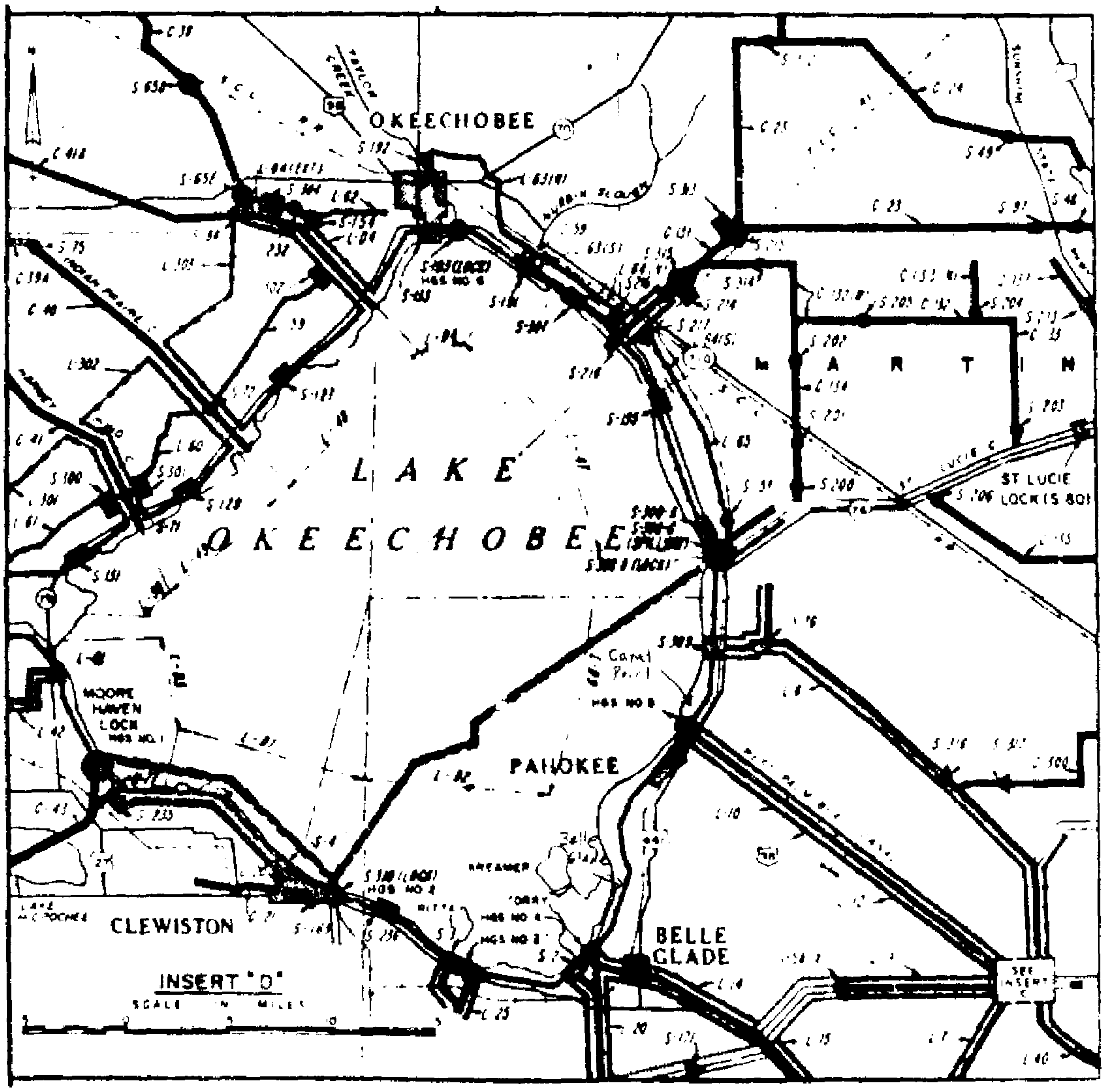
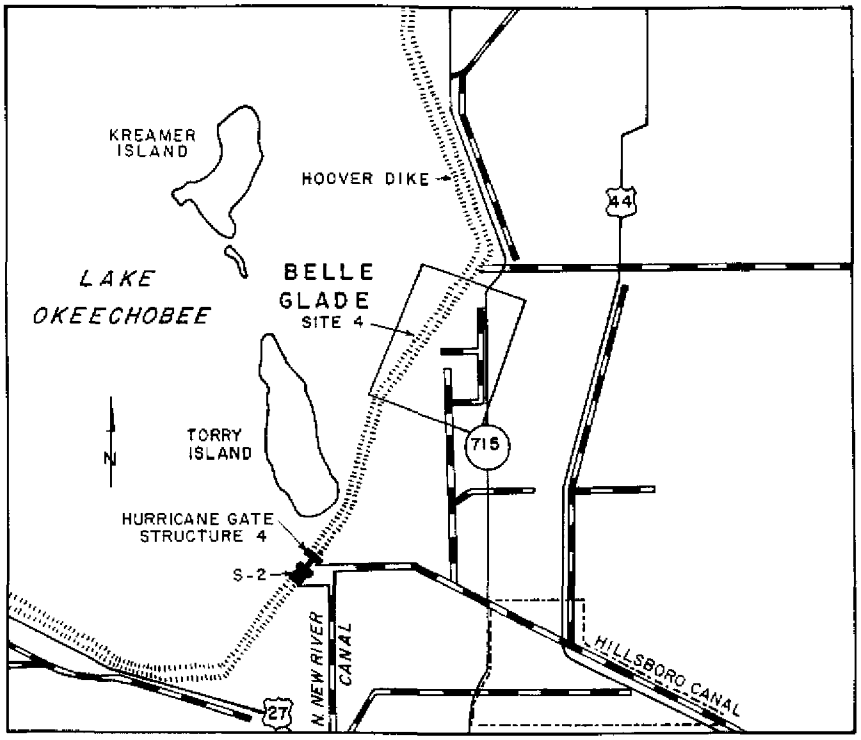


FIGURE 1. Generalized Location of Lake Okeechobee and Surrounding Area



Lake Okeechobee Area Showing Location of Site 4 at Belle Glade

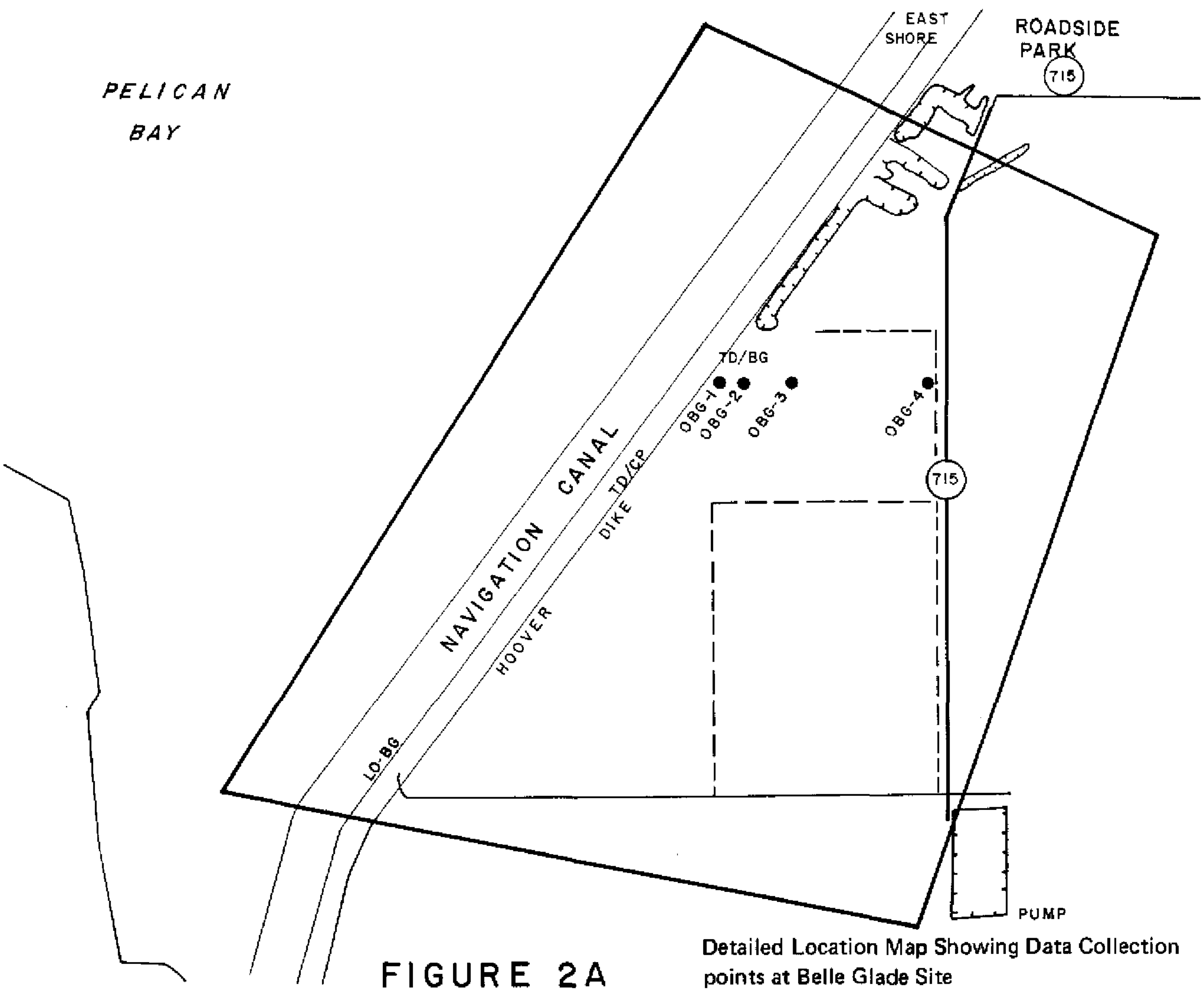
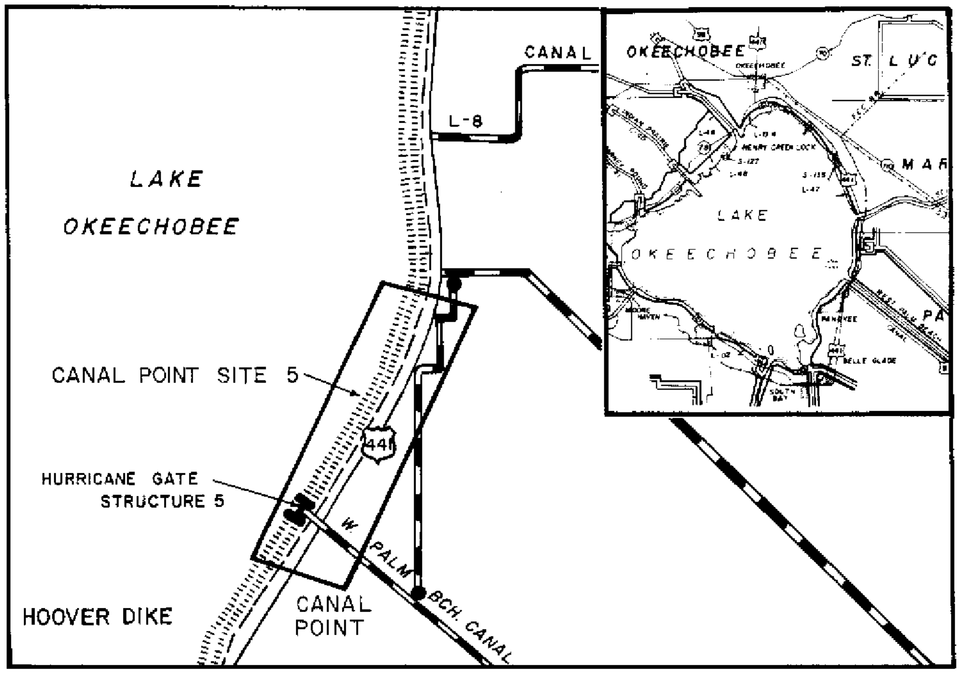
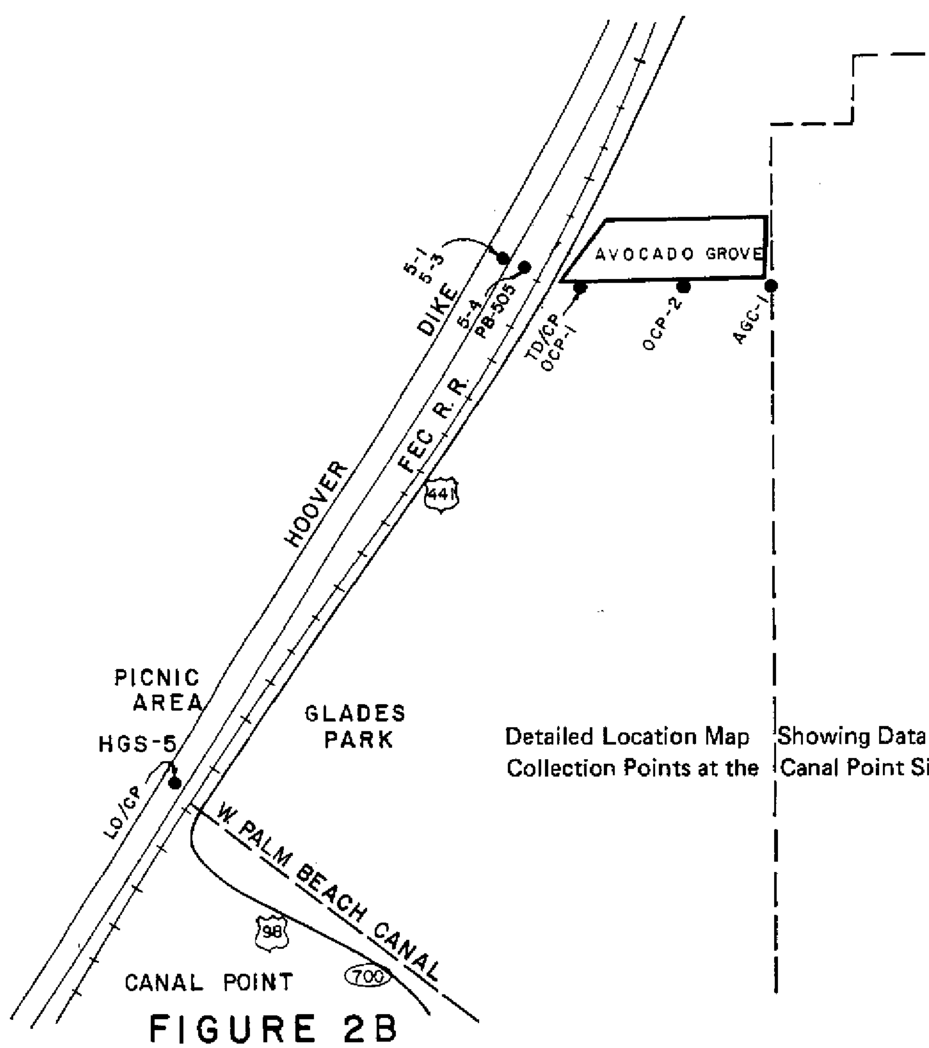


FIGURE 2A

Detailed Location Map Showing Data Collection points at Belle Glade Site



Lake Okeechobee Area Showing Location of Site 5 at Canal Point



Detailed Location Map Showing Data Collection Points at the Canal Point Site

FIGURE 2B

Methods of Investigation

At the Belle Glade site, four observation wells (OBG-1 through OBG-4) were drilled along a cross section perpendicular to the dike, beginning at the landward side of the toe ditch and extending a distance of 2,950 feet from the edge of the lake (Figure 3). Rock samples were collected from each borehole to map the underlying formations. Observation wells were constructed using 2-inch schedule 40 PVC casing fitted with 3-foot PVC wellscreens having slots of .020 inch open to the aquifer. A staff gauge was installed in the toe ditch adjacent to the wells. Unfortunately, no USGS monitor wells were available at this site.

At the Canal Point site, two observation wells (OCP-1 and OCP-2) were drilled perpendicular to the dike and just south of the plot containing avocado trees (Figure 4). These two wells were in direct line with the USGS site 5 cross section. Included in the cross section were two wells on the landward toe of slope (5-4 and PB-505, also known as 5-2 (Meyer, 3)) and a staff gauge in the adjacent toe ditch. Two wells on the lake side toe of slope were also used (5-1 and 5-3). Wells 5-1 and PB-505 are open to the aquifer while wells 5-3 and 5-4 are open to the confining zone. Lake Okeechobee stage is taken from the lake side of Hurricane Gate Structure 5 (HGS-5).

Periodic sample runs were conducted to collect water samples and water level measurements. During each sample run a data sheet was completed with all pertinent information - lake stage and groundwater levels - and the corresponding hydraulic gradients were thus documented. (Appendices).

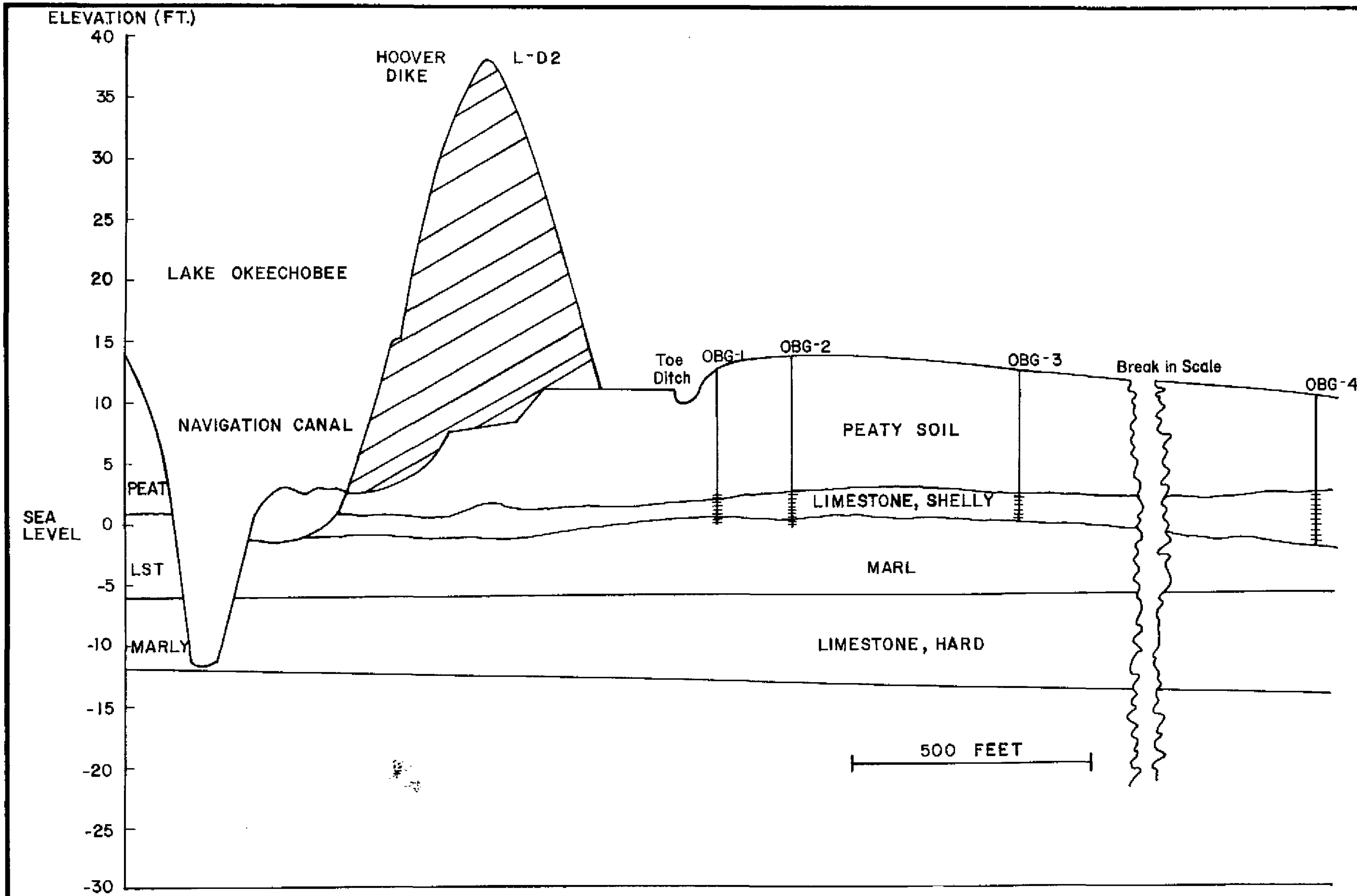


Figure 3. Geologic Cross Section of Belle Glade Site Showing Monitor Wells and Screened Portion

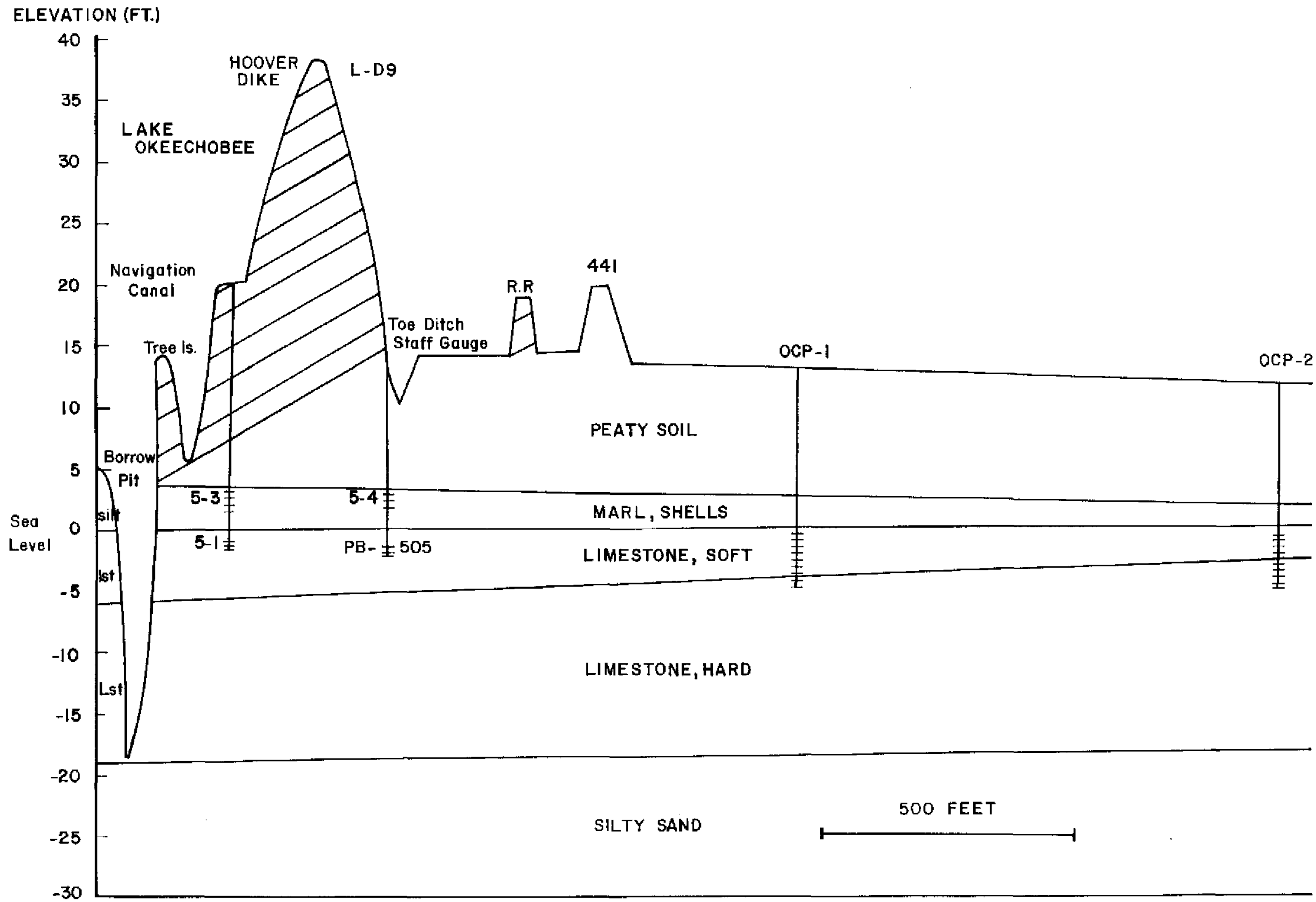


Figure 4. Geologic Cross Section of Canal Point Site Showing Monitor Wells and Screened Portion

Seepage

To determine the seepage through the dike, methods similar to those of Meyer (3) were used. Values obtained from this study can be directly compared to those calculated for 1965 conditions since the same wells were used. Seepage was calculated using the following equation:

$$Q = T\ I\ L$$

where

Q = seepage (L^3T^{-1})

T = transmissivity (L^2T^{-1})

I = hydraulic gradient (dimensionless)

L = length of dike along which T was effective (L).

And

$$I = \Delta h/d$$

where

Δh = difference in head between water conditions in two observation wells in the same formation (L)

d = distance between the two wells (L).

Once the seepage rate is computed, the value can be related to the hydraulic gradient. Seepage (Q) can be expressed by a seepage factor (Se) using the following equation:

$$Se = \frac{Q}{L(hl-hc)}$$

where

Se = the seepage factor, or rate of seepage per length of recharge and discharge boundaries (LT^{-1})

Q = Seepage (L^3T-1)

L - length of recharge boundary (L)

hl = elevation of water at recharge boundary (L)

hc = elevation of water at discharge boundary (L)

HYDROGEOLOGIC SETTING

Details of Levees D2 and D9 are found in "Detail Design Memorandum, Herbert Hoover Dike, Levees D2 (part), D9 and D4, U. S. Corps of Engineers Report on Central and Southern Florida Project, Part IV, Supplement 18". (4). Levee D9 borders Lake Okeechobee in the vicinity of Canal Point. A toe ditch east of the dike conveys runoff and seepage southward to the West Palm Beach Canal. Since it is the seepage through this levee that was in question, emphasis was placed on that portion of the dike.

A geologic cross section of the Canal Point location is shown in Figure 4. Position of the monitor wells along with the opened screen portion is also shown. The upper bed is relatively impermeable and has a maximum thickness of 14 feet. The upper 11 feet of this bed is a black, peaty, organic soil. The lower 3 feet is a shelly marl. The underlying aquifer material has a maximum thickness of 20 feet. The upper 4 feet of the aquifer is a soft, shelly limestone which is underlain by a layer of hard crystalline limestone 10 feet thick. Below this is a soft, porous, shelly limestone that locally contains stringers of sand, Meyer (3).

Results

A summary of water level data is shown in Table 1. Values are given in feet above mean sea level. The elevation of water in the toe ditch remained fairly constant during changing lake stages. Throughout the duration of this study, average lake stage was 15.85 feet with a standard deviation of 1.44 ft. The toe ditch stage had an average elevation of 11.94 feet and a standard deviation of .28 ft. Therefore, during periods of increased lake stage, the stage in the toe ditch remained relatively

Date	Lake Okee.	5-1	5-3	5-4	5-2 PB-505	TD/CP	OCP-1	OCP-2
6-13-79	15.23						11.00	9.86
6-21-79	14.96						10.63	9.49
6-25-79	14.84						10.52	9.28
7-5-79	14.63	13.47	14.89	12.26	12.85	11.60	10.49	9.21
7-17-79	14.60	13.57	14.82	12.44	12.87	11.97	10.49	9.29
8-9-79	14.36	13.30	14.48	12.20	12.64	11.70	10.55	9.55
8-22-79	14.27						11.02	9.80
10-3-79	17.46	16.00	17.73	13.70	14.77	12.25	11.94	10.87
10-10-79	17.58	15.92	17.82	13.54	14.59	12.02	11.64	10.38
11-6-79	17.51	15.83	17.76	13.39	14.46	11.89	11.47	9.86
12-5-79	17.36	15.79	17.60	13.69	14.66	12.40	11.61	10.28
1-17-80	17.36	15.70	17.31	13.37	14.50	11.95	11.70	10.51

TABLE 1A. Summary of Water Level Data from Canal Point Site. Elevation in feet above Mean Sea Level.

Date	Lake Okee.	TD/BG	OBG-1	OBG-2	OBG-3	OBG-4
6-13-79	15.23		8.37	8.32	7.58	6.74
6-21-79	14.96		8.13	8.07	7.30	6.47
6-25-79	14.84	8.36	8.39	8.35	7.61	6.77
7-5-79	14.63	8.70	8.65	8.64	8.05	7.46
7-17-79	14.60	8.50	8.54	8.56	7.97	7.19
8-9-79	14.36	8.82	8.78	8.78	8.34	7.53
8-22-79	14.27	9.36	9.32	9.33	8.99	8.47
10-3-79	17.46	9.46	9.45	9.56	8.82	7.53

TABLE 1B. Summary of Water Level Data from Belle Glade Site. Elevation in feet above Mean Sea Level.

constant. The water level data for Canal Point also indicated that the flow of water in the toe ditch was southward and discharged into the West Palm Beach Canal.

At the Canal Point site a sufficient number of properly placed wells existed to allow for reliable calculations of seepage values. Wells 5-1 and PB-505 were used to calculate the seepage through the aquifer (Qa). Wells 5-3 and 5-4 were used to calculate the seepage through the confining zone (Qc). Both pairs of wells were 285 feet apart. Meyer (3) estimated the transmissivities at this site to be 20,700 gpd/ft for the aquifer and 50 gpd/ft for the confining zone. The seepage for these two pairs of wells were added to determine the total seepage (Qt) and then related to the head difference between the lake and well PB-505 to calculate the seepage factor. The seepage factor, Se, is the rate of seepage per a one mile length of recharge per foot of head between the recharge and discharge boundaries. These results are shown in Table 2, and may be compared to those results of Meyer (3) also shown in Table 2.

Surface water samples and groundwater samples were collected twice during this study. These were taken at both the Belle Glade and Canal Point sites. All 23 samples were analyzed for the parameters listed in Table 3. The results of the chemical analyses are shown in Table 4. Table 5 is a summary of the mean and standard deviation of all 23 samples for each parameter.

Discussion

It is apparent from Figure 5 that water levels in PB-505 and the lake stage are highly correlative. Fluctuations in lake stage correspond directly to the change in groundwater elevation in PB-505. Both of these water levels increased noticeably after major rainfall events. Increased

DATE	Lake Okee. (Ft.)	5-1 (Ft.)	PB-505 (Ft.)	5-3 (Ft.)	5-4 (Ft.)	Δh (Ft.)	Qc (cfs/mi)	Qa (cfs/mi)	Qt (cfs/mi)	Se (cfs/ft)
1-14-65	~14.38					0.66	0.002	0.246	0.248	0.38[1]
6-4-65	~12.42					.23	.0002	.0845	.0847	.37[1]
10-11-65	~14.54					.64	.003	.193	.196	.31[1]
7-5-79	14.63	13.47	12.85	14.89	12.26	1.78	.004	.36	.37	.21
7-17-79	14.60	13.57	12.87	14.82	12.44	1.73	.003	.40	.42	.24
8-9-79	14.36	13.30	12.64	14.48	12.20	1.72	.003	.39	.40	.23
10-3-79	17.46	16.00	14.77	17.73	13.70	2.69	.006	.73	.73	.28
10-10-79	17.58	15.92	14.59	17.82	13.54	2.99	.006	.79	.80	.27
11-6-79	17.51	15.83	14.46	17.76	13.39	3.05	.006	.82	.83	.27
12-5-79	17.36	15.79	14.66	17.60	13.69	2.70	.006	.67	.68	.25
1-17-80	17.36	15.70	14.50	17.31	13.37	2.86	.006	.71	.72	.25

TABLE 2. Seepage (Q) and Seepage Factor (Se) of Aquifer and Confining Zone[2]

1. Data from Meyer (1971)

2. In this table: Qa = seepage between wells 5-1 and PB-505 in aquifer
   Qc = seepage between wells 5-3 and 5-4 in confining bed
   Qt = total seepage in aquifer and confining bed (Qa + Qc)
   Se = seepage factor = Qt/Δh x L
   Δh = difference in head between the Lake and PB-505

   Values used in these calculations are:
   T aquifer = 20,700 gpd/ft
   T confining = 50 gpd/ft
   d = distance for both pairs of wells, 285 feet

PARAMETER	UNITS
Lab Conductivity	umhos/cm
Total Dissolved Solids	mg/l
NA	mg/l
K	mg/l
Ca	mg/l
Mg	mg/l
Cl	mg/l
Sulfate	mg/l
Alkalinity	meq/l
Alkalinity ($CaCO_3$)	mg/l
Hardness	mg/l $CaCO_3$
Total Dissolved Iron	mg/l

TABLE 3. Chemical Parameters and Units used in Laboratory Analyses

SAMPLE NUMBER	DATE MO/DA/YR	TIME HOUR,MIN	STATION CODE	LAB COND UMHOS/CM	T.DIS.SD MG/L
JES - 1	12/ 5/79	930.	OBG-1	1120.	749.0
JES - 2	12/ 5/79	945.	OBG-2	1140.	766.0
JES - 3	12/ 5/79	1000.	OBG-3	1400.	972.0
JES - 4	12/ 5/79	1020.	OBG-4	8800.	5986.0
JES - 5	12/ 5/79	1025.	BG-TD	1000.	771.0
JES - 6	12/ 5/79	1030.	BG-LD	620.	438.0
JES - 7	12/ 5/79	1200.	OCP-1	1020.	733.0
JES - 8	12/ 5/79	1220.	OCP-2	2500.	1632.0
JES - 9	12/ 5/79	1225.	CP-TD	1000.	695.0
JES - 10	12/ 5/79	1230.	CP-LD	630.	385.0
JES - 11	1/18/80	1000.	OBG-1	1140.	731.0
JES - 12	1/18/80	945.	OBG-2	1200.	799.0
JES - 13	1/18/80	930.	OBG-3	1440.	946.0
JES - 14	1/18/80	915.	OBG-4	9100.	5965.0
JES - 15	1/18/80	1005.	BG-TD	1140.	773.0
JES - 16	1/18/80	1020.	BG-LD	600.	375.0
JES - 17	1/18/80	1100.	OCP-1	1060.	706.0
JES - 18	1/18/80	1115.	OCP-2	2650.	1573.0
JES - 19	1/18/80	1120.	AGC-1	2000.	1232.0
JES - 20	1/18/80	1200.	5-4	990.	586.0
JES - 21	1/18/80	1215.	5-1	800.	436.0
JES - 22	1/18/80	1205.	CP-TD	1400.	1047.0
JES - 23	1/18/80	1220.	CP-LD	560.	341.0

TABLE 4. Results of Chemical Analyses

SAMPLE NUMBER	NA MG/L	K MG/L	CA MG/L	MG MG/L	CL MG/L
JES - 1	93.81	7.87	83.35	49.10	149.1
JES - 2	84.35	10.82	76.03	57.69	171.2
JES - 3	125.36	12.43	91.26	62.84	208.5
JES - 4	1529.02	32.24	115.39	150.57	2098.4
JES - 5	73.84	5.79	109.06	38.03	161.8
JES - 6	53.86	4.40	47.36	18.29	94.2
JES - 7	83.30	19.49	93.64	40.00	91.9
JES - 8	374.71	21.03	35.30	35.37	573.0
JES - 9	67.95	6.65	93.24	41.89	96.5
JES - 10	55.96	4.83	49.73	18.29	94.2
JES - 11	113.80	7.20	75.94	44.24	141.6
JES - 12	116.55	9.30	75.61	52.87	155.0
JES - 13	143.84	11.84	79.73	53.75	196.4
JES - 14	2274.57	34.75	103.95	138.24	521.9
JES - 15	100.05	7.14	104.44	37.20	130.5
JES - 16	78.04	4.53	42.67	15.50	89.1
JES - 17	119.79	20.35	52.23	44.24	94.7
JES - 18	521.43	21.51	29.66	30.60	1389.2
JES - 19	267.36	6.63	59.14	39.18	151.7
JES - 20	80.46	7.30	52.06	41.34	79.1
JES - 21	55.06	5.51	56.84	29.72	63.4
JES - 22	102.31	7.17	146.44	62.55	113.7
JES - 23	62.34	4.45	44.32	18.94	81.3

TABLE 4. Results of Chemical Analyses (Continued)

SAMPLE NUMBER	SO4 MG/L	ALK MEQ/L	ALKCACO3 MG/L	HARDNESS MG/LCACO	TDISS FE MG/L
JES - 1	57.3	6.75	337.5	410.2	< 0.02
JES - 2	43.7	7.36	368.0	427.3	0.04
JES - 3	103.4	7.36	368.0	486.5	< 0.02
JES - 4	815.2	17.99	899.5	907.9	< 0.02
JES - 5	70.8	7.12	356.0	428.9	0.19
JES - 6	54.6	2.34	117.0	193.5	0.07
JES - 7	19.3	8.60	430.0	398.5	< 0.02
JES - 8	38.3	9.96	498.0	233.7	< 0.02
JES - 9	73.6	6.62	331.0	405.2	0.05
JES - 10	50.5	2.21	110.5	199.5	0.09
JES - 11	79.9	4.74	237.0	371.7	< 0.02
JES - 12	81.3	6.96	348.0	406.4	< 0.02
JES - 13	121.2	7.08	354.0	420.3	0.04
JES - 14	815.1	15.24	762.0	828.6	< 0.02
JES - 15	122.7	4.15	207.5	413.9	0.04
JES - 16	52.0	2.34	117.0	170.3	0.02
JES - 17	30.7	8.19	409.5	312.5	0.02
JES - 18	76.0	19.55	977.5	200.0	0.02
JES - 19	97.3	3.14	157.0	308.9	0.04
JES - 20	12.0	7.33	366.5	300.1	0.56
JES - 21	6.7	4.25	212.5	264.3	0.08
JES - 22	166.5	9.67	483.5	623.1	0.11
JES - 23	38.7	2.40	120.0	188.6	0.05

TABLE 4. Results of Chemical Analyses (Continued)

Parameter	Mean	Standard Deviation	Minimum	Maximum
Lab Conductivity	1883.0	2294.2	560	9100
Total Dissolved Solids	1233.3	1492.9	341	5986
NA	286.0	5339.0	55.06	2274
K	11.9	8.8	4.40	34.75
CA	74.7	29.6	29.66	146.44
MG	48.7	33.1	15.50	150.57
Cl	302.0	483.4	63.4	2098.4
Sulfate	131.6	219.0	6.7	815.2
Alkalinity	7.5	4.7	2.21	19.55
Alkalinity ($CaCO_3$)	372.5	234.9	110.5	977.5
Hardness	386.9	189.6	170.3	907.9
Total Dissolved Iron	.07	.11	<0.02	0.56

TABLE 5. Statistical Summary of Chemical Analyses

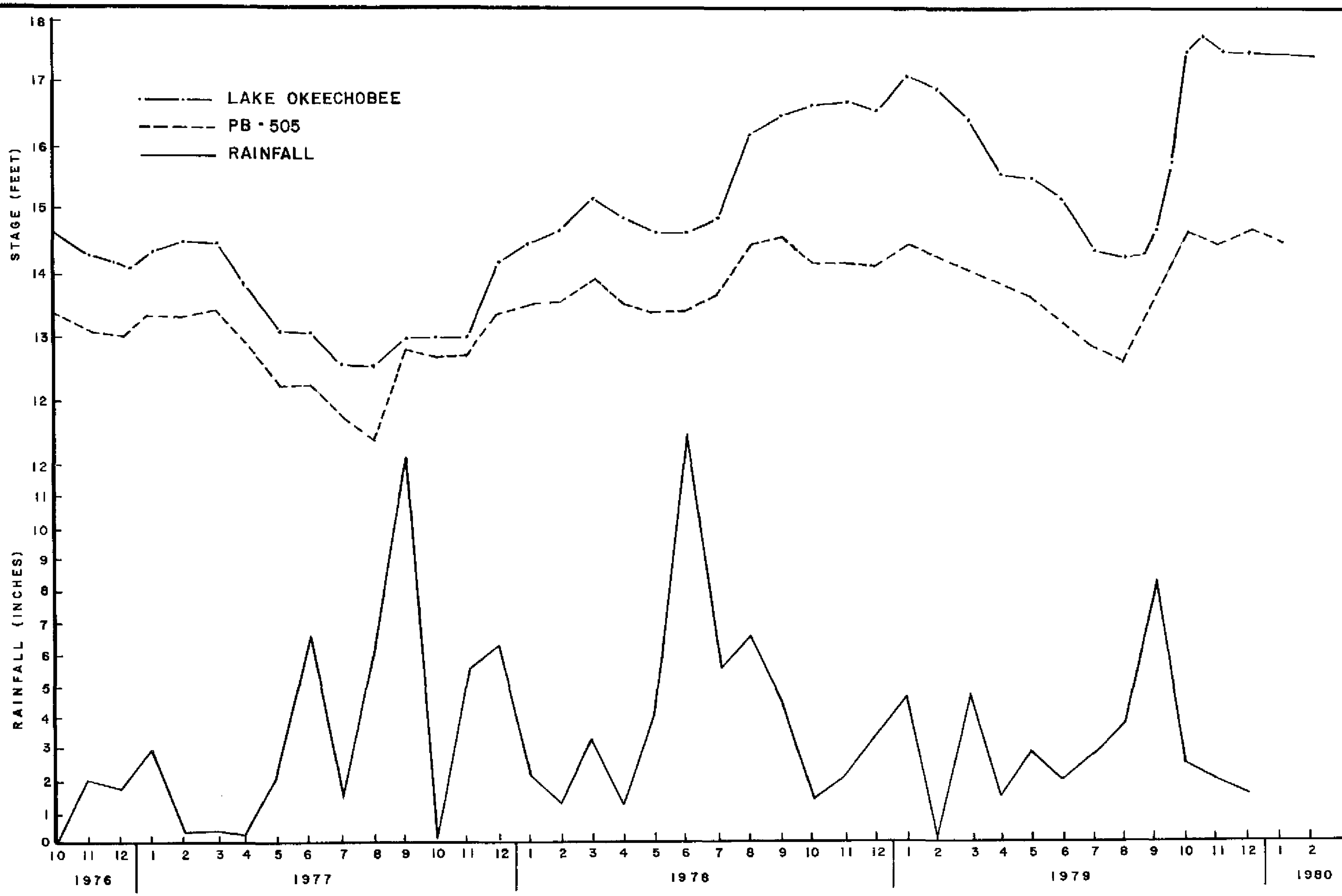


Figure 5 LAKE OKEECHOBEE STAGE AND HEIGHT OF WATER LEVEL IN PB-505 COMPARED TO RAINFALL

water levels in PB-505 may be attributed to the lake stage increasing during a rainfall event and then reflecting that increase in PB-505, or by rain falling in the immediate vicinity of the well which will also directly affect water levels, or a combination of both mechanisms.

Further examination of Figure 5 shows that the difference between lake stage and the water level in PB-505 increases with time. In January 1977 the difference was 1.0 ft., while in January the difference was 3.0 ft. This was probably due to the influence of the filtercake. The formation of a filtercake occurs along the seepage interface of the lake side of the dike and is caused by the deposition of silt and clay particles in the pore spaces. With increased time, this filtercake becomes more impermeable and will reduce the amount of seepage through the dike.

In 1965 the average seepage factor was .35 cfs/mi/ft. (Meyer (3)). For this study, the average seepage factor was .25 cfs/mi/ft. This change was probably also due to the build up of filtercake. Meyer (3, pg. 42) stated:

> "The present effect of the filtercake in the Navigation Canal is included in the value of the seepage factor but the value can be expected to decrease as the filtercake continues to build up and the lake level is raised. The data suggest that the filtercake causes a 68 percent reduction in seepage from the lake. If the filtercake has formed uniformly since the excavation of the Navigation Canal in the early thirties then the build up of the filtercake has reduced the seepage about 2 percent per year, however, there are no data to support this conclusion. Therefore no attempt was made to relate the seepage factor to future changes in the filtercake, but it is apparent that the value of the seepage factor will decrease in the future."

Data presented in this study indicates that during the last fifteen years the seepage factor has decreased 2.7 percent per year. This is a significantly greater decrease than that predicted by Meyer (3) and confirms his conclusions that the seepage factor decreases with time.

The discharge relationship between the lake and PB-505 (Q_t) can be compared to that between OCP-1 and OCP-2 (Q_t') at different lake stages (Table 6A). It can be seen that there is little variation of flow through the aquifer under the avocado grove, while flow between the lake and PB-505 (which penetrates the aquifer) varies with lake stage. Table 6B shows that the lake stage and Q_t are significantly correlated ($r = .97$) while lake stage and Q_t' are not ($r = .36$ not significant). It would therefore appear that flow through the dike is discharged mainly via the intervening toe ditch and does not affect the aquifer adjacent to eastward portions of the lake.

Water flows into the toe ditch from both east and west directions. The direction of flow through the confining bed was eastward from the lake and westward from the groundwater mound beneath the sand ridge towards the toe ditch. Flow of the aquifer was eastward from the lake to the agricultural area (McKenzie (2)). The toe ditch drains southward into the West Palm Beach Canal. Meyer (3, p. 85) pointed out:

> "Prior to the excavation of the toe ditch in August 1964, the area between the dike and the sand ridge was periodically inundated following periods of heavy rainfall. Many local residents believed that the flooding was caused by seepage from the lake. However, hydrologic data, and on-site investigation of the flooded area have led this investigator to conclude that flooding was due chiefly to inadequate surface drainage and to seepage westward from the sand ridge and not due to seepage from the lake... After the toe ditch was excavated the water level in well 4 declined and since then no flooding has been observed."

Major cation and anion chemistry of waters in the study area was examined to determine the origin and movement of water in the aquifer. Twenty-three samples were collected and analyzed, and the results shown in Table 4. Waters of similar origin would be expected to show close similarities in chemistry; specifically, the effect of movement of water from the lake to the surrounding aquifer should be apparent.

Lake Stage (feet)	Qt (cfs/mi)	Qt' (cfs/mi)
14.63	0.37	0.23
14.60	0.42	0.21
14.36	0.40	0.18
17.46	0.74	0.19
17.58	0.80	0.22
17.51	0.83	0.28
17.36	0.68	0.23
17.36	0.72	0.21

TABLE 6A. Comparison of Discharge Between the Lake and Well PB-505 (Qt) with that Between Wells OCP-1 and OCP-2 (Qt') Relative to Lake Stage

	Lake	Qt	Qt'
Lake	1	.97	.36
Qt		1	-.20
Qt'			1

TABLE 6B. Correlation Coefficients of Results in 6A

To highlight chemical similarities, a graphical presentation known as a Piper Trilinear Plot was used (Figure 6). This is actually three plots showing cation, anion, and combined cation and anion percentages. On these graphs, waters of similar chemistry plot close together. Mixing of different types of water is shown by points which plot intermediate between sources of different chemical compositions (Freeze and Cherry, 1).

Figure 6 is a plot of cation and anion percentages for 13 samples (JES-11 through JES-23) taken from the lake and from wells and canals along an eastward line from the Belle Glade and Canal Point sites. Points 16 and 23 (BG-LO and CP-LO) represent Lake Okeechobee water. These points plot relatively close together and provide a reference for the other points. Points 15 and 22 (BG-TD and CP-TD) represent samples from the toe ditch at the Belle Glade and Canal Point sites, respectively. When compared with lake water samples, the toe ditch samples show a reduction in Na and Cl content with respect to Ca, M_g, SO_4 and CO_3.

Points 11, 12, 13 and 14 represent waters from the aquifer at successively greater distances from the lake at the Belle Glade site area. All except 14 show broadly similar cation and anion chemistry but with marked increase of M_g, CO_3 and HCO_3 and decrease in Ca and SO_4 with respect to lake water samples. The value of Na and Cl remain intermediate between the values for the lake and toe ditch. Sample 14 with high Na and SO_4 percentages apparently represents water from a different source. Point 19 represents the sampling point at the canal east of the avocado grove. The water chemistry is intermediate between wells OBG-4 and OCP-2 and the lake water in both cation and combined percentages.

Samples 20, 21, 17 and 18 are from wells in the aquifer. The first two are from wells on the lakeward side and landward side of the dike, respectively. The others being taken from wells at increasing distances from the

11	OBG-1
12	OBG-2
13	OBG-3
14	OBG-4
15	BG-TD
16	BG-LO
17	OCP-1
18	OCP-2
19	AGC-1
20	5-4
21	5-1
22	CP-TD
23	CP-LO

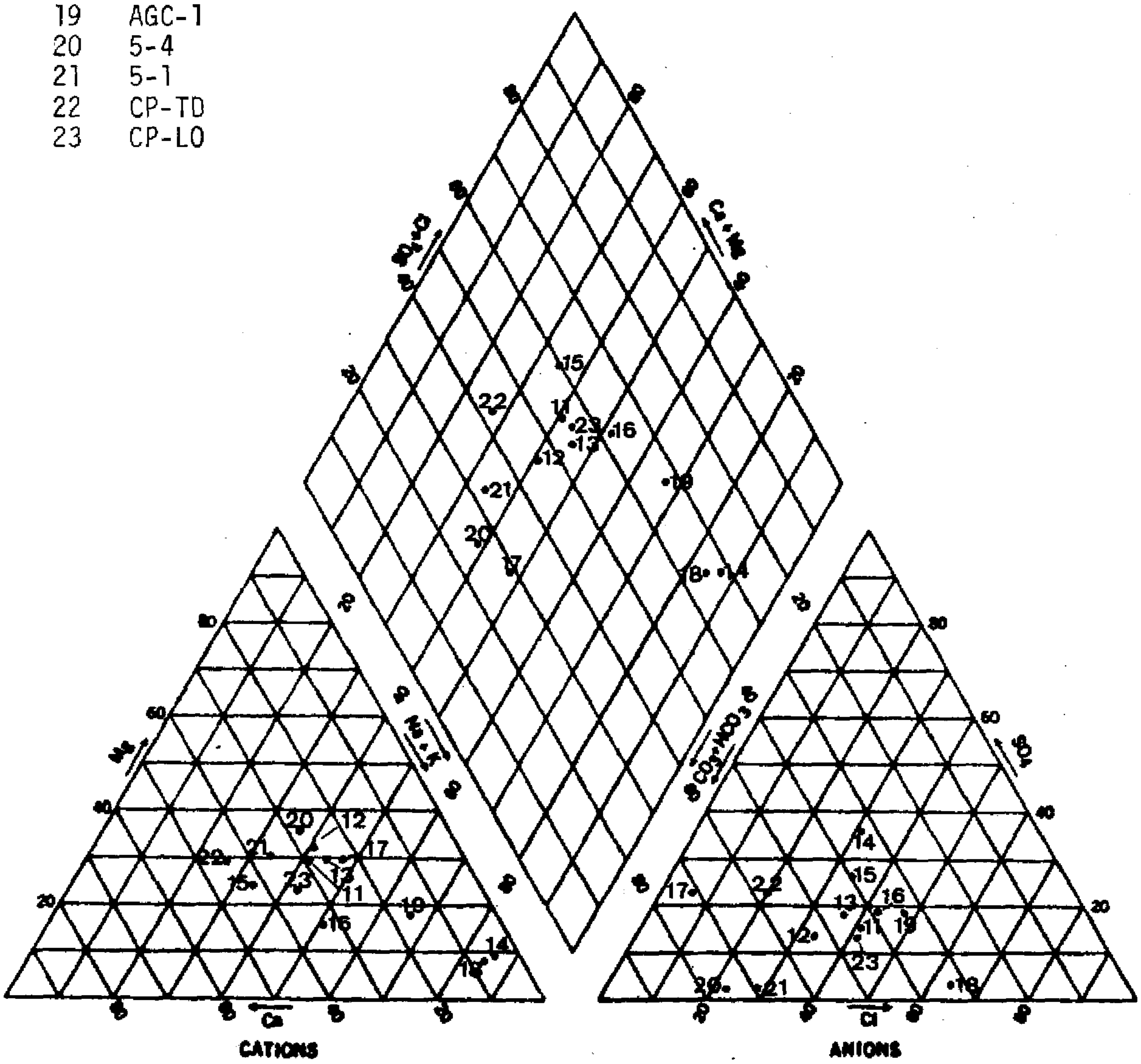


Figure 6. Piper Diagram Showing Cation and Anion Distribution for Water Samples

lake toward the east in a line from the Canal Point site. All except sample 18 show similarities, especially in cation content, with some variations in anion content. Cation content is also similar to lake and toe ditch samples at this site.

The general conclusions which can be drawn from these analyses are:

1. In the vicinity of the Belle Glade site the water in the aquifer and the water in the lake and toe ditch are broadly similar, except for the most easterly well where the water is similar to the water in the adjacent canal.

2. In the vicinity of the Canal Point site the water quality is progressively altered away from the lake. Ca and M_g increase at the expense of Na + K. CO_3 + HCO_3 increases at the expense of SO_4 and Cl, except for water from OCP-2 (the most easterly), which is similar to the canal water east of the grove (ACG1).

Since well OCP-2 is located very near the avocado grove, it may be concluded that the leakage from the lake to this area is not the principal source of groundwater below the grove. The groundwater immediately adjacent to the lake is generally lower in sulfate (SO_4) and chloride (Cl) content than the lake water and, therefore, a major contribution from the lake to the flow in the vicinity of this well is not suggested.

CONCLUSIONS

1. Due to the build up of a filtercake, the current seepage factor between the lake and PB-505 is lower than the seepage factor for conditions 15 years ago. For the same lake stage, the head loss within the groundwater system increases with time. Therefore, groundwater levels have become lower for corresponding lake stages.
2. The seepage factor has decreased within the last 15 years from an average of .35 cfs/mi/ft to the present value of .25 cfs/mi/ft. This represents a 2.7 percent reduction per year in the seepage factor since the year 1965.
3. Seepage landward of the dike is proportionally less for increased lake stage.
4. Groundwater flows into the toe ditch from both the east and west and then southward to the West Palm Beach Canal from the Canal Point site.
5. Groundwater immediately adjacent to the lake is lower in sulfate and chloride, while the groundwater from OCP-2 adjacent to the avocado grove is higher in sulfate and chloride and similar in composition to the eastward canal. The similar water chemistry suggests that the canal, rather than the lake, is the source of the groundwater underlying the avocado grove.
6. Concerning the avocado grove, the general conclusion is that higher lake stages should not materially affect groundwater levels or the quality of water underlying the grove.

REFERENCES CITED

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2. McKenzie, Donald J., 1973. Lake Okeechobee Seepage Monitoring Network, U. S. G. S. Open-file Report No. 73018.
3. Meyer, Frederick W., 1971. Seepage Beneath Hoover Dike Southern Shore of Lake Okeechobee, Florida. Florida Bureau of Geology, Report of Investigation No. 58.
4. U. S. Army Corps of Engineers, 1962. Detail Design Memorandum, Herbert Hoover Dike, Levees D2 (Part), D9 and D4. Central and South Florida Project, Part IV, Supplement 18.

APPENDICES

Data Sheets Containing Water Level and Water Quality Data Collected in the Field

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	6/13/79		12.85	4.48	8.37			
OBG-2	"		13.23	4.91	8.32			
OBG-3	"		12.07	4.49	7.58			
OBG-4	"		10.24	3.50	6.74			
OCP-1	6/12/79		13.19	2.19	11.00			
OCP-2	"		12.28	2.42	9.86			
Toe Ditch-BG								
Lake-BG					15.23			
Toe Ditch-CP								
Lake-CP					15.23			
PB-505			18.76					
5-4			18.56					
5-1			22.70					
5-3			23.02					

Recorded by JES

Field Service Data: HGS-5 _____ _____

L-8 Sand Cut _____

Rainfall: Rainfall: Clewiston _____

Canal Point _____

S 5A _____

Barometric Pressure ____

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	6/21/79	1445	12.85	4.72	8.13	75.9	1140	
OBG-2	"	1430	13.23	5.12	8.07	76.5	1140	
OBG-3	"	1420	12.07	4.77	7.30	77.0	1380	
OBG-4	"	1355	10.24	3.77	6.47	73.9	7440	
OCP-1	"	1130	13.19	2.56	10.63	76.5	1100	
OCP-2	"	1200	12.28	2.79	9.49	76.5	2480	
Toe Ditch-BG	"	1450				86.4	1140	
Lake-BG	"	1515			14.96	88.2	650	
Toe Ditch-CP	"	1230			12.91			
Lake-CP	"				14.96			
PB-505	"		18.76					
5-4	"	1235	18.56	5.51	13.01			
5-1	"	1240	22.70	8.86	13.84			
5-3	"	1250	23.02	7.84	15.18			

Recorded by JES

Field Service Data: HGS-5 _____ _____

L-8 Sand Cut _____

Rainfall: Rainfall: Clewiston _____

Canal Point _____

S 5A _____

Barometric Pressure _____

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	6/25	1145	12.85	4.40	8.39	75.9	1150	
OBG-2	"	1200	13.23	4.87	8.35	76.3	1166	
OBG-3	"	1205	12.07	4.46	7.61	76.5	1376	
OBG-4	"	1330	10.24	3.47	6.77	74.1	7136	
OCP-1	"	1025	13.19	2.67	10.52	76.5	1142	
OCP-2	"	1050	12.28	3.00	9.28	76.3	2574	
Toe Ditch-BG	"	1150			8.36	84.4	1150	
Lake-BG	"	1355			14.84	91.0	668	
Toe Ditch-CP	"				-			
Lake-CP	"				14.84			
PB-505	"		18.76					
5-4	"		18.56					
5-1	"		22.70					
5-3	"		23.02					

Recorded by JES

Field Service Data: HGS-5 12.95 14.85 open 4 ft.

L-8 Sand Cut 13.75

Rainfall: Rainfall: Clewiston 0.10

Canal Point 0

S 5A 0

Barometric Pressure ____

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	7/5	1015	12.85	4.20	8.65	75.2	1133	
OBG-2	"	0955	13.23	4.59	8.64	75.9	1153	
OBG-3	"	0940	12.07	4.02	8.05	76.3	1416	
OBG-4	"	0910	10.24	2.78	7.46	73.9	6360	
OCP-1	"	1120	13.19	2.70	10.49	76.3	1104	
OCP-2	"	1145	12.28	2.07	9.21	76.0	2572	
Toe Ditch-BG	"	1025			8.70	82.0	1224	
Lake-BG	"	1050			14.63	89.0	664	
Toe Ditch-CP	"	1245			11.60	85.3	943	
Lake-CP	"	1315			14.63	91.2	588	
PB-505	"	1240	18.76		12.85			
5-4	"	1250	18.56	6.30	12.26			
5-1	"	1255	22.70	9.23	13.47			
5-3	"	1310	23.02	8.13	14.89			

Recorded by JES

Field Service Data: HGS-5 11.32 14.63

L-8 Sand Cut 14.00

Rainfall: Rainfall: Clewiston 0.04

Canal Point 0

S 5A 0

Barometric Pressure 29.20

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	7/17/79	1110	12.85	4.31	8.54	75.7	1150	
OBG-2	"	1035	13.23	4.67	8.56	76.1	1171	
OBG-3	"	1040	12.07	4.10	7.97	77.0	1411	
OBG-4	"	1010	10.24	3.05	7.19	74.5	9516	
OCP-1	"	1250	13.19	2.70	10.49	77.8	1182	
OCP-2	"	1220	12.28	2.99	9.29	76.4	2677	
Toe Ditch-BG	"	1115			8.50	81.6	1134	
Lake-BG	"	1120			14.60	89.2	632	
Toe Ditch-CP	"	1330			11.97	83.0	1115	
Lake-CP	"	1355			14.60	92.6	590	
PB-505	"	1325	18.76		12.87			
5-4	"	1325	18.56	6.12	12.44			
5-1	"	1345	22.70	9.13	13.57			
5-3	"	1345	23.02	8.20	14.82			

Recorded by JES

Field Service Data: HGS-5 11.89 14.62 closed

L-8 Sand Cut 13.72

Rainfall: Rainfall: Clewiston 0.45

Canal Point 0.65

S 5A 0.65

Barometric Pressure 30.00

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	8/9/79	1015	12.85	4.07	8.78	75.5	1110	
OBG-2	"	0955	13.23	4.45	8.78	75.8	1112	
OBG-3	"	0940	12.07	3.73	8.34	76.9	1380	
OBG-4	"	0915	10.24	2.71	7.53	74.8	8472	
OCP-1	"	1150	13.19	2.64	10.55	-	-	
OCP-2	"	1200	12.28	2.73	9.55	-	-	
Toe Ditch-BG	"	1015			8.82	77.8	1081	
Lake-BG	"	1030			14.36	85.8	659	
Toe Ditch-CP	"	1215			11.70	82.8	821	
Lake-CP	"	1240			14.36	86.6	610	
PB-505	"	1215	18.76		12.64			
5-4	"	1220	18.56	6.36	12.20			
5-1	"	1230	22.70	9.40	13.30			
5-3	"	1235	23.02	8.54	14.48			

Recorded by JES

Field Service Data: HGS-5 10.07 14.12 closed

L-8 Sand Cut 13.07

Rainfall: Rainfall: Clewiston 0.02

Canal Point 0.25

S 5A 0.03

Barometric Pressure 31.40

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	8/22/79	1005	12.85	3.53	9.32			
OBG-2	"	1000	13.23	3.90	9.33			
OBG-3	"	0955	12.07	3.08	8.99			
OBG-4	"	0950	10.24	1.77	8.47			
OCP-1	"	1040	13.19	2.17	11.02			
OCP-2	"	1045	12.28	2.48	9.80			
Toe Ditch-BG	"				9.36			
Lake-BG	"				14.27			
Toe Ditch-CP	"				-			
Lake-CP	"				14.27			
PB-505	"		18.76		-			
5-4	"		18.56		-			
5-1	"		22.70		-			
5-3	"		23.02		-			

Recorded by JES

Field Service Data: HGS-5 _____ _____

L-8 Sand Cut _____

Rainfall: Rainfall: Clewiston _____

Canal Point _____

S 5A _____

Barometric Pressure 30.00

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	10/3/79	1120	12.85	3.40	9.45	76.9	1140	
OBG-2	"	1105	13.23	3.67	9.56	76.8	1180	
OBG-3	"	1045	12.07	3.25	8.82	78.5	1355	
OBG-4	"	1015	10.24	3.71	7.53	75.5	9515	
OCP-1	"	1320	13.19	1.25	11.94	-	-	
OCP-2	"	1310	12.28	1.41	10.87	-	-	
Toe Ditch-BG	"	1120			9.46	76.8	1260	
Lake-BG	"	1140			17.46	85.0	703	
Toe Ditch-CP	"	1330			12.25	78.2	1304	
Lake-CP	"	1350			17.46	75.0	550	
PB-505	"	1335	18.76		14.77			
5-4	"	1335	18.56	4.88	12.70			
5-1	"	1340	22.70	6.70	16.00			
5-3	"	1340	23.02	5.29	17.73			

Recorded by JES

Field Service Data: HGS-5 11.17 17.47 closed

L-8 Sand Cut 14.72

Rainfall: Rainfall: Clewiston 0

Canal Point 0

S 5A 0

Barometric Pressure 29.97

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	10/10/79	1000	12.85	3.50	9.35	75.5	1164	
OBG-2	"	0950	13.23	3.79	10.44	76.2	1218	
OBG-3	"	0930	12.07	3.41	8.66	77.6	1459	
OBG-4	"	0910	10.24	2.62	7.62	75.0	9548	
OCP-1	"	1100	13.19	1.55	11.64	-	-	
OCP-2	"	1110	12.28	1.90	10.38	-	-	
Toe Ditch-BG	"	1010			9.18	74.2	1136	
Lake-BG	"	1015			17.58	98.0	917	
Toe Ditch-CP	"	1120			12.02	76.1	1234	
Lake-CP	"	1125			17.58	84.4	512	
PB-505	"	1130	18.76		14.59			
5-4	"	1135	18.56	5.02	13.54			
5-1	"	1140	22.70	6.78	15.92			
5-3	"	1145	23.02	5.20	17.82			

Recorded by JES

Field Service Data: HGS-5 10.34 17.57 closed

L-8 Sand Cut 13.05

Rainfall: Rainfall: Clewiston 0

Canal Point 0

S 5A 0

Barometric Pressure 29.00

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	11/6/79	0930	12.85	3.17	9.68			
OBG-2	"	0915	13.23	3.49	9.74			
OBG-3	"	0900	12.07	3.09	8.98			
OBG-4	"	0845	10.24	2.27	7.97			
OCP-1	"	1100	13.19	1.72	11.47			
OCP-2	"	1115	12.28	2.42	9.86			
Toe Ditch-BG	"	1005			9.74			
Lake-BG	"	1020			17.51			
Toe Ditch-CP	"	1200			11.89			
Lake-CP	"	1205			17.51			
PB-505	"	1210	18.76		14.46			
5-4	"	1215	18.56	5.17	13.39			
5-1	"	1220	22.70	6.87	15.83			
5-3	"	1225	23.02	5.26	17.76			

Recorded by JES

Field Service Data: HGS-5 11.32 17.53 closed

L-8 Sand Cut 13.06

Rainfall: Rainfall: Clewiston 0

Canal Point 0

S 5A 0

Barometric Pressure 30.05

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	12/5/79	1020	12.85	3.30	9.55			2-500 ml spls taken
OBG-2	"	1000	13.23	3.59	9.64			"
OBG-3	"	0945	12.07	3.17	8.90			"
OBG-4	"	0930	10.24	2.23	8.01			"
OCP-1	"	1200	13.19	1.58	11.61			"
OCP-2	"	1210	12.28	2.00	10.28			"
Toe Ditch-BG	"	1025			9.60			"
Lake-BG	"	1030			17.36			"
Toe Ditch-CP	"	1215			12.40			"
Lake-CP	"	1240			17.36			"
PB-505	"	1220	18.76		14.66			"
5-4	"	1225	18.56	4.87	13.69			"
5-1	"	1230	22.70	6.91	15.79			"
5-3	"	1230	23.02	5.42	17.60			"

Recorded by JES

Field Service Data: HGS-5 12.26 17.35 open 1 ft

L-8 Sand Cut 12.35

Rainfall: Rainfall: Clewiston 0

Canal Point 0

S 5A 6

Barometric Pressure 30.05

Hydrogeologic Investigation Along the Eastern Portion of Lake Okeechobee

Data Sheet

Station	Date	Time	Elev. @ M.P.	W.L. below M.P.	Elev. of Water	Water Temp.	Water Cond.	Comments
OBG-1	1/17/80	1000	12.85	3.02	9.83	75	-	2-500 ml spls coll't
OBG-2	"	0945	13.23	3.24	9.99	75	-	"
OBG-3	"	0930	12.07	2.84	9.23	76	-	"
OBG-4	"	0915	10.24	2.00	8.24	74	-	"
OCP-1	"	1100	13.19	1.49	11.70	78	-	"
OCP-2	"	1115	12.28	1.77	10.51	78	-	"
Toe Ditch-BG	"	1005			10.02	68	-	"
Lake-BG	"	1020			17.36	68	-	"
Toe Ditch-CP	"	1200			11.95	66		"
Lake-CP	"	1205			17.36	69		"
PB-505	"	1210	18.76		14.50			"
5-4	"	1215	18.56	5.19	13.37			"
5-1	"	1220	22.70	7.0	15.70			"
5-3	"	1225	23.02	5.71	17.31			"

Recorded by JES

Field Service Data: HGS-5 ______ ______

L-8 Sand Cut ______

Rainfall: Rainfall: Clewiston ______

Canal Point ______

S 5A ______

Barometric Pressure 30.05