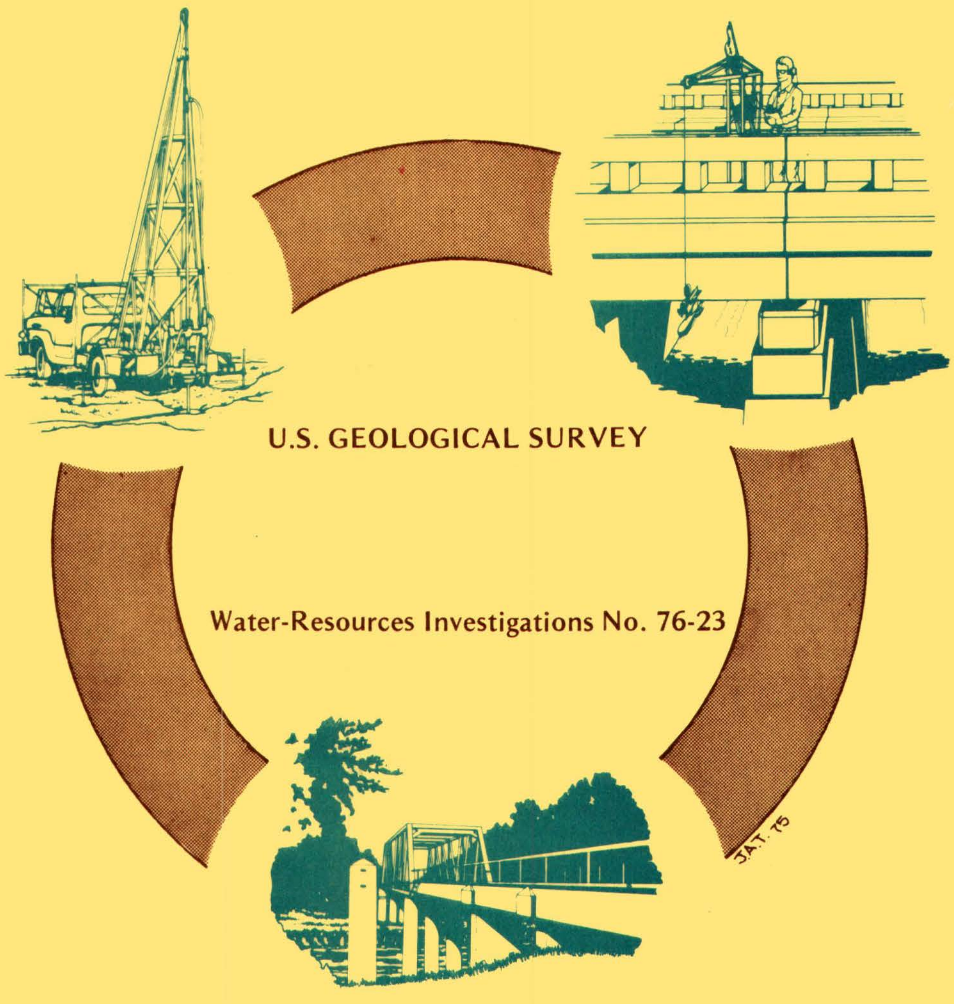
PROPOSED CROSS-FLORIDA BARGE CANAL: WATER QUALITY ASPECTS WITH A SECTION ON WASTE-ASSIMILATIVE CAPACITY



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations No. 76-23

Prepared in cooperation with
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
Jacksonville, Florida

Report duplicated by:

U.S. Army Corps of Engineers
Jacksonville District
P. O. Box 4970
Jacksonville, Florida 32201

PROPOSED CROSS-FLORIDA BARGE CANAL:

WATER-QUALITY ASPECTS

By A. G. Lamonds

WITH A SECTION ON

WASTE-ASSIMILATIVE CAPACITY

By M. L. Merritt

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Jacksonville, Florida

February 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

Open file report

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SUMMARY AND CONCLUSIONS

(With an index and summary in matrix form)

The results of this investigation indicate that the chemical character of both surface and ground water in the area of the Cross-Florida Barge Canal is strongly influenced by the limestone and dolomite of the Floridan aquifer, the principal source of fresh-water supplies in the area. In that part of the Oklawaha River valley south of Silver Springs, the Floridan aquifer yields calcium bicarbonate water whose average dissolved solids concentration is about 180 mg/l. In the Oklawaha River valley downstream from Silver River and in part of the St. Johns River valley the water from the Floridan aquifer at depth contains chloride in excess of 250 mg/l and dissolved solids concentration in excess of 500 mg/l. In some parts of the Barge Canal area east of Ocala, water for domestic and municipal use is obtained from a shallow aquifer consisting of sand and shell beds that overlie the carbonate rocks of the Floridan aquifer. The quality of water in this shallow aquifer varies areally, but with the exception of the lower Oklawaha River valley, the water in this aquifer is generally a calcium bicarbonate water lower in dissolved solids concentration than that in the Floridan aquifer. In the lower Oklawaha River valley the concentration of dissolved solids and chloride in water in the shallow aquifer often is high because of the upward seepage of water from the Floridan aquifer.

The quality of water in the three streams within the Barge Canal route is affected by the Floridan aquifer in that these streams receive large amounts of ground water from springs. In low-flow periods, flow of the lower Oklawaha River consists largely of water from Silver Springs, which discharges down Silver River to the Oklawaha River. Consequently, during low-flow periods, the lower Oklawaha River contains a very hard calcium bicarbonate water whose average dissolved solids concentration is similar to that of Silver Springs (287 mg/l). During periods of high flow, the Oklawaha River above Silver River contributes a large part of the flow, and dissolved solids concentration of the lower river is appreciably less than that of Silver Springs. However, the upper part of the river generally is higher in color, turbidity, BOD, coliform bacteria, nitrogen and phosphorus than that part downstream from Silver River.

In the area of Lake Ocklawaha the concentrations of nitrogen and phosphorus decline perceptibly because of the uptake of these nutrients by hydrilla and other aquatic plants. There, the growth of aquatic plants is dense. Plant productivity also results in large diel fluctuations in dissolved oxygen concentrations. In late summer and into late fall, when these plants begin to die, stratification of dissolved oxygen and extended periods of low dissolved oxygen concentrations are common in Lake Ocklawaha.

The St. Johns River at Palatka generally contains a very hard, sodium chloride water with an average dissolved solids concentration of about 600 mg/l due to the inflow of saline ground water in the basin above the Oklawaha River. Chloride concentration in the river at Palatka occasionally exceeds 250 mg/l. The St. Johns River is more highly colored and generally has slightly higher BOD and concentrations of nitrogen, particularly organic nitrogen, and phosphorus than the lower Oklawaha River. Dissolved oxygen concentrations in the St. Johns River generally exceed 6.0 mg/l but have been less than 3.0 mg/l.

The Withlacoochee River on the west end of the Barge Canal receives a large amount of ground water from Rainbow Springs which discharges down Blue Run to the Withlacoochee River. However, the average dissolved solids concentration of water from Rainbow Springs is much lower than that of Silver Springs. During periods of low flow, Rainbow Springs and the Withlacoochee River generally contain hard to very hard calcium-bicarbonate water with an average dissolved solids concentration of about 180 mg/l. During periods of high flow the dissolved solids concentration of the Withlacoochee River is less than 180 mg/l. The part of the river above Blue Run generally is higher in color and concentrations of nitrogen than the part of the river below Blue Run. Color, turbidity, and BOD, however, are generally lower in the Withlacoochee River basin than in the Oklawaha River basin.

In the area of Lake Rousseau, dense growths of hydrilla and other aquatic plants utilize nitrogen, resulting in a reduction in the concentration of nitrogen. Although plants also utilize phosphorus, no reduction in phosphorus was measured. However, bottom sediments in the lake contain extremely high concentrations of phosphorus. Dissolved oxygen stratification occurred at several sites in the lake in the summer and fall of 1975. Except for the site above Inglis Dam, however, the concentrations of dissolved oxygen near the bottom were greater than 2.0 mg/l. Concentrations of dissolved oxygen near the bottom were much smaller in Lake Ocklawaha than in Lake Rousseau.

The specific conductance of ground water varies in response to seasonal patterns in rainfall and to extended periods of excessive rainfall or drought. With the exception of ground water adjacent to the canal west of Inglis Lock, however, there have been no significant changes in the dissolved solids concentration of ground water, other than those due to unusual climatic conditions. An increase in salinity of ground water adjacent to the canal between Inglis Lock and the Gulf has probably occurred from salt water intrusion, but the area affected is probably small.

Where construction of the canal has not altered the flow pattern, there has been no significant change in the dissolved solids concentration of water in these streams, except for variations in response to climatic conditions. The impoundment of Lake Ocklawaha and the subsequent growth of aquatic plants has resulted in stratification of dissolved oxygen and a decrease in concentrations of nitrogen and phosphorus in this reach. Operation of Inglis Lock occasionally introduces salt water into the canal just above the lock, but this salt water is diluted and flushed into the lower Withlacoochee River through the bypass channel. The specific conductance of water in Lake Rousseau has not increased as a result of operating the lock. The salt water flushed into the lower Withlacoochee causes temporary increases in the specific conductance of the river below the bypass channel, but these increases have been slight--generally less than 60 micromhos/cm--and of short duration.

The quality of surface and ground water in the area of the Barge Canal is suitable for most uses. Water in the area is used chiefly for irrigation, domestic purposes, and recreation. Most of the water used for irrigation and domestic supply comes from wells and springs. Except in the lower Oklawaha River valley, the quality of ground water generally is suitable for irrigation and domestic water supply. In the lower Oklawaha River valley much of the ground water is too saline for irrigation or domestic supply.

The water in the lower St. Johns River generally is suitable for recreational uses but not for irrigation or domestic uses because it often contains fairly high concentrations of dissolved solids. The quality of water in the Oklawaha and Withlacoochee Rivers, particularly downstream from the major springs, is suitable for most uses. Concentrations of coliform bacteria are occasionally high and concentrations of dissolved oxygen in the lakes are sometimes low during the summer and fall. Most of the time, however, the quality of water in these streams meets water quality criteria established by the Florida Department of Environmental Regulation for water used for recreation and for the propagation of fish and wildlife.

During 1975, approximately 643 tons (583 tonnes) of nitrogen and 29 tons (26 tonnes) of phosphorus were released from Lake Ocklawaha. Nutrient loads released from Lake Rousseau during 1975 amounted to about 504 tons (457 tonnes) of nitrogen and 42 tons (38 tonnes) of phosphorus. Estimated budgets for 1975 indicate that about 196 tons (178 tonnes) of nitrogen were retained in Lake Ocklawaha and about 84 tons (76 tonnes) of nitrogen were retained in Lake Rousseau. During 1975, 13.2 tons (12.0 tonnes) of phosphorus was retained in Lake Ocklawaha but in Lake Rousseau the phosphorus output exceeded the measured input by 3.6 tons (3.3 tonnes). Analyses of bottom sediments indicate that phosphorus rich bottom sediments may be contributing phosphorus to Lake Rousseau.

The capacity of the Oklawaha and Withlacoochee Rivers and the lakes in these drainage systems to assimilate organic wastes, without decreasing dissolved oxygen concentrations below acceptable limits, was studied with the aid of a mathematical model. The various factors that influence dissolved oxygen and BOD levels in the stream systems were included in the model and the estimated input parameters were varied until the dissolved oxygen and BOD profiles produced by the model matched the values measured in the field.

This calibration indicated that in the natural, high-velocity reaches of the rivers, the factor having the greatest influence on dissolved oxygen concentration is reaeration. In the slow-moving reaches of the river, such as the wide controlled channel of the Oklawaha River near Moss Bluff, and in Lakes Ocklawaha and Rousseau, reaeration and productivity (the oxygen production and consumption by aquatic life) are major factors controlling dissolved oxygen concentration.

In order to test the effect of an increase in BOD load on the dissolved oxygen concentration in the river system, the introduction of the effluent from a sewage treatment plant for a small town with a population of 10,000 people, into the upper end of Lake Ocklawaha was simulated in the model. The effect of the BOD contributed by the effluent on average dissolved oxygen concentrations in the lake was very small in comparison to factors such as the production and consumption of oxygen by aquatic life, reaeration, and naturally occurring BOD.

Impacts on water quality of the various alternative plans to complete or not complete the canal, are described in the latter part of this report. To facilitate summarizing the impacts and to provide an index to the detailed discussions in the text, these impacts are listed in the accompanying matrix. In this matrix, expected impacts of each alternative are given, in abbreviated form, for the six reaches of the canal. A change in a physical or chemical characteristic is denoted by a (+) and (-) preceding the abbreviation of that property or constituent. Page numbers referencing the discussion of these impacts in the text are also given. This matrix is designed to aid the reader in noting significant impacts and to compare the anticipated impacts of one alternative with those of another. However, the matrix should not be used without the benefit of the text, because the relative importance of impacts identified in the matrix cannot be assessed separately from the text. Blank sections in the matrix indicate that no significant impacts on water quality are anticipated.

Examination of the impacts listed in the matrix indicates that during the construction period of most of the alternative plans, increases in turbidity, suspended sediment, BOD, nitrogen and phosphorus may be expected. These increases would result from excavation, dredging, land clearing, and the erosion of cleared areas. Small temporary increases in turbidity, suspended sediment and BOD may also be expected during the adjustment period for many of the alternatives. In the several alternative plans for Eureka Pool, color and BOD are likely to increase and dissolved oxygen concentration to decrease during the adjustment period as inundated organic material decays. In all three of the impoundments (Lake Ocklawaha, Eureka Pool, and Lake Rousseau) increased plant productivity and decreased concentrations of dissolved oxygen, nitrogen, and phosphorus are expected in the stabilized period. In the two alternatives involving draining Lake Ocklawaha, increases in dissolved solids and chloride in surface and ground water in the area of the lake can be expected during the stabilized period because of the upward movement of saline ground water. In the adjustment and stabilization periods of almost all of the alternative plans to complete the canal, degradation of water quality by increased boat and barge traffic and by spillage of toxic materials is possible.

INDEX AND SUMMARY OF ANTICIPATED IMPACTS ON WATER QUALITY *

REACH	PERIOD	ALTERNATIVES FOR COMPLETING THE CANAL: AUTHORIZED ALINEMENT (136-161)	EUREKA TO HWY. 40 NON-RIVER ALTERNATIVE: FLOOD PLAIN ALINEMENT (162-167)	EUREKA TO HWY. 40 NON-RIVER ALTERNATIVE: UPLAND ALINEMENT (162-167)	EUREKA TO DOSH LOCK NON-RIVER ALTERNATIVE: FLOOD PLAIN ALINEMENT (167-171)	EUREKA TO DOSH LOCK NON-RIVER ALTERNATIVE: UPLAND ALINEMENT (167-171)	SUMMIT REACH ALTERNATIVE (171-174)	WEST END ALTERNATIVE (174-177)	ALTERNATIVES FOR NOT COMPLETING THE CANAL: PRESERVE COMPLETED WORKS (178-180)	RESTORE TO ORIGINAL CONDITION (180-183)	ABANDONMENT (183-185)
PALATKA TO BUCKMAN LOCK	Construction	+TURB, +SS, +N&P, +BOD, +PP, –DO (140)	→	→	→	→	→	→		+TURB, +SS (181)	+TURB (183)
	Adjustment	+TURB, +SS, +N&P (141) AS, MVC	→	→	→	→	→	→		+N&P, +BOD (181) +TURB, +SS (182)	+N&P, +BOD, +TURB (184)
	Stabilized	AS, MVC	→	→	→	→	→	→		+DO, –PP, +N&P +TURB (182)	+N&P, +TURB (184)
BUCKMAN LOCK TO EUREKA LOCK (Lake Ocklawaha)	Construction	+TURB, +SS, (142) +N&P, +BOD (143) –DO (143)	→	→	→	→	→	→		+TURB, +SS (181)	
	Adjustment	+TURB, +SS (143) –DO (144) AS, MVC	→	→	→	→	→	→		+N&P, +BOD (181) +TURB, +SS, +CL "GW" (182)	+N&P, +BOD, +TURB, +CL "GW", +DS "GW" (184)
	Stabilized	–DO, +PP (144) AS, MVC	→	→	→	→	→	→		+DO, –PP, +N&P, +TURB, +CL "GW" (182)	+DO, +N&P, +TURB (184) –DO, +CL "GW", + DS "GW" (185)
EUREKA LOCK TO DOSH LOCK (Eureka Pool)	Construction	+TURB, +SS, +COLOR, (145) –DO, +BOD (146) +N&P (145-146) All of flood plain affected	(162-164) → RIVER and CANAL Part of the flood plain affected downstream from Hwy. 40	(162-164) → CANAL Flood plain not affected downstream from Hwy. 40	(167-169) → RIVER and CANAL Part of the flood plain affected downstream from Dosh Lock	(167-169) → CANAL Part of the flood plain affected between Dosh Lock and Hwy. 40, but not downstream from Hwy. 40.	→	→			
	Adjustment	+TURB, +SS (146) –DO, +BOD, +COLOR –DS (147) AS, MVC All of flood plain affected	(164-165) → RIVER and CANAL Part of the flood plain affected downstream from Hwy. 40	(164-165) → CANAL Flood plain not affected downstream from Hwy. 40	(169-170) → RIVER and CANAL Part of the flood plain affected downstream from Dosh Lock	(169-170) → CANAL Part of the flood plain affected between Dosh Lock and Hwy 40, but not downstream from Hwy. 40	→	→			
	Stabilized	–SS, –DO (148-149) +PP, –N (149) –DS "GW" (149-150) AS, MVC All of flood plain affected	(165-167) → RIVER and CANAL Part of the flood plain affected downstream from Hwy. 40	(165-167) → CANAL Flood Plain not affected downstream from Hwy. 40	(170-171) → RIVER and CANAL Part of the flood plain affected downstream from Dosh Lock	(170-171) → CANAL Part of the flood plain affected between Dosh Lock and Hwy 40, but not downstream from Hwy. 40	→	→			
DOSH LOCK TO DUNNELLON LOCK (SummitReach)	Construction	+TURB (151) +TURB "GW" (151)	→	→	→	→	(172) Less penetration of Floridan Aquifer with less potential effect on "GW" quality	→			
	Adjustment	+PP (151) AS, MVC	→	→	→	→	(172-173) Less penetration of Floridan Aquifer with less potential effect on "GW" quality	→			
	Stabilized	+PP, +TURB, +N&P, (153) AS, MVC	→	→	→	→	(173-174) Less penetration of Floridan Aquifer with less potential effect on "GW" quality	→			
DUNNELLON LOCK TO INGLIS LOCK (LakeRousseau)	Construction	+TURB, +SS, +N&P, +BOD, +PP, –DO (155-156)	→	→	→	→	→	→		+TURB, +SS (181)	
	Adjustment	+TURB, +SS, –DO (157) AS, MVC	→	→	→	→	→	+DO (176) +TURB, +SS (157) AS, MVC			
	Stabilized	–DO (158) AS, MVC	→	→	→	→	→	+DO (176) +TURB, +SS (157) AS, MVC			
INGLIS LOCK TO GULF OF MEXICO (West End)	Construction	+TURB, +N&P, +SS (159)	→	→	→	→	→	+TURB, SS (175)		+TURB, +SS (181)	
	Adjustment	+TURB (159) AS, MVC	→	→	→	→	→	(242-243) –Cl,–DS in River, Canal and Aquifer downstream from Lake (175-176)		–CL,–DS "GW" (183)	
	Stabilized	AS, MVC	→	→	→	→	→	–Cl,–DS in River, Canal and Aquifer downstream from Lake (176-177)		–CL,–DS "GW" (183)	

EXPLANATION

Each block of the matrix considers possible effects on turbidity (TURB), nitrogen and phosphorus (N&P), suspended sediment (SS), dissolved solids (DS), chloride (CL), dissolved oxygen (DO), biochemical oxygen demand (BOD), plant productivity (PP), and COLOR on ground water ("GW") and surface water. The effects of possible accidental spills (AS) and motor vessel contamination (MVC) are also considered. For TURB, N&P, SS, DS, CL, DO, BOD, PP, and COLOR (+) indicates increase and (–) indicates decrease—no expected impacts in blank areas. Impacts would be same in blocks through which an arrow passes. Numbers refer to page (191) or pages (191-193) in the text where the subject is discussed.

NOTE: Maintenance dredging would effect the quality of water in the various reaches in much the same way as would construction dredging

Prepared by U.S. Geological Survey, February, 1976

*Cross-Florida Barge Canal area

ABSTRACT

The route of the partly completed Cross-Florida Barge Canal follows the St. Johns, Oklawaha and Withlacoochee Rivers. If the canal is completed, the Summit Reach, connecting the Oklawaha and Withlacoochee Rivers will be excavated into the Floridan aquifer. Large springs that discharge from this limestone and dolomite aquifer flow to the Oklawaha and Withlacoochee Rivers. These streams and the aquifers in much of the area contain a calcium bicarbonate water which has an average dissolved solids concentration of less than 300 mg/l and generally is suitable for most uses. Dense growths of aquatic plants in Lake Ocklawaha and Lake Rousseau, existing impoundments for the Barge Canal, have caused large diel variations and stratification of dissolved oxygen. In the summer and fall when these plants begin to die, low dissolved oxygen concentrations are common, particularly in Lake Ocklawaha. These aquatic plants also assimilate large amounts of nitrogen and phosphorus. Major impacts of several alternative plans to complete or not complete the canal, on the quality of water in the area, include increased turbidity and suspended sediment concentrations during dredging and land clearing operations. The impoundment of Eureka Pool in the Oklawaha River will probably result in increased aquatic plant production and large variations in dissolved oxygen concentrations similar to those in Lake Ocklawaha. In some parts of the canal, canal water will move into the aquifer, so the quality of ground water in those places will depend partly upon the quality of water in the canal. Seepage from the canal to the aquifer is expected to be larger in the Summit Reach than in any other reach.

INTRODUCTION

Construction of the Cross-Florida Barge Canal was started in 1964 and was more than one-third complete when work was halted by executive order in January 1971 on the basis of environmental considerations. Congressional action in June 1972 required the U.S. Army Corps of Engineers to make an assessment of the impact of the canal on the environment and to prepare an environmental impact statement (EIS) in accordance with the National Environmental Policy Act. One aspect of direct concern was the effect of the canal on the surface- and ground-water resources of central Florida.

The start of the environmental impact assessment was delayed by litigation ending in a ruling by Judge Harvey M. Johnsen, United States District Court, Eighth Circuit, January 31, 1974, that the Corps complete an EIS in 6 months from that date. In March 1974, the Corps established an Interagency Coordinating Group (ICG) of Federal and State agencies to assist in the preparation of a plan of study (POS) and to help establish guidelines to insure a comprehensive and legally sufficient environmental assessment. The POS, completed in July 1974, called for a final EIS by June 30, 1976. The court was asked for the necessary extension of the deadline, but an extension was granted to only May 1, 1975, with any needed further extension dependent on adequate justification. Completion of the task by the deadline was not possible and a status report was, accordingly, submitted to the court on April 22, 1975 asking for an extension to September 30, 1976. While awaiting the court's decision, the assessment continued and the POS was revised in October 1975 calling for a draft EIS by October 8, 1976 and the final EIS by January 14, 1977. As of late autumn 1975, the court had not yet acted on the application for the extension submitted on April 22, 1975.

Phase I of the Cross-Florida Barge Canal environmental impact assessment was completed and the results were presented in a 3-volume report by Battelle Columbus Laboratories (1974) in October 1974. The Phase I study analyzed the existing environmental data base and defined additional data needs, including methods of meeting these needs, that would be necessary to accomplish Phase II, the actual environmental impact assessment on which the Corps would base the final EIS. Based in part on the initial plan of study and in part on the Battelle report, several environmental studies were started in December 1974 and January 1975 in partial fulfillment of Phase II, requiring a data collection period of approximately 1 year.

The U.S. Geological Survey was requested by the Corps to make the necessary study pertaining to water quality. Other studies include: (a) fisheries and wildlife, by the Game and Fresh Water Fish Commission, State of Florida; (b) plankton and benthos, Environmental and Research Technology, Inc.; (c) aquatic vegetation, Joyce Environmental Consultants, Inc.; and (d) terrestrial vegetation, Department of Agriculture, U.S. Forest Service.

Results of these special studies, including the Survey's water-quality study, will be integrated by a separate contractor, Meta Systems, Inc. of Cambridge, Massachusetts, into a comprehensive environmental assessment of the several alternatives to construct or not construct the canal. In addition, an assessment of secondary impacts of the Barge Canal project will be accomplished by Meta Systems, Inc. through a contract with the U.S. Environmental Protection Agency.

Purpose and Scope

The purpose of the study pertaining to water quality is to provide water-quality information needed to assure preparation of a comprehensive, legally sufficient Environmental Impact Statement for all of the alternative plans to construct or not construct the Cross-Florida Barge Canal. The study is limited to defining present water quality and evaluating potential impacts on water quality by each of the alternatives.

The study must adequately define the impacts on water quality of the two general alternatives, that is: (1) complete the canal or (2) do not complete the canal. It must also define the impacts on water quality of the several subalternatives listed below for either completing or not completing the canal:

1. Complete the canal:

    a. Authorized alinement
    b. Eureka to Highway 40 non-river alinement
    c. Eureka to Bert Dosh Lock non-river alinement
    d. Summit Reach alternate plan
    e. West end alternate plan

2. Not complete the canal:

    a. Preserve completed works
    b. Restore to original condition
    c. Abandonment of completed works

The Lake George alternate route is not considered in this report.

The water-quality study by the U.S. Geological Survey for the environmental impact assessment consisted of a 1-year intensive water-quality data collection program from January through December 1975. Data collected during this period supplemented data collected as part of the cooperative hydrologic monitoring program between the Geological Survey and the U.S. Army Corps of Engineers in the area of the Barge Canal since July 1966. Water-quality data also were collected by the Geological Survey at numerous sites in the area of the canal before 1966 as a part of programs with the Corps and other cooperating agencies. In addition to data collected by the U.S. Geological Survey, the study includes water-quality data collected by other State and Federal agencies.

This report describes the surface- and ground-water quality in the Barge Canal area based on available data for the period of record and under hydrological conditions that existed during the 1-year period of specific data collection for the water-quality study (January-December 1975). The potential impact on water quality of each of the alternatives and subalternatives for construction or nonconstruction of the canal is described. This report is intended to furnish the information necessary to fulfill the following specific objectives:

1. Provide a record of water quality of the Barge Canal area as determined from surface-water and ground-water quality data collected through December 1975.

2. Determine, to the extent possible, any actual or potential (short- or long-term) changes in the quality of surface and ground waters in the area that would result from the various alternatives to construct or not construct the canal.

3. Determine the current and future water-quality suitability of the surface and ground waters for various uses, including municipal, agricultural, recreational and wildlife uses. This requires a comparison of the quality of these waters to accepted water-quality standards.

4. Determine the capacity of the water in the canal and in the major streams to assimilate wastes that have a dissolved oxygen demand. This involves a discussion of the effects of such wastes on the dissolved oxygen concentration of the receiving water and the rates of recovery.

5. Determine the input-output plant nutrient budget for the canal waters. Data evaluated in the water-quality study provides only a minimal nutrient budget. However, the basin input-output nutrient budget defined in the report may be used later, in conjunction with the results of other environmental studies, in a dynamic nutrient model to predict the distribution and movement of nutrients through the various compartments within the system, and to identify and determine the significance of the various retention media.

6. Determine the effect of mixing waters from separate systems. Included are the effects of mixing surface water from different basins and the effect of mixing surface water with ground water.

Acknowledgments

Many individuals aided the authors in various aspects of data collection, data analyses and report preparation and review. Without their efforts, the timely completion of this report would not have been possible.

The urgent need for the early completion of the report in order to meet the court-ordered deadline for the EIS required that the authors receive advice and review comments on technical matters and report preparation throughout the project from all Survey staff levels. Many U.S. Geological Survey personnel throughout the Florida District and elsewhere were of immeasurable assistance.

Conversion Factors

The English units appearing in the text of this report are followed by the equivalent metric value in parentheses. In several tables, however, space did not permit the entry of the metric equivalent for values expressed in English units. The metric equivalents for these values may be computed using the following conversions:

1 acre	=	0.4047 hectare (ha)
1 inch (in)	=	25.40 millimetres (mm)
1 foot (ft)	=	.3048 metre (m)
1 mile (mi)	=	1.609 kilometres (km)
1 pound	=	.4536 kilograms (kg)
1 square mile (mi^2)	=	2.590 square kilometres (km^2)
1 cubic foot per second (ft^3/s)	=	.02832 cubic metres per second (m^3/s)
1 ton	=	.9072 tonne
1 million gallons per day (Mgal/d)	=	.04381 cubic metres per second (m^3/s)

Temperature in degrees Celsius can be converted to degrees Fahrenheit as follows:

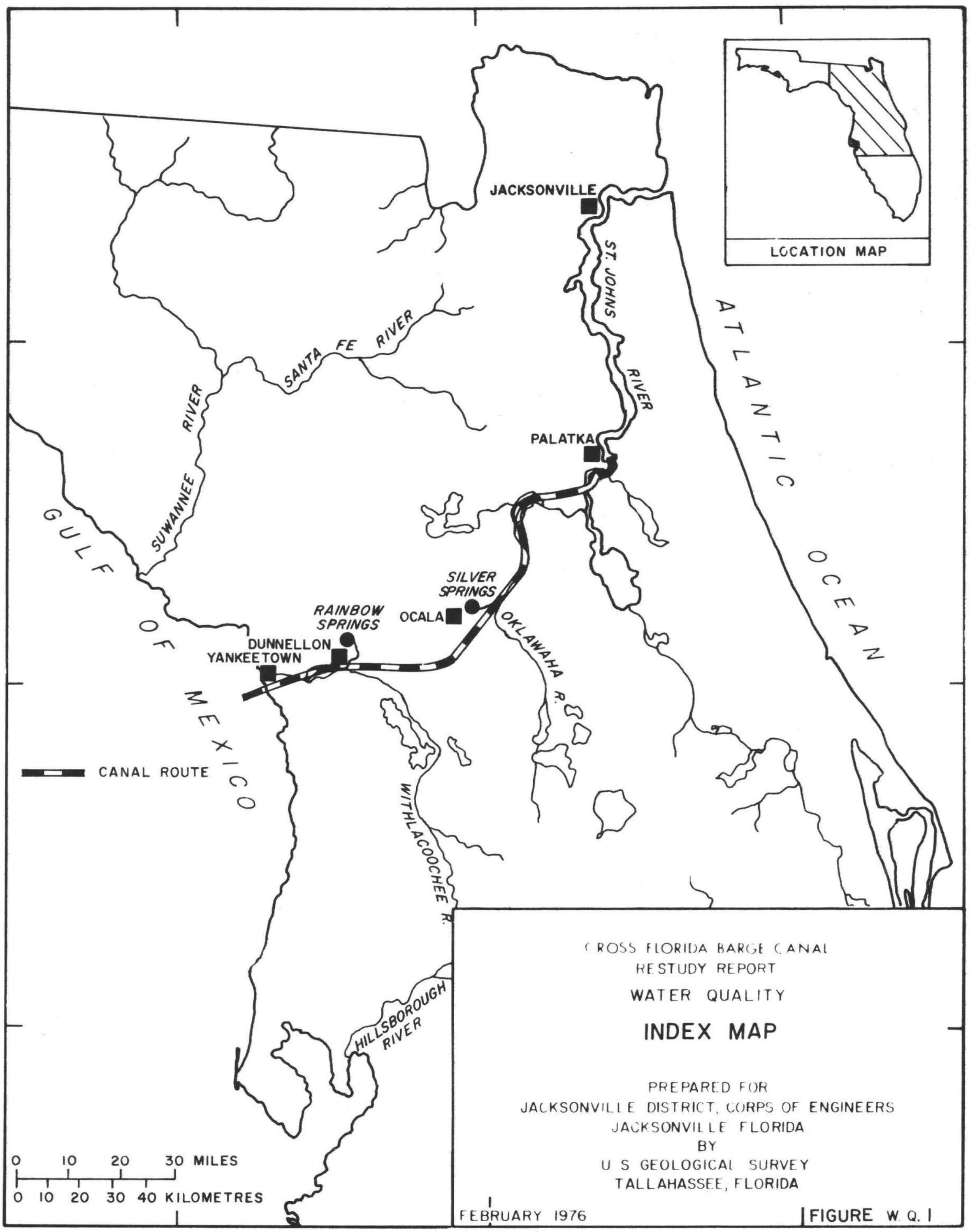
$$°F = 32 + 1.8 \times °C$$

DESCRIPTION OF THE AREA

The authorized route of the Cross-Florida Barge Canal extends from Palatka to the Gulf of Mexico near Yankeetown, Florida, a distance of about 107 mi (172 km) (fig. W.Q. 1). From Jacksonville to Palatka, a distance of about 78 mi (126 km), canal traffic would utilize the St. Johns River.

From the St. Johns River near Palatka the canal alinement follows a modified course of the St. Johns and Oklawaha Rivers to a point near Silver Springs. The Summit Reach of the canal route, where land surface is as high as 110 ft (34 m) above sea level, extends from the Oklawaha River valley near Silver Springs to a point near Dunnellon. From Dunnellon, the canal route follows a modified course of the Withlacoochee River to the Gulf.

The relief of the area traversed by the canal route is low. Land-surface altitudes are near sea level at each end of the canal and are mostly between 65 and 100 ft (20 and 30 m) along the Summit Reach (Faulkner, 1973a, p. 15). Where the canal route follows the Oklawaha River, land-surface altitudes are less than 40 ft (12 m) and the area is fairly flat. Swampy areas are common along much of the Oklawaha River valley. In the Summit Reach the terrain is gently rolling with numerous shallow sinkhole-related depressions. Because of the high


83°
82°
81°
31°
30°
29°
28°
LOCATION MAP
JACKSONVILLE
ST. JOHNS RIVER
ATLANTIC OCEAN
SANTA FE RIVER
SUWANNEE RIVER
PALATKA
GULF OF MEXICO
SILVER SPRINGS
OCALA
RAINBOW SPRINGS
DUNNELLON
YANKEETOWN
OKLAWAHA R.
CANAL ROUTE
WITHLACOOCHEE R.
HILLSBOROUGH RIVER
0 10 20 30 MILES
0 10 20 30 40 KILOMETRES
CROSS FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY
INDEX MAP
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U S GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA
FEBRUARY 1976
FIGURE W.Q. 1

permeability of most surficial materials in the area of the Summit Reach, perennial streams and lakes are few. West of Dunnellon, much of the canal route traverses fairly flat terrain and land-surface altitudes are less than 50 ft (15 m).

HYDROLOGY AND HYDROGEOLOGY

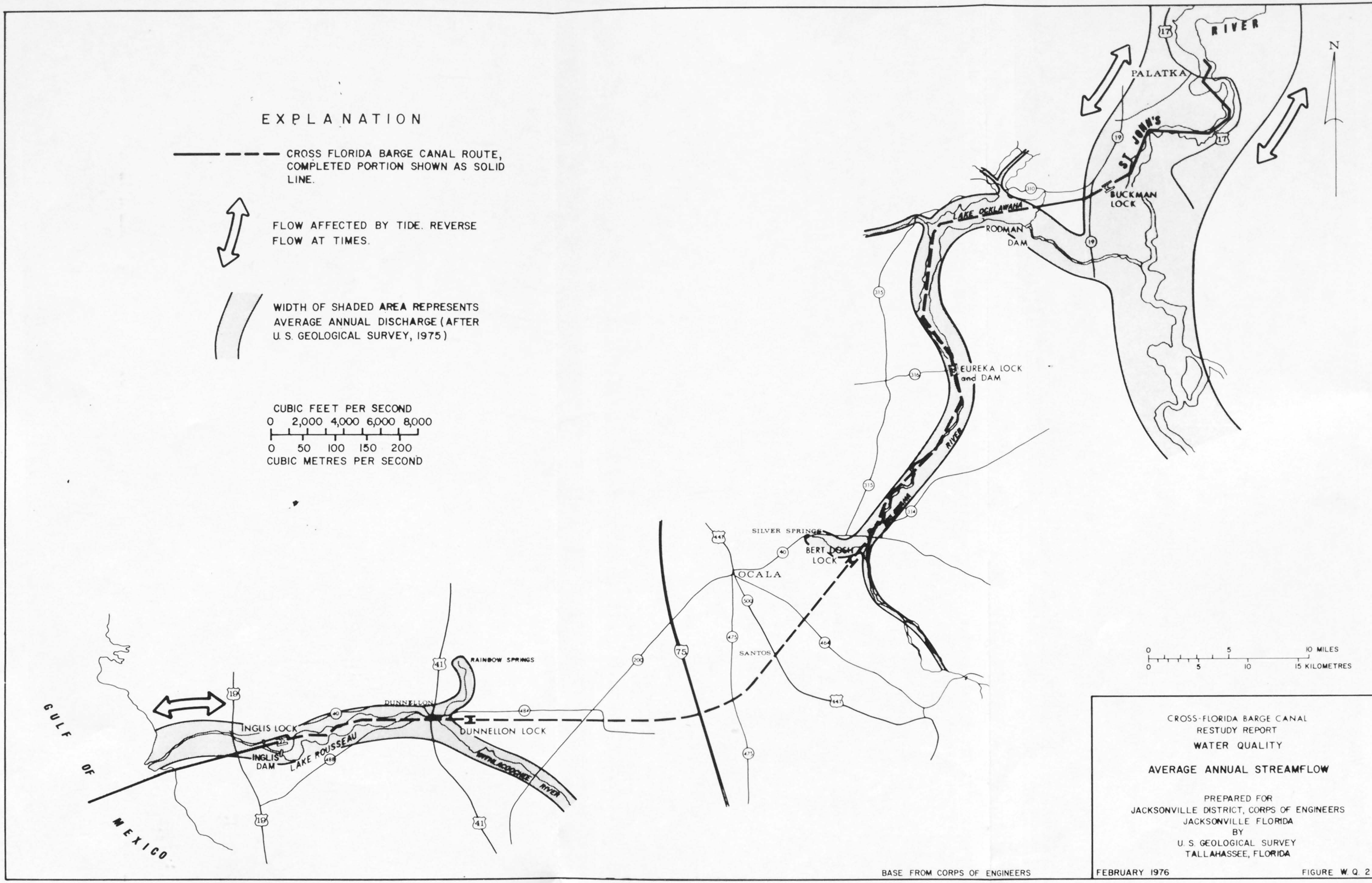
The Barge Canal is designed to alter the natural hydrologic system as little as possible. Water from the principal streams, the Oklawaha, St. Johns and Withlacoochee Rivers, and two large springs, Rainbow and Silver Springs, will serve to maintain navigation depths in the lower reaches of the canal. In the Summit Reach, the canal is to be excavated into the Floridan aquifer and the stage in this reach will fluctuate with the natural fluctuations of the potentiometric surface of the Floridan aquifer. The surface- and ground-water systems are described briefly in the following sections. Much of the following discussion is excerpted and summarized from reports by Faulkner (1970; 1973a). For more detailed discussion the reader is referred to these publications.

The canal route traverses, from northeast to southwest, the following three surface drainage basins as outlined by Kenner, Pride, and Conover (1967): (1) St. Johns River basin below Oklawaha River, (2) Oklawaha River basin, and (3) Withlacoochee River basin. In addition, the west end of the Barge Canal area includes parts of the coastal drainage areas between the Withlacoochee and Suwannee River basins and between the Hillsborough and Withlacoochee River basins.

The eastern part of the Cross-Florida Barge Canal area is drained to the Atlantic Ocean by the Oklawaha and St. Johns Rivers, and the western part to the Gulf by the Withlacoochee River (fig. W.Q. 2). The gradients of these streams are low, and poorly drained swampy areas are common in the flood plains of the streams. Most of the area between the Oklawaha and Withlacoochee River flood plains is drained through the subsurface and has no interconnecting surface drainage system (Faulkner, 1973a).

Both the Oklawaha and Withlacoochee Rivers have a mean discharge of about 1,900 ft^3/s (54 m^3/s)(fig. W.Q. 2). The flow in the St. Johns River is affected by tide, and at times reverse flow occurs. A maximum daily reverse flow at Palatka of 20,400 ft^3/s (577 m^3/s) was measured on June 6, 1968 (U.S. Geol. Survey, 1974).

Spring discharge is the most consistent and commonly the largest contributor to flow in the lower Oklawaha and Withlacoochee Rivers. During wet periods and floods, direct surface runoff, partly from the overflow of lakes and swamp areas in the river valleys, may be the major contributor to streamflow (Faulkner, 1973a). The relationship and relative magnitudes of river and spring discharge on a monthly basis are given for the 10-year period 1966-75 in figure W.Q. 3. Monthly rainfall is also presented.



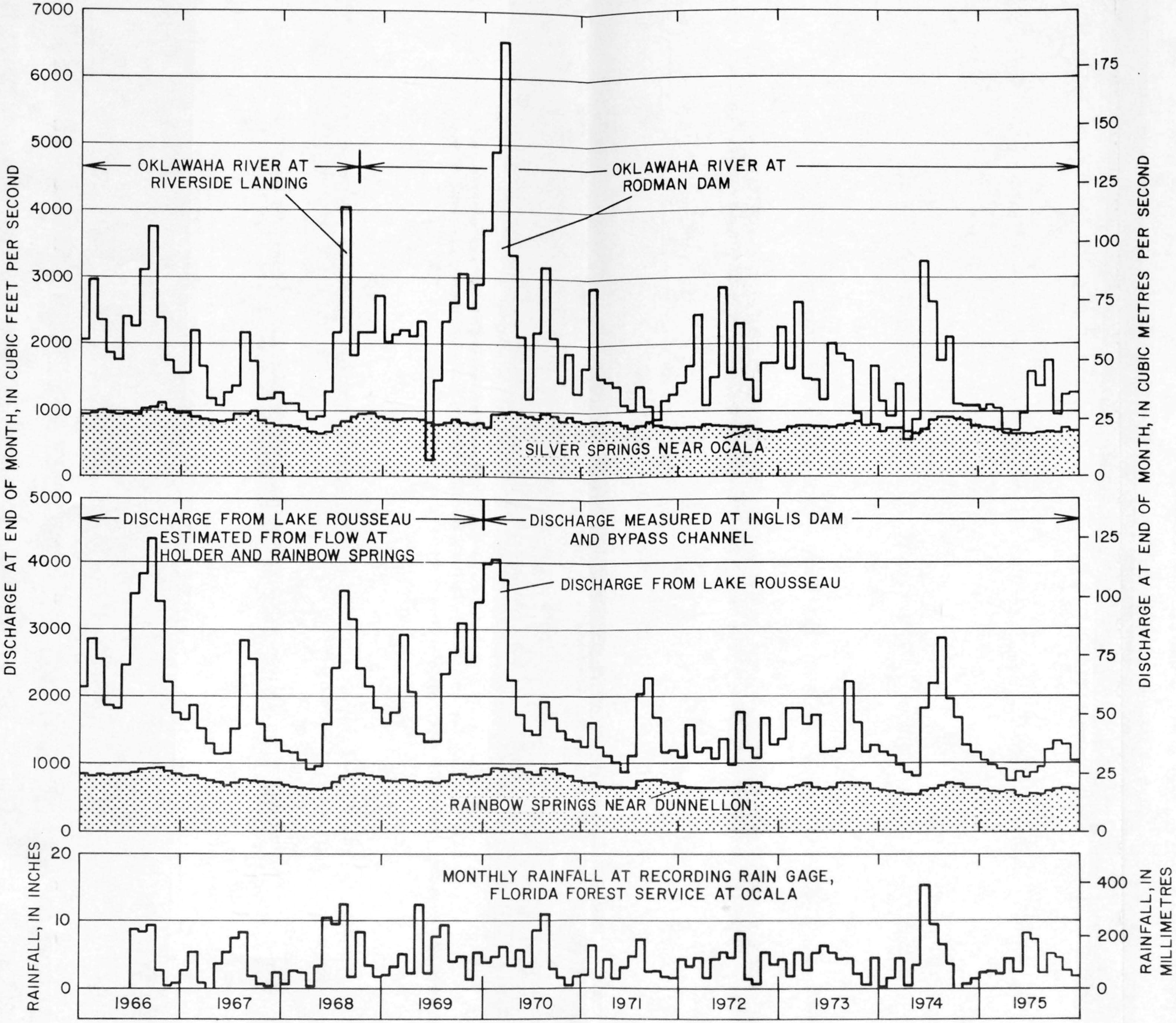
CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

AVERAGE ANNUAL STREAMFLOW

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U.S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976

FIGURE W.Q. 2



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

MONTHLY RAINFALL AND DISCHARGE FROM HYDROLOGIC SYSTEM

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 3

The ground-water system of the Cross-Florida Barge Canal area includes two fresh-water aquifers, the Floridan aquifer, by far the more important of the two, and a shallow aquifer (Hyde, 1965). The shallow aquifer consists of permeable sand and shell beds, often of limited horizontal and vertical extent, within the stratigraphic section that overlies carbonate rocks of the Floridan aquifer. Materials composing the shallow aquifer range in age from lower Miocene to Holocene.

The shallow aquifer in the study area is generally thought of as a water-table aquifer. However, it is not uncommon to find a permeable bed confined above and below by relatively impermeable beds that can maintain the water in the permeable bed under artesian pressure. The hydraulic head in the shallow aquifer may differ considerably from that in the underlying Floridan aquifer (Faulkner, 1970).

Most of the shallow-aquifer wells in the Barge Canal area are east of Silver Springs and Ocala, where continuous Miocene-Pliocene (?) sedimentary cover is present (Faulkner, 1973a). Sand deposits as much as 300 ft (90 m) thick locally underlie the area. Wells in the shallow aquifer are mostly for domestic use where only small supplies are needed.

In hilly areas underlain by the Hawthorn Formation, of Miocene age, the shallow aquifer absorbs large amounts of water from precipitation, and during wet periods helps to maintain water levels in small ponds and in short intermittent streams flowing to sinkholes. Also, during wet periods the shallow aquifer helps stabilize the flow of larger streams, such as the Oklawaha River, by short-term aquifer storage (Faulkner, 1973a).

The name "Floridan aquifer" is commonly applied to that part of the principal artesian aquifer of the southeastern United States that is in Florida. The aquifer consists mostly of limestone and dolomite, middle Eocene to middle Miocene in age, which act more or less as a hydrologic unit in most of Florida, in southeastern Georgia, and in parts of Alabama and South Carolina. The aquifer is, however, of variable porosity and permeability and in many places contains zones with well developed cavern systems separated by zones of low permeability which act as confining layers within the aquifer. Thus, in places the Floridan aquifer may be thought of as a compound aquifer consisting of several subaquifers. The principal artesian aquifer of the southeastern United States, including the Floridan aquifer, is one of the most extensive limestone aquifers in the United States (Stringfield, 1966, p. 95).

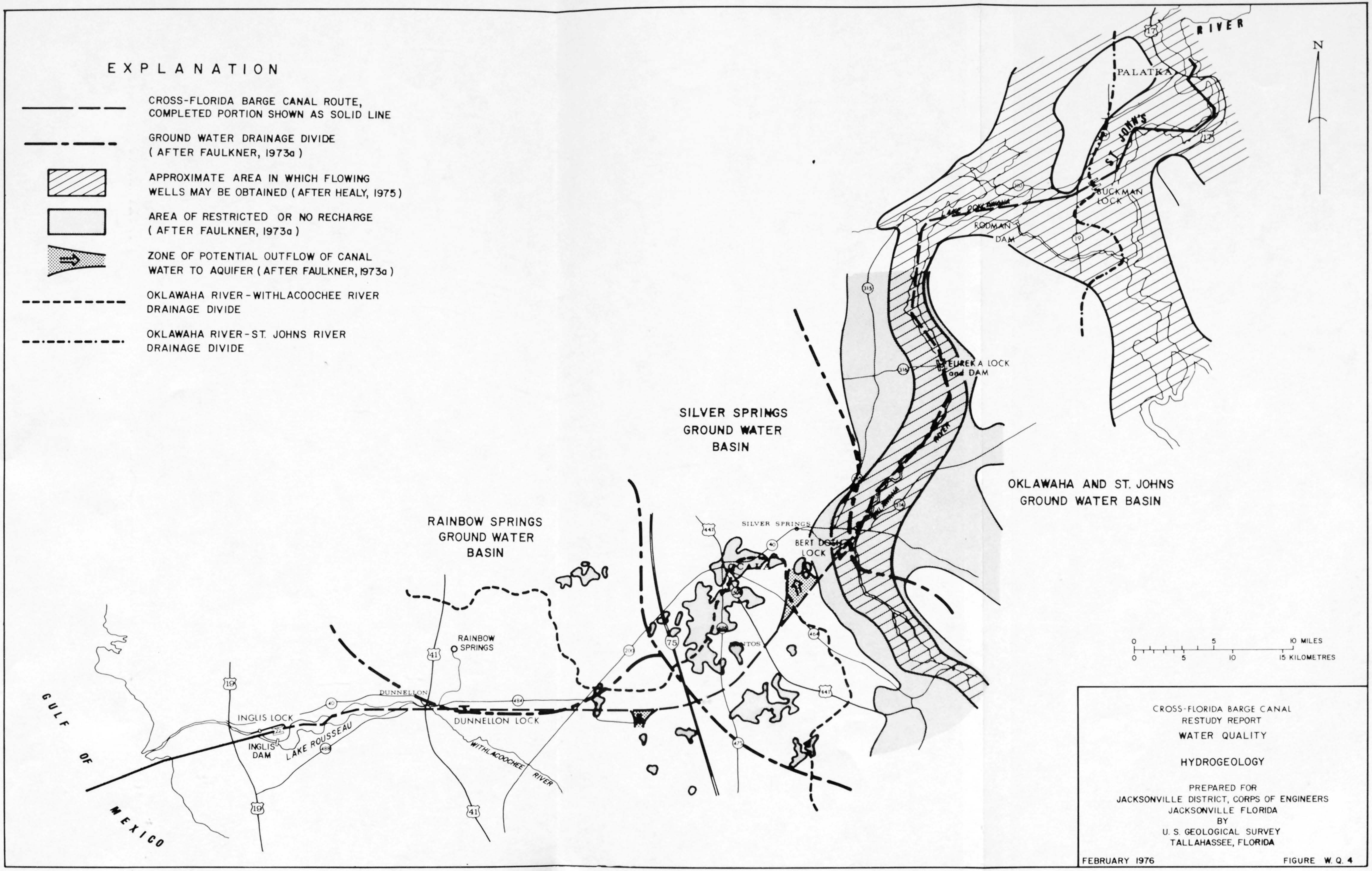
Much of the rock of the Floridan aquifer in the Barge Canal area is cavernous and, therefore, highly permeable. Its high permeability is the result of solution of the limestone by ground water circulating along a dual system of northeast- and northwest-trending and intersecting tension fractures and faults (Faulkner, 1970).

Northeast of Silver Springs the Floridan aquifer is confined by the thick sequence of poorly permeable deposits underlying the Oklawaha River valley. Because of the thick confining layer, the valley is an area of artesian flow (fig. W.Q. 4). Southwest of Silver Springs, along the canal route to the Gulf, a confining layer is virtually absent, the aquifer receives direct recharge, and at least its upper part is under water-table conditions. These hydrogeologic factors are of fundamental importance to the design and operation of the Cross-Florida Barge Canal (Faulkner, 1973a).

Much of the Barge Canal area is subject to subsurface drainage, particularly in the vicinity of the canal's 28-mi (45-km) Summit Reach (reach between Bert Dosh Lock and Dunnellon Lock). The subsurface drainage system is well developed, and the boundaries of the ground-water drainage areas do not necessarily correspond to the surface drainage basin divides. The ground-water and surface drainage divides are shown in figure W.Q. 4.

Over most of the Barge Canal area west of Silver Springs, the limestone of the Floridan aquifer is near the surface, covered by only a few tens of feet of permeable sand and clayey sand through which the aquifer is recharged by infiltration of local rainfall and over which no surface stream system exists. The ground water moves down the hydraulic gradient through a highly developed solution channel system in the limestone to two major points of discharge, Silver Springs near the east end of the Summit Reach and Rainbow Springs near the west end of the Reach. Most of the ground water that discharges at Silver and Rainbow Springs probably circulates through the upper 100 to 200 ft (30 to 60 m) of the Floridan aquifer (Faulkner, 1970).

Silver and Rainbow Springs are important features of the drainage system of the Barge Canal area. Silver Springs, a few miles east of Ocala, discharges, on the average, 823 ft^3/s (23.2 m^3/s) from the Floridan aquifer, 41 percent of the average annual discharge of the Oklawaha River. Maximum discharge of record for Silver Springs is 1,290 ft^3/s (36.5 m^3/s) and the minimum is 539 ft^3/s (15.2 m^3/s). Flow from Silver Springs is down the 4-mi (6.5-km) long Silver River to the Oklawaha River and thence northeastward to the St. Johns River and then to the Atlantic Ocean. Silver Springs will be the most reliable and constant water supply to the Oklawaha River part of the Barge Canal.


EXPLANATION
CROSS-FLORIDA BARGE CANAL ROUTE, COMPLETED PORTION SHOWN AS SOLID LINE
GROUND WATER DRAINAGE DIVIDE (AFTER FAULKNER, 1973a)
APPROXIMATE AREA IN WHICH FLOWING WELLS MAY BE OBTAINED (AFTER HEALY, 1975)
AREA OF RESTRICTED OR NO RECHARGE (AFTER FAULKNER, 1973a)
ZONE OF POTENTIAL OUTFLOW OF CANAL WATER TO AQUIFER (AFTER FAULKNER, 1973a)
OKLAWAHA RIVER - WITHLACOOCHEE RIVER DRAINAGE DIVIDE
OKLAWAHA RIVER - ST. JOHNS RIVER DRAINAGE DIVIDE
RIVER
N
PALATKA
ST. JOHNS
BUCKMAN LOCK
RODMAN DAM
EUREKA LOCK and DAM
SILVER SPRINGS GROUND WATER BASIN
OKLAWAHA AND ST. JOHNS GROUND WATER BASIN
RAINBOW SPRINGS GROUND WATER BASIN
SILVER SPRINGS
BERT DOSH LOCK
RAINBOW SPRINGS
DUNNELLON
DUNNELLON LOCK
INGLIS LOCK
INGLIS DAM
LAKE ROUSSEAU
WITHLACOOCHEE RIVER
GULF OF MEXICO
0 5 10 MILES
0 5 10 15 KILOMETRES
CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
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HYDROGEOLOGY
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA
FEBRUARY 1976
FIGURE W. Q. 4

A few miles north of Dunnellon, Rainbow Springs discharges, on the average, 788 ft^3/s (22.3 m^3/s) from the Floridan aquifer, about 43 percent of the flow of the Withlacoochee River. Maximum discharge of record for Rainbow Springs is 1,230 ft^3/s (34.8 m^3/s) and the minimum is 487 ft^3/s (13.8 m^3/s). Flow from Rainbow Springs drains southwestward down the 5-mi (8-km) long Blue Run to the Withlacoochee River and thence westward to the Gulf of Mexico. Rainbow Springs will be the most reliable and constant water supply to the Withlacoochee River part of the Barge Canal.

From the Gulf to the west edge of the Oklawaha River valley, about 1.5 mi (2.4 km) southwest of Bert Dosh Lock, most of the canal will be excavated into the rocks of the Floridan aquifer to depths ranging from 12 to 27 ft (3.6 to 8.2 m) below the water table. Northeastward from Bert Dosh Lock the canal will not penetrate the Floridan aquifer. Most of the way to the St. Johns River, the canal and its reservoirs will be located in the Oklawaha River valley, and will be separated from the Floridan aquifer by sediments of comparatively low permeability which underlie the valley floor. In places, some water from the Floridan aquifer probably leaks upward into the river channel through these poorly permeable materials. Also, minor leakage occurs in association with some fault zones in and along the edges of the Oklawaha River valley, particularly near the east edge. This is indicated by small, rather abrupt increases either in stream discharge or in specific conductance and chloride concentration of the river water, as well as observed relations between two possible fault emplaced outcrops of the Hawthorn Formation (Faulkner, 1973a).

Should the canal be completed, a dynamic inflow-outflow relation will exist between the Summit Reach and the Floridan aquifer. In the Summit Reach, the canal will be excavated into Floridan aquifer material. An important source of water for the Summit Reach will be ground water that discharges into the canal from the Floridan aquifer where the potentiometric surface of the aquifer is higher than the water level in the canal. Ground water inflow to the canal will be balanced by outflow to the aquifer in parts of the Summit Reach where the potentiometric surface is lower than the water level in the canal (Faulkner, 1973a). The canal water level in the Summit Reach to a large extent will be dependent upon natural fluctuations of the ground water level. Surface-water runoff will be a negligible source of supply to the Summit Reach.

Along most of the 28-mi (45-km) Summit Reach, under planned operating conditions, water will flow from the aquifer to the canal, and only two zones of flow from the canal to the aquifer are expected (fig. W.Q. 4). The most important zone of flow from the canal is about 4 mi (6 km) long and its center is about 5 mi (8 km) south of Silver Springs. A smaller zone of outflow from the canal about 1.5 mi (2.4 km) long is located west of the Silver Springs drainage area. A small amount of outflow southward toward the Withlacoochee River may occur through this zone (Faulkner, 1970).

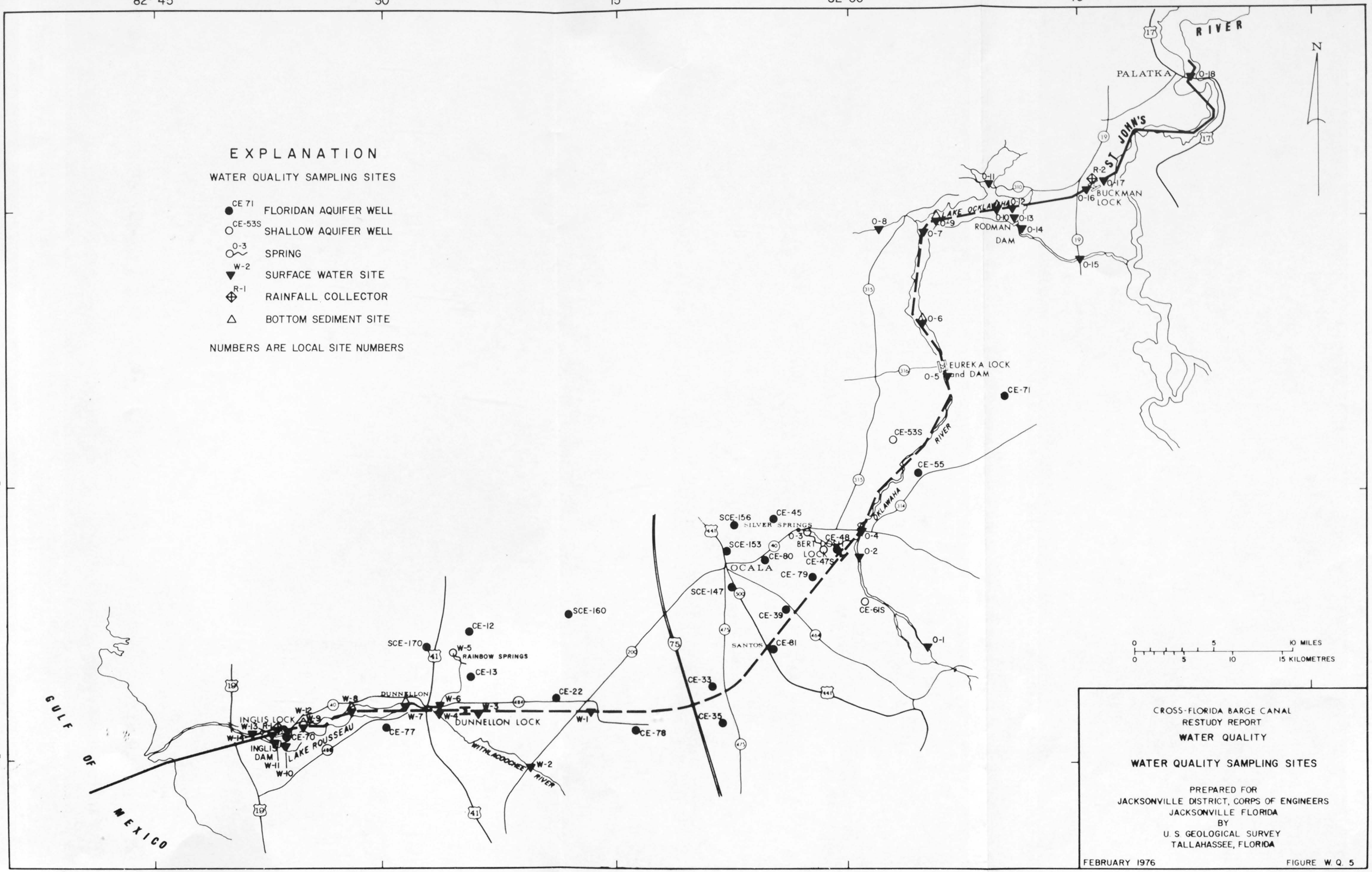
WATER QUALITY IN THE AREA OF THE CROSS-FLORIDA BARGE CANAL

As part of a cooperative hydrologic monitoring program between the U.S. Geological Survey and the U.S. Army Corps of Engineers, the quality of ground water in the area of the Barge Canal has been measured at about 20 wells in the Floridan aquifer on a bimonthly basis during the period 1966 through 1972 and semiannually since 1972. The quality of surface water has been measured at several sites in the area of the Barge Canal since the early 1950's. In 1968 the cooperative program with the U.S. Army Corps of Engineers was modified to include bimonthly sampling at two surface-water sites and semiannual sampling at 8 additional surface-water sites in the area of the Barge Canal. As parts of the Barge Canal were completed, the water-quality program was expanded and the frequency of data collection was increased. By 1974, 11 surface-water sites were being sampled bimonthly and 9 semiannually.

The ground-water data collection program was judged to be sufficient to meet the requirements of the court-ordered, environmental impact assessment. However, the existing surface-water data collection program was inadequate to meet the needs of the impact assessment. Consequently, in January 1975 the water-quality measuring program for surface waters in the area of the Barge Canal was expanded to include 32 sampling sites and the sampling frequency increased to monthly sampling at 21 sites. The intensive water-quality data program also included the sampling and analysis of bulk precipitation (rainfall and dry fallout) at two sites and of bottom materials at six sites (3 in Lake Ocklawaha and 3 in Lake Rousseau). The locations of ground-water and surface-water sampling sites, bottom sediment sampling sites and the bulk precipitation sampling sites are shown on figure W.Q. 5. The type of analyses and frequency of data collection are given in table 1 for the surface-water and bulk precipitation sampling sites and in table 2 for the ground-water sampling sites.

Bulk Precipitation

Rainfall contains much lower concentrations of dissolved solids than do most surface and ground waters. The major dissolved constituents in most surface and ground waters (calcium, magnesium, sodium, bicarbonate, chloride and sulfate ions) are seldom found in concentrations greater than a few milligrams per litre in rainfall. These constituents usually are dissolved from the rocks and soils in the drainage basin; and direct rainfall does not constitute a major source of these constituents. However, concentrations of the plant nutrients nitrogen and phosphorus in rainfall are frequently comparable to concentrations found in lake and stream waters (Joyner, 1974). Consequently, rainfall is a significant source of nitrogen and phosphorus for many waters and must be taken into account when appraising nutrient input. Rainfall



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

WATER QUALITY SAMPLING SITES

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976

FIGURE W. Q. 5

Table 1.--Surface-water and rainfall sampling sites and frequency of data collection in the area of the Cross-Florida Barge Canal.

Site number	Station name	Latitude (North)	Longitude (West)	Frequency of data collection[1]							Date water quality record began
				Specific conduct-ance	Partial[2] physical and chemical	Nutrients and bacterio-logical	Major anions and cations	Trace elements	Profiles of dissolved oxygen and temper-ature	Nutrients and pesticides in bottom materials	
O-1	Oklawaha River at Moss Bluff	29°04'52"	81°52'51"	W	M[3]	M[3]	S	S			Apr. 1956
O-2	Oklawaha River near Ocala	29°11'00"	81°59'40"		M	M	P				Jan. 1975
O-3	Silver Springs near Ocala	29°12'44"	82°03'15"		B	B	S	S			May 1954
O-4	Oklawaha River near Conner	29°12'52"	81°59'10"		M[3]	M[3]	P				May 1966
O-5	Oklawaha River at Eureka	29°22'00"	81°54'00"		M[3]	M[3]					Sept. 1970
O-6	Lake Ocklawaha near Orange Springs	29°25'02"	81°55'10"				S	S	Q	A	Feb. 1975
O-7	Lake Ocklawaha near Orange Springs	29°29'58"	81°54'45"						Q		Feb. 1975
O-8	Orange Creek at Orange Springs	29°30'34"	81°56'47"		M[4]	M[4]	P				Apr. 1956
O-9	Lake Ocklawaha near Orange Springs	29°30'47"	81°53'40"				S	S	Q	A	Feb. 1975
O-10	Lake Ocklawaha near Orange Springs	29°31'24"	81°49'50"				S	S	Q	A	Feb. 1975
O-11	Deep Creek near Rodman	29°32'28"	81°50'12"		M[4]	M[4]	P				Apr. 1956
O-12	Lake Ocklawaha near Orange Springs	29°31'30"	81°49'10"		M[3]	M[3]	P				July 1970
O-13	Oklawaha R ab Rodman Dam, nr Orange Springs	29°30'30"	81°48'15"				P		Q		Sept. 1970
O-14	Oklawaha R at Rodman Dam, nr Orange Springs	29°30'30"	81°48'15"		M[3]	M[3]	S	S			May 1970
O-15	Oklawaha R at SH 19 nr Salt Springs	29°29'00"	81°44'00"	W	S	S	S	P			Jan. 1964
O-16	Barge Canal above Buckman Lock nr Palatka	29°32'40"	81°43'50"	C	M[3]	M[3]	P				Nov. 1968
O-17	Barge Canal at Buckman Lock nr Palatka	29°32'45"	81°43'35"	W	M[4]	M[4]	P				Nov. 1968
O-18	St. Johns River at Palatka	29°38'48"	81°37'32"		M	M	M	Q			June 1967
W-1	Unnamed lake in Ross Prairie nr Shady	29°02'40"	82°17'20"			S					Aug. 1975
W-2	Withlacoochee R near Holder	28°59'19"	82°20'59"	W	M[3]	M[3]	M	Q			Jan. 1950
W-3	Unnamed lake near Dunnellon	29°02'40"	82°24'43"			S					Aug. 1975
W-4	Withlacoochee R ab Blue Run nr Dunnellon	29°02'33"	82°27'27"		M	M					Jan. 1975
W-5	Rainbow Springs nr Dunnellon	29°06'08"	82°26'16"		B	B[4]	S	S			May 1956
W-6	Blue Run at Dunnellon	29°02'57"	82°26'53"		M[4]	M[4]	P				May 1968
W-7	Lake Rousseau nr Dunnellon	29°02'47"	82°29'33"		M	M	S	S	Q	A	Jan. 1975
W-8	Lake Rousseau nr Dunnellon	29°02'30"	82°30'15"		M	M	S	S	Q	A	Jan. 1975
W-9	Lake Rousseau nr Dunnellon	29°01'46"	82°35'36"		M	M	S	S	Q	A	Jan. 1975
W-10	Withlacoochee R at Inglis Dam nr Dunnellon	29°00'35"	82°37'01"	W	M[4]	M[4]	P		Q		Mar. 1963
W-11	Withlacoochee R bl Inglis Dam nr Dunnellon	29°00'35"	82°37'01"	W	M[4]	M[4]	P				Mar. 1963
W-12	Barge Canal above Inglis Lock nr Inglis	29°01'31"	82°36'42"	C	M[3]	M[3]					Nov. 1969
W-13	Barge Canal at Inglis Lock nr Inglis	29°01'30"	82°37'00"	W	M[4]	M[4]					May 1970
W-14	Withlacoochee R bypass ch bel str nr Inglis	29°01'15"	82°38'20"	W	M[4]	M[4]	P				Sept. 1969
R-1	Rainfall at Inglis Lock nr Inglis	29°01'30"	82°36'51"			M					Jan. 1975
R-2	Rainfall at Buckman Lock nr Palatka	29°32'45"	81°43'36"			M					Jan. 1975

[1] Frequency is indicated by the symbol C for continuous, W for weekly, M for monthly, B for bimonthly, Q for quarterly, S for semiannually, A for annually, and P for less than annually.
[2] Includes analyses for specific conductance, hardness, chloride, turbidity, temperature and color.
[3] Sampled bimonthly prior to 1975.
[4] Sampled semiannually prior to 1975.

Table 2.--Ground-water sampling sites and frequency of data collection in the area of the Cross-Florida Barge Canal.

Site number	Location	Latitude (North)	Longitude (West)	Well depth in feet	Frequency of data collection[1]			Date water quality record began
					Partial[2] physical and chemical	Nutrient and bacterio-logical	Major ions	
Shallow aquifer wells								
CE-47S	2.0 mi (3.2 km) SE of Silver Springs	29°11'30"	82°01'50"	21	I	I	I	May 1966
CE-53S	5.5 mi (8.9 km) SW of Eureka	29°18'10"	81°57'00"	19	I	I	I	May 1966
CE-61S	6.0 mi (9.7 km) SE of Silver Springs	29°08'30"	81°58'40"	40	I	I	I	May 1966
Floridan aquifer wells								
CE-12	8.0 mi (12.9 km) NE of Dunnellon	29°07'39"	82°24'57"	46	S	S	I	May 1966
CE-13	1.5 mi (2.4 km) SE of Rainbow Springs	29°04'47"	82°25'09"	93	S	S	I	Mar. 1966
CE-22	9.0 mi (14.5 km) E of Dunnellon	29°03'12"	82°19'06"	60	S	S	I	Mar. 1966
CE-33	8.0 mi (12.9 km) S of Ocala	29°04'00"	82°09'10"	80	S	S	I	Mar. 1966
CE-35	11.0 mi (17.7 km) S of Ocala	29°01'30"	82°08'20"	70	S	S	I	Mar. 1966
CE-39	5.0 mi (8.0 km) SE of Ocala	29°08'20"	82°03'20"	72	S	S	I	April 1966
CE-45	2.0 mi (3.2 km) NW of Silver Springs	29°13'10"	82°04'50"	40	S	S	I	April 1966
CE-48	3.0 mi (4.8 km) SW of Silver Springs	29°11'00"	82°01'00"	177	S	S	I	July 1966
CE-55	7.0 mi (11.3 km) S of Eureka	29°16'00"	81°55'00"	165	S	S	I	April 1966
CE-70	At Inglis Lock	29°01'18"	82°36'41"	67	S	S	I	Feb. 1966
CE-71	5.0 mi (8.0 km) SE of Eureka	29°21'10"	81°51'00"	300	S	S	I	Sept. 1968
CE-77	2.0 mi (3.2 km) SW of Dunnellon	29°02'16"	82°29'20"	190	S	S	I	Aug. 1968
CE-78	13.0 mi (20.9 km) SW of Ocala	29°01'32"	82°13'30"	82	S	S	I	July 1968
CE-79	3.5 mi (5.6 km) S of Silver Springs	29°09'53"	82°03'13"	86	S	S	I	Sept. 1968
CE-80	2.5 mi (4.0 km) SE of Silver Springs	29°11'40"	82°05'27"	90	S	S	I	Sept. 1968
SCE-147	1.5 mi (2.4 km) S of Ocala	29°09'00"	82°07'00"	145	S	S	I	Sept. 1968
SCE-153	1.3 mi (2.1 km) N of Ocala	29°12'20"	82°08'00"	62	S	S	I	Sept. 1968
SCE-156	2.8 mi (4.5 km) N of Ocala	29°14'00"	82°07'00"	70	S	S	I	Sept. 1968
SCE-160	8.0 mi (12.9 km) NE of Rainbow Springs	29°08'50"	82°18'05"	100	S	S	I	Sept. 1968
SCE-170	4.0 mi (6.4 km) N of Dunnellon	29°06'14"	82°27'48"	180	S	S	I	Sept. 1968

[1] Frequency is indicated by the symbol S for semiannually or I for once only.
[2] Includes analyses for specific conductance, hardness, chloride, turbidity, temperature and color.

and dry fallout (bulk precipitation) is the major source of nitrogen and phosphorus in the conservation areas of the Florida Everglades (Waller, 1975) and is an important contributor to the streams and impoundments in the area of the Cross-Florida Barge Canal.

To estimate the significance of nitrogen and phosphorus contributed to the drainage area of the Cross-Florida Barge Canal by bulk precipitation, rainfall and dry fallout collectors were installed at Inglis Lock and at Buckman Lock. Samples were removed from the plastic collectors after each rainfall and were refrigerated. The samples were composited monthly and analyzed for both orthophosphate phosphorus and total phosphorus, organic nitrogen, ammonia nitrogen, nitrate nitrogen, and nitrite nitrogen. Only nine of the monthly samples were used for the computations--three of the samples were contaminated. Table 3 shows that bulk precipitation in the area of the Cross-Florida Barge Canal during January 1974 through December 1975 contains an average of 0.91 mg/l nitrogen and 0.05 mg/l phosphorus. These average concentrations were slightly lower than those measured in bulk precipitation by Waller (1975), but were slightly higher than concentrations measured in rainfall by Joyner (1974) and Brezonik and others (1969).

The average concentrations of nitrogen and phosphorus in bulk precipitation exceeds the concentrations in most of the samples collected from streams and impoundments during this investigation. Based on the average concentrations of nitrogen and phosphorus and the annual rainfall of 50 in (December rainfall estimated), bulk precipitation contributed 10.3 pounds of nitrogen per acre (11.5 kg/ha) and about 0.57 pounds of phosphorus per acre (0.64 kg/ha) during 1975. Concentrations of nitrogen and phosphorus in bulk precipitation tend to be slightly higher during periods of little rainfall. During 1975 most of the nitrogen and phosphorus loads were contributed during the months of June through September, the season when more than half of the annual rainfall occurred.

Ground Water

The Shallow Aquifer

The shallow aquifer is heterogeneous, and therefore the quality of its water may vary greatly from one area to another. Most shallow-aquifer wells in the area of the Barge Canal are screened in sand. Water from these wells generally has much lower dissolved solids concentration than water from wells in the more soluble limestone of the Floridan aquifer. Where the shallow aquifer is not overlain by poorly permeable materials, it is recharged directly by rainfall and contains soft water with concentrations of dissolved solids frequently less than 150 mg/l. In areas where the shallow aquifer consists of shell beds or where recharge primarily is from upward leakage from

Table 3.--Concentrations of nutrients in bulk precipitation in the area of the Cross-Florida Barge Canal, January-December 1975.
(Concentrations are in milligrams per litre.)

Nutrients	Site R-1 at Inglis Lock				Site R-2 at Buckman Lock				Mean[1] of all samples
	Number of samples	Max.	Min.	Mean[1]	Number of samples	Max.	Min.	Mean[1]	
Nitrate as N	9	0.49	0.10	0.21	8	0.59	0.14	0.21	0.21
Nitrite as N	9	.01	.00	.01	8	.02	.00	.01	.01
Ammonia as N	9	.61	.14	.25	8	.78	.18	.37	.31
Organic Nitrogen as N	8	.39	.00	.23	8	.77	.01	.55	.38
Total Nitrogen as N	8	1.45	.25	.70	8	1.47	.34	1.14	.91
Orthophosphate as P	9	.04	.01	.02	8	.07	.01	.05	.03
Total Phosphorus as P	9	.05	.01	.04	8	.09	.01	.06	.05

[1] Mean concentration weighted for differences in amount of rainfall among the sampling periods.

the Floridan aquifer, water in the shallow aquifer is more highly mineralized. Some shallow-aquifer wells in the lower Oklawaha River valley contain very hard water with concentrations of dissolved solids greater than 500 mg/1.

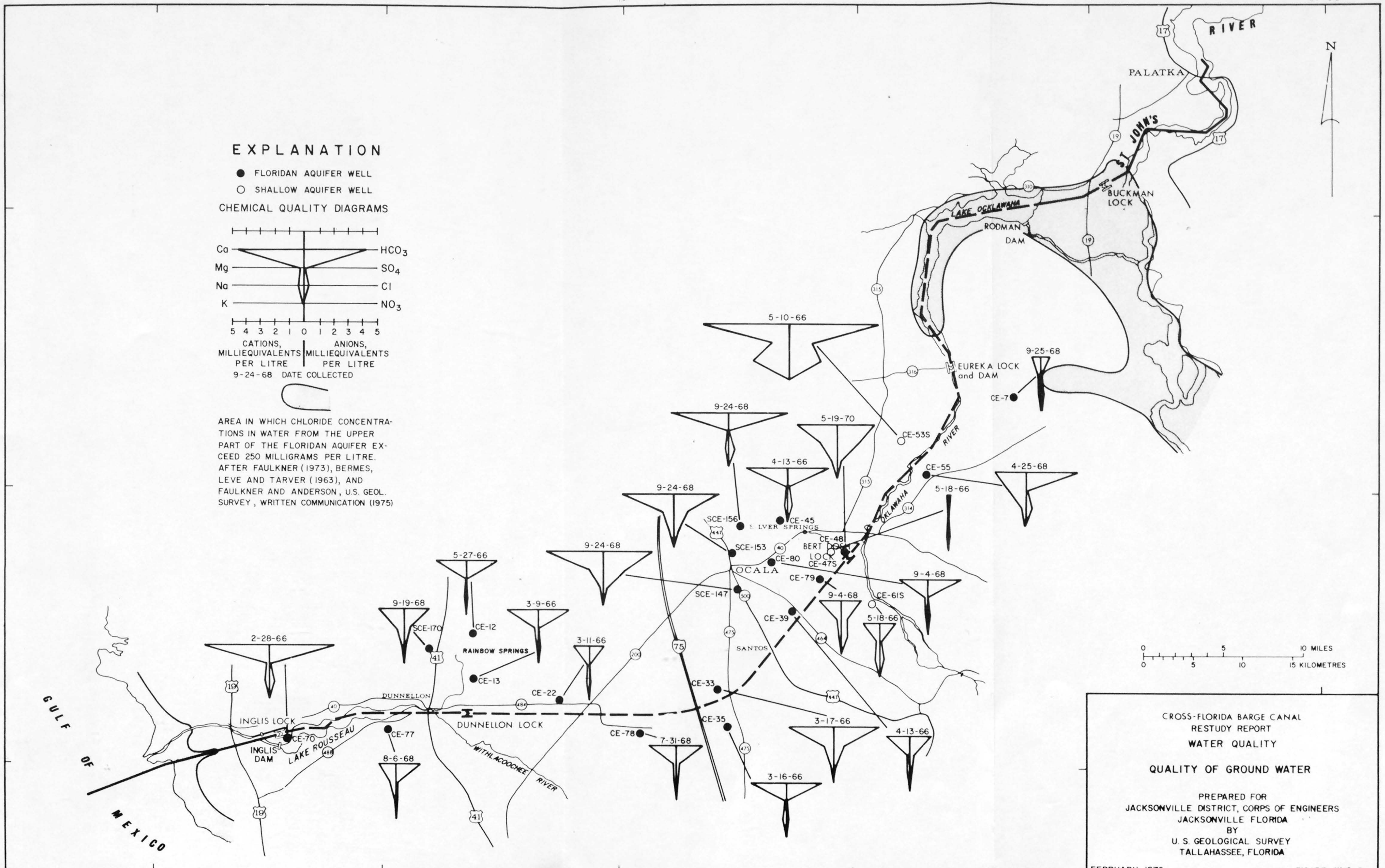
Areal variations in the quality of water in the shallow and Floridan aquifers can be seen by comparing the Stiff diagrams for the three wells for which data are available (fig. W.Q. 6). Water from the two shallow-aquifer wells east of Ocala is a calcium bicarbonate water lower in dissolved solids than water from most of the Floridan aquifer wells. However, the shallow-aquifer well northeast of Ocala contains more highly mineralized water. Water from this well is also a calcium bicarbonate water, but it contains relatively high concentrations of sodium and chloride ions suggesting possible upward leakage from the Floridan aquifer which contains saline water in the area of the lower Oklawaha River.

Data are sparse on the quality of water in the shallow aquifer in the area of the Barge Canal. Table 4 summarizes the available ground-water quality data in the vicinity of the Barge Canal. Iron and turbidity are not included in the summary, but are sometimes common problems in the ground water from the shallow aquifer. High concentrations of iron which can cause unpleasant tastes and staining of laundry and plumbing fixtures is the most common problem with water supplies utilizing the shallow aquifer. Iron is most often a problem in very shallow wells and in wells adjacent to lakes and streams (Faulkner, 1973a, p. 57).

The Floridan Aquifer

Water moving through the limestones and dolomites of the Floridan aquifer dissolves calcium carbonate, magnesium carbonate and other minerals present in the rocks. Water from the Floridan aquifer contains a higher concentration of dissolved solids than does most of the water from the shallow aquifer. Stiff diagrams representing the quality of water from 19 wells in the upper part of the Floridan aquifer are shown in figure W.Q. 6. These diagrams indicate that water in the Floridan aquifer generally is a calcium bicarbonate water. Concentrations of sodium and chloride ions are low in water from the upper Floridan aquifer at the sites depicted, but several wells contain water with significant concentrations of magnesium and sulfate ions.

The variations in the mineral concentration of water among wells in the Floridan aquifer are due primarily to areal variations in recharge and to variations in well depths (Faulkner, 1973a). In areas where rainfall recharges the aquifer directly, water near the top of the aquifer is low in dissolved solids. The mineral concentration of the water usually increases with depth. Water from deep in the aquifer contains not only more calcium and magnesium carbonate dissolved



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

QUALITY OF GROUND WATER

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976

FIGURE W. Q. 6

Table 4.--Summary of ground-water quality in the area of the Cross-Florida Barge Canal. (For site location see fig. W.Q. 5, for period of record and sampling frequency see table 2.)
(Results in milligrams per litre)

Constituent or property	Shallow aquifer (3 wells)				Floridan aquifer (20 wells)			
	Number of samples	Max.	Min.	Mean	Number of samples	Max.	Min.	Mean
Specific conductance (µmhos at 25°C)	3	915	18	368	229	498	74	261
Temperature (°C)	3	24.5	21.0	23.0	265	26.5	19.0	23.0
pH	3	7.9	6.9	7.4[1]	59	8.5	6.4	7.5[1]
Color	3	5	5	5	232	320	0	8
Turbidity (JTU)	-	-	-	-	516	350	0	13
Major cations								
Calcium	3	119	1	47	20	90	11	48
Magnesium	3	15	.4	5.8	20	16	.6	4.8
Potassium	3	1.0	.0	.3	19	2.3	.0	.4
Sodium	3	58	1.4	22	19	8.3	1.9	4.1
Strontium	-	-	-	-	9	.1	.0	.0
Major anions								
Bicarbonate	3	368	7	148	19	272	38	147
Carbonate	3	0	0	0	19	0	0	0
Chloride	3	77	1.5	30	227	24	1.0	6.7
Sulfate	3	76	0	27	19	79	0	17
Fluoride	3	.6	.0	.2	19	1.0	0	.2
Nutrients								
Nitrate as N	3	.04	.00	.03	223	4.50	.00	.38
Nitrite as N	-	-	-	-	209	.03	.00	.00
Ammonia as N	-	-	-	-	209	.41	.00	.04
Organic nitrogen as N	-	-	-	-	209	.87	.00	.13
Total nitrogen as N	-	-	-	-	236	4.5	.04	.60
Orthophosphorus as P	-	-	-	-	206	2.7	.00	.05
Total phosphorus as P	-	-	-	-	208	4.7	.00	.10
Silica, as SiO_2	3	27	5.8	20	51	55	1.2	9.8
Dissolved solids (Residue at 180°C)	-	-	-	-	10	324	63	179
Hardness as $CaCO_3$								
Total	3	358	4	142	249	284	32	133
Noncarbonate	3	57	0	22	19	88	0	20
Total organic carbon	-	-	-	-	161	44	0	4.5

[1]Median pH

from the limestone and dolomite, but also frequently contains higher concentrations of sulfate ions because of the more common occurrence of gypsum and other sulfate minerals at depth. Faulkner (1973a) reported sulfate concentrations in excess of 250 mg/l in a well 1,083 ft (330 m) deep near Ocala. Most wells in the area of the Barge Canal are less than 200 ft (61 m) deep and high concentrations of sulfate are not a problem. Table 4 summarizes chemical analyses of water from 20 wells from the upper part of the Floridan aquifer varying from 40 to 300 ft (12 to 91 m) deep. The data in this table indicate that water in the upper part of the aquifer is a hard, calcium bicarbonate water with an average dissolved solids concentration of about 180 mg/l. The concentration of sulfate in water from these wells averaged 17 mg/l, but was as high as 79 mg/l in one well.

Water near the top of the Floridan aquifer is more highly mineralized in areas where recharge of the aquifer is restricted than in areas where rainfall recharges the aquifer. There is no continuous confining bed overlying the aquifer in the area west of Silver Springs but locally recharge to the aquifer is retarded by poorly permeable materials. In these areas, much of the water near the top of the aquifer has traveled from areas of high recharge and has been in contact with the aquifer longer. The longer residence time in the aquifer may result in more opportunity for minerals to be dissolved from the rocks in the aquifer.

Dissolved solids concentrations were estimated by multiplying the specific conductance by a factor of 0.65. Based on the specific conductance measurements in table 4, the dissolved solids concentration of water from the upper part of the Floridan aquifer ranges from less than 100 mg/l to about 350 mg/l.

This difference in water quality with depth, together with differences in water temperature, constitutes the basis for Faulkner's (1973a) conclusion that although water from both Silver Springs and Rainbow Springs comes from the upper part of the Floridan aquifer, the water from Silver Springs has a longer residence time and comes from somewhat deeper in the aquifer. The dissolved solids concentration of water from Silver Springs averaged 287 mg/l, three times that of water from Rainbow Springs. Concentrations of sulfate in Silver Springs water averaged 41 mg/l, more than six times that in water from Rainbow Springs.

Although the quality of water in the Floridan aquifer varies both areally and with depth, public and domestic water supplies may be developed from the upper part of the Floridan aquifer in most of the area. Concentrations of chloride in water from the upper part of the aquifer generally were less than 10 mg/l except very near that part of the Barge Canal which contains salt water from the Gulf of Mexico and along the lower Oklawaha and St. Johns Rivers where chloride concentrations exceeded 250 mg/l.

As with water from the shallow aquifer, iron and hydrogen sulfide are sometimes troublesome in water from wells that tap the upper part of the Floridan aquifer. High concentrations of iron are more common in water from shallow wells than in water from deep wells. The iron concentrations in water vary areally and in many places shallow wells in the Floridan aquifer do not contain water high in iron. High concentrations of dissolved hydrogen sulfide gas cause odor problems in water from some upper Floridan aquifer wells in the area of the Barge Canal.

Pesticides are not a problem in water from the Floridan aquifer wells. Water sampled from 21 Floridan aquifer wells in May and September 1969 was analyzed for pesticides. Water sampled from several wells in May 1969 contained small amounts of DDT, but the maximum concentration of 0.03 ug/l was well below the recommended limit of 50 ug/l for public water supplies (Environmental Protection Agency, 1973). None of the wells sampled in September 1969 contained detectable amounts of pesticides.

The concentration of nitrogen and phosphorus in water from the Floridan aquifer averaged about 0.60 and 0.10 mg/l, respectively (table 4). Water from the aquifer contains, on the average, less nitrogen but more phosphorus than the bulk precipitation samples whose analyses are summarized in table 3. Nitrate is the dominant form of nitrogen in water in the Floridan aquifer. Concentrations of nitrate nitrogen in 233 water samples from Floridan aquifer wells were as high as 4.5 mg/l but averaged 0.38 mg/l. The average concentration of nitrate nitrogen in water from these wells exceeded that in bulk precipitation and in water from Rainbow Springs. However, nitrate nitrogen concentrations in water from Silver Springs averaged 0.50 mg/l, which is relatively high compared to average concentrations in water from most wells and from Rainbow Springs. Although the average concentration of total nitrogen in Silver Springs water is twice that of water from most wells in the area, it is only slightly higher than that of bulk precipitation. The concentration of phosphorus in Silver Springs water averaged 0.04 mg/l, less than half that of water from the Floridan aquifer wells sampled.

Water in the Floridan aquifer is generally free of bacteriological contamination. In most areas the limestone is overlain by sand which serves as a natural filter that removes bacteria and particulate materials from the water percolating downward. Because of the very permeable nature of the limestone, however, there is the potential for local contamination of the aquifer near drainage wells and sinkholes. At these sites bacteria and other contaminants may be introduced directly into the cavernous flow system. Contamination of the water in a few shallow Floridan-aquifer wells near Ocala has been reported; however, because most ground water sampled in the Ocala area is free of contamination, the problem is probably very local. In view of the longstanding use of drainage wells in the Ocala area and the good quality of water in most public and domestic supply wells, it is possible that many contaminants may be removed as the water moves through the limestone and the potential for widespread contamination is remote.

Surface Water

The Barge Canal route, as authorized, would utilize parts of three major rivers: the St. Johns River between Jacksonville and a point about 12 miles (19 km) upstream from Palatka, the Oklawaha River from the St. Johns River to a point near Ocala, and the Withlacoochee River from Dunnellon to the Gulf of Mexico. The Oklawaha and Withlacoochee Rivers would be connected by the Summit reach, a 28-mile (45 km) long channel excavated into the Floridan aquifer. Water in the Summit pool, before backpumping from the lower pools, would be primarily ground water and the quality of that water would be essentially that of water in the upper part of the aquifer. Water levels in the lower pools (two in the Oklawaha River basin and one in the Withlacoochee River basin) would be maintained by the natural flow of the streams.

Oklawaha River Basin

During periods of low-flow, the flow of the lower Oklawaha River consists almost entirely of Silver Springs water and ground water contributed by upward leakage along the lower part of the river. Consequently, the quality of water in the lower Oklawaha River during low flow periods is very similar to that of Silver Springs. During periods of high flow, however, the quality of water in the lower Oklawaha River more closely resembles that of surface runoff, including overflow from the numerous lakes and ponds in the upper basin above Moss Bluff and drainage from the swamps and marshes in the lower basin.

Summaries of physical and related chemical characteristics of surface waters in the Oklawaha basin are given in table 5. Usually the surface waters in the basin are highly colored, slightly alkaline, low in turbidity and concentrations of suspended sediment, and usually well oxygenated. Color, for example, ranged from 0 in Silver Springs water, to more than 300 units (platinum-cobalt units) in Deep Creek, and 400 units in the Oklawaha River at Moss Bluff. Biochemical oxygen demand ranged from 0 mg/l in water from Silver Springs to 12 mg/l in the Oklawaha River at Moss Bluff. Turbidity generally was less than 50 JTU (Jackson Turbidity Units) with the higher values usually occurring in and downstream from lakes and impoundments. Increased turbidity at these sites was more often due to high concentrations of phytoplankton rather than to high concentrations of suspended sediment. Variability for most parameters was large.

Table 5.--Summary of physical and related chemical characteristics in surface waters in the Oklawaha River basin. (For period of record and sampling frequency see table 1.)

Constituent or property	Number of Samples	Max.	Min.	Mean
Temperature (°C)	1124	32.0	10.0	23.5
Specific conductance (μmhos at 25°C)	703 [1]	760	56	375
pH	349	8.4	5.6	7.5 [2]
Dissolved oxygen (mg/l)	894	11.4	.1	6.0
Biochemical oxygen demand (mg/l)	348	12.0	.0	1.2
Color (platinum-cobalt units)	512	400	0	59
Turbidity (JTU)	413	680	0	12
Secchi disk transparency (in.)	8	177	48	102
Suspended sediment (mg/l)	94	442	0	13

[1] Does not include daily values above Buckman Lock
[2] Median pH

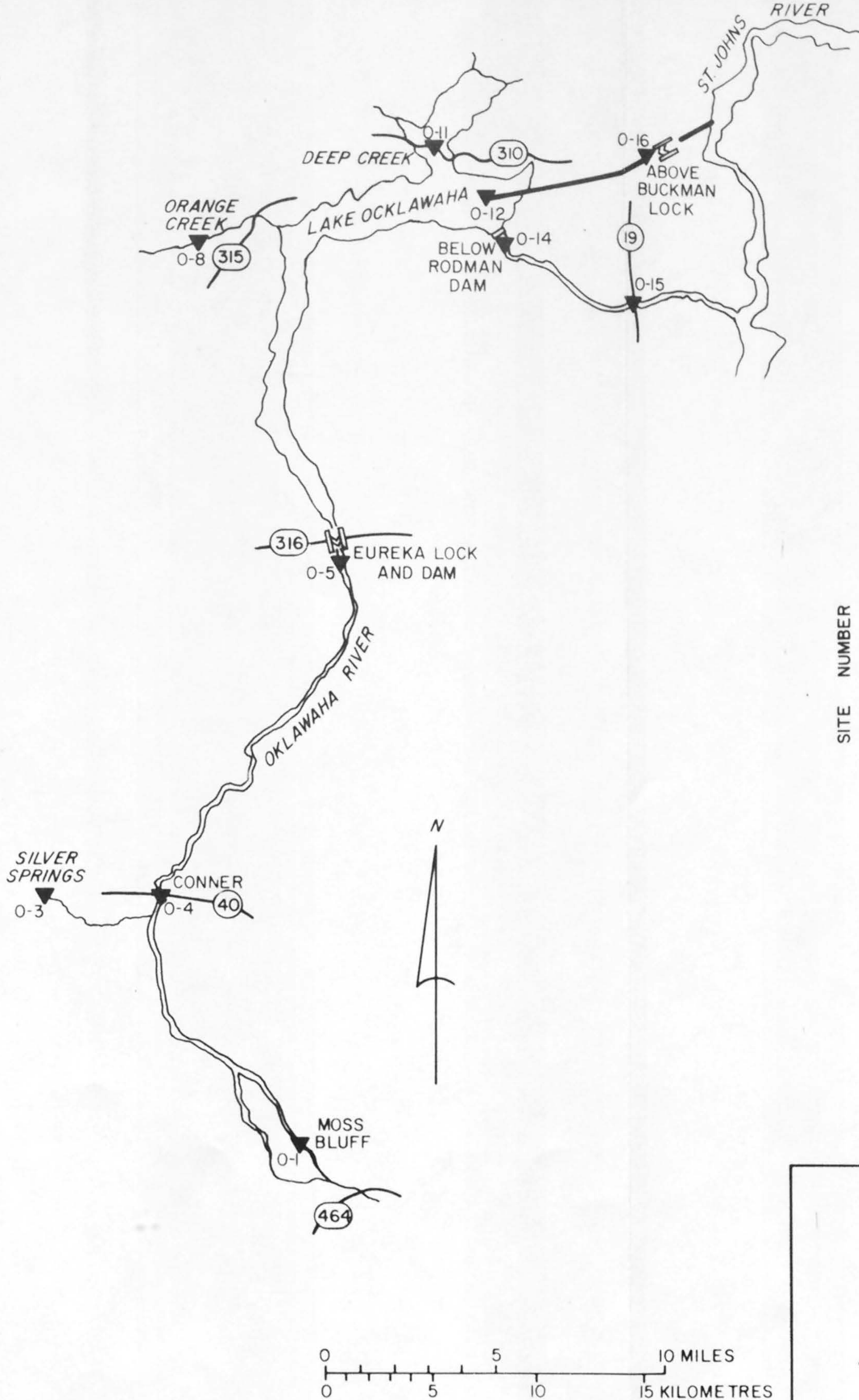
The color and turbidity of the mainstem of the lower Oklawaha River are generally low due to the clarity and lack of color in the discharge of Silver Springs. Suspended sediment concentrations were also usually low, seldom exceeding 30 mg/l. However, high concentrations of suspended sediment and high turbidity were sometimes associated with dredging, construction and land clearing. Dredging operations in the Oklawaha River above Moss Bluff have resulted in turbidity as high as 680 JTU and concentrations of suspended sediment as large as 442 mg/l at the Moss Bluff site. The highest color recorded at Moss Bluff (400 platinum cobalt units) also occurred during these dredging operations. In addition, the turbidity was generally the highest at Moss Bluff.

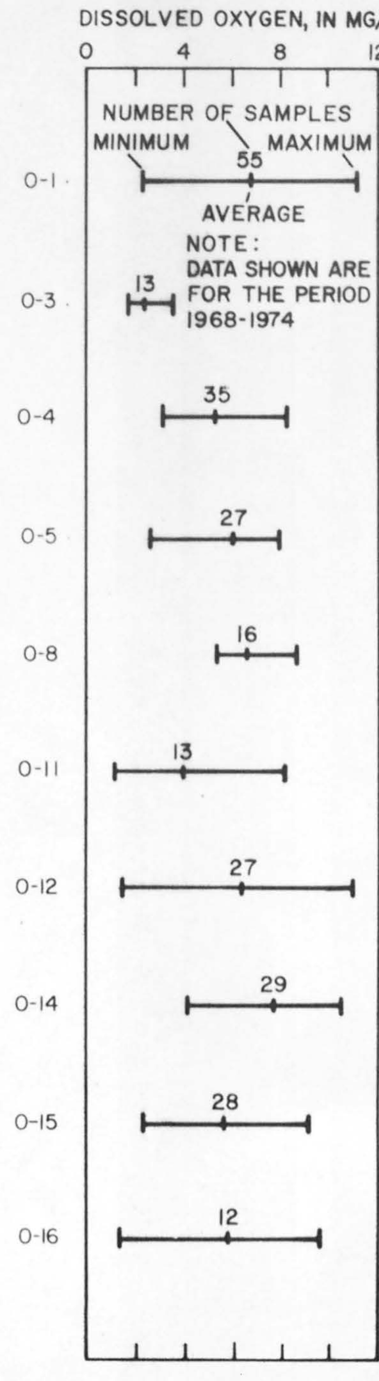
Dissolved Oxygen

A summary of the dissolved oxygen data collected at selected sites in the Oklawaha River basin from 1968 through 1974 is given in figure W.Q. 7. Most measurements were made between midmorning and midafternoon.

The greatest variability in the dissolved oxygen concentration occurred at Moss Bluff and in Lake Ocklawaha. However, all the sites exhibited some concentration variability. The minimum average concentration of dissolved oxygen was measured in Silver Springs. The inflow of low dissolved oxygen water from Silver Springs appears to decrease oxygen concentrations in the Oklawaha River between sites 0-4 and 0-5. At most sites, except Orange Creek and the Oklawaha River below Rodman Dam, the concentration of dissolved oxygen was less than 4.0 mg/l.

Concentrations of dissolved oxygen in surface waters may vary daily and seasonally in response to changes in the solubility of oxygen with changes in temperature, changes in plant productivity, and changes in the BOD loads carried into the streams by surface runoff. Seasonal variations in dissolved oxygen concentrations at five sites in the Oklawaha River basin are shown in figure W.Q. 8. The dissolved oxygen concentrations generally are highest in the winter and lowest in summer and fall. Seasonal variation in the concentration of dissolved oxygen in the Oklawaha River at Eureka differs somewhat from that of other sites. The highest concentration at Eureka has commonly occurred in May rather than in January or February. This is probably because the discharge of the Oklawaha River above Silver Springs is normally high in May when the lakes in the upper basin are lowered in preparation for the hurricane season. Consequently, the effect of Silver Springs discharge which is low in dissolved oxygen concentrations is less apparent at downstream sites, particularly the Eureka site (0-5). Monthly dissolved oxygen concentrations measured in 1975 are also shown in figure W.Q. 8. In May 1975, the concentrations of dissolved oxygen were highest of the year at Eureka, in Lake Ocklawaha, and below Rodman Dam. The relatively high concentrations of dissolved oxygen in May-July 1975, and the low concentrations in the late summer and fall of 1975, particularly in Lake





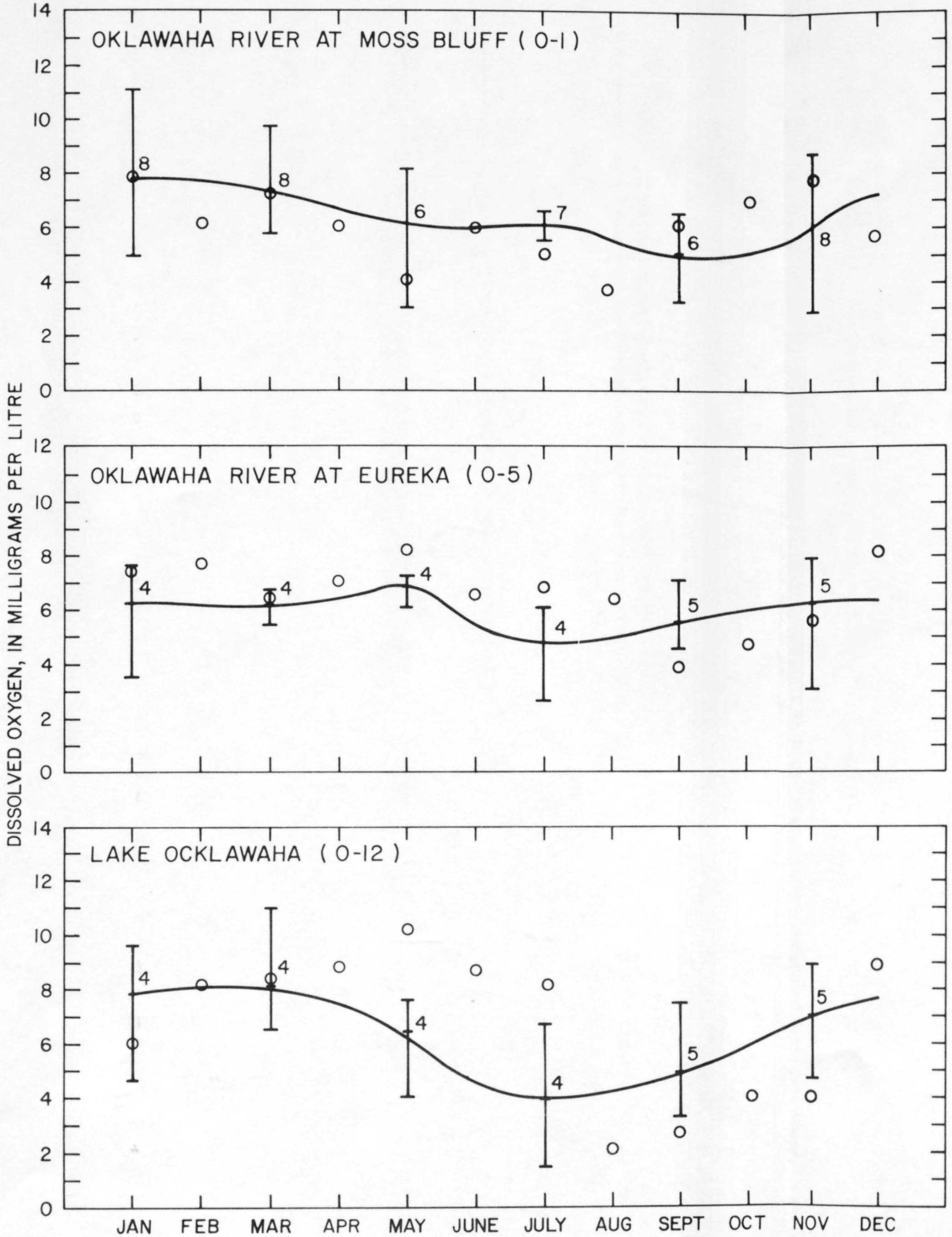
CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT

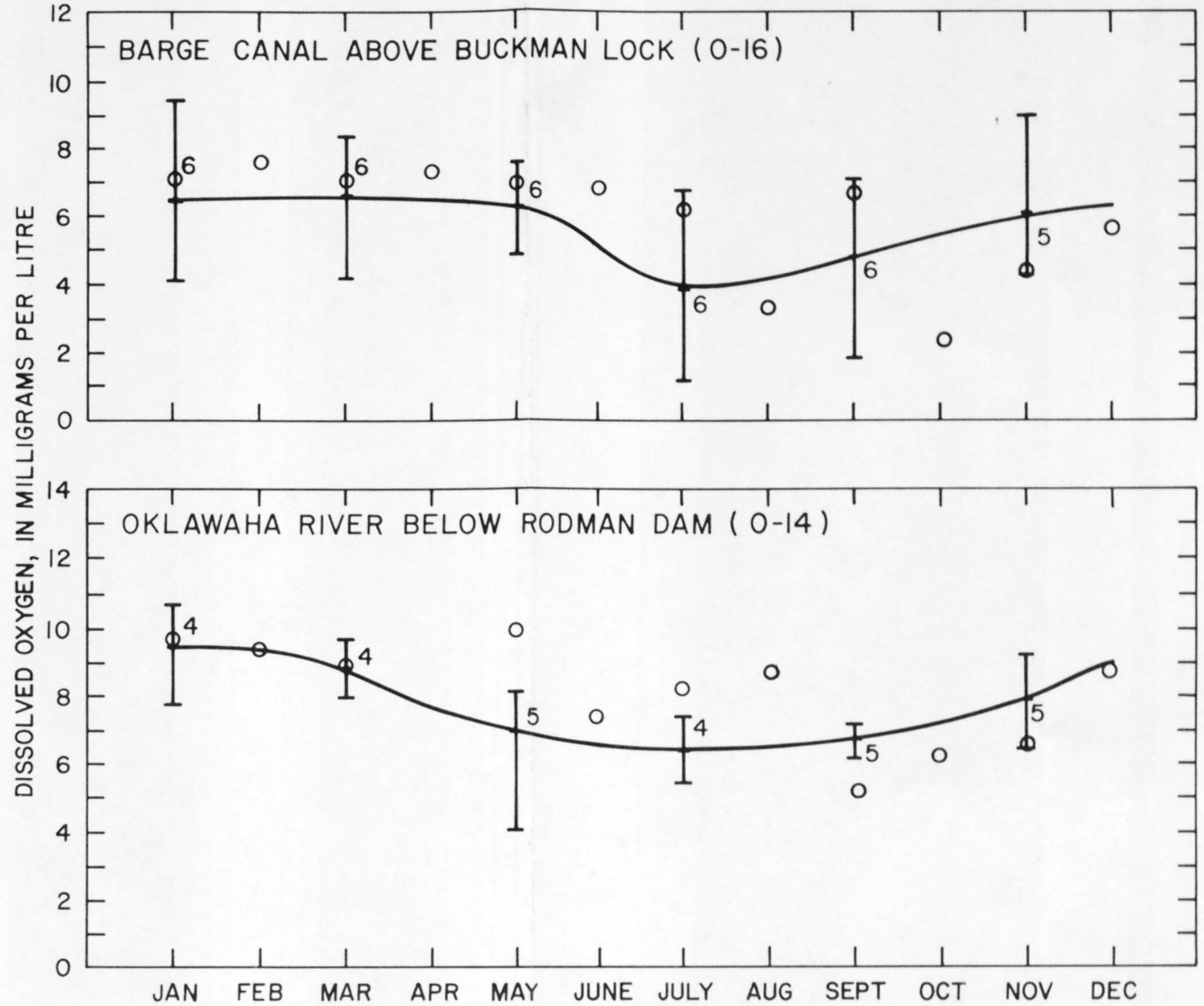
WATER QUALITY

MAXIMUM, MINIMUM AND AVERAGE DISSOLVED OXYGEN AT SITES IN THE OKLAWAHA RIVER BASIN

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE . W. Q. 7





EXPLANATION

MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISSOLVED OXYGEN CONCENTRATION (DAY-TIME MEASUREMENTS) DURING THE PERIOD 1968-1974.

— MAXIMUM
AVERAGE — 6 — NUMBER OF SAMPLES
MINIMUM —

○ DISSOLVED OXYGEN CONCENTRATION MEASURED IN 1975

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY
SEASONAL VARIATIONS IN
DISSOLVED OXYGEN CONCENTRATIONS
IN THE OKLAWAHA RIVER BASIN
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 8

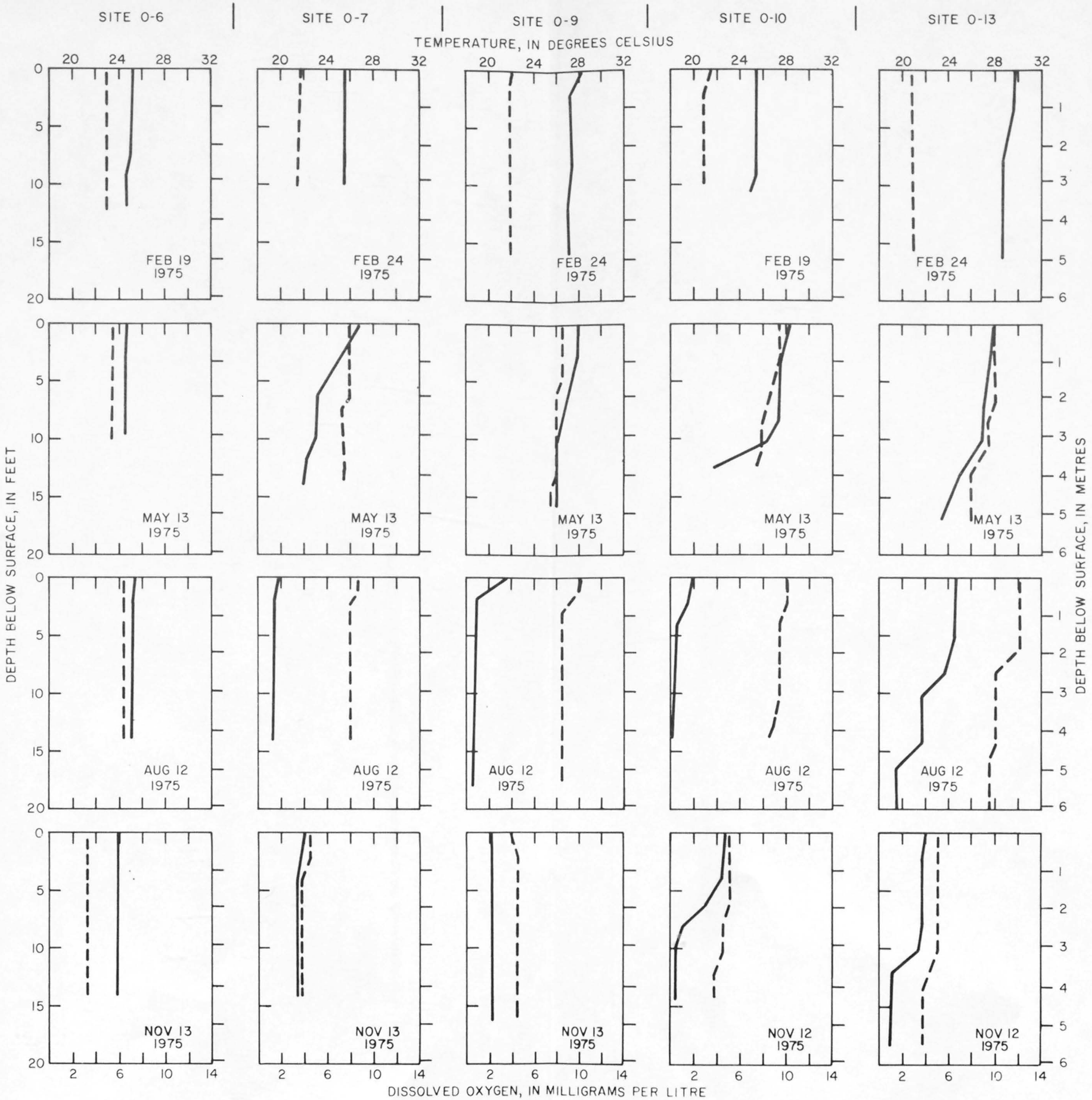
Ocklawaha (O-12), are probably a result of the variable primary productivity of the rooted aquatic plants.

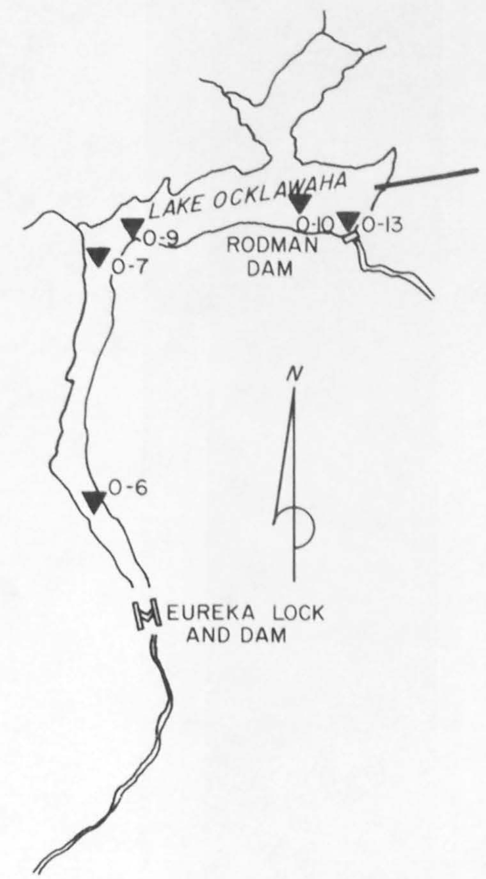
High temperatures and low flows in spring and early summer tend to cause thermal stratification in Lake Ocklawaha. As the surface water of the lake heats it becomes less dense than the cool bottom water. Under these conditions, mixing of the waters by winds and turbulence is restricted and the lake thermally stratifies. In addition, the lake also becomes stratified with respect to dissolved oxygen. Plant productivity occurs primarily in the upper waters and results in large diel variations in dissolved oxygen. In the absence of mixing, bottom waters often become low in or devoid of oxygen (Duchrow, 1971, 1972; Holcomb, 1973).

During the present study, temperature and dissolved oxygen profiles were measured quarterly at five sites between Eureka and Rodman Dam. Temperature and dissolved oxygen were relatively uniform from top to bottom at all sites in February (fig. W.Q. 9). During the other months oxygen decreased with depth at all but the most upstream site, O-6. At site O-6 the relatively narrow, well defined channel and high flow velocities kept the water column well mixed. Site O-6 is typical of natural stream conditions rather than that of an impounded reservoir.

Stratification of dissolved oxygen occurred in Lake Ocklawaha downstream of site O-6 during the summer and fall of 1975. Concentrations of dissolved oxygen near the bottom were low during this period. At site O-10 the concentration near the bottom was less than 0.5 mg/l in August 1975. At site O-13 above Rodman Dam the concentration of dissolved oxygen varied from more than 6.0 mg/l near the surface to less than 2.0 mg/l at a depth of 20 feet in August.

During daylight hours the aquatic plants in Lake Ocklawaha produce through photosynthesis large quantities of oxygen resulting in oxygen supersaturation. During the hours of darkness and periods of cloud cover, these plants, along with associated organisms, utilize oxygen and can greatly reduce oxygen concentration in the water. In August 1971, dissolved oxygen measurements made by the Florida Game and Fresh Water Fish Commission indicated that dissolved oxygen was essentially exhausted from dense weed beds by sundown (Holcomb and others, 1973). Additional studies by the Florida Game and Fresh Water Fish Commission in August 1972 indicated that concentrations of dissolved oxygen in dense weed beds dropped from 16 mg/l (almost 200 percent saturation) in the late afternoon to 0.0 mg/l at sunset. These studies also indicated that dissolved oxygen concentration in weed beds sometimes exceeded 21 mg/l (about 300 percent saturation) during the middle of the day. During the present study a dissolved oxygen concentration of 17 mg/l was measured in a dense weed bed near site O-10 on August 14, 1975. The dissolved oxygen studies conducted in Lake Ocklawaha by Florida Game and Fresh Water Fish Commission did not include open-water sites but were





EXPLANATION

- - - - - - TEMPERATURE
——— DISSOLVED OXYGEN
(DAYTIME MEASUREMENTS)

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT

WATER QUALITY

PROFILES OF TEMPERATURE AND DISSOLVED OXYGEN IN LAKE OCKLAWAHA

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W.Q. 9

primarily concerned with changes in the concentration of dissolved oxygen in the dense weed beds.

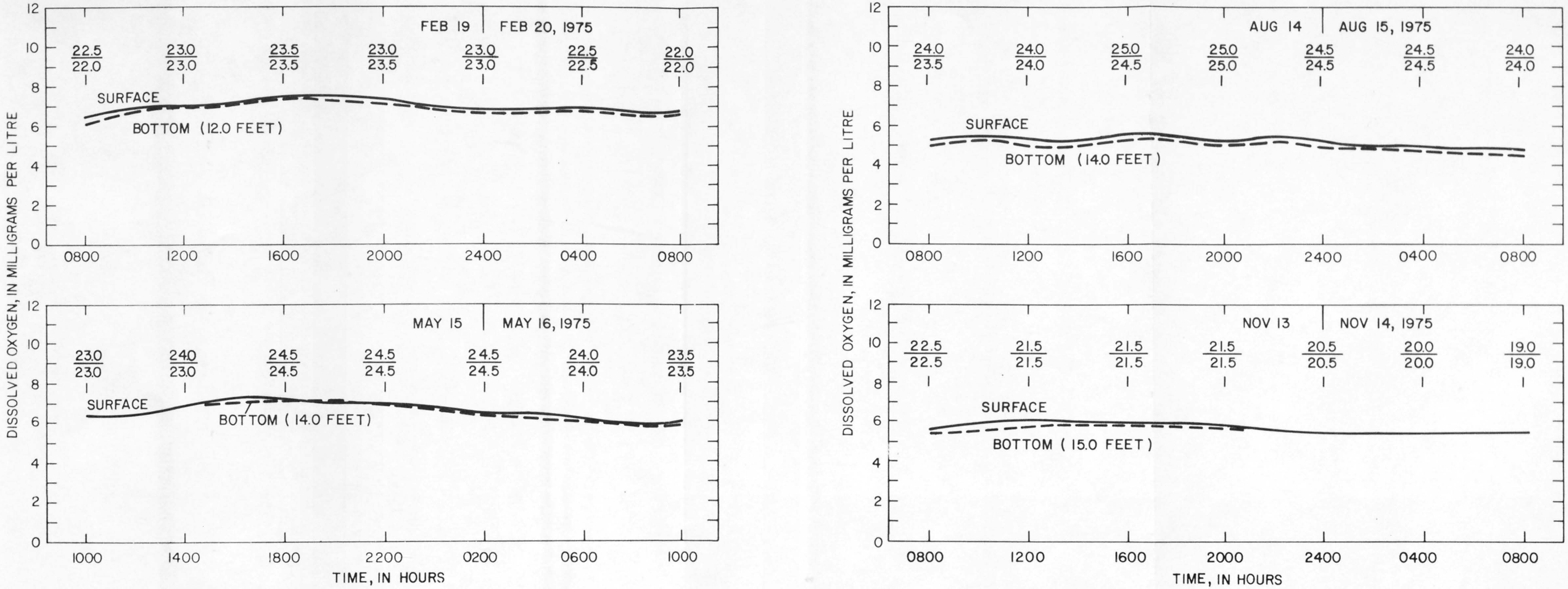
Dissolved oxygen concentrations were measured over a 24-hour period at site 0-10 in an open-water part of Lake Ocklawaha in February, May, August and November 1975. This site is in the canal cut in the widest part of the lake. Although aquatic weeds are present in the lake on either side of the canal, they are absent at site 0-10. For purposes of comparison, diel variations in dissolved oxygen concentrations were also measured in February, May, August, and November 1975, at site 0-6. This site is more representative of natural stream conditions and was free of the aquatic weeds found in the lake. Graphs of the dissolved oxygen diel variations at site 0-6 and 0-10 are shown in figures W.Q. 10 and W.Q. 11.

Figure W.Q. 10 shows that dissolved oxygen concentrations were relatively high at site 0-6 and that there was little variation in the dissolved oxygen concentration over the 24-hour period or throughout the water column. However, the concentrations of dissolved oxygen did vary slightly during the year. The minimum concentrations of slightly less than 6.0 mg/l occurred in August. Concentrations were 6.0 mg/l or slightly higher in February, May, and November 1975.

Dissolved oxygen concentrations at site 0-10 in the lake varied greatly during the 24-hour periods (fig. W.Q. 11). Diel variations in dissolved oxygen concentrations at the surface ranged from about 3 mg/l in February to more than 6 mg/l in August. Daily concentrations in August ranged from over 6.0 mg/l near midday to near zero in the early morning. In February the dissolved oxygen concentrations were above 5.0 mg/l near the bottom, but concentrations near the bottom were less than 4.0 mg/l in May and near 0.0 mg/l in August.

Specific Conductance

Summaries of specific conductance data at the 10 sites in the Oklawaha River for 1968-74 are shown in figure W.Q. 12. The specific conductance of surface waters in the basin ranged from less than 60 to more than 700 micromhos/cm. Specific conductance of the Oklawaha River increases substantially at the point where Silver Springs discharges into the river. Below Silver Springs the average specific conductance remained relatively high, increasing slightly in a downstream direction. The high specific conductance at site 0-15 is possibly due to seepage of ground water with comparatively high dissolved solids concentration into the lower river during periods when the discharge at Rodman Dam is low. Also, during periods of low flow below Rodman Dam, backwater from the highly mineralized St. Johns River may extend up the Oklawaha River to site 0-15. The maximum specific conductance at this site occurred in 1968 when Lake Ocklawaha was being filled and little water was being released through the dam. The average and minimum specific conductance



EXPLANATION

(14.0 FEET)
DEPTH AT WHICH BOTTOM MEASUREMENT WAS MADE

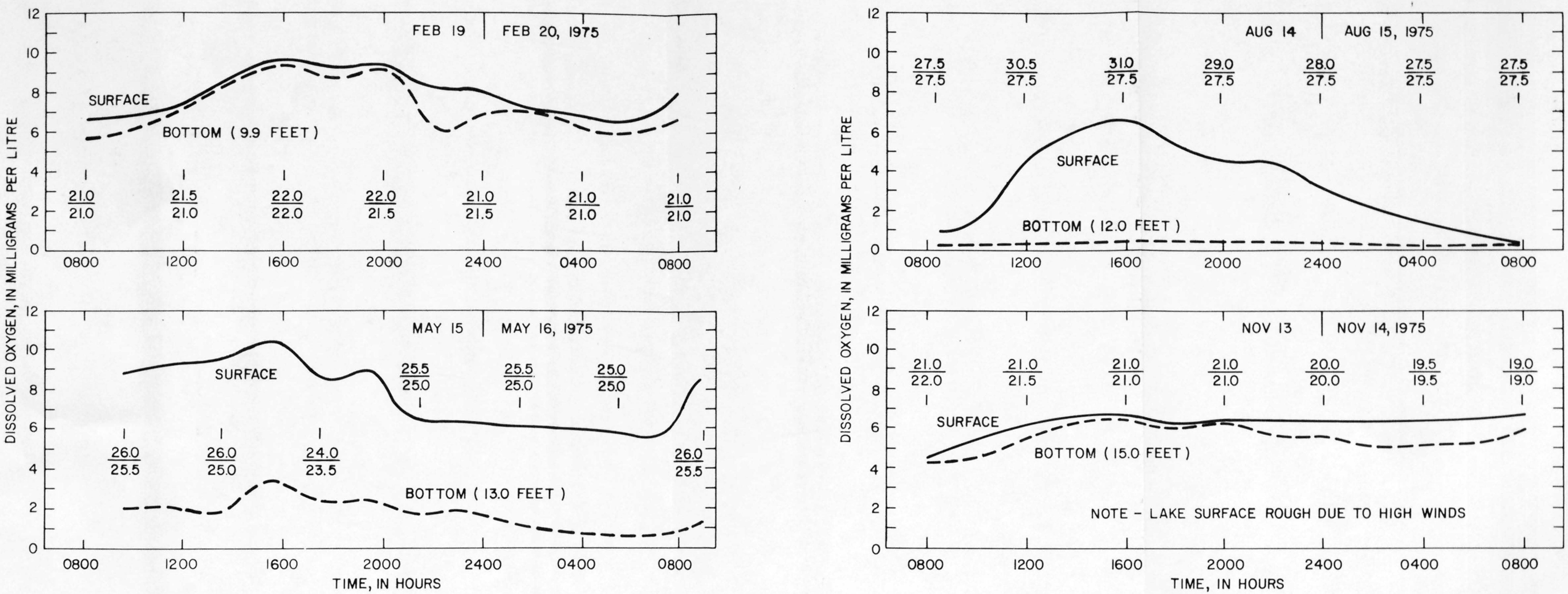
22.5 - SURFACE TEMPERATURE
22.0 - BOTTOM TEMPERATURE
IN DEGREES CELSIUS

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

DIEL VARIATIONS IN DISSOLVED OXYGEN IN LAKE OCKLAWAHA (SITE O-6)

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 — FIGURE W.Q. 10



EXPLANATION

(9.9 FEET)
DEPTH AT WHICH BOTTOM MEASUREMENT WAS MADE

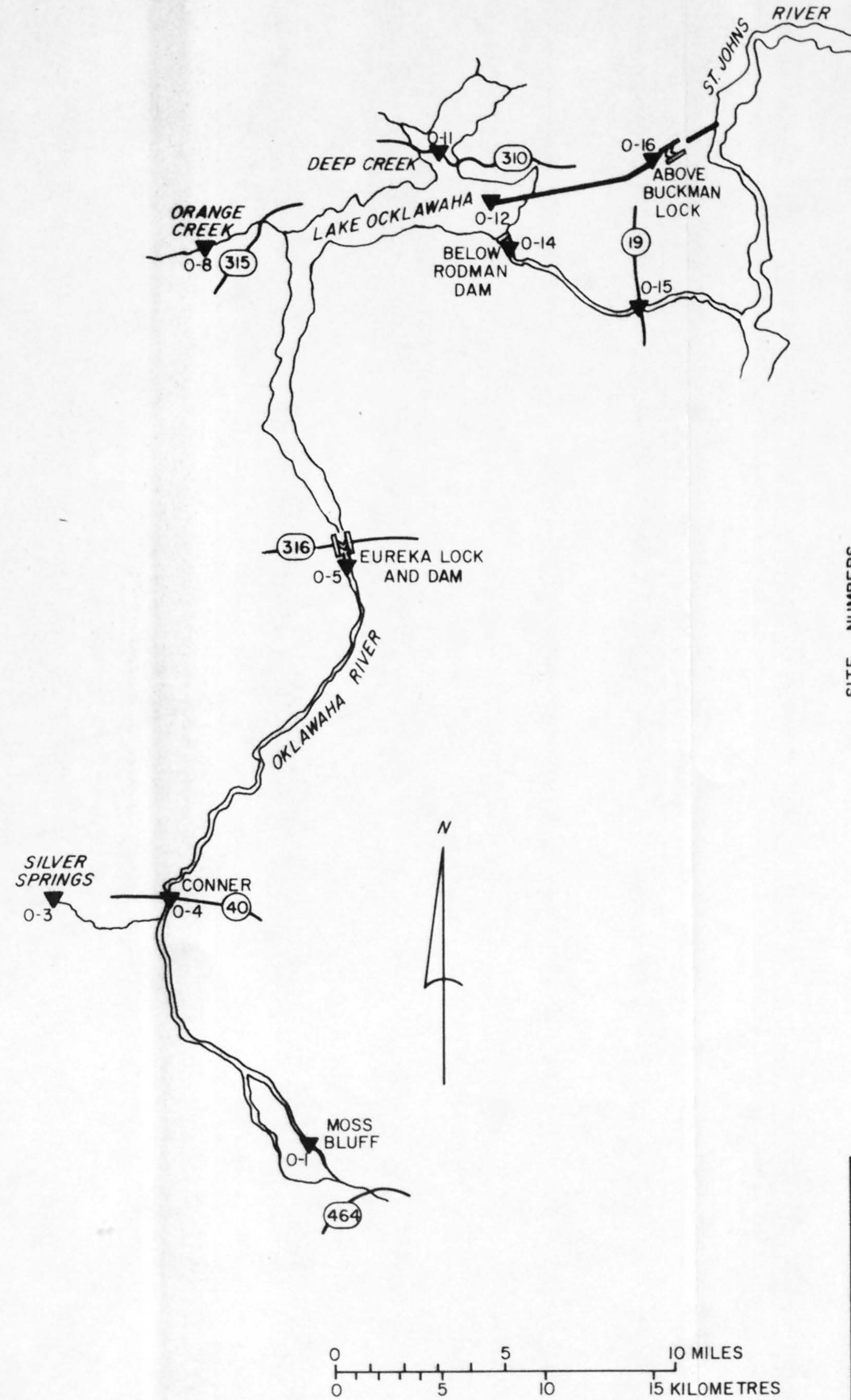
25.5 - SURFACE TEMPERATURE
25.0 - BOTTOM TEMPERATURE
IN DEGREES CELSIUS

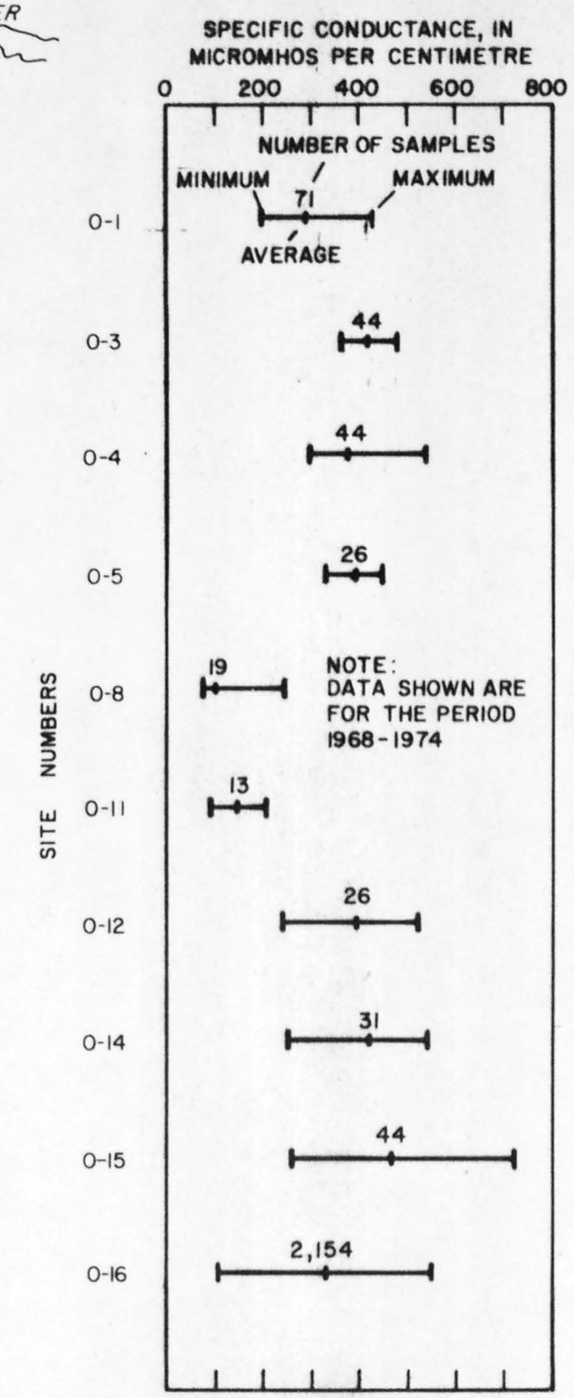
CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

DIEL VARIATIONS IN DISSOLVED OXYGEN
IN LAKE OCKLAWAHA (SITE O-10)

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W.Q. 11





CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT

WATER QUALITY

MAXIMUM, MINIMUM AND AVERAGE SPECIFIC CONDUCTANCE AT SITES IN THE OKLAWAHA RIVER BASIN

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 12

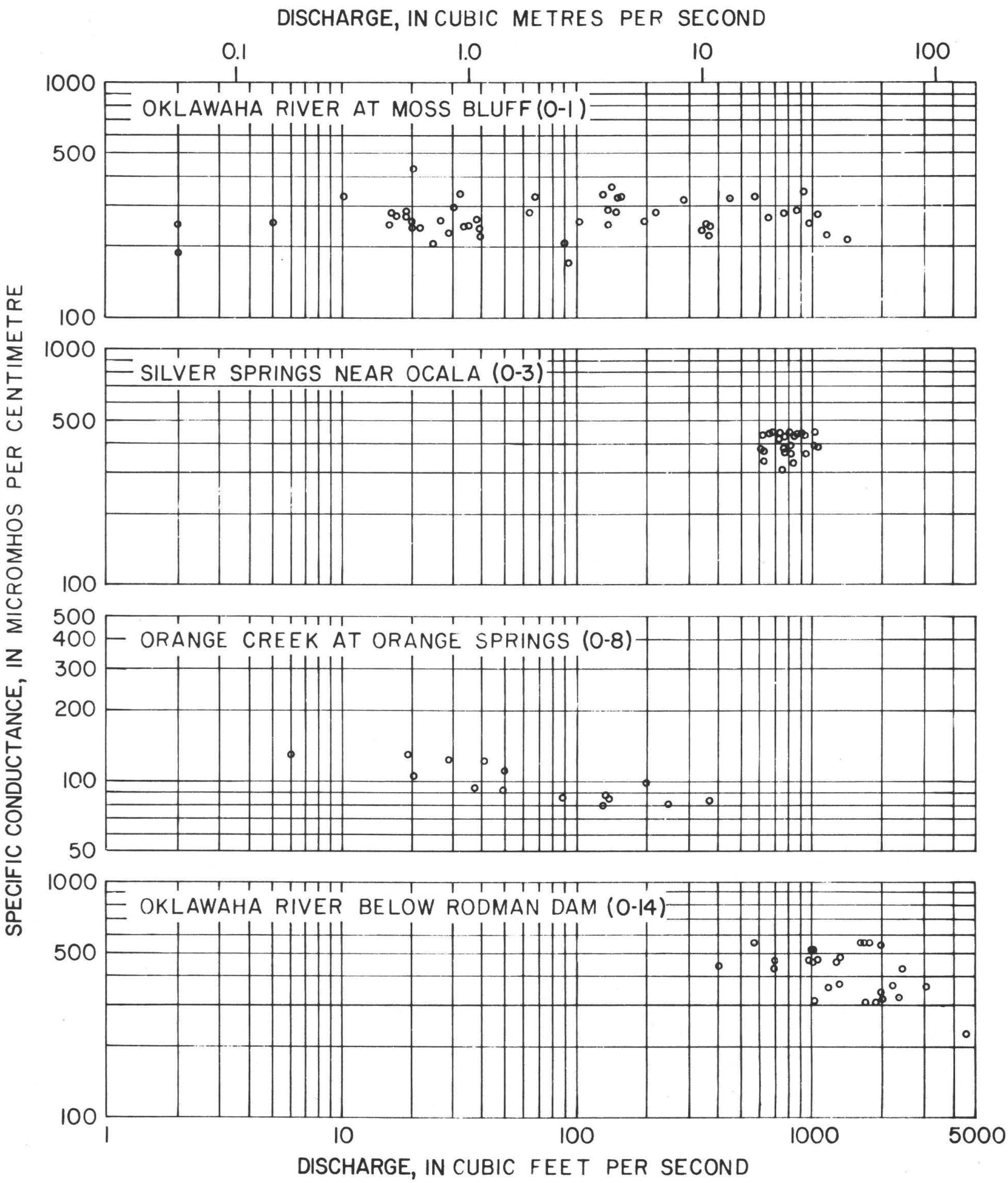
at site 0-16 is less than that in Lake Ocklawaha and suggests that surface runoff low in mineral concentration is entering the canal between the lake and Buckman Lock. Deep Creek and Orange Creek contain the least mineralized water.

The specific conductance of surface waters in the Oklawaha River basin depends largely upon the ratio of ground water inflow to surface runoff. Ground water generally is more highly mineralized than surface runoff. In many hydrologic situations this results in an inverse relation between the specific conductance of surface water and discharge (fig. W.Q. 13). The inverse relation between specific conductance and discharge is evident in the graph for Orange Creek. The scatter at the sites at Moss Bluff (0-1) and below Rodman Dam (0-14) is due to the impoundment and regulation of flow at the Moss Bluff structure and at the dam. High discharge below these structures is often due to water release practices and not to high surface runoff.

Selected Chemical and Bacteriological Characteristics

Summaries of selected chemical and bacteriological characteristics in surface waters of the Oklawaha River basin are given in table 6. Surface waters in the basin contained an average of 230 mg/l dissolved solids and had an average calcium carbonate hardness of 150 mg/l. Both the average dissolved solids concentration and hardness were greater than that of ground water from most Floridan aquifer wells sampled because of the influence of Silver Springs on the quality of the lower Oklawaha River. The dissolved solids concentration and hardness of Silver Springs water are appreciably higher than of water from most of the wells sampled because some of the flow of Silver Springs is from a greater depth in the aquifer than that penetrated by most of the wells. Dissolved solids concentrations and hardness of the Oklawaha River above Silver Springs, Deep Creek and Orange Creek are generally less than that of water from most Floridan aquifer wells.

Calcium and bicarbonate ions make up the bulk of the dissolved solids in most surface waters but the data in table 6 indicate that some waters contained appreciable concentrations of magnesium, sodium, sulfate and chloride ions. The chemical quality of water at seven sites in the basin is shown by Stiff diagrams in figure W.Q. 14. This figure shows that the quality of Silver Springs discharge was the dominant influence on the quality of the lower Oklawaha River during periods of low flow. A comparison of the diagrams in figure W.Q. 14 indicates a slight increase in the concentration of chloride and sulfate downstream from Silver Springs. These increases are due to the seepage of ground water high in chloride and sulfate along the lower reaches of the Oklawaha River. The increase in chloride concentrations along the lower part of the river was also observed during the pre-impoundment studies, by the Federal Water Pollution Control Administration (1967). However,



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

DISCHARGE-SPECIFIC CONDUCTANCE RELATION
OKLAWAHA RIVER BASIN

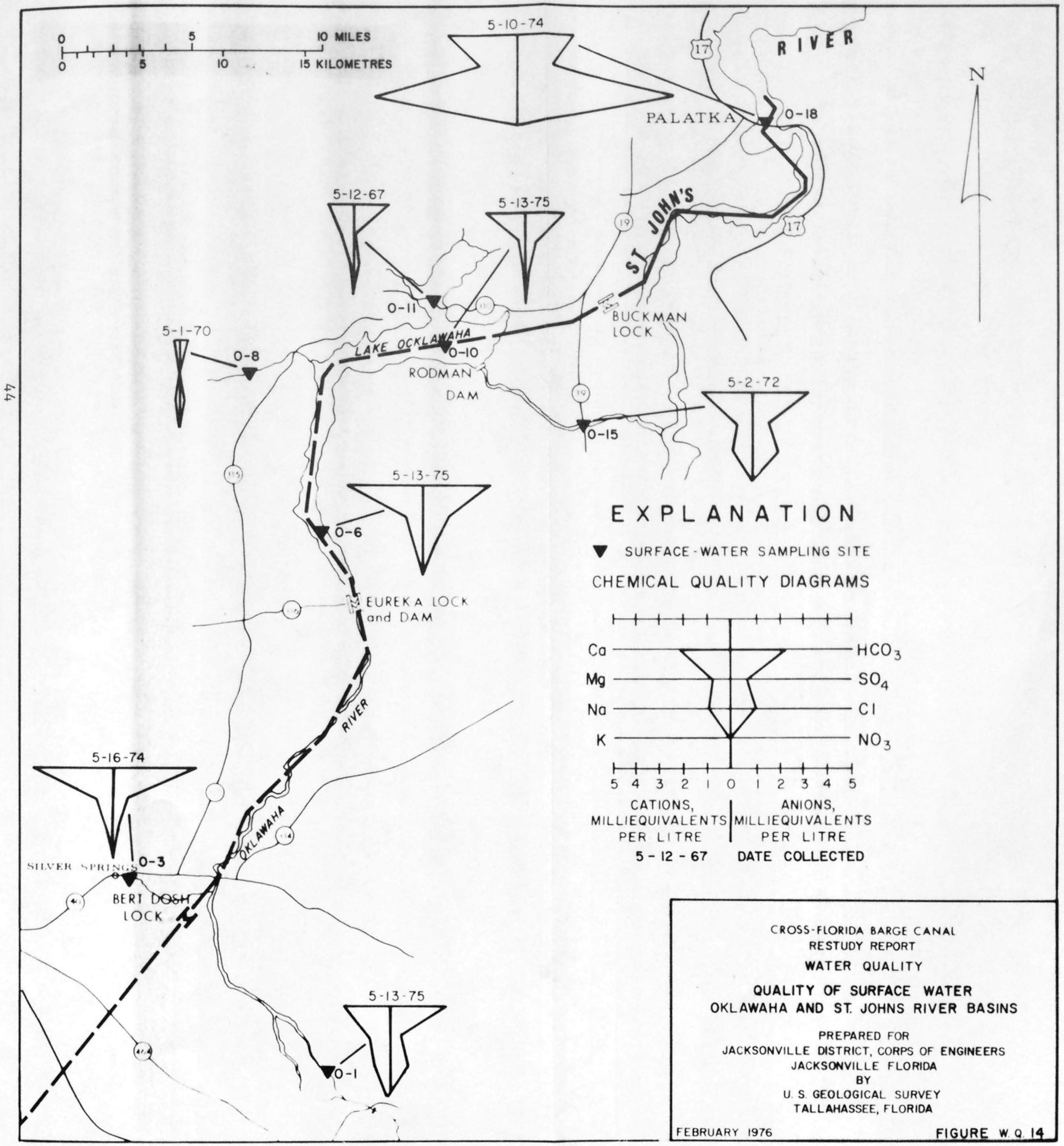
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 **FIGURE W Q. 13**

Table 6.--Summary of chemical and bacteriological characteristics in surface waters of the Oklawaha River basin. (For period of record and sampling frequency see table 1.)

(Results in milligrams per litre except as indicated)

Constituent or property	Number of samples	Max.	Min.	Mean
Major cations				
Calcium	154	76	5	42
Magnesium	154	96	.2	12
Sodium	151	83	2.9	18
Potassium	151	27	.1	2.3
Major anions				
Bicarbonate	250	222	18	130
Carbonate	129	54	0	0
Chloride	499	140	4.0	25
Sulfate	151	110	.4	30
Fluoride	149	4.0	.0	.3
Alkalinity as $CaCO_3$	251	182	15	100
Hardness as $CaCO_3$				
Total	503	400	19	150
Noncarbonate	248	140	0	41
Dissolved solids				
Residue at 180°C	128	476	49	230
Total organic carbon	287	134	0	12
Coliform bacteria (colonies per 100 ml)				
Total	322	82,000	0	1500
Fecal	92	820	0	65



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

QUALITY OF SURFACE WATER
OKLAWAHA AND ST. JOHNS RIVER BASINS

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976

FIGURE W.Q. 14

chloride and sulfate concentrations in the lower Oklawaha River and in Lake Ocklawaha are well below levels considered harmful for fish and wildlife.

The average concentration of total coliform bacteria in surface waters in the basin (1,500 colonies/100 ml) exceeds the standards of 1,000 col/100 ml established by the Florida Pollution Control Board (1973) for waters used for body contact recreational activities. However, this average is heavily weighted by some very high concentrations observed at Moss Bluff and in the Barge Canal above Buckman Lock. Concentrations of total coliform bacteria have been as high as 82,000 colonies/100 ml at Moss Bluff and 44,000 colonies/100 ml above Buckman Lock. Concentrations of coliform bacteria in Silver Springs and in the Oklawaha River downstream from Silver Springs generally are well below the limits established for waters used for recreational activities.

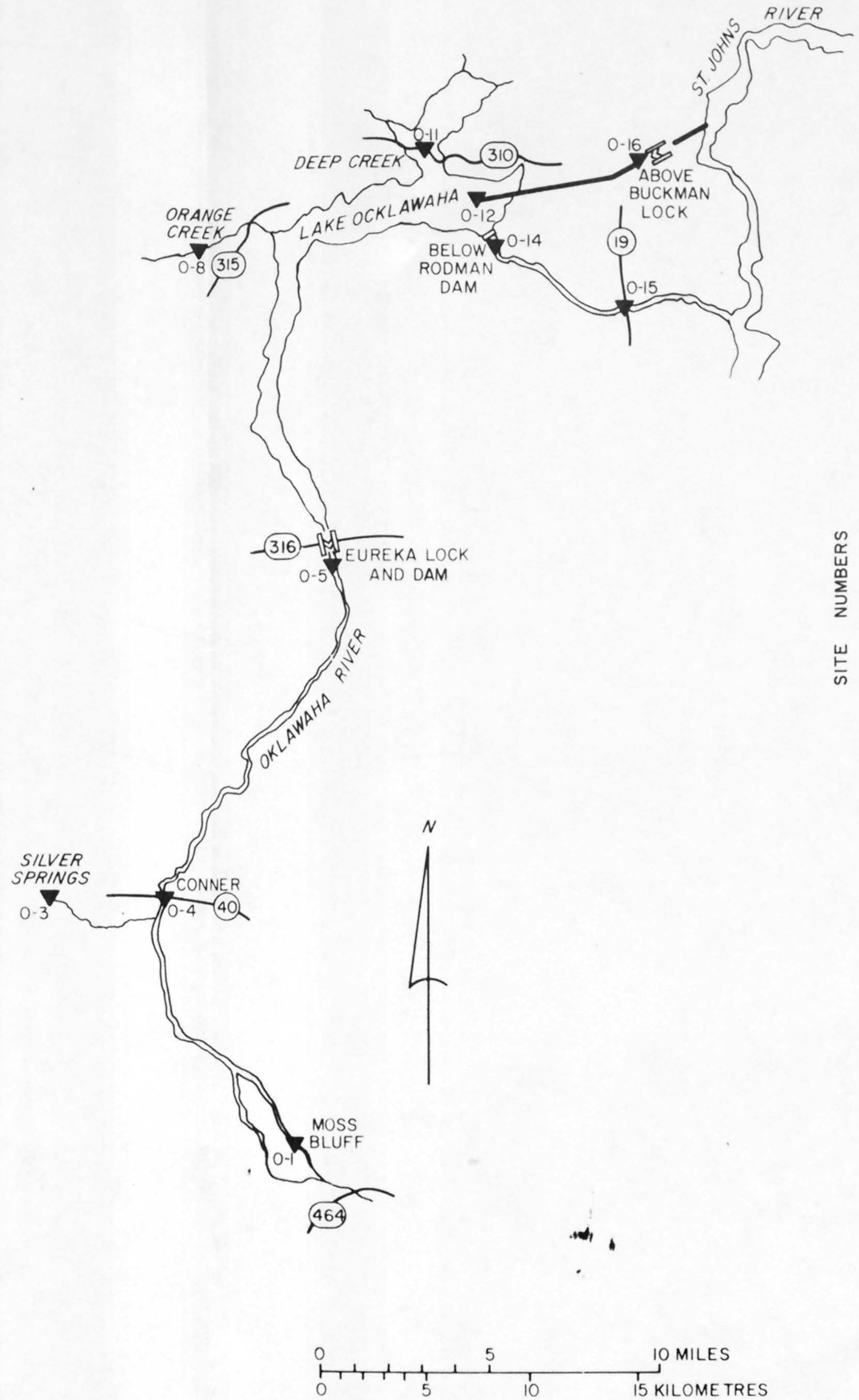
Nitrogen and Phosphorus

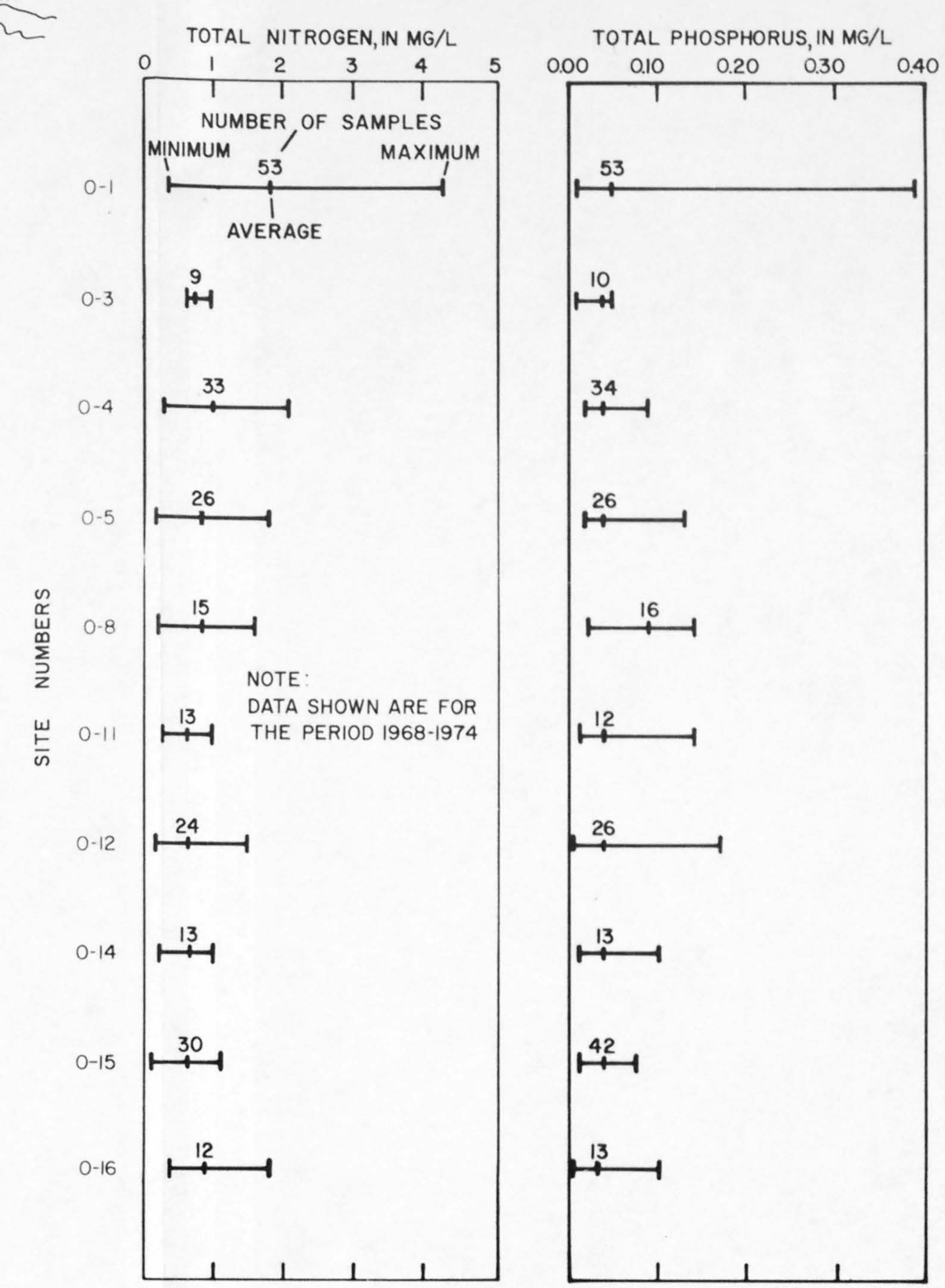
A summary of nutrient data for selected sites in the Oklawaha River basin is given in table 7. Total nitrogen and phosphorus concentrations (most samples were not filtered) in the river basin averaged 0.93 mg/l and 0.05 mg/l respectively, but occasionally concentrations exceeded 4.0 mg/l nitrogen and approached 0.60 mg/l phosphorus (table 7). About 75 percent of the average total nitorgen in surface waters is in the organic form and about 20 percent of the total nitrogen is nitrate. Approximately 80 percent of the average total phosphorus concentration is soluble orthophosphate.

Summaries of nitrogen and phosphorus concentrations for 1968-74 are shown at ten stations in the Oklawaha River basin in figure W.Q. 15. The largest range in both nitrogen and phosphorus concentrations occurred at the Moss Bluff site. The average concentration of nitrogen at the Moss Bluff site was almost twice that at any other site. The average concentration of nitrogen decreased downstream except above Buckman Lock. The average concentration at site 0-15 near the mouth of the Oklawaha River was 0.63 mg/l compared to average concentrations of 1.00 mg/l at Conner (site 0-4) and 1.80 mg/l at Moss Bluff (Site 0-1). In the reach between Eureka (site 0-5) and Rodman Dam, average concentrations of nitrogen decreased from 0.89 mg/l to 0.62 mg/l. Reduction in total nitrogen concentration probably was largely the result of the uptake of nitrate and other forms of inorganic nitrogen by aquatic plants in Lake Ocklawaha. The fact that the reduction in inorganic nitrogen was much greater than the increase in organic nitrogen suggests that uptake was primarily by rooted aquatic plants rather than by phytoplankton. During 1975 the average concentration of nitrate was 0.38 mg/l at Eureka (site 0-5) decreasing to 0.02 mg/l at Rodman Dam (site 0-14). The average decrease in total inorganic nitrogen concentration between Eureka and Rodman Dam

Table 7.--Summary of nitrogen and phosphorus analyses of surface waters in the Oklawaha River basin. (For period of record and sampling frequency see table 1.)
(Results in milligrams per litre)

Constituent	Number of samples	Max.	Min.	Mean
Nitrate as N	501	4.3	0.00	0.18
Nitrite as N	427	.27	.00	.01
Ammonia as N	387	1.4	.00	.06
Organic nitrogen as N	396	4.0	.00	.71
Total nitrogen as N	366	4.3	.06	.93
Orthophosphorus as P	437	.65	.00	.04
Total phosphorus as P	419	.57	.00	.05





CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT

WATER QUALITY

MAXIMUM, MINIMUM AND AVERAGE CONCENTRATIONS OF NITROGEN AND PHOSPHORUS AT SITES IN THE OKLAWAHA RIVER BASIN

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U S GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W Q 15

was 0.34 mg/l. The concentration of total organic nitrogen increased downstream averaging 0.35 mg/l at Eureka and 0.46 mg/l at Rodman Dam. Pre-impoundment studies by the Federal Water Pollution Control Administration (1967) indicate that in 1967 the downstream decrease in the concentration of nitrogen was less than during recent years since impoundment.

Concentrations of nitrogen in the Oklawaha River basin may vary as much as an order of magnitude in a year. Although concentrations of nitrogen tend to be higher during the rainy season (June-September) there is considerable variability among the years. There is, however, somewhat of a seasonal pattern in the way that the relative concentrations of inorganic and organic nitrogen fluctuate. Nitrate is most abundant in the winter months probably because its assimilation by plants is low. During the summer when plant productivity increases, nitrate is utilized rapidly and concentration in the water decreases. In addition, the organic nitrogen concentrations are often higher in the summer because much of the available nitrogen has been assimilated into organic tissue. In Lake Ocklawaha, where aquatic plants are particularly abundant, the uptake of nitrate is so great that it is virtually absent from the water during much of the summer. During this period ammonia is the most common form of inorganic nitrogen in and downstream from the lake.

The maximum concentration of phosphorus observed in the Oklawaha River basin during 1968-74 was 0.39 mg/l at the Moss Bluff site. This was more than twice that of any other sample (fig. W. Q. 15). However, the average concentration of phosphorus at Moss Bluff was less than that in Orange Creek (O-8), which averaged 0.09 mg/l. Except in Orange Creek, average phosphorus concentrations ranged from 0.03 to 0.05 mg/l. No significant trends in concentration were evident downstream through Lake Ocklawaha (1968-74), but in 1975 a small decrease in average concentration of phosphorus was observed between Eureka and Rodman Dam. A similar decrease in phosphorus concentration was observed in the river before impoundment (Federal Water Pollution Control Administration, 1967).

In Lake Ocklawaha and in the river below the lake, phosphorus concentrations were generally very low in May and increased during the rainy season (June-September). The uptake of phosphorus by aquatic plants probably is the reason for low concentrations in May, the beginning of the growing season. Higher concentrations of phosphorus in the lake during the rainy season are probably the result of the relatively high concentrations of phosphorus in bulk precipitation. Apart from the overall increase in phosphorus concentrations in the rainy season at some sites, no other patterns of variations were evident.

Seasonal Profiles of Selected Characteristics

Difference in concentrations of selected physical, chemical, and biological variables with depth were examined in May and August 1975 at sites 0-6, 0-9, and 0-10 (Table 8; see Table 1 for site locations). Differences in the concentrations between surface and bottom samples were small, with several exceptions. Some variability between surface and bottom waters were recorded for total organic carbon in August (sites 0-6; 0-9), specific conductance in May (site 0-10), and dissolved oxygen in August (site 0-10). Concentrations of dissolved oxygen were 6.0 mg/l or more except at site 0-10 in August when concentrations ranged from 1.5 mg/l at the surface to virtually zero near the bottom. Associated with the low dissolved oxygen concentrations at site 0-10 in August were relatively high concentrations of ammonia (0.11 and 0.36 mg/l at the surface and bottom respectively) and phosphorus (0.03 and 0.10 mg/l at the surface and bottom). Ammonia is a common form of nitrogen under anaerobic conditions. The relatively low concentrations of dissolved oxygen indicate a high rate of bacterial decomposition of organic material at this time of year.

Coliform bacteria were measured in relatively low numbers ranging from 0 to 540 colonies per 100 ml. Numbers of fecal coliform were greatest at site 0-6 where they ranged from 0 to 35 colonies per 100 ml.

Trace Elements

A summary of analyses of selected trace elements in the surface waters in the Oklawaha River basin is given in table 9. The summary indicates that the average concentrations of most of these trace elements are generally low, but some variability does exist. The trace elements occurring in highest concentrations were aluminum, boron, iron, strontium, and zinc. All occur naturally in the silicate and carbonate rocks in the basin.

Aluminum and iron are only slightly soluble and occur primarily in particulate or colloidal form as is evident from a comparison of total and dissolved concentrations in table 9. In some surface waters in the basin iron concentrations are in excess of a few hundred micrograms per litre; a result of iron being complexed with organic materials.

Boron is essential to plant growth, but is toxic to many plants in high concentrations. Although citrus crops are especially sensitive to boron, concentrations of boron reported in surface waters in the Oklawaha River basin are much less than those reported to be harmful to citrus (U.S. Salinity Laboratory Staff, 1954).

Table 8.--Quality of surface and bottom waters in Lake Ocklawaha, Florida.

Date	Depth below water surface (ft)	Temperature (C)	Dissolved oxygen (mg/1)	Specific Conductance (umhos)	Turbidity (JTU)	Total organic carbon (mg/1)	Biochemical oxygen demand (mg/1)	Total coliform (colonies/100 ml)	Fecal coliform (colonies/100 ml)	Suspended sediment (mg/1)	Total iron (ug/1)	Total manganese (ug/1)	Nutrients (mg/1) Nitrate (NO_3-N)	Nitrite (NO_2-N)	Ammonia (NH_3-N)	Organic nitrogen (N)	Total nitrogen (N)	Ortho-phosphorus (P)	Total phosphorus (P)
Lake Ocklawaha (0-6)																			
5-13-75	1	23.5	6.6	422	1	2	.8	280	5	2	60	10	0.31	0.00	0.01	0.10	0.42	0.03	0.03
5-13-75	9	23.5	6.6	428	4	1	1.1	300	0	3	50	10	.37	.01	.02	.12	.52	.03	.06
8-12-75	1	24.5	7.3	421	3	5	.7	340	35	3	280	10	.32	.01	.05	.29	.67	.03	.04
8-12-75	13	24.5	7.3	421	3	11	.7	540	15	3	220	10	.32	.01	.04	.33	.70	.03	.04
Lake Ocklawaha (0-9)																			
5-13-75	1	26.5	9.4	491	1	5	1.5	0	0	0	60	10	.01	.00	.00	.28	.29	.01	.01
5-13-75	9	26.0	7.8	520	1	7	1.0	62	0	3	30	10	.01	.00	.01	.26	.28	.01	.02
8-12-75	1	27.0	8.0	418	3	15	.9	38	0	1	250	20	.04	.01	.06	.62	.73	.02	.02
8-12-75	17	26.0	6.0	423	2	9	.7	-	-	0	250	10	.07	.01	.07	.59	.74	.02	.02
Lake Ocklawaha (0-10)																			
5-13-75	1	27.5	9.7	483	1	3	1.1	0	0	1	40	10	.01	.00	.00	.35	.36	.00	.01
5-13-75	9	26.0	8.6	555	1	6	1.0	12	0	4	40	10	.01	.00	.00	.32	.33	.00	.02
8-12-75	1	28.0	1.5	398	3	9	2.1	25	0	1	200	10	.01	.01	.11	.72	.85	.01	.03
8-12-75	13	26.5	.1	391	-	10	-	0	0	-	-	20	.01	.01	.36	-	-	.07	.10

Table 9.--Summary of trace element analyses of surface waters in the Oklawaha River basin. (For period of record and sampling frequency see table 1.)
(Results in micrograms per litre)

Constituent	Number of samples	Max.	Min.	Mean
Aluminum, total	22	3200	0	250
Aluminum, dissolved	2	80	50	60
Arsenic, total	24	20	0	4
Arsenic, dissolved	13	20	0	5
Boron, total	3	70	30	40
Cadmium, total	24	3	0	0
Cadmium, dissolved	6	0	0	0
Chromium, total	10	10	0	4
Copper, total	9	10	0	0
Copper, dissolved	28	14	0	4
Iron, total	37	1400	0	170
Iron, dissolved	95	410	0	60
Lead, total	24	15	0	10
Lead, dissolved	33	12	0	4
Manganese, total	34	50	0	15
Manganese, dissolved	42	50	0	8
Mercury, total	25	.8	.0	.1
Nickel, total	15	20	0	0
Strontium, dissolved	57	800	0	390
Zinc, total	9	40	0	20
Zinc, dissolved	28	280	0	40

Strontium and, to a lesser extent, zinc, occur in carbonate rocks in the basin. The average concentration of strontium in surface waters in the Oklawaha River basin is higher than the median concentration of 0.06 mg/l reported in major North American rivers by Durum and Haffty (1963). High concentrations of strontium in surface waters in the basin are due to the high concentrations of strontium in Floridan aquifer water. The average concentrations of zinc in the surface waters in the area were also slightly higher than might be expected, and are due to higher concentration of zinc in some of the ground water inflow. The maximum concentration of zinc, however, was well below the limit recommended by the U.S. Public Health Service (1962) for drinking water. Recommented limits of concentrations for several trace elements are given in table 22 in a later section of this report.

Pesticide Compounds

From September 1968 through May 1971, 22 water samples were collected from 10 surface water sites in the basin and analyzed for eight chlorinated hydrocarbon insecticides, including the DDT group of insecticides (table 10). Results show that the mean concentration of all eight insecticides in the 22 samples was 0.00 ug/l. Eight of the 22 samples contained small amounts of one or more of these insecticides, but the highest concentration of any one insecticide was only 0.02 ug/l.

The highest combined concentration of insecticides in any one sample was 0.05 ug/l which was found in a sample collected above Buckman Lock in November 1968. Combined concentrations of 0.02 ug/l were found in samples collected from the Barge Canal above Buckman Lock and from the Oklawaha River at Moss Bluff and at highway 19 downstream from Rodman Dam. Four samples collected from sites at Moss Bluff, Conner, Lake Ocklawaha and Silver Springs had insecticide concentrations of 0.01 ug/l or less. The insecticide DDT was found in 6 of the 22 samples analyzed and was identified more often than any other insecticide.

Herbicides are generally more soluble than insecticides and are more likely to occur in surface water. Very little data are available on the occurrence of herbicides in surface water in the Oklawaha River basin, but the herbicides 2,4-D, 2,4,5-T and Silvex were absent from the three samples collected from Lake Ocklawaha and the Oklawaha River at Eureka and Rodman Dam in September 1970 (table 10). Herbicides are like insecticides in that they are adsorbed onto sediment, but in view of their greater solubility and the use of herbicides to control aquatic weeds, detectable concentrations of herbicides in some surface waters in the area may be expected at times.

Table 10.--Summary of pesticide analyses in surface waters of the Oklawaha River basin. (For period of record and sampling frequency see table 1.) (Results in micrograms per litre)

Constituent	Number of samples	Max.	Min.	Mean
Aldrin	22	trace	0.00	0.00
Lindane	22	0.00	.00	.00
DDD	22	.01	.00	.00
DDE	22	.02	.00	.00
DDT	22	.02	.00	.00
Dieldrin	22	.00	.00	.00
Endrin	22	.00	.00	.00
Heptachlor	22	.00	.00	.00
2,4-D	3	.00	.00	.00
2,4,5-T	3	.00	.00	.00
Silvex	3	.00	.00	.00

Bottom Sediment

Bottom materials in the lakes and streams in the Oklawaha River basin can act as a trap for pesticides, metals and many plant nutrients. Although the incorporation of these materials into the lake bottom removes them at least temporarily from the water mass, they may be recycled into the water by biochemical regeneration and by the resuspension of bottom sediments.

Samples of bottom material were collected for selected analyses at three sites in Lake Ocklawaha during February 1975 (table 11). The data indicate that bottom materials at the narrow headwaters site 0-6, contain very low concentration of carbon, nitrogen, phosphorus, and iron. Velocities at site 0-6 are much higher than near the discharge end of the reservoir and bottom materials consist primarily of coarse sand. By comparison, bottom materials at sites 0-9 and 0-10 contain very high concentrations of these elements. Concentrations of organic carbon, total nitrogen and total iron at sites 0-9 and 0-10 were as much as 100 times those at site 0-6. Phosphorus concentrations at site 0-9 and 0-10 were about 28 times that at site 0-6. Interestingly, differences in the concentrations of manganese at the three sites were small. The higher biochemical oxygen demand for bottom materials at sites 0-9 and 0-10 indicates that these organically rich sediments would exert a large oxygen demand if they were resuspended in the water.

Concentrations of pesticides and related organic chemicals in bottom materials collected at sites 0-6, 0-9, and 0-10 are given in table 12. Although no chlorinated hydrocarbons were detected in water samples collected at these sites, bottom materials at sites 0-9 and 0-10 contained small concentrations of one or more insecticides. The insecticide DDD was found in concentrations of 5.8 ug/kg at site 0-10. At site 0-10, small concentrations of the insecticide DDE were also found. No chlorinated hydrocarbons were detected in the coarser materials collected at site 0-6. The three herbicides 2,4-D; 2,4,5-T; and Silvex were not detected in the three samples.

St. Johns River Basin below Oklawaha River

Water in the St. Johns River downstream from Palatka is a sodium chloride water and its dissolved solids concentration is greater than that of surface waters in the Oklawaha River basin (fig. W.Q. 14). Although the St. Johns River at Palatka is about 78 miles (126 km) upstream from the mouth, the stage at Palatka is affected by tides. However, salt-water intrusion rarely extends this far upstream. The high concentrations of sodium and chloride in the river at that site are due primarily to the inflow of saline ground water in the basin above the Oklawaha River (Kenner and Crooks, 1963, p.6). Although chloride concentrations as high as 400 mg/l have been observed at Palatka, an

Table 11.--Chemical characteristics of bottom materials in Lake Ocklawaha, Florida. (See fig. Q.W. 5 for site location.)

Local Number	Date	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Organic carbon (g/kg)	Total iron (ug/g)	Total manganese (ug/g)	Biochemical oxygen demand 5 day (mg/kg)
0-6	2-13-75	120	23	1	68	40	110
0-9	2-13-75	14,000	630	137	6,800	80	300
0-10	2-13-75	12,000	670	147	3,500	50	790

Table 12.--Concentrations of pesticides and related chlorinated hydrocarbon compounds in bottom materials in Lake Ocklawaha, Florida. (See fig. W.Q. 5 for site location.) (Results in micrograms per kilogram)

	Site 0-6	Site 0-9	Site 0-10
Date	2-13-75	2-13-75	2-13-75
Aldrin	.0	.0	.0
Lindane	.0	.0	.0
Chlordane	0	0	0
DDD	.0	2.6	5.8
DDE	.0	.0	.7
DDT	.0	.0	.0
Dieldrin	.0	.0	.0
Endrin	.0	.0	.0
Toxaphene	0	0	0
Heptachlor	.0	.0	.0
Heptachlor epoxide	.0	.0	.0
PCB	0	0	0
2,4-D	0	0	0
2,4,5-T	0	0	0
Silvex	0	0	0

analysis by Anderson and Goolsby (1973, p. 47) indicates that the maximum daily chloride concentration at that site exceeds 250 mg/l less than 7 percent of the time.

Summaries of physical, chemical, and biological characteristics of the St. Johns River at Palatka are given in table 13. Water in the river generally is a very hard, highly colored, sodium chloride water. The specific conductance averaged almost 1,000 micromhos/cm, twice the average specific conductance of the lower Oklawaha River and reached a maximum of 1,400 micromhos/cm. Dissolved solids concentration averaged about 600 mg/l and sometimes exceeded 880 mg/l. The average dissolved solids concentration in Lake Ocklawaha is less than 300 mg/l, and therefore is slightly less dense than water in the St. Johns River. At times when St. Johns River water is at the lower end of Buckman Lock, it is possible that some of this more dense water may be transported in the locking process to the upper end of the lock. The locked-up water may tend to migrate westward through the canal to Lake Ocklawaha. However, the effect, if any, of lock operation on the dissolved solids concentration of Lake Ocklawaha will probably be negligible, judging from continuous specific conductance measurements from above the lock since activation of the lock in 1968.

The St. Johns River is similar to the lower Oklawaha River in that it contains highly colored water that is low in turbidity and suspended sediment, and is slightly alkaline. Color averaged 85 units in the St. Johns River at Palatka as compared with an average color of 65 units in the lower Oklawaha River. Concentrations of suspended sediment averaged 10 mg/l and turbidity averaged 6 JTU in the St. Johns River at Palatka. Concentrations of dissolved oxygen in the St. Johns River at Palatka averaged 6.5 mg/l, but were occasionally less than 3.0 mg/l. The extremely low dissolved oxygen concentrations and wide variations in concentrations which occur in Lake Ocklawaha apparently do not occur in the St. Johns River at Palatka.

Average concentrations of nitrogen and phosphorus in the St. Johns River at Palatka exceeded those in the Oklawaha basin. The concentration of total nitrogen in the river ranged from 0.14 to 4.8 mg/l and averaged 1.3 mg/l as compared with an average of 0.93 mg/l for the Oklawaha River basin. The St. Johns River, on the average, contains more organic nitrogen, but less nitrate and ammonia nitrogen than does the Oklawaha River. The maximum concentration of nitrate at Palatka (0.54 mg/l) was only slightly higher than the average concentration in Silver Springs discharge (0.50 mg/l). The high concentrations of organic nitrogen and low concentrations of nitrate in the St. Johns River probably result from the assimilation of inorganic nitrogen by upstream phytoplankton.

Table 13.--Summary of physical, chemical and biological characteristics of the St. Johns River at Palatka, Florida. (For period of record and sampling frequency see table 1.)
(Results in milligrams per litre except as indicated)

Constituent or property	Number of samples	Max.	Min.	Mean
Temperature (°C)	37	30.0	12.0	24.5
Specific conductance (umhos at 25°C)	41	1400	510	990
Dissolved oxygen	34	9.3	2.7	6.5
pH	38	9.4	6.7	7.6[1]
Color	38	240	12	85
Turbidity	33	21	1	6
Secchi disk (in)	18	48	14	29
Major cations				
Calcium	32	78	30	50
Magnesium	32	28	10	18
Sodium	31	180	70	120
Potassium	31	8.8	3.1	4.6
Strontium	26	8.6	0	1.2
Major anions				
Bicarbonate	31	150	48	92
Carbonate	24	3	0	0
Chloride	38	400	2.5	216
Sulfate	32	114	36	67
Fluoride	31	.7	.2	.3
Nutrients				
Nitrate as N	38	.54	.00	.08
Nitrite as N	32	.10	.00	.01
Ammonia as N	32	.28	.00	.05
Organic nitrogen as N	32	4.6	.06	1.2
Total nitrogen as N	32	4.8	.14	1.3
Orthophosphorus as P	32	.15	.00	.05
Total phosphorus as P	32	.19	.02	.08
Alkalinity as $CaCO_3$	31	123	39	75
Hardness as $CaCO_3$				
Total	38	310	94	200
Noncarbonate	31	270	66	130
Dissolved solids (Residue at 180°C)	31	885	403	603
Suspended sediment	19	26	4	10
Biochemical oxygen Demand, 5 day	23	3.4	.6	1.7
Total organic carbon	20	52	8	18
Coliform bacteria (colonies per 100 ml)				
Total	29	87000	0	4000
Fecal	17	1200	0	120
Fecal Streptococcus	14	360	0	77

[1] Median pH

Total phosphorus concentrations in the St. Johns River at Palatka range from 0.02 to 0.19 mg/l and averaged 0.08 mg/l (table 13). This average is somewhat higher than the average concentration of phosphorus in the lower Oklawaha River, but the maximum concentration at Palatka is much less than maximum concentrations observed at some sites in the Oklawaha River basin.

The average BOD in the St. Johns River was slightly higher than that in the lower Oklawaha River. However, the maximum BOD at Palatka (3.4 mg/l) was much less than values observed in the Oklawaha River during dredging operations in the area above Moss Bluff.

Concentrations of total coliform bacteria in the St. Johns River averaged 4,000 colonies/100 ml, almost three times the average concentration in surface waters in the Oklawaha River basin. However, this average is heavily weighted by one very high concentration (87,000 colonies/100 ml). If this value is ignored the average concentration would be similar to that for the surface waters in the Oklawaha River basin. The St. Johns and some streams in the Oklawaha River basin contain high concentrations of total coliform bacteria at times. These concentrations sometimes ecxeed the criteria of 2,400 colonies per 100 ml established by the Florida Department of Pollution Control for waters used for body contact activities.

High concentrations of fecal coliform bacteria are more indicative of pollution by sewage effluent than are high concentrations of the total coliform bacteria. The average concentration of fecal coliform bacteria at Palatka was 120 colonies/100 ml, about twice the average concentration in lakes and streams in the Oklawaha River basin. The higher concentrations at Palatka may be the result of the inflow of sewage-treatment-plant effluent at several sites above Palatka.

A summary of trace elements, pesticides, and related organic chemicals in the St. Johns River at Palatka is given in table 14. Only a limited amount of data on the concentration of these consituents in the river are available but these indicate that the concentrations of most trace elements are low. The trace elements which occurred in highest concentrations were aluminum, iron, manganese and zinc. The mean concentration of iron in the St. Johns River at Palatka (231 ug/l) is slightly higher than that in surface waters in the Oklawaha River basin. However, the maximum concentration measured in the Okalawaha River at Moss Bluff (1400 ug/l) is several times the maximum concentration observed at Palatka (560 ug/l). Concentrations of manganese and zinc at Palatka averaged 16 and 19 ug/l, respectively, and are similar in magnitude to mean concentration in surface waters in the Oklawaha River basin. The mean concentration of aluminum was much lower in the St. Johns River at Palatka than in surface waters of the Oklawaha River basin; however, only three samples from the St. Johns River have been analyzed for aluminum.

Table 14.--Summary of trace elements, pesticides and related organic chemicals in the St. Johns River at Palatka. (For period of record and sampling frequency see table 1.) (Result in micrograms per litre)

Constituent or property	Number of samples	Max.	Min.	Mean
Trace elements (total recoverable)				
Arsenic	11	20	0	5
Aluminum	3	150	0	70
Cadmium	11	6	0	1
Chromium	7	20	0	7
Cobalt	9	5	0	1
Copper	9	10	0	4
Iron	11	560	90	231
Lead	11	26	1	7
Manganese	11	30	0	16
Mercury	13	.0	.2	.1
Nickel	3	2	0	1
Selenium	6	10	0	4
Zinc	9	50	0	19
Pesticides				
Aldrin	2	.00	.00	.00
DDD	2	.00	.00	.00
DDE	2	.00	.00	.00
DDT	2	.00	.00	.00
Dieldrin	2	.00	.00	.00
Endrin	2	.00	.00	.00
Heptachlor	2	.00	.00	.00
Lindane	2	.00	.00	.00
Phenols	4	1	0	0

Withlacoochee River Basin

The quality of water in the lower Withlacoochee River is mainly dependent upon ground-water inflow. Rainbow Springs, the second largest spring in Florida, contributes a large part of the lower Withlacoochee River flow during periods of low precipitation. Unlike the Oklawaha River, the Withlacoochee River upstream from Rainbow Springs inflow has a relatively high base flow of 112 ft^3/s (3.17 m^3/s) and an average discharge that exceeds the flow of the springs (Anderson and Faulkner, 1973) (fig. W.Q. 2). Thus, the discharge of Rainbow Springs has less impact on the quality of the lower Withlacoochee River than Silver Springs has on the quality of the Oklawaha River. In addition the discharge from Rainbow Springs has a lower dissolved solids concentration than Silver Springs and it is similar in both concentrations and type to the river water upstream.

Summaries of physical and related chemical characteristics of surface waters in the Withlacoochee River basin are given in table 15. Surface-water sites below Inglis Dam and Inglis Lock are affected by salt water from the Gulf and were not included in this summary. A comparison of tables 5 and 15 shows that surface waters in the Withlacoochee River basin have lower levels of specific conductance, color, turbidity, suspended sediment, and BOD than those in the Oklawaha River basin.

Color ranged from 0 in Rainbow Springs (W-5) to 360 units in the Withlacoochee River at Holder (W-2). Color averaged about 70 units at Holder and was generally highest during periods of high flow. Downstream from Rainbow Springs, which has an average color of less than 5 units, water in the river and in Lake Rousseau has an average color of less than 40 units.

The maximum turbidity was 27 JTU and the maximum suspended sediment concentration was 29 mg/1. Turbidity and suspended sediment averaged 2 JTU and 2 mg/1, respectively. Slightly higher concentrations occurred in the bypass channel at site W-14 where velocities are high.

Dissolved Oxygen

The average concentration of dissolved oxygen was higher and the average BOD lower in surface waters in the Withlacoochee River basin than in surface waters in the Oklawaha River basin. The BOD in the Withlacoochee ranged from 0 to 5.3 mg/1, but averaged only 0.8 mg/1 (table 15). The BOD values were generally higher at sites in and downstream from Lake Rousseau. Dissolved oxygen concentrations ranged from 0.4 mg/1 to a supersaturated 14.4 mg/1, with both extremes occurring in Lake Rousseau. The average concentration was 6.5 mg/1 (table 15).

Table 15 .--Summary of physical and related chemical characteristics in surface waters in the Withlacoochee River basin. (For period of record and sampling frequency see table 1.)

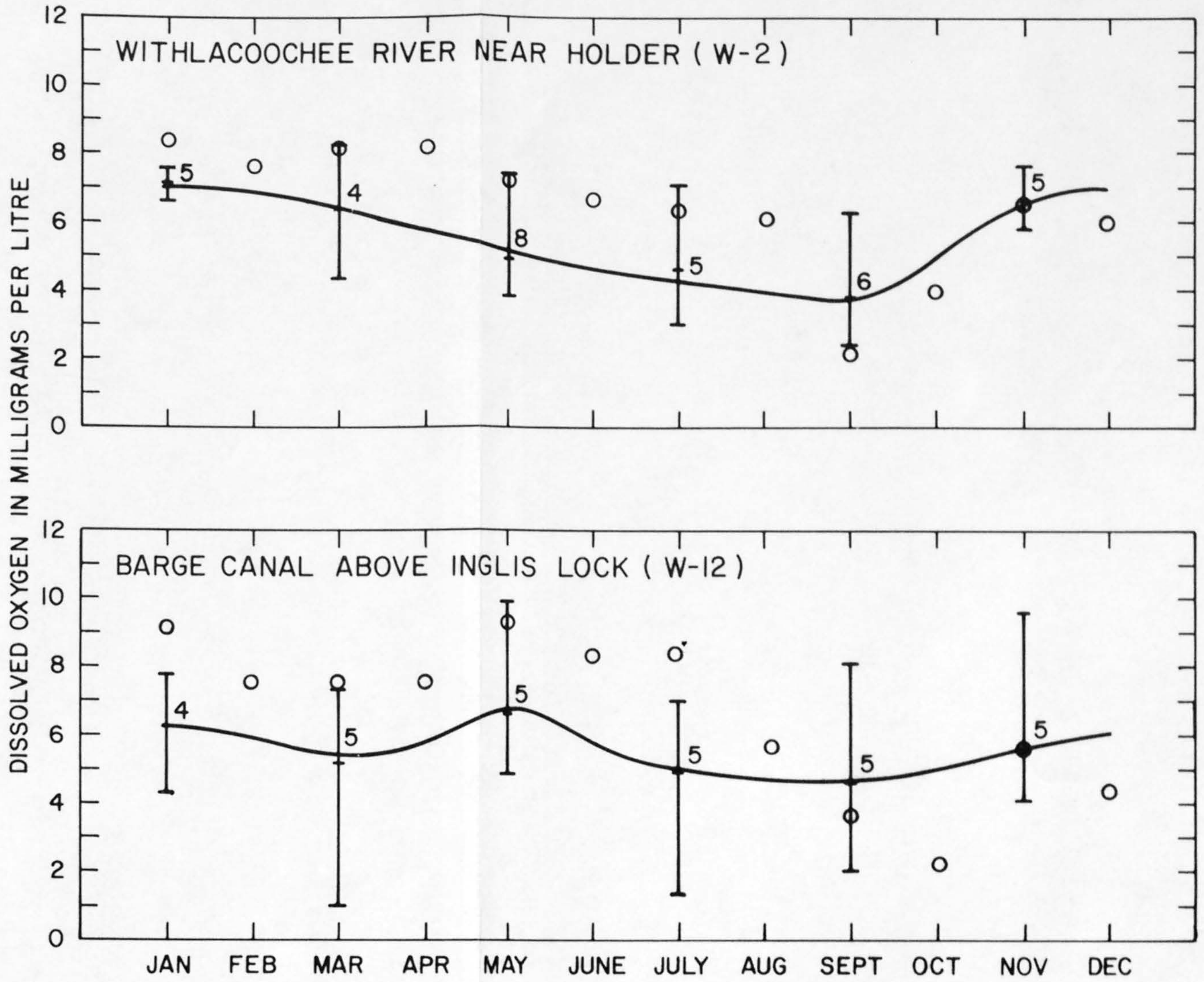
Constituent or property	Number of Samples	Max.	Min.	Mean
Temperature (°C)	1238	32.0	10.0	23.5
Specific conductance (μmhos at 25°C)	619[1]	3400	60	266
pH	348	8.9	6.5	7.6[2]
Dissolved oxygen (mg/l)	991	14.4	.4	6.5
Biochemical oxygen demand (mg/l)	198	5.3	.0	.8
Color (platinum-cobalt units)	438	360	0	40
Turbidity (JTU)	240	27	0	2
Secchi disk transparency (in.)	15	210	29	121
Suspended sediment (mg/l)	91	29	0	2

[1] Does not include daily values above Inglis Lock.
[2] Median pH.

Summaries of dissolved oxygen concentrations for the period 1968-74 are shown for sites in the Withlacoochee River basin in figure W.Q. 16. The greater ranges in concentrations of dissolved oxygen at sites W-10 in Lake Rousseau and W-12 above Inglis Lock compared with the other four sites are apparent in this figure. These wide ranges are due primarily to plant photosynthesis and plant and animal respiration in the lake. The other four sites are in a river channel environment where photosynthesis is more restricted than in a lake. A lake environment is conducive to phytoplankton growth and photosynthesis. The concentration of dissolved oxygen averaged more than 5.0 mg/l at all sites, but on occasion was less than 3.0 mg/l at Holder (W-2), above Inglis Dam (W-10) and above Inglis Lock (W-12). Surprisingly, the dissolved oxygen concentration in water discharging from Rainbow Springs is relatively high, averaging 6.3 mg/l at Rainbow Springs as compared with an average concentration of only 2.6 mg/l at Silver Springs.

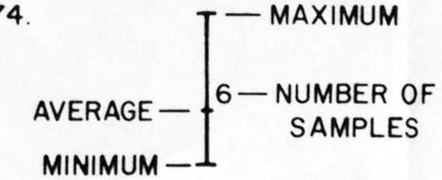
Seasonal variations in the concentration of dissolved oxygen in the Withlacoochee River at Holder (W-2) and in the Barge Canal above Inglis Lock (W-12)are shown in figure W.Q. 17. At Holder the dissolved oxygen concentration was highest during the winter months and lowest in summer and fall. This seasonal variation is similar to that observed at most sites in the Oklawaha River basin (fig. W.Q. 8) and is due largely to the increased solubility of oxygen at lower temperatures and the generally higher BOD during the summer and fall when surface runoff is high. In the Barge Canal above Inglis Lock, seasonal variations in dissolved oxygen concentrations differed somewhat from those at Holder. Concentrations were usually higher in the winter months than during late summer and fall. Concentrations were highest in May. The May peak in dissolved oxygen concentration in the Barge Canal above Inglis Lock was probably due to the rapid increase in the productivity of rooted aquatic plants and phytoplankton, as May is often the beginning of the growing season. High dissolved oxygen concentrations also occurred at this site in May 1975 (fig. W.Q. 17). During the 1975 data collection period high concentrations of dissolved oxygen were measured in May at most sites in and downstream from both Lake Ocklawaha and Lake Rousseau. Also, the dissolved oxygen concentrations at these sites in September through December 1975, generally were less than the average concentrations from 1968 through 1974.

Dissolved oxygen concentrations in Lake Rousseau were lower in the summer and fall and sometimes decreased with depth (W.Q. 18). Temperature and dissolved oxygen concentrations were measured in the vertical profile at four sites in Lake Rousseau in February, May, August, and November 1975 (W.Q. 18). Both temperature and dissolved oxygen concentrations were fairly uniform from top to bottom at all sites in February and in all sampling periods at site W-7. In May, the temperature and dissolved oxygen concentrations were near uniform in



EXPLANATION

MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISSOLVED OXYGEN CONCENTRATION (DAY-TIME MEASUREMENTS) DURING THE PERIOD 1968-1974.



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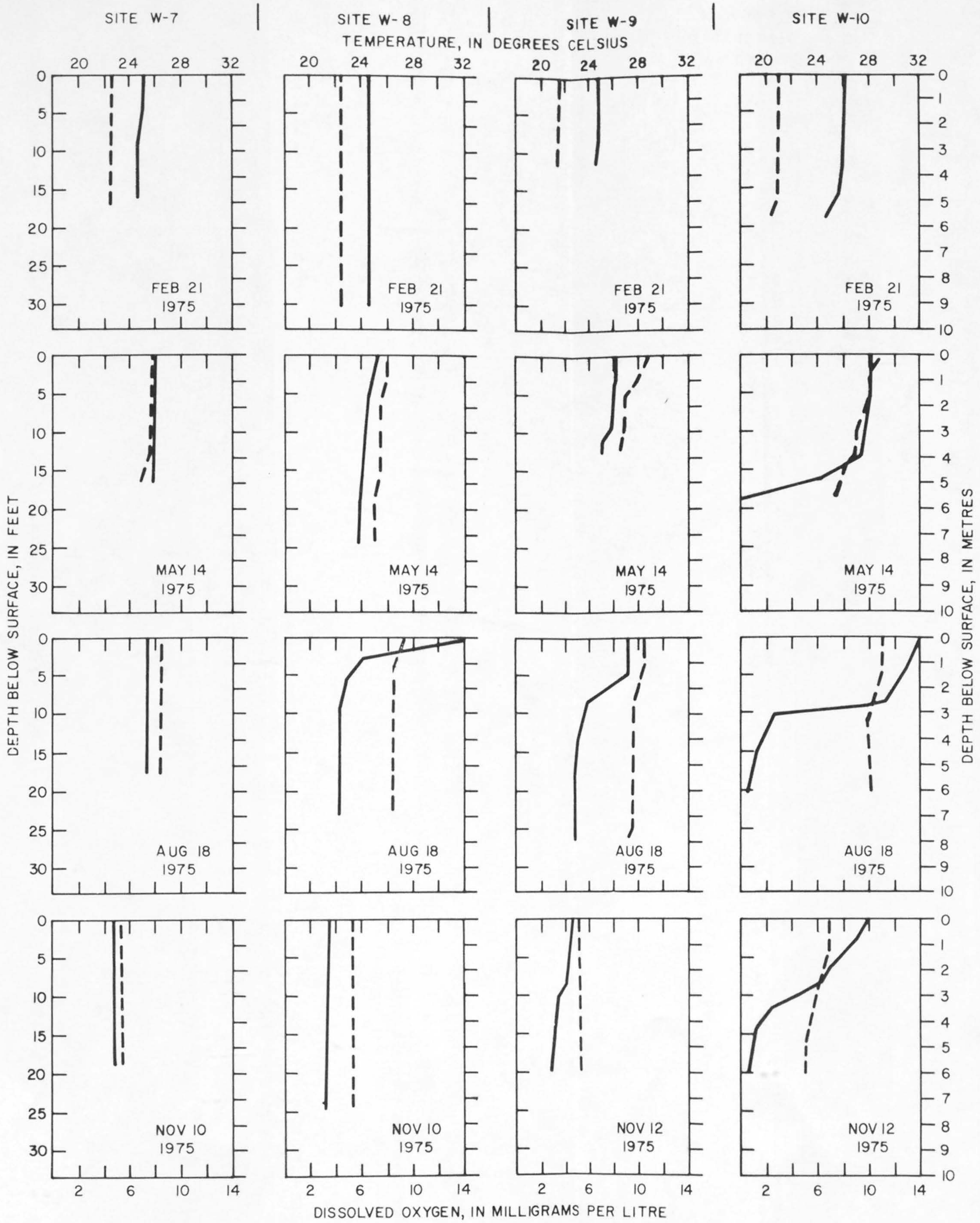
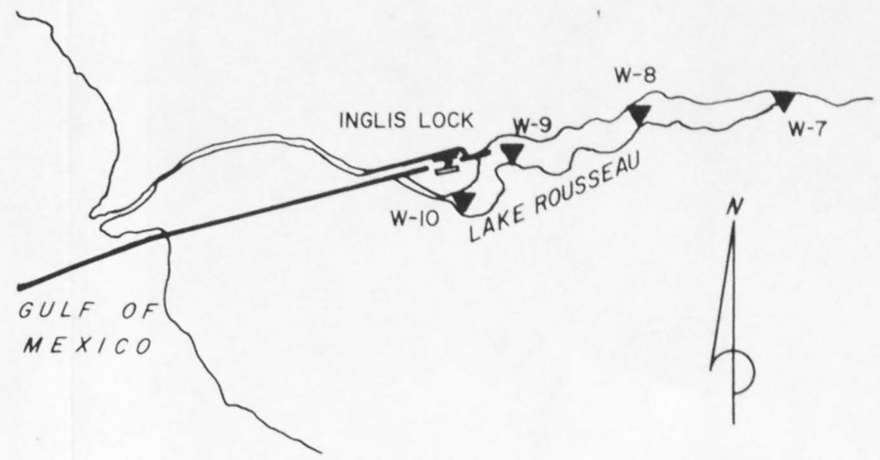
DISSOLVED OXYGEN CONCENTRATION MEASURED IN 1975

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY
SEASONAL VARIATIONS IN DISSOLVED OXYGEN CONCENTRATIONS WITHLACOOCHEE RIVER BASIN
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 17





EXPLANATION

– – – – – – TEMPERATURE

———————— DISSOLVED OXYGEN

(DAYTIME MEASUREMENTS)

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT

WATER QUALITY

PROFILES OF TEMPERATURE AND DISSOLVED OXYGEN IN LAKE ROUSSEAU

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 18

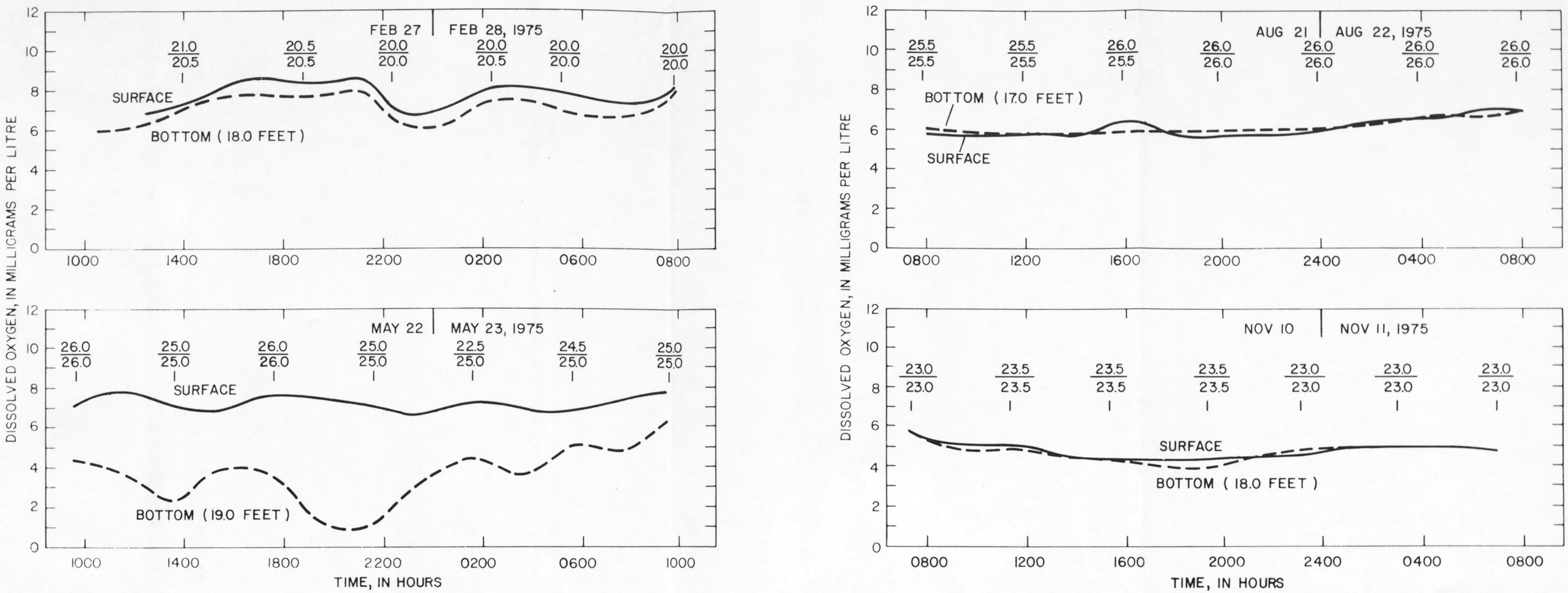
the profiles at three sites, but they were stratified at site W-10 above Inglis Dam. Concentrations of dissolved oxygen at this site decreased from more than 9.0 mg/l at a depth of 13 ft (4.0 m) to near 0.0 mg/l at a depth of about 19 ft (5.8 m) in May 1975. By August, stratification of dissolved oxygen was apparent at three sites. At sites W-8 and W-9 there was an appreciable decrease in dissolved oxygen concentration from the surface to a depth of about 8 ft (2.4 m), but dissolved oxygen concentrations were never less than 4.0 mg/l in the water column. At site W-10 in August there was a very sharp decrease in dissolved oxygen concentration at a depth of 9 to 10 ft (2.7 to 3.0 m) and the concentration near the bottom was less than 1.0 mg/l. In November 1975, dissolved oxygen was stratified only at W-10 ranging from 10.0 mg/l at the surface to less than 1.0 mg/l at a depth of 20 ft (6.0 m).

Temperatures and dissolved oxygen concentrations were relatively uniform in all profiles at site W-7 because this site is located in a fairly narrow part of the lake where velocities are high. The profiles at this site indicate that the water column is well mixed and suggest that temperature and dissolved oxygen stratification may not be a normal occurrence in the natural channel of the Withlacoochee River above Lake Rousseau.

As in Lake Ocklawaha, dissolved oxygen concentrations in Lake Rousseau undergo 24-hour variations due to photosynthesis and respiration of phytoplankton and rooted aquatic plants. Aquatic plants have been a problem in Lake Rousseau for many years, but during this investigation these plants were less abundant in Lake Rousseau than in Lake Ocklawaha. Consequently the effects of plants on the concentration of dissolved oxygen were less apparent in Lake Rousseau than in Lake Ocklawaha.

Diel variations in concentrations of dissolved oxygen were measured at two sites in Lake Rousseau (W-7 and W-8) in February, May, August and November 1975 (figs. W.Q. 19-20). Site W-7 is the most upstream site and is located in the river channel where the lake is narrow and flow velicities are fairly high. Aquatic weeds are not a major problem at this site. Site W-8 is also located in the main channel, but in a wider part of the lake where flow velocities are somewhat lower. Aquatic weeds are absent from the main channel at this site, but they are present on either side of the channel.

The variations in dissolved oxygen concentrations over a 24-hour period at site W-7 were small during all four measurement periods (fig. W.Q. 19). Dissolved oxygen concentrations were high near the surface in all of the diel measurements and were appreciably less near the bottom only in May. In May, dissolved oxygen concentrations near the bottom were from 2 to 6 mg/l less than those near the surface. This decrease in dissolved oxygen with depth indicates that



EXPLANATION

(19.0 FEET)
DEPTH AT WHICH BOTTOM
MEASUREMENT WAS MADE

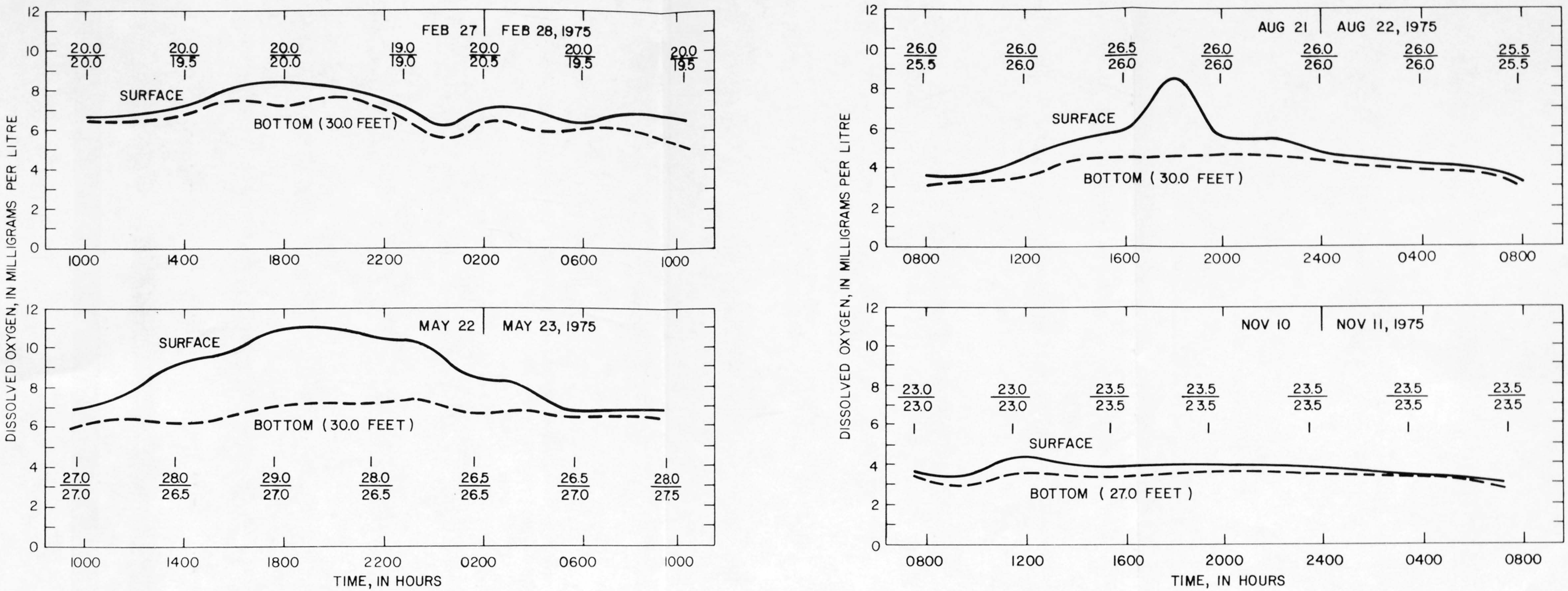
$\frac{22.5}{25.0}$ - SURFACE TEMPERATURE
- BOTTOM TEMPERATURE
IN DEGREES CELSIUS

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

DIEL VARIATIONS IN DISSOLVED OXYGEN IN LAKE ROUSSEAU (SITE W-7)

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U S GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W Q 19



EXPLANATION

(30.0 FEET)
DEPTH AT WHICH BOTTOM MEASUREMENT WAS MADE

26.5 - SURFACE TEMPERATURE
27.0 - BOTTOM TEMPERATURE
IN DEGREES CELSIUS

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

DIEL VARIATIONS IN DISSOLVED OXYGEN
IN LAKE ROUSSEAU (SITE W-8)

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W.Q 20

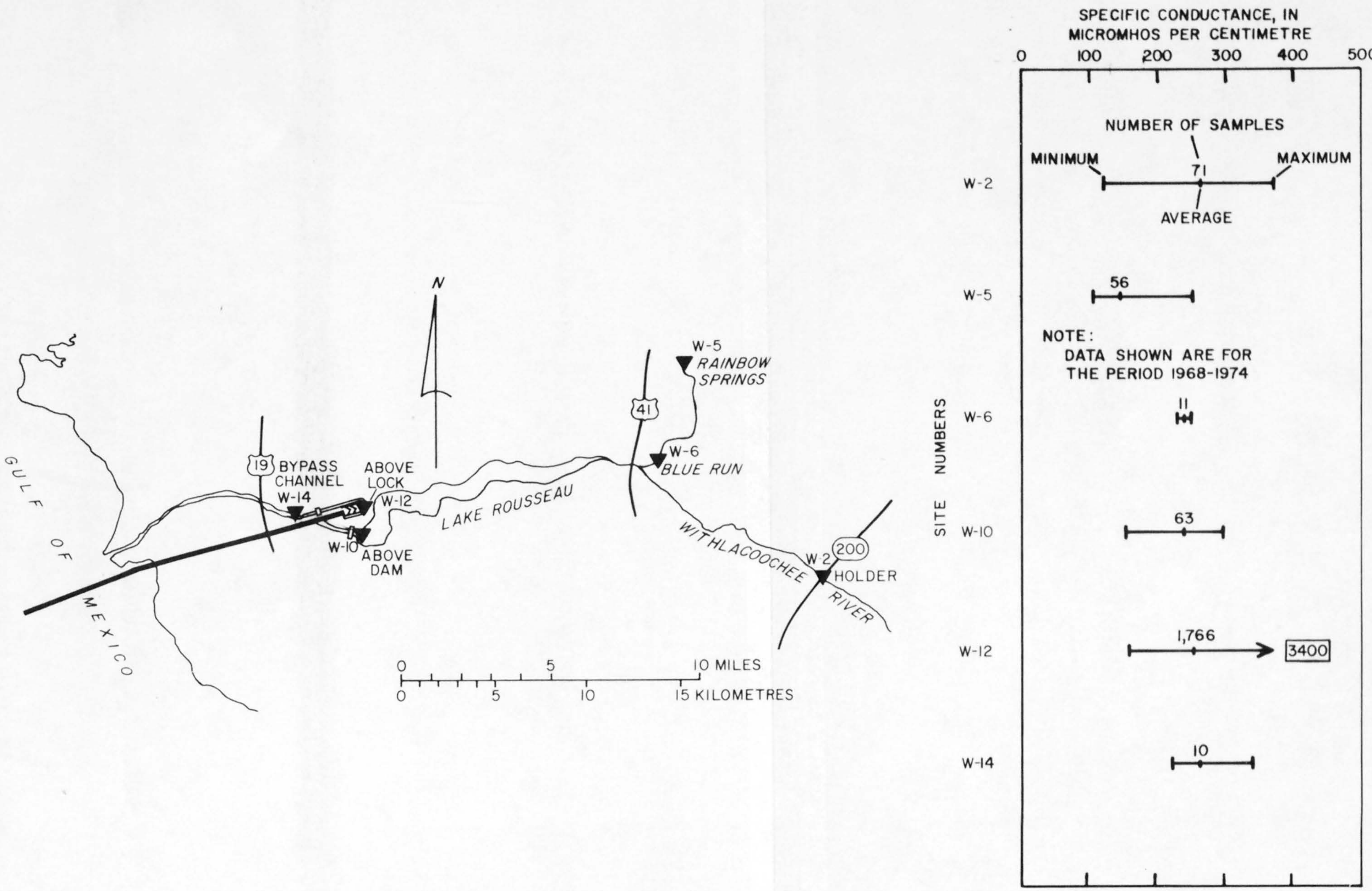
during periods of low flow Lake Rousseau becomes stratified with respect to dissolved oxygen at this site (site W-7). However, the concentration of dissolved oxygen at this site was high (8.0 mg/l) from top to bottom only 8 days before the diel measurement (fig. W.Q. 18). Also, the dissolved oxygen concentration near the bottom at the end of the diel measurement was only slightly less than that at the surface. In the diel measurements made in August and November the dissolved oxygen concentrations were also fairly high ranging from 4 to 6 mg/l with little difference between the concentrations at the surface and the bottom. The cause of the low dissolved oxygen concentrations near the bottom at mid-day and near sundown in May is not readily apparent.

Diel variations in dissolved oxygen concentration at site W-8 (fig. W.Q. 10) were larger than those at site W-7. High concentrations of dissolved oxygen in the afternoon and decreasing concentrations during the hours of darkness due to plant photosynthesis and respiration were apparent at site W-8 in all measurements particularly those made in May and August. Concentrations of dissolved oxygen at this site were lowest in August and November when early-morning concentrations were less than 4.0 mg/l. However, concentrations near the bottom were never less than 3.0 mg/l.

Specific Conductance

The specific conductance of surface waters in the Withlacoochee River basin averages less than 270 micromhos/cm as compared with an average of 375 micromhos/cm for surface waters in the Oklawaha River basin and an average of 990 micromhos/cm for the St. Johns River at Palatka (fig. W.Q. 21). Figure W.Q. 21 shows that the specific conductance at all but one of these sites averaged between 230 and 270 micromhos/cm. The specific conductance at site W-5, the head of Rainbow Springs, averaged about 150 micromhos/cm but increased downstream due to the inflow of more highly mineralized ground water through numerous small springs along Blue Run. At site W-6 near the mouth of Blue Run the average specific conductance of the combined flow of these springs was about 240 micromhos/cm and is only slightly less than the average specific conductance at the site at Holder (site W-2). Water from Blue Run is much less mineralized than is water from Silver Springs which has an average specific conductance of about 400 micromhos/cm.

Specific conductance has exceeded 400 micromhos/cm only above Inglis Lock (site W-12). Site W-12 above Inglis Lock had a specific conductance as high as 3,400 micromhos/cm as a result of locked-up salt water from the Gulf of Mexico. However, the increase in specific conductance that occasionally results from operating the lock is of short duration and any salt water locked up is either used for future lock operations or is diverted into the lower Withlacoochee River through the bypass channel.



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

MAXIMUM, MINIMUM AND AVERAGE SPECIFIC CONDUCTANCE AT SITES IN THE WITHLACOOCHEE RIVER BASIN

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 21

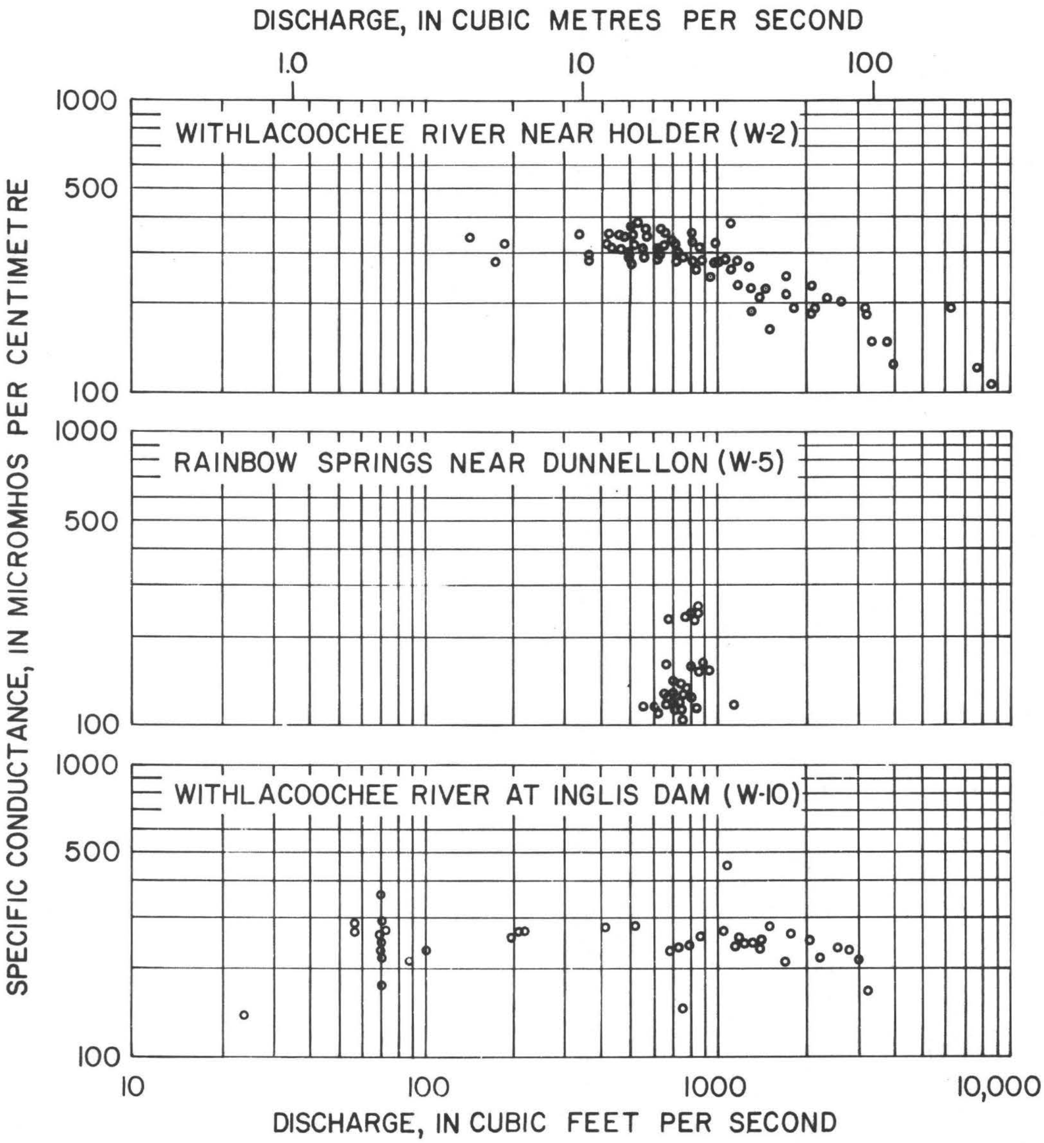
A detailed study of the potential for locking salt water up into Lake Rousseau was made by Bush (1973). He concluded that because of the dilution factor and the diversion of water through the bypass channel, the operation of the lock posed no threat to the quality of water in Lake Rousseau as long as there was flow through the bypass channel. Since the lock was placed in operation the specific conductance of water at site W-12, between the lock and the entrance to the bypass channel, has averaged less than 260 micromhos/cm. The average specific conductance at this site is only slightly higher than that above Inglis Dam (site W-10). Any increase that may have occurred in the average specific conductance of the lower Withlacoochee River as a result of lock operation would be very small due to the large dilution in the bypass channel.

Because the upper Withlacoochee River is only partially regulated, the inverse relation between specific conductance and discharge is more apparent in the Withlacoochee River than in the Oklawaha River. The relation between specific conductance and discharge is shown for the Withlacoochee River at Holder, Rainbow Springs and the Withlacoochee River at Inglis Dam in figure W.Q. 22. At Holder the inverse relation is well defined with specific conductances as low as 100 micromhos/cm during peak discharges and as high as 390 micromhos/cm during low-flow periods. The tightly grouped data points in the graph for Rainbow Springs illustrate the fairly constant quality and quantity of discharge from these springs. The variability in the plots at Inglis Dam is due to regulation practices and to the stabilizing effects of a storage reservoir on the specific conductance downstream.

Selected Chemical and Bacteriological Characteristics

Summaries of chemical and bacteriological characteristics in surface waters of the Withlacoochee River basin are given in table 16. The data in this table indicate that collectively the surface waters in the basin are calcium bicarbonate waters with an average dissolved solids concentration of 174 mg/l and a hardness of 123 mg/l. Average concentrations of chloride and sulfate are low, but maximum concentrations indicate that some sites have occasionally had high concentrations of chloride (910 mg/l) and high concentrations of sulfate (122 mg/l). The high concentration of chloride above Inglis Lock (site W-12) is the result of salt water being locked up, maximum concentrations of chloride at other sites in the basin are less than 60 mg/l, well below the limit of 250 mg/l recommended for municipal water supplies (Environmental Protection Agency, 1973, p. 61).

The average concentrations of total coliform bacteria in surface waters in the basin indicate that these waters usually meet the bacteriological standards of 1,000 colonies/100 ml for body contact recreational uses (Florida Pollution Control Board, 1973). The



CROSS FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

DISCHARGE-SPECIFIC CONDUCTANCE RELATION
WITHLACOOCHEE RIVER BASIN

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U S GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 **FIGURE WQ 22**

Table 16.--Summary of chemical and biological characteristics in surface waters of the Withlacoochee River basin. (For period of record and sampling frequency see fig. 1.) (Results in milligrams per litre except as indicated)

Constituent or property	Number of samples	Max.	Min.	Mean
Major cations				
Calcium	232	83	14	43
Magnesium	232	8.0	.0	4.1
Sodium	227	15	.6	4.7
Potassium	225	8.0	.0	.4
Major anions				
Bicarbonate	310	180	31	119
Carbonate	204	6	0	0
Chloride	433	910	2.0	20
Sulfate	241	122	2.4	23
Fluoride	219	.5	.0	.2
Alkalinity as $CaCO_3$	310	148	25	98
Hardness as $CaCO_3$				
Total	436	440	14	123
Noncarbonate	311	150	0	32
Dissolved solids				
Residue at 180°C	209	382	62	174
Total organic carbon	177	31	0	6
Coliform bacteria (colonies per 100 ml)				
Total	194	20,000	0	630
Fecal	189	140	0	17

maximum concentrations of coliform bacteria indicate that high concentrations of total coliform bacteria have occurred at some stations (table 16). Concentrations of total coliform bacteria have been as high as 20,000 colonies/100 ml above Inglis Lock (site W-12) and 10,000 colonies/100 ml at Holder (site W-2), but the maximum concentrations at most sites were less than 6,000 colonies/100 ml.

The chemical quality of water at 5 sites in the Withlacoochee River basin is represented by Stiff diagrams in figure W.Q. 23. A downstream increase in dissolved solids concentration along Blue Run can be seen by comparing the Stiff diagram for Rainbow Springs to that for the site near the mouth of Blue Run. During periods of low flow, the quality of water from Rainbow Springs and the springs along Blue Run is slightly less mineralized, but very similar to the quality of water in the river at Holder. Consequently, during low flow periods the inflow from these springs does not greatly increase the dissolved solids concentration in the Withlacoochee River as does the inflow from Silver Springs in the Oklawaha River. During high flow, the inflow from Blue Run is more highly mineralized than drainage from the Withlacoochee River above Blue Run. Thus, during high flow the springs cause the concentration of dissolved solids in Lake Rousseau to be higher than in the river upstream from the springs.

Nitrogen and Phosphorus

Concentrations of the plant nutrients nitrogen and phosphorus in surface waters of the Withlacoochee River basin averaged 0.54 and 0.04 mg/l, respectively (table 17). These average concentrations were less than the average concentrations of 0.93 and 0.05 mg/l in surface waters of the Oklawaha River basin. Surface waters in the Withlacoochee River basin also contained, on the average, less nitrogen and phosphorus than water from most Floridan aquifer wells (table 17). Concentrations of nitrogen have been as high as 3.4 mg/l. Concentrations of total phosphorus as high as 0.13 mg/l were measured in some samples. On the average, about 70 percent of the total nitrogen is in the organic form. Nitrate nitrogen accounts for about 20 percent of the total nitrogen. About half of the total phosphorus is in the soluble orthophosphate form.

Summaries of nitrogen and phosphorus concentrations for the period 1968-1974 are shown for six sites in the Withlacoochee River basin in figure W.Q. 24. The highest average and the maximum concentration of nitrogen occurred at Holder (site W-2). Concentrations of nitrogen in Rainbow Springs (site W-5) and in Blue Run (site W-6) were, on the average, lower than the concentrations of nitrogen in the Withlacoochee River.

Concentrations of nitrogen decreased slightly below Holder in 1968-74 (only a limited amount of nitrogen data are available for the bypass channel site W-14) (fig. W.Q. 24). Also in 1975 concentrations

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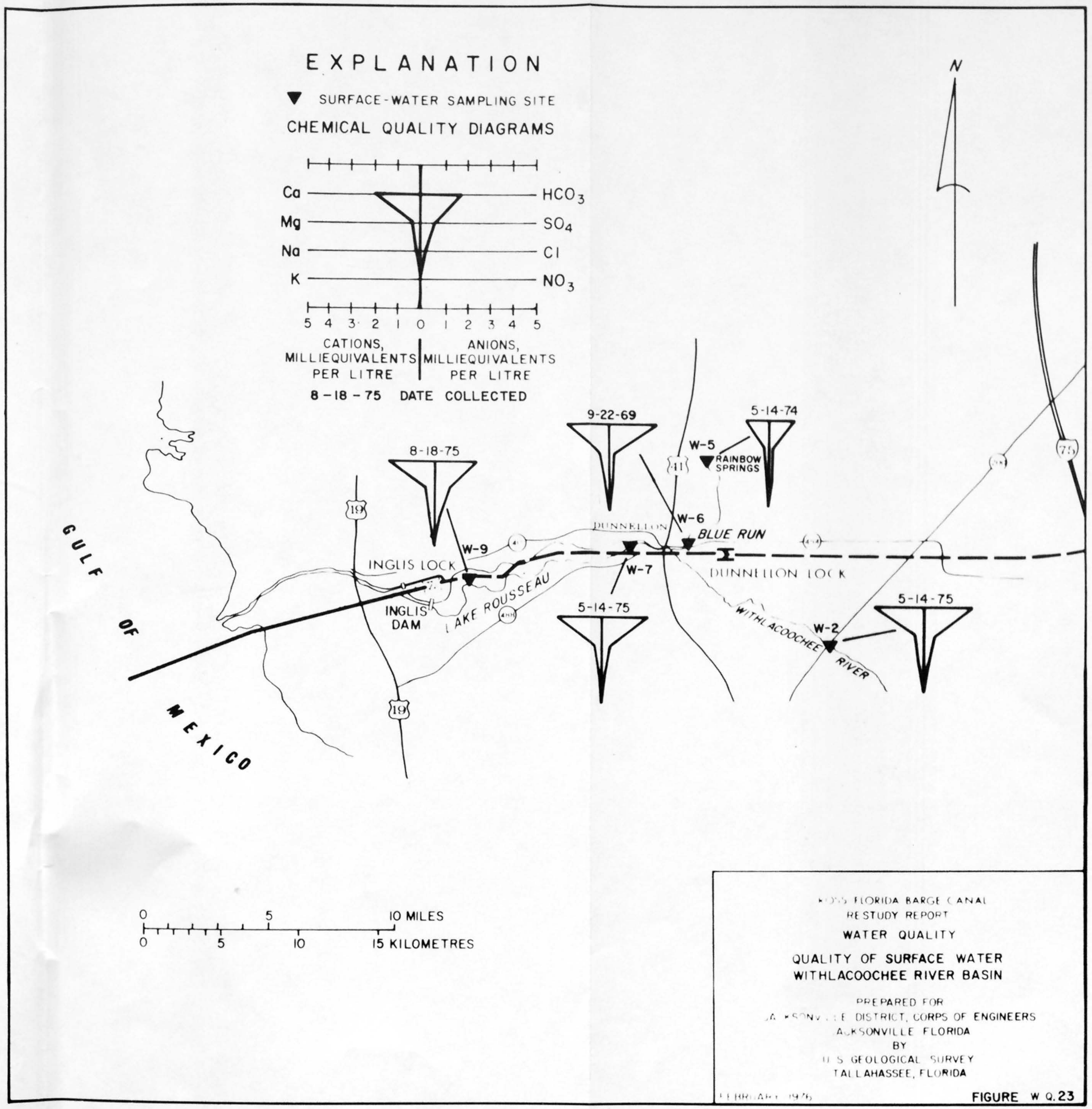


CROSS FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

QUALITY OF SURFACE WATER
WITHLACOOCHEE RIVER BASIN

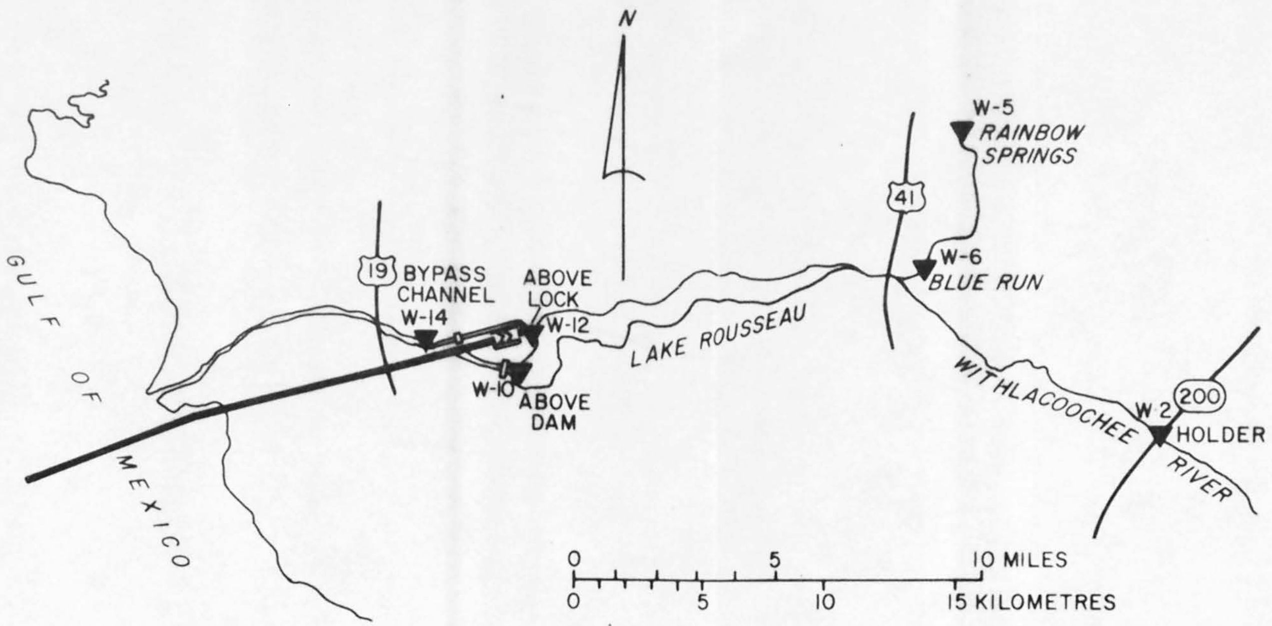
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U.S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

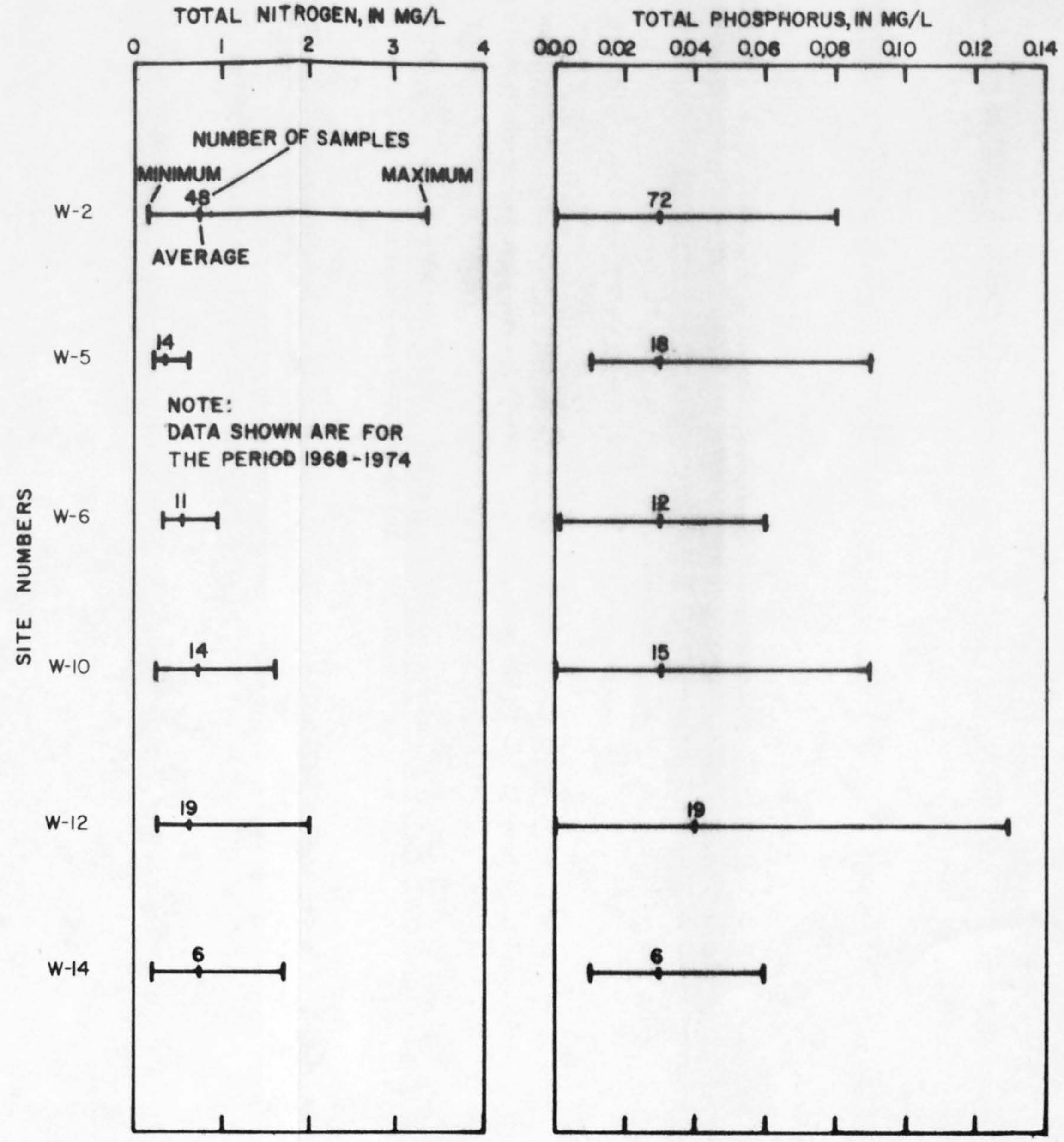
FEBRUARY 1976

FIGURE WQ.23

Table 17.--Summary of nitrogen and phosphorus analyses of surface waters in the Withlacoochee River basin. (For period of record and sampling frequency see table 1.) (Results in milligrams per litre)

Constituent	Number of samples	Max.	Min.	Mean
Nitrate as N	428	1.6	0.00	0.13
Nitrite as N	239	.05	.00	.01
Ammonia as N	203	.31	.00	.04
Organic nitrogen as N	218	3.3	.00	.40
Total nitrogen as N	203	3.4	.16	.54
Orthophosphorus as P	242	.10	.00	.02
Total phosphorus as P	233	.13	.00	.04





CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

MAXIMUM, MINIMUM AND AVERAGE CONCENTRATIONS OF NITROGEN AND PHOSPHORUS AT SITES IN THE WITHLACOOCHEE RIVER BASIN

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W.Q. 24

of nitrogen decreased downstream. However, the Federal Water Pollution Control Administration (1967), in a study in March and April 1967, found that nitrogen concentrations increased slightly in this reach.

Concentrations of nitrogen at sites in the Withlacoochee River basin tend to be highest during the rainy season (June-September). At this time precipitation is a major source of nitrate and other forms of inorganic nitrogen. Inorganic nitrogen increases do not occur in Lake Rousseau because of rapid assimilation by aquatic plants.

The maximum concentration of total phosphorus measured in the Withlacoochee River basin during the period 1968-74 was 0.13 mg/l at site W-12 above Inglis Lock. The average concentration of phosphorus at sites in the basin averaged 0.03 mg/l at all but one site, W-12, which averaged 0.04 mg/l (fig. W.Q. 24). Low and uniform concentrations of total phosphorus along the lower Withlacoochee River were also reported during the 1967 study by the Federal Water Pollution Control Administration (1967). During that study, concentrations of phosphorus were generally less than 0.04 mg/l, except at one site near the outfall from the Dunnellon sewage treatment plant where concentrations were as high as 0.19 mg/l. However, a short distance downstream the concentration was 0.03 mg/l. Plant assimilation was probably the cause of this rapid reduction in concentration.

In addition to phosphorus, the concentration of nitrogen, particularly organic nitrogen, was higher at the site near the Dunnellon treatment plant in 1967. However, the samples collected in in 1975 at site W-7, which is located in the same general area, contained low concentrations of both nitrogen and phosphorus. The maximum concentrations of nitrogen and phosphorus at site W-7 was 0.68 mg/l and 0.06 mg/l. A comparison of the data for site W-7 at the head of Lake Rousseau with that for the bypass channel (site W-14) indicated a downstream reduction in nitrogen concentration in the lake in 1975, but no corresponding decrease in the phosphorus.

Seasonal Profiles of Selected Characteristics

Selected physical, chemical, and biological characteristics were sampled near the surface and the bottom in May and August 1975, at sites W-7, 8, and 9 in Lake Rousseau (table 18). Differences in the concentrations of nutrients and most other constituents in surface and bottom samples were small at site W-7 because flow velocities are high enough to keep the water column well mixed (table 18). At sites W-8 and W-9 where velocites are somewhat lower, the concentration of nitrate increased with depth. The concentration of phosphorus, although very low, was slightly higher near the bottom at all three sites in August. The specific conductance also increased slightly with depth at sites W-8 and W-9 in August. Differences in nitrogen and phosphorus concentrations between surface and bottom samples from Lake Rousseau were generally less than the differences in samples

Table 18.--Quality of surface and bottom waters in Lake Rousseau, Florida.

Date	Depth below water surface (ft)	Temperature (C)	Dissolved oxygen (mg/1)	Specific Conductance (umhos)	Turbidity (JTU)	Total organic carbon (mg/1)	Biochemical oxygen demand (mg/1)	Total coliform (colonies/100 ml)	Fecal coliform (colonies/100 ml)	Suspended sediment (mg/1)	Total iron (ug/1)	Total manganese (ug/1)	Nutrients (mg/1)						
													Nitrate (NO_3-N)	Nitrite (NO_2-N)	Ammonia (NH_3-N)	Organic nitrogen (N)	Total nitrogen (N)	Ortho-phosphorus (P)	Total phosphorus (P)
Lake Rousseau (W-7)																			
5-14-75	1	25.5	7.8	248	1	1	0.9	63	15	1	20	10	0.18	0.01	0.06	0.08	0.33	0.02	0.04
5-14-75	16.5	25.0	7.7	248	1	3	.3	12	0	2	10	10	.18	.01	.05	.11	.35	.02	.03
8-18-75	1	26.5	7.3	280	1	4	.1	100	5	0	60	10	.21	.00	.03	.22	.46	.03	.02
8-18-75	17	26.5	7.3	280	2	2	.2	75	10	0	110	10	.21	.00	.04	.18	.43	.03	.03
Lake Rousseau (W-8)																			
5-14-75	1	26.0	6.6	246	2	3	1.9	0	0	2	20	10	.02	.01	.03	.20	.26	.01	.03
5-14-75	23	25.0	5.6	247	1	1	.6	38	15	1	20	10	.13	.01	.02	.15	.31	.02	.03
8-18-75	1	27.0	5.6	268	2	3	.4	80	20	0	100	10	.10	.00	.03	.21	.34	.01	.02
8-18-75	23	26.5	4.2	280	2	4	.4	90	20	0	60	10	.16	.00	.03	.18	.37	.02	.03
Lake Rousseau (W-9)																			
5-14-75	1	27.5	9.4	240	2	5	.6	100	0	1	20	10	.02	.01	.06	.38	.47	.01	.04
5-14-75	13	26.5	6.8	240	2	3	1.8	120	0	3	40	10	.05	.01	.05	.21	.32	.02	.04
8-18-75	1	28.5	9.0	255	2	1	.7	10	0	0	110	10	.00	.00	.02	.27	.29	.00	.01
8-18-75	24	27.5	4.8	270	1	4	.4	140	0	1	110	10	.10	.00	.03	.24	.37	.01	.02

collected in August at site 0-10 in Lake Ocklawaha. Occasionally very low dissolved oxygen concentrations occurred near the bottom of Lake Rousseau at site W-10 above Inglis Dam (fig. W.Q. 18). During these periods, concentrations of ammonia and phosphorus may be expected to be much higher near the bottom than near the surface because of bacterial decomposition of organic material.

Trace Elements

A summary of analyses of trace elements in surface waters in the Withlacoochee River basin is given in table 19. The average concentration of most of these trace elements is very low. As with surface waters in the Oklawaha River basin, the trace elements occurring in highest concentrations were aluminum, boron, iron, strontium and zinc. Concentrations of these and most of the other trace elements were generally lower in surface waters in the Withlacoochee River basin than in surface waters in the Oklawaha River basin. Average concentrations of chromium, copper and nickel were slightly higher in the Withlacoochee River basin than in the Oklawaha River basin, but were less than 10 ug/l. In high concentrations these metals can be toxic but average concentrations found in either the Withlacoochee or Oklawaha River basin are well below levels considered harmful to aquatic life. Recommended limits of concentration for several trace elements are given in table 22 in a later section of this report.

Pesticide Compounds

During the period September 1968 through May 1970, 14 water samples were collected from 8 surface water sites in the Withlacoochee River basin and analyzed for 8 chlorinated hydrocarbon insecticides. Twelve of these samples were collected from the Withlacoochee River at Holder, Rainbow Springs, Blue Run, the bypass channel, the lower Withlacoochee River downstream from the bypass channel and from sites on the upstream sides of Inglis Lock and Inglis Dam. None of the 12 samples contained detectable amounts of the insecticides aldrin, DDD, DDE, DDT, dieldrin, endrin, heptachlor or lindane.

Two samples were collected on the downstream sides of Inglis Lock and Inglis Dam where the quality of water is affected by salt water from the Gulf of Mexico. A concentration of 0.05 ug/l DDD was found in the sample collected below Inglis Dam in May 1970. Although this concentration is well below the recommended limit of 50 ug/l for public water supplies, it exceeds the maximum concentration of DDT, the parent compound, recommended for the protection of fresh-water aquatic life (Environmental Protection Agency, 1973).

Table 19.--Summary of trace element analyses of surface waters in the Withlacoochee River basin. (For period of record and sampling frequency see table 1.)

(Results in micrograms per litre)

Constituent	Number of samples	Max.	Min.	Mean
Aluminum, total	17	600	0	50
Arsenic, total	19	12	0	2
Arsenic, dissolved	13	10	0	4
Boron, total	5	30	0	10
Cadmium, total	22	1	0	0
Cadmium, dissolved	8	1	0	0
Chromium, total	9	20	0	8
Chromium, dissolved	7	20	0	3
Copper, total	14	40	0	7
Copper, dissolved	21	10	0	3
Iron, total	71	780	0	180
Iron, dissolved	200	450	0	60
Lead, total	22	17	0	6
Lead, dissolved	25	20	0	3
Manganese, total	35	30	0	9
Manganese, dissolved	29	20	0	4
Mercury, total	17	.2	.0	.0
Nickel, total	9	18	0	8
Strontium, dissolved	49	670	0	230
Zinc, total	14	50	0	20
Zinc, dissolved	21	90	0	30

Bottom Sediments

Bottom materials in the lakes and streams in the Oklawaha River basin act as a trap for pesticides, metals, and many of the nutrients. This is particularly true in lakes and in other areas where low velocities allow fine sediments and organic materials to settle to the bottom. The incorporation of these materials into the lake bottom removes them at least temporarily from the aquatic environment, but they may be recycled into the water by way of biochemical regeneration, by changes in water quality which increase the solubility of these compounds, and by the resuspension of these sediments in the water.

Chemical characteristics of bottom materials at three sites in Lake Rousseau are given in table 20. Bottom materials at the upstream site W-7, where velocities are comparatively high, contained the lowest concentrations of nitrogen, phosphorus and iron. A comparison of this table with table 11 indicates that phosphorus, manganese, and iron concentrations were higher in the Lake Rousseau samples than the Lake Ocklawaha samples. Organic carbon in the samples was in the same order of magnitude, indicating a similar organic content in the bottom sediments of both lakes.

Bottom materials in Lake Rousseau contain very high concentrations of phosphorus. Nitrogen to phosphorus ratios in most natural waters and in phytoplankton and many other plants are on the order of 10:1 or 20:1. Ratios of nitrogen to phosphorus in bottom materials at the open water sites in Lake Ocklawaha were within this range, but bottom materials from two of the three sites in Lake Rousseau contained more phosphorus than nitrogen and at site W-7 contained almost twice as much phosphorus as nitrogen. This high concentration of phosphorus suggests that part of the phosphorus may be in the form of an inorganic mineral. Phosphate ore was once mined in areas adjacent to the river near Dunnellon and the high phosphorus content of bottom materials in the lake is probably due to phosphate sediments carried into th lake during mining operations. It is also possible that phosphorus contributed to the river by the Dunnellon sewage treatment effluent is being deposited on the lake bottom through sedimentation or precipitation. In view of the small size of the treatment plant, however, past mining operations appear to be a more reasonable explanation of the high phosphorus concentrations.

Concentrations of pesticides and related organic chemicals in bottom materials collected at sites W-7, W-8 and W-9 are given in table 21. Although no chlorinated hydrocarbons were detected in the lake water, bottom materials at these sites contained DDD, DDE, and chlordane. The insecticide DDD was found in concentrations of 1.9 ug/kg at site W-7 and 0.2 ug/kg at site W-8. The insecticide DDE was found in concentrations of 1.2 ug/kg at site W-7 and 2.2 ug/kg at site W-9. Chlordane was found in concentrations of 1 and 12 ug/kg at sites W-8 and W-9, respectively. The three herbicides 2,4-D; 2,4,5-T and Silvex were not detected.

Table 20.--Chemical characteristics of bottom materials in Lake Rousseau, Florida.

Local Number	Date	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Organic carbon (g/kg)	Total iron (ug/g)	Total manganese (ug/g)	Biochemical oxygen demand 5 day (mg/kg)
W-7	5-14-75	3,800	7,100	27	3,600	150	710
W-8	5-14-75	6,600	8,800	133	9,300	150	1,100
W-9	5-14-75	18,000	11,000	123	9,600	140	260

Table 21.--Concentrations of pesticides and related chlorinated hydrocarbon compounds in bottom materials in Lake Rousseau, Florida.

(Results in micrograms per kilogram)

	Site W-7	Site W-8	Site W-9
Date	5-14-75	5-14-75	5-14-75
Aldrin	.0	.0	.0
Lindane	.0	.0	.0
Chlordane	0	1	12
DDD	1.9	.2	.0
DDE	1.2	.0	2.2
DDT	.0	.0	.0
Dieldrin	.0	.0	.0
Endrin	.0	.0	.0
Toxaphene	0	0	0
Heptachlor	.0	.0	.0
Heptachlor epoxide	.0	.0	.0
PCB	0	0	0
2,4-D	0	0	0
2,4,5-T	0	0	0
Silvex	0	0	0

CHANGES IN WATER QUALITY

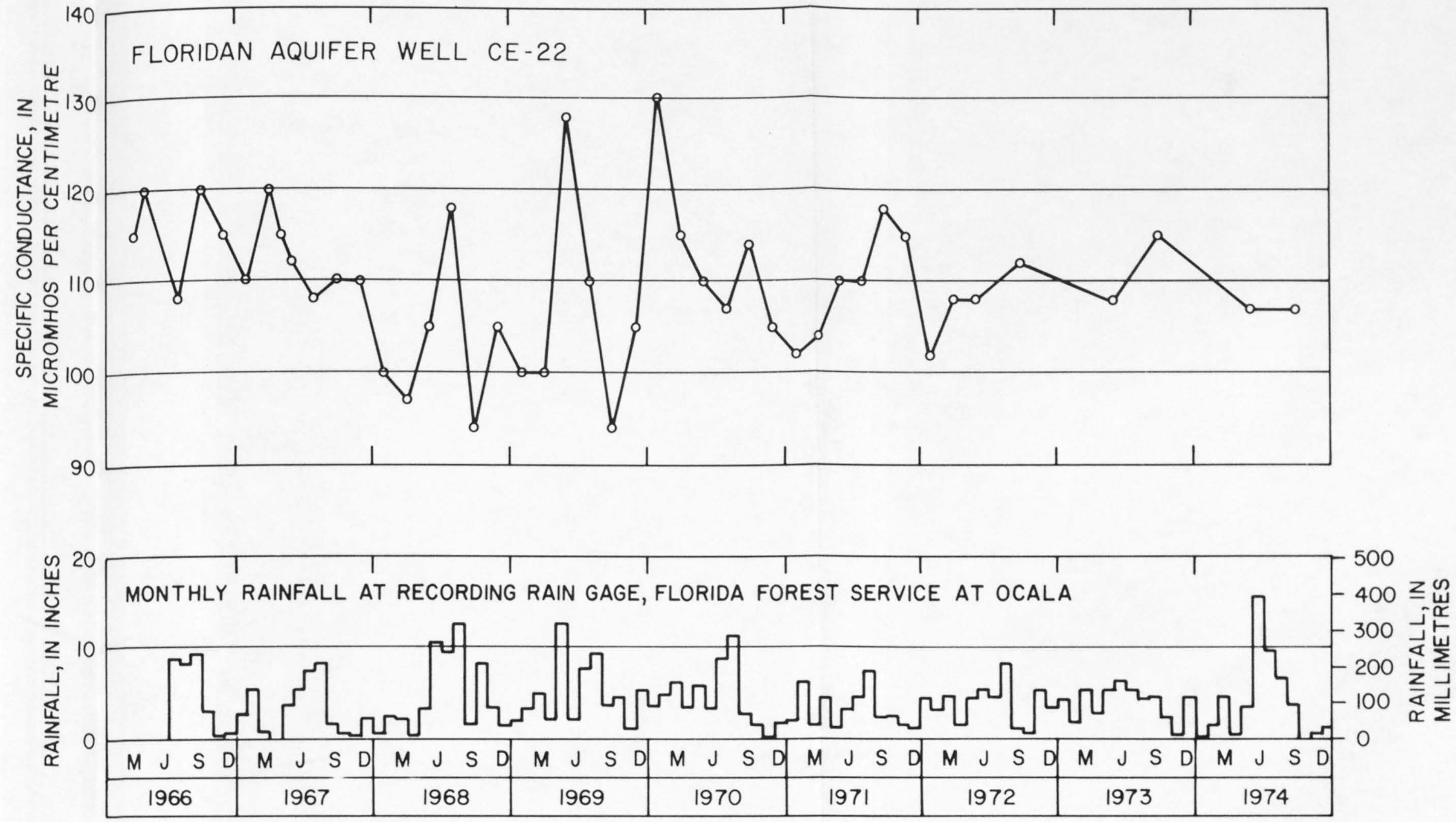
Ground Water

Changes in the specific conductance of water in the Floridan-aquifer well CE-22 located just north of the Barge Canal route and about 9.0 mi (14.5 km) east of Dunnellon are shown for the period 1966 through 1974 in figure W.Q. 25. Although the specific conductance of ground water in this well has ranged from 93 to 130 micromhos/cm, no significant long-term trend change was evident. The pattern of the specific conductance graph indicates seasonal variations in the well water. Monthly rainfall at Ocala, also shown in figure W.Q. 25, indicates that the specific conductance in the well generally is lowest during or shortly after the rainy season and highest during the dry part of the year. However, numerous exceptions to this correlation between specific conductance and rainfall occur due to the overriding effects of floods and droughts and to changes in water levels and hydraulic gradients in the aquifer.

The specific conductance of water from Silver Springs which discharges water from somewhat deeper in the Floridan aquifer than most wells is shown in figure W.Q. 26. From 1956 through 1975 the specific conductance ranged from 350 to 460 micromhos/cm and appreciable fluctuations in the specific conductance occurred in fairly short periods. The larger fluctuations occurred during extended periods of excessive rainfall, as in 1967, 1968, and 1969. During periods of fairly uniform spring discharge, as during 1972 through 1975, the specific conductance was also uniform, ranging from 408 to 460 micromhos/cm.

The relation between the specific conductance and discharge of Silver Springs can be seen by comparing the graphs in figure W.Q. 26. This figure shows a seasonal pattern to the variations in both discharge and specific conductance. Silver Springs discharge is generally high and specific conductance low in October and November shortly after the rainy season, which usually ends in September. Following November the discharge generally decreases with a subsequent increase in conductance. This trend is less apparent during periods of unusually high flow, as during 1960 and 1964 through 1966, or during periods of low flow such as 1956, 1957, 1962, and 1963.

For the 20-year period 1956 through 1975 the specific conductance of Silver Springs was never less than 350 micromhos or more than 460 micromhos. The maximum monthly mean discharge, however, was 2½ times as large as the minimum monthly mean discharge. The range in conductance is narrow because during unusually wet periods the higher water levels and hydraulic head responsible for the high discharge also tend to increase the amount of more mineralized water coming from deeper in the aquifer. During extended dry periods, the water near the top of the aquifer is more mineralized than in wet periods, but the lower water levels of the dry periods result in a smaller percent of the discharge coming from deep in the aquifer.



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT

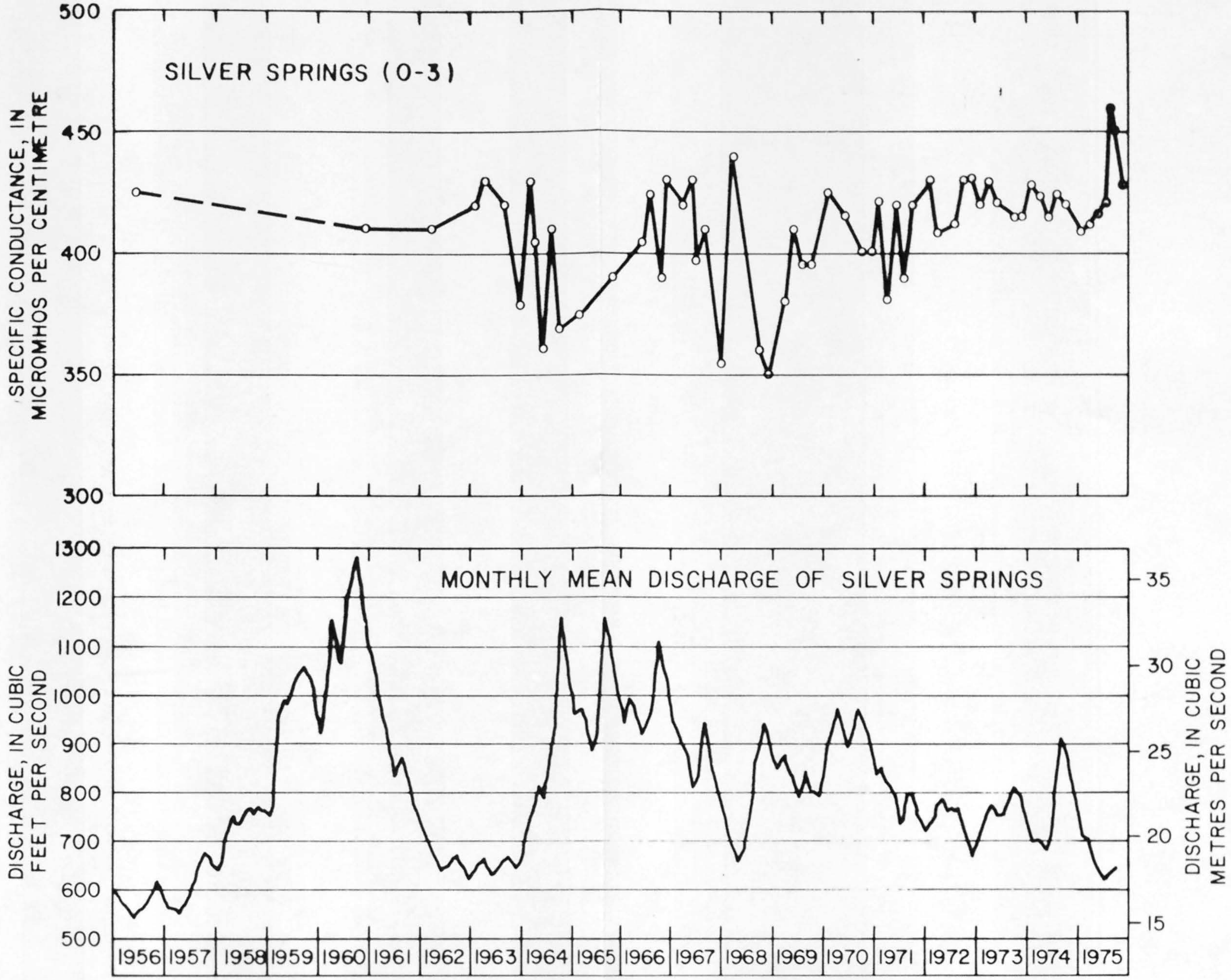
WATER QUALITY

RAINFALL AND SPECIFIC CONDUCTANCE OF WATER IN FLORIDAN AQUIFER WELL CE-22.

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976

FIGURE W Q 25



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

SPECIFIC CONDUCTANCE AND DISCHARGE OF SILVER SPRINGS

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 26

Based on specific conductance data for ground water in the area of the Barge Canal, there has been no significant change in the mineral concentration of these waters except for those changes due to unusual climatic conditions. The mineral concentration of ground water adjacent to the Barge Canal between Inglis Lock and the Gulf of Mexico may have increased due to the movement of sea water up the canal. However, Faulkner's (1973b) analyses indicated that the ground-water gradient was toward the canal and that salt-water intrusion into the aquifer was limited to a narrow area along the canal.

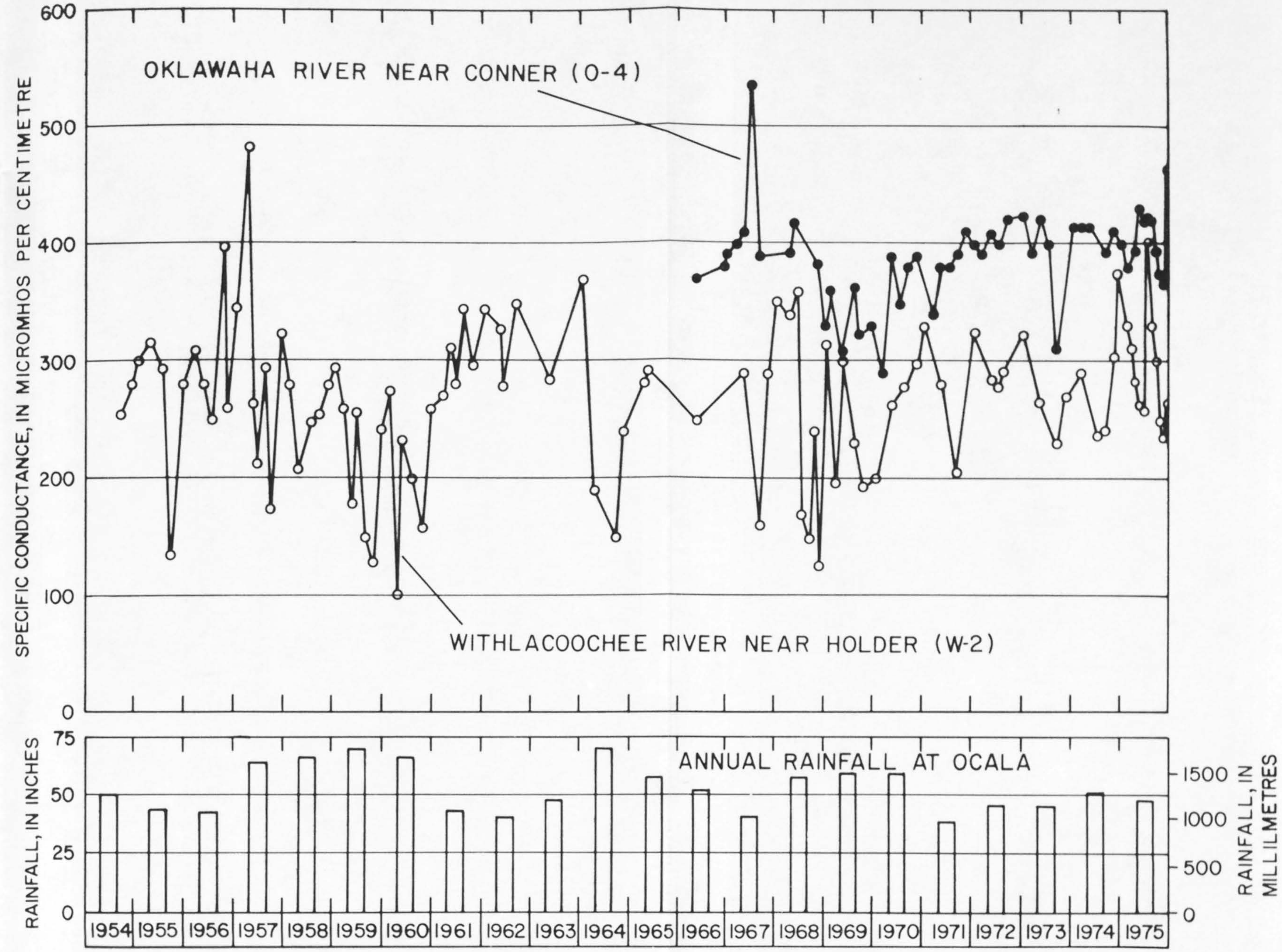
Coliform bacteria have been detected in a few samples of ground water in heavily populated areas. Septic tanks, infiltration galleries, drainage wells, and street runoff to sinkholes may have been sources of these bacteria. Contaminants, including bacteria and nutrients, appear to be a local problem; the available data do not indicate significant increases in either the severity of the problem or the area affected.

Surface Water

The mineral concentration of surface water is generally less than that of ground water, but changes in the quality of surface water can occur rapidly. Because the mineral concentration of surface water generally is inversely related to discharge, the specific conductance of surface waters can vary abruptly in short periods of time. The specific conductance of the Oklawaha River near Conner (site 0-4) and the Withlacoochee River near Holder (site W-2) are shown in figure W.Q. 27. The pattern of this graph illustrates the large variations that occur in water quality at these sites due to seasonal and short-term variations in rainfall. A comparison of the specific conductance graphs with the record of annual rainfall at Ocala (fig. W.Q. 27) indicates that extended periods of excess or deficient rainfall also affect the specific conductance of surface waters.

During the unusually wet years of 1957 through 1960, the specific conductance of the Withlacoochee River near Holder was below average. During the dry years, 1961 through 1963, the specific conductance at this site increased. Similar responses to rainfall patterns can be seen in the specific conductance of the Oklawaha River near Conner. No long-term changes in the specific conductance other than those due to rainfall are apparent in either the Withlacoochee or the Oklawaha Rivers.

However, changes in some characteristics have occurred in the lower reaches of the Oklawaha River as a result of the impoundment of Lake Ocklawaha. For example, stratification of dissolved oxygen now occurs in the lake during much of the summer and concentrations of less than 1.0 mg/l in some parts of the lake are not uncommon. Available



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY
SPECIFIC CONDUCTANCE FOR
OKLAWAHA AND WITHLACOOCHEE RIVERS
AND RAINFALL AT OCALA
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W.Q. 27

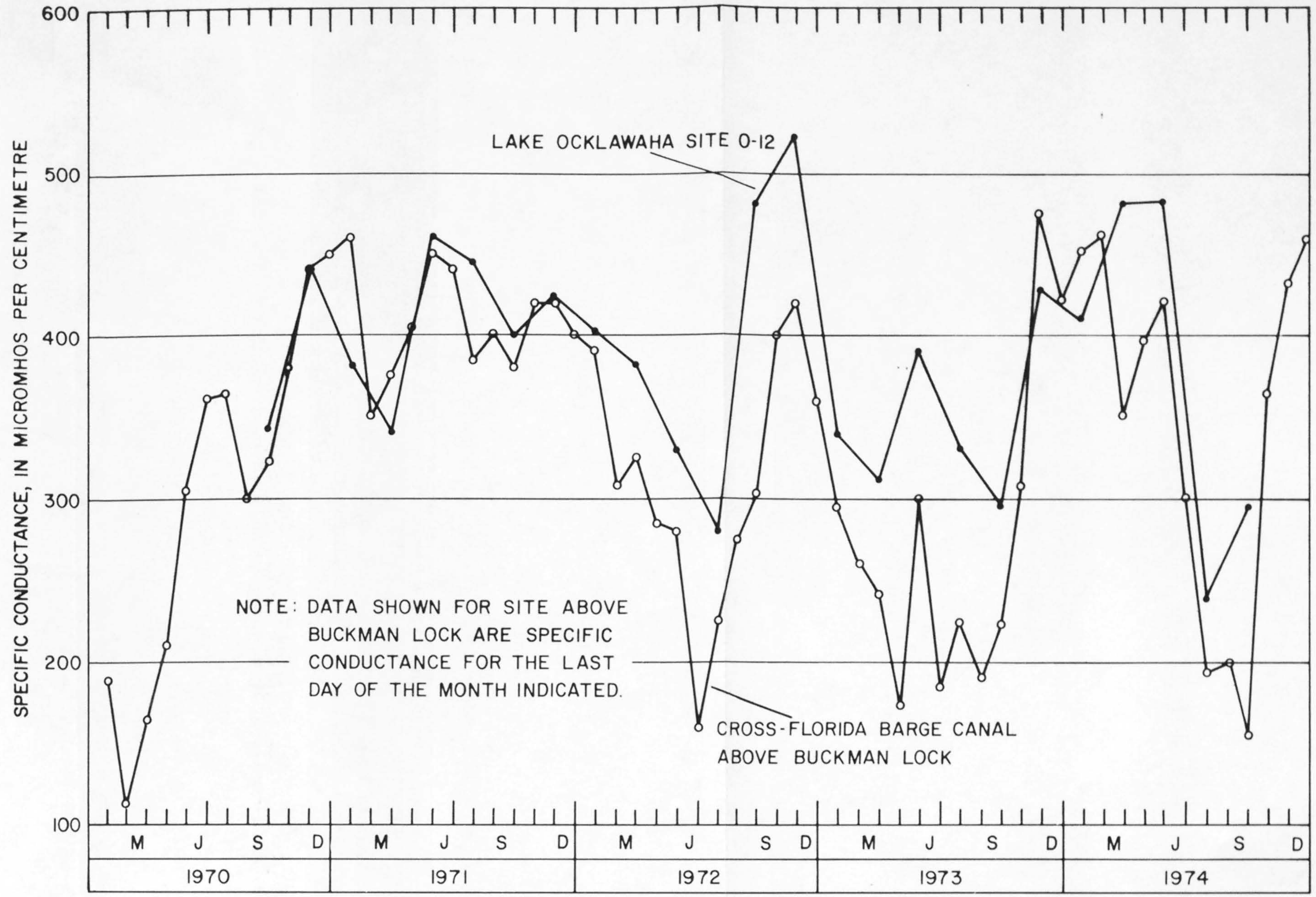
data indicate that this did not occur in the river prior to impoundment. During preimpoundment studies by the Federal Water Pollution Control Administration (1967), the minimum concentration of dissolved oxygen observed in the river below Eureka was 6.0 mg/l.

Because primary productivity in Lake Ocklawaha is much greater than that in the river before impoundment, concentrations of the plant nutrients, nitrogen and phosphorus, downstream of the lake have decreased since impoundment. During the preimpoundment study there was no significant decrease in these nutrients in the reach below Eureka, but in 1975 concentrations of both were substantially reduced in this reach.

Changes in the concentrations of dissolved oxygen, nitrogen and phosphorus, in and downstream from Lake Ocklawaha are closely related to the aquatic weed problems in the lake. Low dissolved oxygen concentrations generally do not occur in nearby lakes which do not have a similar aquatic weed problem.

Because water in the St. Johns River is higher in dissolved solids concentration than that in the Oklawaha River, the operation of Buckman Lock could conceivably increase the concentration of dissolved solids in Lake Ocklawaha. However, a comparison of the specific conductance at the upstream side of the lock with the specific conductance of the lake (fig. W.Q. 28) indicates that this has not happened. The specific conductance of the Barge Canal above the lock is sometimes slightly higher than that of the lake, possibly because more highly mineralized water has been locked up. More often, however, the water above the lock has a lower specific conductance and is less mineralized than that in the lake. This is due primarily to the inflow of surface runoff from a small tributary to the Barge Canal a short distance above Buckman Lock.

Although the specific conductance fluctuates over a wider range in the Barge Canal above the lock than in Lake Ocklawaha, the specific conductance in both the Barge Canal and the lake responds to seasonal and long-term variations in rainfall (fig. W.Q. 28). During much of 1971 and the first half of 1974, when rainfall was deficient, the specific conductance was greater than 400 micromhos/cm. The rainy seasons in 1972, 1973 and 1974 were accompanied by a significant reduction in the specific conductance of Lake Ocklawaha and the Barge Canal above Buckman Lock. The fairly sharp peak in specific conductance in the last half of 1972, was due in part to deficient rainfall but was also due to the lake level being lowered. The lake was drawn down in August 1972 and remained about 5 ft (1.5 m) below normal levels until February 1973 when the lake was again full. During this period, the flow from Silver Springs made up a larger part of the reservoir contents and consequently specific conductance was relatively high.



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY
SPECIFIC CONDUCTANCE
ABOVE BUCKMAN LOCK AND IN LAKE OCKLAWAHA
OKLAWAHA RIVER
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

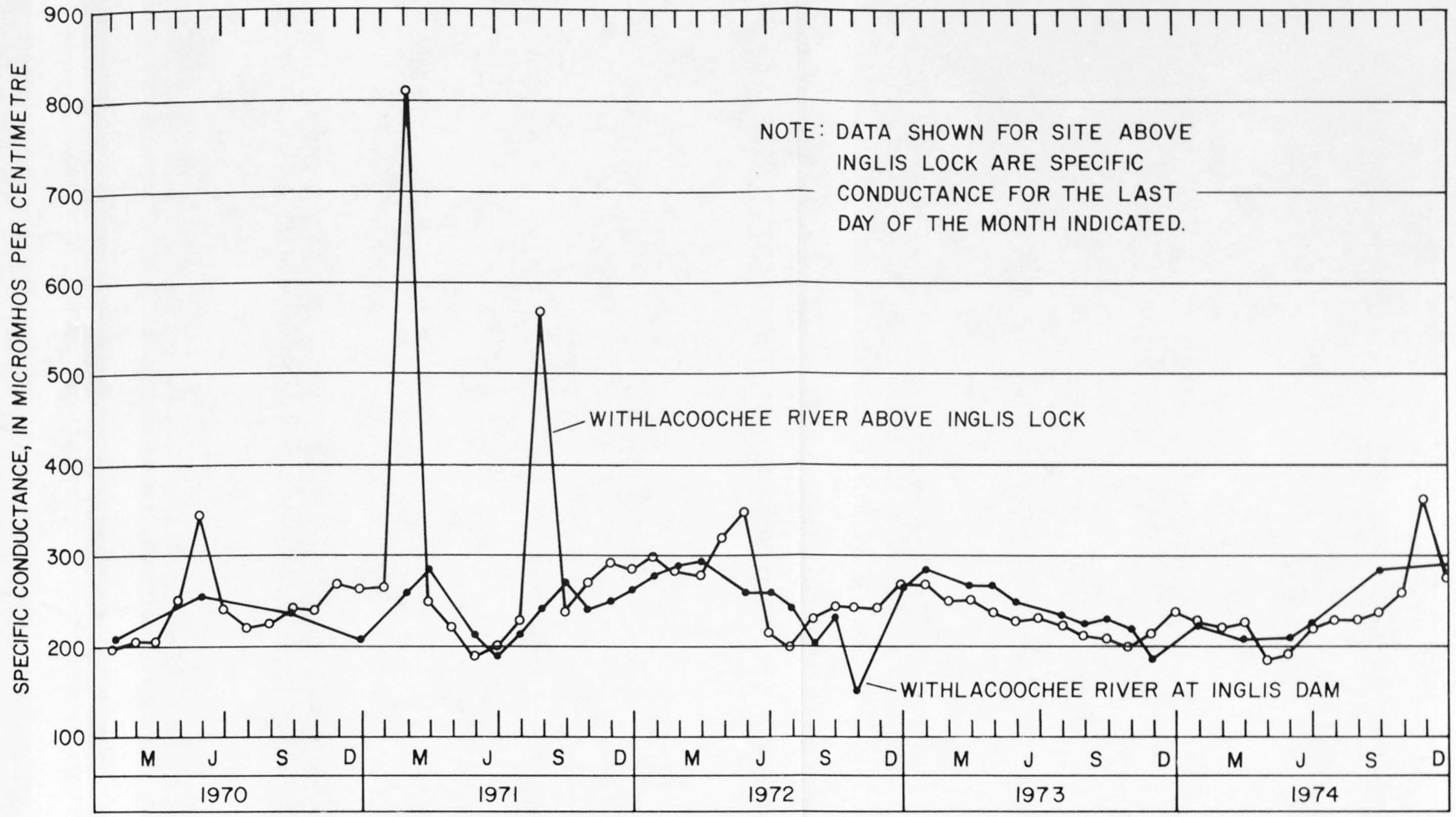
FEBRUARY 1976 FIGURE W. Q. 28

Because Lake Rousseau in the lower Withlacoochee River has been in existence since the early 1900's, recent changes in the quality of water in the lake and in the river above the lake have been small in comparison to changes in water quality in the lower Oklawaha River. During this investigation, the low dissolved oxygen concentrations observed in Lake Ocklawaha in the summer months seldom occurred in Lake Rousseau. Dissolved oxygen concentrations near the bottom of Lake Rousseau were less than 1.0 mg/l at the site above Inglis Dam, but dissolved oxygen concentrations near the surface and at other sites in the lake were generally greater than 4.0 mg/l. Aquatic plant problems were less severe in Lake Rousseau than in Lake Ocklawaha during this investigation, but aquatic plants are reported to have been less of a problem in Lake Rousseau in 1975 than during previous years. Low dissolved oxygen concentrations are closely related to plant problemsand Lake Rousseau may at times have low concentrations of dissolved oxygen.

The effects of the completion of the west end of the Barge Canal on the quality of water in the Withlacoochee River have been most apparent in that part of the river between Inglis Dam and the Barge Canal. Prior to construction this reach of the river was not affected by salt water from the Gulf of Mexico and the quality of water below the dam was similar to that in the lake. During this investigation, very little water was released through the dam and salt water occasionally affected the quality of water below Inglis Dam. In February 1975, the water in the river below the dam had a specific conductance of 2,340 micromhos/cm and a concentration of 600 mg/l chloride. Water in the Barge Canal below Inglis Lock during this investigation had a specific conductance which sometimes exceeded 21,000 micromhos/cm and chloride concentrations as high as 7,100 mg/l.

Graphs of specific conductance at sites above Inglis Lock (site W-12) and in Lake Rousseau (site W-10) are shown in figure W.Q. 29. This figure shows that the specific conductance at both sites generally ranges between 200 and 300 micromhos/cm. However, the month-end specific conductance has on occasion been as high as 800 micromhos/cm above the lock. The sharp peaks in specific conductance above the lock are the result of salt water being locked up; however, increases in specific conductance are temporary. Daily specific conductance records at this site indicate that the specific conductance has at times been as high as 3,400 micromhos/cm but the effects of locking salt water up generally last only a few hours.

If water were not diverted from the Barge Canal just upstream of the lock, the salt water locked up could migrate into Lake Rousseau. A comparison of the specific conductance above the lock with that in the lake (fig. W.Q. 29) indicates that this has not happened. Although salt water has occasionally been locked to the upper level, there has been no resultant increase in the specific conductance of Lake Rousseau. This substantiates Bush's (1973) conclusion that the chances of salt water reaching the lake are very low as long as there is discharge in the bypass channel.



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY
SPECIFIC CONDUCTANCE
ABOVE INGLIS LOCK AND ABOVE INGLIS DAM
WITHLACOOCHEE RIVER
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 — FIGURE W.Q. 29

Salt water locked into the Barge Canal above Inglis Lock is effectively flushed down the bypass channel into the Withlacoochee River. This has probably resulted in a very small increase in the average specific conductance and average chloride concentration in the river. However, any salt water entering the bypass channel is greatly diluted by water from Lake Rousseau and changes in the quality of water below the bypass channel are small. Bush (1973, p. 24) reported that increases in specific conductance in the Withlacoochee River below the bypass channel were generally less than 60 micromhos/cm and usually lasted less than 20 hours. During the present investigation the specific conductance of water in the bypass channel ranged from 200 to 337 micromhos/cm and was not appreciably higher than that observed prior to the completion of the lock (Federal Water Pollution Control Administration, 1967).

WATER USE WITH RESPECT TO WATER QUALITY STANDARDS

Surface-water and ground-water supplies in the area of the Cross-Florida Barge Canal are abundant. The use of these waters, however, is largely dependent upon the physical, chemical and sanitary characteristics. In the Oklawaha and Withlacoochee River basins the major uses of the surface water are for recreation and irrigation. Most of the ground water used is for irrigation and domestic water supplies. Some ground water and surface water are used for watering livestock, for industrial purposes, and as cooling water in thermoelectric power generation. However, the amount of water used for these purposes is small compared to irrigation and domestic supply requirements. Only the major types of water use will be discussed in this report.

Irrigation

The largest withdrawal use of water in the area of the Cross-Florida Barge Canal is for the irrigation of citrus, corn, vegetable, and melon crops. In 1970, irrigation withdrawals in Marion County, which encompasses about three-forths of the project area, averaged 6.8 million gallons (298,000 m^3/s) per day (Pride, 1973). Ground-water withdrawals accounted for about 85 percent of the water used for irrigation in Marion County and in other counties the percentage is even greater.

Ground water from the Floridan aquifer is used extensively for irrigation because of its widespread availability. The use of ground water for irrigation is particularly common in the higher, well-drained areas which are well suited to growing citrus. In the lower, flood-plain areas of the Oklawaha and Withlacoochee River basins, where the more fertile, fine textured soils are used to grow corn, various vegetables, and melons, surface water is often used for irrigation.

Properties of principal importance in determining the suitability of water for irrigation are the total concentration of the dissolved solids, the relative proportion of sodium to calcium and magnesium, the concentration of boron or other potentially toxic substances, and the concentration of bicarbonate as compared with the concentrations of calcium and magnesium.

If the concentrations of dissolved salts in irrigation water are high, these salts may accumulate in the soil, and result in saline soil. The specific conductance of the irrigation water is used as an index of the salinity hazard.

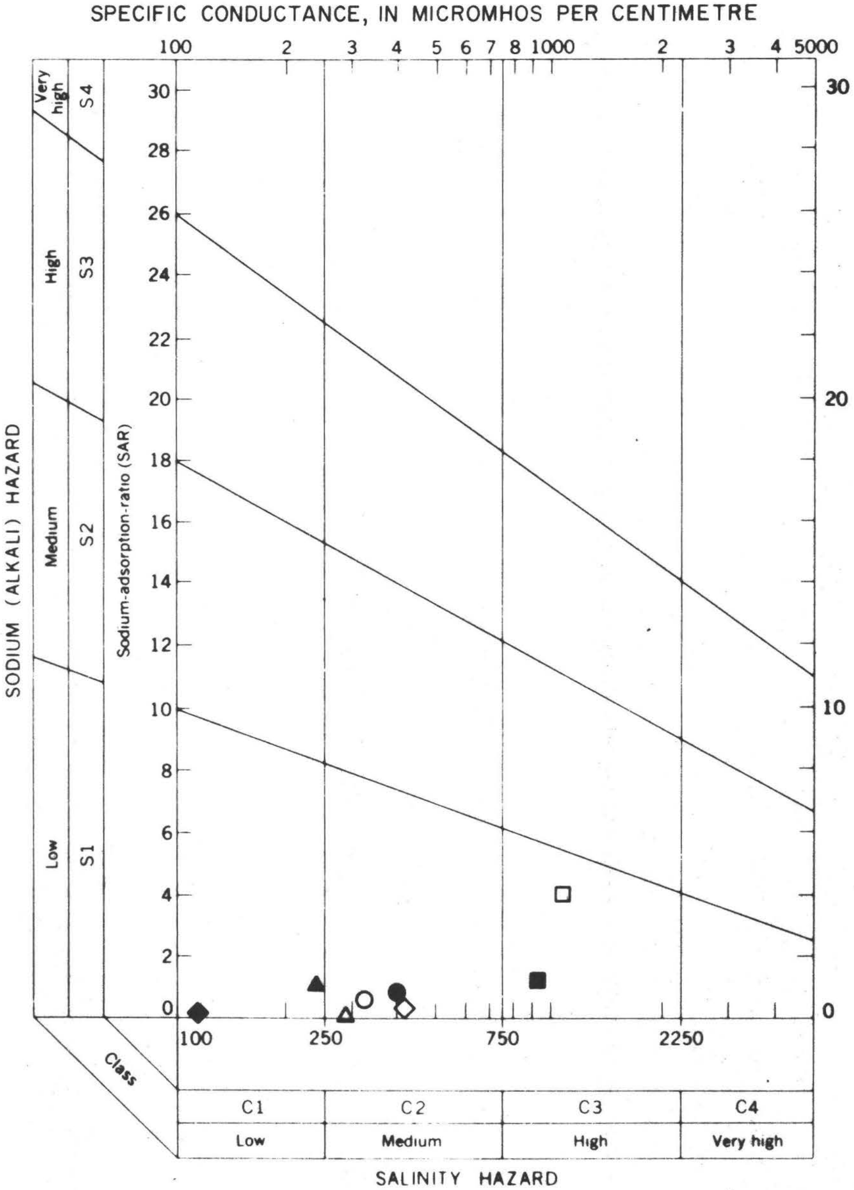
High concentrations of sodium in relation to the concentration of calcium and magnesium in irrigation water may have adverse effects on soil structure preventing the free movement of air and water through the soil. This sodium or alkali hazard as it is called has been studied extensively by the U.S. Salinity Laboratory Staff (1954). The Salinity Laboratory Staff introduced the sodium-adsorption-ratio (SAR) as a measure of the sodium hazard. This ratio is defined by the equation:

$$SAR = \frac{(Na+)}{\sqrt{\frac{(Ca++)+(Mg++)}{2}}}$$

where the concentration of the ions are expressed in equivalents per litre. The Salinity Laboratory Staff also prepared a diagram for classifying irrigation water with respect to its sodium and salinity hazards. That diagram is produced in modified form in figure W.Q. 30.

Data from analyses of surface water and ground water in the area of the Cross-Florida Barge Canal are plotted on figure W.Q. 30. The data, which were selected to represent low-flow conditions, indicate that surface water from both the Oklawaha and Withlacoochee Rivers, as well as water from the Floridan aquifer (Silver and Rainbow Springs), generally have a low sodium hazard and a low to medium salinity hazard. These waters are suitable for irritation of most crops in well drained soils and are suitable for all but low salt tolerance crops in soils with restricted drainage. Waters from the St. Johns River at Palatka and the shallow aquifer near Eureka (well CE-53S) have a high salinity hazard and are not well suited for irrigation. Although no data on the quality of water in the Floridan aquifer in the vicinity of the St. Johns River are shown, that aquifer contains water high in sodium chloride concentrations in the area of the St. Johns River and the lower Oklawaha River downstream of Orange Creek (Shampine, 1965) and is unsuitable for irrigation.

Data on the concentrations of boron in surface and ground water in the project area are scarce, but the continued irrigation of boron-sensitive citrus crops indicates that boron is not a problem. Concentra-



EXPLANATION

- ○ OKLAWAHA RIVER AT MOSS BLUFF, MAY 13, 1974
- ● OKLAWAHA RIVER NEAR SALT SPRINGS, MAY 2, 1972
- □ ST. JOHNS RIVER AT PALATKA, MAY 10, 1974
- △ WITHLACOOCHEE RIVER NEAR HOLDER, MAY 14, 1974
- ▲ LAKE ROUSSEAU NEAR DUNNELLON, MAY 14, 1975
- ◇ SILVER SPRINGS NEAR OCALA, MAY 16, 1974
- ◆ RAINBOW SPRINGS NEAR DUNNELLON, MAY 14, 1974
- ■ WELL CE-53S NEAR EUREKA, MAY 10, 1966

DIAGRAM AFTER U.S. SALINITY LABORATORY STAFF, 1954

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

DIAGRAM FOR THE CLASSIFICATION OF IRRIGATION WATERS

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 30

tions of herbicides in irrigation water in the area of this investigation are normally very low and generally do not present a hazard.

Concentrations of bicarbonate greatly in excess of the concentrations of calcium and magnesium in irrigation water may cause the pH of the soil to increase and may result in "black alkali" soil. Surface and ground waters in the area of the Cross-Florida Barge Canal are calcium, magnesium bicarbonate waters, but the concentrations of bicarbonate generally do not exceed those of calcium and magnesium.

Domestic Use

Safe limits have been established for the concentrations of various chemicals and certain bacteria in water to be used for drinking and other domestic purposes. The limits usually quoted for drinking water are based on the 1962 revision of the U.S. Public Health Service drinking water standards. A recent and more comprehensive report which recommends limits for public water supplies and other use categories is "Water Quality Criteria, 1972," (Environmental Protection Agency, 1973). Some of these recommended limits for water to be used for public water supplies are given in table 22 which also contains summaries of water-quality data from both ground-water and surface-water samples collected in the area of the Cross-Florida Barge Canal.

Water from the Floridan aquifer generally is suitable for use as a public water supply. However, color and concentrations of phenols have occasionally exceeded the recommended limit in some water samples from the Floridan aquifer. Color and concentration of iron in water in the shallow aquifer often exceeds the recommended limit. The analyses of water from the Floridan aquifer summarized in table 22 do not include iron but analyses of public supplies in north-central Florida (Healy, 1972) indicate that iron generally is not a problem in water from the Floridan aquifer. Concentrations of chloride were low in water from both the Floridan and shallow aquifers. No samples were collected from wells tapping either aquifer in the vicinity of the St. Johns River and the Oklawaha River basin below Orange Creek. According to Shampine (1965), the chloride concentration of water from such wells exceeds the recommended public water supply limit of 250 mg/l. A coliform bacteria count of 7,400 colonies/100 ml was measured in the water from one Floridan aquifer well and therefore bacteria may be of local concern.

Mean concentrations of most constituents in surface water in the area of the Cross-Florida Barge Canal are usually less than the recommended limits for public water supply. However, quality of surface water is variable and occasionally the concentrations of constituents exceed the recommended limits. Color and the concentrations of coliform bacteria, ammonia nitrogen, chloride, and iron have exceeded the

Table 22. -- Water quality criteria for public water supplies and summaries of surface-water and ground-water quality in the area of the Cross-Florida Barge Canal.

Constituent or Property	Recommended Limit[1]	Shallow Aquifer (3 wells)			Floridan Aquifer (20 wells)			Surface Waters (21 stations)		
		Number of Samples	Mean	Max.	Number of Samples	Mean	Max.	Number of Samples	Mean	Max.
Physical										
Color (units)	75	3	5	5	232	7.8	320	343	48	400
Microbiological										
Coliform organisms/100 ml.	20,000				199	77	7,400	291	1,527	87,000
Fecal organisms/100 ml.	2,000							119	67	1,200
Inorganic chemicals										
Ammonia nitrogen (mg/l)	.5				209	.04	.41	464	.06	2
Arsenic (ug/l)	100							31	3	12
Cadmium (ug/l)	10							12	1	5
Chloride (mg/l)	250	3	30	77	227	6.4	24	332	154	7,100
Chromium (ug/l)	50							2	0	0
Copper (ug/l)	1,000							37	3	14
Fluoride (mg/l)	1.6[2]	3	.2	.6				58	.3	.7
Iron (ug/l)	300	3	640	1,700				39	84	410
Lead (ug/l)	50							38	4	12
Manganese (ug/l)	50							37	6	40
Mercury (ug/l)	2							30	.1	.5
Nitrate nitrogen (mg/l)	10	3	.1	.2	223	.38	4.50	812	.15	4.3
Nitrite nitrogen (mg/l)	1				209	.00	.03	538	.01	.27
Selenium (ug/l)	10							9	2	8
Sulfate (ug/l)	250	3	27	76				60	38	79
Zinc (ug/l)	5,000							37	14	110
Organic chemicals										
Insecticides										
Aldrin (ug/l)	1				39	.00	.00	36	.00	trace
DDT (ug/l)	50				39	.01	.04	36	.00	.02
Dieldrin (ug/l)	1				39	.00	.00	36	.00	.00
Endrin (ug/l)	.5				39	.00	.00	36	.00	.00
Heptachlor (ug/l)	.1				39	.00	.00	36	.00	.00
Lindane (ug/l)	5				39	.00	.01	36	.00	.00
Phenols (ug/l)	1				39	.6	10	29	1	8

1 Published in "Water Quality Criteria 1972," Environmental Protection Agency, 1972

2 Based on average annual air temperature for north-central Florida.

recommended limits, particularly in samples collected from the St. Johns River at Palatka. The mean concentration of phenols exceeds the recommended limit, but this is due to one high concentration and the small number of samples analyzed for phenols.

No standards or recommended limits for hardness have been established. Hardness in water forms curd when soap is added and is in part responsible for deposits of scale in water pipes, heaters, and boilers. Hardness is due primarily to the concentration of calcium and magnesium in the water. Consequently, water from many areas underlain by limestone and dolomite is harder than desirable.

In the area of the Cross-Florida Barge Canal, the hardness of the water from the Floridan aquifer generally is greater than 120 mg/l (as $CaCO_3$) and the water is classified as hard to very hard. Softening is desirable for most uses. Because ground water contributed by springs makes up a large part of the flow, streams in the area generally contain moderately hard to very hard water. A few small streams and the shallow aquifer in the eastern part of the project area, where the Floridan aquifer is not exposed, contain soft to moderately hard water.

Recreation

Recreation, including swimming, boating and fishing, probably is the largest use of surface-water in the area of the Cross-Florida Barge Canal. The recreational use of water is nonwithdrawal use, but one which is important to the local economy. Silver Springs and Rainbow Springs with their respective average discharges of 823 and 788 ft^3/s (23.3 and 22.3 m^3/s) are the two largest fresh-water springs in Florida (Rosenau and Faulkner, 1974) and are major tourist attractions. The clarity and moderate temperature of the water and the natural beauty of the surroundings make these springs and downstream parts of the Oklawaha and Withlacoochee Rivers popular areas for boating, fishing, swimming, and other water related activities. The lower Oklawaha River, Lake Ocklawaha and the St. Johns River have gained national recognition for the excellent fishing they provide.

Waters used for such recreational purposes necessarily should be esthetically pleasing and free from pathogenic bacteria and substances that are toxic or harmful to humans, other animals or plant life. Most fish and other forms of aquatic life require relatively clean water and a good supply of dissolved oxygen among other factors.

Water-quality criteria established by the Florida Department of Pollution Control for waters used for recreation and the propagation and management of fish and wildlife, recommend that total coliform bacteria not exceed 1,000 colonies/100 ml as a monthly average and that no sample contain more than 2,400 colonies/100 ml. Also the pH should be within the range of 6.0 to 8.5 and the dissolved oxygen concentration should not be less than 4.0 mg/l. Exceedences of pH and dissolved oxygen values outside of these limits must be due only to natural causes.

Surface waters in the area of this investigation are generally free from objectionable floating and suspended materials and are attractive in appearance. The pH of these waters rarely is less than 6.0 or more than 8.5, but the concentration of coliform bacteria sometimes exceeds the recommended limit and the dissolved oxygen concentration is at times less than the recommended minimum concentration.

Concentrations of coliform bacteria in Silver Springs, Rainbow Springs and the lower Oklawaha and Withlacoochee Rivers generally are less than 1,000 colonies/100 ml. However, the concentrations of coliform bacteria frequently exceed this limit in the St. Johns River, and in the upper parts of the Oklawaha and Withlacoochee Rivers, above the spring inflow. Concentrations of coliform bacteria exceeded 1,000 colonies/100 ml in 10 of the 26 samples analyzed for the St. Johns River at Palatka, 24 of the 47 samples analyzed for the Oklawaha River at Moss Bluff, and 11 of the 36 samples analyzed for the Withlacoochee River at Holder.

Dissolved oxygen concentrations in the Oklawaha and Withlacoochee River basins generally exceed 4.0 mg/l, but have occasionally been less than that concentration at most sampling sites. The dissolved oxygen concentration at Silver Springs is less than 4.0 mg/l most of the time. Approximately 10 percent of the dissolved oxygen measurements made in the Oklawaha River at Moss Bluff, at Eureka and in Lake Ocklawaha have been less than 4.0 mg/l, but 6 of the 16 measurements made in Deep Creek have been less than that value. Dissolved oxygen concentrations in the St. Johns River at Palatka have been less than 4.0 mg/l in 3 out of 28 samplings. Of the sampling sites in the Withlacoochee River basin, the station at Holder most frequently had dissolved oxygen concentrations less than 4.0 mg/l. Dissolved oxygen concentrations were less than 4.0 mg/l in 8 of the 40 measurements at that site. About 11 percent of the measurements made in Lake Rousseau above Inglis Dam and none of the measurements made in Rainbow and in the Bypass Channel below the control structure were less than 4.0 mg/l.

NUTRIENT LOADING OF SURFACE WATERS

The plant nutrients, nitrogen and phosphorus, make up only a small part of the dissolved solids in surface waters. However, the concentrations of these nutrients affect the overall quality of the aquatic environment in that they are necessary for growth of aquatic plants. Although high concentrations of phytoplankton do not constitute a problem in the lower parts of the Oklawaha and Withlacoochee Rivers, massive growths of hyacinths and rooted aquatic plants often restrict navigational and recreational uses of these waters. These aquatic plants are particularly troublesome in Lakes Ocklawaha and Rousseau.

Oklawaha River

From January 1 through December 31, 1975, approximately 628 tons (570 tonnes) of nitrogen and 29 tons (26 tonnes) of phosphorus were transported past Rodman Dam and into the St. Johns River. In the same period 15 tons (14 tonnes) of nitrogen and 0.4 tons (.4 tonne) of phosphorus were discharged through Buckman Lock to the St. Johns River. The combined load of these nutrients through the 2 points of discharge in the 1-year period represented a net gain of about 479 tons (435 tonnes) of nitrogen and 22 tons (20 tonnes) of phosphorus between Moss Bluff and the 2 points of discharge from Lake Ocklawaha. This increase in nitrogen and phosphorus loads is attributed largely to the inflow from Silver Springs.

Estimated budgets of nitrogen and phosphorus are given for three reaches of the Oklawaha River (table 23). Instantaneous concentrations and discharges at the time of each monthly sampling were used to estimate the loads for that month. Nitrogen and phosphorus loads contributed by rainfall-dry fallout were computed from the average concentrations in bulk precipitation given in table 3, total rainfall for the period measured at Inglis and Buckman Locks, and the area of the water surface. Nitrogen and phosphorus loads contributed by groundwater inflow and by overland runoff, other than that measured in the larger tributaries could not be measured, but are probably small in comparison to other inputs.

Silver Springs contributed 420 tons (381 tonnes) of nitrogen and 33 tons (30 tonnes) of phosphorus and is the largest nutrient source in the lower Oklawaha River basin (table 23). Although concentrations of nitrogen and phosphorus in Silver Springs are much less than those in the Oklawaha River above the spring, because of its high discharge, Silver Springs contributed about two times as much nitrogen and five times as much phosphorus as the upper Oklawaha River.

Table 23. --Estimated nitrogen and phosphorus budgets for reaches of the Oklawaha River for January-December 1975.

Budget item	Nitrogen load, in tons	Phosphorus load, in tons
Oklawaha River from Moss Bluff (0-1) to near Ocala (0-2)		
Inflow at Moss Bluff (0-1)	164	7.3
Inflow from rainfall-dry fallout	1.0[1]	.1[1]
Outflow at site near Ocala (0-2)	215	7.3
Retained (-) or lost (+)	+50	-.1
Oklawaha River from near Ocala (0-2) to Eureka (0-5)		
Inflow at site near Ocala (0-2)	215	7.3
Inflow from Silver Springs (0-3)	420	33
Inflow from rainfall-dry fallout	1.4[2]	.1[2]
Outflow at Eureka (0-5)	701	36
Retained (-) or lost (+)	+64.6	-4.4
Oklawaha River from Eureka (0-5) to Rodman Dam (0-14)		
Inflow at Eureka (0-5)	701	36
Inflow from Orange Creek (0-8)	36	1.1
Inflow from Deep Creek (0-11)	55	2.9
Inflow from rainfall-dry fallout	47[3]	2.6[3]
Outflow at Rodman Dam (0-14)	628	29
Outflow from Buckman Lock (0-16)	15	.4
Retained (-) or lost (+)	-196	-13.2

[1]Computed from average concentration in table 3 and a surface area of 200 acres.
[2]Computed from average concentration in table 3 and a surface area of 280 acres.
[3]Computed from average concentration in table 3 and a surface area of 9,100 acres.

Nitrogen loads increased in a downstream direction from Moss Bluff to Eureka, but decreased in the Lake Ocklawaha reach between Eureka and Rodman Dam (table 23). In the reach from Moss Bluff to site 0-2 above Silver Springs, the nitrogen load increased by 51 tons (46 tonnes). This represents 24 percent of the total load at site 0-2 and was probably due to discharge from agricultural areas.

The reach from 0-2 to 0-5 is located in and occupies about the same area as the proposed Eureka Pool of the Barge Canal. In this reach the nitrogen load increased by about 65 tons (59 tonnes). Nearly 15 tons (14 tonnes) more than the combined inputs from the upper Oklawaha River, Silver Springs and rainfall-dry fallout. This increase in nitrogen load was 9 percent of the total load at Eureka and was probably due to unmeasured surface runoff and ground water inflow between the sites.

In the Lake Ocklawaha reach (Eureka to Rodman Dam), 196 tons (178 tonnes) of nitrogen were retained during 1975. This was 23 percent of the 839 tons (761 tonnes) of nitrogen contributed by the Oklawaha River, Deep Creek, Orange Creek and rainfall-dry fallout. The nitrogen load at Eureka accounted for about 84 percent of the total nitrogen input to the lake and rainfall-dry fallout contributed 47 tons (43 tonnes) of nitrogen or about 6 percent of the total nitrogen input.

Phosphorus loads decreased slightly downstream from Moss Bluff (site 0-1) to near Ocala (site 0-2) with about 0.1 ton (.1 tonne) being retained in the reach. At Eureka (site 0-5), the phosphorus load was 4.4 tons (4.0 tonnes) less than the input from the upper Oklawaha River, Silver Springs and rainfall-dry fallout. The Lake Ocklawaha reach retained about 13 tons (12 tonnes) of phosphorus or about 31 percent of the total 42.6 tons (38.7 tonnes) input during 1975. About 85 percent of the total phosphorus input to Lake Ocklawaha came from the Oklawaha River above Eureka. Inflow from Deep Creek, the second largest source of phosphorus to Lake Ocklawaha, contributed 2.9 tons (2.6 tonnes) of phosphorus, about 7 percent of the total input. The remaining 8 percent of measured inflow came from rainfall-dry fallout and Orange Creek.

The reduction in nitrogen and phosphorus in the Lake Ocklawaha reach is attributed largely to their assimilation by the aquatic plants in the lake. By August 1975, hydrilla and other rooted aquatic plants were so abundant in some parts of the lake that boating was restricted to the old river channel and to the excavated part of the canal. The retention of nitrogen and phosphorus in the lake was also partly due to the settling of particulate nitrogen and phosphorus to the bottom.

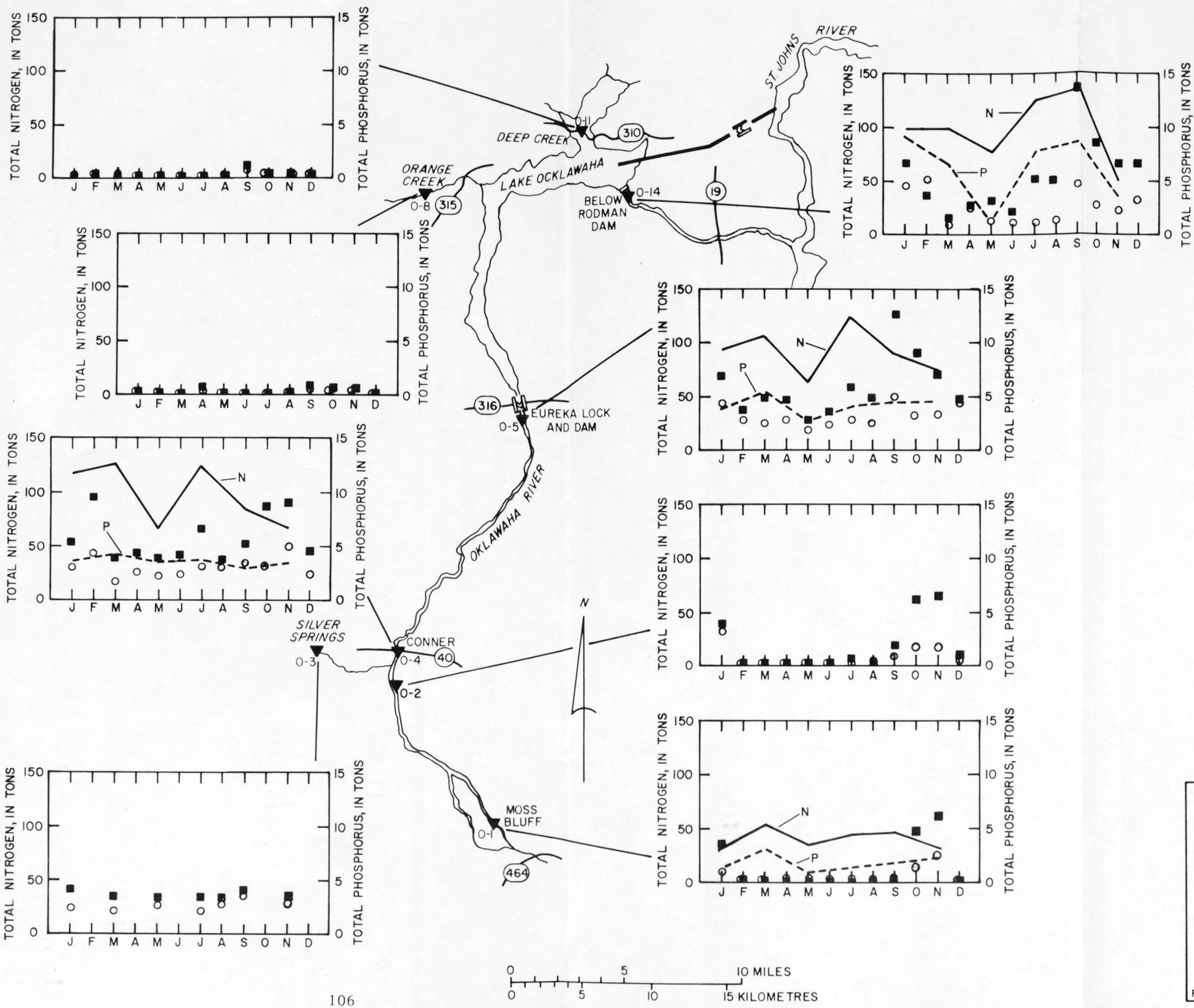
There are no well-defined seasonal patterns in the variations of nitrogen and phosphorus concentrations; therefore, the loads vary mainly as a function of discharge. The seasonal pattern in nitrogen and phosphorus monthly loads at several sites in the Oklawaha River basin for 1975 are given in figure W.Q. 31. In addition to the 1975 data, monthly loads of nitrogen and phosphorus based on data collected from 1968 through 1974 were also calculated for four sites (fig. W.Q. 31). The graphs of figure W.Q. 31 show that nitrogen and phosphorus loads generally are highest during early spring when the discharges are high as a result of the lakes in the upper basin being lowered, and also during late summer and early fall when discharges are normally high from seasonally high rainfall.

A comparison of the 1975 loads and the loads based on 1968-74 averages indicates that nutrient loads were generally lower in 1975 than in previous years. Nitrogen and phosphorus loads were lower in 1975 largely because discharges in 1975 were well below normal and below the average discharges for the period 1968-1974. Also, concentrations of nitrogen and phosphorus in 1975 were slightly less than the average monthly concentrations during the period 1968-1974.

Withlacoochee River

During 1975, approximately 504 tons (457 tonnes) of nitrogen and 42 tons (38 tonnes) of phosphorus were released from Lake Rousseau into the lower Withlacoochee River and the western end of the Barge Canal. About 55 percent of the nitrogen and 74 percent of the phosphorus released from Lake Rousseau originated in that part of the basin below Holder which normally contributes about 60 percent of the water released from the lake. Inflow from Rainbow Springs contributed 281 tons (255 tonnes) of nitrogen and 22 tons (20 tonnes) of phosphorus during this period and was the largest individual source of these nutrients in the basin.

Estimated budgets for nitrogen and phosphorus for two reaches of the Withlacoochee River in 1975 are given in table 24. In the reach between Holder (site W-2) and site W-4 above Blue Run, there was an increase in both the nitrogen and phosphorus loads. A downstream gain of about 58 tons (54 tonnes) of nitrogen and 4 tons (3.6 tonnes) of phosphorus occurred in this reach.



NOTE: TONNES (METRIC) MAY BE CALCULATED BY MULTIPLYING TONS BY 0.9072

LOADS SHOWN ARE TOTAL LOADS FOR THE MONTH

EXPLANATION

NITROGEN (N) AND PHOSPHORUS (P) LOADS CALCULATED FROM AVERAGE DISCHARGE AND AVERAGE MONTHLY CONCENTRATIONS FOR THE PERIOD 1968-1974 ARE SHOWN AS SOLID OR DASHED LINES, RESPECTIVELY.

■ NITROGEN LOAD AT TIME OF SAMPLING, 1975

○ PHOSPHORUS LOAD AT TIME OF SAMPLING, 1975

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

NITROGEN AND PHOSPHORUS LOADS IN THE OKLAWAHA RIVER

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 31

Table 24.--Estimated nitrogen and phosphorus budgets for reaches of the Withlacoochee River for January-December 1975.

Budget item	Nitrogen load, in tons	Phosphorus load, in tons
Withlacoochee River from Holder (W-2) to above Blue Run (W-4)		
Inflow at Holder (W-2)	226	11
Inflow from rainfall-dry fallout	1.3[1]	.1[1]
Outflow above Blue Run (W-4)	285	15
Retained (-) or lost (+)	+57.7	+3.9
Withlacoochee River from above Blue Run (W-4) to Bypass Channel (W-14)		
Inflow above Blue Run (W-4)	285	15
Inflow from Rainbow Springs (W-6)	281	22
Inflow from rainfall-dry fallout	22[2]	1.2[2]
Outflow from Bypass Channel (W-14)	464	40
Outflow from Inglis Dam (W-10)	36	1.8
Outflow from Inglis Lock (W-12)	3.6	.0
Retained (-) or lost (+)	-84.4	+3.6

[1]Computed from average concentration in table 3 and a surface area of 250 acres.

[2]Computed from average concentration in table 3 and a surface area of 4,200 acres.

The nitrogen input between site W-4 above the inflow from Rainbow Springs and the lower end of Lake Rousseau exceeded the amount leaving Lake Rousseau by 84 tons (76 tonnes). The amount of nitrogen retained in the reach accounted for about 14 percent of the total nitrogen input. During the same period, the phosphorus load increased by about 9 percent in this reach. The phosphorus load leaving Lake Rousseau by way of the bypass channel and through Inglis Lock and Inglis Dam was 3.6 tons (3.3 tonnes) more than the measured input.

The retention of 84 tons (76 tonnes) of nitrogen in Lake Rousseau is probably due mainly to the uptake of nitrogen by aquatic plants. Although problems with aquatic plants in Lake Rousseau were generally less severe than those in Lake Ocklawaha in 1975, Lake Rousseau has been plagued with these weeds for many years. In view of the heavy growth of aquatic plants in Lakes Rousseau and Ocklawaha, the retention of nitrogen in these lakes is not surprising. The fact that Lake Ocklawaha retained about 2½ times as much nitrogen as Lake Rousseau is probably due to the more favorable conditions for the growth of these aquatic plants in Lake Ocklawaha. Lake Ocklawaha is shallower and has a much larger surface area than Lake Rousseau.

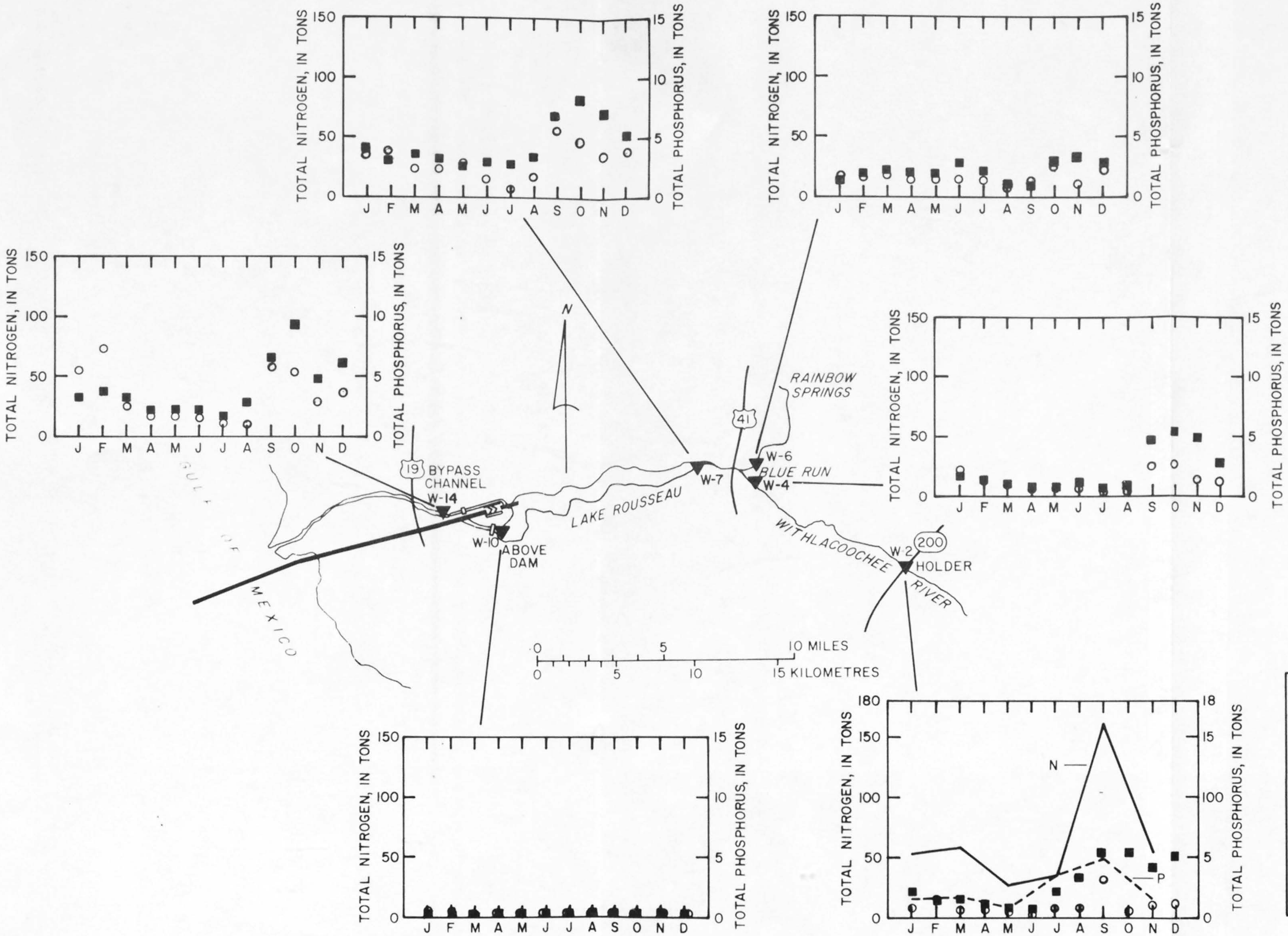
The retention of phosphorus in Lake Ocklawaha is apparent from the budget in table 23. However, the phosphorus budget for Lake Rousseau in table 24 indicates that the lake is receiving phosphorus from a source other than the upper Withlacoochee River, Rainbow Springs and rainfall-dry fallout. Although ground-water inflow and unmeasured surface runoff along this reach of the river contribute some phosphorus, the small increase in flow in this reach suggest that bottom materials in the lake may be releasing phosphorus. This is supported by the fact that analyses given in table 20 indicate that bottom materials in Lake Rousseau contain very high concentrations of phosphorus.

Another possible source of phosphorus is the effluent from the Dunnellon sewage treatment plant which discharges into the Withlacoochee River. However, it is unlikely that the effluent from this small plant is solely responsible for the high phosphorus input. Sewage effluent normally contains much more nitrogen than phosphorus and had this been the source of the phosphorus, a much higher nitrogen load would probably have been measured. Also, concentrations of phosphorus at the sampling site nearest the sewage treatment plant were often less than concentrations of phosphorus in the bypass channel below Lake Rousseau.

Monthly loads of nitrogen and phosphorus at six sites in the Withlacoochee River basin are shown for 1975 in figure W.Q. 32. The graphs show that nitrogen and phosphorus loads are highest in the late summer

NOTE: TONNES (METRIC) MAY BE CALCULATED BY MULTIPLYING TONS BY 0.9072

LOADS SHOWN ARE TOTAL LOADS FOR THE MONTH



EXPLANATION

NITROGEN (N) AND PHOSPHORUS (P) LOADS CALCULATED FROM AVERAGE DISCHARGE AND AVERAGE MONTHLY CONCENTRATIONS FOR THE PERIOD 1968-1974 ARE SHOWN AS SOLID OR DASHED LINES, RESPECTIVELY.

■ NITROGEN LOAD AT TIME OF SAMPLING, 1975

○ PHOSPHORUS LOAD AT TIME OF SAMPLING, 1975

CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT

WATER QUALITY

NITROGEN AND PHOSPHORUS LOADS IN THE WITHLACOOCHEE RIVER

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U.S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976

FIGURE W.Q.32

and fall, near the end of the rainy season when discharges are high. Nitrogen and phosphorus loads were generally lowest in April and May when minimum discharge normally occurs.

The effects of regulation on nutrient loads are much less noticeable in Lake Rousseau than in Lake Ocklawaha. Although a low-head inflatable dam in the river about 17 mi (27 km) upstream from Holder is sometimes used to maintain water levels in a lake which drains to the river, the upper Withlacoochee River is not regulated to the extent that the upper Oklawaha River is regulated. The higher loads of nitrogen and phosphorus that occur in the spring of the year in the lower Oklawaha River do not occur in the lower Withlacoochee River. The phosphorus loads at site W-14 in the bypass channel were high in January and February, but this was due to higher concentrations of phosphorus and not high rates of release from Lake Rousseau.

A graph of monthly loads of nitrogen and phosphorus based on average monthly concentrations and discharges for the period 1968-74 is shown for the site near Holder (W-2) in figure W.Q. 32. A comparison of the 1975 monthly loads at Holder to the monthly loads for the 1968-74 period indicates that although the seasonal patterns were the same, loads of nitrogen and phosphorus were lower in 1975 than in previous years. Concentrations of nitrogen at Holder in 1975 were slightly lower than the average concentration for the period 1968-74, but the smaller loads were due primarily to relatively low discharge during 1975. Loads of nitrogen and phosphorus in the Withlacoochee River basin could be expected to be appreciably higher during periods of average or above average discharge than they were in 1975.

WASTE-ASSIMILATIVE CAPACITY OF THE OKLAWAHA AND WITHLACOOCHEE RIVER SYSTEMS

By
M. L. Merritt

The ability of a river system or water body to assimilate organic wastes without altering its chemical and physical properties beyond acceptable limits depends primarily on the dissolved oxygen concentration. The factors influencing dissolved oxygen concentration, particularly plant oxygen production and respiration, benthic demand, BOD concentration, and reaeration rate, are in turn affected by physical characteristics of the water body, such as width, depth, and velocity of flow. The Cross-Florida Barge Canal, if construction continues according to one of the alternative plans, will change the physical characteristics of the present Oklawaha and Withlacoochee River systems; hence, the factors that influence dissolved oxygen concentration will be affected, thereby affecting waste-assimilative capacities of the two river systems.

This section of the report presents the results of the application of a digital computer model to characteristic types of channel segments with different physical characteristics in the Oklawaha and Withlacoochee River systems to determine the sensitivity of dissolved oxygen concentration to the several factors, both man-caused and natural, that influence it. Since the proposed canal alinement is mostly through rural and predominantly undeveloped areas, which are likely to remain essentially in that condition, the effect of natural oxygen demands assumes greater significance than man-caused influences.

In modeling the two streams, not all parts of the stream systems were used. In fact, there would have been substantial difficulties in doing this since some of the omitted parts (the canal below Lake Ocklawaha and the canal below Inglis Lock and Inglis Dam) either are open to salt water and experience estuarine effects which the DO model is not designed to handle, or do not flow continuously since the locks are opened only for short periods of time at irregular intervals. The two continuous-flow stems, with tributary inflows and outflows, culminating in the natural streams at the lower ends, were considered to be sufficient scope for the present section on assimilative capacity.

The Model

The model used was programmed in FORTRAN at the Gulf Coast Hydroscience Center in Bay St. Louis, Mississippi, to predict stream biochemical characteristics due to man-caused and natural waste inputs (Bauer and Jennings, written commun. 1975). With this model, 24-hour average dissolved oxygen and BOD profiles are determined. "Profile" here refers to a tabulation of concentrations at fixed-distance intervals downstream.

The model is based primarily on the Streeter-Phelps oxygen-sag equation, assumes a one-dimensional system with constant streamflow, and requires the stream system modeled to be broken into a number of segments, or reaches. To make the model work, a set of input parameters representing quantitatively the hydrological factors that influence dissolved oxygen and BOD levels are needed. The input parameters are constant, average values for each reach. Calibration, or verification that the input parameters are reasonable, is necessary before the desired sensitivity analyses and waste load tests can be performed. Calibration is achieved by varying physically realistic estimates of selected input parameters in a series of computer runs until computer-generated profiles match existing field-measured profiles. The calibration is as unique for a given 24-hour time period as are the parameters used.

The Data Input

The following parameters were used: BOD decay rate, background BOD, net productivity, reaeration rate, channel width and depth, temperature, and velocity of flow.

BOD Decay Rate

As organic material decomposes in a stream, it reacts chemically with dissolved oxygen and the levels of both BOD and dissolved oxygen concentration are reduced. Consequently, a coefficient for the rate of decay of BOD must be included in the model. The decay rate is assumed to be a linear function of the amount present so that the BOD concentration will be exponential with time. The BOD decay rate in the area of this investigation was estimated to be about 15 percent per day and a coefficient of 0.15 was used in the model.

Background BOD

In reaches of the Oklawaha and Withlacoochee Rivers which have little runoff and no known waste discharges, the level of BOD at most measuring stations, nonetheless, is often appreciable. Data collected during this investigation indicate that BOD levels fluctuated with time and differed somewhat from one measuring site to another, but generally ranged from 0.5 to 2.0 mg/l. The source of the indigenous or "background" BOD is the death and decay of aquatic plants and organisms, falling leaves, logs, decomposable trash, or other types of organic material. Without continual input or renewal this background BOD level would quickly decay to an unmeasurable quantity. The effect of background BOD is most evident, and often a dominating factor, in large slow-moving impounded streams with a great deal of aquatic life.

In the water-quality model used in this investigation there is no parameter that represents background BOD, but a time rate of occurrence of new background BOD is incorporated into the model by treating it as linear runoff along the river. Discharge of and concentration of BOD--and also dissolved oxygen--from tributary inflow were estimated from field measurements.

Net Productivity

In modeling the Oklawaha and Withlacoochee River systems as described here, values of one single parameter were used to represent the net effect of plant production, respiration, and benthic demand. This parameter is referred to as net productivity (P-R-B parameter). Values of net productivity used in this model were derived from the calibration process. These three variables must be considered in water-quality modeling of streams because of their net effect on dissolved oxygen.

Plants are net oxygen consumers during the night, but produce oxygen during the day when sunlight is available for photosynthesis. In fast-flowing channels where, typically, few vascular plants and little algae are present, production and respiration are slight. In slow-moving channels where aquatic plants are likely to be abundant, production and respiration may be substantial and may significantly outweigh other factors in determining the oxygen concentration profile.

Benthic demand is the other factor considered here that determines the nature of the dissolved oxygen profile. It is possible to account for benthic demand in modeling, but it is often difficult to estimate quantitatively. Consequently, benthic demand is sometimes included in the numerical estimate of net production as in the model of Bella (1970).

Reaeration Rate

The dissolved oxygen concentration in water in any stream is affected by reaeration which increases with velocity and decreases with depth. Stream velocity and depth can be incorporated into models, as can the temperature effects upon reaeration. The effects of wind on reaeration, although important, normally are not incorporated into models because the necessary data are difficult to obtain. Reaeration rate may be computed for each reach by means of the Bennett-Rathbun equation (Bennett and Rathbun, 1972) or may be specified by the user of the model. Reaeration coefficients for each stream segment in the Oklawaha and Withlacoochee Rivers were computed in the model from average velocity, depth, and temperature by the Bennett-Rathbun equation. The Bennett-Rathbun equation, and other empirical equations for estimating reaeration rate, were developed for fast-flowing streams, in which reaeration occurs as a result of turbulence and vertical mixing. In the slow-moving reservoir sections, the only oxygen exchange between the air and water occurs at the surface layer, and the amount exchanged is considerably affected by surface wind. There is very little turbulent mixing, so that oxygen exchange between the various layers of water is the result of a dispersion process. For that reason the Bennett-Rathbun equation may not provide a reliable estimate of the atmospheric reaeration which occurs in the impounded sections nor in the slow-moving reaches of the streams.

However, by virtue of the choice of physical parameters used in the Bennett-Rathbun equation, average velocity of flow and depth, the reaeration rates that it computes for impoundments are very small (2 - 11 percent on the Oklawaha River) compared to those computed for fast-flowing reaches. However, they may still be an overestimate or underestimate of the precise cross-sectional average of reoxygenation from the air. Thus, values computed from the Bennett-Rathbun equation were used, but were considered estimates only.

Width and Depth

Average width and depth of the reaches were estimated from topographic maps and from on-site observation.

Temperature

Stream temperatures in various reaches were estimated from field measurements.

Water Velocity

Stream velocity was determined from published and unpublished data.

Implementation of the Computer Model

Segmentation of the River Systems

Most models provide that a river system be considered as an aggregate of segments with constant, average physical parameters specified for each. The advantages of segmentation are many. Part of the system may be a fast-flowing, clean, natural, undisturbed channel. Other parts might be impounded, low velocity reservoir sections, or low-flow, low velocity channelized streams. Where these different stream types interface, discontinuities in parameters describing temperature, net production, reaeration, and other variables likely will occur. The effects of these discontinuities can be minimized or eliminated by segmenting the river system at these points of discontinuity.

Since it is often not feasible to take cross-sectional spatial variations into account, such as the unequal distribution across a channel of water flow or of aquatic plants, the specified parameters usually must be spatial as well as time averages and refer to the entire part of the river system for which they are specified.

Segmenting the river systems into reaches implies certain assumptions about the physical characteristics of each reach. They are assumed to be uniform in width and depth and temperature. Rate of decay coefficients are assumed uniformly constant throughout each reach. The reaeration rate coefficient is also assumed constant, though the amount of reaeration varies along the reach with the difference between actual concentration and saturation concentration at a given temperature. There is assumed to be no cross-sectional variation in flow, and oxygen production and usage by respiration and benthal demand are considered to be uniformly constant throughout the reach; that is, there is assumed to be no vertical stratification or lateral variation in these parameters. BOD and dissolved oxygen are assumed to vary linearly along the reach, but to have no cross-sectional variation. The rate of linear runoff is considered constant along a reach.

The segmentation of the river system must be done so that each reach best fits the assumptions of uniformity of width, depth, temperature, reaeration rate, rate of runoff, and oxygen production and biochemical use. The assumptions of no vertical stratification or cross-sectional variation are necessary simplifying assumptions which best fit the fast flowing streams for which the dissolved oxygen model was designed. Considerable care must be exercised in trying to use these assumptions for slow-moving impoundments, which are sometimes highly stratified and are better fitted by models for standing waters. In this report, the uniformity assumptions are based upon the interpretation of all parameter values and computed concentrations as cross-sectional averages. These assumptions do not violate the solution of the differential equations in the model, and require cross-sectional averages of field data for calibration.

Both the Oklawaha and Withlacoochee River systems (figs. W.Q. 33 and W.Q. 34) were modeled during this study. The Oklawaha River was modeled through a 64.3-mi (103 km) reach from Moss Bluff, through Lake Ocklawaha, to the confluence with the St. Johns River. The canal above Buckman Lock was not included.

The model was also applied to that part of the Withlacoochee River system beginning at Holder, 36 mi (58 km) from the Gulf of Mexico, and extending past the town of Dunnellon, through Lake Rousseau, through the Inglis Bypass Channel, and down the lower Withlacoochee River to the Gulf of Mexico. Controlled outlets to the canal through the dam and lock structures, and the canal itself, were not included in the model.

The Oklawaha River

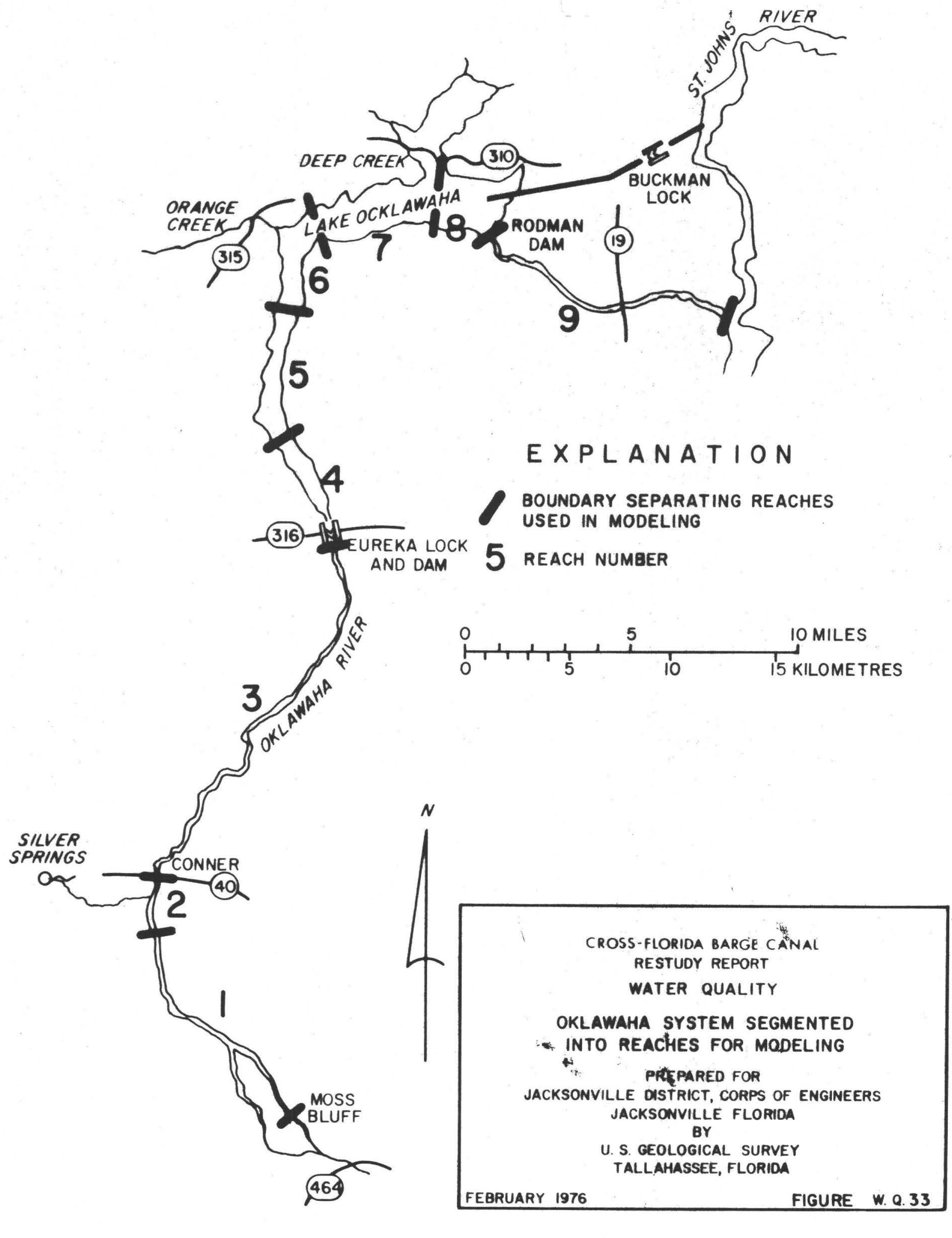
For the purpose of modeling the Oklawaha River downstream from Moss Bluff, the river was divided into nine segments. These segments are listed below and their locations are shown in figure W.Q. 33. Average velocity, and travel time were computed from a set of field measurements collected in May 1975.

Reach and Number	Length (miles)	Average Width (feet)	Average Depth (feet)	Average Velocity1/ (ft/s)	Average Flow (ft^3/s)	Travel Time (days)
1. Moss Bluff (Mile 64.3) to Mile 53.5	10.8	150	6.5	0.02	15	42.90
2. Mile 53.5 to Conner	2.5	150	10.0	0.01	22	10.42
3. Conner to Eureka	17.9	80	7.5	1.22	735	0.89
4. Eureka to Mile 28.3	4.8	100	7.5	0.99	745	0.30
5. Mile 28.3 to Mile 23.0	5.3	700	7.0	0.15	750	2.12
6. Mile 23.0 to Mile 18.4	4.6	2700	8.5	0.03	760	8.49
7. Mile 18.4 to Mile 13.7	4.7	5000	9.0	0.02	770	16.79
8. Mile 13.7 to Rodman Dam	2.0	7700	12.0	0.01	815	13.86
9. Rodman Dam to St. Johns River (Mile 0.0)	11.7	100	7.0	1.17	820	0.61

1/ Average velocity obtained by dividing average flow by average cross-sectional area (truncated internal computation).

The first two reaches, from Moss Bluff to Conner, are channelized streams of controlled flow except for about the lower half of reach 2. Velocities are usually low, and the BOD levels usually are fairly high, possibly as a result of runoff or effluent from agricultural areas and urban development upstream. The channels are, for the most part, clean and free of silt and aquatic plants, but often have high concentrations of phytoplankton.

Reaches 3, 4, and 5, extending downstream from Conner to the open water areas of Lake Ocklawaha and reach 9 below Rodman Dam represent, for the most part, a second type of channel. This is natural channel, through undeveloped land, characterized by rapid stream velocity, narrow width and, except for much of reach 5, surrounding forest. The channel is fairly clean and free of aquatic plants, though some silt deposits and plants are found at bends in the stream.



CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY
OKLAWAHA SYSTEM SEGMENTED
INTO REACHES FOR MODELING
PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA
FEBRUARY 1976 FIGURE W. Q. 33

The reservoir represents a third type of channel, characterized by very low velocity and high travel time, large channel width, and a great deal of aquatic vegetation, particularly near the lower end. For the purpose of modeling the system, only the wider, open-water areas of Lake Ocklawaha (reaches 6, 7, and 8) were classified as this type of channel.

It should be noted that at the 18-ft (5-m) lake elevation maintained at the time of data collection, reach 5 in the upper end of Lake Ocklawaha shows some of the characteristics of both a natural channel and a reservoir, and can be regarded as a transition zone from natural stream to open water. Backwater effects such as flooding of wooded areas and reduced velocities are noticeable. However, velocity is greater and the channel width narrower than in the reservoir sections, and this reach was considered to be more representative of natural channel than the broad, open water areas of the lake.

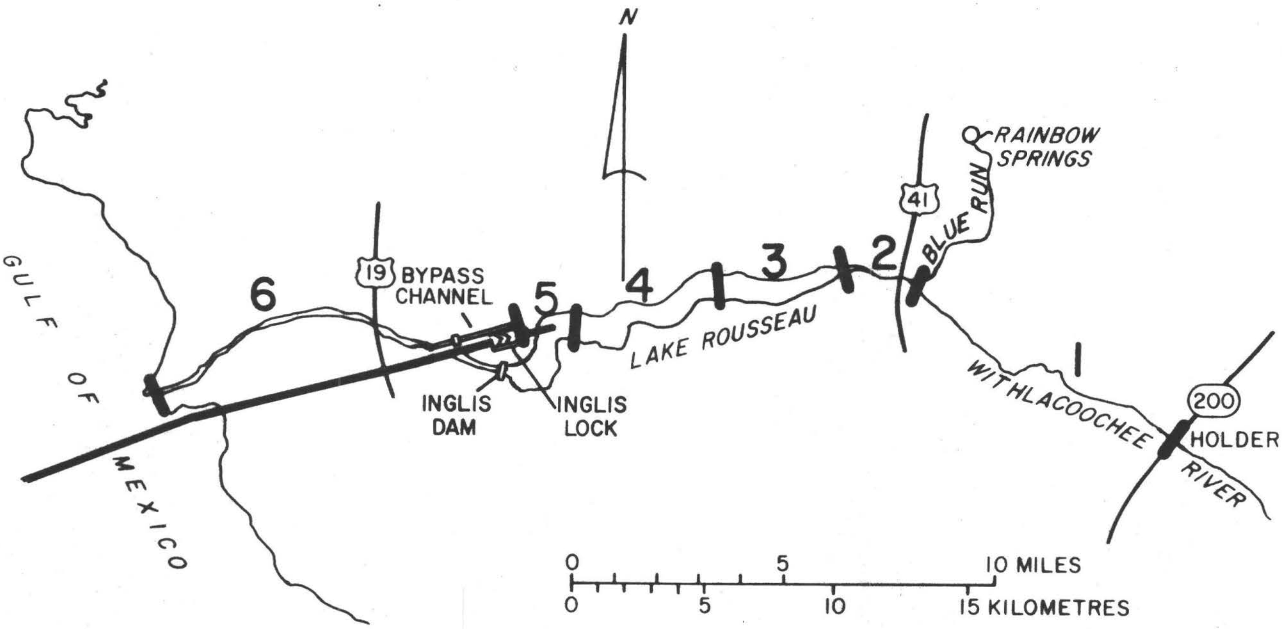
These three channel types are, for convenience, labeled Type A, Type B, and Type C. Their characteristics are summarized as follows:

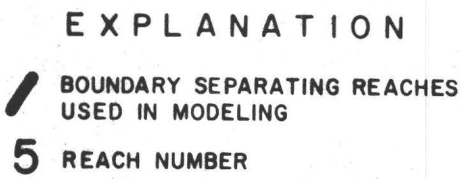
Type A, Natural, high velocity stream
Type B, Low velocity, impounded reservoir
Type C, Controlled, low flow, low velocity stream

The Oklawaha system has a substantial tributary, Silver River, in reach 2 and two smaller tributaries, Orange Creek and Deep Creek in the reservoir reaches. Eaton Creek is a tributary that may provide substantial input during heavy rainfall periods. However, input from this tributary is negligible during much of the year and was not considered in this model. The BOD levels and dissolved oxygen concentrations in the Silver River are low near Silver Springs but the water aerates somewhat and acquires natural ("background") BOD before joining the Oklawaha River. Orange Creek usually contains fairly low levels of BOD and high concentrations of dissolved oxygen. Deep Creek often contains fairly high BOD and low concentrations of dissolved oxygen. The main stem of the Oklawaha River, particularly the upper part, gains more water than can be accounted for by tributary inflow, and this excess is attributed to surface runoff or ground-water inflow.

Withlacoochee River

Six segments or reaches of the Withlacoochee River downstream from Holder were modeled. Descriptions of these reaches are listed below. Their locations are shown on figure W.Q. 34. Average velocity and travel time were computed from a set of field measurements collected in May 1975.





CROSS-FLORIDA BARGE CANAL
RESTUDY REPORT
WATER QUALITY

WITHLACOOCHEE SYSTEM SEGMENTED INTO REACHES FOR MODELING

PREPARED FOR
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE FLORIDA
BY
U. S. GEOLOGICAL SURVEY
TALLAHASSEE, FLORIDA

FEBRUARY 1976 FIGURE W. Q. 34

Reach and Number	Length (miles)	Average Width (feet)	Average Depth (feet)	Average Velocity[1/] (ft/s)	Average Flow (ft^3/s)	Travel Time (days)
1. Holder (Mile 36.0) to Blue Run	12.8	160	10	0.15	240	5.21
2. Blue Run to Mile 20.3	2.9	180	10	0.47	850	0.38
3. Mile 20.3 to Mile 16.5	3.8	2800	8	0.04	855	6.08
4. Mile 16.5 to Mile 11.4	5.1	3100	8	0.03	860	8.99
5. Mile 11.4 to Bypass Channel	1.7	2500	9	0.04	860	2.72
6. Bypass Channel to Gulf of Mexico (Mile 0.0)	9.7	70	10	1.14	800	0.52

1/ Average velocity obtained by dividing average flow by average cross-sectional area (truncated internal computation).

Those parts of the river system from Holder to the headwaters of Lake Rousseau, and below the entrance to the bypass channel are the narrow, high velocity channel type described in the previous section. They were segmented into three reaches, two between Holder and Lake Rousseau and one below the entrance to the bypass channel. Lake Rousseau is a low velocity impounded channel and was segmented into three reaches.

The Withlacoochee system has a major tributary, Blue Run, at the upper end of reach 2 near the town of Dunnellon. This tributary originates in natural springs with low BOD. The Withlacoochee River gradually increases in flow downstream, more than accounted for by inflow, indicating additional surface runoff and ground-water inflow. The most downstream reservoir reach has three controlled outlets, two to the Cross-Florida Barge Canal at Inglis Dam and Inglis Lock, and one, the bypass channel, to the Lower Withlacoochee River.

Calibration of the Model

In general, the input parameters may be chosen and fixed prior to calibration, or they may be varied freely in order to achieve the calibration. Fixed parameters may be based upon ones described in the literature for similar applications, or they may be directly derived from field data measurements, or they may be the result of independent computations using field data measurements. If a parameter is allowed to vary freely in the process of calibration in order to match the computed profiles with the field data measurements, it is then used as a calibration parameter.

Fixed parameters in this application of the model include the reaeration rate, average width and depth of the reaches, stream temperatures and flow rates, discharge and concentration of BOD and dissolved oxygen from tributaries. Linear runoff (also "background BOD"), and net productivity were used as calibration parameters.

Three sets of data were simulated, two on the Oklawaha River system, collected May 7-13 and August 11-12, 1975, and one on the Withlacoochee River system, collected May 14, 1975. These data were not ideal; a preferable way to proceed would have been to collect data on the same day in all parts of the river system, because the same atmospheric and other environmental conditions would affect all parts of the river system. However, such a collection policy was not feasible. Because significant 24-hour variation occurred in such calibration data as dissolved oxygen and water temperature, some judgment had to be used in relating data values collected at a particular time to the daily average values required by the model for computing the daily average BOD and dissolved oxygen profiles.

As discussed earlier, all data computed were cross-section averages because of the model assumptions of cross-sectional uniformity. This meant that data used for calibration had to be depth and cross-section averages, if possible. Some of the calibration data used were sets of values taken at various depths, requiring judgment to be used in determining vertical averages. This type of data was available from many reservoir data collection sites where the greatest stratification existed. No multiple sets of data collected at points across the width of the channels were taken, so surface or depth-averaged values had to be assumed to be cross-sectional averages as well.

A simulation of each set of data was made to fit the observed data as closely as possible. A very close fit of observed BOD and dissolved oxygen values was achieved for all three data sets. The models for each data set were then simplified by averaging calibration parameter values from reaches of similar type in each river system at the same time of year and the results were evaluated. If the average values and the resultant computed profiles were realistic, the averages were considered as the true values of the calibration parameters and assigned to all similar reaches, except where great variation or sensitivity occurred.

Linear runoff values used to exactly simulate the BOD observations were averaged. The total BOD load of the runoff was divided by the reach volume in order to obtain an estimate of the input of BOD by runoff or occurrence of "background BOD" per unit volume. This approach was motivated by the fact that, in the reservoir reaches, BOD entering through runoff was negligible compared with the "background BOD" effect.

The net productivity values were averaged among Type A reaches (fast-flowing natural stream), in which the dissolved oxygen profiles were not sensitive to this parameter and large positive and negative values were used for an exact simulation. The average was close to zero, which corresponds with the hydrologic view that very little biological production or consumption occurred in those reaches. The P-R-B parameter was then set equal to zero. In the reservoir sections, the dissolved oxygen profile was found to be very sensitive to the values of net productivity, so the exact simulation parameter values were used in the simplified model.

Table 25 compares computed dissolved oxygen and BOD with observed DO and BOD as measured in the Oklawaha River system in May and August 1975 and in the Withlacoochee River system in May 1975. The net productivity and linear runoff-background BOD values used in the simulation also are listed.

BOD Results

As shown in the tables, the level of runoff-background BOD input needed to simulate actual conditions ranged from 0.15 to 0.80 mg/l per day. The higher value applied only to the data in Oklawaha reaches 1 and 2 collected in August 1975, and may reflect the presence of actual linear runoff with a high BOD load from agricultural areas upstream. It also reflects the presence of manmade effluents and decaying phytoplankton from upstream lakes. For the natural channel reaches of the Oklawaha River (Type A), runoff/background BOD seemed to change from 0.50 mg/l per day in May to 0.40 mg/l per day in August. For the Type A sections of the Withlacoochee, this parameter seemed to remain constant at 0.30 mg/l per day. Assuming negligible runoff, the impounded reservoir (Type B) reaches of both the Oklawaha and Withlacoochee systems apparently were generating approximately 0.15 mg/l per day of background BOD in May, and in the Oklawaha, this seemed to increase to about 0.40 mg/l per day in August. This may be because of the much heavier biomass of vegetation in the reservoir in August, raising this natural BOD occurrence.

Dissolved Oxygen Results

The model lists the contribution or deficit of oxygen for BOD decay, net productivity, and reaeration at each computation point. The simulation shows that BOD decay, productivity, and reaeration are comparable influences on the dissolved oxygen profile in the Type C channel (low velocity, low flow, large width, man-made control) at the existing BOD levels, that reaeration is the dominating influence in Type A channel (natural, high velocity stream), and that net productivity, BOD decay, and reaeration are comparable influences in the Type B channel (impounded, high volume, low flow reservoir sections).

TABLE 25.--Comparison of computed dissolved oxygen and BOD with observed dissolved oxygen and BOD for three data sets.

Channel type	Reach number	Net oxygen productivity (P-R-B) (mg/1 per day)	Linear runoff and background BOD[a] (mg/1 per day)	Temperature (°C)	BOD (mg/1)		Dissolved oxygen (mg/1)	
					Computed	Observed	Computed	Observed
Oklawaha River, May 1975								
C	1	0.40	0.50	26.5	2.3	2.5	7.3	7.2
C	2	.40	.50	26.0	2.5	-	7.0	-
A	3	.00	.50	24.0	.9	1.2	6.4	8.1
A	4	.00	.50	23.5	1.0	1.1	6.7	6.9
A	5	.00	.50	25.0	1.1	-	7.2	7.0
B	6	.40	.15	26.0	.8	.7	8.9	9.0
B	7	.25	.15	27.0	.8	1.0	9.4	9.3
B	8	.25	.15	28.0	.7	.8	9.8	9.2
A	9	.00	.50	27.0	.9	-	8.8	-
Oklawaha River, August 1975								
C	1	0.40	0.80	29.0	3.2	3.3	5.5	4.9
C	2	0.40	0.80	29.5	3.25	-	4.7	-
A	3	0.0	0.40	24.0	0.8	0.9	6.9	6.4
A	4	0.0	0.40	24.0	0.9	0.7	7.2	7.3
A	5	0.0	0.40	25.5	0.95	-	5.8	-
B	6	-0.70	0.40	26.5	1.8	0.9	0.9	1.0
B	7	0.10	0.40	27.5	1.9	2.0	1.6	1.5
B	8	0.40	0.40	28.0	1.8	2.2	2.9	2.1
A	9	0.0	0.40	29.0	1.8	-	8.6	-
Withlacoochee River, May 1975								
A	1	0.0	0.30	27.0	1.4	1.5	6.6	6.6
A	2	0.0	0.30	26.5	0.7	0.5	7.5	7.8
B	3	0.10	0.15	25.5	0.8	0.7	7.5	7.5
B	4	0.40	0.15	26.5	0.8	1.0	9.3	9.1
B	5	0.20	0.15	27.5	0.7	0.5	9.0	8.7
A	6	0.0	0.30	27.5	0.8	-	8.7	-

a/ For type A and C reaches, both runoff and biological decay contribute. In type B reaches, this quantity is "background BOD."

A selected point on the Type C channel, just below Moss Bluff, shows the following relation among the factors affecting the dissolved oxygen level change between two adjacent computing points. Deficit is defined as the change in dissolved oxygen within the reach increment which is attributable to the specified parameter. A negative deficit indicates oxygen consumption while a positive deficit indicates oxygen production. All values are in mg/l unless otherwise noted.

Oklawaha River, mi 58.0, May 1975

Distance traveled (mi)	Time of travel (hours)	BOD deficit	Net productivity deficit	Reaeration deficit	DO level change	DO	BOD
0.1	8.7	-0.163	0.143	0.033	0.013	7.0	2.3

Oklawaha River, mi 58.0, August 1975

Distance traveled (mi)	Time of travel (hours)	BOD deficit	Net productivity deficit	Reaeration deficit	DO level change	DO	BOD
0.1	5.6	-0.162	0.092	0.076	0.006	5.2	3.2

Note that the net productivity rate used was the same, 0.40 mg/l per day, in both May and August simulations. Increased flow resulted in a higher velocity, lower travel time, increased reaeration, and lower net productivity. The decrease in travel time, together with the higher BOD level, kept the BOD deficit unchanged. The cause of oxygen production in these reaches is not known, but there must be some net productivity to account for the observed dissolved oxygen level measurements.

A selected point is taken on a Type A, natural, high velocity reach of the Oklawaha River, for the same type of comparison among factors affecting the dissolved oxygen level. All values are in mg/l unless otherwise noted.

Oklawaha River, mi 40.0, May 1975

Distance traveled (mi)	Time of travel (min)	BOD deficit	Net productivity deficit	Reaeration deficit	DO level change	DO	BOD
0.1	7.2	-0.001	0.0	0.010	0.009	5.8	0.8

Oklawaha River, mi 40.0, August 1975

0.1	7.2	-0.001	0.0	0.009	0.008	6.5	0.8

The net productivity value was considered zero in both runs, i.e., essentially no oxygen production, respiration, or benthic demand. The BOD deficit was very small due to the low travel time. But reaeration was fairly high because of the high stream velocity. The slight difference from May to August was not due to temperature, which was the same, but was due to the higher dissolved oxygen level in August.

And, finally, a selected point is taken on Type B channel in Lake Ocklawaha. These are high volume, low velocity sections with many aquatic plants. All units are mg/l unless otherwise noted.

Oklawaha River, mi 15.0, May 1975

Distance traveled (mi)	Time of travel (hours)	BOD deficit	Net productivity deficit	Reaeration deficit	DO level change	DO	BOD
0.1	8.6	-0.054	0.089	-0.025	0.010	9.3	0.7

Oklawaha River, mi 15.0, August 1975

0.1	8.1	-0.131	0.033	0.109	0.011	1.5	1.9

Because of the large travel time, the BOD deficit and net productivity effect are large. Reaeration is negative in the first case because the water is supersaturated. Net productivity is sufficiently large to raise the dissolved oxygen level even though the water is supersaturated. Reaeration is substantial in the second case because of the extremely low dissolved oxygen level.

Application of the Model

Once model calibration was achieved for the three data sets considered, it was possible to use the model to study the assimilative capacity of the river systems for various forms of oxygen demand, such as respiration, benthic demand, or waste loads of BOD. The approach taken was to consider the impact upon the system of all factors influencing the dissolved oxygen levels, then to consider the effects of naturally occurring demands, and finally, to simulate a manmade waste load. In this way, each effect would be put into perspective in relation to all other effects upon the dissolved oxygen levels. The tool used to accomplish this is the sensitivity analysis. The technique used was to assign perturbations to selected model parameters in turn, while the others remained fixed. The effect of each perturbation was then evaluated by comparing the change produced in the answer (dissolved oxygen concentration in this study) to the change imposed on the selected parameter.

The choice of which values to compare is somewhat arbitrary. For example, the comparison could be based on average values for a section, or, it could be based on end-of-reach values. In this analysis, sensitivity has been expressed as the percent change in dissolved oxygen at the downstream end of a reach for each percent change in the isolated parameter. The base value of the parameter was adopted as the average value of the parameter weighted for segment length.

First, a sensitivity analysis of the reaction of the river systems to hydrologically feasible changes in net productivity was done to demonstrate the impact that small changes would have on the reservoir dissolved oxygen levels. This tested the effect of a variation in the combined influence of two types of oxygen demand, respiration of aquatic plants and benthic demand. Lengthening the impounded area would cause an increase in the plant population area and the area of bottom sediment deposits, thereby affecting oxygen demand, so a sensitivity analysis to net productivity was also done on a hypothetically lengthened impoundment.

An analysis was made to demonstrate the sensitivity of the dissolved oxygen levels to changes in the BOD concentrations in the river. Since most of the reservoir BOD is natural in origin, this tests the effect of changes in naturally occurring waste loads. A simulation of a sewage plant waste load was made to test its effect. The simulation is for a plant serving 10,000 people, well above all predictions of short-term population increase.

The final analysis, sensitivity to variations in rates of reaeration, tests the effect of oxygen demand caused by stagnant air, which would reduce reaeration.

Sensitivity to Changes in Net Productivity

In the last selected point cited above, BOD decay, reaeration, and production are making comparable contributions to the variation in the dissolved oxygen profile. However, the dissolved oxygen profile is far more sensitive to small changes in the productivity rate than to the other factors. This is because the production deficit in dissolved oxygen varies almost directly with changes in the production rate, but the BOD deficit varies only as a linear factor of the BOD concentration, and reaeration varies as a linear factor of the deficit and is small near saturation in dissolved oxygen.

Several computer runs were made with small variations of the net productivity coefficient along the reservoir (Type B channel) sections of Lake Ocklawaha and Lake Rousseau. The approach taken was to add and subtract 0.1 mg/l per day from rates used in the simplified model. The results are summarized in table 26 and clearly demonstrate the sensitivity of the dissolved oxygen profile to small changes in the net productivity. The sensitivity at mile 11.7 on the Oklawaha River is expressed in two ways, first as a percent change in dissolved oxygen per one percent change in weighted average net productivity (average of results from positive and negative change), then as an absolute change in mg/l of dissolved oxygen per one mg/l per day change in the net productivity rate:

May 1975 - 0.7%/% or 22 $\frac{mg/l}{mg/l/day}$

August 1975 - 2.0%/% or 19 $\frac{mg/l}{mg/l/day}$

For the Withlacoochee River it is:

May 1975 0.3%/% or 9.5 $\frac{mg/l}{mg/l/day}$

These results are physically reasonable. Data from the field have shown that there are in fact drastic day-to-day fluctuations in the average dissolved oxygen profiles of these impounded sections, apart from the hourly variability, which are not explainable by other possible causes.

TABLE 26.--Computed dissolved oxygen profiles for three type-B reach data sets showing sensitivity of dissolved oxygen to small changes in oxygen net productivity rate.

River Mile	Dissolved Oxygen (mg/l)		
	Simplified model production values less 0.1 mg/l/day	Simplified model production values	Simplified model production values plus 0.1 mg/l/day
	Oklawaha River, May 1975		
23.0	7.2	7.2	7.2
21.0	7.7	8.0	8.4
19.0	8.2	8.8	9.3
17.0	8.2	9.0	10.0
15.0	8.0	9.3	10.6
13.0	7.6	9.2	10.9
11.7	7.6	9.8	12.0
	Oklawaha River, August 1975		
23.0	5.8	5.8	5.8
21.0	3.1	3.4	3.7
19.0	.9	1.4	2.0
17.0	.3	1.2	2.1
15.0	.3	1.4	2.7
13.0	.5	2.0	3.4
11.7	1.0	3.0	4.8
	Withlacoochee River, May 1975		
20.3	7.5	7.5	7.5
18.0	7.2	7.5	7.8
16.0	7.2	7.8	8.3
14.0	7.9	8.6	9.2
12.0	8.3	9.1	9.9
9.7	8.1	9.1	10.0

These changes are more marked for the Oklawaha River than for the Withlacoochee River. Lake Rousseau is narrower than Lake Ocklawaha and has a lower travel time and a higher stream velocity. Also reaeration and diffusion are more rapid.

By raising or lowering the net productivity factor uniformly along the entire length of the reservoirs, the effect of the change generated is cumulative, going from zero at the starting point to a maximum at the lower end. This raises the question of whether such a uniform change is physically realistic, and if so, what are the implications. But it does seem that if production is affected by weather conditions, on a daily basis, that these weather conditions would affect the entire reservoir and there should be a correlation between changes in net productivity in one part of the reservoir with another. If this is true, it suggests that changes might be much more pronounced if the reservoir were longer. To examine this possibility Lake Ocklawaha was theoretically lengthened to mile 51.0 at Conner. This could not happen in reality, but would resemble somewhat the conditions that might be expected if Eureka Pool were impounded, although reaeration at Eureka Spillway would not be included in the model.

The simplified model of the Oklawaha May data was modified by theoretically "impounding" reaches 3, 4, and 5 of the Oklawaha River system. This would occur in actuality if the Lake Ocklawaha level were raised, flooding sections 4 and 5, and if Eureka Dam were activated, flooding section 3 to above Conner. The model modification was done by using impoundment widths and depths actually planned for these reaches if the canal project achieves reality and by using corresponding values for the BOD load of linear runoff and for net productivity similar to those used for the Lake Ocklawaha reaches. Some guesswork was involved in choosing the latter parameters, and values were varied to generate a nominal dissolved oxygen and BOD profile which resembled the Oklawaha May data. Because the reaeration at Eureka Spillway is not included in the model, the nominal profiles are not predictions of effects of the authorized alinement alternative. They are simply synthetic profiles which are similar in shape to observed profiles, but which were generated for sensitivity analysis only. Then, as above, the net productivity values for all six "impounded" reaches were raised and lowered by 0.10 mg/l day. The results are summarized in table 27. The sensitivity at mile 11.7 on the Oklawaha River expressed as percent change in dissolved oxygen per one percent change in average net productivity (average of results from positive and negative change) is 0.6%/% for May 1975. Expressed as an actual change in mg/l in dissolved oxygen per one mg/l/day change in the rate of net productivity it is 23.5 mg/l per one mg/l/day. Background BOD is 0.15 mg/l per day in the entire section, and is simulated by linear runoff.

The data in table 27 indicate that the computed dissolved oxygen level at the lower end of this theoretically lengthened impoundment is almost the same as in the 3-reach impoundment which presently exists. There are two reasons for this. First, the higher and lower profiles are limited by reaeration or diffusion; that is, if the dissolved oxygen profile is extremely high or low, then the reaeration/diffusion deficit becomes much larger and tends to balance the effect of the increase or decrease of net productivity. The other reason lies in the character of section 4. Though classed as an impounded section, it is narrower than the other impounded sections, and consequently has a higher velocity and a more rapid rate of reaeration or diffusion. In this lengthened reservoir case, the effect of the two perturbations of the net productivity parameter is noticeably reduced in this reach.

This reinforces an observation made earlier that narrower channels have less sensitivity to the factors of net oxygen productivity and BOD decay.

It should be noted that the conclusions which have been demonstrated are for small perturbations of the net productivity parameter. Gross changes in this parameter might generate results with different hydrologic implications.

Sensitivity to Changes in BOD Concentration

The BOD level was varied by increasing the BOD concentration in the linear runoff entering the three reservoir reaches of the Oklawaha River. This was equivalent to varying the rate of occurrence of background BOD. Table 28 reports the drop in the computed dissolved oxygen profile for these reaches. The sensitivity at mile 11.7 on the Oklawaha River is expressed in three ways: (1) as a percent change in dissolved oxygen per one percent change in weighted average BOD (average results from both changes in May 1975), (2) as an actual change in mg/l of dissolved oxygen per one mg/l change in the BOD level, and (3) as an actual change in mg/l of dissolved oxygen per one mg/l/day change in the rate of occurrence of "background BOD" required to maintain the increased BOD level:

May 1975 - 0.3%/% or 5.6 $\frac{mg/l}{mg/l}$ or 19 $\frac{mg/l}{mg/l/day}$

August 1975 - 2.0%/% or 3.7 $\frac{mg/l}{mg/l}$ or 14 $\frac{mg/l}{mg/l/day}$

It is seen that an increase in the background BOD has a substantial effect on the oxygen levels in the reservoir, particularly in the August data set. When the oxygen levels are already very low, it can cause anaerobic conditions. Such a large increase in the naturally occurring background BOD might be caused in actuality by a large dieoff of aquatic vegetation or animals.

TABLE 27.--Computed dissolved oxygen profiles for parts of one data set showing sensitivity of dissolved oxygen to small changes in oxygen productivity rate with three additional reaches flooded. (synthetic profile for sensitivity analysis only)

Reach number	Oxygen net productivity (P-R-B) for nominal profile (mg/l per day)	River Mile	Dissolved Oxygen (mg/l)		
			Nominal profile productivity value less 0.1 mg/l/day	Nominal profile productivity value	Nominal profile productivity value plus 0.1 mg/l/day
Oklawaha River, May 1975					
3	0.20	51.2	4.4	4.4	4.4
3	.20	49.0	5.0	5.8	6.6
3	.20	47.0	5.2	6.5	7.9
3	.20	45.0	5.3	7.0	8.8
3	.20	43.0	5.3	7.4	9.5
3	.20	41.0	5.4	7.7	10.0
3	.20	39.0	5.4	7.9	10.5
3	.20	37.0	5.5	8.1	10.8
3	.20	35.0	5.5	8.2	11.0
4	.25	33.0	5.6	8.3	11.1
4	.25	31.0	6.7	8.5	10.2
4	.25	29.0	7.4	8.6	9.7
5	.25	27.0	7.6	8.6	9.6
5	,25	25.0	7.7	8.6	9.6
5	.25	23.0	7.7	8.7	9.6
6	.30	21.0	7.8	8.8	9.9
6	.30	19.0	8.0	9.0	10.1
7	.25	17.0	7.9	9.2	10.5
7	.25	15.0	7.9	9.4	10.9
8	.25	13.0	7.5	9.3	11.2
8	.25	11.7	7.5	9.8	12.2

TABLE 28.--Computed dissolved oxygen profiles for parts of two data sets showing sensitivity of dissolved oxygen to increases in BOD.

Reach number	River mile	Simplified Model			Modification One			Modification Two		
		Increase in BOD in runoff (percent)	BOD (mg/l)	DO (mg/l)	Increase in BOD in runoff (percent)	BOD (mg/l)	DO (mg/l)	Increase in BOD in runoff (percent)	BOD (mg/l)	DO (mg/l)
Oklawaha River, May 1975										
6	23.0	0	1.1	7.2	106	1.1	7.2	209	1.1	7.2
6	21.0	0	.9	8.1	106	1.3	7.9	209	1.7	7.7
6	19.0	0	.9	8.5	106	1.5	8.3	209	2.1	7.9
7	17.0	0	.8	9.1	54	1.3	8.1	208	2.2	7.0
7	15.0	0	.7	9.3	54	1.2	8.1	208	2.3	6.0
8	13.0	0	.7	9.2	76	1.2	7.7	135	1.8	4.7
8	11.7	0	.7	9.8	76	1.2	7.6	135	1.7	4.2
Oklawaha River, August 1975										
6	23.0	0	0.9	5.8	55	0.9	5.8	-	-	-
6	21.0	0	1.5	3.4	55	2.0	3.2	-	-	-
6	19.0	0	1.7	1.4	55	2.6	.8	-	-	-
7	17.0	0	1.9	1.2	40	2.7	.0	-	-	-
7	15.0	0	1.9	1.5	40	2.7	.0	-	-	-
8	13.0	0	1.8	2.0	40	2.5	.1	-	-	-
8	11.7	0	1.8	2.9	40	2.5	.3	-	-	-

Another interesting question relates to the effect of discharging sewage effluent into the reservoir on the dissolved oxygen profile. Such a dump into upper (Type A) reaches would have almost no effect because the swift velocity of flow would quickly carry the waste down into the reservoir before a substantial amount of decay could occur. One reference (Sartor and Boyd, 1972) suggested that 250 lb (114 kg) per day of BOD would be representative of the waste output of a secondary-process sewage plant serving a community of 10,000 persons. Therefore, this load was hypothetically dumped into the channel at the beginning of reach 6 (in Lake Ocklawaha) in both the May and August simplified models. In the May (high dissolved oxygen level) model, the maximum decrease in dissolved oxygen level resulting from this load was 0.4 percent and the maximum increase in BOD concentration was 5.6 percent. In the August (low dissolved oxygen level) model, the maximum dissolved oxygen level decrease was 3.5 percent from 0.89 mg/l to 0.86 mg/l, and the maximum BOD level increase was 6.2 percent. These variations, which are cross-sectional averages, are quite small, even in the case where the dissolved oxygen profile was already very low because of low oxygen net productivity. Apparently, the simulated sewage plant effluent of a town of 10,000 is negligible in its influence on the dissolved oxygen profile compared with natural factors such as net oxygen production by aquatic plants or by variations in the natural background BOD from death and decay of aquatic organisms.

Sensitivity to Changes in Reaeration Rate

The results of reaeration rate sensitivity analysis may test the effect of natural conditions such as windy weather or stagnant air, or they may test the effect of incorrectly specifying or computing the reaeration rate coefficient in applying the model. The Oklawaha River August simulation was used as a worst case; because of the low dissolved oxygen levels in many reaches, the reaeration deficit was more pronounced than in other simulations and therefore more sensitive to perturbations in the rate of reaeration. The rate coefficient for each reach was increased and decreased by 50 percent of the rates computed in the simplified model by way of the Bennett-Rathbun equation, which has the effect of a small change of small rate coefficients and a large change of large ones. Table 29 lists a few points along the river channel with the nominal and varied dissolved oxygen profiles. The sensitivity at mile 0.0 on the Oklawaha River, expressed as percent change in dissolved oxygen per one percent change in weighted-average reaeration rate (average of results from positive and negative change) in August 1975 is 0.2%/%. Expressed as an absolute change in mg/l of dissolved oxygen, it is 0.013 mg/l per one percent change in reaeration rate.

The effect of variances in the reaeration rate is seen to be greatest when the dissolved oxygen level is most different from saturation, which is because the reaeration effect is greatest in these cases.

TABLE 29.--Computed dissolved oxygen profiles for parts of one data set showing sensitivity of dissolved oxygen to changes in the rate of reaeration.

Reach number	River mile	Bennett-Rathbun reaeration rate	Dissolved Oxygen (mg/1)		
			Computed from Bennett-Rathbun coefficient less 50 percent	Computed from Bennett-Rathbun coefficient	Computed from Bennett-Rathbun coefficient plus 50 percent
Oklawaha River, August 1975					
1	64.3	0.109	3.8	3.8	3.8
1	60.0	.109	4.7	5.1	5.8
1	55.0	.109	4.7	5.4	5.9
3	50.0	.810	5.3	5.4	5.5
3	45.0	.810	5.8	6.0	6.3
3	40.0	.810	6.2	6.5	6.9
3	35.0	.810	6.5	6.8	7.2
4	30.0	.738	6.8	7.1	7.5
5	25.0	.787	5.9	6.2	6.7
6	22.0	.081	4.2	4.6	5.1
6	20.0	.081	1.7	2.4	3.2
7	18.0	.050	.0	1.0	2.3
7	15.0	.050	.1	1.5	3.2
8	13.0	.022	.6	2.0	3.5
9	10.0	1.102	8.2	9.5	10.8
9	5.0	1.102	8.0	9.0	9.8
9	0.0	1.102	7.8	8.6	9.1

Summary of the Results of Model Studies

The computations from the mathematical model were used to show that the major influence on dissolved oxygen in the natural, swift (Type A) reaches is reaeration, but that BOD decay, aquatic oxygen production and consumption, and reaeration are comparable influences on all slow-moving stream types (B and C), such as the controlled channel in the Moss Bluff area and in the two reservoirs. The effect of net productivity and BOD decay upon the dissolved oxygen levels is very much a function of travel time, with the productivity and BOD deficits increasing markedly with increasing travel time. The important point made is that BOD decay and net productivity as well as their variations have significantly less effect on dissolved oxygen levels in narrower channels, with decreased travel time, than in wide channels with lower flow velocities. In narrow channels, dissolved oxygen levels tend more to stabilize toward saturation because of increased reaeration.

Consideration was given to the effect of BOD decay and net oxygen productivity in a lengthened impoundment, which would occur if the stage of Lake Ocklawaha were raised and Eureka Dam put into operation. It was found by using the model that the effect of similar BOD loads and oxygen productivity levels, and of their variations, was similar in the lengthened system, and was not magnified by increasing the length of the system.

The output of a sewage treatment plant for a small town, one of 10,000 persons, was simulated in part of Lake Ocklawaha, and the effect on the BOD and dissolved oxygen levels averaged over the cross-section was found to be negligible. The natural factors of runoff and background BOD, of oxygen production and consumption by aquatic life, and of reaeration were found to be completely dominant in the modeling results.

Because of the uncertainty in choosing the proper reaeration rate coefficients, the Bennett-Rathbun coefficients were varied by 50 percent to determine the differences in the dissolved oxygen levels. Varying the coefficients by this amount caused a relatively small difference in the computed dissolved oxygen levels except when the levels were very low or high. It appears that when nearly anaerobic or extremely supersaturated conditions prevail, this level of variation in the reaeration rate can have a fairly significant effect.

IMPACTS ON WATER QUALITY OF ALTERNATIVE PLANS FOR COMPLETING OR NOT COMPLETING THE CROSS-FLORIDA BARGE CANAL

A major objective of this study is to define the impact of each of several alternate plans to complete or not complete the Barge Canal, on the quality of surface and ground water in the area. These alternatives are described and the potential impacts on water quality by the various courses of action being considered are discussed in the following sections of this report. Descriptions of the several alternatives are taken from the preliminary engineering report (U.S. Corps of Engineers, 1975) and from descriptions of the alternatives furnished by the Jacksonville District of the Corps of Engineers (written commun., 1975). The discussions of potential impacts of these alternatives on water quality are based on: (1) comparisons of water quality in completed parts of the canal with that in the natural streams; (2) changes in water quality that have occurred since construction began; and (3) the present (1975) and historical water-quality data presented earlier in this report.

For purposes of discussing the environmental impacts, the canal route is subdivided into six reaches separated by locks. Impacts on the separate reaches are discussed for three time phases, (1) the construction phase, (2) an adjustment phase, and (3) a stabilized, post-construction phase. During the construction period, dredging, land-clearing or other construction activities sometimes can cause fairly large changes in water quality in a short period of time. These changes are usually temporary, however. The period of adjustment as cited in this report refers to the period of change in water quality that often occurs when the flow system is altered. Water quality generally changes more slowly during this period than during the construction period. The period following this adjustment period is referred to in this report as the stabilized post-construction period. Although the quality of water is never truly stabilized, this term is used to describe that post-construction period when the water quality reflects the adjustment to the altered flow system and other changes in the environment brought about by construction.

The effects on the quality of water in the area of the alternative plans to complete or not complete the canal are discussed in terms of expected deviations from the present quality. The effects discussed in this report relate directly to the construction, operation, and use of the canal or to the alternative plans for not completing the canal.

The effects of regulation schedules, maintenance dredging, and aquatic-weed control programs, which must be a part of any plan to complete the canal or preserve the completed parts of the canal, were not specifically discussed for each reach or for every alternative. Maintenance dredging would affect the quality of water in the various reaches in much the same way as would construction dredging. For this reason, the effects of maintenance dredging are not specifically addressed. The effects of drawdowns to control the growth of aquatic weeds are discussed in the section entitled "Alternatives for not completing the canal but preserving completed works." Since the effects of drawdowns in the other reaches and for the various other alternatives would be similar, the effects of drawdowns were not specifically discussed for the other alternatives.

Specific impacts on a particular reach are described, but the effects of the resulting change in water quality in that reach on the downstream reach or reaches are not necessarily stated. Certain effects on the downstream reaches may be implied, however. For instance, dredging is expected to cause high turbidity in the immediate area of dredging and the turbid conditions are expected to extend downstream but with diminishing intensity. The downstream extent of turbid conditions would depend on various factors including flow velocity, physical and chemical character of the suspended sediment, and types and methods of operation of downstream control structures. Although the extent to which the impacts in a given reach will, in turn, affect downstream reaches are not necessarily discussed in this report, the possibility should not be overlooked that changes in the quality of water in one reach will affect downstream reaches.

As elsewhere in Florida, population in the Barge Canal area doubtlessly will increase in the next few decades. However, significant changes in water quality as a result of secondary impacts from increases in population due to the canal are not anticipated. Preliminary results of a population growth survey by Meta Systems, Inc., late in 1975 indicate that population growth in the Barge Canal area with a canal is expected to be no more than about 10 percent greater than growth without a canal (written commun., 1975).

Expected increases in population, with or without the canal, will increase the potential for ground-water contamination from waste waters. However, State and Federal regulations for treatment and disposal of waste waters should preclude widespread contamination of ground water. For example, new sewage or industrial waste discharges directly to the canal waters probably will not be permitted. Population increases will also gradually intensify the recreational use of both natural and man-made water bodies in the area, increasing the potential for water-quality degradation. However, canal shoreline development is to be highly restricted and increased recreational use in not expected to appreciably affect the quality of water in the area.

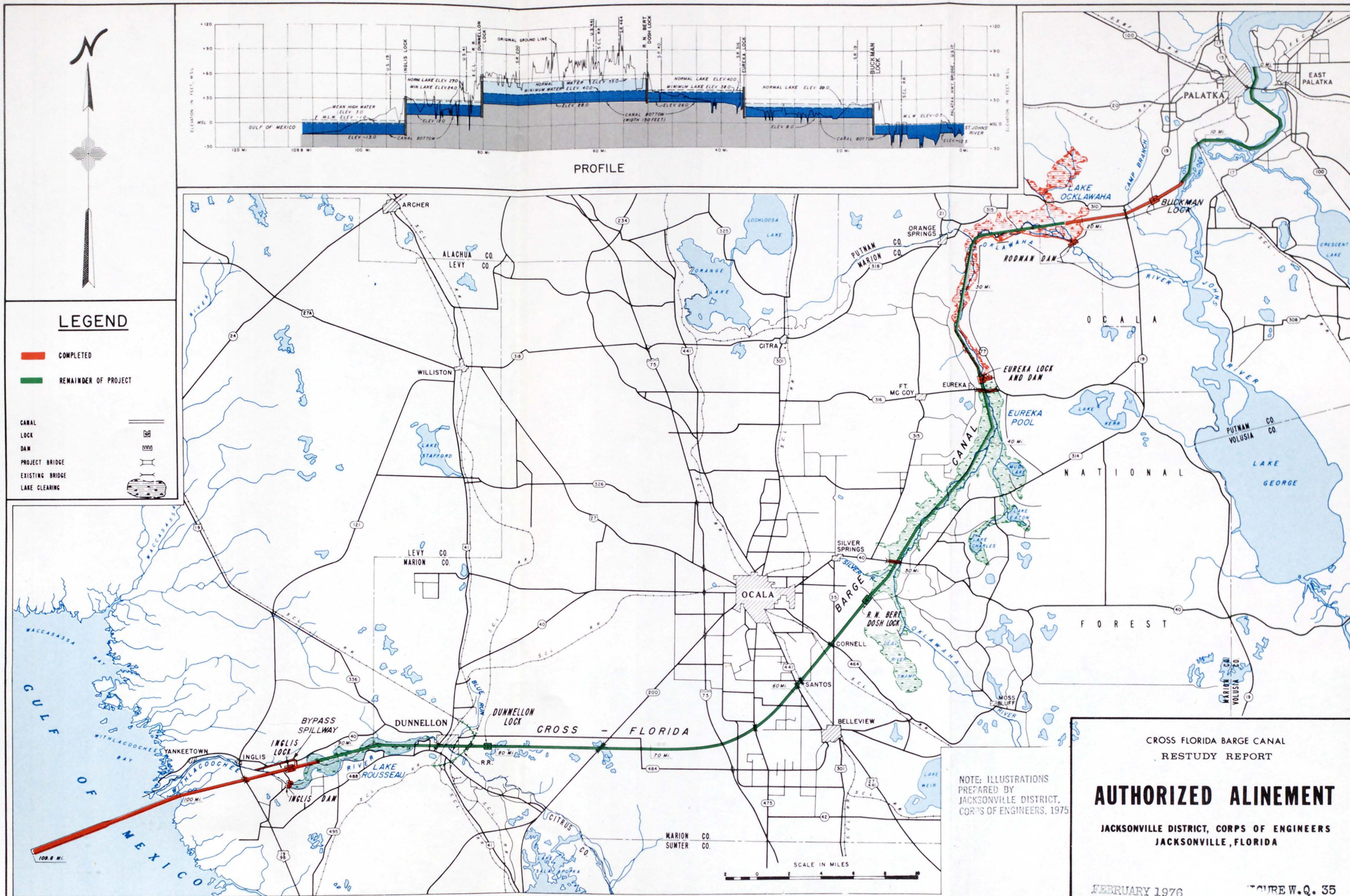
All anticipated impacts on water quality are described, but the impacts are not classified as to whether they might be adverse or beneficial. Such classification would depend on a consideration of many environmental factors other than water quality alone. Furthermore, what may be adverse in one regard may be beneficial in another. The water-quality information provided in this report is basic to the needs of several of the other special environmental studies carried out by other investigators to furnish a base of information for the Barge Canal environmental impact assessment. Inasmuch as the results of all of the special studies, including the water-quality investigation, ultimately will be integrated into one comprehensive environmental assessment, a judgment as to whether an impact on water quality is adverse or beneficial needs to be made in the context of the full environmental impact assessment. Likewise, it is beyond the scope of this report on water quality to list measures to minimize or mitigate adverse impacts, summarize unavoidable impacts, or to determine whether or not there has been an irreversible commitment of resources.

Completion of the Canal along the authorized alinement

The Cross-Florida Barge Canal project as authorized by Congress in 1942 provided for a high-level barge canal, as opposed to a sea-level ship canal, about 110 mi (177 km) long extending from the St. Johns River at Palatka to deep water in the Gulf of Mexico near Yankeetown. The canal was to be 12 ft (3.6 m) deep and 150 ft (46 m) wide. Water-level elevations in the canal were to range from near sea level at each end of the canal to about 55 ft (17 m) above mean sea level in the summit pool. The project provided for five navigation locks, three reservoirs with dams and spillways and one pumping station. The authorized projects, including the canal, locks, and dams, is shown in figure W.Q. 35.

Construction of the canal began in 1964. The project was about one-third complete when construction was halted by Executive order in January, 1971. Completed parts of the project, shown in red in figure W.Q. 35, include Rodman Dam, Lake Ocklawaha, parts of the canal east of Lake Ocklawaha and west of Lake Rousseau, and Buckman, Eureka, and Inglis Locks.

The potential impacts of the various alternatives for completing the canal on the quality of water are discussed for three time periods in each of the six reaches in the following sections. The first reach begins in the St. Johns River at Palatka and the last reach ends at the Gulf of Mexico.



NOTE: ILLUSTRATIONS PREPARED BY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS, 1975

CROSS FLORIDA BARGE CANAL
RESTUDY REPORT

AUTHORIZED ALINEMENT

JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

FEBRUARY 1976 FIGURE W.Q. 35

Palatka to Buckman Lock

The canal alinement from Palatka essentially follows the St. Johns River upstream for 13 mi (21 km) to the landcut entrace to Buckman Lock. From there the canal extends to Buckman Lock about 2 mi (3 km) west of the river. As shown in figure W.Q. 35, the lock and that part of the canal between the lock and the river have been completed. The reach of the canal along the St. Johns River remains to be completed. The authorized design provides for three cutoffs through marsh areas along the river to lessen canal bending. The river reach excavation would be by hydraulic pipeline. Dredged material from construction and subsequent maintenance would be deposited in seven upland sites along the river. Land clearing for this reach of the canal would require the removal of 945 acres (382 ha) of swamp forest.

Construction Period

Land clearing and dredging required to complete the reach of the canal along the St. Johns River is expected to take 1 to 2 years. These operations will result in the suspension of silt, clay, and organic material in the river, and turbidity of the river will be appreciably increased during dredging operations. Past dredging operations in the Oklawaha River above Moss Bluff resulted in turbidities as high as 680 JTU and concentrations of suspended sediment in excess of 400 mg/l. Similar increases in turbidity and suspended sediment also may occur during dredging of the St. Johns River. However, flow velocities in the river are low most of the time, particularly downstream from Palatka where the river is wide. For that reason, much of the sediment placed in suspension by dredging would probably settle to the bottom within a few miles of the construction.

The suspension of bottom materials in the river also would cause a temporary increase in the concentration of nitrogen, phosphorus, and other nutrients, and would increase BOD. Higher nutrient concentrations would tend to increase the productivity of phytoplankton and vascular aquatic plants. However, in highly colored streams such as the St. Johns, light penetration may be more important than nutrients in limiting production of rooted aquatic plants. A higher BOD would reduce the concentration of dissolved oxygen in the river.

The construction of the canal is not expected to have an appreciable effect on the quality of ground water in this reach. The movement of surface water into the shallow aquifer in this reach would not increase as a result of canal construction except for the local areas where the dredged material is to be deposited. Large amounts of water are used to move materials through the hydraulic pipeline dredge; but soils are not highly permeable in the disposal areas. It is unlikely that the quantity of water moving into the shallow aquifer would be large enough to have a significant effect on the quality of ground water in the area.

Period of Adjustment

The impact of completing this reach of the canal on water quality will be greatest during the construction period, but the quality of water in the river may be affected by runoff from the canal banks, disposal areas, and other cleared lands until these areas are stabilized by vegetation. Turbidity and suspended sediment concentrations which are likely to be high in the river during dredging are expected to be much less after construction has ended. During periods of heavy rainfall, however, erosion of cleared areas, canal banks and the diked disposal areas may temporarily increase turbidity and concentrations of suspended sediment and nutrients. Also, some of the fine material which had settled to the bottom of the river downstream from the dredging operation may be resuspended during periods of high flow.

Temporary increases in turbidity, suspended sediment, and nutrient concentrations from the resuspension of bottom material and from erosion of canal banks and cleared areas might occur during the first year after construction; but these increases are expected to be small in comparison to those during construction. Cleared areas are expected to be at least partly revegetated and stabilized within 1 year after the construction period. Seasonal high flows during the first year after construction should be sufficient to remove most of the sediment likely to be resuspended. The quality of ground water in this reach probably will not be affected during this adjustment period.

Stabilized Post-Constuction Period

After the canal banks and cleared areas have been stabilized by vegetation and seasonal high flows have removed part of the sediment deposited along the river bottom during construction, the canal may have little effect on the quality of water in the river. However, several effects on water-quality are possible: (1) reduced flooding of the river could decrease nutrient uptake in areas that were covered by swamp forest or marsh; (2) reduced flow velocity in the design cutoffs will decrease vertical mixing and could result in occasional dissolved-oxygen stratification (however, such stratified conditions probably now occur in the numerous old river meanders along the St. Johns); and (3) accidental spills of toxic materials by boat and barge traffic, as in other parts of the Barge Canal, could occur.

Because completion of the canal in this reach is not expected to change the relation between surface and ground water, the quality of ground water should not be appreciably different from that prior to construction.

Buckman Lock to Eureka Lock (Lake Ocklawaha)

From Buckman Lock the completed part of the canal extends westward about 6 mi (10 km) into Lake Ocklawaha which was impounded by Rodman Dam in 1968. As shown in figure W.Q. 35, the completed part of the canal extends about 1 mi (1.6 km) into the lake. The remainder of the canal route through the lake (about 15 mi or 24 km) has been cleared but no dredging has been done. The canal in this reach would be excavated by hydraulic pipeline dredge. Excavated material and future maintenance material would be deposited at six upland disposal sites along the north and west shores of Lake Ocklawaha.

Construction Period

Dredging of the 15-mi (24-km) reach of canal through the lake would resuspend silt, clay, and organic material in the lake, greatly increasing the turbidity. Downstream from Orange Creek where the lake is fairly wide and flow velocities are low, bottom materials consist largely of fine silt, clay and large amounts of organic detritus. Where resuspended by dredging, these materials would tend to remain in suspension longer than the coarser materials in the upper end of the reservoir. Very high turbidities can be expected in the immediate area of dredging in the lower part of the lake. However, dense growths of aquatic weeds in that part of the lake are expected to limit the movement of the turbid water and remove much of the turbidity. While the lower end of the lake is being dredged, the turbidity of the Oklawaha River below Rodman Dam will probably increase somewhat but the increase probably will be much less than in the immediate area of the dredging.

Upstream from Orange Creek, Lake Ocklawaha narrows and flow velocities are fairly high compared with those below Orange Creek. Consequently, bottom materials above Orange Creek tend to be somewhat coarser and contain less organic material. When resuspended by dredging, these coarse materials would settle out faster than the finer materials in the lower end of the lake, but the higher velocities in the upper reaches may carry the sediment in suspension much farther downstream than would the velocities prevalent in the lower reaches of the lake. Because, in the upper end of the lake, aquatic weeds are not so dense and velocities are higher, much of the bottom material resuspended by dredging above Orange Creek could be carried into the lower end of the lake. Some of the resuspended material will probably be carried through the lower reaches of the lake along the old river channel, where velocities are slightly higher than average for that part of the lake, and released into the Oklawaha River below Rodman Dam. However, in view of the distance to be traveled and the tortuous path of the old river channel, the turbidity of the river below the dam probably will be much less than that in the upper part of the reservoir during construction. Deposition of sediment along the river below the dam is unlikely. Flow velocities in that reach of the river probably are sufficient to keep in suspension sediment that is discharged through the dam.

The resuspension of bottom materials in Lake Ocklawaha also would temporarily increase the BOD and the concentrations of nitrogen and phosphorus. Because bottom materials at the lower end of the lake contain much higher concentrations of nitrogen, phosphorus, and organic material than at the upper end of the lake, resuspension would have a greater affect on nutrient concentrations and BOD at the lower end. The dense growth of aquatic weeds in the lake would probably assimilate these nutrients fairly rapidly. The BOD exerted by the resuspended sediments would tend to decrease the already low dissolved oxygen concentrations that occur during summer. For example, at the lower end of the lake on August 14-15, 1975 dissolved oxygen near the bottom was virtually absent and at the surface dropped to less than 1 mg/l over a diel cycle. (See page 57.) An increase in oxygen demand and the depletion of oxygen in the area of dredging might be expected from the resuspension of bottom materials but, as with turbidity, these effects would probably be limited to the immediate area of dredging.

The increased concentrations of nitrogen and phosphorus and increased turbidity and BOD discussed above are to be expected during construction even though the design plans call for dredged material to be placed in diked upland disposal areas. If the dredged material were to be placed alongside the canal to form spoil islands, even larger increases in turbidity, nutrients, and BOD might be expected unless a different method of dredging were employed.

The quality of ground water in the area is not expected to change appreciably as a result of the completion of the canal. Because of the fairly low permeability of surface materials and high ground-water levels in this part of the basin, little, if any, surface water moves into the aquifer in the upper reaches of Lake Ocklawaha. Some seepage into the aquifer occurs in the lower end of the lake but due to the low permeability of the bottom materials, this seepage is not expected to have an appreciable effect on the quality of water in the shallow aquifer.

Period of Adjustment

After construction is completed, the effects of the canal on the quality of water in Lake Ocklawaha will be much less noticeable. However, during the first year after construction, temporary increases in turbidity may be expected during periods of heavy rainfall and high flows. Fine sediments deposited on the aquatic plants and on the lake bottom during dredging may be resuspended during periods of high flow. Runoff from the disposal areas also may increase the turbidity temporarily until these areas are stabilized by vegetation. These temporary increases in turbidity would probably be very small in comparison to those expected during dredging.

Some changes in water quality associated with the growth of aquatic weeds may also occur during this period. Sediment deposition on these plants and reduced light penetration due to high turbidities will probably kill some plants in the immediate area of dredging. The decay of the dead plants will temporarily reduce the dissolved oxygen concentration in the water. This probably will be followed by a brief period during which those areas may be relatively free of aquatic weeds, and dissolved oxygen concentrations would not undergo the large diel variations common to areas with dense growths of aquatic weeds. In view of the rate at which these plants have spread through the lake in recent years, new growth of aquatic weeds in these areas probably would occur within 1 year.

Because of the limited amount of seepage from the lake to the aquifer, no appreciable change in the quality of ground water in this reach of the river is expected during this period.

Stabilized Post-Construction Period

After the period of adjustment described above, the effects of the canal on the quality of water in Lake Ocklawaha will be primarily related to dissolved oxygen concentrations. Stratification and extremely low dissolved oxygen concentrations at the lower end of the lake during the summer months are occurring presently and probably will continue unless a method of controlling the aquatic weeds is found. Stratification and conditions for the occurrence of low dissolved oxygen concentrations will exist at the lower end of the lake with or without the completion of the canal, but the completion of the canal may spread these problems to the upper end of the lake. It is not known whether the weed problem will, in time, spread to the upper end of the lake even without the canal. However, it appears that the higher velocities in that part of the river may be preventing these plants from becoming established in the upper end of the lake. If the canal is completed, velocities in the canal itself will still be fairly high but slack-water conditions may exist in parts of the river channel cut off by the canal. Lower flow velocities and reduced mixing in parts of the river on either side of the canal will tend to increase dissolved oxygen stratification and will be more suitable for the growth of aquatic weeds. If these weeds become established in the upper part of the lake, as they have in the lower end of the lake, similar problems with dissolved oxygen concentrations can be expected during the summer.

Inasmuch as Lake Ocklawaha has been in existence for about 7 years and the completion of the canal through the lake is not expected to appreciably change the rate of seepage into or out of the lake, no additional effects on the quality of ground water in the area are anticipated. Additional barge and boat traffic will contribute small amounts of oil and grease to the lake but in view of the large surface area and the amount of vegetation in the lake, this is not expected to be a major pollution hazard. Accidental spills of pollutants, as in other reaches of the canal, however, are a potential hazard. The effect of an accidental spill would, of course, depend upon the amount and nature of the material introduced into the water. The effect of an accidental spill on the quality of water in Lake Ocklawaha and the lower Oklawaha River could be minimized by rapidly lowering the lake level by discharging water to the St. Johns River through Buckman Lock. This would affect the quality of water in the St. Johns River but the pollutant would be diluted by water from the lake.

Eureka Lock to Dosh Lock (Eureka Pool)

The authorized alinement for this reach of the canal follows the Oklawaha River upstream from Eureka Lock about 16.5 mi (26.5 km) as shown in figure W.Q. 35. Eureka Lock and Dam and bridges at state highways 316 and 40 have been constructed but no clearing or dredging has been done in this reach. No work has been done on Dosh Lock located east of Ocala and about 2 mi (3 km) upstream from the inflow from Silver Springs. Design plans call for about 7,250 acres (2,930 ha) of swamp forest to be cleared in the area of Eureka Pool. Excavation of the pool would be by hydraulic pipeline dredge. Dredged materials would be deposited in five diked upland disposal areas along the river.

Construction Period

Because of the amount of land to be cleared and the amount of dredging to be done, the impact of construction on water quality will be greater in this reach than in any other. Runoff from the cleared areas along the river will introduce sediment into the river increasing turbidity, color, and suspended sediment concentrations. Prior to impoundment, the velocity of the river will probably be sufficient to carry much of this sediment into Lake Ocklawaha increasing turbidity in the upper end of the lake. After Eureka Pool is impounded, dredging of the canal through the pool will probably result in large increases in turbidity, color, and suspended sediment. The coarser materials resuspended by dredging will be deposited in Eureka Pool where flow velocities will be fairly low. This pool initially will contain little aquatic vegetation to aid the sedimentation of suspended materials, however, and the finer material may be carried into Lake Oklawaha increasing the turbidity in the upper end of the lake.

Materials placed in suspension during construction also will exert an oxygen demand. The biochemical oxidation of the organic materials suspended in the water can be expected to slightly reduce dissolved oxygen concentrations. Prior to the impoundment of Eureka Pool, increased BOD in the river will have a greater effect on the dissolved oxygen concentration in Lake Ocklawaha than in the river. High velocities in the river will carry the organic material into Lake Ocklawaha before much decay can occur. After impoundment of Eureka Pool, the effects of increased BOD due to dredging on dissolved oxygen concentration will be greatest in the pool. Reaeration at the Eureka Spillway would greatly reduce the effect of the increased BOD in Eureka Pool on the dissolved-oxygen concentration in the upper end of Lake Ocklawaha.

Because of the relatively small amount of aquatic vegetation in the area of Eureka Pool, nutrients released by sediment during construction would have less effect on this reach of the river than on Lake Ocklawaha. During the warmer months when aquatic weeds are growing rapidly, the nutrients carried into the lake would probably be assimilated by plants in the lake. During the winter months when plant growth is slow, some of these nutrients could be carried through the lake and into the St. Johns River.

This reach of the Oklawaha River normally receives ground-water inflow. Because construction prior to filling Eureka Pool is not expected to change the amount or direction of seepage along the river no change in the quality of ground water in this reach is expected during pre-impoundment construction. After impoundment, the level of Eureka Pool will be about 15 ft (4.6 m) higher than the natural potentiometric surface in the vicinity of the lower end of the pool and the direction of seepage will be reversed (Faulkner, 1973a, p. 84). The effect of seepage from Eureka Pool on the quality of ground water will be greatest after the pool has been filled. For that reason, the effects on quality of ground water will be discussed in the following sections.

Period of Adjustment

After the canal has been dredged through Eureka Pool, problems with high turbidity and suspended sediment will decrease greatly. During periods of heavy rainfall and high flows, sediments deposited on the lake bottom during dredging may be resuspended temporarily increasing the turbidity. Runoff from the disposal areas and cleared areas also may temporarily increase the turbidity until these areas are stabilized by vegetation. However, these temporary increases in turbidity would probably be very small in comparison to those expected to occur during dredging.

The decay of organic material inundated by Eureka Pool will decrease dissolved oxygen concentrations and increase color and concentrations of organic carbon in the impoundment. According to Holcomb and others (1973) dissolved oxygen concentrations in Lake Ocklawaha generally were less than 5.0 mg/l during and for a short time after the filling of the lake. Because of the similarities in Lake Ocklawaha and Eureka Pool, dissolved -oxygen concentrations in Eureka Pool might also be expected to be within this range. A slight increase in color similar to that experienced when Lake Ocklawaha was impounded can also be expected in Eureka Pool.

Chemical changes due to the mixing of water of different chemical characteristics can be expected to occur in Eureka Pool following impoundment. Silver Springs the dominant source of inflow to Eureka Pool, and the Oklawaha River below Silver Springs generally contain very hard calcium-bicarbonate water which is fairly low in color, but higher in specific conductance and dissolved solids than most surface waters in the area. Mud Lake, Lake Eaton, and Lake Charles, which will be inundated by Eureka Pool (fig. W.Q. 35), are lower in dissolved solids concentration than the Oklawaha River. When sampled in August 1975, the specific conductance of these lakes ranged from 89 micromhos/cm in Lake Charles to 315 micromhos/cm in Mud Lake as compared to a specific conductance of 460 micromhos/cm at Silver Springs and 362 micromhos/cm in the Oklawaha River at Eureka. Lakes Eaton and Charles were much more highly colored than the river, and all three lakes were lower in hardness than the river.

When filled, Eureka Pool will contain a mixture of waters from inundated lakes and swamps, from Silver Springs and from the Oklawaha River above Silver Springs. The high color in many of the lakes and swamps will increase the color in Eureka Pool, but the quality of water in the pool will, in many respects, more closely resemble the quality of water from Silver Springs than that of the lakes and swamps inundated. The hardness and dissolved solids concentration of water in Mud Lake, Lake Eaton, and Lake Charles will increase when these lakes are inundated and the calcium-magnesium-sulfate water in Mud Lake and Lake Charles will change to a calcium-bicarbonate water.

The natural water level in the Floridan aquifer is presently (1975) above the stage of the Oklawaha River in the lower half of this reach and some ground water is seeping upward into the river. This seepage is responsible for slight increases in concentrations of chloride in that part of the Oklawaha River and the comparatively high concentration of sulfate in some lakes in that part of the basin. When filled, the level of Eureka Pool will be about 40 ft (12 m) above mean sea level which is about 20 ft (6 m) above the operating stage of Lake Oklawaha and about 15 ft (5 m) above the natural potentiometric level of the Floridan aquifer in the area of Eureka Lock and Dam. The impoundment of Eureka

Pool will thus reverse the direction of seepage along the lower half of this reach and the seepage of ground water with comparatively high concentrations of dissolved solids, chloride and sulfate into the river would be stopped. Consequently, slight decreases in dissolved solids, chloride, and sulfate concentrations at Eureka will occur after impoundment. However, the ground-water inflow along this reach is small and any change in the quality at Eureka due to the cessation of this inflow would be very small.

Seepage from Eureka Pool into the aquifer would also affect the quality of ground water but changes in the quality would occur slowly due to the slow rate of movement from the pool to the aquifer. The effects of impoundment on the quality of ground water might not be readily apparent during the adjustment period and are therefore discussed in the following section.

Stabilized Post-Construction Period

After Eureka Pool is filled, this reach of the river will in many respects be similar to Lake Ocklawaha. Flow velocities will be greatly reduced and suspended materials carried into the impoundment would settle and be incorporated into the bottom materials. Consequently, the amount of suspended sediment carried into Lake Ocklawaha can be expected to decrease.

The temperature of the surface water in this section of the river can be expected to fluctuate over a larger range, after impoundment. Impoundment of the river will greatly increase the surface area and will result in higher water temperatures during warm weather and lower water temperatures during cool weather. Impoundment of the river also will increase water depth by as much as 20 ft (6 m) in some areas and will tend to increase thermal stratification during the summer. Differences in surface and bottom temperatures of 2°C to 3°C similar to those measured in Lake Ocklawaha during this investigation can be expected.

Increased depth of water and thermal stratification during the summer would also result in dissolved oxygen stratification similar to that which presently occurs in Lakes Ocklawaha and Rousseau. Differences in dissolved oxygen concentrations at the surface and near bottom were as much as 5.0 mg/l in Lake Ocklawaha and 13 mg/l in Lake Rousseau during this investigation. Concentration of dissolved oxygen near bottom were, at times, less than 1.0 mg/l in both lakes.

Dissolved oxygen concentrations in Eureka Pool will also be affected by aquatic plant productivity which is expected to greatly increase after impoundment, as was the case in Lake Ocklawaha. As plant biomass increases, large diel variations in dissolved oxygen can be expected. During the night, dissolved oxygen concentrations may drop to nearly zero as the plants and other organisms respire. During the day, concentrations may far exceed saturation levels as the plants photosynthesize. In Lake Ocklawaha concentrations of dissolved oxygen have changed from nearly 0 to 200 percent of saturation over 24 hours.

Other changes to be expected with increased plant productivity are the accumulation of organic material and its effects on water chemistry. As plants grow they take up nutrients from the water or sediment, and thus can decrease downstream concentrations of these nutrients. With the expected increase in plant biomass in Eureka Pool, nutrient flow downstream should decrease. Such changes in Lake Ocklawaha have already been documented; for example, average concentrations of total nitrogen decreased about 30 percent over that reach. The increase in plant biomass will also result in more dead and dying plant matter which will sink and consume oxygen. In the absence of mixing, dead plants accumulate and deplete oxygen from bottom waters. Low oxygen concentrations near the bottom are common in Lake Ocklawaha. Under conditions of low oxygen concentration the breakdown of organic matter is greatly slowed and it tends to accumulate as organic sediment.

Severe plant-related water-quality problems in Lake Ocklawaha developed over a period of about 6 years. A similar pattern can be expected in Eureka Pool unless aquatic plants can be controlled.

As mentioned in the previous section, some water is expected to leak from Eureka Pool into the shallow aquifer and the Floridan aquifer in the downstream or northern half of this reach. This area is underlain by a thick sequence of poorly permeable deposits and the amount of water leaking into the aquifers is not expected to be large. However, this downward leakage would, in time, raise the potentiometric surface in this part of the reach to a point of equilibrium with the stage of the pool. More leakage to the aquifers is expected to occur to the east of the pool than to the west; but significant rises in ground-water levels are not expected to extend for more than a few miles on either side of the pool (Faulkner, 1973a, p. 84).

The downward leakage of water from Eureka Pool will affect the quality of water in both the shallow and the Floridan aquifers. Near the upstream end of this reach where downward seepage is not expected, ground water is generally less mineralized than the water in the river below Silver Springs. However, there is a marked increase in the concentration of chloride, dissolved solids, and hardness in ground water underlying the Oklawaha River valley downstream from Silver Springs. In the area of the downstream end of Eureka Pool where downward seepage will occur, water in the Floridan aquifer is higher in concentrations of dissolved solids and chloride than in is the water that Eureka Pool will contain. Upward leakage of water from the Floridan aquifer also has resulted in fairly high concentrations of dissolved solids and chloride in the shallow aquifer in this part of the basin, as indicated by figure W.Q. 6. Consequently, downward seepage from Eureka Pool would tend to reduce the concentration of dissolved solids, chloride and hardness of water in both the shallow aquifer and the Floridan aquifer in the area of the downstream end of Eureka Pool.

Accidental spills of toxic materials in this reach would not only affect surface-water quality, but could leak downward into the shallow and Floridan aquifer. However, the rate of seepage is not expected to be high and accidental spills are less of a threat to the quality of ground water in this reach than in areas where the surface materials are more permeable.

Dosh Lock to Dunnellon Lock (Summit Reach)

The Summit Reach will be about 28 mi (45 km) long and will traverse the higher ground in the central part of the State. In this reach, the canal will be excavated below the water table in the unconfined Floridan aquifer. Canal excavation will be accomplished by draglines, scrapers, and other land-operated equipment. Rock from the excavation will be used for slope protection. Excess material will be deposited along both sides of the alinement.

Water used to operate Dosh and Dunnellon Locks will be replaced by back-pumping from Eureka Pool, and there will be a direct exchange of water between the aquifer and the canal. Water levels in the canal will fluctuate over a range of about 10.5 ft (3.2 m) in response to natural fluctuations in ground-water levels. Throughout most of this reach, water will seep from the aquifer to the canal but two zones of outflow from the canal to the aquifer are expected. The zones of potential outflow were described by Faulkner (1973a) and are shown in figure W.Q. 4. The larger and more important of these zones is a 4-mi (6-km) reach of the canal from which water will enter the aquifer and move toward Silver Springs 5 mi (8 km) to the north.

Construction Period

The construction of this reach of the canal is not expected to have an appreciable effect on the quality of surface water. Because of the well developed subsurface drainage system, there are no perennial streams in this area. A few swampy prairies are located in the western half of this reach where the water table is near land surface; but many of these prairie lakes contain water only when the water table is high. The Summit Reach of the canal will cross several of these prairie lakes but the effects of construction on the quality of water in these lakes is not expected to be large. If these lakes contain water during construction, turbidity in the immediate area of excavation will increase. Due to the shallow grassy nature of these prairie lakes, however, effects of construction should be limited in areal extent.

Because this reach of the canal will be excavated below the water table, there is some potential for construction to affect the quality of ground water. Ground water exposed by excavation will be turbid in the immediate area of construction. Throughout most of the reach ground water will be flowing from the aquifer to the excavated part of the canal: turbid surface water will not enter the aquifer. Where the water level in the canal is higher than the water level in the aquifer (fig. W.Q. 4), turbid water could move from the canal into the aquifer. If large solution channels or fractures are encountered, construction could increase the turbidity of ground water some distance from the canal downgradient from the areas of outflow. This is not expected to be a major problem, however, and may not occur at all if water levels at the construction site are temporarily lowered during construction. If water levels can be lowered sufficiently by pumping water from the excavation site, seepage from the canal to the aquifer may be eliminated.

Period of Adjustment

Because this is the longest reach of the canal, construction may take several years. Consequently, parts of this reach may be completed long before the entire reach is operational. During this period of construction, little mixing is expected to occur in the completed part of the reach. Initially, the dissolved oxygen concentration in the canal water, like that of the ground water entering the canal will be fairly low and may decrease with depth in the canal. As aquatic plants become established in this reach of the canal, the dissolved oxygen concentration is expected to increase, at least during the day.

Analyses of ground water from the Floridan aquifer summarized earlier in this report indicate that ground water contains enough nitrogen and phosphorus to support aquatic plants. The depth of this reach and the fairly steep sides of the canal may limit the growth of rooted aquatic plants to areas near the shore. However, the clarity and low color of ground water coming into the Summit Reach and the low velocities expected during this period will favor the growth of phytoplankton as well as rooted aquatic plants. Prior to canal operation, the dissolved oxygen concentration of water in the Summit Reach will depend largely upon photosynthesis by these plants.

No significant impacts on the quality of surface water are expected during this period. Although the west end of this reach of the canal will cross several prairie lakes, levees will presumably separate the canal from these shallow lakes. An analysis of a sample collected from one of these lakes in August 1975 indicates that they sometimes contain water lower in dissolved solids and pH but much higher in color than water from most Floridan aquifer wells. Consequently, the canal is expected to contain water higher in dissolved solids and pH but lower in color than the prairie lakes through which it will pass. This difference in water quality between the lakes and the canal is not expected to appreciably affect the quality of water in these lakes because the water level in the canal will be slightly lower than the lake levels. If water were to be exchanged between the canal and the lakes it would move from the lakes into the canal. During dry periods when the water table is low, the lakes often contain no water.

Stabilized Post Construction Period

When the Summit Reach is completed, an inflow-outflow relation between the canal and the Floridan aquifer will exist. Water in this reach of the canal will move into the aquifer at the principal zone of outflow and in time will be discharged at Silver Springs. Some water may also move from the canal through a smaller outflow zone toward the Withlacoochee River. Consequently, the quality of ground water down-gradient from these zones of outflow will be to some degree dependent upon the quality of water in this reach of the canal.

Because the water in the Summit Reach will be largely ground water, the quality of water in this reach of the canal is expected to be similar to that of ground water in the Floridan aquifer. Based on the summary of ground-water analyses in table 4, water in the Summit Reach should be slightly alkaline, low in color and turbidity, and have a dissolved solids concentration between 150 and 200 mg/l. However, the quality of water in this reach may be affected by continued operation of the canal. Pumpage from Eureka Pool to the Summit Reach to replace lockage losses is likely to consist of a mixture of waters from Silver Springs and the upper Oklawaha River. Because the average discharge of Silver Springs is more than twice that of the Oklawaha River at Moss Bluff, the quality of water pumped into the Summit Reach probably will more closely resemble the quality of Silver Springs water than that flowing from Moss Bluff. If this is true, then pumpage to the Summit Reach would also be slightly alkaline and fairly low in color and turbidity, but would have a higher dissolved solids oncentration and nitrogen concentration than water in the Summit Reach. Therefore, backpumping water consisting largely of Silver Springs water, which has a dissolved solids concentration of about 280 mg/l and a nitrogen concentration about twice that of water in most Floridan aquifer wells, could be expected to result in a slight increase in dissolved solids and nitrogen concentrations in the Summit Reach. The slight increase in nitrogen concentration might increase plant productivity somewhat but the introduction of Silver Springs water into the Summit Reach would not present a serious threat to the quality of water in the canal or the aquifer.

During periods of high discharge, a large part of the pumpage to the Summit Reach would be derived from the upper Oklawaha River basin. Although the average concentration of dissolved solids in the Oklawaha River at Moss Bluff is similar to that expected in the Summit Reach, water from the upper Oklawaha River basin is often highly colored and turbid, and frequently contains high concentrations of nitrogen and coliform bacteria. If a significant amount of this comparatively poor-quality water were pumped to the Summit Reach, the quality of water in this reach would be degraded and the quality of ground water in the outflow areas might be affected. However, in view of the proximity of Silver Springs inflow to the proposed pumping stations and the relative magnitude of Silver Springs discharge, it is unlikely that the quality of water pumped from Eureka Pool would have a significant effect on the quality of water in the Summit Reach except when discharge is unusually high or when the canal or the river above Eureka Pool is being dredged.

The upper end of Eureka Pool might become turbid and contain high concentrations of nutrients during maintenance dredging of the canal below Dosh Lock or the Oklawaha River above Eureka Pool, and perhaps during periods of very high discharge from the upper Oklawaha River basin. If this were to happen, back-pumping would temporarily increase the turbidity and nutrient concentrations in the east end of the Summit Reach. When discharge is unusually high, pumping into the Summit Reach might also decrease the pH of water in the east end of this reach. The lower pH would tend to increase the rate at which the carbonate rock would be dissolved; but in view of the slightly alkaline nature of ground water entering the canal and the abundance of alkaline material along this reach, it is unlikely that this would significantly affect seepage rates in the zone of outflow.

Another effect of canal operation on the quality of water in the Summit Reach would be that caused by barge and boat traffic. Turbulence resulting from barge and boat traffic would help keep the waters in the canal mixed thereby reducing stratification of dissolved oxygen in the canal. This turbulence would also tend to increase the turbidity of the canal waters by resuspending fine sediment in the water. This is not expected to be a major problem, however, because most of the bottom materials alongtthis reach of the canal will consist of limestone and fairly clean sand. Silt and clay which are more easily disturbed and remain in suspension for long periods make up only a small part of the bottom material. The stabilization of the canal banks with rock also should help to control turbidity in the canal water.

The operation of boats and barges can be expected to introduce small amounts of oil, grease, gasoline and certain engine exhaust products into the canal water. Because of the small surface area, the effects of boat operation on the quality of water may be somewhat greater in the canal than in other lakes and streams in Florida. However, the effects of boat operation on the quality of water in most lakes and streams have been minor. Many of the contaminants adhere to soils and vegetation along the shore and are eventually decomposed. Thus, while a slight increase in the concentration of oil and grease and other organic material in the Summit Reach may result from the operation of barges and boats, normal use of the canal is not expected to present a major pollution hazard to the canal waters.

Although normal use is not expected to pollute the water in the canal, there is a risk of the Summit Reach being contaminated by accidental spills. If a barge were to spill pollutants into the canal, these pollutants would be carried toward the outflow zones and from there into the aquifer if preventive measures were not taken. In the event that oil or some other insoluble material were spilled into the canal the outflow zones would need to be dammed off, if possible, until the material could be skimmed off or pumped out of the canal. If the contaminants were highly soluble and could not be removed by the methods just described, the Summit Reach could be temporarily lowered by rapidly draining the canal through the locks. This would reverse the flow in the zones of outflow and water from the canal could not enter the aquifer. The aquifer would be contributing water to the canal along the entire reach under these conditions and any contaminant which might have gotten into the aquifer may be flushed out. This would, of course, degrade the quality of water in the lower pool but would reduce the chance for the pollutant to enter the aquifer. The pollutant would be diluted in the lower pools but if the material were highly toxic, it might still represent a serious risk to aquatic life.

Once the Summit Reach is completed and in use, its operation is not expected to affect the quality of surface water in the area significantly. Operation of the locks on either end of this reach will release a mixture of ground water and water pumped from Eureka Pool into the lower pools. However, differences in the expected quality of these waters are not large and the release of water from the Summit Reach probably will not have a significant effect on the quality of the lower pools except during emergencies such as an accidental spill.

Dunnellon Lock to Inglis Lock (Lake Rousseau)

This reach of the canal is 12.5 mi (20.1 km) long. It will extend westward from Dunnellon Lock to Lake Rousseau, a distance of about 5 mi (8 km). From there the canal will extend through the lake for about 7 mi (11 km) to the landcut entrance to Inglis Lock. As shown in figure W.Q. 35, completed works in this reach include Inglis

Lock, about 1 mile of canal between Inglis Lock and Lake Rousseau, and a new structure at Inglis Dam. A bypass channel with a control structure to divert water from the upstream side of Inglis Lock to the lower Withlacoochee River has also been completed. Excavation of the remaining part of this reach will be by dragline between Dunnellon Lock and the city of Dunnellon and by hydraulic pipeline dredge in Lake Rousseau. Where the dragline will be used, excavation materials will be deposited along both sides of the canal. Dredged material will be deposited in five diked upland disposal areas around Lake Rousseau.

Construction Period

Excavation by dragline in the eastern end of this reach is not expected to affect appreciably the quality of surface water or ground water. No major surface-water features are along that part of the canal alinement between Dunnellon Lock and the Withlacoochee River at Dunnellon. The effects of construction on ground water in this part of the reach would be limited primarily to increased turbidity in the ground water exposed by excavation. Although turbidities may be high in the immediate area of excavation, little or no movement of this turbid water into the aquifer is expected. The direction of flow is likely to be from the aquifer into the canal, particularly if water is drained or pumped from the canal during construction.

Excavation by hydraulic pipeline dredge in that part of the reach west of the city of Dunnellon is expected to have an appreciable effect on the quality of water in Lake Rousseau and to a lesser degree in the lower Withlacoochee River. Dredging will resuspend the fine sediments and organic matter in the bottom materials of Lake Rousseau and will greatly increase the turbidity of water in the lake. Turbidity and suspended sediment during canal dredging will probably be a greater problem in Lake Rousseau than in Lake Ocklawaha. Because Lake Rousseau is a much older reservoir, the layer of fine sediment and organic materials on the bottom probably is thicker than in Lake Ocklawaha. Consequently, since average flow velocities will be higher in Lake Rousseau than in Lake Ocklawaha, the sediments disturbed by dredging in Lake Rousseau would tend to remain in suspension longer. Rooted aquatic plants which are abundant in Lake Rousseau would retard the movement of suspended sediment and reduce the turbidity. However, in view of the higher velocities, smaller surface area, and the lower density of aquatic plants in Lake Rousseau, plants will probably be less effective in reducing turbidity in Lake Rousseau than in Lake Ocklawaha.

Dredging is also expected to temporarily increase the concentration of nutrients and the BOD in Lake Rousseau. Analyses of bottom sediments in Lake Rousseau contain unusually high concentrations of phosphorus, and concentrations of nitrogen and carbon somewhat similar to those in bottom sediments of Lake Ocklawaha. The resuspension of these sediments could result in a large increase in the concentration of nitrogen and a much larger increase in the concentration of phosphorus in the lake. Much of the nitrogen and phosphorus released by the sediments would probably be assimilated by aquatic plants and the growth rate of these troublesome plants would be temporarily increased. However, the effect of dredging on the growth rate of these plants is not expected to be much greater in Lake Rousseau than in Lake Ocklawaha. The increase in phosphorus concentrations as a result of dredging is expected to be much larger in Lake Rousseau than in Lake Ocklawaha, but it is unlikely that phosphorus is a limiting factor in the growth of these plants.

As in Lake Ocklawaha, the resuspension of carbonaceous material in Lake Rousseau would be expected to increase the oxygen demand. Although during this investigation dissolved oxygen concentrations in Lake Rousseau were generally higher than those in Lake Ocklawaha, the increased oxygen demand could remove dissolved oxygen from the water in the immediate area of dredging. Plant photosynthesis would replace much of the oxygen removed so that the effects of dredging on dissolved oxygen concentrations may be limited to the area near construction.

Dredging is expected to increase the BOD, turbidity, and concentrations of nitrogen and phosphorus in Lake Rousseau even though dredged materials will be deposited in diked upland sites. If dredged materials were deposited in the lake to form spoil islands, construction would have a much greater effect on the quality of water in Lake Rousseau. The bottom materials in Lake Rousseau doubtlessly contain large amounts of silt and organic material which have been deposited there since the early 1900's when the lake was impounded. Consequently, the placement of dredged materials in the lake is likely to result in a greater increase in turbidity, nutrient concentrations and BOD in Lake Rousseau than in Lake Ocklawaha.

The quality of ground water in the area of Lake Rousseau is not expected to change appreciably as a result of canal construction. Potentiometric levels in the Floridan aquifer are close to the normal stage of Lake Rousseau and the amount of water exchanged between the lake and the aquifer is expected to be small. Some ground-water inflow is expected to occur near the upper end of this reach, below Dunnellon Lock, as a result of canal construction, but no increase in the movement of water from the lake to the aquifer is expected. Some water will flow from the lake to the aquifer in the area of Inglis Dam, Inglis Lock, and the bypass channel due to the differences in head in the aquifer above and below the structures. The amount of water moving from the lake into the aquifer is believed to be small except at Inglis Dam. There, leakage around the dam through solution channels in the aquifer averages about 70 ft^3/s (2.0 m^3/s). Consequently, if the turbidity and concentrations of nutrients in Lake Rousseau were greatly increased during construction, turbidity and nutrient concentrations in ground water might be expected to increase in these areas of outflow. Effects of construction on the quality of ground water are expected to be limited primarily to small areas near the structures. In many instances much of the water moving into the aquifer will be returned to the stream or canal on the downstream side of the structure.

Period of Adjustment

During the first year after this reach of the canal is completed, temporary increases in turbidity may be expected during periods of heavy rainfall and high flows. Disposal areas would be diked but erosion of the dikes and spoil piles could temporarily increase turbidity and suspended sediment concentrations until these areas are stabilized by vegetation. Also, fine sediments deposited on aquatic plants and on the lake bottom during dredging may be resuspended during periods of high flow. The amount of sediment likely to be resuspended during this period is not expected to be large, and temporary increases in turbidity should be very small in comparison to those expected during construction.

Some changes in the quality of water in Lake Rousseau associated with the growth of aquatic plants also may occur during this period. Sediment deposition and reduced light penetration due to high turbidity during the construction will probably kill some of these plants in the immediate area of dredging. The decay of these dead plants may temporarily reduce dissolved oxygen concentrations in the water. If the aquatic plants along the canal become fewer, the diel variation in dissolved oxygen concentrations would also be reduced. New growth of aquatic plants alongside the canal would probably occur within a year.

The operating stage of this reach of the canal will be very near the present stage of Lake Rousseau and the exchange of surface water and ground water is expected to be comparatively small. Consequently, the completion of this reach of the canal is not expected to have much effect on the quality of ground water in the area.

Stabilized Post-Construction Period

Normal operation and use of this reach of the canal, should it be completed, is not expected to have an appreciable impact on the quality of ground water but may cause some minor changes in the quality of surface water. Additional barge and boat traffic will contribute a small quantity of oil and grease to Lake Rousseau but in view of the relatively large surface area and the amount of vegetation in the lake, this is not expected to be a major pollution hazard.

As in the other impoundments, low concentration of dissolved oxygen may occasionally be a problem during the summer when aquatic plant growth becomes dense. During the summer and fall of 1975, dissolved oxygen concentrations were generally higher in Lake Rousseau than in Lake Ocklawaha. However, some stratification of dissolved oxygen with low concentrations near the bottom did occur above Inglis Dam as shown in figure W.Q. 18. Stratification at this site was due in large part to the fact that the dam was closed and flow velocities in this part of the lake were not sufficiently high to keep the lake mixed. Under these conditions, some stratification of the lake near the dam can be expected during summer and fall with or without the canal. Dissolved oxygen may stratify in other parts of the lake if the canal is completed because most of the flow through the lake would be in the canal and flow velocities in other parts of the lake would likely be reduced somewhat. That is, the decrease in velocity would reduce mixing and, hence, would tend to increase stratification. However, stratification of dissolved oxygen should not be appreciably greater in other areas of the lake than that near Inglis Dam where stratification apparently has been occurring seasonally for many years.

Although normal operation and use of this reach of the canal is not expected to greatly affect the quality of water in the area, an accidental spill could cause the lake to become polluted. The extent or nature of such pollution would, of course, depend upon the amount and nature of the material introduced into the water. In view of the fairly short flow-through time, calculated to be about 5 days (U.S. Dept. of Agriculture, Forest Service, 1973), any pollutant spilled in this reach could move through Lake Rousseau and into the lower Withlacoochee River fairly rapidly. The effects of an accidental spill on water quality in Lake Rousseau and in the river below the lake could be minimized by rapidly lowering the lake level by discharging water to the Gulf of Mexico through Inglis Lock. This would also reduce the threat to the quality of ground water, tending to result in water moving from the aquifer to the lake instead of from the lake to the aquifer. This would have an adverse effect, however, on the quality of water in the west end of the canal and in the Gulf of Mexico at the entrance to the canal.

Inglis Lock (Lake Rousseau) to the Gulf of Mexico

This reach of the canal extends 16.8 mi (27.0 km) from Inglis Lock to deep water in the Gulf of Mexico. The canal intersects the lower Withlacoochee River about 1 mi (1.6 km) below Inglis Dam. The canal and that part of the river between the canal and Inglis Dam are subject to salt-water intrusion from the Gulf of Mexico. An earthen dam separates the canal from the downstream part of the Withlacoochee River north of the canal. Flow in this part of the lower Withlacoochee River is maintained by the diversion of water from Lake Rousseau above Inglis Lock through a bypass channel with a control structure.

Construction Period

This reach of the Cross-Florida Barge Canal is complete (fig. W.Q. 35). The land-cut part was dug by dragline and the material excavated was deposited on both sides of the canal. The part in the Gulf reach was dredged by hydraulic pipeline and barge-mounted dragline and the waste piled in mounds along the south side of the alinement. Since the completion of the canal most of the flow from Lake Rousseau less than about 1,600 ft^3/s (45 m^3/s) has been through the bypass channel to the lower Withlacoochee River. Except when flow from the lake exceeded the capacity of the bypass channel (about 1,700 ft^3/s or 48 m^3/s), flow in the canal has consisted of water used to operate Inglis Lock and about 70 ft^3/s (2 m^3/s) of leakage around Inglis Dam.

Construction of this reach was completed in 1969. Consequently the only future construction likely to affect the quality of water in the canal or in the lower Withlacoochee River, should the canal be completed, is that in the reach upstream of Inglis Lock and Dam. Dredging in Lake Rousseau is expected to cause turbidity and nutrient concentrations in the lake to increase appreciably. In view of the fairly short flow-through time in Lake Rousseau, some increases in turbidity and nutrient concentrations also can be expected in the lower Withlacoochee River. Velocities in the lower Withlacoochee River will be sufficient to carry much of the suspended sediment to the Gulf of Mexico, but some sediment may be deposited along the river during dredging. Sediment most likely will be deposited in this part of the river during dredging in the lower end of the lake, but the quantity deposited probably will be less than when the bypass channel was dredged. Although some of the nutrients carried into the lower Withlacoochee River will be taken up by aquatic plants, most probably will be carried to the Gulf. When inflow to Lake Rousseau is high, discharge through Inglis Dam may be sufficient to increase the turbidity and nutrient concentrations in the Barge Canal between the lock and the Gulf of Mexico.

Period of Adjustment

Inasmuch as the reach of the canal from Lake Rousseau into the Gulf was completed in 1969, most of the changes in the quality of surface and ground water related to the completion of the canal have already occurred. These changes were discussed earlier in this report and in reports by Bush (1973) and Faulkner (1973a and 1973b). During the period of adjustment after the construction period in Lake Rousseau, the lower Withlacoochee River may increase slightly in turbidity when discharge through the lake is high. However, these increases should be much smaller than those expected during the construction period.

Stabilized Post-Construction Period

Barge and boat traffic in this completed reach of the canal may cause some turbidity and add some oil and grease to the canal water. However, because the canal bottom consists largely of limestone and sand in this reach, turbidity is not expected to be a major problem. The small amount of oil and grease likely to be introduced into this reach of the canal during normal operation is not expected to be a major pollution hazard. These materials will adhere to vegetation and soils along the canal bank and will tend to be oxidized or slowly flushed from the canal by tidal fluctuations and flow through Inglis Lock and Inglis Dam.

An accidental spill of a toxic material or other pollutant in this reach of the canal could seriously threaten aquatic life in the canal and in the Gulf near the mouth of the canal because normal flow from Lake Rousseau into this reach of the canal is fairly small. Little dilution would occur unless additional water were released from the lake specifically to dilute the spill. Any soluble pollutant spilled in this reach would eventually be carried into the Gulf. But, in view of the low flows in this reach of the canal and the effects of tidal fluctuation on the movement of water in the canal, the pollutant could remain in the canal for many days. Because water tends to move from the canal to the aquifer immediately adjacent to the canal during high tide, the presence of a pollutant in this reach of the canal also could have an effect on the quality of ground water. It is unlikely that a pollutant would move very far through the aquifer, however, because during low tide the direction of flow would be from the aquifer to the canal. In areas near the canal where the quality of ground water is likely to be affected, ground water may already be unsuitable for many uses due to high salt content.

Few changes in the quality of water in the lower Withlacoochee River are expected as a result of barge and boat traffic in the canal. Bush (1973) reported that the operation of Inglis Lock sometimes caused the sodium chloride concentration above the lock to increase temporarily and that this sodium chloride was carried into the lower Withlacoochee River by way of the bypass channel. This resulted in small, temporary increases in sodium chloride concentrations in the lower river. As the lock is used more and more, these temporary increases in sodium chloride will become more frequent. However, sodium chloride concentrations of the magnitude expected in the lower river likely will not cause any serious problems. Bush (1973) found that increases in specific conductance in the lower river chargeable to operation of the lock were usually less than 60 micromhos/cm. The specific conductance of water in the lower river is less than 300 micromhos/cm on the average. A specific conductance increase of

60 micromhos/cm beyond a baseline of 300 micromhos/cm probably is equivalent to less than 40 mg/l of sodium chloride, and would not significantly affect the suitability of water in the river for domestic or recreational use.

The quality of water in the lower Withlacoochee River, on the other hand, could be affected markedly if a toxic fluid were spilled in Lake Rousseau. Because most of the outflow from the lake is used to maintain the flow of the lower Withlacoochee River any pollutant spilled in the lake would be carried into the lower river. The impact of such a spill on the quality of the water in the lower river would depend upon the nature of the material spilled and the extent to which the spilled fluid had become diluted in the lake.

Downstream from the bypass channel, the Withlacoochee River is generally lower than the ground-water level in the aquifer. Consequently, the general direction of flow is from the aquifer to the river and the quality of ground water in this area is not likely to be affected by the canal.

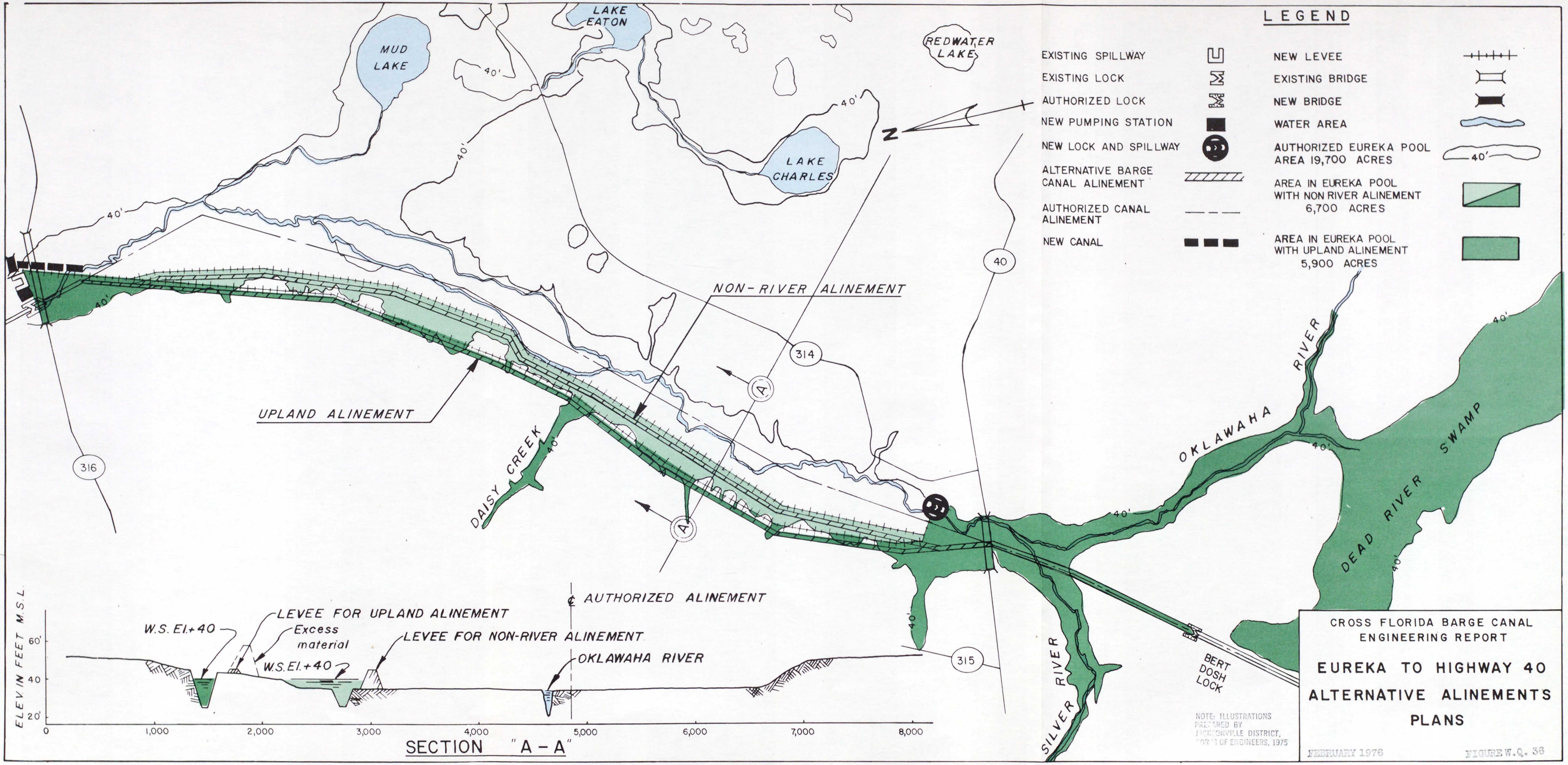
Completion of the Canal along the Eureka to Highway 40 alternate alinements

In both of two alternate alinements which would bypass about 20 mi (32 km) of the Oklawaha River between Eureka Lock and Dam and State Road 40 (fig. W.Q. 36) the canal would be located west of the Oklawaha River and the authorized alinement. A continuous levee between Eureka Dam and a point near Highway 40 would separate the canal from the Oklawaha River. The objective would be to allow the natural setting of the Oklawaha River and much of the flood plain to remain intact and thus help maintain historic water quality conditions in this reach of the river. A spillway in the levee near Highway 40 would be used to maintain normal flow in the natural river channel, and a lock would be provided to maintain recreational navigation on the Oklawaha River. At the downstream end of this reach of the river, the east end of Eureka Dam would be cut and a canal would divert the river into Lake Ocklawaha. The existing spillway at Eureka Dam would be used only when discharge is high. Normally, there would be no discharge from this reach of the canal to Lake Ocklawaha except for lockage losses and those would be replaced by backpumping.

The two alternatives for this reach of the canal shown in figure W.Q. 36 are similar in that they generally parallel the authorized alinement. The tie-in-levee and structure arrangement just north of Highway 40 and the modification of Eureka Lock and Dam are the same for both alternatives. But, the locations of the canal and levee for the two alternatives differ: in one case the canal and levee are in the flood plain and in the other they are outside the flood plain. The alternative referred to, simply as "non-river alinement" in figure W.Q. 36, calls for the canal and levee to be located along and inside the northwest edge of the flood plain. The "upland alinement" calls for the canal and levee to be located farther to the northwest on higher ground completely out of the flood plain and would maintain the natural setting in virtually the entire flood plain in this reach. The surface area of Eureka Pool under either of these alternatives would be much smaller than that of the authorized Eureka Pool (19,700 acres or 8,000 ha). The stage of the pool would be the same in these alternate alinements as in the authorized plan but the non-river alinement and upland alinement would have surface areas of only 6,700 acres (2,700 ha) and 5,900 acres (2,400 ha), respectively.

Construction Period

Excavation of the canal along either of these alternate routes will be primarily by dragline and other land operated equipment. Material from the excavation will be used to construct a continuous levee along the east side of the canal. The only places where the canal will intersect streams of any size will be near each end of this reach. Near


LEGEND
EXISTING SPILLWAY
EXISTING LOCK
AUTHORIZED LOCK
NEW PUMPING STATION
NEW LOCK AND SPILLWAY
ALTERNATIVE BARGE CANAL ALINEMENT
AUTHORIZED CANAL ALINEMENT
NEW CANAL
NEW LEVEE
EXISTING BRIDGE
NEW BRIDGE
WATER AREA
AUTHORIZED EUREKA POOL AREA 19,700 ACRES
AREA IN EUREKA POOL WITH NON RIVER ALINEMENT 6,700 ACRES
AREA IN EUREKA POOL WITH UPLAND ALINEMENT 5,900 ACRES
MUD LAKE
LAKE EATON
LAKE CHARLES
REDWATER LAKE
NON-RIVER ALINEMENT
UPLAND ALINEMENT
DAISY CREEK
OKLAWAHA RIVER
DEAD RIVER SWAMP
SILVER RIVER
BERT DOSH LOCK
40'
40
314
316
315
N
AUTHORIZED ALINEMENT
LEVEE FOR UPLAND ALINEMENT
W.S. El.+40
Excess material
W.S. El.+40
LEVEE FOR NON-RIVER ALINEMENT
OKLAHAWA RIVER
ELEV IN FEET M.S.L.
60'
40
20'
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
SECTION "A - A"
NOTE: ILLUSTRATIONS PREPARED BY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS, 1975
CROSS FLORIDA BARGE CANAL ENGINEERING REPORT
EUREKA TO HIGHWAY 40
ALTERNATIVE ALINEMENTS PLANS
FEBRUARY 1976
FIGURE W.Q. 36

Eureka Lock and Dam the Barge Canal will intersect the natural channel of the Oklawaha River and a bypass channel will be excavated to carry the flow of the river around the dam. Near the upstream end of this reach, south of Highway 40, where the canal will follow the authorized alinement, the canal will intersect Silver River which carries the discharge from Silver Springs into the Oklawaha River. Excavation in the areas where major streams are intersected will temporarily increase turbidity in these streams. During periods of heavy rainfall, runoff from the levee, canal banks, and cleared areas, also, could temporarily increase turbidity and suspended sediment concentrations in the canal and in the river. The impacts of land clearing and excavation in the area above Highway 40 on the quality of water in the Oklawaha River will be the same as those described in the section on the authorized alinement.

Construction of these alternate alinements is not expected to affect the quality of ground water in the area. The canal may be excavated below the potentiometric surface, but prior to impoundment no significant movement of water from the canal to the aquifer is expected.

Period of Adjustment

After the canal, levee, and structure in this reach of the river are constructed, Eureka Pool will be filled. Because the volume of Eureka Pool under either of these alternate plans will be much smaller than that of the authorized plan, the pool could probably be filled in less than a month. During this period and for a short time thereafter, the quality of surface and ground water along the canal would change slightly.

Prior to filling, the water in the excavated canal would be derived essentially from ground-water inflow and will be similar in quality to water in the shallow aquifer. As shown in figure W.Q. 6, the quality of water in the shallow aquifer is quite variable, and frequently contains comparatively high concentrations of sodium, chloride, and sulfate ions in the area of the downstream end of this reach of the canal. The pool will be filled with a mixture of Silver Springs and Oklawaha River in which the concentration of these ions in very low. As the level of the pool rises, the movement of water from the shallow aquifer into the lower end of this reach of the canal will be reversed. The effects of seepage from the canal on the quality of ground water will be discussed in the following section.

Another effect of filling Eureka Pool would be a slight increase in color and concentration of organic carbon as the inundated organic material begins to decay. This effect would be less in the lower part of the reach than in the upper part due to the smaller surface area in that part of the pool. In the non-river alternate alinement below Highway 40, part of the flood plain will be inundated but that reach of the pool will still be fairly narrow. Even less area will be inundated under the upland alinement plan. There, water would be confined to the canal throughout much of the reach between Highway 40 and Eureka Lock and Dam. Consequently, the increase in color due to decaying timber and other organic material expected in the area above Highway 40 probably will be smaller in the area of the alternative alinements, especially if the upland alinement is used.

Dissolved oxygen concentrations in inflow to the canal below Highway 40 are expected to average less than 6.0 mg/l due to the influence of Silver Springs. The decay of organic material may further reduce the concentration of dissolved oxygen in this reach and the relatively small surface area may limit chances for reaeration. After the pool is filled there may be no flow through the canal north of Highway 40, much of the time. The lack of mixing will tend to aggravate problems with low concentrations and stratification of dissolved oxygen in this part of the canal.

Although the natural setting of the Oklawaha River downstream from the lock and spillway near Highway 40 will be preserved, slight changes in the quality of water in this part of the river also may occur during this period. Temporary increases in turbidity due to runoff from the levee and cleared areas in the upper part of the pool can be expected until these areas are stabilized by vegetation. The color of water in the river will probably increase slightly as the rising water inundates trees and organic materials in the upper end of the pool. BOD in the river may also increase but dissolved oxygen concentrations in the river should be fairly high due to the reaeration which is expected to occur as water passes over the spillway.

Stabilized Post-Construction Period

After this reach of the canal has been completed and the pool has been filled, water in the river channel downstream from the spillway near Highway 40 may contain less sediment and plant nutrients than it presently contains. Inflow to this reach of the river will be a mixture of waters from Silver Springs and the upper Oklawaha River, as in the past. However, much of the suspended sediment and plant nutrients transported by the upper Oklawaha River may be removed in the upper end of Eureka Pool. The color of water in the river channel probably will be higher after this reach of the canal is completed; but in view of the amount of flow contributed by Silver Springs the increase in color is not expected to be greater than when Lake Ocklawaha was impounded. Dissolved oxygen concentrations in this part of the river will be relatively high due to the reaeration likely to occur at the spillway.

Although no serious water-quality problems are expected in that part of the river bypassed by these alternate alinements, problems with low concentrations and stratification of dissolved oxygen are likely in the canal during the summer. Under normal conditions less water will move in the canal between Highway 40 and Eureka Lock and Dam than in the Summit Reach. While boat and barge traffic in the canal will mix the canal water, to some extent, it is unlikely that this would be sufficient to prevent stratification of dissolved oxygen in some parts of the reach.

The growth of aquatic plants in the canal will also affect dissolved oxygen concentrations to some extent. Rooted aquatic plants similar to those which have become so abundant in Lake Ocklawaha and Lake Rousseau are almost certain to spread to Eureka Pool. Experience in Lake Ocklawaha indicates that the depth of water in the canal itself may limit these aquatic plants to the shallower areas adjacent to the canal. In view of the fairly small amount of shallow water in the non-river alinement and the near absence of shallow water areas in the upland alinement, aquatic plants probably will be more abundant in the area upstream from Highway 40, which is relatively shallow, than in the area of the non-river and upland alinements. Consequently, plants will probably have less of an effect on dissolved oxygen concentrations in the area downstream from Highway 40 than above it.

Initially, increased plant productivity will probably increase the normally low dissolved oxygen concentration expected in the lower part of Eureka Pool. Within a few years, however, these plants may become as dense in Eureka Pool as they are in Lake Ocklawaha. If this happens, extremely large diel variations in dissolved oxygen concentrations can be expected in spring and early summer when plants are growing rapidly. In late summer and fall, when these plants begin to die, dissolved oxygen concentrations may be very low in large areas of Eureka Pool. Dissolved oxygen concentrations were less than 2.0 mg/l at several sites in Lake Ocklawaha in August, 1975.

Because the stage at Eureka Pool in either the alternate alinements or the authorized alinement will be about 15 ft (5 m) higher than the potentiometric level in the Floridan aquifer near Eureka, some water is expected to leak from the pool to the aquifer in the downstream half of this reach of the canal. The amount of seepage from the pool is not expected to be large because of the low permeability of the confining layer which underlies the Oklawaha River valley. However, the confining layer may not be as thick beneath the upland alinement as in the flood plain of the Oklawaha River and seepage from the upland alinement might be greater than that from either the authorized or non-river alinements.

Downward leakage would eventually raise the potentiometric level of the Floridan aquifer to a point of equilibrium with the stage of the pool. Because of the small surface area in the lower end of the pool in the non-river and upland alinements, rises in ground water levels would not extend as far to the east as might be expected with the authorized Eureka Pool. Some of the water moving eastward from the canal of the non-river or upland alinement into the shallow aquifer would probably be intercepted by the Oklawaha River. The quantity of water likely to seep into the shallow aquifer is not known but in the lower end of this reach, the head difference between the pool and the river will be about 20 ft (6 m.)

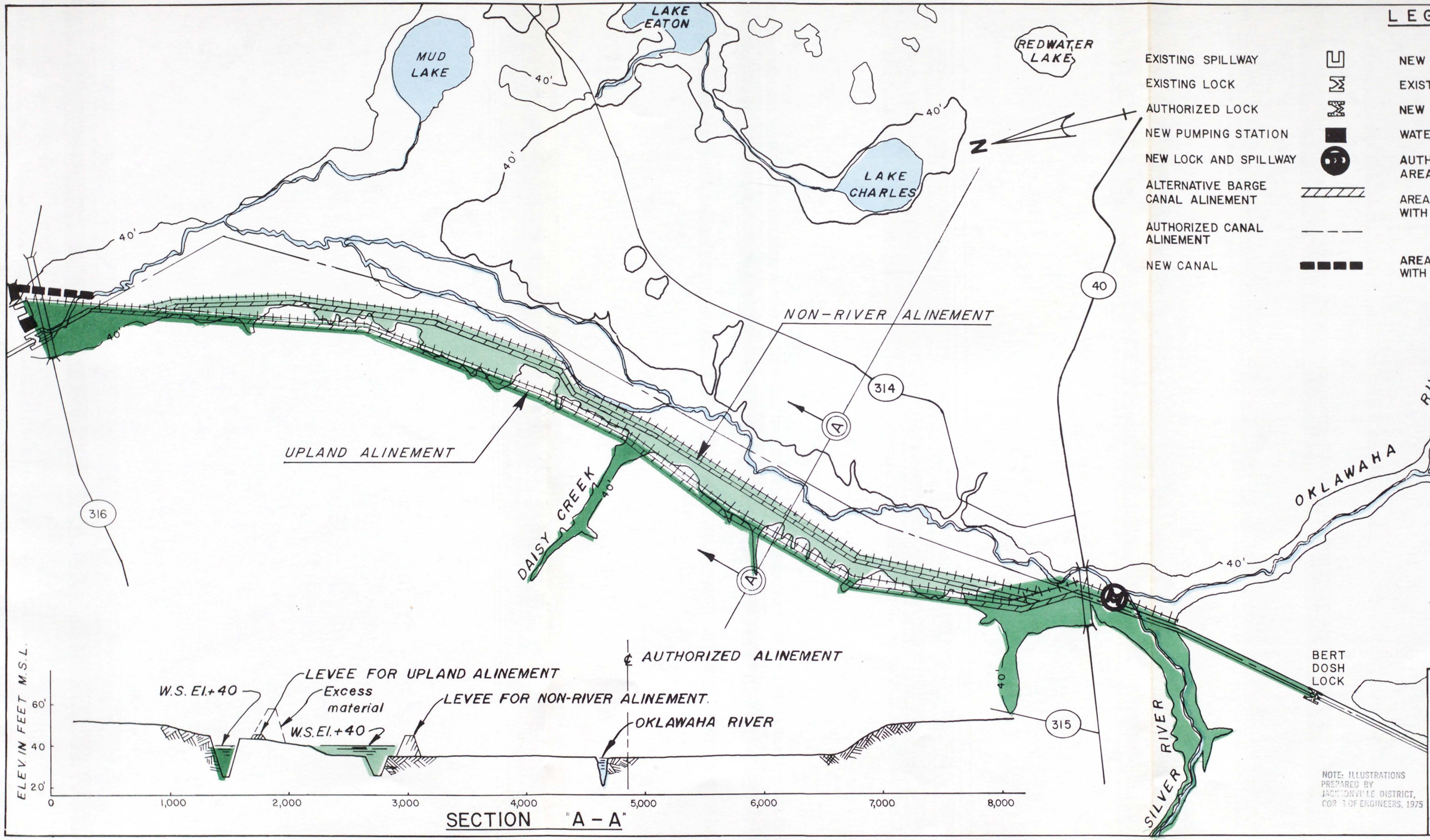
Downward seepage from the lower end of the pool in the alternate alinement would have a similar effect on the quality of ground water as seepage from the authorized Eureka Pool. The concentrations of dissolved solids, chloride and hardness in both the shallow aquifer and Floridan aquifer in the area of the downstream end of Eureka Pool would be reduced somewhat. The quality of water in these aquifers in the immediate area of the pool would, in time, approach that of water in the canal and the Oklawaha River.

Completion of the canal along the Eureka to Dosh Lock alternate alinements

Two alternate alinements which would provide a leveed barge canal between Eureka and Dosh Locks without impounding the Oklawaha River (fig. W.Q. 37) are modifications of the Eureka to Highway 40 alinements. North of Highway 40 the alternate alinements are the same as the non-river and upland alinements described in the previous section. These alinements differ from the Eureka to Highway 40 alternate alinements in that the levee which separates the canal from the Oklawaha River would extend to high ground in the vicinity of Dosh Lock. A spillway and lock would be provided at the point where the levee crosses Silver River. The objectives of these alternate alinements would be to maintain the natural setting of the Oklawaha River and much of the flood plain; and help maintain the present water quality in this reach of the river. The surface area of Eureka Pool for the non-river alinement between Eureka and Dosh Locks would be about 2,300 acres (900 ha) as compared to 19,700 acres (8,000 ha) for the authorized alinement and 6,700 acres (2,700 ha) for the non-river alinement for the Eureka to Highway 40 alternative. The surface area for the upland alinement for the Eureka to Dosh Lock would be even smaller (about 1500 acres or 600 ha).

Construction Period

Construction of either the non-river or upland alinement between Eureka and Dosh Locks would be similar to that described in the section on the Eureka to Highway 40 alternatives. The excavation and construction of the levee is not likely to have appreciable effect on the quality of surface water except in those few areas where the levee will cross major streams. Temporary increases in turbidity may be expected during construction of the bypass channel around Eureka Dam and during construction of the canal and structure at Silver River. Turbidity may also



CROSS FLORIDA BARGE CANAL
ENGINEERING REPORT

EUREKA TO BERT DOSH LOCK ALTERNATIVE ALINEMENTS PLANS

FEBRUARY 1976

FIGURE W.Q. 37

increase temporarily near Eureka Lock and Dam and in the vicinity of Silver River as a result of runoff from the levee and from cleared areas, but this is not expected to be a major problem. The alternate alinements between Eureka and Dosh Locks would require less land clearing than any of the other alternatives considered for this reach of the canal.

Construction of either of the alinements between Eureka and Dosh Locks is not expected to affect the quality of ground water in the area. The canal will be excavated below the potentiometric surface in some areas; but prior to impoundment very little water is expected to seep from the canal to the aquifer.

Period of Adjustment

Because of the comparatively small volume of Eureka Pool in the non-river and upland alinements in this alternative, the pool can probably be filled within a few weeks. Changes in the quality of both surface and ground water during this period would be similar to those described under the Eureka to Highway 40 alternate alinements. However, the pool will be filled with Silver Springs water and not a mixture of water from Silver Springs and the Oklawaha River as in the Eureka to Highway 40 alternatives. Consequently, the pool will be filled with water very low in color and turbidity. Runoff from the levee and cleared areas may temporarily increase turbidity as the pool is being filled, but in view of the small amount of area to be cleared this is not expected to be a serious problem. Dissolved solids concentrations in the pool would be similar to that of water from Silver Springs and would be somewhat higher than that in the Oklawaha River.

Although water from Silver Springs is of excellent quality in many respects, it contains little dissolved oxygen. As shown in figure W.Q. 7, the dissolved oxygen concentration at the head of Silver Springs averages less than 3.0 mg/1. The dissolved oxygen concentration of this water increased downstream due to reaeration and probably averages about 5.0 mg/1 at the confluence with the Oklawaha River. This is somewhat lower than average concentrations of dissolved oxygen at other sites along the river, and filling the pool with water from Silver Springs may increase the dissolved oxygen problems expected in this reach of the canal.

Water from Silver Springs contains, on the average, less total nitrogen but more inorganic nitrogen than the Oklawaha River at Moss Bluff. If the pool is filled with water from Silver Springs the comparatively high concentration of inorganic nitrogen in combination with the clarity and lack of color in the pool may cause an increase in plant growth and a temporary increase in the concentration of dissolved oxygen in the pool. Unless controlled, however, plant growth will probably become very dense in the shallower areas of the pool and may cause dissolved-oxygen problems similar to those in Lake Ocklawaha. Although the small surface area of the upland alinement would tend to limit reaeration of water in the canal, the small extent of shallow water in the upland alinement may limit the growth of aquatic plants and reduce their effect on dissolved oxygen concentration.

No noticeable effects on the quality of water in the Oklawaha River are expected during this period. The flow from Silver Springs into the river would be reduced somewhat while the pool is being filled. This may cause the turbidity, color and concentrations of total nitrogen and phosphorus to increase slightly and the concentration of dissolved solids in the river to decrease slightly. However, these changes in the quality of water in the river can be minimized by filling the pool gradually.

Seepage from the downstream end of Eureka Pool will be the same as that described previously in this report. Because the pool will depend on Silver Springs for most of its water, the dissolved solids concentration of water moving into the aquifer would be somewhat higher than that of seepage from the pool in the Eureka to Highway 40 alternative alinements. The water in the pool probably will have a lower mineral content than that of ground water in the lower end of this reach.

Stabilized Post-Construction Period

The completion of this reach of the canal is not expected to affect the quality of water in the Oklawaha River appreciably after the pool has been filled. If lockage and seepage losses from the pool are replaced by backpumping from Lake Ocklawaha, the amount of flow contributed by Silver Springs to the river should be little less than the present contribution. The dissolved oxygen concentration in flow from Silver Springs into the Oklawaha River may be higher after the canal is completed because of the reaeration that likely will occur as water passes over the spillway.

Water-quality problems in Eureka Pool are likely to develop within a few years after the completion of this reach of the canal. However, the areas affected would be greatly reduced from that of the authorized alinement. The comparatively low dissolved oxygen concentration in the inflow to the pool, the small surface area, and the very low velocities in the canal are likely to lead to low concentrations of dissolved oxygen and dissolved oxygen stratification during the warmer part of the year. If aquatic plants become as troublesome in Eureka Pool as they have in Lake Ocklawaha, dissolved oxygen problems will be even greater. Dissolved oxygen problems related to dense growths of aquatic plants are more likely to occur in the non-river alinement, due to the larger area of shallow water, than in the upland alinement. In addition, the overall area subject to aquatic plant problems in the Eureka Pool upland alinement would be about a third that of the non-river alinement, and, for comparison, about a tenth that of the authorized alinement. A small area also would make control of aquatic weeds more feasible than control in a large area.

No water is expected to seep downward to the shallow and Floridan aquifers in the upper end of the pool, but seepage from the canal is expected at the pool's lower end. The volume of seepage is not expected to be large, however. Nonetheless it may be greater in the upland alinement than in the non-river alinement. Seepage from the pool to the aquifers is generally expected to decrease concentrations of dissolved solids, chloride, and sulfate in ground water in the area. The effects of this seepage on the quality of ground water were discussed in more detail earlier in this report.

As in any other reach of the canal, spillage of an undesirable material could seriously impair the quality of water in the canal. Were the spill to occur in the upper end of the pool, the pollutant could be carried into the Oklawaha River. A spill in the lower part of the pool would not travel far owing to the very low velocity of flow in the pool. This would facilitate clean-up procedures for insoluble materials such as oil. Although seepage out of the canal could carry a soluble pollutant into the aquifers, the rate at which water moves from the canal into the aquifers is expected to be slow. The quality of water in the aquifer could be protected by partly draining the pool into Lake Ocklawaha where the pollutant would be greatly diluted. This would, of course, degrade the quality of water in Lake Ocklawaha to some extent.

Completion of the Canal according to Summit Reach Alternate Plans

Alternate plans for the Summit Reach of the Barge Canal represent only small modifications to the authorized plan. Alternate plans for this reach of the canal provide for excavation to an altitude of 31 ft (9.4 m) as compared to 28 ft (8.5 m) for the authorized design. The higher bottom altitude for the alternate plan would require less excavation and the canal would not penetrate as far into the Floridan aquifer. The Summit Reach was originally designed to accommodate water-level fluctuation between 40.0 and 55.0 ft (12.2 and 16.8 m) above mean sea level. More recent data indicate that water-level fluctuations would probably be in the range of 43.0 to 51.5 ft (13.1 to 15.7 m) above mean sea level if Eureka Pool is maintained at an altitude 38 to 40 ft (11.6 to 16.8 m). Therefore, a bottom altitude of 31 ft (9.4 m) would provide for a minimum depth of 12 ft (3.6 m) of water in the canal at all times so long as ground-water levels remained within ranges of record. A bottom altitude of 31 ft (9.4 m) would not allow for below-record ground-water levels. In an extreme drought that might result in new record low water levels, the depth of water in the canal could be reduced temporarily to less than the design depth of 12 ft (3.6 m).

The authorized design for the Summit Reach called for a single pumping station, located at Dosh Lock, to replace lockage losses. The pumping facility would have a capacity of about 750 ft^3/s (21 m^3/s). In contrast, the alternate plan for the Summit Reach provides for a pumping station at each end of the reach. The alternate plan would provide for a pumping station with a capacity of 210 ft^3/s (5.9 m^3/s) at Dosh Lock and a pumping station with a capacity of 420 ft^3/s (12 m^3/s) at Dunnellon Lock. Back-pumping lockage losses at each end of the Summit Reach is expected to practically eliminate the transfer of water from the Oklawaha River basin into the Withlacoochee River basin.

Construction Period

Construction of this reach of the canal would be similar to that called for in the authorized Summit Reach plans. Alternate plans for this reach provide for a steeper gradient to the side slopes of the canal below an altitude of 40.0 ft (12.2 m) where rock is encountered. The alternate plans also require less excavation because of the higher altitude of the canal bottom. However, these modifications of the authorized design are not likely to change the effects of construction on the quality of surface and ground water in the area. The effects would be little different from those described earlier for the authorized alinement. The turbidity of ground water exposed by excavation and water in some of the prairie lakes near the west end of the reach may increase somewhat during construction, but turbidity problems are expected to be only temporary and of a local nature. Some turbid water could move into the aquifer in the outflow areas, temporarily increasing turbidity in ground water near the canal, but this is not expected to be a major problem unless large fractures or solution channels are encountered during excavation. The effects of construction on the quality of ground water could be minimized by lowering the water level in the canal during excavation.

Period of Adjustment

No serious water-quality problems are expected in this reach of the canal between the times when the excavation is completed and the canal becomes operational. Water levels in the prairie lakes crossed by the canal should be slightly higher than the water level in the canal and no change in the quality of water in these lakes is expected. Water in the canal will be derived nearly entirely from ground-water sources and may have low concentrations of dissolved oxygen. Because flow velocities in this reach of the canal will be very low and little mixing will occur, water in the canal is likely to become stratified with respect to dissolved oxygen.

In the area of the zones of outflow shown in figure W.Q. 4 water will move from the canal to the aquifer. However, the movement of water both into the aquifer from the canal and from the aquifer into the canal may be somewhat less in the alternate plan than in the authorized plan. Aquifer tests in the outflow zones of the Summit Reach indicate that although the permeability of Floridan aquifer materials varies horizontally as well as vertically, the permeability of the material above the planned altitude of the canal bottom is generally less than that below the altitude of the canal bottom (Tibbals, 1975). This does not preclude the possibility that large solution channels will be encountered during excavation of the canal. It does suggest, however, that the higher bottom altitude of the canal in the alternate plan could result in less flow between the aquifer and the canal than with the authorized plan.

Some water will seep from the canal to the aquifer in the outflow zones in both the authorized or alternate plan, but the water in this reach prior to the operation of the canal will be mostly ground water and will not have a very great effect on the quality of water in the aquifer. If large solution channels or fractures are encountered in the outflow zones, phytoplankton and other particulate material could be carried into the aquifer. If such channels and fractures in the outflow zones were found during excavation, the effects of seepage on the quality of water in the aquifer could be minimized if they were plugged.

Stabilized Post-Construction Period

Effects of the operation and use of the Summit Reach, constructed and operated in accordance with the alternate plans, on the quality of water in the area would be very similar to the effects of the authorized plan. Exchange of water between the canal and the aquifer may be somewhat less in the alternate plan than in the authorized plan but the potential effect of the canal on the quality of ground water still is expected to be greater in this reach than in any other.

Normally, the quality of water in the canal will not present a threat to the quality of water in the aquifer. Water in the canal may occasionally have low concentrations of dissolved oxygen and may sometimes have high concentrations of phytoplankton. During maintenance dredging in this reach of the canal, high turbidities can be expected. However, these problems are not expected to present a serious threat to the quality of water in the aquifer unless large solution channels are encountered in the outflow zones. The alternate plan for this reach of the canal would tend to reduce the chances of encountering large solution channels but it will not eliminate this possibility. If large solution channels are encountered, they might be plugged to minimize the chances of contaminating the water in the aquifer.

The effect of back-pumping (to replace lockage losses) on the quality of water in the Summit Reach will be smaller in the alternate plans than in the authorized plan. By replacing lockage losses at each end of the reach, the transfer of water from the Oklawaha River basin to the Withlacoochee River will be essentially eliminated. The water pumped into the Summit Reach from Eureka Pool generally is not expected to degrade the quality of water in the Summit Pool. However, the quality of water in the upper end of Eureka Pool could at times contain high concentrations of suspended sediment and nutrients due to maintenance dredging of the canal or other factors. If enough of this comparatively poor-quality water were pumped into the Summit Pool to replace all lockage losses, this water would move along the canal toward Dunnellon Lock, affecting the quality of water in the canal and possibly in the aquifer adjacent to the outflow zones. In the alternate plan for this reach, lockage losses would be replaced at both ends of the reach. Consequently, if poor quality water were pumped into either end of the Summit Pool the tendency for it to move along the canal would be reduced. Much of the water pumped to the upper pool to replace lockage losses would remain near the locks and would be drained in future lockages.

Back-pumping at Dunnellon Lock should not affect appreciably the quality of water in Eureka Pool except perhaps during maintenance dredging. Water in the canal below Dunnellon Lock would consist of a mixture of ground water, water from Rainbow Springs, and water from the upper Withlacoochee River. Although the upper Withlacoochee River occasionally contains water with fairly high concentrations of suspended sediment and nutrients, it is unlikely that the quality of water in the river would appreciably affect the quality of water in the canal at Dunnellon Lock about 3 mi (5 km) to the east.

Completion of the Canal according to West End Alternate Plans

The west end of the Barge Canal has been completed since 1969 but under consideration are several modifications which would reduce the salinity conditions in the canal below Inglis Lock, prevent advance of salt water up the Withlacoochee River, and increase mixing in the lower end of Lake Rousseau. These modifications consist of an additional lock and spillway on the lower Withlacoochee River just downstream from Yankeetown and the replacement of one of the standard spillway gates at Inglis Dam with a slot gate which could be set to discharge up to 200 ft^3/s (6 m^3/s). The objective is for the lock and spillway to provide for an optimum headwater elevation of about 3.0 ft (0.9 m) in the lower Withlacoochee River with reduced flow through the bypass channel. This would provide adequate depths at docks and boatslips upstream of the lock. The positive head at the spillway would prevent salt water from moving upstream of the lock and would provide some additional protection against tidal flooding. Reduction in flow through the bypass channel would make it possible to increase the flow through the spillway at Inglis Dam. This would decrease the salinity of water below the dam and in the canal below Inglis Lock, thereby reducing the amount of salt water locked into the pool above the lock. Increased discharge through Inglis Dam would, at the same time, increase velocities in the downstream end of Lake Rousseau and tend to reduce temperature and dissolved oxygen stratification which sometimes occurs there.

Construction Period

Replacement of a standard spillway gate at Inglis Dam with a slot gate should have little effect if any on the quality of water in Lake Rousseau or in the river below the dam. If a dike or piling curtain is placed in front of the dam during this modification, a temporary increase in turbidity in the immediate area may occur. The increase in turbidity is not expected to be large, however, and would be only temporary.

Construction of the lock and spillway downstream from Yankeetown will affect the quality of water in the tidal reach of the lower Withlacoochee River. Construction of the lock and spillway doubtless will require some excavation in fairly fast moving water. Bottom sediments along this part of the river consist largely of clean sand and limestone but some increase in turbidity can be expected during construction. Some sediment may be deposited along the lower part of the river, but velocities should be sufficient to carry most of the suspended materials to the Gulf. Increases in turbidity downstream from the construction site would be temporary. Once the construction site is diked off or the river is routed around the construction site, the effects of construction on the quality of water in the river should be minimal.

Construction is not expected to affect the quality of ground water in the area to an appreciable extent. The general direction of flow is from the aquifer to the river, although at high tide the flow may be temporarily reversed.

Period of Adjustment

Following the structural modifications described above, flow through the bypass channel will be less than 400 ft^3/s (11.3 m^3/s) most of the time. Except for lockages, the remaining flow from the lake will be discharged through the spillway at Inglis Dam, which is presently closed much of the time. The minimum flow through the dam spillway will be 200 ft^3/s (6 m^3/s), but about 50 percent of the time flow is expected to be at least 1,000 ft^3/s (28 m^3/s). These changes in the flow regime will affect the quality of water in the river and the canal, and to a lesser extent in the downstream end of Lake Rousseau. Changes in the quality of water are expected to occur fairly rapidly after the flow regime is changed. Salinity of water in the river below the dam and in the canal below the lock would be reduced appreciably in a fairly short period. Higher discharges through the dam would promote mixing in the lower end of Lake Rousseau and would result in higher concentrations of dissolved oxygen during the summer when this part of the lake is sometimes stratified. Reduced flow velocities through the bypass channel and the lower Withlacoochee River will reduce mixing in that part of the river, but velocities are expected to be sufficient to maintain high concentrations of dissolved oxygen. A slight decrease in salinity of the river above the proposed spillway and an increase in salinity below the proposed spillway can be expected as a result of the positive head and reduced flow at the structure.

Stabilized Post-Construction Period

When the quality of water in the canal and lower Withlacoochee River has stabilized after the flow regime is modified, the canal below Inglis Lock is expected to contain fresh water similar to that in Lake Rousseau. This would tend to reduce salt-water intrusion of ground water in the area and reduce the amount of salt water locked to the pool above Inglis Lock. Studies by Bush (1973) show that salt water locked to the pool is not a serious threat to the quality of water in Lake Rousseau or the Lower Withlacoochee River. However, operation of the lock does result in temporary increases in specific conductance of as much as 60 micromhos/cm in the Withlacoochee River below the bypass channel. These small increases in specific conductance due to operation of the lock will be greatly reduced or eliminated if the discharge through Inglis Dam is increased.

The reduced velocities in the lower part of the river probably will not have a significant direct effect on the dissolved oxygen concentrations in the river because the water is well aerated as it passes through the control structure in the bypass channel. However, the reduced velocities in the river will tend to promote the growth of aquatic plants which can affect the concentration of oxygen in the river.

The 3.0-ft (0.9-m) optimum head of fresh water in the river above Yankeetown would prevent salt water from moving into this reach of the river. It would also tend to lower the salt-water-fresh-water interface in the Floridan aquifer beneath that part of the river above the proposed lock and spillway. Because the flow of the river will be reduced, the part of the river downstream from the proposed lock and spillway will probably become more consistently saline.

With the proposed structure near Yankeetown, inflow to the river could be temporarily stopped by closing the gates in the Inglis bypass channel. Presently (1975), discharge through the bypass channel is required to prevent movement of salt water up the Withlacoochee River. The structure near Yankeetown would serve as a salinity control dam and would prevent salt water encroachment even if there were temporarily no flow through the bypass channel. This would make it possible to isolate the lower Withlacoochee River below Inglis bypass channel from contamination in the event a pollutant were spilled in Lake Rousseau.

As described in the previous section, the increased discharge through Inglis Dam would increase circulation in the lower end of Lake Rousseau. This would reduce the stratification of dissolved oxygen that sometimes occurs in this end of the lake during the summer and fall. This would also tend to encourage movement of any suspended material or other pollutants that might be spilled into the lower end of the lake. The effects of spill of toxic fluid on the quality of fresh water could be minimized by closing the gates at Inglis Dam and in the bypass channel and partly draining Lake Rousseau through Inglis Lock.

Alternative for not completing the canal but preserving completed works

Under this alternative, the Cross-Florida Barge Canal would not be completed but the completed parts of the canal, including Lake Ocklawaha and Lake Rousseau would be maintained and operated so as to maximize recreation and wildlife benefits. Buckman Lock would continue to be operated and maintained as at present to allow recreational boats and maintenance equipment to pass. Rodman Dam and Spillway would continute to be maintained and operated for the purpose of managing the level of lake Ocklawaha to control aquatic plants and maximize recreational, fisheries, and wildlife potentials. Inglis Lock and the spillways at Inglis Dam and in the Inglis bypass channel would be maintained and operated as at present to serve existing and potential commercial and recreational traffic. The gap in the earthen dam at Eureka, through which the river flows, would remain open, and the natural state of the Oklawaha River above Eureka would be maintained. Proposals that would help preserve this reach of the river and maximize the recreational use include maintaining this reach of the Oklawaha River as a scenic river and developing nature trails and bicycle paths along the river. Wildlife management areas adjacent to Lake Ocklawaha are also being considered as an option to increase recreational and wildlife use of the area.

Construction Period

There would be very little construction under this alternative. Eureka Lock would be fenced off to prevent access to the structure. The lock gates would remain open. If nature trails and bicycle paths are constructed along the river, a minimal amount of clearing may be required, but this is expected to have little effect on the quality of water in the area.

Period of Adjustment

In view of the small amount of construction involved in the alternative and the lack of significant effects on water quality, there would be no period of adjustment recognized as affecting water quality.

Stabilized Post-Costruction Period

Because the intent of this alternative is to preserve and maintain present conditions, the quality of water in the area should not be changed appreciably if this alternative plan of action is taken. The quality of both surface and ground water in the area of the canal should be similar to that described earlier in this report for the January-December 1975 period.

The use of nature trails and bicycle paths and boating activities along the Oklawaha and Withlacoochee Rivers probably will not significantly affect the quality of water in the rivers, but water management practices in the lakes could affect water quality. Water levels in Lakes Ocklawaha and Rousseau would be periodically drawn down in an attempt to control aquatic plants and so reduce some of the problems with low concentrations of dissolved oxygen during the summer and fall months.

Management plans for Lake Ocklawaha proposed by the Corps of Engineers call for the lake level to be lowered about 5.0 ft (1.5 m) to an altitude of 15.0 ft (4.6 m) for about 60 days within the period of September through November. At this time of the year, Lake Ocklawaha frequently contains water very low in dissolved oxygen concentration and is often stratified. Reaeration due to turbulence at the spillway at Rodman Dam generally is sufficient to maintain concentrations of dissolved oxygen above 5.0 mg/l in the Oklawaha River below the dam. However, during this investigation dissolved oxygen concentrations in this part of the river were appreciably lower in the months of September through November than at any other time. The rapid release of a large volume of water as might be expected during a drawdown could result in even lower dissolved oxygen concentrations in this part of the river. Because of the stratification in the lake and the large plant biomass that will remain in the lake, the drawdown and subsequent decay of organic matter might further reduce the low dissolved oxygen concentration in the lake. If this were to happen large areas of the lake could be depleted of oxygen.

A drawdown in January or February would affect the quality of water in the lake and in the river below Rodman Dam less than would the proposed September or October drawdown. Data collected in February 1975 suggest that the dissolved oxygen concentration in Lake Ocklawaha is normally high and that the lake is well mixed in February. A drawdown in January or February would not decrease the dissolved oxygen concentrations downstream from the lake and the dissolved oxygen concentrations in the lake would be less likely to be depleted by decaying organic matter.

Past experience in Lake Ocklawaha indicates that the proposed drawdown of about 5 ft (1.5 m) may not be very successful in controlling the growth of hydrilla and other aquatic plants. The lake appears to have an ample supply of plant nutrients in the inflow derived from Silver Springs, and the clarity of water in the lake is such that light penetration is sufficient for rooted aquatic plants to become established in areas where water depth is less than about 10 ft (3 m). The proposed drawdown of about 5 ft (1.5 m) would no doubt provide some temporary relief from the aquatic-weed problems and the dissolved-oxygen problems which are frequently associated with these plants. However, a larger drawdown or a series of drawdowns designed to kill the hydrilla tubers will probably be required to effectively control the growth of these plants.

The level of Lake Rousseau will probably be managed much like that of Lake Ocklawaha. Because of the many similarities in the Withlacoochee and Oklawaha River systems, many of the problems in trying to control the growth of aquatic plants in Lake Ocklawaha will also be encountered in Lake Rousseau. However, data collected during this investigation indicate that dissolved-oxygen stratification and low concentrations of dissolved oxygen are less of a problem in Lake Rousseau than in Lake Ocklawaha. A drawdown of Lake Rousseau would probably be through the spillway at Inglis Dam and the Inglis bypass channel. This could decrease the dissolved oxygen concentrations downstream from these structures. However, due to the somewhat higher dissolved oxygen concentrations in Lake Rousseau and the reaeration expected to occur at these structures, a September drawdown would probably have less effect on the dissolved oxygen concentration below Lake Rousseau than below Lake Ocklawaha.

Alternative for Restoring the Area to its Original Condition

Under this alternative the entire project area would be returned to a natural setting insofar as possible. All buildings, dams and levees would be removed to natural ground level. Buckman Lock, Rodman Dam and Spillway, Eureka Lock and Dam, Inglis Lock and the bypass channel control structure would be removed to approximately 3.5 ft (1.1 m) below natural ground level. Completed parts of the canal and the bypass channel would be filled to natural ground level using levee material. Natural drainage would be restored and the filled areas would be grassed and planted to conform to the surrounding areas to the extent possible. Lake Ocklawaha would be drained and flow returned to the natural river channel. The pool area would be reforested to resemble pre-impoundment conditions as nearly as practicable. Inglis Dam and Spillway would be retained to maintain the preconstruction conditions in Lake Rousseau.

Construction Period

The amount of construction required to return the area of the Barge Canal to a natural setting would be large and would probably take several years to complete. The effects of this alternative on the quality of water would be greatest during this period of construction.

Lake Ocklawaha would be drained. This probably would not have an appreciable effect on the dissolved oxygen concentrations in the lower Oklawaha and St. Johns Rivers unless the lake were rapidly drained during the summer or fall when dissolved oxygen concentrations in the lake are normally low. If the lake were drained in the summer or fall, the reduction in dissolved oxygen concentrations downstream of the dam could be minimized by draining the lake slowly. Data collected during this investigation indicate that reaeration at the spillway is sufficient to maintain concentrations of dissolved oxygen above 5.0 mg/l below the dam for most discharge rates.

Increases in turbidity and suspended sediment concentration in the Oklawaha and St. Johns Rivers can be expected during construction. These increases would be only temporary and would be smaller than those that might be expected during dredging if the canal were to be finished. If Lake Ocklawaha were drained and the canal plugged at the point where it enters the St. Johns River, the removal of Buckman Lock and filling the canal would have little effect on turbidity and suspended sediment concentrations in either the St. Johns or Oklawaha Rivers. Turbidity and suspended sediment may temporarily increase in the St. Johns River when the canal is plugged, but the effects of this construction may last only a few days.

Turbidity and suspended sediment concentrations will increase temporarily in the lower Oklawaha River when Rodman Dam is cut. However, if the lake is first drained, the removal of the spillway and much of the dam can be done without introducing large amounts of sediment into the river. Increases in turbidity and suspended sediment in the river may also occur when Eureka Lock and Dam is removed, but these increases would probably be small and very temporary because much of the dam, the spillway and lock are located off to one side of the river.

Similar increases in turbidity and suspended sediment concentrations would occur during construction in Lake Rousseau and the lower Withlacoochee River. Here again, the problems with increased turbidity and suspended sediment could be minimized if the canal and bypass channel were first plugged and drained. Removal of structures and filling the intermediate reaches of the canal and bypass channel would then have little effect on the quality of water in the lake or in the river.

Period of Adjustment

After Lake Ocklawaha is drained, the decomposition of organic material could be expected to contribute to the nutrient concentrations and BOD in the river due to runoff from the exposed lake bottom. However, after a few months, the organic bottom sediment should begin to dry, compact, and become stabilized by vegetation. When this happens the effects of runoff should be greatly reduced.

After the buildings, locks, and control structures are removed and the canal is filled the cleared areas and the area of Lake Ocklawaha will be planted with grass and trees to conform as much as possible to the natural surroundings. It may be months, however, before these areas are stabilized by vegetation. During that time, erosion of these areas may result in some temporary increases in turbidity and suspended sediment concentrations in surface waters in the area.

Cleared areas in Lake Ocklawaha would be reforested after draining the lake, but years would pass before these areas would begin to approach pre-impoundment conditions. Until a dense forest canopy develops along the river channel through the area of Lake Ocklawaha, the temperature of water in the river, though lower than that in the lake, would be somewhat higher than pre-impoundment temperatures. Plant productivity in the river would also be somewhat higher than it was prior to impoundment due to the greater exposure to sunlight. This somewhat higher plant productivity could result in slightly lower concentrations of nutrients and perhaps a slightly higher turbidity and BOD in the river. than existed prior to impoundment. However, plant productivity in the restored river would be much less than that presently in the lake. The large reduction in aquatic plants that would result from draining the lake and restoring the river, would also greatly reduce the nutrient uptake and increase the concentrations of nutrients in the Oklawaha River below the area of Rodman Dam.

A gradual change in the quality of ground water in the area of Lake Ocklawaha might also be expected during this period. The direction of seepage will probably be reversed in some areas when the lake is drained. This will result in the upward movement of saline ground water resulting in some increase in the dissolved solids and chloride concentrations in ground water in the vicinity of the lake.

Stabilized Post-Construction Period

The quality of water in the Oklawaha and Withlacoochee Rivers would gradually return to pre-canal quality. Problems with low concentrations of dissolved oxygen in the lower Oklawaha River would be essentially eliminated by draining the reservoir and greatly reducing the aquatic weed problems. The higher velocities would tend to limit the growth of these plants in the river. However, reducing the aquatic weeds in this reach of the river would also reduce nutrient uptake. Consequently, the nutrient concentrations in the lower Oklawaha River would be increased as a result of restoring the river to its natural state. Turbidity might also increase somewhat with the higher velocities of the restored river. The upward movement of saline ground water would increase the dissolved solids and chloride concentrations in ground water and in the river in the area of Lake Ocklawaha. Ground water seepage into the river would result in a slight downstream increase in the dissolved solids and chloride concentrations in the river similar to that which occurred prior to impoundment.

Changes in the quality of water due to the restoration of the canal area to its pre-project condition would be less apparent in the Withlacoochee River basin than in the Oklawaha River basin. Lake Rousseau would not be drained. Filling the canal would have little effect on the quality of water in the lower Withlacoochee River except that the intermittent slight increase in specific conductance resulting from the operation of Inglis Lock would be eliminated. The salinity of ground water in the vicinity of the filled canal west of Inglis Lock would be gradually reduced as the water table rises to approximate pre-canal levels and the shallow ground water is diluted by rainfall recharge. Eventually the quality of ground water along the canal would approach pre-canal quality.

Alternative for abandoning the canal

Under this alternative, the Cross-Florida Barge Canal would be left in a non-operational but safe condition. Lock gates, except Inglis, would be left open. Machinery would not be removed, but the lock sites would be fenced. Spillway gates at Rodman Dam and in the Inglis bypass channel would be removed. Spillway gates at Eureka Dam would remain in place but not in use. The Spillway at Inglis Dam would remain in operation and Lake Rousseau would be maintained at pre-project conditions. All spillway areas would be fenced. Nothing would be done to the canal except where the canal severs a small stream just west of Buckman Lock. There, the canal would be plugged on both sides of the stream and the natural southward flow across the canal alinement would be restored. Lake Ocklawaha would cease to exist, but Lake Rousseau would be maintained as it had been before the canal was built.

Construction Period

Construction in this alternative plan of action would include removing the spillway gates at Rodman Dam, and fencing the locks and spillways. Lake Ocklawaha would then drain into the lower Oklawaha River. This probably would not affect dissolved oxygen concentrations in the river below the dam unless the lake was rapidly drained during the summer or fall when dissolved oxygen concentrations in the lake are often very low. High velocities through the spillway would help to reaerate the water but would probably cause a slight increase in turbidity downstream.

Some construction would also be required to restore flow to the small stream which crosses the canal just west of Buckman Lock. The canal would be plugged on either side of the stream and the levee cut to allow flow to return to the original channel. Presumably this construction would occur after Lake Ocklawaha is drained and before the lock gates are opened. If so, the canal would contain little if any water and the construction would have no significant effect on water quality.

Removal of the spillway gates from the control structure in the Inglis bypass channel would have little effect on the quality of water in the Withlacoochee River. Because of the limited discharge capacity of the bypass channel and the elevation of the bottom of the control structure, the gates at this structure are frequently wide open. The removal of the gates would not have a significant effect of Lake Rousseau or on the quality of water downstream.

Period of Adjustment

The only area in which water quality might undergo a period of gradual change following the construction period would be in and downstream from the area of Lake Ocklawaha. Following the draining of Lake Ocklawaha, runoff from the exposed lake bottom could be expected to contribute to the nutrient concentrations and BOD in the river. Runoff from this area could also result in a small temporary increase in turbidity in the river. However, after a few months, the exposed organic bottom sediment should begin to dry, compact, and become stabilized by vegetation. When this happens the effects of runoff from the exposed lake bottom on the quality of water in the river would be greatly reduced. As with the alternative plan discussed immediately above, draining Lake Ocklawaha would increase the upward movement of saline ground water, thereby increasing concentrations of dissolved solids and chloride in ground water in the area.

Stabilized Post-Construction Period

The quality of water in the Oklawaha River in the area of Lake Ocklawaha would slowly revert to pre-impoundment quality as described in the section on restoring the area to its original condition. Instances of low dissolved oxygen concentration would be greatly reduced with increased flow velocity and other factors that would reduce aquatic plant growth. But nutrient concentrations and turbidity would increase as a result of not reforesting the exposed lake bottom. Consequently, it would take much longer for this area to be stabilized by vegetation and for the swamp forest to be reestablished than it would take if it were planted. The quality of water in this part of the river would eventually return to pre-impoundment quality, but this change would occur more slowly under this plan of action than it would if the cleared areas were grassed and reforested.

The quality of water in that part of the canal east of the point where the canal would be plugged could deteriorate somewhat when all flow through the canal is stopped. The depth of water in the canal and the high color of the water will probably limit the troublesome aquatic weeds to the shallow areas near the shore. However, the depth of the canal, the color of the water, and the lack of flow would result in dissolved oxygen stratification and low concentrations of dissolved oxygen during the summer and fall. As discussed earlier, the upward movement of saline ground water in the area of Lake Ocklawaha would result in an increase in dissolved solids and chloride concentrations in ground water and in the lower Oklawaha River. However, seepage into the river is not expected to be large and any increase in dissolved solids or chloride concentration would be small.

The only change in the quality of water in the Withlacoochee River that would result from this plan of action would be elimination of the intermittent increase in the specific conductance of water in the river below the bypass channel due to locking operations. Inglis Lock would not be operated and no salt water would be locked to the pool above the lock to then be flushed to the lower river through the bypass channel.

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