- 2024B-08.01 -

2024B-08.01

LAKE ROUSSEAU
Operations and Management Study

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

LAKE ROUSSEAU

OPERATIONS AND MANAGEMENT STUDY

February, 1989

BY

H. C. Downing, Jr., M. S. Flannery, M. J. Buickerood,
J. A. Mann, and W. M. Matheison

00527

Southwest Florida Water Management District
2379 Broad Street, Brooksville, FL. 34609-6899

LAKE ROUSSEAU OPERATIONS AND MANAGEMENT STUDY

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Governing Board

Withlacoochee River Basin Board

We wish to acknowledge
Linda Eichhorn for typing the manuscript and
Kelly Reck for graphics.

TABLE OF CONTENTS

TECHNICAL REPORT

Page

ECI

ENGINEERING COMPANY INC.
CONSULTING ENGINEERS
79 MILK ST., SUITE 600, BOSTON, MA 02109

TEL (617) 338-2296
FAX (617) 426-6925

May 23, 1994

Lois D. Cashell, Secretary
Federal Energy Regulatory Commission
825 North Capitol Street, NE
Washington, DC 20426

SUBJECT: Inglis By Pass Dam Hydroelectric
Project, FERC # 10893-001

Dear Secretary:

Please be advised that Engineering Company, Inc. (ECI) has relocated its engineering offices, effective May 26, 1994 to:

Engineering Company, Inc.
Orchard Hill Office Park
354 Turnpike Street
Canton, Massachusetts 02021

Telephone: (617) 821-4338
Telefax: (617) 821-5721

Respectfully submitted,

ENGINEERING COMPANY, INC.

Richard A. Volkin

Richard A. Volkin, PE

cc:Service List for Project No. 10893 (attached)

It would seem eminently reasonable to point out also that the statement from the Withlacoochee Regional Planning Council, which Citrus County attaches, is dated May 21, 1992. Said date is clear evidence that the statement was made prior to the Legislature's determination resulting in Section 253.7829 F.S. Since the statute finds hydroelectric power generation a compatible use of lands, and the Council itself states that its Comprehensive Regional Policy Plan will have to be amended "when the management plan is adopted," ECI could assert that the project is no longer inconsistent with the regional plan.

Sec. 11:- ECI is also aware of the uses of the river and its water and would agree that the maintenance of water quality is of prime concern. ECI would state further that it has fully addressed this and all related issues.

Sec 13 & 15:- Sec. 253.7829 F.S. speaks for itself. It does not automatically grant all necessary State authorizations.

Sec 19:- ECI has addressed manatee and those protections associated with the proposed project. The suggested area for the depositing of fill is the same location the USACOE used to place dredge spoils and fill from the By Pass Channel and Canal.

ECI would only restate the determination of the Florida Legislature, that hydroelectric power generation is a compatible use of that land adjacent to the spillway.

Town of Yankeetown, Florida dated April 6, 1994 - no specific comments required.

Respectfully submitted,
ENGINEERING COMPANY, INC.

Richard A. Volkin, PE

cc: Service List

SERVICE LIST FOR
PROJECT NO. 10893

Department of the Army
Jacksonville District, Corps of Engineers
PO BOX 4970
Jacksonville, Florida 32232-0019
Attn: Lois Obenchain

Withlacoochee Area Residents, Inc.
PO BOX 350
Inglis, Florida 34449-0350

James Townsend
PO BOX 207
Inglis, Florida 34449-0207

Town of Yankeetown
PO BOX 280
Yankeetown, Florida 34498

Louis Rosenman, Esquire
Attorney at Law
Suite 800
1725 DeSales Street NW
Washington, DC 20036

Southwest Florida water Management District
2379 Broad Street
Brooksville, Florida 34609
Attn: Mark Farrell

Larry Haig, Esquire
County Attorney
Citrus County
Suite 8
107 North Park Avenue
Inverness, Florida 34450

Hy Power Energy Company
c/o Robert Karow
7008 Southwest 30th Way
Gainesville, Florida 32601

Florida Department of Environmental Protection
Southwest District
3804 Coconut Palm Drive
Tampa, Florida 33619
Attn: Gregory Colianni

License to present, through several meetings and documents, ECI has emphatically explained that the Inglis By Pass Dam Hydroelectric Project is a "Run-of-the-River" with no control over the water resource. Any and all decisions regarding flows and lake levels will not lie with Hy Power Energy Company, but with the State of Florida.

Motion for Late Intervention and Notice of Intervention, Town of Inglis dated April 27, 1994.- This motion is highly irregular at this late date of the proceedings and, in fact, is contrary to all previous correspondence, meetings and statements made by the Town of Inglis, Florida. This request for intervention is a stratagem and in conflict with prior position. ECI asserts that the Town of Inglis has not provided sufficient grounds to warrant the granting of a late intervention status in this matter and therefore the Commission should deny this Motion for Late intervention. However, Hy Power Energy Company and ECI, representative for Hy Power Energy Company, have always been concerned and is on record addressing the concern of insuring that the water and other natural qualities of the Lower Withlacoochee River are preserved, all in concert with the Town of Inglis. Hy Power Energy Company and ECI have come forth at many meetings with Town Officials and Town residents and have assured them that the Project will meet the above concerns. There were many schemes proposed by various State Agencies which would have defeated these concerns. Fortunately, the State of Florida Legislature denied the various proposed reconfigurations of the Withlacoochee River and supported hydropower as a compatible use of the land adjacent to the By Pass Dam Spillway. As stated in the Additional Information, Hy Power Energy Company's project protects and insures the goals and objectives for the Lower Withlacoochee River, all within the limits of Federal and State laws.

Office of The County Attorney, Citrus County letter dated April 27, 1994.- Sec 5 & 6:- This statement brings to mind the Intervention in Opposition filed by Citrus County in the instant proceeding. Since the proposed project is entirely within the boundaries of Levy County, ECI was mildly surprised that the Citrus County Attorney stated that the project was within the boundaries of Citrus County and therefore in Citrus County's jurisdiction. If one were to accept this statement as fact, which it clearly is not, then one would also erroneously assume that the Citrus County Comprehensive Plan would apply.

ECI

ENGINEERING COMPANY INC.
CONSULTING ENGINEERS
79 MILK ST., SUITE 600, BOSTON, MA 02109

TEL (617) 338-2296
FAX (617) 426-6925

June 1, 1994

Lois D. Cashell, Secretary
Federal Energy Regulatory Commission
825 North Capitol Street, NE
Washington, DC 20426

SUBJECT: Inglis By Pass Dam
Hydroelectric Project
FERC No. 10893-001

Dear Secretary:

Engineering Company, Inc. (ECI) hereby responds to those specific comments purportedly supplied by the following regarding the Additional Information supplied by ECI in the instant proceedings.

Southwest Florida Water Management District letter of April 21, 1994
Motion For Late Intervention and Notice Of Intervention, Town of Inglis dated April 27, 1994
Office of The County Attorney, Citrus County letter of April 27, 1994
Town of Yankeetown, Florida letter dated April 6, 1994

In general, all flows and technical data have been verified with United States Geodetic Survey data, analyzed by both sophisticated computer software and manually. All conditions are based on actual field observations and measurements incorporated into the historic data obtained from the various State and Federal Agencies. ECI is confident that anything more than mere perusal of the totality of the information and technical data supplied by ECI meets all the requirements established by law for the issuance of a license for Project Number 10893-001.

The following are specific related comments to the respective above noted documents.

Southwest Florida Water Management District (SFWMD) letter dated April 21, 1994 - Volume 2, Meetings: There is no documentation of Florida Department of Environmental Protection placing certain requirements on Hy Power Energy Company that would have to be met prior to gaining the State's support for this project. In addressing item 3) "Hy Power must relinquish in writing all control over the water resource." From the initiation of the Application for

Florida Department of Environmental Protection
3900 Commonwealth Blvd.
Tallahassee, Florida 32399-3000

Florida Department of Environmental Protection
Office of Greenways Management
Building 500
325 John Knox Road
Tallahassee, Florida 32303
Attn: Fred Ayer

US Departemnt of Interior
National Park Service
Southeast Regional Office
75 Spring Street, SW
Atlanta, Georgia 30303

US Fish and Wildlife
Division of Law Enforcement
Room 1218
75 Spring Street, SW
Atlanta, Georgia 30303
Attn: Don Palmer

US Fish and Wildlife
Suite 310
6620 Southpoint Drive, S.
Jacksonville, Florida 32216-0012

Town of Inglis
PO BOX 486
Bronson, Florida 32621
Attn: Peter Langley, III, Esquire

DATE: 06/07/94

OFFICE OF THE EXECUTIVE DIRECTOR
SWFWMD CORRESPONDENCE LOG # 7211-94

TIME: 13:00:35

DATE ASSIGNED: 06/07/94
SOURCE AND SUBJECT: RICHARD VOLKIN, ECI/INGLIS BY PASS DAM HYDROELECTRIC PROJECT #10893-001

ASSIGNED TO: M. FARRELL
DATE REQUIRED: / /

ASSIGNED BY: DKM
INSTRUCTIONS: FOR YOUR INFORMATION AND APPROPRIATE DISPOSITION

ACTION TAKEN:

COPIES TO: PGH/RVM/EAS/DLM/EBH;GEP/R.WESER
DATE COMPLETED: 06/07/94

APPENDICES

LIST OF FIGURES

Page No.

Page No.

Page No.

LIST OF TABLES

Page No.

EXECUTIVE SUMMARY

The primary objective of this study is the development of an operations and management plan for Lake Rousseau that would improve the environmental qualities and recreational potential of the reservoir. Lake Rousseau, a 4,163-acre impoundment of the Withlacoochee River, was created in 1909. The existing water control structures at the reservoir were constructed between 1965 and 1969 by the United States Army Corps of Engineers (USACOE) as part of the Cross Florida Barge Canal (CFBC) project. Due to environmental and water resource concerns, work on the CFBC ceased in 1971. However, the completed part of the project from the Ingis Complex to the Gulf remains authorized. That part of the project east of Inglis, including Lake Rousseau, is in the process of being deauthorized, pending enactment of appropriate legislation by the State of Florida. Upon deauthorization, it will become part of the Cross Florida National Conservation Area. The State of Florida is cooperating with the USACOE in developing a management plan for the conservation area.

Ecologically, Lake Rousseau is rapidly progressing toward a more marsh-like system, characterized by excessive aquatic plant growth, accumulated bottom sediments, and poor water circulation. Dense stands of the aquatic weed Hydrilla and floating islands of vegetation, called tussocks, cover large areas of the reservoir. Stumps remaining in the reservoir have accelerated the expansion of the tussocks by obstructing the movement of floating vegetation through the reservoir. Water quality problems in shallow areas of the reservoir have resulted from shading and reduced circulation caused by the dense aquatic weeds. Flocculent organic sediments have accumulated in the reservoir, adversely affecting water quality and sportfish habitat.

Since the Inglis Dam was constructed in 1909, water levels in Lake Rousseau have been largely stabilized. It has been widely reported, however, that lakes and reservoirs maintain healthier ecological conditions if water levels are allowed to fluctuate. The Florida Game and Freshwater Fish Commission (FG&FWFC) has suggested that periodic extreme drawdowns would improve Lake Rousseau's habitat characteristics and sportfish production. It is also the conclusion of this report that the following benefits (both immediate and long-term) should result from an extreme drawdown program:

(1) a periodic reduction in accumulated plant biomass, possibly resulting in improved water quality, particularly light penetration, vertical mixing, and increased dissolved oxygen concentrations;
(2) it would facilitate the partial removal of stumps within the reservoir, thus helping control tussock expansion;
(3) the drying and compaction of the flocculent organic sediments; and
(4) an increase in sportfish size and numbers.

To determine whether an extreme drawdown of Lake Rousseau would be feasible, the following items were considered:

(1) the fresh-water inflow needs of the Withlacoochee River estuary;
(2) the quantity of reservoir inflow and the time required to refill the reservoir;
(3) the operation of upstream water control structures and their effects on inflows to Lake Rousseau;
(4) ground-water effects (potentiometric surface response and salt-water intrusion potential);
(5) navigation and reservoir access; and
(6) the hydraulic capacity of the USACOE water control structures.

After consideration of the above items, it was determined that operation of the upstream water control structures has minimal effects on reservoir inflows. Mathematical simulations of drawdowns indicate the reservoir could be refilled within suitable periods of time while maintaining minimum flows to the lower river. Salt-water intrusion could be a potential threat to some ground-water supplies during drawdown and therefore, should be closely monitored. Navigation during a drawdown will be severely limited in the reservoir and reduced along portions of the upstream river.

Substantial modifications of the existing USACOE water control structures would be necessary to maintain flows to the lower river and estuary during a drawdown. Modifications to both the bypass facility and barge canal (lower river reconnect) were investigated. For reservoir management, the barge canal option is preferred because it would allow constant flushing of the western end of Lake Rousseau. This option would be the least expensive and would restore the original configuration of the lower river channel. Access to Lake Rousseau from the barge canal would not be possible with this option, but access would become available from the lower river through the Inglis Lock which would still be functional. Existing flood control capabilities for the lower river would be maintained with the bypass facility option. With the barge canal option, an overflow weir would be designed to limit flood flows to non-damaging levels. Finally, either option would allow better moderation of flows to the barge canal than is currently possible, providing increased management capabilities for the estuary. However, these modifications may not be viable because pending deauthorization of the barge canal may restrict structural modifications of barge canal facilities.

Without modifications to the USACOE water control structures, the current operations plan for the reservoir is the only practical alternative. However, the stabilization of water levels in the reservoir has undesirable ecological consequences and limits the potential to maximize sportfish production. Lake Rousseau is an important regional economic asset due to its value as a recreational and fishery resource. The implementation of drawdown capabilities should be strongly considered because of the potential benefits to the reservoir's ecology and resource value.

RECOMMENDATIONS

1. It is recommended that extreme drawdown capabilities be pursued as an effective operation and management tool for Lake Rousseau, and that a Steering Committee be formed comprised of one representative each from the Counties of Citrus, Levy and Marion; and the Cities of Dunnellon, Inglis and Yankeetown; and the Withlacoochee River Basin Board to monitor public discussion of the drawdown question.

2. It is further recommended that a Technical Advisory Committee (TAC) be formed comprised of representatives from the FG&FWFC, the FDNR, the FDER, the SWFWMD, and the USACOE to present technical aspects of the drawdown to the Steering Committee and to the public. The TAC shall assist the Steering Committee in evaluating the overall feasibility of an extreme drawdown and in making a final recommendation on the matter.

3. Because of the potential for localized well problems related to a drawdown, it is recommended that a well inventory in the project area be undertaken as part of additional assessment of drawdown feasibility.

4. In the event that a drawdown is accomplished, it is recommended that a network of monitoring wells be

established in strategic locations to monitor ground-water levels and water quality.

5. It is recommended that an extreme drawdown be to an elevation of 18 feet and that the reservoir be held at that level for a minimum of 90 days to allow for adequate drying of sediments and plant material. If desired, the drawdown could be extended to allow additional drying, or to facilitate execution of various management techniques such as sediment removal or stump cutting.

6. Depending on the timing of drawdown, it is recommended that reservoir refilling begin either during February and March or during the wet season from June through October. This would allow for fall/winter or spring drawdowns, or a combination of the two. Compared to multiple drawdowns, periodic single drawdowns would cause fewer alterations of flow to the lower river and less problems with reservoir access. Thus, it is recommended that a fall/winter or a spring drawdown be implemented first and evaluated for effectiveness.

7. It is recommended that stumps be cut and removed in selected areas during drawdown. These areas should be prioritized to aid in control of tussocks and to enhance water quality.

8. It is recommended that various aquatic plant control techniques such as biological control agents, sediment covers, or the application of herbicides to sediments, be tested during the drawdown.

9. It is recommended that during an initial drawdown, the feasibility of sediment removal in selected areas be evaluated.

10. It is recommended that in advance of a drawdown, regulatory agencies be contacted in an effort to expedite permitting procedures for extension of boat ramps, and maintenance of seawalls, bulkheads, canals and channels during the drawdown.

11. It is recommended that the existing outflow capacity of 1,540 cfs to the lower river be maintained at a reservoir drawdown elevation of 18 feet. It is further recommended that minimum flow schedules be used only for reservoir refilling after extreme drawdown.

12. It is recommended that minimum flow releases for reservoir refilling after an extreme drawdown be used no more frequently than once every four years.

13. Seasonal water level fluctuations within a range of 3.5 feet below normal reservoir stage could be implemented as a supplement to periodic extreme drawdown. However, it is recommended that the implementation of any seasonal fluctuation plan be done after the careful evaluation of ecological factors, particularly the distribution of aquatic plants in the reservoir.

14. It is recommended that refilling during seasonal water level fluctuations not reduce outflows by more than ten percent on a daily basis. Lower percentage flow reductions should be used if they will bring the reservoir up within a suitable period of time.

15. Because of pending deauthorization of the CFBC, federal funding of modifications to existing structural facilities on Lake Rousseau will require Congressional approval and authorization. Therefore, if it is determined that a drawdown is in the best public interest, it is recommended that the USACOE, as part of the development of a comprehensive management plan for lands and water within the Conservation Area which is to be created upon deauthorization of the CFBC, investigate the preliminary engineering feasibility of structural modifications to facilitate a drawdown including placing a weir across the barge canal and re-connecting the two sections of the Withlacoochee River channel.

TECHNICAL SUMMARY

INTRODUCTION

The primary objective of the study is the development of operational guidelines for Inglis Dam[1], Inglis Lock, and the bypass spillway which would benefit and enhance the long-term ecology of the reservoir and downstream river and estuary. Results of the study include recommendations for optimizing operations and management plans for the reservoir.

Lake Rousseau is a 4,163 acre impoundment of the Withlacoochee River, located 11 miles upstream of the river's mouth. It is one of the oldest impoundments of its kind in Florida, and was constructed in 1909 by Florida Power Corporation to produce electric power. The power facility ceased operation in 1965.

Structures that control outflow from the reservoir are part of the Cross Florida Barge Canal (CFBC) facilities. Construction of these facilities took place between January 1965, and December 1969. However, in 1971, work on the canal was stopped because of environmental and water resources concerns. Deauthorization of the project is pending enactment of appropriate legislation by

---

[1] In this report, the following facilities nomenclature is equivalent to that USACOE nomenclature indicated: Inglis Dam equivalent to USACOE, Inglis Main Spillway; Bypass Channel and Control Structure equivalent to USACOE, Inglis Bypass Spillway or Bypass Spillway.

the State of Florida. The west end control facilities at Lake Rousseau and westward to the Gulf remain authorized and in operational status. Outflow from Lake Rousseau is at three points; to the main section of the lower Withlacoochee River channel via the bypass channel and spillway, to the CFBC via Inglis Dam and a short section of the old channel of the Withlacoochee River, and to the CFBC via Inglis Lock.

Most of the riverine inflow to the reservoir up to 1,540 cfs passes through the Bypass channel and spillway, discharging to the lower Withlacoochee River. Flows in excess of the capacity of the Bypass Spillway are discharged down the CFBC via the Inglis Dam.

WATER BALANCE

For up to and including average flow conditions, the single most contributing inflow to Lake Rousseau is the ground-water discharge from Rainbow Springs and other springs along Blue Run. Blue Run, on the average, provides an inflow of 700 cfs with a variation from 538 to 1,000 cfs. When high conditions of surface water runoff prevail, the riverine system predominates with Blue Run providing a decreasing percentage of the total inflow.

In the upstream river area near the City of Inverness and Lake Tsala Apopka there are several water control structures which have the potential to affect flows entering Lake Rousseau. Of these structures, the Wysong Dam, an inflatable fabri-dam, has the most potential for affecting flows entering the reservoir by impounding and diverting water into Lake Tsala Apopka.

Wysong Dam usually functions at a head differential between 0.25 and 2.75 feet for flows up to 1,200 cfs (low to moderate flow conditions); when flows in excess of 1,200 cfs are reached the dam is deflated. Flow contribution analyses indicate that during average flow conditions operation of the dam could induce a conservative 9.3 percent average streamflow reduction at the dam and could have an average 3.8 percent reduction of flows entering Lake Rousseau.

During extreme low flow conditions on the river when the dam would have the most effect, the flow reduction to Lake Rousseau would increase. During extreme drought conditions similar to the spring of 1985 the flow reductions could increase to 10 percent.

Regardless of whether the dam had minimal or significant effect on inflow to Lake Rousseau, operation of Wysong Dam would have no significant bearing on a management plan developed for the reservoir for the following reasons: (1) refilling of the reservoir after a possible drawdown can occur during higher flow conditions of the year when Wysong Dam effects are minimal; (2) Blue Run discharges stabilize flows into the reservoir during average low flow conditions minimizing the 3.8 percent effect from the dam; (3) extreme low flow conditions on the river, when the dam would have the most effect (10 percent), do not occur that frequently; and (4) the Southwest Florida Water Management District (SWFWMD) has removed Wysong Dam.

Over geologic time the Withlacoochee River has eroded thin layers of sand and clayey sand exposing the underlying limestone formations of the Upper Floridan aquifer in many places along the river. The Ocala Limestone formation of this aquifer is the major source of almost all water supplies in the basin. During low flow periods, the principal source of water to the river is from ground-water discharge from the Ocala Limestone. Rainbow Springs discharges from this formation. In the area of Lake Rousseau, both the Ocala and the underlying Avon Park Limestone formation (where exposed by erosion) are generally covered with a thin layer of sand and clayey sand.

In the vicinity of Lake Rousseau the limestone is highly solutioned and faulted, yielding high flow-rate characteristics in the Upper Floridan aquifer. Although this aquifer generally is a confined aquifer system, a majority of the area west of Dunnellon is considered to be unconfined. The fact that there are little or no confining sediments in the area support this conclusion, as do the results from U. S. Geological Survey (USGS) hydrologic studies which indicate that 7.4 percent (109 cfs or

70 mgd) of the average daily surface inflow to the reservoir leaves as recharge to the Upper Floridan aquifer.

The results of a 1983 study indicates that both the CFBC and Lake Rousseau are thought to influence the position of the salt-water/fresh-water interface in the area; and that there is also a possibility that conduit flow in the aquifer through solution cavities may also be a factor controlling its position.

A 1973 USGS study indicates that the CFBC intercepts ground-water flow from about a six square mile area that formerly (before canal construction) contributed inflow to the Withlacoochee River downstream of Inglis Dam. This reduction in ground-water flow contribution represented only a 0.5 percent reduction in the average fresh-water flow in this reach of river during the 1971 water year; a rather insignificant reduction.

AQUATIC PLANTS

Lake Rousseau supports a great quantity and diversity of aquatic plants including several exotic species. During most years aquatic plants grow to very dense levels in the reservoir, hindering recreation, impacting water quality, and altering sportfish habitat. The most abundant macrophyte in the reservoir is Hydrilla verticillata, which has colonized large areas of Lake Rousseau since its introduction to the reservoir. However, hydrilla, managed at low densities, provides beneficial fish habitat and positive responses in fish populations have been documented by the FG&FWFC researchers. Another serious aquatic plant problem are the abundant tussocks, which are large floating mats of mixed vegetation. The numerous stumps found in the reservoir increase the rate of tussock formation by creating obstructions which tie up the floating mats of vegetation.

The large amounts of aquatic vegetation in Lake Rousseau are closely related to the reservoir's physical and chemical characteristics. The reservoir's morphometry allows rooted aquatic plants, particularly hydrilla, to colonize much of the reservoir bottom. The Withlacoochee River provides a constant source of nutrient rich water to those plants which utilize or rely on water-borne nutrients. In addition to having moderately high levels of nitrogen and phosphorus, river waters are well buffered with high levels of bicarbonate alkalinity, thus creating an ideal growth medium for aquatic plants. The widespread organic sediments in Lake Rousseau are also an important nutrient source for plants which are rooted in them.

Between 1977 and 1987, the SWFWMD conducted aquatic plant control on Lake Rousseau, overseen by the Florida Department of Natural Resources with funds provided by the USACOE. For the period October 1, 1986 through June 20, 1987, fifty-six thousand dollars ($56,000) was spent for control of water hyacinths, water lettuce and minor plants, while $193,000 was spent for hydrilla control. Application of the herbicide SONAR for hydrilla control was initially effective, but eleven months after treatment hydrilla regrowth was evident and biomass was nearing pre-treatment levels in all plots.

In September 1987, the USACOE assumed full direct supervision of the aquatic plant management program for the reservoir and established a full-time ranger position for the Lake Rousseau Management Area. Long-term USACOE management goals are; maintain problem plants (water lettuce, hyacinths and hydrilla) at lowest possible levels with available funds, reduce acreage of tussocks and break up large mats to increase edge habitat and access, encourage the re-establishment of native aquatic plants, increase water movement and reduction of sediment build-up, monitor water quality and nutrient inputs, and maintain safe and properly marked navigation channels.

The goals of the USACOE aquatic plant management plan for 1988 are to control hydrilla and other exotic weeds, reduce the size of the tussocks by 10% to 20%, and mark the main river channel through the reservoir. It is expected that aquatic plant control in the next year will be done exclusively with chemical control methods, including the herbicides SONAR for hydrilla control and RODEO for control of the tussocks.

SEDIMENTS

To assess problems with organic sediment accumulation in Lake Rousseau, sediments were sampled in the reservoir as part of this study. These results are compared to surveys of Lake Rousseau sediments performed by the FG&FWFC in 1977 and 1978. For this study, eighteen sediment cores were taken on selected transects in Lake Rousseau during October 1987. The total thickness of the sediment layer and conspicuous sediment horizons were measured and selected sediment intervals were sampled for laboratory analysis. In the laboratory, sediments were analyzed for percent water and percent organic matter content.

The total depth of sediments for the eighteen cores ranged from 2 to 39 inches, with an average value of 20 inches. At the bottom of these sediments were found either woody material, sand, or blue-gray clay, all which represent the original forest floor. Virtually all the overlying sediments appeared to be organic mucks with some cores containing hyacinth or other macrophyte remains. Percent water and organic matter determinations on 33 samples taken from 13 cores confirmed that the sediments were organic mucks with very high water content. Except for four samples taken from near the bottoms of cores, percent water content averaged 94% with high values found for both deep (2 to 3 feet) and near surface samples. Percent organic matter (of dry weight) was also high, averaging 59% for the 29 samples not taken from near the bottoms of cores.

The FG&FWFC conducted surveys of the sediments in Lake Rousseau during 1977 and 1978. Each year sediments were sampled from six transects, four which were in the same area as the District sampling and two which were upstream. For the two years, average sediment depths for the six transects ranged from 6.1 to 43.3 inches. The average depth of sediments for all samples was 16 inches.

Based on the results of these two studies, sediments in Lake Rousseau are fairly uniform in composition but are somewhat variable in depth. Although average sediment depths for the two studies were 16 and 20 inches, sediment depths at different sites ranged from only a few inches to over four feet. Although sediments in the reservoir are not extremely deep at this time, the sedimentation rate in the reservoir is high. Since its impoundment in 1909, sedimentation rates in many parts of the reservoir have averaged at least one-quarter inch per year. The high sedimentation in Lake Rousseau is indicative of the rapid rate the reservoir is aging and progressing to a more marsh-like system.

WATER QUALITY

To examine water quality, four stations were sampled in the Rousseau/Withlacoochee system three times during the summer of 1987. Additionally, vertical profiles for temperature and dissolved oxygen were measured at several different sites in the reservoir on three dates during roughly the same period. Other water quality data evaluated for the study area were collected by the USACOE, USGS, University of Florida, and the SWFWMD aquatic plant control program.

The water chemistry of Lake Rousseau is strongly influenced by the Withlacoochee River including Blue Run. Above Dunnellon, the Withlacoochee is generally well-buffered with moderately high levels of color and nutrients, most notably reactive phosphorus. Blue Run is a typical spring-fed stream, with clear isothermal waters which are well-buffered, bicarbonate rich, and have moderately high levels of dissolved nutrients (ortho-phosphorus and nitrate/nitrite) but low levels of organically bound nutrients. Water quality below the confluence of the Withlacoochee River and Blue Run reflects the inflows of these two sources, and shows differences between dry and wet seasons. During dry periods, flows are dominated by Blue Run and other springs in the Withlacoochee basin and color levels are relatively low. During wet periods, surface drainage becomes more important and color, organic nitrogen, and total phosphorus concentrations increase. Linear regression analysis of data collected at the Inglis Dam shows that color, organic nitrogen, total nitrogen, and total phosphorus were positively correlated with flow, indicating that considerable organic material is delivered to the river from the abundant wetlands in the Withlacoochee basin. There was no significant relationship found between flow and nitrate/nitrite, ammonia, and orthophosphorus concentrations.

Although nutrient concentrations in the river are moderately high, the Withlacoochee River is largely unpolluted. Comparison of water quality in the river at Dunnellon to data for three other regional rivers (Suwannee, Hillsborough, Oklawaha) indicates the Withlacoochee has good water quality that is characteristic of north and central Florida streams. Although chlorophyll *a* data for the river are very limited, it appears the river does not support large phytoplankton populations, due possibly to rapid flow, turbulence, or light limitation.

Compared to the river, water quality in Lake Rousseau reflects the transition from a riverine to a reservoir environment. For the 1987 sampling, mean chlorophyll *a* concentrations were much higher in the reservoir indicating the greater development of phytoplankton populations in the more lake-like system. Orthophosphorus and nitrate/nitrite concentrations were low in the reservoir, probably due to uptake by phytoplankton or the large macrophyte assemblage including periphyton. Values for color, hardness, alkalinity and specific conductance in the reservoir were very similar to the river. Like the river, water chemistry in the reservoir responds to differences in dry and wet season flows. This may be particularly important with regard to color as low flows result in low color concentrations, thus increasing light penetration in the reservoir during the dry seasons.

To assess the conditions in Lake Rousseau relative to other Florida lakes, water quality data for the reservoir were compared to results published by Canfield (1981), who sampled 165 Florida lakes during 1979 and 1980. When compared to frequency distributions of water quality values collected throughout the state, Lake Rousseau was high in alkalinity, specific conductance, and hardness, reflecting the input of bicarbonate-rich ground water from springs to the reservoir. The mean color value for the reservoir was also high, due to the basin's large wetlands drainage. Lake Rousseau had values near the median for total nitrogen and chlorophyll a, indicating average conditions for Florida lakes. The reservoir was comparatively more enriched in total phosphorus with values corresponding to the upper quartile, but water clarity (secchi disk) was somewhat better than the norm. Overall, these comparisons indicate that Lake Rousseau has nutrient, phytoplankton (chlorophyll), and light penetration conditions that are about average for Florida lakes. Using the formulas published by Huber et al. (1982), a Trophic State Index

(TSI) value of 45.2 was calculated for Lake Rousseau indicating mesotrophic conditions. However, this TSI value and the comparisons to the Canfield data set are misleading for they do not represent the abundant nutrients and biomass incorporated into the huge macrophyte assemblage in the reservoir.

The morphometry and physical structure of Lake Rousseau have important implications regarding the reservoir's water quality. The reservoir is deep only in the areas which correspond to the impounded river channel. The reservoir areas which correspond to the original forest are generally shallow and contain numerous stumps and dense stands of aquatic plants. The average residence time for the entire reservoir is only 9.7 days, but water is probably exchanged more slowly than this in the clogged shallow areas and more rapidly in the channel. Because of the rapid turnover of water in the channel areas, water quality may remain relatively good there despite moderately high nutrient concentrations. In the off-channel areas which are more stagnant, localized processes such as sediment nutrient exchange, benthic oxygen demand, and macrophyte metabolism probably have greater impact on water quality.

In addition to restricting lateral water movement, the dense aquatic macrophytes greatly reduce vertical mixing and aeration in the shallow areas of the reservoir. Temperature profiles showed that pronounced thermal stratification occurred in the areas with abundant macrophytes, although well-mixed conditions were found in the channel. Low bottom dissolved oxygen concentrations were commonly found in the weeded areas, probably due to reduced turbulence and mixing plus shading by the macrophyte vegetation, particularly the tussocks. By incorporating large amounts of organic material and detritus in the shallow areas, the macrophyte assemblages represent a large potential source of oxygen demand.

Another factor affecting water quality in Lake Rousseau are the widespread, flocculent organic sediments. Because of their flocculent nature and high organic content, it is expected that sediment oxygen demand and nutrient release potential for these sediments are high. The relative impacts on sediments on nutrient and oxygen concentrations in bottom waters is probably greatest in the more stagnant areas where water exchange and aeration from mixing is low.

The Withlacoochee River is the overwhelming source of nutrient loading to Lake Rousseau. Because the river is largely unpolluted external nutrient loading can not be significantly reduced, and strategies for water quality improvements have to center on internal factors and processes within the reservoir.

If achievable, large reductions in macrophyte coverage and biomass in the reservoir would have beneficial effects on water quality. These benefits would result from reduced shading by macrophytes and increased circulation and mixing in the shallow reaches of the reservoir. Improvements in water quality, particularly light penetration, vertical mixing, and dissolved oxygen concentrations can be realized if the areal extent of both the "topped out" hydrilla and the tussocks can be significantly reduced. Plant control efforts should try to reduce adjacent, continuous stands of vegetation to improve circulation in the off-channel areas of the reservoir.

The cutting and removal of stumps from the reservoir would help control the rate of tussock growth and may, therefore, provide significant water quality benefits through improved circulation. Because of cost considerations, it may be practical to remove stumps only in parts of the reservoir and these areas should be prioritized for maximum benefit.

Establishing the capacity to fluctuate water levels, including extreme drawdown, should benefit water quality in Lake Rousseau. Periodic extreme drawdown would reduce accumulated plant biomass and provide at least temporary hydrilla control and the establishment of desirable aquatic plant species after refilling. Extreme drawdown, combined with stump removal, would be an effective tool for controlling the tussocks.

Extreme drawdown would also be valuable for compacting the flocculent organic sediments in the reservoir. Sediment drying and compaction should reduce the potential for sediment resuspension and sediment oxygen demand. Also, the release of nutrients from sediment interstitial water might be reduced if the sediments were drier and more compact. The feasibility of mechanically removing sediments from selected areas could be evaluated during an initial drawdown.

Because of the high plant biomass and accumulation of organic sediments in the reservoir, extreme drawdown would be necessary to achieve maximum water quality benefits. Seasonal water level fluctuations, if implemented, should be done as a supplement to extreme drawdown. Of the structural modifications options available for establishing drawdown capabilities, re-connecting the lower river and utilizing Inglis Dam is the best for water quality benefits as it would allow constant flushing of the west end of the reservoir.

RESERVOIR OUTFLOW CHARACTERISTICS AND FRESHWATER FLOW REQUIREMENTS OF THE WITHLACOOCHEE RIVER ESTUARY

Reservoir management plans that affect the outflows from Lake Rousseau must take into consideration the freshwater inflow needs of the downstream ecosystems. At the Gulf, near the mouths of both the lower Withlacoochee River and the barge canal, there exists a large estuary where salt water from the Gulf mixes with fresh waters from these two sources. The timing and volume of freshwater inflows to this estuary are major factors determining that ecosystem's physicochemical characteristics and biological productivity.

The ecology and freshwater inflow needs of the estuarine portion of the lower Withlacoochee River and the adjacent areas of the Gulf have been recently studied by the SWFWMD in collaboration with Mote Marine Laboratory. That report, which is in preparation, will contain elaboration on the ecology of the Withlacoochee River estuary. As supporting information, however, a brief discussion of the findings of that study regarding salinity distributions is presented here. Based on the preliminary findings of the SWFWMD/Mote study and historical outflow records for the reservoir, recommendations are presented for outflow requirements for operations/management plans that affect freshwater outflows from Lake Rousseau. These outflow requirements are formulated to provide for the ecological health of the downstream environments while allowing water level fluctuations or the physical manipulation of the reservoir.

To assess the relationships of outflows from Lake Rousseau to the ecology of downstream areas the current operating schedule for the reservoir is first described. Also pertinent to this topic are the seasonal and historical (pre-1970) flow characteristics of the lower Withlacoochee River. December 1969 represents the completion of the barge canal facilities and implementation of the current reservoir operating schedule.

Before the completion of the hydroelectric dam at Lake Rousseau in 1909 the Withlacoochee River flowed to the Gulf unaffected by any structural controls. The initial impoundment of the river probably caused slight decreases (7 to 10% of average flow) in flows to the lower river in two ways; 1) evaporative losses were increased due to the large reservoir surface area, and, 2) recharge to the ground water near the reservoir was increased due to greater head differences. Although these factors presented a net loss of water from the reservoir, they probably had little impact on the seasonality of flows to the lower river. In sum, between 1909 and the completion of the barge canal facilities in 1969, outflows from Lake Rousseau flowed to the Gulf through the natural channel of the lower Withlacoochee River in basically unaltered seasonal cycles.

Completion of the barge canal facilities and its associated structures on Lake Rousseau changed the pattern of outflows from the reservoir. The current operating schedule and physical constraints of the structures require that most of the flows below 1,540 cfs go through the bypass channel and spillway to the lower Withlacoochee River. Reservoir outflows above 1,540 cfs are discharged through the Inglis Dam to the barge canal. Three other less important schedules for reservoir outflows also occur: 1) Periodic operation of the Inglis Lock releases relatively small amounts of water to the barge canal; 2) During extended periods when outflows are less than 1,540 cfs, 200 cfs is periodically released at Inglis Dam to facilitate flushing in the western end of the reservoir; and, 3) When flooding is anticipated along the Withlacoochee River, the reservoir is temporarily lowered by as much as 3.5 feet, thus reducing flows through the bypass spillway with the excess water discharged at Inglis Dam.

The current operating schedule for Lake Rousseau has changed the streamflow characteristics of the lower Withlacoochee River from pre-1970 conditions by restricting maximum flows to 1,540 cfs. At total outflows below this amount, flows in the lower river are similar to what they would have been under pre-1970 conditions. Compared to many Florida rivers, the seasonal variation of flows in the lower Withlacoochee River is relatively stable since the river receives substantial baseflow from Blue Run and maximum flows are restricted to 1,540 cfs.

Compared to flows in the lower Withlacoochee River, flows in the barge canal from releases at Inglis Dam are much more sporadic and cover a wider range of values. The USGS reports a flow of 70 cfs for springs located just below the Inglis Dam. For approximately 50% of the time, flows to the barge canal are comprised primarily of this spring discharge. Flows above 70 cfs reported for the Inglis Dam gaging station represent outflows from Lake Rousseau through Inglis Dam. These reservoir outflows vary greatly in magnitude, ranging from small releases (<100 cfs) to a maximum daily value of 4,500 cfs recorded in 1979. Because of the periodic release of high flows through Inglis Dam, mean annual flow for this site is substantial, averaging 423 cfs for the period 1970 to 1985. During many years, the periodic release of high flows at Inglis Dam follows periods of primarily spring-fed baseflow producing hydrographs for this site which show extreme seasonal fluctuation.

Along its length the lower Withlacoochee River progresses from a freshwater to an estuarine system. In the Withlacoochee River estuary, a horizontal salinity gradient is established with lowest salinities usually found in the river channel some distance upstream from the river mouth. Salinity gradually increases in the river toward the Gulf and continues to increase at greater distances into the Gulf until values approaching seawater are found. This horizontal salinity gradient is dynamic and changes in response to tidal, meterologic, and streamflow conditions.

The presence of horizontal salinity gradients is one of the most important factors controlling biological structure and productivity in estuaries. The distribution of plant and animal communities and the utilization of estuaries by the immature stages of many marine fish species are related to the presence of salinity gradients. If the existing biological structure and levels of productivity are to be maintained for the Withlacoochee River estuary, management of Lake Rousseau must account for the freshwater needs of the estuary for maintaining suitable salinity gradients and other ecological functions.

Salinity distributions in the Withlacoochee River estuary were investigated as part of the SWFWMD/Mote Marine Laboratory study and also in a study performed by the U.S. Geological Survey (Yobbi, 1989). Data collected in both of these studies identified salinity distributions under a wide range of streamflow conditions. Generally, a steep salinity gradient was observed in the estuary, particularly upstream of the river mouth. High tide salinity values averaged 27.5 ppt (parts per thousand) 4.7 miles into the Gulf, 15.4 ppt at the river mouth and 1.1 ppt 2.96 miles upstream of the river mouth. The response of salinity distributions to changes in freshwater inflow was examined by monitoring the location of various salinity concentrations. Linear regression analysis of the location of three surface or bottom salinity concentrations found that both freshwater flow in the lower river and tide stage at the mouth of the river had a significant effect on the location of the 5.0 ppt and 0.5 ppt salinity concentrations. As freshwater inflow decreased, salinity concentrations moved further upstream. Linear regression equations were developed which predict the high tide location of 0.5 and 5.0 salinity concentrations as a function of tide stage and flow in the lower Withlacoochee River.

In an analysis of the response of salinity at fixed stations to combined flow from the lower river and barge canal, it was found that salinity at stations seaward of the mouth of the river showed increased response to changes in freshwater flow at total discharges above 1,800 cfs. It is suggested that the delivery of substantial quantities of freshwater to the estuary from the barge canal at these levels of discharge may affect this relationship. If structural modifications are pursued on Lake Rousseau to facilitate reservoir drawdown, more information should be gathered regarding the effects of barge canal discharges on the salinity and water quality characteristics of the adjacent inshore environment. Flow release schedules could then be designed to improve estuarine conditions and biological productivity near the mouth of the canal. Preliminarily, it is suggested that the current extreme variability of flows to the barge canal be reduced or moderated.

Since biologically important salinity gradients in the Withlacoochee River estuary respond to changes in fresh-water flows, the management of outflows from Lake Rousseau has important consequences for the estuarine ecosystem. To provide for the health of the downstream ecosystems, outflow levels are recommended for the lower Withlacoochee River for periods when the reservoir is either being refilled or maintained at low stage elevations. These outflow levels pertain to extreme drawdown or minor water level fluctuations which would require structural modifications, and not to operations plans utilizing the existing water control structures. Outflow recommendations are made only for the lower Withlacoochee River, because outflows to the barge canal have been sporadic in the past and long periods of very low flow have occurred in previous years. As previously mentioned, the operational plan for Inglis Dam should be reviewed if structural modifications are ever pursued on the barge canal or structures on Lake Rousseau. The recommendations provided below would still apply if the operational plan for the Inglis Dam is ever changed.

It is recommended that the existing outflow capacity of 1,540 cfs to the lower river at a reservoir stage of 27.5 feet be maintained at an elevation of 18 feet. Completion of the barge canal facilities has already changed the streamflow characteristics of the lower river to some degree. Optimally, further modifications to allow drawdown should not cause any additional alterations of flows to the lower river. If the existing flow capacity to the lower river is maintained at an elevation of 18 feet, drawdowns could be induced for longer periods of time or done relatively frequently without increasing flow reductions to the lower river during low water periods. This would allow maximum flexibility in designing drawdown schedules to meet reservoir management needs.

For the ecological health of the lower river and estuary the most potentially harmful impacts that must be evaluated are the reductions in outflows which would occur during reservoir refilling after a possible drawdown. If the existing biological structure of the estuary is to be maintained, freshwater inflow and salinity values should not be manipulated beyond the range of naturally occurring conditions. Using this approach, monthly minimum flow levels were determined from historical record and correspond to the natural low-flow conditions of the river. The method used here to determine monthly minimum flow levels employed monthly flow duration analysis. A synthetic discharge station representing the total outflows from Lake Rousseau was created, and duration analysis was done separately on each of the twelve monthly subsets of values. For nine months, excluding May through July, the monthly minimum flow level selected was the 90 percent exceeded interval for that month, rounded to the nearest 10 cfs. For the months May, June and July, the 90 percent exceedance intervals were the lowest of the year and ranged from 648 to 675 cfs. The minimum flows for these months were adjusted to 700 cfs to allow a slightly greater margin of safety for the downstream ecosystems and to give a consistent value for the months April through July, when low flows generally occur in the Withlacoochee basin.

When the natural level of outflow from the reservoir exceeds the applicable minimum flow level, the minimum flow level should be released from the reservoir with the remaining water kept for reservoir refilling. When the natural level of outflow falls below the monthly minimum flow, the minimum flow does not have to be maintained but the natural outflows of the reservoir should not be reduced. In addition to reservoir refilling after a possible drawdown, the recommended minimum flows can serve as general guidelines for other operation/management schedules for Lake Rousseau which would require structural modifications. However, the exact method of their implementation for other purposes would have to be examined in a separate analysis which accounts for other pertinent factors. It is strongly emphasized that these minimum flow levels do not represent the monthly quantity of water the lower river and estuary need on a permanent basis to retain their ecological health. The recommended minimum flow levels represent monthly flows during unusually dry periods, and not normal flows to the lower river and estuary. The repeated occurrence of abnormally low flows, whether due to drought, water diversion or reservoir management would have deleterious ecological effects. In this report, the implementation of minimum flows is described for a extreme reservoir drawdown, with the understanding that this will occur no more frequently than every four years. Also, flow releases to the lower river should not be held at minimum flow levels for several months at a time. As demonstrated in the modeling section, reservoir refilling to 27.5 feet msl after extreme drawdown should not normally require more than seventy days using the recommended minimum flows.

Seasonal fluctuations in water levels are used here to indicate raising and lowering reservoir levels within a 3.5 feet range below the normal operating stage of 27.5 feet. It is suggested that modification to the water control structures at Lake Rousseau would be necessary for seasonal water level fluctuations to be practical, regularly used, management tool. If employed as a management strategy, this type of fluctuation schedule might be done relatively often with seasonal low water achieved once or twice each year. Because they would be done much more frequently, the considerations for outflow requirements for seasonal water level fluctuations are different than those for extreme drawdown. Also, for seasonal water level fluctuations it is probably not necessary to bring the reservoir up as rapidly as after extreme drawdown. For these reasons, it is recommended that water retained for reservoir refilling during managed seasonal fluctuations be based on a percentage of reservoir outflows. This will ensure that flows to the lower river and estuary retain their natural cyclic patterns and are not greatly altered on a frequent basis.

Small percentage flow reductions would cause the least disruptions of flows to the lower river, and it is recommended that flows not be reduced by more than 10% on a daily basis. Also, reservoir outflows should not be reduced when the natural level of outflow falls below 700 cfs. In this report simulations are presented which model reservoir refilling from elevations 3.5, 2.5, and 1.5 feet below normal reservoir stage using five and ten percent daily flow reductions for outflows above 700 cfs. These simulations indicate that most of the time five percent flow reductions bring the reservoir up to normal stage in suitable lengths of time. Optimally, percentage flow reductions should be kept near five percent or less, but could periodically be increased up to ten percent to achieve a desired stage more quickly.

FEASIBILITY OF A RESERVOIR DRAWDOWN AND OTHER WATER LEVEL FLUCTUATIONS

Drawdown of Lake Rousseau, or the planned lowering of the level of the reservoir for a specified period of time after which refilling to a more natural level occurs, has been discussed in the past. Drawdown for improvement of the fisheries in the reservoir was recommended by the FG&FWFC in 1978. Benefits of a drawdown discussed by the Lake Management and Planning Task Force included: (1) consolidation of bottom sediments, (2) improvement of quality and quantity of sport fish populations, in particular largemouth bass, (3) return of desirable native vegetation, (4) increase in fish food organisms, and (5) increase in sport fish size. Disadvantages of a drawdown mentioned by the Task Force included: (1) limited access to the reservoir during the time of drawdown, and (2) the resulting loss of revenue to businesses that depend upon the reservoir for their income.

Advantages of extreme drawdown not mentioned by the Task Force include: at least temporary reduction of accumulated submersed plant biomass; an excellent opportunity to cut stumps to aid navigation and help reduce tussocks; and, possible benefits to reservoir circulation and water quality resulting from reduced plant biomass. Disadvantages to extreme drawdown not mentioned by the Task Force include: possible drying out and refloating of logs, debris, or mud mats; and temporary impacts to waterfowl habitat and associated hunting opportunities.

There are case histories of successful drawdowns in other Florida lakes including Lake Griffin located in Lake County and Lake Kissimmee and West Lake Tohopekaliga located in Osceola County. Probably the greatest success with drawdowns has occurred on Lake Tohopekaliga where three drawdowns have been accomplished over a period of several years.

The drawdown recommended on Lake Rousseau in 1978 by the FG&FWFC stated that the reservoir should be drawndown to an elevation of 18 feet which would expose approximately 65% of the bottom area. It was further recommended that the reservoir be held at this level for a minimum of 90 days to allow for adequate drying of organic sediments and desiccation of plant tissues. At one time, a less extreme drawdown of three and one-half feet to elevation 24 feet was considered for the reservoir. However, it was felt by the FG&FWFC that such a minimal drawdown would not accomplish sufficient dry-out of bottom sediments.

Currently, with existing structures on the barge canal and Lake Rousseau, a drawdown to a level of 18 feet cannot be accomplished and still provide adequate flows to the lower river. This is because the discharge capacity of the bypass spillway is greatly reduced at elevations below 27.5 feet and flows to the lower river completely cease below the control elevation of 21 feet. With these physical limitations, even minor seasonal water level fluctuations in the reservoir are presently impractical. The limited discharge capacity of the bypass spillway at lowered reservoir elevations was one of the reasons that the drawdown recommended in 1978 was not implemented. Structural modifications discussed in the past to implement an extreme drawdown have included: pumped bypass of the 21-foot control elevation on the bypass channel, (2) reconnecting the two sections of the lower river channel below Inglis Lock and Dam and below the bypass channel to re-establish discharge capabilities to the lower river with the 11.3-foot control elevation at Inglis Dam, and, (3) the possible construction by private interests of a hydro-electric power generating facility on the bypass channel which would in effect be designed to bypass the 21-foot control elevation of the bypass structure. However, these modifications may not be viable because of pending deauthorization of the barge canal which may restrict structural modifications of barge canal facilities.

STEP-BACKWATER CALIBRATION FOR DRAWDOWN ANALYSIS IN LAKE ROUSSEAU AND THE ASSOCIATED RIVER

The effects on water levels from drawdown of Lake Rousseau will not be confined to just the reservoir area. To simulate a drawdown and its upstream effect, water surface profiles were generated using a step-backwater computer program for various Lake Rousseau target pool elevations and inflow. Water surface profiles began at the west end of the reservoir and progressed upstream to SR 200. Profiles were also generated for Blue Run. The difference between the predicted and recorded water surface elevations for the flow conditions modeled (calibration runs) ranged from 0.03 to 0.17 feet for Dunnellon, 0.5 to 0.33 feet for Holder, and -0.01 to 0.56 feet for Rainbow Springs.

After calibration, the model was used to predict the water surface response of the river system to a simulated drawdown of Lake Rousseau. Water surface response to three drawdown elevations on the reservoir were simulated; 27.48 feet which represents the elevation at which the reservoir is usually maintained, 21.8 feet which represents the elevation to which the reservoir was lowered in 1972 for structure maintenance, and 18 feet which is the FG&FWFC's previously recommended level for an extreme drawdown, and the drawdown level which was discussed with the Lake Management Planning Task Force in 1986.

Since Lake Rousseau is actually a reach of the Withlacoochee River, any starting elevation chosen will not be maintained for the entire length of the reservoir. The three modeled flow conditions selected were the drought of 1985, which represented an extreme event in regard to drawdown effects; October 1972 conditions which represented about average conditions or those most likely to occur during a drawdown, and April 1960 conditions which represented a flood event which historically occurred during the time period a drawdown possibly would be scheduled, and which would show the effect a drawdown would have on lowering water surface elevations in the Dunnellon area during such a flood event.

The drawdown of Lake Rousseau to 18 feet under conditions similar to the May 1985 drought would create water level decreases of almost eight feet at Dunnellon, 0.3 feet at Rainbow Springs, and four feet at Holder. The difference between the recorded and simulated elevations at Holder indicates, for low flow conditions, that the drawdown effects would progress farther upstream than Holder. During an extreme drawdown, under these conditions, boat navigation on the river would be affected and on the reservoir severely limited. The problem area on the river appears to be in the vicinity of SR 200 near Holder.

The drawdown of Lake Rousseau under average flow conditions similar to October 1972 would create a water level decrease of six feet at Dunnellon, 0.1 feet at Rainbow Springs, and almost 1.5 feet at Holder. Navigation would still be a problem along a majority of the reservoir and river system; however, a two foot minimum clearance can be maintained in the main river channel from the outlet structures on the reservoir upstream to SR 200. The comparison of calculated water surface elevations for a drawdown to 18 feet from a starting elevation of 27.48 feet indicates that significant lowering for most of the reservoir could be achieved during these average flow conditions.

An analysis of the water surfaces generated for the April 1960 conditions indicate that the lowering of Lake Rousseau will not substantially affect water surface elevation beyond Dunnellon. The elevations indicate that less than three-tenths of a foot drop at Dunnellon will be realized as a result of lowering the reservoir to 21.8 feet with no further decrease as a result of lowering the reservoir to 18.0 feet. It is doubtful that a drawdown under these conditions would do much to benefit the reservoir because three miles upstream of the outlet structures the water surface will rise from 18 feet to 22 feet and seven miles upstream it will rise to 24 feet. These elevations would not allow sufficient desiccation of the muck bottom to facilitate consolidation. Navigation during these April 1960 conditions would be limited in Lake Rousseau only.

Areas where flooding is a primary concern are the lower Withlacoochee River and that section of the river near Dunnellon and Rainbow Springs. A USACOE study indicated that significant flood damage would not occur on the lower river from reservoir releases until a discharge of 7,000 cfs (not accounting for tidal surges from tropical storms) is realized. Such a discharge cannot happen without substantial modification to the Lake Rousseau outflow facilities; the bypass spillway has a discharge capacity of only 1,540 cfs at a lake elevation of 27.5 feet.

Flooding potential in the Dunnellon-Rainbow Springs area is limited to a few dwelling structures. Methods of reducing flood elevations in this area include increasing stream discharge capacity through and downstream of the affected area, and/or decreasing tailwater conditions (downstream control elevations).

To simulate lowered tailwater conditions an 18 foot drawdown elevation was simulated on Lake Rousseau by utilizing modifications to the control facilities to facilitate a drawdown to 18 feet; however, this elevation could not be maintained during a significant flood event.

Results of the simulation indicated for a discharge of 9,500 cfs at Dunnellon and a reservoir level of 18.0 feet, that there was no significant change in flood elevations from the Dunnellon area upstream. However, further analysis indicated that there is an increasing effect on Dunnellon stages from lowering the reservoir as river flows decrease. For example, for discharges around 4500-5500 cfs, it appears that the USACOE can lower river stages between 0.5-0.9 feet at Dunnellon thus keeping the river below the flood stage of 29.0 feet at Dunnellon. Currently, it is recommended that the reservoir not be lowered below 24.0 feet so that fresh-water flows to the lower river can be maintained. Also, it appears that lowering the reservoir below 24.0 feet would not provide significant additional flood protection for the Dunnellon area.

The other alternative was to increase the conveyance (discharge capacity) of the river from the problem area to a point slightly downstream of that area. However, a 1975 CFBC Restudy Report by the USACOE determined that channel improvements to increase conveyance were not cost-effective.

GROUND-WATER RESPONSE TO DRAWDOWN

Because of the supporting evidence of Lake Rousseau's role in recharging the Upper Floridan aquifer system, there was some concern for the effects on surrounding aquifer levels and movement of the saltwater-freshwater interface in the event of a drawdown. To answer these questions a finite difference, ground-water flow model was developed for the area.

The basic model was developed from modelling performed by Adams in 1985. Her model results indicate that the Lake Rousseau area was a significant recharge area having an average calibrated-recharge rate of 20 inches per year.

To simulate aquifer response to drawdown, two reservoir level conditions were modelled; the average condition at elevation 27.48 feet, and the extreme drawdown condition of 18.0 feet. Analysis of a cell-by-cell flow terms in the model indicated that the reservoir contributed a net 120 cfs to the aquifer; this verified an earlier referenced USGS study which indicated that on the average 109 cfs left the reservoir as ground-water recharge. The model also indicated that more than 50 percent of the ground-water recharge occurred in the west end of the reservoir. For drawdown modeled conditions, the model indicated the net ground-water recharge from the reservoir to the aquifer was 42 cfs.

The major ground-water concerns as a result of a drawdown are decreased potentiometric surface levels and the resulting potential for undesirable waters to migrate into potable supply zones through two processes: salt water intrusion and upwelling.

It is anticipated that the depressed aquifer levels associated with the drawdown of Lake Rousseau will have the greatest impact in the barge canal area. Public supply sources most vulnerable to contamination are Inglis and Yankeetown. During the 1972 lowering of the reservoir, some private wells in the vicinity of the reservoir experienced supply problems but it appears these problems were from loss of pump capacity rather than from contamination.

POTENTIAL AQUATIC PLANT RESPONSE TO DRAWDOWN

Drawdown has been utilized for aquatic plant control in a number of case studies. Factors such as drawdown timing, duration, frequency, and weather conditions during drawdown are important and various plant species can respond differently to a given drawdown scenario. Generally, emergent native plant species increase their distribution during drawdown. Whether these species remain established after refilling is usually related to water depths upon refilling and the timing of the drawdown.

For submersed species the reported effects of drawdown are more varied and differ for various plant species. Using a series of multiple drawdowns, McKinney and Coleman (1981) found hydrilla was effectively controlled in Fox Lake, Florida, but cattails became dominant. In Lake Oklawaha, an impoundment of the Oklawaha River that is somewhat similar to Lake Rousseau, Haller and Shireman (1988) found that hydrilla quickly recolonized areas that had been exposed during drawdowns. Recolonization was due to sprouting of plants from reproductive propagules in the sediments and the spread of hydrilla plants which survived in the inundated areas below the drawdown level. Despite this, these investigators recommended implementing water level fluctuations for Lake Oklawaha, including fall/winter drawdowns every three to four years. It was suggested that periodic drawdowns would desiccate the high plant biomass which builds up over time and allow for the desiccation of organic bottom sediments.

From results presented in the literature, it is concluded that extreme drawdown would be a useful tool for managing aquatic plant populations in Lake Rousseau. Development of an optimum drawdown scenario, however, will probably require some trial and error on the reservoir and analysis of the results. Drawdown schedules for aquatic plant control would have to be coordinated with other management objectives such as sediment compaction or stump cutting and removal.

Extreme drawdown to 18 feet (9.5 foot lowering) would expose 65% of the bottom area and most of submersed macrophytes in the reservoir to desiccation. This would limit the occurrence of live donor populations which could float into the exposed areas upon refilling to a much smaller degree than occurred in Lake Oklawaha where drawdown levels were only five feet below normal state. The desiccation of the huge amounts of plant biomass that have accumulated in Lake Rousseau would be of significant benefit. For hydrilla, however, this reduction might only be short term as new plants will probably resprout from reproductive propagules. It is difficult to predict how long reductions in hydrilla biomass will persist after refilling. It is doubtful that hydrilla would return to pre-drawdown levels in one growing season, but after one or more years, return of hydrilla to pre-drawdown levels is possible.

Extreme drawdown would probably be a valuable tool for controlling the formation and growth of the tussocks. Although some of the mixed tussock vegetation would thrive on the reservoir bottom during drawdown, most of the floating mat should desiccate with either plant death or loss of vigor resulting. During the low-water period, 150 to 200 acres of minor plants in the tussocks should be treated with BANVEL 720 at a rate of 2 quarts per acre. Also, the cutting and removal of stumps in the reservoir should be an essential part of any plan to control the tussocks.

Other aquatic plant control techniques which could be used in conjunction with drawdown should be investigated. The use of *Bagous affinis*, a weevil that feeds on exposed hydrilla tubers, should be considered. Similarly, consideration could be given to conducting experiments with the application of SONAR to exposed sediments in test plots. Although they are largely untested in

Florida waters and there are questions regarding their effectiveness, sediment covers could be deployed in small test plots during drawdown to test their applicability for weed control in small areas such as beaches or private docks.

Various researchers have suggested that multiple drawdowns might be an effective means of aquatic plant control. The drawdown schedule proposed for Lake Rousseau by the FG&FWFC in 1978 consisted of multiple drawdowns over a three year period, but recent experience indicates that integrated management using chemical plant control and periodic single drawdowns might be as effective (FG&FWFC, verbal communication). Multiple drawdowns did not achieve desired results in Lake Oklawaha, however, and Haller and Shireman (1988) recommended a single winter drawdown every three to four years combined with lesser, seasonal water level fluctuations. Compared to periodic single drawdowns, multiple drawdowns would cause greater inconvenience on the reservoir and more alteration of flows to the lower river. It is the conclusion of this report that at least a single fall/winter drawdown every four to six years would be very beneficial, and this or a spring drawdown should be attempted first before multiple drawdowns are considered.

SEDIMENT COMPACTION OR REMOVAL DURING DRAWDOWN

Sediment compaction or removal are two lake restoration techniques commonly used to improve sediment conditions. The drying and compaction of flocculent, organic sediments has been observed in other Florida lakes which have had extreme drawdown. Results from McKinney and Coleman (1981) and Fox et al. (1977), indicate that sediment compaction from drawdown is in the range of 39 to 50 percent. Because of their high water and organic content, it is expected that Lake Rousseau sediments would shrink as least to these amounts if exposed during drawdown. It is the conclusion of this report that extreme drawdown would cause significant beneficial changes in the reservoir’s sediments by reducing water content, creating a firmer substrate for invertebrate and fish utilization, reducing the potential for sediment resuspension, and possibly reducing sediment oxygen demand and nutrient exchange potential. The maximum drying and compaction of the sediments in the reservoir would occur during hot, dry conditions. Therefore, drawdown during the spring dry season (April-May) would be optimal for sediment compaction, but low water during the fall might also be effective.

Sediment removal can be an effective means of improving bottom substrate characteristics, but due to the labor and cost involved, is often used only in selected areas rather than as a whole-lake operation. Selected sediment removal has been successfully done by the FG&FWFC on Lake Tohopekaliga. The most practical method of sediment removal for Lake Rousseau would be scraping the substrate with a bulldozer and piling the sediments to either be hauled by trucks, burned, or given to the public as fertilizer or soil amendment. Excessive sediment thickness should not pose a problem for removal as most of the sediments should be less than 1.5 feet thick after drying. The operation could be hindered, though, by the numerous stumps which are found in the reservoir. Based upon modelling of drawdown in the reservoir, suitable areas for sediment removal might be found in the lower pool. An accurate estimate of the necessary work involved and its cost cannot be made unless the reservoir is drawn-down and the actual conditions assessed. If drawdowns on Lake Rousseau are pursued, the feasibility of removing selected sediments from the reservoir could be evaluated during the initial drawdown. Sediment removal would be considered as a dredge and fill activity, and come under the jurisdiction of the Florida Department of Environmental Regulation and require the appropriate permits.

STUMP CUTTING AND REMOVAL DURING DRAWDOWN

An extreme drawdown of Lake Rousseau would present an opportunity to enhance the recreational, safety, and ecological aspects of the reservoir by snagging (cutting and removal) stumps in the reservoir. Since the stumps provide substrate and habitat for aquatic invertebrates and fish, it is not advisable to remove the entire stump. Cutting the stump to a sufficient depth below the low water level will achieve the desired ecological and recreational benefits while preserving habitat value.

A previous snagging project on the reservoir during 1984 and 1985 resulted in cutting almost 15 miles of trails at a cost of $258,000. The average cost per mile for a 30-foot swath was $17,200. This operation utilized barge mounted hydraulic shears for stumps less than 26 inches in diameter and a scuba diver with an underwater chain saw for larger ones. Any stump cutting which could be done during drawdown would not require that work be done below the water surface, thus possibly reducing the costs from previous efforts. However, the cost of any snagging operation done during drawdown will be unknown until the ability to work and manuever in the exposed areas of the reservoir can be assessed.

TIMING AND DURATION OF EXTREME DRAWDOWN

Various schedules for extreme drawdown in Lake Rousseau were investigated. For each drawdown schedule, hydrologic simulations were performed to see if the drawdown could be accomplished while providing adequate flows to the lower river. It is recommended that extreme drawdowns in Lake Rousseau be done sometime during the period from mid-October to mid-June to take advantage of the fall or spring dry seasons. Drawdowns during the summer would be hampered by heavy rainfall which would prevent sediment drying and possibly cause erosion of sediments into the river channel. For extreme drawdown, the reservoir should be lowered to an elevation of 18 feet and held at that level for a minimum of 90 days to allow for the adequate drying of sediments and plant material. This minimum period could be extended if abnormally high rainfall occurs or if the additional drying of sediments or aquatic plants is desired.

Depending on the timing or length of drawdown, it is recommended that reservoir refilling begin either during February and March or during the wet season from June through October. February and March represent the wettest months during the fall to spring period so reservoir refilling then would require the shortest amounts of time, thus minimizing downstream impacts. If a later refilling is desired, it should be initiated in June or July to take advantage of the onset of summer rains. Given the option of either February/March or June/July refilling, either fall/winter or spring drawdowns can be accomplished with 90 days of extreme low water levels. If a longer drawdown is desired, some combination of fall/winter and spring drawdowns could be combined to give a longer continuous drawdown.

The advantages of a fall/winter drawdown with reservoir refilling beginning in February are: Rainfall is normally low during

November through January thus facilitating the desiccation of sediments and plant biomass during drawdown; low water levels during November through January would allow cold snaps and frost to damage aquatic plant propagules; refilling in February and March will restore normal reservoir levels in the spring to minimize the germination and spread of emergent aquatic plants, if this were an established management goal; normal water levels in the spring will allow fish to utilize shallow areas for feeding and spawning; and normal reservoir levels in the spring will allow easy access to the reservoir when fishing pressure is normally the highest.

The disadvantages of a fall/winter drawdown with refilling beginning in February are: sediment and plant drying might be less than during the hotter spring months; depending on the viability of reproductive propagules hydrilla may resprout in the spring during reflooding; the germination and establishment of native emergent plant communities would not be maximized; there would be a temporary loss of habitat for wintering waterfowl; and duck hunting would be inhibited during the drawdown.

Using a mathematical model of Lake Rousseau, simulations were run for a fall/winter drawdown and refilling of the reservoir to 27.5 feet beginning on February 1. Using historic streamflow record, fifteen simulations were run for the water years from 1971 to 1985. The length of refill times for these years ranged from 22 to 154 days, which corresponds to February 22 and July 6, respectively. Two very dry years, 1976 and 1985, had markedly longer refill times (127 and 154 days) than the other years. For the remaining thirteen years, refill times ranged from 22 to 84 days, averaging 47 days. Probability analysis found that the 50 percent probability refill time is 51 days, while the 10 percent probability refill time is 109 days. These analyses indicate that except during drought years, the reservoir can be brought to normal stage by late February to late April using this schedule and the monthly reservoir outflow (minimum flow) requirements specified in this report.

The simulations for February refilling were also run, utilizing a minimum flow level of 700 cfs for February and March rather than the specified monthly minimum flows. Using 700 cfs as the minimum flow level for these two months dropped the refill times appreciably. The fifty percent probability refill time was reduced to 35 days and the 10 percent probability refill time was reduced to 72 days. Except for the two drought years, the reservoir would have been full by February 22 to March 15 for the separate years. If having the reservoir full during March was an established management goal, the minimum flows for February and March could be adjusted to 700 cfs. However, if rising water levels into April are not perceived as a problem, minimum flows for February and March should remain as specified at 900 cfs and 790 cfs, respectively.

If a spring drawdown is desired, the reservoir could be lowered in February and the water level held at 18 feet during March, April, and May. Refilling could be started in June, which is the transitional month between dry and wet seasons in the Withlacoochee basin. Although rainfall is significantly greater in June than in April or May, June actually has the lowest average monthly streamflow of the year due to the lag effect caused by the abundant wetland storage in the Withlacoochee basin. During many years, flows are higher in late June than earlier in the month. If desired, drawdowns could easily be extended into or through June if dry conditions persist.

The advantages of a spring drawdown are: The hot, dry conditions would allow for the maximum drying and compaction of bottom sediments; low water levels during the spring would prevent germination of hydrilla from reproductive propagules during that period; it would encourage the establishment of native, emergent plants in shallow areas; and it would cause less impact to the utilization of the reservoir by wintering waterfowl and associated hunting than would fall/winter drawdown.

The disadvantages of a spring drawdown are: Access to the reservoir would be limited during the spring when recreational use is normally high; the utilization of shallow areas for spawning and feeding by fish would be limited; it would encourage the establishment of emergent aquatic plants, this would only be a problem if it were not a desired management goal; compared to fall/winter drawdown spring drawdown would be more likely to stimulate hydrilla establishment and growth in the deeper areas of the reservoir.

For the simulations of June refilling total refill times took less than 70 days except for three dry years. For two of the dry years, 1975 and 1977, refilling would have been completed by late September or early October. For 1981, however, refill time would have taken 283 days because of the prolonged low flows which occurred in the river. For the other thirteen years, refill times averaged 42 days. For reservoir refilling beginning June 1, the 50 percent probability refill time is 39 days while the 10 percent probability is 131 days. Simulations of reservoir refilling beginning July 1 gave slight reductions in refill times from June schedules. As expected, the same three dry years (1975, 1977, and 1981) had prolonged refill periods. The 50 percent probability time for July refilling is 37 days while the 10 percent probability time is 125 days.

In sum, the simulations of Lake Rousseau for the period 1970 to 1985 show that reservoir refilling beginning in either February, June, or July is feasible and could be done while still allowing minimum flows to the river. Reservoir refilling would generally take less than 70 days, but refilling could take longer than desired for optimum reservoir management during droughts. However, of the dry years examined, only the June and July refillings for 1981 took extremely long amounts of time.

SEASONAL WATER LEVEL FLUCTUATIONS WITH STRUCTURAL MODIFICATIONS

In addition to extreme drawdown, seasonal fluctuations of water levels in a range of 3.5 feet below normal stage could be considered for Lake Rousseau. Because the discharge capacity of the bypass spillway is greatly reduced at lowered reservoir elevations, structural modifications would be required if seasonal water level fluctuations are to be frequently used as a management tool. It has been widely observed throughout the state that the water levels of lakes fluctuate both seasonally and yearly, and that the artificial stabilization of lake levels often has undesirable ecological consequences. In 1982, the staff of the SWFWMD Lake Levels Project reviewed information available for Lake Rousseau and suggested that the reservoir would benefit from periodic fluctuations between 24.0 and 28.0 feet elevation, but noted that lakeshore residents would be inconvenienced during low water periods. In an investigation of Lake Oklawaha, Haller and Shireman (1988) suggested that seasonal fluctuations within a three-foot range combined with winter drawdowns would benefit the ecology of that reservoir.

The implementation of any seasonal water level fluctuations for Lake Rousseau would have to account for the unique characteristics of the reservoir. Because of the numerous stumps in Lake Rousseau, any seasonal lowering of water levels will make the stump situation less predictable and more hazardous. If seasonal water level fluctuations become part of the operations plan for the reservoir, additional stump cutting and removal should be undertaken at a minimum in boat trail areas.

Regardless of the stumps, seasonal low water levels will hinder boat access to the reservoir. The degree that access will be hindered will vary for different water levels and in different parts of the reservoir. Conceivably, some access channels to deep areas from public boat ramps or commercial fish camps could be improved if necessary. Any significant channel improvements would require approval and permits from the appropriate state and federal agencies.

Of extreme importance to any implementation of seasonal water level fluctuations in Lake Rousseau would be the status of weed populations in the reservoir. Water levels which are too low may encourage the establishment of hydrilla at greater depths in the reservoir. This could be a problem since color and probably light penetration in Lake Rousseau are related to flows in the Withlacoochee River. Low flows in the spring, with high proportions of ground-water inflow, would give relatively high water clarity when hydrilla plants are germinating and beginning their growth cycle. Although low water levels in the spring is the typical seasonal pattern for Florida lakes, it might significantly increase light penetration in the deeper areas of Lake Rousseau and stimulate hydrilla growth there. Secondly, seasonal water level fluctuations in the reservoir should be managed to avoid the occurrence of "topped out" conditions where aquatic weeds reach the water surface or fill a majority of the water column. Possibly, water levels in Lake Rousseau could be low in the spring and rise with the wet season without worsening the relative density of weeds in the reservoir. However, if low water levels significantly increase the degree that submersed aquatic plants fill the water column, this could have negative impacts on circulation, water quality, and fish habitat.

Seasonal low water can also increase the distribution of emergent wetland species, in fact, this is one of the most commonly cited reasons for managing seasonal water level fluctuations. In Lake Rousseau the establishment of emergent plants during seasonal low water would occur in shallow areas, most of which are adjacent to shorelines. Based on the size and bathymetry of the reservoir, any increases in emergent plant coverage are expected to be within acceptable limits. Accompanying any increases in emergent plant coverage would also be changes in plant community species composition and habitat structure. Preliminarily, it is suggested here that any expansion of emergent wetland plants in

Lake Rousseau during low water periods would benefit the reservoir as a whole but would cause access problems in certain shallow areas.

Using a mathematical model of Lake Rousseau and historic outflow record from 1971 to 1985, simulations were run for reservoir refilling from elevations of 24, 25, and 26 feet, which represent water levels 3.5, 2.5, and 1.5 feet below normal operating stage of 27.5 feet. Reservoir refilling was simulated using both five and ten percent flow reductions for outflows above 700 cfs. As for extreme drawdown, simulations were run for February and June refillings to mimic hydrologic cycles in the Withlacoochee basin. Although refilling was simulated only for February and June, refilling during other periods is also possible. Hydrologic conditions can be extremely variable in normally dry months and water levels in the reservoir could be manipulated in response to periodic high flows into the reservoir.

For the simulations of a 3.5 feet water level fluctuation with refilling beginning February 1, five percent flow reduction brought the reservoir back up to normal stage in February during wet years (1983 and 1984), but extended refilling into the late summer during very dry years (1981 and 1985). Excluding these two drought years, average time to reach normal operating stage was 89 days, which corresponds to April 29. Increasing the flow reduction to 10 percent significantly decreases the time to raise the reservoir to 27.5 feet. Excluding two dry years average refill time was 49 days, which corresponds to March 18. During most years, ten percent flow reductions will have water levels back up to normal stage before the spring dry season. If high water is desired in the spring with a 3.5 foot fall fluctuation this seems to be a workable schedule. If continued rising water levels are tolerable in the spring, five percent flow reductions should be used.

Simulated refill times are appreciably shorter for the 2.5 and 1.5 feet fluctuations with refilling beginning February 1. For the 2.5 feet fluctuation, five percent flow reductions would have water levels to normal stage at least by mid-March to mid-April except in unusually dry years. This would be a suitable schedule if slightly low water levels are acceptable in the early spring. Ten percent flow reductions brought the reservoir up by February or March in most cases. The simulations for a 1.5 feet fluctuation show fast reservoir recovery, with five percent flow reductions bringing the reservoir to normal stage by February or March in most years.

Simulations were also run for 3.5, 2.5, and 1.5 water level fluctuations with reservoir refilling beginning June 1. Using five percent flow reductions with a 3.5 feet fluctuation, simulations indicate the reservoir can be refilled by September in most years. Since peak water levels often occur in September in Florida lakes, five percent flow reductions adequately mimic natural seasonal fluctuations for Lake Rousseau. Increasing flow reductions to ten percent brings the reservoir up by July or August in most years. For 2.5 feet fluctuations, five percent flow reductions bring the reservoir up to normal stage by August, except for dry years. Refill times are very fast for both five and ten percent flow reductions and 1.5 feet fluctuations.

SUMMARY OF EXTREME DRAWDOWN AND SEASONAL FLUCTUATION SIMULATIONS AND RECOMMENDATIONS

The fluctuation of water levels in Lake Rousseau should improve the ecological condition of the reservoir. If desired, a combination of seasonal water level fluctuations and extreme drawdown could be scheduled. It is concluded, though, that extreme drawdown is essential if maximum benefits are to be achieved. As a minimum, fall/winter drawdowns should be very beneficial and not cause extreme interruptions to reservoir access and recreational use. Single drawdowns every four to six years would cause less inconvenience and alterations of flows to the lower river than multiple drawdowns. For the first drawdown cycle, either a single fall/winter or a spring drawdown should be implemented and tested for effectiveness.

Although the implementation of seasonal water level fluctuations on Lake Rousseau is probably desirable, an optimal schedule for these fluctuations is difficult to predict and will require some experimentation and analysis of results for the reservoir. Similar to extreme drawdown, low water levels in the fall would probably be beneficial and not create ecological problems or severely limit recreational use. Although spring low water would mimic natural seasonal cycles, potential problems with submersed aquatic weeds might complicate this schedule.

It is emphasized the timing of seasonal fluctuations need not be the same from year to year and could be varied for different desired effects. Also, the heights of seasonal fluctuations can vary. Simulations for seasonal fluctuations 3.5 feet below the normal operating stage were run but this level may be extreme for yearly fluctuations. Simulations for 2.5 and 1.5 foot fluctuations indicate that five percent flow reductions refill the reservoir in suitable amounts of time and ten percent reductions give quick reservoir refilling. Simulations for the 3.5 foot drawdown show that five percent flow reductions can raise the reservoir similar to natural lake fluctuations, but ten percent flow reductions would be necessary for certain management objectives.

OUTLET STRUCTURE MODIFICATIONS REQUIRED FOR A DRAWDOWN

To accomplish any significant manipulation of Lake Rousseau's water levels would require extensive control structure modifications. When reservoir levels are lowered below 27.5 feet, the discharge capacity of the bypass spillway quickly diminishes until an elevation of 21.0 feet is reached at which time it is no longer possible to release freshwater to the lower Withlacoochee River. Consequently, at the recommended drawdown level of 18 feet for Lake Rousseau, structural modifications of the CFBC facilities would be required to maintain fresh-water flows to the lower river. Such structural modifications would also allow for minor seasonal fluctuations of reservoir levels which are currently impractical due to the limited discharge capacity of the bypass spillway at elevations below 27.5 feet. However, these modifications may not be viable because of pending deauthorization of the barge canal which may restrict structural modifications of barge canal facilities.

Two areas where structural modifications will be considered are the barge canal, and the bypass spillway and channel. Because of the freshwater flow requirements of the lower Withlacoochee River, the following condition was placed on the structural modifications investigated: the existing discharge capability (1,540 cfs) to the lower Withlacoochee River at a reservoir elevation of 27.5 feet be maintained at the recommended drawdown elevation of 18 feet.

An analysis of the bypass channel flow system indicated that if the spillway was modified to pass 1,540 cfs at a reservoir elevation of 18 feet, the channel and access road crossing would not be of sufficient design to convey that amount of flow. To overcome this would require either mechanical lifting of the water from a reservoir elevation of 18 feet to 27.5 feet in the bypass channel, or modification of the complete bypass system to facilitate gravity flow.

For the option of mechanically lifting water into the bypass channel during drawdown, total power requirements to pump 1,540 cfs would be about 2,400 horse power. Since the estuary would be dependent upon uninterrupted flows from the pumping station, standby units would be required to ensure continuous flow. Estimated cost for the pump station is 1.5 million dollars; this does not include the cost of constructing a barrier in the bypass channel to prevent backflow to the reservoir. Energy requirements to operate the pump station will be about $300,000 for 120 days of pumping.

Complete modifications of the bypass channel system to facilitate gravity flow would include the spillway, bypass channel, and access crossing to the Inglis Lock. Estimate costs are as follows; 1.6 million dollars for the spillway and energy dissipating system, 1.7 million dollars for the bypass channel, and 500,000 dollars for replacing the access road crossing, bringing the total cost to 3.8 million dollars. Of the two bypass options evaluated to provide flows to the lower river during drawdown (pumping and gravity), the gravity system is the better option because it provides several advantages over the pumping system.

An option proposed by the USACOE in 1975 was the construction of a dam and overflow weir system in the barge canal just downstream of where the old river channel flows into the canal. Concurrently, the rock dam that segregates the barge canal from the lower Withlacoochee River would be removed, essentially reconnecting the lower Withlacoochee River. Under this configuration, regulation of discharges to the lower river would be transferred from the bypass spillway to the Inglis Dam, which has a discharge capacity of 4,800 cfs at an elevation of 18 feet. The overflow weir would provide for the partial diversion of flood waters to the barge canal to prevent flooding along the lower river.

From a reservoir management perspective, this option is the most preferred of those investigated for several reasons. It provides better control of releases, over a wider range of reservoir inflows and levels, than any other option investigated. This option would also restore the section of the lower river that now leads to the barge canal and provide it with continuous flows. Similarly, it is the only option that would allow for the continuous flushing of the western end of Lake Rousseau. Modifying the barge canal also provides the capability to lower the reservoir below 18 feet, if desired, while maintaining flows to the lower river. Finally, at an estimated cost of two million dollars this option appears to be the least expensive option of all those investigated. One possible disadvantage to the option is the loss of access to Lake Rousseau from the barge canal. However, this loss of access from the barge canal would be replaced by access to Lake Rousseau from the lower river, through the Inglis Lock which would still be functional.

COST OF MAINTAINING EXISTING FACILITIES

The pending deauthorization of the CFBC includes a non-completion alternative for the project. For the area under study in this report, it included preservation of Lake Rousseau and the West End of the completed authorized project to the Gulf. This includes Inglis Lock and Dam, the bypass channel, and the canal between Inglis Lock and the Gulf. These facilities would be operated and maintained to serve existing and potential commercial and recreational boat traffic.

Under the selected non-completion alternative, the USACOE’s-CFBC Restudy Report, Final Summary points out that Lake Rousseau could be intensively managed for aquatic plant control, fisheries, wildlife and recreation. It is further stated that the impacts of the non-completion alternatives on water quality in the reservoir would depend upon management programs adopted for the remaining resources.

A Wildlife Study prepared by the FG&FWFC as part of the restudy of the CFBC Project stated that maintenance of flow release facilities related to Lake Rousseau would allow greater flexibility for water level manipulation in the reservoir, which might slow the process of aging and preserve for a longer period the present health of the reservoir.

Cost estimates for non-completion alternatives (preservation of completed works) are based on operation and maintenance of existing facilities essentially as is currently being done, including: Operation and Maintenance of Inglis Dam and Spillway, Inglis Bypass Channel and Spillway, and recreation facilities; and maintenance and "on-call" operation of Inglis Lock; debris removal, snagging, aquatic plant control, mosquito control, and collection of hydrologic data in Lake Rousseau; and maintenance of canal slopes and berms, periodic surveys and inspection of structures, acquisition and maintenance of work equipment, condition surveys, maintenance dredging and overhead.

The following are average annual operation and maintenance costs, and average annual costs for other requirements for the years 1980-86, for the completed West End works. Averages were computed from annual figures supplied in personal communications from the Construction and Operations Division of the USACOE; January 1988.

Inglis Lock and Spillway and the Bypass Channel and Spillway	$215,000
*Other Requirements (est.)	219,000
Total	$434,000

*Estimated by SWFWMD from figures for the entire project from Lake Rousseau and the West End, to the most easterly lock and dam of the completed portions of the authorized project.

The annual cost (rounded to $1,000) for aquatic plant control on Lake Rousseau, for the three fiscal years 1985-1987, was $276,000, $301,000 and $286,000, respectively. These were federal funds from the USACOE, administered by the DNR and expended by SWFWMD.

MANAGEMENT OPTIONS

Considerations for management plans for Lake Rousseau are summarized for options which utilize the existing water control structures and those options which would require structural modifications. The emphasis of this summary is how the ecological qualities of the Lake Rousseau/Withlacoochee system could be enhanced by optimizing operational plans for the water control structures at the reservoir. The USACOE is directly responsible for the management of Lake Rousseau. Because the

USACOE has extensive experience in aquatic weed control and navigation maintenance, this report is not intended to provide details regarding immediate aquatic weed control plans or other duties such as channel marking or maintenance.

Stabilized Water Levels With Existing Control Structures

The first management alternative is the stabilization of reservoir elevations between 27.0 and 27.5 feet using the existing water control structures. This essentially is a continuation of the current operations plan for the reservoir. The stabilization of water levels is due to the limited discharge capacity of the bypass spillway at elevations less than 27.5 feet and the need to maintain adequate flows to the lower river.

The stabilization of water levels in Lake Rousseau has accelerated certain undesirable ecological effects, such as; increased sediment build-up in shallow areas, a transition in aquatic plant communities from native to exotic species, and dense periphyton growth on stumps, markers, and other structures. Despite these problems, Lake Rousseau remains a valuable resource and maintains an economically important sport fishery. A range of $242,111 to $448,312 was estimated as the annual value of fishing on Lake Rousseau. FG&FWFC fishery sampling in the reservoir, however, indicates that the ratio of intermediate to adult size sportfish is not optimum, and historical data have consistently shown poor survival of bass greater than 15 inches. The FG&FWFC states that the management of hydrilla to allow greater establishment of native aquatic plants would benefit sportfish production. The FG&FWFC also suggested that the accumulation of flocculent organic sediments has had a negative impact on sportfish production in the reservoir. With the current impracticality of significant water level fluctuations in the reservoir, the ability to encourage the establishment of native plant communities or to oxidize the bottom sediments is very limited. Indirectly, the stabilization of water levels limits the potential to maximize sportfish production in the reservoir.

Aquatic plant control in Lake Rousseau in recent years has been primarily by the use of herbicides, although some mechanical control has also been employed. Total costs for aquatic plant control on the reservoir were $276,000, $301,000, and $286,000, for 1985, 1986, and 1987, respectively. Because of the costs involved and the potential for high sedimentation and nutrient build-up resulting from repeated herbicide applications, a sole reliance on chemical plant control methods is probably not optimal for the long term management of Lake Rousseau.

In short, maintenance of the existing facilities and aquatic weed control on the reservoir involve considerable expense. Also, due to the limitations of the existing structures, the current operations plan for the reservoir is not optimal for sportfish production. These factors must be considered when assessing the relative costs for implementing structural modifications to allow reservoir level fluctuations, including extreme drawdown.

With the existing structures, flows to the lower river should be maximized to the greatest practical extent by releasing total outflows below 1,540 cfs to the lower river through the bypass spillway. The current practice of periodically releasing small (50 to 200 cfs) slugs of water through the Inglis Dam to facilitate flushing in the western end of the reservoir should be continued, as this probably doesn't represent a significant disruption of flow to the lower river. Other diversions of flow which would normally go through the bypass spillway may be necessary at times for operations such as structure repair, but the objective of maximizing flows to the lower river should always be considered.

Given the limitations of the existing structures and the flow needs of the lower river, large water releases through the Inglis Dam are generally restricted to times when total reservoir outflows exceed 1,540 cfs. This schedule produces hydrographs for the barge canal which often show extreme seasonal fluctuations, which may not be desirable for water quality and biological conditions in the canal and the adjacent inshore environment. Although further research is needed, it is suggested that structural modifications allowing greater moderation of flows to the barge canal would be desirable.

With the existing control structures, flood control capabilities on the lower Withlacoochee River are more than adequate; the Inglis Bypass Spillway is restricted to a discharge of 1540 cfs at a reservoir stage of 27.5 feet. Inglis Dam, however, is designed to pass the Standard Project Flood (SPF) discharge of 18,000 cfs at a reservoir elevation of 27.0 feet. The SPF has an estimated return period in excess of 200-years.

Minor Water Level Fluctuation With Existing Structures

Because of the reduced discharge capacity of the bypass spillway at lowered reservoir elevations, even minor (3 ft.) water level fluctuations are impractical for frequent use as they would result in reduced flows to the lower river. For example, a three foot water level fluctuation would require lowering the reservoir to an elevation of 24.5 feet. Maintaining the reservoir at this elevation would limit flows to the lower river to 600 cfs, an extreme low flow level which was exceeded 97% of the time during 1970 to 1985. This outflow would have to be maintained during the low water period, which should last for 90 days, and during reservoir refilling. This type of water level fluctuation would put the lower river through an extended low-flow period, similar to the occurrence of a drought. Therefore, it is not a viable alternative for frequent use.

A three foot water level fluctuation is not a substitute for extreme drawdown and will not produce nearly the same results for the drying and compaction of bottom sediments. Similarly, large populations of hydrilla will thrive below the low water level, and it is not expected that a 3 foot lowering of the reservoir will have a major effect on the tussocks. Because of the flow alterations it would cause in the lower river and because the expected benefits in the reservoir are limited, a three foot lowering of the reservoir with the existing structures is not perceived as a good long-term management tool for Lake Rousseau.

Extreme Drawdown and Seasonal Water Level Fluctuations Requiring Structural Modifications

It is the conclusion of this report that periodic extreme drawdowns would benefit the immediate and long-term management of Lake Rousseau, and various aspects of extreme drawdown have been examined in detail in this report. During drawdown, a program of stump cutting and removal during drawdown would also be valuable for controlling the rate of formation and growth of the tussocks. Also, minor (1-3 feet) seasonal water level fluctuations could be managed as a supplement to extreme drawdown. Significant structural modifications would be necessary if extreme drawdown or seasonal fluctuation capabilities are to be realized. The relative advantages of structural modifications to either the bypass system or the barge canal are summarized below.

Of the structural modification options available, the barge canal modification (lower river re-connection) is most desirable for reservoir water quality benefits, as it would allow constant flushing of the west end of the reservoir. This option would also allow lowering the reservoir below 18 feet, if desired, while still providing adequate flows to the lower river. It would also restore the 1.1 miles of lower river between Inglis Dam and the barge canal and provide it with continuous flow.

Structural modifications to achieve drawdown capabilities would also allow moderation of flows to the barge canal, possibly enhancing estuarine productivity there. With the barge canal modification, an overflow weir to the barge canal could be modified to allow incremental flows to the barge canal at less than flood flows. With the bypass system modification, the flow capacity to the lower river would be increased at normal stages, so high flows could be incrementally divided between the lower river and the barge canal, thus moderating flows in the canal. Further analysis is necessary before it can be determined which structural modification option would be optimal for management of the estuary.

Existing flood control capabilities for the lower river would be maintained with the bypass facility option. With the barge canal option, an overflow weir would be designed to limit flood flows to non-damaging levels. However, as mentioned elsewhere in this report, these modifications may not be viable because of pending deauthorization of the CFBC which may restrict structural modification of barge canal facilities.

INTRODUCTION

Lake Rousseau is a man-made impoundment of the Withlacoochee River formed by Inglis Dam; an earthen dam with a concrete control structure. The dam is located 11 miles upstream from the mouth of the river (Figure 1). At this location the watershed area drained is approximately 2,020 square miles (mi^2). Lake Rousseau is about 11 miles long and has a surface area of 4,163 acres or 6.5 mi^2 (at elevation 27.5 feet NGVD)[1]. The impoundment was completed in 1909 and was constructed by Florida Power Corporation to produce hydroelectric power. The power plant ceased operation in 1965.

The Cross Florida Barge Canal (CFBC) was to traverse Lake Rousseau, but was only partially completed when all work was suspended in 1971 because of concerns regarding its impact on the environment and regional water resources. Those barge canal works completed which directly affect the reservoir are: the Inglis Lock (which is operational) and approach channel to the reservoir; that part of the barge canal west of the lock which connects the reservoir and the Gulf; the Inglis Dam which replaces the old power plant control facility; and the bypass channel and control structure which connects the reservoir and

---

[1] Whenever a land surface or water surface elevation is used in this report, that elevation is referred to National Geodetic Vertical Datum-NGVD; formerly referenced as Mean Sea Level-MSL, Datum of 1929.

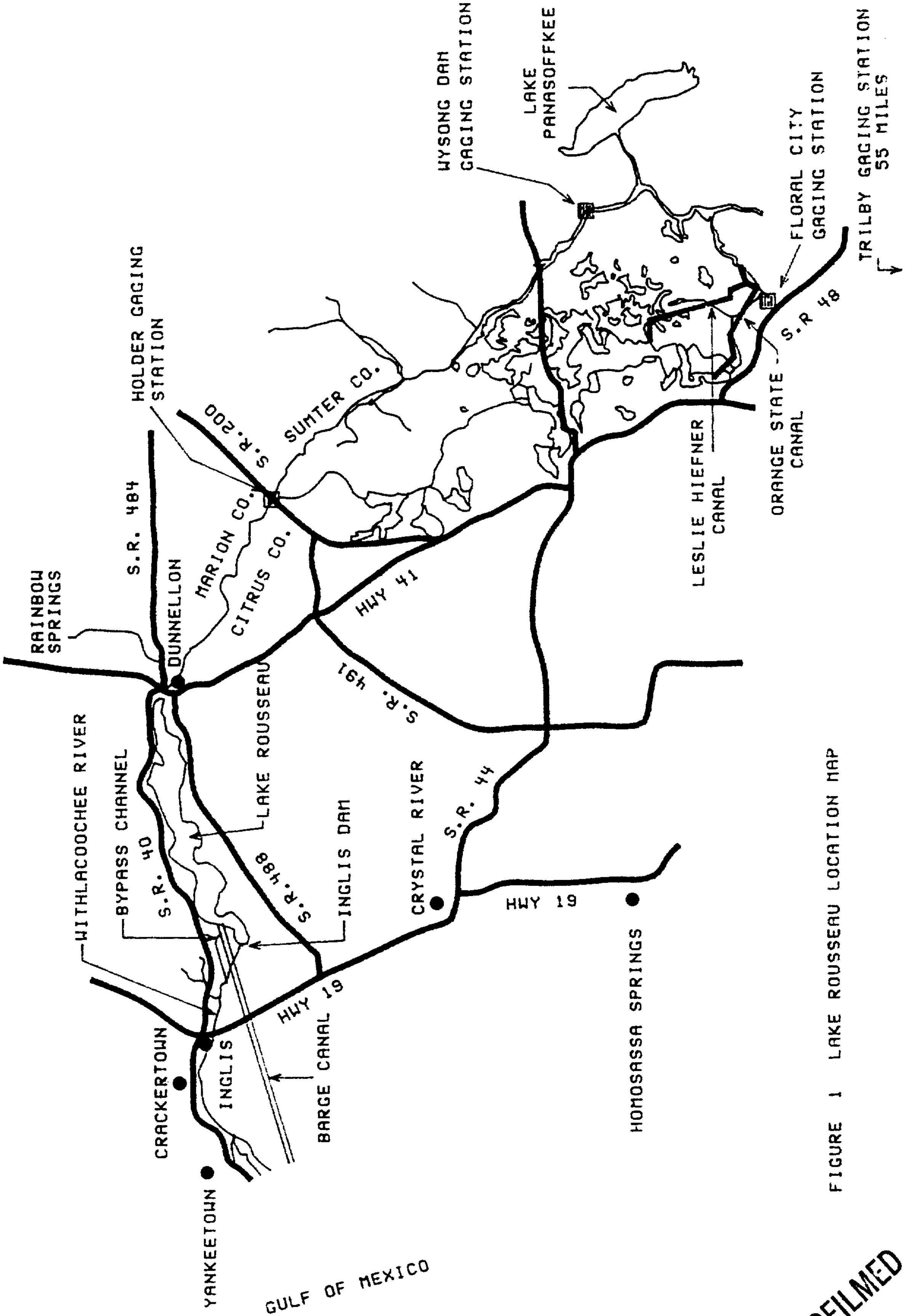


FIGURE 1 LAKE ROUSSEAU LOCATION MAP

the lower reaches of the Withlacoochee River (Figure 2). These facilities were constructed between January, 1965, and December, 1969.

Inglis Dam controls discharge to the barge canal via a short section of the old river channel, and the bypass channel structure controls discharge to the main section of the lower river channel through Inglis and Yankeetown. Thus, discharge can leave the reservoir at three points: (1) by lockages to the barge canal, (2) by discharge through Inglis Dam to a short section of the old river channel and thence to the barge canal, and (3) by discharge through the bypass channel structure to the channel of the lower Withlacoochee River.

Since its impoundment almost 80 years ago, Lake Rousseau has experienced many of the problems associated with a rapidly aging reservoir. There has been an accumulation of organic sediments in the reservoir, with sediments averaging 16-20 inches in depth but being at least 54 inches deep in some areas. Stumps which remain from the riverine forests flooded by the impoundment continue to cause significant navigational problems and hindrances to water-based recreation. Aquatic plant growth is extensive and in the upper-half of the reservoir floating islands of aquatic plants have reached several hundreds of acres in size.

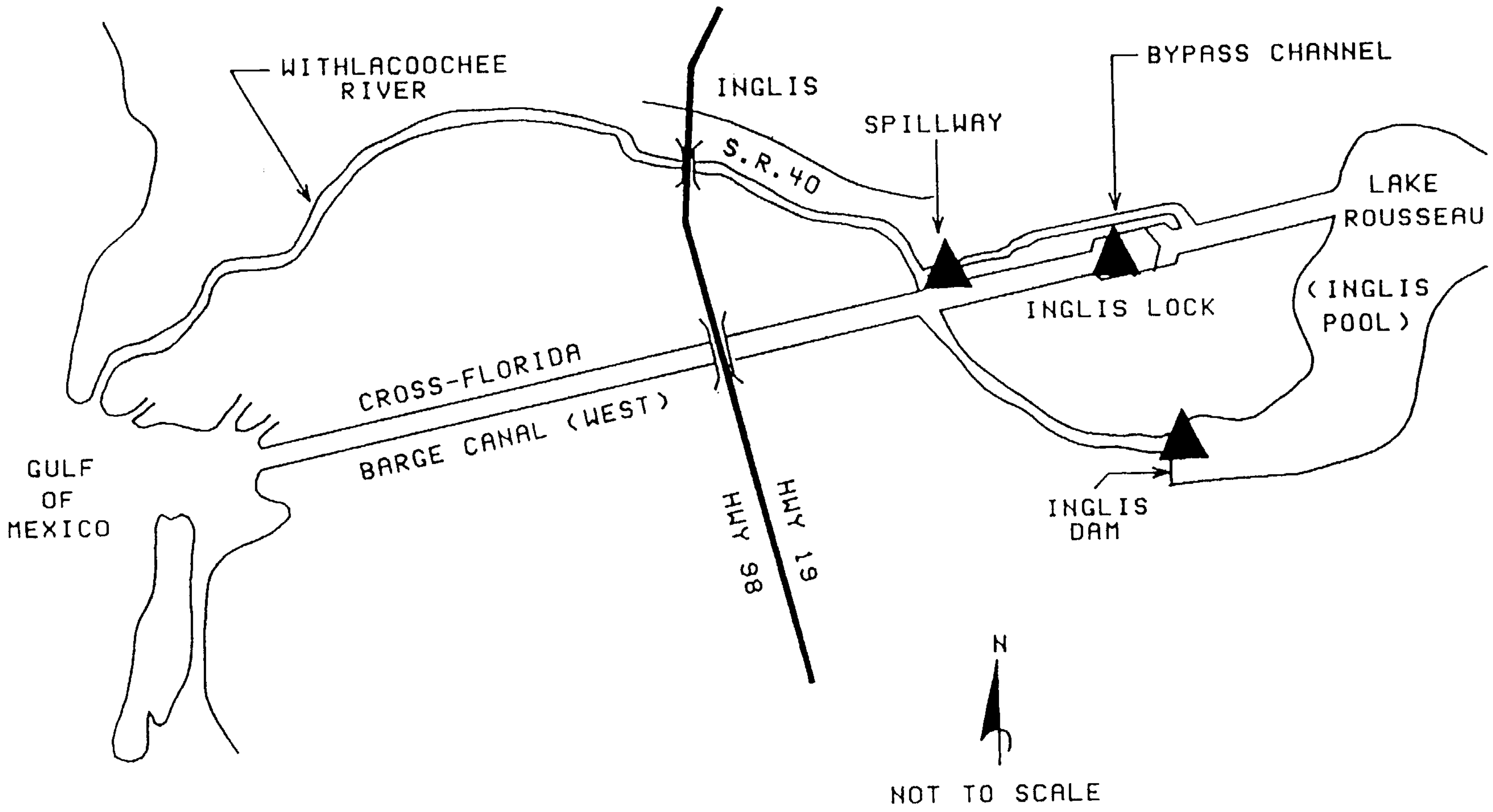


FIGURE 2 LOCATION OF DISCHARGE CONTROL FACILITIES IN THE LOWER WITHLACOOCHEE RIVER BASIN.

Because of poor water circulation patterns, accelerated aquatic plant production, extensive shallow areas, and the accumulation of bottom sediments, the reservoir has a long history of aquatic plant, fisheries and water quality problems. Aquatic plant control has required large expenditures of funds and serious problems with aquatic weed infestations persist. There has been some recent success on the reservoir with SONAR, a new chemical for treatment of hydrilla, and presently the fisheries aspect of the reservoir has been characterized as somewhat healthy and productive. However, the overall characterization of the reservoir is that of being in an accelerated state of eutrophication.

Over the years there have been other problems which were thought to have been associated with the reservoir and/or water releases from it; flooding in the Dunnellon area which would have been alleviated had construction of the barge canal been completed in that area, flooding below Inglis Dam along the short section of the old river channel, flooding below the bypass channel on the main section of the lower river channel, and complaints of less than adequate fresh-water releases down the bypass channel to maintain the fresh-water and estuarine environments of the lower Withlacoochee River.

Water level records for Lake Rousseau show that prior to completion of the barge canal facilities in 1969 there was periodic seasonal lowering of one to three feet in reservoir water level in response to flooding in the Dunnellon area (Figure 3). In December 1969, the U.S. Army Corps of Engineers (USACOE) assumed operation of the water control structures at Lake Rousseau. In 1972, reservoir levels were temporarily lowered by 4.5 to 5.5 feet to allow work on the structures. Since 1973, reservoir levels have been largely stabilized at elevations between 27.0 and 27.5 feet, except for five occasions between 1979 and 1988, when the reservoir was briefly lowered as much as 3.5 feet to address potential flooding in Dunnellon. It has been widely observed that natural Florida lakes seem to maintain a healthier state if their water levels fluctuate through some desirable range, either naturally or by man's inducement if water control facilities are available (Wegener and Williams, 1974; Dooris and Courser, 1976; Leslie, 1988). Such fluctuations may also benefit man-made impoundments (Haller and Shireman, 1988), but must be managed to account for the unique physical and biological characteristics of each impoundment.

During April and May, 1986, a Lake Rousseau Management-Planning Task Force group was formed under the chairmanship of the USACOE to address problems associated with the reservoir. The task force agreed that its long-term goals were to: (1) complete a Lake Rousseau management plan; (2) use the new chemical, SONAR, for aquatic plant control; (3) mark primary and secondary navigation channels; (4) improve the quality and quantity of sport fish populations, particularly largemouth bass; (5) achieve

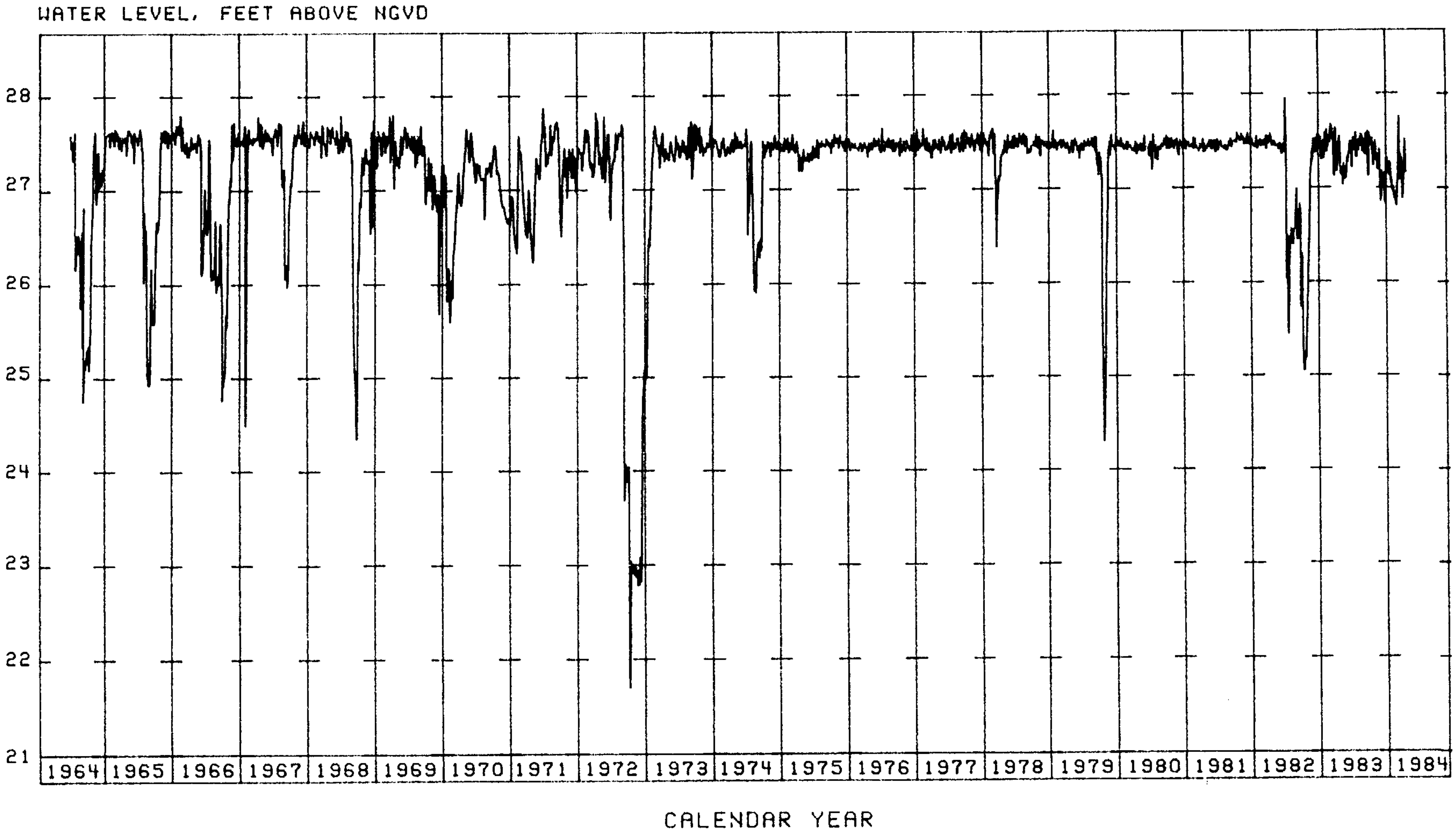


FIGURE 3 STAGE HYDROGRAPH FOR LAKE ROUSSEAU NEAR DUNNELLON, FLORIDA.

consolidation of reservoir bottom sediments; (6) get answers to persistent flooding and flow release problems; (7) prevent unacceptable salt-water intrusion in the river downstream from Inglis; and (8) conduct management planning for the entire Withlacoochee watershed.

About the same time the task force was forming, project planning began for the Southwest Florida Water Management District's (SWFWMD) 1987 fiscal year (October 1, 1986 through September 30, 1987). Because of the long-standing problems on Lake Rousseau, and because the SWFWMD had been doing aquatic plant control on the reservoir for a number of years and was involved in a fresh-water flow study in the Withlacoochee River estuary, the Withlacoochee River Basin Board directed staff to develop a project to address problems with the reservoir. The project was named the Lake Rousseau Operations and Management Study and became a priority work effort for the 1987 fiscal year.

The study officially began October 1, 1986. It was to be coordinated with the Florida Game and Fresh Water Fish Commission (FG&FWFC) and the USACOE, with local citizen groups being kept advised of its development. Existing data and reports were to form the main basis of the study with minimal new information to be collected. The FG&FWFC completed a fisheries update for the study (Appendix A), and reviewed and commented on other sections of the report pertinent to the fisheries aspect of the study.

Included in the study were most of the long-term goals that had been established by the Lake Rousseau Management-Planning Task Force. The scope of work for the study included the following tasks: (1) conduct a water balance for the system, (2) establish fresh-water inflow needs for the estuary, (3) update water level information for the reservoir, (4) document flooding, (5) characterize water quality, (6) examine fisheries, (7) discuss aquatic plant control, (8) develop a recommended fluctuation schedule and operational procedures for the reservoir, (9) examine the feasibility of reservoir drawdown, and (10) discuss the cost of maintaining existing facilities.

On November 17, 1986, just as the new fiscal year was beginning and work on this study was taking shape, President Reagan signed into law the Omnibus Water Resources Development Act. Pending enactment of appropriate lesislation by the State of Florida, Section 1114 of that act deauthorizes that part of the CFBC project east of the Inglis Complex, including Lake Rousseau, and establishes, instead, the Cross Florida National Conservation Area. As part of the re-designation, a conservation management area will be created and the State of Florida is to cooperate with the USACOE in developing a management plan for the area. Included in the national conservation area is Lake Rousseau.

The act which deauthorizes the canal provided that the State of Florida retain responsibility over water resources planning, development, and control of surface and ground waters pertaining to lands cited in the act consistent with the purposes of the act. Because the SWFWMD exercises jurisdiction and has responsibilities in those areas, the CFBC Authority requested that SWFWMD participate in development of the management plan for the conservation area.

Although the USACOE had been directed to consult with other federal agencies and the State of Florida to develop a management plan for the conservation area, monies for the studies to prepare the plan were never appropriated. Had the studies been funded and implemented, the SWFWMD's study on Lake Rousseau would have been a duplication of effort. However, because funds were not appropriated, those federal studies did not materialize and it was decided to proceed with the SWFWMD study that had just begun. Should the study by the USACOE receive funding and materialize, whatever had been accomplished on the SWFWMD study would be incorporated into the USACOE's study. If the USACOE's study did not receive funding at some future date, the SWFWMD study would proceed to completion. Either avenue would result in a completed study on Lake Rousseau.

PURPOSE AND SCOPE

The project consists of the development of an Operations and Management Plan for Lake Rousseau. The primary objective of the project is the development of operational guidelines for Inglis Dam, Inglis Lock, and the bypass channel structure which would benefit and enhance the long-term ecology of the reservoir and downstream river and estuary. These structures are operated by the USACOE in accordance with the Operations Plan for the CFBC.

The study area was limited to the Withlacoochee River estuary, the river channels and the barge canal below the structures on Lake Rousseau, the reservoir itself, and that reach of river upstream of the reservoir to just above the confluence of Blue Run and the main river, generally the extent of the pool created by Inglis Dam (Figure 1). A flow contribution analysis of the riverine system, which was done for this study, indicated that for average flow conditions or less the single most contributing inflow to Lake Rousseau is the ground-water discharge from Rainbow Springs and other springs along Blue Run. Thus, since a management plan for Lake Rousseau would be most critical during times when inflow was lowest, coincident with average to low flow conditions when Rainbow Springs is the major contributor to the reservoir, the study area was limited to the river area downstream of and including Blue Run. This rather constant, substantial ground-water discharge to the lower river ensures an adequate supply of flow for reservoir level management and to refill the reservoir following possible drawdowns.

The results of the study will include formal recommendations for optimizing the operations and management plan for the reservoir. It is likely that accomplishing the optimum would require significant and costly control structure modifications, especially if periodic drawdowns and significant fluctuations in reservoir levels seem justifiable on the basis of benefits/costs and are aesthetically and economically acceptable to the residents of the area who would be most affected. Of course, any plan recommended would have to be acceptable to the USACOE and implementable within the authorized operational constraints for the barge canal and water control structures on Lake Rousseau.

structures, the Wysong Dam, an inflatable fabri-dam, has the most potential for affecting flows entering the reservoir. When the dam is inflated, there is the potential to reduce inflows to Lake Rousseau by impounding and diverting waters above the dam into the Floral City Pool of Lake Tsala Apopka.

FLOW CONTRIBUTION ANALYSIS

A flow contribution analysis of the Withlacoochee River was conducted to determine what part various reaches of the upstream river system played in contributing inflow to Lake Rousseau. To determine the source of Lake Rousseau's inflows, the Withlacoochee River was divided into flow reaches based upon the location of USGS gaging stations (Figure 1). The flow contribution reaches analyzed are as follows:

(1) upstream of Floral City;
(2) upstream of Wysong Dam;
(3) between Wysong Dam and Floral City;
(4) between Holder and Floral City;
(5) between Holder and Wysong Dam;
(6) between Lake Rousseau outlets and Holder with Blue Run flows removed; and,
(7) Blue Run.

For up to and including average inflow conditions to Lake Rousseau, a time series analyses indicated that the single most contributing source of freshwater inflow to Lake Rousseau is the ground-water discharge from springs along Blue Run. The time series analyses provides methodology whereby corresponding flows from other stations can be analyzed simultaneously. The analyses indicated that as Lake Rousseau's inflow drops below average flow conditions Blue Run provides a greater proportion of total inflow to the reservoir. Blue Run on the average provides about 700 cfs inflow to Lake Rousseau with a variation between 538 and 1,000 cfs depending on ground-water hydrologic conditions.

The next largest contributing source of inflow to Lake Rousseau for average flow conditions or less is the reach of river between Holder and Floral City. Most inflow to this reach appears to be ground-water inflows from springs and from water table seepage into the river. A basin-wide reconnaissance conducted by the USGS (Anderson and Laughlin, 1982) indicated that the Floridan aquifer is in close proximity to the land surface throughout much of the river basin facilitating ground-water flow to the river. This ground-water inflow was further substantiated by visual sitings of springs (overflight May 1, 1987) along the Withlacoochee River between Wysong Dam and Holder, and by the documented spring flow into Lake Panasoffkee which discharges to the Withlacoochee River (Figure 1).

At a combined discharge rate of 1,000 cfs from Lake Rousseau, the flow contribution percentages from Blue Run and the Holder/Floral City reach are 60% and 28%, respectively. These flow percentages have been adjusted in regard to the sum of flow for the Withlacoochee River at Holder and the flow of Rainbow Springs near Dunnellon (USGS gaging stations) because their totals are greater than the combined discharges from Lake Rousseau. This apparent water loss from Lake Rousseau occurs due to the recharging of the Floridan aquifer in the Lake Rousseau area. A USGS study (German, 1978) reported that 7-10% of the inflows may leave Lake Rousseau as ground-water recharge. The geohydrology of Lake Rousseau will be further discussed in a later section of this report.

As surface inflows increase to Lake Rousseau, Blue Run provides less of the total flow into the reservoir. For discharges around 3,000 cfs to the reservoir, Blue Run provides 26% of the total inflow. This does not mean that Blue Run flows decrease; but, rather that, the river flows as a result of increased surface runoff become more predominant. Figures 4 and 5 provide the cumulative flow contribution for the reaches presented in comparison to Lake Rousseau discharges.

Flow contributions for the reach upstream of the USGS gaging station near Floral City were based upon a linear-regression model. Floral City discharges have only recently been collected on a daily basis, which required the generation of daily flow data for the same period of record available at the other gaging stations used in the analysis.

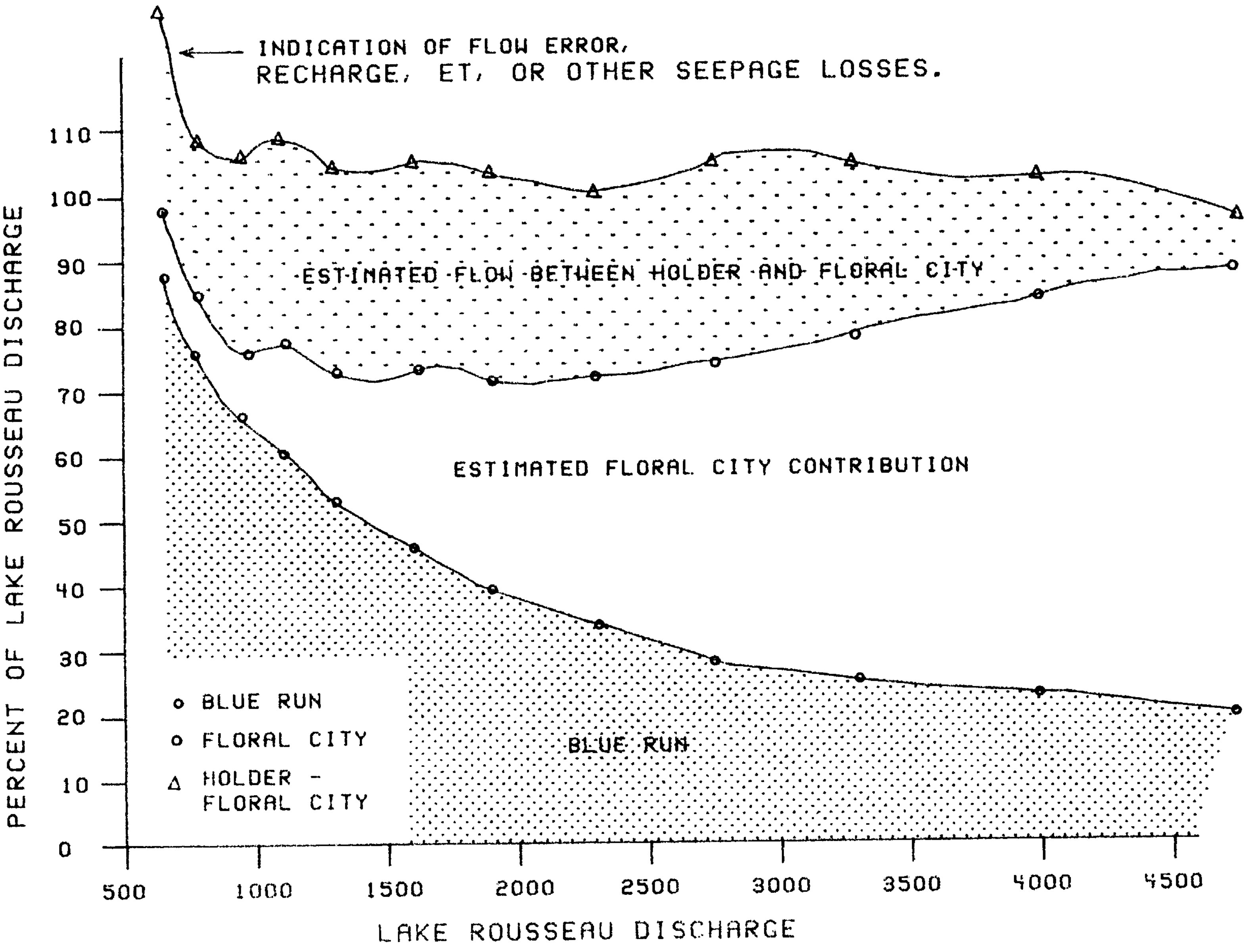


FIGURE 4 CUMULATIVE FLOW CONTRIBUTION TO LAKE ROUSSEAU.

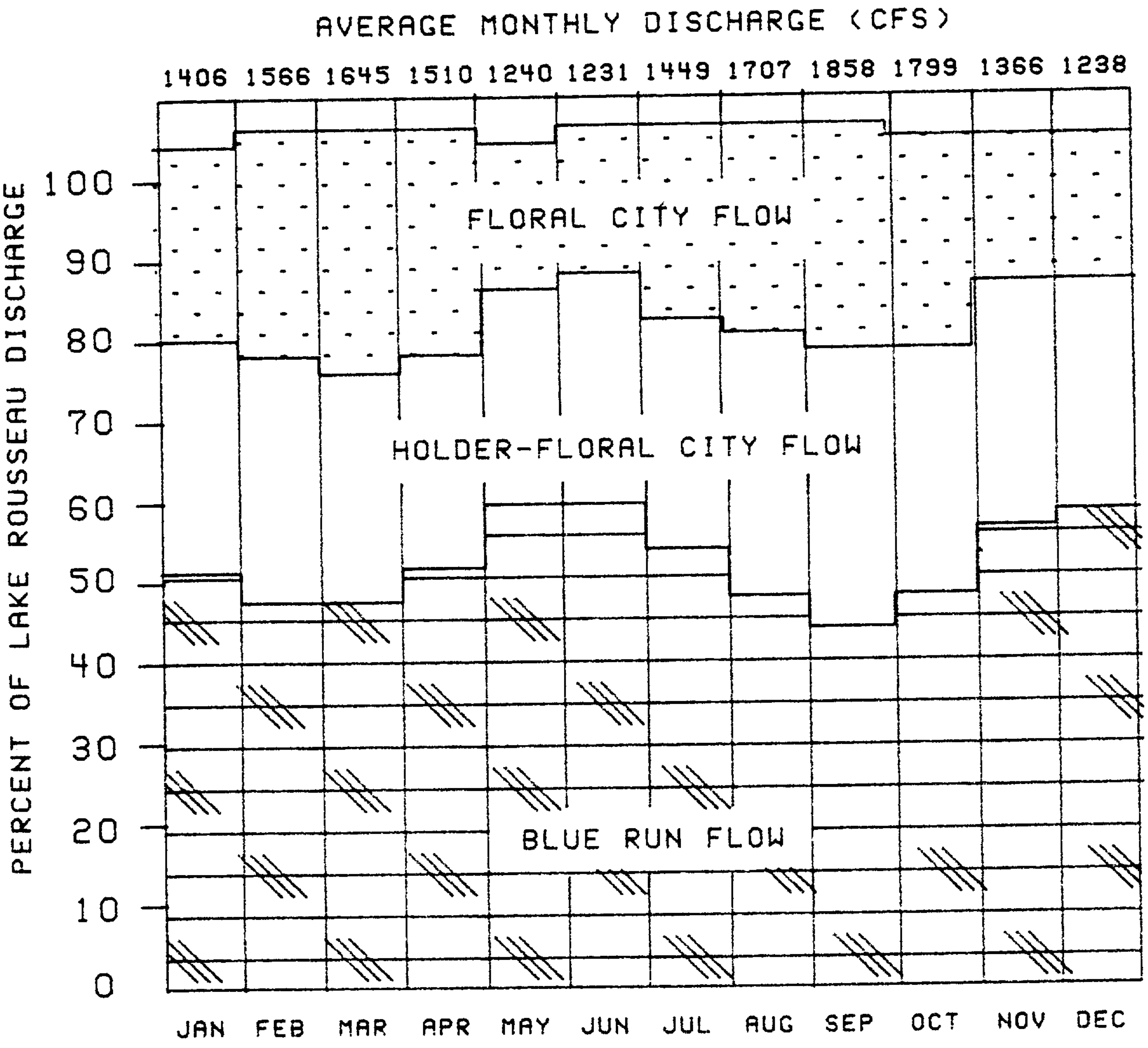


FIGURE 5 AVERAGE MONTHLY FLOW CONTRIBUTIONS INTO LAKE ROUSSEAU

The linear-regression model (Appendix B) provided the means whereby the flows at the Floral City gaging station could be predicted. This allowed the estimation of the flow contributions for the river reach above Floral City as well as the flow contribution down-stream of Floral City.

Wysong Dam Effects on Withlacoochee River Flows

As mentioned earlier in this section of the report, the Wysong Dam has the potential to affect Withlacoochee River flows, and thus inflow to Lake Rousseau.

The dam is inflated during low flows, and of course a major concern in developing a management scheme for Lake Rousseau is low flow conditions that arise from droughts, and those that could arise when refilling the lake after a drawdown, when flow reductions through the Lake Rousseau outlet structures would be required.

To determine whether the operation of the dam could have significant effects on flows entering Lake Rousseau, and to determine the flow regime of the Withlacoochee River in the vicinity of the dam, linear-regression techniques, time series analysis, and the separation of the various flow conditions at the dam were used. This analysis was restricted to the quantification of the surface-flow reduction associated with dam operation. No analysis was performed to determine the detailed hydrologic and hydraulic responses to the dam operation; i.e. increased surface-water storage effects or ground-water flow reductions.

A comparison of Wysong Dam flows to the combined Floral City and Lake Panasoffkee flows indicates that at discharges near 1,200 to 1,400 cfs at the dam, significantly more flow is received by the reach of river between Wysong Dam and Floral City than is discharged over the dam. A Wysong-Panasoffkee study performed by the District (Mann, 1984) indicated at these higher discharges some surface water received by this reach is diverted across a natural overflow into the Lake Tsala Apopka. For flows less than 1,200 cfs across the dam, when the fabri-dam is usually inflated, surface water can be diverted into the Lake Tsala Apopka via the control structures on the Orange-State and Leslie Heifner Canals near Floral City. Therefore, depending on the flow condition at the dam, water is either naturally diverted into the Lake Tsala Apopka when flows in excess of 1,200 cfs are occurring, or water can be structurally diverted when the fabri-dam is inflated and the Orange-State and Leslie Heifner Canals are open (Figure 1).

The Wysong Dam usually functions at a differential head between 0.25 and 2.75 feet for flows up to 1,200 cfs. When flows in excess of 1,200 cfs are reached the dam is deflated. The amount of head differential that can be maintained across the dam is generally inversely proportional to the flow over the dam. Since Wysong Dam is usually in operation during low flow conditions, a methodology had to be devised whereby the flow reduction to Lake Rousseau could be estimated due to dam operation.

A review of the Wysong Dam flow records revealed that three general flow conditions exist at the dam:

1. low to moderate flow with dam inflated;
2. low to moderate flow with dam deflated; and,
3. moderate to high flow with dam deflated.

The low to moderate flow condition is characterized by flows over the dam that are 1,200 cfs and less. The moderate to high flow condition is characterized by flows greater than 1,200 cfs. The dam deflated versus inflated conditions were determined by the head differential measured across the dam. When the head differential across the dam was greater than 0.25 feet, the dam was considered inflated.

Six variables were analyzed to determine the effects of Wysong Dam inflation on inflow to Lake Rousseau:

1. Water surface elevation above Wysong Dam;
2. Trilby flow;
3. Wysong Dam flow;
4. Water surface elevation below Wysong Dam;
5. Holder flow; and,
6. the head differential maintained across the dam.

The recorded flows at Trilby and Holder provided comparative information regarding hydrologic conditions in the upstream and downstream areas of the basin about 55 river-miles apart. The water surface elevations above and below the dam provided the necessary information to categorize the data in regard to dam operation, while Wysong Dam flow allowed categorization based upon flow conditions. After these variables were categorized based upon flow conditions at the dam, statistical analyses were performed to determine the mean, standard deviation, standard error, and other statistical information for the variables. Since the main concern is for Wysong Dam effects, only the statistics for the low to moderate flow conditions are presented. For the dam inflated condition, seven years of daily streamflow records were available from the 1970 through 1983 period. For the same period but with dam deflated conditions, over four years of daily streamflow records were available.

A cursory analysis of the mean Wysong Dam flows for the two flow categories presented (dam inflated/dam deflated), indicates that when the dam is inflated there would be 215 cfs decrease in the mean flow at Wysong (624 cfs-409 cfs) and a 238 cfs decrease in flow at Holder (839 cfs-601 cfs). However, the mean flow data presented for the various stations in Table 1 indicates that this flow reduction may not be totally attributed to dam operation. A review of the flow records at the Trilby gaging station located 55 miles upstream from Floral City indicates a significant difference in the hydrologic conditions upstream of Wysong for the two flow conditions. The mean Trilby flow for the dam inflated condition is one-half the mean flow for the deflated condition (123 cfs vs. 239 cfs). This indicates that the mean flow reduction realized at Wysong with the dam inflated is not only attributable to dam operation, but to the change in the upstream hydrologic conditions as well.

To quantify the effects of upstream hydrologic conditions on the dam inflated versus dam deflated categories, a flow contribution reach analysis was required. The flow contribution reaches analyzed are:

1. the reach above Trilby,
2. the reach between Trilby and Wysong, and
3. the reach between Wysong and Holder.

TABLE 1. Flow Conditions at Wysong Dam

Statistics for Dam Deflated Condition:

Variable	Label	N	Mean	Standard Deviation	Std Error of Mean	Minimum Value	Maximum Value	Range	CV
X1	Head above Wysong Dam	1535	38.45	0.73	0.01	37.05	40.66	3.61	1.92
X2	Trilby Flow	1535	239.11	240.57	6.14	13.00	2060.00	2047.00	100.61
X3	Wysong Dam Flow	1535	624.50	275.97	7.04	123.00	1200.00	1077.00	44.19
X4	Head below Wysong Dam	1535	38.38	0.73	0.01	36.98	40.57	3.59	1.90
X5	Holder Flow	1535	839.32	361.71	9.23	207.00	2100.00	1903.00	43.09
DIFF	Hd. diff. across Wysong Dam	1535	0.06	0.02	0.00	-0.15	0.25	0.40	44.54

Statistics for Dam Inflated Condition:

Variable	Label	N	Mean	Standard Deviation	Std Error of Mean	Minimum Value	Maximum Value	Range	CV
X1	Head above Wysong Dam	2545	38.92	0.35	0.00	37.70	39.92	2.22	0.90
X2	Trilby Flow	2545	123.14	141.81	2.81	7.30	1310.00	1302.70	115.16
X3	Wysong Dam Flow	2545	409.17	184.53	3.65	85.00	1200.00	1115.00	45.09
X4	Head below Wysong Dam	2545	37.25	0.49	0.00	36.10	39.22	3.12	1.32
X5	Holder Flow	2545	601.27	282.63	5.60	138.00	2270.00	2132.00	47.00
DIFF	Hd. diff. across Wysong Dam	2545	1.67	0.40	0.00	0.29	2.73	2.44	24.50

The inflow received by each reach along with the flows measured at each gaging station were compared for the dam inflated versus dam deflated condition. A method of analyzing the two flow categories is to compare the various flow contribution ratios for the individual reaches and gaging stations for the two flow categories. The following ratios (Table 2) expressed in percentages were determined:

TABLE 2

Contributing Flow Ratios for Various Gaging Stations and River Reaches

Description	Dam Deflated	Dam Inflated
Trilby/Wysong	38.3%	30.1%
Wysong-Trilby/Wysong	61.7%	69.9%
Wysong/Holder	74.4%	68.0%
Holder-Wysong/Holder	25.6%	31.9%

From the above ratio table, the Wysong/Holder ratio decreased from 74.4% (dam deflated condition) to 68% (dam inflated condition). If it is assumed that this percentage decrease in flow ratios is directly attributable to dam operation, then the dam would have effected a mean 54 cfs reduction using the mean Holder flow of 839 cfs as a base. This 54 cfs reduction attributed to inflating the dam is significantly different from the 215 cfs previously estimated which did not consider the difference in the average hydrologic conditions for the two flow categories. To further substantiate the 54 cfs average flow reduction as a result of inflating the dam, the flow contribution analysis was continued to cover the upstream and downstream portions of the river from the dam.

There are two river reaches out of the three analyzed where inflows are not substantially affected by the operation of the dam: the reach above Trilby, and the reach between Wysong and Holder. The Floral City gaging station was not used in this analysis because of its short term record and the operation of the Wysong Dam has been shown to affect flows beyond the Floral City gage (Mann, 1984). Progressing from upstream to downstream, the three river reaches analyzed indicated the following percentage changes (Table 3) in flow from dam deflated to dam inflated condition:

TABLE 3

Percentage Change in Reach Inflow from Dam Deflated to Dam Inflated Conditions

1.	Above Trilby	48.5%	(239-123)/239,
2.	Between Trilby and Wysong	25.7%	(385-286)/385, and
3.	Between Wysong and Holder	10.7%	(215-192)/215

Since Trilby flows are not affected by dam operation, the flow difference exhibited by the two categories for the Trilby-Wysong reach is an indication of the average flow reduction realized by dam operation and change in hydrologic conditions. The 385 cfs for dam deflated minus the 286 cfs for dam inflated condition indicates an average 99 cfs flow reduction resulting from inflation of the dam and changes in hydrologic conditions. To remove the hydrologic effect from the 99 cfs estimate, the percentage change in the inflow for the Wysong-Holder reach was used as a control. The percentage change in inflow for the Wysong-Holder reach was 10.7% where as the total percentage change in the Trilby-Wysong reach was 25.7%. The assumption is that the hydrologic conditions above Wysong Dam are similar to the hydrologic conditions below the dam. Therefore, the (25.7%-10.7%) should represent a liberal estimate of the average flow reduction realized as a result of inflating the dam with the changes in hydrologic conditions removed. This 15% flow reduction for the Trilby-Wysong reach represents a 58 cfs average flow reduction for the dam's inflated condition. This is in general agreement with the 54 cfs previously calculated from the percentage change in contribution of Wysong's flow to Holder's flow (68% vs. 74.4%) for the two categories.

The 54-58 cfs flow reduction should be a liberal estimate of the potential dam effects in that it represents the maximum average influence of inflating the dam. Based upon the decreasing percentage change in inflow for each reach progressing downstream from Trilby (Table 3), the flow reduction realized from inflating the dam is probably less than the 54-58 cfs estimated. The

Trilby reach exhibited a 48.5% flow reduction while Wysong-Holder reach exhibited a 10.7% flow reduction between the two flow categories. The Trilby-Wysong reach exhibited a 25.7% flow reduction which is almost between the 48.5% and 10.7% flow reductions for the other two reaches. This tends to indicate that the dam has less of an effect on river flows than the 53-58 cfs average reduction previously determined.

In summary, the above analysis indicates that the operation of Wysong Dam could induce a conservative 9.3% average reduction in streamflow measured at Wysong. In regard to percentage effects on the flows entering Lake Rousseau, the dam would induce an average 3.8% reduction. During extreme low flow conditions the total amount of flow reduction realized should not change much from average conditions, but the percentage reduction should increase. If the 58 cfs flow reduction is assumed to remain constant, the percentage effect on flows entering Lake Rousseau will increase from 3.8% for average conditions to 10% for extreme drought conditions similar to the Spring of 1985.

The complexity of the Withlacoochee River flow regime in the Floral City/Lake Tsala Apopka area has made it difficult to analyze the operational effects of the dam on downstream flows. The analyses performed thus far indicated that a major study effort would be required to determine an overall water budget and flow scheme for the Lake Tsala Apopka area if an operational plan was to be developed for the Wysong Dam to enhance downstream flow. However, such an operation plan probably would have no significant bearing on the Management scheme to be developed for Lake Rousseau for the following reasons:

(1) refilling of Lake Rousseau after a drawdown can be made to occur during higher flow conditions of the year when Wysong Dam effects are minimal;

(2) Blue Run discharges stabilize flows into Lake Rousseau during average to low flow conditions minimizing the average 3.8 percent effect from Wysong Dam;

(3) the extreme low flow conditions on the river, when the dam would have the most effect (10 percent), do not occur that often; and,

(4) the District has initiated plans to dismantle the Wysong Lock and Dam facilities.

HYDROGEOLOGY AND GROUNDWATER FLOW ASPECTS OF WATER BALANCE

Lake Rousseau is bounded on the east in the Dunnellon area by what has been termed the "Ocala Uplift" (Figure 6). It is hypothesized that the uplift is the result of a westward shift of the Peninsular Arch, which is considered by some as the "backbone" of Florida (Figure 7). These phenomenon are believed to be the result of crustal stresses that forced the underlying limestone formations to fracture and buckle. The Ocala Uplift prevented runoff from the Withlacoochee River Basin from discharging through the Dunnellon area until this portion of the uplift was crested. Once crested, the surface was gradually eroded forming what is now termed the "Dunnellon Gap". After the gap was formed, the surface water followed the path of least resistance and developed the present Withlacoochee River system. It is interesting to note that even though the Ocala Uplift is a structural high 230-miles long and 70-miles wide major portions of the uplift area in the Withlacoochee Basin are topographic lows.

Over geologic history the river flow from the Withlacoochee Basin has eroded the thin layers of sand and clayey sand exposing the underlying limestone formations in many places along the river bed. From Dunnellon westward, the predominating limestones that the Withlacoochee River has eroded to are the Ocala and Avon Park Limestones (Figure 7). The Avon Park consists of 200 to 400 feet of brown, finely fragmented limestones and dolomite with porosity

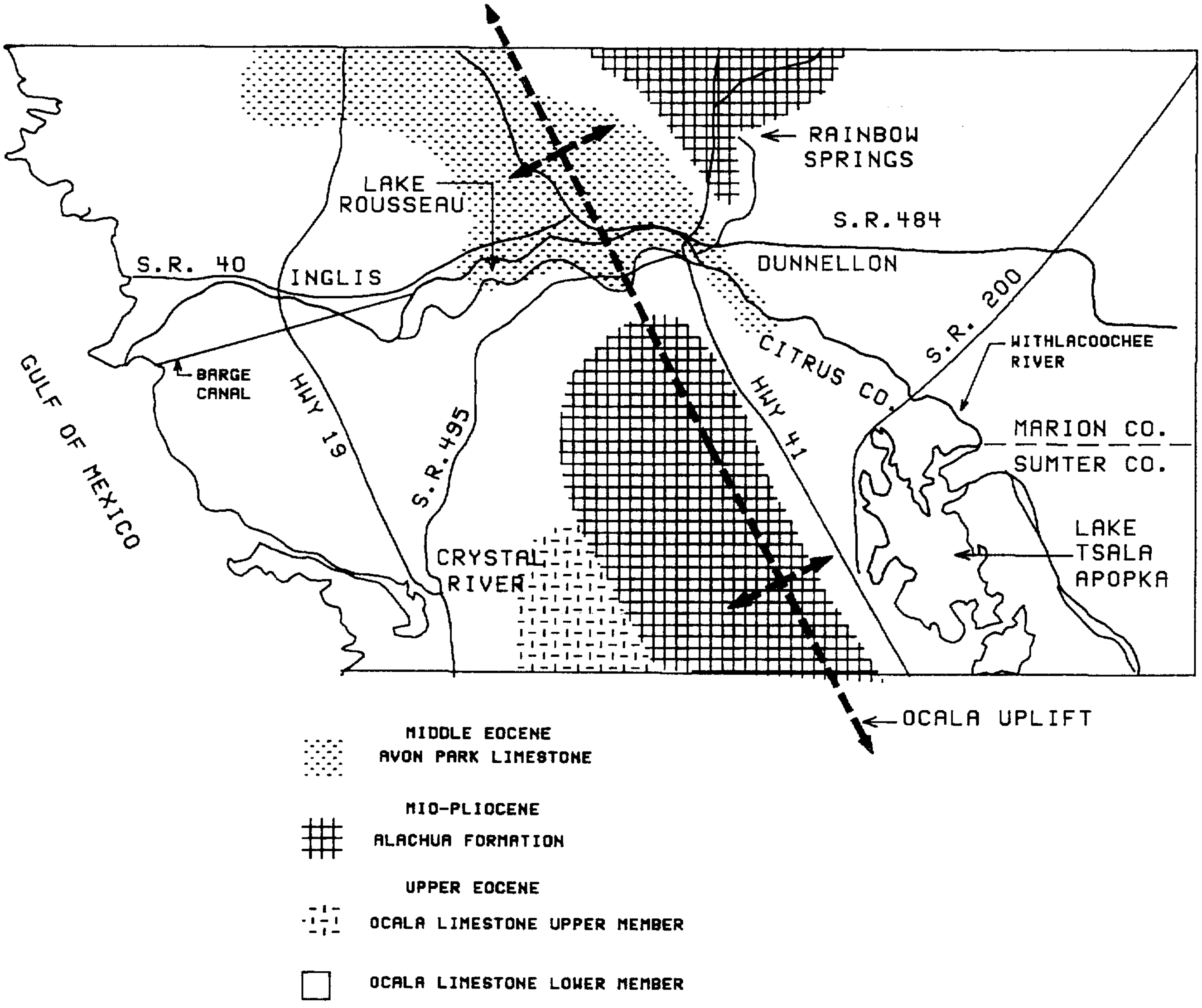
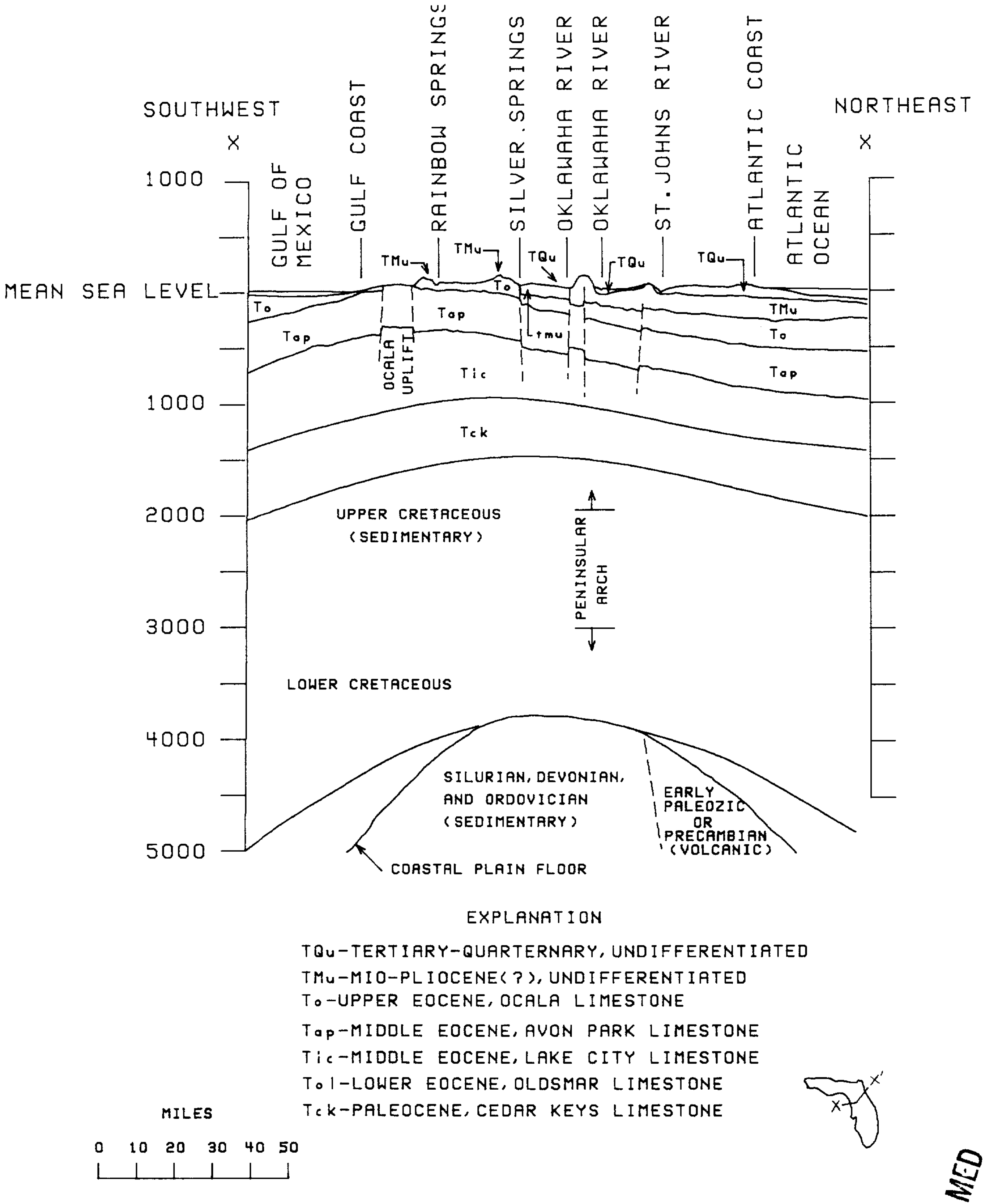


FIGURE 6 GEOLOGIC FORMATIONS AT OR NEAR LAND SURFACE IN THE LAKE ROUSSEAU AREA.



EXPLANATION

TQu-TERTIARY-QUARTERNARY, UNDIFFERENTIATED
TMu-MIO-PLIOCENE(?), UNDIFFERENTIATED
To-UPPER EOCENE, OCALA LIMESTONE
Tap-MIDDLE EOCENE, AVON PARK LIMESTONE
Tic-MIDDLE EOCENE, LAKE CITY LIMESTONE
Tol-LOWER EOCENE, OLDSMAR LIMESTONE
Tck-PALEOCENE, CEDAR KEYS LIMESTONE

FIGURE 7 GEOLOGIC SECTION (X-X') OF NORTH PENINSULAR FLORIDA THROUGH AREA OF CROSS-FLORIDA BARGE CANAL.

varying from poor to good. The Avon Park Limestone is present at or near the surface along the crest of the Ocala Uplift in the Dunnellon area.

The Ocala Limestone usually overlies the Avon Park Limestone except in the uplift area of Dunnellon. The absence of the Ocala in this area may be attributed to removal by various erosional processes. The Ocala Limestone is a productive water-bearing formation of the Upper Florida aquifer, which is the major source of municipal, agricultural, industrial and individual domestic water supplies in the basin. During low flow periods, the principal source of water to the Withlacoochee River is ground-water discharge from the Ocala Limestone. Rainbow Springs near Dunnellon, one of the largest springs in Florida, discharges from this limestone formation.

The Ocala Limestone has been divided into an upper and lower member based upon lithologic and faunal differences (Applin and Applin, 1944, and Stringfield, 1966). The lower member of the Ocala Limestone is predominant in the Lake Rousseau area and ranges from five feet to about 80 feet thick. The Ocala Limestone consists of granular, highly fossiliferous to coquinal, tan and brown limestone. The CFBC penetrates this formation west of the Inglis Lock. In the area of Lake Rousseau, both the Ocala and Avon Park Limestones are generally covered with a thin layer of sand and clayey sand.

General Groundwater Flow Characteristics

The general ground-water flow direction in the Floridan aquifer, in the Lake Rousseau area is southwesterly from the Citrus County Potentiometric High, northwest of Dunnellon, to the Gulf of Mexico (Figure 8). In the reservoir vicinity, the limestone is highly solutioned and faulted yielding high flow-rate characteristics in the Upper Floridan aquifer. A steady-state ground-water flow model of the area, developed by the District (Adams, 1985), verifies that the aquifer transmissivities (aquifer flow capability) are quite high, varying between 0.22 and 11.9 million gallons per day per foot of aquifer thickness. Transmissivity values appear to increase downgradient from the potentiometric highs.

Although the Floridan aquifer is generally a confined aquifer system, a majority of the area west of Dunnellon is considered to be unconfined. This is supported by the fact that, in this area, little or no confining sediments are found above the highly productive Ocala and Avon Park Limestones. Also, a USGS hydrologic study of the Lake Rousseau (German, 1978) indicated that 7.4% of the average daily surface inflow to Lake Rousseau leaves the reservoir as ground-water recharge. This translates into 109 cfs or 70-million gallons per day (MGD) that is recharging the Upper Floridan aquifer, further evidence of the unconfined nature of

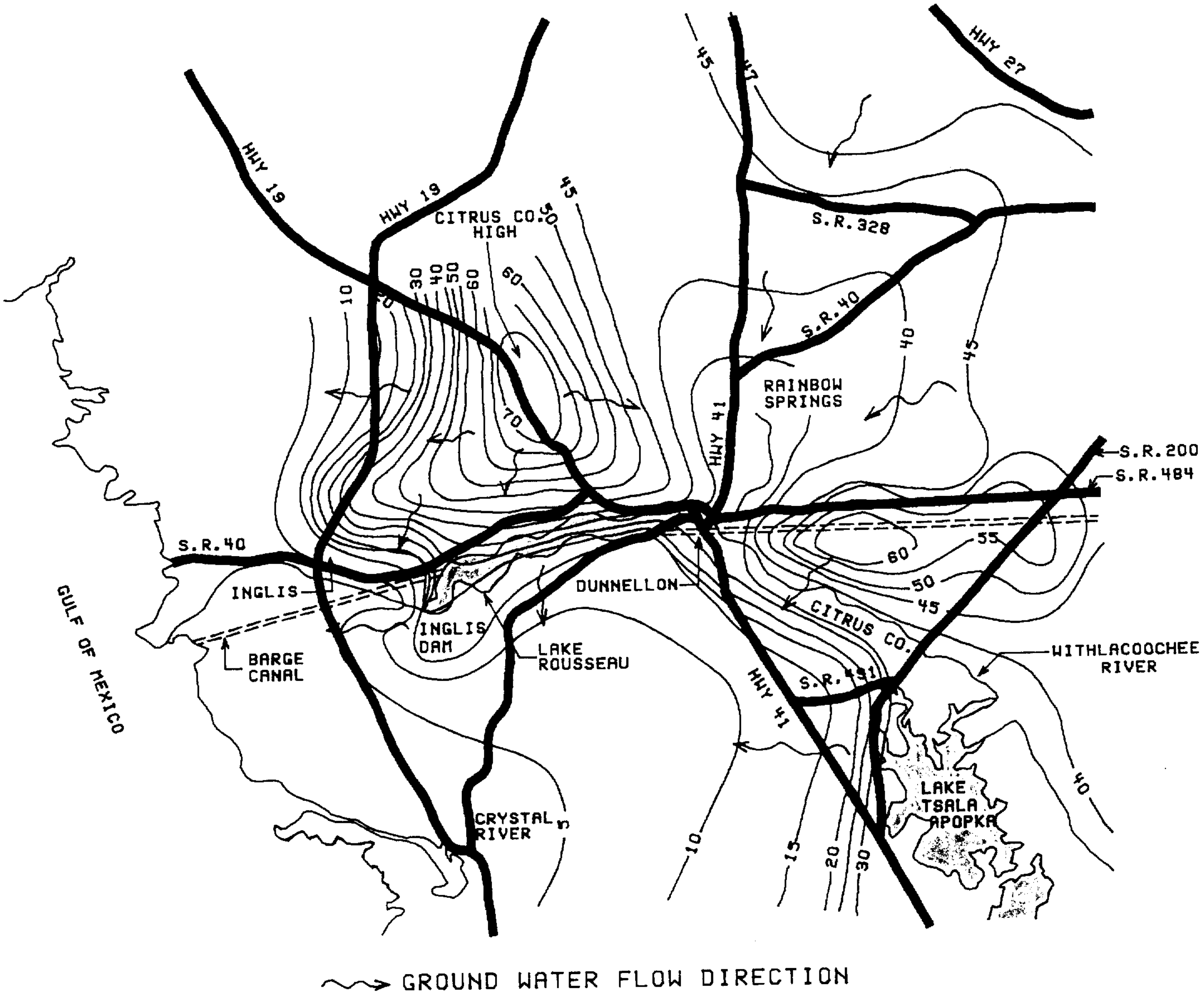


FIGURE 8 POTENTIOMETRIC SURFACE OF UPPER PART OF FLORIDAN AQUIFER IN SEPTEMBER 1968 (HIGH WATER PERIOD), CROSS-FLORIDA BARGE CANAL AREA.

the area, and the importance of the ground-water-surface-water relationships in water budget analyses.

Salt Water - Fresh Water Interface

A 1983 report, by the Water Resources Research Center of the University of Florida, on evaluation of an electromatic method (EM) for detection and monitoring of the salt-water-fresh-water interface in the Gulf Coast area of Pasco, Hernando, Citrus, and Levy Counties discussed a major interface reentrant just south of the CFBC and Lake Rousseau (Figure 9). The figure is based upon an interpretation of the EM sounding data. It is pointed out however, that the exact location of the reentrant is uncertain because of low data density in the area. No geophysical or geochemical data were available to confirm the location of the reentrant. However, two other reentrants discussed in the same study, one in the vicinity of Crystal River and the other near Homosassa Springs, also defined by EM methods, were confirmed by other investigators based on geochemical and geophysical data. Thus, some credibility can be attributed to the results of the EM survey in the CFBC-Lake Rousseau area. Authors of the study point out that both the CFBC and Lake Rousseau would influence the position of the interface in the area, but if the reentrant is south of the CFBC, some additional influence must also be a control. One possibility mentioned for that additional influence is conduit flow in the aquifer which may allow the infiltration

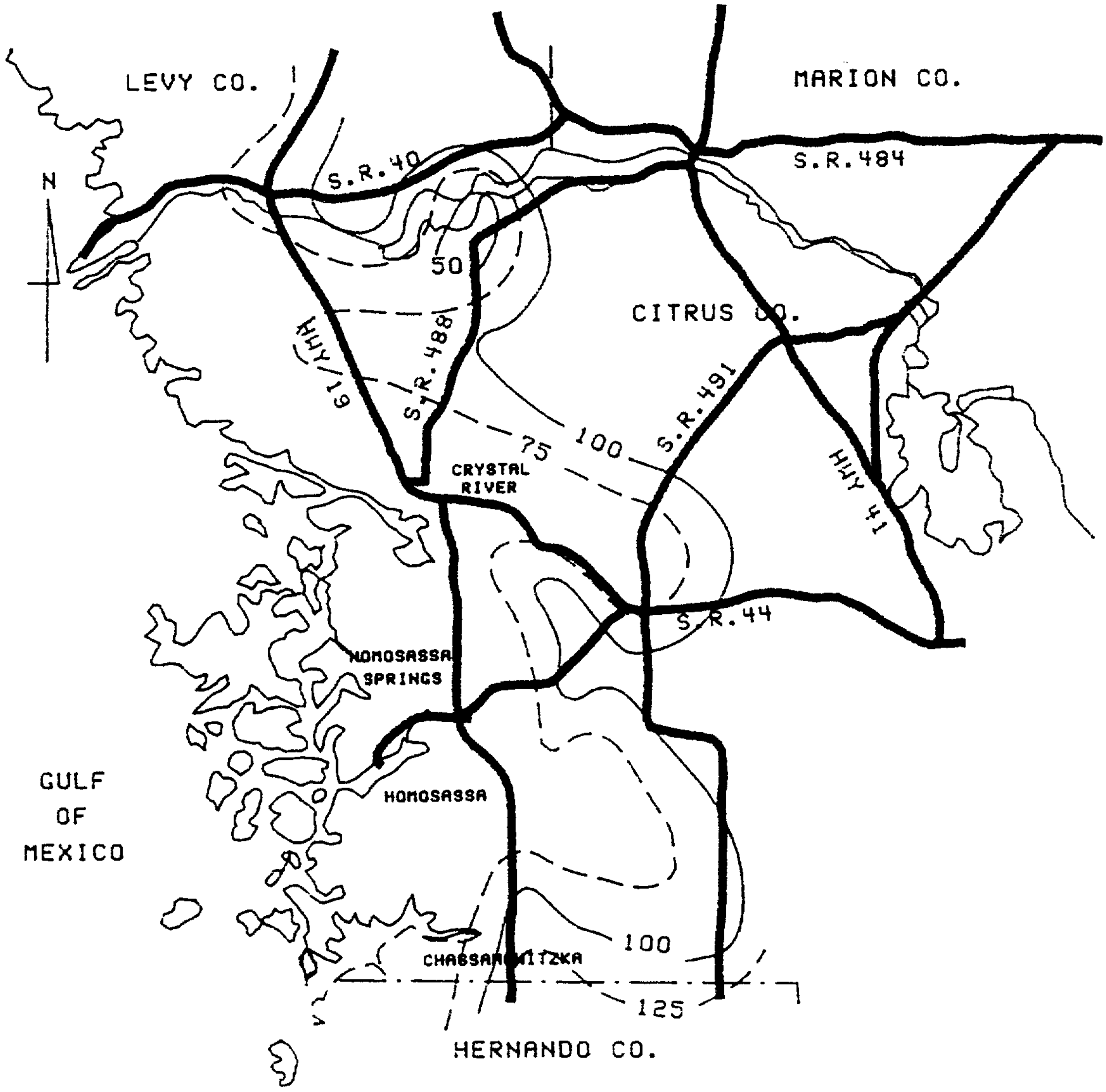


FIGURE 9 DEPTH TO THE SALT-WATER-FRESH-WATER INTERFACE RELATIVE TO NGVD; AFTER REPORT BY WATER RESOURCES RESEARCH CENTER, 1983.

of salt water. The report points out that further research is needed to better define and locate the reentrant in the area. In discussion of the reentrant in the Homosassa Springs area, the authors mentioned conduit flow within the karstic limestone aquifer as a factor controlling that reentrant.

In a 1973 USGS report on ground-water conditions in the lower Withlacoochee River - CFBC area the author points out that the potentiometric surface of the Floridan aquifer, in the area west of the Inglis Lock and adjacent to the lower Withlacoochee River and the CFBC, slopes toward the river and the canal (Figure 10). When tides in the Gulf are low, ground water discharges to the river and the canal, but when tides are high ground-water inflow to the river is retarded or halted, and the direction of ground-water flow may even reverse. Thus, there is a potential for salt water to temporarily intrude the aquifer immediately adjacent to the canal.

The author further points out, that the only apparently significant effect of the canal on ground-water quality in the river-canal complex area is a tendency for the fresh-water-salt-water zone of diffusion (that zone within which the interface lies) in the aquifer to rise in the area where ground-water levels have been lowered as a result of the presence of the canal. This theoretical before/after canal construction interface relation is illustrated in Figure 11.

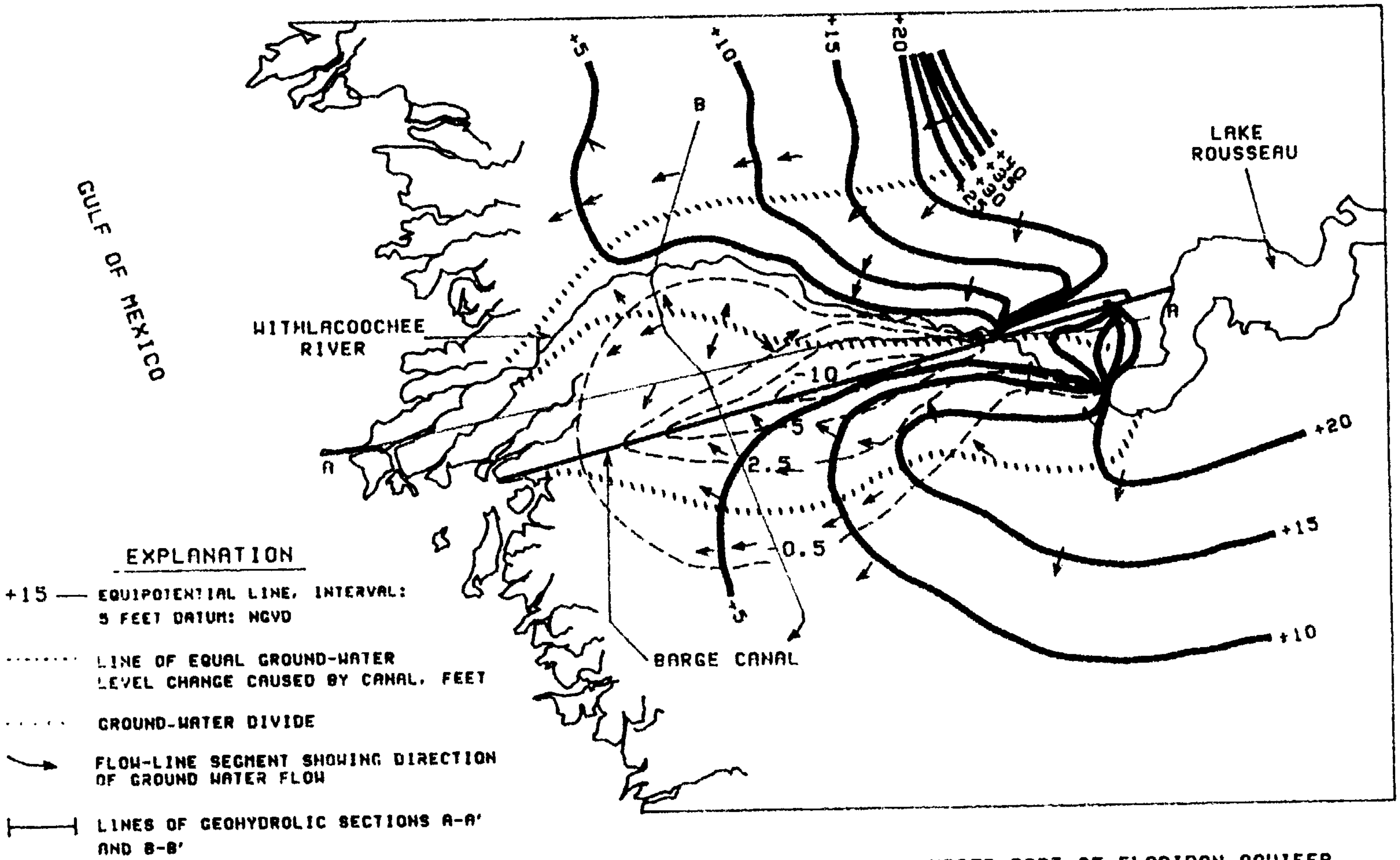


FIGURE 10 POTENTIOMETRIC-SURFACE MAP, UPPER PART OF FLORIDAN AQUIFER, AUGUST 18, 1971 (A HIGH-WATER CONDITION); AFTER FALKNER, 1973.

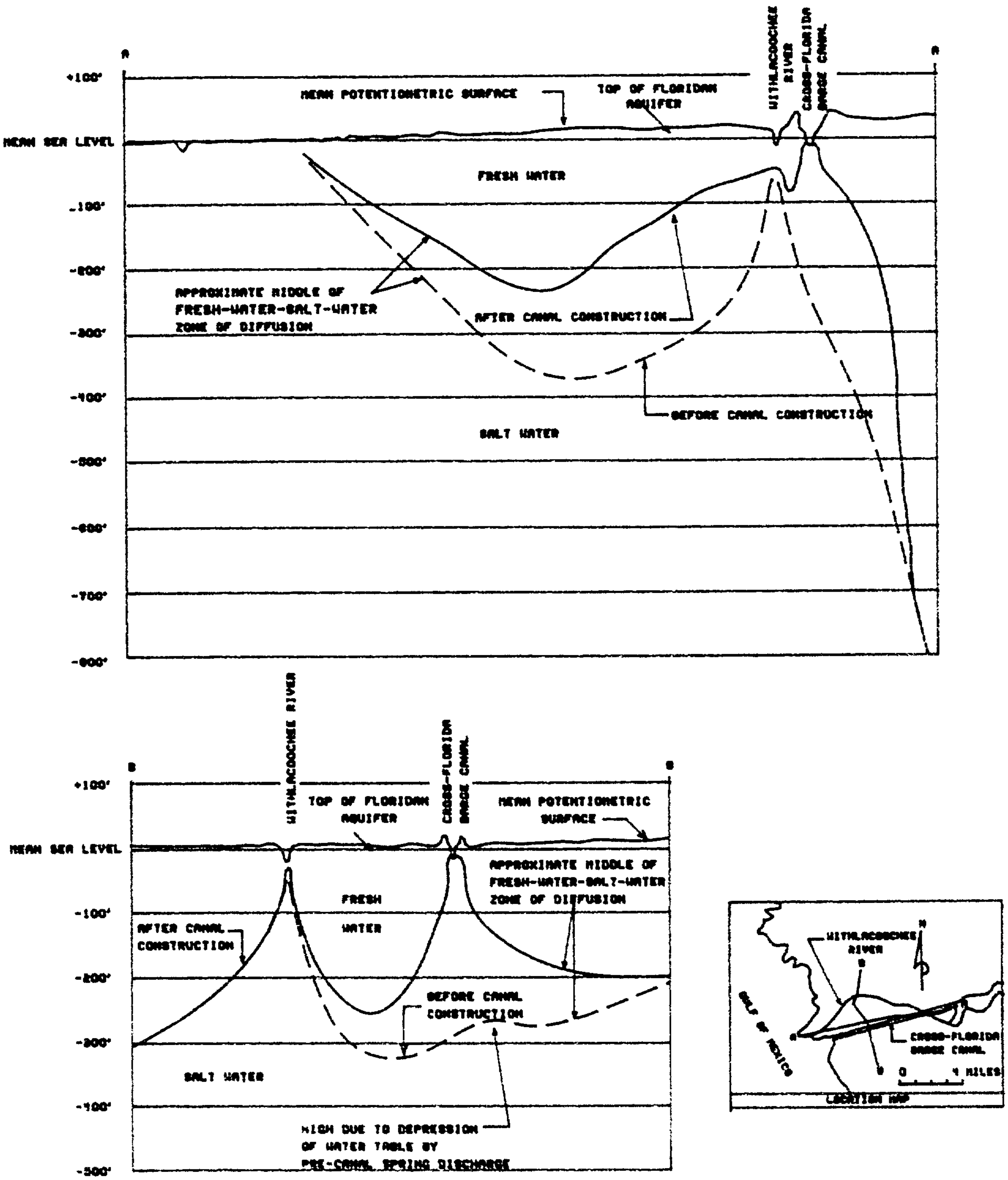


FIGURE 11 GEOHYDROLOGIC SECTIONS A-A' AND B-B', ILLUSTRATING, BY AN APPLICATION OF THE GHYBEN-HERZBERG PRINCIPLE. THE THEORETICAL EFFECT OF THE CROSS-FLORIDA BARGE CANAL ON THE POSITION OF THE FRESH-WATER-SALT-WATER ZONE OF DIFFUSION; AFTER FALKNER 1973.

Reentrants in the potentiometric surface in the CFBC, Lake Rousseau area as documented in this 1973 study confirm the EM data in the previously discussed study by the Water Resource Research Center. It is further pointed out in the 1973 study that the lower Withlacoochee river downstream of the bypass channel influences the location and shape of the potentiometric surface because the river channel is incised into the top of the Floridan aquifer and as such acts as a hydrologic boundary. Thus, the river modifies the effect from the canal north of the canal, and causes a greater effect south of the canal. The EM data seemed to indicate that the reentrant in the interface might be located slightly south of the CFBC and that some other influence on its shape and location might be the reason, other than the canal and Lake Rousseau. The river channel appears to be that other influence. Further discussion on the fresh-water-salt-water interface will be presented in the section entitled, "Ground Water Response To A Drawdown".

The 1973 study indicates that the canal intercepts ground-water flow from about a six-square mile area of the 29-square mile ground-water basin that contributed inflow to the Withlacoochee River downstream of Inglis Dam before canal construction. This is equivalent to about 20% reduction in ground-water flow contribution to the lower reach of the river which equals an estimated 5 cfs reduction in flow. However, the author points out that a

20% reduction in ground-water flow contribution represents only 0.5% reduction in the average fresh-water releases to this reach of river during 1971 (water year) had the canal not been constructed. This is a rather insignificant reduction.

AQUATIC PLANTS

PLANT ABUNDANCE AND DISTRIBUTION

Lake Rousseau supports a great quantity and diversity of aquatic plants, including several exotic species. During most years aquatic plant populations in the reservoir grow to dense levels, hindering recreation, increasing organic sediment deposition rates, and altering sportfish habitat. The abundance (coverage) of aquatic macrophytes in the reservoir is regularly monitored by the Florida Department of Natural Resources (FDNR). Their most recent complete survey of the reservoir in 1986 quantified the coverage of 43 aquatic macrophyte species (Table 4).

The most abundant macrophyte in the reservoir during the 1986 survey was hydrilla (*Hydrilla verticillata* Royle). Hydrilla is an exotic weed which has been found in Florida since the early 1960's (Haller, 1976). Since its introduction, hydrilla has rapidly spread throughout the state and created serious problems in many fresh-water bodies by outcompeting native vegetation and forming dense, mono-specific stands. The rooted hydrilla plants often grow all the way to the water surface creating a "topped out" condition which impedes boating, alters fish habitat, and impacts water quality. In many areas of Lake Rousseau hydrilla reaches topped out conditions during the summer and early fall.

Table 4. Coverages of Commonly Occurring Aquatic Plants in Lake Rousseau During 1986 Survey (FDNR, 1986)

Common name	Species name	Acreage
Alligator weed	**Alteranthera philoxeroides**	45
Water Fern	**Azolla caroliniana**	2
Bacopa	**Bacopa caroliniana**	2
	Bidens spp.	11
	Brachiaria purpurascens	4
Coontail	**Ceratophyllum demersum**	180
Chara	**Chara sp.**	5
	Cicuta mexicana	5
	Colocasia esculenta	400
	Cyperus elegans	40
	Cyperus sp.	10
	Egeria densa	0.1
Water hyacinths	**Eichhornia crassipes**	50
Filamentous algae		800
Hydrilla	**Hydrilla verticillata**	1400
Pennywort	**Hydrocotyle spp.**	65
Duckweed	**Lemna spp.**	10
	Limnobium spongia	45
	Ludwigia peruviana	4
	Ludwigia repens	0.1
	Myriophyllum aquaticum	3
	Myriophyllum laxum	3
	Myriophyllum pinnatum	4
Southern Niad	**Najas quadalupensis**	15
Nitella	**Nitella sp.**	20
Spatterdock	**Nuphar luteum**	10
Maidencane	**Panicum hematomon**	60
	Paspalidium geminatum	18
Water paspalum	**Paspalum fluitans**	5
Water lettuce	**Pistia stratiotes**	250
Smartweed	**Polygonium spp.**	640
Pickeralweed	**Pontederia lanceolata**	40
Illinois pondweed	**Potomogeton illinoensis**	40
	Sacciolepsis striata	60
Arrowhead	**Sagittaria kurziana**	20
Arrowhead	**Sagittaria lancifolia**	4
Arrowhead	**Sagittaria latifolia**	1
Willow	**Salix spp.**	5
Salvinia	**Salvinia rotundifolia**	8
Cattails	**Typha spp.**	110
Bladderwort	**Utricularia foliosa**	10
Tape grass	**Vallisneria americana**	200
	Zizania aquatica	0.1

The 1986 FDNR survey found hydrilla covered 1,400 of Lake Rousseau's 4,000 total acres, while a 1987 survey of major weed species found hydrilla covered 1,600 acres (FDNR, 1987). In 1982 and 1983, FDNR surveys found hydrilla to be somewhat more abundant with coverages reported between 2,400 and 2,600 acres. In 1978, a survey of the reservoir by the Florida Game and Fresh Water Fish Commission indicated that hydrilla was found in approximately 90% of the reservoir. The lower hydrilla coverages reported for the 1986 and 1987 surveys were due to chemical weed control efforts during that period.

Also found in the reservoir are large floating masses of mixed vegetation called tussocks. Many of these tussocks have become very large and form island-like assemblages in the reservoir. Apparently, the total acreage of tussocks has increased significantly in recent years. Tussocks can form in various ways. Rafts of floating vegetation form which trap enough organic matter so that rooted emergent plants can take hold in the mat. The abundant stumps in Lake Rousseau have greatly increased the rate of tussock formation by creating obstructions which tie up the mats of vegetation.

In addition to the stumps, the great amount of aquatic vegetation found in Lake Rousseau is closely related to the reservoir's physical and chemical characteristics. The reservoirs shallow morphometry allows rooted aquatic plants to colonize large amounts of the reservoir's area. This is particularly a problem with hydrilla, which can grow at low light intensities and thus become established in relatively deep waters. Recent observations in the reservoir indicate that hydrilla is established in some areas of nine feet of depth or greater. Secondly, the inflowing waters of the Withlacoochee River are nutrient-rich and provide an inexhaustible nutrient supply for those plants which utilize or rely on water-borne nutrients. In addition to containing moderately high levels of dissolved nitrogen and phosphorus compounds, the river waters are well-buffered with high levels of hardness and alkalinity, thus creating an ideal growth medium for aquatic plants. Rooted aquatic plants also directly utilize sediments as a primary nutrient source. The bottom sediments in Lake Rousseau are largely comprised of highly organic sediments overlying the old forest floor. These sediments comprise a rich nutrient pool which is directly available to rooted aquatic plants. Also, as described in the Water Quality section of this report, these sediments may exchange nutrients with the overlying water.

PREVIOUS SWFWMD AQUATIC PLANT CONTROL

The SWFWMD assumed responsibility for aquatic plant management on Lake Rousseau in October 1977, under a contractual agreement with the FDNR. Management activities were funded 100% by the USACOE through the Removal of Aquatic Growth (RAG) program, and overseen by the FDNR Bureau of Aquatic Plant Management. This arrangement continued until August 1987, when the USACOE assumed aquatic plant management responsibilities for the reservoir.

During the District's ten year term of management various methods of aquatic plant control were utilized. One of the District's spray crews (consisting of two men, both certified pesticide applicators, an air boat, and a 1/2 ton pick-up truck) was permanently assigned to Lake Rousseau to control water hyacinths (Eicchornia crassipes), water lettuce (Pistia stratioties), and various minor plants through the use of herbicides approved by the U.S. Environmental Protection Agency and the FDNR. Mechanical methods of plant control such as harvesting and mechanical clearing (cookie-cutter) have been used extensively on the reservoir.

From October 1, 1986, through June 20, 1987, the District controlled 615 acres of water hyacinths and water lettuce at a total cost of $36,500. Approximately 185 acres of minor plants, mainly smartweed (Polygonium spp.), pennywort (Hydrocotyle umbellata), and mixed grasses were treated at a cost of $20,000. The primary control technique was herbicide application by airboat. During this same period 425 acres of hydrilla were treated at a cost of $193,000. Of this hydrilla acreage, 240 acres were treated in December with the herbicide SONAR. This treatment has proven to be successful, especially regarding the initial control. A large percentage of the hydrilla in the main body of the reservoir (from the Smith's pasture area on downstream to Inglis Lock and Dam) was cleared. Eight months after-treatment, little regrowth was evident in the application sites. Approximately eleven months after-treatment, however, hydrilla regrowth was evident and biomass was nearing pre-treatment levels in all plots. Those areas nearest the Inglis Dam showed the least regrowth.

CURRENT USACOE AQUATIC PLANT CONTROL

In September 1987, the USACOE assumed full direct supervision of the aquatic plant management program for the reservoir and established a full time ranger position for the Lake Rousseau Management Area. This ranger position gives the USACOE a higher presence on the reservoir in order to more closely monitor biological conditions and be immediately responsive to the public's concerns.

The USACOE has published an Aquatic Plant Management Plan for the reservoir that identifies both current (1988) and long term goals for the reservoir (Appendix C). The USACOE long term aquatic plant management goals for the reservoir are:

1. Maintain non-native, problem plants at the lowest level possible with available funds. Problem plants include water hyacinths, water lettuce and hydrilla.

2. Reduce acreage covered by tussocks to less than 30 percent of present acreage and break up large mats into smaller mats for increased edge habitat and better access.

3. Encourage native aquatic plants to re-establish their dominance along shorelines and other areas.

4. Increase water movement and reduction of sediment build-up.

5. Monitoring of water quality and nutrient inputs to the lake.

6. Maintenance of open, safe, properly marked navigation channels.

The more immediate goals of the aquatic plant management plan are listed in Appendix C. Efforts during 1988 are to control hydrilla and other exotic weeds, reduce the size of the tussocks by 10% to 20%, and mark the main river channel through the reservoir. It is expected that aquatic plant control in the next year will be done exclusively with chemical control methods, including the herbicides SONAR for hydrilla control and RODEO for control of the tussocks.

SEDIMENTS

As previously mentioned, one of the goals of the Lake Management and Planning Task Force was the consolidation of bottom sediments, which would be an expected benefit from an extreme drawdown of the reservoir. It is also suggested here that there is the possibility of removal of sediments from selected areas if a drawdown is accomplished. Selected sediment removal during a drawdown on Lake Tohopekaliga has been accomplished by the FG&FWFC.

To better assess problems with flocculent organic sediments in Lake Rousseau, sediments were sampled in the reservoir as part of this study. These results are compared to surveys of Lake Rousseau's sediments performed by the FG&FWFC in 1977 and 1978. For this study, sediment cores were taken at points on selected transects in Lake Rousseau during October 1987 utilizing graduated clear plexiglass tubes 1-1/2 inches in diameter (Figure 12). The tubes were pushed vertically through the sediments as far as possible. Most samples penetrated the total sediment column to encounter the natural sand beneath the litter of the riverine forest which existed prior to inundation of the reservoir. A movable rubber piston actuated by a cord was used to seal and create a vacuum in the tubes as they were pushed into the sediments. A rubber plunger was used to immediately seal the bottom of the tube underwater when it was extracted from the

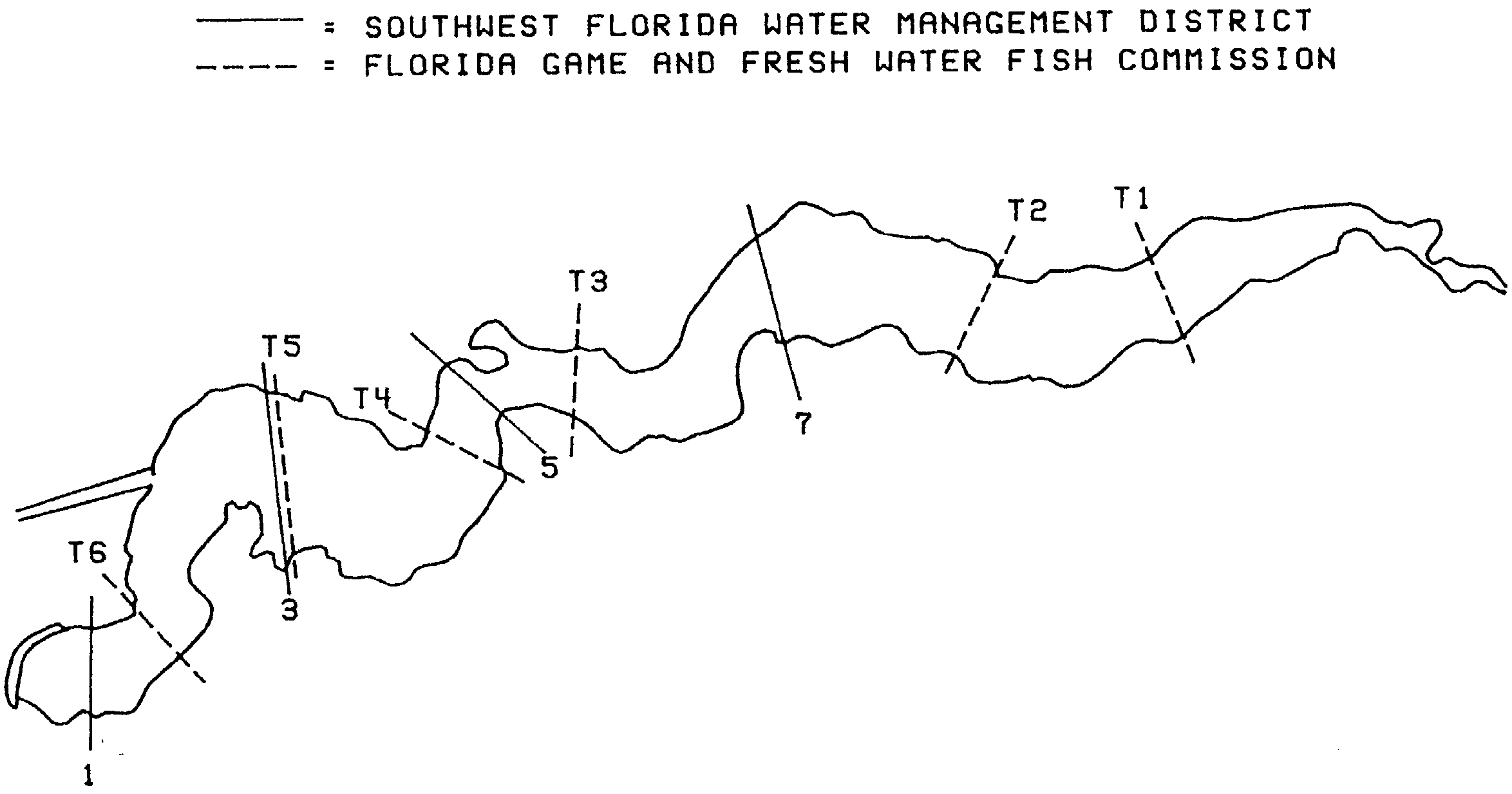


FIGURE 12 LOCATIONS OF SEDIMENT SAMPLE CROSS SECTIONS AND TRANSECTS.

sediments. Various sediment intervals were measured by visual inspection through the clear tubes. Sediments were then pushed out of the tubes with a plunger and samples were taken for laboratory analysis. Pushing was done from the bottom of the tubes, wasting-off water and flocculent material from the sediment column at the top of the tubes. Wasting continued until consistent material was encountered. The laboratory samples were taken from top to bottom of the sediment column as apparent consistency, color, etc., changed. The depths of the samples from the sediment surface were recorded and the samples were placed in plastic bags, sealed and labeled for analysis. In the laboratory, percent water was measured by weight loss after drying at $100^{\circ}C$ and percent organic matter was measured as percent dry weight loss after ignition at $500^{\circ}C$.

The plan for sediment sampling was to take cores at water depths of three, six, and nine feet at each transect on both sides of the main channel. However, this proved almost impossible to accomplish because of the extensive aquatic plants, stumps, and the very gradual bottom slope prior to reaching the main channel area. Near the main channel the bottom slope became very steep and it was practically impossible to anchor the boat stationary in nine feet of water, even with only a slight wind. Thus, of the eighteen total cores taken, fourteen were taken in water depths of six feet or less and four other cores were taken in 6.5, 7, 8 and 9 feet of water. A list of all sediment cores taken along with corresponding water depths, total sediment depths, and field observations are presented in Appendix D. Also listed are the sediment intervals which were sampled for percent water and organic matter determinations.

The total depth of sediments for the eighteen cores ranged from 2 to 39 inches with an average value of 20 inches. At the bottom of these sediments was found either woody material, blue-gray clay, or sand, all of which represent the original forest floor. Virtually all the overlying sediments appeared to be organic mucks with some cores containing hyacinth or other aquatic macrophyte remains. One core, 5C, had a sand-clay lense found between layers of organic sediments.

Percent water and organic matter determinations were performed on a total of thirty-three samples from thirteen cores. As many as four samples were taken from a single core. These determinations confirmed that nearly all the sediments were organic mucks with very high water content. Percent water was above 89% for 29 of the 33 samples, with the lower values found near the bottoms of three sediment cores and the sand/clay lense in core 5C. Excluding these four samples, percent water content averaged 94%, and was high for both near-surface and deeper sediments. For two of the longest cores, 5D and 7B, percent water content was greater than 93% near two and three feet below the sediment surface, respectively. The sediments which had high water content were also rich in organic matter. For the twenty-nine samples with high water content, percent organic matter ranged from 26% to 70% of dry weight, and averaged 59%. For the four bottom or sand/clay lense samples, organic matter ranged from 6.5% to 13.0% of dry weight.

The FG&FWFC conducted surveys of the sediments in Lake Rousseau during 1977 and 1978 (FG&FWFC, 1978). Sediments were examined from six transects, four which were in the same area as the 1987 District sampling and two which were upstream (Figure 12). The sampling at each transect averaged 14 observations during 1977 and nine observations during 1978. The FG&FWFC study did not include any laboratory analyses, but sediments were visually characterized into two classes: suspended flocculent/detritus and mud. The total depth of these two classes was expressed as the total sediment depth above a firm substrate. The FG&FWFC reported there was considerable variability of total sediment depth between transects and within the same transect. For the 1977 sampling, average total sediment depths for the six transects ranged from 8.3 to 43.3 inches. For the 1978 sampling, average total sediment depths ranged from 6.1 to 25.2 inches. The average depth of sediments for the two years was 16 inches, which is similar to the 20 inch average found for the 1987 District sampling.

For each of the twelve transects sampled during the two years, the FG&FWFC reported separate mean depths for the suspended flocculent/detritus sediments and the mud. For the two years, the suspended flocculent/detritus fraction averaged 65 percent of the total sediment depth. District core samples, however, indicate that deeper sediments contain almost as much water and organic matter as the shallower sediments, indicating the organic sediments found in Lake Rousseau are fairly homogeneous from top to bottom. Based on the District and FG&FWFC studies, the organic sediments in the reservoir are fairly uniform in composition but are variable in depth. Although average sediment depths for the two studies were 16 and 20 inches, sediment depths at different sites ranged from only a few inches to over four feet. Possibly, deeper sediment deposits might be found in some isolated areas. It is worth noting that although sediments in the reservoir are not extremely deep at this time, the sedimentation rate in the reservoir is high. Since the reservoir was impounded in 1909, sedimentation rates in many parts of the reservoir have averaged at least one-quarter inch per year. The high sedimentation in Lake Rousseau is indicative of the rapid rate the reservoir is aging and progressing to a more marsh-like system.

WATER QUALITY

INTRODUCTION

In this section the water quality characteristics of Lake Rousseau are examined with regard to the ecological health of the reservoir. Existing water quality data for the reservoir are reviewed and compared to data collected during 1987 as part of this study. Averages and ranges of values for various water quality parameters are listed and compared to data from other fresh-water bodies throughout the state to assess the relative conditions in Lake Rousseau. Other characteristics of the reservoir which can affect water quality such as basin morphometry, residence time, aquatic plants and sediments are discussed in that context. Finally, management strategies for water quality improvements in Lake Rousseau are assessed.

Station Locations and Methods

Four water quality stations located in the Withlacoochee River and Lake Rousseau were sampled for this study (Figure 13). As discussed below, two of these stations also have other available data. The locations of the four stations are as follows:

Station 1 is located one-half mile upstream of the confluence of Blue Run and the Withlacoochee River. This

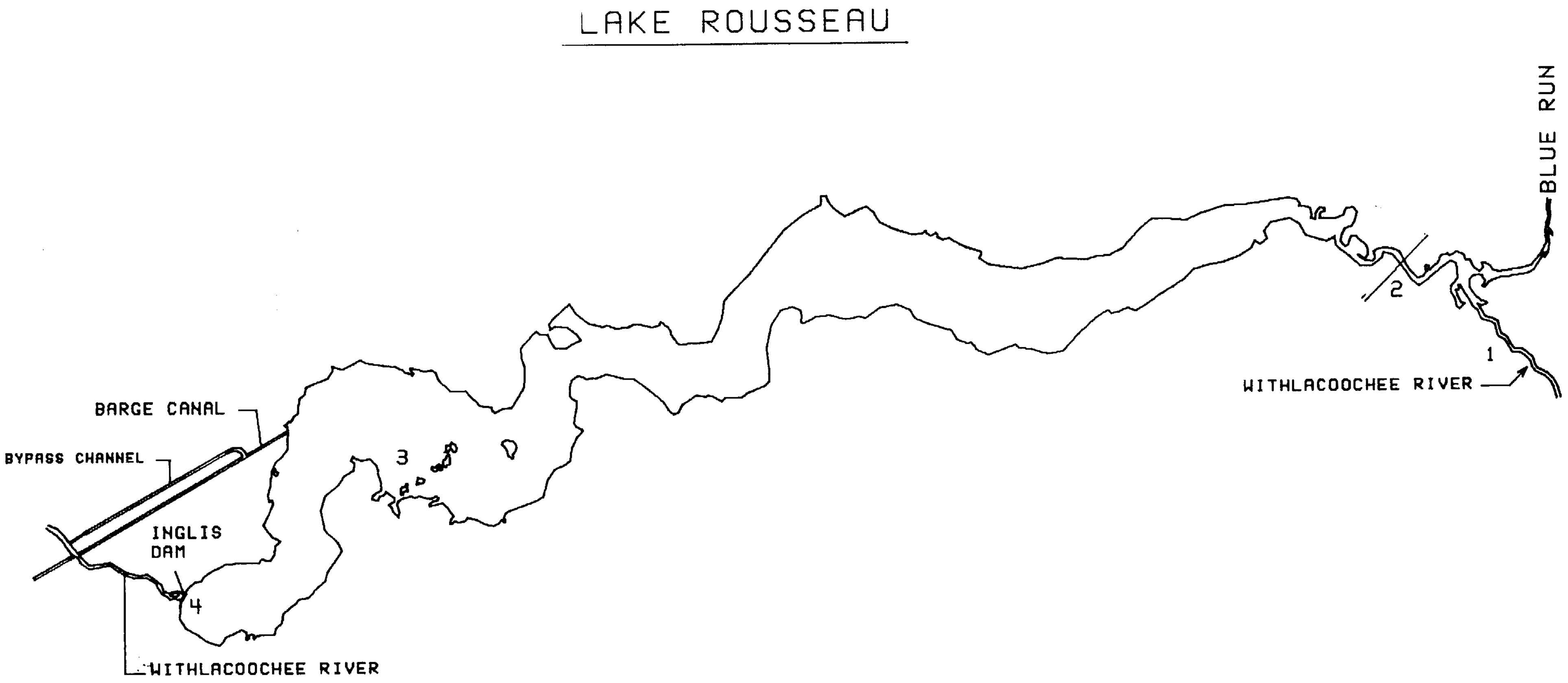


FIGURE 13 WATER QUALITY SAMPLING STATIONS
JUNE - AUGUST, 1987.

site was chosen since minimal influence on water quality from Blue Run inflow was expected.

Station 2 is located just upstream of the Highway 41 bridge at the City of Dunnellon, approximately one-half mile below the confluence of the Withlacoochee River and Blue Run.

Station 3 is within Lake Rousseau about two miles upstream of the Inglis Dam on the south side of the reservoir, 75 yards from the shore. This area was infested with aquatic macrophytes, primarily hydrilla and water hyacinths.

Station 4 is just above the Inglis Dam about 100 yards from the south shore and is located within the old river channel.

Surface water samples for water chemistry analyses were collected at these stations on June 8, July 14, and August 10, 1987. The results of these analyses plus mean values for each station are presented in Tables 5, 6, 7 and 8. Tests were performed for color, total hardness, ammonia, organic nitrogen, nitrate/nitrite, orthophosphorus, total phosphorus, inorganic carbon, organic carbon, alkalinity, chloride, sulfate, fluoride, calcium, copper, iron, lead, magnesium, potassium, sodium, zinc, suspended solids, dissolved solids, total and fecal coliform, bacteria, chlorophyll a and pheophyton a. Analyses were conducted by the SWFWMD laboratory according to Standard Methods (APHA, 1985).

Table 5. Surface-Water Quality Data for Station 1, Withlacoochee River. June-August 1987

Parameter*	June 8	July 14	August 10	Mean
Temperature (°C)	27.0	30.5	31.5	29.7
Dissolved Oxygen	3.8	4.6	4.9	4.5
Specific Conductance (umhos/cm)	253	265	280	266
pH (SU)	7.40	7.25	7.45	7.37
Color (PCU)	150	150	30	110
Total Hardness mg/l $CaCO_3$	130	156	133	140
Ammonia Nitrogen	0.03	<0.03	0.03	0.03
Organic Nitrogen	0.55	0.57	0.56	0.56
Nitrate/Nitrite	0.20	0.09	0.12	0.14
Total Nitrogen	0.78	0.69	0.71	0.73
Ortho Phosphorus	0.043	0.029	0.010	0.027
Total Phosphorus	0.089	0.040	0.060	0.063
Inorganic Carbon	27.3	36.0	35.8	33.0
Organic Carbon	16.2	10.5	6.9	11.2
Total Alkalinity mg/l $CaCO_3$	104	110	116	110
Chloride	7.0	4.0	8.0	6.3
Sulfate	10.0	13.0	14.0	12.3
Fluoride	0.10	---	0.16	0.13
Calcium	45.8	55.0	46.0	48.9
Copper	<0.02	<0.02	<0.02	<0.02
Iron	0.47	0.20	0.10	0.26
Lead	<0.05	<0.05	<0.05	<0.05
Magnesium	3.8	4.5	4.4	4.2
Potassium	0.5	0.6	0.4	0.5
Sodium	5.2	3.9	3.5	4.2
Zinc	<0.01	<0.01	<0.01	<0.01
Suspended Solids	1.44	0.17	---	0.81
Total Dissolved Solids	152	156	175	161
Turbidity (NTU)	2.3	0.8	0.9	1.3
Secchi (meters)	1.1	3.0	3.6	2.6
Total Coliform #/100ml	820	190	387	466
Fecal Coliform #/100ml	4	28	---	16
Chlorophyll <u>a</u> (mg/m^3)	0.5	1.3	1.1	1.0
Pheophyton <u>a</u> (mg/m^3)	1.5	1.0	3.5	2.0

---

* All parameters expressed in mg/l unless noted.

--- Data not available.

Table 6. Surface-Water Quality Data for Station 2, Withlacoochee River. June-August 1987

Parameter*	June 8	July 14	August 10	Mean
Temperature (^{o}C)	25.4	28.2	27.9	27.2
Dissolved Oxygen	4.5	5.2	5.3	5.0
Specific Conductance (umhos/cm)	241	245	257	248
pH (SU)	7.65	7.40	7.45	7.50
Color (PCU)	100	125	10	78
Total Hardness mg/l $CaCO_3$	122	138	119	126
Ammonia Nitrogen	0.03	0.03	0.03	0.03
Organic Nitrogen	0.31	0.36	0.57	0.39
Nitrate/Nitrite	0.40	0.31	0.39	0.37
Total Nitrogen	0.74	0.70	0.99	0.79
Ortho Phosphorus	0.048	0.034	0.010	0.031
Total Phosphorus	0.076	---	0.040	0.057
Inorganic Carbon	25.8	27.7	30.2	27.9
Organic Carbon	9.8	5.8	5.9	7.2
Total Alkalinity mg/l $CaCO_3$	103	106	106	105
Chloride	5.0	5.0	6.0	5.3
Sulfate	8.0	11.0	11.0	10.0
Fluoride	0.11	---	0.18	0.15
Calcium	42.3	47.0	40.0	43.1
Copper	<0.02	<0.02	<0.02	<0.02
Iron	0.27	0.10	0.10	1.57
Lead	<0.05	<0.05	<0.05	<0.05
Magnesium	4.0	4.9	4.6	4.5
Potassium	0.3	0.5	0.4	0.4
Sodium	4.3	3.9	3.5	3.9
Zinc	<0.01	<0.01	<0.01	<0.01
Suspended Solids	0.36	1.53	---	0.95
Total Dissolved Solids	135	140	147	141
Turbidity (NTU)	1.0	0.7	0.8	0.8
Secchi (meters)	1.6	5.0	6.5	4.4
Total Coliform #/100ml	1000	850	265	705
Fecal Coliform #/100ml	7	26	---	11
Chlorophyll a (mg/m^3)	1.1	1.3	1.6	1.3
Pheophyton a (mg/m^3)	1.8	1.2	1.5	1.5

---

* All parameters expressed in mg/l unless noted.

--- Data not available.

Table 7. Surface Water Quality Data for Station 3, Lake Rousseau. June-August 1987

Parameter*	June 8	July 14	August 10	Mean
Temperature (°C)	27.4	31.0	32.0	30.1
Dissolved Oxygen	6.2	5.2	7.0	6.1
Specific Conductance (umhos/cm)	236	245	237	239
pH (SU)	7.35	7.15	7.30	7.27
Color (PCU)	100	150	10	87
Total Hardness mg/l $CaCO_3$	119	129. 2	109	119
Ammonia Nitrogen	<0.03	0.03	<0.03	<0.03
Organic Nitrogen	0.60	0.35	---	0.48
Nitrate/Nitrite	0.01	<0.01	0.01	<0.01
Total Nitrogen	<0.64	<0.39	---	0.52
Ortho Phosphorus	0.022	<0.010	<0.010	<0.014
Total Phosphorus	0.067	0.020	0.040	0.042
Inorganic Carbon	25.5	29.1	32.5	29.0
Organic Carbon	11.9	6.7	5.2	7.9
Total Alkalinity mg/l $CaCO_3$	102	106	100	102.7
Chloride	6.0	5.0	6.0	5.7
Sulfate	7.0	10.0	9.0	8.7
Fluoride	0.11	---	0.17	0.14
Calcium	41.4	44.0	36.0	40.5
Copper	<0.02	<0.02	<0.02	<0.02
Iron	0.14	0.10	0.10	0.11
Lead	<0.05	<0.05	<0.05	<0.05
Magnesium	3.7	4.7	4.6	4.3
Potassium	0.3	0.5	0.4	0.4
Sodium	4.3	2.9	3.0	3.4
Zinc	<0.01	<0.01	<0.01	<0.01
Suspended Solids	2.89	2.39	---	2.64
Total Dissolved Solids	133	128	140	134
Turbidity (NTU)	1.3	1.1	0.9	1.1
Secchi (meters)	1.2	1.8	1.7	1.6
Total Coliform #/100ml	210	1	12	74
Fecal Coliform #/100ml	3	1	---	2
Chlorophyll _a_ (mg/m^3)	23.5	10.7	6.7	13.6
Pheophyton _a_ (mg/m^3)	11.3	3.0	4.0	6.1

---

* All parameters expressed in mg/l unless noted.

--- Data not available.

Table 8. Surface Water Quality Data for Station 4, Lake Rousseau. June-August 1987

Parameter*	June 8	July 14	August 10	Mean
Temperature (^{o}C)	28.1	30.0	31.9	30
Dissolved Oxygen	8.0	8.5	8.9	8.5
Specific Conductance (umhos/cm)	227	242	235	235
pH (SU)	7.85	7.75	8.25	7.95
Color (PCU)	125	150	5	93
Total Hardness mg/l $CaCO_3$	120	111	108	113
Ammonia Nitrogen	<0.03	<0.03	<0.03	<0.03
Organic Nitrogen	0.61	0.44	0.30	0.45
Nitrate/Nitrite	<0.01	<0.01	<0.01	<0.01
Total Nitrogen	<0.65	<0.48	<0.34	<0.49
Ortho Phosphorus	0.010	0.010	0.010	0.01
Total Phosphorus	0.032	0.020	0.020	0.024
Inorganic Carbon	25.0	27.4	30.6	27.7
Organic Carbon	1.6	6.7	5.0	4.4
Total Alkalinity mg/l $CaCO_3$	103	104	90	99
Chloride	5.0	6.0	6.0	5.7
Sulfate	7.0	8.0	8.0	7.7
Fluoride	0.11	---	0.16	0.14
Calcium	41.9	37.0	36.0	38.3
Copper	<0.02	<0.02	<0.02	<0.02
Iron	0.14	0.10	0.10	0.11
Lead	<0.05	<0.05	<0.05	<0.05
Magnesium	3.8	4.6	4.5	4.3
Potassium	0.3	0.5	0.4	0.3
Sodium	4.3	3.4	3.0	3.6
Zinc	<0.01	<0.01	<0.01	<0.01
Suspended Solids	3.73	2.85	---	3.29
Total Dissolved Solids	128	124	135	129
Turbidity (NTU)	2.0	1.7	1.1	1.6
Secchi (meters)	1.02	4.0	2.3	2.4
Total Coliform #/100ml	15	20	37	24
Fecal Coliform #/100ml	2	9	---	3.7
Chlorophyll a (mg/m^3)	19.9	18.5	4.4	14.3
Pheophyton a (mg/m^3)	9.5	5.3	4.4	6.4

---

* All parameters expressed in mg/l unless noted.

--- Data not available.

Field measurements were recorded for pH using an Orion Research digital meter (Model 201), for specific conductance using a Yellow Springs Instruments SCT meter (Model 33), and for temperature and dissolved oxygen using a Yellow Springs Instruments dissolved oxygen meter (Model 57). Water clarity was estimated using a Secchi disk attached to the end of a polyethylene rope marked in 0.1 meter increments.

In addition to the above surface water sampling dates, dissolved oxygen and temperature profiles were measured for Lake Rousseau on August 10, September 9, and October 15, 1987, at the sites shown in Figure 14.

Other Data Sources

Other water quality data for the study area were evaluated from four separate sources: (1) The USGS monitors surface water quality in the Withlacoochee River at station 2, but only a limited amount of data are available from 1980 through 1986 (Table 9); (2) The USACOE monitors surface water quality at station 4, with data available from 1982 through 1987 (Table 10); (3) The SWFWMD measured selected water quality parameters in surface and bottom waters while responsible for aquatic plant control on Lake Rousseau during 1983 through 1987 (Table 11); (4) Canfield (1981) collected data at three mid-reservoir

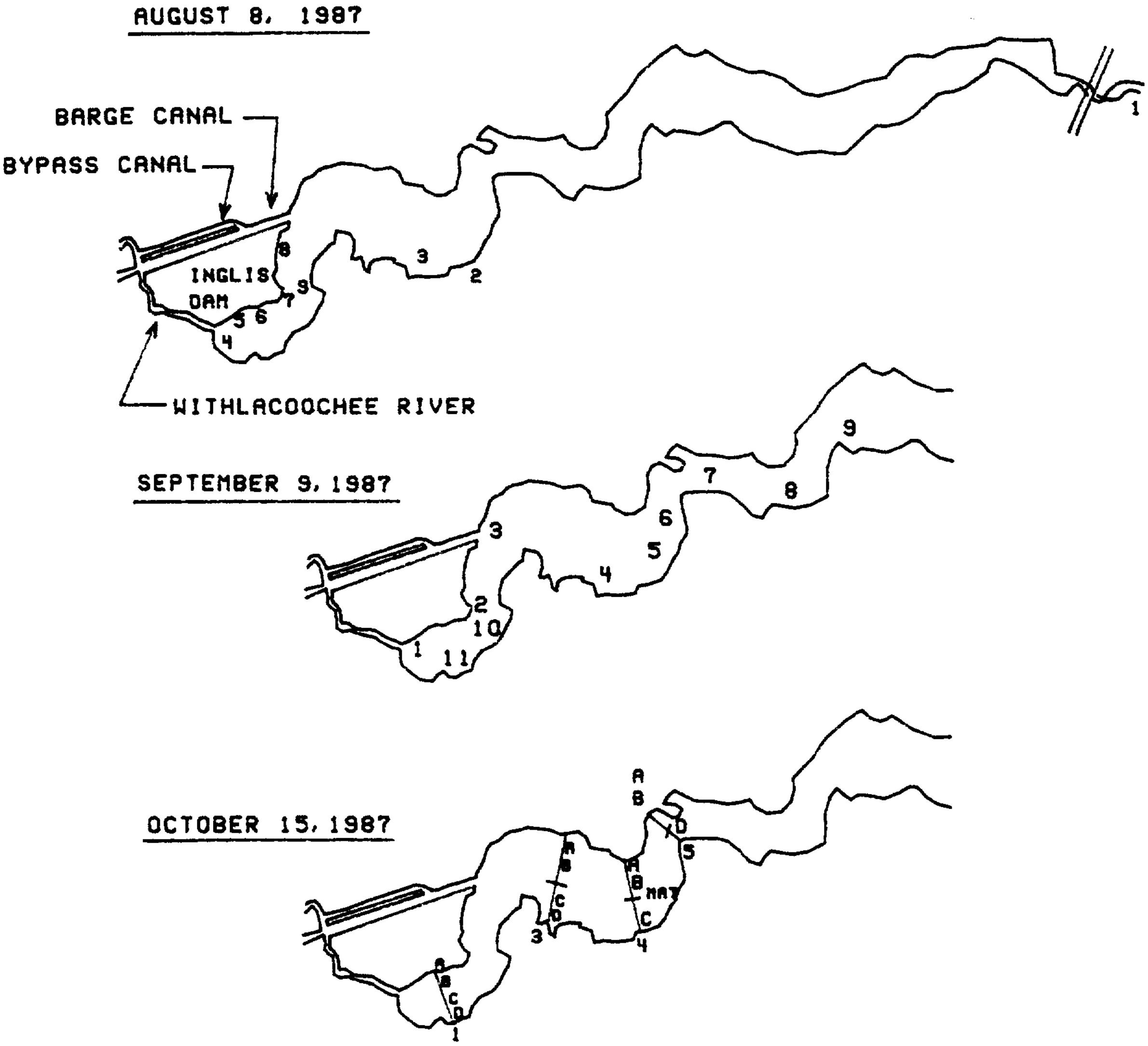


FIGURE 14 TEMPERATURE AND OXYGEN VERTICAL PROFILE LOCATIONS IN LAKE ROUSSEAU

TABLE 9: Surface Water Quality for the Withlacoochee River at Dunnellon, Florida

PARAMETER*	NO. OF OBSERVATIONS	MEAN	MAXIMUM	MINIMUM	PERIOD OF RECORD
Temperature (^{o}C)	37	22.5	27.0	16.5	80/01 - 86/05
Color (PCU)	2	2.5	5	0	81/04 - 84/04
Specific Conductance (umhos/cm)	37	249	319	119	80/01 - 86/05
Dissolved Oxygen	35	6.56	9.9	3.5	80/01 - 86/05
BOD	4	0.3	0.5	0.1	80/05 - 83/04
pH (SU)	35	7.35	8.5	6.1	80/03 - 86/05
Total Alkalinity mg/l $CaCo_3$	1	107			81/04
Total Ammonia (NH_3+NH_4-N)	2	0.01	0.02	0	83/04 - 83/08
Total Kjeldahl Nitrogen	2	0.05	0.09	0	83/04 - 83/08
Nitrate-Nitrite	2	0.19	0.38	0	83/04 - 83/08
Total Phosphorus	2	0.02	0.04	0	83/04 - 83/08
Ortho Phosphorus	2	0.02	0.04	0	83/04 - 83/08
Total Organic Carbon	12	8.49	22	0	80/05 - 85/05
Total Hardness mg/l $CaCO_3$	1	130.0			81/04
Calcium	2	31.0	44.0	18.0	81/04 - 83/04
Magnesium	2	4.1	5.0	3.2	81/04 - 83/04
Sodium	2	2.8	3.6	2.0	81/04 - 83/04
Potassium	2	0.2	0.2	0.1	81/04 - 83/04
Chloride	2	4.7	6.0	4.0	81/04 - 83/04
Sulfate	2	13.0	22.0	4.0	81/04 - 83/04
Fluoride	2	0.1	0.2	0	81/04 - 83/04
Silica	2	4.7	7.1	2.3	83/04 - 83/04
Arsenic (ug/l)	1	1.0			83/04
Cadmium (ug/l)	1	2.0			83/04
Copper (ug/l)	1	2.0			83/04
Iron (ug/l)	1	100.0			83/04
Lead (ug/l)	1	2.0			83/04
Manganese (ug/l)	1	10.0			83/04
Mercury (ug/l)	1	0.1			83/04
Nickel (ug/l)	1	8.0			83/04
Zinc (ug/l)	1	10.0			83/04
Aluminum (ug/l)	1	60.0			83/04
Dissolved Solids	1	147			83/04
Turbidity (NTU)	1	0.2			83/04

---

*All parameters expressed in mg/l unless noted.
Source: U.S. Geological Survey - EPA STORET Retrieval

TABLE 10: Surface Water Quality Data for Lake Rousseau at Inglis Dam

PARAMETER*	NO. OF OBSERVATIONS	MEAN	MAXIMUM	MINIMUM	PERIOD OF RECORD
Temperature (^oC)	21	21.2	30.1	13.3	82/02 - 87/05
Specific Conductance (umhos/cm)	21	273	370	210	82/02 - 87/05
Dissolved Oxygen	21	6.4	10.5	2.4	82/02 - 87/05
pH (SU)	21	7.04	8.94	6.54	82/02 - 87/05
Color (PCU)	19	61	240	5	82/02 - 86/11
Total Alkalinity mg/l $CaCO_3$	20	94	226	45	82/02 - 87/05
Suspended Solids	20	3.4	26.0	0.4	82/02 - 87/02
Organic Nitrogen	19	0.54	1.69	0.23	82/02 - 87/02
Total Ammonia	21	0.094	0.478	0.030	82/02 - 87/05
Nitrite	21	0.01	0.037	0.020	82/02 - 87/05
Nitrate	21	0.228	1.213	0.004	82/02 - 87/05
Total Kjeldahl Nitrogen	19	0.56	0.97	0.14	82/02 - 87/02
Total Phosphorus	19	0.054	0.48	0.01	82/02 - 87/02
Ortho Phosphorus	20	0.026	0.060	0.006	82/02 - 87/05
Organic Carbon	19	10.51	29.12	3.40	82/02 - 87/02
Inorganic Carbon	19	17.38	31.81	0.20	82/02 - 87/02
Hardness mg/l $CaCO_3$	7	143.7	208	112	82/02 - 83/12
Calcium	20	44.0	76.0	27.0	82/02 - 87/05
Magnesium	20	12.8	33.9	3.4	82/02 - 87/05
Sodium	20	6.25	8.9	2.6	82/02 - 87/05
Potassium	20	2.05	15.6	0.2	82/02 - 87/05
Chloride	21	8.2	26.0	4.2	82/02 - 87/02
Sulfate	18	13.72	30.0	4.0	82/02 - 87/02
Fluoride	5	0.10	0.10	0.09	82/02 - 83/08
Silica	3	6.5	9.2	5.0	82/02 - 82/11
Arsenic (ug/l)	19	1.4	2.0	1.0	82/02 - 87/02
Cadmium (ug/l)	21	1.0	7.7	0.1	82/02 - 87/05
Cromium (ug/l)	6	1.5	3.1	1.0	82/02 - 83/08
Cobalt (ug/l)	6	4.0	16.0	1.0	82/02 - 83/08
Copper (ug/l)	20	3.1	13.1	0.1	82/02 - 87/02
Iron (ug/l)	20	70.9	216.0	10.0	82/02 - 87/02
Lead (ug/l)	21	3.9	36.0	0.5	82/02 - 87/05
Manganese (ug/l)	6	3.63	7.60	0.01	82/02 - 83/08
Mercury (ug/l)	20	0.20	0.60	0.01	82/02 - 87/05
Zinc (ug/l)	21	23	123	1	82/02 - 87/05
Dissolved Solids	20	150	221	70	82/02 - 87/02
Turbidity (NTU)	20	1.3	2.8	0.3	82/02 - 87/02

---

*All parameters are expressed in mg/l unless noted.

Source: U. S. Army Corps of Engineers, Jacksonville, Florida

TABLE 11: Surface and Bottom Water Quality Data for Lake Rousseau at Inglis Dam. May 1983–June 1987

PARAMETER	NO. OF OBSERVATIONS	MEAN	MAXIMUM	MINIMUM
Temperature (^{o}C)				
Surface	43	23.8	32.1	11.0
Bottom	42	23.0	30.0	10.1
Specific Conductance (umhos/cm)				
Surface	42	242	379	157
Bottom	42	251	438	176
Dissolved Oxygen (mg/l)				
Surface	40	7.4	11.4	1.3
Bottom	39	5.6	11.4	0.2
pH (SU)				
Surface	42	7.7	8.30	6.80
Bottom	41	7.4	8.10	6.05
BOD (mg/l)				
Surface	43	1.2	3.5	0.1
Bottom	42	1.2	6.4	0.1
Inorganic Carbon (mg/l)				
Surface	43	23.1	33.3	13.7
Bottom	42	24.6	29.7	14.0
Organic Carbon (mg/l)				
Surface	43	7.6	15.9	3.0
Bottom	42	7.3	15.8	2.5

Source: Southwest Florida Water Management District
Federal Aquatic Program

Table 12.

Surface Water Quality Data for Selected Parameters
Lake Rousseau 1979-1980 (Canfield, 1981)

Parameter*	Mean	Min.	Max.	No. of Observations
Temperature (^{o}C)	23.0	17.9	28.0	6
Color (PCU)	70	20	150	9
Specific Conductance (umhos/cm)	209	185	220	9
pH (SU)	7.3	7.0	7.5	9
Total Nitrogen	0.462	0.358	0.716	9
Total Phosphorus	0.048	0.016	0.066	9
Total Alkalinity mg/l CaCo$_3$	92	84	100	9
Total Hardness mg/l CaCo$_3$	110	99	121	9
Chloride	6.3	5.3	7.0	9
Sulfate	9	0	17	9
Sodium	4.1	2.6	5.0	9
Potassium	0.3	0.2	0.4	9
Silica	6.8	5.8	7.7	9
Iron	0.16	0.06	0.33	9
Chlorophyll a (mg/m^3)	2.3	0.4	6.1	9
Secchi (meters)	2.1	1.1	2.6	9

*All parameters expressed in mg/l unless noted.

stations on three sampling dates during 1979 and 1980 (Table 12). In addition, water quality data for Lake Rousseau are available from a USGS report on the CFBC (1976) and evaluation and data reports published by the USACOE (1969, 1975). Data from these latter three sources were not evaluated for this study.

RESULTS AND ANALYSIS

Temperature is one of the most fundamental water quality parameters which influences the metabolic rates of the biota and the solubility of dissolved gases, most importantly oxygen (Hutchinson, 1957). For this analysis, temperature patterns in the Withlacoochee River/Lake Rousseau system were examined by comparing surface water temperatures at the four stations, long-term data at two stations, and vertical temperature profiles at several locations in the reservoir.

A comparison of surface water temperatures demonstrates the influence of Blue Run on the Withlacoochee River system. Blue Run receives most of its flow from Rainbow Springs, which discharges water at temperatures near 23 to 24 degrees centigrade (^{o}C) throughout the year (Rosenau _et al_., 1977). During the 1987 sampling, the thermal effect of Blue Run was apparent at station 2, where temperatures for the three sampling events were consistently lower than for station 1 upstream. The mean surface water temperatures for stations 1 and 2 were 29.7^{o}C and 27.2^{o}C, respectively. Also, for all dates, temperatures were higher at stations 3 (mean 30.1°C) and 4 (mean 30.0°C). These stations were located in Lake Rousseau where reduced vertical mixing, mixing and greater surface area and exposure to solar radiation contribute to warmer surface water temperatures.

Compared to the results for the summer of 1987, surface temperature data from other sources show greater ranges and lower mean values due to their larger seasonal variation of sampling conditions. For station 2 below Blue Run, the USGS reports a mean of 22.5°C with a maximum of 27.0°C and a minimum of 16.5°C. A greater range is recorded by the USACOE for station 4 at Inglis Dam with a maximum and a minimum of 30.1°C and 13.3°C. This larger range of surface temperatures at Inglis Dam is due to the greater response of water temperature to changing climatic conditions, whereas the discharge from Rainbow Springs has a moderating effect on surface water temperatures at Dunnellon.

For the three sampling events during 1987, surface temperatures in Lake Rousseau and the Withlacoochee River upstream of Blue Run were very similar, but these data were limited to the warm summer months. Generally, impoundments cause changes in water temperature patterns from the inflowing rivers. Due to turbulence, streams are generally well-mixed with little difference between surface and bottom temperatures. In reservoirs, however, turbulence is reduced with the transition to a more lake-like system. With reduced turbulence, the gradual warming of surface waters can result in density differences between surface and bottom waters, which is termed "thermal stratification". In warm regions such as Florida, thermal stratification can develop during the summer months, but may be temporary since sudden cold snaps, wind driven turbulence or abundant precipitation can break the stratification. Sometimes, thermal stratification is localized within a lake or reservoir due to differences in basin morphometry, aquatic plants, wind fetch or circulation patterns. In reservoirs like Lake Rousseau, the presence of thermal stratification can be related to the amount of flow through the system, as high flows create more turbulence which can mix surface and bottom waters.

Temperature profiles recorded in Lake Rousseau during 1987 show considerable spatial variability. Figures 15-17 show representative vertical temperature profiles which were recorded on August 10, September 9, and October 15, 1987. The locations of all sites measured are shown on Figure 14. For the August sample, site 4 within the channel near the Inglis Dam was the only stratified channel site found during this study. All channel sites examined in September and October were well-mixed with surface and bottom temperatures varying a maximum of 0.5°C. For all three sampling dates, thermal stratification was found in all of the areas with aquatic vegetation and the open (non-vegetated), off-channel sites. The largest temperature changes

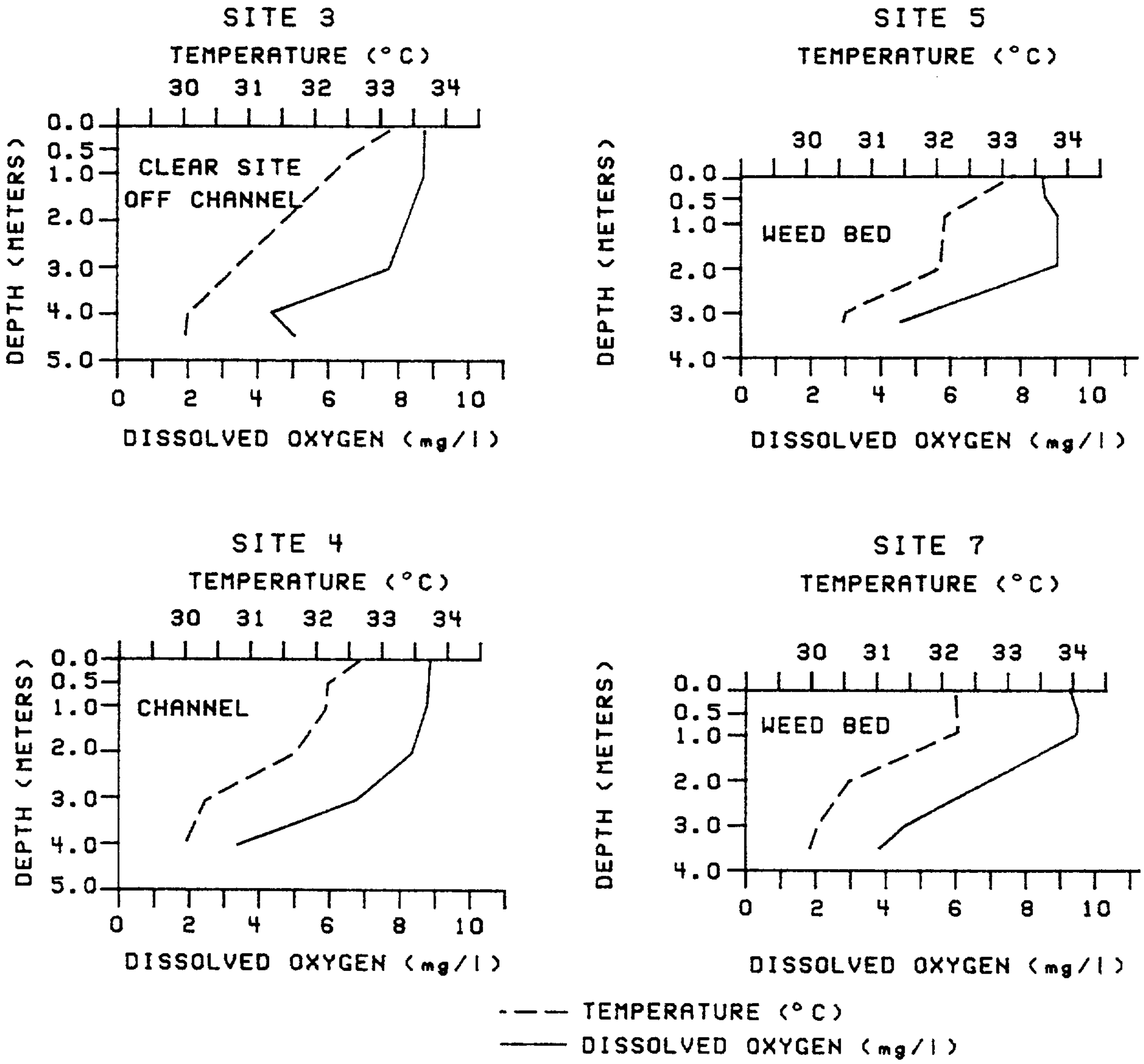


FIGURE 15 VERTICAL PROFILES FOR DISSOLVED OXYGEN (DO) AND TEMPERATURE - LAKE ROUSSEAU, AUGUST 10, 1987.

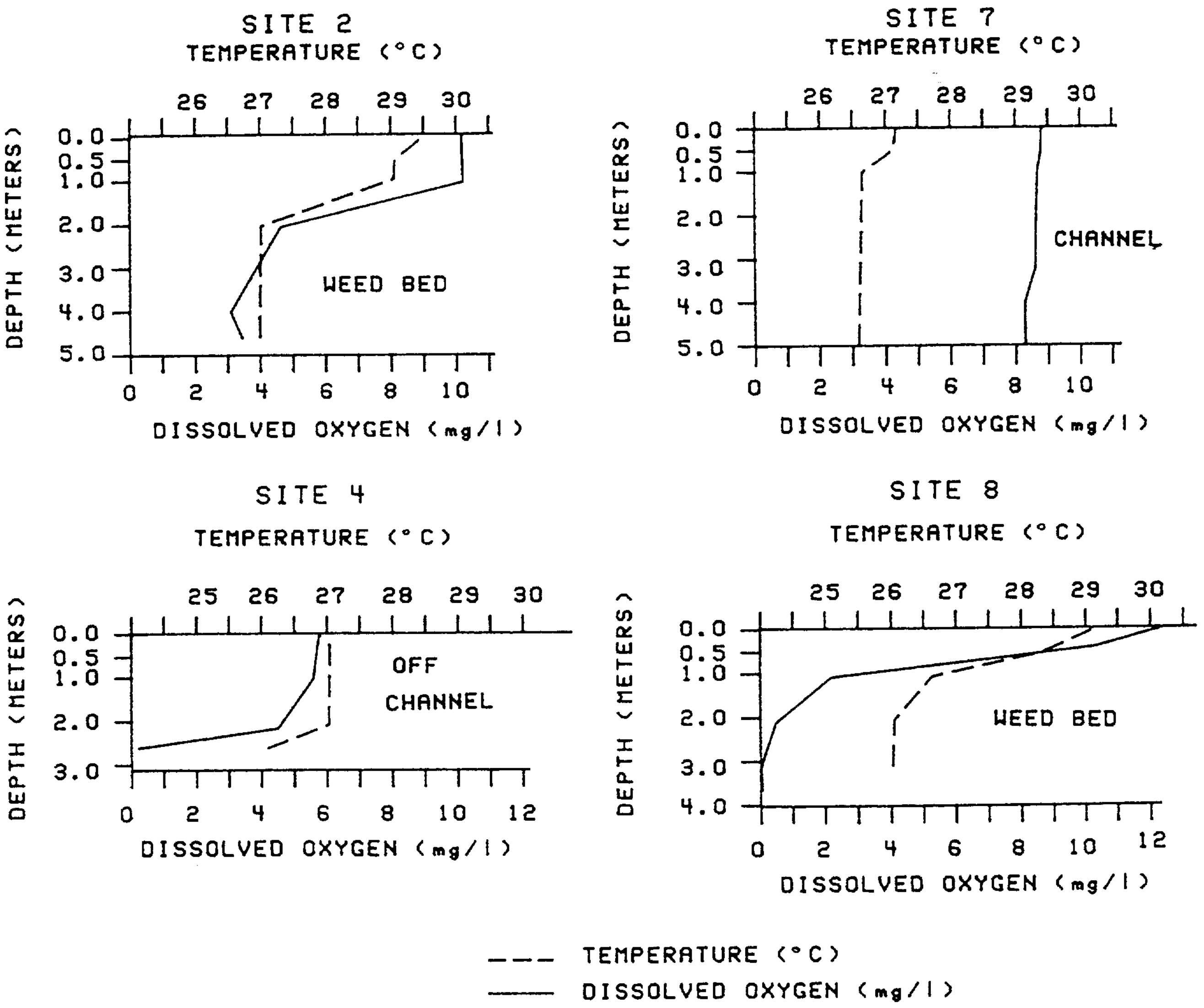
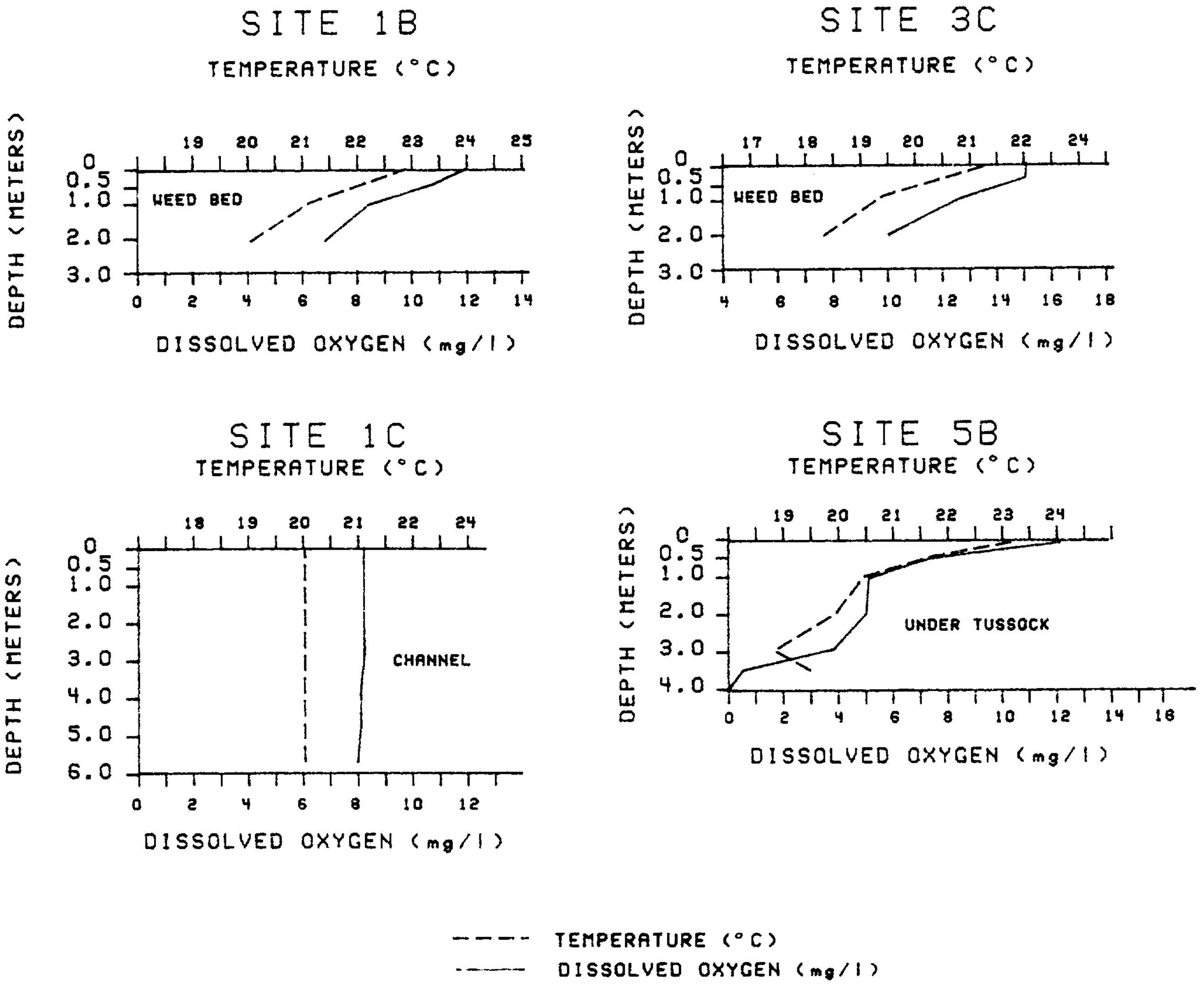


FIGURE 16 VERTICAL PROFILES FOR DISSOLVED OXYGEN (DO) AND TEMPERATURE - LAKE ROUSSEAU, SEPTEMBER 9, 1987


SITE 1B

SITE 3C

SITE 1C

SITE 5B

FIGURE 17 VERTICAL PROFILES FOR DISSOLVED OXYGEN (DO) AND TEMPERATURE
LAKE ROUSSEAU, OCTOBER 15, 1987.

were found at depths of one to two meters, with temperatures dropping about 2.0°C to 3.0°C within the total vertical profile. Thermal stratification was present at all of the off-channel sites into the October sampling, even though the reservoir experienced a gradual decrease in overall temperature. When compared to the channel sites, the off-channel locations generally showed greater temperature variations with warmer surface waters and cooler bottom temperatures. This was the result of less vertical mixing, caused by reduced wind-driven circulation and shading by aquatic vegetation within the shallower regions of the reservoir.

Dissolved oxygen (D.O.) is essential to the metabolic functions of aquatic organisms which respire aerobically and is one of the most important water quality parameters. Concentrations of dissolved oxygen are dependent upon a combination of physical, chemical, and biological factors. The circulation and vertical mixing of waters within a reservoir is important for oxygenation, as water gains oxygen when it contacts the atmosphere. When thermal stratification occurs, bottom waters lose direct contact with the atmosphere thus reducing the diffusion of oxygen to those waters. Temperature also affects dissolved oxygen concentrations as the solubility of oxygen decreases with rising water temperature (Wetzel, 1975). Lastly, biological activity is extremely important since photosynthesis and respiration can have dramatic effects on dissolved oxygen concentrations.

Photosynthesis increases dissolved oxygen concentrations and can cause super-saturation of dissolved oxygen in surface waters. Conversely, respiration by algae, macrophytes or microorganisms may reduce dissolved oxygen concentrations, particularly at night or in cloudy conditions when respiration rates exceed photosynthesis. Problems with low dissolved oxygen occur most often in eutrophic lake conditions where there may be an abundance of algae, microbes, macrophytes or oxidizable organic material (Wetzel, 1975; Petts, 1984).

Surface dissolved oxygen concentrations recorded in the Withlacoochee River during June, July, and August, 1987, were consistently lower than those found in Lake Rousseau. Surface dissolved oxygen concentrations ranged from 3.8 to 5.3 mg/l for stations 1 and 2, with respective means of 4.5 mg/l and 5.0 mg/l. Surface dissolved oxygen concentrations in Lake Rousseau ranged from 5.2 mg/l to 8.9 mg/l. Station 3, located within an area of aquatic vegetation had a mean of 6.1 mg/l while station 4, near Inglis Dam, had a higher mean of 8.5 mg/l.

Other data sources (USGS, USACOE) report wider ranges of surface dissolved oxygen concentrations for both the Dunnellon and Inglis Dam stations (Tables 9 and 10). The ranges reported are similar, 3.5 to 9.9 mg/l at Dunnellon, station 2, and 2.4 to 10.5 mg/l at Inglis Dam, station 4. Compared to the summer District sampling, a greater range of seasonal climatic conditions and also flow rates influence the wider ranges of D.O. concentrations observed for these two data sets.

Dissolved oxygen profiles were measured in Lake Rousseau at the same times and locations as the temperature profiles during August, September and October of 1987 (Figure 14). Representative dissolved oxygen profiles are presented in Figures 15-17. The dissolved oxygen profile for channel site 4 on August 10 was similar to that for temperature, with D.O. concentrations decreasing between two and four meters depth. Conversely, the other channel sites for the next two sampling dates were well mixed, with almost identical dissolved oxygen concentrations near 8.5 mg/l for surface and bottom waters.

The off-channel sites for the three dates all show decreasing oxygen concentrations with depth. Sites within areas of dense aquatic vegetation had highly oxygenated surface waters, and for some sites, supersaturation was present with concentrations near 16 mg/l. These high concentrations quickly declined within the first two meters of the water column. In many cases, dissolved oxygen concentrations near the bottom were well below 4.0 mg/l, indicating stressful conditions for many aquatic organisms.

For these shallow off-channel sites, dissolved oxygen concentrations closely paralleled temperature profiles with low bottom D.O. concentrations found associated with pronounced thermal stratification. Therefore, it appears that reduced vertical mixing limits the oxygenation of bottom waters in these shallow areas. This lack of mixing is largely caused by the dense aquatic vegetation which reduces wave energy and mixing in its vicinity. In the open channel areas where mixing is not so restricted, higher D.O. levels were found in deep waters. It is also pointed out that all the D.O. measurements for this study were made during daylight hours when oxygen concentrations are normally highest. In the presence of dense aquatic vegetation or high microbial or algal populations, D.O. concentrations can be markedly lower at night when respiration exceeds photosynthesis. In Lake Rousseau, it is expected that diurnal D.O. fluctuations would be greatest in the shallow weeded areas where vegetative biomass and organic detritus are most abundant.

Color in natural waters is the product of decaying vegetation and other humic material (Hem, 1970; Kaufman, 1975). These dissolved organic compounds impart a yellowish-brown color to water, often giving lake or river water the appearance of tea. For the four stations sampled during 1987, mean color values ranged from 78 platinum cobalt units (PCU) for station 2 to 110 PCU for station 1. Station 1 receives little or no influence from Blue Run and color values were consistently higher there than below the confluence of the two rivers at station 2. Values within Lake Rousseau reflect the inflows from both the Withlacoochee River and Blue Run with means of 87 PCU and 93 PCU for stations 3 and

4, respectively. Color values dropped dramatically at all four stations for the month of August. Provisional USGS discharge records show that flows to Lake Rousseau were less in August than during the previous two months. Reductions of color for August were probably caused by a greater proportion of ground-water flow to surface runoff.

Other data sources generally confirm the color values reported in this study. Canfield (1981) reports a similar range of color values (20 PCU to 150 PCU) for the reservoir with a mean value of 70 PCU. Long-term data (USACOE) at the Inglis Dam show a greater range of color values from 5 to 240 PCU, probably due to a greater range of flow conditions for the period of time sampled. Linear regression analysis of the data for the Inglis Dam site shows a significant ($P<0.05$) relationship between color and flow for the period 1982 to 1986. The coefficient of variation was not high ($r^2=0.20$), but examination of data shows that six of eight color values at flows of less than 1,200 cfs were less than 22 PCU (Figure 18). During these low flow periods inflows to the reservoir are dominated by ground-water sources resulting in low color values. At higher flow rates, there was considerably more scatter in the relationship but higher color values were generally found.

The **Secchi Disk** is a round black and white disk which is lowered into the water column to obtain an estimate of water clarity or

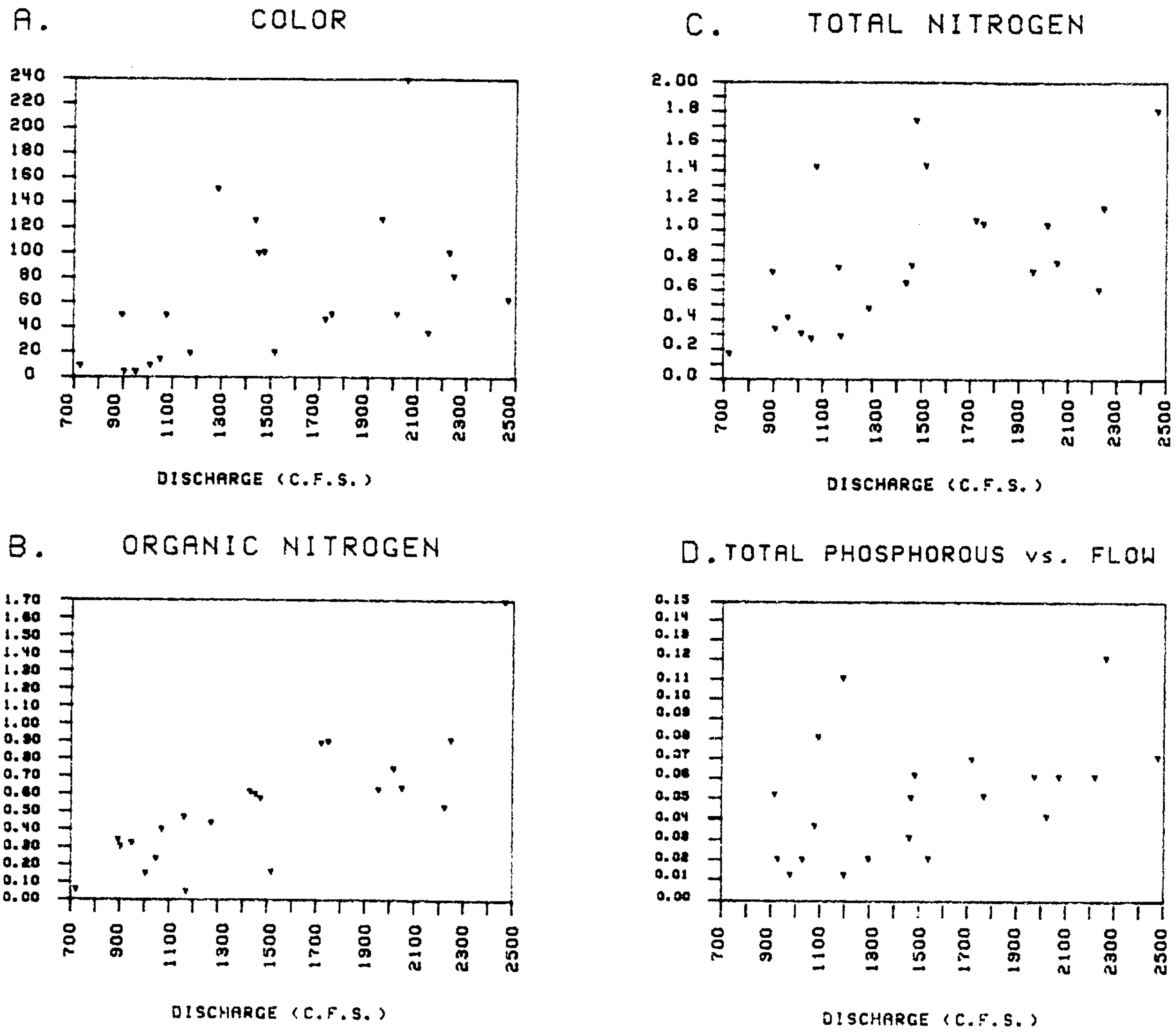


FIGURE 18 RELATIONSHIPS OF COLOR, ORGANIC NITROGEN, TOTAL NITROGEN, AND TOTAL PHOSPHOROUS TO FLOW AT THE INGLIS DAM SITE, LAKE ROUSSEAU (USCOE, SWFWMD).

light penetration. The depth at which the disk disappears from view is referred to as Secchi depth, with high values indicating clear water and low values indicating poor clarity. Secchi depth is generally inversely related to dissolved organic color, algal abundance, and suspended matter in the water column (Brezonik, 1978; Canfield and Hodgson, 1983).

Mean Secchi depth values for four stations sampled during 1987 ranged from 1.7 meters for station 3 to 4.4 meters for station 2. Values for station 2 at Dunnellon were consistently the highest due to the inflow of clear spring water from Blue Run. Mean values for the two reservoir stations were 1.55 for station 3 and 2.44 for station 4. The lowest values recorded for stations 3 and 4 were 1.7 and 1.0 meters, respectively. Similar values were recorded for Lake Rousseau by Canfield (1981), whose measurements for three dates ranged from 1.1 to 2.6 meters, which correspond closely to the values for station 4 observed in this study. The lower Secchi disk depths measured for Lake Rousseau compared to station 2 were likely due to higher algal abundance or suspended matter in the reservoir.

Specific conductance is the capacity of water to conduct an electrical current and serves as an indicator for the abundance of dissolved minerals. Specific conductance data show that the mineralized waters of the Withlacoochee River and Blue Run dominate the waters of Lake Rousseau. For the three sampling dates during 1987, there was a trend for slightly lower values downstream as means for the four stations ranged from 235 microhmos/centimeter (umhos/cm) for station 4 to 266 umhos/cm for station 1. Slight reductions were measured at station 2 from upstream at station 1, with differences for the three sampling dates ranging between 12 and 23 umhos/cm. For two dates, values at stations 3 and 4 were slightly less than values at station 2, with differences ranging between 3 and 22 umhos/cm. For the July sample, values were virtually the same at these three stations.

Long-term data from near Inglis Dam show a greater range of values (119 - 379 umhos/cm), but mean values were similar to the 1987 values, ranging from 242 umhos/cm (SWFWMD) to 273 umhos/cm (USACOE). Canfield (1981) reported a slightly lower mean (209 umhos/cm) for three sampling dates in 1979-80.

Alkalinity is the ability of a body of water to neutralize acids and is implicitly related to pH (Bouwer, 1978). Values recorded for the river and the reservoir stations during this study were all near 100 mg/l with station means ranging from 99 to 110 mg/l. These stable values are due to the influence of well-buffered ground waters originating from limestone formations, including Rainbow Springs and other small springs throughout the Withlacoochee basin.

A greater range of values is reported for the USACOE data at Inglis Dam (45 to 226 mg/l) with a mean (94 mg/l) just slightly lower than most values recorded during this study. A similar mean (92 mg/l) was reported by Canfield with values ranging from 84 to 100 mg/l for three sampling dates.

The **pH** of water is the expression of the hydrogen ion activity based on the negative logarithm of the hydrogen ion concentration. The mobility, solubility, degree of dissociation, and the potential toxicity of many elements is dependent upon pH (Lee and Hoadley, 1967; Fritz, 1980). For the 1987 sampling, individual pH values ranged from slightly alkaline (7.15 standard units, SU) to alkaline (8.25), with station means ranging from 7.27 (station 3) to 7.95 (station 4). Generally, values for station 4 for Inglis Dam were slightly higher than for the other three stations. The ranges of values reported for Inglis Dam and Dunnellon by the USACOE and the USGS are greater than those reported for this study, but means were similar with values of 7.04 to 7.35. The pH values reported by Canfield (1981) ranged from 7.0 to 7.5 with a similar mean of 7.3. In sum, pH and alkalinity data from several sources indicate that Lake Rousseau is usually slightly alkaline and well buffered. Calcareous ground-water inflows to the Withlacoochee system are largely responsible for this condition, but pH may also be influenced by photosynthesis by algae and aquatic macrophytes in the reservoir. Higher pH values can result from the carbonate buffering system responding to the uptake of carbon dioxide and bicarbonate by vegetation (Wetzel, 1975).

Along with phosphorus, **nitrogen** is one of the two most important elements controlling plant productivity in natural waters. In fresh water, nitrogen exists in several forms; dissolved molecular nitrogen, organic compounds such as amino acids, amines, proteins and humic compounds, and inorganic compounds such as ammonia, nitrite and nitrate. The inorganic forms are the most available species for phytoplankton uptake (Wetzel, 1975), but in extremely high concentrations can be toxic to aquatic organisms (USEPA, 1976).

Nitrate (NO_3) is the most oxidized form of nitrogen and is assimilated by algae and macrophytes. Nitrite (NO_2) is a less oxidized form of nitrogen which is quickly converted to nitrate in oxygenated water bodies. Since these two forms of nitrogen are so closely related and nitrite is normally found in very low concentrations, the SWFWMD laboratory utilizes a technique which combines the two species. Results of sampling during 1987 show increases in mean nitrate/nitrite levels for surface waters at station 2 (0.37 mg/l) from levels at station 1 (0.14 mg/l). Other data for Rainbow Springs shows that high levels of nitrate/ nitrite were measured for 1983-1985 (USGS, 1984, 1985b, 1986b) with concentrations averaging near 0.35 mg/l. Concentrations near this level are probably still found in the spring discharge and influence the values reported at Dunnellon (station 2). Nitrate/nitrite concentrations recorded for the reservoir during 1987 were very low with levels at or below 0.01 mg/l for all samplings. This was probably due to uptake of nitrate by algae and macrophytes during the summer sampling months. For the USACOE data near Inglis Dam, nineteen of twenty-two observations for nitrate were less than 0.2 mg/l, with three values found greater than 1.0 mg/l. Linear regression analysis showed no significant relationship between nitrate/ nitrite concentrations and outflows from the reservoir.

Ammonia (NH_3) is a reduced form of nitrogen which results from the decomposition of organic matter or from pollution sources. In oxygenated surface waters receiving little or no pollution, ammonia concentrations are usually low. Like nitrate, ammonia is also readily available for uptake by aquatic plants. During the 1987 sampling, values for ammonia were consistently low at all four stations with concentrations of 0.03 mg/l or less. Long-term data near Inglis Dam show greater variation, but most of the values were at or below 0.10 mg/l with only four values greater than this amount. Linear regression analysis showed no significant relationship between ammonia concentrations and outflows from the reservoir.

Mean **organic nitrogen** concentrations during this study, ranged from 0.39 mg/l for station 2 to 0.56 mg/l for station 1.

Reductions in organic nitrogen were recorded for station 2 from station 1 on two of the three sampling dates. USGS data from Rainbow Springs show that spring discharge to Blue Run is very low in organic nitrogen, averaging 0.13 mg/l for 1983-1985. Under most flow conditions, lower organic nitrogen concentrations would be expected at station 2 compared to station 1 due to the effects of spring discharge. Organic nitrogen concentrations averaged 0.48 mg/l and 0.45 mg/l for stations 3 and 4 in Lake Rousseau. Individual measurements at these two stations ranged from 0.30 to 0.61 mg/l, with highest values recorded in June, the earliest sampling date.

USACOE data at Inglis Dam have a mean organic nitrogen value (0.54 mg/l) similar to the station means for this study, but show a much greater range of values (0.23 to 1.69 mg/l). Linear regression analysis of this data set found a significant relationship ($p<0.001$, $r^2=0.62$) between organic nitrogen concentrations and outflow from the reservoir (Figure 18). Organic nitrogen concentrations increase with rising flow, indicating that considerable organic nitrogen is washed into the reservoir from the watershed.

Total nitrogen is the sum of nitrate, nitrite, ammonia, and organic nitrogen. It is an important parameter which represents the entire pool of nitrogen and is often used for nutrient assessments and trophic state index calculations. For the 1987 sampling, mean total nitrogen values were higher in the river (0.73 mg/l for station 1 and 0.79 mg/l for station 2) than in the reservoir (0.52 mg/l for station 3 and 0.49 mg/l for station 4). Similar total nitrogen concentrations were reported for Lake Rousseau by Canfield (1981), with values ranging from 0.36 to 0.72 mg/l and a mean of 0.46 mg/l. Linear regression of flow versus total nitrogen for the USACOE data at Inglis Dam found a significant relationship ($p<0.005$) between these variables, largely due to the high percentage of organic nitrogen in the system. The coefficient of variation was low ($r^2 = 0.26$), however, and all but four total nitrogen values were less than 1.2 mg/l (Figure 18).

Phosphorus is one of the primary nutrients which regulates plant growth in fresh-water systems. The cycling of phosphorus in aquatic systems is affected by a complex set of biological and chemical interactions. Phosphorus concentrations are generally reported in two forms; orthophosphorus which includes PO4 and some other reactive species, and total phosphorus which is the entire phosphorus pool including the organic forms. Bacterial activity, pH, sediment composition, benthic fauna, algal and macrophyte growth, and dissolved oxygen concentrations can have an effect on the exchange equilibrium of phosphate (Wetzel, 1975).

For the 1987 sampling, total phosphorus concentrations were consistently higher in the Withlacoochee River than for the stations in Lake Rousseau. Mean values were near 0.06 mg/l for stations 1 and 2, becoming progressively lower downstream with a mean value of 0.02 mg/l at station 4. Mean orthophosphorus values showed a similar trend and were 0.01 mg/l or less for five of the six samples taken from stations 3 and 4. This trend for orthophosphorus is not surprising, as phytoplankton uptake in the reservoir should lower orthophosphorus concentrations. Similarly, the results for total phosphorus seem to indicate that phosphorus is being taken up by the macrophyte/periphyton community in the reservoir or is being lost to the sediments, but the data are too limited to draw any conclusions. The data do indicate, however, that the Withlacoochee River supplies considerable phosphorus to the reservoir, sufficient to stimulate high levels of primary productivity.

Long-term USACOE data for Inglis Dam have a mean total phosphorus concentration of 0.054 mg/l, not including one extremely high value of 0.48 mg/l. Omitting this extreme value, linear regression analysis performed on flow and total phosphorus show a significant relationship ($p < 0.05$, $r^2=0.50$). No relationship was found with orthophosphorus concentrations versus flow.

Nitrogen/phosphorus ratios can be used as a rough measure of potential nutrient limitation conditions in a water body. As previously mentioned, nitrogen and phosphorus are normally the two nutrients which most strongly control plant growth in natural waters. If either nitrogen or phosphorus is in short supply the production of phytoplankton may be limited (Canfield, 1983; Sakamoto, 1966). The following nutrient ratios were suggested by Huber et al. (1982), to indicate potential nutrient limitation conditions in Florida lakes.

	Total Nitrogen/ Total Phosphorus (by weight)
Phosphorus limited waters	$TN/TP>30$
Nitrogen limited waters	$TN/TP<10$
Nutrient-balanced waters	$10 \leq TN/TP \leq 30$

For the data collected during 1987, TN/TP ratios were determined for stations 3 and 4 within Lake Rousseau. The TN/TP ratios for individual samples ranged from a minimum of 9.55 at station 3 to a maximum of 24.0 at station 4. Ratios determined from mean nutrient concentrations for stations 3 and 4 are 12.4 and 20.4, respectively. Ratios calculated from the USACOE data for Inglis Dam show a wide range of values from 6.85 to 71.65, with an average ratio of 21.1, indicating nutrient balanced waters. Determinations from Canfield's values (1981) for each site and date from 1979-1980 range from 5.59 to 30.86, with a mean value of 9.65, indicating slight nitrogen limitation.

In sum, most TN/TP ratios calculated for water samples from Lake Rousseau correspond to nutrient balanced waters, although nitrogen or phosphorus limitation is periodically indicated. Low TN/TP ratios are more common than high values, indicating that phosphorus is abundant in the system and periodic nitrogen limitation is more likely than phosphorus limitation. However, in a reservoir such as Lake Rousseau where the turnover rate of water is high, TN/TP ratios may reflect nutrient conditions of inflowing waters more than any limitation of supply. Because of the constant delivery of nutrient-rich waters to Lake Rousseau from the river, phytoplankton may not be limited by nutrient availability but rather by other factors such as light penetration or short water residence times.

Chlorophyll a is a useful indicator of phytoplankton biomass and it is an important factor for determining the trophic state of a water body (Carlson, 1977; Huber et al., 1982). Chlorophyll a concentrations can be affected by algal species composition and physiological state, nutrient availability, atmospheric conditions and pH.

For the 1987 data, chlorophyll a values were markedly higher in Lake Rousseau compared to the upstream river stations. Mean chlorophyll a values were 1.0 and 1.3 mg/l for stations 1 and 2, with a maximum value of 1.6 mg/l. Chlorophyll a values in Lake Rousseau ranged from 4.4 to 23.5 mg/l and averaged 14.3 and 13.6 mg/l at stations 3 and 4, respectively. On three dates during 1979-1980, Canfield (1981) found chlorophyll a values ranging from 0.4 to 6.1 mg/l in the reservoir, with an average value of 2.3 mg/l. The occurrence of higher chlorophyll *a* concentrations in Lake Rousseau compared to the river is due to the transition from a riverine to a reservoir environment. In the Withlacoochee River, rapid water movement, turbulence, and light limitation prevent the establishment of dense phytoplankton populations. In the reservoir, reduced currents and vertical mixing plus increased exposure to solar radiation allow greater phytoplankton populations to develop.

Trophic state index (TSI) models are available to describe the nutrient status of lakes using a single number to express the levels of certain physical, chemical, and biological parameters. Many indices have emerged in the past 20 years with increasing sophistication. The best known and most widely used are those by Carlson (1977). These indices are based on Secchi disk transparency (water clarity), chlorophyll *a*, and total phosphorus concentrations. Since these models were developed primarily for phosphorus-limited north temperate lakes, it was necessary to develop indices for Florida lakes, many of which are nitrogen-limited or nutrient-balanced. Based on Carlson's approach, a trophic state index was developed using linear regression analysis on data from 573 Florida lakes (Huber *et al*., 1982). Subindices were developed for variables including Secchi disk transparency (TSI(SD)), chlorophyll *a* (TSI(Chl*a*)), and total phosphorus (TSI(TP)) and total nitrogen (TSI(TN)) concentrations (see

Appendix B). The average TSI (TSI(AVE)) is the mean of a combination of these sub-indices. All TSI scales range from 0-100, with zero being the lowest trophic state and 100 the highest level of eutrophy (Huber *et al*., 1982). TSI values of 50-60 indicate slight eutrophication and higher values are within the range of moderate to severely eutrophic lakes.

Trophic state index values for Lake Rousseau were computed using data from stations 3 and 4 from this study Canfield (1981), and the USACOE station near Inglis Dam (see Appendix E). Values for Secchi transparency, chlorophyll *a*, total nitrogen and total phosphorus concentrations used for sub-index computation were the averages of mean values form these three studies. The equation for nutrient balanced lakes was used for calculation of the TSI-average. The TSI-average for Lake Rousseau was 45.2 which indicates mesotrophic conditions. This type of trophic state index, however, only describes conditions in the water column and does not account for nutrients and vegetative biomass tied up in macrophytes. Because of the extensive aquatic plant populations in the shallow reaches of Lake Rousseau, the above index value under-estimates the true nutrient status and trophic state of the reservoir. Canfield *et al*., (1983) developed a trophic state index for macrophyte-rich lakes which accounts for the nutrients incorporated in the macrophyte tissues. This type of TSI was not calculated for this study because plant biomass and nutrient content were not available.

WATER QUALITY IN THE WITHLACOOCHEE/ROUSSEAU SYSTEM RELATIVE TO OTHER WATER BODIES IN FLORIDA

In this section water quality in Lake Rousseau is compared to data from other lakes throughout the state. Such comparisons help classify the water quality characteristics of the reservoir and assess the relative severity of any water quality problems found there. Also, this approach can indicate whether water quality in the reservoir is indicative of naturally occurring or polluted conditions. Because water quality in Lake Rousseau is closely linked to conditions in the Withlacoochee River, a brief comparison of the Withlacoochee River near Dunnellon to three similar rivers in Florida is presented first.

Withlacoochee River

To better assess relative water quality in the Withlacoochee River near Dunnellon, data presented in this report are compared to data from three other Florida rivers; the Oklawaha, the Hillsborough, and the Suwannee. Water quality data for these three rivers plus values for the Withlacoochee near Dunnellon are listed in Table 13. These three rivers were chosen because they all drain large wetland areas and are also influenced by groundwater flow from springs. Like the Withlacoochee, the Oklawaha and Hillsborough Rivers both originate in the Green Swamp, an 870 square mile area of swamps and flatwoods about 20 miles west of

Table 13.

Comparisons of Selected Water Quality Parameters of the Withlacoochee River to Three Other Rivers in Florida

Parameter	Withlacoochee River at Dunnellon[1]	Oklawaha Connor[2] 1984-1985	Hillsborough River[3] 1952-1966	Suwannee River[4] 1913-1984
Dissolved Oxygen (mg/l)	3.5-9.9	3.3-8.1	5.05-6.18	6.7-7.6
Specific Conductance (umhos/cm)	119-319	380-438	314-449	53.9-225
Color (PCU)	0-125	-----	-----	62-306
Total Alkalinity (mg/l $CaCo_3$)	103-107	141-171	87-127	2-116
pH (SU)	6.1-8.5	7.4-8.1	7.13-7.47	4.3-7.2
Total Nitrogen (mg/l)	0.70-0.99	0.57-3.5	0.77-1.75	-----
Total Kjeldahl Nitrogen (mg/l)	0.04-0.60	0.4-2.5	0.56-0.95	0.46-1.04
Nitrate/Nitrite (mg/l)	0.19-0.40	0.17-1.0	0.16-0.80	0.02-2.08
Ammonia Nitrogen (mg/l)	0.01-0.03	<0.01-0.10	-----	0.03-0.22
Total Phosphorus (mg/l)	0.020-0.076	0.04-0.09	0.34-0.81	0.07-0.42

[1] Ranges of values, Tables 6 and 9.
[2] Ranges of values, USGS, 1985a and USGS, 1986a.
[3] Ranges of means for 3 USGS stations. See SWFWMD, 1987.
[4] Ranges of means for 5 USGS stations. See FDER, 1985.

Orlando and about 30 miles northeast of Tampa (Grubb and Rutledge, 1979).

For these three rivers, alkalinity, pH and specific conductance values are related to varying quantities of ground water and surface water flows. Alkalinity and specific conductance values were highest for the Oklawaha River, where discharge from Silver Springs contributes approximately 50 percent of the average flow at the mouth of the river (FDER, 1986). Alkalinity values for the two other rivers are similar to the Withlacoochee, although low minimum values are listed for the Suwannee due to the inclusion of upstream stations which are above the influence of springs. The mid and lower Suwannee stations are similar to the Withlacoochee River near Dunnellon (FDER, 1985). Specific conductance values for the Withlacoochee are between those reported for the Suwannee and the Hillsborough Rivers.

Although data for the Withlacoochee River are very limited, nutrient concentrations in the Withlacoochee are generally less than those reported for the three other rivers. The Hillsborough River receives agricultural runoff plus some small point source discharges, slightly elevating nutrient concentrations (Drew, _et al_., in review). The maximum nitrogen and phosphorus concentrations recorded for the Suwannee River are attributed to mining discharges within the upper reaches of the basin (FDER, 1985). Although the Withlacoochee River recieves non-point source runoff from agricultural lands and some limited urban development, the drainage basin of the river is in relatively good condition. As point source discharges to the river are very minor, nutrient concentrations in the river have not been greatly enriched. The Withlacoochee River at Dunnellon has water quality similar to, and at least as good, as three major rivers in the region. It is concluded that mineral and nutrient concentrations in the river are naturally high due to abundant wetland drainage combined with inflows to the river from calcareous ground water sources.

Lake Rousseau

A very useful tool for comparing water quality in Lake Rousseau to other Florida lakes is the data set of Canfield (1981), who sampled 165 Florida lakes in a survey of lakes during 1979-1980. This survey data set provides frequency distributions of values throughout the state for various water quality parameters. Values corresponding to selected points in these frequency distributions are listed for thirteen water quality parameters in Table 14. Also included in Table 14 are average values for these same parameters in Lake Rousseau.

When compared to the 165 lakes in Canfield's survey, Lake Rousseau has high values of total alkalinity, specific conductance and total hardness, all of which were greater than at least 75 percent of the survey lakes. Total alkalinity and hard-

Table 14.

Comparisons of Selected Water Quality Parameters in Lake Rousseau to 165 Other Lakes in Florida

Selected frequency intervals for average water quality parameters for 165 Florida lakes sampled from September 1979, to August 1980 (Canfield, 1981).

Parameter[1]	Lake Rousseau[2]	Min.	1st Quartile	Median	3rd Quartile	Max.
pH (SU)	7.32	4.1	5.8	6.8	7.8	9.2
Total Alkalinity mg/l $CaCO_3$	95.7	0	3	10	35	204
Specific Conductance (umhos/cm)	240	11	50	97	187	5,600
Total Hardness mg/l $CaCO_3$	123	2	12	25	63	70
Sodium	4.62	1	4.9	7.6	13	1,200
Potassium	0.90	0	0.3	1.3	3.2	51
Chloride	6.7	1.7	7.0	14	22	2,300
Sulfate	10.36	3.4	6.5	11	20	186
Total Nitrogen	0.58	0.064	0.37	0.60	1.10	4.60
Total Phosphorus	0.052	0.003	0.013	0.020	0.046	0.834
TN/TP	11.2:1	1.7	17	26	37	98
Chlorophyll *a* (mg/m^3)	8.1	0.5	2.8	5.7	17.4	157
Color (PCU)	74	0	10	30	68	416
Secchi (m)	2.0	0.1	0.7	1.3	2.6	8.1

---

[1] All parameters expressed as mg/l unless noted.

[2] All values for Lake Rousseau are combined means for Stations 3 and 4 (Tables 7, 8) USACOE (Table 10), and Canfield (1981) (Table 12).

ness were particularly high, reflecting the calcium bicarbonate-rich ground-water inputs to the reservoir. According to isograms presented by Canfield, alkalinity, hardness, and specific conductance measurements are similar to those found in the central valley region of the state. Lake Rousseau is comparatively low in sodium and chloride being in the bottom 25 percent of values, reflecting ground-water conditions in the Withlacoochee basin and a relative lack of influence by marine aerosols. Sodium and potassium concentrations are close to median values for the survey data set indicating Lake Rousseau has average values for within the state.

The mean total nitrogen value for Lake Rousseau is just less than the median value for Canfield's survey data set. The reservoir is comparatively more enriched in phosphorus, as the average phosphorus value is within the upper 25 percent of values. The average chlorophyll *a* concentration for Lake Rousseau is 8.1 mg/m^3, which is fairly close to the median value for the survey data set. Based on these comparisons, the reservoir is relatively high in phosphorus but near average for total nitrogen and chlorophyll *a* concentrations. The apparent lack of chlorophyll *a* compared to phosphorus could be due to various factors such as possible nitrogen limitation or low phytoplankton production due to short water residence times or light limited photosynthesis.

Lake Rousseau can be considered a system with relatively high levels of organic color, as the average value was within the upper 25 percent of the values for the survey data set. Despite these high levels of color, water transparency as measured by the Secchi disk is fairly good. The average value for Lake Rousseau is midway between the median and 75 percent values, indicating the Secchi depths in the reservoir are as good as at least half the lakes within the state.

In sum, water quality in Lake Rousseau is closely linked to the Withlacoochee River. Color values in the reservoir on the average are high, but are quite variable due to changing proportions of ground-water and surface-water inflows. Due to the influence of shallow limestone formations in the Withlacoochee system, the waters of the reservoir are well-buffered, being high in hardness and alkalinity. Total phosphorus values in the reservoir are moderately high, indicating eutrophic conditions. These levels, however, are similar to those in the river and are not the result of any major pollution sources. Total nitrogen, chlorophyll a and Secchi disk values are near average for Florida lakes, indicating Lake Rousseau has relatively good water quality overall. However, the reservoir has dense aquatic macrophyte growth and thick sediment accumula-tion resulting in poor circulation and low dissolved oxygen concentrations in many areas of the reservoir.

CHARACTERISTICS OF THE RESERVOIR IMPORTANT TO WATER QUALITY

In developing a management strategy for Lake Rousseau, it is important to examine the interactions of physical, chemical and biological factors within the reservoir. Physical factors including basin morphometry, water residence time, and circulation patterns exert a strong influence on chemical and biological processes within the system. Similarly, the production of algae and macrophytes can affect physical characteristics such as light penetration, thermal stratification, and circulation. In the following section, the characteristics of the reservoir which are important to water quality are discussed.

Morphometry

In particular, the unusual morphometry (shape and depth) of Lake Rousseau determines its biological structure. Because the reservoir was created by inundating a river and its floodplain, the morphometry of Lake Rousseau is different from most Florida lakes (Figure 19). Cross sectional views of Lake Rousseau are generally funnel shaped with broad shallow areas found where the old floodplain existed, changing abruptly to central deep areas corresponding to the old river channel (Figure 20). The shallow areas generally range in depth from 0 to 10 feet, and are dotted by numerous stumps from the old floodplain forest. In many of these areas floating islands of vegetation or tussocks have

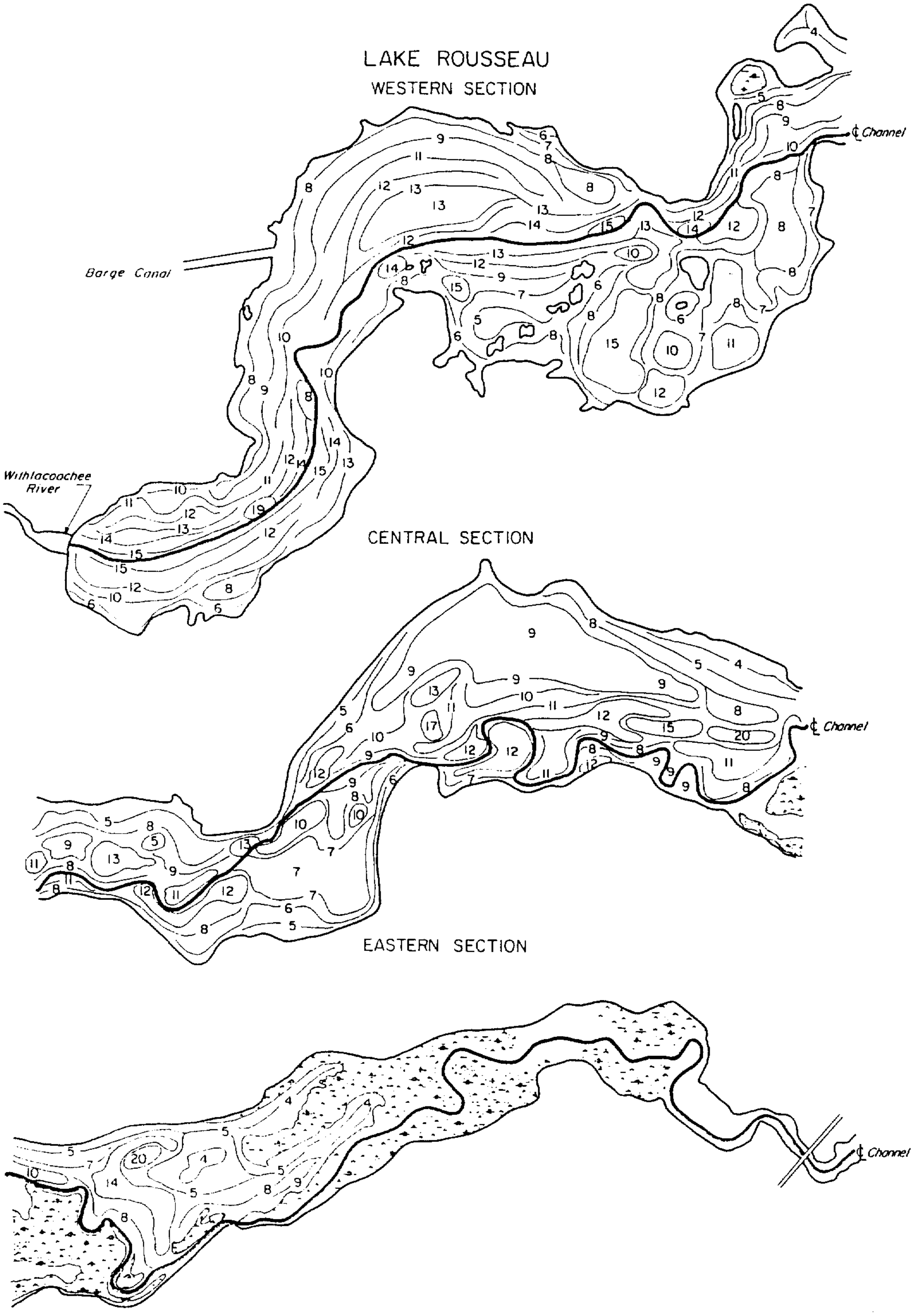


FIGURE 19 BOTTOM CONTOUR MAP OF LAKE ROUSSEAU AT 27.5 FEET. ADAPTED FROM FG & FWFC, 1978.

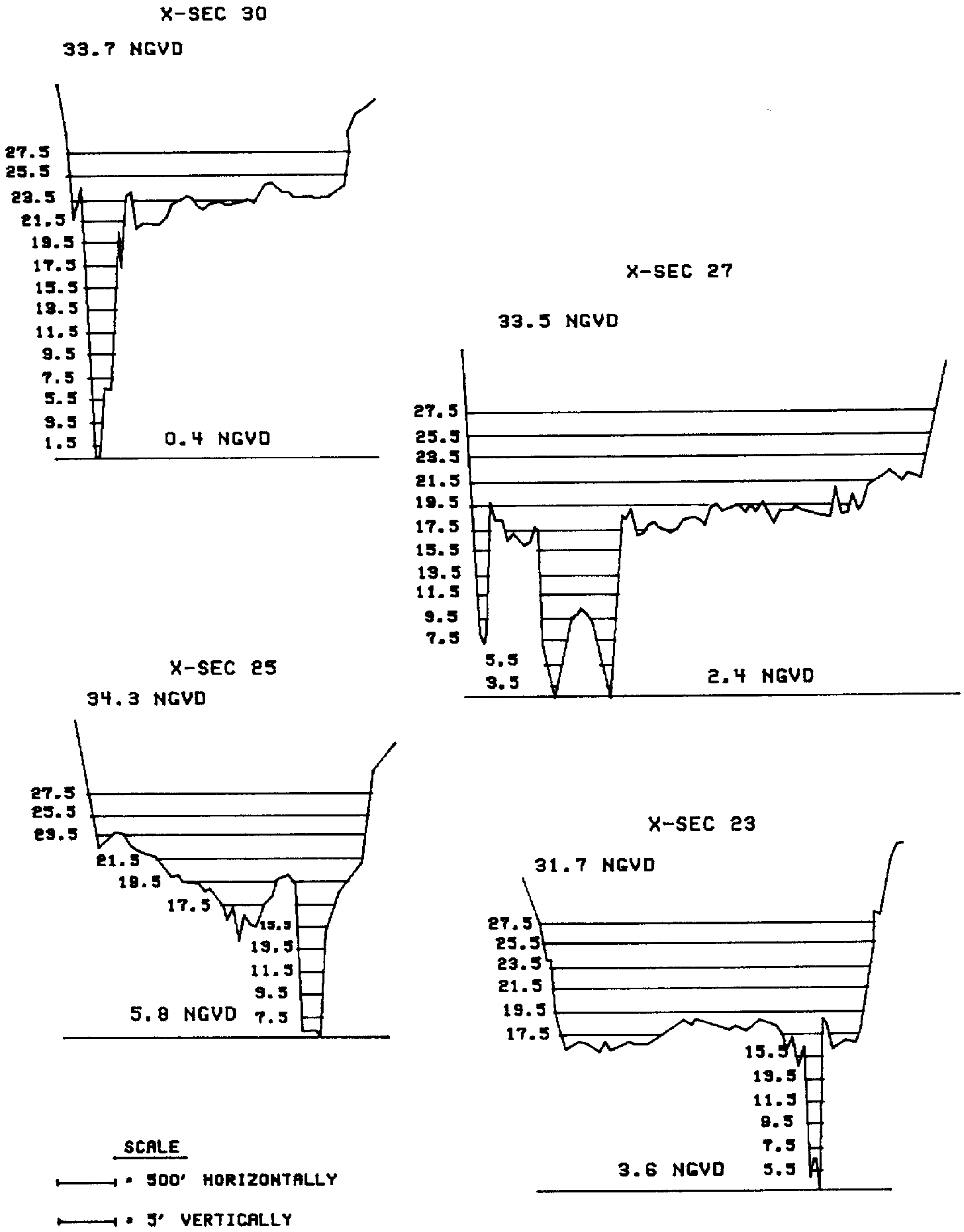


FIGURE 20 LAKE ROUSSEAU CROSS SECTIONS

become established. Much of the remaining shallow areas are densely populated with submersed aquatic plants such as hydrilla or coontail. As previously discussed, the dense vegetation in the shallow zones greatly reduces wave energy, vertical mixing and lateral circulation.

The deeper portions of the reservoir extend in a narrow longitudinal band corresponding to the old river channel. Compared to the total reservoir width this band is very narrow, generally from 150 to 475 feet wide. This deep channel ranges in depth from 10 to 30 feet. Because of the water depth, rooted aquatic plants have not become widely established in the channel allowing for greater mixing and circulation.

Residence Times

Because it is an impounded river, water flows through Lake Rousseau at a much greater rate than is found in most natural lakes. The time that it takes for the volume of a lake or reservoir to be replaced by inflowing water is termed the residence time. High inflow rates and small volumes give short residence times while low inflow rates and large volumes give long residence times. Residence time is a conceptual average value, as some water may be trapped or recirculated within the reservoir and not actually replaced during the residence period.

Residence time is an important physical characteristic, particularly in reservoirs where there is a transition from a riverine to a more lake-like system. If residence time is very short, water quality may retain its riverine characteristics. Relatively high flow rates can mix surface and bottom waters and water may move through the system quickly enough that phytoplankton populations do not grow to their full potential. In Walker's (1982) model of reservoir eutrophication, residence time is inversely related to algal biomass.

Because of the large flows into the reservoir from the Withlacoochee River and the relatively small volume of water impounded, average residence times of water in Lake Rousseau are low. Residence times calculated for five levels of reservoir inflow are listed in Table 15. These inflow levels were selected from a duration analysis of total reservoir outflows (see Figure 4) and correspond to flows exceeded between 99 percent and 10 percent of the time.

Table 15. Residence Times for Lake Rousseau Corresponding to Selected Levels of Streamflow

Flow (cfs)	Percent Time Flow Exceeded	Residence Time (days)
510	99.9	23.8
766	90	15.8
970	75	12.5
1,250	50	9.7
1,670	25	7.3
2,280	10	5.3

The reservoir volume used for residence time calculation is that region of the reservoir 1.5 miles downstream from Dunnellon. At a flow of 766 cfs, which is exceeded 90 percent of the time, the average residence time is 15.8 days. The residence time corresponding to the median inflow is 9.7 days, while the residence time for the 10 percent exceedance inflow is 5.3 days. Therefore, eighty percent of the time the average residence time for Lake Rousseau is between 5.3 and 15.8 days. Because of the substantial baseflow from Rainbow Springs, the longest residence time calculated for the reservoir from daily discharge values for the period 1971-1985 was only 26 days.

It is emphasized that these residence time values are average numbers and the rate of water exchange in Lake Rousseau must vary considerably in different areas of the reservoir. Due to the abundance of stumps, tussocks and submersed vegetation, water circulation is restricted in many off-channel areas and residence times for these areas must be considerably longer. Conversely, in the unvegetated zones of the old river channel, water is exchanged more rapidly than the average residence time. To some extent, Lake Rousseau functions as two water bodies. In the shallow vegetated areas where water exchange is low, local processes such as photosynthesis, respiration, sediment-water nutrient exchange and planktonic nutrient cycling are probably important factors influencing water chemistry. In the deep channel areas, the fast rate of flushing lessens the influence of these factors, and the quality of inflowing river water becomes more important in determining water quality.

Because of the relatively short average residence times in Lake Rousseau, phytoplankton production in the channel may be somewhat limited given the moderately high level of nutrients. Nutrient-chlorophyll data for the lake are limited to 15 samples collected by the District and Canfield (1981) on six separate dates. These values ranged from 0.4 to 23.5 ug/l and averaged 7.0 ug/l. Although the higher values indicate substantial phytoplankton populations, observed chlorophyll values have not reached the excessive levels found in many Florida lakes.

For the three 1987 samples, chlorophyll values for the shallow vegetated site were similar to the channel site. The off-channel area station 3, like much of the shallow areas, was characterized by dense macrophytes, abundant periphyton, and organic sediments, which are indicative of eutrophic lakes. In the shallow off-channel areas, longer residence times should theoretically increase phytoplankton populations, but other factors such as nutrient competition from macrophytes and periphyton may also be important and counteract this effect.

Aquatic Macrophytes

In addition to affecting mixing and circulation in Lake Rousseau, aquatic macrophytes play a major role in the cycling of nutrients and organic matter within the reservoir. The extensive stands of aquatic vegetation in the reservoir represents an enormous pool of nutrients and organic matter. Through the processes of growth, uptake, excretion, senescence and decay, these macrophytes and their associated attached algae continually recycle nutrients among the water, sediments, and their own tissues.

It is difficult to generalize what overall effects the abundant macrophyte assemblage has had on nutrient concentrations in Lake Rousseau. The processes involved in nutrient cycling by aquatic plants are complex, and the magnitude of various processes vary throughout the year. In the spring and early summer when aquatic plant growth is high, the macrophyte assemblage may act to reduce nutrient concentrations in Lake Rousseau. During late fall and winter, when senescence and decay are high, there is probably a net loading of nutrients to the water column. However, senescence and the sloughing off of tissues from growing plants are continual processes and can be important in the summer and other seasons depending on factors such as light penetration, cold snaps, or the presence of any inhibitory compounds. Certainly, the application of herbicides causes extensive decay of plants and the release of nutrients.

Regardless of whether nutrient uptake or release is predominant, intense nutrient cycling occurs throughout the year in the shallow weeded areas of Lake Rousseau. Because of the quick residence time of water in the channel areas, the effects of nutrient cycling in littoral areas may generally not be apparent there. However, large periodic phenomena such as a massive plant die-back might significantly affect water quality in the channel areas. In the shallow areas where the exchange of water is low, the macrophyte assemblage probably has profound short-term and seasonal effects on water chemistry.

Another important function of the extensive macrophyte community in Lake Rousseau has been the retention of organic matter within the reservoir. In contrast to phytoplankton which are transported by water currents, the organic production in macrophyte beds is essentially fixed in place throughout a growing season. Because of the reduced circulation in the macrophyte beds, sedimentation is probably higher there than in the channel areas where circulation and downstream transport are greater. Hypothetically, if the equivalent organic production of the macrophyte beds in Lake Rousseau was incorporated into phytoplankton, a much higher percentage of the biomass would be transported out of the reservoir. As discussed in the aquatic plant section, plant communities in Lake Rousseau are undergoing rapid succession with emergent marshy areas and tussocks more widespread. The retention of organic matter in the reservoir by the macrophyte community helps speed this process. Any management technique that significantly reduces the coverage and biomass of macrophytes in the reservoir might help slow the accelerated rate of succession in Lake Rousseau.

The organic matter produced and retained in the macrophyte beds also affects oxygen concentrations and exchange rates in large areas of the reservoir. Respiration by the large populations of macrophytes and periphyton can exert considerable oxygen demand. At night or during extended cloudy periods, this respiration can significantly lower dissolved oxygen concentrations. Also, the large amounts of detritus that are produced in these areas can be microbially oxidized creating high biological oxygen demand. This detritus may be suspended in the water column or settle out to the sediment surface, where oxygen consumption is generally high. The effects of aquatic macrophytes on reducing vertical mixing and inducing thermal stratification has been previously described. Under prolonged stratification, oxygen consumption in the water column and at the sediment/water interface can markedly reduce dissolved oxygen concentrations in bottom waters.

Influence of Sediments on Water Quality

The sediments in Lake Rousseau probably have an important influence on the reservoir's water quality. As discussed in the

Sediments section of this report, many of the sediments in the reservoir have high water and organic content. Although nutrient analyses or various other tests were not performed on the sediments, the potential effects of these sediments on nutrient cycling and oxygen concentrations are discussed below.

Because of the sediments' high organic content, sediment oxygen demand is expected to be high. The rate of oxygen consumption is probably highest in summer months due to warm water and sediment temperatures. High sediment oxygen demand can have a significant effect on D.O. concentrations, particularly combined with thermal stratification when the aeration of bottom waters is restricted. As discussed in the results for temperature, reduced vertical mixing and thermal stratification occur most often in the macrophyte beds, so this is probably where sediment oxygen demand is the greatest problem.

The high water and organic content of the reservoir's sediments probably affects their potential to recycle nutrients to the water column. The factors controlling sediment/water nutrient exchange are complex, and many variables can affect this relationship. Because of the flocculent organic nature of Rousseau sediments, two general mechanisms; diffusion across concentration gradients and sediment resuspension may be particularly important in this system.

The water that is contained between the solid particles in a sediment is termed interstitial water. This interstitial water may be very high in nutrients resulting form the diagenisis (breakdown) of the solid fraction. When interstitial concentrations are greater than concentrations in the overlying water, a diffusion gradient is established and there is a tendency for nutrients to be released to the overlying water (Wetzel, 1975). Important factors controlling this exchange are oxygen concentrations and the oxidation-reduction potential at the sediment/water interface. When oxygenated conditions are found at the sediment/water interface, many constituents such as phosphorous and certain metals are adsorbed onto sediment particles, thus reducing sediment-water exchange. Conversely, when anoxic conditions are found at the sediment/water interface, many constituents are more mobile and exchange rates are higher. Therefore, in Lake Rousseau it is expected that the release of phosphorus from the sediments is highest in the weeded areas during periods of low bottom dissolved oxygen concentrations. The diffusion of nutrients from the sediments to the water in Lake Rousseau is also probably related to the sediments' high water content. The mobility of constituents in the interstitial water of this loose, flocculent medium might be greater than in a drier, more compact sediment where the solid matrix is more dense and the water content is lower.

Another important mechanism for sediment nutrient release is sediment resuspension. This is a problem particularly in broad, shallow lakes where there is sufficient wave energy to resuspend bottom sediments. Also, the compactness and weight of the sediments are important factors affecting their potential for resuspension. Because of their loose flocculent nature, the surficial sediments in Lake Rousseau might easily be resuspended providing there was sufficient wave energy and turbulence.

MANAGEMENT STRATEGIES FOR WATER QUALITY IMPROVEMENTS

The water chemistry of Lake Rousseau is dominated by the Withlacoochee River, which is the overwhelming source of external nutrient loading to the reservoir. Because the river is largely unpolluted, there are currently no restorative measures which would significantly reduce nutrient loading to Lake Rousseau. At present, management strategies for water quality improvements in Lake Rousseau have to center on internal factors and processes within the reservoir.

If achievable, large reductions in macrophyte coverage and biomass in the reservoir would have beneficial effects on water quality. These benefits would result from reduced shading by macrophytes and increased circulation and mixing in the shallow reaches of the reservoir. Improvements in water quality, particularly light penetration, vertical mixing, and dissolved oxygen concentrations may be realized if the areal extent of both the "topped out" hydrilla and the tussocks can be significantly reduced.

In the past, both chemical (herbicides) and mechanical methods have been used for aquatic plant control in Lake Rousseau. In 1987, the USACOE assumed full direct supervision of the aquatic plant control program for the reservoir. The USACOE has extensive experience and expertise in the field of aquatic plant control and it is not the objective of this report to provide detailed specifics of how either chemical or mechanical plant control should be done. However, some suggestions regarding aquatic plant control methods and the water quality of the reservoir are provided. An important consideration for any aquatic plant control technique is the possible oxygen consumption and nutrient release by decaying plant tissue. This is particularly important for chemical weed control where there can be rapid decay of large amounts of plant biomass after a herbicide treatment. As in the past, caution will have to be used so that herbicide treatments do not interact with climatic conditions and other factors to induce algal blooms or low dissolved oxygen concentrations. Secondly, plant control efforts should try to reduce adjacent continuous stands of vegetation to improve circulation in the off-channel areas of the reservoir. For instance, where vegetation has been cleared near a shoreline, the zone between that shoreline and the channel should also be cleared to facilitate the flow of water through that area. Increasing flow will lessen the chances of low dissolved oxygen problems after aquatic plant control treatments, and generally improve water quality. Because of cost considerations, it is likely that aquatic plant control can be done only in parts of Lake Rousseau. Where practical, continuous areas of the reservoir should be identified where aquatic plant control would significantly improve flow and circulation in that part of the reservoir.

In addition to chemical plant control methods, two management techniques affecting the physical structure of the reservoir should be strongly considered. These management techniques are the cutting and removal of stumps for control of floating vegetation and tussocks, and the fluctuation of reservoir water levels including extreme drawdown. The abundant stumps in the reservoir play an important role in the formation and growth of tussocks and a program of stump cutting and removal would help alleviate this aquatic plant problem. Again, for cost considerations, it may be practical to only remove stumps from portions of the reservoir, and these areas should be prioritized. Secondly, stump removal might be more feasible if done during a drawdown of the reservoir. Greater elaboration on the potential removal of stumps is provided in a subsequent section of this report titled, <u>Stump Cutting and Removal During Drawdown</u>.

Establishing the capacity to fluctuate water levels, including extreme drawdown, should be considered for Lake Rousseau. Observations and results throughout the state indicate that some level of stage fluctuation benefits lakes and reservoirs (see reviews on pages 217-221 and 250-251). Periodic extreme drawdown to an elevation of 18 feet would reduce accumulated submersed macrophyte biomass and provide at least some temporary hydrilla control after refilling. Extreme drawdown should reduce the size and vigor of the tussocks, and if combined with stump removal, significantly improve this aspect of the reservoir. Greater detail regarding the various aspects of extreme drawdown are provided later in this report. Lesser seasonal fluctuations of water levels (1-3 feet) might also improve conditions in the reservoir, but development of a seasonal fluctuation plan will involve several important considerations (see section titled <u>Seasonal Fluctuations</u>).

Extreme drawdown would also be extremely valuable for compacting the flocculent organic sediments in the reservoir. Sediment drying and compaction should reduce the potential for sediment resuspension and sediment oxygen demand. Also, the release of nutrients from sediment interstitial water might be reduced if the sediments were drier and more dense.

Because of the high plant biomass and accumulation of organic sediments in the reservoir, extreme drawdowns would be necessary to achieve maximum water quality benefits. Seasonal water level fluctuations, if implemented, should be a supplement to extreme drawdown. Due to the limited discharge capacity of the bypass channel and spillway, structural modifications would be necessary if any significant water level fluctuation capabilities are to be achieved. Greater elaboration regarding the feasibility, benefits, and costs of establishing water level fluctuations in Lake Rousseau is presented later in this report.

RESERVOIR OUTFLOW CHARACTERISTICS AND FRESH-WATER FLOW REQUIREMENTS OF THE WITHLACOOCHEE RIVER ESTUARY

INTRODUCTION

The implementation of any management plan that affects the outflows from Lake Rousseau must take into consideration the fresh-water inflow needs of the downstream ecosystems. As discussed in the Introduction of this report, water is released from Lake Rousseau at three points: 1) The bypass spillway, 2) the Inglis Dam, and 3) small outflows associated with operation of the Inglis Lock (see Figure 2). Waters released through the Inglis Lock or Dam flow into the barge canal, although releases from Inglis Dam flow through 1.1 miles of the old river channel before reaching the canal. Conversely, outflows from the bypass spillway empty into the natural channel of the lower Withlacoochee River eleven miles above it's mouth at the Gulf of Mexico.

At the Gulf, near the mouths of both the lower river and barge canal, there exists a large estuary where salt water from the Gulf mixes with fresh waters from these two sources. This estuary is characterized by brackish water of low to moderate salinity. Depending on winds, tides, gulf circulation, and the level of fresh-water inflows, brackish water is distributed up into the lower river and barge canal and out on the adjacent areas of the Gulf. The coastal estuary associated with the Withlacoochee drainage is a highly productive aquatic habitat which supports large and economically important sport and commercial fisheries. The timing and volume of fresh-water inflows to the lower Withlacoochee River are major factors controlling biological productivity in the estuary. Similarly, due to its close proximity to the river, the barge canal is an important part of the Withlacoochee estuarine system.

The ecology and fresh-water inflow needs of the estuarine portion of the lower river and the adjacent areas of the Gulf have been recently studied by the SWFWMD in collaboration with Mote Marine Laboratory. Data collection and much of the analyses for that study have been completed and the final report is in preparation. That report will contain elaboration on the ecology of the lower Withlacoochee estuarine system. As supporting information, a brief discussion of the findings from that study regarding salinity distributions is presented here.

Based largely on the preliminary findings of the SWFWMD/Mote Marine study and historical outflow records for the reservoir, recommendations are presented for outflow requirements for operation/management plans that affect fresh-water outflows from Lake Rousseau. These outflow recommendations are formulated to provide for the ecological health of the downstream river and estuarine ecosystems while allowing water level fluctuations or the physical manipulation of the reservoir. Also, the possible enhancement of estuarine productivity is discussed as it pertains to operational (flow release) schedules for the barge canal which could be implemented if modifications to the existing structures on Lake Rousseau are pursued.

To assess the relationships of outflows from Lake Rousseau to the ecology of downstream areas, the current operating schedule for reservoir outflows should first be described. Also pertinent to this topic are the seasonal and pre-1970 flow characteristics of the lower Withlacoochee River. December, 1969 represents the completion of the barge canal facilities and implementation of the current reservoir operating schedule. Accordingly, the pre-1970 and recent flow characteristics of the releases from Lake Rousseau are described below. After that discussion follows a brief description of salinity distributions and the role of fresh-water inflows in the Withlacoochee River estuary. Finally, recommendations for outflows from Lake Rousseau are presented.

PRE-1970 AND RECENT FLOW CHARACTERISTICS OF OUTFLOWS FROM LAKE ROUSSEAU

Before the construction of the hydroelectric dam in 1909 the Withlacoochee River flowed to the Gulf unaffected by any structural controls. The old hydroelectric dam, located at the site of the current Inglis Dam, released water to the lower

Withlacoochee River which from there flowed uninterrupted to the Gulf. This impoundment of the river probably caused slight decreases (7-10% of average flows) in flow to the lower river in two ways; 1) evaporative losses were increased due to the large reservoir surface area, and, 2) recharge to the ground water near the reservoir was increased due to greater head differences. Although these factors represented a net loss of water from the reservoir they probably had little impact on the seasonality of flows to the lower river. Operation of the hydroelectric plant did not directly cause any net reduction in flows. In sum, between 1909 and completion of the barge canal facilities in 1969, releases from Lake Rousseau flowed to the Gulf through the natural channel of the lower Withlacoochee River in basically unaltered seasonal cycles.

Completion of the barge canal and its associated structures on Lake Rousseau changed the pattern of outflows from the reservoir. The current operating schedule and the physical constraints of the structures require that most of the flows below 1,540 cfs go through the bypass channel and spillway to the lower Withlacoochee River. The maximum effective capacity of the bypass spillway at normal reservoir stage is 1,540 cfs, so flows above that amount are diverted through the Inglis Dam to the barge canal. Many times, flows are diverted through Inglis Dam when discharge through the bypass spillway reaches approximately 1,450 cfs. Three other less important schedules for reservoir outflows also occur: 1) Periodic operation of the Inglis Lock releases small amounts of water to the barge canal; 2) During extended periods when flows are less than 1,540 cfs, 200 cfs is periodically released at Inglis Dam to facilitate flushing in the western end of the reservoir; and, 3) When flooding is anticipated along the Withlacoochee River, the reservoir is temporarily lowered by as much as 3.5 feet, thus reducing flows through the bypass spillway with the excess water discharged at the Inglis Dam.

The current operating schedule for Lake Rousseau has changed the streamflow characteristics of the lower Withlacoochee River from pre-1970 conditions. Whereas, all flows formerly went down the river channel, maximum flows in the lower river are now restricted to 1,540 cfs. Figure 21 is a synthesized flow duration curve for the total outflows from Lake Rousseau for the period 1971-85. This synthetic curve was generated from the sum of daily flows from the bypass spillway and Inglis Dam. Theoretically, this curve represents the duration that daily flows would have been exceeded in the lower river during this period if no water was diverted to the barge canal. In this flow release scenario, flows above 1,540 cfs would have occurred in the lower river about 31% of the time. The maximum daily flow during this period was near 5,000 cfs, but these extremely high flows are uncommon as total outflows above 3,000 cfs were exceeded approximately four percent of the time.

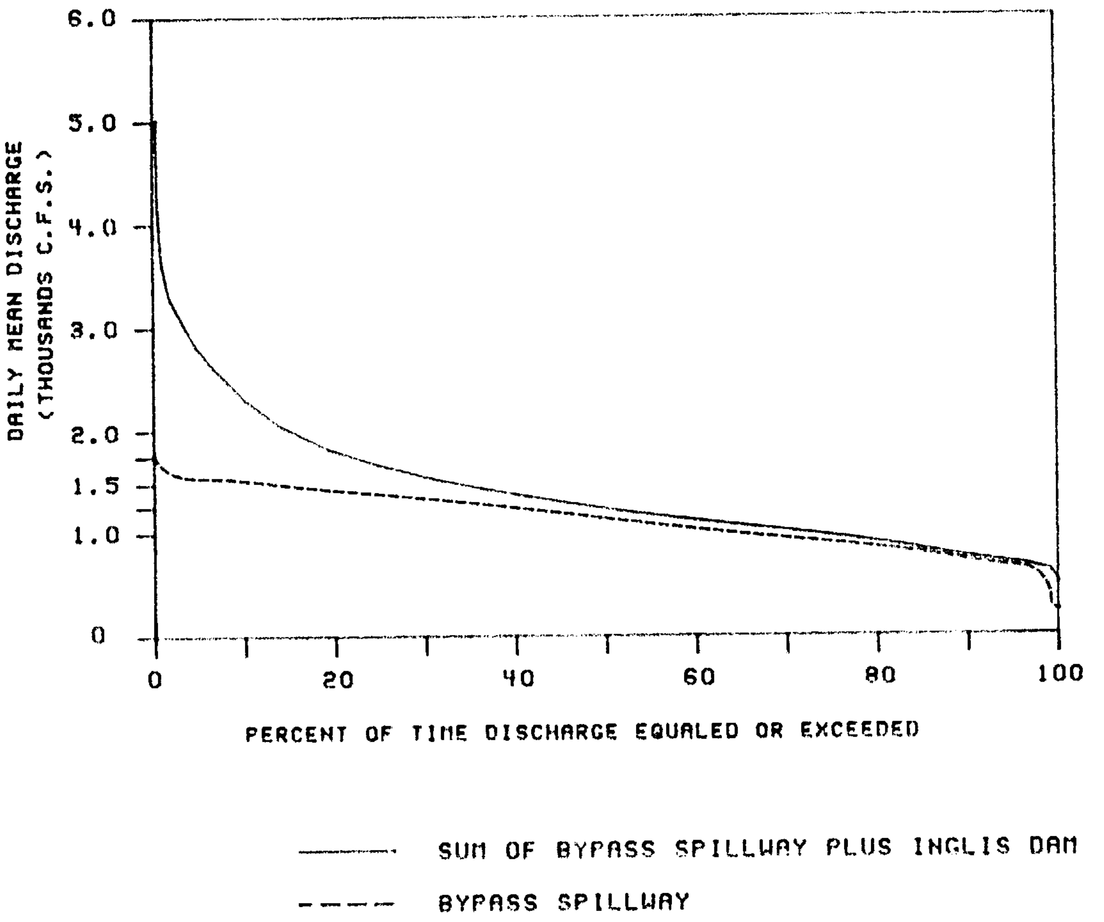


FIGURE 21 FLOW DURATION CURVES FOR THE BYPASS SPILLWAY AND THE SUM OF FLOWS THROUGH THE BYPASS SPILLWAY AND THE INGLIS DAM FOR 1971-1985

Also displayed in Figure 21 is the duration curve for outflows through the bypass spillway for this same period (1970-1985). The similarity of the two duration curves at discharges less than 1,540 cfs demonstrates that low and medium flows in the lower river have been largely unaffected by the barge canal even though the reservoir has been drawn down on occasion for flood control, reducing the flow to the lower river. For approximately 69% of the time (when total flows were less than 1,540 cfs), flows in the lower river were close to what they would have been under pre-1970 conditions. A hydrograph of monthly outflows through the bypass spillway for the period 1978-1986 is shown in Figure 22. Compared to many other Florida rivers, this hydrograph of monthly values is relatively smooth. This is because the lower river receives substantial baseflow from Rainbow Springs and high outflows through the bypass spillway are held near 1,540 cfs.

Compared to flows in the lower Withlacoochee River, flows in the barge canal from releases at Inglis Dam are much more sporadic and cover a wider range of values. The USGS (1985) reports a flow of 70 cfs for springs located just below the Inglis Dam. This value can be considered as baseflow to the barge canal at that gaging station. A flow duration curve for the Inglis Dam site is shown in Figure 23. This figure shows that for much of the time flows at the Inglis Dam gaging station are comprised mainly of the spring discharge. For instance, discharge values

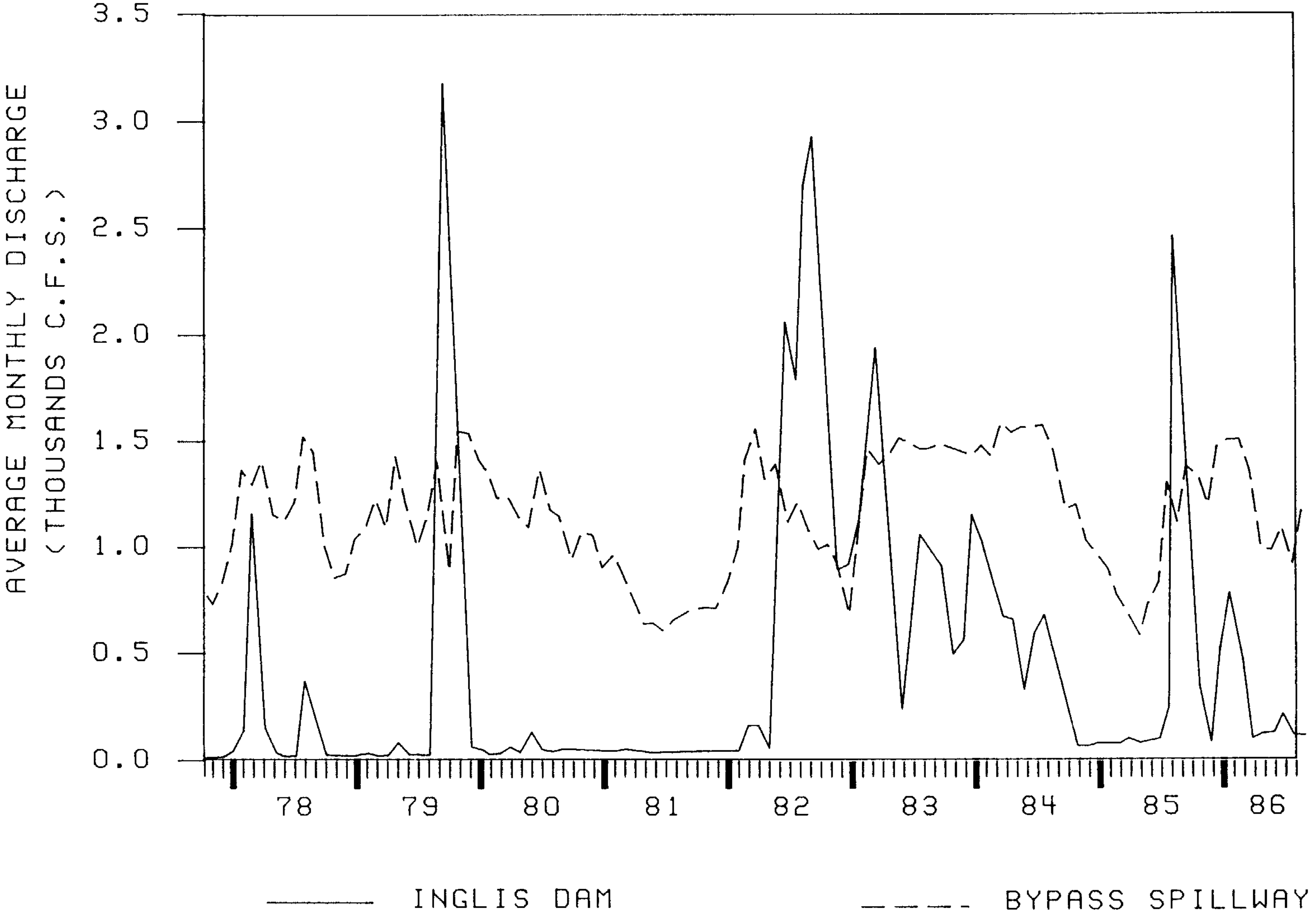


FIGURE 22 MONTHLY FLOWS FOR THE BYPASS SPILLWAY AND INGLIS DAM FOR OCTOBER 1977 TO SEPTEMBER 1986.

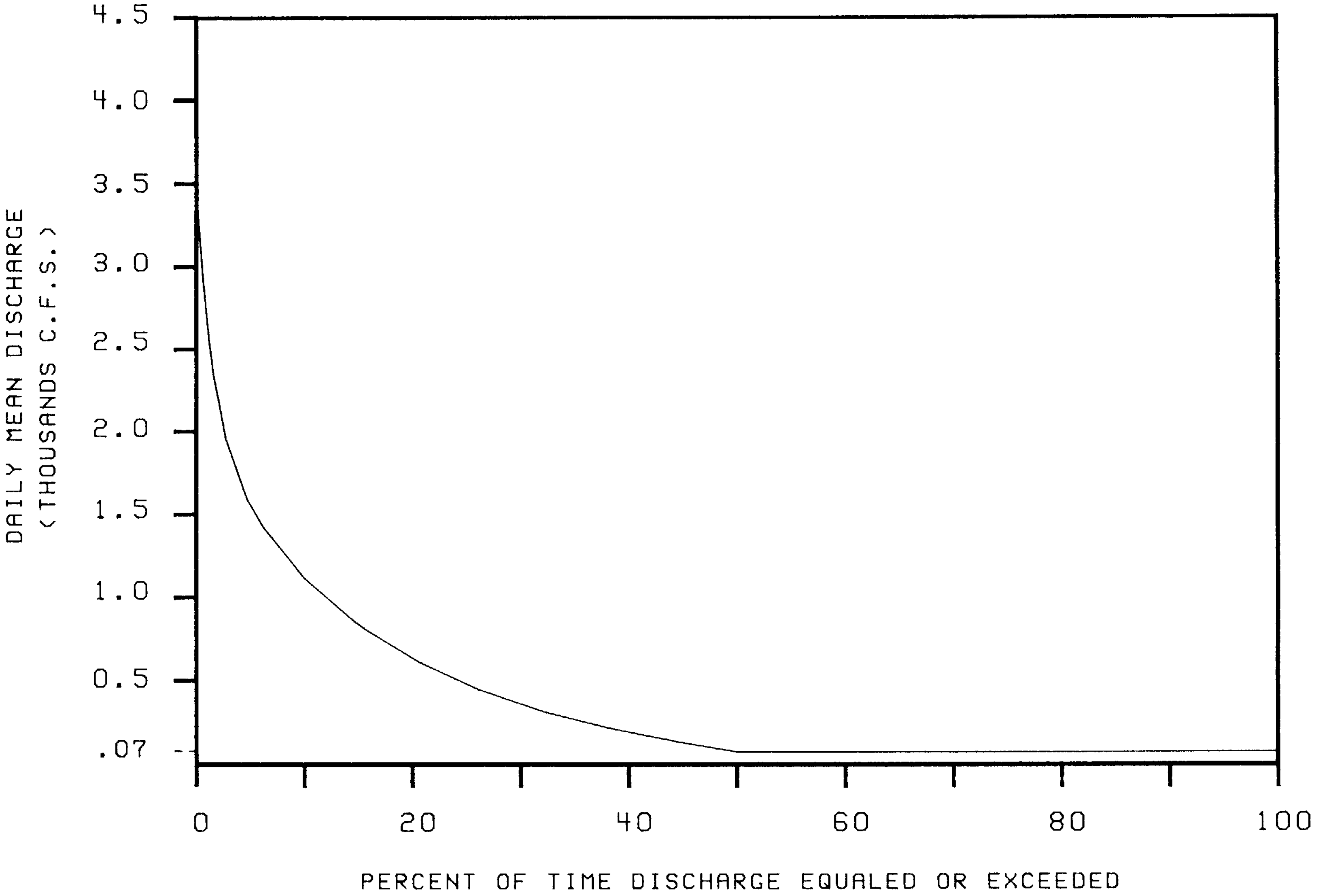


FIGURE 23 FLOW DURATION CURVE FOR THE INGLIS DAM GAGING SITE FOR 1971-1985

above 79 cfs were exceeded only fifty percent of the time while flows above 100 cfs were exceeded forty percent of the time. Discharge values above the 70 cfs spring discharge represent outflows from Lake Rousseau. These outflows through the dam vary greatly in magnitude, ranging from small releases (<100 cfs) to a maximum daily value of 4,500 cfs recorded in 1979. Outflows at Inglis Dam equaling or exceeding the maximum discharges to the lower river (1,540 cfs) occurred approximately five percent of the time during the period of record (1970-1985).

The periodic release of high flows at the Inglis Dam following periods of primarily spring-fed baseflow yields hydrographs for this site which show extreme seasonal fluctuations. In Figure 22, monthly discharges at the dam are plotted for the period 1978-1986. In 1979, 1982, and 1985, prolonged periods of low discharge (<100 cfs) were followed by abrupt peaks of over 1000 cfs in the late summer. This type of seasonal fluctuation is shown in more detail in Figure 24, where the hydrograph of daily values for the 1985 water year is presented. For a ten-month period from November, 1984, to late August, 1985, daily flows at the dam were primarily 70 cfs with periodic pulses of 200 cfs released to flush the western end of the reservoir. Then, because of abundant wet season rainfall and the arrival of Hurricane Elena in early September, discharge at the Inglis Dam increased from 70 to 3560 cfs in a period of six days and averaged 2,430 cfs for the month of September. Due largely to high

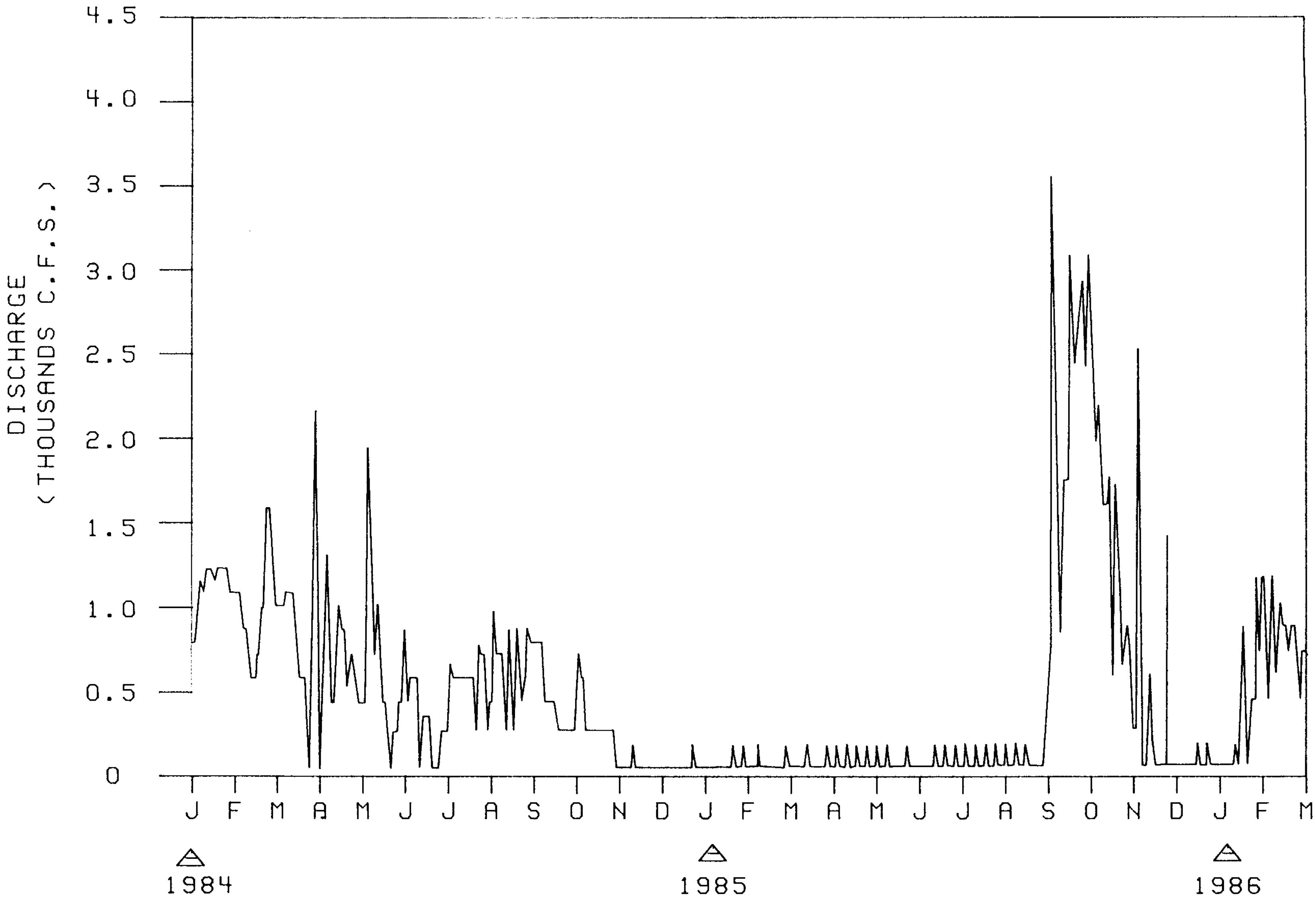


FIGURE 24 DAILY DISCHARGE FOR THE INGLIS DAM GAGING SITE FROM JANUARY 1984 THROUGH FEBRUARY 1986

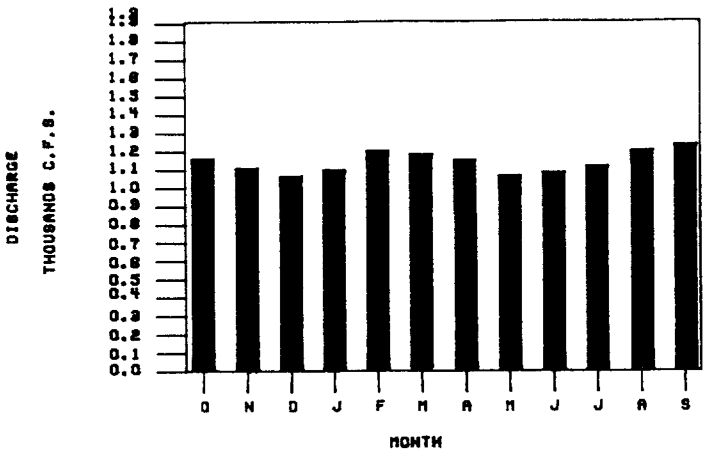
wet season flows such as this, mean annual flow at the Inglis Dam is substantial, averaging 423 cfs for the 1970-1985 period.

SEASONALITY OF FLOW

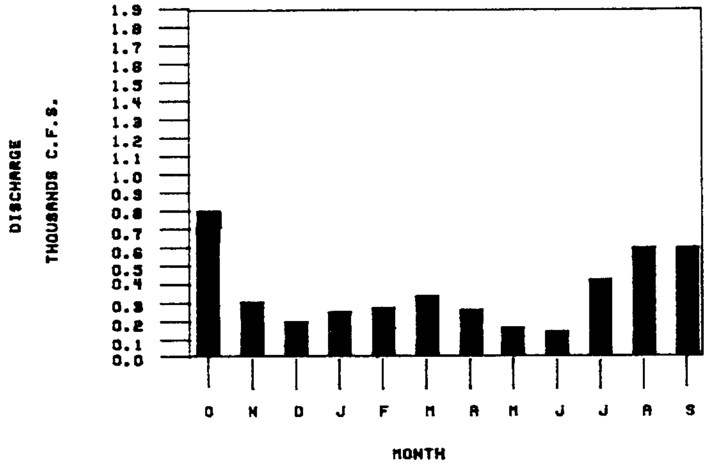
Flows into Lake Rousseau normally follow a seasonal pattern characteristic of west-central Florida streams. Streamflow levels are typically highest in the late summer, with a minor peak occurring in March. Low flows normally occur during the late fall, and especially the late spring or early summer (May or June). However, because of the steady inflow of water from Rainbow Springs, dry season flows are substantial and seasonal streamflow variation is somewhat reduced.

Average monthly flows for the bypass spillway, Inglis Dam, and the total outflow from Lake Rousseau are shown in Figure 25. Monthly flows for the bypass spillway show some seasonal pattern but the differences between dry and wet season flows are limited due to the diversion of high flows down the barge canal. Conversely, flows to the barge canal exhibit greater seasonal variation with monthly average flows ranging between 168 cfs for June and 806 cfs for October. Also shown in Figure 25 are the total outflows from Lake Rousseau. Seasonal variation for this hydrograph is intermediate between those for the bypass spillway and the Inglis Dam, and is representative of seasonal flows in the lower river before there were diversions to the barge canal.

A. BYPASS CHANNEL



B. INGLIS DAM



C. THE SUM OF BYPASS CHANNEL
AND INGLIS DAM

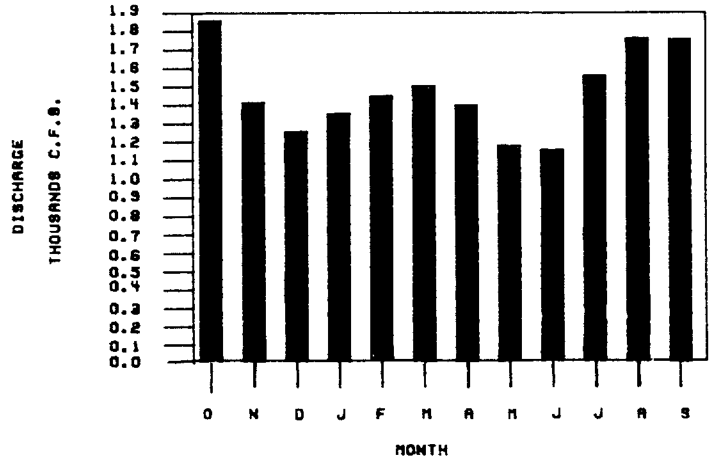


FIGURE 25 AVERAGE MONTHLY DISCHARGES: BYPASS SPILLWAY, INGLIS DAM, AND THE SUM OF THESE TWO STATIONS.

THE ROLE OF FRESH-WATER FLOWS TO THE WITHLACOOCHEE RIVER ESTUARY

The lower Withlacoochee River extends eleven miles from the outfall of the bypass spillway westward to the river mouth at the Gulf. Along its length the lower river progresses from a freshwater to an estuarine system. Estuaries by definition are coastal areas where there is a mixing of fresh and saline waters. In the estuary associated with the Withlacoochee River, a horizontal salinity gradient is established with lowest salinities usually found in the river channel some distance upstream from the river mouth. Salinity gradually increases in the river toward the Gulf and continues to increase at greater distances into the Gulf until salinity values approaching undiluted Gulf water are found. This horizontal gradient of salinity values is dynamic, changing in response to tidal, meteorologic, and streamflow conditions.

The presence of horizontal salinity gradients is one of the most important factors controlling biological structure and productivity in estuaries (Snedaker and DeSylva, 1977). Estuaries are transitional areas between fresh-water and marine systems, and plant and animal communities found there show distinct changes from low to high salinity areas. For instance, the break between fresh-water vegetation and saltmarshes on the lower Withlacoochee River is largely determined by the different salinities of waters flooding those communities on high tides. Certain organisms, such as the commercially valuable oyster, thrive in transitional salinity zones and are tolerant of large seasonal changes in salinity values (Bahr and Lanier, 1981). It has been shown that oyster bars suffer losses in productivity if salinity increases to high, stable levels (Stanley and Sellars, 1986).

One of the most important functions of fresh-water flow in maintaining salinity gradients is related to the utilization of estuaries as nurseries by many marine fish species. It has been estimated that 72-74% of the species comprising Florida's sport and commercial marine fisheries are dependent upon estuaries at some point in their life cycle (Durako et al., 1986). Based on poundage landed, estuarine dependent species comprise approximately 80-95% of the combined sport and commercial fisheries catch. For many estuarine dependent fishes, larval and juvenile life stages are especially tolerant of reduced salinities. These immature fish follow horizontal salinity gradients to low salinity areas where they feed upon abundant food sources and are less susceptible to predation (Snedaker and DeSylva, 1977; Comp and Seaman, 1986). Because low salinity estuarine habitats are important to the population dynamics of many marine species, the preservation of fresh-water inflows is one of the most important elements of good estuarine management (see Cross and Williams, 1981). In documented cases around the world, significant reductions in fresh-water inflows have resulted in marked reductions in fishery stocks (Aleem, 1972; Stevens and Chadwick, 1979). If existing levels of biological productivity in the Withlacoochee River estuary are to be maintained, management of the lower river including Lake Rousseau must account for fresh-water needs of the estuary for maintaining suitable salinity gradients and other ecological functions.

SALINITY DISTRIBUTIONS IN THE LOWER WITHLACOOCHEE RIVER

Salinity distributions in lower Withlacoochee estuary were investigated during 1984 and 1985 as part of the previously mentioned SWFWMD-Mote Marine Laboratory ecological study. During this same period, the USGS performed a study on the relationships of salinity to tide stage and streamflow in this same region (Yobbi, 1989). Data collected in both of these studies have identified salinity distributions in the Withlacoochee River estuary under a wide range of streamflow conditions. Although final reports for both of these studies are in preparation at the time of this writing, much of the analysis of salinity data has been completed. A very brief synopsis of some of these data is presented below in order to provide an overview of the salinity characteristics of the Withlacoochee River estuary.

Mean, minimum, and maximum values for average monthly salinity recorded on high tides by the District or Mote Marine Laboratory between January 1984 and February 1986 are listed by river mile in Table 16 and illustrated in Figure 26. A map of the estuary

Table 16. **Mean, Minimum, and Maximum High Tide Salinity Values (ppt.) for the Withlacoochee River Estuary for the Period January 1984 to February 1986.**

Mile	n	Mean	$S.D._{n-1}$	MIN	MAX
-4.73	18	27.55	3.03	21.08	31.98
-1.63	20	23.28	3.75	14.42	28.58
-0.68	22	20.11	4.14	10.33	25.41
0.00 (mouth)	24	15.38	5.04	3.63	22.17
0.27	24	14.10	4.98	1.57	20.74
0.47	20	12.05	4.19	1.33	16.96
1.00	22	11.27	5.53	0.06	18.56
1.42	23	8.58	5.09	0.03	16.84
1.85	23	5.93	4.45	0.02	13.11
2.32	21	3.31	3.53	0.05	10.91
2.64	23	1.94	2.77	0.02	7.61
2.96	22	1.14	2.05	0.02	5.49
3.45	19	0.35	0.87	0.02	3.41

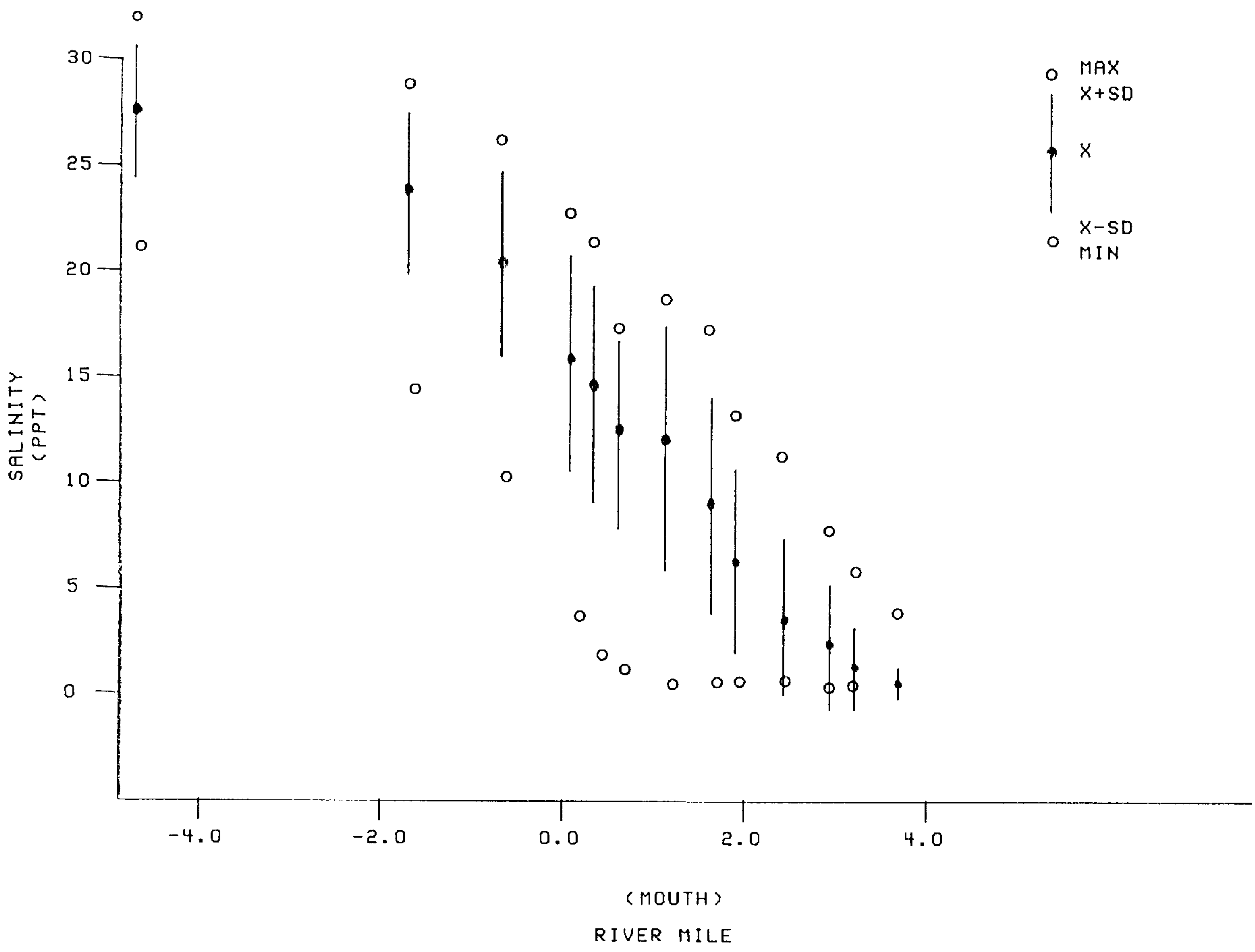


FIGURE 26 MEANS, STANDARD DEVIATIONS, MINIMA AND MAXIMA OF DEPTH INTEGRATED SALINITY VALUES FOR SELECTED LOCATIONS IN THE WITHLACOOCHEE RIVER ESTUARY, JANUARY 1984 TO FEBRUARY 1986.

delineating river miles and station locations is presented in Figure 27. Sampling points within the river were located at the middle of the river channel. Generally, a steep salinity gradient was found in the estuary, particularly upstream of the river mouth. High tide salinity averaged 27.5 ppt (parts per thousand) 4.7 miles into the Gulf, 15.4 ppt at the river mouth, and 1.1 ppt 2.96 miles upstream in the river channel. Salinity varied considerably at most stations, however, as the differences between minimum and maximum monthly salinity values at stations between 2.3 miles upriver and four miles offshore ranged between 10 and 19 parts per thousand.

Another way of depicting salinity distributions in the estuary is by locating selected salinity concentrations. The mean, minimum, and maximum locations of selected salinity concentrations during the study are listed in Table 17. Locations are listed separately for surface and bottom values as the estuary was usually stratified at high tide when the measurements were taken. Because of density differences, there was incomplete vertical mixing of river and gulf waters at most stations, resulting in bottom salinities being considerably higher than surface values.

During these studies, the distribution of salinity values in the estuary responded to changes in fresh-water inflow. General relationships existed where as fresh-water inflow increased, salinity at fixed stations decreased and salinity concentrations

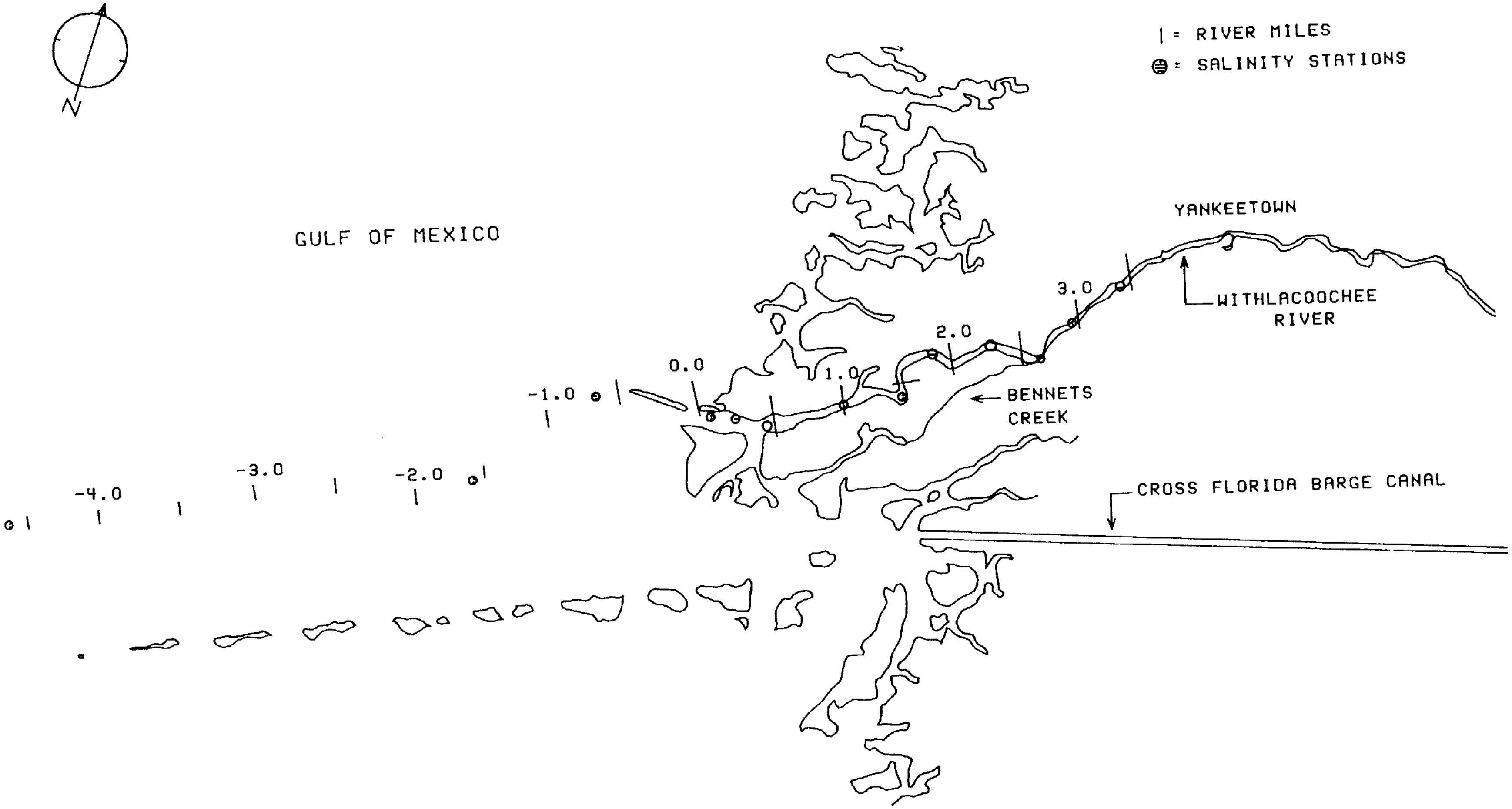


FIGURE 27 RIVER MILES AND SALINITY STATIONS ON THE WITHLACOOCHEE RIVER ESTUARY.

Table 17. Mean, Minimum and Maximum Locations (River Miles) of Selected Salinity Concentrations (ppt.) for Surface and Bottom Waters in the Withlacoochee River Estuary Recorded Between January 1984 and February 1986.

	SURFACE					BOTTOM				
PPT	n	x	S.D.$_{n-1}$	MIN	MAX	n	x	S.D.$_{n-1}$	MIN	MAX
1	21	1.73	0.77	-0.05	2.75	22	2.57	0.85	0.70	3.97
2	21	1.40	0.80	-0.20	2.50	22	2.45	0.89	0.40	3.87
5	21	0.87	0.82	-0.50	2.15	22	2.22	0.89	0.15	3.67
10	21	0.33	0.74	-1.10	1.62	22	1.77	1.01	-0.50	3.02
15	21	-0.22	0.78	-2.35	1.05	21	1.06	1.13	-1.55	2.47
20	21	-1.22	1.19	-4.35	0.30	21	-0.32	1.39	-3.90	1.52
25	15	-2.52	1.03	-4.05	-0.60	15	-1.56	1.08	-3.45	0.30
30	2	-3.50	0.71	-4.00	-3.00	4	-2.80	1.12	-4.25	-1.55

moved downstream or further into the Gulf. This basic relationship is shown in Figure 28, where two-dimensional plots of salinity are illustrated for dates which correspond to high, medium, and low flow periods. Fresh-water inflow, however, is not the only factor affecting salinity distributions in the Withlacoochee estuary, as tides and winds can have major effects on salinity. Consequently, fresh-water inflow explained only part of the observed variability in salinity distributions, and other factors caused considerable scatter in this relationship. Despite these sources of variability, statistical tests supported the validity of the causal relationship between fresh-water inflow and salinity. Discussed below are the results from multiple regression analyses examining the effects of fresh-water inflow and tides on the location of selected salinity concentrations, and on salinity values at fixed stations.

In Figure 29, the location of three salinity concentrations are plotted versus discharge from the bypass spillway. These salinity concentrations are the 0.5 ppt for surface and bottom waters, and the 5.0 ppt concentration for bottom waters. The 0.5 ppt concentration can be considered the edge of the salt-water/ fresh-water interface. As shown in Figure 29, salinity concentrations moved downstream as fresh-water inflow increased. There is considerable scatter in the data, however, and much of this was due to differences in tide stage. Although all measurements were taken on slack high tides, these high tides

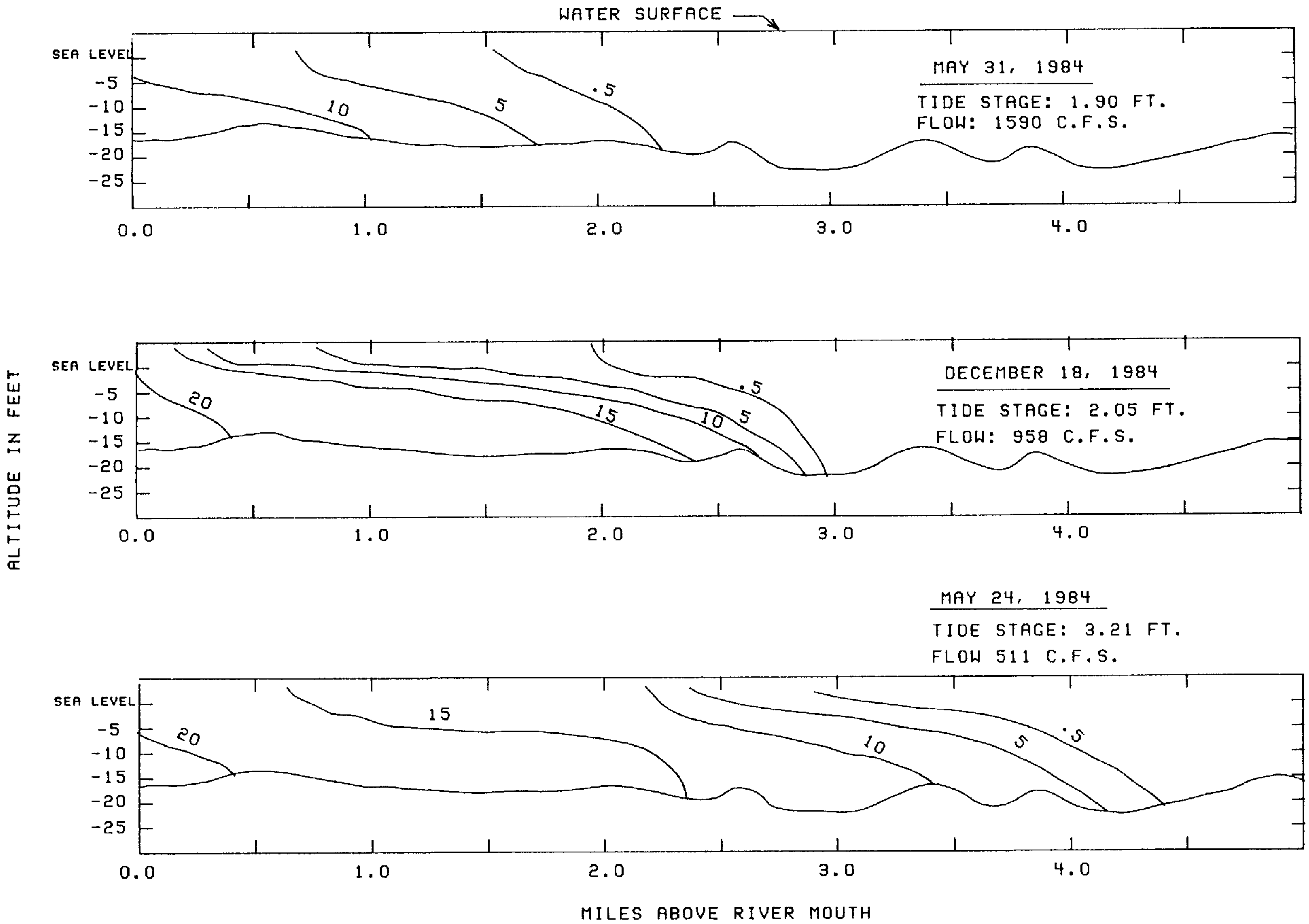


FIGURE 28 TWO DIMENSIONAL SALINITY PROFILES FOR THE 0.5, 5, 10, 15, AND 20 PPT. SALINITY CONCENTRATIONS IN THE WITHLACOOCHEE RIVER ESTUARY FOR VARIOUS FLOW AND HIGH TIDE CONDITIONS.
(reprinted from Yobbi, 1989)

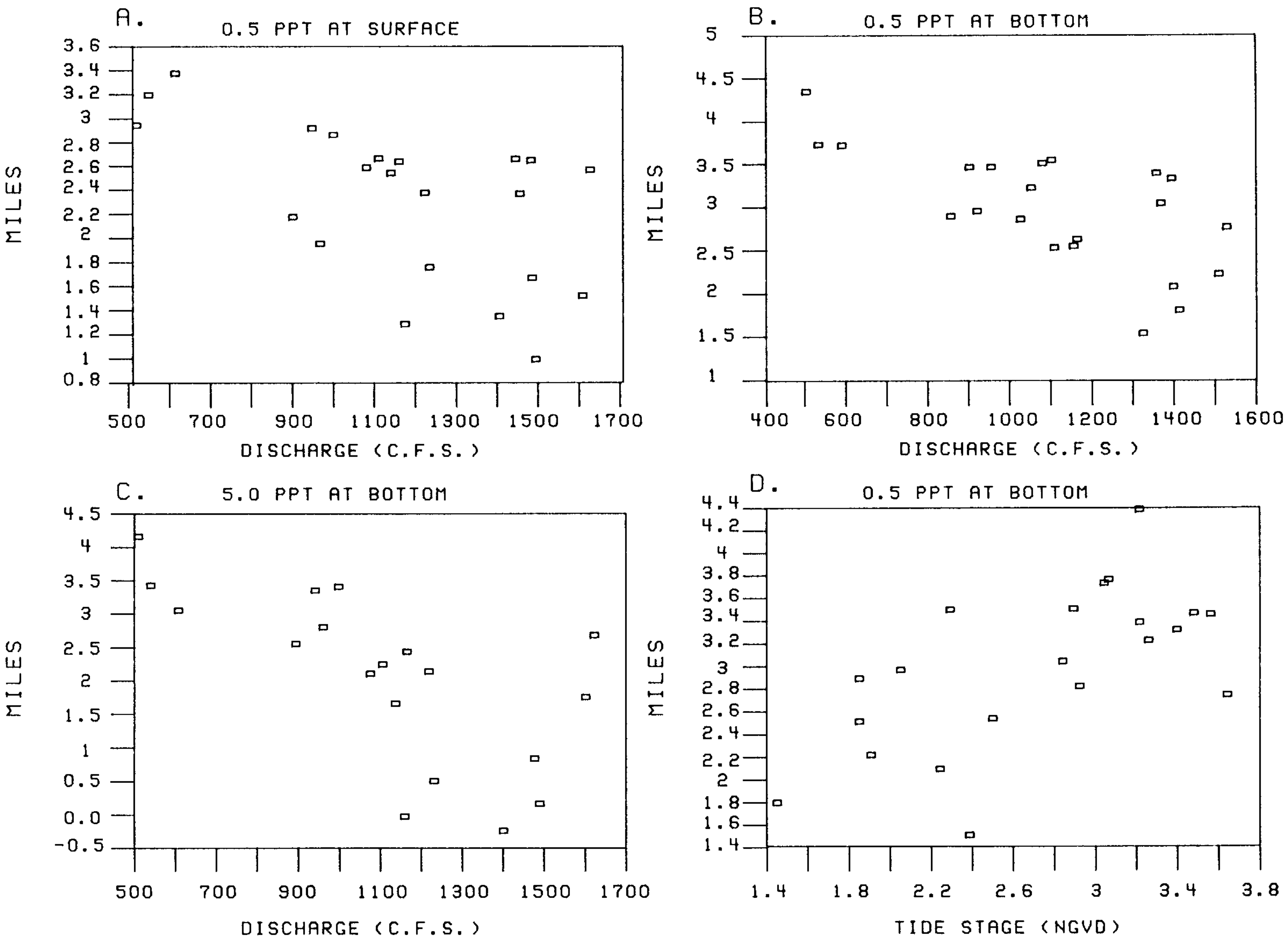


FIGURE 29 RELATIONS BETWEEN THE LOCATION OF SELECTED SALINITY CONCENTRATIONS AND OUTFLOWS THROUGH THE BYPASS SPILLWAY (A, B, and C) AND TIDE STAGE AT THE MOUTH OF THE RIVER (D).

ranged in height from 1.45 to 3.64 feet recorded at the mouth of the river. The height of the tide is important because higher tides push more gulf water into the river increasing salinity and pushing salinity concentrations upstream. The effect of tide height is clearly shown in Figure 29-d, where the 0.5 ppt concentration on the bottom moves upstream with increasing tide height. The effects of tide height and fresh-water inflow were both evaluated using multiple linear regression analysis. In this analysis, salinity concentration location (dependent variable) was measured as a function of the tide height and fresh-water inflow (independent variables). The predictive equations that were developed from this analysis are presented in Table 18 along with corresponding statistical values. For all three relationships examined, both tide height and fresh-water inflow were found to have significant ($p<.05$) effect on salinity location. The multiple correlation coefficients (r^2) for these equations ranged from 0.58 for the 5.0 ppt bottom location to 0.84 for the bottom 0.5 ppt location. Using the equations presented in Table 18, the location of these three salinity concentrations can be predicted if values of fresh-water inflow and tide height are known.

A different representation of fresh-water inflow/salinity relationships is presented in Figure 30, where salinity values at four stations are plotted versus fresh-water inflow. In these graphs, discharge is the sum of flows from the bypass spillway

Table 18. Regression Equations Relating the Location of Selected Salinity Concentrations in the Withlacoochee River Estuary to Discharge from the Bypass Spillway (cfs) and Tide Height (feet) at the Mouth of the River. All Equations Significant at the .001 Level.

Dependent Variable (location of salinity concentration in miles)	R^2	Degrees of Freedom	Equation
5.0 ppt. bottom	.58	21	location = 2.14 + .80 (tide height) - .0020 (discharge)
0.5 ppt. surface	.85	21	location = 1.43 + .71 (tide height) - .0009 (discharge)
0.5 ppt. bottom	.72	21	location = 2.89 + .55 (tide height) - .0012 (discharge)

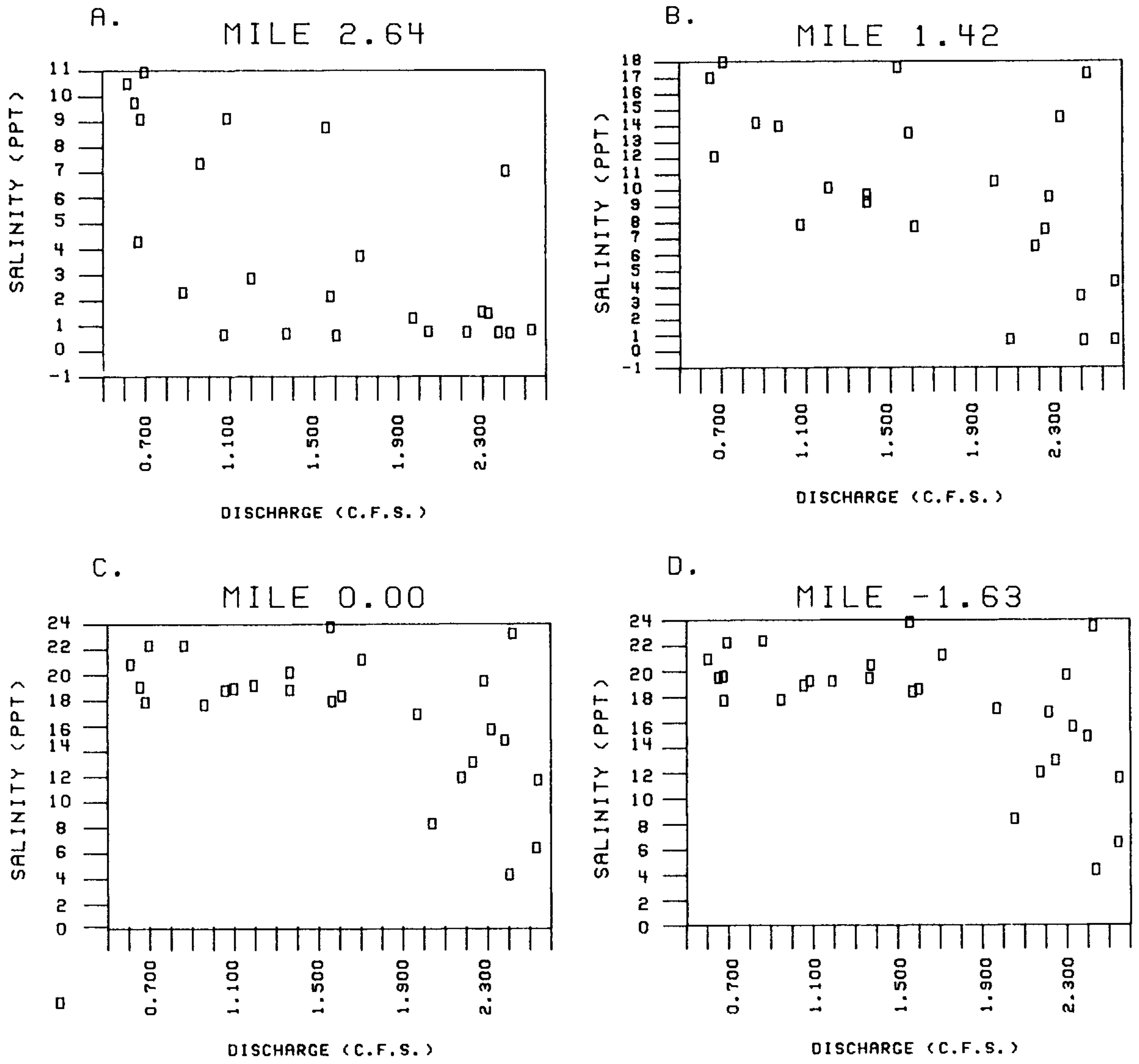


FIGURE 30 RELATIONS BETWEEN DEPTH INTEGRATED SALINITY AT FOUR LOCATIONS AND TOTAL DISCHARGE FROM THE BYPASS SPILLWAY AND INGLIS DAM.

and the Inglis Dam. An effect of fresh-water inflow is apparent, as salinity generally decreases at the higher inflow levels. Again, multiple regression analysis indicated that both tide height and fresh-water inflow have a significant effect on salinity. As shown in Figure 30, an unusual pattern was observed at the mouth of the river (mile=0.00) and 1.63 miles offshore. For these stations, the response of salinity to increasing fresh-water inflow was much more pronounced for flows greater than 1800 cfs. The reasons for this pattern are uncertain. Possibly these high flows represent a physical threshold above which circulation patterns change and the effects of fresh-water inflows are more apparent seaward. Also, these high flow periods represent times when substantial flows were being released through the barge canal via the Inglis Dam. The delivery of fresh water to the estuary at this second location must cause some change in circulation and salinity patterns, but to what degree is not known.

Data collected in the Withlacoochee River estuary to date have demonstrated some basic relationships between fresh water inflow and salinity in this system. These studies were limited, however, and many physical factors controlling salinity distributions are not well defined at present. The effects of winds and gulf circulation patterns on salinity are probably most pronounced for stations seaward of the river mouth. Therefore, the applicability of the current data base for predicting salinity as a function of fresh water inflow is most valid for the lower river channel where the effects of gulf circulation are diminished.

One unique factor to this system that may warrant further study is the periodic discharge of high flows through the barge canal and its effect on the estuary. Given the limits of the existing structures on Lake Rousseau, the current operating schedule for the Inglis Dam is the only practical plan. However, changes to the flow release schedule for the barge canal would be possible if modification to the structures on Lake Rousseau on the barge canal are pursued to facilitate reservoir drawdown. If structural modifications are pursued, more information should be gathered regarding the effects of barge canal discharges on the salinity and water quality characteristics of the adjacent inshore environment. Flow release schedules could then be designed which should improve estuarine conditions and biological productivity near the mouth of the canal. Preliminarily, it is suggested that the current extreme variability of flows to the barge canal should be moderated.

OUTFLOW LEVELS FOR RESERVOIR OPERATIONS PLANS

Since biologically important salinity gradients in the Withlacoochee River estuary respond to changes in fresh-water inflow, the management of outflows from Lake Rousseau has important consequences for the estuarine ecosystem. The current operating schedule for the reservoir provides for the ecology of the lower river and estuary by not altering flows below 1,540 cfs. Various management plans for Lake Rousseau could, however, result in alterations of these flows. Any significant fluctuation of water levels in the reservoir will have an impact on the timing of flows from the system. Outflows from Lake Rousseau must exceed inflow rates to lower water levels in the reservoir, and conversely, outflows must be reduced below inflow rates if water levels are to rise. The selection of outflow schedules for Lake Rousseau should optimally provide for the health of the downstream ecosystems while allowing maximum management capabilities for the reservoir.

In this section, outflow levels are recommended for operational plans which would require modifications to the water control structures at Lake Rousseau. Outflow levels are recommended for periods when the reservoir is either being refilled or maintained at low stage elevations. More specifically, outflow levels are recommended for:

1. Outflow capacity that should be maintained to the lower river from the reservoir at an extreme drawdown elevation of 18 feet.

2. Minimum monthly outflows to be released during reservoir refilling after extreme drawdown.

3. Percentages of outflow that can be retained for reservoir refilling during seasonal fluctuations of reservoir stage.

These outflow recommendations are presented only for the lower Withlacoochee River and are not defined for the CFBC because outflows to the barge canal have been sporadic in the past and long periods of very low flow have occurred in previous years. As previously discussed, however, the operational plan for Inglis Dam should be reviewed if significant structural modifications are ever pursued on the barge canal or the structures at Lake Rousseau. The recommendations provided below would still apply if the operational plan for the Inglis Dam is ever changed.

Outflow Capacity at Reservoir Elevation of 18 Feet

As discussed in the next section, even minor water level fluctuations in the reservoir are presently impractical if adequate flows to the lower river are to be maintained. The establishment of drawdown capabilities would, therefore, require significant modifications to the existing structures at Lake Rousseau or the barge canal. The primary reason for these modifications would be the need to discharge water to the lower river at low reservoir elevations.

In this study, it is recommended that the existing outflow capacity of 1,540 cfs to the lower river at reservoir stage of 27.5 feet be maintained at an elevation of 18 feet. Completion of the barge canal facilities has already changed the streamflow characteristics of the lower river to some degree. Optimally, further modifications to allow drawdown should not cause any further alterations of flows to the lower river. For extreme drawdown, the reservoir should be held at an elevation of 18 feet for a minimum of 90 days, although somewhat longer periods might be desired for certain management strategies. Also, drawdowns may be induced every four to six years. If the existing flow capacity to the lower river is maintained, drawdowns could be induced for longer periods of time or done relatively frequently without increasing flow reductions to the lower river during low water periods. This would allow maximum flexibility for scheduling drawdowns to meet reservoir management needs.

Minimum Flow Levels For Reservoir Refilling After Extreme Drawdown

For the ecological health of the lower river and estuary, the most potentially harmful impacts that must be evaluated are the reductions in outflows which would occur during reservoir refilling after a possible drawdown. Low outflow levels allow for rapid reservoir refilling, but outflows that are too low may not provide adequate water for the ecological needs of the downstream ecosystems. Presented in the following section are suggested monthly minimum flow levels which should serve as outflow guidelines for the lower river during reservoir refilling after drawdown.

If the existing biological structure of the lower river is to be maintained, fresh-water inflow and salinity values should not be manipulated beyond the range of naturally occurring conditions. Levels for monthly outflow levels during refilling should correspond to outflows that have occurred under natural conditions in the past. Using this approach, monthly minimum flow levels can be determined from historical record and correspond to the natural low-flow conditions of the river.

The method used here to determine minimum flow levels employs monthly flow duration analysis. Existing discharge record (1970-1985) for the USGS stations at the bypass spillway and the Inglis Dam were examined, and a third synthetic station was computed as the sum of discharges at these two sites. Duration curves for daily discharge values for these three stations were presented in Figure 21. For minimum flow determination, duration analysis was carried one step further and performed on a monthly basis. That is, all daily flows within each month were grouped together and duration analysis was performed on these twelve subsets. Since flows out of the Lake Rousseau vary seasonally, monthly duration analysis gives a good representation of typical low flows within each season.

To select minimum flow levels which allow quick reservoir refilling while keeping outflows within the range of naturally occurring conditions, monthly minimum flows were chosen to represent outflow levels during typical dry years. Using monthly duration analysis, minimum flows can then be determined as flows which have been exceeded a high percentage of time within each month. In Table 19, flows which have been exceeded 80 and 90 percent of the time within each month are listed for the bypass spillway and the synthetic total discharge station. As previously discussed and illustrated in Figure 21, duration intervals for low flows are very similar for these two stations because large quantities of water are generally not discharged through Inglis Dam until flows in the bypass spillway exceed 1,540 cfs. However, there are some differences in the listed exceedance intervals for the two stations presented in Table 19 because periodic discharges are made through the Inglis Dam during low flows. The results for the two stations in Table 19 are particularly close for the months March through August. To maximize flows to the lower river during recovery from a possible drawdown, no discharges should be made to the barge canal during reservoir refilling. Therefore, the duration intervals in Table 19 for the total computed discharge from Lake Rousseau are most applicable for selecting minimum flows below 1,540 cfs.

Table 19. The 80 and 90 Percent Exceedence Values for Discharges from the Bypass Spillway and the Sum of the Bypass Spillway and Inglis Dam (1970-1985).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
80%												
Bypass Channel	899	930	853	802	722	740	827	938	1,010	811	848	865
Channel and Dam	980	980	868	803	741	742	837	960	1,160	990	920	950
90%												
Bypass	785	859	776	696	648	652	675	766	741	696	707	729
Channel and Dam	911	902	793	700	645	652	665	776	940	825	803	848

For nine months, excluding May through July, the monthly minimum flow level selected was the 90 percent exceeded interval for that month, rounded to the nearest ten cfs. Based on the record from 1970-1985, this means that water for reservoir refilling is available during those months approximately 90 percent of the time. For the months May, June, and July, the 90 percent exceedance intervals were the lowest of the year and ranged between 645 and 665 cfs. These flows were adjusted to 700 cfs to allow a slightly greater margin of safety for the downstream ecosystems and to give a consistent value for the months April through July, when low flows generally occur in the Withlacoochee basin. In sum, the monthly minimum flow levels recommended for outflows to the lower river are listed in Table 20. When the natural level of outflow from the reservoir exceeds the applicable minimum flow level, the minimum flow level should be released from the reservoir with the remaining water kept for reservoir refilling. When the natural level of outflow falls below the minimum flow, the minimum flow should not be maintained, but the natural outflows of the reservoir should not be reduced. These minimum flows were used in simulating reservoir response to drawdown discussed in a subsequent section of this report.

Table 20. **Monthly Minimum Flows For The Lower Withlacoochee River**

January - 910 cfs
February - 900 cfs
March - 790 cfs
April - 700 cfs
May - 700 cfs
June - 700 cfs
July - 700 cfs
August - 780 cfs
September - 940 cfs
October - 820 cfs
November - 800 cfs
December - 850 cfs

In addition to reservoir refilling after a possible drawdown, these minimum flow recommendations can serve as general guidelines for other operation/management schedules for Lake Rousseau which would require structural modifications. The exact method of their implementation for other purposes would have to be examined in a separate analysis which accounts for other pertinent factors. It is strongly emphasized that these minimum flow levels do not represent the monthly quantity of water the lower river and estuary need on a permanent basis to retain their ecological health. The recommended minimum flow levels represent monthly flows during unusually dry periods, and not normal flows to the lower river and estuary. The repeated occurrence of abnormally low flows, whether due to drought, water diversion, or reservoir management, would have deleterious ecological effects. In this report, the implementation of these minimum flows is described for a possible extreme reservoir drawdown, with the understanding that this will occur no more frequently than every four years. Also, flow releases to the lower river should not be held at these minimum flow levels for several months at a time.

As demonstrated in the modeling section, reservoir refilling after extreme drawdown should not normally require more than seventy days using the recommended minimum flows.

Outflow Manipulations For Seasonal Water Level Fluctuations

Seasonal fluctuations in water levels are used here to indicate raising and lowering reservoir levels within a 3.5 feet range below the normal operating stage of 27.5 feet. As discussed later in this report, it is recommended that modifications to the water control structures at Lake Rousseau would be necessary before seasonal water level fluctuations could be implemented on a regular basis. If employed as a management strategy along with structural modifications, this type of fluctuation schedule might be done relatively often with seasonal low water achieved once or twice each year. Because they would be done much more frequently, the considerations for outflow requirements for seasonal water level fluctuations are different than for extreme drawdown. Also, for seasonal water level fluctuations it is probably not necessary to bring the reservoir up as rapidly as after extreme drawdown. For these reasons, it is recommended that water retained for reservoir refilling during managed seasonal fluctuations be based on a percentage of reservoir outflows. This will ensure that flows to the lower river and estuary retain their natural cyclic patterns and are not greatly altered on a frequent basis.

Small percentage flow reductions would cause the least disruptions of flows to the lower river, and it is recommended that flows not be reduced by more than 10% on a daily basis. Also, reservoir outflows should not be reduced any when the natural level of outflow falls below 700 cfs. On pages 256-262, simulations are presented which model reservoir refilling from elevations 3.5, 2.5, and 1.5 feet below normal reservoir stage using five and ten percent daily flow reductions for outflows above 700 cfs. These simulations indicate that most of the time five percent flow reductions bring the reservoir up to normal stage in suitable lengths of time. Optimally, percentage flow reductions should be kept near 5 percent or less, but could periodically be increased up to 10 percent to achieve a desired stage more quickly.

FEASIBILITY OF RESERVOIR DRAWDOWN AND OTHER WATER LEVEL FLUCTUATIONS

INTRODUCTION

Drawdown of Lake Rousseau, or the planned lowering of the level of the reservoir for a specified period of time after which refilling to a more natural level occurs, has been discussed in the past. One of the goals of the Lake Management and Planning Task Force was the consolidation of lake bottom sediments, which would be an expected benefit from an extreme drawdown. Another goal of the Task Force was improvement of the quality and quantity of sport fish populations, in particular largemouth bass, and such improvement has resulted from extreme drawdowns on several natural lakes in Florida. Drawdown for improvement of the fisheries in the reservoir was recommended by the FG&FWFC in 1978 (FG&FWFC, 1978). More recently, the FG&FWFC discussed possible drawdown for Lake Rousseau in their report entitled, <u>A Report on the Status of the Fishery in Lake Rousseau, Florida</u>, found in Appendix A of this report.

In addition to the above benefits, other benefits of drawdown discussed by the Task Force included: (1) return of desirable native vegetation, (2) increase in fish food organisms, and (3) increase in sport fish size. Disadvantages of a drawdown mentioned by the Task Force included: (1) limited access to the reservoir during the time of drawdown, and (2) the resulting loss of revenue to businesses that depend upon the reservoir for their income. Advantages of extreme drawdown not mentioned by the Task Force include: at least temporary reduction of accumulated submersed plant biomass; an excellent opportunity to cut stumps to aid navigation and help reduce tussocks; and, possible benefits to reservoir circulation and water quality resulting from reduced plant biomass. Disadvantages to extreme drawdown not mentioned by the Task Force include: possible drying out and refloating of logs, debris, or mud mats; and temporary impacts to waterfowl habitat and associated hunting opportunities.

There are case histories of successful drawdowns in other Florida lakes, including Lake Griffin located in Lake County and Lake Kissimmee and West Lake Tohopekaliga located in Osceola County (Williams, 1987). Probably the greatest success with drawdowns has occurred on Lake Tohopekaliga where three drawdowns have been accomplished over a period of several years. In conjunction with the most recent drawdown, over one million cubic yards of muck was removed from five miles of shoreline. A series of drawdowns was also done on Lake Oklawaha, an impoundment of the Oklawaha River which is younger but somewhat similar to Lake Rousseau. Although these drawdowns gave only short term reductions in aquatic weed abundance, the investigators (Haller and Shireman, 1988) suggested that seasonal one to three foot fluctuations of reservoir levels combined with periodic fall/winter drawdowns would benefit Lake Oklawaha.

As previously mentioned, the FG&FWFC in 1978 recommended drawdowns for Lake Rousseau to consolidate bottom sediments, help control aquatic weeds, and improve the sport fishery. Their recommendations stated that the reservoir should be drawn down to an elevation of 18 feet which would expose approximately 65% of the bottom area. The reservoir should be held at this level for a minimum of 90 days to allow for the adequate drying of organic sediments and desiccation of plant tissues (Sam McKinney, pers. comm.). Therefore, a complete drawdown cycle on Lake Rousseau would probably require 150 to 190 days; 30 days to reach the drawdown level of 18 feet, 90 days at that level, and 30 to 70 days to refill to a normal operating stage depending on the level of reservoir inflows.

It is possible that lesser but more frequent seasonal water level fluctuations would also benefit Lake Rousseau. It has been observed that stabilized water levels in Florida lakes are detrimental to these systems, and that lakes seem to maintain a healthier state if allowed to fluctuate through some desirable range (Wegener and Williams, 1974; Dooris and Courser, 1976). Although seasonal water levels might be of benefit to Lake Rousseau, it is not felt that they would achieve the restoration effects of extreme drawdown. At one time, a less extreme drawdown of three and one-half feet to elevation 24 feet was considered for the reservoir. However, it was felt by the FG&FWFC (Lake Management and Planning Task Force Meeting minutes, July 1986) that such a minimal drawdown would not accomplish sufficient dry-out of bottom sediments. It is suggested here that if lesser seasonal water level fluctuations are to be managed on Lake Rousseau, they should be used in conjunction with and not as a substitute for extreme drawdown.

Currently, with the existing structures on the barge canal and Lake Rousseau, a drawdown to a level of 18 feet cannot be accomplished and still provide adequate flows to the lower river. This is because all flows to the lower Withlacoochee River now pass through the bypass channel and spillway. As shown in Table 21, the discharge capacity of the bypass spillway is greatly reduced at reservoir elevations below 27.5 feet, and flows to the lower river completely cease below the control elevation of 21 feet. With these physical limitations, even minor seasonal water level fluctuations in the reservoir are impractical. For instance, a reduction of water levels by 1.5 feet to an elevation of 26.0 feet reduces discharge capacity to the lower river from 1,540 to 1,040 cfs. Such reductions would be unacceptable due to impacts to the downstream river and estuarine ecosystems.

Table 21. Discharge Capacity of the Bypass Spillway Facilities at Various Water Level Elevations in Lake Rousseau.

Reservoir Elevation (feet NGVD)	Discharge (c.f.s.)
27.5	1540
27	1360
26	1040
25	740
24	480
23	260
22	100
20.87	0

Because of the limited discharge capacity of the bypass channel and spillway at lowered reservoir elevations, the implementation of extreme drawdown or even seasonal water level fluctuations on Lake Rousseau would require significant modifications to existing structures if adequate flows to the lower river and estuary are to be maintained. Structural modifications mentioned in the past have included: (1) pumped bypass of the 21-foot control elevation on the bypass channel, (2) reconnecting the two sections of the lower river channel below Inglis Lock and Dam and below the bypass channel to re-establish discharge capabilities to the lower river with the 11.3-foot control elevation at Inglis Dam, and (3) the possible construction by private interests of a hydro-electric power generating facility on the bypass channel. This power generating facility should be designed to provide existing bypass channel flow capability of 1,540 cfs at a reservoir elevation of 18 feet; in effect, bypassing the 21-foot control elevation of the bypass structure. However, to meet minimum flow requirements in the river downstream of the bypass channel structure, and to provide adequate flow for power generation during drawdowns, significant modification to the bypass channel would be required to convey adequate flow to the turbines at a reservoir elevation of 18 feet. Option two, reconnecting the two sections of the lower river channel, was a structural modification considered during the restudy phase of the CFBC (USACOE, 1975).

The Water Resource Development Act of 1986 provided for deauthorization of that part of the CFBC east of the Inglis Complex, and continued authorization of the completed project from the Inglis Complex to the Gulf. Implementation of these provisions of the Act is pending enactment of appropriate legislation by the State of Florida. Implementation of any structural modification plan for the CFBC facilities would require Congressional approval as part of the recommendations for protecting and enhancing the values of the Cross Florida National Conservation Area, which is to be established upon deauthorization of the CFBC.

An extreme drawdown of Lake Rousseau to an elevation of 18 feet would affect the water surface profile, and consequently river widths and depths, as far upstream as the USGS gaging station at State Road 200 near Holder. This site is about 25 miles upstream of the Inglis Dam. The effects would be most pronounced during medium to low streamflow periods. During extreme low flow some slight affect may go as far upstream as the Wysong Dam which is about 45 miles upstream of Inglis Dam. Effects would also reach upstream on Blue Run to within two miles of the main springs (Figure 1).

Lowered water levels in the reservoir, Blue Run, and the upstream Withlacoochee River will cause inconveniences and navigational problems; however, the extent of these problems probably cannot be assessed until the reservoir is lowered. There is an existing Federal Navigation Project on the river authorized by the River and Harbor Act of 1946 which requires USACOE maintenance of a draft of about two feet for approximately half the year as far upstream as Croom which is about 65 miles upstream of Inglis Dam. Since a drawdown probably would be accomplished during the drier months when the river would be in its natural low cycle with corresponding minimum channel depths, and since the span of time of a drawdown when channel depths would be most affected should not exceed six months, there should not be a problem with the Federal Navigation Project. However, the USACOE has not taken an official position on the effect of a drawdown on the Navigation Project.

For the lower river and estuary, the refilling period following reservoir drawdown would be a critical part of the cycle because reservoir outflows must be reduced. Recommended reservoir outflow levels that should be maintained during reservoir refilling were identified in the section of this report titled, Reservoir Outflow Characteristics and Fresh-water Flow Requirements of the Lower Withlacoochee River and Estuary. A positive aspect of reservoir refilling is the steady inflow to the reservoir from Rainbow Springs, which has an average flow of 725 cfs. This springflow plus surface runoff from the large drainage basin above Lake Rousseau would allow the reservoir to be filled in less than 60 days in most cases. Reservoir refilling during droughts, however, could extend for prolonged periods of time. Greater elaboration on the probable durations of reservoir refilling is discussed in a subsequent section entitled, Timing and Duration of Extreme Drawdown.

The economic impact that would result from a drawdown on businesses that depend upon the reservoir for their income is discussed in the Appendix A of this report, the FG&FWFC's fishery status report, 1987. Potential impacts on the ground-water system in the vicinity of the reservoir that would result from a drawdown is discussed in a subsequent section of this report entitled, Ground-water Response to a Drawdown. The specific effects on surface water levels in the area resulting from a simulated drawdown to elevation 18 feet are discussed under Drawdown Effects. The potential effects of drawdowns on aquatic plant populations and organic sediments in the reservoir are discussed under Potential Aquatic Plant Response to Drawdown and

Sediment Compaction or Removal During Drawdown. Considerations regarding the cutting or removal of stumps in the reservoir during drawdown are discussed under Stump Removal During Drawdown.

Drawdowns have been generally successful on several Florida lakes and reservoirs, and experiences on these water bodies allow predictions of the benefits and drawbacks which might be expected from a drawdown of Lake Rousseau. This study is simply an examination of the preliminary feasibility of a reservoir drawdown; can it be accomplished, what structural modifications would be required, what would be the resultant water levels, what are the expected benefits and drawbacks, what would be the economic impact, etc. When and if the question regarding an extreme drawdown is ever called, pursuit of the matter will be undertaken through the appropriate routes including investigating permitting requirements and interagency coordination/approval, public meetings, public hearings, etc. The ultimate decision regarding the question of drawdown must involve those individuals, businesses, communities, etc., which would be most directly affected by the drawdown.

STEP-BACKWATER CALIBRATION FOR DRAWDOWN ANALYSIS IN LAKE ROUSSEAU AND THE ASSOCIATED RIVER

General

The drawing down of Lake Rousseau will not be confined to just the reservoir area. Between the outlet structures on Lake Rousseau and Wysong Dam, there are no control structures to limit the upstream migration of water levels in response to a drawdown. Consequently, a water surface profile analysis was required to predict the effects from a drawdown on Lake Rousseau and the river system. Since inflows into Lake Rousseau can vary widely, the development of several water surface profiles was necessary to determine the upstream water surface response for a given Lake Rousseau target pool elevation and inflow. Water surface profiles were generated using the USACOE's 1985 micro-computer version of HEC-2 (Water Surface Profile) program, which is a steady-state model that uses the Manning's N for calculating friction loss and the standard step method for predicting water surface elevations. The water surface profiles generated begin at the west end of Lake Rousseau, where the CFBC structures are located, and then progress 25 miles upstream to State Road 200, which is about 20 miles downstream of the Wysong Dam. Blue Run water surface profiles were also generated, using HEC-2, beginning at the confluence and ending at Rainbow Springs.

Cross sections used in the modelling effort came from several sources. Cross sections between the outlet structures on Lake Rousseau and the Blue Run confluence were furnished by the USACOE in Jacksonville, Florida. Cross sections between the Blue Run confluence and the spring head were developed from a field survey conducted by District staff. Between the Blue Run confluence and State Road 200, no cross-sectional data below the waterline were available for the Withlacoochee River. Consequently, cross sections were developed using 1"=200', 1972 District aerial-topographic mapping down to the water's edge. Below the water's edge a parabolic section was developed based upon the water surface top width estimated from the 1972 aerial mapping and the invert elevation of the river at that location. Invert elevations used for this reach came from a USACOE report (USACOE, 1976). The HEC-2 model input data used in the analysis is contained in Appendix F.

Model Calibration

Before the model was used to predict water surface profiles for specific Lake Rousseau target pool elevations and inflows, it was calibrated against three historical flow conditions. These flow conditions varied from an extreme low flow to flood conditions: the May 1985 drought; the October 1972 USACOE drawdown of Lake Rousseau; and the April 1960 flood, a one in 50-year event. These flow conditions not only provided a wide variation in flows for model calibration, but also provided a wide variation in starting pool elevations.

Six USGS gaging stations were used to establish the flow conditions and corresponding water surface elevations necessary for model calibration. Gaging stations used in the model calibration are as follows (Figure 31):

	Station	USGS Sta. ID
(1)	Inglis Dam	02313230
(2)	Inglis Bypass Channel	02313250
(3)	Lake Rousseau Water Level Station	02313229
(4)	U.S. 41 Bridge at Dunnellon	02313200
(5)	Rainbow Springs	02313100
(6)	Holder at S.R. 200	02313000

Flows along the Withlacoochee River for modelling purposes were varied according to the flows recorded at the Rainbow Springs and Holder gaging stations. The measured flows at Holder and Rainbow Springs appeared to represent the total flow contribution to the Lake Rousseau outlet structures. The flow contribution between Holder and Rainbow Springs appeared negligible. Levels used for calibration came from Lake Rousseau, the U.S. 41 Bridge at Dunnellon, Rainbow Springs, and the Holder gaging station.

During model calibration, only the Manning's N-values for the model reaches were adjusted. These N-values were adjusted until

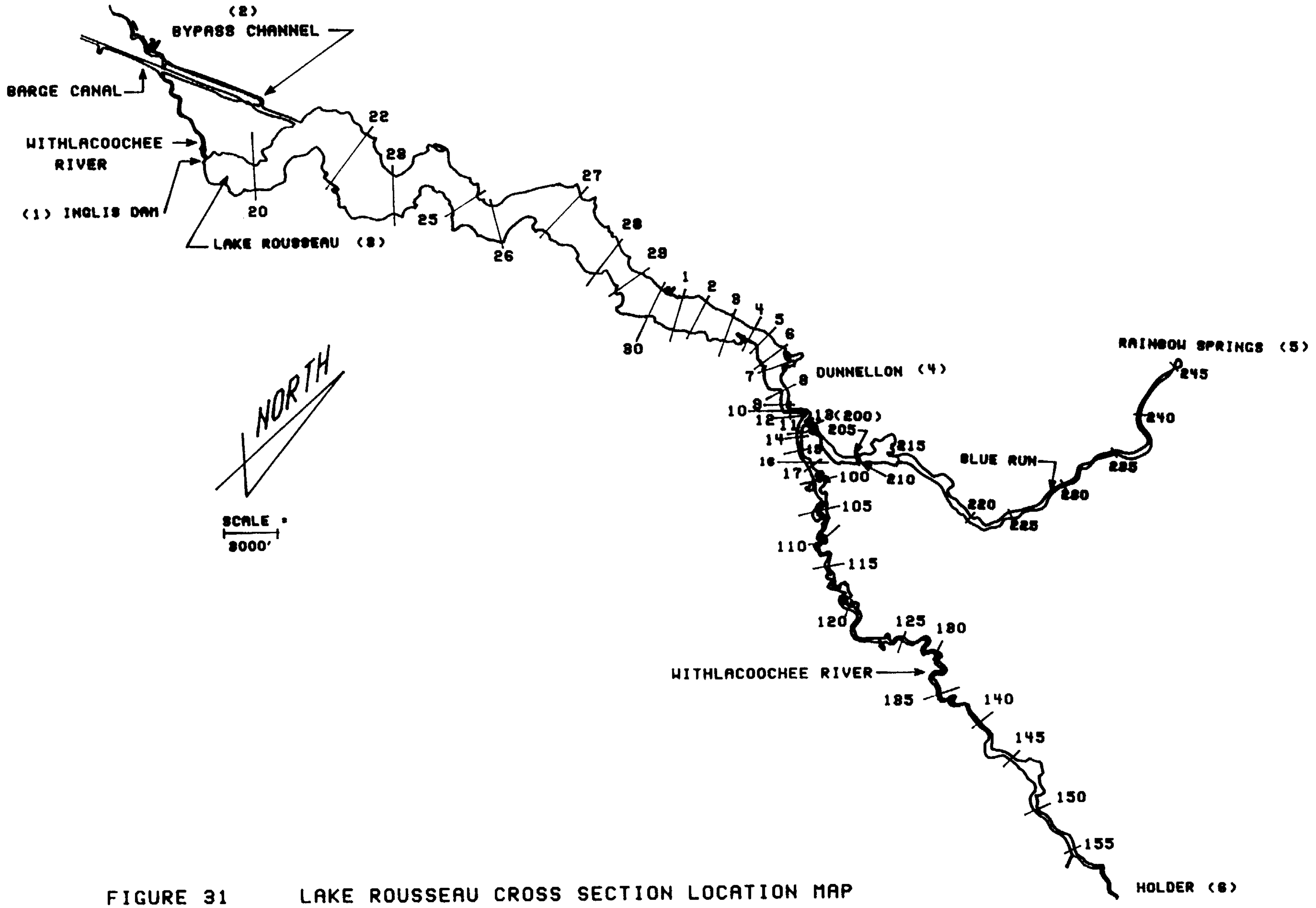


FIGURE 31 LAKE ROUSSEAU CROSS SECTION LOCATION MAP

there was little difference between the predicted and recorded water surface elevations for the flow conditions modelled. A N-value of 0.065 was used for the main river channel, while a N-value of 0.070 was used for the off-channel areas in the reservoir to just upstream of Dunnellon. Above Dunnellon to S.R. 200 an overbank N-value of 0.075 was used. For the Blue Run tributary a Manning's N-value of 0.04 was used.

The final N-values used in the calibrated model appear to represent the existing stream and overbank conditions. The N-value of 0.065 corresponds with published values for streams characterized by a high degree of meandering, varying cross sections, and aquatic growth. The 0.04 N-value is more characteristic of streams that have little meander, uniform cross sections, and little aquatic growth to effect channel flow resistance (Ven De Chow, 1959).

The results of the three calibration runs are tabulated below:

Model Calibration results

		NGVD		
Station Location	cfs Discharge	Recorded Elevation	Modeled Elevation	Difference
May 1985 Drought				
Inglis (two outlets)	700	27.48	27.48	(control)
Dunnellon	---	27.60	27.54	0.06
Rainbow Springs	583	30.34	30.12	0.22
Holder @ S.R. 200	100	27.77	27.67	0.10

October 1972 (USACOE Drawdown)

Inglis	1,200	21.80	21.80	(control)
Dunnellon	---	23.10	23.14	0.04
Rainbow Springs	740	*30.54	30.55	-0.01
Holder @ S.R. 200	450	28.37	27.81	0.33

April 1960 Flood (one in 50-year event)

Inglis	9,500**	unknown Assumed (no record)	27.48	(control)
Dunnellon	---	33.00	32.83	0.17
Rainbow Springs	940	34.24	33.68	0.56
Holder @ S.R. 200	8,660	40.80	40.85	-0.05

*Estimated Value
**USACOE Preliminary Restudy Report 1975.

The difference between the predicted and recorded water surface elevations at Dunnellon for the three flow conditions ranged between 0.03 and 0.17 feet. At Holder, the difference between predicted and recorded water surface elevations ranged between-0.5 and 0.33 feet. The 0.33 foot difference is for the October 1972 USACOE drawdown and is probably high due to unsteady flow conditions that resulted from opening the Inglis Dam gates during this period. Rainbow Springs water surface differences ranged between -0.01 and 0.56 feet. The 0.56 foot difference was for April 1960 flood condition which is probably high due to the extrapolation of water surface elevations above available survey data for the cross sections. For example, at Rainbow Springs the highest land surface elevation used for the cross section was 31.29 feet. This means that the cross section was extended almost three feet vertically beyond the available data (from 31.29 to 34.24 feet).

The predicted water surface elevations matched fairly well with the recorded stage data. The calibrated model appeared to deviate from recorded stage data when water surface elevations exceeded cross section data or unsteady flow conditions were encountered. Since the flows should remain fairly steady during a drawdown, the calibrated model should reasonably predict a water surface response of the river system to a drawdown.

DRAWDOWN EFFECTS

General

Once the backwater model was calibrated to historical flow conditions, the model was then used to predict the water surface responses of the river system to a simulated drawdown of Lake Rousseau. The only difference between the calibrated flow conditions and those conditions used to predict the water surface response to a reservoir drawdown are the starting elevations. The starting elevations used to predict drawdown effects were 27.48, 21.8 and 18.00 feet. The starting elevation of 27.48 feet represents the elevation Lake Rousseau is usually maintained. The 21.8 foot elevation represents the elevation that Lake Rousseau was lowered in 1972, and the 18 foot elevation is the FG&FWFC's previously recommended level for an extreme lowering of the reservoir which was presented to the Lake Rousseau Management Planning Task Force in 1986. This 18 foot level was recommended because 65% of the reservoir bottom would be exposed enabling significant consolidation of the organic bottom sediments (Figure 32). The percent exposure was computed by FG&FWFC from an area capacity curve (USACOE, 1976).

Since Lake Rousseau is actually a reach of the Withlacoochee River, any starting elevation chosen will not usually be maintained for the entire reservoir. Consequently, for all

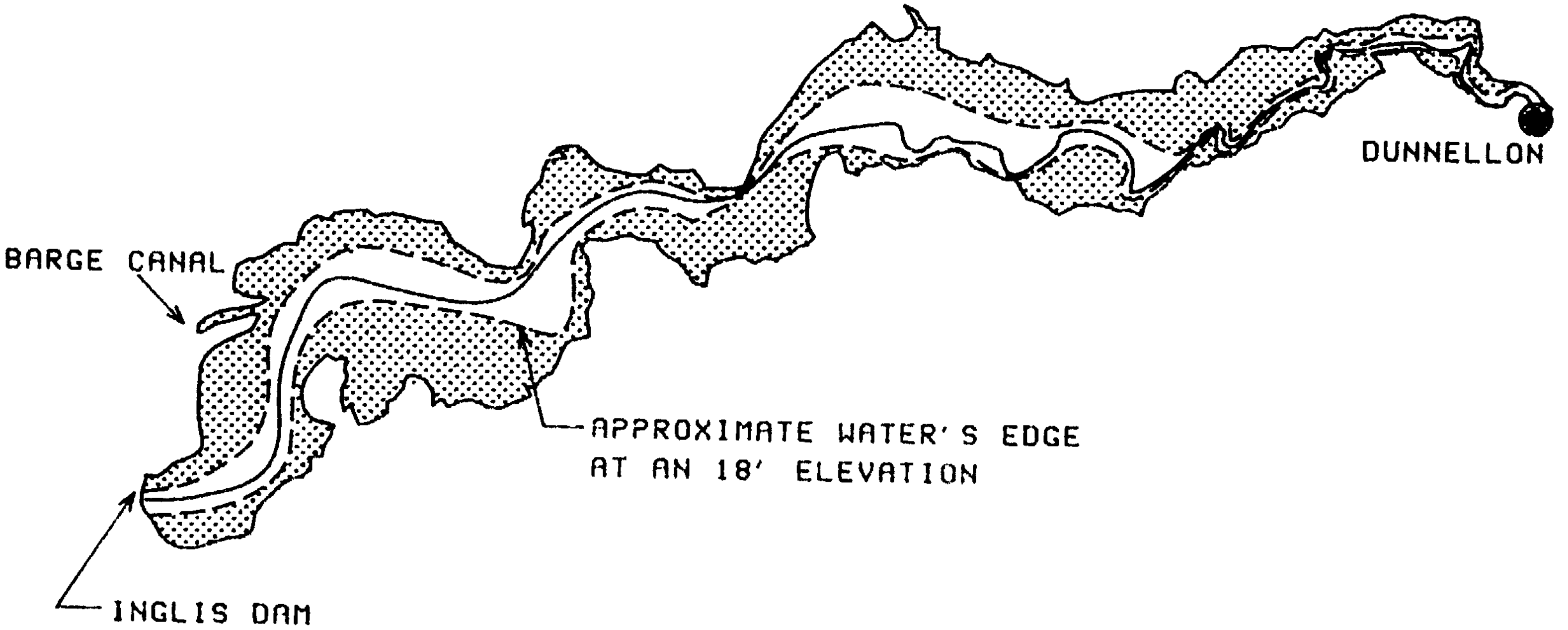


FIGURE 32 AREA OF EXPOSURE DUE TO A DRAWDOWN OF LAKE ROUSSEAU.

backwater analyses performed, the starting or control elevation will be the elevation at the upstream side of Inglis Dam. The specific purpose for performing these drawdown impact analyses is to determine the upstream extent and magnitude of a reservoir lowering. State Road 200 was used as the most upstream study limit for the analyses because it was presumed that the effect of the Lake Rousseau lowering would not progress past that point. It will be demonstrated later that this is not always the case. Another aspect of the drawdown impact analyses is the determination of where boat navigation could be a problem. Areas where navigation could be a problem will be identified by conditions where water depths would be two feet or less as a result of a drawdown.

Results of Simulated Drawdowns for May 1985 Conditions

Water Surface Response Main River

The drought of 1985 was selected for one of the modelled flow conditions because it represented an extreme event or worst case situation in regard to drawdown effects. A new low flow of record, 95 cfs, was established for the Holder station during this period. The total inflow to Lake Rousseau during this period was estimated around 700 cfs which is significantly lower than the 1,200 to 1,600 cfs average monthly inflow to the reservoir. Water surface profiles on Figures 33-35 depict this drought condition.

During the drought of 1985, Lake Rousseau's most westward elevation was 27.48 feet. The corresponding elevations for the 1985 conditions at Dunnellon, Rainbow Springs and Holder were 27.60, 30.34 and 27.77 feet respectively (Table 22). As can be seen in the data, the hydraulic gradient between the Lake Rousseau outlet structures and S.R. 200 was almost non-existent with a slope of 0.013 feet per mile. The elevation was 27.77 feet at Holder as compared to 27.48 feet at Lake Rousseau.

Table 22. Summary Table for Estimated Drawdown Effects

Starting Condition	Elev. at Dunnellon	Elev. at Rainbow	Elev. at Holder S.R. 200
<u>May 1985 Drought Conditions</u>			
recorded (27.48)	27.60	30.34	27.77
21.8 starting	22.30	30.0	23.9
18.00 starting	19.9	No Change	23.6
<u>October 1972 Conditions</u>			
27.48 starting	27.66	30.66	29.40
recorded 21.8	23.10	30.54	28.37
18.0 starting	21.60	No Change	28.04
<u>April 1960 Condition</u>			
27.48 starting	32.83	33.68	40.85
21.8 starting	32.57	33.49	No Change
18.00 starting	No Change	No Change	No Change

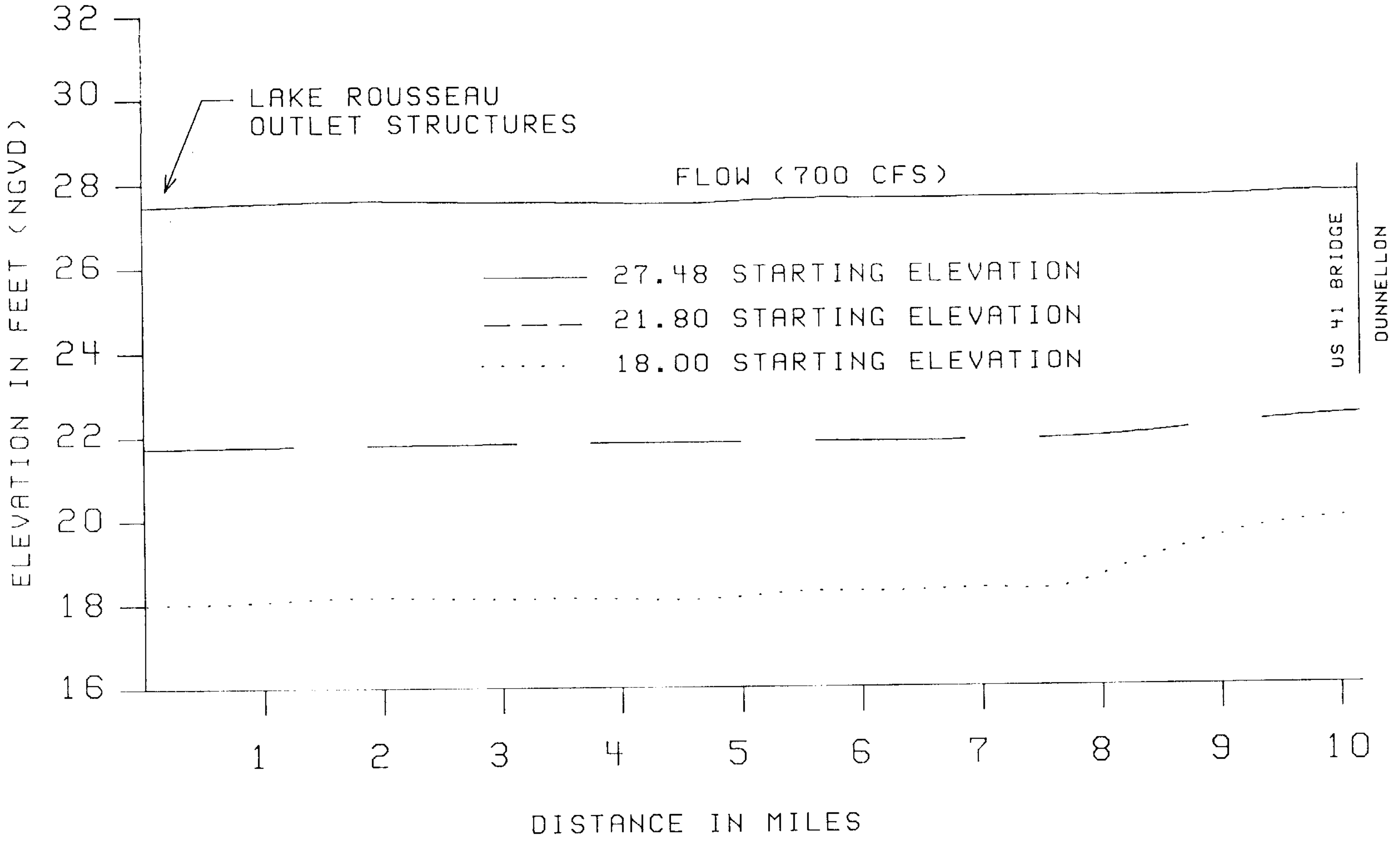


FIGURE **33** WATER SURFACE PROFILES BETWEEN LAKE ROUSSEAU OUTLET STRUCTURES AND US 41, MAY 1985 CONDITIONS.

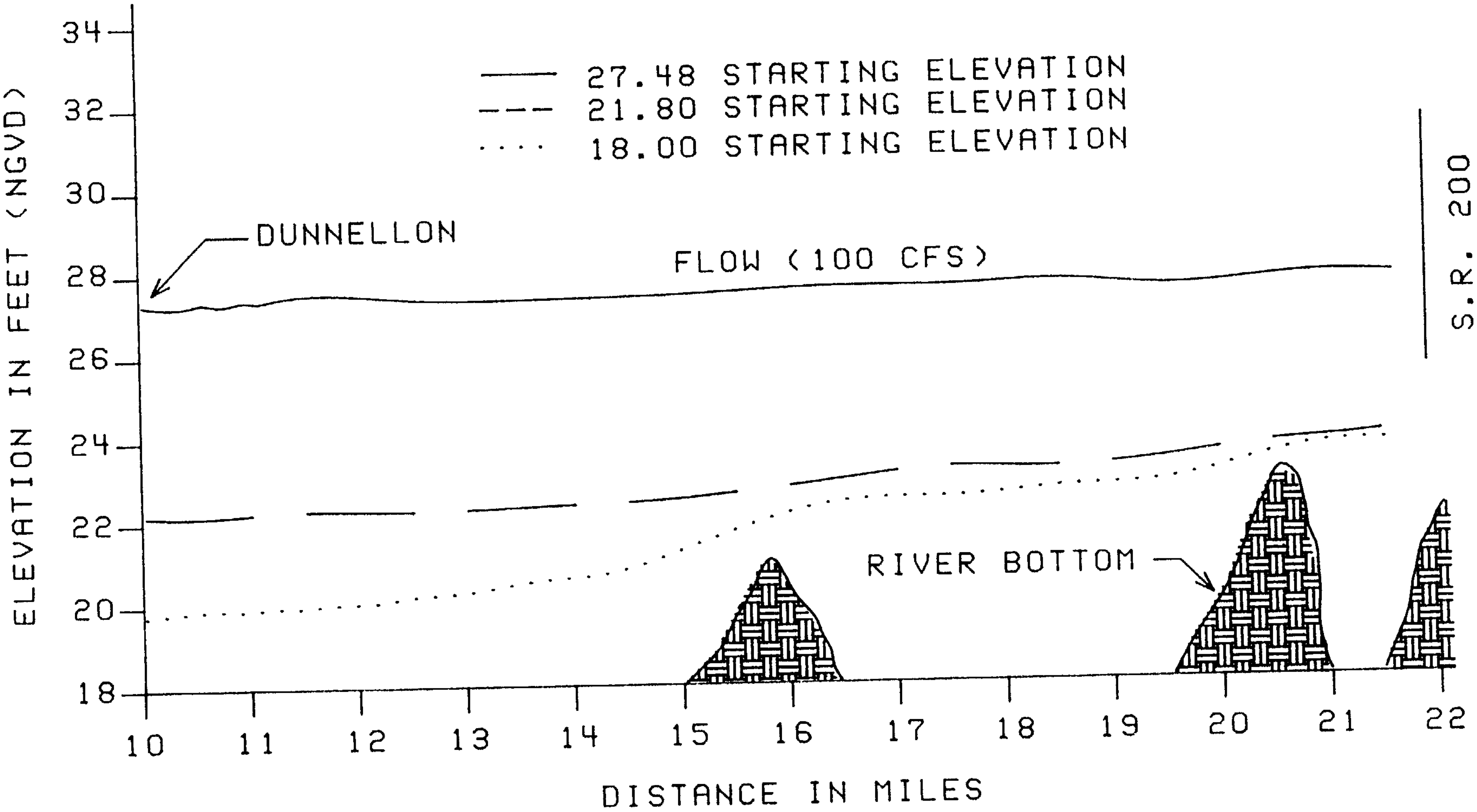


FIGURE 34 WATER SURFACE PROFILES BETWEEN DUNNELLON AND SR 200, MAY 1985 CONDITIONS.

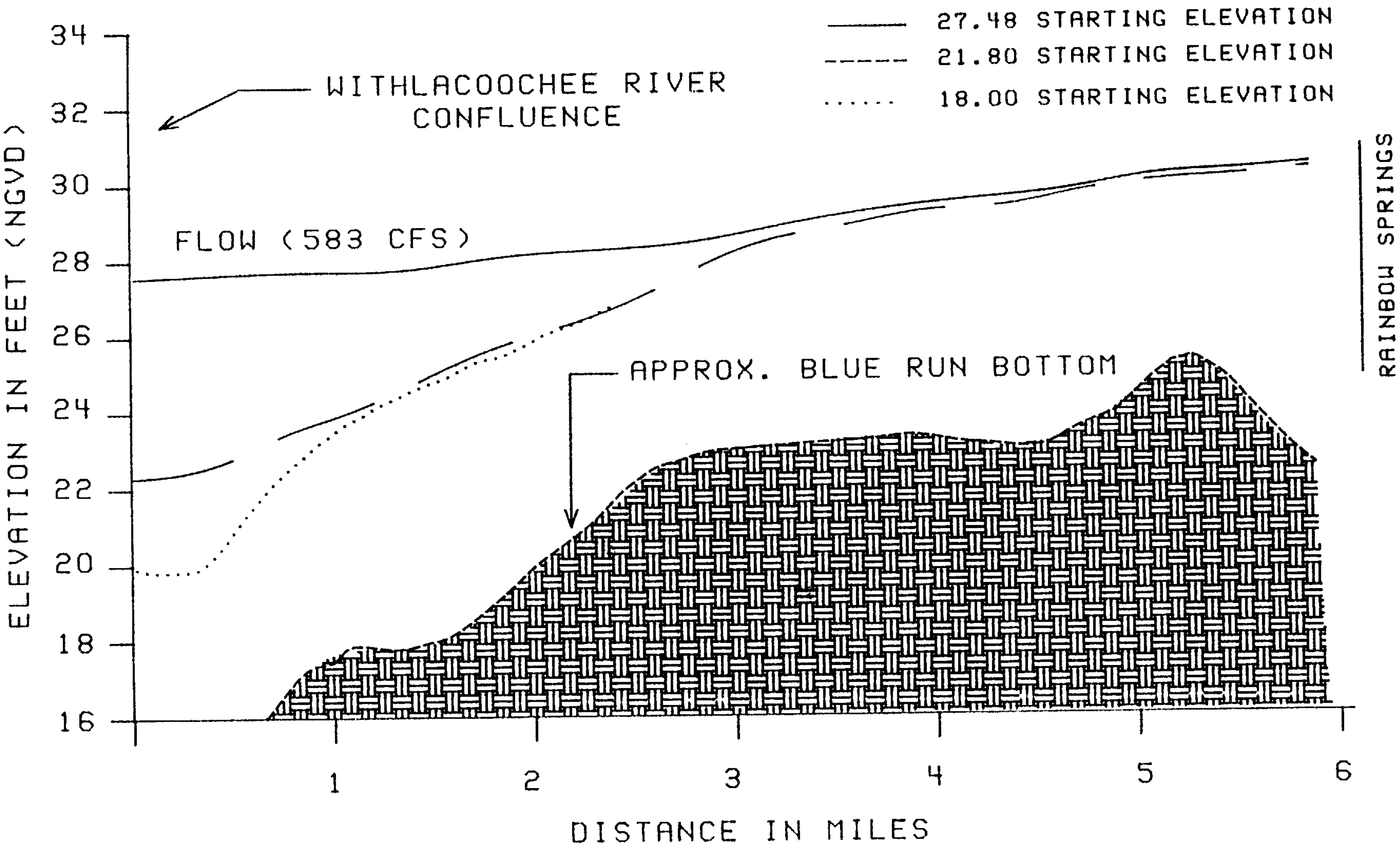


FIGURE 35 WATER SURFACE PROFILES FOR BLUE RUN, MAY 1985 CONDITIONS.

If Lake Rousseau were drawn down to a water surface elevation of 21.8 feet at the outlet structures for the drought 1985 conditions, the corresponding water surface elevations at Dunnellon, Rainbow Springs and Holder would have been 22.3, 30.0, 23.9 feet respectively. The simulated water surface elevation of 23.9 feet at Holder for a 21.8 foot starting elevation at Lake Rousseau is significantly less than the 27.77 feet recorded for May 1985 drought. This difference between the recorded and simulated elevations at Holder indicates that for low flow conditions the drawdown effects would progress past the Holder gaging station.

If Lake Rousseau were drawn down to an elevation of 18.0 feet at the outlet structures, the water surface elevations at Dunnellon, Rainbow Springs and Holder would be 19.9, 30.0 and 23.6 feet respectively. This indicates that further lowering of water surface elevations along the Withlacoochee River system would occur between the Lake Rousseau outlet structures and Holder gage as a result of lowering the lake from 21.8 to 18 feet. However, the migration of drawdown effects upstream of Holder as a result of lowering Lake Rousseau below 21.8 feet will not be as significant. The drawing down of Lake Rousseau to 18 feet under similar conditions of the May 1985 drought would create water level decreases of almost 8 feet at Dunnellon and 4 feet at the Holder as compared to the elevations recorded for that period.

Water Surface Response Blue Run

An analysis of the Blue Run water surface profile, as a result of a simulated drawdown, indicates that the drawdown effect would not significantly progress beyond K. P. Hole which is a couple miles downstream of Rainbow Springs. The water surface decrease at Rainbow Springs, as a result of a drawdown, will be on the order of a 0.1 to 0.3 feet for average or below flow conditions in the Withlacoochee River.

Most of the inflow into Blue Run occurs upstream of K. P. Hole as spring discharge. The water surface elevations in the spring area and in the adjoining Floridan aquifer regulate the amount of ground water that is discharged. An increase in Rainbow Springs water surface for a specified Floridan aquifer potentiometric level will have the tendency to decrease flows while a decrease in Rainbow Springs water surface will have the tendency to increase spring flows. It is estimated that the predicted 0.1 to 0.3 foot decrease in the water surface at Rainbow Springs as a result of a drawdown, will create minimal increases in spring discharges. The lowering of Lake Rousseau should also lower the potentiometric surface in the area, thereby counteracting the effects from lowering surface water levels in the springs area.

Navigation

An extreme lowering of Lake Rousseau to an elevation of 18 feet will effect boat navigation on the Withlacoochee River. Large surface areas in Lake Rousseau will be exposed while other areas will lack the necessary depth in order to provide protection from submerged objects. A Federal Navigation Project on the river requires the USACOE to maintain a two foot minimum draft clearance for approximately half the year from the Withlacoochee River mouth upstream to Croom. It is not clear whether this act requires a minimum two foot clearance for the majority of the normal surface area of the river or just the main channel. In either event, a two foot clearance cannot be maintained if drought conditions similar to May 1985 occur during a drawdown. The drawdown simulations performed thus far indicate that this two foot clearance in the main river channel will not be maintained in the vicinity of State Road 200. However, the main river channel downstream of this area should have sufficient depth for boat navigation.

Navigation in Lake Rousseau as a result of a drawdown will be severely limited. Two-thirds of the lake area will be exposed with boat trails lacking sufficient depth to provide access to the main river channel. Docking and maneuvering around most of the river banks and shore lines may also be impossible limiting river access. The actual areas where safe boating could be conducted and access possible are not known. If a drawdown is determined to be feasible and acceptable, then proper channel markings, warning signs and locations of river accesses should be provided.

Results of Simulated Drawdowns for October 1972 Conditions

Water Surface Response Main River Channel

The October 1972 period was chosen for drawdown conditions because flows were about average in the river; consequently, representing the conditions most likely to occur during a drawdown. Also, Lake Rousseau was drawn down by USACOE during this period providing information whereby river hydraulic characteristics could be better calibrated for the drawn down condition. Water surface profiles on Figures 36-38 depict this average flow condition.

Lake Rousseau was lowered to an elevation of 21.8 feet during this period with corresponding elevations at Dunnellon, Rainbow Springs and S.R. 200 at 23.10, 30.54, 28.37 feet, respectively (Table 22). If the reservoir was not drawn down and a normal water surface elevation of 27.48 feet was maintained at the west end of the lake, the resulting simulated water surface elevations at Dunnellon, Rainbow Springs and Holder would have been 27.66, 30.66 and 29.40 feet respectively. Consequently, even for

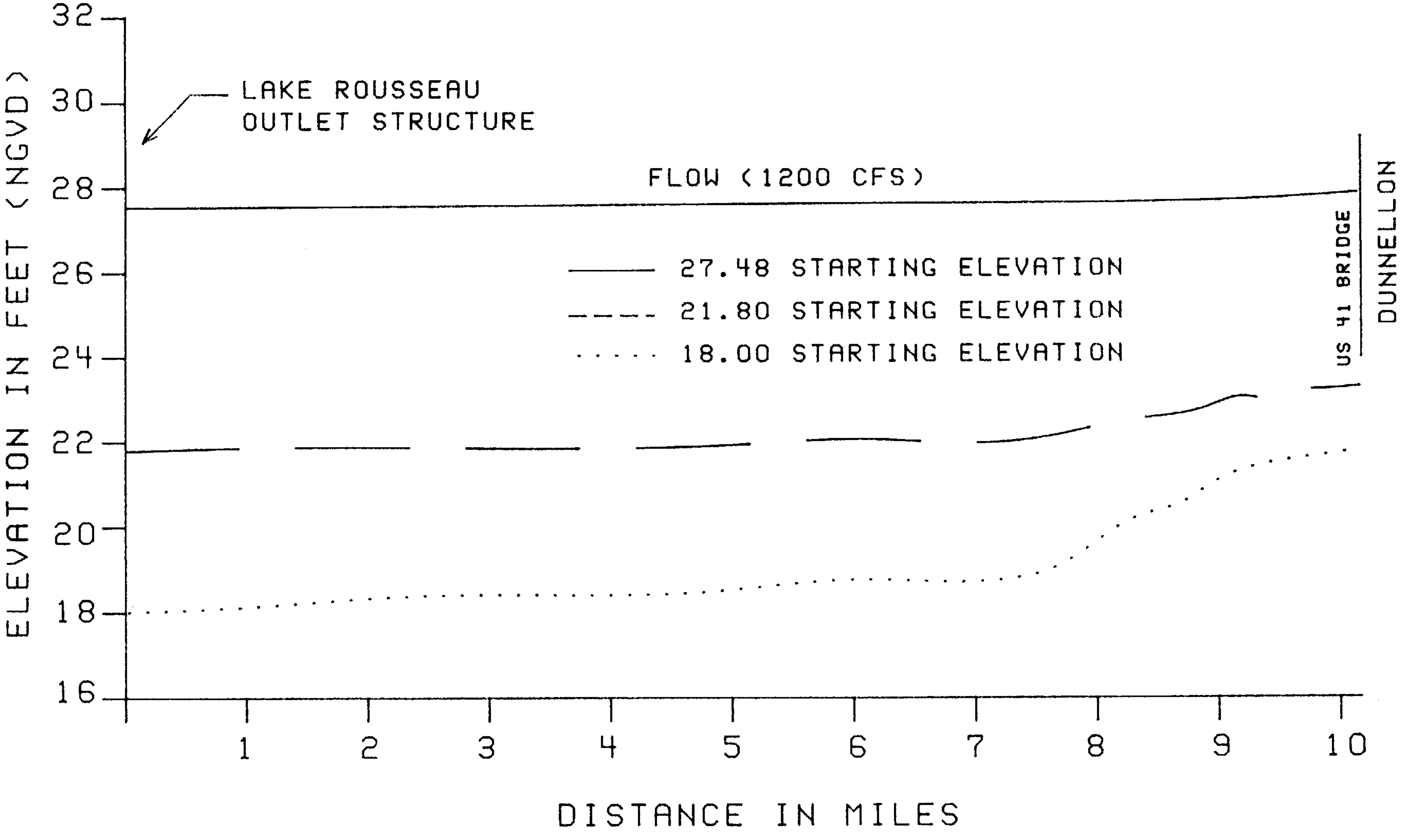


FIGURE 36 WATER SURFACE PROFILES BETWEEN LAKE ROUSSEAU OUTLET STRUCTURES AND U.S. 41, OCTOBER 1972 CONDITIONS.

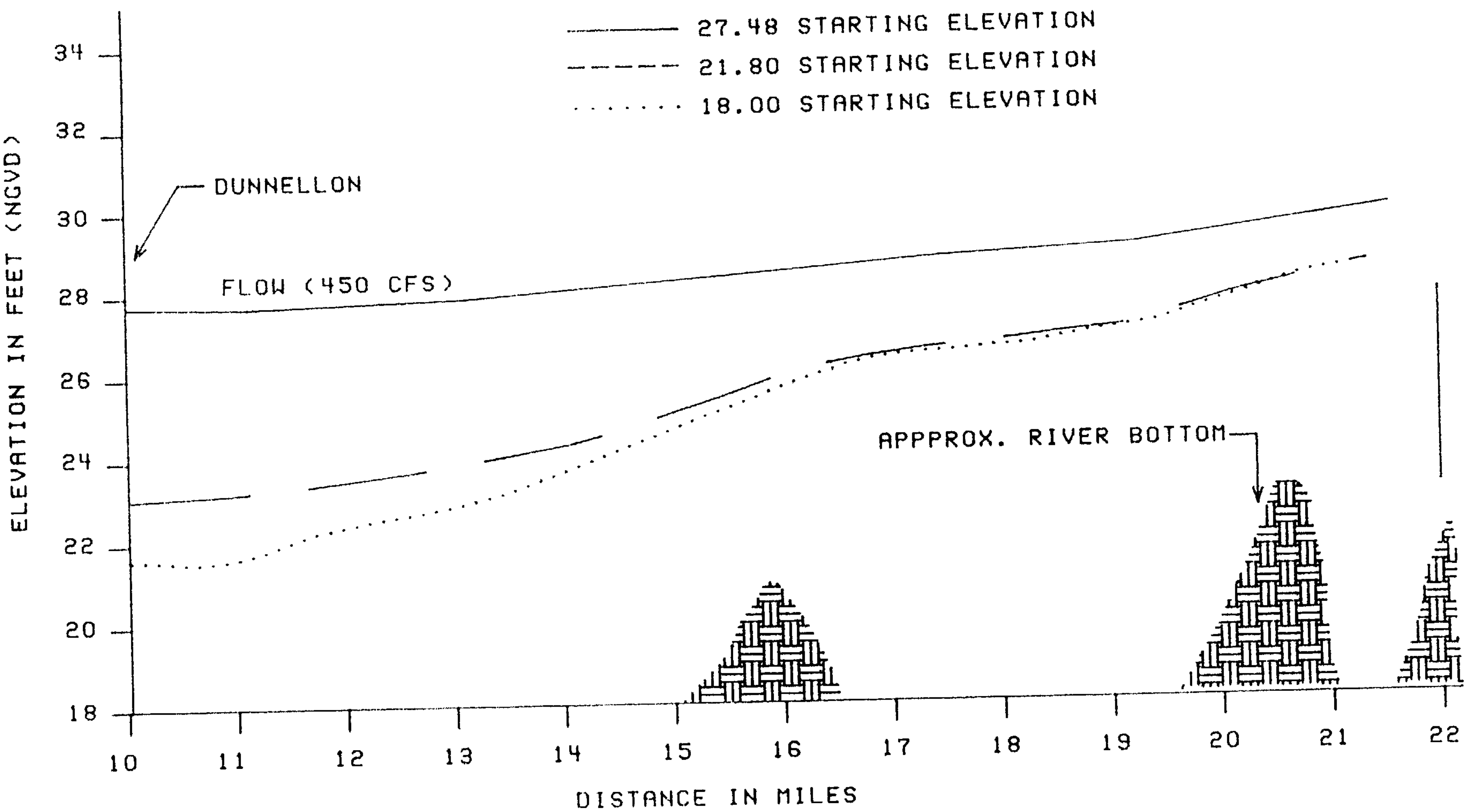


FIGURE 37 WATER SURFACE PROFILES BETWEEN DUNNELLON AND S.R. 200, OCTOBER 1972 CONDITIONS.

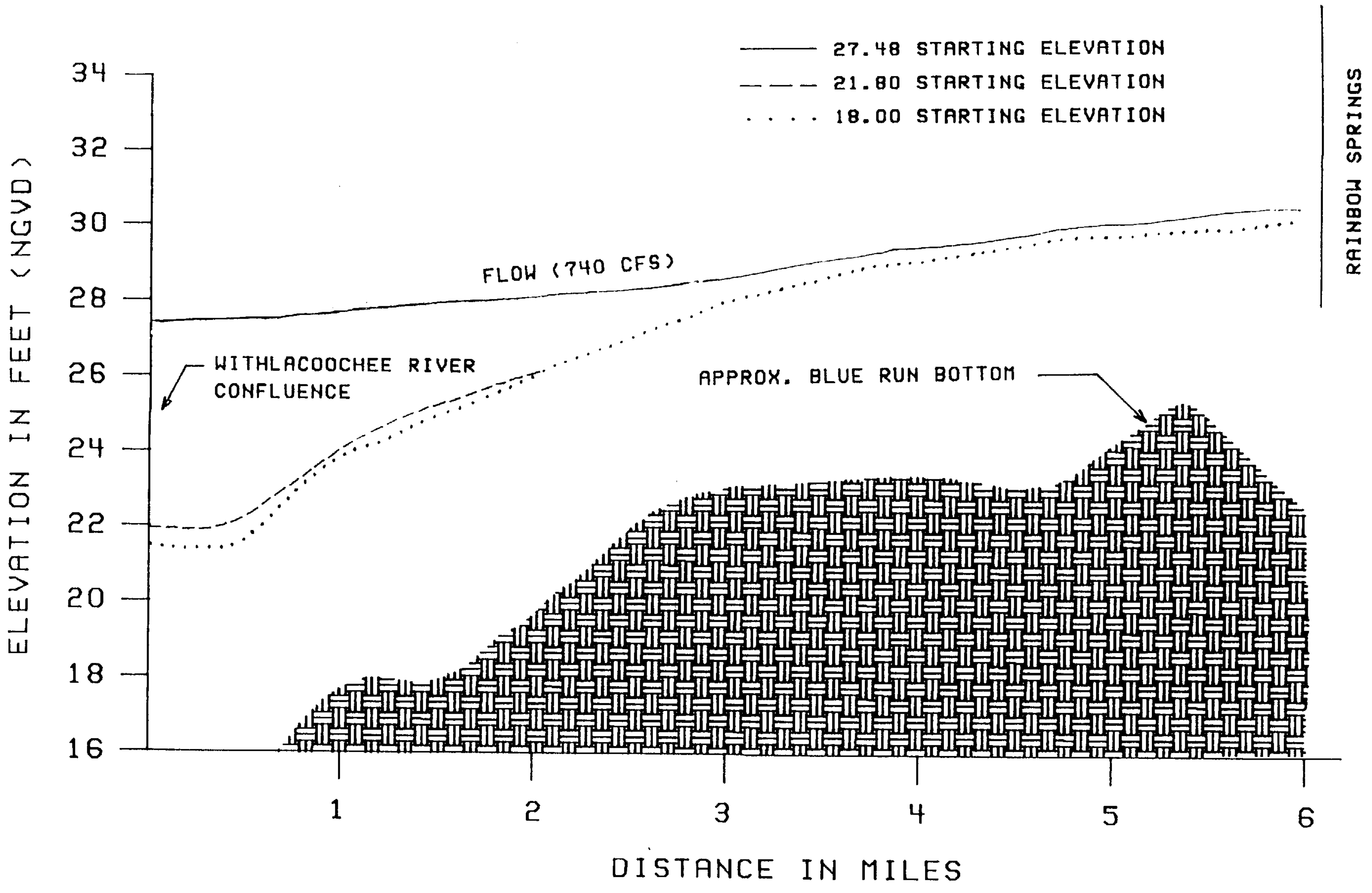


FIGURE 38 WATER SURFACE PROFILES FOR BLUE RUN, OCTOBER 1972 CONDITIONS.

average flow conditions, the drawdown effect will migrate beyond S.R. 200.

If Lake Rousseau had been drawn down to the recommended 18 foot level for these conditions, the resulting water surface elevations at Dunnellon, Rainbow Springs and S.R. 200 would have been 21.60, 30.55 and 28.04 feet respectively. The comparison of the calculated water surface elevations for a 27.48 foot starting elevation to the water surface elevations for an 18.00 foot starting pool elevation would indicate that significant lowering for most of Lake Rousseau could be achieved during average flow conditions with about a 1.4 foot water level decrease occurring at S.R. 200.

Water Surface Response Blue Run

The resultant surface water response along Blue Run for average flow conditions in the Withlacoochee are very similar to the drought simulation. The only difference that would occur is that the lower portions of Blue Run water surface elevations would be higher by a couple of feet. The Rainbow Springs elevation would be essentially unaffected as a result of a drawdown.

Navigation

Navigation would still be a problem along a majority of the reservoir and river system. However, a two foot minimum clearance in the main river channel could be maintained under these flow conditions from the outlet structures on the lake upstream to S.R. 200. Hazardous conditions would still exist in the reservoir requiring channel marking, warning signs and locations of access points.

Results of Simulated Drawdowns for April 1960 Conditions

Water Surface Response Main River Channel and Blue Run

April 1960 conditions were chosen for simulating drawdown effects for two reasons: flooding events, such as the April 1960 flood, have historically occurred during the time period a drawdown would be scheduled, and the need to determine what effect a drawdown would have on decreasing water surface elevations in the Dunnellon area during such an event. Water surface profiles on Figure 39-41 depict this flow condition. Another section of the report has been reserved to discuss specifically the details of lowering Lake Rousseau in the event of a flood.

An analysis of the water surfaces generated for the April 1960 conditions indicate that the lowering of Lake Rousseau will not

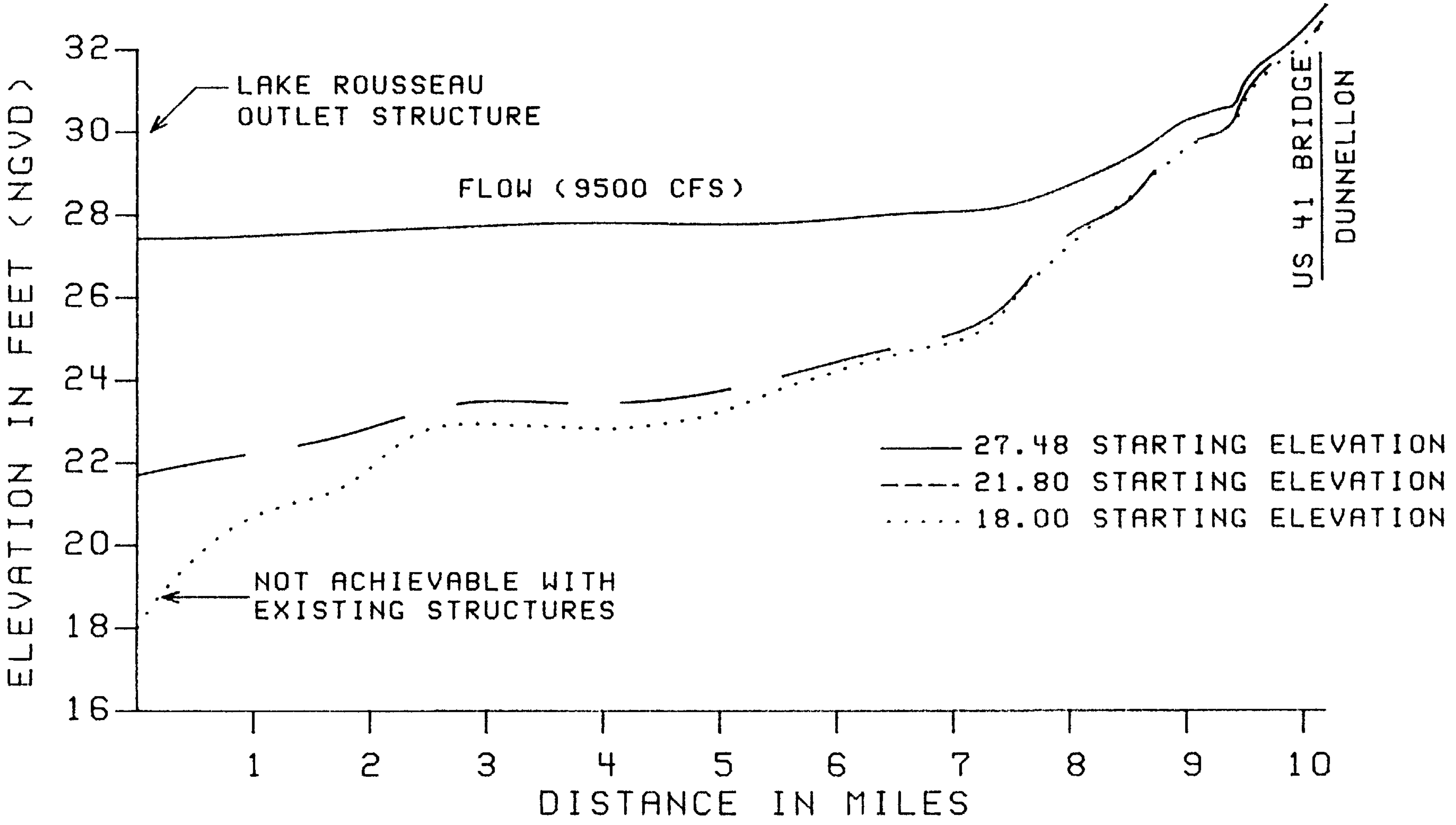


FIGURE 39 WATER SURFACE PROFILES BETWEEN LAKE ROUSSEAU OUTLET STRUCTURES AND U.S. 41, APRIL 1960 CONDITIONS.

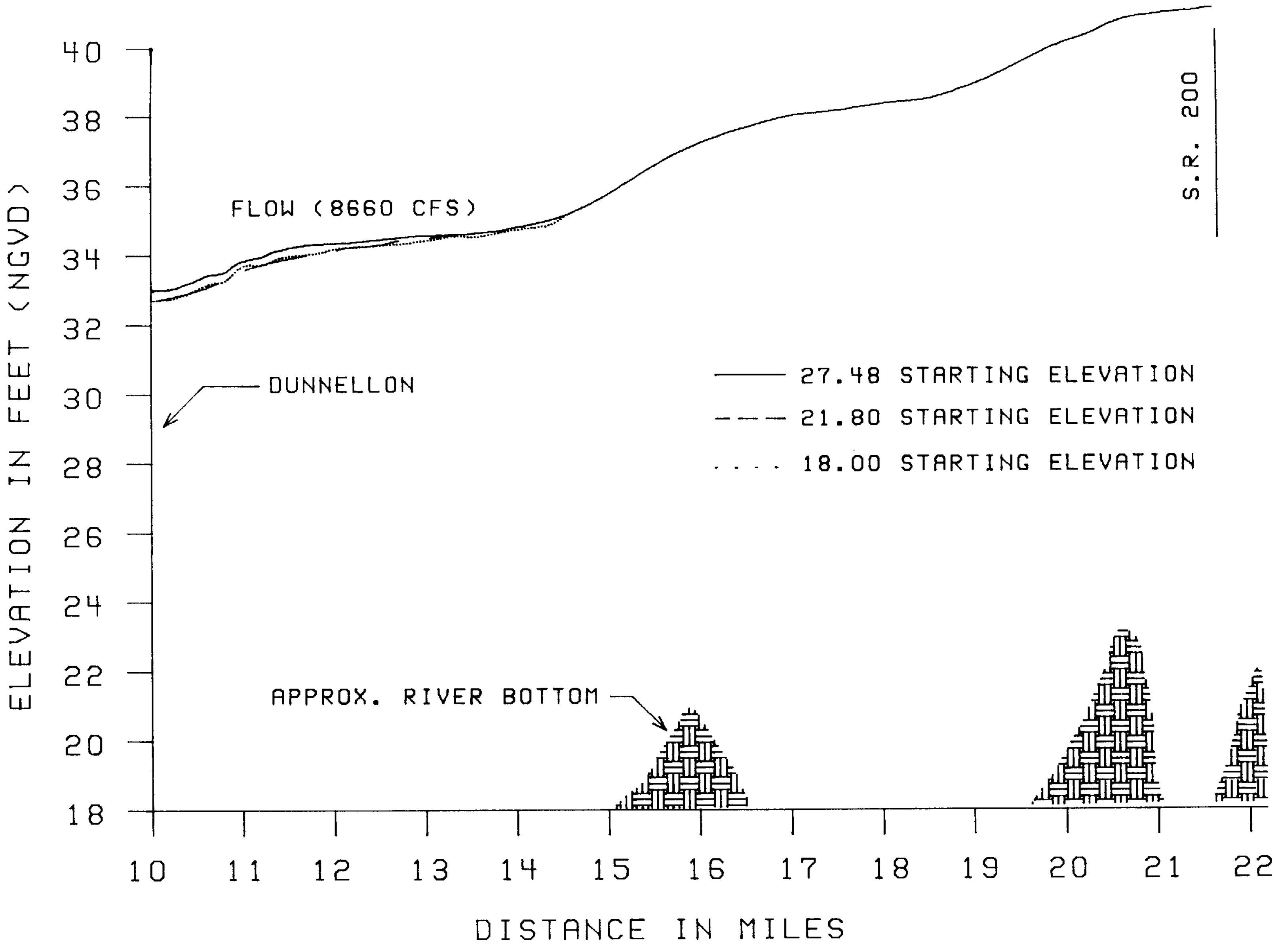


FIGURE 40 WATER SURFACE PROFILES BETWEEN DUNNELLON AND S.R. 200, APRIL 1960 CONDITIONS.

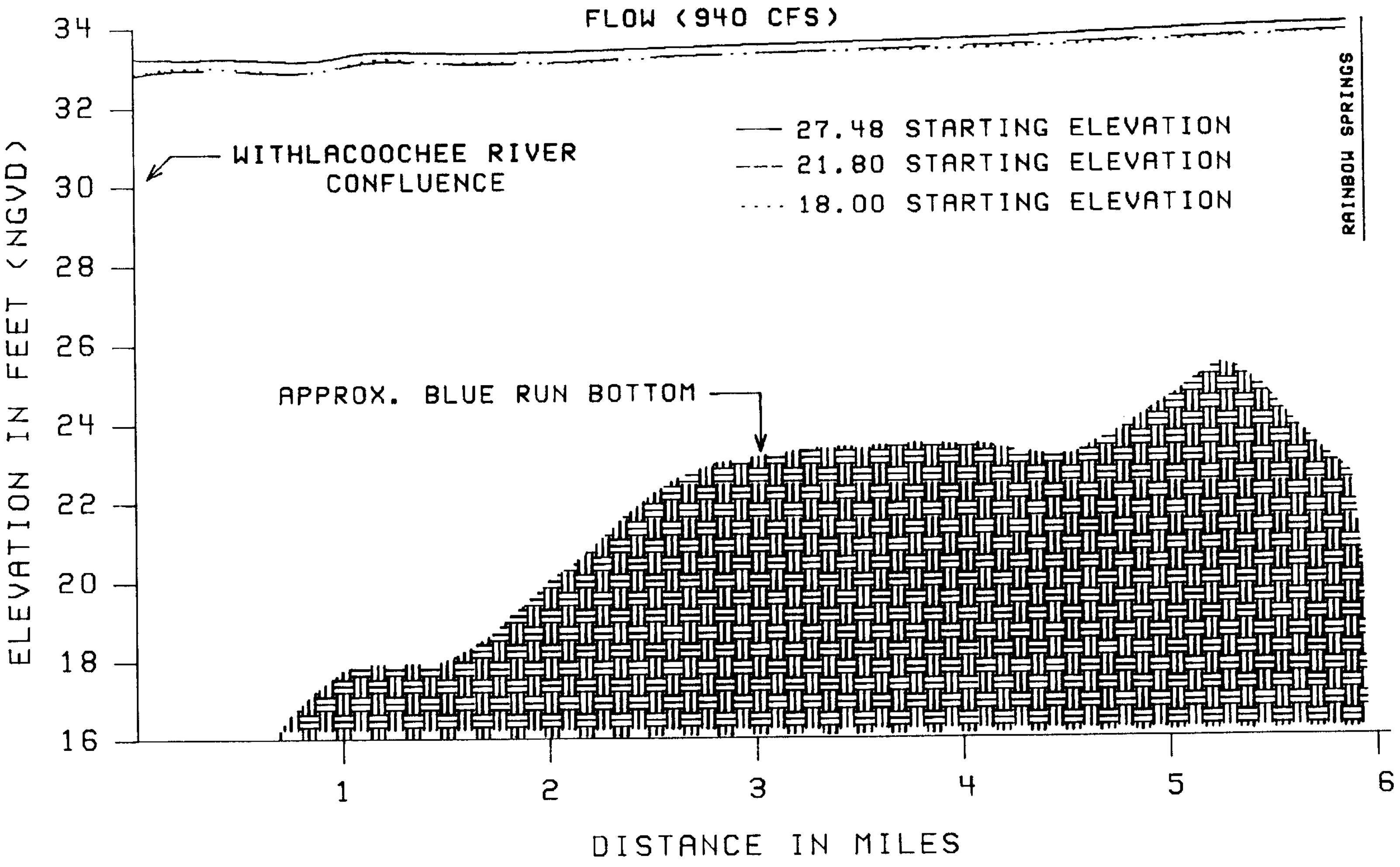


FIGURE 41 WATER SURFACE PROFILES FOR BLUE RUN,
APRIL 1960 CONDITIONS.

substantially effect water surface elevations beyond Dunnellon. The resulting water surface elevations at the U.S. 41 bridge at Dunnellon for a starting pool elevation at the west end of Lake Rousseau of 27.48, 21.8 and 18.00 feet for April 1960 conditions are 32.83, 32.57 and 32.57 feet respectively (Table 22). These elevations indicate that less than a three-tenths of a foot drop at Dunnellon will be realized as a result of lowering Lake Rousseau to 21.8 feet with no further decrease as a result of lowering the reservoir to 18.00 feet. It should be noted that Lake Rousseau could not be lowered much below 22 feet for this discharge rate (9,500 cfs) because the hydraulic capacity of the existing outlet structures are limiting. Figure 42 presents the stage discharge curve for Inglis Dam and bypass spillway.

Since it usually takes about two to four weeks for a flood wave to pass before normal flow conditions are re-established, it is doubtful that being in a drawdown configuration under these conditions would do much to benefit the reservoir. The water surface profile through Lake Rousseau under these conditions is far from being level. Three miles upstream of the outlet structures, the water surface elevations will rise from 18 feet to 22 feet as the floodwave passes. Seven miles upstream, the water surface elevation will have achieved 24 feet which is 6 feet above the 18-foot target elevation. These elevations would not allow sufficient drying out of the muck bottom to facilitate consolidation. Also, rainfall could inhibit the drying of the

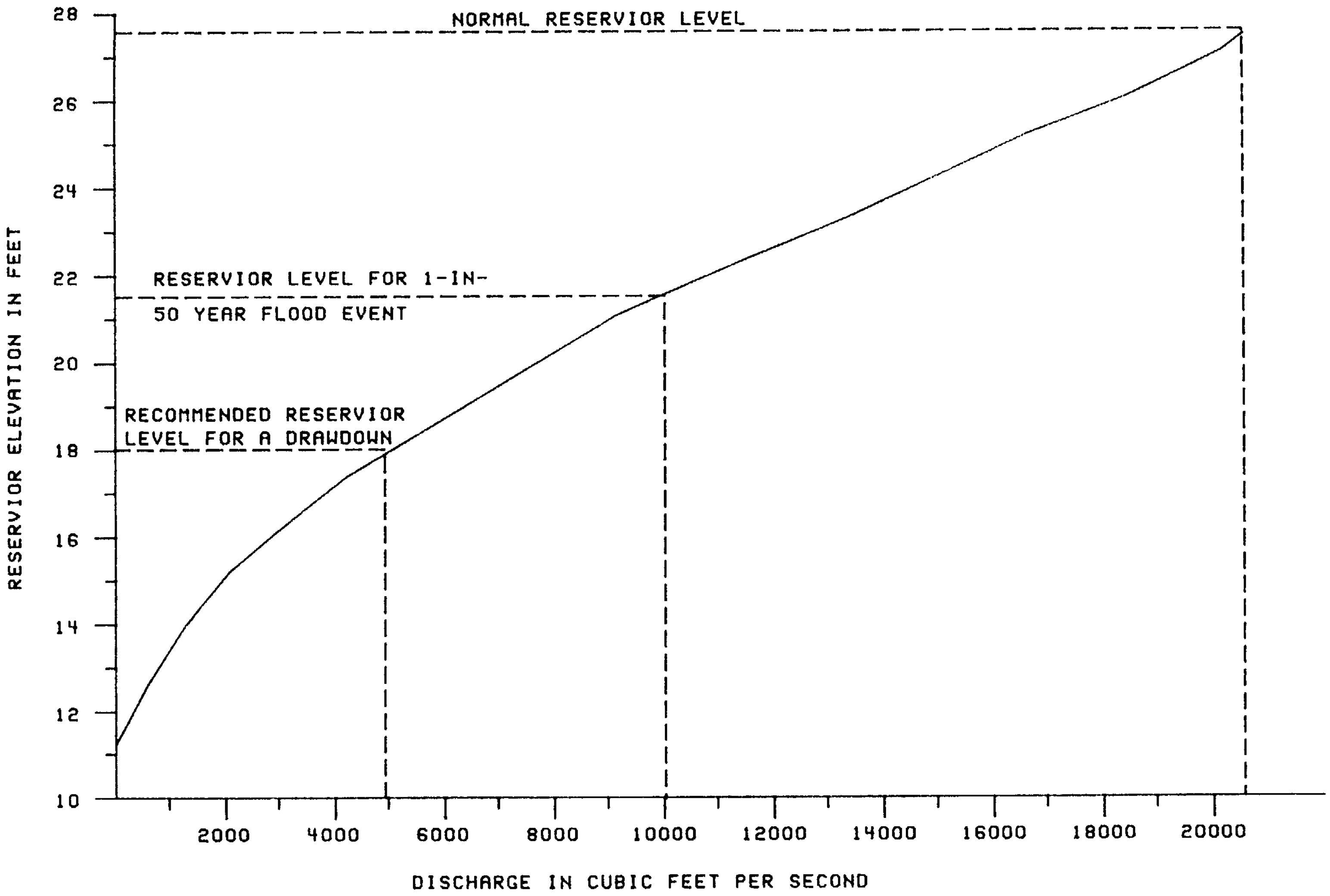


FIGURE 42 COMBINED DISCHARGE CAPACITY OF INGLIS DAM AND BYPASS SPILLWAY

muck unless the event was a single event that occurred either at the beginning or tail-end of the drawdown cycle.

Navigation

Navigation for the April 1960 conditions would be limited in the Lake Rousseau area only. All other areas should have enhanced navigation ability due to the increased water surface elevations as a result of the flood. Debris and increased channel velocities would be the only hazard to boating upstream of Lake Rousseau. During flooding conditions boat access has been limited by local authorities to prevent property damage from vandalism and looting.

DRAWDOWN FOR FLOOD CONTROL WITH EXISTING USACOE CONTROL STRUCTURES

The Inglis Dam and the bypass channel and spillway are the primary USACOE control structures whereby surface water is released from Lake Rousseau. The bypass spillway has a discharge capacity of 1,540 cfs when Lake Rousseau is at an elevation of 27.5 feet. The surface water from the bypass spillway is discharged to the lower Withlacoochee River passing by the communities of Inglis, Crackertown, and Yankeetown before entering the Gulf of Mexico (Figure 1). The Inglis Dam, on the other hand, has a discharge capacity of 18,000 cfs when the lake elevation is 27.0 feet. This 18,000 cfs discharge is the Standard Project Flood (a one-in-200 year event) and is almost doubled the peak discharge of the April 1960 flood. Discharge from Inglis Dam is routed down a short section of the old river channel before it enters the CFBC that connects to the Gulf of Mexico.

Areas where flooding is a primary concern are the lower Withlacoochee River and the river section located near Dunnellon and Rainbow Springs. Due to the limiting capacity of the bypass channel system, flooding along the lower river is practically impossible as a result of bypass releases. A USACOE study of the lower river system indicated that significant flood damage would not occur on the lower river until a discharge of 7,000 cfs is realized at normal tide levels. In order to discharge 7,000 cfs to the lower river substantial modifications to the CFBC structures would be required. However, flooding of the lower river can occur as a result of other forces such as tidal surges from hurricanes. There is nothing that can be done to relieve tidal flooding other than the normal operating procedure of reducing freshwater releases from the bypass spillway so as not to exacerbate the situation.

Upstream flooding potential is limited to a few dwelling structures in the Dunnellon area. A survey was conducted by District staff in March 1986, to determine which structures were subject to flooding. Based on this survey, there were eight structures that have floor elevations below 33 feet. Thirty-three feet corresponds to a one-in-50 year flood elevation on the Withlacoochee River at the U.S. 41 Bridge in Dunnellon.

Methods for reducing the flood elevation in the Dunnellon area include increasing river conveyance (stream discharge capacity) through and downstream of the affected area, and/or decreasing tailwater conditions (reservoir level). A decrease in the reservoir level would be the simplest method to employ for decreasing water levels in the Dunnellon area. The USACOE structures on Lake Rousseau could be used to lower tailwater conditions for the river. Using these existing barge-canal structures, Lake Rousseau's west water level could be maintained just below 22 feet with a discharge of 9,500 cfs, a one-in-50 year event. This 22-foot elevation is approximately 5.5 feet lower than the level the reservoir is usually maintained. However, under these conditions, there would virtually be no discharge down the bypass channel to the lower Withlacoochee River. Thus creating a potentially damaging situation for the estuary. Therefore, it is not recommended that Lake Rousseau be lowered below 24 feet during flood events using these existing structures. The USACOE currently uses this option to keep stages at Dunnellon below the flood stage at 29 feet, NGVD, as much as practical.

If a drawdown of Lake Rousseau is pursued from a management standpoint, then the proposed structure modifications necessary to facilitate a drawdown could be used to lower Lake Rousseau below 24 feet in the event of an impending flood while maintaining flows to the lower river. Three tailwater conditions were used in a backwater analysis to determine what effect that lowering Lake Rousseau would have on flood levels in the Dunnellon area at a 9,500 cfs discharge. The elevations are 27.5 (the normal lake level), 21.8 and 18.0 feet. The 18.0 foot elevation was used in the analysis to determine whether there would be any effect on flood levels from near the Dunnellon area upstream even though this elevation could not be maintained for the higher discharges.

The results of the step-backwater analyses using these three tailwater elevations for the April 1960 peak flow conditions indicates that there would be no significant change in water surface elevations from about the Dunnellon area upstream (Figures 39-41). General convergence of the profiles occurred regardless of the tailwater conditions used. However, further analyses indicated that as river flows decrease, that there will be a gradual increasing effect on river stages in Dunnellon from lowering Lake Rousseau. For example, at a river flow around 5,000 cfs at Dunnellon, the estimated effect from lowering the reservoir in the Dunnellon area is about 0.5-0.9 feet, depending on river hydrologic conditions.

Since the profiles generated in the step-backwater analyses were steady-state, it was determined that the full potential of flood relief through tailwater lowering had not been investigated. Steady-state models do not utilize the full Saint-Venant Equations in regard to open-channel flow. Significant Saint-Venant terms that are not included in steady-state backwater analysis are storage and acceleration.

In order to investigate the full potential of tailwater control on upstream water surface elevations, a U.S. Weather Bureau's Dynamic Wave and Operation Model (DWOPER) was used. This model can dynamically simulate the time propagation of a flood wave along a river reach. This dynamic model was used to simulate resultant elevations at Dunnellon for the flood wave generated as a result of Hurricane Elena, 1985, as if Lake Rousseau had been lowered to 18 feet. The hypothesis was that the lowering of Lake Rousseau prior to flood-wave arrival should reduce upstream flood elevations by creating additional water storage and higher discharges.

Hurricane Elena dumped around five inches of rainfall on the Withlacoochee River Basin between August 28, and September 3, 1985. However, the corresponding flood-wave peak did not pass the Holder gaging station until three weeks later (Figure 43). This flood-wave peak represents about a one-in-five-year event. The DWOPER model was used to simulate this flood wave as if the reservoir were drawn down to 18 feet one week prior to Hurricane Elena arrival and a month prior to the corresponding flood-wave peak arrival.

Before the 18-foot lowered tailwater condition was simulated, the DWOPER model was first calibrated to the prevailing conditions. After an acceptable calibration was achieved, the model was then used to simulate the Hurricane Elena floodwave as if the west end of Lake Rousseau had been lowered to 18.0 feet prior to its arrival. Figure 43 demonstrates the difference between the tailwater conditions (Lake Rousseau's west end water levels) simulated and the actual tailwater conditions imposed by the USACOE during that period. The combined discharge hydrograph for

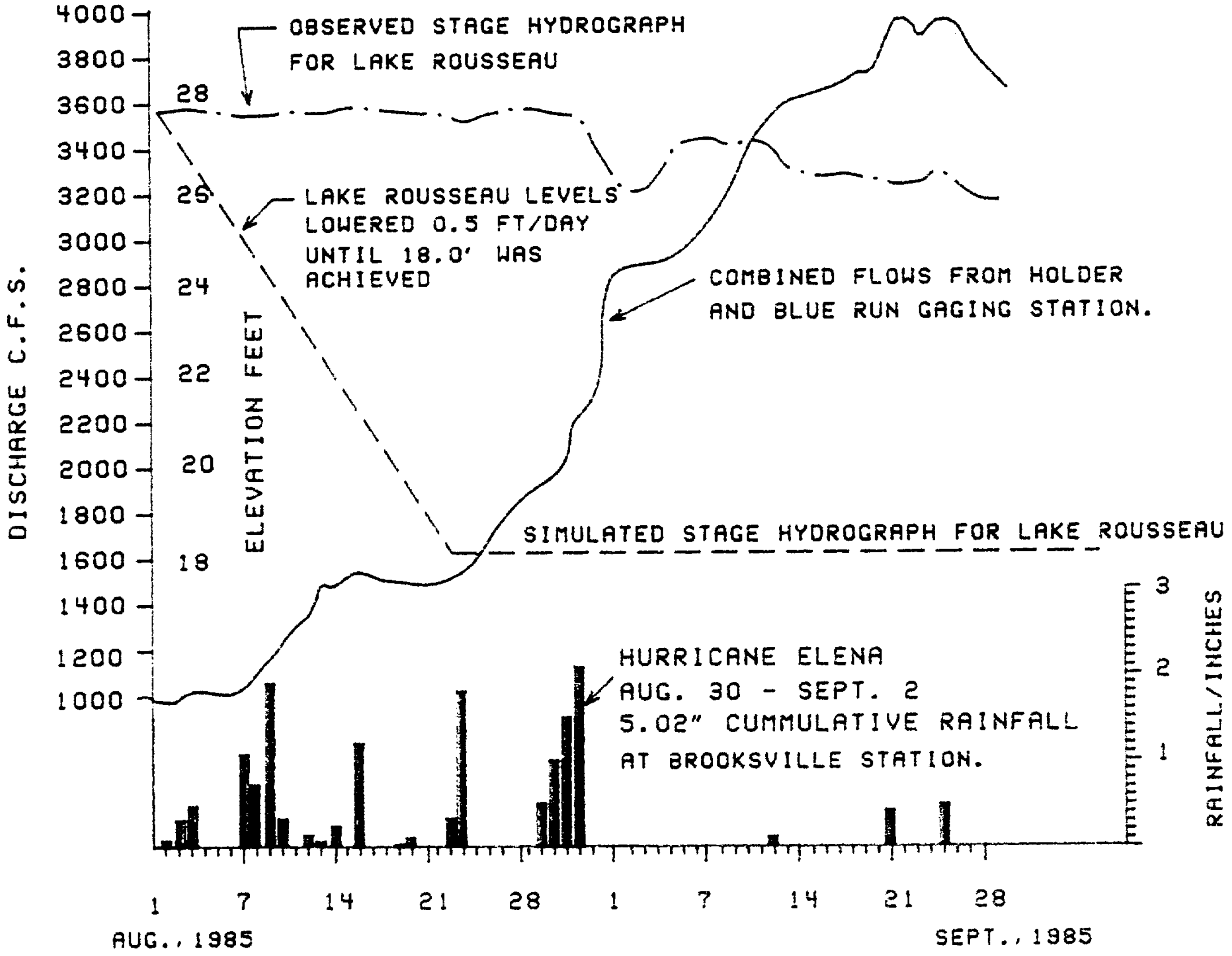


FIGURE 43 SIMULATED AND RECORDED LEVELS FOR LAKE ROUSSEAU AND SUPERIMPOSED DISCHARGE HYDROGRAPH AND BROOKSVILLE HYETOGRAPH.

Blue Run and Holder is also presented to demonstrate the time lag between commencement of simulated tailwater lowering and the flood-wave passage.

The model results indicated that prior to Hurricane Elena's flood-wave arrival, the simulated lowering of Lake Rousseau was also manifested in the Dunnellon area. As the flood wave progressed, river elevations in the Dunnellon began to rise in relation to the river discharge. The river elevations continued to rise in the Dunnellon area until the peak of the flood wave passed. The end result was that there was no significant additional lowering of the peak flood elevation in Dunnellon by drawing down Lake Rousseau to 18 feet. The time effect of tailwater lowering on river elevations in the Dunnellon area is presented on Figure 44). The input data used in the DWOPER simulations are presented in Appendix G.

Since very little added difference in elevation for the Hurricane Elena flood wave was achieved in the Dunnellon area, it was concluded that little to no benefit would occur from lowering Lake Rousseau for the higher discharge events such as the April 1960 flood. The only other alternative for lowering flood elevations in the Dunnellon area for such events is to increase the conveyance capacity of the river. Figure 45 demonstrates that there is very little difference in the conveyance capacity of the river from about the abandoned tram-crossing upstream (see

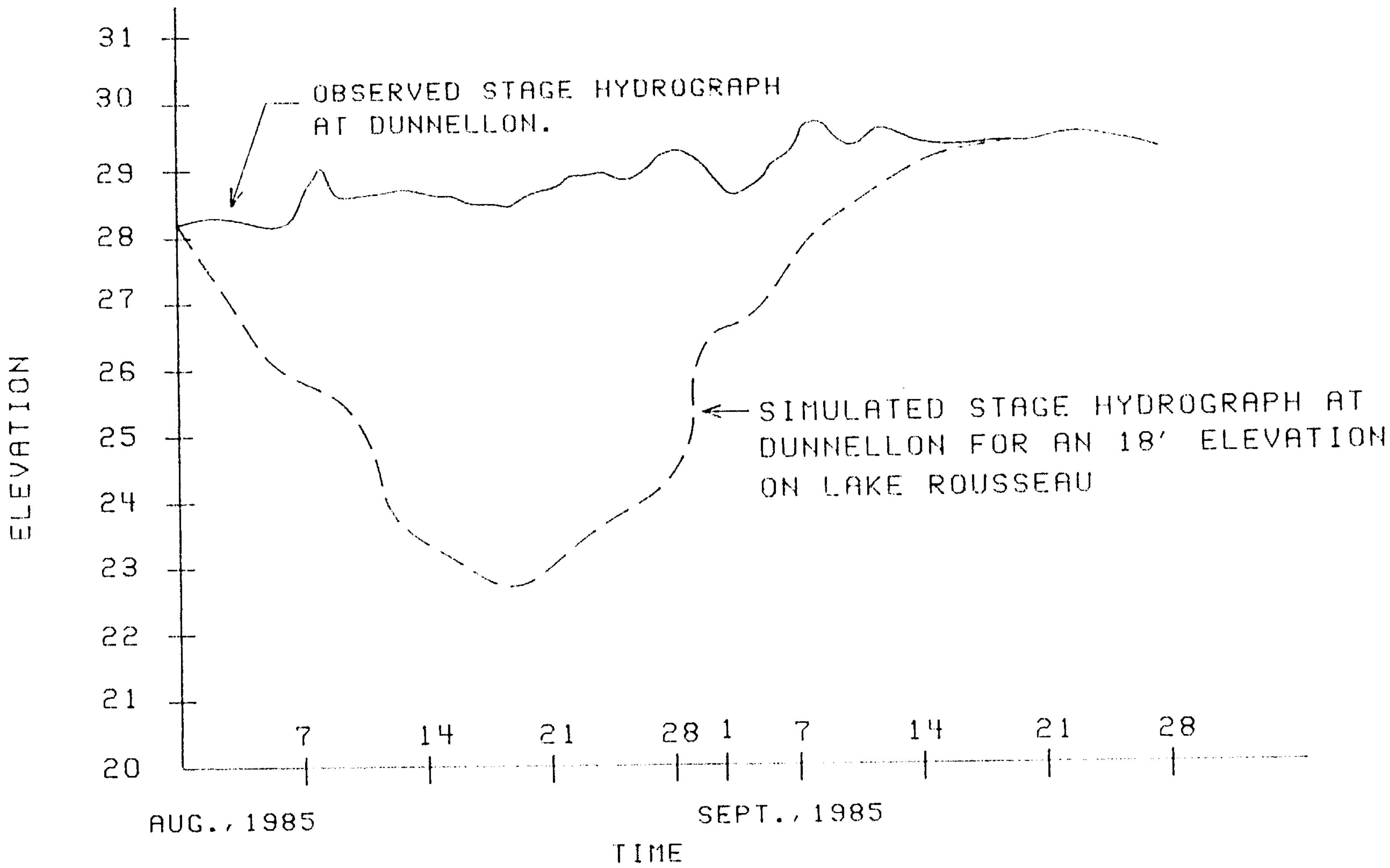


FIGURE 44 COMPARISON OF OBSERVED AND SIMULATED STAGE HYDROGRAPHS AT DUNNELLON FOR HURRICANE ELENA, 1985.

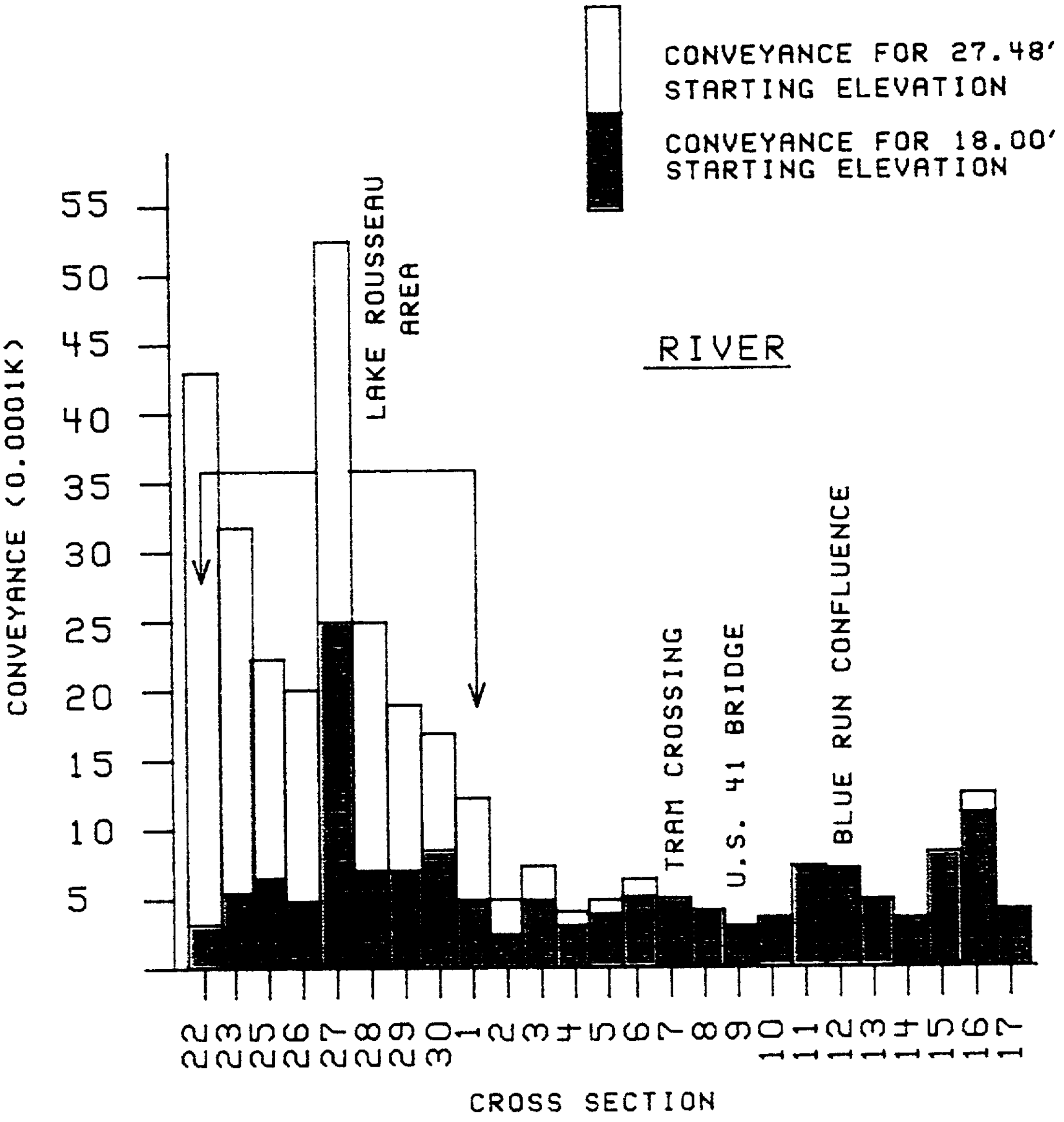


FIGURE 45 RIVER CONVEYANCE FOR APRIL 1960 PEAK FLOWS

Figure 31 for location) for the 27.48 versus the 18.0-foot tailwater condition on Lake Rousseau for the 1960 flow conditions. However, there was a large variation in the reservoir conveyance for the two tailwater conditions which explains why lowering Lake Rousseau's water levels was explored as an option for decreasing flood levels in the Dunnellon area. The USACOE in their CFBC Restudy Report, June 1975, proposed channel improvements from just inside the Lake Rousseau area to just upstream of the Blue Run confluence which corresponds to the areas where little change in conveyance was observed. The channel improvements presented in that study were for the 10- and 30-year flood events determined for the Four River Basins' Project. In brief, it was determined by the USACOE at that time that channelization to increase the conveyance capacity of this river section was not cost-effective.

GROUND-WATER RESPONSE TO A DRAWDOWN

Introduction

Due to the supporting evidence of Lake Rousseau's role in the recharging the Upper Floridan aquifer system, there was some concerns for the effects on surrounding aquifer levels and salt-water-fresh-water interface movement in the event of a drawdown. To address these concerns, a USGS, finite difference, ground-water flow program (MODFLOW) was used to develop a model for the area based upon pervious work (Adams, 1985). Adams' model was regional in nature and had no model cells specifically representing Lake Rousseau. Consequently, only the calibrated aquifer characteristics could be used from that model. Adams, for the most part, treated the Lake Rousseau area as part of an unconfined aquifer system and modelled the area as a single layer. Her model results indicated that the Lake Rousseau area was a significant recharge area having an average calibrated-recharge rate of 20-inches per year.

The model specifically developed for analyzing drawdown effects in this study is a single layer steady-state model that used 500 by 2,000-foot cells (Figure 46). This cell size is less than one percent of the cell size used in the Adams' model and was chosen because it provided better definition of the Lake Rousseau area. Cells representing the model boundaries and Lake Rousseau were

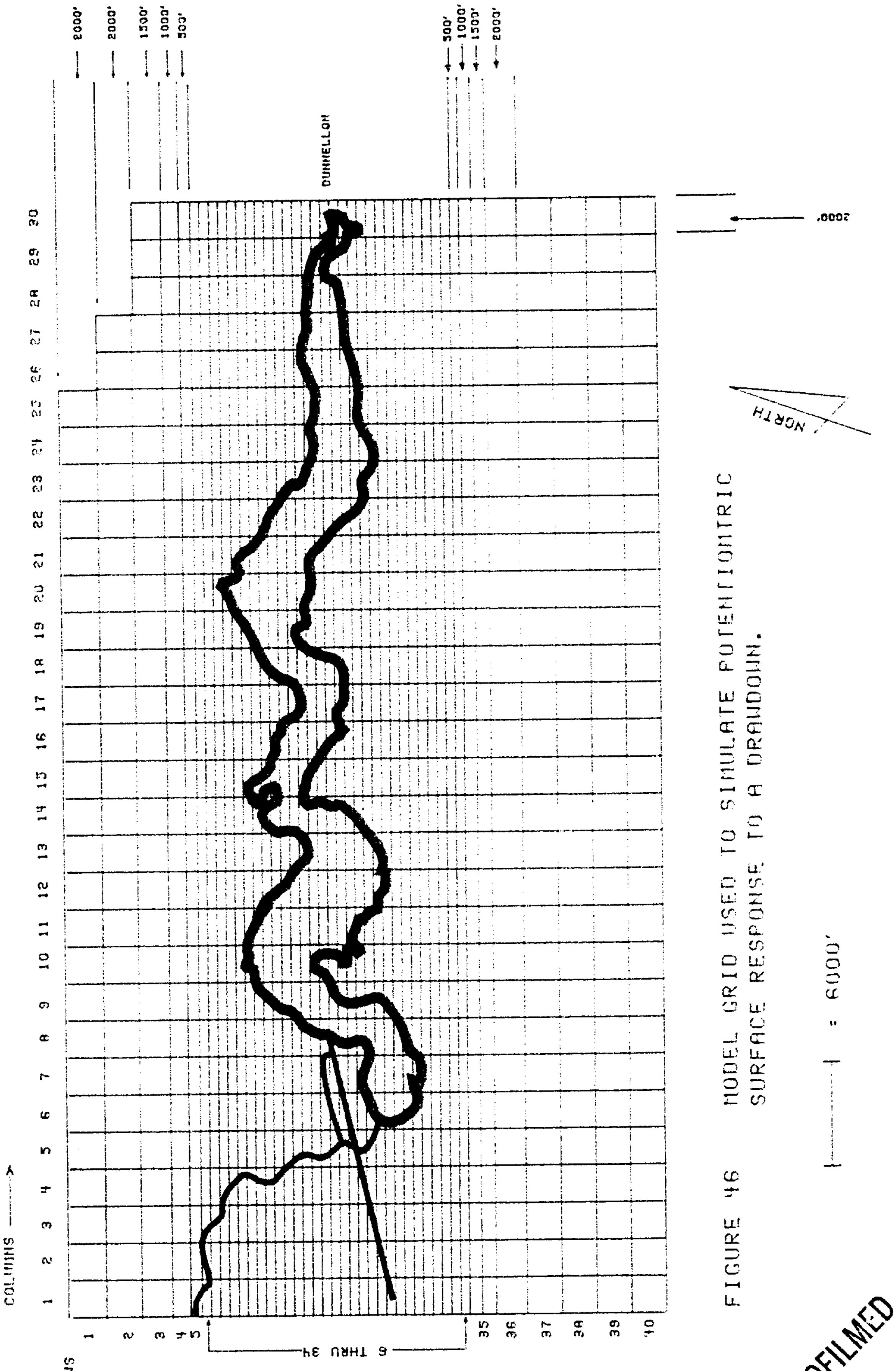


FIGURE 46 MODEL GRID USED TO SIMULATE POTENTIOMETRIC SURFACE RESPONSE TO A DRAWDOWN.

set up as constant head cells, while the flow characteristics for each of the model cells were based on the results of Adams' model. Assigned heads for the constant head boundary cells were based upon the simulated heads from Adams' model and the assigned heads for cells representing Lake Rousseau were based upon prevailing reservoir conditions (Table 23). Appendix H contains the model input data used simulate the ground-water response to a drawdown.

In order to simulate the surrounding aquifer response to a drawdown, two reservoir levels were modelled: The average existing condition and the drawn-down condition. Since Lake Rousseau is usually maintained at an elevation of 27.5 feet, this elevation was used for the average existing condition. For the drawn-down condition, 18 feet was used because it was the extreme low level recommended by the FG&FWFC.

Model Results

Existing Conditions

For the existing conditions, Lake Rousseau was modelled at a constant elevation of 27.5 feet. An analysis of the cell-by-cell flow terms for Lake Rousseau indicated that the reservoir contributed a net 120 cfs to the surrounding aquifer. As previously mentioned, a USGS water balance study for Lake

Table 23. **Lake Rousseau Constant Head Boundary Elevations and Constant Head Nodes Representing Lake Rousseau.**

North Boundary (west to east)

Row	Column	Elevation	Row	Column	Elevation	Row	Column	Elevation
1	1	13.0	1	11	26.67	1	21	41
1	2	14.75	1	12	27.78	1	22	41.33
1	3	16.5	1	13	28.89	1	23	41.67
1	4	18.3	1	14	30.0	1	24	42
1	5	20	1	15	32.5	1	25	41.67
1	6	21.1	1	16	35.0	2	26	41.33
1	7	22.2	1	17	37.5	2	27	41.0
1	8	23.3	1	18	40	3	28	40.66
1	9	24.44	1	19	40.33	3	29	40.33
1	10	25.56	1	20	40.67	3	30	40

South Boundary (west to east)

Row	Column	Elevation	Row	Column	Elevation	Row	Column	Elevation
40	1	6.8	40	11	8.93	40	21	12.71
40	2	7.01	40	12	9.15	40	22	13.26
40	3	7.23	40	13	9.36	40	23	13.8
40	4	7.44	40	14	9.57	40	24	14.34
40	5	7.65	40	15	9.79	40	25	14.88
40	6	7.87	40	16	10.0	40	26	15.43
40	7	8.08	40	17	10.54	40	27	15.97
40	8	8.29	40	18	11.09	40	28	16.51
40	9	8.51	40	19	11.63	40	29	17.06
40	10	8.72	40	20	12.17	40	30	17.6

Table 23, continued.

West Boundary (north to south)

Row	Column	Elevation	Row	Column	Elevation	Row	Column	Elevation
1	1	13.0	15	1	11.03	29	1	9.73
2	1	12.67	16	1	10.94	30	1	9.6
3	1	12.34	17	1	10.86	31	1	9.47
4	1	12.02	18	1	10.77	32	1	9.33
5	1	11.87	19	1	10.69	33	1	9.2
6	1	11.8	20	1	10.6	34	1	9.07
7	1	11.71	21	1	10.57	35	1	8.87
8	1	11.63	22	1	10.43	36	1	8.53
9	1	11.54	23	1	10.34	37	1	8.10
10	1	11.46	24	1	10.26	38	1	7.67
11	1	11.37	25	1	10.17	39	1	7.23
12	1	11.28	26	1	10.01	40	1	6.8
13	1	11.2	27	1	10			
14	1	11.11	28	1	9.87			

East Boundary (north to south)

Row	Column	Elevation	Row	Column	Elevation	Row	Column	Elevation
1	25	41.67	15	30	34.35	29	30	27.89
2	27	41	16	30	33.91	30	30	27.37
3	30	40	17	30	33.47	31	30	26.84
4	30	39.35	18	30	33.04	32	30	26.32
5	30	38.70	19	30	32.61	33	30	25.79
6	30	38.26	20	30	32.17	34	30	25.26
7	30	37.82	21	30	31.74	35	30	24.47
8	30	37.39	22	30	31.30	36	30	23.15
9	30	36.96	23	30	30.86	37	30	21.31
10	30	36.52	24	30	30.43	38	30	20
11	30	36.08	25	30	30.0	39	30	18.8
12	30	35.65	26	30	29.47	40	30	17.6
13	30	35.21	27	30	28.95			
14	30	34.78	28	30	28.42			

Table 23, continued.

Constant Head Nodes Representing Lake Rousseau.

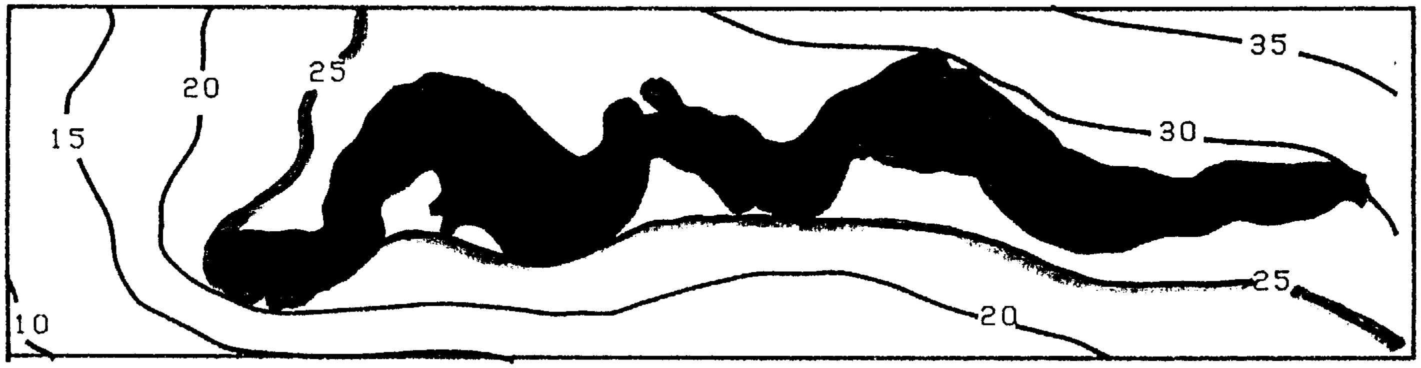
Row	Column	Row	Column	Row	Column	Row	Column	Row	Column
10	20	15	18	18	10	20	18	22	26
11	19	15	19	18	11	20	22	22	27
11	20	15	20	18	12	20	23	22	28
12	9	15	21	18	14	20	24	23	8
12	10	15	22	18	16	20	25	23	12
12	11	16	9	18	17	20	26	23	13
12	19	16	10	18	18	20	27	23	22
12	20	16	11	18	19	20	28	23	23
12	21	16	12	18	20	21	8	23	24
13	9	16	14	18	21	21	11	23	25
13	10	16	15	18	22	21	12	23	26
13	11	16	16	18	23	21	13	24	6
13	18	16	18	19	8	21	14	24	7
13	19	16	19	19	9	21	16	24	8
13	20	16	20	19	11	21	17	24	12
13	21	16	21	19	12	21	18	24	13
14	9	16	22	19	13	21	22	24	23
14	10	17	9	19	14	21	23	24	24
14	11	17	10	19	16	21	24	24	25
14	14	17	11	19	17	21	25	25	6
14	15	17	12	19	18	21	26	25	7
14	18	17	14	19	21	21	27	25	8
14	19	17	15	19	22	21	28	25	12
14	20	17	16	19	23	22	8	25	13
14	21	17	17	20	8	22	11	25	23
15	9	17	18	20	9	22	12	25	24
15	10	17	19	20	11	22	13	26	6
15	11	17	20	20	12	22	22	26	7
15	12	17	21	20	13	22	23	26	8
15	14	17	22	20	14	22	24	27	6
15	15	18	8	20	16	22	25	27	7
15	16	18	9	20	17				

Rousseau indicated that 109 cfs or 7.4% of the average daily surface inflow left the reservoir as ground-water recharge. This agreement between the ground-water model and the USGS water balance generally verifies the modelling results.

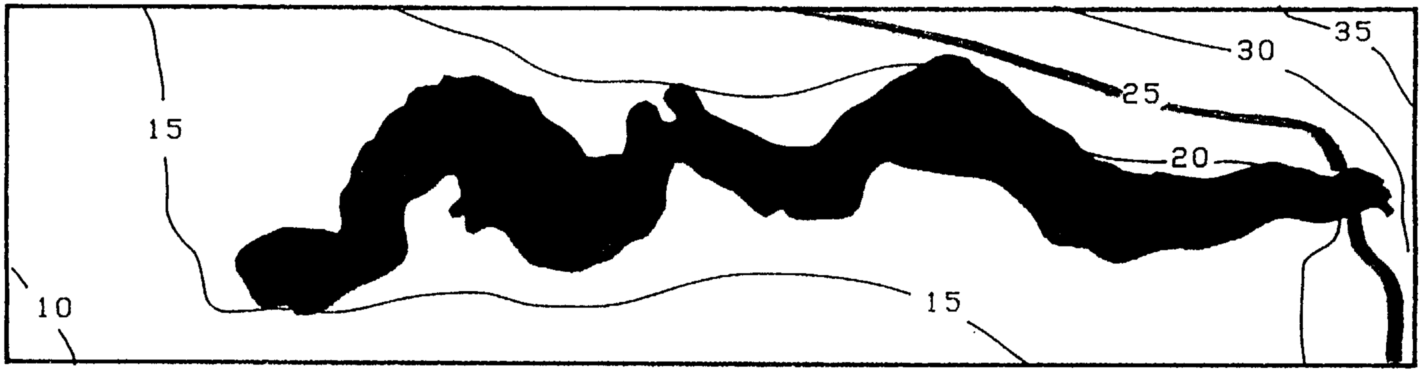
Further analysis of the cell-by-cell flow terms for the constant head nodes representing Lake Rousseau indicates that more than 50% of the ground-water discharge occurred from the west end of the reservoir. From a hydraulic standpoint, this does not appear unusual due to the relative steep hydraulic gradient of the potentiometric surface in the vicinity of the barge canal. This would indicate that the ground-water recharge from Lake Rousseau could prevent salt-water migration into the Upper Florida aquifer via the barge canal and allow the salt-water-fresh-water interface to move further inland. Salt-water intrusion will be discussed in further detail later in this section. The model also indicated that the northeast portions of the reservoir receive ground-water flow while the southwest portions discharge to the ground-water system. Figure 47 indicates the resulting potentiometric surface for the modelled existing conditions (27.5 foot reservoir level).

Drawn-down Modelled Conditions

The simulated potentiometric surface from lowering Lake Rousseau to 18 feet (Figure 47) is significantly altered in the vicinity



GENERALIZED POTENTIOMETRIC SURFACE FOR A 27.5 FT. RESERVIOR LEVEL.



GENERALIZED POTENTIOMETRIC SURFACE FOR AN 18.0 FT. RESERVIOR LEVEL.

FIGURE 47 GENERALIZED POTENTIOMETRIC SURFACE AROUND LAKE ROUSSEAU FOR 27.5 AND 18.0 FEET DRAWDOWN of the reservoir. This should be the worst case situation in regard to drawdown effects because no confining units are used in the model and steady-state rather than transient conditions are assumed. An analysis of the cell-by-cell flow terms of the reservoir nodes indicates that the net ground-water recharge from the reservoir under these conditions would be 42 cfs. This is a 65% net reduction of the reservoir's recharge capacity to the Upper Florida aquifer as compared to the recharge capacity at a normal reservoir level of 27.5 feet. This reduction in potentiometric surfaces and recharge rates could have a detrimental effect on ground-water supplies in the reservoir area.

Ground-Water Impacts from a Drawdown

The major ground-water concerns as a result of a drawdown are the decreased potentiometric surface levels and the resulting potential for undesirable waters to migrate into potable supply zones. From discussions with District Consumptive Use Permitting staff, the upper 50-100 feet of the aquifer in the reservoir area has high iron concentrations. Below 200-feet from land surface, the aquifer contains highly mineralized water leaving a production zone of approximately 100-feet thick that will meet potable supply standards without treatment. The depressed aquifer levels that would result from an extended drawdown could create a potential for salt-water contamination of this potable zone through two processes: salt-water intrusion and upwelling.

A Time Domain Electromagnetic (TDEM) survey was conducted in the barge canal area in the early part of 1986 (Earth Technology Corporation, 1986). The purpose of the TDEM survey was to locate the salt-water interface to determine whether the construction of the barge canal has significantly altered the interface location. The study results indicated that the construction of the barge canal has not significantly altered the salt-water-fresh-water interface. However, there is an indication that the barge canal construction has provided an additional discharge area for the aquifer system creating localized areas of upwelling. The mineralized water associated with the upwelling is not from salt-water, but the migration of connate waters within the Avon Park Formation (Hagemeyer, 1988). Figure 48 demonstrates the location of the upwelling along a cross section located between the Gulf of Mexico and Lake Rousseau.

It is anticipated that the depressed aquifer levels associated with the drawdown of Lake Rousseau will have the greatest effect in the barge canal area. Since the TDEM survey has indicated that localized upwelling may have resulted from the barge canal construction, the potentiometric surface lowering and associated ground-water flow reduction from a drawdown could aggravate this situation. The public supply sources most vulnerable to upwelling are Inglis and Yankeetown. See Figure 49 for their

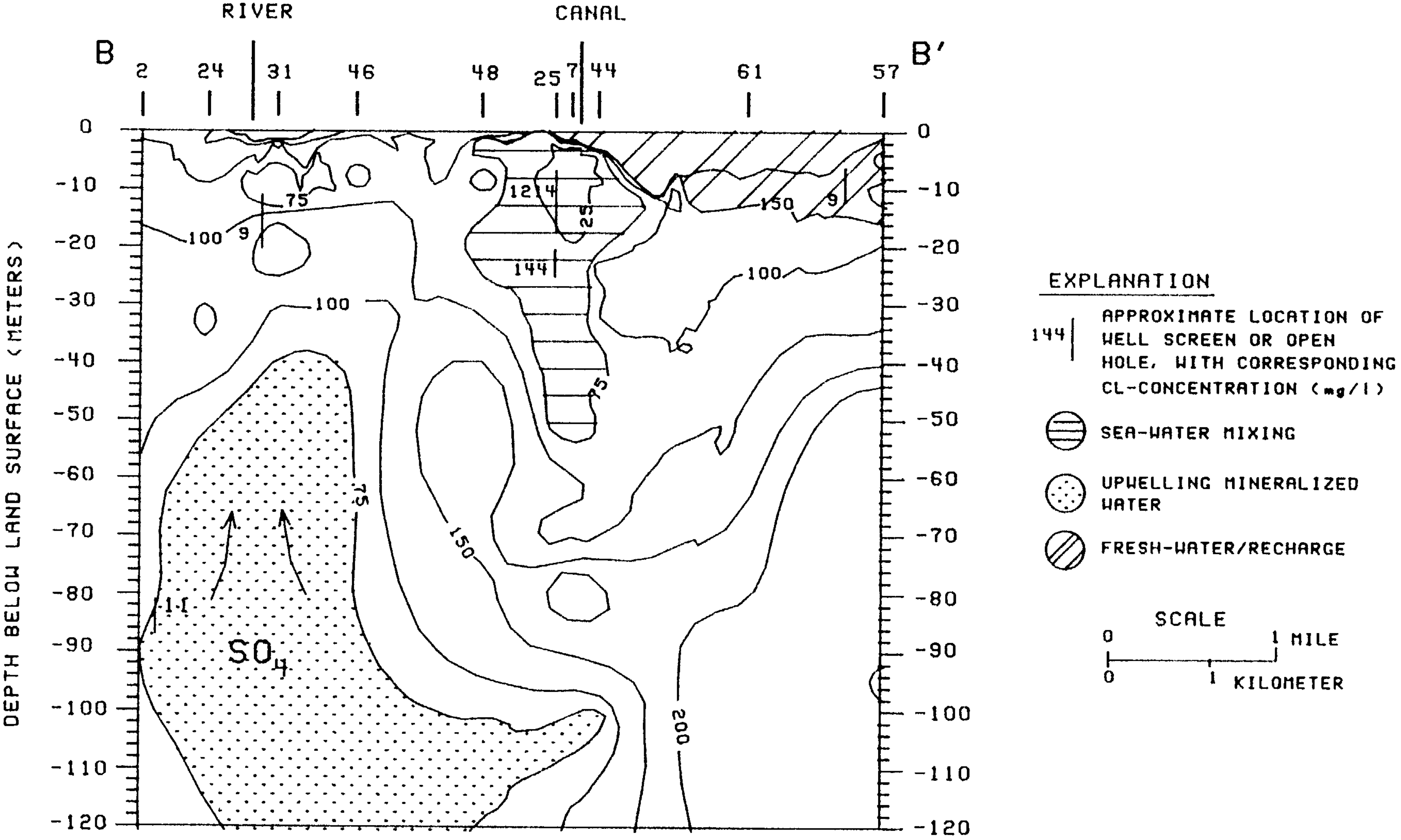


FIGURE 48 A NORTH-SOUTH GEOELECTRIC CROSS SECTION (B-B′) CUTTING ACROSS BOTH THE WITHLACOOCHEE RIVER AND THE CROSS-FLORIDA BARGE CANAL (SEE FIGURE 49 FOR THE LOCATION OF THE CROSS SECTION).

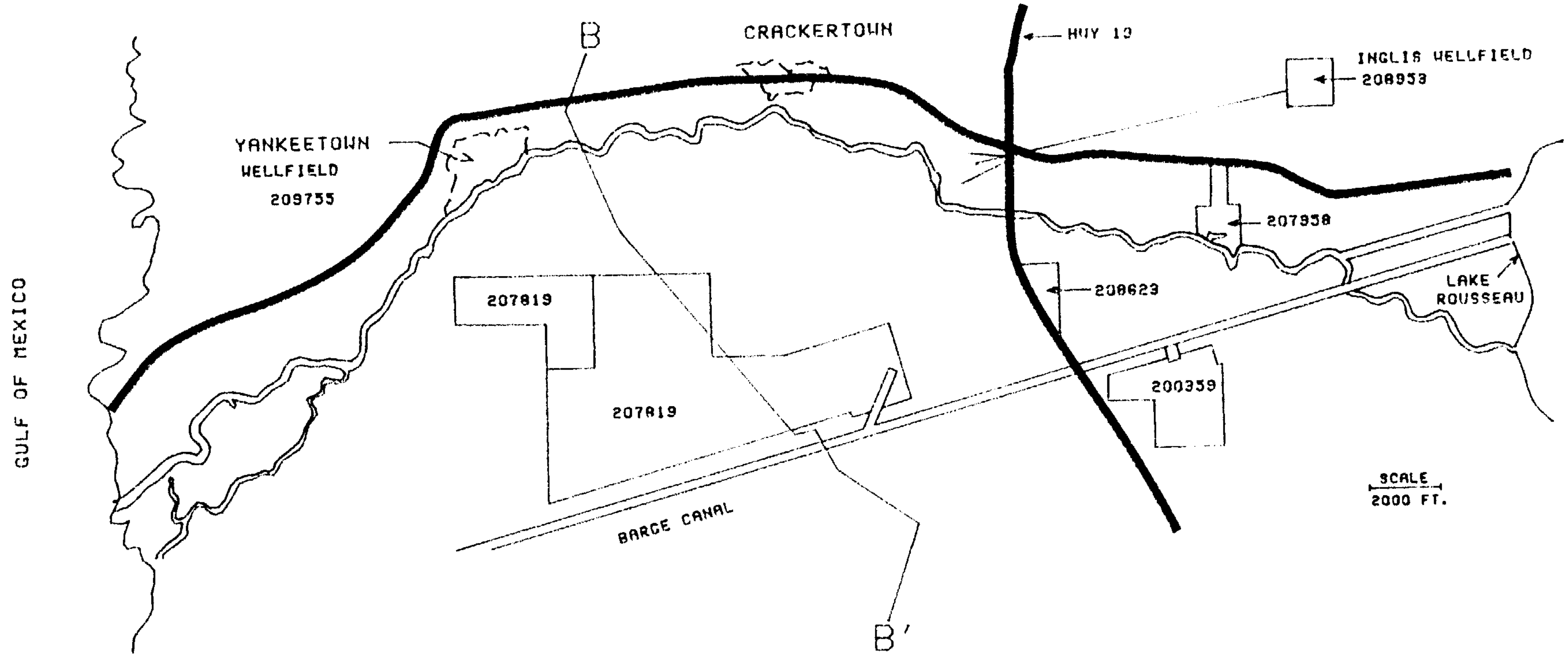


FIGURE 49 PERMITTED WATER USE LOCATIONS AND GEOELECTRIC CROSS SECTION LOCATION.

locations. It is recommended that water quality in these water supply wells be monitored closely during a drawdown.

Individual domestic supply wells on-the-other hand should experience no contamination problems except during the reservoir refill process. From discussions with USACOE, residents in the vicinity of Lake Rousseau, during the October 1972 drawdown, did experience some supply problems. It does not appear that these problems were from contamination, but from the loss of pump capacity as the result of lowered aquifer levels. If any contamination of domestic wells occurs during a refill, it would be the result from reservoir water temporarily migrating into the Upper Floridan aquifer system at above normal rates. This phenomenon would be recognized by well water exhibiting a brownish-red color.

POTENTIAL AQUATIC PLANT RESPONSE TO DRAWDOWN

The response of aquatic plants to possible water level fluctuations in Lake Rousseau is discussed in two sections of this report. Potential plant response to extreme drawdown of the reservoir is discussed in this chapter, while potential plant response to lesser seasonal water level fluctuations is discussed under Seasonal Fluctuations.

Other Drawdown Studies

The responses of aquatic plants to drawdown has been monitored in a number of case studies (see reviews by Cooke, et al., 1986, and Leslie, 1988). In these studies, the effectiveness of drawdown for aquatic weed control has given mixed results. Factors such as drawdown timing, duration and frequency are extremely important, and weather conditions during the drawdown period can affect the success of weed control. Also, various plant species can respond differently to a given drawdown scenario.

Generally, drawdowns cause an increase in the distribution of emergent plant species (e.g., grasses, rushes, sedges) and the establishment or expansion of native emergent plants during a drawdown has been observed in several Florida lakes (Wegener and Williams, 1974; Carter and Hestand, 1975; Johnson et al., 1981; McKinney and Coleman, 1981). During spring and early summer, seeds from these plants can germinate and colonize exposed bottom areas, and if the drawdown period is sufficiently long, even woody species such as willow and buttonbush can become established. The survival of emergent aquatic plant species upon refilling will be related to water depth. If the water is deep enough, emergent plants may die back at some time after refilling (Johnson, et al., 1981). However, if the basin is particularly shallow, emergent plants may persist after return to normal water levels (McKinney and Coleman, 1981). The timing of drawdown can also control the expansion and survivability of emergent species. Low water during the spring encourages the spread of emergent plants while winter drawdowns with high water in the spring may minimize this expansion.

The effects of drawdown on submersed species have been much more varied. The effects of drawdown can differ greatly between species and the biology of the target vegetation must be well known if any aquatic plant control is to be effective. Leslie (1988) and Cooke, et al. (1986) provide tables which list plant species and the observed responses to drawdown from a number of studies. Cooke, et al. (1986) suggests the hydrilla generally increases in abundance after drawdown. Following a fall-winter drawdown on Lake Oklawaha, Hestand and Carter (1975) observed a change in the macrophyte community with Ceratophyllum demersum and Elodea densa decreasing in abundance while hydrilla and water hyacinth increased. The spread of these latter two species was attributed to a mild winter without frost which allowed these species to spread to new areas. In a more recent study of Lake Oklawaha, Haller and Shireman (1988) monitored the effects of four drawdowns over a thirty month period between 1979 and 1981. These drawdowns lowered the level of the reservoir four to five feet with four foot drawdowns exposing approximately 14 percent of the reservoir bottom. The first two drawdowns were of short duration (83 and 31 days) during August-November, 1979, and January-February, 1980. The second drawdowns were 182 days and 165 days, effectively during September 1981-February 1982, and September 1982-February 1983. These drawdowns resulted in temporary control of submersed and aquatic floating weeds with a reduction in hydrilla coverage for two to six months after drawdown. After that period, however, hydrilla had recolonized the exposed areas. The researchers attributed the rapid recolonization by hydrilla to viable propagules (tubers) remaining in the organic sediments and hydrilla plants which thrived in water below the drawdown level floating back into the reflooded areas producing tubers and re-establishing the hydrilla community.

Other pertinent results from this study were that viable hydrilla propagules were reduced where the hydrosoil was predominantly sand but survived in areas with muck type sediments due to the high moisture content. The drawdowns did result in the rapid desiccation of plant biomass in the dewatered areas and the oxidation of organic sediments. Also, the drawdowns did not result in hydrilla colonizing any new areas where it had not already been established. In conclusion, these authors suggested that some fluctuations in water levels within a three-foot range in Lake Oklawaha would be beneficial by encouraging the establishment of wetland species and wildlife habitat on the upland slope. However, caution would have to be used on the lower end of this range so that hydrilla does not colonize deeper areas of the reservoir. Also, seasonal high water followed by declining levels might strand floating aquatic plants such as hyacinths and water lettuce on the shoreline, thus potentially reducing weed control efforts for these species. It was also recommended that extreme drawdown during the winter every three to four years would provide for the oxidation of bottom sediments and the desiccation of high plant biomass which has built up over time. Finally, the judicious use of aquatic herbicides should be undertaken in Lake Oklawaha to keep navigation trails open to deep water areas and to create open holes in hydrilla stands to improve water quality and fish habitat.

In a study of Fox Lake (Brevard County), McKinney and Coleman (1981) monitored plant response to three dewaterings between 1979 and 1980. Dewaterings were scheduled to reduce hydrilla biomass and also kill new hydrilla germinated from tubers and turions. These researchers observed decreases in tubers and turions after each dewatering. Tuber density stabilized at a very low level by project completion while turion densities fluctuated and then decreased to zero by August 1980. Although unseasonable rainfall prevented maximum drying of exposed areas, effective hydrilla control was reported along with the consolidation of bottom sediments. Fox Lake, however, is very shallow (average depth 1 m.) and cattails had colonized much of the basin by the project end. This problem was complicated by the temporary unavailability of effective herbicides for cattail control at the end of the project.

Applications to Lake Rousseau

Based on previous drawdowns conducted throughout the state, the probable advantages and disadvantages of drawdown for aquatic weed control in Lake Rousseau can be addressed. However, because the results of previous drawdowns have been so varied the effectiveness of drawdown for weed control in Lake Rousseau is uncertain. Similarly, an optimum fluctuation schedule for aquatic plant control can be suggested but development of the most effective plan for the reservoir will surely involve some trial and error and analysis of results for the reservoir. Aquatic plant control is only one of the possible uses of reservoir drawdown, and the fluctuation schedules developed for plant control will have to be coordinated with the goals of sediment compaction, sediment removal, or stump cutting operations.

Extreme drawdown would be accomplished by lowering the reservoir to an elevation to 18 feet. This would represent a 9.5 foot lowering of the lake elevation and would expose approximately 65% of the reservoir bottom. Although there may be some hydrilla rooted in greater than nine feet of water, such a drawdown would expose virtually all of the submersed macrophytes in the reservoir to desiccation. This would severely limit the occurrence of any live donor populations which could float into the exposed areas upon refilling, such as happened in Lake Oklawaha.

The desiccation of the huge amounts of plant biomass that have accumulated in Lake Rousseau would be of significant benefit. The reduction of plant biomass would increase water circulation, mixing, and increase usable fish habitat. For hydrilla, however, this reduction in biomass might only be short term as hydrilla will probably resprout from reproductive propagules. It is difficult to predict whether hydrilla would reach levels after drawdown that it had before. Because a Lake Rousseau drawdown would be to 9.5 feet below normal stage, recolonization might not be as rapid as occurred in Lake Oklawaha where drawdowns were only of five feet. It is reasonable to expect that extreme drawdown in Lake Rousseau would provide reductions in hydrilla coverage and biomass somewhat longer than occurred in Lake Oklawaha. It is doubtful that hydrilla biomass would return to pre-drawdown levels in one growing season, but after one or more years, return of hydrilla to pre-drawdown levels is possible.

Extreme drawdown would probably be very useful for reducing the size and rate of increase of the tussocks. These floating mats of vegetation would settle to the reservoir bottom during drawdown. Some of the tussock plants, particularly rooted emergents such as elephant ear and various grasses, would probably thrive on the sediment surface during the low water. Most of the floating mat, though, should desiccate with either plant death or significant loss of vigor resulting. To what extent plants of the tussock would refloat during reservoir refilling is uncertain, but there should be a considerable reduction in the size and biomass of the tussocks. For the desiccation of the tussocks longer drawdowns might be more beneficial. Also, the cutting of stumps in the reservoir should be a part of any plan to control the size and expansion of the tussocks.

As discussed for other reservoir studies, drawdown in Lake Rousseau would stimulate the germination and expansion of native emergent shoreline vegetation in the reservoir. These plants would likely persist in some shallow areas after refilling but die back in the deeper areas. This expansion of shoreline vegetation would increase the abundance of native plant communities in the reservoir. Because of the size of the reservoir and the availability of water at least six feet deep, any expansion of emergent shoreline communities would probably benefit the reservoir as a whole. It is possible, though, that access to the reservoir from certain shore areas might become more difficult. If it were a management goal to limit the expansion of emergent plant communities during drawdown, fall/winter drawdowns with refilling prior to the spring might be most applicable. Conversely, if the expansion of native emergent plant communities is desired, prolonged drawdowns with low water in the spring would be appropriate. Additional discussion of the relationships between plant communities and the timing of low water is presented under Timing and Duration of Extreme Drawdown and Seasonal Fluctuations.

A drawdown of Lake Rousseau should be used in conjunction with other aquatic plant control methods for the most effective results. In order to enhance the management effects of a water level drawdown, herbicidal and biological control methods should be considered. It is recommended that between 150 and 200 acres of minor plants in tussocks be treated prior to refill with BANVEL 720 at a rate of two quarts per acre (pers. comm. Dr. Haller, 1987). This should control the broad leafed species but leave the grasses, which provide soil stabilization. The degree of control of hydrilla might be maximized by the use of Bagous affinis, a tiny weevil which in the larval stage feeds upon exposed hydrilla tubers. The larvae are only effective in drawdown conditions as they cannot survive under water. Research on the effectiveness of the weevil larvae in the control of hydrilla is being conducted by the U.S. Department of Agriculture and the USACOE Waterways Experiment Station. At the time of a possible drawdown of Lake Rousseau, further consideration should be given to the use of the weevil.

During recent drawdowns on Lake Oklawaha and Lake Tohopekaliga test plots have been treated with SONAR to determine its effectiveness when applied directly to the sediments. The results following inundation have indicated that in order to achieve good control, high application rates (up to 4 lbs. of fluridone per acre) are required. While additional testing may be needed, it is not recommended that a large treatment with SONAR be undertaken during a drawdown on Lake Rousseau due to high costs (approximately $850 per gallon of SONAR, plus application costs) and inconclusive data on its efficiency. However, small test plots utilizing a range of application rates could be incorporated into the aquatic plant management plan. A project of this type should be coordinated with the Center for Aquatic Plants, University of Florida, and the USACOE Waterways Experiment Station research facility to allow for further study of the use of SONAR on exposed lake sediments. Additionally, alternative herbicides such as FENAC may be considered for test plots.

Another method of aquatic plant control that is relatively new is the use of sediment covers (see review by Cooke, et al., 1986). These essentially are sheets or screening materials which are placed over the sediments and prevent plants from growing up through them. There are many considerations for using sediment covers including cost, durability, buoyancy, and ease and effectiveness of installation. They are largely untested in Florida waters, and there are many questions regarding their potential effectiveness. During a possible drawdown, Lake Rousseau might provide some good areas where sediment covers could be deployed in small test plots. Due to cost considerations and uncertainties regarding their effectiveness, the use of sediment covers should only be experimental and in very small scale.

Other management techniques which could be implemented during drawdown might help alleviate the aquatic plant problem in the reservoir. As previously mentioned, stump cutting would remove obstructions which are important to the formation of tussocks. Also the removal of organic sediments might diminish the regrowth of submersed plants after reservoir refilling. Haller and Shireman (1988) found that drawdown reduced viable hydrilla propagules in sandy hydrosoils but had little impact where sediments were organic. Conversion of organic mucks to sandy substrates by sediment removal might, therefore, reduce the potential for rapid hydrilla recolonization in those areas.

Multiple Drawdowns

Various researchers have suggested that multiple drawdowns might be the most effective means of aquatic plant control. Multiple drawdowns are designed to damage existing plants and also kill new plants sprouted after the initial drawdown. For the control of hydrilla, Haller, *et al*. (1976) recommended a spring drawdown to kill the standing crop followed by another drawdown prior to tuber production to kill hydrilla sprouted from tubers. McKinney and Coleman (1981) documented a decline in hydrilla plants and reproductive propagules after three dewaterings in Fox Lake. In Lake Oklawaha, however, Haller and Shireman (1988) found that hydrilla returned to pre-drawdown levels after four dewaterings over a 30 month period. In short, the limited evidence to date indicates that the success of multiple drawdowns may be dependent on a number of factors which are unique to each aquatic system.

It is possible that sequential multiple drawdowns might be more effective in reducing hydrilla in Lake Rousseau than a single drawdown. The drawdown schedule proposed for Lake Rousseau by the FG&GWFC in 1978, consisted of multiple drawdowns over a three year period. Recent experience, however, indicates that integrated management using chemical plant control and periodic single drawdowns might be nearly as effective for Lake Rousseau (S. McKinney, pers. comm.). Compared to periodic single drawdowns, multiple drawdowns would cause greater inconvenience on the reservoir and more alteration of flows to the lower river. It is the conclusion of this report that at least a single fall/winter drawdown every four to six years would be very beneficial, and this or a spring drawdown should be attempted first. If results from single drawdowns are not satisfactory, a series of multiple drawdowns could be considered for the second drawdown cycle, approximately five years hence.

SEDIMENT COMPACTION OR REMOVAL DURING DRAWDOWN

As previously mentioned, one of the goals of the Lake Management and Planning Task Force was the consolidation of bottom sediments which would be an expected benefit from an extreme drawdown of the reservoir. It is also suggested here that there is the possibility of considering sediment removal from selected areas if a drawdown is accomplished.

Sediment removal and sediment compaction are two lake restoration techniques commonly used to improve sediment conditions (Cooke _et al_., 1986). Sediment removal can be done by two general methods; floating mechanical or hydraulic dredges, or excavating the sediments during drawdown with bulldozers or other machinery. Dredging will not be considered in this report because dredging a significant portion of the sediments in a large reservoir like Lake Rousseau would be very expensive. Secondly, dredging is not directly linked to any other operations or management technique discussed in this report. On the other hand, since various aspects of drawdown are discussed in this report sediment removal during drawdown is considered. Drawdown is also the technique used for the dewatering and compaction of sediments. Therefore, considerations regarding sediment improvements associated with reservoir drawdown are described below.

control sediments. Also, dried sediments released lower amounts of turbidity and particulate nitrogen and phosphorus to the overlying water due to their tendency not to be so easily resuspended.

The effect of sediment drying and compaction on sediment interstitial water content and nutrient diffusion from undisturbed sediments are unclear. Plotkin (1979) observed increased interstitial phosphorus concentrations in rewetted, highly organic sediments following two, three and four months of drying. Fox _et_ _al_. (1975), found somewhat lower ammonia and orthophosphate interstitial concentrations in dried sediments than controls but the results were inconclusive due to high variability of the data. They point out, however, that dried sediments have lower water content and a dried oxidized crust which might inhibit nutrient release. Nutrient leaching experiments gave inconclusive results, and Fox _et_ _al_. suggested that the main differences in control and dried sediments were changes in physical structure.

Based on available data and communications with other resource managers, it is suggested here that drawdown would cause beneficial changes in the sediments of Lake Rousseau. Compaction and shrinkage would create a firmer substrate, reduce sediment water content and the potential for sediment resuspension. Maximum drying of flocculent sediments in Lake Rousseau would occur during hot, dry conditions. Therefore, low water and maximum sediment exposure during the spring dry season (April to mid-June) would be optimal, although low water during the fall dry period might also be effective. Longer drawdowns would allow for more sediment drying and compaction and some combination of a fall and spring drawdown could be considered.

Sediment Removal

Sediment removal can be an effective means of improving bottom substrate characteristics. Because of the labor and cost involved, however, it is sometimes used only in selected areas rather than as a whole-lake operation. Selected sediment removal was successfully accomplished during a recent drawdown on Lake Tohopekaliga, located in Osceola County. During that project, a total of 115,572 cubic yards of sediment was removed from a 200-400 feet wide strip along six miles of shoreline. This amounted to 216.7 acres and cost $1,138.50 per acre or a total cost of $246,705. (pers. com. Ed Moyer, 1987). The area from which the sediment was removed was of fairly regular contour with little obstructions. This would not be the case in Lake Rousseau, where any sediment removal will have to account for the numerous logs and stumps in the reservoir. Excessive sediment thickness should not be a problem. Because of their high water content, most sediments in Lake Rousseau should significantly shrink during drawdown and be less than 1.5 feet deep after drying. According to the modelling of the Lake Rousseau drawdown, there will be shoreline areas exposed which may be suitable candidates for sediment removal. Most of these areas occur in the lower pool of the reservoir.

The most cost effective sediment removal process for Lake Rousseau would probably be scraping the perimeter by bulldozer and piling the sediments to desiccate. Then, the sediments could either be transported to a disposal site, if available, or possibly be burned. Another alternative would be to give the muck as fertilizer or soil amendment to anyone willing to transport it. This alternative should be further investigated prior to a drawdown.

A similar operation to this type of sediment removal was undertaken during the spring of 1987 in the Hillsborough River Basin, when the floodway connecting the Lower Hillsborough Flood Detention Area and the Tampa Bypass Canal was cleared. An area of approximately 20 acres was cleared of willows, wax myrtle (<u>Myrica cerifera</u>), and small cypress (<u>Taxodium distichum</u>). The work was done by the SWFWMD using a bulldozer with extra wide tracks to disperse ground pressure and minimize soil compaction. The total project cost was approximately $2,800. While it is difficult to estimate the cost for this type of sediment removal from selected littoral areas of Lake Rousseau, an approximate cost should be between $1000 to $2000 per acre depending on soil moisture conditions, method of disposal, and vehicular access to the work site. Other factors which may affect the anticipated costs will be operating conditions, including the density of stumps and snags within the work site. A tight estimate of the work involved and its predicted success cannot be made until the reservoir is drawndown and actual conditions assessed.

The processes of sediment or stump removal, which will be discussed subsequently, require permits from various state and federal agencies. Both operations are considered as dredge and fill activities and therefore come under the jurisdiction of the Florida Department of Environmental Regulation and the USACOE. Dredge and fill permits must be acquired from both agencies and during the permitting process the FG&FWFC and the U.S. Fish and Wildlife Service have the opportunity to comment. Approval must also come from the Florida Department of Natural Resources in order to remove material from State lands; in this case, the submerged lands of the reservoir.

STUMP CUTTING AND REMOVAL DURING DRAWDOWN

An extreme drawdown of Lake Rousseau would present an opportunity to enhance the recreational, safety, and ecological aspects of the reservoir by the snagging (cutting and removal) of stumps which present a nuisance throughout the reservoir. Since the stumps provide substrate and habitat for aquatic invertebrates and fish, it is not advisable to remove the entire snag. Cutting the stump to a sufficient depth below the low water level will achieve the desired ecological and recreational benefits while still preserving habitat value.

Previously, snagging operations on the reservoir were accomplished by the use of barge mounted hydraulic shears. The shears were used to cut stumps of less than 26 inches in diameter. Stumps with diameters greater than 26 inches were cut by a diver with an underwater chain saw. The District contract specified that the stumps would be cut at the sediment level or six feet below the surface where the reservoir depth was greater than six feet.

During a possible drawdown on Lake Rousseau to 18 feet, it is expected that the stumps previously snagged in the secondary navigation channels will be exposed. Additional snagging in these channels and throughout the reservoir could be achieved by cutting at the lowered water line. When the normal lake level is restored, the newly cut stumps would be well below the water surface.

The original snagging project during fiscal years 1984 and 1985 resulted in the cutting of almost 15 miles of trails at a cost of $258,000. The average cost per mile of a 30 foot swath was $17,200. The type of stumping described above for the proposed drawdown period will vary greatly in cost depending on how accessible the areas to be stumped are during lower water. While this stumping would not require work to be done below the surface, the cost per mile might be at or above the cost of the original snagging project due to the difficulty in maneuvering throughout the reservoir. Also, drawdown may cause some submersed logs to be refloated, thus increasing manpower time for their removal.

TIMING AND DURATION OF DRAWDOWN

In this section various schedules for extreme drawdown in Lake Rousseau are presented and the relative advantages and disadvantages of each are summarized. For each drawdown schedule, hydrologic simulations of Lake Rousseau were performed to see if the drawdown could be accomplished while providing adequate flows to the lower river. From these simulations, the viable drawdown alternatives for Lake Rousseau are discussed and preliminary conclusions are made.

The extreme drawdowns considered here are to an elevation of 18 feet, which would expose approximately 65% of the bottom of the reservoir. Although not simulated or discussed here, drawdowns to higher elevations would also be possible. Extreme drawdowns should be done sometime during the period from mid-October to mid-June to take advantage of the fall or spring dry seasons. Late winter/early spring drawdowns mimic natural hydrological patterns and are effective for improving the quality of wildlife habitat. Annual plants such as sedges, grasses, and smartweed supply food for many species of water birds and are favored by growing season drawdowns. Disadvantages of a winter drawdown include inhibition of emergent plant production, and temporary losses of wintering waterfowl habitat and associated hunting opportunities. Further, winter drawdowns are not advisable where wildlife depend heavily, either directly or indirectly, on submersed plants for food. Drawdowns during the summer would be hampered by heavy rainfall which would prevent sediment drying and possibly cause erosion of sediments into the river channel. Although the duration of low water levels during a drawdown could vary, it is recommended that the reservoir be held at an elevation of 18 feet for a minimum of 90 days to allow for adequate drying of sediments and plant material. This minimum period could be extended if abnormally high seasonal rainfall occurs or if the additional drying of sediments or aquatic plants is desired. Also, the implementation of various management techniques such as sediment removal or stump cutting might require longer periods of time at low water level.

Depending on the timing or length of the drawdown, it is recommended that reservoir refilling begin either during February and March or during the wet season from June through October. February and March represent the wettest months during the eight-month fall to spring dry season and have the highest average flows during that period (Figure 25). Refill during February or March would, therefore, require the shortest amount of time thus minimizing downstream impacts. Refill during April or May would require longer periods of time at minimum flow discharges. If a later refill is desired, it should be done in June or July to take advantage of the onset of summer rains. Given the option of either February/March or June/July refilling, either fall-winter or spring drawdowns can be accomplished with 90 days of extreme low water levels. If a longer drawdown is desired, the two periods could be combined and the reservoir refilled in June or July, or the refill period delayed until later in the summer.

The relative advantages and disadvantages of fall/winter versus spring drawdowns are discussed below. Included in this discussion are the results of simulations of Lake Rousseau based upon hydrologic data from 1970 to 1985. These simulations estimate the time that refilling would have taken if initiated during February, June, or July in each of those years.

Fall/Winter Drawdown, Refill Beginning February 1

In Lake Rousseau an effective fall/winter drawdown could be accomplished by lowering the reservoir in mid-September or early October. Assuming that thirty days are used to lower the reservoir, low water levels could be achieved by the first of November and held down through January.

Advantages of a fall/winter drawdown in Lake Rousseau are:

- Rainfall is normally low during November through January thus facilitating the desiccation of sediments and plant biomass during drawdown.

- Depending on the viability of reproductive propagules, hydrilla may resprout in the spring upon reflooding.

- Impacts to wildlife heavily dependent upon submersed plants for food.

Simulations for fall/winter drawdown and reservoir refilling beginning February 1 are presented in Tables 24 and 25. For the fifteen years from 1971 to 1985, dates for which refilling would have given a reservoir elevation of 27.5 feet, ranged from February 22 to July 6 (Table 24). Two dry years, 1976 and 1985, had markedly longer refill times (127 and 154 days) than the other years. The simulated refill periods for these two years occurred during major droughts, so it is encouraging that the reservoir was filled by early July in the worst case. For the remaining thirteen years, refill times ranged from 22 to 84 days, averaging 47 days. For other than drought years the reservoir can be refilled by late February to late April, while providing the minimum flow releases to the river. In Table 24b, the probabilities of various refill times are listed. The average (50 percent probability) refill time for the reservoir is 51 days, while the 10 percent probability refill time is 109 days.

In Table 25 the February refill simulations are presented utilizing a minimum flow of 700 cfs for February and March rather than the 900 and 790 cfs minimum flows specified in Table 20.

Table 24a. Simulated Refill Times for Lake Rousseau from an Elevation of 18.0 to 27.5 Feet Beginning February 1 Using Monthly Minimum Flows Listed in Table 20.

Year	Ending Date	Total Days for Refill
1971	March 14	42
1972	March 9	37
1973	March 19	47
1974	April 5	64
1975	April 25	84
1976	June 4	127
1977	March 6	34
1978	March 7	35
1979	March 13	41
1980	March 1	30
1981	April 23	84
1982	April 5	64
1983	February 27	27
1984	February 22	22
1985	July 6	154

Table 24b. Probabilities of Occurrence for Various Refill Times for Conditions Listed Above.

Probability	# Days	.05 Limit	.95 Limit
.99	14	28	-6
.90	24	37	6
.80	31	44	19
.50	51	66	36
.20	84	109	68
.10	109	146	88
.01	203	310	155

Table 25a. Simulated Refilling Times for Lake Rousseau from an Elevation of 18.0 to 27.5 Feet Beginning February 1 Using a Minimum Flow of 700 cfs.

Year	Ending Date	Total Days for Refill
1971	March 10	38
1972	March 2	31
1973	March 15	43
1974	March 10	38
1975	March 14	42
1976	May 18	108
1977	February 25	25
1978	March 5	33
1979	March 1	29
1980	February 22	22
1981	March 14	42
1982	March 10	38
1983	February 27	27
1984	February 22	22
1985	May 1	90

Table 25b. Probabilities of Occurrence for Various Refill Times for Conditions Listed Above.

Probability	# Days	.05 Limit	.95 Limit
.99	21	30	9
.90	23	32	11
.80	25	34	14
.50	35	44	25
.20	56	69	46
.10	72	93	60
.01	139	204	109

With these lower minimum flow levels, refill times are dropped appreciably. The 50 percent probability refill is reduced from 51 to 35 days, and the 10 percent probability refill time is reduced from 109 to 72 days. Except for the two drought years, refills for the 1970 to 1985 periods would have been accomplished between February 22 and March 15 for the separate years. Having the reservoir full by mid-March would probably help prevent the spread of emergent plants. If a fall/winter drawdown were pursued and preventing the spread of emergent plants was an established management goal, minimum flows for February and March could be adjusted to 700 cfs. However, if emergent plants are perceived as not a problem or even beneficial, minimum flows should remain as specified in Table 20.

Spring or Extended Drawdown with June or July Refill

If a spring drawdown is desired the reservoir could be lowered in February and the water level held at 18 feet during March, April and May. If a longer drawdown is desired, reservoir lowering could begin sooner or the refill period delayed until sometime between July and October. In this analysis, though, only spring drawdowns are described and simulations are run for June and July refillings. Since streamflow is highest during July through October, extension of the drawdown into the summer should pose no problems for reservoir refilling. Also, considerations for beginning the drawdown in the fall or early winter have been covered in the preceding section.

The advantages of a spring drawdown are:

- Spring drawdown would take advantage of hot dry conditions which normally occur in April, May and early June. These conditions would allow for the maximum compaction and oxidation of bottom sediments. Similarly, the establishment of a more firm sediment substrate during this period would benefit possible operations to remove stumps or sediments.

- Low water levels during the spring would prevent germination of hydrilla from reproductive propagules during that period. After refilling, germination may not be as great as would have occurred in the spring. Hydrilla abundance in the subsequent late summer period would probably be less than with fall/winter drawdown.

- Native emergent plants would germinate and sprout in exposed sediment areas during the spring drawdown and some of these plants would persist after refilling. After careful analysis, this could be a desired benefit of drawdown.

- Compared to fall/winter drawdown, spring drawdown would have less impact on the utilization of the reservoir by wintering waterfowl and associated hunting.

Disadvantages of a spring drawdown are:

- Access to the reservoir would be limited during the spring when recreational use is normally high.

- The utilization of shallow areas for spawning and feeding by fishes would be limited. Possibly, the production of one year class of fish might be impacted by poor reproductive success during the drawdown.

- Spring drawdown would cause the spread of emergent aquatic plants. This would be a problem only if this were not a desired management goal.

- Compared to fall/winter drawdown, spring drawdown would be more likely to stimulate hydrilla establishment and growth in the deeper areas of the reservoir.

Reservoir refilling during June or July would take advantage of the onset of the summer rainy season. It is recommended that refill not begin in April or May so that maximum sediment desiccation can occur. June is the transitional month between

Table 27a. Simulated Refill Times for Lake Rousseau from an Elevation of 18.0 to 27.5 Feet Beginning July 1 Using Monthly Minimum Flows Listed in Table 20.

Year	Ending Date	Total Days for Refill
1970	July 20	20
1971	August 11	42
1972	August 5	36
1973	July 30	30
1974	July 29	29
1975	September 29	91
1976	August 31	62
1977	December 5	158
1978	July 26	26
1979	August 7	38
1980	August 3	34
1981	March 14, 1982	257
1982	July 8	8
1983	July 31	31
1984	July 26	26
1985	August 15	46

Table 27b. Probabilities of Occurrence for Various Refill Times for Conditions Listed Above.

Probability	# Days	.05 Limit	.95 Limit
.99	10	27	-11
.90	13	30	-8
.80	18	35	-3
.50	37	56	18
.20	83	115	60
.10	126	188	95
.01	346	612	242

For the remaining thirteen years, simulated refills would have been concluded during July or August. The 50 percent probability refill time is 37 days while the 10 percent probability is 125 days.

Conclusions

The simulations of Lake Rousseau for the period from 1970 to 1985 show that reservoir refilling during February, June, or July is feasible and could be done to achieve management objectives. Although not simulated, refilling during the mid to late summer would also be very feasible. Simulations do indicate that refilling may take longer than desired for optimum reservoir management during droughts. However, of the dry years simulated (1975, 1977, and 1981), only the June and July refillings for 1981, which corresponded to a severe drought, took an extreme amount of time.

With water levels held at the lowest stage for a minimum of 90 days, there are potential advantages to both fall/winter and spring drawdowns. For certain management objectives such as sediment removal or stump clearing, longer drawdowns could be established. Any final decision to implement drawdown schedules on Lake Rousseau will be done after public meetings, public hearing, and approval by the proper agencies. It is suggested here, though, that drawdown capabilities on Lake Rousseau would enable resource managers to slow the aging of the reservoir, and improve its water quality, habitat characteristics and value as a fishery resource. As a minimum, fall/winter drawdowns should improve the ecological characteristics of the reservoir and probably not cause unacceptable inconvenience or problems with limited access.

SEASONAL WATER LEVEL FLUCTUATIONS WITH STRUCTURAL MODIFICATIONS

It has been widely observed throughout the state that the water levels of lakes fluctuate both seasonally and yearly and that the artificial stabilization of lake levels often has undesirable ecological consequences (Wegener and Williams, 1974; Dooris and Courser, 1976; Leslie, 1988). Dooris and Courser (1976) proposed guidelines for managing water levels in lakes with control structures. These guidelines were designed to simulate the natural fluctuation cycles observed over a five-year period in central Florida lakes. The findings of Dooris and Courser (1976) have been incorporated into the Lake Levels Project of the Southwest Florida Water Management District. This project reviews hydrological, biological, and cultural information for various lakes and recommends management levels for each lake. Greater details regarding the objectives and methodologies of the Lake Levels Project can be found in the Lake Levels Project Information Guide (SWFWMD, 1987).

In 1982, staff from the District Lake Levels Project reviewed information available for Lake Rousseau and suggested that the reservoir would benefit from seasonal fluctuations between 24.0 and 28.0 feet, but noted that lakeshore residents would be inconvenienced during low water periods (see Appendix I). In the investigation of drawdowns on Lake Oklawaha, Haller and Shireman (1988) suggested that seasonal fluctuations within a three-foot range combined with periodic winter drawdowns would benefit that reservoir. These researchers suggested that seasonal high water would strand floating vegetation on the shoreline and seasonal low water would encourage the establishment of beneficial emergent and wetland species around the reservoir shoreline.

Considerations for Lake Rousseau

The reduced discharge capacity of the bypass spillway at lowered reservoir elevation make seasonal water level fluctuations impractical for frequent use if adequate flows are to be provided to the lower river. If seasonal water level fluctuations are to be a viable management alternative, modification to the water control structures at Lake Rousseau would be required. Also, any schedule for seasonal fluctuations of water levels in Lake Rousseau would have to account for the unique characteristics of that system. Most of the available information regarding strategies for seasonal water level fluctuations has been developed from observations of natural lakes. Lake Rousseau, however, is an eighty-year old impoundment with unusual features such as abundant hydrilla, numerous stumps, and large floating islands or tussocks. Special considerations for seasonal water level fluctuations in Lake Rousseau are discussed below.

Currently, Lake Rousseau contains many stumps, some of which protrude above the water surface at an elevation of 27.5 feet and some which are submersed just below. Any seasonal lowering of water level in the reservoir will make the stump situation less predictable and more hazardous, even to boaters familiar with the reservoir. If seasonal water level fluctuations become part of the operations plan for the reservoir, stump cutting should be undertaken at a minimum in boat trail areas. Stumps should be cut or removed at least two to three feet below the minimum seasonal low water level to prevent boat damage and accidents.

Regardless of the stumps, seasonal low water levels will hinder boat access to the reservoir. The degree that access will be hindered will vary for different water levels and in various parts of the reservoir. Conceivably, some access channels to deep areas could be improved for public boat ramps or commercial fish camps, if necessary. This dredging or channel maintenance would require approval and permits from the appropriate state and federal agencies.

Of extreme importance to any implementation of seasonal water levels in Lake Rousseau will be the status of the weed populations in the reservoir. Water levels which are too low may encourage the establishment of hydrilla at greater depths in the reservoir. This could particularly be a problem since color and most likely light penetration in Lake Rousseau are related to streamflow in the Withlacoochee River. Low flows in the spring, with high proportions of ground-water inflow, would give relatively high water clarity when hydrilla plants are germinating and beginning their growth cycle. Although low water levels in the spring is the typical seasonal pattern for natural Florida lakes, it might significantly increase light penetration in the deeper areas of Lake Rousseau and stimulate hydrilla growth. The establishment of seasonal low water levels in the reservoir will have to be done after careful examination of the reservoir's bathymetry and aquatic plant distribution.

As discussed in the water quality section of this report, dense aquatic weeds can have a pronounced effect on circulation and water quality in many shallow areas of the reservoir. As a general rule, seasonal water level fluctuations in the reservoir should be managed to avoid the occurrence of "topped out" conditions, where aquatic weeds reach the surface or fill a majority of the water column. The height of submersed aquatic plants in Florida is normally lowest in late winter or early spring (February/March) and increases through the growing season reaching a peak in September or October. Possibly, water levels in Lake Rousseau could be low in the spring and rise with the wet season without worsening the relative density of weeds in the reservoir. However, if low water levels significantly increase the degree that submersed aquatic plants fill the water column, this could have negative impacts on circulation, water quality, and fish habitat.

Seasonal low water can also increase the distribution of emergent wetland species, in fact, this is one of the most commonly cited reasons for managing seasonal water level fluctuations (Dooris and Courser, 1976; Wegener and Williams, 1975; Haller and Shireman, 1988). The establishment of emergent wetland vegetation along the shoreline is almost always beneficial in those natural Florida lakes which have relatively steep bottom slopes and are phytoplankton-dominated. In these lakes, the morphometric characteristics of the basin prevent emergents from over-expanding, and the shoreline fringe of macrophytes is of great habitat value. In very shallow lakes, however, prolonged low water may induce the germination of large numbers of emergent plants which cover large areas of the lake basin and persist after refilling (McKinney and Coleman, 1981). Depending on the total amount of open water habitat remaining, this can be either a desirable or undesirable result. In Lake Rousseau, the establishment of emergent plants during seasonal low water would occur in shallow areas, most of which are adjacent to shorelines.

It is difficult to assess how much one to three-foot fluctuations in seasonal water levels would increase the abundance of these wetland type plants in the reservoir. Based on the size and bathymetry of the reservoir, though, any increases in wetland plant coverage would probably be within acceptable limits. Accompanying any increases in plant coverage would also be changes in plant community species composition and habitat structure. Preliminarily, it is suggested here that any expansion of emergent wetland plants in Lake Rousseau during low water periods would benefit the reservoir as a whole but would cause access problems in certain shallow areas.

Outflow Requirements and Seasonal Fluctuation Simulations

As discussed in the section of this report dealing with freshwater flow requirements for the lower river and estuary, seasonal water level fluctuations in Lake Rousseau will have an effect on flows to lower river and estuary. The considerations for flow release requirements for seasonal water level fluctuations are different than for extreme drawdown because seasonal water level fluctuations would be done much more frequently. Also, for seasonal water level fluctuations it is probably not desirable to bring the reservoir up as rapidly as after extreme drawdown. For these reasons, it is recommended that water retained for reservoir refilling during managed seasonal fluctuations utilizing structural modifications be based on a percentage of reservoir inflow. This will ensure that flows to the lower river and estuary retain their natural cyclic patterns and are not greatly altered on a frequent basis.

In this section simulations of seasonal water level fluctuations in Lake Rousseau are presented. These simulations were done for reservoir refilling scenarios from elevations of 24, 25 and 26 feet, which represent water levels 3.5, 2.5, and 1.5 feet below the normal operating stage of 27.5 feet. The simulations were run using both five percent and ten percent flow reductions for outflows above 700 cfs to provide water for reservoir refilling. Comparison of the results for these two flow reduction levels gives an indication of the feasibility of managing seasonal water level fluctuations in the reservoir which cause only minor alterations of flow to the downstream ecosystems.

Simulations were run for both February and June refilling. As discussed under the timing and duration of extreme drawdown, refilling during these periods mimics hydrologic cycles in the Withlacoochee basin. With refilling beginning in either February or June, low reservoir levels can occur in either the fall or spring which are normally the driest times of the year. It is emphasized that other seasonal fluctuation schedules are possible. Hydrologic conditions can be extremely variable in normally dry months and water levels in the reservoir could be manipulated in response to periodic high flow periods. Although simulations are presented only for February and June refillings, these results indicate the feasibility of water level fluctuations which could occur during other periods in the year.

February Refilling

Simulated durations for reservoir refillings beginning in February for each year from 1971 to 1985 are listed in Table 28. Refills are simulated from elevations of 24.0, 25.0 and 26.0 feet, for both 5.0 percent and 10.0 percent reductions (retention) of reservoir inflow. The most extreme seasonal fluctuation modelled is for the 24.0 feet elevation, representing a 3.5 foot fluctuation. Results of the simulations for this elevation show that five percent flow reduction would bring the reservoir back up to 27.5 feet in February during wet years (1983 and 1984), but would extend into the late summer during very dry years (1981 and 1985). Excluding these two drought years, average time to reach normal operating stage was 89 days, which corresponds to April 29. Thus, except for wet years, reservoir levels will still be rising during the spring period if continuous refill to normal stage (27.5 feet) is desired.

Increasing the percentage flow reduction to 10 percent significantly decreases the time to raise the elevation to 27.5 feet. The longest refill time was 122 days which corresponds to the 1985 drought. Excluding 1985 and 1976, average time to achieve

Table 28. **Simulated Refill Times for Lake Rousseau from Elevations of 24.0, 25.0, and 26.0 Feet Using 5.0% and 10.0% Flow Reductions for Outflows Above 700 cfs, Beginning February 1.**

		5.0%		10.0%	
Elevation	Year	Date	Total Days Refill	Date	Total Days Refill
24.0	1971	May 12,	101	March 30,	58
	1972	May 1,	90	March 29,	58
	1973	March 11,	39	March 7,	35
	1974	June 24,	144	April 7,	66
	1975	July 30,	180	April 13,	72
	1976	June 24,	145	May 17,	106
	1977	May 31,	122	March 24,	52
	1978	March 5,	33	March 4,	32
	1979	May 15,	104	March 27,	55
	1980	May 6,	95	March 22,	50
	1981	September 2,	216	April 9,	68
	1982	April 7,	66	March 28,	56
	1983	February 20,	20	February 20,	20
	1984	February 10,	10	February 10,	10
	1985	August 29,	212	July 2,	122

		5.0%		10.0%	
Elevation	Year	Date	Total Days Refill	Date	Total Days Refill
25.0	1971	April 5,	64	March 13,	42
	1972	April 5,	64	March 10,	39
	1973	February 27,	27	February 25,	25
	1974	May 3,	93	March 16,	44
	1975	May 14,	103	March 17,	45
	1976	May 26,	115	March 25,	54
	1977	April 12,	71	March 9,	37
	1978	March 3,	31	March 3,	31
	1979	April 14,	73	March 11,	39
	1980	April 6,	65	March 5,	34
	1981	May 12,	101	March 17,	45
	1982	March 27,	55	March 10,	38
	1983	February 16,	16	February 16,	16
	1984	February 7,	7	February 7,	8
	1985	July 7,	158	March 24,	52

		5.0%		10.0%	
Elevation	Year	Date	Total Days Refill	Date	Total Days Refill
26.0	1971	March 9,	37	February 24,	24
	1972	March 15,	44	February 23,	23
	1973	February 20,	20	February 18,	18
	1974	March 26,	54	February 27,	27
	1975	March 28,	56	February 27,	27
	1976	April 5,	64	March 2,	30
	1977	March 12,	40	February 23,	23
	1978	February 28,	28	February 21,	21
	1979	March 18,	46	February 24,	24
	1980	March 11,	40	February 21,	21
	1981	March 27,	55	February 27,	27
	1982	March 10,	38	February 27,	27
	1983	February 13,	13	February 13,	13
	1984	February 4,	4	February 4,	4
	1985	April 10,	69	March 1,	29

27.5 feet was 49 days, which corresponds to March 18. During most years, ten percent flow reductions will have water levels back up to 27.5 feet before the spring dry season. If high water is desired in the spring with a 3.5 foot fall fluctuation, this seems to be a workable schedule. If continued rising water levels are tolerable in the spring, five percent flow reductions should be used.

Results for the yearly simulations for the 25.0 and 26.0 elevations are similar to the 3.5 foot fluctuation but refill times are shorter. For the 25.0 feet elevation (a 2.5 feet fluctuation), five percent flow reductions would have water levels at 27.5 feet at least by mid-March to mid-April except in unusually dry years. This could be viewed as a suitable schedule if slightly low water levels are acceptable in the early spring. Ten percent flow reductions brought the reservoir to 27.5 feet in February or March in 13 of the 15 yearly simulations, which the longest refill going to March 25 in 1976.

The results for the refilling simulations from an elevation of 26.0 feet (1.5 feet fluctuation) show fast reservoir recovery. For the five percent flow reductions 27.5 feet was achieved in February or March except in 1976 and 1985, when refilling extended into April. For this low level of fluctuation, the five percent flow reduction brings the reservoir up at a suitable rate. The ten percent flow reduction brings the reservoir up very quickly, with an average refill time of 22 days.

June Refilling

Simulated times for June refillings for the years from 1970 to 1985, from elevations of 24.0, 25.0, and 26.0 feet are presented in Table 29. Using five percent flow reductions, simulations indicate the reservoir can be refilled from an elevation of 24.0 feet at least by September in most years. Two dry years, 1975 and 1977, gave longer refill times extending into November. The extremely dry year of 1981 extended refill for 228 days to the following January. Since peak water levels often occur in September in Florida lakes, during most years the five percent flow reductions adequately mimic natural seasonal fluctuations for Lake Rousseau. Increasing flow reductions to ten percent generally brings the reservoir up by July or August. Refill for the dry year 1975 extended into September. The extremely dry year, 1981, had a total refill time of 267 days, ending the following October.

Refilling simulations from the 25.0 and 26.0 feet elevations show the same yearly trends as above but with shorter refill times. For the 25.0 feet elevations (2.5 feet fluctuation), five percent flow reductions return the reservoir to the 27.5 feet elevation by August except for dry years. Simulations for the ten percent

Table 29. **Simulated Refill Times for Lake Rousseau from Elevations of 24.0, 25.0, and 26.0 Feet Using 5.0% and 10.0% Flow Reductions for Outflows Above 700 cfs, Beginning June 1.**

		5.0%		10.0%	
Elevation	Year	Date	Total Days Refill	Date	Total Days Refill
24.0	1970	August 12,	73	July 18,	48
	1971	August 21,	82	August 10,	71
	1972	August 26,	87	July 15,	45
	1973	August 26,	87	July 29,	59
	1974	July 12,	42	July 9,	39
	1975	November 1,	153	September 10,	102
	1976	July 30,	60	July 18,	48
	1977	November 2,	160	August 30,	91
	1978	August 13,	74	July 25,	35
	1979	September 14,	106	July 28,	58
	1980	August 4,	64	July 12,	42
	1981	January 16, 1982	228	October 30,	151
	1982	June 25,	25	June 24,	24
	1983	July 3,	33	July 1,	31
	1984	June 20,	20	June 19,	19
	1985	September 1,	93	August 29,	90

		5.0%		10.0%	
Elevation	Year	Date	Total Days Refill	Date	Total Days Refill
25.0	1970	July 27,	57	July 3,	33
	1971	August 17,	78	July 21,	51
	1972	July 19,	49	June 28,	28
	1973	August 13,	74	July 11,	41
	1974	July 4,	34	July 3,	33
	1975	September 26,	117	August 19,	80
	1976	July 12,	42	July 3,	33
	1977	September 21,	112	August 4,	65
	1978	August 5,	66	July 9,	39
	1979	August 15,	76	July 8,	38
	1980	July 7,	37	June 28,	28
	1981	November 17,	168	September 26,	116
	1982	June 23,	23	June 22,	22
	1983	June 26,	26	June 22,	22
	1984	June 10,	10	June 10,	10
	1985	August 30,	91	August 10,	71

		5.0%		10.0%	
Elevation	Year	Date	Total Days Refill	Date	Total Days Refill
26.0	1970	July 2,	32	June 21,	21
	1971	July 27,	57	July 3,	33
	1972	June 22,	22	June 20,	20
	1973	July 18,	48	June 25,	25
	1974	July 2,	32	June 30,	30
	1975	August 24,	85	July 28,	58
	1976	July 2,	32	June 23,	23
	1977	August 12,	73	July 7,	37
	1978	July 16,	46	June 23,	23
	1979	July 14,	44	June 22,	22
	1980	June 27,	27	June 24,	24
	1981	October 2,	122	August 29,	89
	1982	June 21,	21	June 19,	19
	1983	June 12,	12	June 11,	11
	1984	June 6,	6	June 6,	6
	1985	August 14,	75	July 19,	49

flow reductions indicate the reservoir can be refilled from 25.0 feet by July in most cases. For the refillings from 26.0 feet (1.5 foot fluctuations), even five percent flow reductions fill the reservoir by July and ten percent flow reductions give very fast refill times.

SUMMARY OF EXTREME DRAWDOWN AND SEASONAL FLUCTUATION SIMULATIONS AND RECOMMENDATIONS

In previous sections, reservoir refillings were simulated for extreme drawdowns to an elevation of 18.0 feet and for seasonal low water levels ranging from 24.0 to 26.0 feet. Because of the large number of combinations presented, a summary of these simulations along with pertinent conditions and recommendations are presented below.

The implementation of either extreme drawdown or seasonal water level fluctuations will require modifications to the water control structures on Lake Rousseau or the barge canal. The ability to discharge water up to the current capacity of the bypass spillway (1,540 cfs) at low reservoir elevations is necessary for management flexibility in the Rousseau/ Withlacoochee system.

Both February and June refilling schedules were simulated as these periods represent the onset of seasonal wet periods in the

Withlacoochee basin. With the option of these two refilling periods, either fall/winter or spring low water periods could be managed. If a longer low water period is desired, low water could begin sometime after mid-October and run into the next summer. Although this set of options is recommended, other fluctuation schedules could be developed as long as reservoir outflow requirements are met.

Minimum flow stipulations which correspond to periodic extreme drawdowns were presented in Table 20. These outflow stipulations can also be used to refill the reservoir from somewhat higher elevations, but is important that they be employed only on an infrequent basis. It is recommended that minimum flow releases for reservoir refilling be used no more frequently than once every four to six years. For refilling schedules which will happen more frequently, outflows to the lower river should not be reduced by more than five to ten percent on a daily basis. Low percentage flow reductions should be used if they will bring the reservoir up within a suitable period of time.

The fluctuation of water levels in Lake Rousseau should improve the ecological condition of the reservoir. If desired, a combination of seasonal water level fluctuations and extreme drawdowns could be scheduled. It is recommended here, though, that the implementation of extreme drawdowns is essential. Periodic extreme drawdowns would cause the maximum desiccation of sediments and plant biomass and also allow for possible sediment removal or stump cutting and removal. Simulations indicate that both February and June or July refillings are feasible with the reservoir reaching normal operating stage (27.5 feet) in acceptable amounts of time except during extreme droughts. As a minimum, fall/winter drawdowns would be very beneficial and not cause extreme interruptions of access and recreational use.

Although the implementation of seasonal water level fluctuations on Lake Rousseau is probably desirable, an optimal schedule for these fluctuations is difficult to predict and will require some experimentation and analysis of results for the reservoir. Similar to extreme drawdown, low water levels in the fall would probably be beneficial and not create ecological problems or severely limit recreational use. Although spring low water would mimic natural seasonal cycles, potential problems with submersed aquatic weeds might complicate this schedule.

It is emphasized the timing of seasonal fluctuations need not be the same from year to year and could be varied for different desired effects. Also, the heights of seasonal fluctuations can vary. Simulations for seasonal fluctuations 3.5 feet below the normal operating stage were run but this level may be extreme for yearly fluctuations. Simulations for 2.5 and 1.5 foot fluctuations indicate that five percent flow reductions refill the reservoir in suitable amounts of time and ten percent reductions give quick reservoir refilling. Simulations for the 3.5 foot drawdown show that five percent flow reductions can raise the reservoir similar to natural lake fluctuations, but ten percent flow reductions would be necessary for certain management objectives.

OUTLET STRUCTURE MODIFICATIONS REQUIRED FOR A DRAWDOWN

Prior to the construction of the CFBC facilities, the former Florida Power Corporation facility, constructed in 1909, was used to regulate water levels within Lake Rousseau. The facility consisted of 4 tainter gates of which three were used for flood control. The fourth gate was used to regulate flows to a electric power generation facility. All reservoir releases under this configuration were discharged to the lower Withlacoochee River.

According to a USGS report (Rabon, 1966), the gates were 20-feet wide and had a sill elevation of 10.82 feet. Based on this design configuration, the facility had the capability to discharge over 3,000 cfs at a reservoir elevation of 18.0 feet, assuming negligible tailwater effects. Consequently, the facility would have provided for extreme water level manipulation of the reservoir while maintaining fresh-water flows to the lower river.

The quantity of fresh water released to the lower river is now controlled by the bypass spillway and channel. The bypass spillway is a gate and weir structure with a crest elevation of 21.0 feet, whereas the earthen channel conveys surface water a distance of 8,500 linear feet from Lake Rousseau to the spillway (Figure 50).

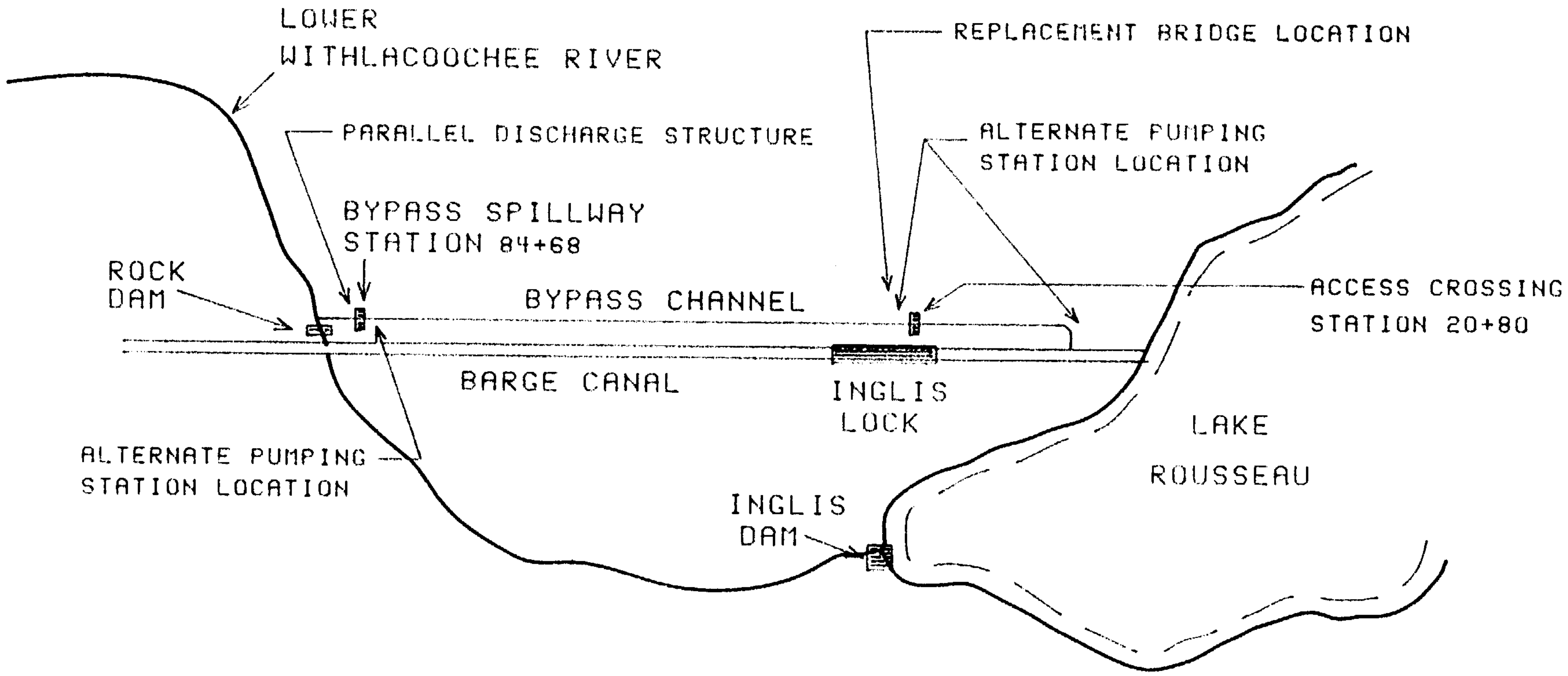


FIGURE 50 POTENTIAL LOCATION OF BYPASS STRUCTURE MODIFICATIONS NECESSARY TO FACILITATE A DRAWDOWN.

When the water level in Lake Rousseau is 27.5 feet the quantity of water released to the lower river is regulated according to the inflow into Lake Rousseau. Inflows to Lake Rousseau that are not discharged through the bypass spillway are discharged through the Inglis Dam to the barge canal. When water levels in Lake Rousseau are lowered below 27.5 feet, the discharge capacity of the bypass spillway quickly diminishes until an elevation near 21 feet is reached (see page 159). When reservoir levels are at 21 feet or less, then it is no longer possible to release fresh water to the lower Withlacoochee River. Consequently, at the recommended drawdown level of 18 feet for Lake Rousseau, structural modifications of the CFBC facilities would be required to maintain fresh-water flows to the lower river. Such structural modifications would also allow for minor seasonal fluctuations of reservoir levels which are currently impractical due to the limited discharge capacity of the bypass spillway at elevations below 27.5 feet.

The structural modifications investigated will be restricted to either the Cross Florida Barge Canal or the bypass spillway and channel. All modifications considered will be subject to the condition that the existing discharge capability of the bypass system (1,540 cfs) at a reservoir elevation of 27.5 feet can be maintained when Lake Rousseau is drawdown to an elevation of 18 feet. As discussed on pages 147-148, maintaining the current discharge capacity at an elevation of 18 feet will prevent additional alterations to the flow regime of the lower river and allow flexibility for managing effective drawdown schedules. Since the bypass system is currently used to regulate flows to the lower Withlacoochee River, structural options pertaining to the bypass system will be considered first.

Bypass Modifications

An analysis of the existing bypass structures indicate that when Lake Rousseau is at an elevation of 18 feet, no single structure of the bypass system alone can be modified to allow the same discharge capability of the existing bypass system at a reservoir elevation of 27.5 feet. The maximum discharge capability of the existing bypass facilities at a reservoir elevation of 27.5 feet is 1,540 cfs; this flow will be the design basis for the structural modifications considered.

The bypass system consists of three structures: the spillway, the channel, and the access road crossing. The analysis indicated that if only the bypass spillway was modified to discharge 1,540 cfs at a reservoir elevation of 18 feet, then the bypass channel and access road crossing would not allow the 1,540 cfs to be conveyed to the spillway. In fact, the analysis indicated that the maximum discharge capability of the system provided that the spillway was no longer restrictive, would be less than 400 cfs. Therefore, in order to convey 1,540 cfs to the lower Withlacoochee River during a drawdown, either mechanical lifting of the water from Lake Rousseau or modification of the complete bypass system would be required.

Mechanical Lifting

The required 1,540 cfs can be conveyed through the existing bypass structures provided that the water surface elevation at the east end of the bypass canal is 27.5 feet or greater. This elevation can be achieved during a drawdown only by mechanically lifting or pumping the water into the bypass channel. An auxiliary structure would be required to prevent the pumped water from flowing back into Lake Rousseau. A possible location for the auxiliary structure would be the access road crossing provided that the existing culverts could be modified to act as a dam and concurrently withstand the hydrostatic forces generated as a result of the head differential. The differential across the culverts would be about ten feet, the required lift by the pumping stations. The bypass channel would also require modification from the barge canal to the access road crossing in order to deliver 1,540 cfs to the pumping facility. If the existing box culverts could not be converted into a back-flow prevention system then the pumping station could be located at the bypass spillway or at the intersection of the barge canal and bypass channel. To construct the pumping station at the bypass spillway would require substantial modification to the bypass channel and access road crossing and, therefore, not recommended. Construction of the pumping facility at the bypass/barge canal intersection would require the additional construction of an operable structure to prevent backflow to the reservoir.

The station's pump capacity would be 1,540 cfs. If the pumping facility was constructed at the access road crossing or at the bypass/barge canal intersection, then the water surface elevation on the suction side of the pumps would be about 18 feet while the pressure side would be about 27.5 feet, the elevation required to discharge 1,540 cfs over the bypass spillway. The total power requirement for the pumping station would be about 2,400 horsepower or 1,800 kilowatts. The pumping station would be operated at a minimum of 120 days during a drawdown. Since the estuary would be dependent upon flows from the pumping station, standby units would be required to ensure continuous flow to the estuary. The back flow prevention structure needed in connection with the pumping facility would require operable capability so that gravity flow in the bypass system can be restored after the reservoir has been refilled. All inflows in excess of the 1,540 cfs discharge capacity of the pumps would be released through the Inglis Dam except when refilling the reservoir.

The pumping station would probably consist of four pumps with power plants. Pump sumps would be constructed from reinforced concrete, while pumps and power plant supports would be of structural steel. The estimated construction cost for the station is about 1.5 million dollars. This estimate does not include the costs associated with constructing a barrier to prevent backflow. As previously mentioned, the access road crossing is a possible location provided that the culverts could be modified. If this is not the case, substantial cost would be added to this option pushing the total cost in excess of two million dollars.

Operating cost for the facility is also high. During a drawdown the pumping facility would operate a minimum of 120 days or 2,880 hours. Based upon the energy requirements for the system, it will cost about $300,000 to operate the pumping station for the 120 days. Simulations of drawdowns for historical flow conditions indicates that there is a high probability that more than 120 days of pumping would be required to complete a drawdown. A continuous simulation of the 1981 drought conditions indicated it would take more than a year to reestablish a normal reservoir level of 27.5 feet while maintaining minimum flows to the lower river. Further discussion of drawdown timing and duration is discussed in a separate section of the report.

Gravity System

Since the overall bypass system is not capable of discharging by gravity 1,540 cfs at a reservoir elevation of 18 feet, complete modification of the bypass system will be required: the spillway, bypass channel, and access crossing. In regard to the spillway, a parallel structure is recommended. Preliminary analysis indicates that the parallel structure would be similar to the existing spillway. An energy dissipating system would be required as a result of dropping the channel invert from about seven feet on the upstream side to a minus ten feet on the downstream side. The minus ten-foot elevation is the existing invert on the downstream side of the bypass spillway. The estimated construction cost of the spillway and energy dissipating system is about 1.6 million dollars.

As previously indicated, the paralleling of the existing bypass spillway is not all that is required. Modification of both the access road crossing and bypass channel will also be required. The existing channel is constructed at an invert elevation of 12.0 feet with a five-foot bottom and three-on-one side slopes. This configuration will have to be modified to a channel that has an invert elevation around 7.0 feet, a 40-foot bottom width, and three-on-one sides slope for the total distance of 8,500 feet. This will require the excavation of 485,000 cubic yards of material from the bypass channel. The estimated cost for removing the material is 1.7 million dollars. This cost may vary depending on the haul distance for the spoil and whether additional land will have to be furnished for spoil disposal.

In regard to the access-road crossing a parallel structure consisting of box culverts could be constructed to provide the required flow capacity. Another option is to construct a bridge across the bypass channel and then remove the existing box culverts. This later option would be aesthetically preferred. The estimated cost for constructing a replacement structure is $500,000. This brings the total construction cost for the gravity system up to 3.8 million dollars.

Of the two bypass options evaluated (pumping and gravity), the gravity system is the better option because it provides several advantages over the pumping system. Under normal operating reservoir levels, the gravity system would provide additional flow capacity to the lower river. It is estimated that the flow capacity would be increased from 1,540 cfs to well over 3,000 cfs at a reservoir elevation of 27.5 feet. The increased capacity of the bypass channel would allow total outflows from the reservoir to be managed so that the diversion of high flows to the barge canal could be more moderated than at present. The pumping system provides no additional discharge capability through the bypass channel to the lower river under normal resevoir conditions. Maintenance costs are lower for the gravity system since there is very little mechanical equipment associated with this alternative. Also, overall dependability is higher for the gravity system. Dependability is critical when the estuary is under consideration. If a major pumping failure should occur during a drawdown, complete cessation of flows to the lower river could occur resulting in damage to the estuary. Finally, operating costs are substantially lower for the gravity system. There is virtually no power cost associated with the gravity system as compared to the pump alternative. The only disadvantage of the gravity system is the initial cost of construction.

Barge Canal Modification

The barge canal construction divided the Withlacoochee River downstream of Lake Rousseau into two segments. The two segments are separated by an earthen dam and the barge canal. One segment now conveys fresh-water releases from Inglis Dam to the barge canal, while the other longer segment conveys fresh-water releases from the bypass spillway to the Gulf of Mexico. Consequently, reconnection of the segments would require modification of the barge canal. This modification could be accomplished by constructing a dam in the barge canal just below the area where the shorter river segment enters the barge canal (Figure 51). This option would utilize the existing Inglis Dam,

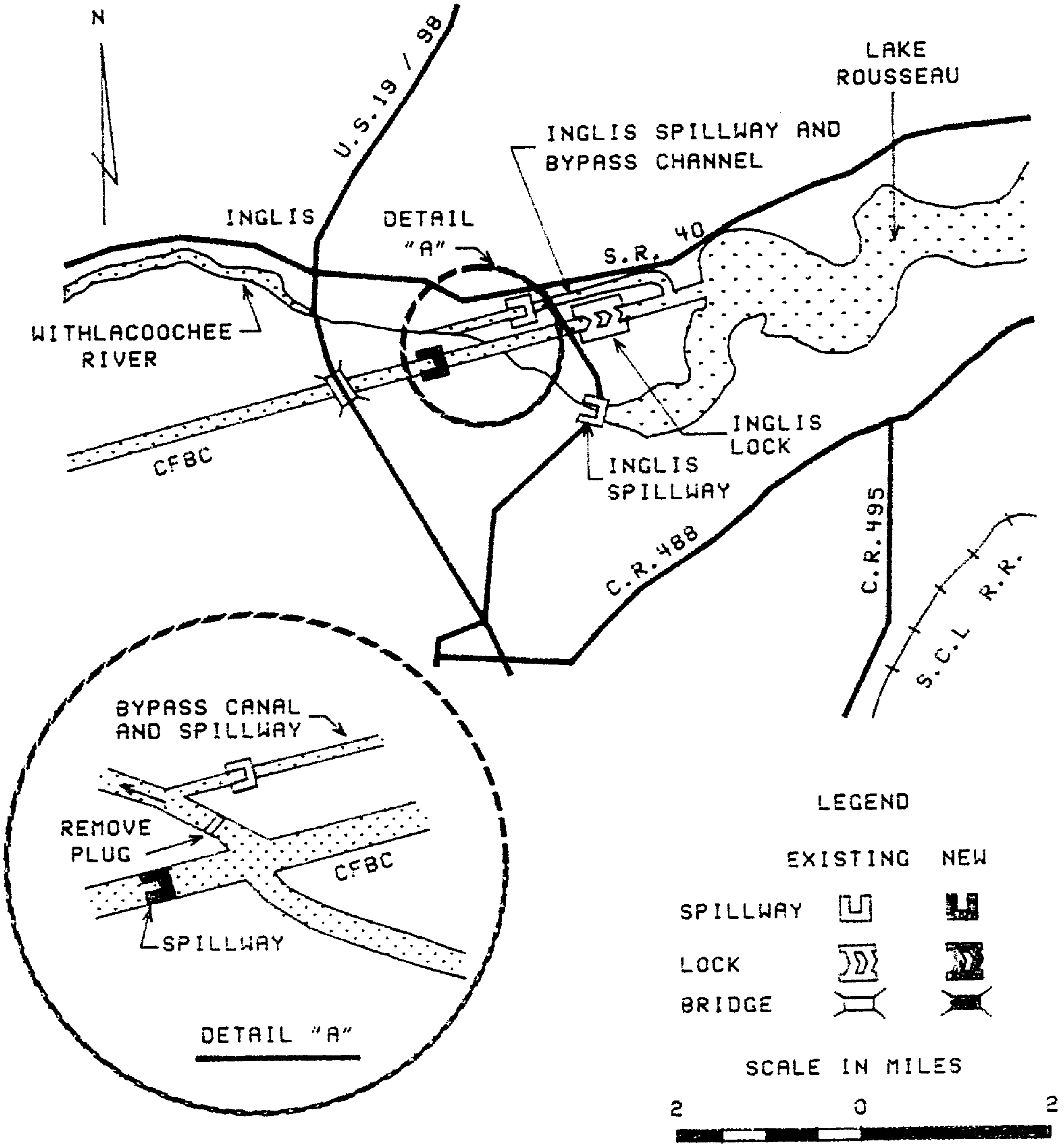


FIGURE 51 CENTRAL FLORIDA BARGE CANAL (CFBC) PROPOSED MODIFICATION REQUIRED FOR A DRAWDOWN

which has a discharge capacity of 4,800 cfs at an elevation of 18 feet, to regulate reservoir levels and flows to the lower river.

This option was proposed in the USACOE Restudy Report, (USACOE, 1975) and required the removal of an earthen plug (Rock Dam) in the old river channel and the construction of a dam and overflow weir in the barge canal. This alternative would restore for the most part the original river configuration and at the same time provide for the maintenance of fresh-water flows to the estuary during a drawdown of the reservoir. In fact, this option would allow for the lowering of Lake Rousseau below 18 feet while maintaining flows to the lower river and estuary. The overflow weir proposed by the USACOE provided for the partial diversion of flood water to the barge canal in order to prevent flooding along the lower river. The estimated cost for this option is 2 million dollars. It is suggested here that other flood control alternatives could be examined as part of a barge canal modification, if this option is pursued. Also, consideration should be given to designing any new structures so that flows to the barge canal could be moderated more than is possible at present.

From a reservoir and river management perspective, this option is the most preferred of those options investigated for several reasons. The option provides better control of releases, over a wider range of reservoir inflows and levels, than any other option investigated. This option would restore the section of the lower river that now leads to the barge canal and provide it with continuous flows. Similarly, this is the only option that would allow for the continuous flushing of the western end of Lake Rousseau. At present, poor circulation and stagnation are chronic problems in this part of the reservoir during low flow periods. Modifying the barge canal also provides the capability to lower the reservoir below 18 feet, if desired, while maintaining flows to the lower river. Finally, this option appears to be the least expensive option of all those investigated. The only major disadvantage to this option is the loss of access to Lake Rousseau from the barge canal. However, this loss of access from the barge canal would be replaced by access to Lake Rousseau from the lower river, through the Inglis Lock which would still be functional.

Currently, a Federal Court injunction prohibits any further construction or alteration of the existing Cross-Florida Barge Canal lands or facilities until a final decision has been made concerning their outcome. The Federal Government and the State of Florida have developed legislation concerning the destiny of the Cross-Florida Barge Canal in the Water Resources Act of 1986. This Act basically states that all lands owned by the Canal Authority and State are to be turned over to the USACOE and that these lands and facilities will be maintained in a National Conservation Area.

The Water Resource Act of 1986 prohibits any modification of the existing barge canal facilities that would disrupt their original intended function; therefore, the proposed weir construction in the barge canal and removal of the earthen plug in the lower Withlacoochee River would not be a viable optio. However, the State of Florida has not enacted the legislation that would implement the Water Resources Act of 1986 which may still make this option viable.

COST OF MAINTAINING EXISTING FACILITIES

The pending deauthorization of the CFBC includes a non-completion alternative for the project. For the area under study in this report, it included preservation of Lake Rousseau and the West End of the completed authorized project to the Gulf. This includes Inglis Lock and Dam, the bypass channel and spillway, and the canal between Inglis Lock and the Gulf. These facilities would be operated and maintained to serve existing and potential commercial and recreational boat traffic.

Under the selected non-completion alternative the <u>USACOE's - CFBC Restudy Report, Final Summary February 1977</u>, points out that Lake Rousseau could be intensively managed for aquatic plant control, fisheries, wildlife and recreation. A Wildlife Study prepared by the FG&FWFC as part of the restudy of the CFBC Project stated that maintenance of flow release facilities related to Lake Rousseau would allow greater flexibility for water level manipulation in the reservoir, which might slow the process of aging and preserve for a longer period the present health of the reservoir.

The summary of Benefits and Costs for the selected preservation alternative, of the non-completion alternatives evaluated in the above Restudy Report by the COE, included, at 1977 dollars, annual benefits of $2,608,000 and annual costs of $2,490,000-

2,531,000 (costs for operation, maintenance and replacement-OMR); a benefit-cost ratio of from 1.03 to 1.05. The above benefit/costs apply to entire selected preservation, non-completion alternative for the CFBC Project which, in addition to the Lake Rousseau and the West End of the completed authorized project, includes the most easterly lock and dam of the authorized project. Total benefits were in the area of recreation.

Cost estimates for non-completion alternatives (preservation of completed works) are based on operation and maintenance of existing facilities essentially as is currently being done including: Operation and Maintenance of Inglis Dam and Spillway, Inglis Bypass Channel and Spillway, and recreation facilities; and maintenance and "on-call" operation of Inglis Lock; debris removal, snagging, aquatic plant control, mosquito control, and collection of hydrologic data in Lake Rousseau; and maintenance of canal slopes and berms, periodic surveys and inspection of structures, acquisition and maintenance of work equipment, condition surveys, maintenance dredging and overhead.

The following are average operation and maintenance costs, and average costs for other requirements for the years 1980-86, for the completed West End works. Averages were computed from annual figures supplied in personal communications from the Construction and Operations Division of the USACOE; January, 1988.

Inglis Lock and Spillway and the Bypass Channel and Spillway	$215,000
*Other Requirements (est.)	219,000
Total	$434,000

*Estimated by SWFWMD from figures for the entire project from Lake Rousseau and the West End, to the most easterly lock and dam of the completed portions of the authorized project.

The annual cost (rounded to $1,000) for aquatic plant control on Lake Rousseau, for the three fiscal years 1985-87, was $276,000, $301,000 and $286,000 respectively. These were federal funds from the USACOE, administered by the DNR and expended by SWFWMD.

MANAGEMENT OPTIONS

INTRODUCTION

In this section, considerations for management plans for Lake Rousseau are summarized for both options which utilize the existing water control structures and those which would require structural modifications. This discussion will primarily concern operational plans for the water control structures on the reservoir and the barge canal. The operation of these structures directly influences not only the water levels and ecological characteristics of the reservoir, but also local ground-water conditions, flood control capabilities, and fresh-water flows to valuable downstream ecosystems. This analysis was performed because of the District's central role in the management of regional water resources, which is recognized in the pending deauthorization of the barge canal when the Congressional Act of deauthorization provided that the State of Florida retain responsibility over water resources planning development and control of surface and ground waters pertaining to the lands cited in the act.

With pending deauthorization of the CFBC, established in its place will be the Cross Florida National Conservation area. As part of the re-designation of the barge canal, a conservation management area will be created and the State of Florida is directed to cooperate with the USACOE in the development of a management plan for the area. Included in the National Conservation Area is Lake Rousseau.

The pending deauthorization of the barge canal includes a non-completion alternative for the project. A USACOE Restudy Report of completion options points out that Lake Rousseau could be intensively managed for aquatic plant control, fisheries, wildlife, and recreation. A Wildlife Study prepared as part of the restudy stated that maintenance of flow release capabilities related to Lake Rousseau would allow greater flexibility for water level manipulation in the reservoir, which might slow the process of aging and preserve for a longer period the present health of the reservoir.

The USACOE is directly responsible for operation of the water control structure and the management of Lake Rousseau. Recently, the USACOE established a ranger position for Lake Rousseau in an effort to more intensely manage the reservoir and be receptive to the public's concerns. Because the USACOE has extensive experience in aquatic weed control and navigation maintenance, this report is not intended to provide details regarding immediate aquatic plant control plans or other duties such as channel marking or maintenance. Similarly, the FG&FWFC monitors the fishery resources of the reservoir and periodically recommends fishery management plans. The emphasis of this report is how the ecological qualities of the Lake Rousseau/ Withlacoochee system could be enhanced by optimizing operational plans for the water control structures. A brief summary of the advantages and disadvantages of various options are presented below, while greater detail regarding these considerations can be found in the preceding text.

STABILIZED WATER LEVELS WITH EXISTING CONTROL STRUCTURES

This option essentially is a continuation of the present operations and management plan for the reservoir. The option utilizes existing water control structures and maintains relatively stable water levels in the reservoir at elevations between 27.0 and 27.5 feet. This stabilization of water levels is due to the limited discharge capacity of the bypass spillway at elevations less than 27.5 feet and the need to maintain adequate levels of flow to the lower river.

With the existing structures, flows to the lower river should be maximized to the greatest practical extent by releasing total outflows below 1,540 cfs to the lower river through the bypass spillway. The current practice of periodically releasing small (50 to 200 cfs) slugs of water through the Inglis Dam to facilitate flushing in the western end of the reservoir should be continued, as this probably doesn't represent a significant disruption of flow to the lower river. Other diversions of flow which would normally go through the bypass spillway may be necessary at times for operations such as lockage or structure repair, but the objective of maximizing flows to the lower river should always be considered.

Given the limitations of the existing structures and the flow needs of the lower river, large water releases through the Inglis Dam are largely restricted to times when total reservoir outflows exceed 1,540 cfs. This schedule often produces hydrographs for the barge canal which show extreme seasonal fluctuations, which may not be desirable for water quality and biological conditions in the canal and the adjacent inshore environment. Since the canal is in place, it should be considered as a new tributary to the Gulf and fresh-water flows there should be optimized to enhance estuarine productivity. Although further research is needed, it is suggested that the current extreme variation of flows to the barge canal is not desirable. Given the limits of the existing structures, however, the current flow release schedule for the Inglis Dam is the only plan that is practical.

Many researchers throughout the state have suggested that lakes and reservoirs maintain healthier ecological states if water levels are allowed to fluctuate through a normal seasonal range in response to hydrologic conditions. The stabilization of water levels in Lake Rousseau has probably had undesirable consequences. This stabilization has probably resulted in; increased sediment build-up in shallow areas, a transition in aquatic plant communities from native to exotic species, and dense persistent periphyton growth on stumps, markers, and other structures.

Despite its problems, Lake Rousseau remains a valuable resource and maintains an economically important fresh-water fishery. A range of $242,111 to $448,312 was estimated as the annual value of fishing on Lake Rousseau (see Appendix A). Fish population sampling on the reservoir during 1987 indicated that Lake Rousseau supports a diverse fishery. Evidence of sportfish reproduction and growth into intermediate-size classes was clear, but the ratio of intermediate to adult sportfish was not considered optimum. Historical fish population data have consistently shown poor survival of bass greater than 15 inches in Lake Rousseau. The FG&FWFC states that the variable occurrence and density of hydrilla in the reservoir has been a major factor affecting fish production. The management of hydrilla to allow establishment of native aquatic plants should result in a more stable habitat which would benefit sportfish production. The FG&FWFC also suggested that the accumulation of flocculent organic sediments has had a negative impact on sportfish production in the reservoir. With the current impracticality of significant water level fluctuations in the reservoir, the ability to encourage the establishment of native plant communities or to oxidize bottom sediments is very limited.

Indirectly, the stabilization of water levels probably limits the potential to maximize sportfish production in the reservoir.

Aquatic plant control in Lake Rousseau in recent years has been primarily by the use of herbicides, although some mechanical control has also been employed. Treatments during 1987 with the herbicide SONAR were initially effective, but hydrilla regrowth was evident in most treated areas eleven months after application. Chemical control methods are also used for control of water lettuce and hyacinths, plus reduction of the tussocks. Total costs for aquatic plant control on the reservoir were $276,000, $301,000, and $286,000, for 1985, 1986, and 1987, respectively. Because of the costs involved and the potential for high sedimentation and nutrient build-up resulting from repeated herbicide applications, a sole reliance on chemical plant control methods is probably not optimal for the long term management of Lake Rousseau.

In sum, the stabilization of water levels in Lake Rousseau has probably contributed to ecological conditions which are not optimal for sportfish production or the establishment of native aquatic plant communities. Although the reservoir currently supports an acceptable sport fishery and considerable recreational use, the reservoir is demonstrating signs of rapid succession or aging, and the long-term outlook for the reservoir causes concern. With the current operations plan, costs for aquatic plant control have been high. These costs, plus the economic value of the reservoir and its long term management perspective, should be considered when assessing the cost of implementing structural modifications for other operations plans.

With the existing control structures, flood control capabilities on the lower Withlacoochee River are more than adequate. Reservoir outflows above 1,540 cfs are discharged to the barge canal through Inglis Dam which has a 19,600 cfs discharge capacity at a lake surface elevation of 27.5 feet. This capacity is considerably greater than the estimated 100-year peak inflow to Lake Rousseau.

MINOR WATER LEVEL FLUCTUATIONS WITH EXISTING STRUCTURES

If adequate flows to the lower river are to be maintained, extreme drawdown is impossible with the existing water control structures on Lake Rousseau and minor water level fluctuations are impractical. No water can be discharged to the lower river at elevations below 21 feet, and the discharge capabilities of the bypass spillway at slightly lowered reservoir elevations are greatly reduced, such as; 1,040 cfs at 26 feet, 740 cfs at 25 feet, and 480 cfs at 24 feet. Because of these limited discharge capacities, even small seasonal water level fluctuations in the reservoir are impractical for they would result in frequent reductions in flows to the lower river.

As an example, a three-foot water level fluctuation would require lowering the reservoir to an elevation of 24.5 feet. Maintaining the reservoir at this elevation with the existing water control structures would limit flows to the lower river to 600 cfs, an extreme low-flow level which was exceeded 97% of the time during 1970 to 1985. In contrast to water level fluctuations possible with structural modifications, when flow reductions would only occur during reservoir refilling, this level of discharge would have to be maintained during the low water period which should probably last for 90 days. For reservoir refilling, bypass outflows should be allowed to increase in response to rising reservoir levels with the bypass spillway gates fully open until an elevation of 24.8 feet is reached, above which a minimum flow of 700 cfs through the bypass spillway should be maintained. This type of water level fluctuation would put the lower river through an extended low-flow period, similar to the occurrence of a drought. Therefore, this type of water level fluctuation is not a viable alternative for frequent use.

It is emphasized that this type of 3 foot water level fluctuation is not a substitute for extreme drawdown. Compared to an extreme drawdown with a 9.5 feet lowering of reservoir, a three foot fluctuation would not give nearly the same results for the drying and compaction of bottom sediments. Similarly, large donor populations of hydrilla would persist below the low water level and the desiccation of large quantities of accumulated plant biomass would not occur. Although some floating plants might be stranded during the low water, it is not expected that a 3 feet lowering of the reservoir would have a major effect on the tussocks. Additionally, increased access problems and increased aquatic plant problems are likely with little benefit to the lake ecology. In short, extreme drawdown will be necessary for significant desiccation of the excessive quantities of vegetation and sediments that have accumulated in Lake Rousseau. Because of the flow alterations it would cause in the lower river and because the expected ecological benefits in the reservoir are limited, a three feet lowering of the reservoir with existing structures is not perceived as a good long-term management tool for Lake Rousseau.

Flood control capabilities on the lower river with this management plan for the reservoir would be the same as with the present operations and management plan of stabilized water levels.

Extreme Drawdown and Seasonal Water Level Fluctuations Requiring Structural Modifications

Various aspects of implementing extreme drawdown or seasonal water level fluctuations on Lake Rousseau have been discussed in detail in preceding sections of this report. The relative advantages and disadvantages of implementing extreme drawdown or seasonal water level fluctuations are briefly summarized below, along with a brief comparison of the structural modification options that would be required.

It is the conclusion of this report that periodic extreme drawdowns would benefit the immediate and long-term ecological characteristics of Lake Rousseau. In reports published in 1978 and 1987, the FG&FWFC suggested that periodic extreme drawdowns would reduce organic sediments, stimulate the expansion of native aquatic plants, and enhance sportfish production in Lake Rousseau. It is suggested here that a program of stump cutting and removal during drawdown would also be a valuable tool for controlling the rate of formation and growth of the tussocks. Other lake management techniques such as sediment removal or sediment application of herbicides could be evaluated or tested during drawdown.

For extreme drawdown, it is recommended that reservoir levels be held at an elevation of 18 feet for a minimum of 90 days to allow for the adequate drying of sediments and plant biomass. An entire drawdown cycle would therefore require at least 150 to 190 days for completion; 30 days to lower the reservoir, 90 days at low water, and 30 to 70 days for refilling. It is expected that reservoir drawdowns should be conducted every four to six years. Mathematical models of Lake Rousseau using historical streamflow data indicate that either spring, fall/winter, or combined drawdowns can be conducted while providing minimum flows to the lower river during reservoir refilling. Access to the reservoir will be limited during the drawdown period. Compared to multiple drawdown schedules, periodic single drawdowns would cause less problems with reservoir access and alterations of flows to the lower river. It is concluded that periodic fall/winter drawdowns would be very beneficial and not cause unacceptable problems with reservoir access, and this or a spring drawdown should be attempted first. If desired, minor (1 to 3 feet) seasonal fluctuations in water levels could be implemented as a supplement to periodic extreme drawdowns. These fluctuations need not be the same from year to year, but must be scheduled to positively interact with the unique ecological characteristics of the reservoir. In accord with plans for extreme drawdowns or seasonal water level fluctuations, it might be beneficial to improve boat channels from public boat ramps or commercial fish camps.

Significant structural modifications would be necessary if extreme drawdown or seasonal fluctuation capabilities are to be realized. Of the structural modification options available, the barge canal modification (lower river re-connection) is most desirable for reservoir water quality benefits, as it would allow constant flushing of the west end of the reservoir. This option would also allow lowering the reservoir below 18 feet, if desired, while still providing adequate flows to the lower river. This option would also restore the 1.1 miles of lower river between Inglis Dam and the barge canal and provide it with continuous flow. However, there is some questions to the viability of this option: See section entitled, "Outlet Structure Modifications Required for a Drawdown".

Structural modifications to achieve drawdown capabilities would also allow moderation of flows to the barge canal, possibly enhancing estuarine productivity there. With the barge canal modification, an overflow weir to the barge canal could be designed to allow incremental flows to the barge canal at less than flood flows. With the bypass system modification, the flow capacity to the lower river would be increased at normal stages, so high flows could be incrementally divided between the lower river and the barge canal, thus moderating flows in the canal. Further analysis concerning many factors is necessary before it can be determined which structural modification option would be optimal for management of the estuary.

An overflow weir would provide for partial diversion of flood water to the barge canal to prevent flooding along the lower river. Disregarding any effects of storm tides, this option would limit flood flows in the lower river to non-damaging levels.

However, it should be remembered that neither of the options may be viable because of pending deauthorization of the CFBC which may restrict structural modifications of barge canal facilities.

LITERATURE CITED

Adams, A. 1985. Groundwater supplement to the Wysong-Panasoffkee Study. Southwest Florida Water Management Department. Brooksville, Fl.

Aleem, A. A. 1972. Effect of river outflow management on marine life. J. Mar. Biol. 15:200-208.

American Public Health Assoc., American Water Works Assoc., and Water Pollution Control Federation. 1985. Standard methods for the examination of water and wastewater, 16th ed. New York, N.Y.

Bahr, L. M. and W. P. Lanier. 1981. The ecology of intertidal oyster reefs of the South Atlantic Coast: a community profile. Report FWS/OBS-81/15 for the U. S. Fish and Wildlife Service. Washington, D.C.

Bouwer, H. 1978. Groundwater hydrology. McGraw-Hill. New York, N. Y.

Brezonik, P. L. 1978. Effect of organic color and turbidity on Secchi disc transparency. J. Fish. Res. Bd. Can. 35: 1410-1416.

Canfield, D. E., Jr. 1981. Chemical and trophic state characteristics of Florida lakes in relation to regional geology. Final Report. Submitted to Florida Cooperative Fish and Wildlife Unit. University of Florida, Gainesville, Fla.

________________. 1983. Prediction of chlorophyll a concentrations in Florida lakes: The importance of phosphorus and nitrogen. Water Resources Bulletin 19: 255-262.

Canfield, D. E., Jr. and L. M. Hodgson. 1983. Prediction of Secchi disc depths in Florida lakes: impact of algal biomass and organic color. Hydrobiologia 99:51-60.

Canfield, D. E., Jr., K. A. Langeland, M. J. Maceina, W. T. Haller, J. V. Shireman, and J. R. Jones. 1983. Trophic State Classification of lakes with aquatic macrophytes. Can. J. Fish. Aq. Sci. 40:1713-1718.

Carlson, R. E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-369.

Chow, V. T. 1959. Open-channel hydraulics. McGraw-Hill. New York.

Comp, G. S. and W. Seaman, Jr. 1985. Estuaries. In: W. Seaman, Jr. (Ed.). Florida Aquatic Habitat and Fishery Resources, Fla. Chap. Amer. Fish Soc., Kissimmee, Fl.

Cooke, G. D. 1980. Lake-level drawdown as a macrophyte control technique. Water Res. Bull. 16:317-322.

Cooke, G. D., E. B. Welch, S. A. Peterson, and P. R. Newroth. 1986. Lake and reservoir restoration. Butterworth Publishers. Stoneham, Ma.

Cross, R. D. and D. L. Williams (Eds.). 1981. Proceedings of the National Symposium on freshwater inflow to estuaries. Report FWS/OBS-81/04 to the U. S. Fish and Wildlife Service. Washington, D.C.

Dooris, P. M. and W. D. Courser. 1976. Determining stages and fluctuation schedules for regulated lakes in central and south Florida. Fla. Scientist 39:14-18.

Drew, R. D., N. S. Schomer, and S. H. Wolfe. In review. An ecological characterization of the Tampa Bay Watershed. U.S. Dept. of Interior Fish and Wild. Service. Biol. Rept. 88(xx). Washington, D.C. 20240.

Durako, M. J., J. A. Browder, W. L. Kruczynskii, C. B. Subrahmanyam, and R. E. Turner. 1985. Salt marsh habitat and fishery resources of Florida. In: W. Seaman, Jr. (Ed.). Florida Aquatic Habitat and Fishery Resources, Fla. Chap. Amer. Fish. Soc., Kissimmee, Fl.

Faulkner, G. L. 1970. Geohydrology of the Cross-Florida Barge Canal area with special reference to the Ocala vicinity. U.S.G.S. in cooperation with the USACOE. Jacksonville, Fl.

_________________. 1973. Ground-water conditions in the Withlacoochee River - Cross-Florida Barge Canal Complex Area. Water Res. Inv. 4-72. U. S. Geological Survey.

Florida Department of Environmental Regulation. 1985. Limnology of the Suwannee River, Florida. FDER, Tallahassee.

_________________. 1986. Water quality inventory for the State of Florida Technical Appendix. FDER, Tallahassee.

Florida Game and Fresh Water Fish Commission. 1978. Central Florida region 1977-1978 fish management report. Ocala, Fl.

Florida Department of Natural Resources. 1986. Florida aquatic plant survey. Tallahassee, Fl.

_________________. 1987. Florida aquatic flora survey report. Tallahassee, Fl.

Fox, J. L., R. L. Brezoik, and M. A. Keirn. 1977 Lake drawdown as a method of improving water quality. EPA-600/3-77-005. Corvallis, Oregon.

Fread, D. L. 1984. Dynamic wave and operations manual. National Weather Service. NWS Hydrologic Research Laboratory, Silver Spring, Md.

Fritz, E. S. 1980. Potential impacts of low pH on fish and fish populations. U.S. Fish Wildl. Serv., Biol. Serv. Prog., Power Plant Project, FWS/OBS-80/40.2. Washington, D. C.

Grubb, H. F. and A. T. Rutledge. 1979. Long-term water supply potential, Green Swamp area, Florida. Water Res. Inv. 78-99. U.S. Geological Survey. Tallahassee, Fla.

Hagemeyer, R. T. 1988. Resistivity study of the Lower Withlacoochee River - Cross-Florida Barge Canal Complex. M. S. thesis. Univ. of South Florida, Tampa, Fl.

Haller, W. T. 1976. Hydrilla: a rapidly spreading aquatic weed problem. Florida Agric. Exp. Sta. Circ. S-245. Gainesville, Fl.

Haller, W. T., J. L. Miller, and L. A. Garrard. 1976. Seasonal production and germination of hydrilla vegetative propagules. J. Aquat. Plant. Manage. 14:36-29.

Haller, W. T. and J. V. Shireman. 1988. Monitoriing study for Lake Ocklawaha Lake Management Plan. Final Project Report to the U. S. Army Corps of Engineers. Jacksonville, Fl.

Hem, J. D. 1959. Study and interpretation of the chemical characteristics of natural water. U.S. Geol. Surv. Water Supply Pap. 1473. 363 p.

Hestand, R. S. and C. C. Carter. 1975. Succession of aquatic vegetation in Lake Ocklawaha two growing seasons following a winter drawdown. Hyacinth Control J. 13:43-47.

Huber, W. C., P. L. Brezonik, and J. P. Heaney. 1982. A classification of Florida lakes. Univ. of Florida. Gainesville, Fla.

Hutchinson, G. E. 1957. A treatise on limnology. Vol. I. John Wiley and Sons, N.Y.

Johnson, W. E., D. A. Dobbins, and D. E. Holcomb. 1981. Drawdown response of a hypereutrophic Florida lake. Proc. Ann. Conf. S.E. Assoc. Fish and Wildlife Agencies. 35:394-407.

Kaufman, M. I. 1975. Color of water in Florida streams and canals. U.S. Geol. Surv. Map Series No. 35.

Lee, G. F. and A. W. Hoadley. 1967. Biological activity in relation to the chemical equilibrium composition of natural waters. p. 319-338. Equilibrium concepts in natural water system. Am. Chem. Soc. Advances in Chemistry Ser. 67.

Leslie, A. J. 1988. Literature review of drawdown for aquatic plant control. Aquatics 10(1):12-18.

Mann, J. A. 1984. Wysong-Panasoffkee study: Citrus and Sumter Counties, Florida. Southwest Florida Water Management District. Brooksville, Fl.

Matalas, N. C. 1963. Probability distribution of low flows. U. S. Geological Survey. Washington, D. C.

McDonald, M. G. and A. W. Harbaugh. 1984. A modular three-dimentional finite-difference ground-water flow model. U.S. Geological Survey. Open-file report 83-875. Reston, Va.

McKinney, S. P. and W. S. Coleman. 1981. Hydrilla control and vegetation response with multiple dewaterings. Proc. Ann. Conf. S. E. Assoc. Fish and Wildlife Agencies. 35:383-393.

Petts, G. E. 1984. Impounded rivers. John Wiley and Sons Ltd. Chichester.

Plotkin, S. 1979. Changes in selected sediment characteristics due to drawdown of a shallow eutrophic lake. M. S. thesis, Univ. of Washington, Seattle, Wa.

Rabon, J. W. 1966. Inflow-outflow characteristics of Lake Rousseau (Inglis Reservoir) on Withlacoochee River, Florida. U. S. Geological Survey. Tallahassee, Fl.

Rosenau, J. C., G. L. Faulkner, C. W. Hendry, Jr., and R. W. Hull. 1977. Springs of Florida. Bureau of Geology Bulletin No. 31. Florida Dept. of Natural Resources. Tallahassee, Fl.

Sakamoto, M. 1966. Primary production by phytoplankton community in some Japanese lakes and its dependence on lake depth. Arch. Hydrobiol. 62:1-28.

Snedaker, S. C. and D. P. deSylva. 1977. Role of freshwater in estuarine ecosystems. Final Report to the Alafia and Pinellas-Anclote Basin Boards of the Southwest Florida Water Management District. Brooksville, Fl.

Southwest Florida Water Management District. 1987. Lake levels project informational guide. Brooksville, Fl.

Stanley, J. G. and M. A. Sellars. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico)--American oyster. U. S. Fish Wildlife Ser. Biol. Rep. 82(11.64) U. S. Army Corps of Engineers. TR EL-82-4. Washington, D. C.

Stevens, D. E. and H. K. Chadwick. 1979. Sacramento-San Joaquin Estuary, biology and hydrology. Fisheries, 4(4):2-6.

Stewart, M. T. and M. C. Gray. 1983. Evaluation of a ground transient electromagnetic remote sensing method for the deep detection and monitoring of salt water interfaces. Water Res. Research Ctr. Publ. 73. Univ. of Fl. Gainesville, Fl.

United States Army Corps of Engineers. 1967. Detail design memorandum No. 10 Cross-Florida Barge Canal Inglis Lock Bypass Channel. Jacksonville, Fl.

________________. 1968. Detail design memorandum No. 3 Supplement I Cross-Florida Barge Canal Inglis Lock Bypass Channel. Jacksonville, Fl.

________________. 1969. Cross Florida Barge Canal Project: Water Quality Data. Serial No. 16. Jacksonville, Fl.

________________. 1975. Phase I Report Lake Rousseau (Inglis Reservoir). Jacksonville, Fl.

________________. 1977. Cross-Florida Barge Canal restudy report-final summary. Jacksonville, Fl.

________________. 1985. HEC-2 Water Surface Profile users manual. Hydrologic Engineering Center (HEC). Davis, Ca.

United States Environmental Protection Agency. 1976. Quality Criteria for Water. U.S.E.P.A. Office of Water and Hazardous Materials. Washington, D.C.

United States Geological Survey. 1976. Proposed Cross-Florida Barge Canal: Water Quality Aspects of with a Section On Waste-Assimilative Capacity. Water Resources Investigations No. 76-23. U.S.G.S. Tallahassee, Fl.

United States Geological Survey. 1984. U.S. Geological Survey Water-Data Report FL-84-3A. U.S.G.S., Tallahassee, Fla.

__________________. 1985a. U.S. Geological Survey Water-Data Report FL-85-1A. U.S.G.S., Tallahassee, Fla.

__________________. 1985b. U.S. Geological Survey Water-Data Report FL-85-3A. U.S.G.S., Tallahassee, Fla.

__________________. 1986a. U.S. Geological Survey Water-Data Report FL-86-1A. U.S.G.S. Tallahassee, Fla.

__________________. 1986b. U.S. Geological Survey Water-Data Report FL-86-3A. U.S.G.S. Tallahassee, Fla.

Vernon, R. O. 1951. Geology of Citrus and Levy Counties, Florida. Geological Bulletin No. 33. Florida Geological Survey. Tallahassee, Fl.

Walker, W. W., Jr. 1985. Empirical methods for predicting eutrophication in impoundments. Technical Report E-81-9 for the U. S. Army Corps of Engineers. Washington, D. C.

Wegener, W. and V. Williams. 1974. Lake Tohopekaligia drawdown study - completion report. D-J project F-29. Florida Game and Fresh Water Fish Commission. Tallahassee, Fl.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Co., Philadelphia.

Yobbi, D. K. 1989 (in review). Salinity and flow relations in the Weeki Wachee River, Crystal River, and Withlacoochee River Estuaries, Southwest Florida. U. S. Geological Survey. Tallahassee, Fl.

APPENDIX A

FLORIDA GAME AND FRESH WATER FISH COMMISSION

CENTRAL REGION

A Report on the Status of the Fishery in Lake Rousseau, Florida

July 1987

SUMMARY:

The fish population of Lake Rousseau has been evaluated on five occasions between 1977 and 1987. Public complaints of poor fishing and a need to improve the fishery have been the primary reasons for conducting fish population studies and developing a fishery management plan. An aquatic habitat restoration plan to improve the sportfishing was prepared but could not be implemented due to the lack of public support and the necessity to alter a water control structure.

Fish population sampling in 1987 indicated that Lake Rousseau was supporting a diverse fishery. Evidence of sportfish reproduction and growth into intermediate-sized classes was clear from the data, but the ratio of intermediate to adult sportfish was not considered optimum.

The poor growth of largemouth bass into size-classes greater than 15 inches was documented in 1978 blocknet samples. Analysis of the 1987 data indicated largemouth bass recruitment into classes greater than 15 inches was still less than desirable. Similar recruitment problems were evident in other sportfish populations based upon 1987 length-frequency data.

The collection rates of fish were much higher in 1987 than in 1980 or 1981. The 1980 and 1981 fish populations were considered marginal while the 1987 fish population was considered average.

The major habitat change from 1980 to 1987 was an increase in the areal coverage of hydrilla (*Hydrilla verticillata*). Although hydrilla is an exotic plant, it provides a substrate for fish food organism production much like native plants. The change in the fish production is attributed to the expansion of hydrilla.

Since hydrilla grows rapidly, becomes dense, and often out-competes native plants, efforts are generally taken to reduce or eliminate it. Such actions result in drastic fish habitat change and consequently an unstable fishery is produced. The primary recreational use of Lake Rousseau is sport fishing. The most popular sportfish species is largemouth bass -- particularly bass of trophy size. Historical fish population data has consistently shown poor survival of bass greater than 15 inches (approximately 2.0 pounds) in Lake Rousseau. The variable occurrence and density of hydrilla in the lake has been a major factor in fish production in the reservoir. The management of hydrilla to allow establishment of native aquatic plants should subsequently result in a more stable habitat.

A soft organic layer covers much of Lake Rousseau's hydrosoil. This layer is formed primarily by the deposition of decayed aquatic plants. Sufficient nutrients are discharged into the reservoir to cause excessive aquatic plant growth. Consequently, the depth of the organic layer continues to increase. This same layer stores nutrients which may be released to sustain or increase an undesirable growth of aquatic vegetation.

The quality of the fishing in Lake Rousseau, as well as other lakes, is dependent upon the management of water quality, aquatic plants, and bottom condition. Parameters that reflect the quality of a fishery may be expressed as the value of the fish produced or the money spent by anglers to use the resource.

The value of fish in Lake Rousseau was estimated to be $4,045,360 based upon blocknet data collected by the Game and Fresh Water Fish Commission (Commission) in 1978 and values reported in "Fish Values", published in 1971 by the Florida Department of Air and Water Pollution Control.

A range of $242,111 to $448,312 was estimated as the annual value of fishing in Lake Rousseau. The values were based on information collected by the Commission during a creel census in 1975 and a 1986 angler survey.

BACKGROUND:

Extensive fish population sampling was conducted in 1977 and 1978 using blocknets, gill nets, and trammel nets. Organic sediment depths, aquatic vegetation mapping and bottom contour mapping were done concurrently. A management plan for Lake Rousseau was prepared by the Commission in 1978 entitled "A Fisheries Management Plan for Lake Rousseau with Emphasis on Aquatic Weed Control". Additional fish population data were collected in 1980 and 1981.

The findings of the fish population sampling were reported in the GFC Central Region Fish Management Annual Reports for the fiscal years 1977-78, 1978-79, 1980-81, and 1981-82.

PROCEDURES:

Fish population sampling was conducted in Lake Rousseau by electrofishing in April 1987. Seven samples were collected and sample time varied from 15 to 45 minutes (actual pedal time) for a total of 3.3 hours. Fish were identified to species, sorted by inch group, and weighed.

For comparison purposes, the fish were divided into four general categories: sportfish (largemouth bass, bluegill, redear sunfish, redbreast sunfish, spotted sunfish, warmouth, black crappie, chain pickerel, and redfin pickerel); commercial fish (catfish, bullheads, and golden shiners); rough fish (gar, bowfin, and lake chubsucker); and miscellaneous fish. Sportfish were further divided into harvestable individuals based on length (Swingle, 1950). Largemouth bass are considered harvestable at ten inches, bream at six inches, black crappie at nine inches, and chain pickerel at 14 inches.

FINDINGS:

A good diversity of fish species was collected from Lake Rousseau during approximately 3.3 hours (197 minutes) of electrofishing (Table 1). Sportfish comprised 66.9% by number and 64.3% by weight of the total sample. Catfish were collected infrequently due in part to the limitation of the sampling equipment. Rough fish composed less than 10.0% by number but almost 30.0% by weight of the total sample.

Approximately 20.0% to 25.0% of all of the sportfish species were harvestable except for spotted sunfish (Table 1). The percent of harvestable spotted sunfish was only 12.6%. This is due to the inherent small size of the adults and not poor growth or survival.

Length-frequency analysis of largemouth bass indicates reproduction, growth, and survival to harvestable sizes has occurred (Figure 1). Over 62.0% of the bass collected were in the five to eight inch size-class. These bass were probably one-year-old and may indicate a strong year-class produced in 1986. Another peak occurred in the 11 to 13 inch size range. Extensive grouping of various age fish may occur in these inch-classes, so this peak is not necessarily indicative of another strong year-class. Over 27.0% of the largemouth bass sampled were 10 inches or larger, but only 5.6% were larger than 15 inches in length. Additionally, the largest bass collected was only 20 inches in total length. It aopears that Lake Rousseau is supporting a good population of either young or slow-growing bass (11 to 13 inches), but recruitment into size-classes greater than 15 inches has been poor.

TABLE 1

Summary of fish collected during 3.3 hours of electrofishing on Lake Rousseau, April 1987.

SPECIES	SIZE RANGE (inches)	NO.	% NO.	TOTAL WEIGHT (lbs.)	% WT.	NO. PER MIN.	WT./ MIN. (lbs.)	AVG. WT. (lbs.)
Largemouth bass	1-20	286	4.66	127.96	19.90	1.45	0.65	0.45
Bluegill	1- 9	2388	38.94	159.46	24.80	12.10	0.81	0.07
Redear sunfish	1-10	431	7.03	39.88	6.20	2.18	0.20	0.09
Redbreast sunfish	1- 8	380	6.20	23.66	3.68	1.92	0.12	0.06
Spotted sunfish	1- 7	159	2.59	10.27	1.60	0.81	0.05	0.06
Warmouth	1- 8	429	6.99	40.14	6.24	2.17	0.20	0.09
Black crappie	6-13	8	0.13	5.62	0.87	0.04	0.03	0.70
Chain pickerel	2-23	17	0.28	6.30	0.98	0.09	0.03	0.37
Redfin pickerel	2- 9	8	0.13	0.46	0.07	0.04	0.00	0.06
Brown bullhead	12-17	3	0.05	5.77	0.90	0.02	0.03	1.92
Yellow bullhead	9-11	2	0.03	1.37	0.21	0.01	0.01	0.69
Florida gar	11-21	14	0.23	12.30	1.91	0.07	0.06	0.88
Longnose gar	25-33	2	0.03	4.52	0.70	0.01	0.02	2.26
Lake chubsucker	2-15	352	5.74	162.99	25.34	1.78	0.83	0.46
Bowfin	22-23	3	0.05	12.72	1.98	0.02	0.06	4.24
Golden shiner	2-11	297	4.84	26.20	4.07	1.50	0.13	0.09
Taillight shiner	1- 2	3	0.05	0.00	0.00	0.02	0.00	0.00
Coastal shiner	2- 3	56	0.91	0.18	0.03	0.28	0.00	0.00
Tadpole madtom	3	1	0.02	0.01	0.00	0.01	0.00	0.01
Pirate perch	1- 3	11	0.18	0.08	0.01	0.06	0.00	0.01
Brook silverside	2- 4	352	5.74	1.49	0.23	1.78	0.01	0.00
Dollar sunfish	1- 3	48	0.78	0.57	0.09	0.24	0.00	0.01
Pygmy sunfish	1	3	0.05	0.00	0.00	0.02	0.00	0.00
Bluespotted sunfish	1- 2	104	1.70	0.43	0.07	0.53	0.00	0.00
Swamp darter	1	20	0.33	0.01	0.00	0.10	0.00	0.00
Mosquitofish	1- 2	488	7.96	0.28	0.04	2.47	0.00	0.00
Sailfin molly	1- 2	17	0.28	0.04	0.01	0.09	0.00	0.00
Threadfin shad	5	3	0.05	0.14	0.02	0.02	0.00	0.05
Bluefin killifish	1- 2	210	3.42	0.19	0.03	1.06	0.00	0.00
Seminole killifish	4	1	0.02	0.02	0.00	0.01	0.00	0.02
Least killifish	1	16	0.26	0.00	0.00	0.08	0.00	0.00
Golden topminnow	2	21	0.34	0.06	0.01	0.11	0.00	0.00
TOTAL		6133	100.00	643.10	100.00	31.06	3.26	
Sport		4106	66.95	413.74	64.34	20.80	2.10	
Commercial		302	4.92	33.34	5.18	1.52	0.17	
Rough		371	6.05	192.53	29.94	1.88	0.98	
Miscellaneous		1354	22.08	3.49	0.54	6.86	0.02	
Harvestable sportfish								
Largemouth bass	10-20	78	27.27	102.45	80.07	0.40	0.52	1.31
Bluegill	6- 9	478	20.02	103.18	64.70	2.42	0.52	0.22
Redear sunfish	6-10	112	25.99	29.48	73.94	0.57	0.15	0.26
Redbreast sunfish	6- 8	90	23.68	16.93	71.56	0.46	0.09	0.19
Spotted sunfish	6- 7	20	12.58	4.49	43.72	0.10	0.02	0.22
Warmouth	6- 8	109	25.41	29.26	72.91	0.55	0.15	0.27
Black crappie	9-13	6	75.00	5.36	95.34	0.03	0.03	0.89
Chain pickerel	15-23	3	17.65	6.12	97.27	0.02	0.03	2.04

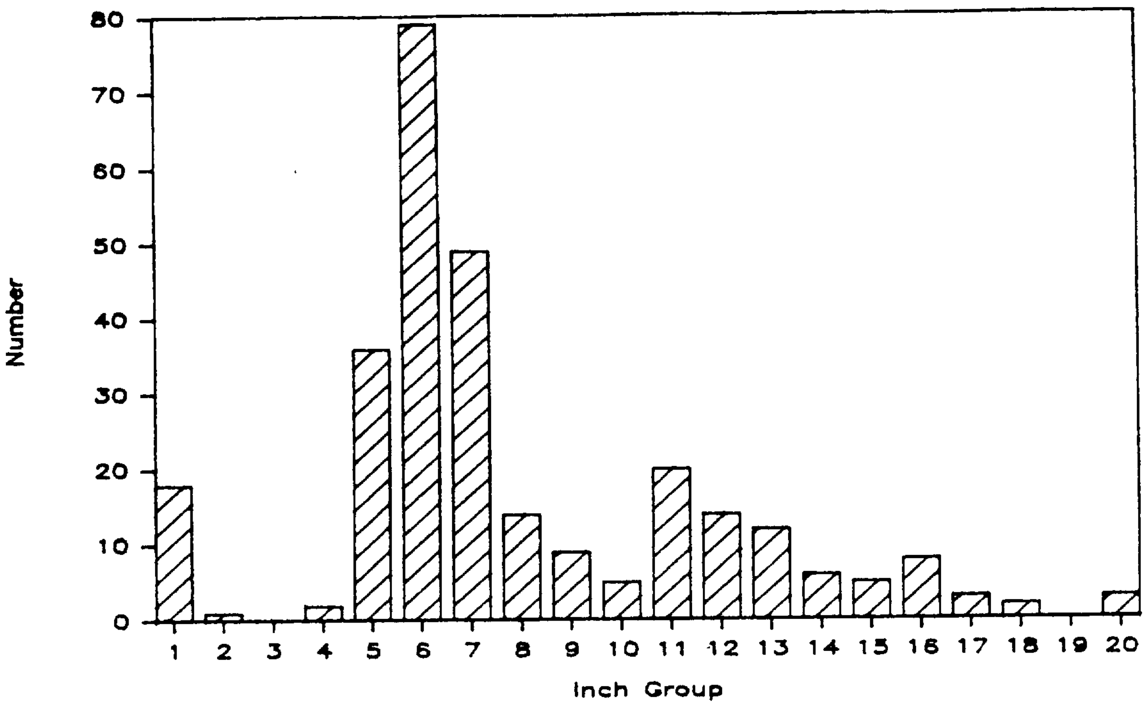


FIGURE 1. Length-frequency of largemouth bass collected from Lake Rousseau during 3.3 hours of electrofishing, April 1987.

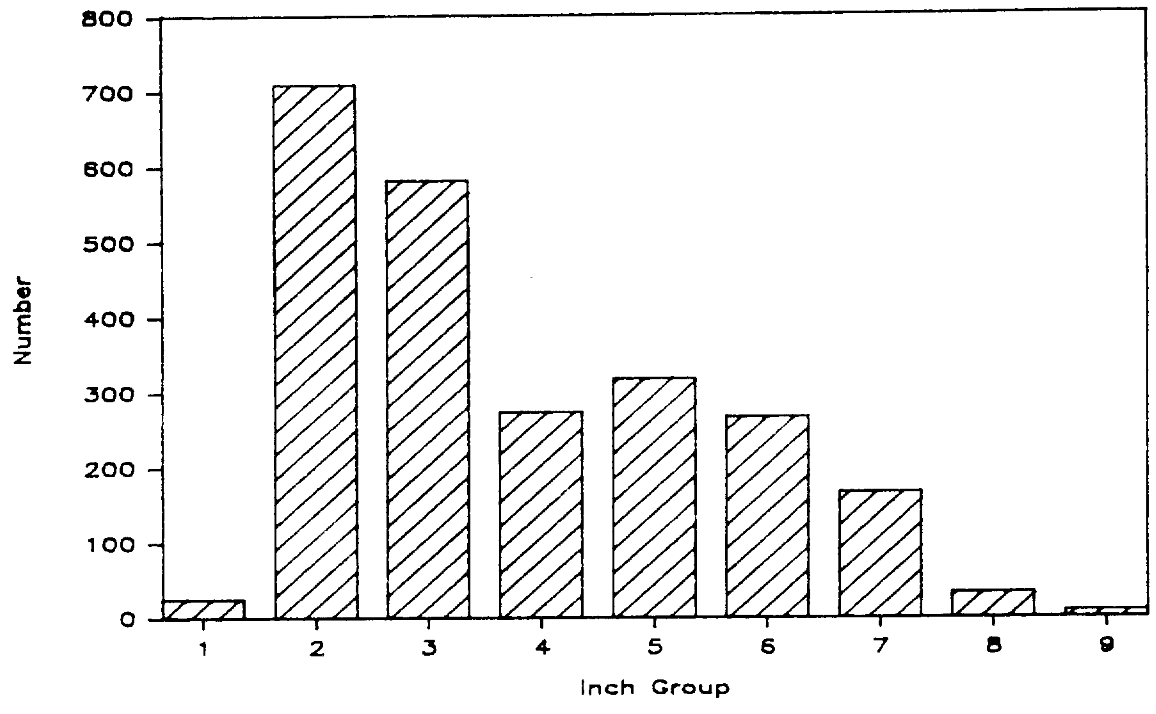


FIGURE 2. Length-frequency of bluegill collected from Lake Rousseau during 3.3 hours of electrofishing, April 1987.

Bluegill and redear sunfish had successfully reproduced and grown into intermediate-sized classes based on 1987 data. Recruitment into adult lengths was marginal. Although bluegill were collected in far greater numbers than redear sunfish, the ratio of intermediate to adult sizes was very similar (Table 1 and Figures 2 and 3). Approximately 50.0% of these species were in the three to five inch groups (intermediate), while the proportion of adult fish (six inches or greater) was slightly higher for redear (26.0%) than bluegill (20.3%).

Redbreast sunfish, spotted sunfish, and warmouth, which prefer riverine habitat, were collected from Lake Rousseau in 1987. A slightly higher percentage of harvestable to intermediate fish was calculated for these species (Table 1 and Figures 4, 5, and 6).

Too few black crappie and chain pickerel were collected to allow population analyses other than to document the presence of juvenile and adult fish (Table 1).

In general, the forage fish to carnivorous fish relationship appears to be unbalanced. The relative abundance of intermediate-sized forage sport species (bluegill, redear sunfish, redbreast sunfish, warmouth, and spotted sunfish) and the poor recruitment of largemouth bass above 15 inches support this conclusion.

COMPARISON OF 1980, 1981, AND 1987 ELECTROFISHING DATA

Comparison of catch-per-unit-effort (CPUE) parameters indicates an overall increase in fish production from 1980 to 1987. Total number of fish, harvestable sportfish, rough fish, miscellaneous species, and total weight collected per minute were all higher than in 1980 or 1981 (Table 2). Based upon catch per hour of harvestable fish, largemouth bass increased 483.0%,

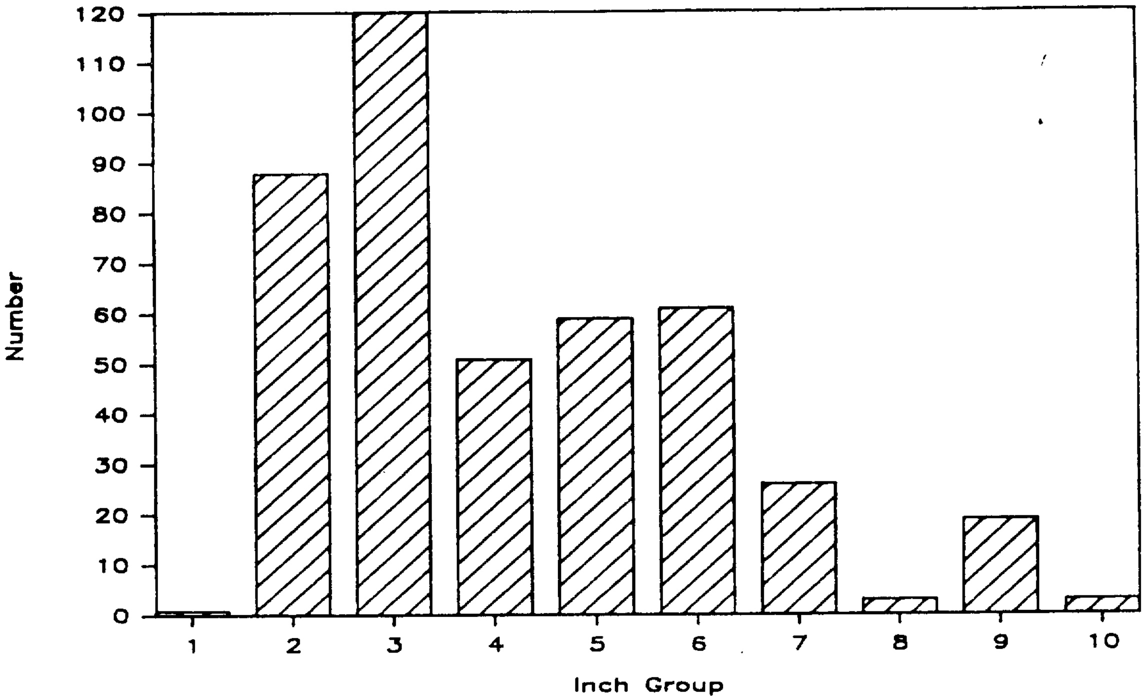


FIGURE 3. Length-frequency of redear sunfish collected from Lake Rousseau during 3.3 hours of electrofishing, April 1987.

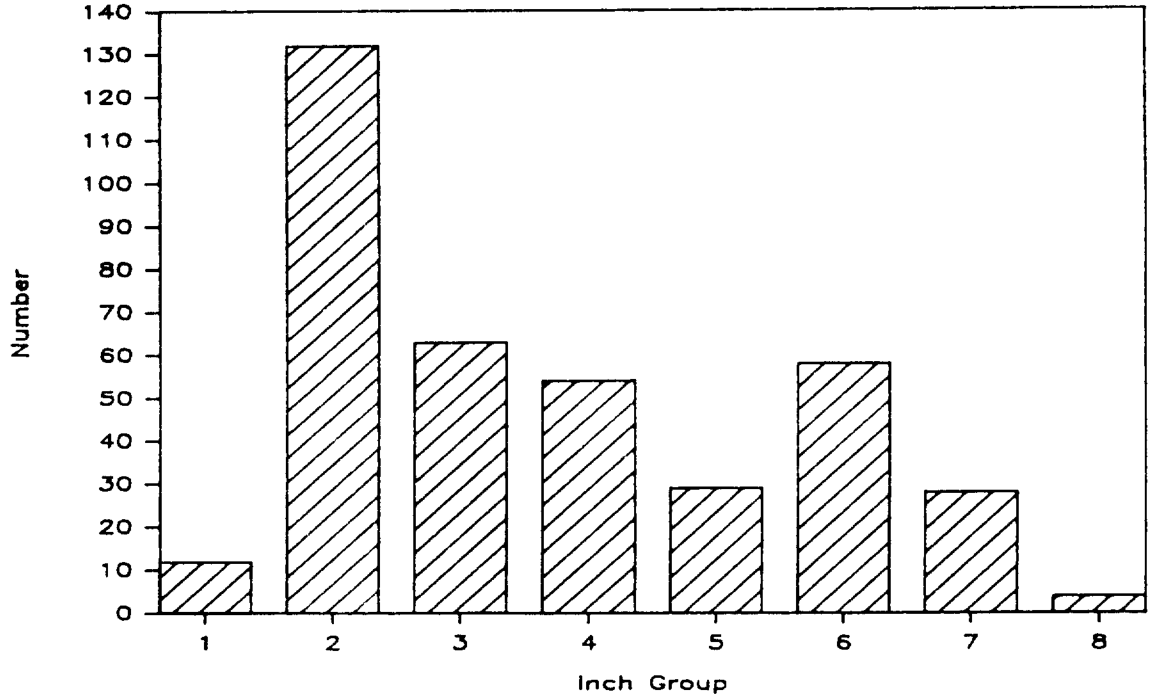


FIGURE 4. Length-frequency of redbreast sunfish collected from Lake Rousseau during 3.3 hours of electrofishing, April 1987.

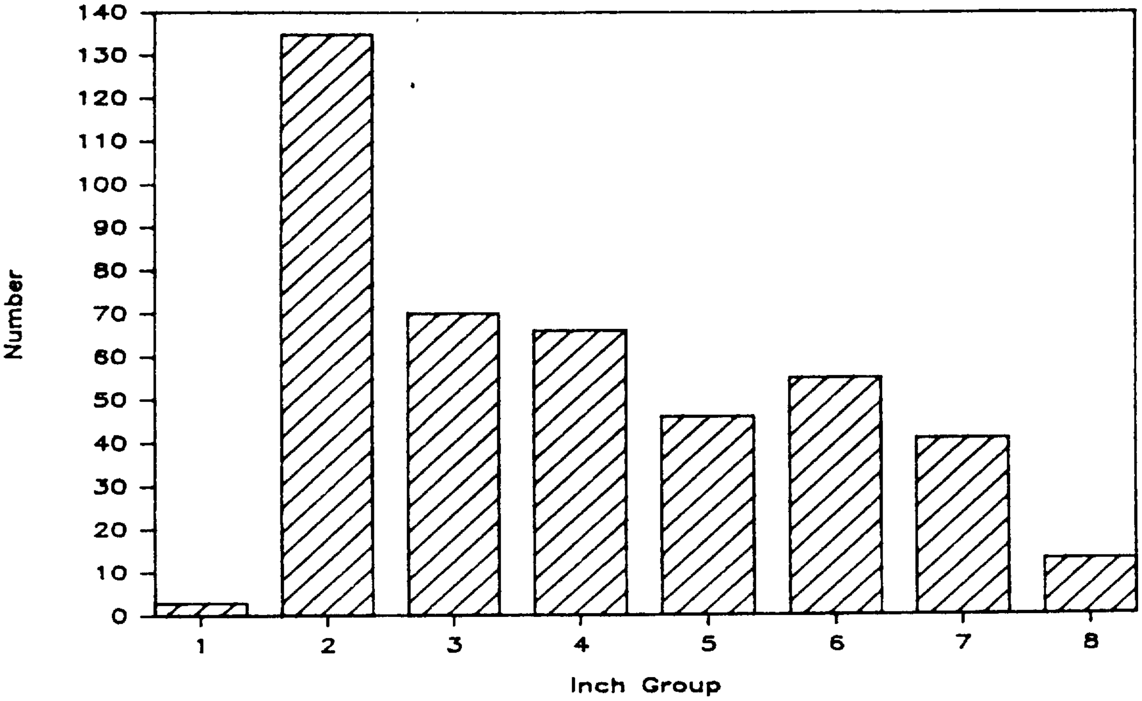


FIGURE 5. Length-frequency of warmouth collected from Lake Rousseau during 3.3 hours of electrofishing, April 1987.

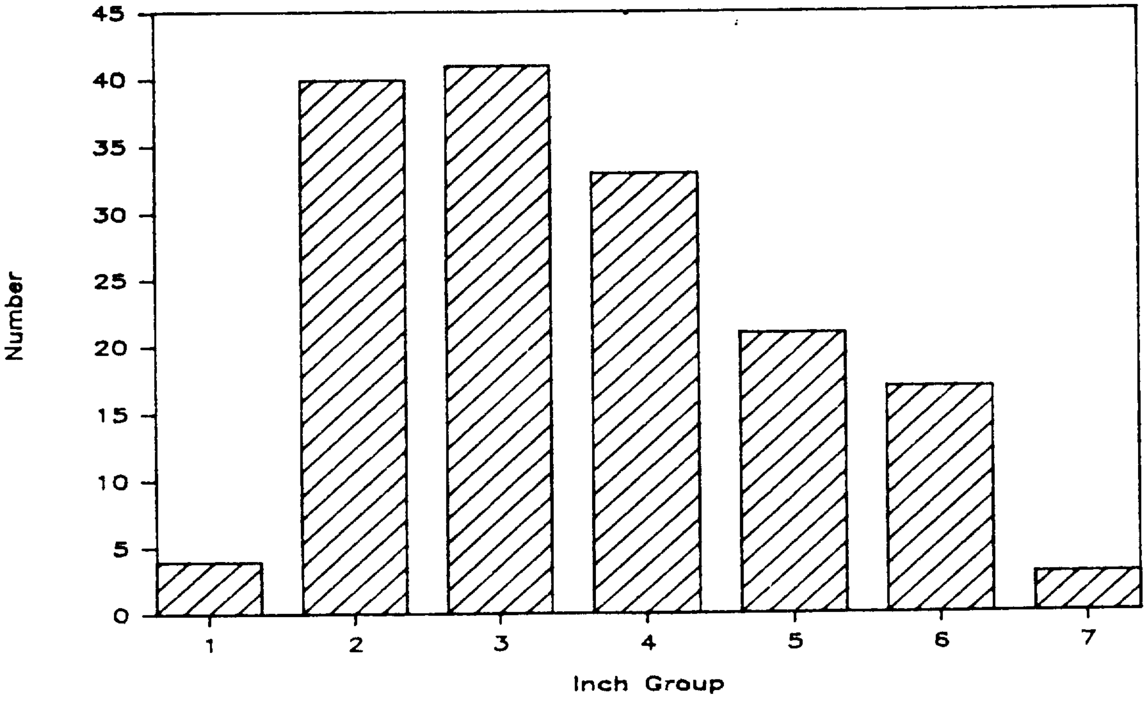


FIGURE 6. Length-frequency of spotted sunfish collected from Lake Rousseau during 3.3 hours of electrofishing, April 1987.

TABLE 2

Comparison of catch per minute of fish collected by electrofishing during 1980, 1981, and 1987.

	NO./MIN.			WT./MIN.		
SPECIES	1980	1981	1987	1980	1981	1987
Largemouth bass	0.42	0.41	1.45	0.09	0.10	0.65
Bluegill	0.65	0.86	12.10	0.07	0.04	0.81
Redear sunfish	0.21	0.26	2.18	0.03	0.01	0.20
Harvestable						
Largemouth bass	0.07	0.05	0.40			
Bluegill	0.16	0.10	2.42			
Redear sunfish	0.06	0.01	0.57			
Gamefish	1.69	1.83	20.80	0.22	0.18	2.10
Commercial fish	0.01	Tr	0.03	0.02	Tr	0.04
Rough fish	0.35	0.31	1.88	0.32	0.19	0.98
Miscellaneous fish	0.34	0.34	8.36	0.04	0.01	0.15
TOTAL	2.39	2.48	31.06	0.60	0.38	3.26

bluegill increased 1,353.0%, and redear sunfish increased 844.0% over data collected in 1981. Length-frequency distribution of largemouth bass, bluegill, and redear sunfish collected in 1987 also indicate more harvestable fish were produced (Table 3).

The 1980 and 1981 data were reflective of a marginal fishery, while the 1987 data was comparable to fishery data from other lakes which support average sportfish populations.

Samples were taken in 1980 and 1981 in response to angler complaints of poor fishing and an apparent reduction in the total fish population. Concurrent with these complaints was the disappearance of hydrilla (*Hydrilla verticillata*) from Lake Rousseau and the Withlacoochee River. Samples were taken in 1987 after several years of moderate to heavy growth of hydrilla. Hydrilla provides excellent cover for fish and substrate for fish food organism production much like native vegetation, but can also grow to undesirable areal coverage often requiring costly actions to control this exotic plant. Variation in the plant coverage and density subsequently results in an unstable fish population.

Based upon the 1987 data and comparison with 1980 and 1981 data, Lake Rousseau is supporting an acceptable sportfishery. However, recruitment of intermediate sportfish into desirable harvestable size-classes was not optimum.

TABLE 3

Length distribution and average number per hour of largemouth bass, bluegill, and redear sunfish from Lake Rousseau for the years 1980, 1981, and 1987.

	Catch/hr. Largemouth bass						Catch/hr. Bluegill					
INCH GROUP	1980		1981		1987		1980		1981		1987	
1	0.0		0.0		5.5		0.1		1.4		7.9	
2	0.0		0.3		0.3		1.9		7.8		215.8	
3	4.0		1.9		0.0		10.3		10.0		176.9	
4	7.1		5.0		0.6		9.6		16.6		83.3	
5	5.3		4.5		10.9		7.5		9.5		96.7	
6	2.4		1.1		24.0		3.5		4.1		81.2	
7	0.9		2.6		14.9		3.3		1.3		50.8	
8	0.8		3.4		4.3		2.0	-10.0	0.4	-6.4	0.3	-145.3
9	0.6		2.5		2.7		0.9		0.3		3.0	
10	0.5		1.5		1.5		0.3		0.3		0.0	
11	0.8		0.4		6.1		0.0				0.0	
12	0.8		0.0		4.5							
13	1.1	-4.1	0.0	-3.3	3.7	-23.9						
14	0.4		0.3		1.8							
15	0.4		0.1		1.5							
16	0.0		0.3		2.4							
17	0.0	-0.5	0.3	-1.1	0.9	-6.3						
18	0.0		0.1		0.6							
19	0.0		0.3		0.0							
20	0.0		0.0		0.9							
21	0.1		0.0		0.0							

TABLE 3 (continued)

Catch/hr.

Redear sunfish

INCH GROUP	1980		1981		1987	
1	0.1		0.0		0.3	
2	2.4		2.8		26.7	
3	2.1		3.4		36.5	
4	2.8		6.4		15.5	
5	1.8		2.3		17.9	
6	1.0	3.6	0.6	0.8	18.5	34.0
7	0.5		0.1		7.9	
8	0.9		0.0		0.9	
9	0.4		0.0		5.8	
10	0.4		0.1		0.9	
11	0.4		0.0		0.0	

MONETARY VALUE OF FISH IN LAKE ROUSSEAU

Conversion of standing crops of fish and hours of angling effort into monetary terms is useful in determining the "value" of a body of water (Wegener and Holcomb, 1972). The value of fish in Lake Rousseau was estimated to be $4,045,360 based on blocknet data collected in 1978 (Central Region Fish Management Report, 1979) and according to values established in "Fish Values" (1971).

Sportfish accounted for 63.7% of the total value of the fishery. Commercially valuable species (yellow bullhead, brown bullhead, and golden shiner) contributed less than 0.1% to the total value (Table 4).

Some species do not qualify as sportfish or commercial fish because of their small adult size. Examples include bluespotted sunfish, bluefin killifish, and taillight shiner. These three species composed 33.5% of the value of the fish population of Lake Rousseau. Their relative abundance and size make them valuable as forage species for largemouth bass, crappie, and other predatory fish.

MONETARY VALUE OF FISHING IN LAKE ROUSSEAU

The monetary value of fishing was estimated between $242,111 and $448,312 and is based upon the total amount of fishing effort, the average length of a fishing trip, and a range of costs for an average fishing trip.

The Game and Fresh Water Fish Commission performed a creel census on Lake Rousseau as a part of the Cross Florida Barge Canal Restudy (1976). The data from that study was used to determine the hours of fishing effort on the reservoir.

TABLE 4

Value of fish in Lake Rousseau based upon standing crop estimates collected by blocknetting in 1978 and value of fish reported in "Fish Values", Department of Air and Water Pollution Control, 1971.

SPECIES	VALUE/ ACRE	TOTAL VALUE
Largemouth bass	$ 85.81	$ 343,240.00
Chain pickerel	20.52	82,080.00
Bluegill	329.88	1,319,520.00
Redear sunfish	125.80	503,200.00
Warmouth	71.33	285,320.00
Black crappie	1.50	6,000.00
Redbreast sunfish	0.08	320.00
Spotted sunfish	9.27	37,080.00
Redfin pickerel	0.04	160.00
Yellow bullhead	0.08	320.00
Brown bullhead	0.12	480.00
Longnose gar	0.04	160.00
Florida gar	0.11	440.00
Lake chubsucker	9.63	38,520.00
Gizzard shad	0.28	1,120.00
Threadfin shad	0.02	80.00
Golden shiner	0.82	3,280.00
Seminole killifish	0.28	1,120.00
Bluespotted sunfish	230.04	920,160.00
Golden topminnow	0.52	2,080.00
Pirate perch	0.35	1,400.00
Sailfin molly	3.43	13,720.00
Bluefin killifish	100.69	402,760.00
Dollar sunfish	2.21	8,840.00
Least killifish	3.35	13,400.00
Mosquitofish	1.73	6,920.00
Taillight shiner	8.06	32,240.00
Everglades pygmy sunfish	3.96	15,840.00
Swamp darter	0.32	1,280.00
Brook silverside	0.55	2,200.00
Madtom	0.52	2,080.00
TOTAL		4,045,360.00

The Commission polled a segment of anglers during 1986 who purchased fishing licenses for FY 1985-86 (Hardin, memo, 1987). The information collected from this poll was used to determine average length of a fishing trip and a range of dollars spent on an average fishing trip.

The estimated value of fishing was calculated by dividing the total fishing effort in hours for one year by an average fishing trip of six hours. This division gave an estimate of the total number of fishing trips in one year. The total number of fishing trips was then multiplied by the minimum, median, and maximum cost estimates for a six-hour fishing trip. Therefore, a range of estimated dollars spent on a fishing trip was established.

Angling for largemouth bass consumed 63.0% of the total fishing effort and consequently contributed 63.0% to the value of fishing in Lake Rousseau (Table 5). Contributions from other fish were 24.0% for bream, 2.0% for catfish, and less than 0.5% for crappie (speckled perch).

Approximately 11.0% of the fishing effort was for fish other than those listed in Table 5 and was not included in the value estimate.

The total estimated value of fishing for largemouth bass, bream, catfish, and crappie should be considered conservative. As stated before, the creel census was taken during 1975-76. Fishing effort has probably increased since that time. Additionally, angling effort for all species was not included in the estimates.

TABLE 5

Value of fishing in Lake Rousseau based on 1976 creel survey and 6 hr/fishing trip.

	VALUE/ TRIP	MAN- HOURS	NO. TRIPS	$ VALUE
Largemouth bass				
Minimum	$19.62	46,940	7,823	$153,487.00
Median	26.79			209,578.00
Maximum	36.33			284,210.00
Bluegill				
Minimum	19.62	17,774	2,962	58,114.00
Median	26.79			79,352.00
Maximum	36.33			107,609.00
Catfish				
Minimum	19.62	1,363	227	4,454.00
Median	26.79			6,081.00
Maximum	36.33			8,247.00
Black crappie				
Minimum	19.62	310	52	1,020.00
Median	26.79			1,393.00
Maximum	36.33			1,889.00
Total				
Minimum	19.62	74,040	12,340	242,111.00
Median	26.79			330,589.00
Maximum	36.33			448,312.00

Dollars generated by goods or services are commonly increased two to three times based on the multiplier effect. This is done to more accurately express the value of dollars spent in the community where the goods or services were provided. The values on Table 5 were not adjusted, but rather based upon one-time expenditures.

Even using conservative data, fishing in Lake Rousseau is still of considerable economic value.

RECOMMENDATIONS

Bottom substrate conditions, aquatic vegetation (species composition, areal coverage, and density), and water quality are primary habitat parameters that dictate fish production. Therefore, we recommend the Southwest Florida Water Management District and U.S. Army Corps of Engineers jointly develop and implement a management plan that includes techniques to: (1) remove, or consolidate and compact bottom sediments; (2) decrease hydrilla coverage and density; (3) encourage the expansion of native aquatic plants, (4) reduce the influx of excessive nutrients, and (5) improve sportfish production.

No single technique will accomplish all of these goals. An extreme lake drawdown of proper timing and duration is the most economical and effective method presently known to reduce organic sediments and stimulate the expansion of native plants which will subsequently improve sportfish production.

Production of largemouth bass, as well as most other sportfish species, was improved following restoration by drawdown (Williams, 1987) in Lakes West Tohopekaliga, Kissimmee, Talquin, and Griffin. The improvement varied with the productivity of various lakes, but sportfish production was enhanced in all lakes. Largemouth bass and other sportfish populations are projected to improve if an integrated program of hydrilla control and water level fluctuation is implemented on Lake Rousseau.

LITERATURE CITED:

McKinney, S. and W. Coleman. 1978. Central Region Fish Management Report. Florida Game and Fresh Water Fish Commission.

_______ and _______. 1979. Central Region Fish Management Report. Florida Game and Fresh Water Fish Commission.

McKinney, S., W. Borkowski, and L. Snyder. 1981. Central Region Fish Management Report. Florida Game and Fresh Water Fish Commission.

McKinney, S., L. Snyder, and W. Borkowski. 1982. Central Region Fish Management Report. Florida Game and Fresh Water Fish Commission.

Swingle, H. 1950. Relationships and Dynamics of Balanced and Unbalanced Fish Populations. Agricultural Experiment Station of the Alabama Polytechnic Institute.

Wegener, W. and D. Holcomb. 1972. An Economic Evaluation of the 1970 Fishery in Lake Tohopekaliga, Florida. Proc. Ann Conf. S.E. Assoc. of Game and Fish Comm. 26:628-634.

Fish Values. 1971. Florida Department of Air and Water Pollution Control, Tallahassee, Florida.

Cross Florida Barge Canal Restudy. 1976. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.

Hardin, S. 1987. Value of Bass Fishing in Florida (memo).

Williams, Vincent P. et al. 1987. Fish Population and Angler Use Responses to Extreme Drawdown on Four Selected Florida Lakes. (To be presented at North American Lake Mngmt. Society Ann. Meet., Orlando, FL, November 1987.)

APPENDIX B

LINEAR REGRESSION MODEL TO PREDICT STREAMFLOW AT FLORAL CITY

The linear-regression technique provided the means whereby the linear relationships between dependent and independent variables can be determined. Once a linear relationship is determined, the generation of historical data is possible.

This generation of historical data was made possible by the development of the linear-regression model of the Floral City flows (dependent variable) equal to the Wysong Dam flows, and the difference in water surface elevations above and below Wysong Dam (independent variables).

The linear-regression equation used to generate historical Floral City flows is as follows:

$$\begin{aligned}\text{Log}_{10}\ (\text{Floral City Flows}) &= 1.62516 * \text{Log}_{10}\ (\text{Wysong Dam Flows}) \\ &\quad + 0.14524 * (\text{Difference in Water} \\ &\quad\ \ \text{Surface Elevations Above \& Below} \\ &\quad\ \ \text{Wysong Dam}) - 2.10076\end{aligned}$$

The equation produced a high R^2 value of 0.99 (correlation coefficient squared) with the two independent variables, Wysong Dam flow and the water surface difference across the dam being statistically significant. The R^2 value indicates a high linear relationship between the Floral City flows, Wysong Dam flows, and operation of the dam. Several other tests were performed to determine the degree of auto correlation and collinearity between the variables. These tests indicated that auto correlation and collinearity does exist with the consequence of effecting the model predictions ability for each individual model parameters. It was decided that the model could be used to provide general information on historical Floral City flows even though autocorrelation and collinearity exist. It was not necessary to determine the effect of each individual model parameter on Floral City flows (i.e., the manipulation of the head difference across the dam and its subsequent effect on Floral City flows). The results of this type of analysis would be highly questionable using this equation.

Autocorrelation is the dependency of the observed data to adjacent observed data (i.e., today's water level in dependent upon yesterday's water level). Collinearity, on the other hand, is cross-variable dependency. In regard to the equation under discussion, collinearity is exhibited through the condition where Wysong Dam operation (difference is upstream and downstream dam elevations) affects Wysong Dam flows and Floral City flows.

APPENDIX C

USACOE - LAKE ROUSSEAU

AQUATIC PLANT MANAGEMENT PLAN

1988

Long Term Goals

1. Maintain non-native, problem plants at the lowest level possible consistent with available funds. Problem plants include water hyacinths, water lettuce and hydrilla.

2. Reduce acreage covered by tussocks (mats of floating and/or rooted vegetation) to less than 30% of present acreage and break up large mats into smaller mats for increased edge habitat and better access.

3. Encourage native aquatic plants to re-establish their dominance along shorelines and other areas.

4. Increase water movement and reduction of sediment build up.

5. Monitoring of water quality and nutrient inputs to Lake.

6. Maintenance of open, safe, properly marked navigation channels.

1988 Goals

1. Maintenance control of floating plants at the lowest level possible so they are kept in check by using the least herbicide and crew time. This will also minimize the plants contribution to sediment build up.

2. Reduce the total acreage now covered by tussocks by 10% to 20%. This will be achieved by eliminating some smaller mats and by reducing the margins of large tussocks and cutting trails and open areas into the larger tussocks. With the help of some volunteers who know where old trails or side creeks have been covered over by the mats, we may be able to re-establish some old access areas and increase water circulation at the same time.

3. The hydrilla acreage in Rousseau needs to be reduced to allow for better navigation and a more balanced population of native plant species such as eelgrass, coontail, etc. Since hydrilla is very expensive to control, we will have to limit treatment. Our effort will be concentrated on keeping established trails and other access areas open. Public boating access and commercial access will receive priority. In addition to trails and access areas, we plan to treat up to 300 acres of hydrilla (see map) with a chemical called SONAR. SWFWMD treated about 240 acres with SONAR in December 1986. Our proposed control areas for 1988 will be treated in late February or March and have been located in an effort to enhance the 1986 treatments.

4. Herbicide treatments will begin as soon as environmental conditions favor effective control. Generally, the major control efforts will begin at the west end of the Lake and proceed eastward. Floating plants will be treated wherever they become gathered for efficient treatment.

5. The Corps is presently installing floating buoys to mark the main river channel through Lake Rousseau. So far, this marking operation is going according to schedule and should be completed in March. As the amount of aquatic vegetation is reduced, these markers will become more important in following the main channel. We ask everyone to help maintain these markers by reporting any movement or damage to them to the Corps Park Ranger, Nancy Allen, at Inglis Lock 447-2933. Should you observe vandalism or abuse to the markers, please report it along with a boat number if possible. Please help us take care of your markers.

6. It is important that we get an early start on our control efforts if we are to succeed in reducing nuisance vegetation coverage in the most environmentally sound manner. We need to get the plants down before the growing season is in full swing and the water warms up. We need the cooperation and help of everyone in this respect.

7. Purposes of this Management Plan:

a. Reduce (and possibly eliminate some) competition from exotic plant species while encouraging native plants to re-establish.

b. Increase quantity of fish habitat by improving vegetation type and reducing acreages of problem plants.

c. Improve quality of fish habitat by maximizing the edge effect, encouraging native vegetation and shifting some areas toward a food chain more conducive to game fish. (Microphytes)

d. Reduction of sedimentation and detritus buildup.

e. Improved access for boating, fishing and other recreation activities by restoring more open water.

f. When we have reduced nuisance plants to maintenance control levels, less money and less herbicides will be required to maintain smaller acreages of plants resulting in a reduction of detritus build up. This will be a step toward improved bottom conditions and better fisheries.

Work Accomplished 1987

A private contractor - Applied Aquatic Management, Inc. was the successful bidder for Aquatic Plant Management Services on Lake Rousseau for 1987 and began work in September. To date, they have chemically treated:

Floating Vegetation (hyacinths, lettuce etc)		534 acres
Hydrilla (mostly trails)		234 acres
Various grasses and alligatorweed		3 1/2 acres
	Total	771 1/2 acres

APPENDIX D.

Data from Sediment Cores and Results of Laboratory Analysis of Samples from the Cores.

Sediment Core No.	Water Depth (feet)	*Total Depth of Sediments	Sample Depth from Top of Core	% Water	% Organic (of dry weight)	Remarks and Excerpts from Field Notes
1 A 1	6	51 cm./20 in.	5-10 cm. 30-35 cm.	91.6 89.4	32.8 27.0	Core taken 50-75 ft. from north shoreline of lake.
1 A 2	6	60 cm./24 in.	none taken	---	---	Measured 60 cm. and encountered resistance at this depth of sample. This was second sample at point 1 A to attempt to get a good inclination of total depth of muck.
1 C	4.5	5 cm./2 in.	none taken	---	---	No sample taken because of small depth of sediments; 5 cm. of muck (mixed plant and organic material) and sand. Core taken about 200 ft. from south shoreline of lake.
1 D	9	20 cm./8 in.	10-15 cm.	90.7	35.3	Twenty cm. of organic material, some slight indication of sand which probably fell out of sampler as it was extracted from the sediments. Fathometer did not indicate any muck where depth was about 6 ft. and only slight muck at this core site. Core taken about 500 ft. from south shoreline of lake and about 500 ft. landward of main channel markers.
3 A	3.5	5 cm./2 in.	none taken	---	---	Total core depth was 65 cm. (26 in.) but 60 cm. of it was sand. No sample was taken because of small depth (5 cm.) of muck (very fibrous); core taken 75-100 ft. from north shoreline of lake.

Appendix D (continued)

Sediment Core No.	Water Depth (feet)	*Total Depth of Sediments	Sample Depth from Top of Core	% Water	% Organic (of dry weight)	Remarks and Excerpts from Field Notes
3 B	6	15 cm./6 in.	1-4 cm.	83.3	11.4	Total core depth 55 cm. (22 in.) but about 40 cm. of it was sand; 15 cm. of organic mix. Started to pick up sand at 15 cm. Blue-gray clay at bottom of core; core taken about 175 ft. from north shoreline of lake.
3 C	5	48 cm./19 in.	none taken	---	---	Forty-eight cm. of organic mud on top of 10 cm. of sand; appeared about same as on north side of lake; therefore, did not take a sample. Did not have blue-gray clay at bottom that was found in core on north side of this cross-section. Core taken about 75 ft. from south shoreline of lake.
3 D	8	52 cm./20 in.	5-10 cm.	95.5	39.4	Fifty-two cm. of mud on top of 10 cm. of sand. Core taken about 500 ft. from south shoreline of lake.
			30-35 cm.	91.7	41.8	
			45-50 cm.	89.1	36.5	
5 A 1	2	92 cm./36 in.	5-10 cm.	98.3	51.4	Ninety-two cm. (36 in.) of muck on top of 3 cm. of woody material and and 9 cm. of sandy material. Core taken amount 300 ft. from north shoreline of lake.
			34-40 cm.	96.0	45.6	
			75-80 cm.	94.4	46.4	
			95-100 cm.	51.2	14.2	
5 A 2	about same as 5 A 1	65 cm./25 in.	none taken	---	---	Second core taken at about same location of 5 A 1. 60 cm. of flock-like mud on top of 5 cm. of woody mud with sand material at 65 cm. into the core.

Appendix D (continued)

Sediment Core No.	Water Depth (feet)	*Total Depth of Sediments	Sample Depth from Top of Core	% Water	% Organic (of dry weight)	Remarks and Excerpts from Field Notes
5 B	4.5	25 cm./10 in.	5-10 cm.	96.3	59.5	Twenty centimeters of flock-like mud on top of 5 cm. of woody mud and 60 cm. of sand; appeared to be about the same as core 5 A. Therefore, only took one sample for analysis. Total depth of core 85 cm. Core taken about 500 ft. from north shoreline of lake.
5 C	7	26 cm./10 in.	0-6 cm. 8-12 cm. 20-26 cm.	97.7 46.9 82.1	46.6 6.5 25.6	Eight cm. of muck on top of sand and clay lense. At 15-26 cm. organic mix below sand lense. Total depth of core - 84 cm. remainder being sand. Core taken about 1,000 ft. from north shoreline of the lake and about 150 ft. landward of main channel markers.
5 D	6	90 cm./35 in.	5-10 cm. 35-40 cm. 65-70 cm.	91.9 93.6 93.2	46.2 55.9 51.8	Eighty-five centimeters of brownish mud over 5 cm. of peaty-mud, then sand. At 75-80 cm. color changes from dark brown to olive, and at 85 cm. changes to peat, about 5 cm. of peat over sand. Core taken about 300 ft. from south shoreline of lake.
5 E	3.5	+50 cm./20 in.	5-10 cm. 35-40 cm. 60-68 cm.	96.8 94.5 63.8	61.4 58.7 13.3	Probably was similar to core 5 D. Field notes say bottom of core was firm. Analysis results of the 60-68 cm. sample interval indicates that material probably was sand or clay. Core taken off south shoreline of lake but distance was not recorded.

Appendix D (continued)

Sediment Core No.	Water Depth (feet)	*Total Depth of Sediments	Sample Depth from Top of Core	% Water	% Organic (of dry weight)	Remarks and Excerpts from Field Notes
7 A	4	65 cm./20 in.	5-10 cm.	96.7	52.7	Only field notes..."at 65 cm. switches to sand".
			35-40 cm.	89.0	56.8	
			55-60 cm.	82.6	58.8	
7 B	6.5	100 cm./39 in.	5-10 cm.	96.3	61.5	Total core depth was 106 cm; 75 cm. of dark muck over 25 cm. of light mud, over 5 cm. of sand. Bottom 10 cm. is light color forest litter.
			35-40 cm.	97.2	70.8	
			85-90 cm.	94.3	42.2	
7 C	4.5	110 cm./43 in.	5-10 cm.	96.2	59.2	Total core depth was 110 cm; bottom of core was in wood-fiber and hyacinths remains, and grayish-clayey muck. Core taken off south shoreline of lake between core 7 D and shoreline.
			35-40 cm.	96.7	69.8	
			75-80 cm.	90.0	26.4	
7 D	3.0	+80 cm./31 in.	5-10 cm.	97.8	65.1	Total core depth 109 cm. Core taken about 200 ft. from south shoreline of lake and about 300 ft. landward of main channel markers.
			35-40 cm.	95.7	50.4	
			75-80 cm.	94.5	41.6	

*Determined from description of core in field notes.
+Estimated from laboratory analysis of samples.

APPENDIX E

TROPHIC STATE INDEX MODELS

<u>For nutrient-balanced lakes</u>:

$$\mathrm{TSI(AVE)} = 1/3\ [\mathrm{TSI(chl\underline{a})} + \mathrm{TSI(SD)} + 0.5\ [\mathrm{TSI(TPB)} + \mathrm{TSI(TNB)}]]$$

$$\mathrm{TSI(chl\underline{a})} = 16.8 + 14.4 \ln \mathrm{chl\underline{a}}$$

$$\mathrm{TSI(SD)} = 10[6.0 - 3.0/\mathrm{SD}]$$

$$\mathrm{TSI(TPB)} = 10[1.86 \ln \mathrm{TP} - 1.84]$$

$$\mathrm{TSI(TNB)} = 10[5.6 + 1.98 \ln \mathrm{TN}]$$

chl<u>a</u> = chlorophyll <u>a</u>
SD = Secchi depth
TPB = Total phosphorus for nutrient balanced lakes
TNB = Total nitrogen for nutrient balanced lakes

Values calculated for Lake Rousseau using data provided by the USCOE (Table 6), Canfield (Table 8) and analyzed during this study (Tables 3 and 4).

TSI(AVE) = 46.32
TSI(Chl<u>a</u>) = 50.06
TSI(SD) = 38.75
TSI(TPB) = 55.09
TSI(TNB) = 45.21

From: Huber, et al., 1982
Source: Huber, et al., 1982

APPENDIX F

HEC-2 INPUT DATA DECK USED TO STIMULATE THE LAKE ROUSSEAU AND WITHLACOOCHEE RIVER RESPONSE TO A DRAWDOWN

```
T1  LAKE ROUSSEAU DRAWDOWN ANALYSIS
T2  DATE AUGUST 12 1987 RUN WITH TRAMCROSSING
T3   LAKE ROUSSEAU STARTING POOL OF 27.48 FEET
J1   -10        5                                                          27.48
NC  .070     .070     .065       .1       .3
QT     4      700     1200     4600     9500
X1    22       82   2350.0   4050.0
GR  29.0       71     23.9       74     19.1      100     21.8      150     17.4      200
GR  20.1      250     21.6      300     20.7      450     21.0      500     22.2      550
GR  23.2      650     23.4      750     22.4      850     19.4      900     21.8     1000
GR  23.8     1250     23.7     1300     23.2     1350     21.9     1400     21.6     1450
GR  22.1     1650     22.5     1750     22.4     1800     21.2     1850     20.6     1900
GR  21.9     1950     21.6     2000     20.3     2050     21.1     2100     21.5     2150
GR  19.4     2250     18.2     2350     15.2     2500     15.2     2600     12.8     2650
GR  16.3     2725      7.4     2750      4.9     2775      1.4     2800     -0.6     2825
GR  -0.6     2850      6.5     2875     12.5     2900     17.4     2950     18.3     3000
GR  16.7     3050     13.4     3100     12.4     3150     13.9     3200     14.8     3300
GR  14.5     3350     15.3     3400     14.8     3500     15.9     3550     15.2     3600
GR  16.9     3650     15.2     3700     15.4     3750     16.3     3800     15.8     3850
GR  16.2     3900     17.5     3950     18.2     4050     18.4     4150     17.9     4250
GR  18.8     4350     20.4     4450     22.6     4550     23.1     4600     22.7     4650
GR  23.1     4700     22.4     4750     21.2     4800     21.7     4850     20.4     4900
GR  21.4     4950     22.9     5000     22.2     5050     24.0     5100     28.4     5105
GR  28.7     5150     29.0     5250
X1    23       51   2256.0   2682.0   4921.0   3858.0   4094.0
GR  32.6        0     31.7       50     29.1      150     27.4      195     26.0      212
GR  24.3      257     24.3      283     20.3      306     17.6      356     16.4      406
GR  17.0      506     16.8      606     16.2      706     17.0      756     16.3      806
GR  17.0      956     16.7     1006     16.7     1106     18.8     1456     18.4     1506
GR  18.9     1556     17.9     1856     18.2     1906     17.9     2006     18.8     2106
GR  18.3     2256     17.7     2306     16.1     2356     17.3     2406     14.7     2456
GR  16.4     2506      8.4     2533      4.9     2556      6.4     2583      6.4     2606
GR   3.6     2632      5.4     2656     18.8     2682     18.4     2706     16.2     2756
GR  16.9     2856     16.8     2956     17.9     3006     20.1     3056     25.5     3142
GR  27.4     3152     28.2     3156     28.0     3200     32.9     3300     34.3     3350
GR  34.3     3400
X1    25       47   1900.0   2450.0   6496.0   7205.0   6850.0
GR  34.3       10     30.5       50     29.0       80     27.8      100     22.8      200
GR  23.8      300     24.1      350     24.1      400     22.9      500     22.5      550
GR  22.0      700     21.5      750     20.6      800     20.1      850     20.3      900
GR  19.7      950     19.6     1100     18.8     1150     19.1     1200     17.6     1300
GR  16.3     1350     17.4     1400     14.3     1450     16.8     1500     15.8     1550
GR  15.7     1600     17.0     1650     17.8     1700     18.3     1750     19.9     1800
GR  20.3     1900     19.3     1950     10.3     1975      6.3     2000      6.3     2125
GR   5.8     2150      7.3     2175     14.3     2200     16.4     2250     18.7     2350
GR  19.6     2450     21.3     2550     23.8     2600     27.3     2642     29.3     2645
GR  30.3     2700     31.1     2800
X1    26       52   2775.0   3050.0   3386.0   1614.0   1965.0
GR  31.9       50     29.0      150     29.3      290     27.3      305     21.1      400
GR  20.3      450     22.7      500     21.8      550     20.8      700     20.3      800
GR  20.0      900     20.8     1050     20.4     1100     20.8     1150     20.5     1200
GR  19.8     1450     19.8     1500     20.3     1550     20.5     1650     20.3     1700
```

```
GR  19.7    1750    19.8    1950    19.5    2000    19.5    2050    19.8    2100
GR  20.8    2150    21.3    2200    21.0    2250    21.3    2300    18.8    2350
GR  16.2    2400    17.3    2450    17.3    2500    19.0    2550    17.6    2600
GR  17.6    2650    19.3    2750    23.3    2775     7.3    2800     3.8    2825
GR   2.8    2850     3.4    2875     5.5    2900    15.8    2925    23.3    2950
GR  19.8    3000    22.1    3050    27.3    3088    28.3    3090    29.0    3100
GR  30.6    3150    31.8    3200
X1    27      76   450.0  1425.0  4960.0  6614.0  5512.0
GR  33.5      35    27.4      65    21.9     100     8.4     150     7.4     175
GR   7.7     200     9.1     225    15.7     245    19.9     250    18.3     300
GR  18.3     350    16.4     400    17.0     450    16.1     550    16.3     600
GR  17.7     650    17.1     675     7.4     700     2.4     800     4.6     850
GR   7.9     900     9.6     950     9.9    1000    10.4    1050     9.9    1100
GR   9.2    1150     7.4    1200     2.4    1300     6.4    1350    11.4    1400
GR  18.6    1425    18.3    1450    19.2    1500    16.8    1550    16.9    1600
GR  17.6    1650    17.9    1700    17.4    1750    17.0    1850    17.3    1900
GR  18.2    1950    18.4    2050    18.2    2100    17.6    2150    19.2    2200
GR  19.4    2250    18.9    2300    19.4    2450    18.8    2500    19.4    2550
GR  18.8    2600    19.6    2650    18.9    2700    17.6    2750    18.9    2800
GR  18.8    2900    19.2    2950    18.9    3000    18.4    3175    18.4    3250
GR  20.9    3300    18.6    3350    18.6    3400    20.2    3450    18.9    3500
GR  19.4    3550    21.0    3600    22.2    3800    21.4    3900    22.0    3950
GR  21.5    4050    25.1    4150    27.4    4187    28.0    4200    30.1    4230
GR  31.8    4300
X1    28      70  3100.0  3700.0  5827.0  5433.0  7480.0
GR  32.9       0    29.4     108    27.8     200    27.4     201    24.0     250
GR  23.7     300    21.4     350    23.5     400    23.2     450    22.9     500
GR  22.6     800    22.2     850    22.3    1000    21.9    1050    21.7    1100
GR  22.1    1150    21.7    1300    21.9    1350    21.6    1550    19.7    1600
GR  19.8    1650    20.4    1700    21.3    1750    16.9    1800    17.6    1850
GR  20.0    1900    19.6    2050    19.9    2100    17.8    2150    19.3    2200
GR  16.4    2250    16.3    2300    15.4    2350    14.3    2400    17.9    2450
GR  18.8    2500    18.6    2550    16.1    2600    17.9    2650    16.3    2700
GR  20.2    2750    20.2    2800    21.9    2850    21.0    2900    21.0    2950
GR  17.4    3000    19.0    3050    22.1    3100    21.8    3125    11.9    3175
GR   8.6    3200     8.1    3225     8.4    3250     7.3    3275     7.2    3300
GR   7.8    3325    17.9    3350    20.1    3400    20.9    3450    21.3    3500
GR  22.3    3700    22.8    3750    20.9    3800    22.6    3850    23.9    3950
GR  26.5    4000    23.9    4050    28.0    4062    30.4    4125    31.0    4175
X1    29      66  2295.0  2600.0  2756.0  2362.0  3543.0
GR  34.1       0    32.4      50    30.2     100    28.0     170    27.5     200
GR  26.5     250    26.0     350    25.0     450    24.0     500    25.2     600
GR  25.2     750    25.5     800    25.2     850    22.8    1000    21.6    1200
GR  21.9    1250    21.7    1300    19.0    1345    20.9    1395    21.6    1450
GR  21.7    1600    21.7    1650    22.3    1700    22.5    1745    21.4    1795
GR  22.0    1897    19.4    1950    17.5    2000    19.1    2045    20.7    2095
GR  19.9    2245    20.0    2295    17.5    2350    16.4    2375    16.0    2400
GR  18.5    2425    11.2    2450     6.7    2475     4.5    2500     3.4    2525
GR   4.8    2550     8.1    2575    19.3    2600    18.5    2650    19.2    2700
GR  17.9    2750    20.0    2800    19.9    2850    17.8    2900    20.4    2950
GR  15.7    3000    21.2    3100    23.7    3200    22.5    3250    24.3    3350
GR  24.7    3400    24.8    3450    25.6    3500    24.8    3600    25.8    3650
```

```
GR  27.5    3680    28.0    3690    29.5    3695    29.2    3750    29.7    3800
GR  30.0    3900
X1    30      51   300.0   750.0  4803.0  3150.0  5433.0
GR  33.7     100    30.5     150    29.0     185    27.3     187    25.4     200
GR  21.5     250    24.5     300    10.3     350     4.9     375     1.9     400
GR   0.5     425     0.4     450     3.1     475     6.6     500     6.5     550
GR   7.6     575    12.5     600    20.5     625    17.3     650    23.5     700
GR  24.1     750    20.8     800    21.2     850    21.2    1000    21.7    1050
GR  23.0    1100    23.7    1250    23.5    1300    22.8    1350    22.5    1400
GR  22.9    1450    23.2    1550    22.9    1600    23.1    1750    23.4    1800
GR  23.1    1850    24.0    1900    24.7    1950    24.9    2000    24.0    2100
GR  24.0    2150    23.6    2200    23.5    2500    24.7    2650    27.5    2685
GR  29.3    2687    29.6    2700    31.0    2750    31.5    2800    31.7    2850
GR  32.2    2900
X1     1      49   625.0   875.0  2992.0  2756.0  4724.0
GR  41.1       0    39.8     100    37.1     200    31.2     300    30.5     325
GR  28.3     350    29.5     375   26.88     400    20.1     425    20.4     450
GR  21.7     475    24.9     500    21.6     600    21.0     625    17.8     650
GR  19.2     675    11.3     700     8.9     725     8.9     825    18.2     850
GR  25.0     875    27.5     900    27.1     915    23.5     925    22.2     950
GR  20.2    1025    21.3    1050    22.6    1100    22.2    1200    22.9    1300
GR  23.3    1400    24.4    1500    25.1    1600    24.9    1700    25.3    1800
GR  25.1    1900    25.3    2000    25.4    2100    24.9    2200    23.8    2300
GR  23.9    2400    24.2    2500    25.3    2600    24.2    2700    25.3    2800
GR  35.1    3350    34.4    3450    37.1    3600    41.6    3975
X1     2      41   550.0   860.0  1496.0  1496.0  1575.0
GR  44.2       0    43.3      25    29.4     175    28.5     235    26.7     240
GR  25.4     250    21.7     275    23.5     300    24.5     325    24.2     350
GR  25.4     450    25.2     475    24.1     500    25.1     525    25.1     550
GR  24.7     575    22.9     600    15.7     625    14.7     650    11.9     675
GR  12.2     750    13.3     775    18.9     800    27.6     860    27.0     900
GR  26.7    1100    24.6    1125    24.4    1175    27.0    1200    27.0    1375
GR  25.1    1400    26.7    1800    26.7    1975    24.6    2000    24.7    2025
GR  26.4    2050    25.0    2075    29.2    2150    29.6    2175    37.9    2300
GR  41.4    2400
X1     3      62  2125.0  2325.0  1949.0  1929.0  2953.0
GR  40.9       0    40.1      50    36.8     150    35.2     250    32.8     300
GR  34.7     350    33.9     500    32.4     550    30.2     725    29.4     735
GR  26.9   735.1    21.7     765    21.4     775    27.1     800    27.1     850
GR  26.7     875    25.0     900    25.0     925    26.4     950    27.1     975
GR  27.1    1100    26.9    1250    25.1    1275    24.4    1400    25.7    1550
GR  24.2    1600    23.6    1650    19.5    1675    22.1    1700    22.0    1725
GR  23.3    1750    22.9    1800    26.9    1825    24.8    1850    21.9    1900
GR  21.1    1925    24.8    1950    27.0    1975    28.1    2050    25.4    2100
GR  26.5    2125    17.1    2175    16.2    2200     9.4    2250     8.9    2275
GR  18.7    2300    24.8    2325    21.9    2375    26.3    2400    22.3    2425
GR  24.4    2450    24.7    2500    20.6    2525    19.7    2550    21.7    2625
GR  21.0    2650    21.6    2675    28.7    2700    24.7    2715    32.2    2725
GR  38.3    2825    40.3    2900
X1     4      40  1325.0  1525.0  1496.0  1614.0  1496.0
GR 43.76       0    40.6      75    34.7     150    31.7     250    31.0     600
GR  30.7     700   29.94     755   30.41     775    30.7     950    29.9     955
```

```
GR  28.1     957    20.7    1000    17.7    1025    25.1    1050    26.7    1060
GR  27.3    1065    28.4    1110    26.7    1125    26.5    1275    27.1    1300
GR  29.2    1320    26.7    1325    13.5    1375    13.2    1400    11.4    1425
GR  12.7    1450    12.2    1500    29.2    1525    29.2    1575    26.7    1625
GR  26.6    1675    27.4    1700    26.1    1725    26.1    1750    27.7    1775
GR  27.6    1800    29.6    1850    32.9    1875    37.1    1900    39.5    1925
X1     5      50   816.0  1000.0  1181.0  1575.0  1575.0
GR 41.29      10    40.3      25    40.1     100    37.5     200    33.9     250
GR  31.6     300    30.6     400    30.6     422    27.6     425    17.9     450
GR  19.2     475   26.73     500    27.7     505    29.2     506    30.6     525
GR  29.5     570   26.73     578    23.4     600    22.2     675    23.9     700
GR  25.2     750   26.73     770    28.7     812   26.73     816    18.2     850
GR  15.1     875    10.7     900     9.9     925    16.9     975    29.3    1000
GR  27.6    1025    28.0    1100    26.1    1150    26.4    1200    28.0    1250
GR  26.7    1300    27.1    1325    26.0    1350    27.2    1375    27.5    1450
GR  26.5    1475    27.5    1500    26.5    1525    27.3    1550    27.8    1650
GR  28.4    1675    32.0    1725    40.5    1800    42.6    1825    43.9    1850
X1     6      64   856.0   950.0  1220.0  1181.0  1417.0
GR  42.1      50    40.7      75    38.0     100    23.8     150    22.4     175
GR  21.7     225    23.4     250    24.0     275    27.0     300    27.3     350
GR  28.6     375    29.0     400    27.7     425    27.4     450    21.4     525
GR  27.8     550    29.7     575    24.6     650    25.5     675    25.5     700
GR  28.9     750    29.0     800    26.5     825    28.5     850    28.2     856
GR  27.0     860    12.9     875     9.0     900    12.6     925    20.1     950
GR  25.1     975    21.7    1025    20.8    1050    20.8    1125   27.01    1150
GR  30.0    1160    31.1    1175    30.0    1200    29.5    1225    27.7    1240
GR  24.2    1275    24.8    1350    26.9    1375    27.4    1400    27.0    1425
GR  26.9    1500    25.7    1525    26.8    1550    27.1    1575    27.3    1750
GR  28.3    1800    27.1    1850    27.6    1925    27.2    1950    27.0    1975
GR  27.6    2000    28.2    2150    29.8    2225    30.2    2275    30.8    2300
GR  31.2    2400    39.9    2420    38.7    2450    41.0    2500
X1   701      19   850.0  1060.0  2400.0  2400.0  2400.0
GR  40.4       0    38.5     100    37.3     250    37.2     350    37.8     400
GR  37.5     500    36.7     575    38.5     625    39.0     700    38.4     750
GR  38.1     850   26.84     900     6.8     935     6.8    1007    12.0    1025
GR 22.48    1060    27.0    1100    30.0    1800    38.6    1900
NC 0.070   0.070   0.065     0.4     0.8
X1   702      40   925.0  1067.0   100.0   100.0   100.0
GR  40.4       0    38.5     100    37.3     250    37.2     350    37.8     400
GR  37.5     500    36.7     575    38.5     625    39.0     700    38.4     750
GR  38.1     850   26.84     900    23.0     915    29.7     916   32.33     925
GR 32.28     930   30.51     933     6.8     935     6.8     985   29.13     986
GR 32.74    1000    6.84    1007    12.0    1025    22.4    1060   32.52    1062
GR 36.45    1067    37.7    1100    37.9    1150    37.4    1300    37.6    1550
GR  37.4    1600    37.8    1650    38.1    1800    38.4    1850    38.7    2000
GR  38.4    2050    38.6    2100   39.88    2450   39.38    2500   40.28    2550
X1   703      40   925.0  1067.0   300.0   300.0   300.0
GR  40.4       0    38.5     100    37.3     250    37.2     350    37.8     400
GR  37.5     500    36.7     575    38.5     625    39.0     700    38.4     750
GR  38.1     850   26.84     900    23.0     915    29.7     916   32.33     925
GR 32.28     930   30.51     933     6.8     935     6.8     985   29.13     986
GR 32.74    1000    6.84    1007    12.0    1025    22.4    1060   32.52    1062
```

```
GR 36.45    1067    37.7    1100    37.9    1150    37.4    1300    37.6    1550
GR  37.4    1600    37.8    1650    38.1    1800    38.4    1850    38.7    2000
GR  38.4    2050    38.6    2100   39.88    2450   39.38    2500   40.28    2550
X1   704      19   850.0  1060.0   100.0   100.0   100.0
GR  40.4       0    38.5     100    37.3     250    37.2     350    37.8     400
GR  37.5     500    36.7     575    38.5     625    39.0     700    38.4     750
GR  38.1     850   26.84     900     6.8     935     6.8    1007    12.0    1025
GR 22.48    1060    27.0    1100    30.0    1800    38.6    1900
NC 0.070   0.070   0.065     0.1     0.3
X1     8      29   200.0   543.0  2283.0  2283.0  2283.0
GR  37.4       0    39.0      25    37.5      50    38.3     100    37.2     125
GR  27.7     150    27.8     175    31.6     200    31.4     225    30.0     250
GR  31.5     275    28.2     300    28.3     325    26.9     335    16.7     350
GR  14.8     375    11.4     400     9.5     425     8.9     450    11.6     500
GR  18.9     525    26.9     532    28.3     537    32.8     538    34.0     542
GR  37.0     543    38.4     550    43.1     575    47.1     600
X1     9      27   150.0   475.0   984.0   984.0   984.0
GR  34.9       0    34.4      25    34.2      50    34.6      75    34.6     100
GR  35.1     125    35.0     150    34.6     175    30.6     200    28.2     225
GR 26.94     235    24.3     250    19.5     275    12.9     300    10.9     325
GR  11.1     350    16.3     375    24.2     400   26.94     415    27.8     425
GR  32.2     450   32.73     475    34.3     500   34.89     502    36.2     525
GR  38.2     550   43.26     600
X1    10      28   200.0   700.0   472.0   472.0   472.0
GR  39.5      50    39.3      75    39.9     100    40.8     125    39.4     150
GR 40.47     200    39.6     225    35.6     275    34.1     300    29.8     350
GR  26.9     375    18.1     400    15.3     425    14.6     450    10.4     475
GR  10.9     500    12.5     525    15.6     550    23.9     575   26.94     590
GR  30.3     600    31.3     625    31.2     675    31.7     700    31.2     725
GR  31.5     750    32.2     775   31.34     800
X1    11      36   375.0   800.0   826.0   315.0   590.0
GR  37.4       0    37.6      25    37.4      50    37.6      75    38.5     100
GR  35.7     125    36.0     150    34.3     175    34.8     200    34.3     225
GR  34.5     250    32.9     275    33.5     300    32.8     325    32.3     350
GR 32.42     375    31.6     400    30.4     425    28.5     450    28.0     475
GR 26.94     485    19.4     500     9.8     530     9.4     575    10.5     600
GR  11.4     625    11.8     650    11.1     675    11.7     700    13.9     725
GR  18.1     750    24.3     775   26.94     780    31.7     800    35.8     825
GR  39.2     850
NC 0.075   0.075   0.065     0.1     0.3
X1    12      52  1220.0  1470.0   787.0  1260.0  1181.0
GR  36.4      20    35.2      30    35.6      50    35.4      70    37.6      80
GR  37.5     100    35.3     150    35.6     200    34.8     250    33.3     300
GR  32.2     400    31.9     450    33.9     480    30.3     550    29.3     600
GR  27.4     605    25.3     615    26.8     625    27.8     630    27.8     675
GR  29.9     685    30.2     700    31.6     750    33.3     800    34.0     850
GR  33.2     900    33.1     950    31.8    1000    31.4    1050    30.8    1100
GR  29.6    1150    28.6    1175    26.5    1185    25.8    1190    25.9    1202
GR  27.3    1206    28.0    1220    25.1    1255    22.6    1260    22.7    1275
GR  17.7    1300    10.0    1325     5.5    1350     4.5    1375     4.5    1400
GR   9.0    1425    20.0    1450    24.7    1460    29.1    1470   33.68    1535
GR 37.20    1540    40.2    1550
```

```
X1    13      42   965.0  1136.0   874.0  1968.0  1574.0
X2  8660
GR  42.5      50    41.7      65    41.4     100    40.8     150    40.1     200
GR  40.1     250    37.1     280    37.5     283    36.3     295    36.3     300
GR  34.8     350    32.3     400    30.5     450    30.2     483    31.0     500
GR  30.8     512    26.7     515    25.6     523    25.3     605    27.5     607
GR  31.1     610    29.1     650    28.9     850    28.4     900    28.2     950
GR  28.3     965    26.9     975    23.5     990    20.1     995    18.6    1000
GR  14.6    1075    16.0    1100    20.0    1115    23.6    1120    26.7    1128
GR  21.7    1132    29.3    1136    27.4    1165    26.2    1178    26.2    1200
GR  27.2    1250    34.9    1500
X1    14      18    25.0   200.0   236.0   236.0   236.0
GR 36.30       0    32.3       3    31.5       7    27.3      18    24.7      25
GR  16.2      50    16.8      65    17.5      85    17.1     100    18.8     125
GR  18.3     150    23.6     175    24.7     200    21.2     225    25.2     235
GR  28.5     250    32.4     260   36.78     263
X1    15      47  1520.0  3000.0  1102.0  1102.0  1102.0
GR  40.3    1300    39.1    1320    30.8    1335    30.0    1350    32.4    1375
GR  32.3    1420    29.3    1440    28.8    1475    27.6    1507    31.0    1520
GR  30.8    1527    29.1    1535    28.5    1550    29.1    1700    28.4    1750
GR  28.6    1800    27.8    2100    26.5    2150    27.4    2200    27.6    2350
GR  28.8    2362    29.6    2400    27.4    2450    26.2    2475    22.3    2500
GR  12.3    2525    13.0    2550    13.9    2575    17.8    2600    21.5    2615
GR  25.7    2625    28.4    2645    27.9    2690    27.3    2705    26.0    2750
GR 29.08    3000    28.3    3050    28.1    3100    27.4    3150    28.1    3170
GR  32.3    3180    32.5    3195    29.4    3210    36.1    3525    38.1    3555
GR  40.6    3600    41.7    3650
X1    16      56  1500.0  1950.0   984.0  1378.0  1180.0
GR  40.5     530    38.0     550    37.8     600    38.9     650    39.0     700
GR  37.8     750    36.5     790    39.1     795    39.0     807    36.7     815
GR  35.6     825    37.5     830    37.4     850    37.8     900    36.1     950
GR  34.8     970    30.5     980    30.3    1000    28.7    1050    27.7    1200
GR  28.4    1250    30.5    1260    30.2    1300    31.3    1400    31.0    1450
GR  31.4    1500    31.2    1583    29.2    1585    26.9    1595    18.7    1600
GR   4.2    1625    -1.8    1650    -2.4    1675    -5.0    1700     4.8    1725
GR  13.1    1750     6.3    1775    10.6    1800    17.2    1825    26.9    1835
GR  28.8    1840    30.6    1845    31.1    1850    33.6    1900    41.0    1950
GR  41.3    2870    38.5    2900    36.6    2915    29.6    2940    27.8    2960
GR  21.7    3000    20.0    3050    13.8    3080    26.4    3095    28.4    3115
GR  42.5    3143
X1    17      30   500.0   800.0  1181.0   197.0   590.0
GR  41.9     362    36.4     380    35.5     400    32.7     450    30.4     500
GR  29.6     525    27.2     528    25.1     530    21.1     545    20.3     550
GR  15.7     575    15.3     600    12.1     625    14.3     650    15.2     675
GR  17.7     700    25.4     725    30.7     740    29.1     750    31.2     800
GR  31.7     810    35.0     825    38.0     835    38.1    1000    38.5    1050
GR  39.7    1100    39.8    1133    38.5    1147    39.8    1159    40.3    1200
X1   100      23     270     490    1050    1150    1100
GR    35       0      34      25      33      55      32      85      31     130
GR    30     145      29     170      28     270      25     280      22     290
GR    20     300      17     330    15.5     370      17     425    21.0     450
GR    24     490   24.75     520      25     550      26    1000      27    1150
```

```
GR      28    1180      33    1190    37.5    1200
X1     105      25     430     750    2200    2300    2200
GR      33       0      32      50      31      90      30     110      29     125
GR      28     210    27.9     430      25     470      22     485      20     500
GR      18     510      17     540      16     570      17     600      18     620
GR      20     650      23     670      25     680      27     705      28     750
GR      29    1050      30    1150      31    1225      32    1305      33    1365
X1     110      26    1000    1300    3400    2000    3400
GR      35       0      34      25      33      40      32      55      31      72
GR      30      90      29     110    28.5     150      28     500    27.8    1000
GR      25    1020    22.5    1035      20    1050      18    1100    17.5    1170
GR      18    1220      20    1235    22.5    1255      26    1270      27    1290
GR    27.5    1300      29    2350      30    2500      32    2600      34    2700
GR      36    2800
X1     115      26    1460    1630    1900    2600    3800
GR      35       0      34      20      33      60      32     100      31     110
GR      30     115      29     125      28    1460      27    1475    22.5    1495
GR      20    1500      18    1510      17    1515      16    1535      17    1565
GR      20    1580      25    1600      27    1615      28    1630      29    1840
GR      30    3190      31    3240      32    3340      33    3415      34    3480
GR      35    3540
X1     120      22     260     550    4000    4000    6400
GR      35       0      34      40      33     120      32     180      31     210
GR      30     230      29     260      27     320      20     340      18     350
GR    16.5     375    17.5     410      19     430      21     440      27     460
GR      28     475      29     550      30     575      31     600      30     700
GR      30    1020      35    1030
X1     125      19     650     800    6600    5500    7200
GR      35       0      34      10      33      30      32     160      31     380
GR      30     610      29     650      28     655      25     675    22.5     690
GR      21     700      20     730    22.5     780      30     800      31     805
GR      32     820      33     920      34     980      35    1050
X1     130      18     220     400    2800    2800    4600
GR      35       0      34      35      33      60      32     110      31     203
GR      30     220    27.5     240      25     250      20     270      17     300
GR    17.7     330      28     380      30     400      31     690      32     740
GR      33     795      34     840      35     860
X1     135      23     140     320    3300    3400    5200
GR      37       0      36      37      35      90      34     105      33     110
GR      32     120      31     130      30     140    27.5     150      20     170
GR    17.5     180    16.5     200    17.5     230    20.5     250      27     280
GR      29     295      30     320      31    1115      32    1312      33    1600
GR      34    1775      35    1920      37    1970
X1     140      21     240     400    4300    3400    5600
GR      40       0      39      30      38      65      37      90      36     120
GR      35     190      34     220      31     240      29     255      18     295
GR      16     310    15.5     325    16.5     350      31     400      32     540
GR      33     780      34    1365      35    1410      36    1435      37    1470
GR      40    1640
X1     145      17     110     240    5200    4200    5200
GR      40       0      39      85      35      95      31     110      25     125
GR    20.5     140    19.5     150      21     170      27     200      28     205
```

```
GR    30     225      31     240      32     260      33     280      34     305
GR    35     325      40     530
X1   150      19      60     250    6000    4900    6000
GR    40       0      35      40      30      60      24      75      20      90
GR  18.5      95      17     110    18.5     130      22     150    27.5     185
GR    29     200      31     250      32     920      33    1170      34    1225
GR    35    1265      36    1330      37    1410      38    1515
X1   155      20     290     460    4000    4000    4500
GR    40       0      39      80      38     100      37     130      36     185
GR    35     210      34     230      33     270      32     290      25     330
GR  19.2     358    19.5     392      20     400      32     460      33     525
GR    34     530      35     540      36     550      37     560      38     650
NC  .050    .050    .040      .1      .3
X1   -12      52  1220.0  1470.0       0       0       0
X2   940
GR  36.4      20    35.2      30    35.6      50    35.4      70    37.6      80
GR  37.5     100    35.3     150    35.6     200    34.8     250    33.3     300
GR  32.2     400    31.9     450    33.9     480    30.3     550    29.3     600
GR  27.4     605    25.3     615    26.8     625    27.8     630    27.8     675
GR  29.9     685    30.2     700    31.6     750    33.3     800    34.0     850
GR  33.2     900    33.1     950    31.8    1000    31.4    1050    30.8    1100
GR  29.6    1150    28.6    1175    26.5    1185    25.8    1190    25.9    1202
GR  27.3    1206    28.0    1220    25.1    1255    22.6    1260    22.7    1275
GR  17.7    1300    10.0    1325     5.5    1350     4.5    1375     4.5    1400
GR   9.0    1425    20.0    1450    24.7    1460    29.1    1470   33.68    1535
GR 37.20    1540    40.2    1550
X1   200      30     350     585    1600    1600    1600
X5    -5     .05     .05     .05     .05     .05
GR  33.2       0    33.2      50    33.7     100    33.7     150    33.5     200
GR  33.4     250    33.1     290    31.2     297    27.3     299    27.0     300
GR  15.4     325    14.6     350    26.8     375    24.1     400    25.6     425
GR  25.1     450    26.7     480    27.4     500    26.5     515    26.2     525
GR  26.5     535    28.6     550    28.9     585    26.9     590    26.9     600
GR  28.4     610    28.8     645    27.0     665    27.0     685   29.83     700
X1   205      13       0     154    3600    3600    3600
GR  28.6       0    27.6       1    26.9       7    25.9      14    22.2      34
GR  19.4      45    18.6      60    17.8      75    19.7      91    22.7     105
GR  25.0     115    26.4     121    28.6     154
X1   210      13       0     154      40      40      40
GR  28.6       0    27.6       1    26.9       7    25.9      14    22.2      34
GR  19.4      45    18.6      60    17.8      75    19.7      91    22.7     105
GR  25.0     115    26.4     121    28.6     154
X1   215      10       0     188    2600    2600    2600
GR  28.8       0    27.8       1    24.6      25    19.8      51    17.9      85
GR  24.2     113    25.3     148    26.2     177    27.6     186    28.8     188
X1   220      11       0     199    5600    5600    5600
GR  29.3       0    27.7       1    26.3      52    23.8      81    22.2     105
GR  23.4     141    24.9     167    25.8     172    27.3     186    28.4     195
GR  29.3     199
X1   225      10       0     200    2800    2800    2800
GR 29.58       0    27.3       1    23.0      12    24.8      32    25.4      52
GR  25.5      92    25.6     120    26.6     150    26.9     194   29.58     200
```

```
X1   230      9       0      169    3550    3550    3550
GR  30.1      0     27.3      23    23.3      47    23.3      77    24.3      95
GR  26.4    117     26.0     141    27.8     157    30.1     169
X1   235     11       0      223    3400    3400    3400
GR 30.53      0     28.6       1    26.5      23    22.8      49    24.1      77
GR  25.4    102     26.3     134    26.4     166    27.2     185    29.6     217
GR 30.53    223
X1   240      9       0      216    4100    4100    4400
GR  30.9      0     30.1       3    27.5      20    25.5      52    25.2      88
GR  26.5    124     27.2     158    26.7     186    30.9     216
X1   245     10       0      216    3500    3500    3500
GR 31.29      0     29.3      20    27.6      38    24.4      66    23.4      93
GR  22.2    120     23.0     151    25.6     188    27.1     196   31.29     216
EJ
T1  LAKE ROUSSEAU DRAWDOWN ANALYSIS
T2  DATE AUGUST 12 1987 RUN WITH TRAMCROSSING
T3   LAKE ROUSSEAU STARTING POOL OF 21.80 FEET
J1   -10       5                                                   21.80
J2     2
T1  LAKE ROUSSEAU DRAWDOWN ANALYSIS
T2  DATE AUGUST 12 1987 RUN WITH TRAMCROSSING
T3   LAKE ROUSSEAU STARTING POOL OF 18.00 FEET
J1   -10       5                                                   18.00
J2    15


ER
```

APPENDIX G

INPUT DATA FOR THE U. S. WEATHER BUREAU'S DYNAMIC WAVE AND OPERATIONAL (DWOPER) MODEL FOR SIMULATING THE 1985 HURRICANE ELENA FLOODWAVE PASSAGE AT DUNNELLON

G - 1

CALIBRATED INPUT DATA FOR THE HURRICANE ELENA FLOODWAVE PASSAGE AT DUNNELLON

```
    1   40   70    2    1   61   40    4    8    1    1    1    1
ALONE
       0.05         5        5.       0.8      0.55       1.0      24.0
          1        61         1         2         0        10         4
          8                                        1         1         0
          1
          0
          0
          0
         40
          2
          1
         40         2
          1         2         3         4         5         6         7         8
          9        10        11        12        13        14        15        16
         17        18        19        20        21        22        23        24
         25        26        27        28        29        30        31        32
         33        34        35        36        37        38        39        40
          1        21
      27.52       0.0
   HOLDER
       1.16      1.17      1.28      1.34      1.31      1.26      1.42      1.68
       1.96      2.18      2.33      2.85      2.78      2.92      2.93      2.84
       2.78      2.74      2.71      2.73      2.81      2.88      3.07      3.31
       3.62      3.87      4.00      4.14      4.26      4.43      5.02      5.89
       6.44      6.46      6.45      6.45      6.48      6.56      6.67      6.81
       6.98      7.19      7.42      7.60      7.69      7.75      7.79      7.82
       7.86      7.91      8.01      8.08      8.33      8.31      8.25      8.22
       8.33      8.17      8.04      7.91      7.80
    DUNNELLON
      27.98     28.08     28.08     28.08     28.03     28.00     27.96     27.98
      28.30     28.80     28.40     28.39     28.40     28.42     28.46     28.42
      28.38     28.34     28.26     28.24     28.22     28.20     28.28     28.40
      28.50     28.60     28.62     28.58     28.56     28.62     28.86     28.98
      29.08     28.70     28.40     28.32     28.46     28.74     28.90     28.94
      28.96     29.02     29.10     29.28     29.26     29.10     29.00     29.00
      28.96     28.96     29.02     29.04     29.08     29.10     29.12     29.06
      29.12     29.20     29.08     28.88     28.80
       338.      340.      371.      384.      376.      362.      406.      481.
       563.      628.      670.      823.      802.      844.      849.      821.
       804.      787.      779.      785.      808.      829.      887.      960.
      1050.     1120.     1160.     1200.     1240.     1290.     1510.     1850.
      2070.     2080.     2080.     2080.     2090.     2120.     2160.     2230.
      2310.     2420.     2530.     2630.     2670.     2700.     2720.     2730.
      2760.     2790.     2840.     2880.     3030.     3020.     2980.     2960.
      3040.     2940.     2860.     2790.     2730.
      27.76     27.80     27.84     27.79     27.69     27.63     27.60     27.59
      27.76     27.75     27.70     27.71     27.72     27.77     27.82     27.77
      27.74     27.69     27.64     27.58     27.56     27.54     27.54     27.65
      27.73     27.76     27.74     27.68     27.63     27.57     27.46     26.94
      26.27     25.95     25.90     26.14     26.73     27.09     27.15     27.80
      27.02     27.01     27.06     26.97     26.56     26.34     26.33     26.26
```

```
 26.23    26.22    26.28    26.17    26.10    26.05    26.02    26.02
 26.26    26.17    25.74    25.74    25.74
   0.
  100.     170.     250.     300.     350.     420.     650.    1080.
  105.     190.     850.    1120.    1190.    1270.    1480.    1870.
   70.      90.     130.     180.     220.     310.     400.     520.
   80.     120.     150.     500.    1140.    1230.    1350.    1630.
  115.     180.    1000.    1150.    1380.    1620.    1800.    1970.
  120.     190.     480.     580.     700.     800.     860.     950.
  120.     150.     180.     600.     850.     980.    1050.    1200.
  120.     145.     310.     800.     850.     980.    1030.    1100.
  120.     180.    1700.    3050.    3120.    3200.    3300.    3570.
  220.     270.     300.     470.    1850.    2210.    2380.    2740.
  170.     240.     310.     580.     930.    1020.    1290.    1720.
  170.     230.     700.     880.     900.    1000.    1050.    1180.
  150.     160.     180.     200.     210.     230.     330.     410.
  200.     220.     230.     235.     260.     680.     890.     950.
  100.     170.     360.    1530.    1740.    1980.    2100.    2200.
  110.     150.     200.     220.     225.     230.     240.     250.
  130.     150.     240.     370.     800.     880.     980.    1160.
  135.     170.     200.     259.     480.    1100.    1190.    1260.
  230.     260.     275.     280.     295.     300.     430.     700.
  140.     170.     200.     220.     280.     490.     900.    1300.
   90.     115.     140.     190.     220.     250.     315.     710.
  179.     180.     190.     210.     300.     390.     395.     415.
  130.     170.     200.     520.     910.     930.     950.    1000.
  100.     112.     130.     140.     170.     180.     195.     210.
  100.     112.     130.     140.     170.     180.     195.     210.
  130.     170.     200.     520.     910.     930.     950.    1000.
   75.      80.     250.    1000.    1850.    2050.    2250.    2300.
  140.     170.     550.     560.    1200.    1250.    1400.    1500.
  125.     150.     465.     710.     870.     890.    1600.    1720.
  125.     150.     530.    1130.    1960.    2000.    2220.    2250.
  180.     250.     600.    1900.    1970.    2030.    2090.    2140.
  160.     200.     415.    1120.    2350.    2570.    2750.    2910.
  300.     400.    1250.    2370.    2400.    2530.    2580.    2780.
  140.     170.     850.    1500.    2290.    3030.    3470.    3660.
  189.     220.    1150.    2450.    3500.    3820.    3930.    4100.
  700.    1080.    2070.    2770.    3940.    4000.    4150.    4230.
  125.     150.    1310.    2490.    2635.    2740.    2870.    2980.
  225.     260.     310.     930.    1780.    2370.    2450.    2550.
  149.     165.     300.     650.    2640.    2760.    2930.    3050.
  150.     185.    1600.    2450.    3300.    4950.    5050.    5200.
  26.0     32.0     32.8     33.8     35.6     37.0     39.0     41.4
  26.6     30.8     31.9     32.9     34.2     35.6     37.8     41.5
  25.4     28.4     31.2     32.9     34.6     37.0     38.8     39.8
  22.0     26.0     31.0     32.9     34.0     35.2     36.6     39.8
  25.0     30.0     31.0     31.8     32.7     33.8     34.9     37.0
  26.0     30.0     30.9     31.7     32.6     33.8     35.3     37.4
  24.9     29.9     31.8     32.6     34.2     36.9     37.0     38.0
  23.0     27.2     29.5     30.6     32.2     33.0     34.9     37.0
  23.0     28.0     28.8     29.9     31.0     32.0     32.8     35.0
```

```
   23.0     27.0     27.5     27.8     28.5     29.0     29.9     35.0
   22.0     26.0     27.9     28.1     29.0     30.0     32.4     36.0
   22.0     24.7     25.9     27.2     28.0     28.9     30.6     35.0
   19.6     21.5     23.4     26.4     29.0     29.6     31.4     34.9
   14.0     18.0     22.0     24.0     27.8     31.2     32.6     35.2
   20.0     26.6     27.5     29.0     29.4     32.1     34.1     36.2
   20.0     22.7     25.0     26.8     28.3     29.8     31.8     34.0
   20.2     26.7     27.3     27.7     29.0     30.6     32.0     34.9
   18.0     22.0     24.0     28.0     31.2     32.1     33.2     34.0
   16.4     20.0     22.0     24.0     26.0     28.0     32.4     36.0
   18.0     22.0     26.0     28.0     31.0     32.0     34.0     36.0
   18.0     21.1     24.0     28.0     30.0     32.0     34.0     36.0
   18.0     22.0     25.0     28.2     29.5     30.8     32.9     36.0
   18.0     24.6     26.7     28.2     29.9     32.0     32.5     36.0
   21.0     24.0     26.5     29.0     29.7     32.0     34.0     36.0
   21.0     24.0     26.5     29.0     29.7     32.0     34.0     36.0
   18.0     24.6     26.7     28.2     29.9     32.0     32.5     36.0
   17.8     19.7     24.9     26.4     27.5     29.4     31.0     36.0
   19.5     24.1     25.7     26.7     27.6     30.4     31.6     35.0
   18.0     24.1     26.6     27.5     28.5     30.0     31.8     34.7
   17.8     21.7     22.9     25.4     26.4     29.9     32.9     34.0
   17.5     23.5     24.6     26.1     28.2     30.4     32.4     34.3
   16.2     19.4     23.0     24.0     25.0     27.8     30.5     32.4
   17.0     20.6     22.9     24.4     25.6     29.2     30.8     32.0
   13.4     18.4     19.2     20.8     22.8     26.2     28.1     30.1
   15.3     18.6     19.5     21.7     23.4     25.8     28.8     30.9
   10.9     16.5     18.2     19.4     21.6     23.9     29.0     31.5
   11.4     17.5     19.6     22.1     24.1     26.2     28.4     30.0
   12.0     15.0     16.6     18.6     21.2     23.2     26.2     29.2
   10.0     15.3     16.6     17.2     18.2     21.4     25.7     28.8
   10.0     13.8     18.0     20.2     22.4     22.8     28.0     29.0
   475.     663.     275.     375.     625.     700.     400.     575.
   575.     975.     700      750.     650.    1975.     550.     250.
   450.    1275.    1125.     650.     450.    1025.    1225.     846.
   846.    1225.     475.     825.     775.     560.     850.    1025.
  3125.    1000.    1125.    3025.     825.    1175.     575.    1000.
    0.0      0.0      0.0
     0.    4500.   10500.   15700.   21300.   26500.   31100.   38300.
 44700.   48500.   51900.   54100.   55200.   55790.   56970.   58072.
 58308.   59882.   61063.   61653.   62125.   63109.   65292.   65392.
 65692.   65792.   67292.   68709.   702841   71780.   74733.   76308.
 81032.   86465.   90008.   97488.  103000.  104965.  111815.  115909.
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   17
   631.     633.     635.     636.     636.     636.     636.     637.
   641.     646.     648.     653.     661.     666.     673.     678.
   683.     687.     690.     694.     697.     700.     703.     708.
   711.     715.     720.     724.     726.     728.     739.     749.
```

```
    764.      778.      790.      802.      815.      830.      847.      860.
    870.      879.      890.      899.      903.      908.      909.      910.
    911.      911.      913.      914.      915.      915.      914.      914.
    913.      913.      909.      904.      902.
 1464.00     12.00         2
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0      27.5
    350.      350.      350.      350.      350.      350.      350.      350.
    350.      350.      350.      350.      350.      350.      350.      350.
    350.     1250.     1250.     1250.     1250.     1250.     1250.     1250.
   1250.     1250.     1250.     1250.     1250.     1250.     1250.     1250.
   1250.     1250.     1250.     1250.     1250.     1250.     1250.     1250.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
     18.       25.       30.       40.
```

```
       18.       25.       30.       40.
       18.       25.       30.       40.
       18.       25.       30.       40.
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .045      .045      .040      .030
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
      .022      .022      .018      .018
LAKE ROUSSEAU ANALYSIS
END
EXIT
```

G - 2

INPUT DATA FOR THE HURRICANE ELENA FLOODWAVE PASSAGE AT DUNNELLON WITH LAKE ROUSSEAU HAVING A SIMULATED DRAWDOWN OF 18.00 FEET PRIOR TO ITS ARRIVAL

```
   1   40   70    2    1   61   40    4    8    1    1    1    1
ALONE
     0.05         5          5.        0.8       0.55        1.0       24.0
        1        61           1          2          0         10          4
        8                                           1          1          0
        1
        0
        0
        0
       40
        2
        1
       40         2
        1         2           3          4          5          6          7          8
        9        10          11         12         13         14         15         16
       17        18          19         20         21         22         23         24
       25        26          27         28         29         30         31         32
       33        34          35         36         37         38         39         40
        1        21
    27.52       0.0
   HOLDER
     1.16      1.17        1.28       1.34       1.31       1.26       1.42       1.68
     1.96      2.18        2.33       2.85       2.78       2.92       2.93       2.84
     2.78      2.74        2.71       2.73       2.81       2.88       3.07       3.31
     3.62      3.87        4.00       4.14       4.26       4.43       5.02       5.89
     6.44      6.46        6.45       6.45       6.48       6.56       6.67       6.81
     6.98      7.19        7.42       7.60       7.69       7.75       7.79       7.82
     7.86      7.91        8.01       8.08       8.33       8.31       8.25       8.22
     8.33      8.17        8.04       7.91       7.80
   DUNNELLON
    27.98     28.08       28.08      28.08      28.03      28.00      27.96      27.98
    28.30     28.80       28.40      28.39      28.40      28.42      28.46      28.42
    28.38     28.34       28.26      28.24      28.22      28.20      28.28      28.40
    28.50     28.60       28.62      28.58      28.56      28.62      28.86      28.98
    29.08     28.70       28.40      28.32      28.46      28.74      28.90      28.94
    28.96     29.02       29.10      29.28      29.26      29.10      29.00      29.00
    28.96     28.96       29.02      29.04      29.08      29.10      29.12      29.06
    29.12     29.20       29.08      28.88      28.80
     338.      340.        371.       384.       376.       362.       406.       481.
     563.      628.        670.       823.       802.       844.       849.       821.
     804.      787.        779.       785.       808.       829.       887.       960.
    1050.     1120.       1160.      1200.      1240.      1290.      1510.      1850.
    2070.     2080.       2080.      2080.      2090.      2120.      2160.      2230.
    2310.     2420.       2530.      2630.      2670.      2700.      2720.      2730.
    2760.     2790.       2840.      2880.      3030.      3020.      2980.      2960.
    3040.     2940.       2860.      2790.      2730.
    27.76     27.25       26.75      26.25      25.75      25.25      24.75      24.25
    23.75     23.25       22.75      22.25      21.75      21.25      20.75      20.25
    19.75     19.25       18.75      18.25      18.00      18.00      18.00      18.00
    18.00     18.00       18.00      18.00      18.00      18.00      18.00      18.00
    18.00     18.00       18.00      18.00      18.00      18.00      18.00      18.00
    18.00     18.00       18.00      18.00      18.00      18.00      18.00      18.00
```

```
 18.00    18.00    18.00    18.00    18.00    18.00    18.00    18.00
 18.00    18.00    18.00    18.00    18.00
   0.
  100.     170.     250.     300.     350.     420.     650.    1080.
  105.     190.     850.    1120.    1190.    1270.    1480.    1870.
   70.      90.     130.     180.     220.     310.     400.     520.
   80.     120.     150.     500.    1140.    1230.    1350.    1630.
  115.     180.    1000.    1150.    1380.    1620.    1800.    1970.
  120.     190.     480.     580.     700.     800.     860.     950.
  120.     150.     180.     600.     850.     980.    1050.    1200.
  120.     145.     310.     800.     850.     980.    1030.    1100.
  120.     180.    1700.    3050.    3120.    3200.    3300.    3570.
  220.     270.     300.     470.    1850.    2210.    2380.    2740.
  170.     240.     310.     580.     930.    1020.    1290.    1720.
  170.     230.     700.     880.     900.    1000.    1050.    1180.
  150.     160.     180.     200.     210.     230.     330.     410.
  200.     220.     230.     235.     260.     680.     890.     950.
  100.     170.     360.    1530.    1740.    1980.    2100.    2200.
  110.     150.     200.     220.     225.     230.     240..    250.
  130.     150.     240.     370.     800.     880.     980.    1160.
  135.     170.     200.     259.     480.    1100.    1190.    1260.
  230.     260.     275.     280.     295.     300.     430.     700.
  140.     170.     200.     220.     280.     490.     900.    1300.
   90.     115.     140.     190.     220.     250.     315.     710.
  179.     180.     190.     210.     300.     390.     395.     415.
  130.     170.     200.     520.     910.     930.     950.    1000.
  100.     112.     130.     140.     170.     180.     195.     210.
  100.     112.     130.     140.     170.     180.     195.     210.
  130.     170.     200.     520.     910.     930.     950.    1000.
   75.      80.     250.    1000.    1850.    2050.    2250.    2300.
  140.     170.     550.     560.    1200.    1250.    1400.    1500.
  125.     150.     465.     710.     870.     890.    1600.    1720.
  125.     150.     530.    1130.    1960.    2000.    2220.    2250.
  180.     250.     600.    1900.    1970.    2030.    2090.    2140.
  160.     200.     415.    1120.    2350.    2570.    2750.    2910.
  300.     400.    1250.    2370.    2400.    2530.    2580.    2780.
  140.     170.     850.    1500.    2290.    3030.    3470.    3660.
  189.     220.    1150.    2450.    3500.    3820.    3930.    4100.
  700.    1080.    2070.    2770.    3940.    4000.    4150.    4230.
  125.     150.    1310.    2490.    2635.    2740.    2870.    2980.
  225.     260.     310.     930.    1780.    2370.    2450.    2550.
  149.     165.     300.     650.    2640.    2760.    2930.    3050.
  150.     185.    1600.    2450.    3300.    4950.    5050.    5200.
  26.0     32.0     32.8     33.8     35.6     37.0     39.0     41.4
  26.6     30.8     31.9     32.9     34.2     35.6     37.8     41.5
  25.4     28.4     31.2     32.9     34.6     37.0     38.8     39.8
  22.0     26.0     31.0     32.9     34.0     35.2     36.6     39.8
  25.0     30.0     31.0     31.8     32.7     33.8     34.9     37.0
  26.0     30.0     30.9     31.7     32.6     33.8     35.3     37.4
  24.9     29.9     31.8     32.6     34.2     36.9     37.0     38.0
  23.0     27.2     29.5     30.6     32.2     33.0     34.9     37.0
  23.0     28.0     28.8     29.9     31.0     32.0     32.8     35.0
```

```
     23.0      27.0      27.5      27.8      28.5      29.0      29.9      35.0
     22.0      26.0      27.9      28.1      29.0      30.0      32.4      36.0
     22.0      24.7      25.9      27.2      28.0      28.9      30.6      35.0
     19.6      21.5      23.4      26.4      29.0      29.6      31.4      34.9
     14.0      18.0      22.0      24.0      27.8      31.2      32.6      35.2
     20.0      26.6      27.5      29.0      29.4      32.1      34.1      36.2
     20.0      22.7      25.0      26.8      28.3      29.8      31.8      34.0
     20.2      26.7      27.3      27.7      29.0      30.6      32.0      34.9
     18.0      22.0      24.0      28.0      31.2      32.1      33.2      34.0
     16.4      20.0      22.0      24.0      26.0      28.0      32.4      36.0
     18.0      22.0      26.0      28.0      31.0      32.0      34.0      36.0
     18.0      21.1      24.0      28.0      30.0      32.0      34.0      36.0
     18.0      22.0      25.0      28.2      29.5      30.8      32.9      36.0
     18.0      24.6      26.7      28.2      29.9      32.0      32.5      36.0
     21.0      24.0      26.5      29.0      29.7      32.0      34.0      36.0
     21.0      24.0      26.5      29.0      29.7      32.0      34.0      36.0
     18.0      24.6      26.7      28.2      29.9      32.0      32.5      36.0
     17.8      19.7      24.9      26.4      27.5      29.4      31.0      36.0
     19.5      24.1      25.7      26.7      27.6      30.4      31.6      35.0
     18.0      24.1      26.6      27.5      28.5      30.0      31.8      34.7
     17.8      21.7      22.9      25.4      26.4      29.9      32.9      34.0
     17.5      23.5      24.6      26.1      28.2      30.4      32.4      34.3
     16.2    . 19.4      23.0      24.0      25.0      27.8      30.5      32.4
     17.0      20.6      22.9      24.4      25.6      29.2      30.8      32.0
     13.4      18.4      19.2      20.8      22.8      26.2      28.1      30.1
     15.3      18.6      19.5      21.7      23.4      25.8      28.8      30.9
     10.9      16.5      18.2      19.4      21.6      23.9      29.0      31.5
     11.4      17.5      19.6      22.1      24.1      26.2      28.4      30.0
     12.0      15.0      16.6      18.6      21.2      23.2      26.2      29.2
     10.0      15.3      16.6      17.2      18.2      21.4      25.7      28.8
     10.0      13.8      18.0      20.2      22.4      22.8      28.0      29.0
     475.      663.      275.      375.      625.      700.      400.      575.
     575.      975.      700       750.      650.     1975.      550.      250.
     450.     1275.     1125.      650.      450.     1025.     1225.      846.
     846.     1225.      475.      825.      775.      560.      850.     1025.
    3125.     1000.     1125.     3025.      825.     1175.      575.     1000.
      0.0       0.0       0.0
       0.     4500.    10500.    15700.    21300.    26500.    31100.    38300.
   44700.    48500.    51900.    54100.    55200.    55790.    56970.    58072.
   58308.    59882.    61063.    61653.    62125.    63109.    65292.    65392.
   65692.    65792.    67292.    68709.    702841    71780.    74733.    76308.
   81032.    86465.    90008.    97488.   103000.   104965.   111815.   115909.
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      17
     631.      633.      635.      636.      636.      636.      636.      637.
     641.      646.      648.      653.      661.      666.      673.      678.
     683.      687.      690.      694.      697.      700.      703.      708.
     711.      715.      720.      724.      726.      728.      739.      749.
```

```
     764.      778.      790.      802.      815.      830.      847.      860.
     870.      879.      890.      899.      903.      908.      909.      910.
     911.      911.      913.      914.      915.      915.      914.      914.
     913.      913.      909.      904.      902.
  1464.00     12.00         2
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0      27.5
     350.      350.      350.      350.      350.      350.      350.      350.
     350.      350.      350.      350.      350.      350.      350.      350.
     350.     1250.     1250.     1250.     1250.     1250.     1250.     1250.
    1250.     1250.     1250.     1250.     1250.     1250.     1250.     1250.
    1250.     1250.     1250.     1250.     1250.     1250.     1250.     1250.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
      18.       25.       30.       40.
```

```
     18.      25.      30.      40.
     18.      25.      30.      40.
     18.      25.      30.      40.
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .045     .045     .040     .030
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
    .022     .022     .018     .018
LAKE ROUSSEAU ANALYSIS LAKE LOWERED TO 18 FEET NGVD
END
EXIT
```

APPENDIX H

INPUT DATA FOR STIMULATING THE
GROUND-WATER RESPONSE TO
A DRAWDOWN USING THE USGS MODFLOW MODEL

H - 1

MODFLOW BASIC INPUT DATA FOR STIMULATING GROUND-WATER RESPONSE FOR A NORMAL LAKE LEVEL OF 27.5 FEET

```
LAKE ROUSSEAU DRAWDOWN ANALYSIS OF GROUNDWATER SYSTEM
 SURROUNDING AQUIFER ANALYSIS FOR A NORMAL LAKE LEVEL OF 27.5 FEET
         1        40        30         1         4
 11 00 00 00 00 00 00 00 12 00 00 15
         0         1
         1         1 (T6,30I2)                  -2
  1  -2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2 0 0 0 0 0
  2  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2-2 0 0 0
  3  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2-2 0
  4  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
  5  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
  6  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
  7  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
  8  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
  9  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 10  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2 2 2 2 2 2 2 2 2 2-2
 11  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2-2 2 2 2 2 2 2 2 2 2-2
 12  -2 2 2 2 2 2 2 2-2-2-2 2 2 2 2 2 2 2-2-2-2 2 2 2 2 2 2 2 2-2
 13  -2 2 2 2 2 2 2 2-2-2-2 2 2 2 2 2 2-2-2-2-2 2 2 2 2 2 2 2 2-2
 14  -2 2 2 2 2 2 2 2-2-2-2 2 2-2-2 2 2-2-2-2-2 2 2 2 2 2 2 2 2-2
 15  -2 2 2 2 2 2 2 2-2-2-2-2 2-2-2-2 2-2-2-2-2-2 2 2 2 2 2 2 2-2
 16  -2 2 2 2 2 2 2 2-2-2-2-2 2-2-2-2 2-2-2-2-2-2 2 2 2 2 2 2 2-2
 17  -2 2 2 2 2 2 2 2-2-2-2-2 2-2-2-2-2-2-2-2-2-2 2 2 2 2 2 2 2-2
 18  -2 2 2 2 2 2 2-2-2-2-2-2 2-2 2-2-2-2-2-2-2-2-2 2 2 2 2 2 2-2
 19  -2 2 2 2 2 2 2-2-2 2-2-2-2-2 2-2-2-2 2 2-2-2-2 2 2-2-2-2 2-2
 20  -2 2 2 2 2 2 2-2-2 2-2-2-2-2 2-2-2-2 2 2 2-2-2-2-2-2-2-2 2-2
 21  -2 2 2 2 2 2 2-2 2 2-2-2-2-2 2-2-2-2 2 2 2-2-2-2-2-2-2-2 2-2
 22  -2 2 2 2 2 2 2-2 2 2-2-2-2 2 2 2 2 2 2 2 2-2-2-2-2-2-2-2 2-2
 23  -2 2 2 2 2 2 2-2 2 2 2-2-2 2 2 2 2 2 2 2 2-2-2-2-2-2 2 2 2-2
 24  -2 2 2 2 2-2-2-2 2 2 2-2-2 2 2 2 2 2 2 2 2 2-2-2-2 2 2 2 2-2
 25  -2 2 2 2 2-2-2-2 2 2 2-2-2 2 2 2 2 2 2 2 2 2-2-2 2 2 2 2 2-2
 26  -2 2 2 2 2-2-2-2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 27  -2 2 2 2 2-2-2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 28  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 29  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 30  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 31  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 32  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 33  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 34  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 35  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 36  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 37  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 38  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 39  -2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2-2
 40  -2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2
      99.9
         1         1.  (15F5.2)                  -9
 13.0 14.8 16.5 18.3 20.0 21.1 22.2 23.3 24.4 25.6 26.7 27.8 28.9 30.0 32.5
 35.0 37.5 40.0 40.3 40.7 41.0 41.3 42.0 42.0 41.2  0.0  0.0  0.0  0.0  0.0
 12.7 14.0 16.0 18.0 19.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 29.0 32.0
 34.0 36.0 39.0 39.0 39.0 40.0 41.0 41.0 41.0 41.0 41.3 41.0  0.0  0.0  0.0
```

MICROFILMED

```
12.3 14.0 16.0 17.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 29.0 31.0
33.0 35.0 38.0 38.0 38.0 40.0 40.0 41.0 41.0 41.0 40.0 41.0 40.7 40.3 40.0
12.0 13.0 15.0 17.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 30.0
32.0 34.0 37.0 37.0 37.0 39.0 40.0 40.0 40.0 40.0 40.0 40.0 40.0 40.0 39.3
11.9 13.0 15.0 17.0 18.0 20.0 21.0 21.0 22.0 23.0 24.0 25.0 26.0 28.0 30.0
31.0 33.0 36.0 36.0 36.0 39.0 39.0 40.0 40.0 40.0 39.0 40.0 40.0 39.0 38.7
11.8 13.0 15.0 16.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 29.0
30.0 32.0 35.0 35.0 35.0 38.0 39.0 39.0 39.0 39.0 38.0 39.0 39.0 39.0 38.5
11.7 13.0 15.0 16.0 18.0 19.0 20.0 20.0 21.0 22.0 23.0 24.0 25.0 27.0 29.0
29.0 31.0 34.0 34.0 34.0 38.0 38.0 39.0 39.0 39.0 37.0 39.0 39.0 38.0 37.8
11.6 12.0 14.0 16.0 17.0 19.0 20.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 28.0
29.0 29.0 33.0 33.0 33.0 37.0 38.0 38.0 38.0 38.0 36.0 38.0 38.0 38.0 37.4
11.5 12.0 14.0 15.0 17.0 18.0 19.0 19.0 20.0 21.0 22.0 23.0 24.0 26.0 28.0
28.0 28.0 32.0 32.0 32.0 37.0 37.0 38.0 38.0 38.0 35.0 38.0 37.0 37.0 37.0
11.5 12.0 14.0 15.0 17.0 18.0 19.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 27.0
28.0 27.0 31.0 31.0 27.5 36.0 36.0 37.0 37.0 37.0 35.0 37.0 36.0 36.0 36.5
11.4 12.0 14.0 15.0 16.0 18.0 18.0 18.0 19.0 20.0 21.0 22.0 23.0 25.0 27.0
27.0 26.0 30.0 27.5 27.5 36.0 35.0 36.0 37.0 36.0 34.0 36.0 36.0 36.0 36.1
11.3 11.0 13.0 14.0 16.0 17.0 18.0 18.0 27.5 27.5 27.5 22.0 23.0 24.0 26.0
27.0 26.0 29.0 27.5 27.5 27.5 34.0 35.0 36.0 35.0 34.0 36.0 35.0 35.0 35.7
11.2 11.0 13.0 14.0 16.0 17.0 17.0 17.0 27.5 27.5 27.5 21.0 22.0 24.0 26.0
26.0 25.0 27.5 27.5 27.5 27.5 33.0 34.0 36.0 34.0 33.0 35.0 35.0 35.0 35.2
11.1 11.0 13.0 14.0 15.0 17.0 17.0 17.0 27.5 27.5 27.5 21.0 22.0 27.5 27.5
26.0 25.0 27.5 27.5 27.5 27.5 32.0 33.0 35.0 33.0 33.0 34.0 34.0 34.0 34.8
11.0 11.0 13.0 13.0 15.0 16.0 16.0 16.0 27.5 27.5 27.5 27.5 21.0 27.5 27.5
27.5 24.0 27.5 27.5 27.5 27.5 27.5 32.0 34.0 32.0 32.0 33.0 34.0 34.0 34.3
10.9 10.0 12.0 13.0 15.0 16.0 16.0 16.0 27.5 27.5 27.5 27.5 21.0 27.5 27.5
27.5 24.0 27.5 27.5 27.5 27.5 27.5 31.0 33.0 31.0 32.0 32.0 33.0 33.0 33.9
10.9 10.0 12.0 13.0 14.0 16.0 15.0 15.0 27.5 27.5 27.5 27.5 20.0 27.5 27.5
27.5 27.5 27.5 27.5 27.5 27.5 27.5 30.0 32.0 34.0 31.0 31.0 32.0 32.0 33.5
10.8 10.0 12.0 12.0 14.0 15.0 15.0 27.5 27.5 27.5 27.5 27.5 27.5 27.5 23.0
27.5 27.5 27.5 27.5 27.5 27.5 27.5 27.5 31.0 34.0 31.0 30.0 32.0 32.0 33.0
10.7 10.0 12.0 12.0 14.0 15.0 14.0 27.5 27.5 16.0 27.5 27.5 27.5 27.5 23.0
27.5 27.5 27.5 22.0 22.0 27.5 27.5 27.5 30.0 33.0 27.5 27.5 27.5 31.0 32.6
10.6  9.0 11.0 12.0 13.0 15.0 14.0 27.5 27.5 16.0 27.5 27.5 27.5 27.5 22.0
27.5 27.5 27.5 21.0 21.0 29.0 27.5 27.5 27.5 27.5 27.5 27.5 27.5 31.0 32.2
10.5  9.0 11.0 11.0 13.0 14.0 14.0 27.5 14.0 15.0 27.5 27.5 27.5 27.5 22.0
27.5 27.5 27.5 20.0 20.0 28.0 27.5 27.5 27.5 27.5 27.5 27.5 27.5 30.0 31.7
10.4  9.0 11.0 11.0 13.0 14.0 13.0 27.5 14.0 15.0 27.5 27.5 27.5 19.0 21.0
22.0 21.0 19.0 19.0 19.0 28.0 27.5 27.5 27.5 27.5 27.5 27.5 27.5 30.0 31.3
10.3  9.0 11.0 11.0 12.0 14.0 13.0 27.5 13.0 14.0 15.0 27.5 27.5 19.0 21.0
21.0 21.0 19.0 18.0 18.0 27.0 27.5 27.5 27.5 27.5 27.5 27.0 28.0 29.0 30.9
10.3  8.0 10.0 10.0 12.0 27.5 27.5 27.5 13.0 14.0 15.0 27.5 27.5 18.0 20.0
21.0 21.0 18.0 17.0 17.0 27.0 22.0 27.5 27.5 27.5 26.0 26.0 27.0 29.0 30.4
10.2  8.0 10.0 10.0 12.0 27.5 27.5 27.5 13.0 13.0 14.0 27.5 27.5 18.0 20.0
20.0 19.0 18.0 17.0 16.0 26.0 21.0 27.5 27.5 28.0 25.0 26.0 26.0 28.0 30.0
10.0  8.0 10.0 10.0 11.0 27.5 27.5 27.5 12.0 13.0 14.0 15.0 16.0 17.0 19.0
20.0 19.0 17.0 16.0 15.0 26.0 20.0 23.0 25.0 28.0 25.0 25.0 25.0 28.0 29.5
10.0  8.0 10.0  9.0 11.0 27.5 27.5 27.5 12.0 12.0 13.0 14.0 15.0 17.0 19.0
19.0 18.0 17.0 16.0 14.0 25.0 20.0 23.0 30.0 27.0 24.0 25.0 24.0 27.0 29.0
 9.9  8.0 10.0  9.0 11.0 27.5 27.5 11.0 12.0 12.0 13.0 14.0 15.0 16.0 18.0
19.0 18.0 16.0 15.0 13.0 25.0 19.0 22.0 30.0 26.0 24.0 24.0 23.0 26.0 28.4
```

```
 9.7  8.0  9.0  9.0 10.0 12.0 11.0 11.0 11.0 12.0 12.0 13.0 14.0 16.0 18.0
18.0 17.0 16.0 15.0 13.0 24.0 19.0 21.0 29.0 26.0 23.0 23.0 22.0 25.0 27.9
 9.6  8.0  9.0  9.0 10.0 11.0 11.0 11.0 11.0 11.0 12.0 13.0 14.0 15.0 17.0
18.0 17.0 15.0 15.0 13.0 23.0 18.0 21.0 29.0 24.0 23.0 22.0 21.0 25.0 27.4
 9.5  8.0  9.0  8.0 10.0 11.0 10.0 10.0 11.0 11.0 12.0 12.0 13.0 15.0 17.0
17.0 16.0 15.0 14.0 13.0 22.0 17.0 20.0 28.0 24.0 20.0 21.0 21.0 24.0 26.8
 9.3  7.0  9.0  8.0  9.0 11.0 10.0 10.0 10.0 11.0 11.0 12.0 13.0 14.0 16.0
17.0 16.0 14.0 14.0 13.0 21.0 17.0 19.0 28.0 23.0 20.0 20.0 20.0 24.0 26.3
 9.2  7.0  9.0  8.0  9.0 10.0 10.0 10.0 10.0 10.0 11.0 11.0 12.0 14.0 16.0
16.0 15.0 14.0 14.0 13.0 20.0 16.0 18.0 27.0 23.0 19.0  0.0 20.0 23.0 25.8
 9.1  7.0  8.0  8.0  9.0 10.0  9.0 10.0 10.0 10.0 11.0 11.0 12.0 13.0 15.0
16.0 15.0 14.0 13.0 13.0 19.0 16.0 18.0 26.0 22.0 17.0 18.0 19.0 23.0 25.3
 8.9  7.0  8.0  8.0  9.0 10.0  9.0  9.0  9.0 10.0 10.0 11.0 11.0 13.0 14.0
15.0 14.0 13.0 13.0 13.0 18.0 15.0 17.0 25.0 21.0 16.0 18.0 19.0 22.0 24.5
 8.5  7.0  8.0  8.0  8.0  9.0  9.0  9.0  9.0 10.0 10.0 10.0 11.0 12.0 14.0
14.0 14.0 13.0 13.0 13.0 14.0 15.0 17.0 24.0 20.0 16.0 17.0 18.0 21.0 23.2
 8.1  7.0  8.0  7.8  8.0  9.0  8.0  9.0  9.0  9.0 10.0 10.0 10.0 12.0 13.0
13.0 13.0 13.0 12.0 13.0 14.0 14.0 15.0 23.0 19.0 15.5 16.0 18.0 21.0 21.3
 7.7  7.0  7.6  7.6  8.0  9.0  8.0  9.0  9.0  9.0  9.0 10.0 10.0 11.0 12.0
12.0 12.0 12.0 12.0 13.0 13.0 14.0 15.0 20.0 18.0 15.5 16.0 17.0 18.0 20.0
 7.2  7.0  7.4  7.5  8.0  8.0  8.0  9.0  9.0  9.0  9.0 10.0 10.0 10.0 10.0
11.0 11.0 12.0 12.0 13.0 12.8 13.5 14.0 17.0 16.0 15.5 16.0 17.0 17.5 18.8
 6.8  7.0  7.2  7.4  7.7  7.9  8.1  8.3  8.5  8.7  8.9  9.1  9.4  9.6  9.8
10.0 10.5 11.1 11.6 12.2 12.7 13.3 13.8 14.3 14.9 15.4 16.0 16.5 17.1 17.6
    1.0E08         1        1.0
```

H - 2

MODFLOW BASIC DATA FOR STIMULATING GROUND-WATER RESPONSE FOR A LAKE LEVEL OF 18.0 FEET

```
12.3 14.0 16.0 17.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 29.0 31.0
33.0 35.0 38.0 38.0 38.0 40.0 40.0 41.0 41.0 41.0 40.0 41.0 40.7 40.3 40.0
12.0 13.0 15.0 17.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 30.0
32.0 34.0 37.0 37.0 37.0 39.0 40.0 40.0 40.0 40.0 40.0 40.0 40.0 40.0 39.3
11.9 13.0 15.0 17.0 18.0 20.0 21.0 21.0 22.0 23.0 24.0 25.0 26.0 28.0 30.0
31.0 33.0 36.0 36.0 36.0 39.0 39.0 40.0 40.0 40.0 39.0 40.0 40.0 39.0 38.7
11.8 13.0 15.0 16.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 29.0
30.0 32.0 35.0 35.0 35.0 38.0 39.0 39.0 39.0 39.0 38.0 39.0 39.0 39.0 38.5
11.7 13.0 15.0 16.0 18.0 19.0 20.0 20.0 21.0 22.0 23.0 24.0 25.0 27.0 29.0
29.0 31.0 34.0 34.0 34.0 38.0 38.0 39.0 39.0 39.0 37.0 39.0 39.0 38.0 37.8
11.6 12.0 14.0 16.0 17.0 19.0 20.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 28.0
29.0 29.0 33.0 33.0 33.0 37.0 38.0 38.0 38.0 38.0 36.0 38.0 38.0 38.0 37.4
11.5 12.0 14.0 15.0 17.0 18.0 19.0 19.0 20.0 21.0 22.0 23.0 24.0 26.0 28.0
28.0 28.0 32.0 32.0 32.0 37.0 37.0 38.0 38.0 38.0 35.0 38.0 37.0 37.0 37.0
11.5 12.0 14.0 15.0 17.0 18.0 19.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 27.0
28.0 27.0 31.0 31.0 18.0 36.0 36.0 37.0 37.0 37.0 35.0 37.0 36.0 36.0 36.5
11.4 12.0 14.0 15.0 16.0 18.0 18.0 18.0 19.0 20.0 21.0 22.0 23.0 25.0 27.0
27.0 26.0 30.0 18.0 18.0 36.0 35.0 36.0 37.0 36.0 34.0 36.0 36.0 36.0 36.1
11.3 11.0 13.0 14.0 16.0 17.0 18.0 18.0 18.0 18.0 18.0 22.0 23.0 24.0 26.0
27.0 26.0 29.0 18.0 18.0 18.0 34.0 35.0 36.0 35.0 34.0 36.0 35.0 35.0 35.7
11.2 11.0 13.0 14.0 16.0 17.0 17.0 17.0 18.0 18.0 18.0 21.0 22.0 24.0 26.0
26.0 25.0 18.0 18.0 18.0 18.0 33.0 34.0 36.0 34.0 33.0 35.0 35.0 35.0 35.2
11.1 11.0 13.0 14.0 15.0 17.0 17.0 17.0 18.0 18.0 18.0 21.0 22.0 18.0 18.0
26.0 25.0 18.0 18.0 18.0 18.0 32.0 33.0 35.0 33.0 33.0 34.0 34.0 34.0 34.8
11.0 11.0 13.0 13.0 15.0 16.0 16.0 16.0 18.0 18.0 18.0 18.0 21.0 18.0 18.0
18.0 24.0 18.0 18.0 18.0 18.0 18.0 32.0 34.0 32.0 32.0 33.0 34.0 34.0 34.3
10.9 10.0 12.0 13.0 15.0 16.0 16.0 16.0 18.0 18.0 18.0 18.0 21.0 18.0 18.0
18.0 24.0 18.0 18.0 18.0 18.0 18.0 31.0 33.0 31.0 32.0 32.0 33.0 33.0 33.9
10.9 10.0 12.0 13.0 14.0 16.0 15.0 15.0 18.0 18.0 18.0 18.0 20.0 18.0 18.0
18.0 18.0 18.0 18.0 18.0 18.0 18.0 30.0 32.0 34.0 31.0 31.0 32.0 32.0 33.5
10.8 10.0 12.0 12.0 14.0 15.0 15.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 23.0
18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 31.0 34.0 31.0 30.0 32.0 32.0 33.0
10.7 10.0 12.0 12.0 14.0 15.0 14.0 18.0 18.0 16.0 18.0 18.0 18.0 18.0 23.0
18.0 18.0 18.0 22.0 22.0 18.0 18.0 18.0 30.0 33.0 18.0 18.0 18.0 31.0 32.6
10.6  9.0 11.0 12.0 13.0 15.0 14.0 18.0 18.0 16.0 18.0 18.0 18.0 18.0 22.0
18.0 18.0 18.0 21.0 21.0 29.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 31.0 32.2
10.5  9.0 11.0 11.0 13.0 14.0 14.0 18.0 14.0 15.0 18.0 18.0 18.0 18.0 22.0
18.0 18.0 18.0 20.0 20.0 28.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 30.0 31.7
10.4  9.0 11.0 11.0 13.0 14.0 13.0 18.0 14.0 15.0 18.0 18.0 18.0 19.0 21.0
22.0 21.0 19.0 19.0 19.0 28.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 30.0 31.3
10.3  9.0 11.0 11.0 12.0 14.0 13.0 18.0 13.0 14.0 15.0 18.0 18.0 19.0 21.0
21.0 21.0 19.0 18.0 18.0 27.0 18.0 18.0 18.0 18.0 18.0 27.0 28.0 29.0 30.9
10.3  8.0 10.0 10.0 12.0 18.0 18.0 18.0 13.0 14.0 15.0 18.0 18.0 18.0 20.0
21.0 21.0 18.0 17.0 17.0 27.0 22.0 18.0 18.0 18.0 26.0 26.0 27.0 29.0 30.4
10.2  8.0 10.0 10.0 12.0 18.0 18.0 18.0 13.0 13.0 14.0 18.0 18.0 18.0 20.0
20.0 19.0 18.0 17.0 16.0 26.0 21.0 18.0 18.0 28.0 25.0 26.0 26.0 28.0 30.0
10.0  8.0 10.0 10.0 11.0 18.0 18.0 18.0 12.0 13.0 14.0 15.0 16.0 17.0 19.0
20.0 19.0 17.0 16.0 15.0 26.0 20.0 23.0 25.0 28.0 25.0 25.0 25.0 28.0 29.5
10.0  8.0 10.0  9.0 11.0 18.0 18.0 18.0 12.0 12.0 13.0 14.0 15.0 17.0 19.0
19.0 18.0 17.0 16.0 14.0 25.0 20.0 23.0 30.0 27.0 24.0 25.0 24.0 27.0 29.0
 9.9  8.0 10.0  9.0 11.0 18.0 18.0 11.0 12.0 12.0 13.0 14.0 15.0 16.0 18.0
19.0 18.0 16.0 15.0 13.0 25.0 19.0 22.0 30.0 26.0 24.0 24.0 23.0 26.0 28.4
```

```
 9.7  8.0  9.0  9.0 10.0 12.0 11.0 11.0 11.0 12.0 12.0 13.0 14.0 16.0 18.0
18.0 17.0 16.0 15.0 13.0 24.0 19.0 21.0 29.0 26.0 23.0 23.0 22.0 25.0 27.9
 9.6  8.0  9.0  9.0 10.0 11.0 11.0 11.0 11.0 11.0 12.0 13.0 14.0 15.0 17.0
18.0 17.0 15.0 15.0 13.0 23.0 18.0 21.0 29.0 24.0 23.0 22.0 21.0 25.0 27.4
 9.5  8.0  9.0  8.0 10.0 11.0 10.0 10.0 11.0 11.0 12.0 12.0 13.0 15.0 17.0
17.0 16.0 15.0 14.0 13.0 22.0 17.0 20.0 28.0 24.0 20.0 21.0 21.0 24.0 26.8
 9.3  7.0  9.0  8.0  9.0 11.0 10.0 10.0 10.0 11.0 11.0 12.0 13.0 14.0 16.0
17.0 16.0 14.0 14.0 13.0 21.0 17.0 19.0 28.0 23.0 20.0 20.0 20.0 24.0 26.3
 9.2  7.0  9.0  8.0  9.0 10.0 10.0 10.0 10.0 10.0 11.0 11.0 12.0 14.0 16.0
16.0 15.0 14.0 14.0 13.0 20.0 16.0 18.0 27.0 23.0 19.0  0.0 20.0 23.0 25.8
 9.1  7.0  8.0  8.0  9.0 10.0  9.0 10.0 10.0 10.0 11.0 11.0 12.0 13.0 15.0
16.0 15.0 14.0 13.0 13.0 19.0 16.0 18.0 26.0 22.0 17.0 18.0 19.0 23.0 25.3
 8.9  7.0  8.0  8.0  9.0 10.0  9.0  9.0  9.0 10.0 10.0 11.0 11.0 13.0 14.0
15.0 14.0 13.0 13.0 13.0 18.0 15.0 17.0 25.0 21.0 16.0 18.0 19.0 22.0 24.5
 8.5  7.0  8.0  8.0  8.0  9.0  9.0  9.0  9.0 10.0 10.0 10.0 11.0 12.0 14.0
14.0 14.0 13.0 13.0 13.0 14.0 15.0 17.0 24.0 20.0 16.0 17.0 18.0 21.0 23.2
 8.1  7.0  8.0  7.8  8.0  9.0  8.0  9.0  9.0  9.0 10.0 10.0 10.0 12.0 13.0
13.0 13.0 13.0 12.0 13.0 14.0 14.0 15.0 23.0 19.0 15.5 16.0 18.0 21.0 21.3
 7.7  7.0  7.6  7.6  8.0  9.0  8.0  9.0  9.0  9.0  9.0 10.0 10.0 11.0 12.0
12.0 12.0 12.0 12.0 13.0 13.0 14.0 15.0 20.0 18.0 15.5 16.0 17.0 18.0 20.0
 7.2  7.0  7.4  7.5  8.0  8.0  8.0  9.0  9.0  9.0  9.0 10.0 10.0 10.0 10.0
11.0 11.0 12.0 12.0 13.0 12.8 13.5 14.0 17.0 16.0 15.5 16.0 17.0 17.5 18.8
 6.8  7.0  7.2  7.4  7.7  7.9  8.1  8.3  8.5  8.7  8.9  9.1  9.4  9.6  9.8
10.0 10.5 11.1 11.6 12.2 12.7 13.3 13.8 14.3 14.9 15.4 16.0 16.5 17.1 17.6
    1.0E08         1        1.0
```

OTHER INPUT DATA NECESSARY FOR USGS MODFLOW:

(1) BLOCK CENTER FLOW DATA

(2) STRONGLY IMPLICIT PROCEDURE DATA

(3) OUTPUT CONTROL DATA

```
        1        -2
 0
        0         1.
        0      2000.
       11       500.  (20F4.2)                   -8
4.0 4.0 3.0 2.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 2.0 3.0 4.0 4.0
       11     3.39E5  (15F5.1)
  6.4  6.4  6.4  1.8  1.8  1.8  1.8  1.8  1.0  1.0  1.0  1.0  1.0  1.0  0.7
  0.7  0.7  0.7  0.7  0.7  1.7  1.7  1.7  1.7  1.7  0.0  0.0  0.0  0.0  0.0
  6.4  6.4  1.8  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.0  1.0  1.0  0.7
  0.7  0.7  0.7  0.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  0.0  0.0  0.0
  6.4  6.4  1.8  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  6.4  6.4  1.8  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  6.4  6.4  1.8  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  6.4  6.4  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.8  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  6.4  6.4  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.8  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.8  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  1.8  1.8  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.7  0.7  0.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  1.8  1.8  1.8  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  5.0  5.0  5.0  1.5  1.5  1.5  1.5  1.5  1.5  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  5.0  5.0  5.0  1.5  1.5  1.5  1.5  1.5  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  5.0  5.0  5.0  1.5  1.5  1.5  1.5  1.5  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.7  1.7  1.7  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.5  1.5  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.5  1.5  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.5  1.5  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.7  1.7  1.7
  5.0  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.5  1.5  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.5  1.5  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
```

```
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  0.7  0.7  0.7
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  0.7  0.7  0.7  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  0.8  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  0.8  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  0.8  0.8  0.8  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
  5.0  5.0  5.0  5.0  5.0  5.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
 10.0 10.0 10.0 10.0 10.0 10.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
 10.0 10.0 10.0 10.0 10.0 10.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  0.8  0.8  0.8  1.5  1.5  1.5  1.5  1.5  1.5  1.5
 10.0 10.0 10.0 10.0 10.0 10.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.5  1.5  1.5  1.5  1.5  1.5  1.5
 10.0 10.0 10.0 10.0 10.0 10.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.5  1.5  1.5  1.5  1.5  1.5  1.5
 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  1.9  1.9  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.5  1.5  1.5  1.5  1.5
 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  1.9  1.9  1.9  1.9
  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  3.5  1.5  1.5
 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0  1.9
  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  3.5  3.5  3.5
 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
 35.0 35.0  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  1.9  3.5  3.5  3.5
 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10.0
 35.0 35.0 35.0 35.0 35.0 35.0  1.9  1.9  1.9  1.9  1.9  1.9  3.5  3.5  3.5
```

```
      20        5
     1.0       .1        1                   5
```

```
         -6        6        6        6
          0        1        0        1
          1        0        0        0
```

APPENDIX I

June 30, 1982

MEMORANDUM

TO: J. T. Ahern, Attorney-General Administration, Legal

FROM: P. M. Dooris, Environmental Manager, Resource Regulation Department PMD
DFR D. F. Richters, Water Resource Technician, Resource Regulation Department

RE: Lake Rousseau (Withlacoochee Backwaters)

As you requested, I am forwarding information in support of Item 3 of O. R. DeWitt's letter of February 19, 1982, to T. E. Cone, Jr.

An analysis of the period of record and a field investigation was made of Lake Rousseau in respect to management levels. In analyzing the record, it should be realized that the lake is a reservoir formed by a dam on the Withlacoochee River. The levels are controlled and the reservoir is not allowed to fluctuate as a natural lake. The period of record indicates levels as high as 28.01' msl and as low as 21.70' msl with normal seasonal highs of approximately 27.75' msl. The record from 1964 through 1974 indicates an average fluctuation range of approximately 2.6', however, from 1975 to current, the lake has been stabilized within an average range of less than .70'.

Field work indicates that no significant damage occurs at or below elevation 28.00' msl, but would start to occur at higher elevations. It appears that the lake would benefit from seasonal lows of approximately 24.00' msl, however, lakeshore residents may be inconvenienced by the low water.

From our analysis of the record, field work and our knowledge of area lakes that fluctuate naturally, we recommend the following tentative range of levels for Lake Rousseau.

Minimum Flood	28.00' msl
Minimum Level (Low Management)	24.00' msl
Minimum Level (Extreme Low Management)	23.00' msl

PMD:DFR:kk

cc: O. R. DeWitt

00527

REPORT NAME
   OPERATIONS & MANAGEMENT STUDY
AUTHOR
   STAFF FEBURARY 1989
KEY WORD
   LAKE ROUSSEAU
BASIN
   19