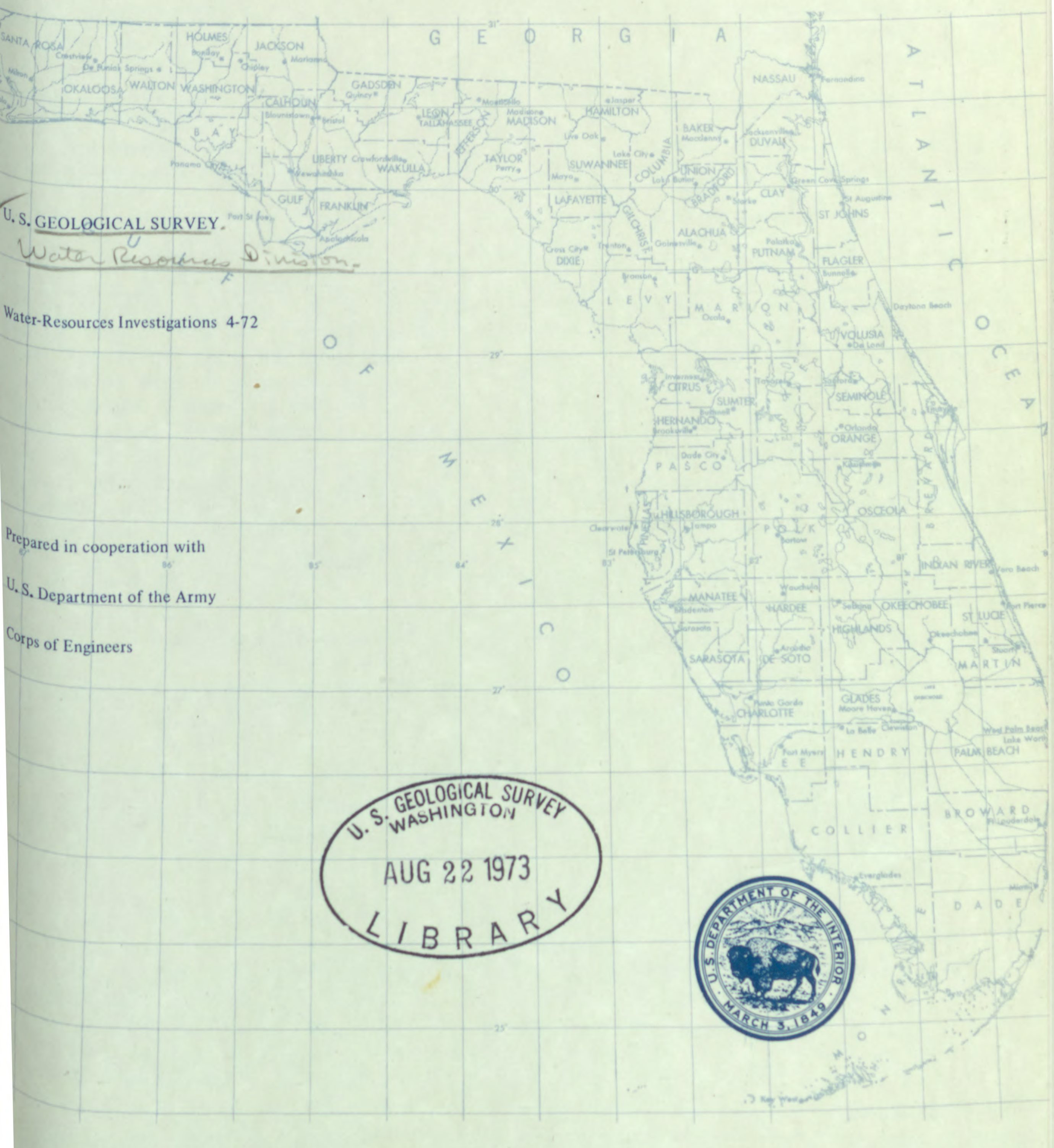
GROUND-WATER CONDITIONS IN THE LOWER WITHLACOOCHEE RIVER - CROSS-FLORIDA BARGE CANAL COMPLEX AREA



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Water Resources Division

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16. Abstracts Construction of the westernmost 7-mile reach of the Cross Florida Barge Canal, which intersects the lower Withlacoochee River 9 miles above its mouth, began in 1965 and completed in 1969. The river channel and the canal penetrate the cavernous limestone of the Floridan Aquifer below the water table. Ground-water levels in a 15-square mile area centered at the canal about 4.5 miles from the Gulf of Mexico are 0.5 foot-15 feet lower than had the canal not been built. In another 0.7 square-mile area surrounding the Inglis Lock bypass channel the ground-water level has been raised 0.5 foot-20 feet above the pre-canal level. The average ground-water contribution to the flow of the lower river is 20 percent, 7 cfs, less than before the canal was built. This is about 0.5 percent of the average fresh-water flow that would have passed down the river from October 1, 1970 through September 30, 1971, had the canal not been built. The fresh water-salt water zone of diffusion in the aquifer tends to rise in the area where the ground-water levels have been lowered.

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CONCLUSIONS

The water levels in both the lower Withlacoochee River and the Cross-Florida Barge Canal between Inglis Lock and the Gulf of Mexico nearly coincide with the water table of the immediately adjacent Floridan aquifer, and they all fluctuate with the tide. The potentiometric surface of the Floridan aquifer slopes toward the river and the canal. When the tide is low, ground water discharges to the river and the canal, but, when the tide is high, ground-water inflow is retarded or halted, and the direction of flow may even reverse.

Ground-water levels in a 15-square-mile area centered at the Barge Canal near the U.S. Highway 19 bridge are 0.5 foot to nearly 15 feet lower than they would be had the canal not been built. The affected area is slightly larger during dry periods, when water levels are naturally low, than during wet periods, when they are naturally high. The maximum decline in water level due to the drawdown effect of the canal is greatest during high-water periods. In another 0.7 square-mile area surrounding the Inglis Lock bypass channel, where the water level in the channel is higher than the water table, the ground-water level has been raised between 0.5 foot and about 20 feet above what it would have been had the canal not been built.

The canal captures ground-water flow from about 6 square miles of the 29-square-mile upper-Floridan-aquifer drainage area that contributed ground-water flow to the Withlacoochee River below Inglis Dam before the canal was built. Thus, the average ground-water contribution to fresh-water flow in the river between the Inglis Lock bypass channel and the gulf has been reduced about 20 percent, or a little less than 7 cfs (cubic feet per second). This amount is only about 0.5 percent of the average fresh-water flow that would have passed down this reach of the river from October 1, 1970 through September 30, 1971, had the canal not been built. During the same 1-year period, an average of 237 cfs of surface water was discharged through Inglis Dam and diverted down the canal to the gulf. Had the canal not been built, this water would have flowed to the gulf via the river and would have amounted to about 16 percent of the fresh-water discharge of the river for the 1-year period. The long-term average flow in the river below the bypass channel, based on analysis by Bush (1972), is expected to be about 23 percent less than before the canal was built. The canal also captured about 6 cfs of ground-water flow from a 5-square-mile area that formerly discharged at the gulf coast.

Ground water in the upper part of the Floridan aquifer in the river-canal complex area is naturally hard, its dissolved iron content commonly is excessive, and, except in most places within about 2 miles of the coast, its chloride content is low. The only apparently significant effect of the canal on water quality in the river-canal complex area is a tendency for the fresh-water-salt-water zone of diffusion in the aquifer to rise in the area where ground-water levels have been lowered as a result of the presence of the canal.

When fresh-water flow from Inglis Dam to the Barge Canal is very low, the water level in the canal is at or very near sea level, and salt water from the gulf moves inland by way of the canal to Inglis Lock and part way up the 1.5 mile reach of the river between the canal and the dam. Therefore, a potential exists with high tides for salt-water to intrude the aquifer temporarily immediately adjacent to the canal. Also, because of the near-sea-level stage of the canal, when fresh-water flow through the dam is low, there is a potential for the fresh-water-salt-water interface in the aquifer underneath the canal to rise to the canal. Because of generally increasing ground-water head with distance inland from the coast, the potential for salt-water intrusion of the aquifer adjacent to the canal diminishes with distance inland from the coast. Also, when the fresh-water flow in the canal toward the gulf is appreciable, inland movement of gulf water is retarded, and salt-water intrusion of the aquifer is inhibited in much the same manner as along tidal reaches of the river.

The area in which ground-water levels have been lowered more than 0.5 foot as the result of the canal extends about 2 miles south of the canal, as compared with about 1.5 miles north of the canal. The Withlacoochee River acts as a hydrologic boundary north of the canal and, for practical purposes, limits the northward extent of the drawdown effect of the canal. The water level in the river, rather than that in the canal, tends to regulate the lower limit of the water table adjacent to the river.

The average stage of the river is slightly lower, probably no more than 0.3 foot, as the result of reduced discharge in the river below the Inglis Lock bypass channel since December 1969. The water table immediately adjacent to the river is lowered less than the river stage is lowered, and the effect of the lowered river stage on the water table diminishes with distance from the river. Therefore, any effects of the canal on ground-water levels and quality north of the river are slight, and they are not distinguishable from effects of other hydrologic factors.

GROUND-WATER CONDITIONS IN THE LOWER WITHLACOOCHEE RIVER - CROSS-FLORIDA BARGE CANAL COMPLEX AREA

By
Glen L. Faulkner

INTRODUCTION

The Lower Withlacoochee River - Cross-Florida Barge Canal complex consists of the Withlacoochee River from Inglis Dam to the Gulf of Mexico and the west end of the Cross-Florida Barge Canal from Inglis Lock to the gulf, including the lock and the lock bypass channel (fig. 1). The complex area, as treated in this report, occupies about 45 square miles in Citrus and Levy counties, Florida.

The Inglis Dam was built in the early 1900's to impound water of the Withlacoochee River for electrical power generation. Although power is no longer generated at the site, a dam and spillway is used to maintain water levels in the impoundment above Inglis Lock. The impoundment is referred to in this report as the "Withlacoochee River backwater". Construction of the westernmost 8 miles of the Barge Canal from January 1965 to December 1969 further altered the hydrology of the area. The canal, which intersects the natural channel of the Withlacoochee River about 9 river miles above the mouth of the river and about 1.5 miles downstream from Inglis Dam, diverts fresh-water flow from the dam and spillway away from the lower 9 miles of river channel. The canal penetrates 13 to 25 feet of limestone and dolomite of the Floridan aquifer to 13 feet below mean sea level, which results in some lowering of the water table and permits gulf water to flow along a straight-line route 7 miles inland to Inglis Lock.

To obtain facts needed to answer questions about actual effects of the canal on the hydrologic regime, a 1-year investigation began in September 1970 to determine the movement of saline water, with respect to various combinations of tide and fresh-water discharge, in the river-canal complex between Inglis Lock and the gulf. In the spring and summer of 1971 an additional investigation was made to determine the minimum discharge needed to flush accumulated sediment from the river channel. Also, during the summer and early fall of 1971, an investigation was made to determine ground-water conditions in the area and to estimate pre-canal ground-water conditions. Figure 1 shows the area of investigation and location of hydrologic-data-collection stations.

This report presents the results of the ground-water aspects of the hydrologic investigations, whereas another report (Bush, 1972) deals with the results of the investigation of the movement of surface water and salt water and scour of river-channel sediment.

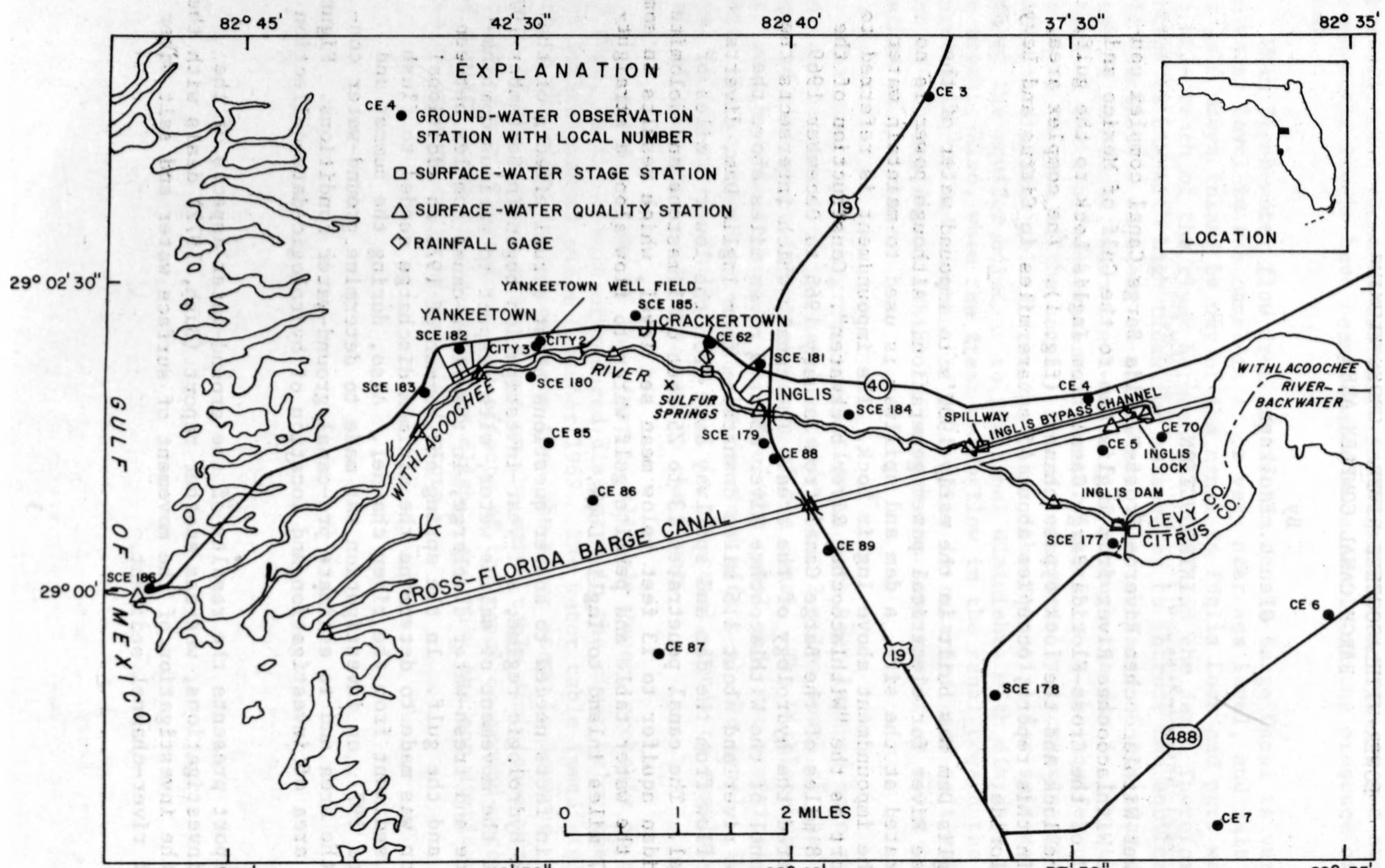

Figure 1.-Index map of Lower Withlacoochee River - Cross-Florida Barge Canal complex area.

Acknowledgments

The investigation was made by the U. S. Geological Survey in cooperation with the U. S. Department of the Army, Corps of Engineers. The cooperation of local landowners and the Florida Department of Transportation in permitting construction of hydrologic observation stations in the area of investigation is appreciated. Thanks are also extended to the many local residents, who in many different ways assisted the writer, especially by providing historical information acquired through their experience in the area.

Purpose and Scope

The purpose of this ground-water investigation was to provide comprehensive qualitative and quantitative appraisals of the effects of the canal on the ground-water regimen in the area of the Lower Withlacoochee River - Cross-Florida Barge Canal complex. Although the general effect of this reach of the canal on the hydrology of the area was discussed in an earlier report on the geohydrology of the greater canal area (Faulkner, 1970, p. 165), the small amount of data available at that time made it impossible to provide the specific information now needed.

The scope of this investigation was threefold. First, determination of existing (post-construction) ground-water conditions with respect to shape and altitudes of the potentiometric surface of the Floridan aquifer during periods of both low- and high-water levels, recharge and discharge characteristics of the aquifer, directions of flow and some facts about volume of flow in the aquifer, water-quality characteristics of the aquifer, and depth to salt water in the aquifer. Second, estimation of the pre-canal ground-water conditions from a knowledge of existing ground-water conditions and an understanding of how they are controlled by factors of stage, flow, and water quality in the canal and river. Third, provision of qualitative and (or) quantitative answers to questions about the following canal effects on the basis of knowledge of both the pre- and post-construction conditions: (1) areal and vertical extent of ground-water-level change, (2) areal and volumetric extent of canal diversion from the river of ground-water inflow, (3) changes in recharge-discharge relations, and (4) changes in water quality and depth to salt water.

Data Network

Basic data used in the ground-water investigation consisted mostly of water-level and water-quality measurements in a network of 24 wells, which penetrate limestone and (or) dolomite of the upper few to several tens of feet of the Floridan aquifer. Five of the observation wells were drilled in June 1971 expressly for this investigation. Six of the others were drilled in 1966 as a part of the Cross-Florida Barge Canal area ground-water monitoring network constructed that year and since operated by the Geological Survey in cooperation with the Corps of Engineers (Faulkner, 1970, p. 18). Most of the remaining 13 wells, two of which have bimonthly water-level records that extend from pre-canal days in the early 1960's to the present were water-supply wells drilled before this investigation. Each well in the network is

Table 1.--Description of wells in ground-water observation network.

U. S. Geological Survey Latitude-Longitude Number	Local Well Number	LOCATION: ¼¼¼ Section	LOCATION: ¼¼ Section	LOCATION: ¼ Section	LOCATION: Section	LOCATION: Township - South	LOCATION: Range - East	Owner-ship	Date Drilled (Year)	Well Depth (feet)	CASING: Depth (feet)	CASING: Diameter (inches)	Well Finish	Method Drilled	Pump Type	Water Use	Aquifer	Depth to Top of Aquifer (feet)	Altitude of land surface datum (feet)	WATER LEVEL: Below land Surface datum (feet)	WATER LEVEL: Date of Meas.	WATER LEVEL: Frequency of Meas.	CHEMICAL ANALYSIS: Type	CHEMICAL ANALYSIS: Frequency of Sampling	Local Well Number
285812N0823609.1	CE 7	NE	NE	SE	29	17	17	F	1966	64	30	2	X	C	N	U	Floridan	29	21.97	9	6-66	B	C	O	CE 7
285918N0823810.1	SCE 178	SW	NW	NW	19	17	17	P	-	27	-	2	X	C	N	U	Floridan	-	24.67	10	6-71	I	C	O	SCE 178
285935N0824109.1	CE 87	SW	SW	SW	15	17	16	F	1971	28	20	3	X	H	N	U	Floridan	1	9.79	8	6-71	B	C	O	CE 87
285951N0823509.1	CE 6	SW	NW	SW	15	17	17	F	1966	68	39	2	X	C	N	U	Floridan	15	27.92	7	6-66	B	C	O	CE 6
290004N0824541.1	SCE 186	NE	SE	NW	14	17	15	S	-	20	-	2	X	C	C	D	Floridan	-	-	4	8-71	I	J	O	SCE 186
290023N0823936.1	CE 89	SW	SW	SE	11	17	16	F	1971	30	21	3	X	H	N	U	Floridan	7	17.87	9	6-71	B	C	O	CE 89
290027N0823707.1	SCE 177	SE	SE	SE	7	17	17	P	-	78	42	2	X	C	C	D	Floridan	-	24.67	13	6-71	I	C	O	SCE 177
290047N0824141.1	CE 86	NE	NE	SW	9	17	16	F	1971	30	8	3	X	H	N	U	Floridan	1	10.39	8	6-71	B	C	O	CE 86
290107N0824005.1	CE 88	SW	NW	NW	11	17	16	F	1971	58	19	3	X	H	N	U	Floridan	11	15.85	13	6-71	B	C	O	CE 88
290112N0823711.1	CE 5	NE	NE	NE	7	17	17	F	1966	125	84	6	X	C	N	U	Floridan	34	25.39	21	7-71	C	C	O	CE 5
290114N0824209.1	CE 85	NE	NE	NE	8	17	16	F	1971	24	18	3	X	H	N	U	Floridan	17	8.80	6	6-71	B	C	O	CE 85
290115N0824010.1	SCE 179	SE	SE	SE	3	17	16	P	1952	40	-	4	X	C	C	C	Floridan	-	16.13	16	6-71	I	C	O	SCE 179
290118N0823641.1	CE 70	SE	SE	SW	5	17	17	F	1966	67	62	4	X	C	S	U	Floridan	36	29.26	11	2-66	B	S	Bp,Sn	CE 70
290128N0823928.1	SCE 184	NE	SW	SE	2	17	16	P	1967	60	28	2	X	C	C	D	Floridan	-	15.48	11	12-70	I	C	O	SCE 184
290138N0823719.1	CE 4	NW	NE	SE	6	17	17	F	1966	64	47	2	X	C	N	U	Floridan	32	31.37	26	2-66	B	C	O	CE 4
290138N0824320.1	SCE 183	NW	NE	SE	6	17	16	P	1969	30	-	2	X	C	N	U	Floridan	-	5.14	4	6-71	I	J	O	SCE 183
290145N0824219.1	SCE 180	SW	SE	NE	5	17	16	P	1971	61	30	3	X	H	C	D	Floridan	0	10.20	8	6-71	I	C	O	SCE 180
290153N0824016.1	SCE 181	NE	SE	NE	3	17	16	P	-	57	-	2	X	C	N	U	Floridan	-	15.51	10	6-71	I	P	O	SCE 181
290200N0824259.1	SCE 182	SE	NW	NW	5	17	16	P	-	47	-	4	X	C	H	U	Floridan	-	6.55	4	7-71	I	P	O	SCE 182
290202N0824039.1	CE 62	NW	NW	NE	3	17	16	N	-	155	-	4	X	C	C	N	Floridan	-	12.67	7	3-61	B	J	Bj	CE 62
290203N0824213.1	City 3	SE	NE	NE	5	17	16	M	1962	59	49	6	X	C	C	Ps	Floridan	-	10.14	13	6-63	I	C	O	City 3
290205N0824212.1	City 2	NE	NE	NE	5	17	16	M	1950	52	49	4	X	C	C	Ps	Floridan	-	10.10	10	6-71	I	C	O	City 2
290215N0824123.1	SCE 185	SW	SE	SE	33	16	16	C	-	58	-	2	X	C	C	U	Floridan	-	10.00	6	3-61	B	C	O	SCE 185
290402N0823849.1	CE 3	NW	NE	NW	25	16	16	F	1966	37	25	2	X	C	N	U	Floridan	25	41.52	3	2-66	B	C	O	CE 3

EXPLANATION

WELL NUMBERS: See text for explanation.

OWNERSHIP: F, Federal; S, State; C, County, M, City; N, Company; P, Private.

WELL FINISH: X, open hole.

METHOD DRILLED: C, cable tool; H, rotary.

PUMP TYPE: S, submersible; C, centrifugual; H, hand; N, none.

WATER USE: Ps, public supply; N, industrial; D, domestic; U, unused; C, commercial.

WATER LEVEL BELOW LAND SURFACE: nearest foot.

DATE OF MEASUREMENT: month and year.

FREQUENCY OF MEASUREMENT: C, continuous; B, bi-monthly; I, irregular.

CHEMICAL ANALYSIS, TYPE: C, standard complete; J, conductance and chloride; P, partial; S, special.

FREQUENCY OF SAMPLING: O, original; Bp, bimonthly partial; Sn, semiannual nutrient, pesticide and bacteriological; Bj, bimonthly chloride.

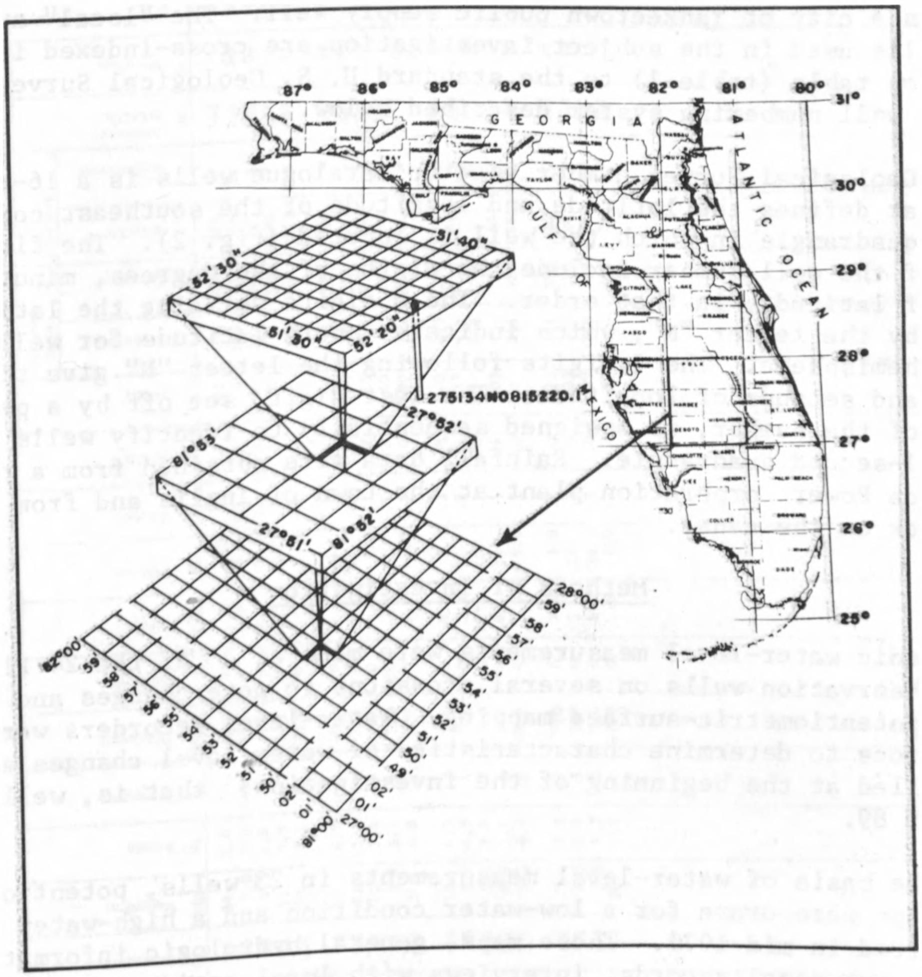

Figure 2.--Diagram illustrating U. S. Geological Survey well-numbering system.

identified on figure 1 by a "local" number of one to three digits preceded by the prefix "CE," "SCE," OR "City." The prefix designates a well's status as either a part of the basic (CE) or supplementary (SCE) Barge Canal area monitoring networks operated by the Geological Survey throughout the canal area or as a city of Yankeetown public supply well. The "local" numbers for the 24 wells used in the subject investigation are cross-indexed in the well description table (table 1) to the standard U. S. Geological Survey latitude-longitude well numbering system described below.

The Geological Survey number used to catalogue wells is a 16-character number that defines the latitude and longitude of the southeast corner of a 1-second quadrangle in which the well is located (fig. 2). The first 6 characters of the well number include the digits of the degrees, minutes, and seconds of latitude, in that order. The 6 digits defining the latitude are followed by the letter "N", which indicates north latitude for wells in the northern hemisphere. The 7 digits following the letter "N" give the degrees, minutes, and seconds of longitude. The last digit, set off by a period from the rest of the number, is assigned sequentially to identify wells inventoried within a 1-second quadrangle. Rainfall data were obtained from a rain gage at the Florida Power Corporation plant at the town of Inglis and from one at Inglis Lock on the canal.

Methods of Investigation

Periodic water-level measurements were made at 23 of the 24 Floridan aquifer observation wells on several occasions to note changes and to obtain data for potentiometric-surface mapping. Water-level recorders were used for short periods to determine characteristics of water-level changes at all five wells drilled at the beginning of the investigation; that is, wells CE 85 through CE 89.

On the basis of water-level measurements in 23 wells, potentiometric-surface maps were drawn for a low-water condition and a high-water condition that occurred in mid-1971. These maps, general hydrologic information derived from a few pre-canal records, interviews with local residents, and a knowledge of the kinds of hydrologic changes expected as a result of the canal were used to prepare conceptual maps for these same high- and low-water conditions, showing the potentiometric surface as it would most likely be if the canal did not exist. The contour-intersection technique was then used to derive maps showing the areal extent and vertical magnitude of ground-water-level changes caused by the canal. Also, by the contour-intersection technique, the area of canal diversion from the river of ground-water inflow was delineated.

Water-quality data from all 24 Floridan aquifer wells were used in the investigation. Standard complete analyses of samples collected from 13 wells during the investigation and from six wells in 1966 in the extreme eastern part of the investigation area are listed in table 2. Field measurements of specific conductance, chloride, and iron were also obtained. Variations and (or) similarities in ground-water quality also are depicted in the form of Stiff geometric diagrams plotted on a chloride-concentration map (fig. 10).

Table 2.--Standard complete analyses of ground-water from selected observation stations (analyses by U.S. Geological Survey).

U.S. Geological Survey Latitude-Longitude Number	Local Well Number	Date of Collection	Specific Conductance (umhos at 25°C) K x 10⁶	pH	Temperature (degrees Celsius) °C	Milligrams per liter (mg/l) Silicate SiO_2	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Bicarbonate HCO_3	Carbonate CO_3	Sulfate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Iron (total) Fe	Dissolved Solids: Determined	Dissolved Solids: Calculated	Hardness: as $CaCO_3$	Hardness: noncarbonate	Alkalinity as $CaCO_3$ Alk	Strontium Sr	Color Units	Local Well Number
285812N0823609.1	CE 7	6-02-66	316	8.1	23.5	4.2	43	14	2.8	.0	198	0	..0	.5.0	.1	.0	.05	-	167	165	3	162	-	5	CE 7
285918N0823810.1	SCE 178	6-30-71	278	7.9	24.0	33	42	9.8	3.6	1.0	166	0	4.8	8.0	.3	.0	.04	195	185	146	10	136	.06	0	SCE 178
285935N0824109.1	CE 87	6-22-71	430	7.9	23.0	3.6	83	4.3	4.8	.1	268	0	2.8	9.0	.1	.5	1.8	241	240	225	5	220	.09	5	CE 87
285951N0823509.1	CE 6	6-01-66	342	8.1	23.5	7.6	50	12	3.5	.1	193	0	12	6.0	.1	.2	.04	-	186	174	17	158	-	5	CE 6
290023N0823936.1	CE 89	6-22-71	580	8.1	22.5	3.3	114	63	3.2	.0	328	0	45	7.0	.1	.0	1.7	368	341	311	42	269	.11	60	CE 89
290027N0823707.1	SCE 177	7-13-71	392	8.0	-	6.4	52	17	6.7	.2	240	0	4.8	14	.1	.0	.73	291	219	200	3	197	.09	0	SCE 177
290047N0824141.1	CE 86	6-21-71	700	8.1	22.5	6.4	96	27	15	.4	386	0	12	33	.3	.0	.26	380	380	351	34	317	.09	0	CE 86
290107N0824005.1	CE 88	6-22-71	448	8.2	24.0	9.2	77	12	3.4	.5	292	0	4.8	7.0	.2	.8	.15	258	259	242	2	239	.17	0	CE 88
290112N0823711.1	CE 5	2-24-66	466	8.0	22.5	7.8	91	3.8	5.2	.1	290	0	.0	11	.1	.5	.10	-	262	242	5	238	-	0	CE 5
290114N0824209.1	CE 85	6-23-71	590	8.0	21.5	3.3	73	34	4.8	.1	388	0	9.6	8.0	.4	.0	.80	329	324	322	4	318	.09	5	CE 85
290115N0824010.1	SCE 179	7-13-71	442	8.1	22.5	5.1	69	15	4.5	.2	276	0	8.0	9.0	.3	.8	.03	249	248	234	8	226	.11	0	SCE 179
290118N0823641.1	CE 70	2-28-66	424	7.9	22.0	6.8	90	2.7	6.5	.1	272	0	2.8	12	.2	.1	.37	-	255	236	12	223	-	5	CE 70
290128N0823928.1	SCE 184	12-16-70	663	7.4	22.0	4.8	135	2.4	7.4	.7	338	0	68	10	.2	.0	2.2	425	395	347	70	277	.21	20	SCE 184
290138N0823719.1	CE 4	2-15-66	497	7.8	23.5	8.1	101	8.8	7.8	.2	306	0	18	11	.1	.6	.03	-	307	288	37	251	-	0	CE 4
290145N0824219.1	SCE 180	7-03-71	510	8.1	23.0	5.0	101	3.2	4.9	.2	328	0	2.4	9.0	.1	.0	1.5	294	288	267	0	269	.10	5	SCE 180
290202N0824039.1	CE 62	7-13-71	498	7.5	23.0	5.0	96	7.1	3.8	.3	320	0	7.6	7.0	.2	.0	.15	297	285	269	7	262	.14	0	CE 62
290203N0824213.1	City 3	6-24-71	483	8.1	23.0	5.5	91	4.3	7.9	.3	288	0	16	17	.2	.0	.83	287	284	245	9	236	.12	5	City 3
290204N0824212.1	City 2	6-24-71	540	8.2	23.0	5.5	106	3.8	9.7	.4	326	0	8.4	18	.2	.0	.87	326	313	280	13	267	.12	10	City 2
290402N0823849.1	CE 3	2-11-66	459	7.9	24.5	3.4	55	28	1.8	.0	298	0	.0	6.0	.2	.0	.03	-	241	252	8	244	-	0	CE 3

Water-level and water-quality data and maps are used in conjunction with an application of the Ghyben-Herzberg principle of static fresh-water-salt-water balance to illustrate, in two geohydrologic sections, the probable depth relation of fresh and salty ground water in the area.

GEOLOGY AND PHYSIOGRAPHY

Limestone and dolomite strata of the Floridan aquifer are present near the surface of the ground in the area of investigation. These strata are of Eocene age and in most places are covered by at least a thin layer of sandy material of post-Miocene age. The sandy cover ranges in thickness from less than 1 foot at the coast to nearly 40 feet in the vicinity of Inglis Lock, about 7 miles inland. A comprehensive discussion of the geology of the Cross-Florida Barge Canal area is contained in an earlier Barge Canal area report (Faulkner, 1970, pp. 39-88), and the geology of Citrus and Levy counties, Florida, has been described in detail (Vernon, 1951).

The entire area of investigation is in the Coastal Lowlands physiographic province of Cooke (1939). That part of the area of investigation more than about 2 miles from the gulf coast is in the Gulf Coastal Lowlands physiographic subdivision, and the remaining 2-mile coastal strip is in the Coastal Swamps subdivision of Puri and Vernon (1964).

Except for the comparatively steep slope of the land surface into the incised Withlacoochee River channel, the natural land surface slopes gently westward at a uniformly diminishing rate from an altitude of slightly more than 30 feet above sea level near Inglis Lock to sea level at the gulf coast. Except for numerous short tidal channels at the coast, the Withlacoochee River is the only important natural stream in the area of investigation. Local drainage is largely subterranean.

HYDROLOGY

General Hydrologic Relationships

The ground- and surface-water systems in the area of investigation are intimately related. The channel of the Withlacoochee River is incised into cavernous limestone and dolomite of the Floridan aquifer to a depth of 15 to 20 feet below the water table at the river's edge, and most of the time acts as a drain for the upper part of the aquifer. The surface of the river fluctuates with the tide, but generally slopes from 1 to 3 feet above sea level in the vicinity of the Inglis Lock bypass channel to sea level near the river mouth. The river level coincides with the water table adjacent to the river, and the river channel coincides with a trough in the potentiometric surface (water table) of the Floridan aquifer. The river, therefore, is usually a gaining stream, but during flood stages and high tides, the river may become higher than the immediately adjacent water table, and flow between the aquifer and the river temporarily reverses.

Ground-water head in the upper 100 to 200 feet of the aquifer is expected to increase with depth near the river and the coast owing to frictional head loss as the water moves upward through the aquifer to discharge into the river and the gulf. Also, at greater depths poorly permeable zones in the aquifer act as partly confining layers, resulting in increased head with depth. Although the water level is below land surface in wells at least 200 or so feet deep, water levels in wells several hundred feet deep may be above land surface, so such wells can flow.

The average annual rainfall in the area is about 53 inches. A relatively small fraction of this water runs over the land surface directly into the river, canal, or gulf. About 15 inches percolates through the sandy post-Miocene cover to infiltrate the Floridan aquifer and eventually discharge to the river, canal, or gulf. Except for an additional 0.2 inch estimated to be pumped from the aquifer at wells, the remainder of the rainfall is evaporated or transpired. Ground-water levels, which vary in response to variations in rainfall, normally rise during the wet season in summer and early fall and decline during the dry season in winter and early spring. Additional ground water enters the area through the aquifer from the northeast and moves in the direction of decline of the potentiometric gradient to discharge at the river and the coast.

Before the canal was constructed, the major source of fresh water in the lower Withlacoochee River between Inglis Dam and the coast was discharge through Inglis Dam from the Withlacoochee backwater area. Flow through the dam was regulated to maintain desirable stages in the backwater area. The average discharge through the dam for the 38 years from October 1931 through September 1969 was estimated to be 1,900 cfs (cubic feet per second), with a maximum monthly average of 7,940 cfs and a minimum monthly average of 645 cfs (Bush, 1972). Monthly average discharge through the dam during the period of record was cyclic, corresponding with periods of high and low runoff. Consequently, high and low flow in the lower part of the river generally coincided with periods of high and low ground-water levels.

A relationship similar to that between the river and the aquifer exists between the barge canal and the aquifer. The canal penetrates 13 to 25 feet of limestone and dolomite of the Floridan aquifer to 13 feet below sea level, and water exchanges freely between the canal and aquifer. The water level in the canal is near sea level, it fluctuates with the tide, and it coincides approximately with the water table at the canal's edge. Ground-water inflow to the canal has caused a potentiometric trough to form along the axis of the canal. Ground-water inflow, fresh-water discharge from lockages at Inglis Lock, and discharge through Inglis Dam cause the average hydraulic gradient in the canal to be toward the gulf. As in the case of the river, the canal stage may sometimes become higher than the adjacent water table as a result of high tides and (or) high fresh-water discharge. At such times ground-water flow to the canal is halted or retarded and may be temporarily reversed.

One and a half miles below Inglis Dam, the canal intersects the natural river channel. Since December 1969 the canal has diverted water, discharged through Inglis Dam, 6 miles southwestward to the gulf. A plug in the river channel at the north side of the canal prevents any of the diverted flow from entering the lowermost 9-mile reach of the river. Since the canal has been open to the gulf, fresh-water flow from the Withlacoochee River backwater area has been furnished to the lower river through the Inglis Lock bypass channel, which empties into the natural river channel just north of the barge canal crossing. A gated spillway at the west end of the bypass channel holds the stage of the bypass channel at a level nearly equal to that of the backwater area, or on the average about 25 feet above the stage of the river just below the spillway.

Analysis of surface-water discharge and stage records by Bush (1972) shows that the expected long-term average discharge through the bypass channel is about 1,430 cfs, or about 470 cfs less than the approximate long-term average of 1,900 cfs through Inglis Dam before December 1969. It follows that the expected long-term mean tide level (mean stage) of the river below the bypass channel after December 1969 is lower than the mean tide level before December 1969. The analysis by Bush (1972) shows that the expected post-December 1969 long-term mean tide level of the Withlacoochee River at the Crackertown gage, 0.7 mile downstream from U. S. Highway 19, is 0.3 foot lower than before December 1969.

Effects of Canal on Ground-water Regime

Water Levels

Water levels in some wells in the area fluctuated more than 5 feet from June to September 1971. Depths to the water table ranged from less than 1 foot below land surface near the coast to about 22 feet near Inglis Lock. In most of the area, water levels ranged between 5 and 10 feet below land surface; levels tended to be closer to the surface nearest the coast.

Ground-water levels in the area change quickly in response to direct recharge from local rainfall. This is illustrated by the rainfall record and water-level hydrographs in figure 3. This characteristic made it possible to procure in a short time data representative of both low and high ground-water levels. The hydrographs show that the rise in ground-water levels as a result of storms is rapid, but that the ensuing decline is relatively slow. Short-term continuous records collected at several wells located at points about 0.5 mile from the canal and (or) the river show a slight diurnal barometric effect on water levels but apparently no tidal effect. However, in recorder well CE 5, about 800 feet south of the canal and about 2,000 feet southwest of Inglis Lock, tidal effect is pronounced.

Figure 4 shows the potentiometric surface of the Floridan aquifer on July 16, 1971, a time of relatively low water. Figure 5 shows the potentiometric surface on August 18, 1971, a time of relatively high water. The general shapes of the low- and high-water maps are similar, and little difference in the flow patterns is evident. The change in ground-water levels from July 16 to August 18 ranged from about 1 foot in the vicinity of Inglis Lock to as much as 5 feet to the west between the canal and the river. The variations in amount of change from place to place may have been caused partly by varia-

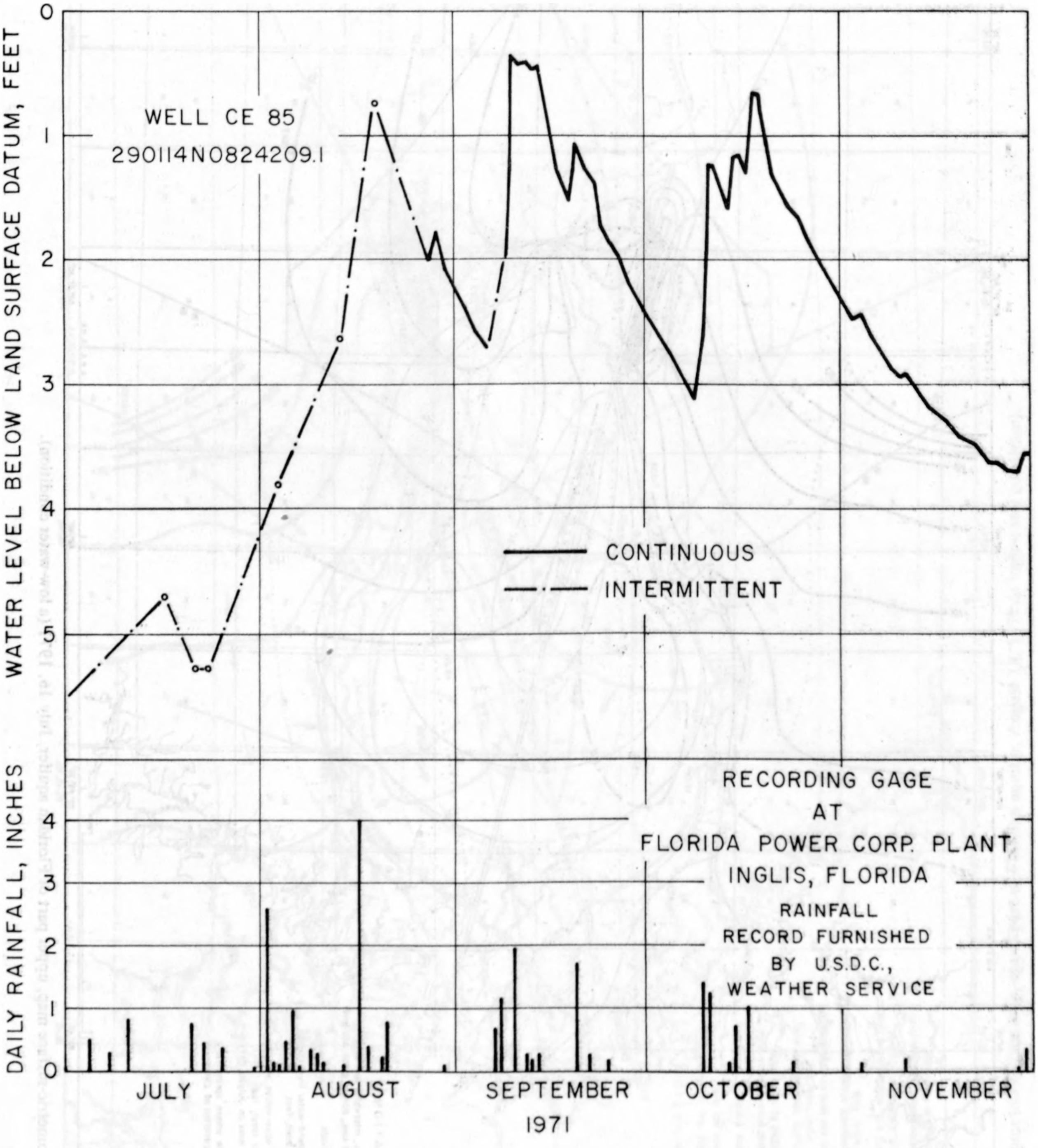

Figure 3.–Hydrographs showing relationship between daily rainfall and groundwater-level fluctuations in upper part of Floridan aquifer.

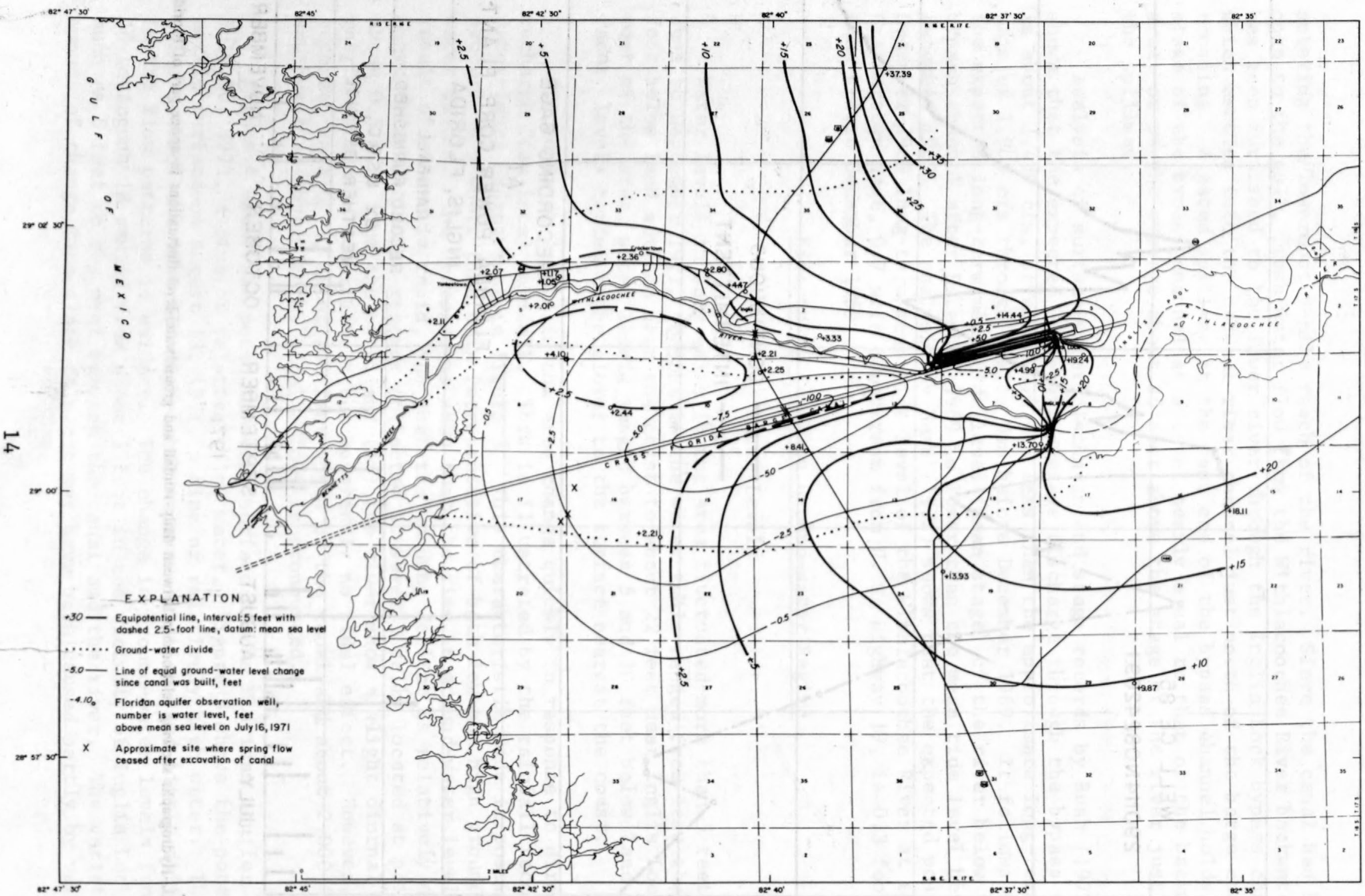

Figure 4.--Potentiometric-surface map, upper part of Floridan aquifer, July 16, 1971 (a low-water condition).

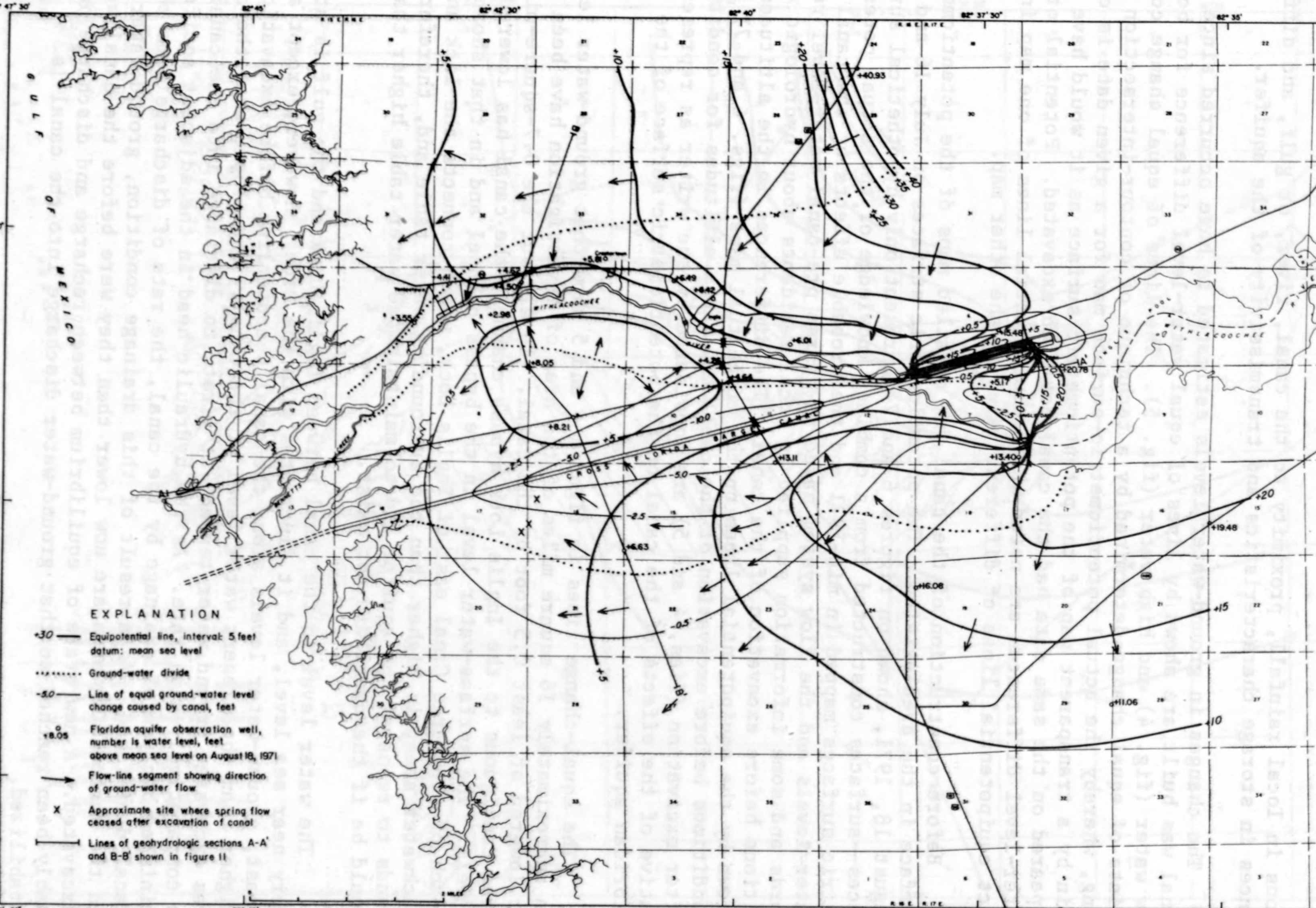

Figure 5.–Potentiometric-surface map, upper part of Floridan aquifer, August 18, 1971 (a high-water condition).

tions in local rainfall, proximity to the canal, river, or gulf, and differences in storage characteristics and transmissivity of the aquifer.

The changes in ground-water levels estimated to have occurred since the canal was built are shown by lines of equal water-level difference for both low water (fig. 4) and high water (fig. 5). The lines of equal change connect points of equal change determined by a technique of contour-intersection mapping, whereby the actual potentiometric-surface map for a given date is overlain by a transparent map of the potentiometric surface as it would have appeared on the same date had the canal not been excavated. Potential or water-level differences are noted where equipotential lines of one map intersect equipotential lines of different value on the other map.

Before construction of the canal, no detailed maps of the potentiometric surface in the area existed. The potentiometric surfaces on July 16 and August 18, 1971, shown on figures 6 and 7 represent only hypothetical surfaces--surfaces constructed from a combined knowledge of the actual potentiometric surfaces mapped in mid-1971 and the probable effects of the canal on water levels and the flow system based on sparse pre-canal water-level records and some information supplied by local residents about hydrologic conditions before excavation of the canal. The differences in the altitudes shown by the equipotential lines on the conceptual maps (figs. 6 and 7) for conditions before excavation of the canal and those altitudes for conditions after excavation (figs. 4 and 5) are considered by the writer as representative of the effects of the canal on the potentiometric surface of the Floridan aquifer.

The equal-change lines in figures 4 and 5 show that ground-water levels in approximately 16 square miles of the area of investigation have been raised or lowered at least 0.5 foot by the canal. In all but the 0.7-square-mile area contiguous to the Inglis Lock bypass channel, the canal has lowered levels. The surface-water level in the bypass channel and in that short reach of the Barge Canal east of Inglis Lock, which connects the lock and backwater area, is higher than the surrounding water table and, therefore, tends to recharge the aquifer and to maintain the water table higher than it would be if the canal did not exist.

The water level in the canal between Inglis Lock and the gulf is at or very near sea level, and it fluctuates with the tide. However, except at the coast, ground-water levels along the canal's centerline before excavation were higher than the present water level of the canal. Therefore, when the canal was excavated ground water tended, at first, to discharge into the canal at a comparatively high rate. As the hydraulic head in the adjacent aquifer diminished because of drainage by the canal, the rate of discharge into the canal diminished. As a result of this drainage condition, ground-water levels in the surrounding area are now lower than they were before the canal was excavated. A new state of equilibrium between recharge and discharge has probably been reached so that ground-water discharge into the canal is stabilized.

The area in which ground-water levels are lowered 0.5 foot or more is

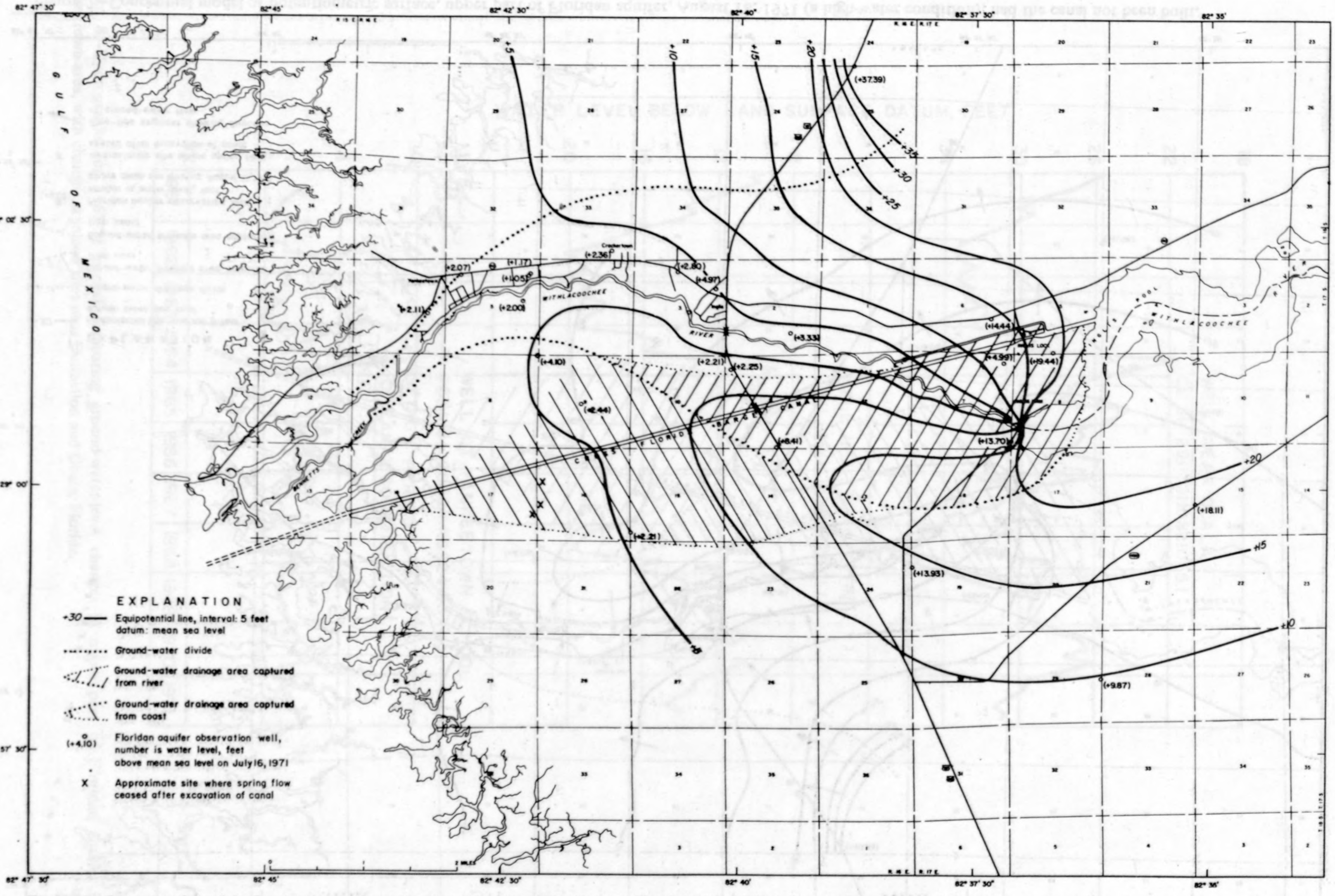

Figure 6.--Conceptual model of potentiometric surface, upper part of Floridan aquifer, July 16, 1971 (a low-water condition), had the canal not been built.

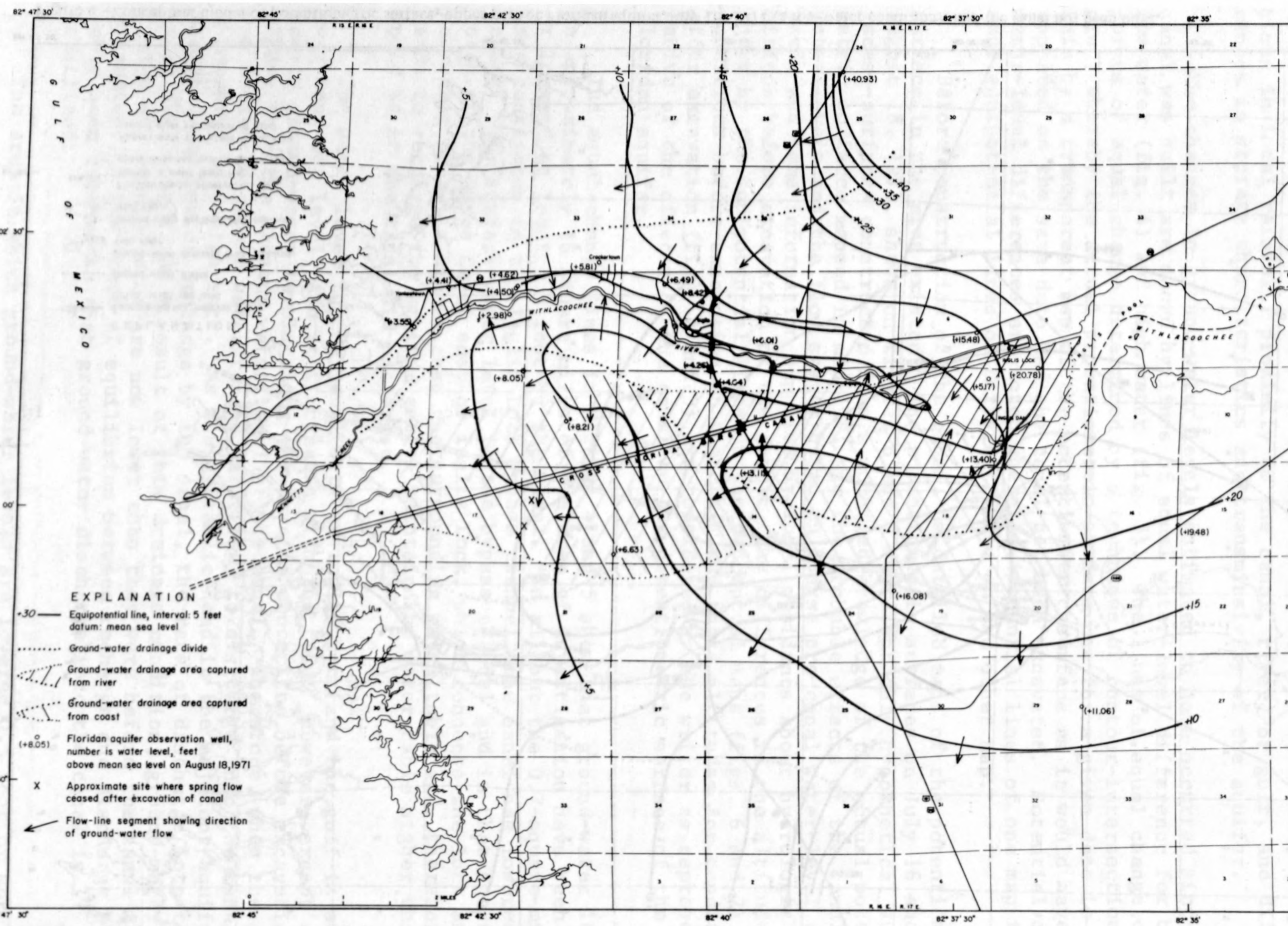

Figure 7.–Conceptual model of potentiometric surface, upper part of Floridan aquifer, August 18, 1971 (a high-water condition), had the canal not been built.

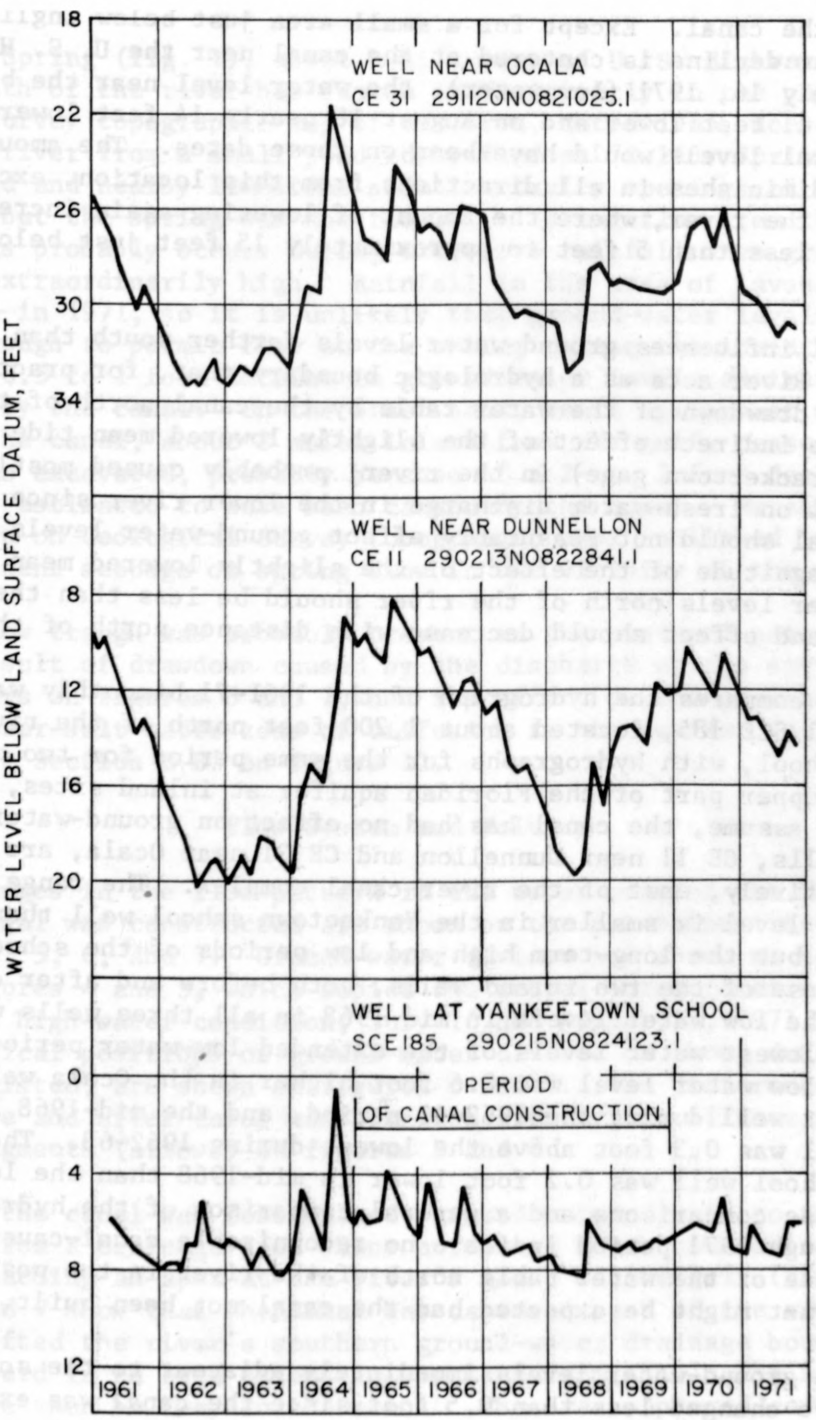

Figure 8.–Hydrographs for 1961-71 period comparing ground-water-level changes in upper part of Floridan aquifer in the Yankeetown area, with changes at inland sites near Dunnellon and Ocala, Florida.

somewhat larger during low water than during high water. It is roughly teardrop shaped and points northeastward, with its longitudinal axis coincident with that of the canal. Except for a small area just below Inglis Lock, the area of maximum decline is centered at the canal near the U. S. Highway 19 bridge. On July 16, 1971 (low water), the water level near the bridge was estimated to be 11 feet lower and on August 18 nearly 14 feet lower than the probable natural levels would have been on those dates. The amount of water-table change diminishes in all directions from this location, except along the canal east of the river, where the amount of lowering again increases northeastward from less than 5 feet to approximately 15 feet just below Inglis Lock.

The canal influences ground-water levels farther south than north, as the Withlacoochee River acts as a hydrologic boundary that, for practical purposes, limits drawdown of the water table by the canal north of the river. Except for the indirect effect of the slightly lowered mean tide level (0.3 foot at the Crackertown gage) in the river, probably caused mostly by changes in the control on fresh-water discharge in the lower river since December 1969, the canal should not measurably effect ground-water levels north of the river. The magnitude of the effect of the slightly lowered mean river stage on ground-water levels north of the river should be less than the decrease in river stage, and effect should decrease with distance north of the river.

Figure 8 compares the hydrograph of the 1961-71 bimonthly water-level record at well SCE 185, located about 1,200 feet north of the river at the Yankeetown school, with hydrographs for the same period for two observation wells in the upper part of the Floridan aquifer at inland sites, where, it is reasonable to assume, the canal has had no effect on ground-water levels. The two inland wells, CE 11 near Dunnellon and CE 31 near Ocala, are 8 and 28 miles, respectively, east of the river-canal complex. The range of fluctuation in water level is smaller in the Yankeetown school well than it is in the inland wells, but the long-term high and low periods of the school well are similar to those of the two inland wells, both before and after canal construction. The low water levels in mid-1968 in all three wells were very close to the lowest water levels of the extended low-water period of 1962-63. The mid-1968 low water level was 0.6 foot higher in the Ocala well than the lowest in that well during the 1962-63 period, and the mid-1968 low in the Dunnellon well was 0.3 foot above the lowest during 1962-63. The level in the Yankeetown school well was 0.2 foot lower in mid-1968 than the lowest during 1962-63. These comparisons and a general comparison of the hydrographs during the 1969 through 1971 period indicate no recognizable canal-caused difference in the altitude of the water table north of the river in the post-construction period from what might be expected had the canal not been built.

Although ground-water levels immediately adjacent to the south bank of the river have changed less than 0.5 foot since the canal was excavated, the hydraulic gradient of the water table on the south side of the river has diminished appreciably, with an attendant reduction of ground-water discharge to the river. The reduction in gradient could account in part for the present absence of spring boils at the surface of the river, which were reportedly observed at times by local residents in pre-canal days, especially at low tide.

Quantitative effects of lowered ground-water levels on ground-water discharge to the river are discussed later in the report.

Sulfur Spring (fig. 1), about a mile west of U. S. Highway 19 and about 700 feet south of the river has flowed intermittently in the past. The U. S. Geological Survey topographic map of the area, dated 1955, does not indicate flow to the river from a small pond identified as "Sulfur Spring." In mid-1971 the pond and nearby limestone solution-cavity openings at the surface were found, but the spring was not flowing. Spring flow from the solution cavity openings probably occurs during excessive rainfall when ground-water levels are extraordinarily high. Rainfall in the area of investigation was below normal in 1971, so it is unlikely that ground-water levels would have been high enough to permit flow at the spring during the investigation, even without the 0.5 to 1 foot decline in ground-water levels estimated to have been caused by the canal. On the other hand, small springs at several locations near the canal, about 2 miles inland from the gulf, ceased to flow after the canal was excavated, probably because of a 2- to 3-foot decline in ground-water levels estimated to have been caused by the canal. Marshy surface conditions shown on Geological Survey topographic maps published in 1954 and 1955 suggest frequent seepage or spring flow in the vicinity of the springs.

A shallow trough was probably present in the precanal potentiometric surface as a result of drawdown caused by the discharge at the springs. Such a trough appears on figures 6 and 7, and its effect on the precanal position of the fresh-water-salt-water zone of diffusion in the aquifer is reflected in geohydrologic Section B-B' on figure 11.

Flow System and Volumes

The changes in the flow pattern in the upper part of the Floridan aquifer since the canal was constructed are shown on the potentiometric-surface maps in figures 4, 5, 6, and 7. Ground-water divides are shown as heavy dotted lines on figures 4 and 5, which depict the actual potentiometric surfaces for a low- and a high-water condition, July 16 and August 18, 1971, respectively. The hypothetical positions of ground-water divides on those dates, had the canal not existed, are shown on figures 6 and 7. The differences in the flow system before and after canal construction are further illustrated by plotted flow-line segments (arrows) on figures 5 and 7.

Before the canal was constructed, ground water flowed to the river below Inglis Dam from a drainage area whose north and south boundaries converged westward, reaching an apex at the river's mouth on the gulf (figs. 6 and 7). Figures 6 and 7 show that the canal has captured part of the river's drainage area and shifted the river's southern ground-water drainage boundary, or divide, northward in an area extending westward from the Inglis Lock and Dam vicinity more than halfway to the coast. The area captured covers about 6 square miles and is centered a little west of the lock and dam sites. The river's southern drainage divide is now the axis of a low ridge or elongate mound that has been induced in the potentiometric surface between the river and canal. The change in the position of the ground-water drainage divide north of the river is negligible, as the effect of the canal on ground-water levels north of the river is slight.

A ground-water drainage divide has developed south of the canal in response to water-level drawdown by the canal in the area between this divide and the canal. Figures 6 and 7 also show that west of the drainage area captured from the river the canal has captured ground-water flow that formerly discharged to the gulf. The canal, therefore, acts as an open-channel drain that eases flow to the gulf and, thus, has lowered ground-water levels in the areas influenced by the canal.

The area contributing ground water to the river-canal complex from the upper part of the Floridan aquifer totals 36 square miles (fig. 9). Before the canal was built, the ground-water drainage area contributing to the river below Inglis Dam was 29 square miles. The added 7 square miles now in the river-canal-complex drainage area drained to the coast before the canal was built. Two of these 7 square miles still drain to the coast between the river and the canal, but drainage from the remaining 5 square miles discharges to the canal.

Average annual discharge from the ground-water drainage area of the river-canal-complex, based on earlier determinations for the Silver Springs and Rainbow Springs drainage areas (Faulkner, 1970), is estimated to be 15 inches, or the equivalent of 1.1 cfs per square mile. Therefore, based on a 36-square-mile drainage area, the combined average ground-water flow to the river, canal, and gulf coast from the upper part of the Floridan aquifer is estimated to be 40 cfs. The canal has captured some drainage area that formerly drained to the river. Ground-water flow to the river below the Inglis Lock bypass channel is now derived from 23 square miles and is estimated at 25 cfs, or about 7 cfs less than the average inflow to the river below Inglis Dam before the canal was built. The ground-water flow to the canal is derived from 11 square miles of captured river and coastal drainage area and is estimated to average less than 13 cfs.

Based on provisional daily discharge figures, the average surface-water flow from the Withlacoochee River backwater area to the river below the Inglis Lock bypass channel was 1,170 cfs during October 1, 1970, to September 30, 1971. The average ground-water inflow to that reach of the river for the same period is estimated to be 25 cfs. Had the canal not existed, an additional 7 cfs of ground-water, as an estimate, would have entered the river channel, part of it in that 1.5-mile reach just below Inglis Dam and now separated by the canal from the lowermost 9-mile reach of the river. Finally, releases and seepage through the Inglis Dam, which averaged 237 cfs during October 1, 1970, to September 30, 1971, plus a nominal amount discharged through Inglis Lock, would have also flowed down the river all the way to the gulf, rather than being diverted via the canal to the gulf. In short, had the canal not existed during the October 1970 - September 1971 period, the average freshwater discharge at the mouth of the Withlacoochee River, as an estimate, would have been slightly in excess of 1,440 cfs, rather than the approximately 1,195 cfs that did flow into the gulf from the river. This amounts to a 17-percent reduction in discharge for the year in the lower river because of

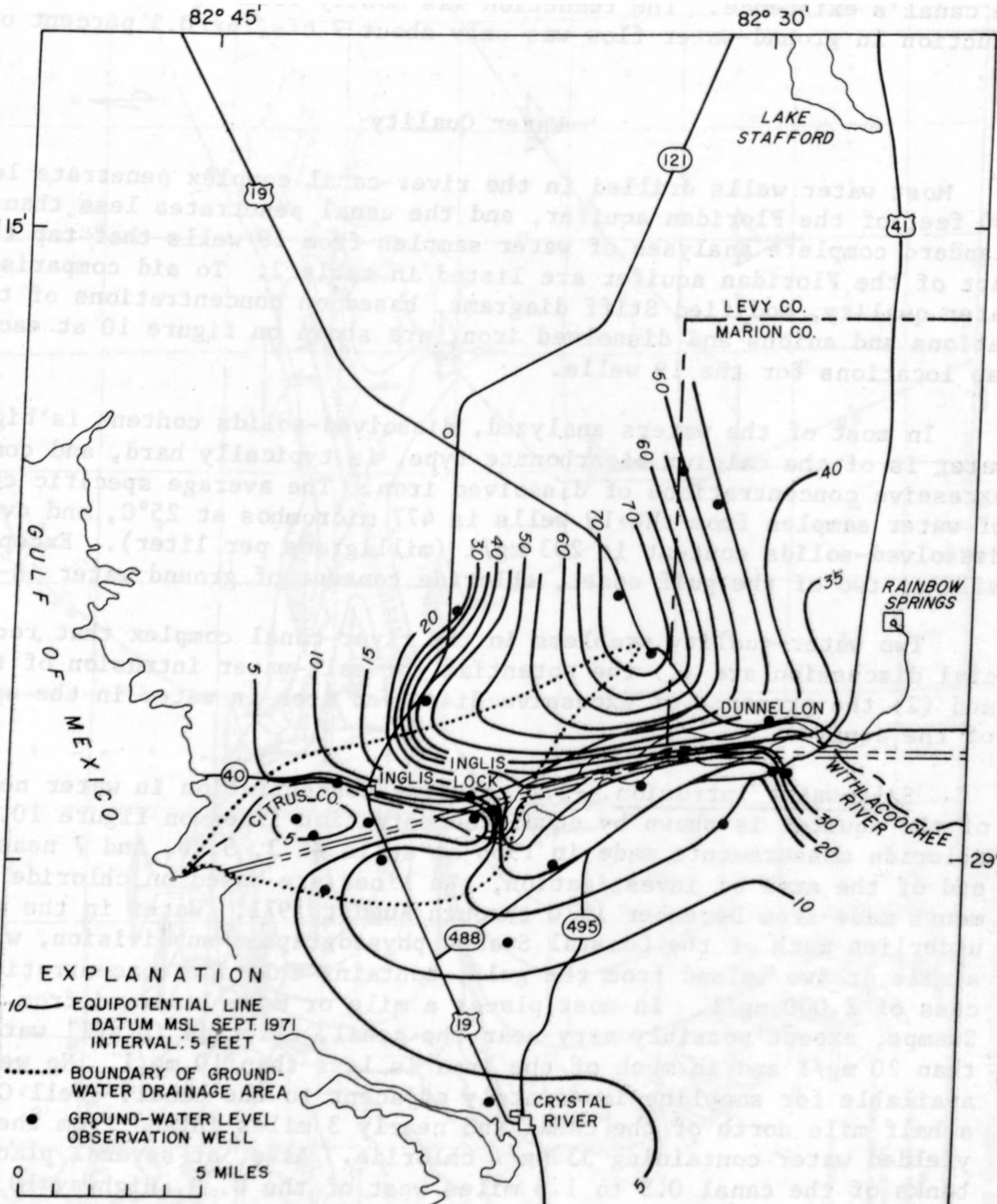

Figure 9.–Regional potentiometric-surface map, upper part of Floridan aquifer, September 1971, showing ground-water drainage area for Lower Withlacoochee River - Cross-Florida Barge Canal complex area.

the canal's existence. The reduction was mostly fresh surface water, as the reduction in ground-water flow was only about 7 cfs, or 0.5 percent of 1,440 cfs.

Water Quality

Most water wells drilled in the river-canal complex penetrate less than 100 feet of the Floridan aquifer, and the canal penetrates less than 25 feet. Standard complete analyses of water samples from 19 wells that tap the upper part of the Floridan aquifer are listed in table 2. To aid comparison of water quality, modified Stiff diagrams, based on concentrations of the common cations and anions and dissolved iron, are shown on figure 10 at each of the map locations for the 19 wells.

In most of the waters analyzed, dissolved-solids content is high. The water is of the calcium bicarbonate type, is typically hard, and commonly has excessive concentrations of dissolved iron. The average specific conductance of water samples from the 19 wells is 477 micromhos at 25°C, and average dissolved-solids content is 293 mg/l (milligrams per liter). Except within a mile or two of the gulf coast, chloride content of ground water is very low.

Two water-quality problems in the river-canal complex that require special discussion are (1) the potential for salt-water intrusion of the aquifer and (2) the presence of excessive dissolved iron in water in the upper part of the aquifer.

Salt-water intrusion.—The chloride concentration in water near the top of the aquifer is shown by equal-concentration lines on figure 10. Except for chloride measurements made in 1966 at wells CE 3, 5, 6, and 7 near the east end of the area of investigation, the lines are based on chloride measurements made from December 1970 through August 1971. Water in the aquifer that underlies much of the Coastal Swamps physiographic subdivision, which extends a mile or two inland from the gulf, contains chloride concentrations in excess of 2,000 mg/l. In most places a mile or more landward from the Coastal Swamps, except possibly very near the canal, chloride in well water is less than 20 mg/l and in much of the area is less than 10 mg/l. No wells were available for sampling immediately adjacent to the canal. Well CE 86, about a half mile north of the canal and nearly 3 miles inland from the coast, yielded water containing 33 mg/l chloride. Also, at several places in the banks of the canal 0.5 to 1.5 miles west of the U. S. Highway 19 bridge, water issuing from cavities between high- and low-tide levels had a chloride content of about 3,500 mg/l when sampled at low tide on December 29, 1970. These and other factors to be discussed indicate that a potential exists for intrusion of sea water into the aquifer farther inland from the mouth of the canal than from elsewhere along the coast.

All along the coast, as a natural condition, a wedge of sea water extends inland in the aquifer underneath the fresh water. This is due basically to the greater density of sea water, but the extent of intrusion of this wedge depends on several factors. These factors include the altitude of the fresh water table above sea level, permeability of the aquifer, the amount of re-

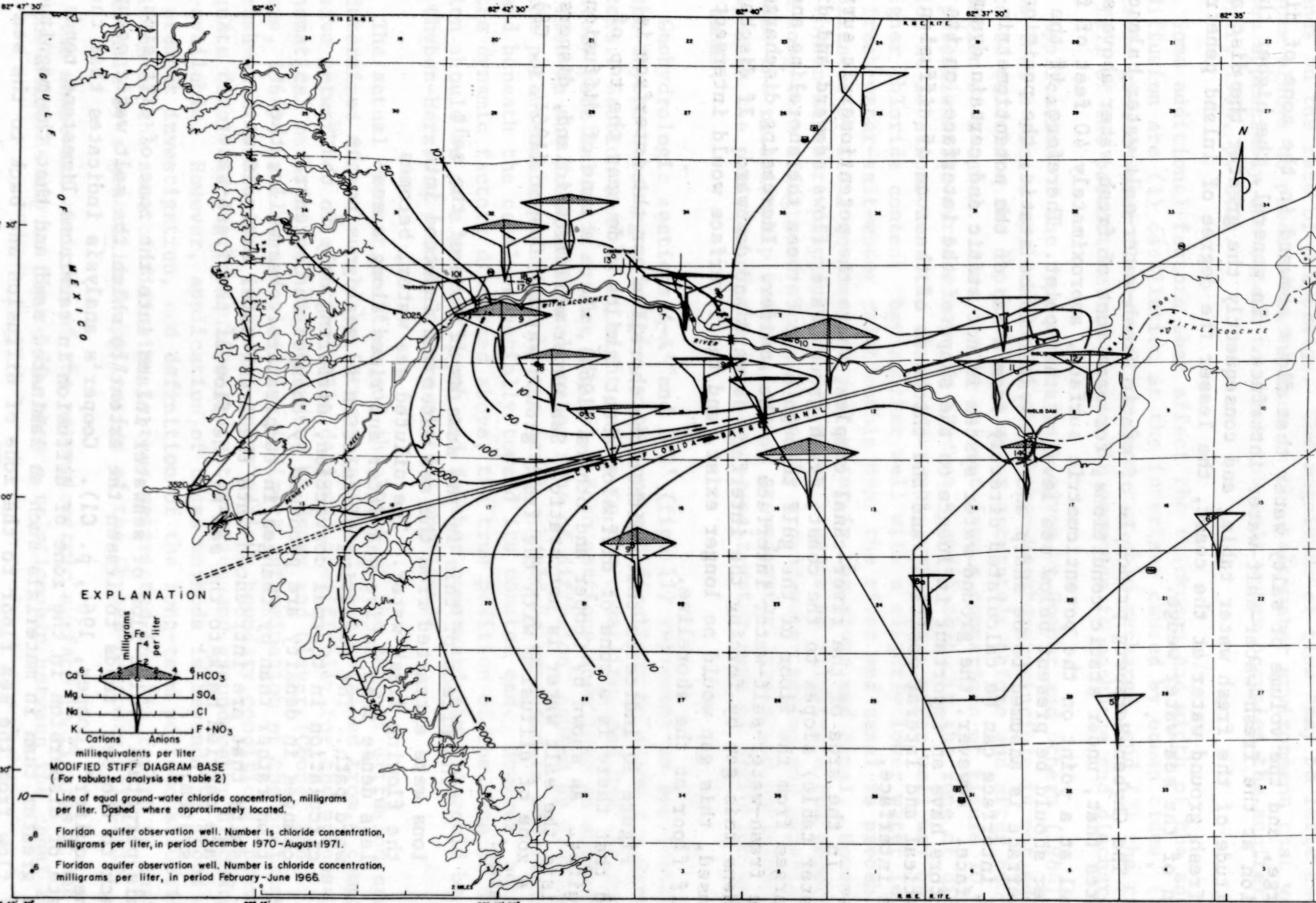

Figure 10.–Ground-water-quality map showing coastward increase in chloride content and a graphic comparison of standard complete analyses.

charge, and the volume of salty water that flows seaward in the zone of diffusion at the fresh-water-salt-water interface. In general, the higher the altitude of the fresh water table, and consequently the greater the discharge of fresh ground water at the coast, the lesser the degree of inland penetration of the sea-water wedge.

The Ghyben-Herzberg principle of static fresh-water-salt-water balance states that, under static conditions, for each foot of fresh water above sea level at a point on the potentiometric surface, approximately 40 feet of fresh water should be present below sea level at that point. Therefore, if the interface is assumed to be sharp and the system to be static, the position of the interface can be calculated directly from a map of the potentiometric surface. However, the ground-water system is not static and certain dynamic factors have an important influence on the shape of the interface, on its vertical and lateral position, and the thickness of the zone of diffusion at the interface.

In the area of the river-canal complex, where the potentiometric surface (water table) slopes to the coast, fresh ground water flows seaward and discharges from the floor of the gulf through a gap between the shoreline and the fresh-water-salt-water interface in the aquifer. Increasing discharge widens this gap by forcing the interface seaward and downward. If discharge ceased, this gap would no longer exist, and the interface would intersect the gulf floor at the shoreline.

Figure 10 indicates that neither the shoreline nor the interface is sharp and that there is a zone of diffusion about 2 miles wide near the top of the aquifer. As shown by Cooper and others (1964), where a zone of diffusion exists the salt water is not static. Sea water will flow inland, dispersing in a zone of diffusion with the fresh ground water. Cooper (1964, p. C8) states:

> "The effect of this is the same as if some of the salt ions were extracted from the sea water and injected into the flowing fresh water. The diluted sea water, becomes less dense than native sea water and rises along a seaward path. The resulting circulation is analogous to the circulation in thermal convection, differing only in that changes in density are produced by changes in concentration rather than by changes in temperature. Meanwhile, the salts that are introduced into the fresh-water environment are carried back to the sea by the flow of the fresh-water system."

This perpetual cyclic flow of seawater inland into the zone of diffusion and back to the sea "tends to lessen the extent to which the salt water occupies the aquifer" (Cooper, 1964, p. C1). Cooper's analysis indicates that the rate of dispersion in the zone of diffusion in cavernous limestone tends to be greater than in materials such as laminated sand and that the magnitude of flow from the sea floor to the zone of diffusion and back to the sea floor depends on the rate of dispersion. The magnitude of flow "may be large enough in some places to produce head losses in the salt-water environment that would lessen appreciably the extent to which the salt water occupies the aquifer" (Cooper, 1964, p. C12).

Some additional factors that affect the thickness and width of the zone of diffusion are (1) oscillation at the interface caused by ocean tides, (2) variable ground-water flow resulting from variable recharge, and (3) the rise and fall of the potentiometric surface in response to recharge and discharge.

Application of the type of analysis given by Cooper and others (1964) shows that a simple application of the Ghyben-Herzberg principle is not adequate to calculate the depth to salt water accurately before and after construction of a canal. Also, it is evident from a comparison of figure 10 with the potentiometric-surface maps in figures 4 and 5 that, in the zone of diffusion at locations near the river and canal, water in a given well may have a higher chloride content than another well with a slightly lower water level. The fresh-water-salt-water relationship near the river and canal is probably complicated by tidal movement of salt water in the river and canal. However, the Ghyben-Herzbert principle is useful as a means to illustrate the generalized long-term effects of the canal on the ground-water regime and especially to show the relationship between lowered ground-water levels and anticipated changes in the position of the fresh-water-salt-water zone of diffusion near the canal.

Geohydrologic sections A-A' and B-B' (fig. 11) represent an application of the Ghyben-Herzberg principle, with some modifications to allow for dynamic factors. Section A-A' is at right angles to the coastline, and B-B' is approximately parallel to it. (See fig. 5). Both sections show that an appreciable rise in the fresh-water-salt-water zone of diffusion, caused by drawdown of the potentiometric surface by the canal, should be expected in the vicinity of and beneath the canal, especially toward its coastal end. However, because of the dynamic factors discussed above, the true position of the zone of diffusion should be at a greater depth and farther coastward than it would be if the Ghyben-Herzberg principle were rigidly applicable.

The actual current position and thickness of the zone of diffusion can be determined directly only by interpretation of data obtained from a comprehensive network of observation wells designed specifically for the purpose. Mathematical methods, such as discussed by Henry and Glover (Cooper and others, 1964), have been devised for indirect determination of the position of a fresh-water-salt-water interface under various boundary conditions, provided adequate data relating to aquifer characteristics and ground-water discharge are available. However, application of these methods is beyond the scope of the present investigation, and definition of the long-term post-construction position of the zone of diffusion is thus restricted in this report to that attainable by a generalized application of the Ghyben-Herzberg principle.

The shape and altitude of the potentiometric surface in figures 4 and 5, and the chloride map in figure 10, show a relationship between the canal and

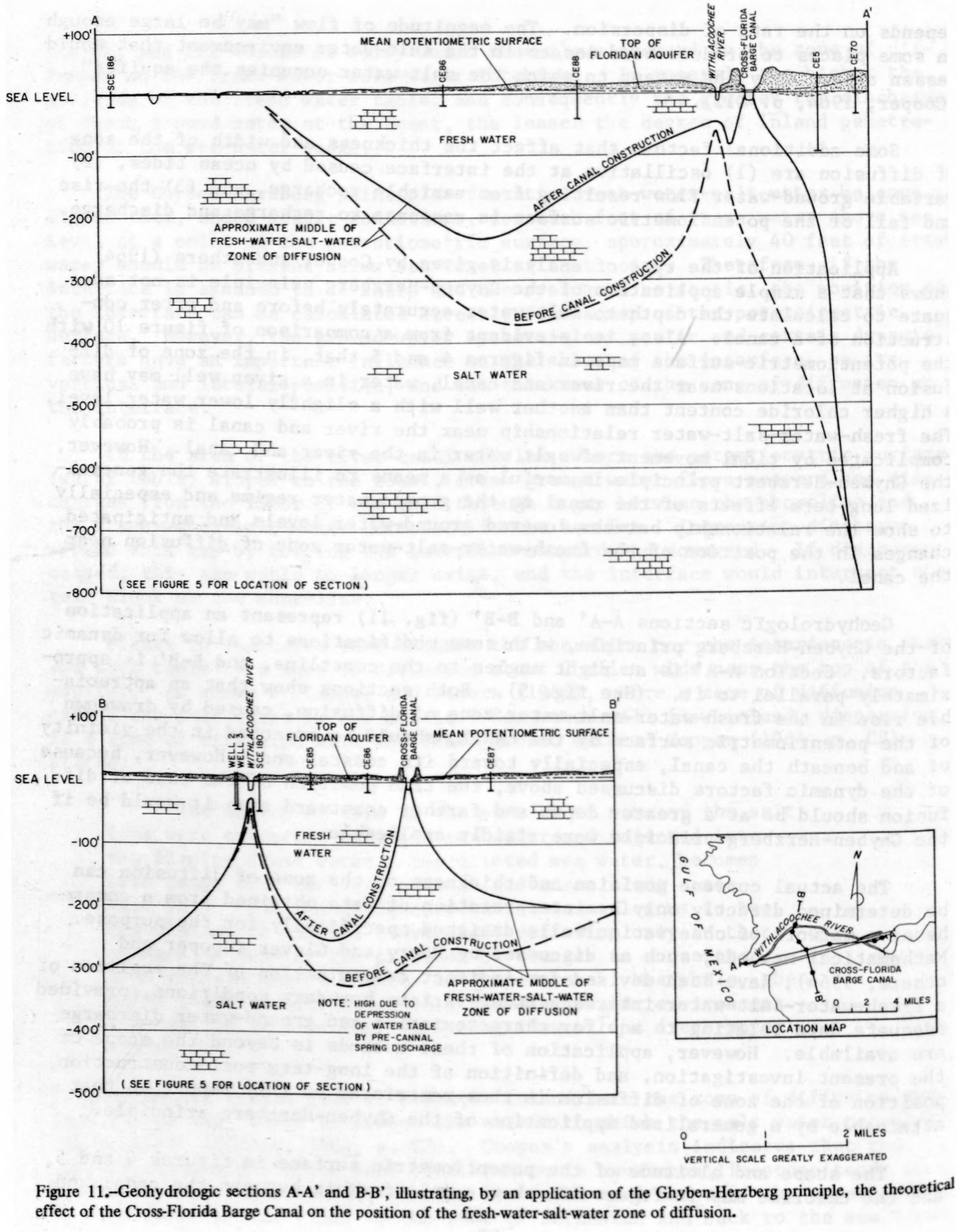

Figure 11.–Geohydrologic sections A-A' and B-B', illustrating, by an application of the Ghyben-Herzberg principle, the theoretical effect of the Cross-Florida Barge Canal on the position of the fresh-water-salt-water zone of diffusion.

the aquifer similar to that between the gulf and the aquifer. When fresh-water discharge from the Withlacoochee River backwater area to the canal is very low, the water level in the canal is at sea level, and the salinity of water in the canal is close to that of the gulf (Bush, 1972). Therefore, there is a tendency for fresh ground water to flow downward and laterally to the canal, as the canal is, in essence, a narrow inlet of the gulf. In addition, the absence of fresh-water head in the canal tends to permit the fresh-water-salt-water zone of diffusion under the canal to rise to the canal along virtually its entire length, just as the zone of diffusion rises to the gulf floor at the coast.

When fresh surface-water flow contributed to the canal from the backwater area is appreciable, the canal stage stands above sea level, and fresh-water head and coastward flow build up in the canal, so that landward intrusion of sea water is retarded as it is retarded in the river. At such times the zone of diffusion is depressed below the canal along most of its length. Some of the relationships just discussed are illustrated on Sections A-A' and B-B' in figure 11.

<u>Excessive Dissolved Iron</u>.--Excessive dissolved iron, naturally present in water in the shallow part of the Floridan aquifer, is a common problem for water users in much of the Withlacoochee River basin and in many other places near Florida's west coast (R. N. Cherry, oral commun., 1971). Many wells in the area of investigation yield water containing far more than the 0.3 mg/l maximum recommended by the U. S. Public Health Service for drinking water (U. S. Public Health Service, 1962). The highest concentrations of iron tend to be in the water near the top of the aquifer. The horizontal distribution is somewhat erratic. Iron concentrations in well water in the area of investigation ranged from 0.03 mg/l to 2.2 mg/l. The iron content in water from the two city of Yankeetown wells was 0.83 and 0.87 mg/l in June 1971 and in water from a private well just south across the river from the city wells, 1.5 mg/l.

The recommended limit for iron in drinking water is not based on physiological reasons, but rather on esthetic and taste considerations. The daily nutritional requirement for human beings is 1 to 2 mg (milligrams) of iron, and most diets contain 7 to 35 mg per day, with an average of 16 (McKee and Wolf, 1963, p. 202). Therefore, even the high concentrations observed in some of the ground water in the canal area would not significantly increase an individual's normal daily intake of iron.

Dissolved iron in ground water is in the ferrous state, which is readily oxidized to insoluble ferric hydroxides when the water is brought to the surface and allowed to aerate. Precipitates form that tend to agglomerate, flocculate, and settle on exposed surfaces. The precipitates make the water turbid. They accumulate in pipes, and they stain laundry and porcelain fixtures. Iron also imparts an undesirable taste to the water.

The source of the iron in the ground water may be the surficial materials through which recharge to the Floridan aquifer must filter. Because the iron content of water in the Floridan aquifer varies areally and diminishes with depth, not all well water in the area is excessive in iron content. The problem of excessive iron possibly can be solved by drilling and casing wells to greater depths or by drilling new wells at different sites. Drilling deeper wells may be impracticable where salt water is at shallow depths and well relocation may not be feasible where iron is widespread. However, various methods of water treatment are available that either tend to hold the iron in solution when the water is aerated or that induce rapid precipitation, so that the iron will settle or filter out of the water before distribution to the user.

Iron occurs naturally in some ground water in the area of investigation. What effect, if any, lowered ground-water levels resulting from the canal would have on dissolved iron content in local wells is not known.

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