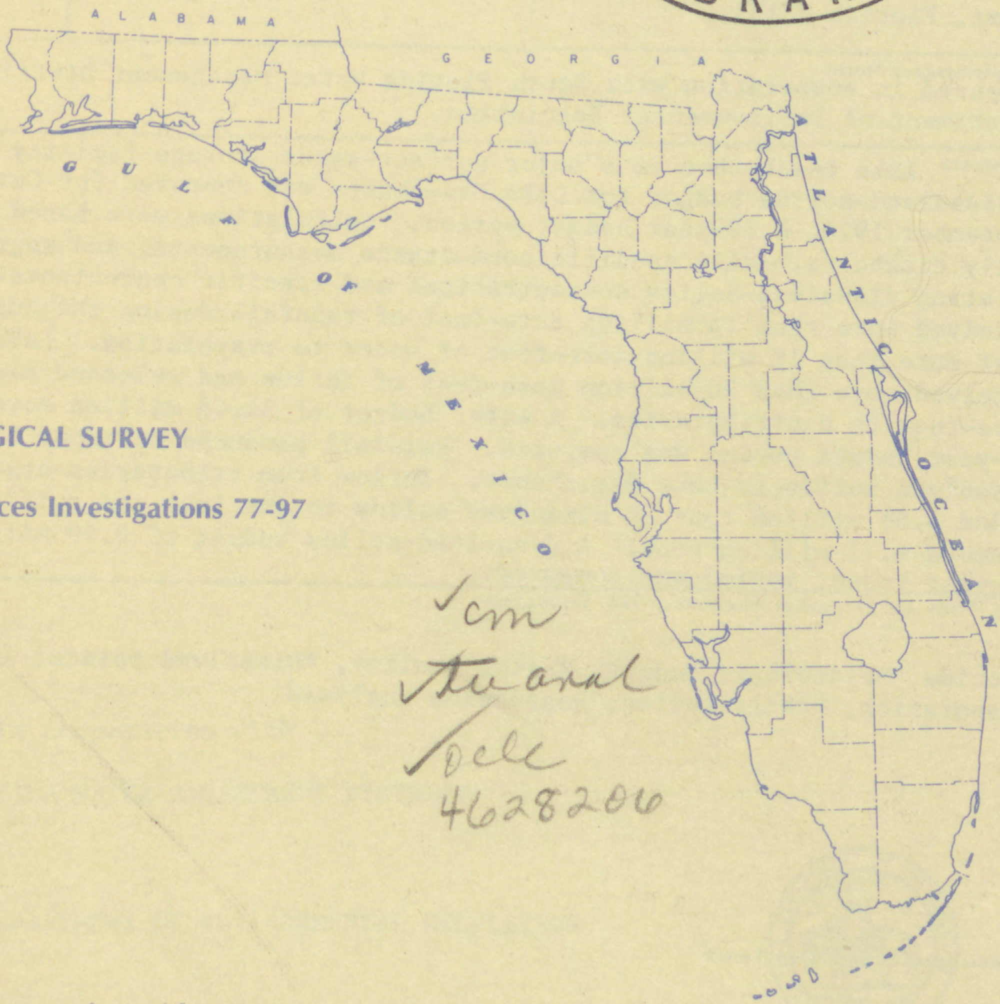
DISSOLVED-SOLIDS BUDGET OF LAKE OKEECHOBEE, FLORIDA, OCTOBER 1964 TO SEPTEMBER 1974



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-97

Prepared in cooperation with
SOUTH FLORIDA WATER MANAGEMENT DISTRICT
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CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

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

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DISSOLVED-SOLIDS BUDGET OF LAKE OKEECHOBEE, FLORIDA,

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David V. Maddy

ABSTRACT

Lake Okeechobee is a major surface-water storage facility for south Florida. A dissolved-solids budget for Lake Okeechobee was computed for October 1964 to September 1974, a 10-year budget period. Calculations were based on records of daily discharge, daily specific conductance measurements, and regression equations relating dissolved-solids concentrations and specific conductance. The lake received more than 13 million acre-feet of rainfall during the budget period and lost more than 18 million acre-feet of water to evaporation. Lake Okeechobee received more than 20 million acre-feet of inflow and released almost 16 million acre-feet to distributaries. A water budget of 34.48 million acre-feet for the 10-year budget period was computed. Rainfall produced an input of 460,000 tons of dissolved solids to Lake Okeechobee. Inflow from tributaries and distributaries added 5.51 million tons of dissolved solids to the lake and outflow to distributaries removed 6.71 million tons. A dissolved-solids budget of 6.99 million tons for the 10-year budget period was computed.

INTRODUCTION

Lake Okeechobee is in south-central Florida about 150 mi north of the southern tip of the peninsula (fig. 1). The lake serves as the major storage facility for surface water in south Florida and provides water for maintenance of navigable water levels, for irrigation of agricultural lands, and for water supply of several towns. The lake also provides for retention of flood waters, for disposal of excess water produced by both natural and artificial drainage of farmlands, for recreational boating and water sports, and for preservation of fish and wildlife. The water of Lake Okeechobee is used indirectly for preventing and controlling fires, for recharging major aquifers, and for retarding saltwater intrusion.

Realizing the importance of Lake Okeechobee to south Florida, the objective of this report is to present a water and dissolved-solids budget for the lake for a 10-year period, October 1, 1964 to September 30, 1974. This objective will serve three interrelated purposes. First, this report will provide a data base for future reports on the

Figure 1.--Location of Lake Okeechobee, Fl.

Lake Okeechobee area. Second, this report will provide guidelines for similar studies on systems of different scales. Third, this report will provide a basis for determining the necessity and the direction of further studies of the hydrologic system of the Lake Okeechobee area.

The objective will be arrived at by first developing the water budget, taking into consideration inflow, outflow, rainfall, evaporation and changes in storage, and then developing the dissolved-solids budget.

The data analyzed for these budgets were collected by the USGS (U.S. Geological Survey) and the FCD (South Florida Water Management District). A forerunner of this work was an analysis of historical water-quality data presented in another report by the USGS in cooperation with the FCD (Goolsby and others, 1976). The budget was developed for dissolved solids since Goolsby and others (1976) indicated that most of the major inorganic constituents are highly correlated to dissolved solids and could easily be computed on the basis of that correlation.

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

English	Multiply by	Metric
inch (in)	2.54	centimeters (cm)
feet (ft)	.3048	meters (m)
cubic feet per second (ft^3/s)	2.832×10^{-2}	cubic meters per second (m^3/s)
acre-feet (ac-ft)	1.233×10^{-3}	cubic hectometers (hm^3)
acre	.4047	hectares (ha)
ton (short, 2000 lb)	907.03	kilogram (kg)
square miles (mi^2)	2.59	square kilometers (km^2)
miles (mi)	1.609	kilometers (km)

DESCRIPTION OF THE LAKE OKEECHOBEE AREA

History

The Lake Okeechobee depression is believed to be between 4,000 and 6,000 years old (Brooks, 1974), and is considered to be the result of subsidence of Miocene clays. As the depression filled with fresh water, the natural outlets became blocked by vegetation. Lake Okeechobee probably reached its modern size and shape by about the 3d century A.D. Lake Okeechobee is one of the few freshwater lakes occurring within the semitropics (Davis, 1975).

In 1883 the Caloosahatchee River channel was extended to Lake Okeechobee. In the early 1900's four major channels were excavated from Lake Okeechobee southeastward through the Everglades to the Atlantic Ocean: the North New River Canal, the Miami Canal, the Hillsboro Canal, and the West Palm Beach Canal. The four canals were fully operational by 1921 (Leach, 1972). The completion of the St. Lucie Canal in 1928 brought Lake Okeechobee to its present (1975) system of tributaries and distributaries (fig. 2).

A low muck levee was constructed on the south and east sides of Lake Okeechobee before 1925. This levee was overtopped and breached in 1926 and again in 1928 by hurricane-driven storm surges. A newer, 25-ft high earth levee (Hoover Dike) was completed by 1938 on the west, south and east sides of the lake, at about the 15-ft mean sea level contour. The base of the levee ranges from 125 to 150 ft in width and the crest ranges from 10 to 30 ft in width; the levee is approximately 85 mi long.

Physical Features

Lake Okeechobee lies within the coastal lowlands of Florida as part of the Pamlico terrace, a plain formed by recession of the sea in the late Pleistocene. It is the largest freshwater lake within a single state and is second in size only to Lake Michigan of lakes entirely within the United States. It has a surface area of 720 mi^2 and a volume of 4.02 million ac-ft at a stage altitude of 15 ft. The lake is 35 mi long, north-south, and 30 mi wide. The mean depth of Lake Okeechobee is less than 10 ft and the maximum depth is less than 17 ft.

Tributaries

Approximately 4,400 mi^2 of land north of Lake Okeechobee are drained by five major tributaries: the Kissimmee River, Fisheating Creek, Taylor Creek, Harney Pond Canal, and Indian Prairie Canal. The Kissimmee River is the largest tributary with about 70 percent of the inflow area.

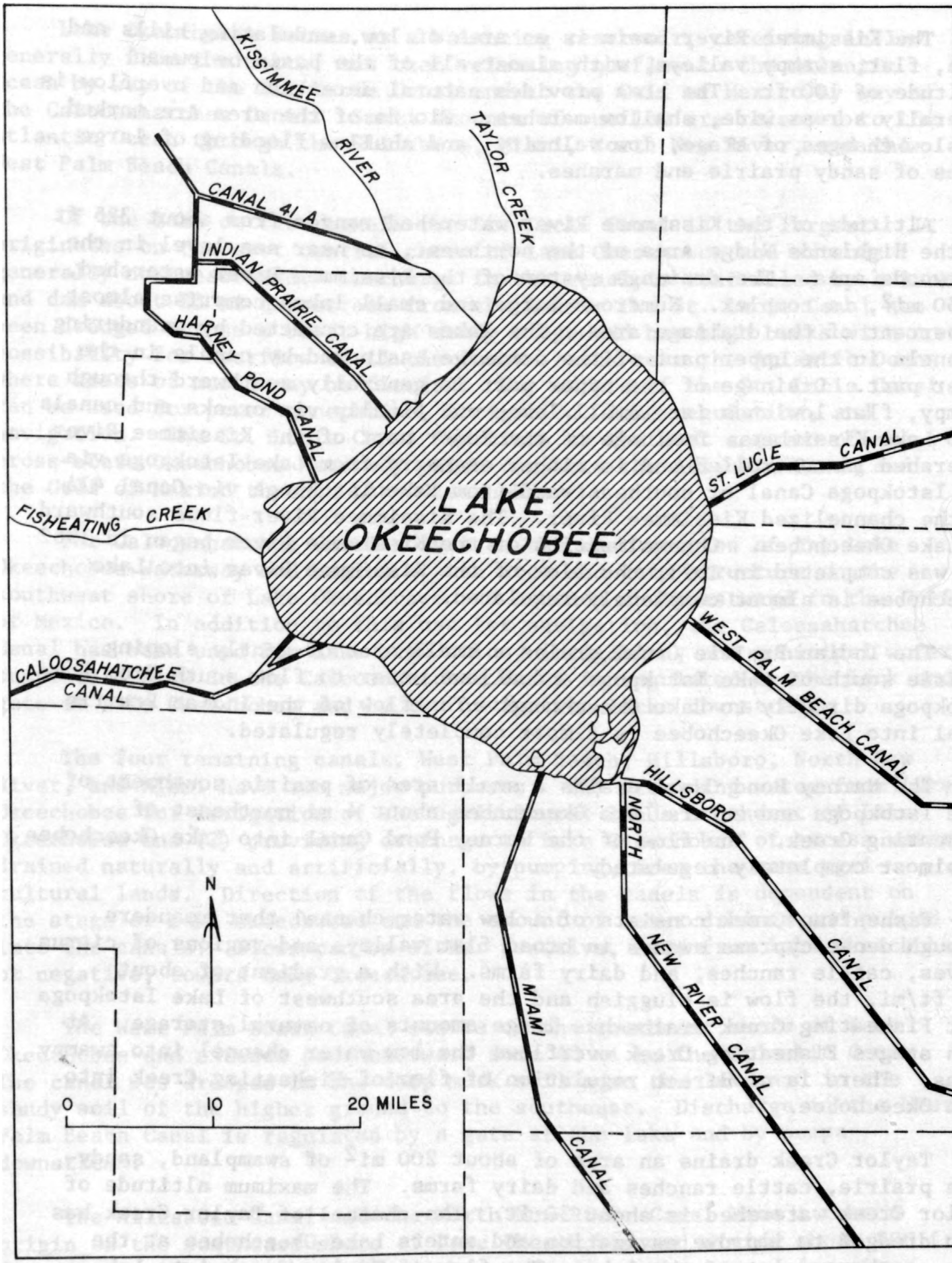

Figure 2.--Present (1975) system of tributaries and distributaries of Lake Okeechobee, Fl.

The Kissimmee River basin is an area of low, undulating hills and wide, flat, swampy valleys, with almost all of the basin below an altitude of 100 ft. The area provides natural detention and overflow is generally across wide, shallow marshes. Floods of the area are marked by slow changes of stage, low velocity, and shallow flooding of large areas of sandy prairie and marshes.

Altitude of the Kissimmee River watershed ranges from about 325 ft in the Highlands Ridge area of the northwest, to near sea level in the Flatwoods area. The drainage system of the Kissimmee River watershed, 2,950 mi^2, is complex. Numerous large and small lakes comprise almost 10 percent of the drainage area. The lakes are connected by meandering channels in the upper part of the drainage basin and by canals in the lower part. Drainage of the upper part is generally southward through swampy, flat lowlands into small lakes and finally via creeks and canals into Lake Kissimmee. Drainage of the lower part of the Kissimmee River watershed is controlled and is either eastward from Lake Istokpoga via the Istokpoga Canal or southeastward from Lake Istokpoga via Canal 41A to the channelized Kissimmee River. The Kissimmee River flows southward to Lake Okeechobee. Channelization of the Kissimmee River began in 1962 and was completed in 1971; the flow of the Kissimmee River into Lake Okeechobee is almost completely regulated.

The Indian Prairie Canal drains a small area of gently sloping prairie south of Lake Istokpoga and allows water to flow south from Lake Istokpoga directly to Lake Okeechobee. The flow of the Indian Prairie Canal into Lake Okeechobee is almost completely regulated.

The Harney Pond Canal drains a small area of prairie southwest of Lake Istokpoga and enters Lake Okeechobee about 4 mi northeast of Fisheating Creek. The flow of the Harney Pond Canal into Lake Okeechobee is almost completely regulated.

Fisheating Creek consists of a low water channel that meanders through dense cypress swamps in broad flat valleys and regions of citrus groves, cattle ranches, and dairy farms. With a gradient of about 0.5 ft/mi, the flow is sluggish and the area southwest of Lake Istokpoga that Fisheating Creek drains has large amounts of natural storage. At high stages Fisheating Creek overflows the low water channel into swampy areas. There is no direct regulation of flow of Fisheating Creek into Lake Okeechobee.

Taylor Creek drains an area of about 200 mi^2 of swampland, sandy-pine prairie, cattle ranches and dairy farms. The maximum altitude of Taylor Creek watershed is about 50 ft. The channel of Taylor Creek has been dredged to improve navigation and enters Lake Okeechobee at the most northern point of the lake. The flow of Taylor Creek into Lake Okeechobee is almost completely regulated.

Distributaries

Lake Okeechobee serves as a balancing reservoir, receiving inflow generally from the north, and then releasing outflow to the Atlantic Ocean by way of the St. Lucie Canal and to the Gulf of Mexico by way of the Caloosahatchee Canal. Small amounts of outflow are released to the Atlantic Ocean through the Hillsboro, Miami, North New River, and the West Palm Beach Canals.

Of the lake outflow canals the St. Lucie Canal is the largest. It originates on the east central shore of Lake Okeechobee and extends generally northeastward. Discharge in the canal is controlled by a lock and dam about 25 mi downstream from the lake. The St. Lucie Canal has been dredged across a 30-ft high sandy ridge and has high banks with no possibility for overflow until the lowest reach near the Atlantic Ocean where areas of marsh may be flooded. The waters of the St. Lucie Canal can be used for power generation, irrigation, lake regulation, and navigation. The St. Lucie Canal functions as the east section of the cross-state Okeechobee Waterway which connects the Atlantic Ocean and the Gulf of Mexico through Lake Okeechobee.

The Caloosahatchee Canal serves as the west section of the Lake Okeechobee Waterway and begins at the lock and gate structure on the southwest shore of Lake Okeechobee and extends southwestward to the Gulf of Mexico. In addition to this use for navigation, the Caloosahatchee Canal has been used for lake regulation, irrigation, and municipal water supplies. Flow in the Caloosahatchee Canal is regulated by the lock and gate at Lake Okeechobee and by two navigation locks downstream.

The four remaining canals, West Palm Beach, Hillsboro, North New River, and Miami have two major purposes: (1) providing water from Lake Okeechobee for irrigation of the agricultural lands southeast of Lake Okeechobee and (2) providing drainage to Lake Okeechobee of excess water drained naturally and artificially, by pumping, from the same agricultural lands. Direction of the flows in the canals is dependent on the stage of Lake Okeechobee and the amount of water drained and pumped into the canals. Flows can be either positive, away from Lake Okeechobee, or negative, toward Lake Okeechobee.

The West Palm Beach Canal starts on the southeast shore of Lake Okeechobee and extends southeastward some 40 mi to the Atlantic Ocean. The canal was dredged in the deep muck soil near the lake and in the sandy soil of the higher ground to the southeast. Discharge in the West Palm Beach Canal is regulated by a gate at the lake and by pumpa downstream.

The Hillsboro Canal and the North New River Canal have a common origin on the southeast shore of Lake Okeechobee and divide about 800 ft downstream. The Hillsboro Canal then extends southeastward for about 50 mi to the Atlantic Ocean. The North New River Canal extends southeastward for about 60 mi before entering the Atlantic Ocean. Some water from the North New River Canal enters the water conservation areas south of Lake Okeechobee. Discharge in the two canals is regulated by a gate structure and a pump at the lake and by pumpage downstream.

The Miami Canal originates on the south-central shore of Lake Okeechobee and extends south and east to the Atlantic Ocean some 80 mi away. The Miami Canal was dredged in the deep muck soil near the lake and required some removal of rock in the lower reaches. Some water from the Miami Canal enters the water conservation areas south of Lake Okeechobee and water in the Miami Canal provides recharge to the aquifer of the Miami well fields (Leach, 1972). Discharge in the Miami Canal is regulated by a pump and a gate structure at the lake and by pumpage downstream.

ELEMENTS OF THE WATER BUDGET

Rainfall

The annual rainfall of the Lake Okeechobee area averages 53 inches but has ranged from 38 inches (1961) to 117 inches (1947). There are distinct wet and dry seasons. Almost 75 percent of the annual rainfall occurs from June to November, and only 25 percent of the annual rainfall occurs from December to May. The amount and distribution of rainfall over the area is variable and is influenced by the proximity of numerous smaller inland lakes, the Gulf of Mexico, and the Atlantic Ocean.

Monthly total rainfall was tabulated from annual summaries of climatological data published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and averaged for four stations on the perimeter of Lake Okeechobee: Belle Glade, Canal Point, Clewiston, and Moore Haven (table 1).

For the budget period, rainfall was only 24 inches less than the total annual average. The 1970 water year was the wettest with 66.58 inches, more than 13 inches greater than the annual average rainfall, while 1967 was the dryest with 36.24 inches, almost 17 inches less than the annual average. The wet season, June to November, had about 360 inches, or about 72 percent of the total rainfall, while the dry season, December to May, had about 145 inches, or about 28 percent of the total. The maximum monthly total rainfall was 14.33 inches, June 1968, and the minimum was 0.03 inches, April 1970. The maximum dry season monthly total rainfall was 14.09 inches, March 1970, and the minimum wet season monthly total rainfall was 0.13 inches, November 1971.

Radar analysis of rainfall rates directly over Lake Okeechobee made by the Experimental Meterological Laboratory, National Oceanic and Atmospheric Administration, Miami, Florida has shown appreciably lower rates on the lake surface than on the surrounding land area (Riebsame and others, 1974). Since the monthly rainfall totals were obtained from land based gages around the lake, the totals were reduced by 20 percent. A similar adjustment was made by the FCD (Davis, 1975).

Table 1.--Monthly total rainfall, October 1964 to September 1974, Lake Okeechobee, Fl.
(In inches)

Water Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
October	5.84	9.88	4.29	3.70	6.32	8.80	3.68	5.77	1.18	1.89
November	0.53	0.31	0.21	0.19	1.93	1.87	0.13	2.61	3.26	0.31
December	2.30	1.39	0.71	1.79	0.08	2.48	0.19	1.06	1.65	1.54
January	0.58	4.55	0.84	0.26	1.97	3.00	0.47	1.21	2.49	0.85
February	4.23	2.77	2.60	2.37	1.87	2.37	1.48	1.59	2.22	0.36
March	2.59	0.70	0.85	1.15	5.92	14.09	0.46	1.87	3.07	0.35
April	1.96	2.65	0.07	0.93	2.96	0.03	0.19	4.42	0.94	1.02
May	2.10	5.23	1.79	8.16	5.87	5.43	4.57	6.40	4.75	3.32
June	11.11	12.07	8.64	4.33	8.29	6.10	9.38	9.15	8.03	11.77
July	6.63	8.49	6.24	8.94	5.39	8.66	7.83	5.95	8.38	9.44
August	5.61	8.70	4.19	4.03	9.15	9.98	6.25	5.10	5.95	6.28
September	7.01	6.10	5.81	8.89	7.05	3.77	6.45	2.00	5.76	4.87
Totals	50.49	62.84	36.24	54.74	56.80	66.58	41.08	47.13	47.68	42.00

Evaporation

The Lake Okeechobee area has an average temperature of 24°C with the summertime maximum averaging about 32°C. The area generally experiences mild winters, with only occasional short cool periods, and long, warm, humid summers. The large amount of surface area exposed for evaporation by Lake Okeechobee; the large amount of solar radiation; the light, persistent wind; the high humidity; and the high temperature combine to produce an average lake evaporation of over 50 inches.

Monthly total evaporation was tabulated from annual summaries of climatological data published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and averaged for three stations on the perimeter of Lake Okeechobee: Belle Glade, Clewiston, and Moore Haven (table 2). Evaporation was measured in a standard Weather Service Class A evaporation pan and a pan coefficient of 0.8 was used (Gray, 1973) for the stations at Belle Glade and Moore Haven and a coefficient of 0.98 was used for the sunken pan at the Clewiston station. The 1971 water year had the largest total pan evaporation, 69.20 inches, while 1966 had the smallest 59.34 inches. The maximum monthly total pan evaporation was 8.67 inches, May 1971, and the minimum was 2.79 inches, January 1966. Evaporation is almost equally divided between the wet season, June to November, and the dry season, December to May.

Tributary Inflow

Records of daily discharge are available for six tributaries: Fisheating Creek, Harney Pond Canal, Indian Prairie Canal, Kissimmee River, Canal 41A, and Taylor Creek. Maximums, minimums, and means of daily discharge are given in table 3. The Kissimmee River had the largest mean daily discharge, 2,680 ft^3/s, in 1970 and the Indian Prairie Canal had the smallest, 12 ft^3/s, in 1968. The Kissimmee River also had the largest maximum daily discharge, 23,500 ft^3/s, in 1970 and all tributaries had minimum daily discharges of 0 ft^3/s in some years.

Distributary Outflow

Records of daily discharge are available for six distributaries: St. Lucie, West Palm Beach, Hillsboro, North New River, Miami, and Caloosahatchee Canals. Maximums, minimums and means of daily discharge are given in table 4. The Caloosahatchee Canal had the largest mean daily discharge, 3,720 ft^3/s, in 1970 and the Miami Canal had the smallest, -132 ft^3/s, in 1968. The negative outflow figure for the Miami Canal is the result of pumping through the canal into Lake Okeechobee -- water that has been drained from the agricultural land southeast of the lake. The flow has been negative -- to, rather than from, Lake Okeechobee -- from time to time in the West Palm Beach, North New River, Miami, and the Caloosahatchee Canals. The St. Lucie Canal had the largest maximum daily discharge, 11,500 ft^3/s, in 1970 and the Hillsboro Canal had the smallest minimum, -2,930 ft^3/s, in 1973.

Table 2.--Monthly total pan evaporation, October 1964 to September 1974, for Lake Okeechobee, Fl.
(In inches)

Water Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
October	4.34	4.42	3.44	5.40	5.27	4.66	5.92	4.67	5.51	6.22
November	3.36	3.69	4.05	4.09	3.78	3.67	3.98	3.99	3.27	4.19
December	3.00	2.97	3.15	3.27	3.18	3.23	3.41	3.50	3.35	3.16
January	3.34	2.79	3.41	3.29	3.29	2.94	3.53	3.35	3.02	3.52
February	3.91	3.36	3.60	4.06	4.13	3.69	4.25	4.00	3.37	4.67
March	5.33	5.29	5.75	6.25	4.84	5.32	6.61	6.15	5.81	6.70
April	6.86	6.66	7.69	6.98	6.18	7.19	7.46	6.84	7.10	7.48
May	8.11	6.87	8.32	6.63	7.15	7.90	8.67	7.36	7.71	7.82
June	6.65	6.61	6.19	6.23	6.54	7.33	7.01	6.80	6.84	6.24
July	6.31	5.45	6.86	6.98	6.66	6.71	6.75	6.95	5.96	6.30
August	6.23	6.31	5.94	6.58	6.54	7.03	6.27	6.28	5.56	6.05
September	5.36	4.92	5.84	6.17	4.92	6.50	5.34	6.16	5.20	5.94
Totals	62.80	59.34	64.24	65.93	62.48	66.17	69.20	66.05	62.70	68.29

Table 3.--Maximums, minimums, and means of daily discharge, October 1964 to September 1974, for tributaries of Lake Okeechobee, Fl.
(In cubic feet per second)

Water year	Fisheating Creek(1) Max	Min	Mean	Harney Pond Canal(2) Max	Min	Mean	Indian Prairie Canal(3) Max	Min	Mean
1965	1580	0	153	643	0	48	248	0	21
1966	3330	0	328	2390	0	469	1090	0	82
1967	1510	0	157	1980	0	145	612	0	28
1968	3360	0	282	2910	0	324	1470	0	12
1969	2040	.40	220	1900	0	190	1140	0	62
1970	7210	0	494	4670	0	301	2130	0	85
1971	2390	0	159	3040	0	133	1500	0	41
1972	2600	.02	116	1940	0	99	1290	0	24
1973	1620	0	213	1890	0	166	875	0	27
1974	8030	0	422	1970	0	279	675	0	63

Water year	Kissimmee River(4) Max	Min	Mean	Canal 41A(5) Max	Min	Mean	Taylor Creek(6) Max	Min	Mean
1965	3210	0	1170	2770	0	125	194	1.0	16
1966	5240	500	2180	2140	0	349	1520	3.4	110
1967	3740	0	855	727	0	27	1280	1.4	98
1968	10200	0	1680	1730	0	86	1890	1.3	139
1969	6830	0	1540	2530	0	398	2360	8.2	171
1970	23500	0	2680	4080	0	506	2280	5.6	175
1971	5000	0	641	1390	0	52	1060	1.7	105
1972	10500	0	588	1600	0	165	1190	2.8	50
1973	7060	0	1600	2300	0	349	750	4.1	73
1974	14000	0	2110	2380	0	315	1370	0	113

(1) USGS Station 02256500, Fisheating Creek at Palmdale.
(2) USGS Station 02257800, Harney Pond Canal at S-71, near Lakeport.
(3) USGS Station 02259200, Indian Prairie Canal at S-72, nr Okeechobee.
(4) USGS Station 02273000, Kissimmee River at S-65E, near Okeechobee.
(5) USGS Station 02273300, Canal 41A at S-84, near Okeechobee.
(6) USGS Station 02274500, Taylor Creek above Okeechobee.

Table 4.--Maximums, minimums, and means of daily discharge, October 1964 to September 1974, for distributaries of Lake Okeechobee, Fl.
(In cubic feet per second)

Water year	St. Lucie Canal(1) Max	Min	Mean	West Palm Beach Canal (2) Max	Min	Mean	North New River Canal (3) Max	Min	Mean
1965	1170	10	46	1240	0	221	714	-1370	- 50
1966	6550	10	1330	1590	0	138	948	-1560	13
1967	90	10	35	905	-1060	245	858	-1110	113
1968	8110	20	1240	806	- 298	186	527	-1390	-107
1969	6710	18	652	1160	0	208	826	-1290	- 84
1970	11500	18	2450	1340	0	160	858	-1550	- 81
1971	48	12	30	948	-1010	97	501	- 909	1.2
1972	28	12	20	712	0	114	362	- 961	- 60
1973	20	12	16	693	- 4.4	164	507	- 983	- 23
1974	7130	12	356	1090	-1090	234	547	- 905	- 50

Water year	Hillsboro Canal(4) Max	Min	Mean	Miami Canal (5) Max	Min	Mean	Caloosahatchee Canal(6) Max	Min	Mean
1965	1110	-1760	139	1960	-1840	29	2130	10	257
1966	1560	-2370	142	2280	-1890	101	4300	10	1400
1967	1180	-1980	270	606	-1630	- 61	3330	5.0	325
1968	989	-2080	- 38	440	-2070	-132	1340	5.0	102
1969	1860	-1560	165	1750	-1360	269	5540	5.0	974
1970	1430	-2330	-112	1420	-2790	- 78	8290	5.0	3720
1971	1310	-2180	50	947	-2110	76	845	- 652	107
1972	1040	-2100	-109	472	-2100	3.0	2910	5.0	136
1973	1240	-2930	61	1120	-1650	122	689	5.0	74
1974	1470	-2410	144	1470	-1400	231	7580	-2010	1010

(1) USGS Station 02277000, St. Lucie Canal at lock, near Stuart.
(2) USGS Station 02278000, West Palm Beach Canal at HGS-5, at Canal Point.
(3) USGS Station 02280500, Hillsboro Canal below HGS-4, near South Bay.
(4) USGS Station 02283500, North New River Canal below HGS-4, nr S. Bay.
(5) USGS Station 02286400, Miami Canal at HGS-3, and S-3, at Lake Harbor.
(6) USGS Station 02292000, Caloosahatchee Canal at Moore Haven.

Lake-level Regulation

The level of water in Lake Okeechobee is regulated for flood control and water supply. The current desired range in stage is from 14 to 16 ft mean sea level. The actual range in stage is from 10.5 to 16.5 ft because of the difficulty in maintaining lake stages. This difficulty is caused by the short residence time of the lake water and by variable climatic conditions. The lower lake stages are maintained during the summer and early fall to provide maximum storage for flood control. The higher stages are needed to meet water-supply demands during the drier winter and spring months. The regulation of Lake Okeechobee is based on four climatic periods: (1) May to September - rainy period; (2) September to November - possible storm period; (3) November to February - dry period, and (4) February to May - low-water period.

The amount of lake surface area available for the rainfall inputs and evaporation losses previously described was determined from records of stage and a stage-surface area table. Records of stage were taken from publications of the U.S. Geological Survey, Water Resources Data for Florida, and consist of the average daily stage at three lake stations. The stage-surface area table was furnished by the FCD and was applied to average monthly values of stage to provide an average monthly lake surface area, table 5, used in determining rainfall inputs and evaporation losses for Lake Okeechobee. Rainfall inside the leveed area, but not on the water surface is considered as part of the assumed unmeasured flow. The largest average monthly surface area of Lake Okeechobee was 452,600 acres, November 1970 and the smallest was 326,000 acres, June 1971.

Water Budget

A water budget for a body of water can be expressed by the following equation:

$$QI - QO = SC$$

where QI is the inflow, QO is the outflow, and SC is the storage change in the body of water. The storage change is the difference in volume of water in the water body at the beginning and at the end of the period over which the budget is to be determined. For this study, inflow consists of rainfall directly on the lake surface, discharge of the six tributaries to the lake, and the flow into the lake from some of the distributaries. Outflow consists of the flow from the lake through the six distributaries and evaporation. A computer program was developed to process the discharge, rainfall, and evaporation data for October 1964 to September 1974 and the water budget as determined is given in table 6. In summary,

$$QI = 33.41 \text{ million ac-ft}$$
$$QO = 34.48 \text{ million ac-ft}$$

The net quantity of water stored in Lake Okeechobee--water that entered the lake but did not leave the lake during the budget period--can be added to outflow or subtracted from inflow in the water budget. In

Table 5.--Average monthly surface area, October 1964 to September 1974, for Lake Okeechobee, Fl.
(In thousands of acres)

Water Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
October	442.1	445.3	450.9	440.5	449.1	452.0	438.7	434.2	404.1	448.5
November	444.1	448.4	450.5	441.4	451.0	452.6	430.9	441.8	389.4	446.1
December	442.3	447.3	448.5	431.8	450.0	451.0	406.0	436.2	386.0	440.7
January	438.9	447.8	446.4	419.2	449.5	451.9	390.6	429.2	383.6	437.2
February	437.0	449.4	443.4	402.6	448.9	450.2	385.0	423.9	389.2	426.0
March	441.7	449.5	438.2	386.4	449.8	450.9	377.3	403.5	396.0	402.6
April	441.7	446.0	406.0	378.6	444.8	451.9	352.0	391.7	432.4	379.4
May	436.0	436.7	379.0	369.5	439.8	437.4	329.4	392.3	381.8	345.6
June	389.0	430.0	371.8	411.0	433.9	438.0	326.0	415.5	377.0	345.6
July	403.0	435.1	387.8	448.4	428.4	438.0	344.7	433.6	384.7	436.2
August	425.7	441.6	402.9	446.5	440.7	437.2	368.3	430.3	418.1	449.3
September	434.5	447.2	423.5	445.1	443.8	437.2	405.0	429.6	443.2	449.2

Table 6.--Water budget, October 1964 to September 1974, for Lake Okeechobee, Fl.

Source	Quantity (In thousands of acre-feet)	Percentage
Inflow		
Rainfall	13,380	38.9
Fisheating Creek	1,840	5.3
Harney Pond Canal	1,560	4.5
Indian Prairie Canal	390	1.1
Kissimmee River	10,900	31.7
Canal 41A	1,720	5.0
Taylor Creek	760	2.2
West Palm Beach Canal	150	.4
Hillsboro Canal	790	2.2
North New River Canal	1,030	3.0
Miami Canal	850	2.5
Caloosahatchee Canal	40	.1
Subtotal	33,410	96.9
Assumed unmeasured flow	1,070	3.1
Total	34,480	100.0
Outflow		
Evaporation	18,160	52.7
Storage	640	1.9
St. Lucie Canal	4,470	13.0
West Palm Beach Canal	1,430	4.1
Hillsboro Canal	620	1.8
North New River Canal	1,530	4.4
Miami Canal	1,220	3.5
Caloosahatchee Canal	6,410	18.6
Total	34,480	100.0

table 6, the value for the quantity of water stored, 640,000 ac-ft, was added to the outflow.

As table 6 indicates, the water budget does not balance numerically: inflow is 1.07 million ac-ft less than outflow. For purposes of this report, this quantity is called assumed unmeasured flow, and includes, among other things, errors of measurement, runoff from rainfall on areas marginal to Lake Okeechobee, other ungaged surface-water flow, ground-water inflow, and unmeasured outflow. The unmeasured outflow could consist of transpiration and ground-water seepage. Parker and others (1955) report no substantial ground-water inflow or ground-water seepage, and Meyer (1971) reported only small amounts of seepage. Assumed unmeasured flow is only about 3 percent of the total inflow.

Rainfall accounted for most, 38.9 percent, of the total inflow. The Kissimmee River, the largest tributary, was next, with 31.7 percent of the total inflow. Aggregate inflow from the distributaries accounted for only 8.2 percent of the total inflow.

The storage change accounted for only 1.9 percent of the total outflow. Evaporation accounted for 52.7 percent of the total outflow and the Caloosahatchee Canal, the largest distributary, accounted for 18.6 percent.

The assumed unmeasured flow of 1.07 million ac-ft, representing the difference between outflow and inflow, is small in relation to the accuracy of the data. Five percent of the canal inflow would be more than 1 million ac-ft and 5 percent of the canal outflow would be almost 800,000 acre-ft. If rainfall and evaporation data were in error by 5 percent, the error would almost equal the assumed unmeasured flow. An analysis of maximum probable errors indicates that the difference between inflow and outflow could be as great as 4.21 million ac-ft, so the balance as presented in this report (table 6) appears reasonable.

Although ground-water inflow, as a segment of the assumed unmeasured flow, cannot be ruled out, significant quantities of ground water probably do not leak upward into the lake from the Floridan aquifer. Data presented later (p. 30) suggest that contribution of ground water to the lake is small.

ELEMENTS OF THE DISSOLVED-SOLIDS BUDGET

To compute the dissolved-solids budget, the data developed for the water budget were used, together with information concerning the dissolved-solids concentration of each inflow and outflow element. Once the discharge and the concentration of a particular constituent are known, the load can be determined by the use of the equation $L = 0.0027QC$. L is the load, in tons per day, Q is the discharge, in ft^3/s, C is the concentration of dissolved solids, in mg/L, and 0.0027 is the necessary conversion factor.

To obtain the needed information on the dissolved-solids concentrations in the various inputs and outputs of the budget, the relation between specific conductance and dissolved solids was determined by regression analysis. A plot showing a typical relation is shown in figure 3.

Rainfall

To compute the quantity of dissolved solids brought into Lake Okeechobee by rainfall during the budget period, daily rainfall depths were determined from the four peripheral rainfall stations, Belle Glade, Canal Point, Clewiston, and Moore Haven, as previously discussed. Only generalized information is available on the dissolved-solids concentrations in the rainfall during the budget period. In general, the dissolved-solids concentration in rainfall during the dry season, December-May, is about 40 mg/L and during the wet season, June-November, the concentration is about 20 mg/L. These two concentrations, 20 and 40 mg/L, were used to compute the tonnage of dissolved solids carried into the lake by rainfall directly on the lake during the budget period. A study by Joyner (1974) reported an average dissolved-solids concentration of about 30 mg/L.

Tributary Inflow

Measurements of daily specific conductance are available for three tributaries; Fisheating Creek, Kissimmee River, and Taylor Creek. Maximums, minimums, and means of daily specific conductance are given in table 7. Taylor Creek had the largest mean daily specific conductance, 1,390 micromhos per centimeter at 25°C, in 1967 and the Kissimmee River had the smallest, 110 micromhos, in 1965. Taylor Creek also had the largest maximum daily specific conductance, 3,550 micromhos, in 1971 and Fisheating Creek had the smallest minimum daily specific conductance, 37 micromhos, in 1970.

Miscellaneous water samples for which both specific conductance and dissolved-solids concentration were determined are available for six tributaries: Fisheating Creek, Harney Pond Canal, Indian Prairie Canal, Kissimmee River, Canal 41A, and Taylor Creek. These data form the basis for the regression analysis and are given in table 8. A sample from Taylor Creek on May 11, 1971 had the largest specific conductance, 3,200 micromhos, and the largest dissolved-solids concentration, 1,790 mg/L. A sample from Fisheating Creek on September 11, 1968 had the smallest specific conductance, 78 micromhos, and a sample from Fisheating Creek on August 14, 1970 had the smallest dissolved-solids concentration, 39 mg/L.

Regression equations of the form $DS = A + B(K)$ where DS is dissolved-solids concentration, A is the intercept, B is the slope, and K is the specific conductance, were developed for each of the six tributaries. The equation constants, A and B, and the correlation coef-

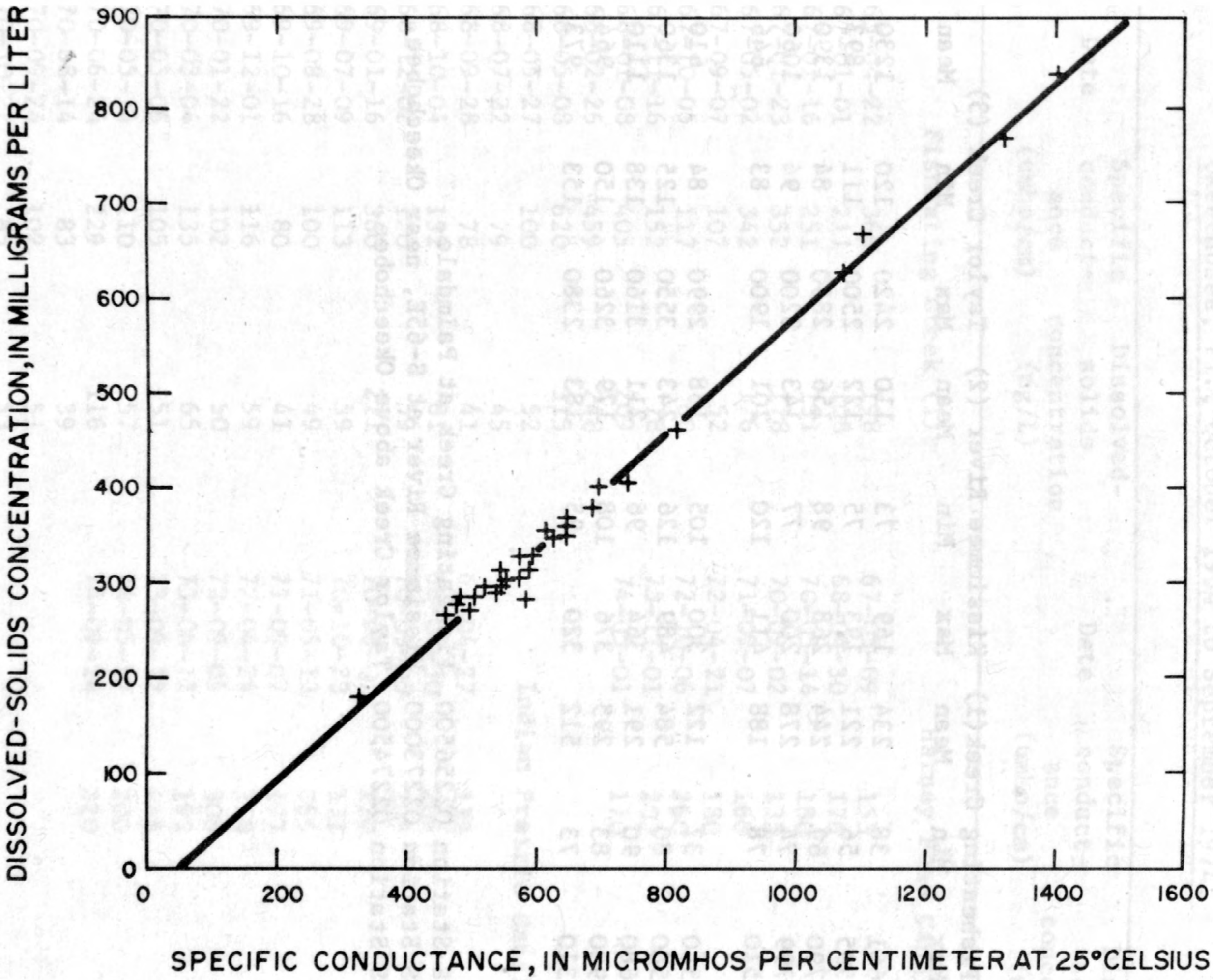

Figure 3.--Relation between specific conductance and dissolved-solids concentration for West Palm Beach Canal at HGS-5, at Canal Point, Fl.

Table 7.--Maximums, minimums, and means of daily specific conductance, October 1964 to September 1974, for tributaries of Lake Okeechobee, Fl.

(In micromhos per centimeter at 25°C)

Water	Fisheating Creek(1)			Kissimmee River (2)			Taylor Creek (3)		
year	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1965	661	38	234	169	73	110	2420	120	1230
1966	595	56	221	193	75	122	2500	111	893
1967	790	69	244	268	98	156	2850	84	1390
1968	799	74	278	200	77	143	3200	94	1060
1969	510	78	188	411	120	201	1900	83	646
1970	540	37	122	300	105	188	2990	84	610
1971	1580	80	584	489	126	243	3550	125	1360
1972	680	90	291	364	96	211	3160	138	1110
1973	930	83	295	376	108	179	3260	150	964
1974	1310	73	512	320	95	183	2380	153	973

(1)USGS Station 02256500, Fisheating Creek at Palmdale.
(2)USGS Station 02273000, Kissimmee River at S-65E, near Okeechobee.
(3)USGS Station 02274500, Taylor Creek above Okeechobee.

Table 8.--Specific conductance and dissolved-solids concentration of water samples collected from six tributaries of Lake Okeechobee, Fl., October 1964 to September 1974.

Date	Specific conductance (umho/cm)	Dissolved-solids concentration (mg/L)	Date	Specific conductance (umho/cm)	Dissolved-solids concentration (mg/L)
Fisheating Creek (1)			Harney Pond Canal (2)		
65-04-22	360	198	67-05-09	155	81
67-01-01	211	108	68-04-30	176	99
67-01-16	251	131	70-05-14	180	99
67-01-23	352	178	70-09-02	135	77
67-05-02	342	176	71-09-07	166	102
67-09-07	107	52	72-04-21	180	100
67-10-05	117	60	72-10-06	260	160
67-11-16	152	78	73-11-01	202	118
68-01-08	405	209	74-05-01	170	96
68-02-26	459	248			
68-05-08	620	315			
68-05-27	100	52	Indian Prairie Canal (3)		
68-07-22	79	45			
68-09-28	78	41	67-04-27	132	70
68-10-04	152	81	68-04-30	209	117
68-12-02	120	59	70-05-05	205	85
69-01-16	360	211	70-06-01	120	70
69-07-09	113	59	70-10-23	171	85
69-08-28	100	49	71-05-13	265	146
69-10-16	80	41	71-09-07	177	107
69-12-01	116	59	72-04-24	218	120
70-01-22	102	50	72-09-06	306	184
70-03-04	135	65	73-06-12	192	108
70-05-06	105	51	73-09-12	445	283
70-05-14	110	57	74-05-27	200	122
70-06-24	229	116	74-09-24	220	134
70-08-14	83	39			
70-09-24	102	51			
70-10-22	85	53			
71-05-14	1460	755			
71-09-07	133	66			
71-11-12	190	100			
72-04-25	363	190			
72-09-06	148	84			
73-06-13	185	94			
74-05-27	740	435			
74-09-24	89	55			

Table 8.--Specific conductance and dissolved-solids concentration of water samples collected from six tributaries of Lake Okeechobee, Fl., October 1964 to September 1974 (continued).

Date	Specific conductance (umho/cm)	Dissolved-solids concentration (mg/L)	Date	Specific conductance (umho/cm)	Dissolved-solids concentration (mg/L)
Kissimmee River (4)			Taylor Creek (6)		
67-05-09	318	179	65-04-13	2370	1390
67-11-17	129	71	65-04-29	1890	1150
67-11-17	139	73	67-05-09	2700	1540
68-01-31	172	93	67-09-01	160	93
68-02-26	182	105	67-09-10	424	234
68-04-16	173	97	67-09-12	262	150
68-07-22	94	55	67-09-23	424	234
68-09-11	162	91	67-11-17	1600	869
68-10-16	134	74	68-01-08	1280	697
68-12-02	219	124	68-02-26	1800	1020
70-02-04	156	87	68-04-16	2220	1230
70-03-03	210	115	68-07-22	122	72
70-05-06	155	85	68-09-11	297	166
70-07-02	250	144	68-10-09	505	278
71-01-27	210	110	68-12-02	950	524
71-05-13	259	125	69-01-15	1450	789
71-08-30	168	98	69-07-01	450	247
72-02-28	265	151	69-09-05	445	238
72-04-27	273	150	69-11-04	210	114
72-05-24	210	110	70-01-09	190	99
72-08-29	150	84	70-03-03	1200	644
73-02-27	165	78	70-05-05	1600	862
73-06-12	190	101	70-06-30	452	247
73-08-21	146	71	70-10-23	510	289
73-09-12	121	64	71-05-11	3200	1790
73-09-12	122	65	71-06-24	88	48
73-12-04	225	123	71-09-07	220	117
74-01-30	255	139	72-02-02	740	409
74-05-22	180	98	72-04-24	1000	530
Canal 41A (5)			72-09-06	145	98
			73-06-12	590	320
65-11-01	180	103	74-05-27	150	832
66-03-31	120	62	74-09-24	1230	730
67-05-09	277	204			
68-04-30	334	244			
70-05-14	115	88			

(1) USGS Station 02256500, Fisheating Creek at Palmdale.
(2) USGS Station 02257800, Harney Pond Canal at S-71, near Lakeport.
(3) USGS Station 02259200, Indian Prairie Canal at S-72, nr Okeechobee.
(4) USGS Station 02273000, Kissimmee River at S-65E, nr Okeechobee.
(5) USGS Station 02273300, Canal 41A at S-84, near Okeechobee.
(6) USGS Station 02274500, Taylor Creek above Okeechobee.

ficients are given in table 9. A plot showing a typical relation between specific conductance and dissolved-solids concentration is shown in figure 3.

Specific conductance was not measured daily from three tributaries: Harney Pond Canal, Indian Prairie Canal and Canal 41A. The dissolved-solids input through these tributaries was estimated on the basis of discharge and on chemical analyses of water in these tributaries and in similar nearby tributaries.

Distributary Outflow

Measurements of daily specific conductance are available for six distributaries: St. Lucie, West Palm Beach, Hillsboro, North New River, Miami, and Caloosahatchee Canals. Maximums, minimums, and means of daily specific conductance are given in table 10. The Hillsboro Canal had the largest mean daily specific conductance, 1,390 micromhos, in 1970 and the Caloosahatchee Canal had the smallest, 406 micromhos, in 1970. The St. Lucie Canal had the largest maximum daily specific conductance, 5,040 micromhos, in 1967 and the West Palm Beach Canal had the smallest minimum daily specific conductance, 100 micromhos, in 1972.

Miscellaneous water samples for which both specific conductance and dissolved-solids concentrations were determined are also available for the six distributaries. These data form the basis for the regression analysis and are given in table 11. A sample from the Hillsboro Canal on September 22, 1970 had the largest specific conductance, 1,620 micromhos, and a sample from the Hillsboro Canal on July 2, 1968 had the largest dissolved-solids concentration, 1,070 mg/L. A sample from the Caloosahatchee Canal on July 1, 1968 had the smallest specific conductance, 272 micromhos, and the smallest dissolved-solids concentration, 156 mg/L.

Regression equations of the form $DS = A + B (K)$ where DS is dissolved-solids concentration, A is the intercept, B is the slope, and K is the specific conductance, were developed for each of the six distributaries. The equation constants, A and B, and the correlation coefficients are given in table 12.

Lake Water

Two series of samples, one collected in July 1940 at a low lake stage and one collected in March 1941 at a high lake stage, show that--for each sampling date--the dissolved-solids concentrations of the lake water, from place to place in the lake, was fairly uniform (Parker, 1955). In the two series of samples, concentrations of dissolved solids ranged from 167 to 207 mg/L. The concentration of dissolved solids in Lake Okeechobee does vary with time, however. For example, samples taken in early 1969 contained about 300 mg/L of dissolved solids and some taken in mid-1970 contained as little as 210 mg/L.

Table 9.—Regression equation constants and correlation coefficients for tributaries of Lake Okeechobee, Fl.

USGS station	Number of samples	A intercept	B slope	Correlation coefficient
02256500, Fisheating Creek at Palmdale	37	- 0.500	0.529	0.998
02257800, Harney Pond Canal at S-71, near Lakeport	9	-19.4	.681	.984
02259200, Indian Prairie Canal at S-72, near Okeechobee	13	-21.6	.669	.980
02273000, Kissimmee River at S-65E, near Okeechobee	29	- 1.82	.555	.984
02273300, Canal 41A at S-84, near Okeechobee	5	-24.2	.801	.967
02274500, Taylor Creek above Okeechobee	33	40.3	.541	.960

Table 10.--Maximums, minimums, and means of daily specific conductance, October 1964 to September 1974, for distributaries of Lake Okeechobee, Fl.

(In micromhos per centimeter at 25°C)

Water year	St. Lucie Canal(1) Max	Min	Mean	West Palm Beach Canal (2) Max	Min	Mean	Hillsboro Canal (3) Max	Min	Mean
1965	1880	360	566	2800	487	849	1990	517	1230
1966	2320	225	506	2310	300	865	2280	118	1170
1967	5040	289	643	1800	480	708	1800	462	957
1968	3900	262	630	1980	360	763	2100	560	1120
1969	1450	308	546	1920	482	796	2310	600	1370
1970	600	180	432	2400	280	814	2100	360	1390
1971	940	240	562	1800	452	715	1920	210	897
1972	1490	220	585	1900	100	739	2200	677	1190
1973	1980	315	1030	1510	520	748	2260	660	1170
1974	3350	320	716	1610	300	761	2160	658	1060

Water year	North New River Canal (4) Max	Min	Mean	Miami Canal (5) Max	Min	Mean	Caloosahatchee Canal(6) Max	Min	Mean
1965	2010	524	1190	1400	500	841	862	160	562
1966	1970	505	1130	1190	508	734	712	264	518
1967	1980	500	950	1180	476	670	860	211	494
1968	1990	555	1100	1520	510	856	705	305	546
1969	1920	505	1120	1630	575	913	1390	230	558
1970	2100	450	1210	1470	445	870	610	200	406
1971	1860	440	844	1200	471	692	665	139	510
1972	1720	300	1050	1310	682	883	1040	305	586
1973	1940	409	1040	1430	612	885	805	310	608
1974	1640	660	976	1600	645	862	790	307	603

(1) USGS Station 02277000, St. Lucie Canal at lock, near Stuart.
(2) USGS Station 02278000, West Palm Beach Canal at HGS-5, at Canal Point.
(3) USGS Station 02280500, Hillsboro Canal below HGS-4, nr South Bay.
(4) USGS Station 02283500, North New River Canal below HGS-4, near S. Bay.
(5) USGS Station 02286400, Miami Canal at HGS-3, and S-3, at Lake Harbor.
(6) USGS Station 02292000, Caloosahatchee Canal at Moore Haven.

Table 11.--Specific conductance and dissolved-solids concentration of water samples collected from six distributaries of Lake Okeechobee, Fl., October 1964 to September 1974.

Date	Specific conduct- ance (umho/cm)	Dissolved- solids concentration (mg/L)	Date	Specific conduct- ance (umho/cm)	Dissolved- solids concentration (mg/L)
St. Lucie Canal (1)			West Palm Beach Canal (2)		
66-05-19	606	328	66-05-04	535	295
67-01-01	670	385	67-01-01	495	274
67-01-11	670	382	67-01-11	490	275
67-01-22	700	412	67-01-21	500	285
67-05-22	1100	593	67-05-01	570	311
67-09-01	442	250	67-09-01	540	300
67-09-01	442	250	67-09-07	630	358
67-09-11	545	309	67-09-16	570	327
67-09-15	545	309	67-11-01	1320	774
67-09-24	595	337	67-12-04	590	329
68-02-07	1250	688	68-01-03	610	356
68-03-20	740	430	68-02-01	640	359
68-06-19	468	265	68-04-01	620	354
68-07-24	345	197	68-05-02	639	367
68-11-20	428	241	68-07-01	810	462
69-01-22	670	406	68-08-01	580	283
69-02-26	1100	664	68-10-01	1070	631
69-06-12	500	290	68-10-31	1400	841
69-07-16	455	247	68-12-03	680	380
69-10-16	500	277	69-03-26	584	321
70-01-21	501	286	69-04-16	584	327
70-05-05	376	210	69-07-17	478	280
70-09-29	450	265	69-08-29	570	309
71-09-13	390	216	69-10-28	540	311
72-04-25	760	420	70-05-05	327	181
72-09-22	590	320	70-07-01	550	305
73-06-21	1210	671	70-08-11	517	296
73-10-23	352	200	70-09-22	456	268
74-05-22	912	642	71-05-13	580	316
			71-09-13	1100	671
			72-05-04	690	400
			72-09-06	640	350
			74-05-22	734	406

Table 11.--Specific conductance and dissolved-solids concentration of water samples collected from six distributaries of Lake Okeechobee, Fl., October 1964 to September 1974 (continued).

Hillsboro Canal (3)

Date	Specific conductance (umho/cm)	Dissolved-solids concentration (mg/L)
66-05-05	571	310
67-05-03	570	315
67-09-01	810	479
67-09-13	850	495
67-09-22	1420	909
67-11-01	950	528
67-12-05	600	337
68-01-05	645	361
68-02-02	610	344
68-04-01	710	402
68-05-03	658	374
68-07-02	1720	1070
68-08-02	1170	747
68-10-04	1470	931
68-10-31	1600	1010
68-12-04	960	554
70-05-05	680	380
70-05-19	480	276
70-07-01	1160	721
70-09-22	1620	1050
71-09-27	1250	774

North New River Canal (4)

Date	Specific conductance (umho/cm)	Dissolved-solids concentration (mg/L)
65-02-11	1400	919
66-05-05	571	314
67-01-07	575	330
67-01-08	710	417
67-01-16	535	298
67-05-03	590	315
67-09-08	815	489
67-09-09	1280	785
67-09-11	785	463
67-11-01	1000	570
67-12-05	590	330
68-01-05	472	360
68-02-02	625	344
68-04-01	690	400
68-05-03	663	378
68-07-02	1450	922
68-08-02	1270	812
68-10-04	1500	958
68-10-31	1590	987
69-07-29	1350	790
69-07-31	1400	835
70-05-05	680	380
70-05-19	480	276
70-07-01	1160	685
72-10-19	722	407
73-04-18	700	395
73-10-17	798	464
74-04-18	703	

Table 11.--Specific conductance and dissolved-solids concentration of water samples collected from six distributaries of Lake Okeechobee, Fl., October 1964 to September 1974 (continued).

Date	Specific conduct-ance (umho/cm)	Dissolved-solids concentration (mg/L)	Date	Specific conduct-ance (umho/cm)	Dissolved-solids concentration (mg/L)
Miami Canal (5)			Caloosahatchee Canal (6)		
66-04-27	740	408	66-05-16	635	285
66-05-03	581	325	67-01-01	550	310
66-05-03	561	300	67-01-10	530	301
67-05-02	595	329	67-01-11	510	289
67-09-09	830	489	67-05-02	555	296
67-09-10	905	568	67-09-01	474	272
67-09-11	875	536	67-09-11	289	166
67-11-01	1060	651	67-09-12	401	231
67-12-01	635	354	67-11-06	541	312
68-01-04	700	383	67-12-04	570	330
68-01-07	920	554	68-01-04	580	342
68-02-01	655	377	68-02-02	645	361
68-04-16	680	389	68-04-02	620	339
68-05-01	634	359	68-05-01	644	362
68-08-01	999	638	68-07-01	272	156
68-10-31	1460	895	68-10-02	328	184
68-11-02	1130	689	68-10-31	842	516
68-12-02	750	431	68-12-02	759	429
69-03-26	663	369	69-03-25	520	286
69-04-16	620	344	69-04-15	505	278
69-07-20	1100	642	69-05-16	482	265
69-10-24	840	498	69-08-27	525	290
70-05-19	490	265	69-10-27	380	213
70-07-01	1100	700	69-11-21	401	227
70-09-22	940	555	70-01-14	298	163
70-10-01	1060	637	70-05-06	461	252
72-10-19	695	394	70-09-22	350	194
73-04-18	700	396	71-04-29	560	305
73-10-17	1070	639	71-09-13	495	283
74-04-18	688	382	72-05-04	600	340
			72-09-06	630	340
			72-10-23	398	219
			74-05-22	721	405

(1) USGS Station 02277000, St. Lucie Canal at lock, near Stuart.
(2) USGS Station 02278000, West Palm Beach Canal at HGS-5, at Canal Point.
(3) USGS Station 02280500, Hillsboro Canal below HGS-4, near South Bay.
(4) USGS Station 02283500, North New River Canal below HGS-4, nr S. Bay.
(5) USGS Station 02286400, Miami Canal at HGS-3, and S-3, at Lake Harbor.
(6) USGS Station 02292000, Caloosahatchee Canal at Moore Haven.

Table 12.--Regression equation constants and correlation coefficients for distributaries of Lake Okeechobee, Fl.

USGS station	Number of samples	A intercept	B slope	Correlation coefficient
02277000, St. Lucie Canal at lock, near Stuart	29	- 4.28	0.580	0.984
02278000, West Palm Beach Canal at HGS-5, at Canal Point	33	-28.4	.615	.998
02280500, Hillsboro Canal below HGS-4, near South Bay	21	-76.1	.681	.998
02283500, North New River Canal below HGS-4, near South Bay	28	-51.3	.655	.993
02286400, Miami Canal at HGS-3, and S-3, at Lake Harbor	30	-72.1	.674	.996
02292000, Caloosahatchee Canal at Moore Haven	33	- 5.29	.569	.979

For the budget period, the variation in concentration of dissolved solids with time was fairly small, so that--for purposes of this study--it is assumed that the concentration of dissolved solids was the same at the start and at the end of the period. The basis for this assumption is that in 1964 the concentration of dissolved solids was about 300 mg/L and at the end, 310 to 320 mg/L. The difference, 3 to 7 percent, is not considered significant.

Dissolved-Solids Budget

The dissolved-solids budget, table 13, for Lake Okeechobee was calculated using miscellaneous water samples with analyses of specific conductance and dissolved-solids concentration, the regression equations relating specific conductance and dissolved-solids concentration, the daily specific conductance measurements and records of daily discharge. This method of arriving at the dissolved-solids budget is similar to that of Steele (1971), Blakey and others (1972), and Frost (1974). The water budget and the dissolved-solids budget are summarized in table 14.

In making the budget, recognition had to be given to the effect of the increase in lake storage and the "assumed" quantity of water-soluble minerals brought into the lake by the assumed unmeasured flow.

First, the increase in storage: On the basis of the assumption that the dissolved-solids concentration of lake water was 300 mg/L at the end of the budget period, it follows--at least for purposes of this report--that the 640,000 ac-ft of water stored in the lake is of the same concentration, 300 mg/L, as the remainder of the lake water. This converts to an assumed tonnage of 280,000. Because of the assumption, the accuracy of this figure is not known, but, as with the volume of water stored, (table 6) it was added to the outflow (table 13).

As table 13 indicates, the dissolved-solids budget does not balance numerically: inflow is 1.02 million tons less than outflow. This quantity is charged to the 1.07 million ac-ft of assumed unmeasured flow. For the 1.07 million ac-ft of water to carry 1.02 million tons of dissolved solids its dissolved-solids concentration would have to be approximately 700 mg/L.

Both Joyner (1971) and Davis (1975) suggest that highly mineralized water may be leaking upward from the Floridan aquifer into Lake Okeechobee. If large quantities of water were leaking upward, there would be places in the lake, in the vicinity of the leakage, where the lake water would be more concentrated in dissolved solids than elsewhere in the lake. This has not been established: extensive sampling of surface and bottom water in the lake indicate that the lake water is fairly uniform in concentration of dissolved solids.

Parker and others (1955) and Joyner (1974) have suggested that the greater concentration of dissolved solids in the lake water--in

Table 13.--Dissolved-solids budget, October 1964 to September 1974, for Lake Okeechobee, Fl.

Source	Dissolved solids (In tons)	Percentage
Inflow		
Rainfall	460,000	6.6
Fisheating Creek	160,000	2.3
Harney Pond Canal	130,000	1.9
Indian Prairie Canal	40,000	.6
Kissimmee River	1,150,000	16.4
Canal 41A	190,000	2.7
Taylor Creek	240,000	3.4
West Palm Beach Canal	150,000	2.1
Hillsboro Canal	1,280,000	18.3
North New River Canal	1,530,000	21.9
Miami Canal	620,000	8.9
Caloosahatchee Canal	20,000	.3
Subtotal	5,970,000	85.4
Assumed unmeasured input	1,020,000	14.6
Total	6,990,000	100.0
Outflow		
Storage	280,000	4.0
St. Lucie Canal	1,520,000	21.7
West Palm Beach Canal	620,000	8.9
Hillsboro Canal	580,000	8.3
North New River Canal	1,250,000	17.9
Miami Canal	570,000	8.2
Caloosahatchee Canal	2,170,000	31.0
Total	6,990,000	100.0

Table 14.--Summary of water budget and dissolved-solids budget, October 1964 to September 1974, for Lake Okeechobee, Fl.

Source	INFLOW Discharge (In acre-feet)	INFLOW Dissolved solids (In tons)	OUTFLOW Discharge (In acre-feet)	OUTFLOW Dissolved solids (In tons)
Tributaries	17,170,000	1,910,000	—	—
Distributaries	2,860,000	3,600,000	15,680,000	6,710,000
Rainfall	13,380,000	460,000	—	—
Evaporation	—	—	18,160,000	0
Storage	—	—	640,000	280,000
Assumed unmeasured	1,070,000	1,020,000	—	—
Totals	34,480,000	6,990,000	34,480,000	6,990,000

comparison to the concentration in inflow--could be caused by the combined effect of relatively dilute inflow waters dissolving the limestone on the floor of the lake and wind action causing the lake to be mixed to its deepest parts, bringing dissolved solids in the sediments back into solution. This mechanism would tend to increase the calcium and bicarbonate concentrations more than the concentration of other major ions, a situation not consistent with the facts: calcium remains nearly constant, while sodium and chloride concentrations are greater in the lake water. Parker and others (1955) considered the possibility that the high concentration of dissolved solids in the water entering the lake from the distributaries was the reason for the high concentration in the lake. They dismissed the consideration as invalid, however, owing to the relatively small amount of water involved. Table 14 shows that while the inflow to Lake Okeechobee from the distributaries is only 2.86 million ac-ft, the distributaries account for 3.6 million tons of dissolved solids entering the lake. Once again, the uniformity of the concentration of dissolved solids in the lake would suggest that the assumed unmeasured flow is not entirely from the distributary inflow.

Evaporation influences the dissolved-solids budget by concentrating dissolved solids in Lake Okeechobee since almost pure water vaporizes and the dissolved solids are left. Table 14 shows that evaporation removes over 18 million ac-ft of water from Lake Okeechobee and that no dissolved solids were removed by evaporation, or that the amounts were insignificant in comparison with other outflow sources. The dissolved-solids budget of Lake Okeechobee may also be influenced by solubility and physical-chemical reaction rates. Calcium may be precipitated out and deposited on the lake bottom. This could partially account for sodium and chloride concentrations being greater in the lake water. Also living organisms and biological processes in Lake Okeechobee remove more calcium than sodium or chloride. The dissolved-solids concentration of Lake Okeechobee varies with time as previously discussed, and the assumed unmeasured flow shown on table 14 may be just a result of this natural variability.

SUMMARY

Lake Okeechobee is a major surface-water feature in south Florida. Its waters are used for navigation, irrigation, municipal supplies, recreation, and fish and wildlife habitat. A dissolved-solids budget was developed for October 1964 to September 1974. The budget calculations were based on records of daily discharge, daily specific-conductance measurements, and regression equations relating specific conductance and dissolved-solids concentration.

Lake Okeechobee serves as a balancing reservoir, receiving inflow from the lake area to the north, and then releasing outflow to both the Atlantic Ocean and the Gulf of Mexico. The lake serves the agricultural area to the south, by providing irrigation water and storage for drainage water.

The lake received more than 13 million ac-ft of rainfall during the budget period and lost more than 18 million ac-ft of water to evaporation. The lake received more than 20 million ac-ft of inflow and released almost 16 million ac-ft to distributaries. During the budget period the water level in the lake showed a net increase of 1.4 ft, and an increase in storage volume of some 640,000 ac-ft. To balance the water budget of 34.48 million ac-ft, an unmeasured flow of 1.07 million ac-ft was assumed.

Rainfall produced an input of 460,000 tons of dissolved solids to Lake Okeechobee. Inflow from tributaries and distributaries added 5.51 million tons. About 6.71 million tons of dissolved solids were removed from the lake as outflow to distributaries. An assume unmeasured input of 1.02 million tons of dissolved solids balanced the dissolved-solids budget of 6.99 million tons.

The objective of this report was to present a water budget and a dissolved-solids budget developed for Lake Okeechobee for a 10-year budget period, October 1964 to September 1974. The two budgets have been developed and discussed, and should serve as a data base for future studies of the Lake Okeechobee area. This report will also provide guidelines for similar studies of various scales in different areas.

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