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Newnans Lake, Florida: Removal of particulate organic matter and nutrients using a short-term drawdown [Phase I]

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EXECUTIVE SUMMARY

Water-level stabilization is commonly employed in Florida to insure year-round access to lakes. However, stabilized water levels may cause accelerated accumulation of nutrient-rich detritus on the lake bottom. This, in turn, can affect aquatic plant communities, reduce water clarity, and eliminate hard-bottom nesting areas for many sportfish.

A 90-day gravity drawdown of shallow, algal-dominated Newnans Lake (Alachua County, Florida) was initiated by the Florida Game and Fresh Water Fish Commission in April 1989 by removing the flashboards on the outflow dam. The study reported here was designed to measure discharge rates of organic matter and nutrients through flushing, and to examine the oxidation and consolidation of exposed littoral substrate in the field and in the laboratory. Sediment characteristics and patterns of sediment deposition and redistribution were also studied, and are documented in the Phase II report (Gottgens and Crisman 1992).

Temporary removal of the flashboards on the dam flushed moderate amounts of suspended solids, particulate organic matter (POM), nitrogen (TKN) and phosphorus (TP) from the lake. Elevated concentrations of POM, TKN, and TP in the discharge were only noted during the first month of dewatering, when adequate head differential was present.

Storms associated with high winds appeared to promote flushing of organic matter and nutrients, probably due to enhanced resuspension of bottom lake sediment.

Field and laboratory tests did not demonstrate a net oxidative removal of organic matter from exposed areas of the lake bottom. Consolidated sediments remained firm after reflooding, providing improved habitat for rooted macrophytes and fish spawning. Gravity drawdowns are inexpensive and can be effective in removing organic matter and nutrients when they are initiated at high lake stage and coincide with frequent wind events. Routine application of this management technique may produce a periodic rejuvenation of the lake ecosystem in situations where water-level stabilization is required.

INTRODUCTION

Newnans Lake is a eutrophic, soft-water lake located 8 km east of Gainesville in Alachua County, Florida. The lake is recognized for its considerable ecological and economical significance. The watershed supports diverse and productive wildlife communities. These include reproducing populations of several state and federally listed threatened and endangered species, such as the bald eagle and the woodstork (Nesbitt, 1973; Collopy and Bohall-Wood, 1986; Parenteau, 1987), as well as species of special interest such as bass and alligators. The diversity of habitats in the basin, the abundance of food and prey organisms in this productive environment, the availability of suitable nesting sites, and the relatively low level of cultural disturbance all contribute to the continuation of these rich communities. In addition, an impressive band of cypress swamp around the open water area of the lake adds substantially to the tranquil, aesthetic beauty of this system.

The economic value of the lake centers around its reputation for excellent sportfishing, characterized as a year-round fishery with a significant spring peak. Since its designation as a Fish Management Area by the Florida Game and Fresh Water Fish Commission (FGFWFC) in conjunction with the Alachua Board of County Commissioners, a continuing program of fishery improvement and management has been conducted on the lake.

This program includes the stocking of sunshine bass, maintenance of boat ramps, installation of fish attractors, and studies of fish populations to determine management needs and effectiveness. The lake has traditionally attracted many sportsmen, naturalists, and tourists annually. In addition, because of its proximity to the University of Florida, this ecosystem serves an important function in research and education.

During the last decade concerns have developed regarding both the ecology and the economics of Newnans Lake. Declining sportfish populations and a disappearance of black crappie (Pomoxis nigromaculatus) are documented in fish management surveys (Florida Game and Fresh Water Fish Commission (FGFWFC), 1982- 1989). The FGFWFC suspects that these declines are caused by an increased accumulation of flocculent sediments in the lake, which reduces the availability of preferred nesting habitat for largemouth bass (Micropterus salmoides) (Bruno, 1984). Bass, an important sportfish, require firm substrate for egg deposition, and appear to use cypress knees (Taxodium sp.) or large spatterdock (Nuphar luteum) rhizomes in the absence of hard-bottom habitat (Bruno, 1984).

These unconsolidated sediments are easily resuspended resulting in increased turbidity and reduced light penetration. This can prevent the re-establishment of native submerged plant communities (e.g. coontail, southern naiad, maidencane) (Reid, 1952). Deposits of flocculent sediment in littoral zone areas eliminate firm substrate for plant growth. Periodic resuspension of sediment particles may also produce sudden increases in inorganic nutrients in the overlying water (Holdren and Armstrong, 1980; Pollman, 1983) and contribute to algal blooms. In addition, organic turbidity exerts considerable oxygen demand, which not only may stress heterotrophic communities in the lake, but also promotes rapid nutrient influx from the sediments (Mortimer, 1971; Theis and McCabe, 1978; Frevert, 1979).

With the construction of a spillway at the lake outlet in 1967, seasonal lake level fluctuations have been reduced. A comparison of pre- and post-spillway stage-duration curves indicated a reduction in fluctuation amplitude of approximately 35 cm (Gottgens, unpub.data). The shallow depth of the lake (mean depth is 1.5 m) and the small elevation gradient in the basin suggest that a reduction in water-level fluctuation of this magnitude could have significant long-term consequences for the lake ecosystem, such as:

a) Accelerated accumulation of organic detritus, flocculent mud, and nutrient-rich deposits on the lake bottom.

b) Reduction of wetland habitat around the lake. Wetland plants and trees need an environment in which the water rises and falls with the season. Constant water levels result in gradual decline of those wetlands and may alter their ability to filter nutrients and sediments that are carried into the lake in runoff from the surrounding uplands. This may contribute to enhanced algal production in the lake.

c) Reducing some kinds of waterfowl and wading bird populations around the lake which are dependent on naturally fluctuating water-levels (Kadlec, 1962; Harris and Marshall, 1963).

In an effort to improve fish growth and recruitment, a three-month gravity drawdown of the lake was initiated in April, 1989 by removing the flashboards on the spillway. Exposing the littoral zone lake-bottom during drawdown allows oxidation and consolidation of this substrate, which may improve this habitat for future fish spawning. Seed germination and firm substrate promote the establishment of desirable littoral plant communities. Research on other Florida lakes has quantified effects of dewatering programs on fish populations (Wegener and Williams, 1974), aquatic invertebrates (Wegener et al, 1974), and littoral plant communities (Holcomb and Wegener, 1971; Goodrick and Milleson, 1974; Hestand and Carter, 1975). However, little information is available on the impact of drawdown practices on the flushing of organic matter and nutrients from Florida lakes.

As such, the specific objectives of this study were:

1. To measure the removal of organic matter, nitrogen and phosphorus in surface discharge from Newnans Lake prior to and during the gravity drawdown.

2. To determine the effect of exposing littoral zone sediments to air on oxidative removal of organic matter.

3. To quantify the net removal of organic matter, nitrogen, and phosphorus from both profundal and littoral zone sediments and to determine changes in bulk density in these locations resulting from drawdown.

4. To combine the above measurements in a comprehensive account of both the total removal of organic matter, nitrogen, and phosphorus from the lake, as well as the redistribution of these materials in the lake following short-term drawdown.

This Phase I report covers objectives 1 and 2, while the Phase II report (Gottgens and Crisman, 1992) covers objectives 3 and 4.

METHODS

Study site

Newnans Lake is located 8 km east of Gainesville, Florida, within the St. Johns River Water Management District (Figure 1). It has a surface area of approximately 3000 ha, a maximum depth of 3.6 m and a mean depth of 1.5 m (Nordlie, 1976). Lake morphometry is summarized in Table 1. The drainage area

Table 1. Morphometry of Newnans Lake, Florida.

Surface Area	3042	ha
Maximum Depth	3.6	m
Mean Depth	1.5	m
Development of Shoreline	1.09	
Drainage Basin Area	308	km^2
Lake Volume	58×10^6	m^3
Lake Detention Time	0.6	yrs

north of the lake supplies surface water inflow via Hatchet Creek, Little Hatchet Creek, and several smaller streams. The lake has a single major surface water outlet, Prairie Creek, which drains to the south (Figure 1). This outflow has been regulated with a spillway since 1967. The elevation of the

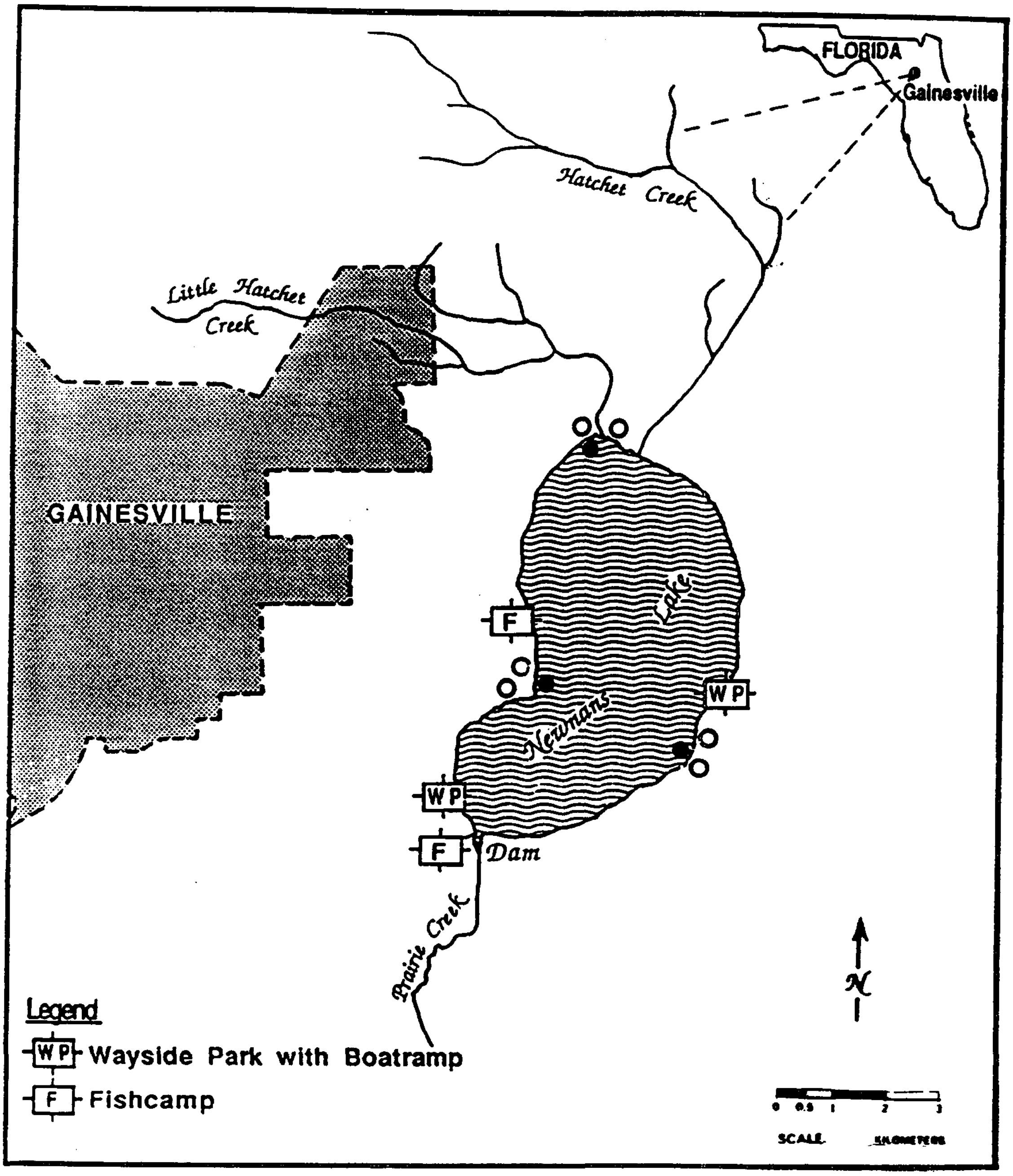

Figure 1. Map of Florida showing study area location and map of Newnans Lake. Open circles indicate the locations of field enclosures, and closed circles indicate the sediment collection sites for the oxidation and consolidation experiments.

top of the spillway boards prevents surface discharge when the water level in the lake drops below 20.1 m (MSL). During this study, one of the top boards was missing, lowering the elevation of a 1.2 m section of the top of the spillway boards to 19.9 m (MSL).

Conditions during the recent past and present characterize Newnans Lake as eutrophic with high nutrient concentrations, high and variable chlorophyll a values, and low Secchi disk transparency (Table 2). Temperature and dissolved oxygen data for Newnans Lake are also typical of shallow, productive systems. Vertical changes in water-column temperature rarely exceed 3°C, regardless of season (Crisman, 1986a). Consequently, thermal stratification rarely, if ever, occurs. Daytime surface water during summer and early fall is often supersaturated, while the water column in the deeper portions of the lake below 3 m approaches anoxia as a result of intense decomposition in surficial sediments (Crisman, 1986a). A review of Newnans lake water quality (Gottgens and Montague, 1987) notes high color (often in excess of 150 mg/l as Pt) as a result of inputs of highly colored water from the surrounding flatwood and cypress communities, and circumneutral (pH of 6.3-7.5) water of low buffering capacity.

The lake has dense growths of filamentous algae and, at times, abundant macrophytes dominated by exotics such as water

Table 2. Summary of water quality for Newnans Lake: Historical data 1957-1980 (top) and 1989 data (bottom).

	Unit	Mean	S.D.	Min.	Max.	N.
Total Nitrogen	mg/l	1.83	0.84	0.23	4.32	35
Total Phosphorus	mg/l	0.10	0.04	0.02	0.18	37
Chlorophyll _a_	mg/m^3	53.8	31.8	8.6	157.8	29
Secchi Disk	m	0.58	0.17	0.30	0.91	32
Total Nitrogen	mg/l	1.93	0.46	1.43	2.64	5
Total Phosphorus	mg/l	0.07	0.01	0.06	0.09	6
Chlorophyll _a_	mg/m^3	25.1	18.8	1.1	56.7	6
Secchi Disk	m	0.60	0.20	0.31	0.81	5

[Source for historical data: Huber et al. 1982.
Source for 1989 data: St. Johns River Water Management District, FL]

hyacinth (_Eichhornia crassipes_) and hydrilla (_Hydrilla verticillata_). Since the early 1970s, periodic applications of herbicides have been made to restrict the spread of these exotics. The lake bottom is covered with a homogeneous layer of highly flocculent, organic sediment (Holly, 1976).

Methods

Discharge through Prairie Creek, rainfall, and lake water-level were measured starting February 20, 1989, 9 weeks prior to dewatering, and continued throughout the dewatering period until July 31, 1989, 2 weeks after the spillway boards were re-installed.

Surface flow from the lake was measured weekly using an Ott meter (Type C2-10150) approximately 30 m downstream from the spillway in Prairie Creek. The frequency of sampling was increased during storm events to include a minimum of 1 pre-storm flow, 1 peak flow, and 1 post-storm flow measurement.

The creek width was divided in 1 m subsections and flow was measured in each section at 0.6 depth (when channel depth < 30 cm) or at 0.2 and 0.8 depth and averaged (when channel depth > 30 cm). Discharge was computed by multiplying flow in each subsection by its cross-sectional area. Total discharge equals the sum of all subsection discharges. If the measured discharge differed from the discharge computed using USGS stage-discharge ratings by more than 10%, then discharge was remeasured and averaged with the first measurement. A calibration flume (Department of Civil Engineering, University of Florida) was used to determine the accuracy of the Ott meter.

Daily rainfall records were kept during the study period using a standard (20.32 cm diameter) Weather Service raingage, located near the center of the watershed (Gainesville Flight Service Station, National Oceanic and Atmospheric Administration). Lake levels were recorded daily by the U.S. Geological Survey (station # 02240900) located on the west side of the lake.

Replicate water samples were collected concurrently with discharge measurements 20 m upstream from the spillway in the center of the creek. Water samples were collected in acid washed Nalgene® containers, immediately stored on ice, and frozen within 1 hour of collection. Samples were analyzed for total suspended solids (TSS), particulate organic matter (POM), total Kjeldahl nitrogen (TKN), and total phosphorus (TP). The analyses were completed within 90 days of collection.

All laboratory analyses were conducted in the Department of Environmental Engineering Sciences, University of Florida. Analysis for TSS was according to Standard Methods (method 209C, A.P.H.A., 1985) using pre-weighed and pre-muffled glass fiber filters (Whatman®, 934-AH, 4.25 cm diameter) with a particle retention of 1.5 μm. Replicate analyses were done on 0.5 l samples. POM was measured as weight loss on ignition (at 550°C for 1 hour, followed by rehydration with distilled water and drying at 95°C for 24 hours, method 209D) of oven-dry samples (95°C for 24 hours). TKN analyses were according to E.P.A. method 351.2 (E.P.A., 1979) using a 40-block digestor and a Technicon II semi-automated manifold. The digested sample was also used for TP determination. The liberated orthophosphate in the digested samples was determined using the ascorbic acid method (method 424F, A.P.H.A., 1985). Absorbance of the samples was read at 880 nm on a Bausch and Lomb© spectrophotometer (model 21) with a light path of 2.5 cm. Both nitrogen and phosphorus analyses were done on replicate samples and averaged.

Oxidation rates of organic matter in exposed littoral zone sediment were measured in the laboratory and the field. Littoral surficial sediment was collected from 3 stations in the lake (Figure 1) and homogenized in a blender in the laboratory. Subsamples (n=25) of 100 ml each were incubated in crucibles at room temperature for 78 days under 3 treatments. One set was allowed to dry completely and remained dry during the test period; one set was kept wet without standing water by adding up to 8 ml of distilled water per week, and a third set was kept inundated (with 2-3 cm of distilled water). The duration of this experiment (78 days) was chosen to coincide with the expected length of time that littoral substrate would be exposed in the field. Crucibles in the laboratory were rotated every 48 hours to promote equal exposure to light conditions (generally between 20-30 Lux). Organic matter content before and after incubation was determined using weight loss on ignition (at 550°C for 1 hour followed by rehydration with distilled water and drying at 95°C for 24 hours) of oven-dry samples (95°C for 24 hours).

PVC enclosures (surface area = 180 cm^2) were installed in pairs at 3 locations in exposed littoral zone sediments (Figure 1). The enclosures were pushed through the top layer of wet organic substrate to a point 5-10 cm into the underlying sand. Enclosed sediment was shielded from precipitation by an elevated plexiglass roof. This design prevented removal of enclosed substrate by water and/or wind erosion. Hardware cloth (1.25 cm mesh size) was put on top of the enclosure to deter animal disturbance.

Organic matter content at the beginning of exposure was quantified by average weight loss on ignition of 3 "core" samples adjacent to the enclosure. Each sample covered an area equivalent to the enclosure and was analyzed in its entirety down to sand. After 28 days of incubation, the organic matter content of the enclosed substrate down to sand was determined. Net oxidative removal (g $m^{-2}day^{-1}$) was computed as the difference between pre- and post-incubation measurements.

A small-scale sediment compaction study was also performed to evaluate changes in substrate bulk density, water content and percent organic matter at various times after exposure and after reflooding. Four vessels (glass, 1 l) containing 500 ml of homogenized littoral substrate were allowed to dry in the laboratory for 51 days, then inundated (to a depth of 10 cm) for 149 days, simulating the water regime in the field. Incubation of the substrate occurred at room temperature, indoor light conditions, and approximately 40% relative humidity. The locations from which sediment samples were collected are shown in Figure 1. Only the top 5 cm of substrate was used. Ten bulk density (mg/cm^3), water content (percent), and organic matter content (percent) determinations were made at 5 times during exposure, at the time of reflooding, and 4 times during reflooding.

RESULTS AND DISCUSSION

During the 3.5 months prior to dewatering lake stage dropped from 20.33 m (MSL) to 20.07 m (MSL) due to lack of rain. The boards in the spillway were removed on April 24, 1989. Water level in the lake dropped from 20.07 m (MSL) to 19.80 m (MSL) in 1 month after board removal (Figure 2). Lake stage remained between 19.70 and 19.80 m MSL for 8 weeks. This stage was the lowest recorded during the last 25 years, with the exception of a brief period during the drought of 1981 (when the lake reached 19.65 m MSL). The maximum drop in water level during dewatering was 36 cm. Severe lack of rain during the months prior to dewatering (Table 3) resulted in lake water-levels approximately 41 cm below average for early spring. This reduced the amplitude of the drop in lake water-level. Small elevation gradients in the basin and the gradual build-up of obstructions in the lake outflow upstream and downstream from the spillway since its construction (personal observation) likely prevented a more dramatic drawdown of water level. Those obstructions to the flow in Prairie Creek may have resulted from the impact of the spillway on stage level and discharge volumes in the creek. Low flow and low stage conditions downstream from the spillway are much reduced compared to the natural hydroperiod of the creek prior to dam construction in 1967 (Gottgens, 1987).

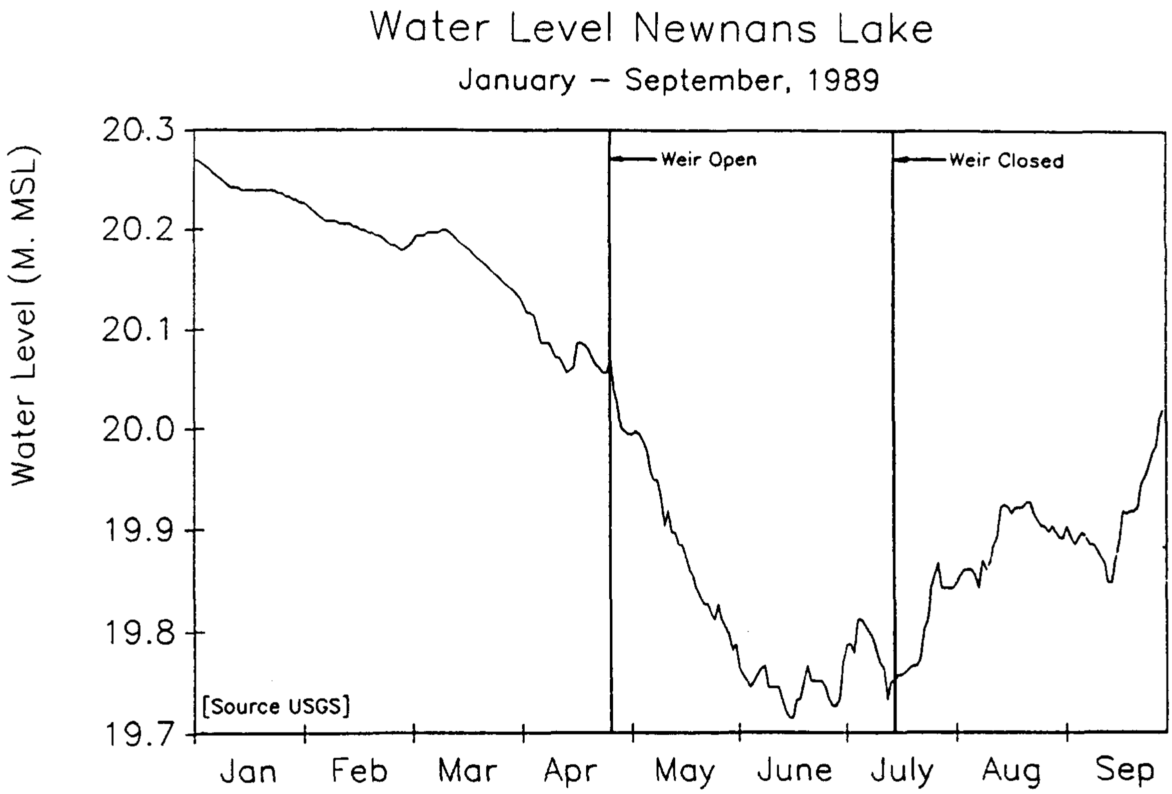

Figure 2. Water level record for Newnans Lake for the period of January-September 1989 [Source: U.G. Geological Survey station # 02240900].

Table 3. Average rainfall (1897-1987) and rainfall during first 7 months of 1989. Records given in cm.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Total
Average	7.7	9.0	9.1	7.6	8.9	16.7	18.2	77.0
1989	2.6	3.0	5.5	7.4	5.2	24.4	10.0	58.1
Deficit	5.1	6.0	3.6	0.2	3.7	-7.7	8.2	19.1

[Source: National Oceanic and Atmospheric Administration, Gainesville Flight Service Station, Florida]

Assuming a reduction of the mean water depth from 1.5 m to 1.2 m during the drawdown, it is estimated that 20% of water volume of the lake was removed during the dewatering period. Assuming unaltered base-discharge rates from the lake through Prairie Creek during the drawdown period, integration of the discharge curve (Figure 3) and then subtracting base-discharge yields an estimate of 1.75×10^6 m^3 of water flushed from the lake by removal of the spillway. Base-discharge is defined as the discharge flowing through the channel with the spillway in place, and is estimated by measuring average discharge prior to dam removal and after re-installation of the flashboards. In both cases an averaging period of 2 weeks was used. Discharge through Prairie Creek returned to approximately

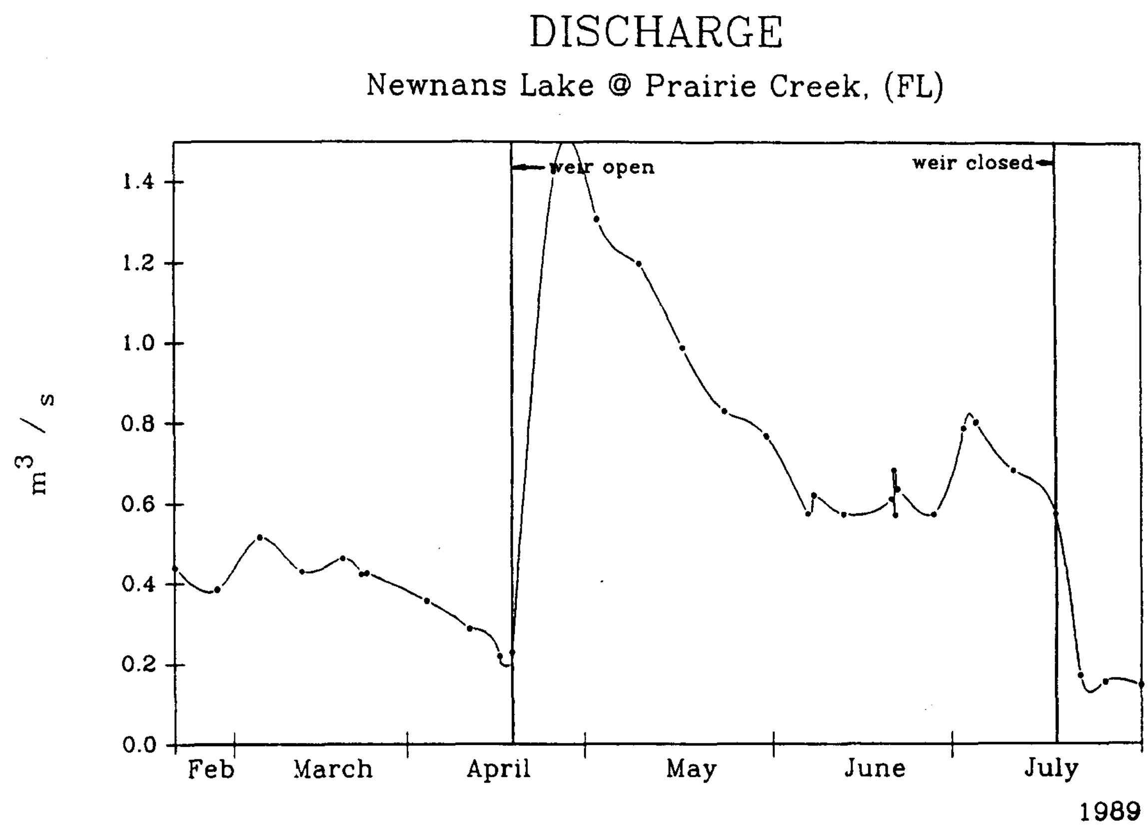

Figure 3. Discharge through Prairie Creek @ S.R. 20.

twice the assumed base-discharge within 6 weeks after spillway removal and remained at that rate until closing of the weir (Figure 3). In spite of low total rainfall, 5 storm events of low to moderate intensity were included in the sampling period (Table 4).

Table 4. Precipitation and wind conditions during sampled storm events, Newnans Lake.

	Dates (1989)	Amount* (cm)	Wind conditions* (km/hr)
Pre-	March 22-23	1.09	0-18 from N
dewatering	April 14-15	2.03	0-12 from N or W
During	May 29	2.26	0-40 misc. dir.
dewatering	June 18-19	4.52	0-16 misc. dir.
	July 16-17	1.42	0-16 misc. dir.

* Measured at spillway with standard 2.54 cm glass raingage and Dwyer handheld windmeter

Removal of particulate matter and nutrients.

Increased flow through Prairie Creek after spillway removal increased discharges (kg/day) of particulate organic matter (POM), total Kjeldahl nitrogen (TKN), and total phosphorus (TP) (Figures 4a, 4b, and 4c). POM was a consistent fraction of total suspended solids during the sampling period (POM = 0.76 × TSS; N=64; R^2=0.96). Assuming base-discharge rates (kg/day) through Prairie Creek during the dewatering period, integration of total discharge rates and subtracting base-discharge rates yields an estimate of the amount (kg) of POM, TKN, and TP flushed from the lake by dewatering (Table 5). These values represent flushing from the lake over and above the assumed base-discharge due to spillway removal.

Table 5. Amounts of total suspended solids, particulate organic matter, total Kjeldahl nitrogen, and total phosphorus flushed in excess of base-discharge from Newnans Lake during drawdown.

	kg dry weight removed by drawdown	mg/m^2 lake area removed by drawdown
Total suspended solids	59,247	2,043
Particulate organic matter	46,537	1,605
Total Kjeldahl nitrogen	8,840	305
Total phosphorus	290	10

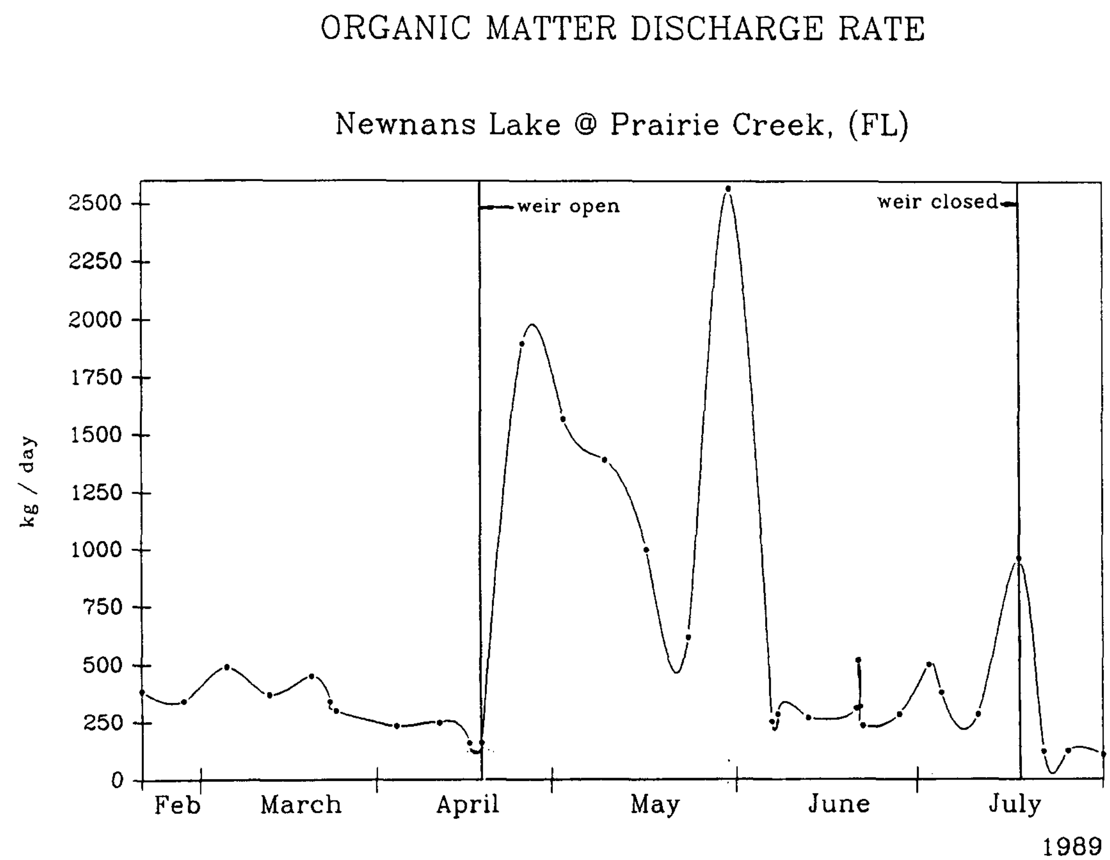

Figure 4a. Discharge rate of particulate organic matter through Prairie Creek @ S.R. 20.

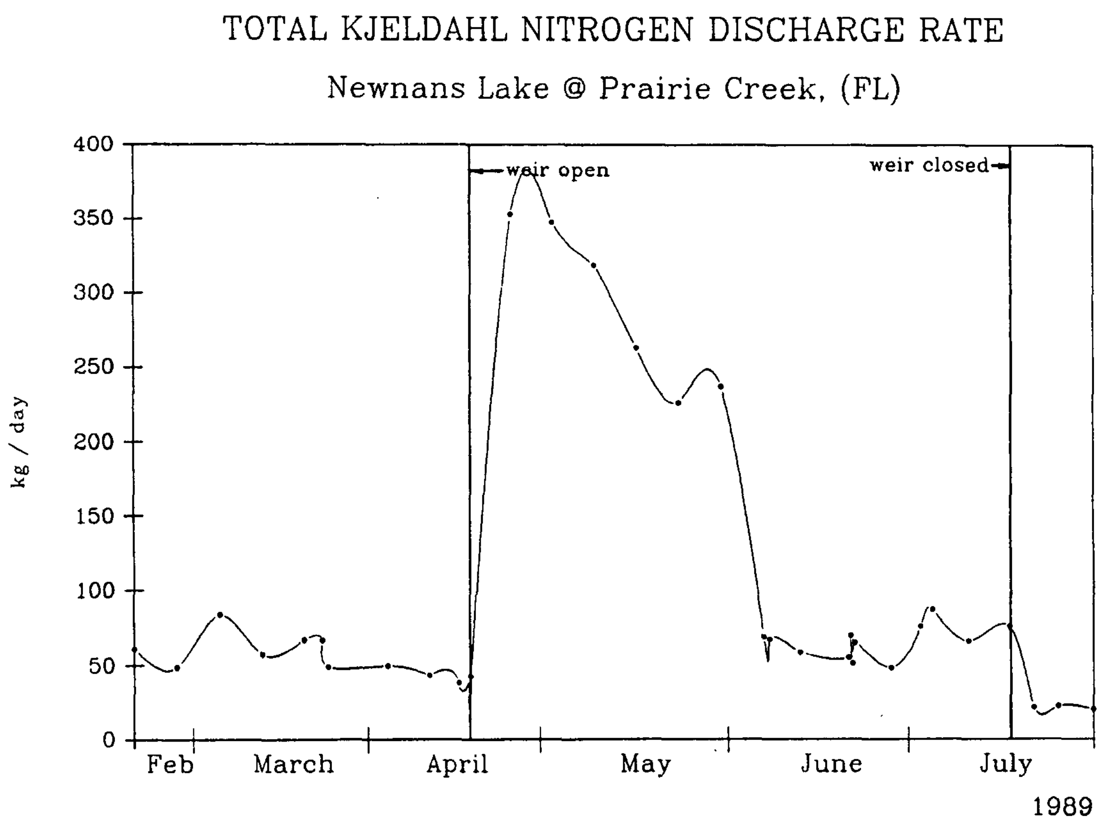

Figure 4b. Discharge rate of total Kjeldahl nitrogen through Prairie Creek @ S.R. 20.

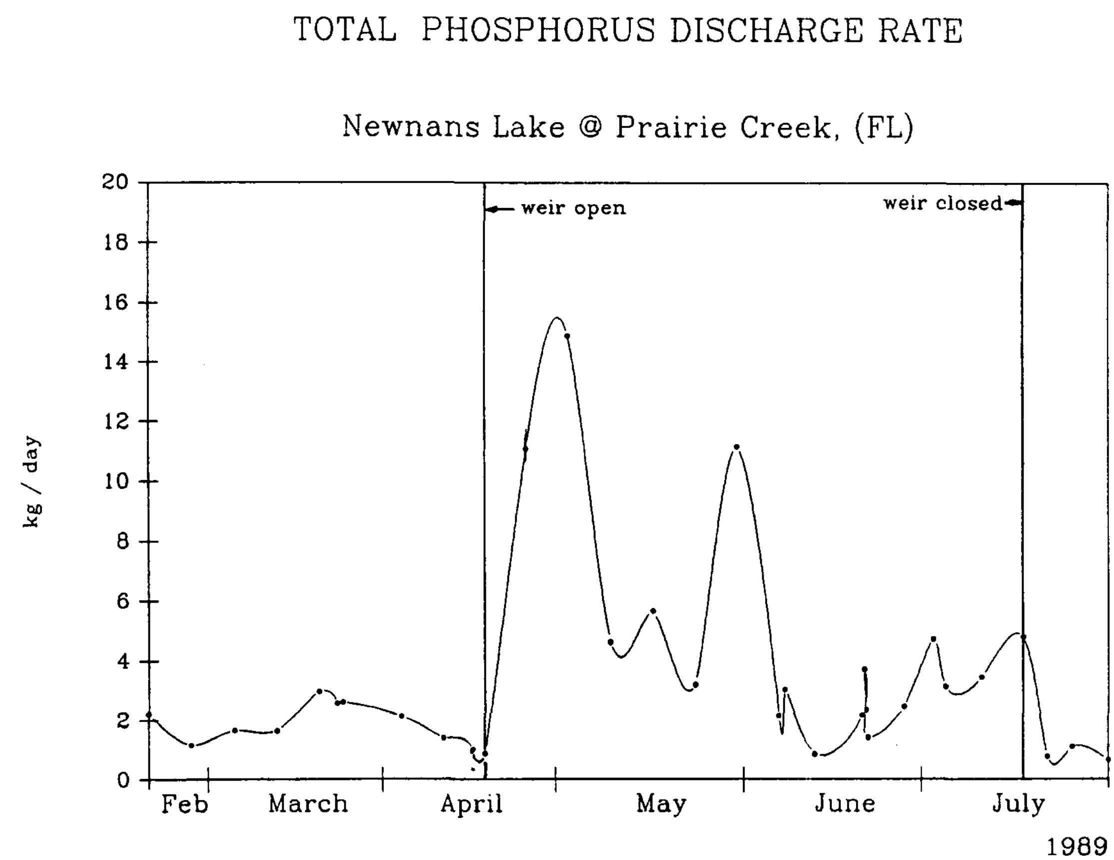

Figure 4c. Discharge rate of total phosphorus through Prairie Creek @ S.R. 20.

Computed on a m^2-basis, these values may be characterized as small compared to the likely stores of flocculent sediment in the lake. The low removal rates of muck from the basin may have resulted from the low water-level at the onset of dewatering. Such levels produced a small hydraulic head and low discharge rates. Low discharge rates depress removal of resuspended material.

Concentrations of POM, TKN, and TP in the lake discharge were significantly higher during the first month of dewatering than during the pre-drawdown period (Figure 5a, 5b, and 5c). These differences are statistically significant ($P<0.05$, $P<0.05$, $P<0.01$, respectively) using a pooled analysis of variance (Byrkit, 1975) and assuming no autocorrelation among data points (Table 6). After this period, when discharge decreases to about twice the assumed base-discharge (see Figure 3) concentrations of POM, TKN, and TP drop to near pre-dewatering levels.

Considerable changes in water quality of the outflow occurred during storm events. Three sampled storm events during the dewatering period produced increases in the concentration of POM, TKN, and TP (Figure 5a, 5b, 5c). Other peaks in these time patterns may have been associated with wind events which were not sampled. Although a more detailed analysis (incorporating daily wind-data and in-lake water quality)

CONCENTRATION OF PARTICULATE ORGANIC MATTER IN DISCHARGE

Newnans Lake @ Prairie Creek. (FL)

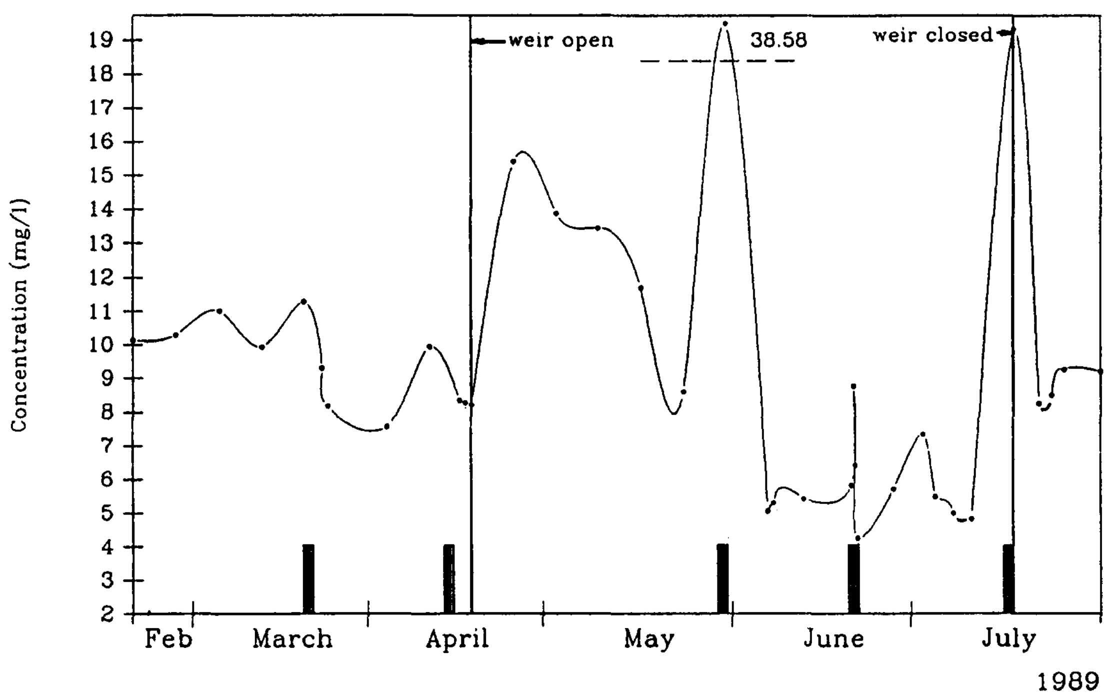

Figure 5a. Concentration of particulate organic matter in discharge through Prairie Creek @ S.R. 20. Bars indicate sampled storm events.

TOTAL KJELDAHL NITROGEN CONCENTRATION IN DISCHARGE

Newnans Lake @ Prairie Creek, (FL)

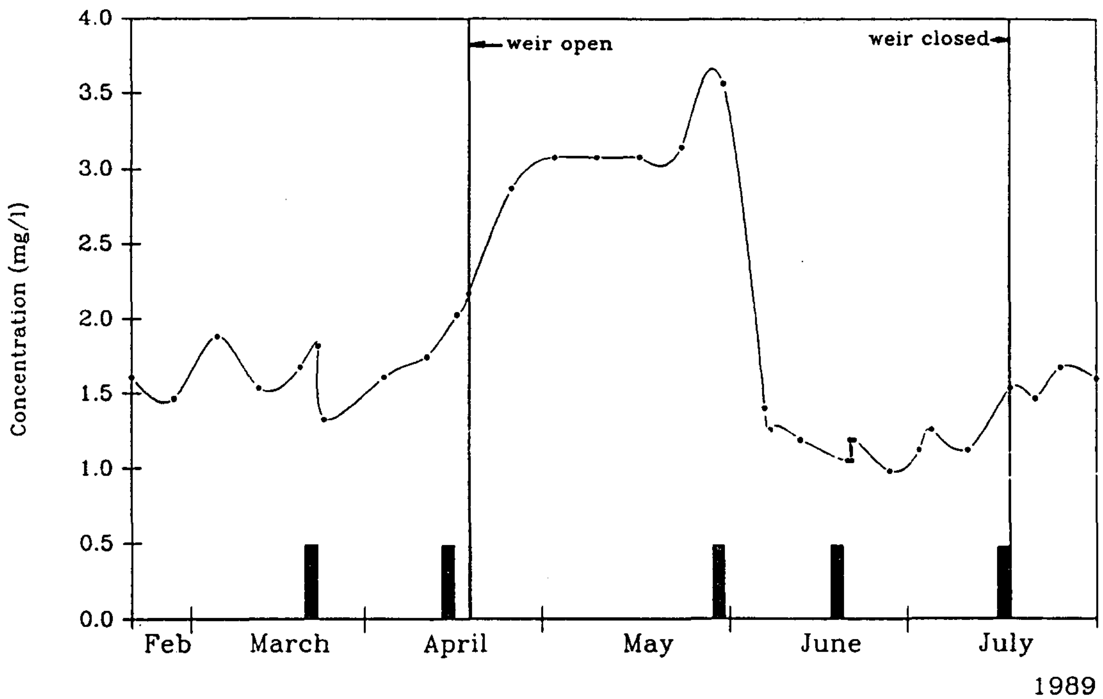

Figure 5b. Concentration of total Kjeldahl nitrogen in discharge through Prairie Creek @ S.R. 20. Bars indicate sampled storm events.

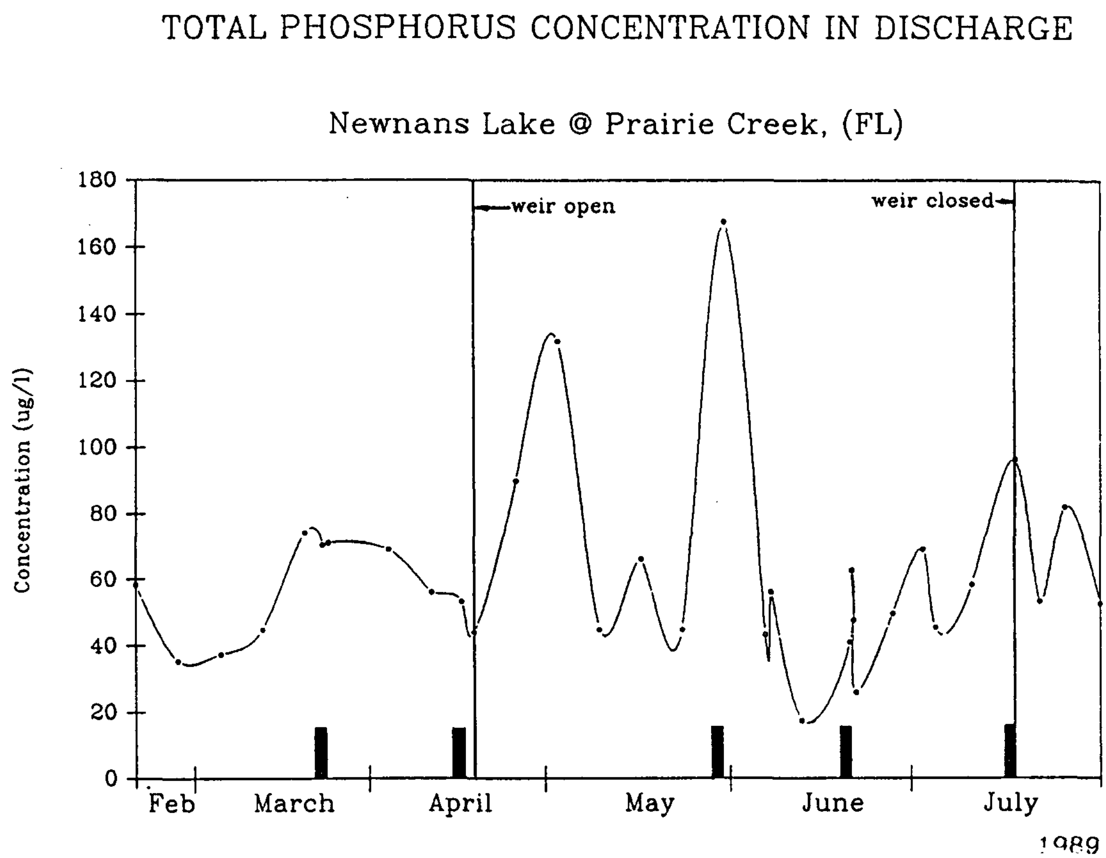

Figure 5c. Concentration of total phosphorus in discharge through Prairie Creek @ S.R. 20. Bars indicate sampled storm events.

would provide better evidence, it appears that sampled storms were effective in resuspending surficial flocculent sediment in Newnans Lake. This corresponds with findings in other shallow lake systems (Sheng and Lick, 1979; Somlyódy, 1982). Mixing of these deposits in the water column enhances their removal through flushing. The lack of high-intensity wind events (e.g. in excess of 30 km/hr) during the study period contributed to the low particle flushing rates encountered.

Table 6. Concentrations of particulate organic matter (POM in mg/l), total Kjeldahl nitrogen (TKN in mg/l), and total phosphorus (TP in μg/l) in surface discharge from Newnans Lake prior to and during the first month of dewatering.

	Pre-dewatering			During 1st month of dewatering		
	Mean	N	S.E.	Mean	N	S.E.
POM	9.48	22	0.25	13.61	8	0.47
TKN	1.72	22	0.05	3.02	8	0.03
TP	55.81	22	2.88	83.13	8	11.42

Two storms of low intensity, sampled prior to removal of the spillway, produced small or no increases in particulate matter and nutrient concentrations of the flow through the section of the dam with the missing top-flashboard. The data indicate that storms are effective in flushing particulates and nutrients from the system. The flushing, however, is typically significant when obstructions, such as the spillway, are removed from the lake outlet.

Net oxidative removal of organic matter from exposed littoral sediments.

A second objective of the short-term drawdown of Newnans Lake was to improve littoral zone habitat. Exposure of littoral zone lake bottom to air may allow oxidative removal of organic material (Wegener et al., 1974) and consolidate flocculent sediments (Fox et al., 1977). This improves the area for future sportfish spawning and provides firm rooting for aquatic macrophytes (Holcomb and Wegener, 1971), which may contribute to a higher standing crop of aquatic macro-invertebrates and, eventually, fish (Wegener and Williams, 1974). A vegetated littoral zone may function as effective nutrient trap and reduce nutrient input from runoff into the lake (Mickle and Wetzel, 1978). Numerous authors have suggested that aquatic macrophytes can inhibit the development of algae (Canfield et al., 1984; Crisman, 1986b), which are perceived as a persistent problem in Newnans Lake.

Net oxidation rates of organic matter in exposed littoral sediment were evaluated in the field and laboratory. No significant net oxidation of littoral zone substrate was detected after 28 days of exposure (Figure 6). A slight, but non-significant, increase in organic matter content was observed in each enclosure, ranging from 0.08 to 11.05 g $m^{-2}day^{-1}$ (Figure 6). Field observations showed production of organic matter in the form of germinated seeds, roots, and above-ground plant biomass inside the enclosures. If oxidation of the sediments occurred it may have been masked by this organic matter production. It is possible that oxidation rates may have been quite low, particularly if the organic sediments were largely humic compounds, which are relatively resistant to microbial degradation (Sederholm et al., 1973).

The laboratory experiments do not provide evidence of oxidation of these sediments either. Oxidation rates were extremely low and not significantly different between dry, moist, and permanently inundated substrate (Table 7). Production of organic matter in these laboratory chambers under the low-light regime was less likely than in the field enclosures. Hence, these experiments suggest that oxidation rates were indeed low. These results support findings by Fox et al. (1977), who noted no significant decomposition of organic matter in muck-type sediment from Lake Apopka, Florida, using a series of laboratory experiments.

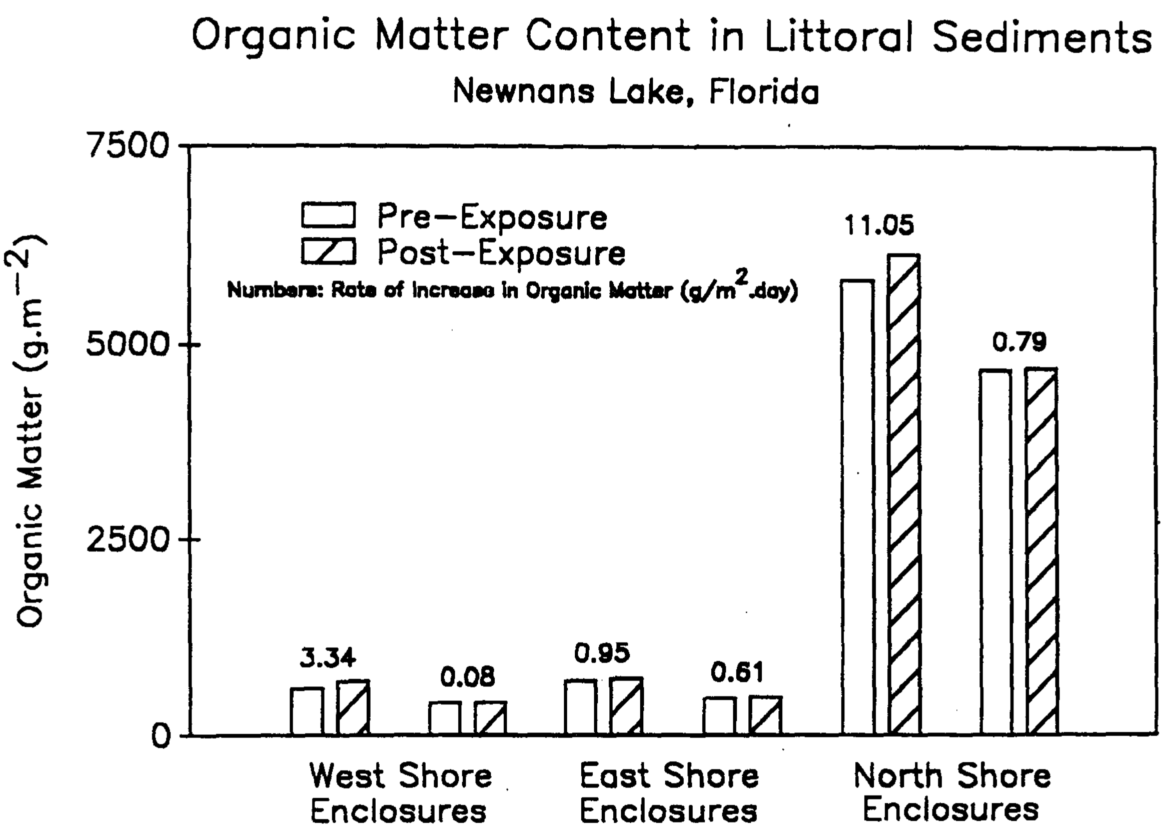

Figure 6. Organic matter content at the onset ("pre") and after 28 days of exposure ("post"), and rate of increase in organic matter in Newnans Lake littoral sediments.

Table 7. Mean oxidation rates of incubated littoral sediments in the laboratory under 3 different treatments.

	N	Mean oxidation rate (mg $g_{dry\ wt}^{-1} day^{-1}$)	S.D.	Range
Inundated	9	0.23	0.05	0.17-0.30
Moist	9	0.24	0.05	0.16-0.35
Dry	7	0.19	0.05	0.13-0.26

Consolidation of littoral sediments

In the laboratory consolidation-experiment, bulk density of exposed sediments increased 5 to 6 fold (Figure 7) and remained moderately compact 149 days after reflooding. Organic matter content remained constant throughout the duration of the experiment (Figure 8). Firmer substrate will reduce rates of resuspension during periods of high winds.

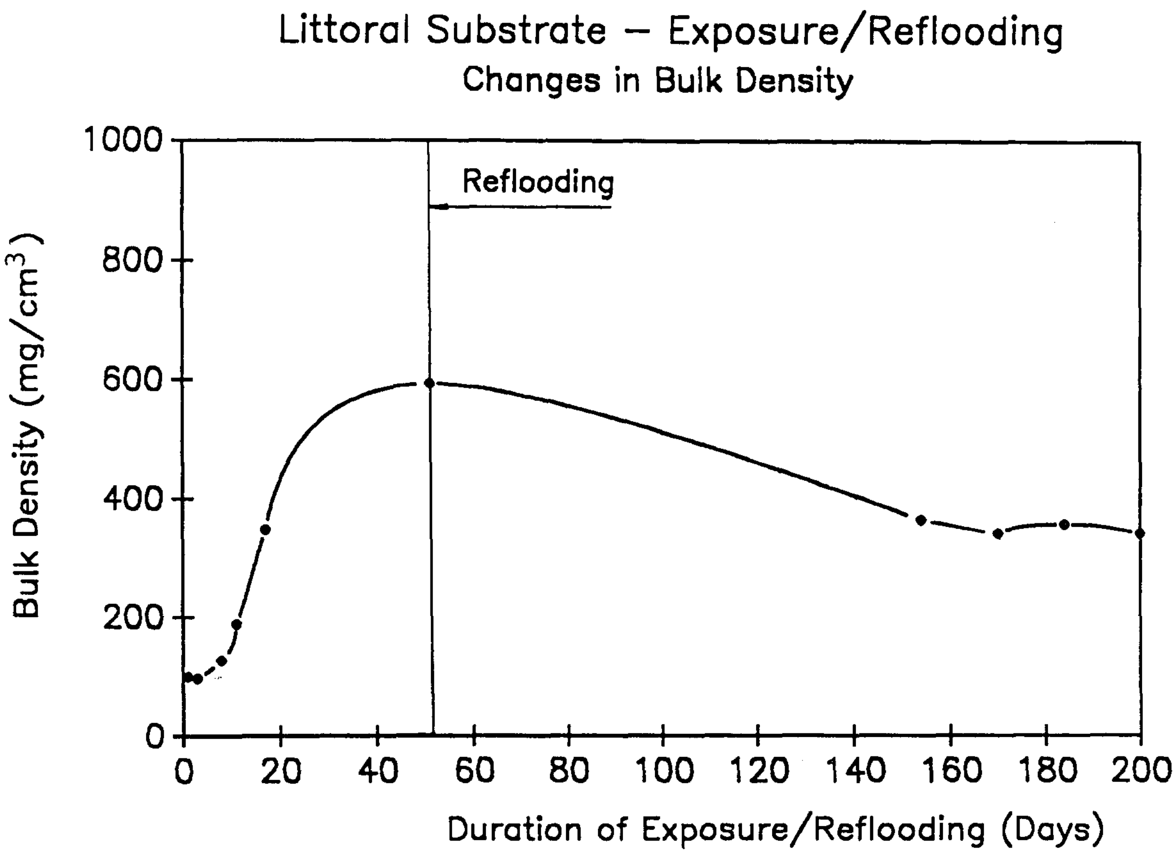

Figure 7. Changes in bulk density in Newnans Lake littoral sediments upon exposure and after reflooding (laboratory data).

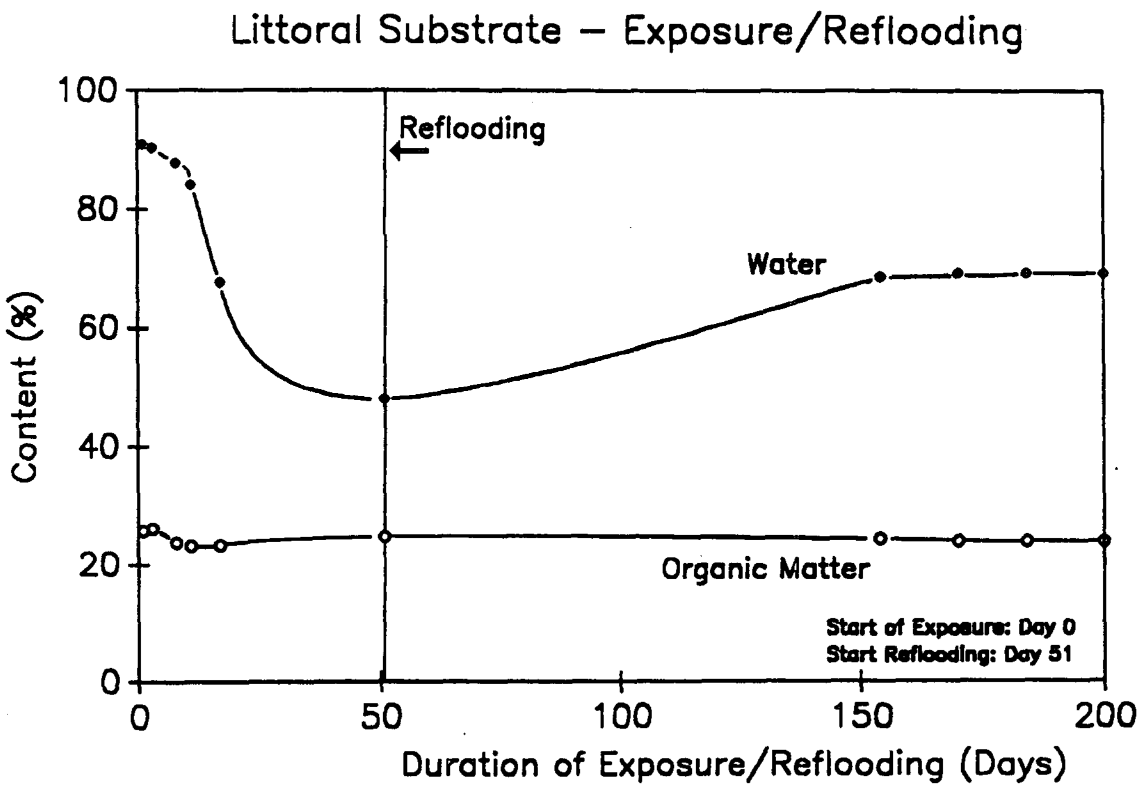

Figure 8. Changes in water and organic matter content (weight/weight ratio) in Newnans Lake littoral sediments upon exposure and after reflooding (laboratory data).

SUMMARY AND RECOMMENDATIONS

Summary

1. The drought of 1989, with 19.1 cm below average precipitation during the 7-month study period, produced a low lake-stage (41 cm below average) at the start of the dewatering period. This reduced the discharge rates from what they would have been at a higher initial lake stage and decreased flushing rates of particulate organic matter and nutrients from the lake.

2. Concentrations of POM, TKN, and TP in the lake discharge were significantly higher during the first month of dewatering than during the pre-drawdown period. These concentrations dropped to near pre-dewatering levels at lower lake stages.

3. Sampled storm events produced increases in concentration of particulate organic matter and nutrients in the discharge from the lake during dewatering. Storms sampled prior to opening of the spillway did not cause such increases. Storms are suspected to resuspend fine particulate deposits and promote flushing of this material.

4. The sill at the mouth of Prairie Creek reduces the likelihood of a gravity drawdown to a stage much lower than that accomplished (19.70 m MSL). At this stage, the water level is barely lakeward of the cypress tree fringe and

drying/consolidation of lake bottom is limited to a narrow littoral zone fringe.

5. Field and laboratory tests did not demonstrate net oxidative removal of organic matter from exposed areas of the lake bottom. Consolidated sediments remained moderately firm after reflooding in a laboratory experiment.

Recommendations

These management recommendations are intended to maximize removal of nutrient-rich deposits from the lake bottom, promote consolidation of littoral substrate, while minimizing the loss of access to the lake for water recreation and sportfishing. Although flushing rates of particulate organic matter and nutrients from the lake were low, this removal was accomplished at low cost. Drawdowns may be an appropriate management strategy in a shallow, exposed lake such as Newnans Lake, where storms likely resuspend bottom sediments and promote flushing. When planning such drawdowns, high particulate matter loading to downstream areas during the period of flushing needs to be anticipated.

Maximum flushing of organic matter and nutrients from Newnans Lake by temporary removal of the dam will occur when such a drawdown is initiated at a high lake stage and coincides with periods of high average wind speed. Maximum monthly lake stage in Newnans Lake occurs either from February to April or from July through September. No wind data were analyzed for North-central Florida, but data for Lake Okeechobee indicate that maximum wind velocities between October and May are approximately 30 percent greater than between June and September (Maceina and Soballe, 1990). Assuming that these data can be applied to Newnans Lake, it appears that short-term drawdowns during February-April have the highest probability of leading to improved lake conditions. Drawdowns during this time-period, however, are not optimal from a fisheries perspective. Fish generally spawn in February in Florida and need nursery areas in Spring and early Summer. Frequent drawdowns (i.e. every year) are therefore not recommended. Spillway closure in May will allow re-filling of the lake by convective summer rains. In order to more firmly establish a recommended time span for board removal, research should focus on (1) analysis of average hourly wind speed throughout the year for the Newnans Lake watershed, and (2) hydrologic modeling to evaluate the refill potential of the lake following drawdown.

LITERATURE CITED

American Public Health Association. 1985. Standard methods for the examination of water and wastewater. Washington, D.C.: 1193 pp.

Bruno, N.A. 1984. Nest site selection by and spawning season vegetation associations of largemouth bass in Orange Lake, Florida. M.S. thesis, University of Florida: 94 pp.

Byrkit, D.R. 1975. Elements of statistics. D. van Nostrand Publ. Co, 2nd edition, New York, NY: 431 pp.

Canfield, D.E. Jr., J.V. Shireman, D.E. Colle, W.T. Haller, C.E. Watkins, and M.J. Maceina. 1984. Prediction of chlorophyll a concentrations in Florida lakes: Importance of aquatic macrophytes. Can. J. Fish. Aquat. Sci. 41: 497-501.

Collopy, M.W. and P. Bohall-Wood. 1986. Reintroduction of southern bald eagles: Recycling as a management technique. Final report. Department of Wildlife and Range Sciences, University of Florida: 12 pp.

Crisman, T.L. 1986a. Algal control through trophic level interactions: Investigations at Lakes Wauburg and Newnan's, Florida. Final report to Florida Dept. Natural Resources, Tallahassee, Florida: 178 pp.

Crisman, T.L. 1986b. Eutrophication control with an emphasis on macrophytes and algae. In N. Polunin (ed.), Ecosystem theory and application. John Wiley & Sons, Ltd.: 200-239.

Environmental Protection Agency. 1979. Methods for the chemical analysis of water and wastes. Method 351.2-Storet 00625, Corvalis, OR.

Florida Game and Fresh Water Fish Commission. 1982-1989. Fish management reports for the Northeast Florida Region. Lake City, Florida.

Fox, J.L., P.L. Brezonik, and M.A. Keirn. 1977. Lake drawdown as a method of improving water quality. E.P.A.-600/3-77005.

Frevert, T. 1979. The pe-redox concept in natural sediment-water systems; its role in controlling phosphorus release from lake sediments. Arch. Hydrobiol. [Supp.] 55: 278-297.

Goodrick, R.L. and J.F. Milleson. 1974. Studies of floodplain vegetation and water level fluctuation in the Kissimmee River Valley. Central and Southern Flood Control District, West Palm Beach, Florida: 60 pp.

Gottgens, J.F. 1987. Water resources of the Prairie Creek area. In M.T. Brown and R.G. Hamann (eds.), The Prairie Creek CARL project. Alachua County Conservation and Recreation Task Force, Florida: D1-4.

Gottgens, J.F. and C.L. Montague. 1987. Orange, Lochloosa, and Newnans lakes: A survey and preliminary interpretation of environmental research data. Final report, St. Johns River Water Management District. Palatka, FL: 82 pp.

Gottgens, J.F. and T.L. Crisman. 1992. Sediments of Newnan's Lake: Characteristics and patterns of redistribution following a short-term drawdown - Phase II. Final report, St. Johns River Water Management District. Palatka, FL: 49 pp.

Harris, S.W. and W.H. Marshall. 1963. Ecology of water level manipulations on a northern marsh. Ecology 44: 331-343.

Hestand, R.S. and C.C. Carter. 1975. Succession of aquatic vegetation in Lake Ocklawaha two growing seasons following a winter drawdown. Hyacinth Contr. J.13: 43-47.

Holcomb, D. and W. Wegener. 1971. Hydrophytic changes related to lake fluctuation as measured by point transects. Proc. 25th Ann. Conf. Southeastern Assoc. Game Fish Comm.: 570-583.

Holdren, G.C. Jr. and D.E. Armstrong. 1980. Factors affecting phosphorus release from intact lake sediment cores. Environ. Sci. Technol. 14 (1): 79-87.

Holly, J.B. 1976. Stratigraphy and sedimentary history of Newnan's Lake. M.S. thesis, University of Florida: 102 pp.

Huber, W.C., P.L. Brezonik, J.P. Heaney, R.E. Dickinson, S.D. Preston, D.S. Dwornik, and M.A. Demaio. 1982. A classification of Florida lakes. Dept. Environmental Engineering Sciences, University of Florida.

Kadlec, J.A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43: 267-281.

Maceina, M.J. and D.M. Soballe. 1990. Wind related limnological variation in Lake Okeechobee, Florida. Lake Reserv. Manag. 6(1): 93-100

Mickle A.M. and R.G. Wetzel. 1978. Effectiveness of submersed angiosperm-epiphyte complexes on exchange of nutrients and organic carbon in littoral systems. I. Inorganic nutrients. Aquatic Bot. 4: 303-316.

Mortimer, C.H. 1971. Chemical changes between sediments and water in the Great Lakes - Speculations on probable regulatory mechanisms. Limnol. Oceanogr. 16: 387-404.

Nesbitt, S.A. 1973. Wood stork nesting in north Florida. Florida Field Naturalist, vol 1.

Nordlie, F.G. 1976. Plankton communities of three central Florida lakes. Hydrobiologia 48 (1): 65-78.

Parenteau, C. 1987. Fauna of the proposed Prairie creek acquisition. In M.T. Brown and R.G. Hamann (eds.), The Prairie Creek CARL project. Alachua County Conservation and Recreation Task Force, Florida: E1-20.

Pollman, C.D. 1983. Internal loading in shallow lakes. Ph.D. dissertation, University of Florida, Gainesville.

Reid, G.K.Jr. 1952. Some considerations and problems in the ecology of floating islands. Quart. J. Fla. Acad. Sciences 15(1): 63-66.

Sederholm, H., A. Mauranen, and L. Montonen. 1973. Some observations on the microbial degradation of humous substances in water. Verh. Int. Verein. Limnol. 18: 1301-1305.

Sheng, P.Y. and W. Lick. 1979. The transport and resuspension of sediments in a shallow lake. J. Geophys. Res. 84: 1809-1826.

Somlyódy, L. 1982. Water-quality modelling: A comparison of transport-oriented and ecology-oriented approaches. Ecol. Modelling 17: 183-207.

Theis, T.L. and P.J. McCabe. 1978. Phosphorus dynamics in hypereutrophic lake sediments. Water Res. 12: 677-685.

Wegener, W. and V. Williams. 1974. Fish population responses to improved lake habitat utilizing an extreme drawdown. Proc. 28th Ann. Conf. Southeast. Assoc. Game and Fish Comm.: 144-161.

Wegener, W., V. Williams, and T.D. McCall. 1974. Aquatic macroinvertebrate responses to an extreme drawdown. Proc. 28th Ann. Conf. Southeast. Assoc. Game and Fish Comm.: 126-143.