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SECTION 1

INTRODUCTION

Lake Hancock is a large, hypereutrophic lake located southeast of the City of Lakeland and north of the City of Bartow in Polk County, Florida. With a surface area of approximately 4550 acres, Lake Hancock is the third largest lake in Polk County and the fourth largest lake in Florida. The drainage basin entering the lake covers 131 square miles and includes drainage from Lakeland and Aurburndale. Lake Hancock is characterized by persistent blue-green algal blooms, high nutrient concentrations, and widely fluctuating levels of dissolved oxygen and pH and has often been recognized as having some of the poorest water quality within the State. The lake contains approximately 18 million cubic yards of nutrient-rich flocculent bottom sediments which frequently resuspend into the overlying water column as a result of wind action. The lake is dominated by fish, vegetation, and wildlife populations which are indicative of hypereutrophic conditions.

A detailed evaluation was performed on Lake Hancock in 1986 by Zellars-Williams Company to prepare a preliminary nutrient budget and develop a restoration strategy for the lake. However, many changes have occurred in the watershed since the mid- to late-1980s which may alter the original nutrient budget prepared in 1986 and impact the previously identified restoration strategies. In 1997, the Southwest Florida Water Management District (District) contracted with Environmental Research & Design, Inc. (ERD) to develop current water and nutrient budgets for Lake Hancock which reflect changes occurring within the watershed since the previous study performed in 1986. The primary goal of this revised study is to identify, design, permit, and provide construction management for a water quality improvement project that would substantially improve the water quality of discharges from Lake Hancock into the Peace River. Water quality improvements in the Peace River are necessary to maintain desired populations of vegetation, fish, and wildlife as well as provide enhanced water quality in municipal withdrawals for potable use. A location map for Lake Hancock is given in Figure 1-1.

1.1 Scope

The work efforts outlined in this report were prepared as partial fulfillment of Agreement No. 98CON000172 titled "Lake Hancock Water and Nutrient Budget and Water Quality Improvement Project" between the District and ERD executed on September 21, 1998. The specific objectives of the Lake Hancock water quality project are to: (1) evaluate historical water quality characteristics in Lake Hancock; (2) develop revised water and nutrient budgets; (3) identify present-day nutrient loadings into the lake; and (4) evaluate an affordable water quality improvement project to enhance the water quality of discharges from the lake into the Peace River.

Evaluation of nutrient inputs into Lake Hancock involved a detailed investigation of inputs from stormwater runoff, baseflow, and groundwater seepage, along with estimates of inputs from bulk precipitation and internal recycling within the lake. Estimates and comparisons of pollutant inputs into Lake Hancock are provided to assist in understanding nutrient dynamics within the lake and identifying sources which must be controlled to improve water quality in the lake as well as reduce pollutants to downstream waterbodies.

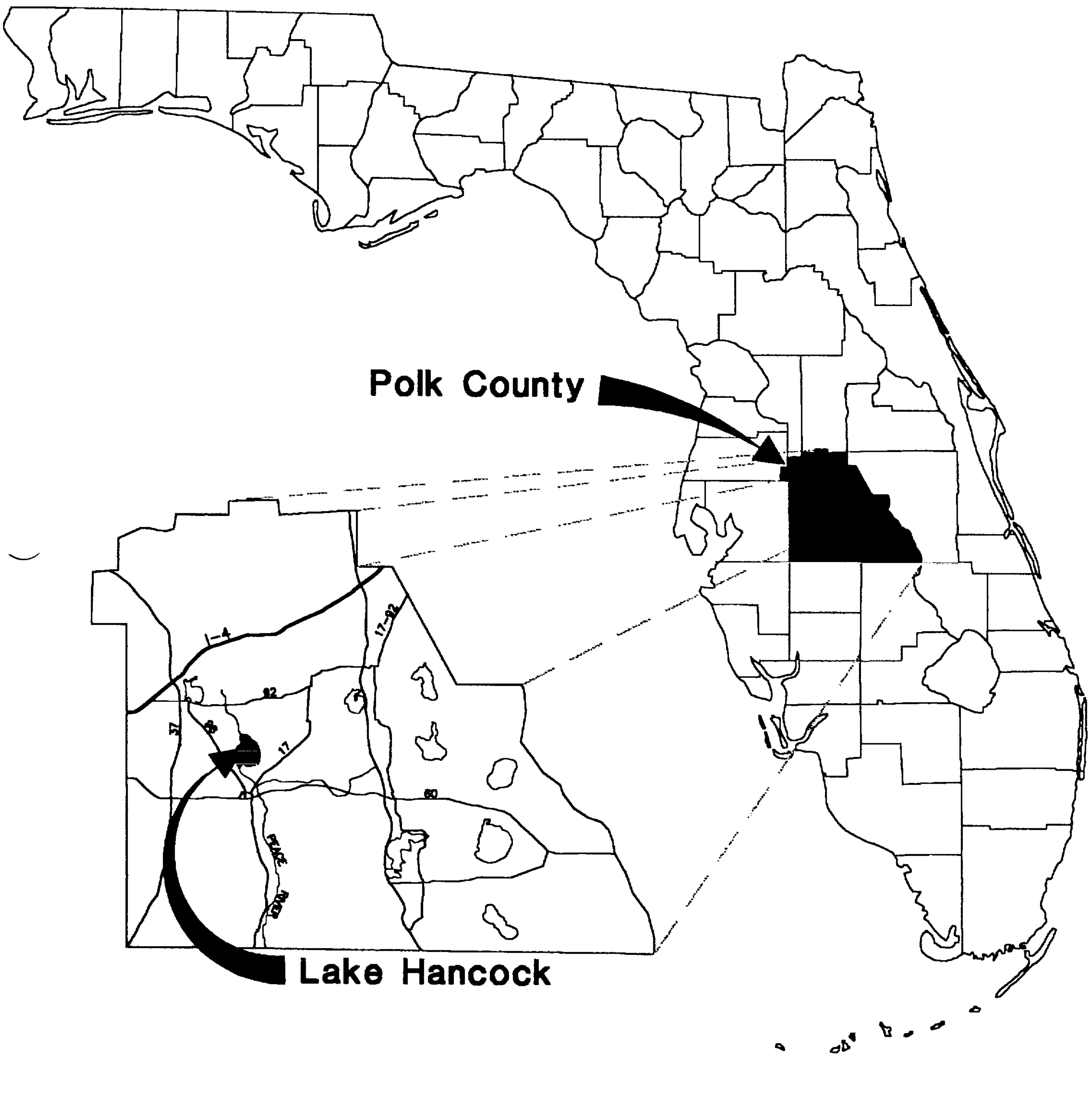


Figure 1-1. Location Map for Lake Hancock.

Work efforts for District Agreement No. 98CON000172 are divided into four separate phases. **Phase I - Project Selection Phase** consists of all work efforts outlined in this report. **Phase II - Preliminary Design,** along with **Phase III - Final Design and Environmental Permitting**, and **Phase IV - Bidding and Construction Services** will be performed at a future date following final selection and approval of the recommended water quality improvement project. Funding for this project was provided by the Southwest Florida Water Management District.

This report is divided into seven separate sections. Section 1 contains an introduction to the report and summarizes work efforts and tasks performed by ERD. Section 2 provides a historical review of water quality characteristics in Lake Hancock and summarizes current data collected and evaluated during this project. Section 3 provides a detailed description of the physical characteristics of the Lake Hancock drainage basin, including hydrology, soils, and land use. Estimates of hydraulic inputs from runoff, baseflow, precipitation, and groundwater seepage are summarized in Section 4. Section 5 contains an evaluation of nutrient and pollutant inputs to Lake Hancock, including a detailed nutrient budget for the lake. Section 6 contains a review of the evaluated water quality improvement options for water discharging from Lake Hancock.

SECTION 2

PHYSICAL AND CHEMICAL CHARACTERISTICS OF LAKE HANCOCK

2.1 Historical Background

Lake Hancock is a large meandered lake, located in central Polk County north of Bartow and west of Winter Haven. The lake is located in a portion of Polk County known as the Polk Upland Area. Lake Hancock is part of the upper Peace River Watershed which constitutes the head waters of the Peace River. The Peace River meanders through Polk, Hardy, De Soto, and Charlotte Counties before discharging into the Gulf of Mexico at Charlotte Harbor. Charlotte Harbor, and the entire Peace River watershed, including Lake Hancock, have been designated as a National Estuary. The Peace River is a regional system of state-wide importance which includes a number of beneficial uses such as wildlife habitat, flood drainage, natural resource recreation, and potable water supply. Lake Hancock is located in the Southwest Florida Water Management District.

Prior to 1962, Lake Hancock consisted primarily of a widened area along the flow path of Saddle Creek. The water level and surface area of the lake fluctuated widely, depending upon flow conditions in Saddle Creek. In 1962, a weir-dam structure was constructed in Saddle Creek, approximately 3500 ft south of Lake Hancock. This structure was used primarily to regulate discharges into the Peace River to reduce flooding in downstream river reaches. Since construction of the dam-weir structure, designated as Structure P-11, water surface elevations in Lake Hancock have been maintained at a relatively stable elevation. A summary of mean monthly lake levels in Lake Hancock from 1958-1999 is given in Appendix A.1 based upon information provided by Polk County. A plot of historical water surface elevations in Lake Hancock from 1958-1999 is given in Figure 2-1. Since construction of Structure P-11 in 1962, water level in Lake Hancock has been regulated primarily between elevation 97.0 and 98.5. A sinkhole formed in the lake in 1968 and rapidly drained the lake to elevation 94.4, exposing most of the organic bottom for a period of seven months.

Over the past 75 years, Lake Hancock has been heavily impacted by man-made activities, including domestic and industrial wastewater treatment plant discharges, urban development, agricultural activities, wetland destruction, and phosphate mining. Discharge of wastewater effluent into Saddle Creek from Lakeland and Auburndale began in 1926. Two citrus processing plants and a distillery in Auburndale began discharging effluent into Lake Lena Run.

In 1962, Coastal Petroleum Company conducted a feasibility study to investigate the possibility of mining phosphate ore located on the bottom of the lake. However, due to limited economic benefits, the plan was later abandoned. A large portion of the land areas on the west and south sides of Lake Hancock has been strip mined for phosphate ore and remains in a partially restored condition.

Concerns over water quality problems in Lake Hancock date back to the early 1950s when the Florida State Board of Health conducted an investigation of water quality in Lake Hancock and the entire Peace River basin prompted by severe industrial abuse of the river system. Domestic and industrial wastewater treatment plant effluent was discharged from the cities of Lakeland and Winter Haven into tributaries which ultimately reach Lake Hancock. As a result of the treatment plant discharges, Lake Hancock began to develop high nutrient concentrations and high levels of pathogenic bacteria. The growth of water hyacinths began to accelerate in the nutrient-rich water. Accumulation of organic matter within the lake began to occur as a result of hypereutrophic conditions within the lake and ongoing herbicide treatments

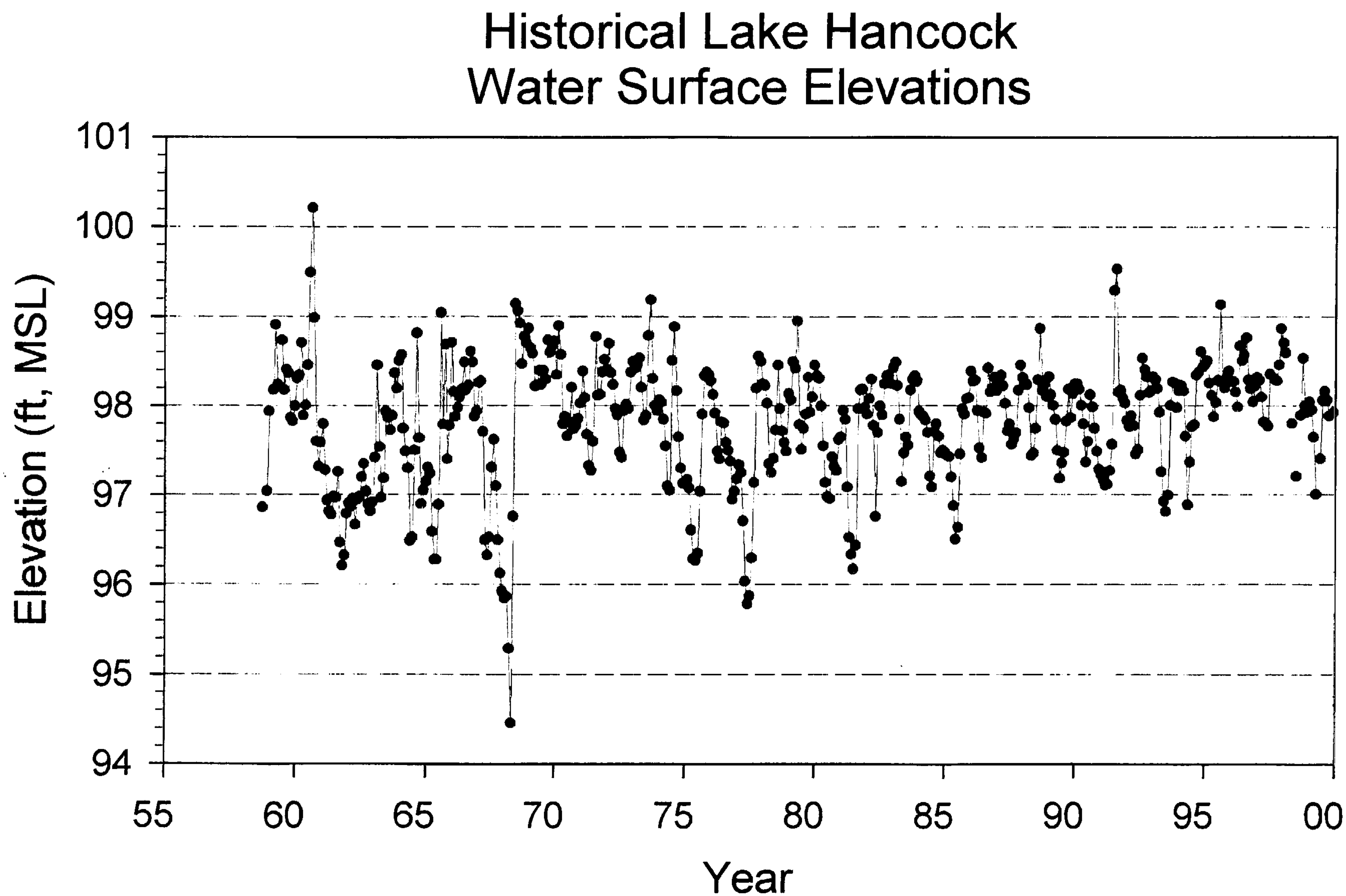


Figure 2-1. Water Surface Elevations in Lake Hancock from 1958-1999.
(SOURCE: Polk County)

to control water hyacinths. The rapid accumulation of organic matter in the lake was noted in 1969 by the Florida Game and Fresh Water Fish Commission which recommended immediate restoration measures for Lake Hancock that included deepening portions of the lake. The organic material on the bottom of Lake Hancock has accumulated to depths as much as 5.5 ft (1.7 m) thick, with an estimated 18 million cubic yards (13.8 x 10^6 m^3) of muck on the bottom of the lake. Water quality discharges from Lake Hancock have caused water quality impacts in the Peace River system as far south as Charlotte Harbor.

By the early 1990s, most of the domestic and industrial discharges into tributaries of Lake Hancock had been totally or partially eliminated. Small improvements in water quality characteristics followed these removals, although Lake Hancock remains in a highly polluted hypereutrophic condition. In 1991, the Florida Game and Fresh Water Fish Commission recommended a partial drawdown of Lake Hancock to consolidate portions of the organic sediments. Additional discussions concerning legislative directives and scientific studies on Lake Hancock are provided by Zellars-Williams (1987).

A revised mining option was evaluated during the late 1990s by IMC-Agrico but was rejected in 1998 due to environmental concerns. As part of this evaluation, IMC-Agrico performed a detailed sediment characterization study which included contour maps of water depth and sediment thickness, chemical analysis of lake bottom sediments for nutrients and metals, and a series of grain size analyses of the collected sediment samples. Sediments in Lake Hancock were found to be somewhat alkaline, with elevated levels of ammonia, NO_x, and TKN. Water depth contour maps for Lake Hancock are also included, indicating maximum water depths of approximately 4-4.5 ft. Estimated sediment thickness contours for Lake Hancock are also provided in the IMC-Agrico report. Estimated sediment thickness ranges from approximately 0.5 ft near the shoreline to 5.5 ft near the center of the lake. A summary of the results of the IMC-Agrico sediment characterization study is given in Appendix B.

In early 1999, representatives of the Florida Chapter of the Sierra Club approached the Polk County Board of County Commissioners and requested that Polk County initiate an effort to restore the upper Peace River system. Much of this discussion revolved around water quality improvement efforts for Lake Hancock. A committee of concerned and impacted parties was developed which was moderated and mediated by former Senator Rick Dantzler. Periodic committee meetings have been held with as many as 75 attendees per meeting, including adjacent property owners; local, regional, state and federal agencies; and environmental groups. The purpose of this group is to develop a consensus and direction for improvement of water quality in Lake Hancock and the Peace River system.

2.2 Physical Characteristics of Lake Hancock

A number of studies and technical reports have been published which provide physical and bathymetric characteristics of Lake Hancock. Due to the shallow nature of the lake, and the low surrounding topography, the surface area of Lake Hancock varies widely, depending upon water level elevation at the time of measurement. Published estimates of lake surface area range from approximately 4450 acres to more than 4600 acres. For purposes of this report, the published surface area of 4519 acres (Polk County, 1998) is assumed.

Under current conditions, the water level in Lake Hancock is maintained at a relatively uniform level throughout the year using the discharge weir (Structure P-11) located in Saddle Creek, downstream from Lake Hancock. This structure was built in 1962. A summary of annual lake level data for Lake Hancock from 1995-1998 is given in Table 2-1, based on information provided by Polk County (1998). Over this four year period, the mean water surface elevation in Lake Hancock was 98.24 ft (MSL), with a mean minimum water level of 97.61 ft and a mean maximum water level of 99.09 ft, corresponding to a mean water level fluctuation less than 1.5 ft (0.46 m). For purposes of this report, a mean water surface elevation of 98.24 ft (MSL) is assumed, based upon the mean water surface elevation from 1995-1998, since this value reflects current operational practices and patterns at Structure P-11. A complete listing of monthly historical lake level data for Lake Hancock from 1958-1999 is given in Appendix A.1.

TABLE 2-1

SUMMARY OF ANNUAL LAKE LEVEL DATA FOR LAKE HANCOCK FROM 1995-1998[1]

YEAR	MEAN LEVEL (ft, MSL)	MINIMUM LEVEL (ft, MSL)	MAXIMUM LEVEL (ft, MSL)
1995	98.32	97.87	99.13
1996	98.33	97.98	98.76
1997	98.21	97.77	98.86
1998	98.10	96.81	99.61
Mean Values	98.24	97.61	99.09

1. Polk County (1998)

A stage-volume relationship for Lake Hancock is given in Table 2-2, based upon information provided in the Zellars-Williams report (1987). At the assumed mean water level of 98.24 ft, the approximate water volume in Lake Hancock is 16,048 ac-ft (19,810,127 m^3). Based upon the previously assumed values for surface area and volume in Lake Hancock, the mean water depth is approximately 3.55 ft (1.08 m). A summary of physical characteristics of Lake Hancock is given in Table 2-3.

TABLE 2-2

STAGE/VOLUME RELATIONSHIP FOR LAKE HANCOCK

STAGE (El. MSL)	VOLUME	
	(ac-ft)	(m^3)
94	360	444,400
95	2,500	3,086,100
96	6,000	7,406,600
97	10,000	12,344,300
98	14,800	18,269,600
99	20,000	24,688,600
100	25,000	30,860,700
101	31,000	38,267,300
102	40,000	49,377,200

SOURCE: Zellars-Williams Company. (December 1987). "Final Report - Lake Hancock Restoration Study", Project No. 29-8047-00; DOE Contract No. 087-045; FIPR No. 86-04-034.

TABLE 2-3

PHYSICAL CHARACTERISTICS OF LAKE HANCOCK

PARAMETER	VALUE
Surface Area	4,519 ac (1,830 ha)[1]
Volume	16,048 ac-ft (19,810,127 m^3)
Mean Depth	3.55 ft (1.08 m)

1. Based on a mean water surface elevation of 98.24 from 1995-1998 (Polk County data)

2.3 Historical Water Quality Characteristics

A routine periodic water quality monitoring program was initiated in Lake Hancock by Polk County in 1984. Although sporadic water quality data and studies were conducted by several agencies prior to this date, the collected data was relatively limited and reflected samples collected primarily in response to water quality concerns. Therefore, it appears that the Polk County data represents the best single source of continuous water quality data for Lake Hancock.

The monitoring program initiated by Polk County in 1984 included three separate monitoring sites in Lake Hancock, designated as "center of lake", "eastern shore of lake", and "southwestern shore of lake". In general, surface water monitoring was performed at each of these monitoring locations on each of the individual monitoring dates from 1984 through 1990. Beginning in 1991, monitoring was performed only at the center of the lake. As a result, water quality characteristics discussed in this section will include only data collected at the center of the lake since this site provides the longest and most complete data set. A complete listing of the Polk County historical water quality data is given in Appendix A.2. A total of 32 separate surface water monitoring events have been performed over the 16-year period from 1984-1999, for a mean of two monitoring events each year. All water quality samples were collected approximately mid-way in the water column at each site.

A summary of mean water quality characteristics measured in Lake Hancock at the center station is given in Table 2-4. During the period from 1984-1999, water quality in Lake Hancock was extremely poor. The lake was characterized by extremely elevated levels of pH, total nitrogen, total phosphorus, turbidity, and chlorophyll-a. It appears that the majority of the measured nitrogen and phosphorus in the water column is particulate in form, presumably reflecting nutrients incorporated into algal biomass. Measured concentrations of total nitrogen in Lake Hancock are typically 3-4 times greater than values normally observed in urban lake systems, with total phosphorus concentrations approximately 10-20 times greater, and chlorophyll-a concentrations approximately 5-10 times greater than typical lake environments. The substantially elevated turbidity measurements collected in Lake Hancock are a direct reflection of the excessive rate of algal production and resuspension of sediment particles into the water column during periods of light to moderate wind activity.

TABLE 2-4

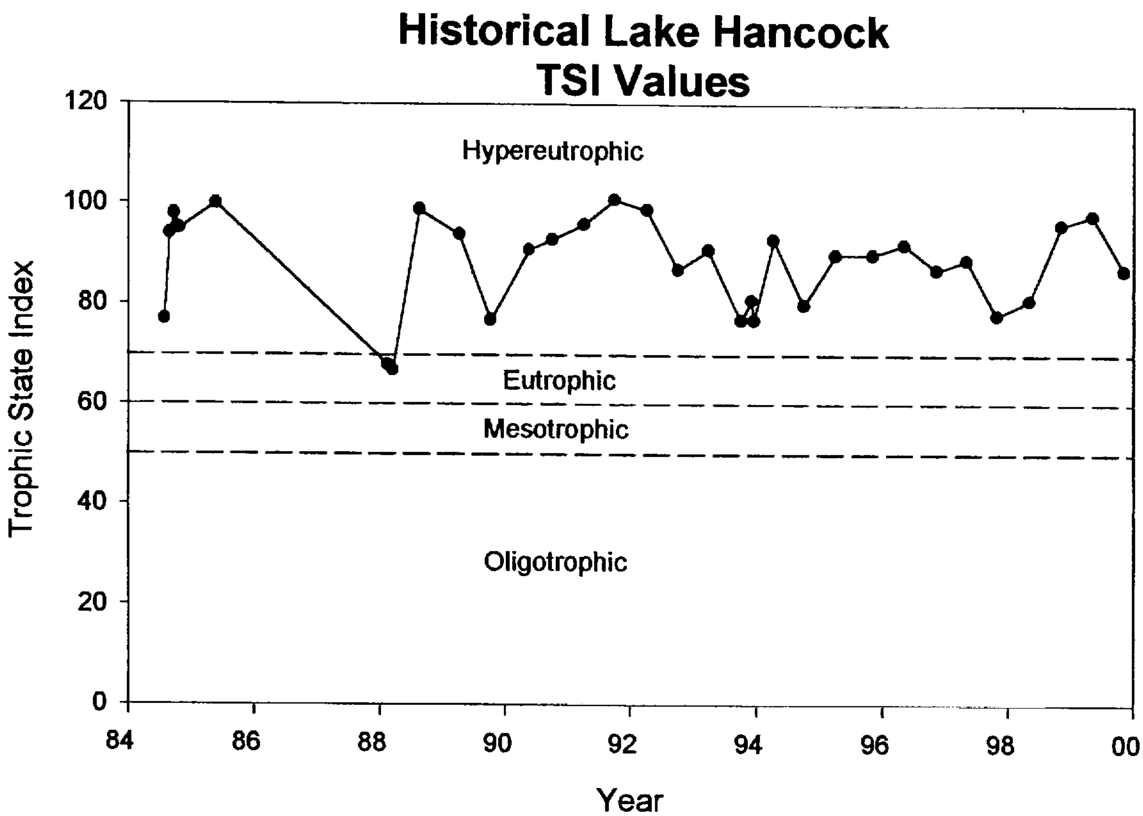
SUMMARY OF HISTORICAL WATER QUALITY CHARACTERISTICS IN LAKE HANCOCK FROM 1985-1999

PARAMETER	UNITS	MEAN VALUE[1]	MINIMUM VALUE	MAXIMUM VALUE
pH	s.u.	9.18	7.38	10.13
Diss. Oxygen	mg/l	8.6	0.9	15.7
Temperature	°C	24.0	15.6	34.3
Specific Conductivity	μmho/cm	275	170	456
Secchi Disk Depth	m	0.2	0.1	0.6
NH_3-N	μg/l	37	BDL[2]	200
NO_x-N	μg/l	10	BDL	50
Organic N	μg/l	5950	1470	15,400
Total N	μg/l	5990	1510	15,630
Total P	μg/l	628	105	2870
Turbidity	NTU	44.6	4.3	104
Color	Pt-Co	58	27	100
Chlorophyll-a	mg/m^3	170	34	350

1. n = 32 samples
2. BDL = Below Detectable Limits

Measured minimum and maximum water quality values in Lake Hancock from 1984-1999 are also provided in Table 2-4. Historically, it appears that water quality characteristics in Lake Hancock have been extremely variable, particularly for parameters such as pH, dissolved oxygen, specific conductivity, total nitrogen, total phosphorus, turbidity, and chlorophyll-a. Extreme variability in measured concentrations for these parameters is a typical characteristic of hypereutrophic lake systems. During the period from 1984-1999, measured pH values in Lake Hancock ranged from approximately neutral to more than 10.0. Similarly, dissolved oxygen concentrations have ranged from near-anoxic conditions to supersaturated conditions. Measured concentrations of total nitrogen have varied by more than an order of magnitude from 1510-15,630 μg/l. A 20-fold variability in total phosphorus was observed, with values ranging from 105-2870 μg/l. A 25-fold difference in turbidity values is also apparent in Table 2-4, with a 10-fold difference in measured values for chlorophyll-a. The reported historical water quality characteristics listed in Table 2-4 indicate that Lake Hancock is easily one of the most polluted lakes in the southeastern United States.

A plot of calculated TSI values for Lake Hancock from 1984-1999, based upon Polk County data, is given in Figure 2-2 based upon the Florida Trophic State Index (TSI), as presented by Brezonik (1984). Calculated TSI values in Figure 2-2 are based entirely on chlorophyll-a concentrations, since water column concentrations of total phosphorus and measured Secchi disk depth are impacted heavily by resuspension of bottom sediments as a result of wind action on the lake surface. As seen in Figure 2-2, with only a few exceptions, Lake Hancock has consistently exhibited hypereutrophic conditions during the past 15 years, with calculated annual mean TSI values ranging from 67-101. The overall mean calculated TSI value of approximately 91 is well into the hypereutrophic range. No trend of either improving or



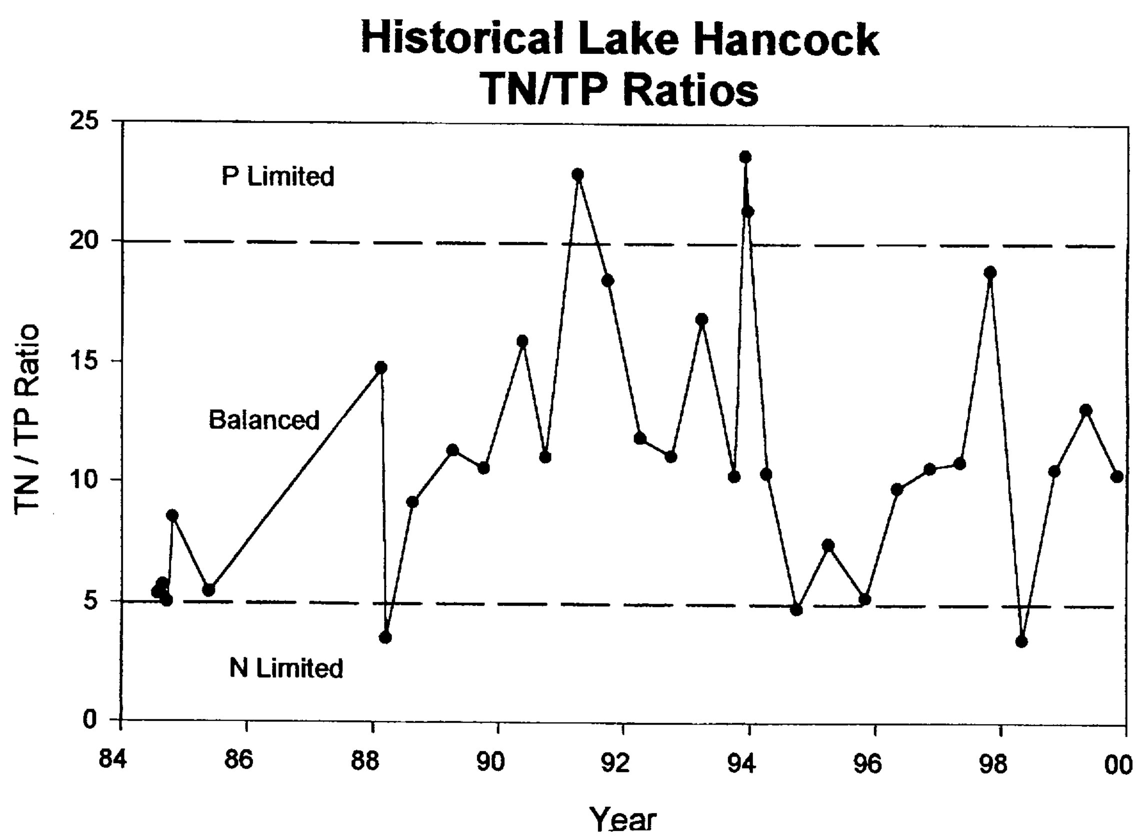


Figure 2-2. Variations in TSI and TN/TP Ratios in Lake Hancock from 1984-1999. (SOURCE: Polk County Data)

declining water quality characteristics is apparent in Figure 2-2, although water quality characteristics over the past 7-8 years appear to be less variable than water quality characteristics observed during the 1980s.

Variations in total nitrogen/total phosphorus (TN/TP) ratios in Lake Hancock from 1984-1999 are also summarized in Figure 2-2. Rates of TN/TP in excess of 20 are thought to suggest phosphorus-limitation, while TN/TP ratios less than 5 suggest nitrogen-limitation. Ratios between these values are either inconclusive or suggest nutrient-balanced conditions. Based upon these calculated ratios, Lake Hancock appears to oscillate between nutrient-balanced and phosphorus-limited conditions, with nitrogen-limitation occurring periodically.

The historical water quality data for Lake Hancock, summarized in Appendix A, was entered into a SAS database for further evaluation of water quality trends. An analysis of variance (ANOVA) comparison of water quality characteristics was performed by comparing water quality characteristics within Lake Hancock measured during the 1980s with water quality measured during the 1990s to determine if trends in water quality could be detected within the lake.

An ANOVA comparison of water quality characteristics in Lake Hancock during the 1980s and 1990s is given in Table 2-5. Mean values for measured water quality characteristics are presented for both the 1980s and 1990s, along with the results of Tukey's Multiple Comparison Test which evaluates the probability of statistically significant differences between the listed mean values for each period. Mean values represented by the same letter in Table 2-5 are not statistically different at the 0.05 level of significance. Values with different letters indicate statistically significant differences between the two measured values at the 0.05 level. No significant differences appear to exist between mean measured water quality characteristics during the 1980s and 1990s for many of the measured parameters. However, statistically significant changes appear to have occurred for total phosphorus, which has decreased substantially from 964 μg/l in the 1980s to a mean of 476 μg/l during the 1990s. A significant decrease in conductivity is also apparent, decreasing from 320 μmho/cm in the 1980s to 254 μmho/cm in the 1990s. Many of these changes in water quality characteristics may be related to the removal of wastewater effluent from tributaries discharging into Lake Hancock.

2.4 Current Water Quality Characteristics

A surface water monitoring program was conducted in Lake Hancock by ERD from October 1998 to July 1999. Surface water monitoring was performed on approximately a monthly basis, with a total of nine separate monitoring events performed during the monitoring period.

Surface water monitoring was performed at four fixed stations in Lake Hancock on each monitoring date. Locations used for collection of surface water samples are indicated on Figure 2-3. Monitoring sites were oriented in a north-south direction, similar to the primary flow path through the lake, to evaluate horizontal fluctuation in water quality characteristics.

2.4.1 Field Measurements

Physical-chemical profiles collected in Lake Hancock were found to be relatively similar between each of the four monitoring locations during the 1998-1999 monitoring period. Although specific measurements of temperature, pH and dissolved oxygen may vary slightly between the four monitoring sites, the same general trends of increasing or decreasing values with increasing water depth were observed at each individual monitoring site on a specific

TABLE 2-5

ANOVA COMPARISON OF WATER QUALITY CHARACTERISTICS DURING THE 1980s AND 1990s IN LAKE HANCOCK

PARAMETER	UNITS	PERIOD	NUMBER OF OBSERVATIONS	MEAN VALUE	TUKEY'S MULTIPLE COMPARISON
pH	s.u.	1990s 1980s	22 7	9.22 9.05	A A
Diss. Oxygen	mg/l	1990s 1980s	22 10	8.7 8.5	A A
Conductivity	µmho/cm	1980s 1990s	10 22	320 254	A B
Secchi Disk Depth	m	1980s 1990s	10 22	0.27 0.19	A A
NH_3	µg/l	1980s 1990s	10 22	51 31	A A
NO_x	µg/l	1980s 1990s	10 22	23 5	A B
Organic N	µg/l	1980s 1990s	10 22	6377 5750	A A
Total N	µg/l	1980s 1990s	10 22	6448 5785	A A
Total P	µg/l	1980s 1990s	10 22	964 476	A B
Turbidity	NTU	1990s 1980s	22 9	45.3 42.7	A A
Color	Pt-Co	1990s 1980s	22 9	61 53	A A
Chlorophyll-a	mg/m^3	1980s 1990s	10 22	176 167	A A
TSI Value	--	1990s 1980s	22 10	88.8 86.9	A A

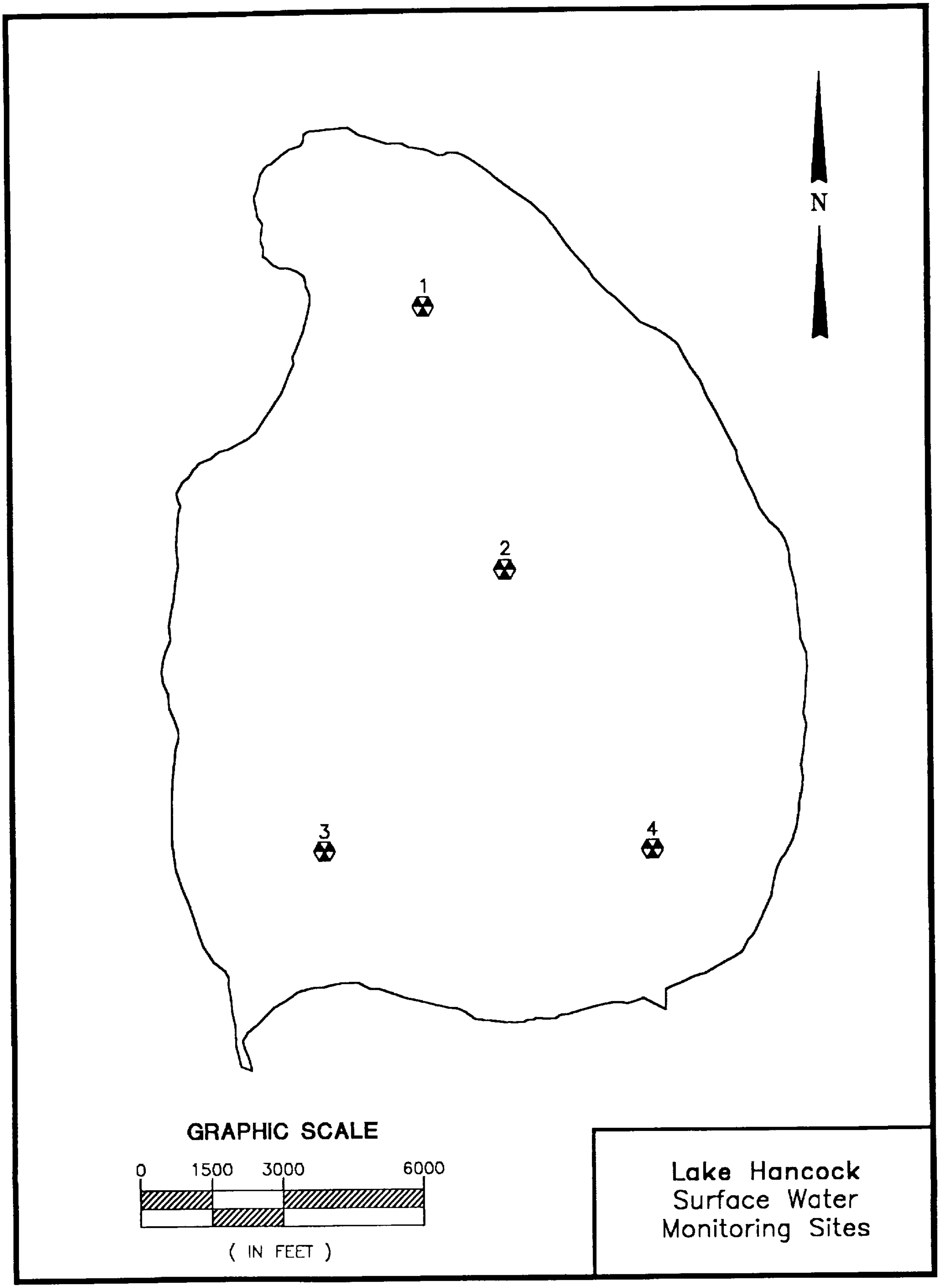


Figure 2-3. Surface Water Monitoring Sites in Lake Hancock.

monitoring date. Therefore, a discussion of physical-chemical profiles collected at Site 2, located near the center of Lake Hancock, is presented for a generalized description of physical-chemical characteristics throughout the lake. A complete listing of physical-chemical profiles collected in Lake Hancock from October 1998 to July 1999 is given in Appendix C.

A summary of field measured values of pH, conductivity, temperature, dissolved oxygen, oxidation-reduction potential (ORP), and Secchi disk depth is given in Table 2-6. Values summarized in this table reflect measurements performed at a depth of 0.5 m at each of the four monitoring sites indicated on Figure 2-3.

TABLE 2-6

MEAN FIELD MEASURED CHARACTERISTICS IN LAKE HANCOCK FROM OCTOBER 1998 TO JULY 1999[1]

PARAMETER[2]	UNITS	MEAN VALUE	MINIMUM VALUE	MAXIMUM VALUE
pH	s.u.	9.44	6.47	10.93
Specific Conductivity	μmho/cm	241	174	496
Temperature	°C	25.27	18.72	30.42
Dissolved Oxygen	mg/l	10.6	0.3	17.2
ORP	mv	596	234	703
Secchi Disk Depth	m	0.21	0.09	0.38

1. n = 36 samples
2. Measured at a depth of 0.5 m

2.4.1.1 pH

As seen in Table 2-6, a high degree of variability is apparent in field measured values for each of the listed parameters. Measured pH values at a depth of 0.5 m in Lake Hancock exhibited a substantial degree of variability, ranging from slightly acidic conditions at a pH of

6.47 to highly alkaline conditions at a pH of 10.93. This range of pH values reflects a 30,000-fold fluctuation in hydrogen ion concentrations within the lake. The high degree of variability in measured pH values is directly related to diurnal fluctuations in pH as well as the location of the photic zone compensation point in relation to the 0.5 m depth at which the data was collected. The overall mean pH value of 9.44 is typical for hypereutrophic lakes with accelerated levels of algal production.

2.4.1.2 Specific Conductivity

A high degree of variability is also apparent in measured values for specific conductivity in Lake Hancock, with measured values at a depth of 0.5 m ranging from 174-496 μmho/cm. Fluctuations in specific conductivity values may be related to fluctuations in the inflows coming into the lake. However, internal recycling, particularly during periods of windy conditions, may also contribute significant quantities of dissolved ions into the overlying water column.

2.4.1.3 Dissolved Oxygen and ORP

As seen in Table 2-6 and in Appendix C, the water column in Lake Hancock is characterized by extreme fluctuations in concentrations of dissolved oxygen. Dissolved oxygen concentrations within Lake Hancock at a depth of 0.5 m ranged from near-anoxic conditions with a concentration of 0.3 mg/l, to supersaturated concentrations in excess of 17 mg/l. Similarly, measured ORP values ranged from mildly reduced conditions (234 mv) to highly oxidized conditions (703 mv). The oxygen regime in Lake Hancock is highly impacted by the explosive rate of algal production within the lake. A tremendous oxygen sink is also present in the highly organic sediment material within the lake. The amount of dissolved oxygen in the water column at any given time is a function of the relative significance of the primary production processes compared with decomposition and respiration processes occurring in the sediments in addition to the location of the photic zone compensation point with respect to the 0.5 m sample depth. The fact that near-anoxic conditions could exist in a waterbody at a depth of only 0.5 m is another indication of the severely degraded condition of Lake Hancock.

2.4.1.4 Secchi Disk Depth

In general, water column visibility in Lake Hancock is extremely poor. Measured Secchi disk values ranged from 0.09 m to a maximum of 0.38 m, with an overall mean Secchi disk depth of 0.21 m. This information suggests that the average water column visibility in Lake Hancock ranges from a few inches to a maximum of approximately 1 ft. Water column visibility is limited substantially by algal biomass within the water column, as well as resuspension of bottom sediments during periods of wind activity on the lake. The low water column visibility observed in Lake Hancock is a common characteristic in hypereutrophic lake systems.

2.4.1.5 Vertical Profiles

Based on field monitoring performed by ERD, Lake Hancock appears to be a polymictic lake, with frequently alternating stratified and unstratified conditions. In general, under calm conditions, Lake Hancock rapidly stratifies with the majority of the algal biomass located in the upper 0.25-0.5 m of the water column. This surface zone of algal biomass and high productivity absorbs much of the solar radiation reaching the surface of the lake, creating a warm surface layer and a cool bottom layer. Elevated levels of pH and dissolved oxygen also begin to develop in the surface zone. The water column below a depth of 0.5 m becomes isolated from solar radiation, and decomposition and respiration processes begin to dominate. This creates a substantial reduction in measured pH values and depletion of much of the dissolved oxygen from the water column.

Mixing and circulation of the water column in Lake Hancock can be accomplished easily by afternoon convection winds due to the shallow water column and long fetch of the lake. These periods of circulation provide mixing of the water column and provide more uniform values for pH and dissolved oxygen in upper parts of the water column. However, substantial decreases in pH and dissolved oxygen are still observed near the bottom sediments even during periods of circulation within the lake.

A comparison of typical stratified and unstratified vertical profiles of temperature, pH, specific conductivity, and dissolved oxygen in Lake Hancock is given in Figure 2-4. Stratified conditions in Lake Hancock are illustrated by physical-chemical profiles collected on May 11, 1999, while unstratified conditions are illustrated by vertical profiles collected on February 27, 1999.

As seen in Figure 2-4, water column temperature decreases steadily with increasing water depth under well-mixed conditions (2/27/99). A temperature difference of approximately 2-3°C exists between the water surface and bottom sediments. Under stratified conditions, the majority of the solar radiation is absorbed in the upper portions of the water column, creating a warm upper zone with a sharp thermocline at a depth of approximately 0.5 m. On May 11, 1999, a temperature decrease of approximately 6°C was observed within the first 0.5 m, followed by a temperature decrease of approximately 0.5°C from 0.5 m to 1.0 m.

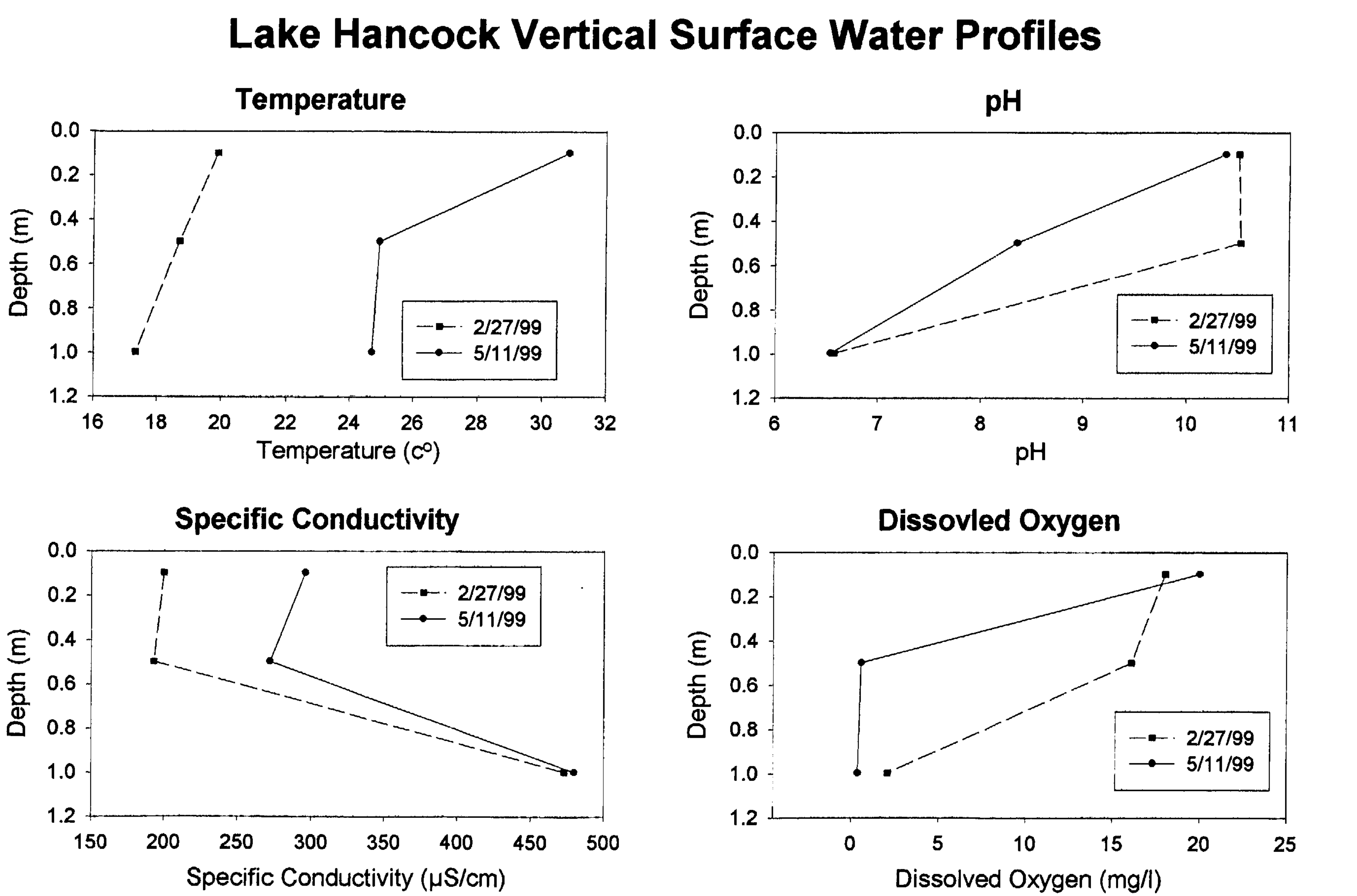


Figure 2-4. Typical Stratified and Unstratified Vertical Profiles in Lake Hancock.

Under well-mixed conditions, elevated pH values extend to a depth of approximately 0.5 m. However, below this depth, pH values drop rapidly, reaching a near-constant level of approximately 6.5 near the bottom sediments. It is not unusual to see a pH decrease of 4-5 units between a depth of 0.5 m and 1.0 m in Lake Hancock. Under well-mixed conditions, a gradual decrease in pH occurs from the water surface to the bottom sediments, although the overall change in pH is similar to that observed during stratified conditions.

As seen in Figure 2-4, dissolved oxygen concentrations in Lake Hancock exhibit super-saturated conditions near the water surface, with a rapid decline to near-anoxic conditions at the sediment/water interface. During periods of circulation in the lake, typically defined by concentrations in excess of 5 mg/l, adequate dissolved oxygen extends to a depth of approximately 0.8 m into the water column. Under stratified conditions, adequate levels of dissolved oxygen typically extend to a depth of approximately 0.4 m in the water column. Near-anoxic conditions are typically observed at depths in excess of 0.5 m under stratified conditions. The near-anoxic conditions near the bottom sediments provide an ideal environment for generation of toxic gases as well as release of phosphorus and other dissolved ions into the overlying water column.

Under well-mixed conditions, specific conductivity in the upper portions of the water column less than 0.5 m deep is relatively uniform. However, a substantial increase in specific conductivity is observed between a depth of 0.5 m and the lake bottom. In general, measured specific conductivity increased by approximately 100-200% near the water sediment surface, compared with values measured at a depth of 0.5 m. Under stratified conditions, specific conductivity decreases slightly at a depth of 0.5 m, presumably due to uptake of ions from the water column by algal biomass. However, specific conductivity increases substantially from

0.5 m to the lake bottom. The dramatic increase in specific conductivity observed near the bottom of the lake is a strong indication of significant internal recycling within the lake and release of large amounts of ions from the bottom sediments into the overlying water column on a continuous basis during both stratified and unstratified conditions.

2.4.2 Laboratory Parameters

Surface water samples were collected at each of the four monitoring sites in Lake Hancock during each of the nine monitoring events. Collected surface water samples were returned to the ERD laboratory for chemical analysis of general parameters, nutrients, and demand parameters. A complete listing of laboratory analyses performed on surface water samples collected at each of the four monitoring sites is given in Appendix D.

One of the primary objectives of the multi-site monitoring program performed by ERD was to evaluate the extent of horizontal variations in water quality characteristics, which are often observed in a large lake such as Lake Hancock. To evaluate this potential, water quality data collected at each of the four monitoring sites was entered into a SAS database for further evaluation of water quality trends. An ANOVA comparison of water quality characteristics was performed by comparing water quality characteristics collected at each of the four monitoring sites. A summary of the ANOVA statistics for comparison of surface water sites in Lake Hancock is given in Table 2-7. Mean values for observed water quality characteristics are presented for each of the four monitoring sites, along with the results of Tukey's multiple comparison test which evaluates the probability of statistically significant differences between the monitoring sites. The values represented by the same letter in the final column of Table 2-7 are not statistically different at the 0.05 level of significance.

TABLE 2-7

ANOVA COMPARISON OF SURFACE WATER CHARACTERISTICS AT LAKE HANCOCK MONITORING SITES

PARAMETER	UNITS	SITE	MEAN VALUE	TUKEY'S MULTIPLE COMPARISON
pH	s.u.	1 2 4 3	9.82 9.73 9.35 8.85	A A A A
Spec. Conductivity	μmho/cm	4 3 2 1	270 262 217 214	A A A A
Diss. Oxygen	mg/l	1 4 2 3	11.9 11.1 11.0 8.3	A A A A
Secchi Disk Depth	m	1 4 3 2	0.22 0.21 0.20 0.20	A A A A
Alkalinity	mg/l	1 2 3 4	55.3 51.3 47.8 47.3	A A A A
NH_3-N	μg/l	4 1 2 3	57 21 20 12	A A A A
NO_x-N	μg/l	1 4 2 3	69 18 12 11	A A A A
Diss. Organic N	μg/l	2 4 3 1	1674 1669 1643 1548	A A A A
Particulate N	μg/l	2 1 3 4	4904 4252 4204 3743	A A A A

TABLE 2-7 (Continued)

ANOVA COMPARISON OF SURFACE WATER CHARACTERISTICS AT LAKE HANCOCK MONITORING SITES

PARAMETER	UNITS	SITE	MEAN VALUE	TUKEY'S MULTIPLE COMPARISON
Total N	μg/l	2	6610	A
		1	5889	A
		3	5869	A
		4	5487	A
Orthophosphorus	μg/l	1	14	A
		4	13	A
		2	9	A
		3	8	A
Particulate P	μg/l	2	540	A
		3	457	A
		1	439	A
		4	391	A
Total P	μg/l	2	580	A
		3	501	A
		1	482	A
		4	441	A
BOD	mg/l	2	19.1	A
		1	17.9	A
		3	17.4	A
		4	17.1	A
Turbidity	NTU	3	320	A
		4	246	A
		2	243	A
		1	187	A
Color	Pt-Co	4	52	A
		2	51	A
		1	51	A
		3	49	A
Chlorophyll-a	mg/m^3	2	223	A
		1	218	A
		3	204	A
		4	187	A

As seen in Table 2-7, no statistically significant differences were observed in water quality characteristics measured at any of the four monitoring sites. Apparently, the measured variability in water quality characteristics at each site is sufficient to mask any significant differences between the individual sites. Therefore, for all practical purposes, Lake Hancock appears to be relatively well-mixed on a horizontal plane.

However, even though statistically significant differences were not observed between the four monitoring sites, several distinct patterns in water quality characteristics are apparent. As seen in Figure 2-3, the primary flow path for water in Lake Hancock is north to south, with the dominant water movement impacting Site 1, followed by Site 2 and finally Site 3. Site 4 is away from the primary flow path of the lake. As seen in Table 2-7, specific conductivity increases substantially during migration through the lake from Site 1 to Site 3. An even higher mean value for specific conductivity is observed at Site 4. These measured increases suggest the release of dissolved ions from the sediments into the overlying water column as water migrates through the lake.

Another trend which is apparent is the general decrease in concentrations of inorganic nitrogen and phosphorus during migration through the lake from north to south, presumably resulting from nutrient uptake by algal species during migration through the lake. As a final trend, many of the measured parameters appear to peak in concentration in the center of the lake. Maximum concentrations of particulate nitrogen, BOD, dissolved organic nitrogen, total nitrogen, total phosphorus, and chlorophyll-a were observed in the center of the lake at Site 2 compared with values measured at the remaining three sites.

In view of the apparent lack of horizontal variations in water quality characteristics in Lake Hancock, collected water quality data for each site were grouped together into a common database for evaluation of overall water quality characteristics within the lake. A summary of laboratory-measured mean water quality characteristics in Lake Hancock from October 1998-July 1999 is given in Table 2-8. Values listed in this table represent the mean of all water quality data measured in the lake based on monitoring performed by ERD. Similar to the trends exhibited by field-measured parameters in Table 2-6, a high degree of variability is also apparent in laboratory-measured characteristics. Differences between minimum and maximum values for many parameters such as NH_3, NO_x, orthophosphorus, and turbidity covered more than two orders of magnitude, while the remaining parameters spanned over one order of magnitude between minimum and maximum values. Extreme variability in water quality parameters is a common characteristic of hypereutrophic systems.

2.4.2.1 Alkalinity and Color

In general, the water column in Lake Hancock appears to be moderately well-buffered, with whole-lake mean alkalinity values ranging from 19.0-89.3 mg/l. Measured values in this range are typical of values observed in lake systems in Central Florida. The overall mean alkalinity value measured in Lake Hancock is 50.4 mg/l.

The water column in Lake Hancock was found to contain moderately high levels of color, with measured concentrations ranging from 34-94 Pt-Co units. The observed color within the water column of the lake is primarily due to highly colored inflow entering the lake through the primary inflow canals. Release of color from the bottom sediments as a result of decomposition processes may also contribute measurable amounts of color.

TABLE 2-8

MEAN LABORATORY-MEASURED WATER QUALITY CHARACTERISTICS IN LAKE HANCOCK FROM OCTOBER 1998 TO JULY 1999[1]

PARAMETER	UNITS	MEAN VALUE	MINIMUM VALUE	MAXIMUM VALUE
Alkalinity	mg/l	50.4	19.0	89.3
NH_3	μg/l	27	< 5	385
NO_x	μg/l	27	< 5	302
Diss. Organic N	μg/l	1634	1023	2674
Particulate N	μg/l	4276	842	10,285
Total Nitrogen	μg/l	5964	2727	11,936
Orthophosphorus	μg/l	11	1	68
Particulate Phosphorus	μg/l	457	139	1262
Total Phosphorus	μg/l	501	168	1291
Turbidity	NTU	249	18	1000
TSS	mg/l	115	27	313
BOD	mg/l	17.9	5.1	34.0
Color	Pt-Co	51	34	94
Chlorophyll-a	mg/m^3	208	63	425
TN/TP Ratio	--	13	8	23

1. n = 36 samples

2.4.2.2 Nitrogen Species

Mean concentrations of ammonia and NO_x appear to be relatively low in value in Lake Hancock, although measured concentrations exhibited a relatively high range of values. Measured values for these nitrogen species were found at below detectable limits on several monitoring dates, indicating possible nitrogen limitation within the lake. On an average basis, inorganic species of ammonia and NO_x represent less than 1% of the total nitrogen measured within the lake.

The dominant nitrogen species in Lake Hancock is particulate nitrogen, representing nitrogen presumably incorporated into algal biomass. On an average basis, particulate nitrogen represents approximately 72% of the total nitrogen measured in the lake. Dissolved organic nitrogen comprises approximately 27% of the total nitrogen within the lake.

Mean total nitrogen concentrations in Lake Hancock ranged from approximately 2700 μg/l to more than 11,900 μg/l, with an overall mean of 5964 μg/l. Values in this range are extremely elevated compared with total nitrogen concentrations typically observed in urban lake systems. A large portion of the total nitrogen measured in the lake during periods of sustained wind activity is particulate matter which has been suspended into the water column as a result of the wind activity. Variations in measured total nitrogen concentrations in Lake Hancock from October 1998 to July 1999 are illustrated in Figure 2-5.

In summary, nitrogen species in Lake Hancock appear to be dominated by dissolved organic nitrogen and particulate nitrogen forms, which together comprise approximately 99% of the total nitrogen measured in the lake. Inorganic species of ammonia and NO_x are relatively low in value in Lake Hancock. Total nitrogen concentrations in Lake Hancock appear to be extremely elevated compared with typical urban lake systems.

2.4.2.3 <u>Phosphorus Species</u>

Mean orthophosphorus concentrations in Lake Hancock were found to be highly variable, ranging from 1-68 μg/l. The overall mean orthophosphorus concentration of 11 μg/l is somewhat elevated in value and suggests an abundance of inorganic phosphorus species within the lake, particularly in comparison to the scarcity of inorganic nitrogen species. On an average basis, dissolved orthophosphorus contributes less than 2% of the total phosphorus measured in

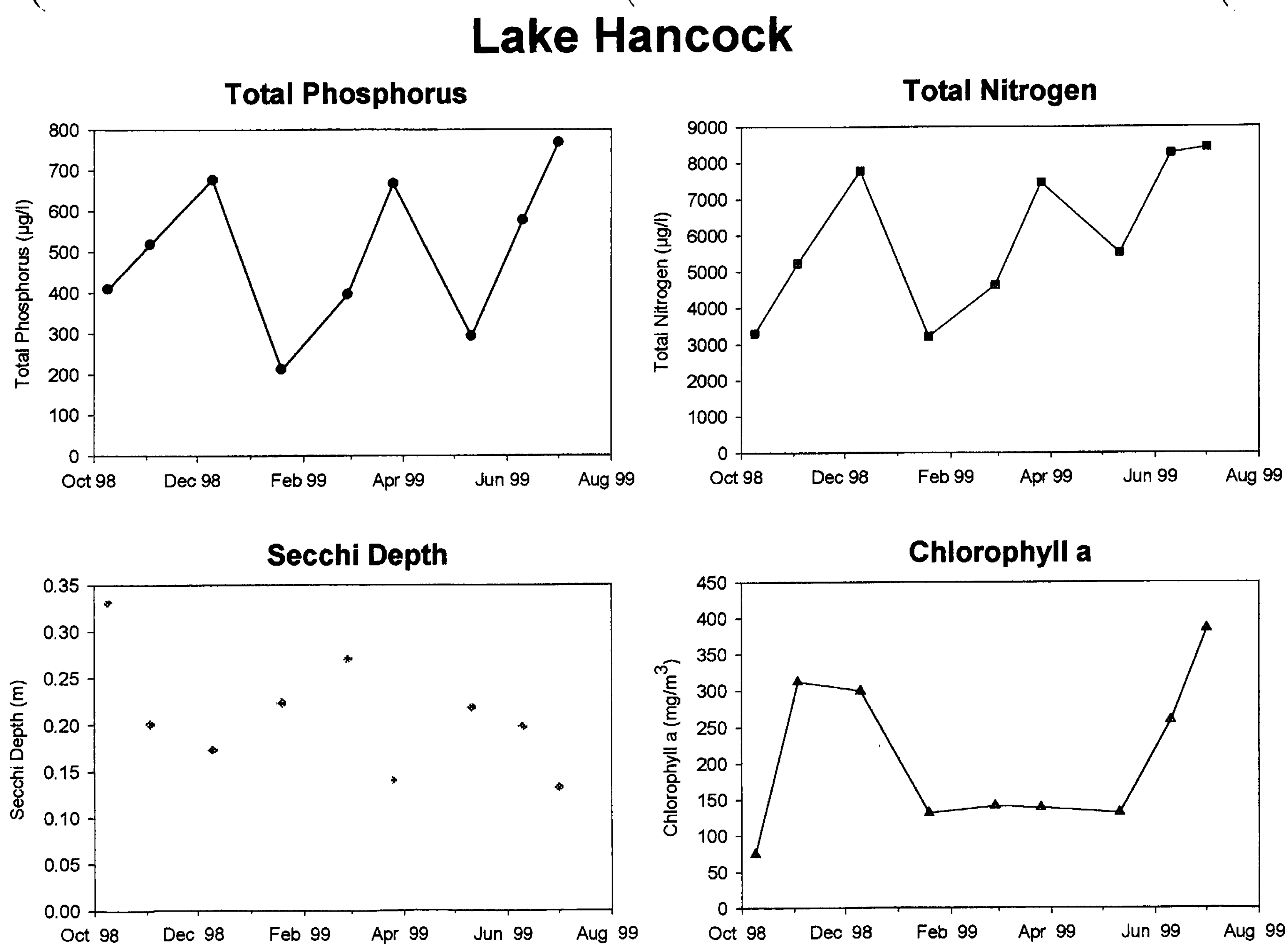


Figure 2-5. Variations in Measured Values of Total Phosphorus, Total Nitrogen, Secchi Disk Depth, and Chlorophyll-a in Lake Hancock from October 1998 to July 1999. (SOURCE: ERD Data)

Lake Hancock. The dominant phosphorus species in Lake Hancock is clearly particulate phosphorus, which comprises more than 98% of the total phosphorus in the lake. Particulate phosphorus observed in the lake is presumably a result of excess algal biomass along with resuspended sediment material.

Total phosphorus concentrations in Lake Hancock were found to be highly variable, ranging from 168-1291 μg/l. Variations in measured total phosphorus concentrations in Lake Hancock from October 1998 to July 1999 are illustrated in Figure 2-5. Much of this variability is related to resuspension of bottom material during wind-driven events. The overall mean total phosphorus concentration of 501 μg/l is extremely elevated and places Lake Hancock in the 95-99 percentile for lake systems within the State of Florida with respect to total phosphorus concentrations.

2.4.2.4 Turbidity, TSS and BOD

Measured turbidity levels in Lake Hancock were found to be extremely variable between the individual monitoring dates. Mean values for turbidity at the four monitoring sites ranged from a low of 18 NTU to a high of 1000 NTU, with an overall mean of 249 NTU. These turbidity values are several orders of magnitude greater than measurements typically observed in urban lake systems. The increased turbidity in Lake Hancock is a direct result of the tremendous amount of algal biomass within the lake along with the resuspended inorganic sediment particles. The overall mean turbidity value of 249 NTU is substantially greater than the Class III surface water criterion for turbidity of 29 NTU, outlined in Chapter 62-302 of the Florida Administrative Code (FAC).

Levels of total suspended solids (TSS) in Lake Hancock also appear to be extremely elevated, as well as highly variable, with measured concentrations ranging from 27-313 mg/l. The overall mean TSS concentration of 115 mg/l is extremely elevated for an urban lake system, which typically has TSS concentrations less than 10 mg/l. The elevated TSS levels observed in Lake Hancock are a direct result of algal biomass and resuspended sediment matter.

Similar to the trends observed for turbidity and TSS, measured concentrations of BOD in Lake Hancock also appear to be extremely elevated as well as highly variable, with measured concentrations ranging from 5.1-34.0 mg/l. The overall mean BOD value of 17.9 mg/l is extremely elevated for an urban lake system and represents a continuous oxygen demand within the lake which must be continuously satisfied. Typical BOD concentrations in the range of values measured in Lake Hancock can quickly create oxygen depletion in the water column when algal production and primary productivity become restricted.

2.4.2.5 Chlorophyll-a

In general, extremely elevated chlorophyll-a levels were observed in Lake Hancock on each of the individual monitoring dates. Mean whole-lake chlorophyll-a values ranged from 63-425 mg/m^3, with an overall mean of 208 mg/m^3. Chlorophyll-a concentrations measured in Lake Hancock reflect the highest chlorophyll-a values ever measured by ERD in large lake systems within the State of Florida. The tremendous rate of algal production within Lake Hancock depends upon continuous nutrient inputs which are necessary to support and sustain the high rate of algal growth. Variations in measured chlorophyll-a concentrations in Lake Hancock from October 1998 to July 1999 are illustrated in Figure 2-5.

2.4.2.6 TSI Values

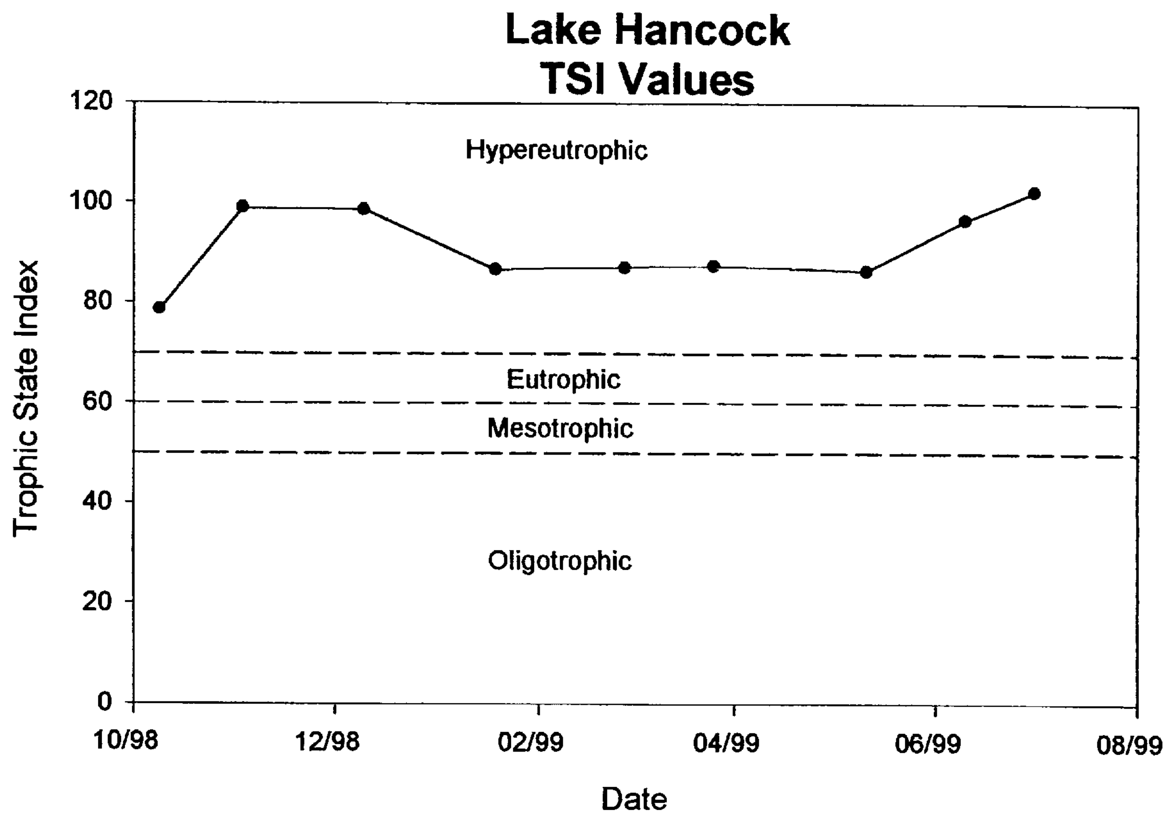
Variations in TSI values in Lake Hancock from October 1998 to July 1999 are illustrated in Figure 2-6. Lake Hancock exhibited hypereutrophic conditions on each of the monitoring dates, with calculated TSI values ranging from approximately 80-100.

2.4.2.7 TN/TP Ratio

Calculated TN/TP ratios in Lake Hancock ranged from 8-23, with a mean ratio of 13. Variations in TN/TP ratios in Lake Hancock from October 1998 to July 1999 are illustrated in Figure 2-6. These values suggest that Lake Hancock exists primarily in a nutrient-balanced condition, although both nitrogen- and phosphorus-limitations can occur at times.

2.4.3 Water Quality Characteristics of Structure P-11

As indicated previously, surface water monitoring was also performed on a periodic basis at Structure P-11 to characterize water quality in discharges from Lake Hancock. In general, water quality characteristics at Structure P-11 were found to be relatively similar to water quality characteristics measured in other areas of the lake. A comparison of water quality characteristics measured at monitoring Site 3, located in the southwest quadrant of Lake Hancock, and Structure P-11 is given in Table 2-9. Although water quality characteristics at the two sites are relatively similar, it appears that a portion of the particulate matter within the water column may be settling out within Saddle Creek prior to reaching Structure P-11. Mean water quality characteristics at Structure P-11 suggest slight reductions in measured concentrations of dissolved organic nitrogen, particulate nitrogen, total nitrogen, particulate phosphorus, total phosphorus, turbidity, TSS, BOD, and chlorophyll-a compared with values



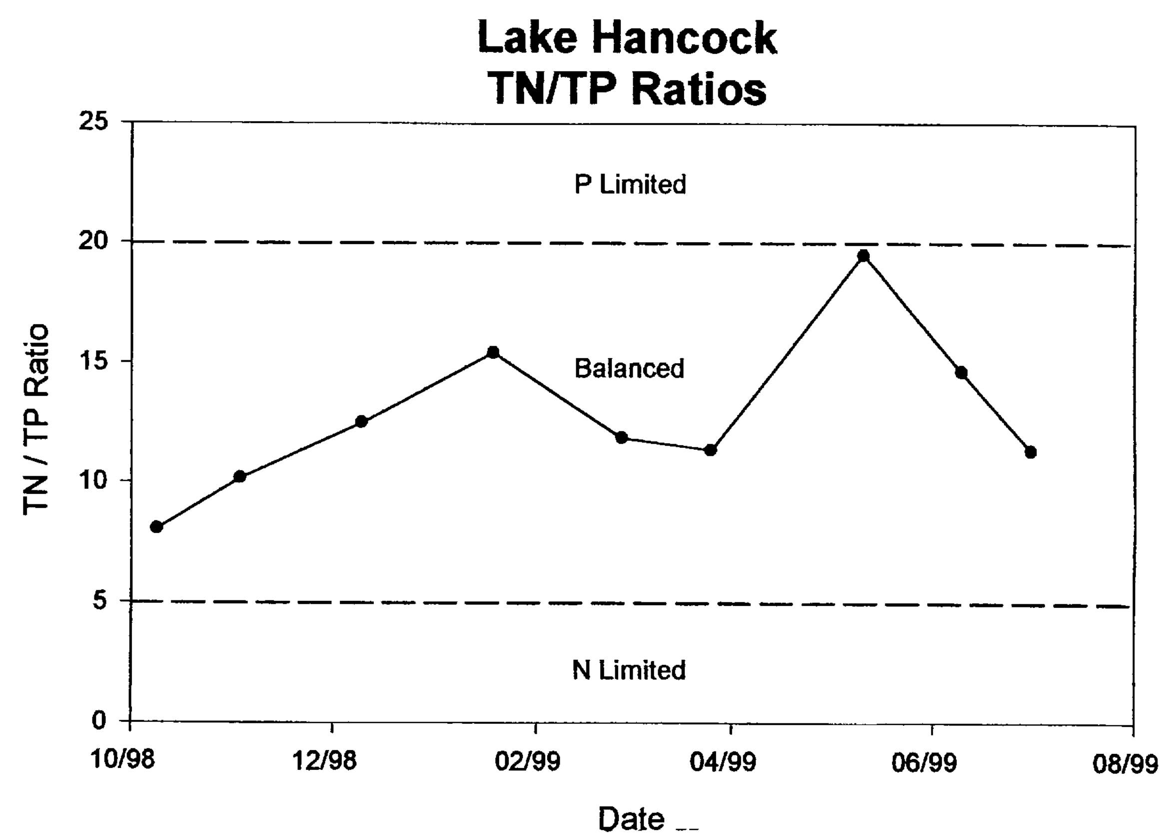


Figure 2-6. Variations in TSI and TN/TP Ratios in Lake Hancock from October 1998 to July 1999. (SOURCE: ERD Data)

measured at Site 3. As seen in Table 2-9, measured concentrations of total nitrogen were reduced by approximately 13% prior to reaching Structure P-11, with a 6% reduction in total phosphorus, 86% reduction in turbidity, 39% reduction in TSS, and 41% reduction in chlorophyll-a. Specific conductivity was also reduced by approximately 21%, suggesting vegetative uptake of dissolved ions during migration through the creek.

TABLE 2-9

COMPARISON OF WATER QUALITY CHARACTERISTICS IN LAKE HANCOCK AND AT STRUCTURE P-11

PARAMETER	UNITS	MEAN VALUE AT MONITORING SITE 3[1]	MEAN VALUE AT STRUCTURE P-11[1]	PERCENT CHANGE
pH	s.u.	8.85	9.10	+ 3
Conductivity	μmho/cm	262	208	- 21
Diss. Oxygen	mg/l	8.3	10.7	+ 29
ORP	mv	573	677	+ 18
Secchi Disk Depth	m	0.20	0.24	+ 20
Alkalinity	mg/l	47.8	68.3	+ 43
NH_3	μg/l	12	68	+ 467
NO_x	μg/l	10	11	+ 10
Diss. Organic N	μg/l	1643	1590	- 3
Particulate N	μg/l	4204	3465	- 18
Total N	μg/l	5869	5134	- 13
Orthophosphorus	μg/l	8	12	+ 50
Particulate P	μg/l	457	438	- 4
Total P	μg/l	501	472	- 6
Turbidity	NTU	320	43.4	- 86
TSS	mg/l	113	69.4	- 39
BOD	mg/l	17.4	15.8	- 9
Color	Pt-Co	49	69	+ 41
Chlorophyll-a	mg/m^3	204	120	- 41

1. n = 9 samples

SECTION 3

CHARACTERISTICS OF THE LAKE HANCOCK DRAINAGE BASIN

Evaluations were performed to quantify the physical, hydrologic, and land use characteristics of the Lake Hancock drainage basin. This information is used to develop input necessary for computer modeling to estimate annual runoff volumes entering the lake, as well as information required for estimation of annual pollutant inputs. A summary of the results of these evaluations is given in the following sections.

3.1 Physical Characteristics of Sub-basin Areas

An approximate delineation of sub-basin areas discharging to Lake Hancock was provided by SWFWMD in the form of a GIS BASINS coverage. The estimated sub-basin boundaries contained in this coverage are based upon an earlier sub-basin delineation performed by the U.S. Geological Survey (USGS). Based upon the USGS evaluation, surface water inflow to Lake Hancock is generated in four primary sub-basin areas, including: (1) sub-basin areas tributary to Banana Creek; (2) sub-basin areas tributary to Lake Lena Run; (3) sub-basin areas tributary to Saddle Creek; and (4) miscellaneous sub-basin areas which discharge to Lake Hancock through small conveyance systems or by direct overland flow. Approximate delineations of the four primary areas discharging to Lake Hancock are indicated on Figure 3-1.

The primary sub-basin areas delineated on Figure 3-1 were further subdivided by Ardaman into numerous smaller sub-catchment areas for modeling areas. These delineations were performed on USGS 7.5-minute quadrangle maps and digitized into the BASINS coverage.

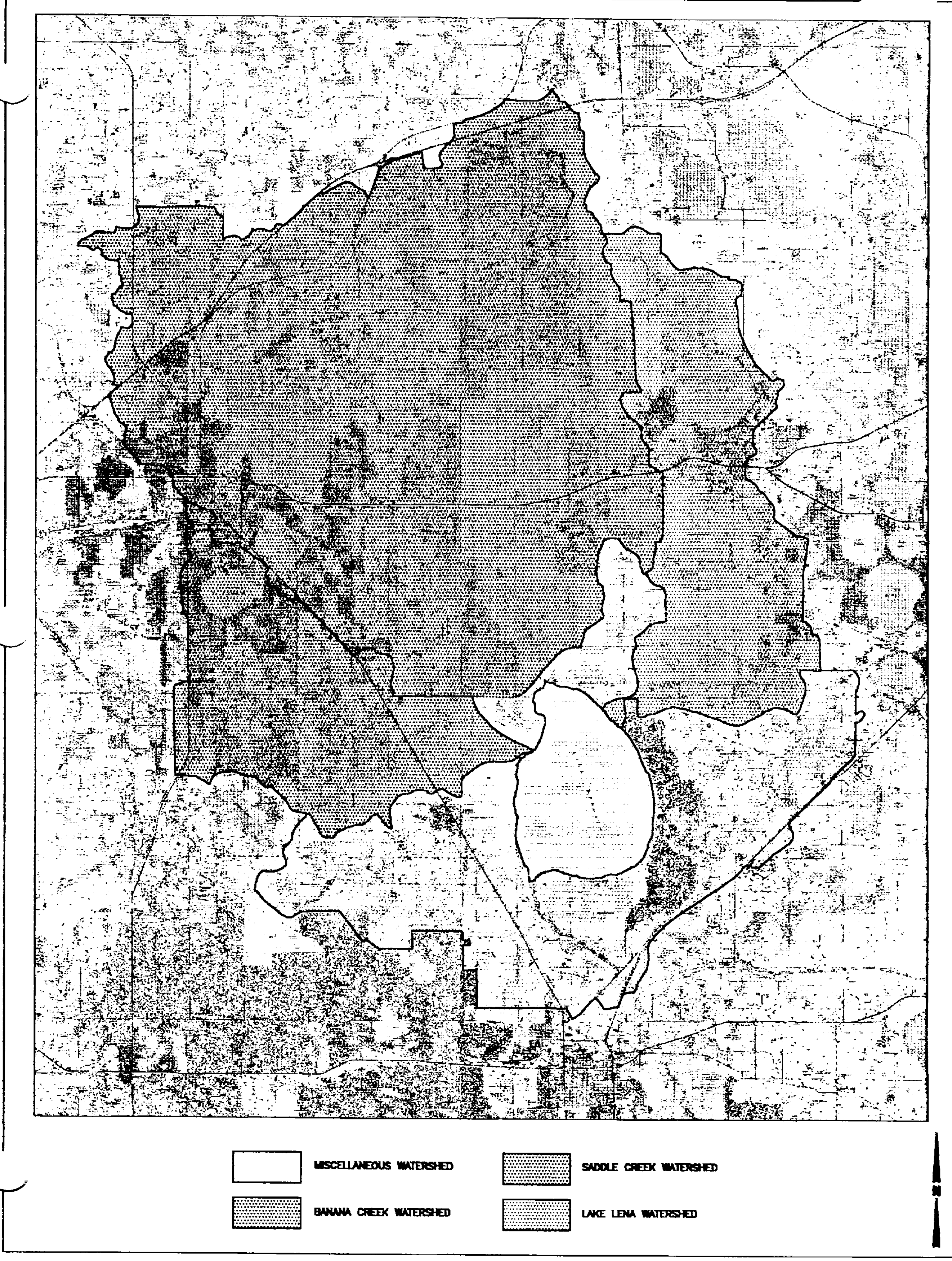


Figure 3-1. Primary Sub-basin Areas Discharging to Lake Hancock.

A total of 75 separate sub-basin catchments were delineated within the four primary sub-basin areas. The BASINS coverage was then used to develop areas and weighted average percent impervious values for each sub-catchment area for hydrologic modeling purposes.

A schematic outline of the 75 delineated sub-basin areas is given in Appendix E. Sub-basin areas designated as 10XXX originate in the miscellaneous watershed areas, with Banana Creek sub-basin areas designated as 20XXX, Lake Lena Run sub-basin areas designated as 40XXX, and Saddle Creek sub-basin areas designated as 30XXX and 50XXX. For purposes of this study, potential inputs to Lake Hancock include all sub-basin areas discharging into Lake Hancock or Saddle Creek upstream from Structure P-11. The delineation included in Appendix E and in Figure 3-1 includes a sub-basin area designated as Sub-basin 10001, which discharges into Saddle Creek downstream from Structure P-11 but upstream of the confluence with the Peace River. Although illustrated in Appendix E and Figure 3-1, Sub-basin 10001 is not included in the hydrologic or pollutant loading evaluations presented in Sections 4 and 5.

A comparison of land areas in the four primary sub-basins discharging to Lake Hancock is given in Table 3-1. Information provided in Table 3-1 includes all areas discharging to Lake Hancock upstream from Structure P-11, and does not include Sub-basin 10001 which discharges into Saddle Creek downstream from Structure P-11. The drainage basin discharging to Lake Hancock upstream from Structure P-11 includes approximately 91,685 acres (37,123 ha) or 143.3 square miles (371.2 km^2). As seen in Table 3-1, the largest sub-basin area is the Saddle Creek basin which comprises approximately 53% of the total land area discharging to Lake Hancock. Miscellaneous areas comprise approximately 19% of the sub-basin area, with 15% in the Banana Creek watershed and 13% in the Lake Lena Run watershed.

TABLE 3-1

COMPARISON OF LAND AREAS IN THE FOUR PRIMARY SUB-BASIN AREAS DISCHARGING TO LAKE HANCOCK

SUB-BASIN AREA	BASIN AREA				PERCENT OF TOTAL AREA (%)
	ac	mi^2	ha	km^2	
Banana Creek	13,578	21.2	5,498	55.0	15
Lake Lena Run	11,754	18.4	4,759	47.6	13
Saddle Creek	49,034	76.6	19,854	198.5	53
Miscellaneous Areas[1]	17,319	27.1	7,012	70.1	19
Totals:	91,685	143.3	37,123	371.2	100

1. Does not include Sub-basin 10001

Information on soil types and coverages was also extracted by Ardaman from the BASINS coverage provided by SWFWMD. Soil types were processed into hydrologic soil groups throughout the watershed to assist in development of the hydrologic model. The soil type coverages provided by SWFWMD were supplemented by soil information contained in the Polk County Soil Survey (October 1990).

3.2 Land Use in Sub-basin Areas

Information on land use in each of the four primary sub-basin areas was provided by Ardaman based upon the 1995 SWFWMD land use coverage. This coverage contains land use polygons as well as attribute codes for the Florida Land Use, Cover, and Forms Classification System (FLUCCS). For hydrologic modeling purposes, land use data were combined into 10 generalized categories, representing the maximum number of land use categories allowed by the SWMM model, and a look-up table was used to assign percent of impervious cover for each of the 10 generalized categories.

A graphical representation of land use characteristics in the four primary sub-basin areas is given in Appendix F. Land use categories represented in this appendix reflect FLUCCS codes provided by SWFWMD based upon the 1995 land use evaluation. Land use characteristics for each of the four primary sub-basin areas are summarized in the following sections.

3.2.1 Banana Creek Sub-basin

A summary of land use in the Banana Creek sub-basin is given in Table 3-2. The dominant land use category in this sub-basin is open water and lakes, which comprise approximately 18% of the total basin area. Significant surface waterbodies in this basin include Lake Mirror, Lake Morton, Lake Horney, Lake Hollingsworth, and Lake Bently, located in the City of Lakeland; along with Lake John, Stahl Lake, Little Banana Lake, and Banana Lake. Additional other un-named waterbodies are also present in this watershed. These waterbodies provide a substantial amount of attenuation, of both flow rates and mass loadings, for runoff inputs generated within the overall sub-basin area. In addition to open water and lakes, wetlands comprise approximately 11% of the overall sub-basin area. Approximately 29% of the overall sub-basin area is covered by open water, lakes, or wetlands.

After open water and lakes, medium-density residential is the most significant land use category in the Banana Creek sub-basin, occupying approximately 17.9% of the overall basin area. Much of this residential area is located in the northwest portion of the sub-basin, associated with the City of Lakeland. Agricultural crops and pasture land occupy 9.4% of the total basin area, with 7.1% covered by open land, 6.0% covered by low-density residential units, and 5.1% covered by upland forests. The remaining land use categories summarized in Table 3-2 occupy 5% or less of the overall basin area.

TABLE 3-2

SUMMARY OF LAND USE IN THE BANANA CREEK SUB-BASIN

LAND USE	AREA (ac)	PERCENT OF TOTAL (%)
Agricultural - Citrus	604.4	4.5
Agricultural - Crops/Pasture	1273.8	9.4
Agricultural - General	458.6	3.4
Commercial	581.3	4.3
Disturbed Land	78.5	0.6
Extractive	85.1	0.6
High-Density Residential	281.0	2.1
Industrial	599.5	4.4
Institutional	97.0	0.7
Low-Density Residential	816.1	6.0
Medium-Density Residential	2432.6	17.9
Open Land	960.4	7.1
Open Water/Lakes	2448.8	18.0
Rangeland	406.8	3.0
Recreational	65.6	0.5
Transportation/Highway	210.9	1.6
Upland Forests	688.9	5.1
Wetlands	1488.9	11.0
Total Area	13,578.0	100.0

3.2.2 Lake Lena Run Sub-basin

A summary of land use in the Lake Lena Run sub-basin, based on the 1995 SWFWMD land use survey, is given in Table 3-3. The dominant land use in the Lake Lena Run sub-basin is medium-density residential, which covers approximately 30% of the overall basin area. The majority of this residential area is associated with the City of Auburndale and the Inwood area of Winter Haven. Extractive land uses, primarily reclaimed phosphate strip mining areas, occupy approximately 15.2% of the sub-basin area.

TABLE 3-3

SUMMARY OF LAND USE IN THE LAKE LENA RUN SUB-BASIN

LAND USE	AREA (ac)	PERCENT OF TOTAL (%)
Agricultural - Citrus	974.7	8.3
Agricultural - Crops/Pasture	1004.7	8.5
Agricultural - General	80.8	0.7
Commercial	836.8	7.1
Disturbed Land	75.9	0.6
Extractive	1788.7	15.2
High-Density Residential	260.8	2.2
Industrial	100.2	0.9
Institutional	282.0	2.4
Low-Density Residential	387.6	3.3
Medium-Density Residential	3484.5	29.6
Open Land	12.5	0.1
Open Water/Lakes	1072.1	9.1
Recreational	377.5	3.2
Transportation/Highway	189.5	1.6
Upland Forests	292.8	2.5
Wetlands	532.7	4.5
Total Area	11,753.6	100.0

As seen in Table 3-3, open water and lakes comprise approximately 9.1% of the overall area. Significant waterbodies in the Lake Lena Run sub-basin include Lake Arietta, Lake Whistler, Lake Ariana, Lake Hart, Lake Lena, Lake Stella, Thomas Lake, Sears Lake, Spirit Lake, and Dinner Lake. Commercial areas occupy approximately 7.1% of the sub-basin area, most of which is located near the City of Auburndale and on the outskirts of Winter Haven. Significant areas of citrus trees and agricultural crops and pasture land are also present in this sub-basin comprising 8.3% and 8.5% of the overall land area, respectively. The remaining land use categories in Table 3-3 comprise less than 5% of the overall sub-basin area.

3.2.3 Saddle Creek Sub-basin

A summary of land use in the Saddle Creek sub-basin area is given in Table 3-4. This sub-basin area is dominated primarily by extractive land use, primarily associated with phosphate strip mining activities. Extractive land use covers approximately 23.7% of the overall sub-basin area. Following extractive activities, open water/lakes and wetlands represent the next most significant land use within the basin, comprising 10.6% and 12.4% of the overall basin area, respectively. Significant water resources in this sub-basin include Lake Gibson, Lake Deeson, Fish Lake, Lake Crago, Lake Parker, Lake Holloway, Lake Bonny, Skyview Lake, Crystal Lake, and Lake Myrtle.

As seen in Table 3-4, agriculture comprises approximately 11% of the overall sub-basin area. Agricultural activities appear to be dominated primarily by row crops and pasture land. Recreational lands and parks comprise approximately 9.2% of the overall basin area, with medium-density residential units occupying approximately 9.4%. The remaining land use categories presented in Table 3-4 represent 5% or less of the overall sub-basin area.

TABLE 3-4

SUMMARY OF LAND USE IN THE SADDLE CREEK SUB-BASIN

LAND USE	AREA (ac)	PERCENT OF TOTAL (%)
Agricultural - Citrus	734.5	1.5
Agricultural - Crops/Pasture	3709.0	7.6
Agricultural - General	716.5	1.5
Commercial	2119.8	4.3
Disturbed Land	42.5	0.1
Extractive	11,636.5	23.7
High-Density Residential	2190.2	4.5
Industrial	1068.7	2.2
Institutional	571.6	1.2
Low-Density Residential	1788.6	3.6
Medium-Density Residential	4596.9	9.4
Open Land	842.9	1.7
Open Water/Lakes	5175.7	10.6
Rangeland	310.0	0.6
Recreational	4502.6	9.2
Transportation/Highway	1125.9	2.3
Upland Forests	1822.8	3.7
Wetlands	6078.8	12.4
Total Area	49,033.5	100.0

3.2.4 Miscellaneous Sub-basin Areas

A summary of land use in the miscellaneous sub-basin areas is given in Table 3-5. As indicated previously, this sub-basin area includes areas which discharge into Lake Hancock through small canals or by direct overland flow. The dominant land use activity in the sub-basin area appears to be agriculture, which occupies approximately one-third of the overall sub-basin area. Agricultural activities appear to be dominated by citrus trees, row crops, and pasture land. Approximately 25% of the overall sub-basin area is covered by undeveloped land, such as upland forests and wetlands.

TABLE 3-5

SUMMARY OF LAND USE IN MISCELLANEOUS SUB-BASIN AREAS

LAND USE	AREA (ac)	PERCENT OF TOTAL (%)
Agricultural - Citrus	2781.3	16.1
Agricultural - Crops/Pasture	2410.6	13.9
Agricultural - General	434.1	2.5
Commercial	129.3	0.7
Disturbed Land	54.8	0.3
Extractive	2427.8	14.0
High-Density Residential	142.2	0.8
Industrial	173.2	1.0
Institutional	213.5	1.2
Low-Density Residential	1057.2	6.1
Medium-Density Residential	1992.5	11.5
Open Land	28.5	0.2
Open Water/Lakes	894.3	5.2
Rangeland	184.2	1.1
Recreational	21.1	0.1
Transportation/Highway	124.2	0.7
Upland Forests	1645.1	9.5
Wetlands	2605.5	15.0
Total Area	17,319.4	100.0

As seen in Table 3-5, approximately 18% of the overall sub-basin area is occupied by residential land use, with medium-density residential areas comprising 11.5% and low-density residential areas comprising 6.1% of the overall sub-basin area. Extractive mining activities, primarily phosphate mining, occupies approximately 14% of the basin area. The majority of these activities are located west of Lake Hancock.

Approximately 5.2% of the overall sub-basin area is occupied by open water and lakes. Significant water resources in the basin include Eagle Lake, Millsite Lake, Grassy Lake, and Crews Lake. Other un-named waterbodies are also present in the watershed. The remaining land use categories listed in Table 3-5 represent 5% or less of the overall sub-basin area.

SECTION 4

EVALUATION OF HYDROLOGIC AND HYDRAULIC INPUTS TO LAKE HANCOCK

Detailed evaluations were performed to provide estimates of annual volumetric inputs entering Lake Hancock from stormwater runoff, dry weather baseflow, direct precipitation, and groundwater seepage. This information is used to develop a hydrologic budget for Lake Hancock as well as for estimation of pollutant loadings from various sources into the lake. The results of the evaluation conducted to quantify each of these hydrologic/hydraulic inputs to Lake Hancock are summarized in the following sections. Estimates of pollutant loadings entering the lake are discussed in Section 5.

4.1 Estimation of Annual Runoff/Baseflow Inputs to Lake Hancock

Detailed hydrologic modeling was conducted by Ardaman & Associates using the USEPA SWMM Model to provide estimates of annual hydrologic inputs of stormwater runoff and dry weather baseflow into Lake Hancock from the three primary inflow tributaries, including Banana Creek, Saddle Creek, and Lake Lena Run. Model calibration was performed using field-measured flow rates in each of the three primary tributaries performed by ERD from December 1998 to June 1999. A discussion of the results of the field monitoring program and the SWMM simulation process is given in the following sections.

4.1.1 Field Monitoring

A field monitoring program was initiated in December 1998 by ERD to characterize the quantity and quality of stormwater runoff and dry weather baseflow discharging to Lake Hancock through each of the three primary inflow tributaries, Banana Creek, Lake Lena Run, and Saddle Creek. Automatic sequential sample collection equipment and recording flow meters were installed in each of the three tributaries to provide a continuous record of discharge as well as collect flow-weighted samples for laboratory evaluation. Locations of monitoring sites utilized by ERD for characterization of stormwater runoff and dry weather baseflow are indicated on Figure 4-1.

A summary of collected field data for the three inflow tributaries to Lake Hancock is given in Table 4-1. Continuous flow records were collected in Banana Creek from December 1998 to June 1999, with flow records performed in Lake Lena Run from December 1998 to June 1999, and in Saddle Creek from December 1998 to June 1999. Flow measurements were performed on a continuous basis at each site and averaged over each 10-minute time interval. This information was stored in the internal memory of the flow monitoring equipment and retrieved by ERD personnel on a weekly basis.

TABLE 4-1

SUMMARY OF COLLECTED FIELD DATA FOR THE THREE INFLOW TRIBUTARIES TO LAKE HANCOCK

TRIBUTARY	MONITORING SITE	FLOW RECORD DATES	
		BEGINNING	ENDING
Banana Creek	@ U.S. 98	12/20/98	6/1/99
Lake Lena Run	@ Thornhill Road	12/21/98	6/1/99
Saddle Creek	@ Polk Expressway	12/21/98	6/1/99

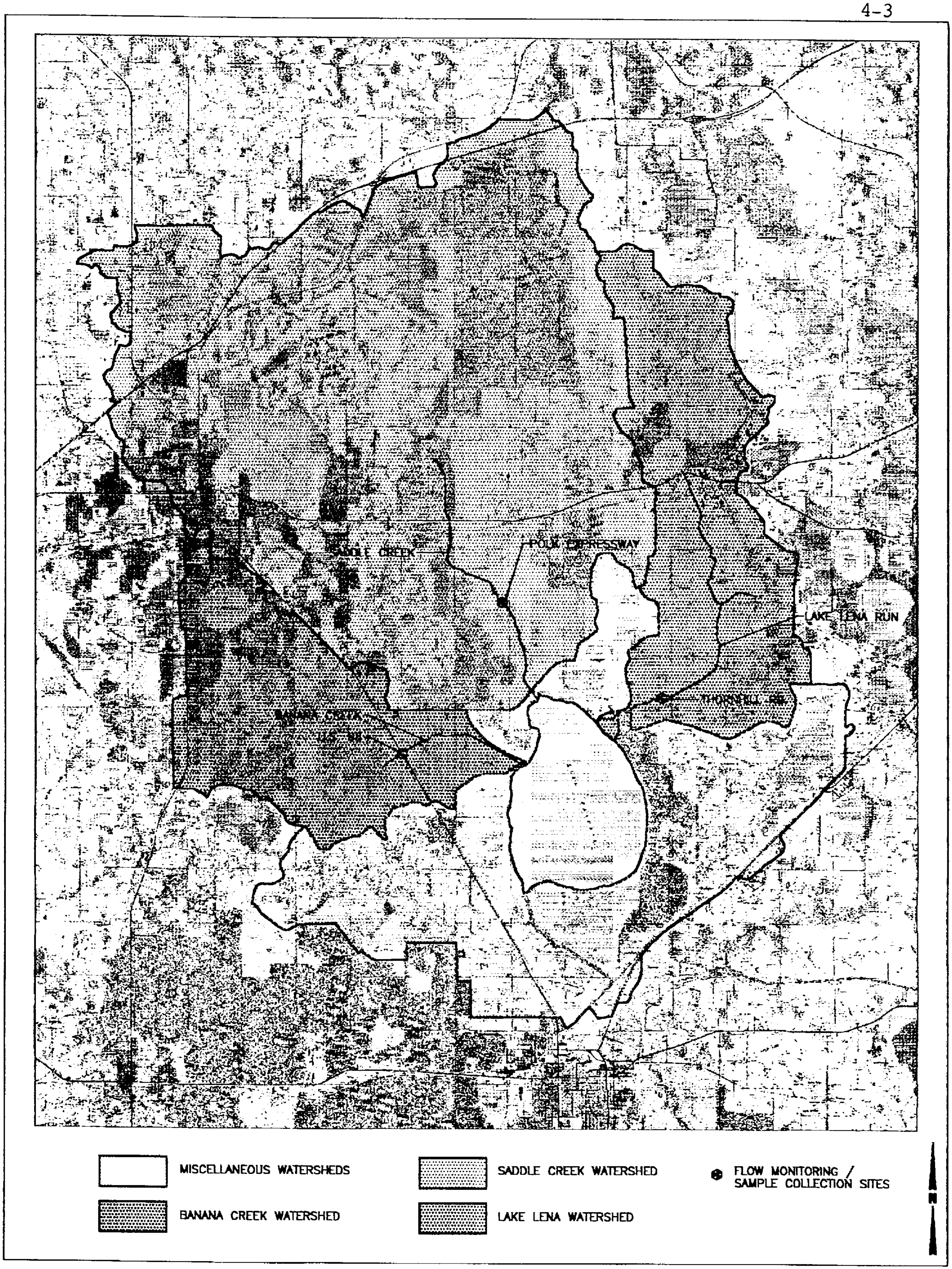


Figure 4-1. Flow Monitoring and Sample Collection Sites in Primary Tributaries Entering Lake Hancock.

Manual flow measurements were performed at each monitoring site on approximately a monthly basis to verify performance of the automatic flow monitoring equipment. Discharge measurements at each site were conducted using the velocity/cross-sectional area method, with a Marsh McBirney Model 201 electromagnetic flow meter. Flow estimates were obtained by multiplying the measured mean velocity within a given cross-section of each channel times the cross-sectional area of flow. A summary of manual field discharge measurements performed by ERD is given in Appendix G.

Plots of monitored discharge rates for Banana Creek, Lake Lena Run, and Saddle Creek are provided in Figures 4-2, 4-3, and 4-4, respectively. A continuous flow was observed at each of the three sites throughout most of the monitoring period. As seen in Figure 4-2, discharge flow rates in Banana Creek appear to both increase and decrease in a relatively gradual fashion. It appears that a large portion of the stormwater runoff generated in this basin is attenuated in the numerous lakes and waterbodies which ultimately discharge into Banana Creek. This process serves to attenuate the peak runoff discharges associated with many of the smaller storm events so that much of the runoff generated during storm events is discharged into the creek on a slow continuous basis following the rain event, rather than as large inputs during an individual rain episode. No measurable increase in flow rates were observed at Banana Creek for any rain events in the watershed, although flow rates may increase gradually over time as drawdown for the rain event occurs.

Measured discharge rates in Lake Lena Run are presented in Figure 4-3. Lake Lena Run appears to be impacted more significantly as a result of individual storm events than was observed in either Banana Creek or Saddle Creek. However, even though more hydrograph peaks are present in the Lake Lena Run data, drawdown of attenuated runoff is still apparent

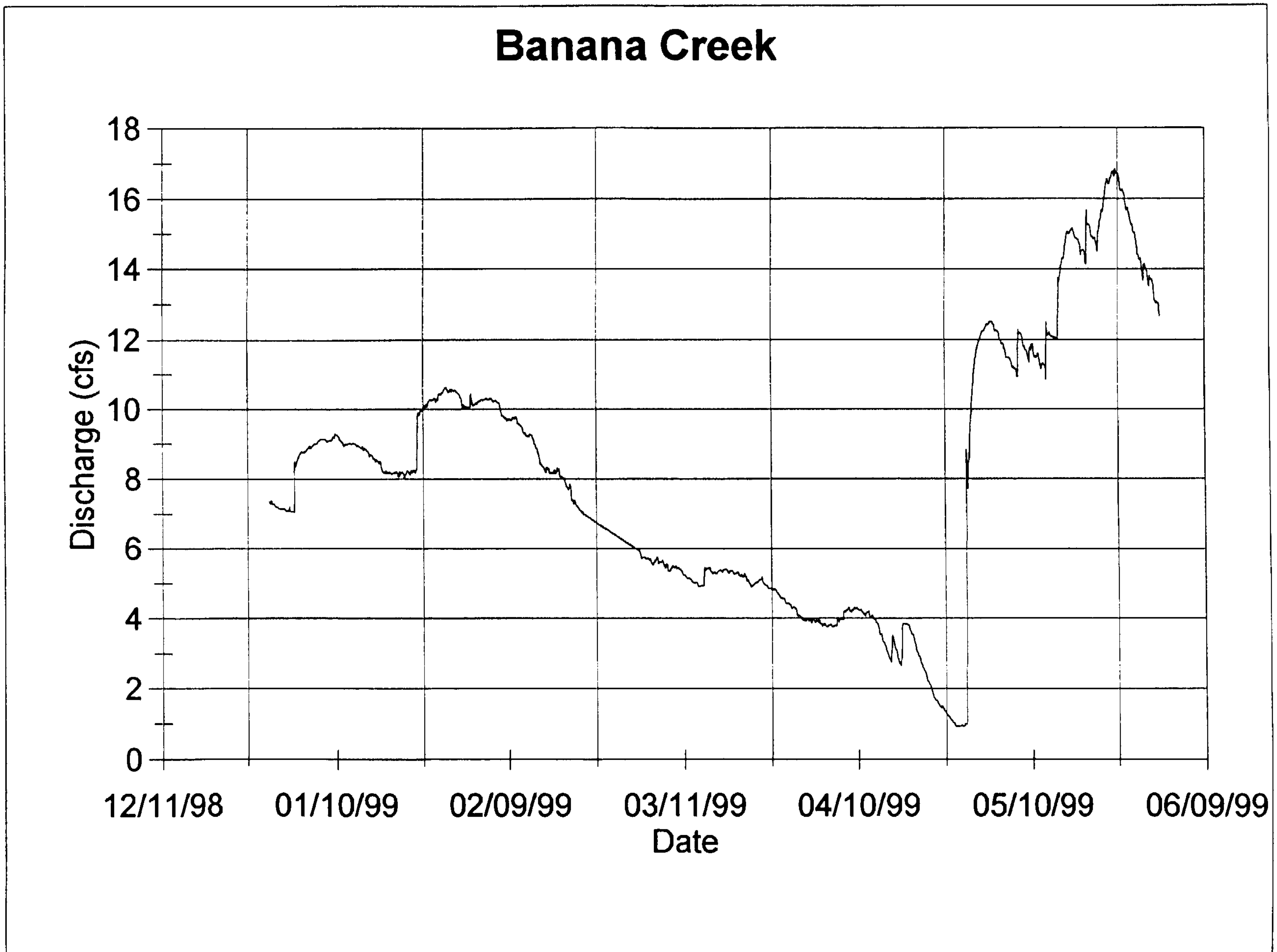


Figure 4-2. Measured Discharge Rates in Banana Creek from December 1998-June 1999.

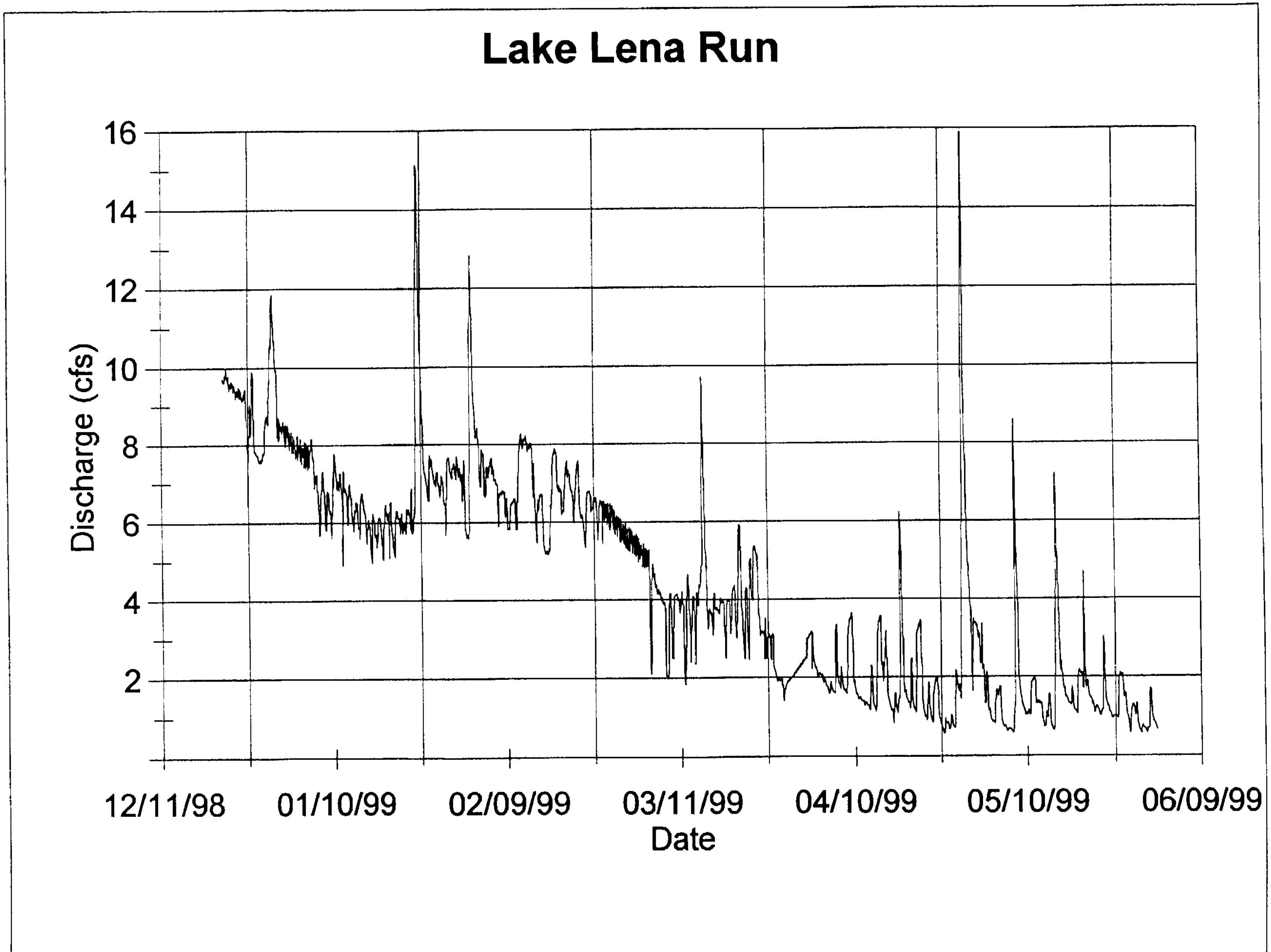


Figure 4-3. Measured Discharge Rates in Lake Lena Run from December 1998-June 1999.

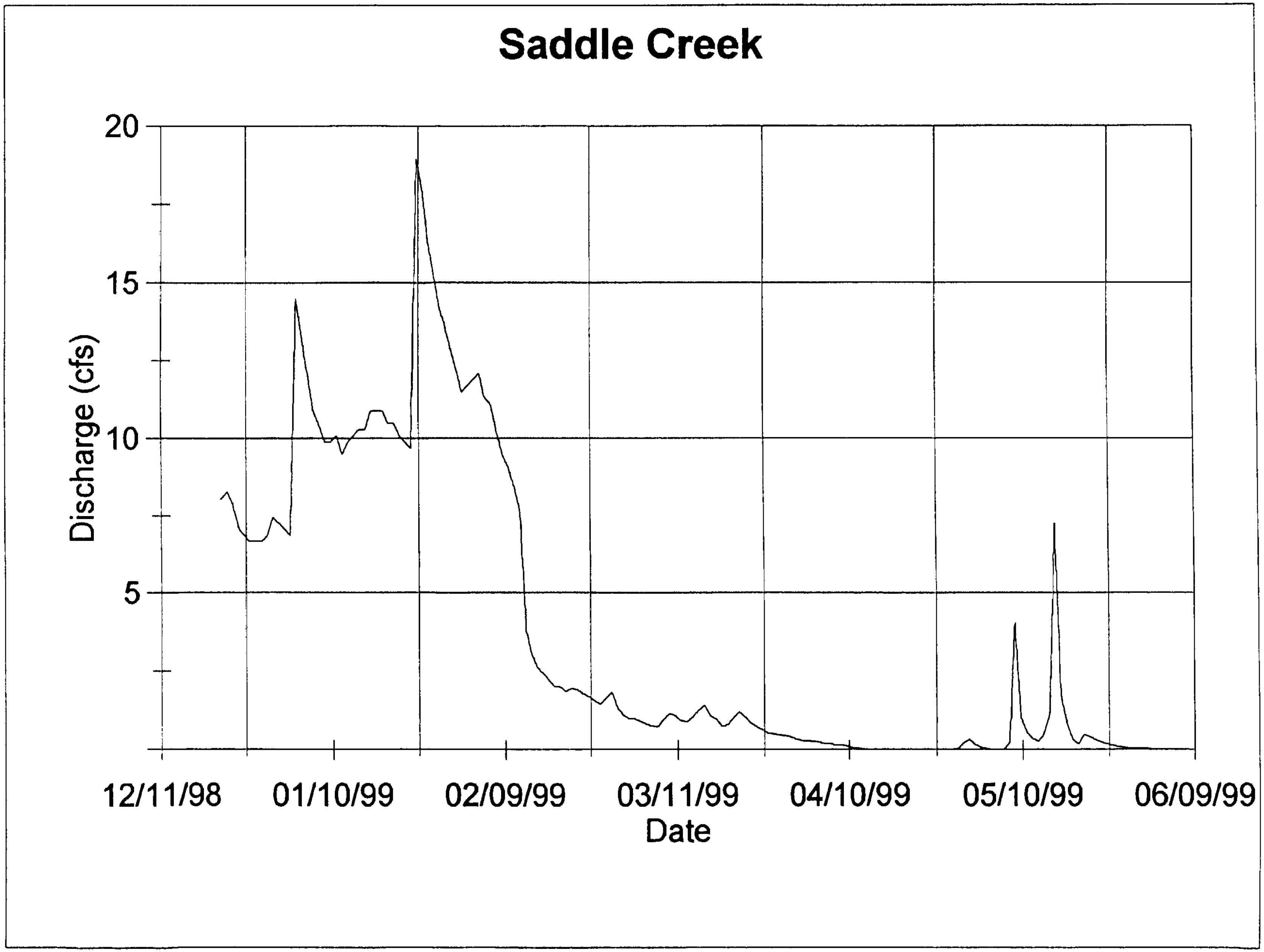


Figure 4-4. Measured Discharge Rates in Saddle Creek from December 1998-June 1999.

following significant storm events. Similar to the trends observed for Banana Creek and Saddle Creek, many of the smaller storm events do not appear to generate significant hydrograph peaks in Lake Lena Run.

Measured discharge rates in Saddle Creek, indicated in Figure 4-4, also exhibit many of the attenuation and drawdown characteristics exhibited by Banana Creek. However, larger storm events in the Saddle Creek watershed are capable of producing distinct hydrograph peaks, followed by a gradual bleed-down as water stored in the drainage basin gradually discharges into Saddle Creek. Although storm event peaks are evident for larger storms, it appears that no measurable peak in discharge rates are apparent in Saddle Creek during ordinary daily rain events.

A statistical summary of monitored flow rate data at the three inflow tributary sites is given in Table 4-2. The measured mean flow rate in Saddle Creek over the six-month monitoring period was approximately 3.93 cfs, with a mean flow rate of 4.54 cfs in Lake Lena Run and 8.02 cfs in Banana Creek. Measured minimum and maximum discharge flow rates for each tributary are also provided.

TABLE 4-2

STATISTICAL SUMMARY OF MONITORED FLOW DATA AT THE INFLOW TRIBUTARY SITES

LOCATION	FLOW RATE (cfs)		
	MEAN	MINIMUM	MAXIMUM
Banana Creek	8.02	0.94	16.86
Lake Lena Run	4.54	0.57	15.91
Saddle Creek	3.93	0.00	18.96

The flow information provided in Figures 4-2, 4-3 and 4-4 was utilized by Ardaman & Associates as one of several calibration tools for the SWMM Model developed for these three tributary basins. Details of the SWMM simulation procedure are provided in the following section.

4.1.2 SWMM Simulation

SWMM simulation modeling was performed by Mr. Rod Ghioto, P.E. of Ardaman and Associates, Inc. (Ardaman) to provide an estimate of annual inflows to Lake Hancock from Banana Creek, Lake Lena Run, and Saddle Creek. This information is then used by ERD to compute a lake water budget and estimate annual pollutant loads to Lake Hancock.

4.1.2.1 Model Construction

The SWMM Runoff Block was chosen by SWFWMD for this project. SWMM represents sub-catchments as rectangular planes and uses a kinematic wave procedure for computation of runoff hydrographs. Computational options chosen include the Horton infiltration model and groundwater modeling to enable calculation of upland evapotranspiration as well as seepage to surface water systems.

Impervious areas in the SWMM Runoff Block are internally considered as separate "directly connected" sub-catchments. Therefore, some adjustments are made to this input parameter to better represent runoff from areas that are not directly connected. These adjustments occur mostly in sub-catchments that contribute to channels that have no downstream attenuation (e.g., lakes) before entering Lake Hancock.

The routing portion of the Runoff Block is a kinematic representation of channels and/or conduits (pipes). These elements receive runoff from sub-catchments and route it through the conveyance system. Conveyance systems in the Lake Hancock watershed are represented as trapezoidal channels. Lakes are also represented as channel elements with downstream weir outlet structures.

Input data requirements for the surface runoff portion of each sub-catchment include: length, width and slope; percent imperiousness; and hydrologic soil group (HSG). These data are generated through use of GIS (Geographical Information System) coverages for soil types, land use and sub-catchment boundaries.

The appropriate soil coverage information was obtained from SWFWMD and processed into Hydrologic Soil Groups (HSGs) throughout the watershed. The SWFWMD 1995 Land Use Coverage (LU-95) was also obtained. This coverage contains land use polygons and attribute codes including the Florida Land Use, Cover and Forms Classification System. Land use data are combined into 10 generalized categories (maximum allowed by SWMM) and a look-up table is used to assign percent impervious for each category.

A "Basins" coverage was also obtained from SWFWMD which contains a USGS representation of major contributing areas. Ardaman supplemented this data set by delineation of numerous smaller sub-catchments. These delineations were performed on USGS 7.5 Minute Quadrangle Maps and digitized into the Basins coverage. A total of 75 basins (sub-catchments) are employed. The above coverages were processed to develop areas and weighted average percent impervious for each sub-catchment.

Daily pan evaporation data for the Lake Alfred Experiment Station were reduced to monthly totals and then daily average values for each month of the simulated period. A pan coefficient of 0.73 (Lee and Swancar, 1997) was applied to provide an estimate of lake evaporation from the computed daily pan evaporation rates.

4.1.2.2 Hydrologic Calibration

Adequate calibration of the model for the three stream watersheds is subject to proper specification of a number of physical and hydrologic parameters, as well as selection of representative historical rainfall stations. Calibration runs were made for a rainfall data set covering the period from January 1, 1997 through May 31, 1999. Throughout the calibration process, adjustments were made to physical and hydrologic input parameters which provided for the most reasonable approximation of measured discharges at Polk County gaging stations on Banana Creek and Lake Lena Run, and at the USGS gaging station on Saddle Creek. Results of the final calibration runs are provided in Figures 4-5, 4-6, and 4-7.

Because initial conditions play a significant role in calibration, the first six months of this simulation period are considered to be inadequate to draw conclusions. Due to spatial variability of local rainfall, it is unlikely that any model at any level of detail would produce exact results on a daily basis. Therefore, the goal of calibration is to produce relatively consistent peak discharges for area-wide events, seasonal trends and similar recession characteristics.

Adjustments to hydrologic parameters were made on a macro-scale for each watershed based on soils. Soils-related calibration parameters are: initial and final infiltration rates; effective porosity; saturated conductivity; field capacity; and wilting point. Overflows from storage areas are assumed, based on physical dimensions of the facilities, and physical data for lake outfalls that was made available from SWFWMD.

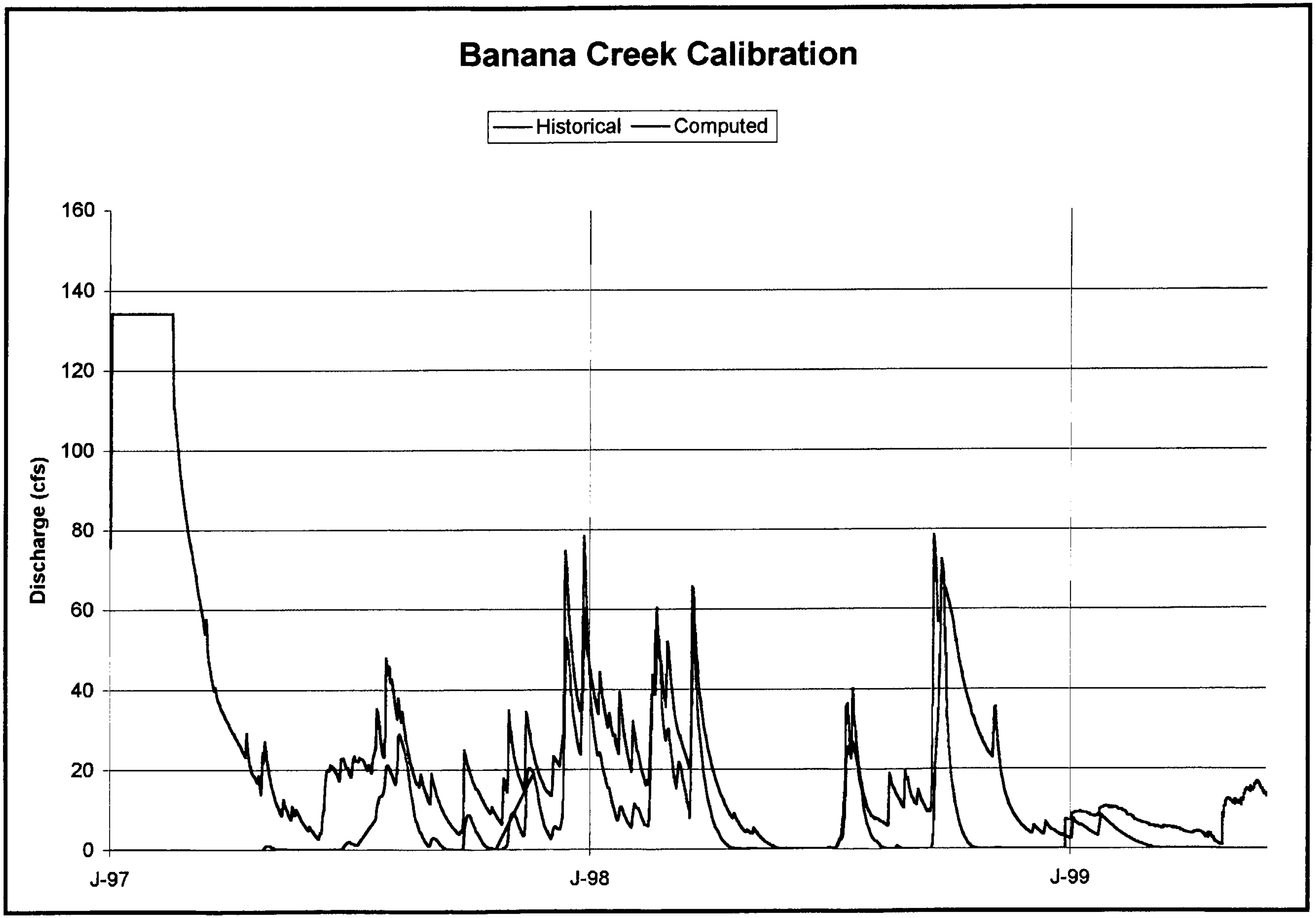


Figure 4-5. Historical vs. Computed Flow Rates in Banana Creek.

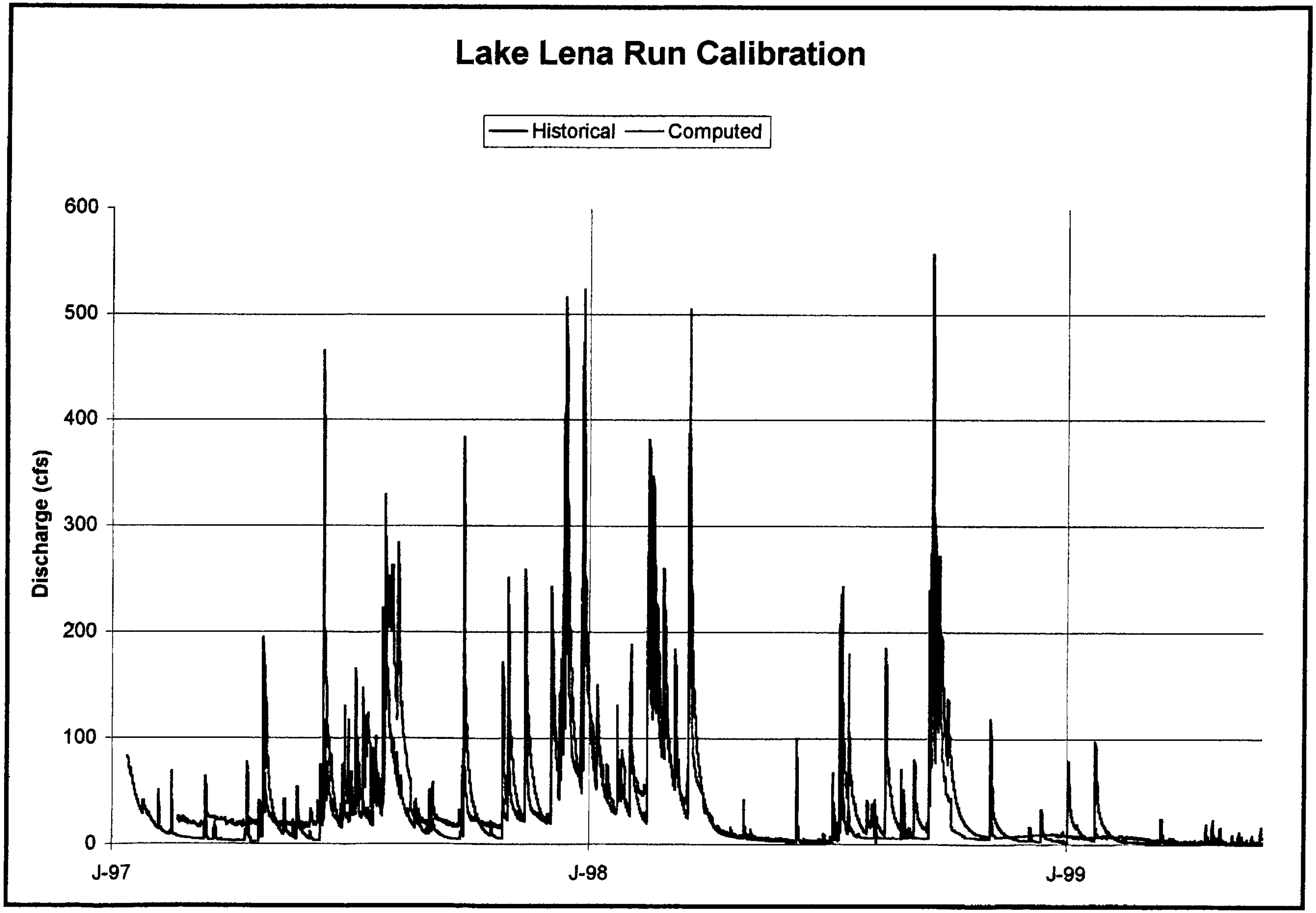


Figure 4-6. Historical vs. Computed Flow Rates in Lake Lena Run.

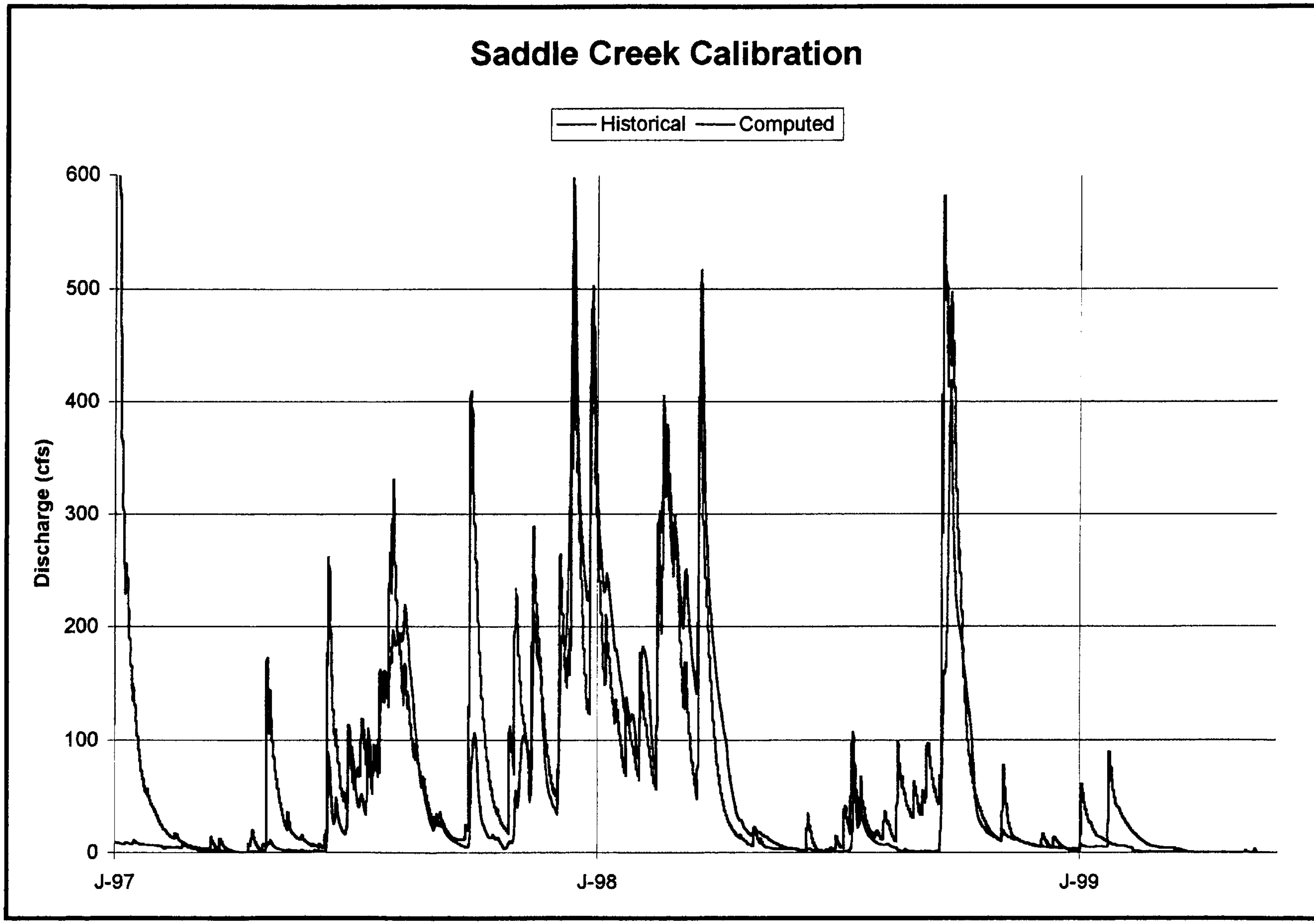


Figure 4-7. Historical vs. Computed Flow Rates in Saddle Creek.

4.1.2.3 Long-Term Hydrologic Simulation

The Lakeland weather station is the only source of long-term precipitation data within the study area. This daily data is used to generate estimates of Lake Hancock inflows from the watershed. Simulation was conducted for the period from January 1, 1960 through December 31, 1998. Results reported here cover the 30-year period from January 1, 1969 through December 31, 1998 to coincide with records used by ERD for determination of other Lake Hancock water budget parameters.

Results of the long-term SWMM simulation from 1969-1998 for the primary Lake Hancock inflow tributaries are summarized in Table 4-3. Runoff generated in each of the three tributary areas appears closely related to annual rainfall patterns. On an annual basis, the Banana Creek watershed contributes approximately 1.78 inches (4.5 cm) of runoff, with the Saddle Creek watershed contributing 10.85 inches (27.6 cm) and the Lake Lena Run watershed contributing 3.19 inches (8.1 cm). As indicated previously, the total generated runoff volume is contributed in an attenuated pattern with gradual inflow occurring over a period of several days following individual rain events.

A summary of estimated mean tributary inflow to Lake Hancock from Banana Creek, Lake Lena Run and Saddle Creek is given in Table 4-4. On an annual basis, the total estimated annual inflow from the three tributaries to Lake Hancock is 49,648 ac-ft, with approximately 87% contributed by Saddle Creek, 4% contributed by Banana Creek, and 9% contributed by Lake Lena Run. Saddle Creek not only produces the largest inflow component of the three in terms of volume, but also produces the highest runoff rate per unit area. The estimated annual inflow volume summarized in Table 4-4 reflects the sum of direct inputs of runoff and baseflow into Lake Hancock from the three primary tributaries.

TABLE 4-3

RESULTS OF LONG-TERM SWMM SIMULATIONS FOR THE PRIMARY LAKE HANCOCK TRIBUTARIES

YEAR	ANNUAL RAINFALL (inches)	ANNUAL RUNOFF (inches)		
		BANANA CREEK	SADDLE CREEK	LAKE LENA RUN
1969	51.02	1.67	10.91	3.13
1970	46.56	1.60	10.08	2.93
1971	39.94	0.91	6.50	1.83
1972	37.30	0.75	5.29	1.61
1973	45.41	1.50	9.53	2.59
1974	42.90	1.36	8.62	2.53
1975	40.51	0.98	6.58	1.92
1976	48.95	1.59	9.63	2.77
1977	40.23	1.03	6.92	1.95
1978	45.16	1.31	8.66	2.45
1979	69.72	3.21	19.47	5.79
1980	46.80	1.50	9.61	2.67
1981	39.57	1.05	6.82	1.96
1982	62.21	2.58	16.18	4.85
1983	63.11	2.34	15.08	4.60
1984	38.58	1.28	8.08	2.16
1985	37.36	0.72	5.08	1.55
1986	48.21	1.42	9.19	2.54
1987	53.44	2.08	13.41	3.73
1988	60.54	3.02	15.45	4.73
1989	52.36	1.96	11.74	3.51
1990	39.43	1.27	7.82	2.16
1991	56.23	2.15	12.80	3.85
1992	49.52	1.57	9.91	2.91
1993	52.38	1.85	12.06	3.47
1994	62.94	2.43	15.57	4.65
1995	58.75	3.57	15.38	4.53
1996	52.82	2.10	11.79	3.49
1997	57.15	1.79	12.04	3.86
1998	54.23	2.74	15.25	4.84
TOTALS:	1493.33	53.31	325.41	95.56
AVERAGE:	49.78	1.78	10.85	3.19

TABLE 4-4

SUMMARY OF ESTIMATED MEAN TRIBUTARY INFLOW INTO LAKE HANCOCK

TRIBUTARY	BASIN AREA (acres)	ANNUAL INFLOW			ANNUAL RUNOFF COEFFICIENT ("C" VALUE)
		(inches)	(ac-ft)	(m^3)	
Banana Creek	11,750	1.78	1,740	2,147,900	0.036
Lake Lena Run	17,376	3.19	4,612	5,693,200	0.064
Saddle Creek	47,898	10.85	43,296	53,445,900	0.218
Total	77,024	7.73[1]	49,648	61,287,000	0.155[1]

1. Weighted average

4.1.3 Miscellaneous Basin Areas

As discussed in Section 3, six separate drainage sub-basin areas discharge directly into Lake Hancock, upstream of Structure P-11, which are not included in the Banana Creek, Lake Lena Run, or Saddle Creek sub-basin areas. These miscellaneous sub-basin areas are designated as Sub-basin 10,000, which includes Lake Hancock along with adjacent areas which discharge directly into the lake by overland flow; Sub-basin 10,001, which discharges into Saddle Creek downstream from Lake Hancock, between Structure P-11 and the Peace River; Sub-basin 10,002, which discharges primarily into Saddle Creek south of Lake Hancock; Sub-basin 10,020, which discharges into Lake Hancock through a system of vegetated ditches; Sub-basin 10,030, which is primarily a self-contained drainage basin with a high level pop-off to Lake Hancock during extreme rain events; Sub-basin 10,040, which discharges into Lake Hancock through a vegetated canal on the northeast quadrant of the lake; and Sub-basin 10,050, which consists of reclaimed strip mine areas on the east side of the lake.

Of the six sub-basin areas listed in the previous paragraph, only three areas (10,000, 10,020, and 10,040) contribute runoff inflow to Lake Hancock on a routine basis. Sub-basin areas 10,001 and 10,002 discharge primarily into Saddle Creek, south of Lake Hancock, and are not included as direct inflows into Lake Hancock. Sub-basin area 10,030 discharges infrequently to Lake Hancock, and is not considered a significant source of nutrient loadings to the lake. Sub-basin 10,050 appears to contribute flow into Lake Hancock on a periodic basis through a fabric-formed weir structure. However, actual flow rates from this basin into the lake were observed to be relatively low on virtually all of the monitoring trips performed by ERD. Flow reversal, with flow discharging from Lake Hancock into Sub-basin 10,050, was observed on several occasions. Therefore, it is assumed that Sub-basin 10,050 does not contribute significantly into Lake Hancock on an annual basis. As a result, only three sub-basin areas (10,000, 10,020, and 10,040) are considered to contribute pollutant loadings to Lake Hancock on a frequent basis. Locations of the miscellaneous sub-basin areas are illustrated on the watershed sub-basin map included in Appendix E.

Estimates of the annual runoff volume generated in miscellaneous watershed areas were calculated by multiplying the estimated runoff coefficient ("C" Value) for individual land use categories times the area contained within each land use category, multiplied by the estimated annual rainfall volume of 49.72 inches (126 cm) per year. Land use for the miscellaneous watershed areas was provided by Ardaman & Associates as a Level 3 FLUCCS code. Each of the Level 3 FLUCCS code categories were grouped into one of 17 general land use categories for which literature-based runoff "C" value information is available.

A summary of general land use categories and estimated annual runoff "C" values used for the miscellaneous watershed basins is given in Table 4-5. General land use categories and runoff "C" values were obtained from the publication titled "Stormwater Loading Rate Parameters for Central and South Florida" (Harper, 1994). Runoff "C" values in this table reflect the estimated portion of annual rainfall which will be discharged as stormwater runoff.

TABLE 4-5

ESTIMATED ANNUAL RUNOFF "C" VALUES FOR MISCELLANEOUS WATERSHED LAND USE CATEGORIES IN THE LAKE HANCOCK BASIN

GENERAL LAND USE	RUNOFF "C" VALUE
Low-Density Residential	0.268
Medium-Density Residential	0.373
High-Density Residential	0.675
Commercial	0.837
Industrial	0.793
Extractive	0.361
Institutional	0.268
Recreational	0.163
Open land	0.163
Agricultural-Crops/Pasture	0.355
Agricultural-Citrus	0.282
Agricultural-General	0.304
Rangeland	0.163
Upland Forests	0.163
Wetlands	0.225
Disturbed Land	0.361
Transportation/Highway	0.783

Estimated annual runoff volumes generated in the three miscellaneous sub-basin areas is summarized in Table 4-6 for each of the 17 general land use categories. Estimated annual

TABLE 4-6

ESTIMATED ANNUAL RUNOFF GENERATED IN MISCELLANEOUS SUB-BASIN AREAS DISCHARGING TO LAKE HANCOCK

BASIN NO	LAND USE	AREA (acres)	ESTIMATED "C" VALUE	ANNUAL RUNOFF VOLUME (ac-ft/yr[1])
10,000	Agricultural-Citrus	228.1	0.282	267
	Agricultural-Crops/Pasture	1060.6	0.355	1560
	Agricultural-General	40.3	0.304	51
	Commercial	10.7	0.837	37
	Extractive	70.8	0.361	106
	Industrial	56.9	0.793	187
	Low-Density Residential	80.7	0.268	90
	Medium-Density Residential	152.0	0.373	235
	Rangeland	5.0	0.163	3
	Transportation/Highway	37.8	0.783	123
	Upland Forests	635.3	0.163	429
	Wetlands	1406.4	0.225	1311
	Sub-Total:	3784.6	0.281[2]	4399
10,020	Agricultural-Citrus	681.5	0.282	796
	Agricultural-Crops/Pasture	138.2	0.355	203
	Agricultural-General	95.1	0.304	120
	Commercial	24.9	0.837	86
	Disturbed Land	13.6	0.361	20
	Extractive	12.0	0.361	18
	High-Density Residential	18.1	0.675	51
	Institutional	41.6	0.268	46
	Low-Density Residential	146.0	0.268	162
	Medium-Density Residential	633.5	0.373	979
	Open Land	28.3	0.163	19
	Recreational	20.2	0.163	14
	Transportation/Highways	9.6	0.783	31
	Upland Forests	154.4	0.163	104
	Wetlands	27.1	0.225	25
	Sub-Total:	2044.1	0.316[2]	2674
10,040	Agricultural-Citrus	23.8	0.282	28
	Agricultural-Crops/Pasture	131.3	0.355	193
	Commercial	2.3	0.837	8
	Extractive	373.7	0.361	559
	Institutional	32.9	0.268	37
	Low-Density Residential	64.4	0.268	72
	Medium-Density Residential	177.9	0.373	275
	Rangeland	120.4	0.163	81
	Recreational	0.5	0.163	0
	Upland Forests	243.1	0.163	164
	Wetlands	383.8	0.225	358
	Sub-Total:	1554.1	0.276[2]	1775
	TOTAL:	**7382.8**	**0.289[2]**	**8848**

1. Based on a mean annual rainfall of 49.72 inches
2. Weighted average

runoff volumes were obtained by multiplying the area within each general land use type times the estimated "C" value times the mean annual rainfall depth of 49.72 inches. On an annual basis, the three miscellaneous sub-basin areas generate approximately 8848 ac-ft of runoff per year.

The estimated annual runoff volume of 8848 ac-ft reflects the total runoff volume generated by each of the individual land use types. Howver, on an annual basis, only a portion of the generated runoff volume will actually reach Lake Hancock. Some of the generated runoff volume will be lost during migration through vegetated drainage canals or be trapped in depressional areas and lost to groundwater seepage or evapotranspiration. For purposes of this evaluation, it is assumed that approximately 25% of the annual generated runoff volume will be lost prior to reaching Lake Hancock. Therefore, it is assumed that approximately 6636 ac-ft (8884 ac-ft x 0.75) of runoff enters Lake Hancock from the miscellaneous areas each year. A comparison of estimated runoff inputs to Lake Hancock from the miscellaneous sub-basins and the three inflow tributaries is given in Figure 4-8.

4.2 Inputs and Losses from Direct Precipitation and Evaporation

During the period from 1943-1995, average annual rainfall at the Lakeland monitoring site has been approximately 49.72 inches (126 cm) per year. A summary of estimated mean monthly rainfall over the same period is given in Table 4-7. Based on an average water surface area of approximately 4519 acres, direct precipitation on the surface of Lake Hancock contributes approximately 18,724 ac-ft/yr to the lake.

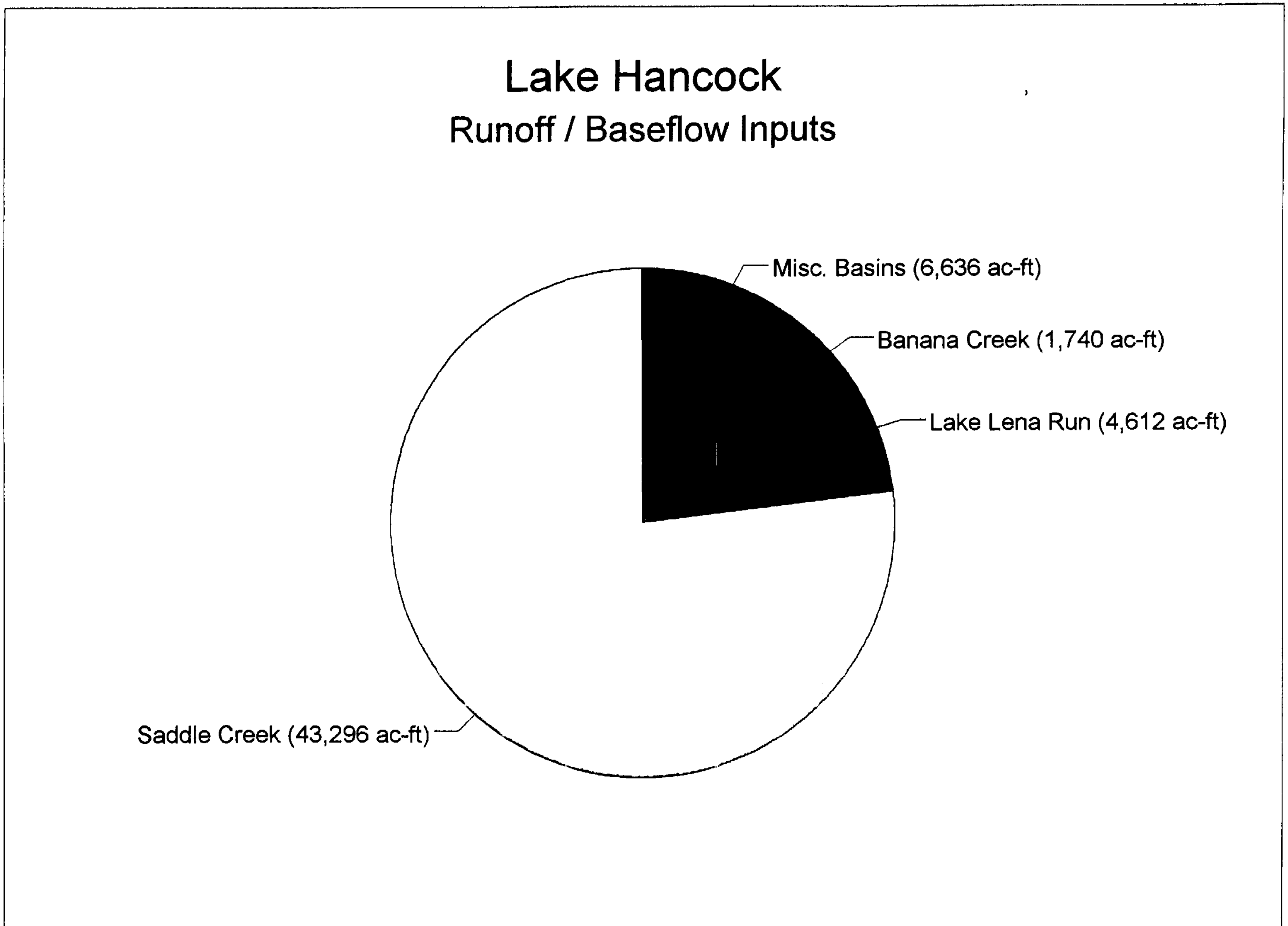


Figure 4-8. Comparison of Estimated Annual Runoff/Baseflow Inputs to Lake Hancock.

TABLE 4-7

ESTIMATED MEAN MONTHLY RAINFALL AND EVAPORATION IN THE LAKE HANCOCK AREA

MONTH	MEAN RAINFALL[1] (inches)	MEAN LAKE EVAPORATION (inches)
January	2.42	2.53
February	2.65	3.08
March	3.65	4.57
April	2.24	5.55
May	3.83	6.18
June	6.92	5.59
July	7.99	5.53
August	7.31	5.23
September	6.20	4.58
October	2.58	4.02
November	1.88	2.91
December	2.05	2.36
TOTAL:	49.72	52.13

1. Mean rainfall at the Lakeland monitoring site from 1943-1995

2. Based on mean pan evaporation at the Lake Alfred Experiment Station from 1969-1998 and a pan coefficient of 0.73

Mean monthly evaporation data is also summarized in Table 4-7 based upon mean pan evaporation measurements performed at the Lake Alfred experiment station from 1969-1998. Pan evaporation measurements performed at this site were adjusted using a pan coefficient of 0.73 to estimate mean lake surface evaporation. The estimated annual mean lake evaporation from Lake Hancock is approximately 52.13 inches/year. Assuming a lake surface area of 4519 acres, evaporation losses from the lake surface will result in a net loss of 19,631 ac-ft/yr.

4.3 Evaluation of Hydraulic Inputs from Shallow Groundwater Seepage

Detailed field investigations were performed to evaluate the quantity and quality of shallow groundwater seepage entering Lake Hancock under existing conditions. Groundwater seepage was quantified using a series of seepage meters installed at various locations throughout the lake. Seepage meters provide a mechanism for direct measurement of groundwater inflow into a lake by isolating a portion of the lake bottom so that groundwater seeping up through the bottom sediments into the lake can be collected and characterized. Use of the direct seepage meter measurement technique avoids errors, assumptions and extensive input data required when indirect techniques are used, such as the Gross Water Budget or Subtraction Method, as well as computer modeling and flow net analyses.

The seepage meter technique has been recommended by the U.S. Environmental Protection Agency (EPA) and has been established as an accurate and reliable technique in field and tank test studies (Lee, 1977; Erickson, 1981; Cherkauer and McBride, 1988; Belanger and Montgomery, 1992). With installation of adequate numbers of seepage meters and proper placement, seepage meters are a very effective tool to estimate groundwater-surface water interactions. One distinct advantage of seepage meters is that seepage meters can provide estimates of both water quantity and quality entering a lake system, whereas estimated methods can only provide information on water quantity.

4.3.1 Seepage Meter Construction and Locations

A schematic of a typical seepage meter installation used in Lake Hancock is given in Figure 4-9. Seepage meters were constructed from a 2.0 ft (0.61 m) diameter aluminum container with a closed top and open bottom. Each seepage meter isolated a sediment area of

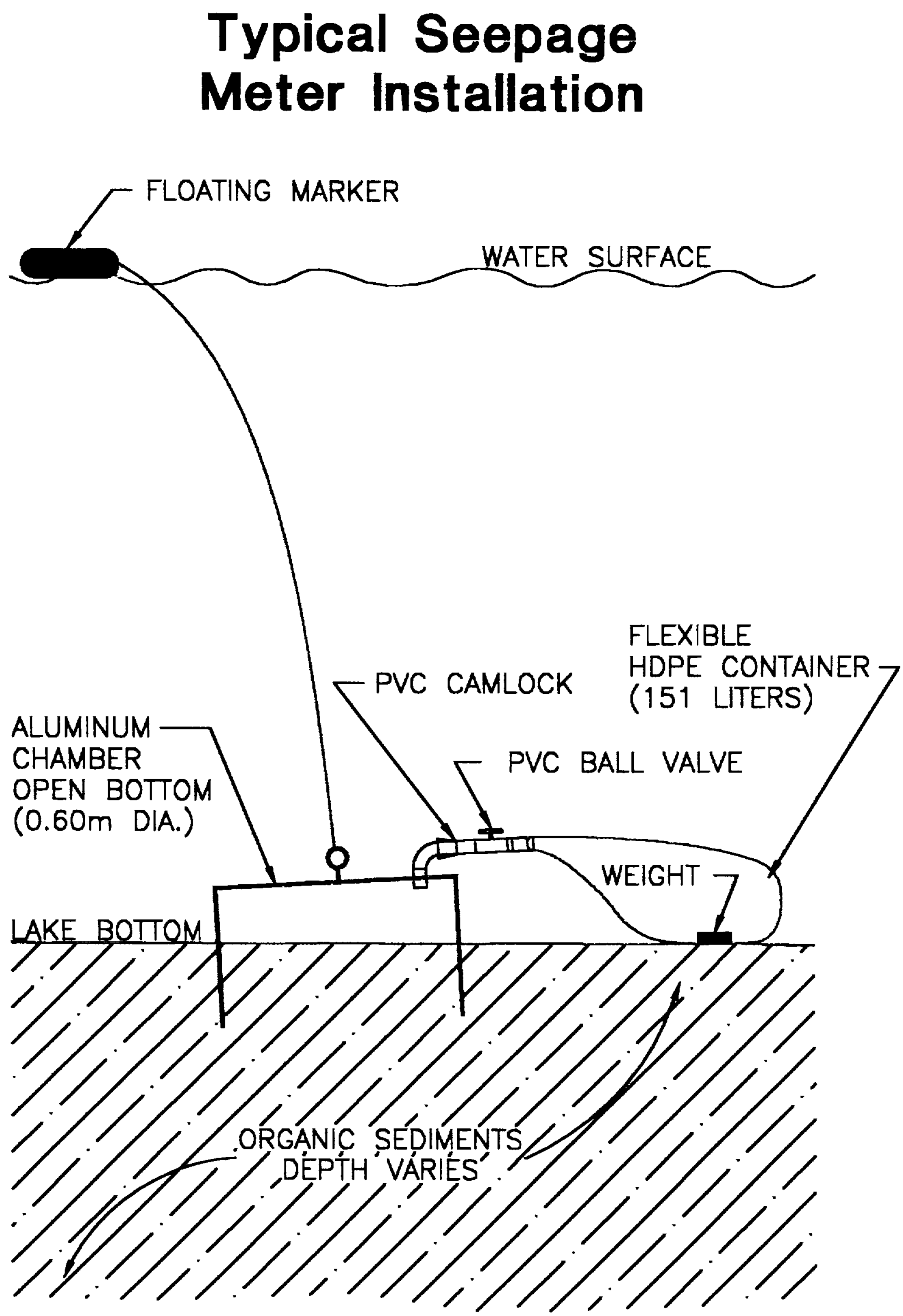


Figure 4-9. Typical Seepage Meter Installation Used in Lake Hancock.

approximately 3.14 ft^2 (0.28 m^2). Seepage meters were inserted into the lake sediments to a depth of approximately 8-12 inches (20-30 cm), isolating a portion of the lake bottom. Approximately 3 inches (7-8 cm) of water was trapped inside the seepage meter above the lake bottom.

A 0.5 inch (1.3 cm) threaded PVC fitting was inserted into the top of the aluminum container and secured using a plastic nut. The 0.5 inch (1.3 cm) PVC fitting was attached to a female quick-disconnect PVC camlock fitting. A flexible polyethylene bag, with an approximate volume of 40 gallons (151 liters) was attached to the seepage meters using a quick-disconnect PVC male camlock fitting with a terminal ball valve. Each of the collection bags was constructed of black polyethylene to prevent light penetration into the bag which could potentially stimulate photosynthetic activity within the sample prior to collection. This activity could result in an undesirable alteration of the chemical characteristics of the sample.

Prior to attachment to the seepage meter, all air was removed from inside the polyethylene collection bag, and the PVC ball valve was closed so that lake water would not enter the collection container prior to attachment to the seepage meter. A diver then connected the collection bag to the seepage meter using the PVC camlock fitting. After attaching the collection bag to the seepage meter, the PVC ball valve was then opened. As groundwater influx occurs into the open bottom of the seepage meter, it is collected inside the flexible polyethylene bag. Each seepage meter was installed with a slight tilt of approximately 2-3° toward the outlet point so that any gases which may be generated inside the seepage meter would exit into the collection container. A plastic-coated fishing weight was placed inside each of the collection containers to prevent the containers from floating up towards the water surface as a result of gases trapped inside the bag. The location of each seepage meter was indicated by a floating marker in the lake which was attached to the seepage meter using a coated wire rope.

A total of 10 seepage meters were installed in Lake Hancock on October 9, 1999. Locations for these seepage meters, identified as Sites 1-10, are indicated on Figure 4-10. Since seepage inflow is affected to a large degree by the water elevation at the point of measurement, seven of the 10 seepage meters were installed around the perimeter of the lake at a uniform water depth of approximately 4 ft (1.2 m) and at a distance of approximately 100-200 ft (30-60 m) from the lake edge. Seepage meters installed at Sites 8, 9, and 10 were located near the center of Lake Hancock at a depth of approximately 6 ft (1.8 m).

Each of the 10 seepage meters were monitored on a biweekly basis from October 1998 to July 1999. A total of 10 separate seepage monitoring events were conducted for evaluation of quantity and quality at each of the 10 sites during this monitoring period, with a total of 80 collected samples.

4.3.2 Seepage Meter Sampling Procedures

Following installation of all seepage meters, a period of 10 days was allowed for each seepage meter to reach equilibrium with the water column and groundwater prior to installing the flexible collection bag. After the initial installation of collection bags, site visits were performed on approximately a biweekly basis to collect groundwater samples.

During the collection process, a diver was used to close the PVC ball valve and remove the collection bag from the seepage meter using the quick-disconnect camlock fitting. The collection bag was placed onto the boat and the volume of seepage collected in the container was measured using a 4-liter graduated cylinder. Seepage samples which contained larger volumes of water were measured using a graduated polyethylene bucket.

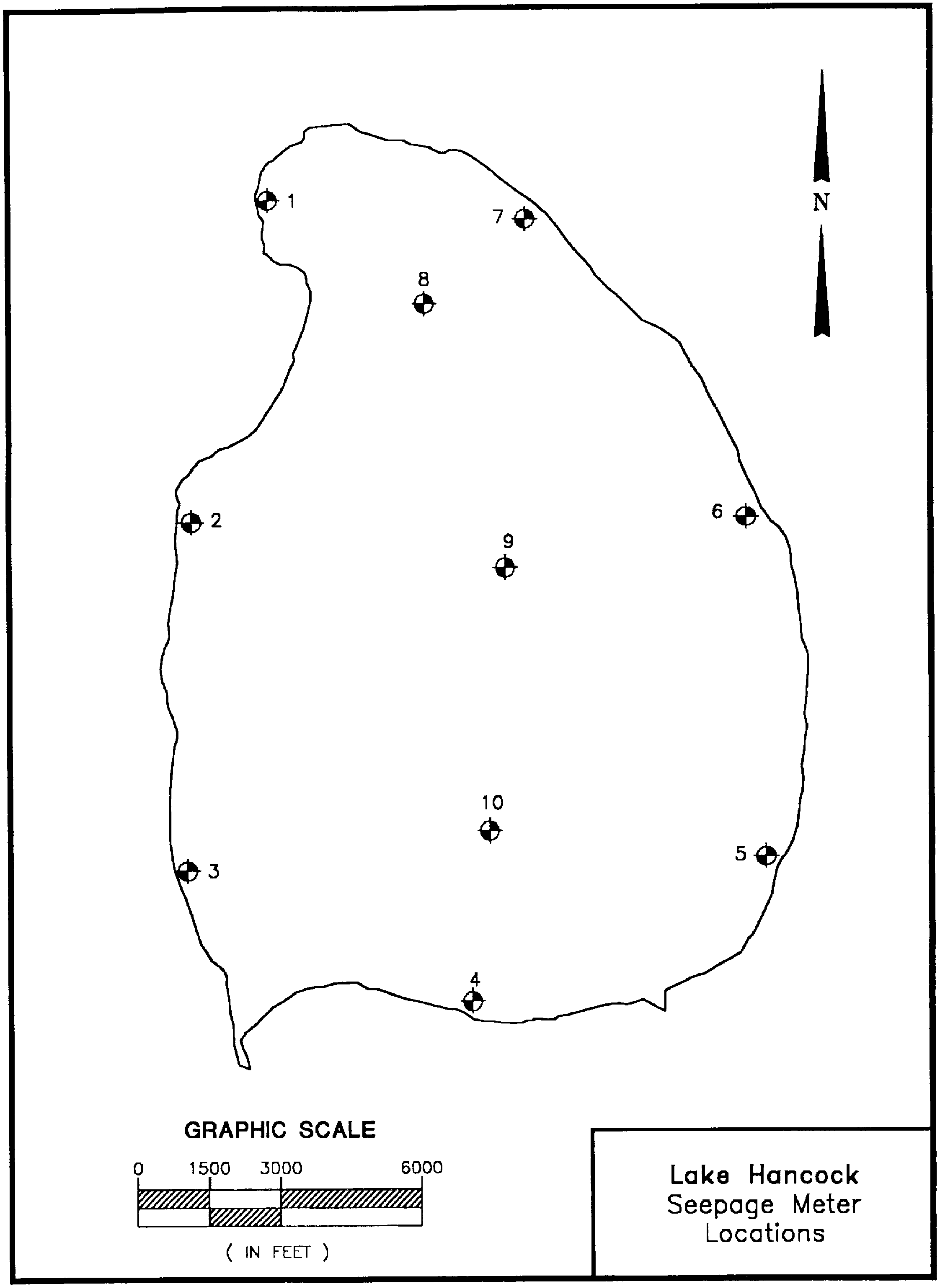


Figure 4-10. Seepage Meter Monitoring Sites in Lake Hancock.

Following the initial purging, seepage meter samples were collected for return to the laboratory for chemical analysis. On many occasions, seepage meter samples were found to contain turbidity originating from the sediments isolated within the seepage meter. As a result, seepage meter samples collected for chemical analyses were field-filtered using a 0.45 micron disposable glass fiber filter typically used for filtration of groundwater samples. A new filter was used for each seepage sample. Seepage samples were filtered immediately following collection using a battery operated peristaltic pump at a flow rate of approximately 1 liter/minute. The filtered seepage sample was placed on ice for return to the ERD laboratory for further chemical analyses.

4.3.3 Field Measurements of Seepage Inflow

Seepage inflow into Lake Hancock was monitored on approximately a biweekly basis at 10 sites from October 1998 to July 1999. A summary of field measurements of seepage inflow collected over this period is given in Appendix H. During collection of groundwater seepage, information was collected on the time of sample collection, the total volume of seepage collected at each site, and general observations regarding the condition of the seepage collection bags and sample filtration details. The seepage flow rate at each location is calculated by dividing the total seepage volume collected by the area of the seepage meter and the time over which the seepage sample was collected.

Variations in overall mean groundwater seepage rates into Lake Hancock for each

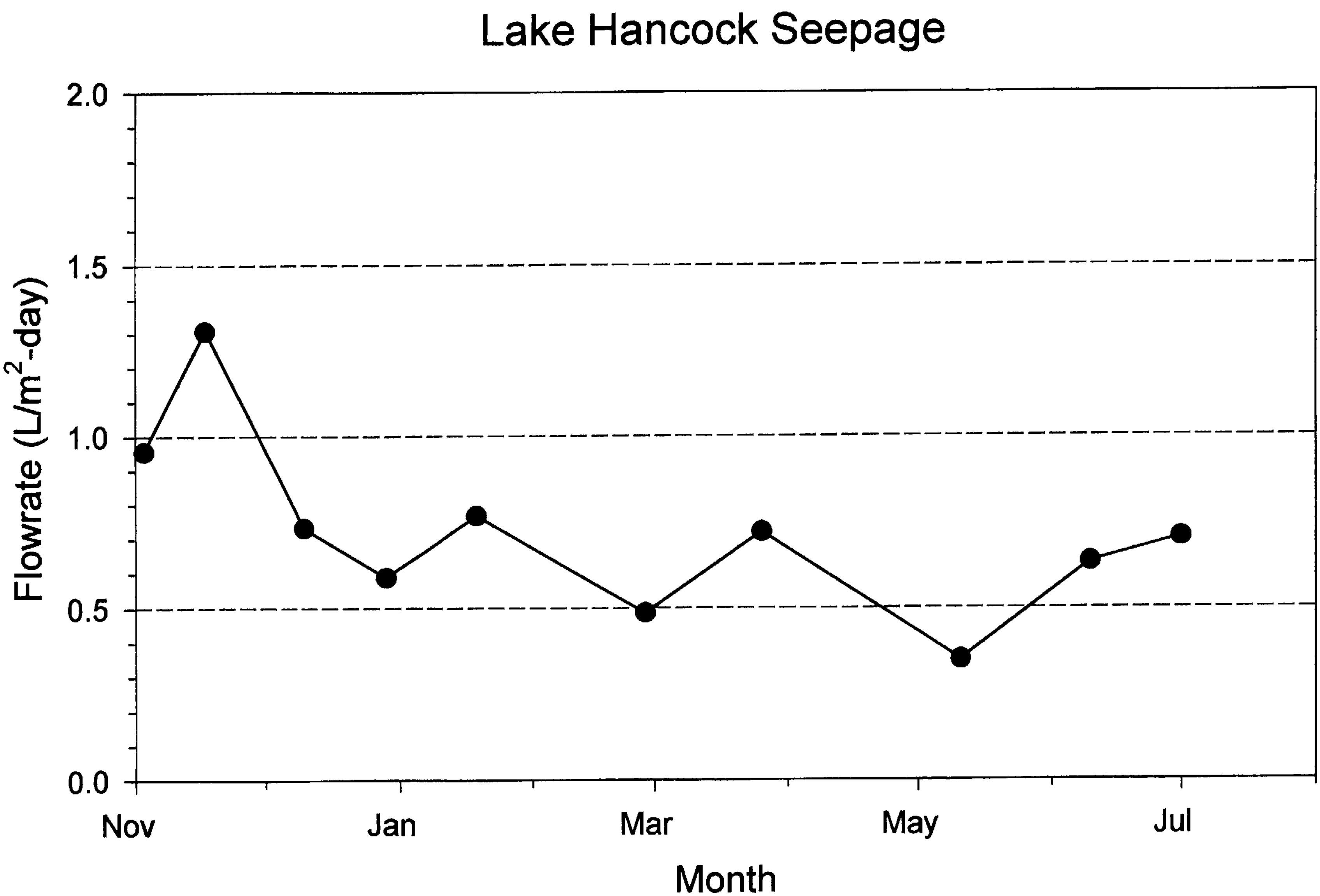


Figure 4-11. Variations in Mean Groundwater Seepage Rates into Lake Hancock.

mean seepage rate of 1.14 liters/m^2-day. Seepage samples collected during the period from January to July 1999, comprising six separate monitoring events, appear to be generally lower in value than the previous measurements and are assumed to represent dry season conditions. The mean seepage inflow into Lake Hancock for this monitoring period is 0.63 liters/m^2-day. The seepage inflow rate during the wet season is approximately twice the dry season rate.

A summary of mean volumetric seepage meter measurements collected during wet and dry season conditions in Lake Hancock is given in Table 4-8. As discussed previously, seepage meters at Sites 1-7 were installed at a water depth of 4 ft (1.2 m), and seepage meters at Sites 8, 9, and 10 were installed near the center of the lake. In general, mean seepage measurements collected at all 10 seepage meter sites are relatively close in value, with the mean seepage values ranging from 0.22-2.37 liters/m^2-day during wet season conditions and from 0.26-1.19 liters/m^2-day during dry season conditions.

TABLE 4-8

VOLUMETRIC SEEPAGE METER FIELD MEASUREMENTS COLLECTED IN LAKE HANCOCK DURING WET AND DRY SEASON CONDITIONS

SEEPAGE METER SITE	WATER DEPTH[1]	SEEPAGE (liters/m^2-day)	
		WET SEASON	DRY SEASON
1	1.2 m (4 ft)	1.41	0.36
2	1.2 m (4 ft)	0.22	0.26
3	1.2 m (4 ft)	0.95	0.40
4	1.2 m (4 ft)	2.37	1.16
5	1.2 m (4 ft)	1.33	0.80
6	1.2 m (4 ft)	2.12	1.05
7	1.2 m (4 ft)	1.31	1.19
8	1.8 m (6 ft)	0.67	0.37
9	1.8 m (6 ft)	0.69	0.40
10	1.8 m (6 ft)	0.30	0.37

1. Depth of water where seepage meter installed

Wet season and dry season isopleth maps were developed to describe seasonal seepage patterns in Lake Hancock. Mean seasonal seepage rates measured at each of the 10 monitoring locations were used to generate seepage flow contour maps for Lake Hancock under wet season and dry season conditions.

Wet season seepage flow isopleths for Lake Hancock, based upon mean seepage values presented in Table 4-8, are shown in Figure 4-12. Seepage rates on the east side of the lake range from 0.8-1.6 liters/m^2-day. The lowest seepage rates occur on the west side of the lake which is primarily pasture/agricultural land use.

Dry season seepage flow isopleths for Lake Hancock, based upon mean seepage values presented in Table 4-8, are shown in Figure 4-13. Seepage rates at the east side of the lake appear to be the greatest, with mean values of 0.6-1.2 liters/m^2-day. Seepage rates on the west side of the lake appear to be substantially lower, ranging from 0.6-0.4 liters/m^2-day.

An estimate of the mean daily seepage inflow into Lake Hancock was obtained by integrating the wet and dry season isopleths indicated on Figures 4-12 and 4-13 to obtain an estimate of the mean daily seepage flow entering Lake Hancock during wet and dry conditions. Daily seepage values were multiplied by 153 days/year for wet season conditions (July, August, September, October and November), and by 212 days/year for dry season conditions (December, January, February, March, April, May and June). Based upon this procedure, the average seepage inflow into Lake Hancock is estimated to be 11.53 ac-ft/day (14,233 m^3/day). On an annual basis, seepage inflow into Lake Hancock contributes approximately 4209 ac-ft/yr (5,195,200 m^3/yr).

4.4 Lake Discharge at Structure P-11

The U.S. Geological Survey (USGS) has maintained a continuous flow recording unit on Saddle Creek at Structure P-11 since 1964. The monitoring site, designated as Station

Lake Hancock

Wet Season Seepage

(liters/m^2-day)

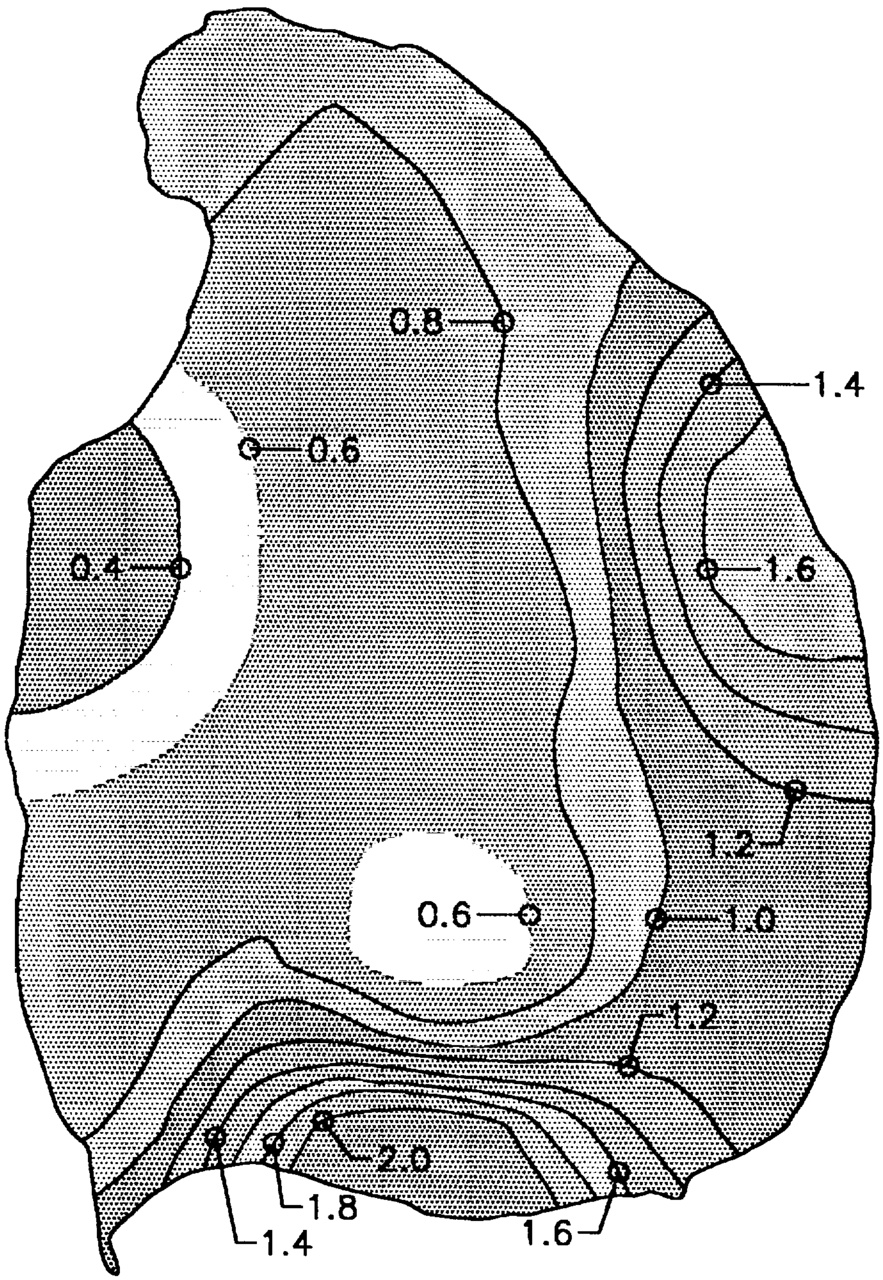


Figure 4-12. Wet Season Seepage Isopleths for Lake Hancock.

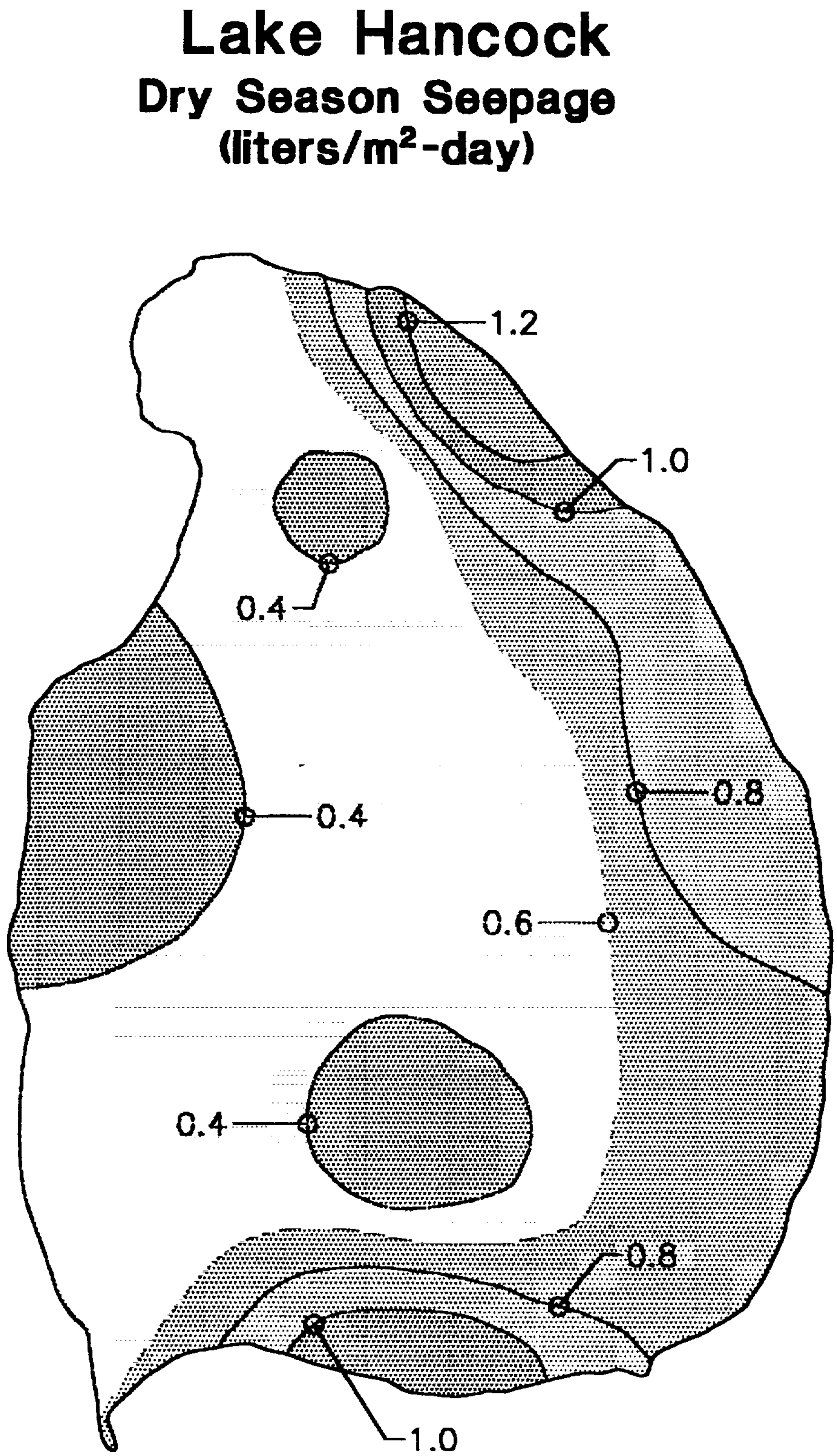


Figure 4-13. Dry Season Seepage Isopleths for Lake Hancock.

02294491, is located approximately 65 ft (20 m) downstream from Structure P-11, 0.7 miles (1.1 km) south of Lake Hancock. The station contains a water stage recorder with a rating curve used to convert water level elevations to estimated discharge rates.

A summary of average monthly discharge from Saddle Creek at Structure P-11 is given in Table 4-9. Flow discharges at Structure P-11 appear to peak in August and September, with substantially lower flows observed in November, December, May and June. Mean annual discharge from Structure P-11 from 1964-1996 is approximately 59.3 cfs, equating to an annual discharge volume of approximately 42,916 ac-ft.

TABLE 4-9

AVERAGE MONTHLY DISCHARGE FROM SADDLE CREEK AT STRUCTURE P-11

MONTH	AVERAGE MONTHLY DISCHARGE	
	cfs	ac-ft
January	52.0	3,197
February	62.1	3,481
March	56.9	3,500
April	49.9	2,968
May	20.0	1,232
June	36.2	2,151
July	76.3	4,689
August	123	7,547
September	120	7,124
October	64.8	3,986
November	26.2	1,561
December	24.1	1,480
	59.3 (mean)	42,916 (total)

1. Based on mean discharge records for the period from 1964-1996

SOURCE: USGS Data, Station 02294491

4.5 Estimation of Lake Hancock Hydrologic Budget

A listing of estimated hydrologic inputs to Lake Hancock is provided in Table 4-10. On an annual basis, approximately 79,217 ac-ft of water enters Lake Hancock. Of this amount, approximately 71% is contributed by stormwater runoff and baseflow, 24% by rainfall, and 5% by groundwater seepage. Annual mean hydrologic inputs to Lake Hancock are summarized in Figure 4-14.

TABLE 4-10

ESTIMATED HYDROLOGIC INPUTS TO LAKE HANCOCK

INPUT SOURCE	ESTIMATED VALUE		PERCENT OF TOTAL
	(ac-ft/yr)	(m^3/yr)	
Stormwater/Baseflow Inputs	56,284	69,478,638	71.1
Groundwater Seepage	4,209	5,195,714	5.3
Direct Rainfall	18,724	23,113,461	23.6
TOTALS:	97,787,813	79,217	100.0

A listing of estimated hydrologic losses from Lake Hancock is provided in Table 4-11. On an annual basis, approximately 42,916 ac-ft/yr of water is discharged from Lake Hancock at Structure P-11. An additional 19,631 ac-ft/yr is lost from the lake due to evaporation. The remaining hydrologic losses from Lake Hancock apparently occur through loss to deep groundwater in portions of the lake with leaky connections to the underlying aquifer. On an annual basis, approximately 54% of the inputs to the lake are discharged at Structure P-11, with 26% lost to evaporation and 20% lost to deep groundwater. Annual mean hydrologic losses from Lake Hancock are summarized in Figure 4-15.

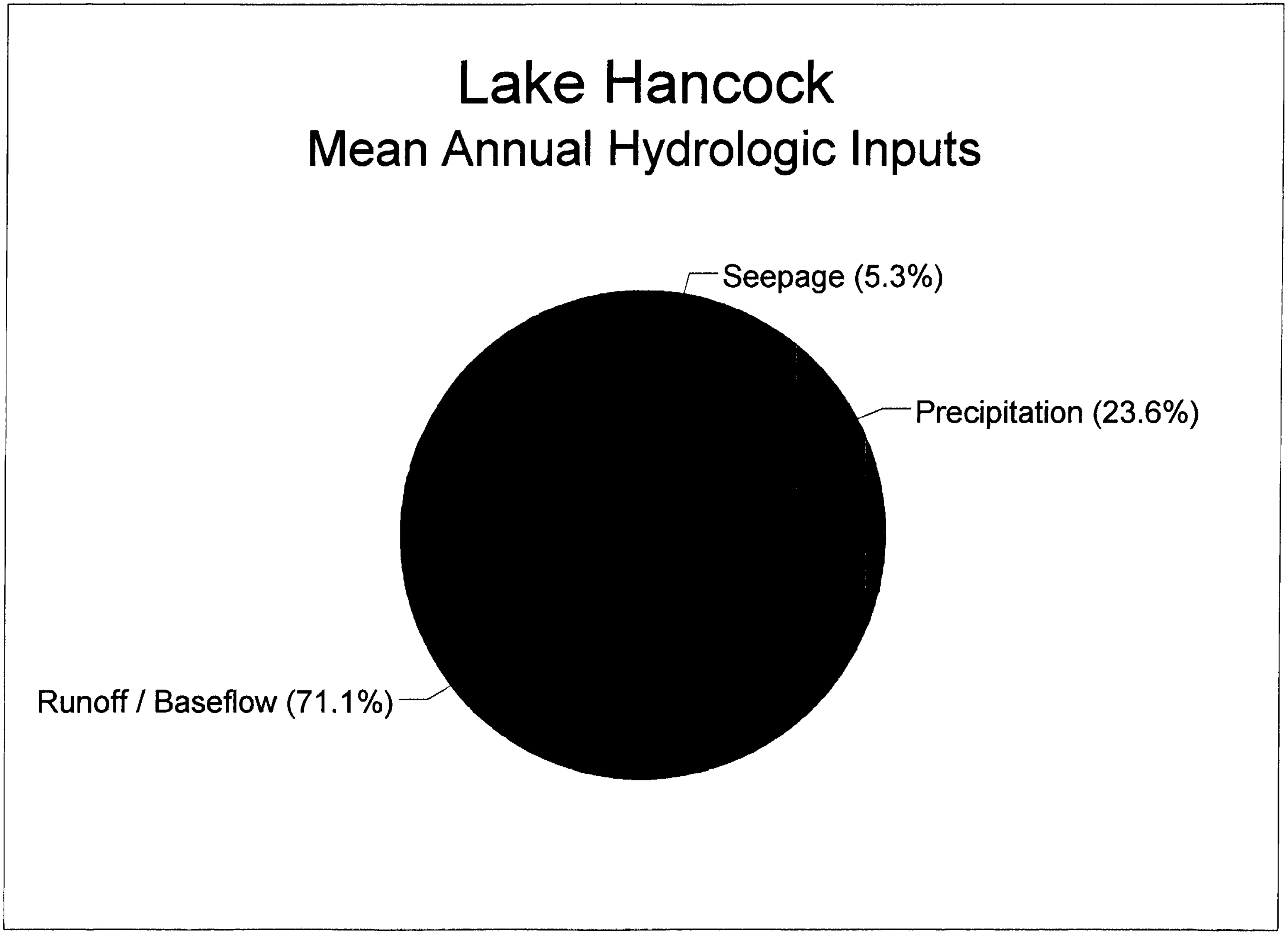


Figure 4-14. Comparison of Annual Mean Hydrologic Inputs to Lake Hancock.

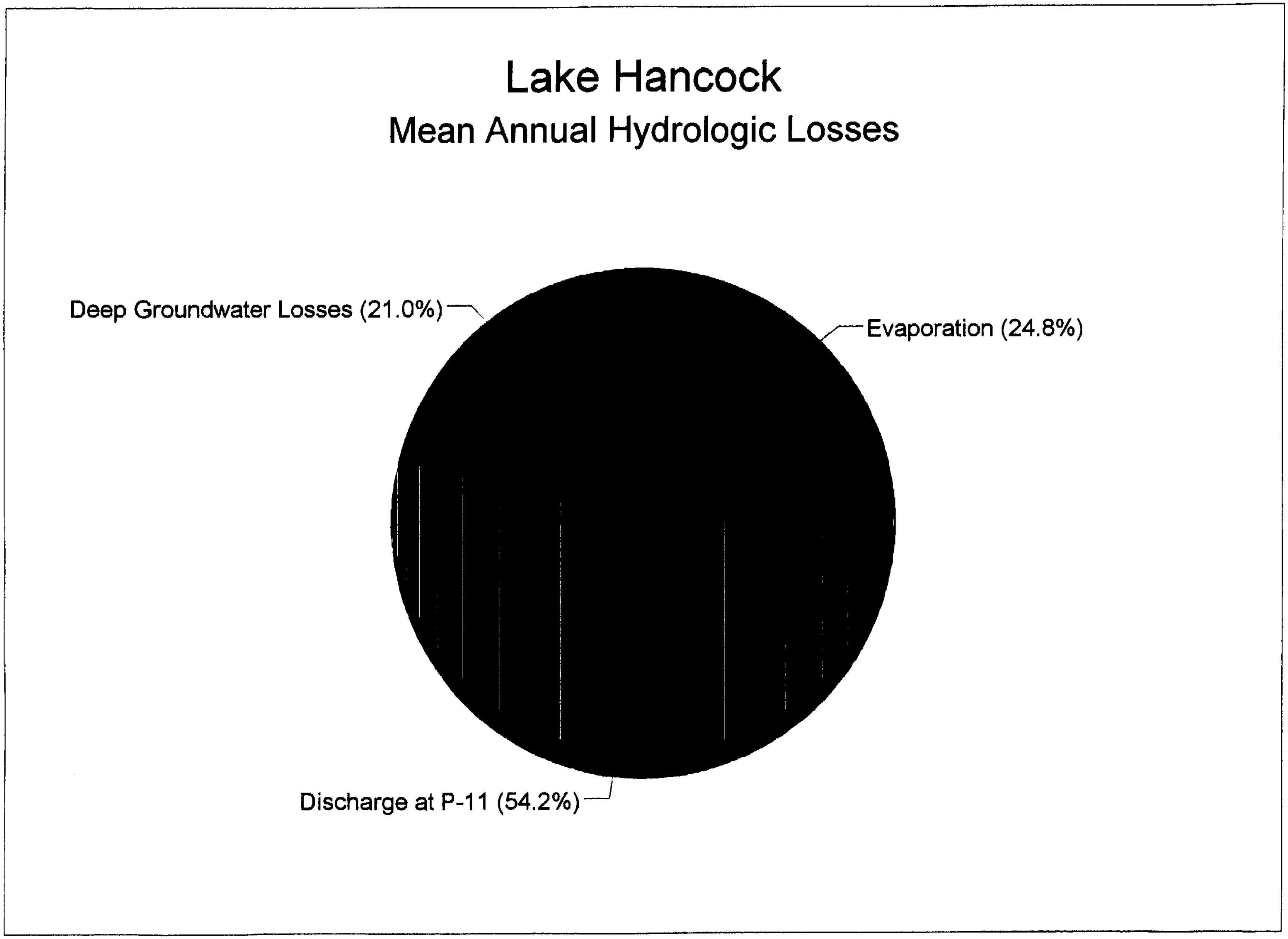


Figure 4-15. Comparison of Annual Mean Hydrologic Losses from Lake Hancock.

TABLE 4-11

ESTIMATED HYDROLOGIC LOSSES FROM LAKE HANCOCK

SOURCE	ESTIMATED VALUE		PERCENT OF TOTAL
	(m^3/yr)	(ac-ft/yr)	
Discharge at Structure P-11	52,976,782	42,916	54.2
Evaporation	24,233,088	19,631	24.8
Deep Groundwater Loss	20,577,943	16,670	21.0
TOTALS:	97,787,813	79,217	100.0

4.6 Mean Hydraulic Residence Time for Lake Hancock

Based upon the bathymetric information for Lake Hancock presented in Section 2, the approximate volume of Lake Hancock is 16,048 ac-ft (19,810,127 m^3). As seen in Table 4-11, the estimated annual inflow to the lake from stormwater, baseflow, direct precipitation, and groundwater seepage is approximately 79,217 ac-ft/yr (97,787,813 m^3/yr). Based upon this inflow volume, the annual residence time in Lake Hancock is approximately 0.20 years or 74 days.

SECTION 5

EVALUATION OF NUTRIENT AND POLLUTANT INPUTS TO LAKE HANCOCK

Field investigations were performed by ERD to evaluate the chemical characteristics of stormwater, baseflow and groundwater seepage entering Lake Hancock under current conditions to provide information necessary for preparation of a nutrient budget for the lake. Automatic sequential stormwater collectors were installed at three locations in the Lake Hancock drainage basin to characterize stormwater runoff and baseflow entering Lake Hancock from the three inflow tributaries. Pollutant inputs from miscellaneous sub-basin areas were estimated using literature-based loading rates for existing land use types in the basin. In addition, a total of 10 groundwater seepage meters were installed in Lake Hancock to characterize the quantity and quality of nutrient inputs from groundwater seepage.

A discussion of the hydrologic characteristics of stormwater runoff, baseflow and groundwater seepage was previously presented in Section 4. A discussion of the chemical characteristics and estimated annual pollutant loadings from stormwater runoff, baseflow, bulk precipitation, and groundwater seepage is given in the following sections.

5.1 Evaluation of Pollutant Loadings from Stormwater Runoff and Baseflow

Estimates of annual pollutant loadings from stormwater runoff and baseflow were generated for each of the four primary sub-basin areas discharging into Lake Hancock, as outlined on Figure 3-1, including the Banana Creek watershed, Lake Lena Run watershed, Saddle Creek watershed, and the miscellaneous watershed areas. These estimates were based upon a combination of field measurements and literature-based loading values. Direct measurements of stormwater runoff and baseflow characteristics were performed in each of the three primary inflow tributaries, including Banana Creek, Lake Lena Run, and Saddle Creek. Chemical characteristics of stormwater runoff in the miscellaneous sub-basin areas surrounding Lake Hancock were estimated using literature-based runoff characteristics for land use types in this basin. Details of evaluation methods used and estimates of annual pollutant inputs from stormwater runoff and baseflow to Lake Hancock are given in the following sections.

5.1.1 Primary Inflow Tributaries

5.1.1.1 Evaluation Methodology

A monitoring program was conducted in the Lake Hancock drainage basin from December 1998 to June 1999 to evaluate the characteristics of stormwater and baseflow entering the lake. Field monitoring of flow rates and automatic flow-weighted sample collection was performed in each of the three primary inflow tributaries, including Banana Creek, Lake Lena Run, and Saddle Creek. Together, these three sub-basin areas comprise approximately 81% of the drainage area discharging to Lake Hancock.

Continuous stormwater monitoring was performed on a flow-weighted basis at each of the three primary inflow tributary sites from December 1998 to June 1999. Each of the automatic sequential samplers was equipped with a bottom base that contained 24 separate 1-liter polyethylene containers. Each of the collected flow-weighted samples was stored in a separate polyethylene container until the samples were retrieved by ERD personnel. Upon return to the ERD laboratory, each of the collected samples was composited to reflect samples collected during discrete rain events or periods of baseflow, based upon the continuous hydrograph collected at each of the monitoring sites. Techniques utilized for collection of stormwater runoff are outlined in the FDEP-approved Comprehensive Quality Assurance Plan (No. 870322G, revised April 1997) prepared by ERD.

Composite samples labeled as "runoff" were collected during peaks in the inflow hydrograph of a particular tributary that was specifically related to an identifiable rain event. Water discharging through each tributary between storm events was identified as "baseflow". However, in many instances, it was extremely difficult to categorize collected samples as either "runoff" or "baseflow" since identifiable hydrograph peaks are present in the three tributaries only during larger storm events. Stormwater runoff generated in each of the three tributary sub-basins is attenuated substantially by the large number of lakes, waterbodies, and depressional areas. Therefore, as discussed in Section 4, much of the runoff generated during storm events discharges through the tributaries in an attenuated pattern as baseflow rather than as distinct hydrographs during storm events.

A summary of the runoff and baseflow samples collected at the three inflow tributary sites is given in Table 5-1. A total of 16 separate stormwater samples were collected at the three inflow tributary sites, with seven samples collected in Banana Creek, four samples in Lake Lena Run, and five samples in Saddle Creek. A total of 55 separate baseflow samples were collected, with 23 samples in Banana Creek, 22 samples in Lake Lena Run, and 10 in Saddle Creek.

TABLE 5-1

SUMMARY OF RUNOFF AND BASEFLOW SAMPLES COLLECTED AT THE THREE INFLOW TRIBUTARY SITES

TRIBUTARY	NUMBER OF SAMPLES COLLECTED	
	STORMWATER RUNOFF	BASEFLOW
Banana Creek	7	23
Lake Lena Run	4	22
Saddle Creek	5	10
TOTALS:	16	55

5.1.1.2 Characteristics of Monitored Stormwater Runoff and Baseflow

A complete listing of the chemical characteristics of stormwater runoff and baseflow collected at the three tributary monitoring sites from December 1998 to June 1999 is given in Appendix I. This data was entered into a SAS data set, and the chemical characteristics of stormwater runoff and baseflow were evaluated at each of the three tributary sites. During this evaluation, it was observed that the chemical characteristics of stormwater runoff and baseflow samples were very similar at each of the individual tributary sites. An ANOVA comparison of baseflow and runoff characteristics was performed for each of the three monitoring sites to evaluate whether or not statistically significant differences exist between water discharging through each of the tributaries under "stormwater" and "baseflow" conditions.

An ANOVA comparison of baseflow and runoff characteristics at the Banana Creek monitoring site is given in Table 5-2. Mean values are provided for samples designated as "baseflow" as well as samples designated as "runoff". The results of a Tukey Multiple

TABLE 5-2

ANOVA COMPARISON OF BASEFLOW AND RUNOFF CHARACTERISTICS AT THE BANANA CREEK MONITORING SITE

PARAMETER	UNITS	TYPE	MEAN VALUE[1]	GROUPING
pH	s.u.	Baseflow Runoff	8.00 7.86	A A
Conductivity	μmho/cm	Baseflow Runoff	234 216	A A
Alkalinity	mg/l	Baseflow Runoff	60.4 59.1	A A
NH_3-N	μg/l	Baseflow Runoff	477 69	A A
NO_x-N	μg/l	Baseflow Runoff	499 252	A A
Diss. Organic N	μg/l	Baseflow Runoff	1384 1298	A A
Particulate N	μg/l	Baseflow Runoff	2696 2154	A A
Total N	μg/l	Baseflow Runoff	5056 3772	A A
Ortho-P	μg/l	Baseflow Runoff	355 334	A A
Particulate P	μg/l	Baseflow Runoff	679 585	A A
Total P	μg/l	Baseflow Runoff	1088 964	A A
Color	Pt-Co	Runoff Baseflow	51 46	A A
TSS	mg/l	Baseflow Runoff	68.2 55.6	A A
BOD	mg/l	Baseflow Runoff	16.5 13.6	A A

1. Based on 23 baseflow samples and 7 runoff samples

Comparison Test between runoff and baseflow characteristics is indicated in the final column of Table 5-2. Means listed with the same letter designation are statistically similar and do not reflect significant differences at the 0.05 level. As seen in Table 5-2, no statistically significant differences exist between baseflow and runoff characteristics measured at the Banana Creek site. This lack of significant difference between runoff and baseflow is presumably due to the large amount of attenuation, and corresponding removal processes, present in the sub-basin areas which appears to attenuate chemical characteristics as well as hydrologic characteristics within this basin.

An ANOVA comparison of baseflow and runoff characteristics at the Lake Lena Run monitoring site is given in Table 5-3. Statistically significant differences between baseflow and runoff characteristics were observed only for pH, particulate phosphorus, and TSS. These findings reflect a lower degree of attenuation in the Lake Lena Run watershed compared with attenuation observed in the Banana Creek watershed. However, similar to the results observed in the Banana Creek watershed, there appears to be little statistically significant difference between runoff and baseflow characteristics in the Lake Lena Run sub-basin area.

An ANOVA comparison of baseflow and runoff characteristics at the Saddle Creek monitoring site is given in Table 5-4. Statistically significant differences between baseflow and runoff characteristics were observed in this watershed for pH, dissolved organic nitrogen, color, and BOD. However, no statistically significant differences were observed for significant nutrient parameters, such as total nitrogen or total phosphorus. In fact, measured concentrations of total nitrogen and total phosphorus in runoff and baseflow samples were virtually identical at this site. A graphical comparison of estimated runoff and baseflow characteristics entering Lake Hancock from each of the three tributary sites is given in Figure 5-1.

TABLE 5-3

ANOVA COMPARISON OF BASEFLOW AND RUNOFF CHARACTERISTICS AT THE LAKE LENA RUN MONITORING SITE

PARAMETER	UNITS	TYPE	MEAN VALUE[1]	GROUPING
pH	s.u.	Baseflow Runoff	8.18 7.93	A B
Conductivity	μmho/cm	Runoff Baseflow	399 397	A A
Alkalinity	mg/l	Runoff Baseflow	147 137	A A
NH_3-N	μg/l	Baseflow Runoff	61 57	A A
NO_x-N	μg/l	Runoff Baseflow	443 311	A A
Diss. Organic N	μg/l	Runoff Baseflow	915 732	A A
Particulate N	μg/l	Baseflow Runoff	340 248	A A
Total N	μg/l	Runoff Baseflow	1663 1444	A A
Ortho-P	μg/l	Runoff Baseflow	224 188	A A
Particulate P	μg/l	Runoff Baseflow	332 79	A B
Total P	μg/l	Runoff Baseflow	605 301	A A
Color	Pt-Co	Runoff Baseflow	152 96	A A
TSS	mg/l	Runoff Baseflow	13.6 5.6	A B
BOD	mg/l	Runoff Baseflow	1.9 1.7	A A

1. Based on 22 baseflow samples and 4 runoff samples

TABLE 5-4

ANOVA COMPARISON OF BASEFLOW AND RUNOFF CHARACTERISTICS AT THE SADDLE CREEK MONITORING SITE

PARAMETER	UNITS	TYPE	MEAN VALUE[1]	GROUPING	
pH	s.u.	Baseflow Runoff	8.03 7.67	A	 B
Conductivity	µmho/cm	Baseflow Runoff	300 291	A A	
Alkalinity	mg/l	Baseflow Runoff	123 119	A A	
NH_3-N	µg/l	Baseflow Runoff	59.2 51.7	A A	
NO_x-N	µg/l	Baseflow Runoff	293 237	A A	
Diss. Organic N	µg/l	Runoff Baseflow	805 520	A	 B
Particulate N	µg/l	Baseflow Runoff	165 145	A A	
Total N	µg/l	Runoff Baseflow	1238 1038	A A	
Ortho-P	µg/l	Baseflow Runoff	335 300	A A	
Particulate P	µg/l	Runoff Baseflow	100 68	A A	
Total P	µg/l	Runoff Baseflow	435 419	A A	
Color	Pt-Co	Runoff Baseflow	133 72	A	 B
TSS	mg/l	Runoff Baseflow	10.9 5.6	A A	
BOD	mg/l	Runoff Baseflow	2.9 1.5	A	 B

1. Based on 10 baseflow samples and 5 runoff samples

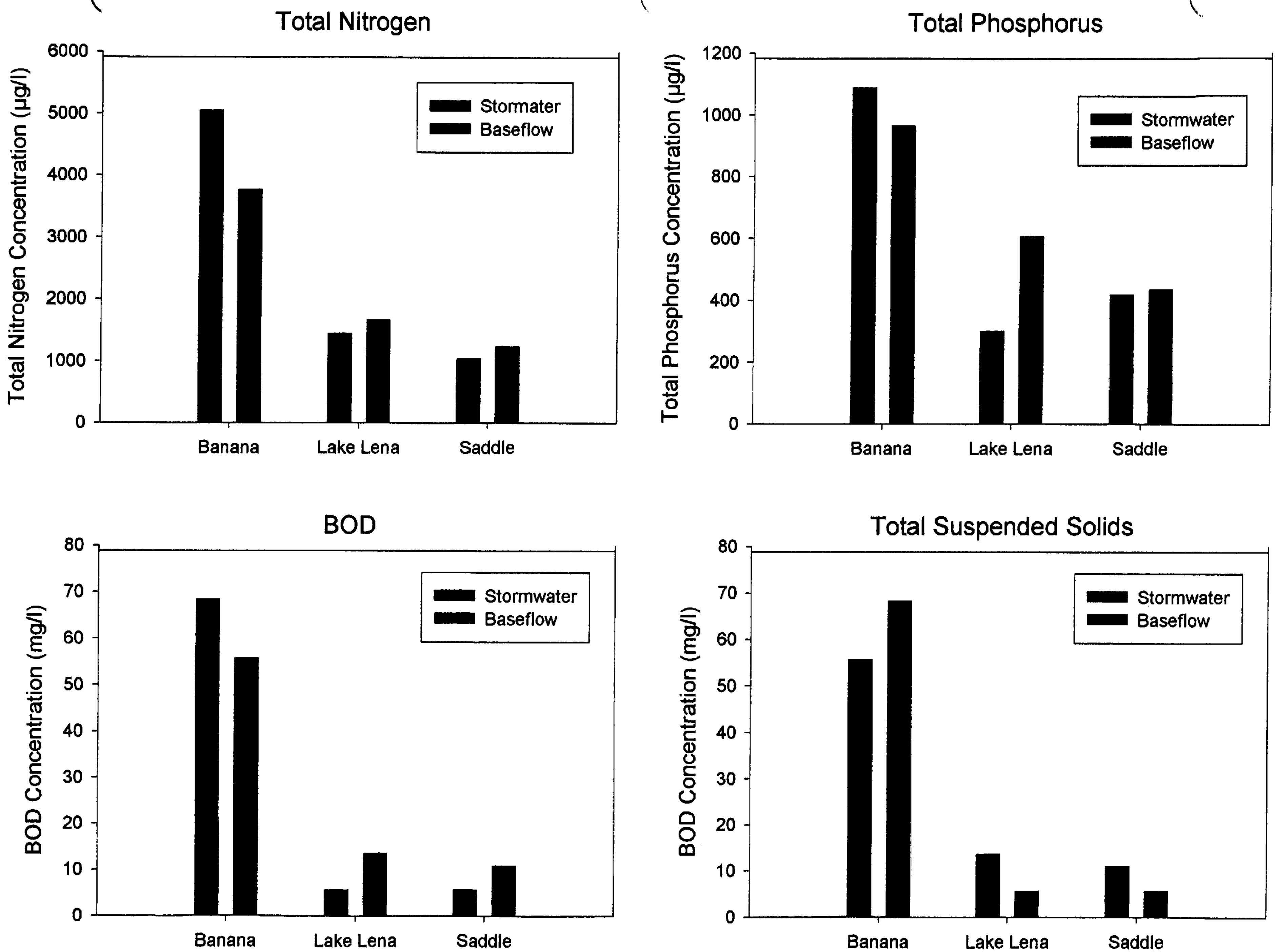


Figure 5-1. Comparison of Estimated Runoff and Baseflow Characteristics Entering Lake Hancock.

In view of the lack of statistically significant differences between chemical characteristics of runoff and baseflow, along with the difficulty in quantifying and characterizing inflow related to discrete storm events versus baseflow inputs, it appears reasonable to estimate the water quality characteristics of water discharging through each of the three tributaries as the overall mean water quality characteristics of the flow-weighted samples collected during each of the monitoring programs.

A summary of mean water quality characteristics of combined runoff and baseflow inputs to Lake Hancock from December 1998 to June 1999 is given in Table 5-5. Measured pH values in each of the three tributaries were slightly alkaline, and relatively close in value, with mean measured pH values ranging from 7.94-8.14. Measured specific conductivity values in each of the three tributaries were typical of values normally measured in stormwater runoff and baseflow, ranging from a low of 230 μmho/cm in Banana Creek to a high of 398 μmho/cm in Lake Lena Run. In general, tributary inflow was found to be moderately to well buffered, with measured alkalinity values ranging from 60.1 mg/l in Banana Creek to 138 mg/l in Lake Lena Run.

Unlike the trends observed for pH and conductivity, a relatively high degree of variability was observed in measured nitrogen species between the three sites. The most elevated concentrations of nitrogen species were observed in Banana Creek, which exhibited the highest mean concentrations for each of the measured nitrogen species. The dominant nitrogen species observed in Banana Creek was particulate nitrogen, which comprised 54% of the total nitrogen observed at this site. Based upon the distinct green coloration in the water column of Banana Creek, it appears that much of the measured particulate nitrogen may be comprised of algal biomass discharging from Banana Lake. Elevated concentrations of inorganic nitrogen species were also observed at this site, with a mean of 381 μg/l for NH_3 and 441 μg/l for NO_x. The measured mean total nitrogen concentration of 4756 μg/l is approximately 2-3 times greater than total nitrogen concentrations typically observed in urban runoff and baseflow.

TABLE 5-5

MEAN WATER QUALITY CHARACTERISTICS OF COMBINED RUNOFF AND BASEFLOW INPUTS TO LAKE HANCOCK FROM DECEMBER 1998 TO JUNE 1999

PARAMETER	UNITS	MEAN VALUE		
		BANANA CREEK	LAKE LENA RUN	SADDLE CREEK
pH	s.u.	7.97	8.14	7.94
Specific Conductivity	μmho/cm	230	398	298
Alkalinity	mg/l	60.1	138	122
NH_3	μg/l	381	60	57
NO_x	μg/l	441	331	280
Diss. Organic Nitrogen	μg/l	1364	761	586
Particulate Nitrogen	μg/l	2570	326	161
Total Nitrogen	μg/l	4756	1478	1084
Orthophosphorus	μg/l	351	193	327
Particulate Phosphorus	μg/l	657	118	75
Total Phosphorus	μg/l	1059	348	423
Color	Pt-Co	47	107	84
TSS	mg/l	65.3	6.9	6.8
BOD	mg/l	15.8	1.7	1.8

The second highest monitored nitrogen levels were observed in Lake Lena Run. Unlike Banana Creek, where particulate nitrogen was the dominant nitrogen species in Banana Creek, the dominant nitrogen species in Lake Lena Run appears to be dissolved organic nitrogen, which comprises approximately 52% of the total nitrogen measured at this site, with particulate nitrogen comprising only 22% of the total nitrogen. Measured concentrations of NH_3 and NO_x in Lake Lena Run are somewhat lower than values measured in Banana Creek, and are typical of values commonly observed in urban runoff and baseflow.

The lowest concentrations of total nitrogen were observed in Saddle Creek. Dissolved organic nitrogen is clearly the dominant nitrogen species in Saddle Creek, comprising 54% of the total nitrogen measured at this site. Particulate nitrogen comprises only approximately 15% of the total nitrogen at this site. Relatively low concentrations of both NH_3 and NO_x were observed in Saddle Creek. The mean total nitrogen concentration for Saddle Creek listed in Table 5-5 appears to be somewhat lower than values typically observed in stormwater runoff and baseflow. It appears that a substantial amount of nutrient assimilation and attenuation may be present in Saddle Creek prior to reaching Lake Hancock.

Similar to the trends observed for nitrogen species, extremely elevated levels of phosphorus were also observed in the Banana Creek tributary. The mean total phosphorus concentration of 1059 μg/l is substantially elevated and appears to be approximately 3-4 times greater than total phosphorus values typically observed in urban runoff. The dominant phosphorus species in Banana Creek is particulate phosphorus, which comprises approximately 62% of the total phosphorus measured. The mean orthophosphorus concentration of 350 μg/l also appears to be substantially elevated compared with values typically observed in runoff and baseflow. Much of the particulate phosphorus measured at this site may also be related to algal biomass discharging from Banana Lake.

Mean values of total phosphorus measured in Lake Lena Run and Saddle Creek appear to be typical of values commonly observed in urban runoff and baseflow. Measured total phosphorus concentrations at these sites ranged from 348-423 μg/l. The dominant phosphorus species in Lake Lena Run appears to be orthophosphorus, which comprises approximately 55% of the phosphorus measured at this site. Orthophosphorus is also the dominant phosphorus species observed in Saddle Creek, comprising 77% of the total phosphorus measured in this tributary. Although the mean values for total phosphorus appear typical, the observed orthophosphorus concentrations at these two sites appear to be somewhat elevated.

Tributary inflow into Lake Hancock is characterized by moderate to high levels of color, with moderate color levels observed in Banana Creek and elevated color levels observed in Saddle Creek and Lake Lena Run. Color is a common constituent in drainage originating in, or passing through, wetlands and hydric soil areas.

Measured concentrations of TSS and BOD appear to be extremely elevated in Banana Creek and low in value in Lake Lena Run and Saddle Creek. Measured concentrations of TSS and BOD in Lake Lena Run and Saddle Creek are lower than values typically observed in urban runoff, and reflect attenuation of these constituents prior to reaching the point of measurement. However, the observed concentrations in Banana Creek appear to be extremely elevated for each of these parameters. The increased TSS values in Banana Creek may also be related to particulate matter in the form of algae discharging from Banana Lake. Respiration by this algal biomass during the five-day BOD test could also create the elevated BOD values observed.

In summary, mean water quality characteristics in Banana Creek appear to be substantially elevated for virtually all of the measured nutrient species, along with TSS and BOD. Much of this impact appears to be related to discharges of algal biomass from Banana Lake. Water quality characteristics of tributary inflow from Lake Lena Run and Saddle Creek appear to be typical of values commonly observed in runoff and baseflow. For purposes of the evaluations outlined in this section, mean water quality characteristics discharging through Banana Creek, Lake Lena Run, and Saddle Creek are assumed to be equal to the water quality characteristics summarized in Table 5-5.

An ANOVA comparison of water quality characteristics at the three Lake Hancock monitoring sites is given in Table 5-6. Statistically significant differences were observed between the three sites for specific conductivity, alkalinity, dissolved organic nitrogen, particulate nitrogen, total nitrogen, orthophosphorus, particulate phosphorus, total phosphorus, color, TSS, and BOD. In most instances, where significant differences were observed, the highest concentration of the measured parameter was found in Banana Creek. Banana Creek was observed to exhibit statistically higher concentrations for dissolved organic nitrogen, particulate nitrogen, total nitrogen, particulate phosphorus, total phosphorus, TSS, and BOD compared with mean values observed at the other sites.

5.1.2 Estimated Annual Tributary Loadings to Lake Hancock

Estimates of annual pollutant loadings to Lake Hancock were calculated for each of the three primary tributary areas by multiplying the weighted mean runoff/baseflow characteristics for each sub-basin times the estimated annual mean tributary inflow generated in each sub-basin area, as summarized in Table 4-4. A summary of estimated annual pollutant loadings from the three tributary inflows generated by this procedure is given in Table 5-7.

As seen in Table 5-7, Saddle Creek is the largest single source of total nitrogen, total phosphorus, BOD, and TSS entering Lake Hancock from tributary inflow. On an overall basis, Saddle Creek contributes approximately 76% of the total nitrogen, 84% of the total phosphorus, 69% of the BOD, and 51% of the TSS entering Lake Hancock from the three primary tributary

TABLE 5-6

ANOVA COMPARISON OF WATER QUALITY CHARACTERISTICS AT THE LAKE HANCOCK MONITORING SITES

PARAMETER	UNITS	SITE	MEAN VALUE[1]	GROUPING
pH	s.u.	Lake Lena Run Banana Creek Saddle Creek	8.14 7.97 7.94	A A A
Conductivity	µmho/cm	Lake Lena Run Saddle Creek Banana Creek	398 298 230	A B C
Alkalinity	mg/l	Lake Lena Run Saddle Creek Banana Creek	138 122 60.1	A A B
NH_3-N	µg/l	Banana Creek Lake Lena Run Saddle Creek	382 60 57	A A A
NO_x-N	µg/l	Banana Creek Lake Lena Run Saddle Creek	441 331 280	A A A
Diss. Organic N	µg/l	Banana Creek Lake Lena Run Saddle Creek	1364 761 586	A B B
Particulate N	µg/l	Banana Creek Lake Lena Run Saddle Creek	2569 326 161	A B B
Total N	µg/l	Banana Creek Lake Lena Run Saddle Creek	4756 1477 1084	A B B
Ortho-P	µg/l	Banana Creek Saddle Creek Lake Lena Run	351 327 193	A A B
Particulate P	µg/l	Banana Creek Lake Lena Run Saddle Creek	657 118 75	A B B
Total P	µg/l	Banana Creek Saddle Creek Lake Lena Run	1059 423 348	A B B
Color	Pt-Co	Lake Lena Run Saddle Creek Banana Creek	107 84 47	A A B
TSS	mg/l	Banana Creek Lake Lena Run Saddle Creek	65.3 6.9 6.8	A B B
BOD	mg/l	Banana Creek Saddle Creek Lake Lena Run	15.8 1.8 1.7	A B B

inflows. Although the runoff characteristics observed in Saddle Creek, as summarized in Table 5-5, are somewhat lower in value than concentrations observed in Banana Creek or Lake Lena Run for many parameters, the substantially larger estimated inflow volume in Saddle Creek causes this tributary to be the primary contributor of pollutant loadings from the three primary inflow points.

TABLE 5-7

ESTIMATED ANNUAL MASS LOADINGS FROM TRIBUTARY INFLOW ENTERING LAKE HANCOCK

DRAINAGE SUB-BASIN	ANNUAL INFLOW		ESTIMATED ANNUAL LOADINGS (kg/yr)			
	(m^3)	(ac-ft/yr)	Total N	Total P	BOD	TSS
Banana Creek	2,147,900	1,740	10,009	2,229	33,249	137,415
Lake Lena Run	5,693,200	4,612	8,240	1,940	9,649	39,246
Saddle Creek	53,445,900	43,296	56,775	22,218	95,819	355,525
TOTALS:	61,287,000	49,648	75,024	26,387	138,717	532,186

5.1.3 Estimated Annual Loadings from Miscellaneous Sub-basin Areas

Estimates of annual pollutant loadings from stormwater runoff were generated for each of the three miscellaneous sub-basin areas discharging to Lake Hancock, including Sub-basin Nos. 10,000, 10,020, and 10,040. As discussed in Section 4.1.3, these are the only miscellaneous sub-basin areas which are thought to contribute runoff inflow to Lake Hancock on a routine basis. Other miscellaneous sub-basin areas discharge into Saddle Creek south of Lake Hancock or contribute flow into Lake Hancock on an infrequent basis.

Estimated annual pollutant loadings were calculated for each of the three sub-basin areas by multiplying areal annual mass loading rates for total nitrogen, total phosphorus, BOD, and TSS by the area contained in general land use categories for each basin. Surface areas assumed for each of the general land use categories are identical to the land use summaries outlined in Table 4-6 used for estimation of annual runoff volumes generated in the miscellaneous sub-basin areas. Estimated areal annual mass loadings for the general land use categories are summarized in Table 5-8 based upon information provided by Harper (1994).

A summary of estimated annual runoff generated mass loadings of total nitrogen, total phosphorus, BOD, and TSS in miscellaneous sub-basin areas discharging to Lake Hancock is given in Table 5-9. Estimated annual loadings are provided for each of the listed parameters for each of the general land use categories as well as the estimated overall loading discharging from each sub-basin area.

The estimated annual mass loadings summarized in Table 5-9 reflect the pollutant mass which will be generated by each listed land use type. However, on an annual basis, only a portion of the generated mass loadings will actually reach Lake Hancock. Some of the generated loadings will be lost due to plant uptake, soil adsorption, or infiltration into shallow groundwater. For purposes of this evaluation, it is assumed that approximately 25% of the annual generated mass loadings of total nitrogen, total phosphorus, and BOD will be attenuated prior to actually reaching Lake Hancock. Since a significant opportunity exists for attenuation of suspended solids within the watershed, it is assumed that approximately 50% of the generated TSS loading will be attenuated prior to reaching the lake.

Estimated mean runoff characteristics and mass loadings from miscellaneous watershed areas entering Lake Hancock are summarized in Table 5-10. Mass loading estimates

TABLE 5-8

ESTIMATED AREAL MASS LOADINGS FOR GENERAL LAND USE TYPES IN MISCELLANEOUS WATERSHED AREAS

GENERAL LAND USE	AREAL MASS LOADINGS (kg/ac-yr)			
	TOTAL N	TOTAL P	BOD	TSS
Low-Density Residential	2.88	0.32	7.6	31.9
Medium-Density Residential	4.68	0.59	14.3	56.1
High-Density Residential	8.51	1.72	38.4	256
Commercial	5.18	0.65	36.1	343
Industrial	7.30	1.24	39.5	383
Extractive	2.21	0.28	18.0	176
Institutional	2.88	0.32	7.6	31.9
Recreational	1.07	0.046	0.96	7.6
Open Land	1.07	0.046	0.96	7.6
Agricultural-Crops/Pasture	4.54	0.88	8.0	126
Agricultural-Citrus	2.91	0.20	3.6	21.9
Agricultural-General	3.62	0.55	5.8	74.0
Rangeland	1.07	0.05	1.0	7.6
Upland Forests	1.07	0.05	1.0	7.6
Wetlands	1.81	0.22	5.0	11.2
Disturbed Land	2.21	0.28	18.0	176
Transportation/Highway	6.69	1.32	21.9	182

TABLE 5-9

ESTIMATED ANNUAL RUNOFF GENERATED MASS LOADINGS IN MISCELLANEOUS SUB-BASIN AREAS DISCHARGING TO LAKE HANCOCK

BASIN NO.	LAND USE	AREA (acres)	ANNUAL LOADING (kg/yr)			
			Total N	Total P	BOD	TSS
10,000	Agricultural-Citrus	228.1	664	46	821	4995
	Agricultural-Crops/Pasture	1060.6	4815	933	8485	133,632
	Agricultural-General	40.3	146	22	234	2983
	Commercial	10.7	55	7	384	3653
	Extractive	70.8	156	20	1274	12,454
	Industrial	56.9	415	71	2248	21,797
	Low-Density Residential	80.7	232	26	613	2573
	Medium-Density Residential	152.0	711	90	2174	8527
	Rangeland	5.0	5	0	5	38
	Transportation/Highway	37.8	253	50	828	6885
	Upland Forests	635.3	680	32	635	4828
	Wetlands	1406.4	2546	309	7032	15,752
	Sub-Total:	3784.6	10,678	1,606	24,733	218,117
10,020	Agricultural-Citrus	681.5	1983	136	2453	14,924
	Agricultural-Crops/Pasture	138.2	627	122	1105	17,408
	Agricultural-General	95.1	344	52	551	7034
	Commercial	24.9	129	16	899	8544
	Disturbed Land	13.6	30	4	245	2392
	Extractive	12.0	27	3	216	2112
	High-Density Residential	18.1	154	31	694	4628
	Institutional	41.6	120	13	316	1326
	Low-Density Residential	146.0	421	47	1110	4658
	Medium-Density Residential	633.5	2965	374	9058	35,537
	Open Land	28.3	30	1	27	215
	Recreational	20.2	22	1	19	154
	Transportation/Highways	9.6	64	13	210	1742
	Upland Forests	154.4	165	8	154	1174
	Wetlands	27.1	49	6	136	304
	Sub-Total:	2044.1	7130	827	17,193	102,152
10,040	Agricultural-Citrus	23.8	69	5	86	520
	Agricultural-Crops/Pasture	131.3	596	116	1051	16,549
	Commercial	2.3	12	1	81	772
	Extractive	373.7	826	105	6726	65,769
	Institutional	32.9	95	11	250	1050
	Low-Density Residential	64.4	185	21	489	2054
	Medium-Density Residential	177.9	833	105	2544	9981
	Rangeland	120.4	129	6	120	915
	Recreational	0.5	1	0	0	4
	Upland Forests	243.1	260	12	243	1848
	Wetlands	383.8	695	84	1919	4299
	Sub-Total:	1554.1	3701	466	13,509	103,761
	TOTAL:	**7382.8**	**21,509**	**2,899**	**55,435**	**424,030**

summarized in this table represent the portion of the generated mass loadings, summarized in Table 5-9, which actually discharge to Lake Hancock on an annual basis. Mean estimated runoff characteristics for the miscellaneous watershed areas are also provided in Table 5-10. These values were obtained by dividing the estimated annual mass load generated in the miscellaneous watershed areas by the estimated total runoff volume.

TABLE 5-10

MEAN RUNOFF CHARACTERISTICS AND ESTIMATED MASS LOADINGS FROM MISCELLANEOUS WATERSHED AREAS ENTERING LAKE HANCOCK

BASIN AREA	ANNUAL MASS LOAD (kg/yr)				RUNOFF VOLUME (ac-ft/yr)
	TOTAL N	TOTAL P	BOD	TSS	
10,000	8,009	1,205	18,550	109,059	3,299
10,020	5,348	620	12,895	51,076	2,006
10,040	2,776	350	10,132	51,881	1,331
Totals:	16,133	2,175	41,577	212,016	6,636
Mean Concentration (mg/l)	1.97	0.266	5.1	25.9	

5.1.4 Comparison of Runoff Characteristics in Tributary and Miscellaneous Sub-basin Areas

A graphical comparison of runoff characteristics in the three tributary basins and in miscellaneous basin areas is given in Figure 5-2. Estimated inflow concentrations of total nitrogen and total phosphorus in the miscellaneous sub-basin areas are similar to combined runoff and baseflow characteristics measured in Lake Lena Run and Saddle Creek. Estimated concentrations of BOD and TSS in the miscellaneous sub-basin areas are somewhat higher than

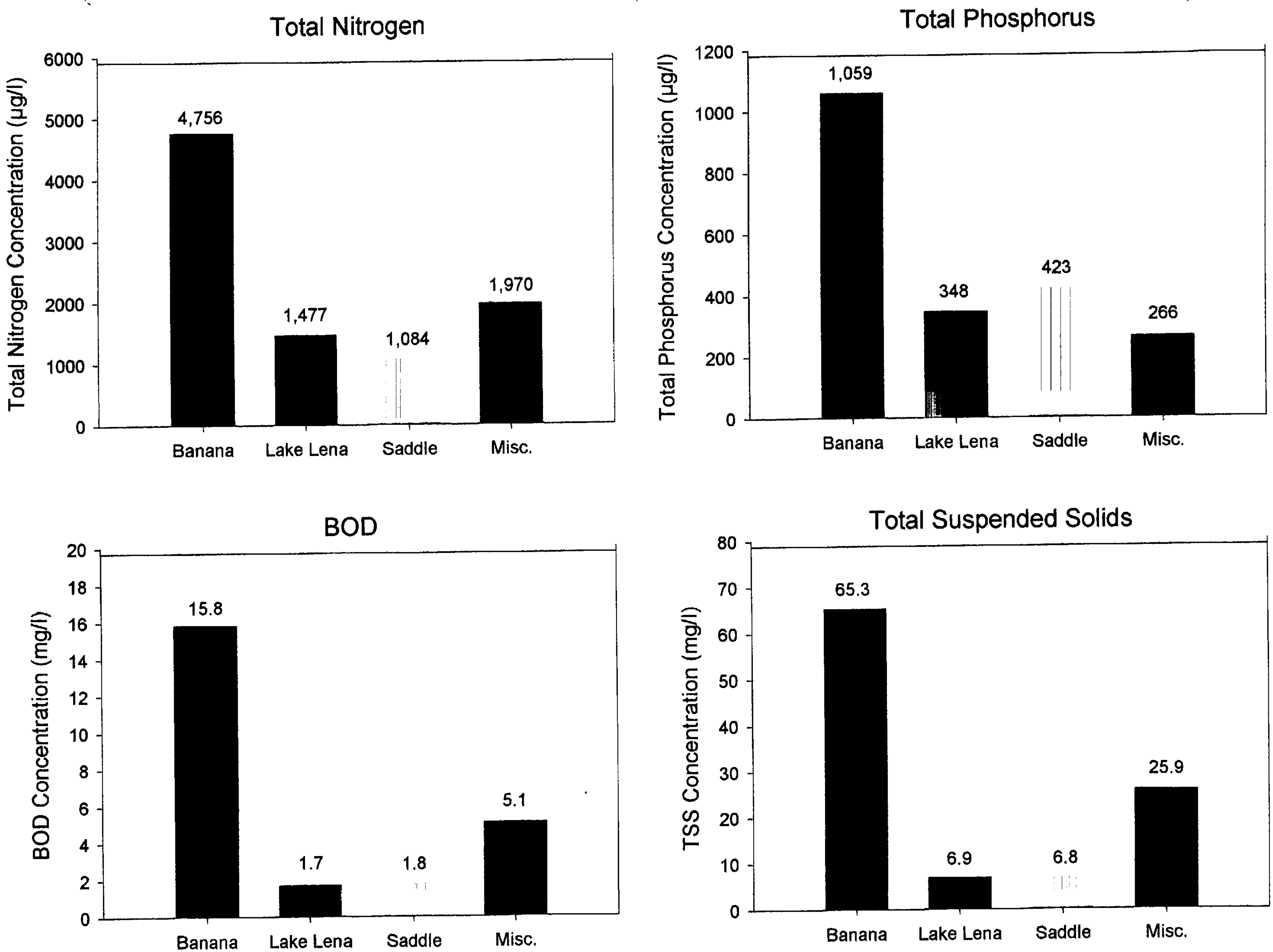


Figure 5-2. Comparison of Runoff Characteristics in Tributary and Miscellaneous Basin Areas Discharging to Lake Hancock.

concentrations measured in Lake Lena Run and Saddle Creek, although lower than values measured in Banana Creek.

A summary of estimated annual mass loadings of runoff/baseflow entering Lake Hancock is given in Table 5-11. Inputs are included for Banana Creek, Lake Lena Run, Saddle Creek, and miscellaneous areas. The combined inputs from Banana Creek, Lake Lena Run, and Saddle Creek are significant since they represent existing mass loadings which may be altered by a potential water quality improvement project on one of the three tributaries. Due to the diffuse nature of inputs to Lake Hancock from the miscellaneous watershed areas, pollutant attenuation projects in these areas would be more difficult and expensive. As seen in Table 5-11, Saddle Creek is the largest contributor of runoff generated annual mass loadings to Lake Hancock. The second largest contributor appears to be the miscellaneous areas, followed by approximately equal contributions from Banana Creek and Lake Lena Run. Based on the apparent significance of Saddle Creek with respect to runoff related input to Lake Hancock, it appears that water quality improvement projects should first be targeted in this watershed.

TABLE 5-11

SUMMARY OF ESTIMATED RUNOFF GENERATED ANNUAL MASS LOADINGS TO LAKE HANCOCK

DRAINAGE AREA	ANNUAL MASS LOAD (kg/yr)				PERCENT OF TOTAL (%)			
	TN	TP	BOD	TSS	TN	TP	BOD	TSS
Banana Creek	10,009	2,229	33,249	137,415	11	8	18	15
Lake Lena Run	8,240	1,940	9,649	206,989	9	7	5	23
Saddle Creek	56,775	22,218	95,819	355,525	62	78	53	39
Miscellaneous Areas	16,133	2,175	41,577	212,016	18	7	24	23
Totals:	91,157	28,562	180,294	911,945	100	100	100	100

5.2 Evaluation of Pollutant Loadings from Bulk Precipitation

As indicated in Section 4.2, direct rainfall on the surface of Lake Hancock contributes an estimated annual volume of approximately 18,724 ac-ft/yr to the lake. This volume represents a significant portion of the annual hydrologic budget to the lake, second only to annual hydrologic inputs from runoff and baseflow, and represents a potential source of additional nutrient inputs to the lake system.

5.2.1 Estimation of Bulk Deposition Rates

Direct collection and analysis of bulk precipitation or deposition in the Lake Hancock watershed was not conducted as part of this evaluation. However, a study of bulk atmospheric deposition within the Tampa Bay watershed was published in September 1996 by the Tampa Bay National Estuary Program as Technical Publication #08-96 titled "Assessment of Bulk Atmospheric Deposition to the Tampa Bay Watershed - Final Report". This report provides estimates of mean seasonal loadings of total phosphorus and total nitrogen as a result of dry and wet deposition in a southwest Florida watershed area. For purposes of this evaluation, it is assumed that atmospheric deposition at Lake Hancock is similar to deposition observed in the Tampa Bay area. A summary of estimated bulk deposition rates for Lake Hancock, based upon the information contained in the Tampa Bay report, is given in Table 5-12. In general, atmospheric deposition rates for total nitrogen and total phosphorus appear to be greatest during the summer months and lowest during the winter months.

TABLE 5-12

SUMMARY OF ESTIMATED BULK DEPOSITION RATES FOR LAKE HANCOCK

PARAMETER	UNITS	ESTIMATED MEAN ANNUALIZED LOADINGS BY QUARTER*				MEAN VALUE
		QUARTER 1	QUARTER 2	QUARTER 3	QUARTER 4	
Total N	kg/ac-yr	2.40	3.82	5.77	4.02	4.00
Total P	kg/ac-yr	0.25	0.38	0.52	0.51	0.42

*NOTE: Quarter 1: Months 12, 1 and 2
Quarter 2: Months 3, 4 and 5
Quarter 3: Months 6, 7 and 8
Quarter 4: Months 9, 10 and 11

Direct estimates of deposition rates for BOD and TSS in the Tampa Bay area were not provided in Technical Publication #08-96. However, ERD has performed extensive evaluations on the characteristics of bulk precipitation in Central Florida as part of other projects conducted for the St. Johns River Water Management District and the Florida Department of Environmental Protection. Based upon these evaluations, typical measured concentrations of BOD and TSS in bulk precipitation are equal to approximately 0.8 mg/l and 6.2 mg/l, respectively. These values were assumed to be representative of bulk deposition within the Lake Hancock watershed and were utilized for estimation of annual loadings from bulk deposition to Lake Hancock.

5.2.2 Estimated Annual Loadings from Bulk Precipitation

Estimates of annual mass loadings from bulk precipitation into Lake Hancock were calculated for total nitrogen and total phosphorus based upon the estimated bulk deposition rates presented in Table 5-12. The estimated bulk deposition rates in this table were multiplied by the lake surface area of 4519 acres and the number of calendar days contained within each of the four quarters. This procedure resulted in an estimate of loadings of total nitrogen and total phosphorus for each quarter which were then summed to provide an estimate of the total annual deposition into Lake Hancock.

Estimates of annual loadings for BOD and TSS were calculated based upon the assumed concentrations for these parameters discussed previously and the estimated annual direct rainfall volume of 18,724 ac-ft/yr to the lake. Estimates of annual loadings from bulk precipitation to Lake Hancock for each of the four parameters are presented in Table 5-13, based upon the assumptions outlined previously. On an annual basis, bulk precipitation contributes approximately 18,127 kg/yr of total nitrogen, 1878 kg/yr of total phosphorus, 18,473 kg/yr of BOD, and 143,168 kg/yr of TSS.

TABLE 5-13

ESTIMATED ANNUAL LOADINGS FROM BULK DEPOSITION TO LAKE HANCOCK

PARAMETER	ANNUAL LOADING (kg/yr)
Total N	18,127
Total P	1,878
BOD	18,473
TSS	143,168

5.3 Evaluation of Pollutant Loadings from Groundwater Seepage to Lake Hancock

Detailed field investigations were performed to evaluate the chemical characteristics of groundwater seepage entering Lake Hancock. Hydrologic and chemical characteristics of groundwater seepage were measured in Lake Hancock from October 1998 to June 1999. As seen in Table 4-10, groundwater seepage into Lake Hancock contributes a significant annual inflow to Lake Hancock, representing approximately 5% of the annual hydrologic input into the lake. Chemical characteristics of seepage inputs are discussed in the following sections.

5.3.1 Chemical Characteristics of Groundwater Seepage

A complete listing of chemical analyses conducted on groundwater seepage samples collected in Lake Hancock from October 1998 to July 1999 given in Appendix J. This appendix contains a listing of individual laboratory analyses for each seepage sample collected on each individual sample date. A total of 10 separate seepage monitoring events were conducted at each of the 10 monitoring locations during the monitoring period, with a total of 80 samples collected for laboratory analysis of seepage characteristics.

A comparison of mean chemical characteristics of groundwater seepage collected at the 10 monitoring sites in Lake Hancock from October 1998 to July 1999 is given in Table 5-14. In general, a considerable degree of variability appears to exist between mean characteristics measured at some of the monitoring sites. Locations of the 10 monitoring sites are given in Figure 4-10. An evaluation of potential differences in seepage characteristics based upon location within the lake as well as time of year is provided in a later section.

Overall mean values for individual parameters in groundwater seepage are provided in the final column of Table 5-14. Mean values presented in this column reflect the average of 80 separate analyses for each parameter, indicating a relatively high degree of confidence that the mean values in this column accurately reflect general seepage characteristics entering Lake Hancock. Detailed discussions for specific parameter groups are provided in the following sections.

5.3.1.1 pH, Specific Conductivity and Alkalinity

In general, groundwater seepage entering Lake Hancock is slightly alkaline in pH, with mean pH values measured at individual monitoring sites ranging from 7.63-8.12. Seepage samples collected near the center of Lake Hancock at Sites 8, 9, and 10 are relatively uniform in value, with mean pH values ranging from 7.69-7.77. A higher degree of variability is apparent in pH values measured near shoreline areas at Sites 1 through 7.

A relatively high degree of variability is apparent in mean values for specific conductivity measured at the 10 monitoring sites. Mean values at the 10 sites ranged from 279-514 μmho/cm, with an overall mean conductivity of 397 μmho/cm in the seepage samples.

A relatively high degree of variability is also apparent in mean measured concentrations of alkalinity at the 10 monitoring sites. Mean alkalinity values ranged from a low of 67.0 mg/l at Site 3, located adjacent to agricultural land use, to a high of 226 mg/l at Site 5, located adjacent to the reclaimed strip mine areas on the west side of the lake. In general, groundwater seepage at each of the monitoring sites was found to be relatively well buffered, with an overall mean alkalinity of 167 mg/l.

TABLE 5-14

COMPARISON OF MEAN CHARACTERISTICS OF GROUNDWATER SEEPAGE COLLECTED IN LAKE HANCOCK FROM OCTOBER 1998 TO JULY 1999

PARAMETER	UNITS	MONITORING LOCATION SITE										OVERALL MEAN
		1	2	3	4	5	6	7	8	9	10	
pH	s.u.	7.63	7.75	7.86	8.01	7.71	8.12	7.85	7.69	7.77	7.94	7.82
Specific Conductivity	μmho/cm	454	514	279	323	414	436	319	389	426	402	397
Alkalinity	mg/l	209	213	67.0	95.7	226	190	78.6	197	162	195	167
NH_3	μg/l	10,075	20,220	1228	4247	16,398	11,755	3023	8397	14,598	0.645	10,289
NO_x	μg/l	1271	1131	4916	2233	81	2230	10,055	915	519	384	2391
Organic Nitrogen	μg/l	6509	3394	2975	1136	3562	1522	3434	3670	1952	2227	3146
Total Nitrogen	μg/l	17,855	24,745	9119	7616	20,041	15,507	16,509	12,982	17,069	13,257	15,826
Orthophosphorus	μg/l	2352	2861	917	529	1846	1694	1469	1157	1631	935	1571
Total Phosphorus	μg/l	2471	3077	999	555	2069	1796	1593	1228	1858	1009	1702
BOD	mg/l	10.3	11.2	4.6	2.3	8.7	4.2	7.2	9.6	10.1	9.0	7.9
Color	Pt-Co	84	45	44	53	88	128	102	54	55	59	71
Flow	l/m^2-day	0.63	0.25	0.48	1.56	0.91	1.20	1.22	0.44	0.48	0.36	0.74
Number of Samples:		8	8	7	6	10	7	9	9	7	8	79

5.3.1.2 Nitrogen Species

In general, an extremely high level of variability was observed in measured concentrations of nitrogen species at the 10 monitoring sites. This variability is apparent in mean concentrations of total nitrogen as well as each of the individual nitrogen species. Measured concentrations of ammonia ranged from a low of 1228 μg/l at Site 3, located adjacent to an agricultural land use area, to a high of 20,220 μg/l at Site 10, located in the central southern portion of the lake. Six of the 10 monitoring sites were found to exhibit ammonia concentrations in excess of 10,000 μg/l. The overall mean ammonia concentration in groundwater seepage is 10,289 μg/l. This value is approximately 380 times greater than ammonia concentrations typically measured in the water column of Lake Hancock.

An extremely high degree of variability is also apparent for measured concentrations of NO_x (nitrite + nitrate) in groundwater seepage samples. In general, measured concentrations of NO_x appear to have an inverse relationship with ammonia. Sites characterized by elevated levels of ammonia are typically observed to have relatively low levels of NO_x, while monitoring sites with low levels of ammonia are observed to have elevated levels of NO_x. Differences in the relationships between these species is probably related to redox conditions within the seepage meter, with reduced conditions favoring formation of NH_3 (ammonia) and oxidized conditions favoring formation of NO_x. Mean measured concentrations of NO_x ranged from a low of 81 μg/l at Site 5, near the reclaimed strip mine area, to a high of 10,055 μg/l at Site 7, located in the northeast corner of the lake. The overall mean NO_x concentration in groundwater seepage is 2391 μg/l. This value is approximately 90 times greater than NO_x concentrations measured in the water column of Lake Hancock.

In general, a much lower degree of variability is apparent in measured concentrations of organic nitrogen in groundwater seepage at each of the 10 monitoring sites. Mean concentrations of organic nitrogen ranged from a low of 1136 μg/l at Site 4 to a high of 6509 μg/l at Site 1. The overall mean organic nitrogen concentration measured in groundwater seepage is 3146 μg/l.

A large degree of variability is apparent for measured concentrations of total nitrogen at each of the 10 monitoring sites. Mean measured concentrations of total nitrogen ranged from a low of 7616 μg/l at Site 4 to a high of 24,745 μg/l at Site 10, located in the southern central portion of the lake. Mean total nitrogen concentrations in excess of 10 mg/l were measured at eight of the 10 monitoring sites. The overall mean total nitrogen concentration in groundwater seepage is 15,826 μg/l. This value is approximately three times greater than total nitrogen concentrations typically measured in the water column of Lake Hancock.

As seen in Table 5-14, ammonia is the dominant nitrogen species present in groundwater seepage entering Lake Hancock. On an overall basis, ammonia accounts for approximately 65% of the total nitrogen species measured. NO_x comprises approximately 15% of the total nitrogen, with the remaining 20% comprised of organic nitrogen.

5.3.1.3 Phosphorus Species

Similar to the trends observed for species of nitrogen, phosphorus species exhibit a large degree of variability in mean concentrations between the 10 monitoring sites. Measured concentrations of orthophosphorus in groundwater seepage range from a low of 529 μg/l at Site 4 to a high of 2861 μg/l at Site 10. The overall mean orthophosphorus concentration in groundwater seepage is 1571 μg/l which is approximately 140 times greater than the mean orthophosphorus concentrations found in the water column of Lake Hancock. Groundwater seepage is apparently a significant source of readily available phosphorus into the water column of Lake Hancock.

A similar degree of variability is also apparent for mean measured concentrations of total phosphorus. Total phosphorus concentrations range from a low of 555 μg/l at Site 4 to a high of 3077 μg/l at Site 10. Mean total phosphorus concentrations at eight of the 10 sites exceed 1000 μg/l. The overall mean total phosphorus concentration in groundwater seepage is approximately 1702 μg/l. This total phosphorus concentration is approximately three times greater than total phosphorus concentrations typically observed in the water column of Lake Hancock. Dissolved orthophosphorus is clearly the dominant phosphorus species present in groundwater seepage, comprising 92% of the total phosphorus measured.

5.3.1.4 BOD and Color

A relatively high degree of variability is also apparent for mean measured concentrations of BOD and color in groundwater seepage entering Lake Hancock. Mean measured BOD concentrations range from a low of 2.3 mg/l at Site 4 to a high of 11.2 mg/l at Site 10. The overall BOD value of 7.9 mg/l is approximately half of the BOD concentration typically measured in the water column of Lake Hancock. On an overall basis, groundwater seepage does not appear to be a significant contributor of BOD to the water column of Lake Hancock.

Mean concentrations of color in groundwater seepage range from a low of 44 Pt-Co units at Site 3 to a high of 128 Pt-Co units at Site 6. Groundwater seepage entering Lake Hancock appears to be moderately to highly colored. The overall mean color concentration in groundwater seepage is 71 Pt-Co units.

5.3.2 Comparison of Wet Season and Dry Season Seepage Characteristics

A comparison of seepage characteristics in Lake Hancock during wet and dry season conditions is given in Table 5-15. Wet season and dry season monitoring events are allocated based upon the rationale presented in Section 4.3 which evaluates seepage inflow rates. Wet season samples are assumed to have been collected during November, while dry season samples represent the remaining sample events.

TABLE 5-15

COMPARISON OF LAKE HANCOCK SEEPAGE CHARACTERISTICS DURING WET AND DRY SEASON CONDITIONS

PARAMETER	UNITS	MEAN VALUES	
		WET SEASON[1]	DRY SEASON[2]
Seepage	liters/m^2-day	1.14	0.63
pH	s.u.	7.49	7.91
Conductivity	µmho/cm	399	397
Alkalinity	mg/l	118	180
NH_3	µg/l	10,084	10,345
NO_x	µg/l	1959	2509
Organic Nitrogen	µg/l	3560	3033
Total Nitrogen	µg/l	15,603	15,887
Orthophosphorus	µg/l	1639	1553
Total Phosphorus	µg/l	1755	1687
BOD	mg/l	6.5	8.4
Color	Pt-Co	57	79

1. n = 17 samples
2. n = 62 samples

With the exception of seepage flow rates, characteristics of groundwater seepage during wet season and dry season conditions appear to be relatively similar for each of the measured constituents. Extremely close agreement appears to exist between measured concentrations of conductivity, total nitrogen, orthophosphorus, total phosphorus, and BOD.

An ANOVA comparison was performed to identify significant differences between chemical characteristics of groundwater seepage during wet season and dry season conditions. Of the parameters listed in Table 5-15, only seepage flow was found to be statistically different between wet season and dry season samples. No statistically significant differences were observed in mean concentrations of the other listed parameters.

Wet season concentration isopleths for total nitrogen in groundwater seepage entering Lake Hancock are illustrated in Figure 5-3. Elevated total nitrogen concentrations in groundwater seepage appear to occur along the northeast perimeter, northwest perimeter, and southeast perimeter of the lake. Substantially lower total nitrogen concentrations are apparent in the center and southern portions of the lake.

Dry season concentration isopleths for total nitrogen in groundwater seepage entering Lake Hancock are illustrated in Figure 5-4. Elevated nitrogen concentrations during dry season monitoring appear to occur primarily along the western edge of the lake.

Wet season concentration isopleths for total phosphorus concentrations in groundwater seepage entering Lake Hancock are illustrated in Figure 5-5. Elevated concentrations of total phosphorus entering Lake Hancock in groundwater seepage are apparent along the western shore of the lake and the southeast quadrant. Total phosphorus concentrations in groundwater seepage in other areas of the lake appear to be substantially lower.

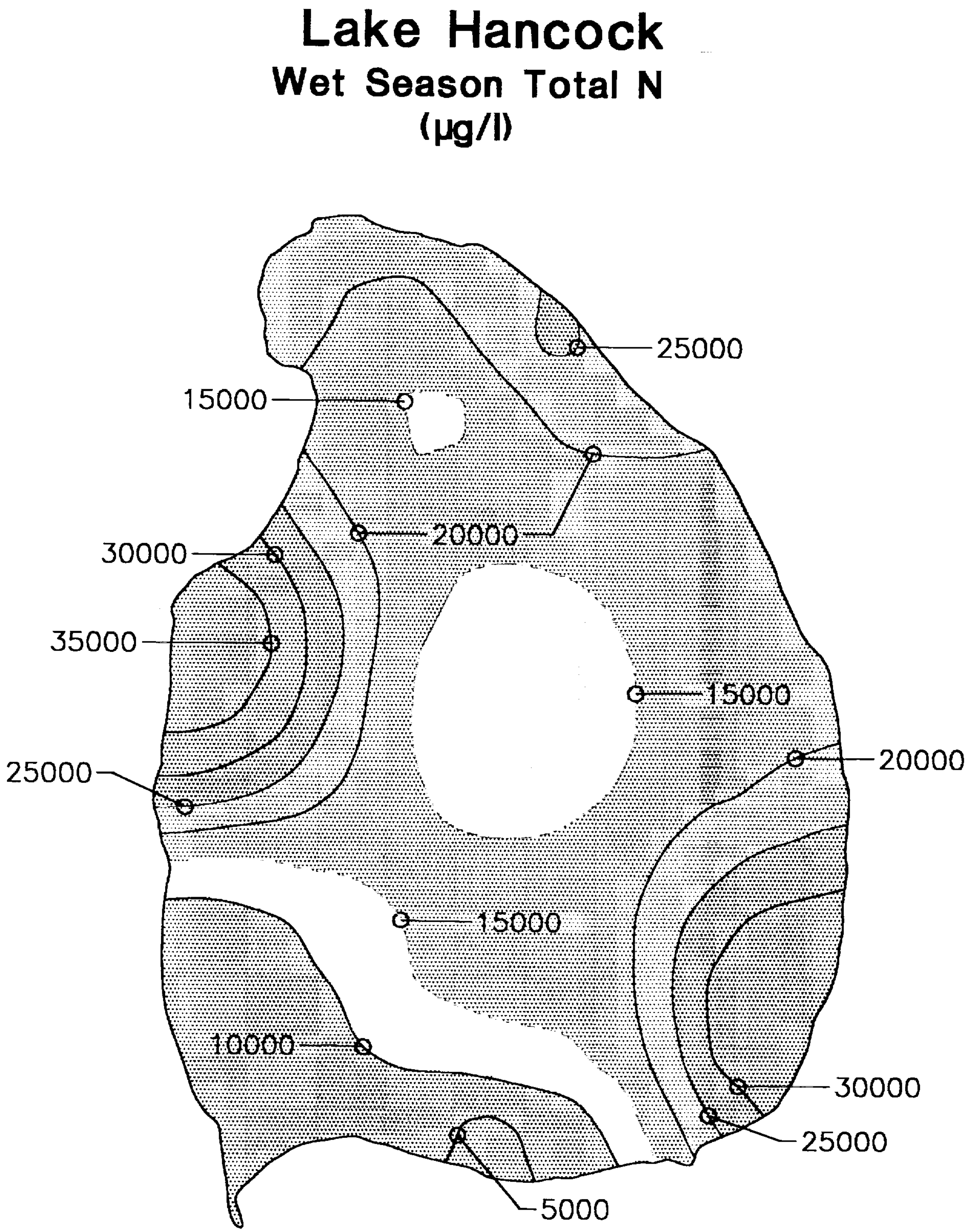


Figure 5-3. Wet Season Concentration Isopleths for Total Nitrogen in Groundwater Seepage Entering Lake Hancock.

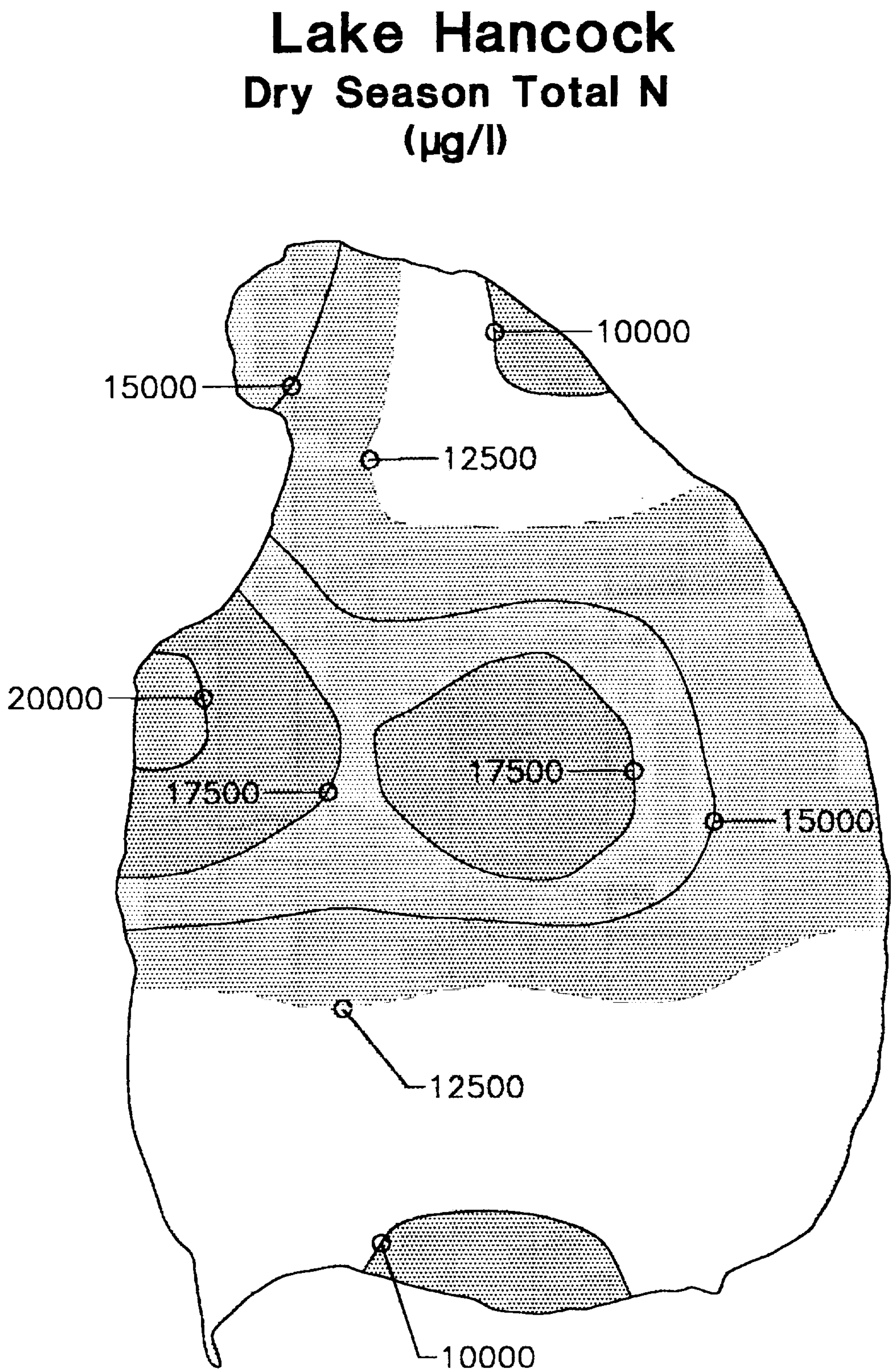


Figure 5-4. Dry Season Concentration Isopleths for Total Nitrogen in Groundwater Seepage Entering Lake Hancock.

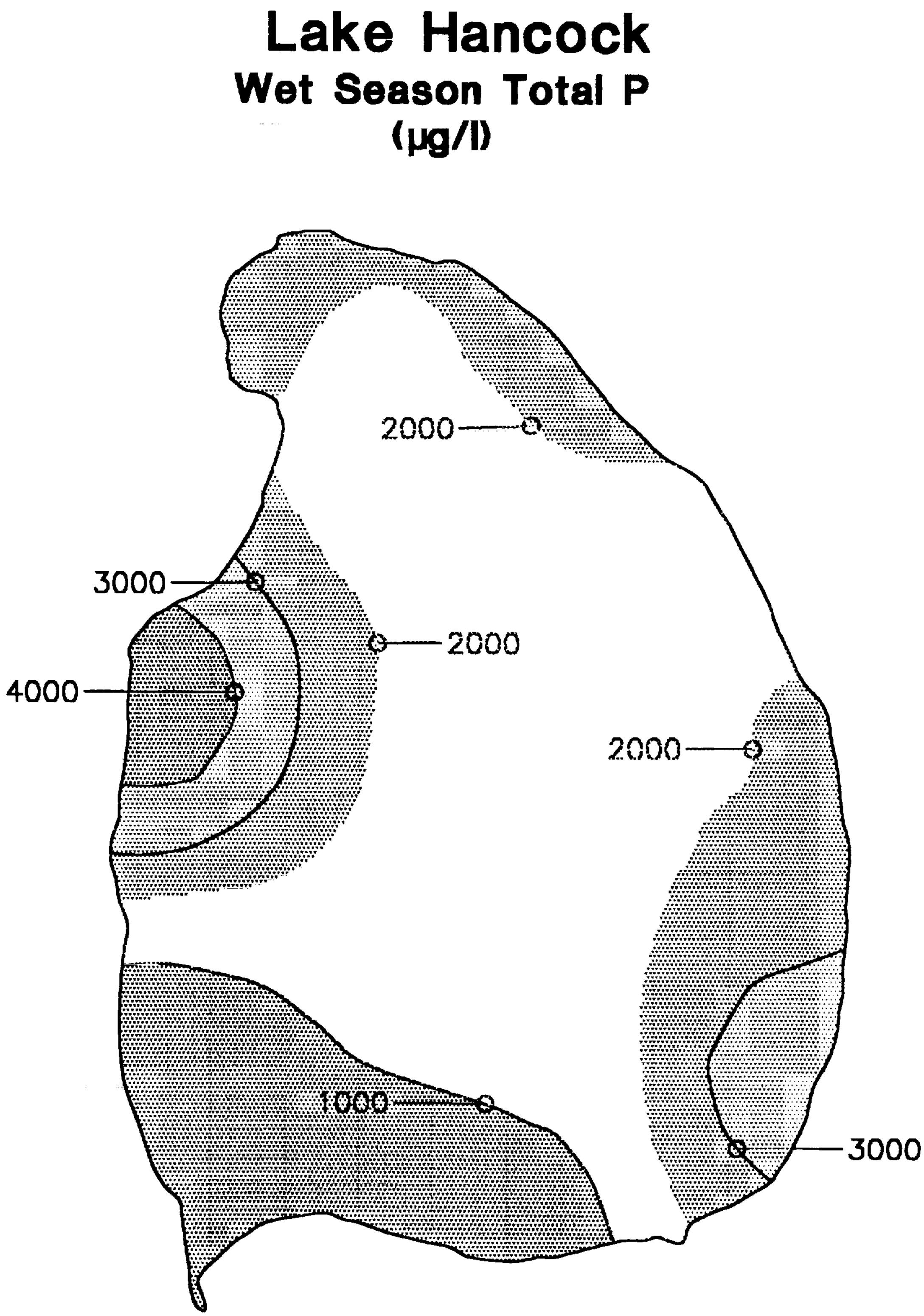


Figure 5-5. Wet Season Concentration Isopleths for Total Phosphorus in Groundwater Seepage Entering Lake Hancock.

Dry season concentration isopleths for total phosphorus in groundwater seepage entering Lake Hancock are given in Figure 5-6. Elevated concentrations of total phosphorus during the dry season appear to occur primarily along the western shoreline of the lake, with substantially lower concentrations in the remaining areas.

5.3.3 Estimated Mass Loadings from Groundwater Seepage to Lake Hancock

Estimated mass loading isopleths for total nitrogen entering Lake Hancock from groundwater seepage under wet season conditions are presented in Figure 5-7 in units of μg TN/m^2-day. These isopleths were developed by combining the concentration-based wet and dry season characteristics presented in Table 5-15 with the wet and dry season inflow rates at each of the 10 monitoring sites summarized in Table 4-8. The estimated annual mass loading of total nitrogen into Lake Hancock from groundwater seepage under wet season conditions was attained by integrating the isopleth areas indicated on Figure 5-7. For purposes of this evaluation, wet season characteristics are assumed to occur during the period from July-November, which occupies 153 days of the year. As seen in Figure 5-7, primary inputs of total nitrogen during wet season conditions appear to occur along the eastern shore of the lake adjacent to the reclaimed strip mine areas.

Mass loading isopleths for total nitrogen entering Lake Hancock in groundwater seepage under dry season conditions are illustrated in Figure 5-8. The estimated daily mass of total nitrogen entering Lake Hancock under dry season conditions was obtained by integrating the isopleths indicated on Figure 5-8, based on the assumption that the dry season occurs from December-June, which occupies 212 days of the year. As seen in Figure 5-8, influx of total nitrogen under dry season conditions is also concentrated primarily along the eastern shoreline of the lake.

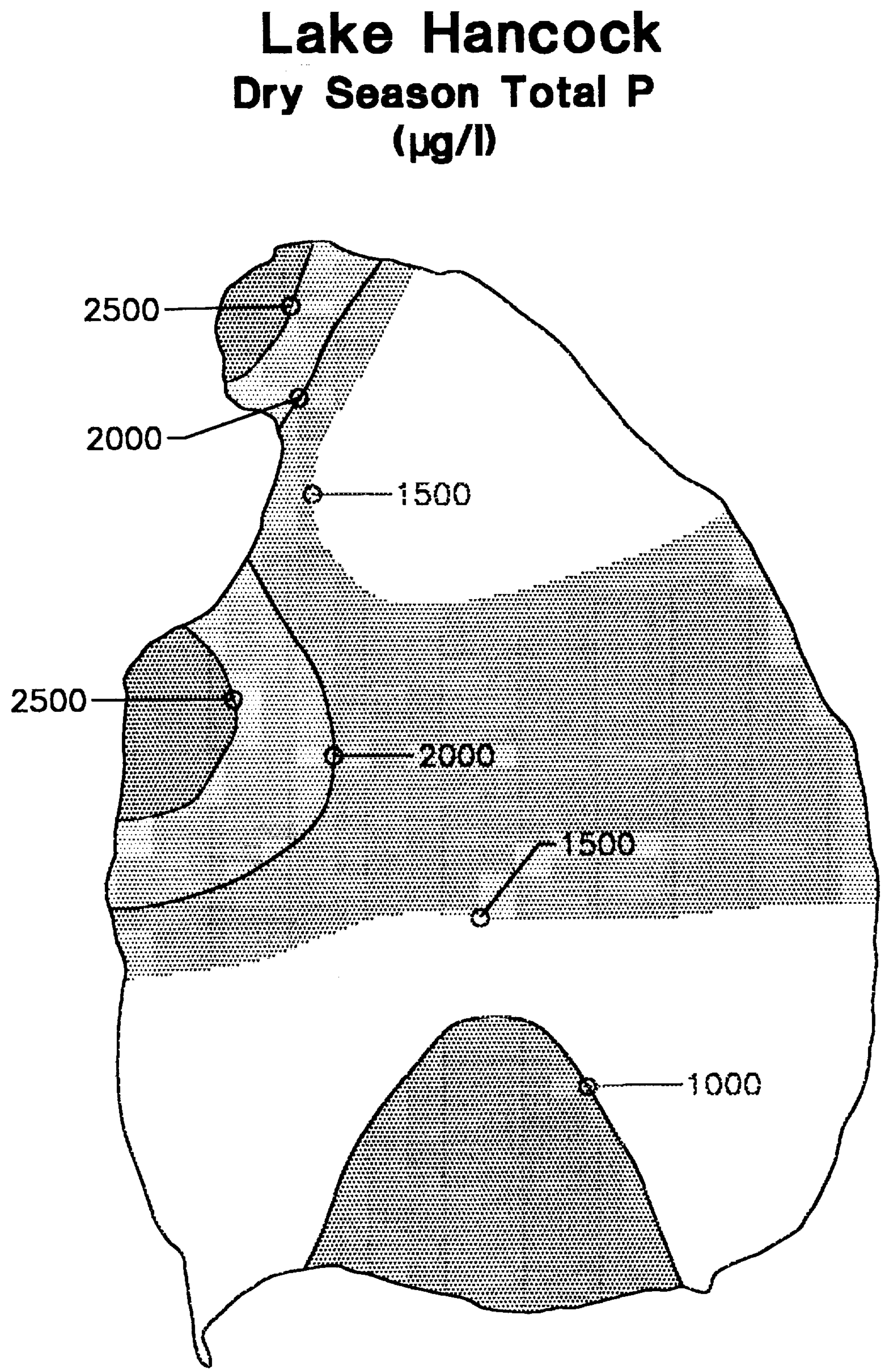


Figure 5-6. Dry Season Concentration Isopleths for Total Phosphorus in Groundwater Seepage Entering Lake Hancock.

Lake Hancock
Wet Season Total N Mass Influx
(μg/m²-day)

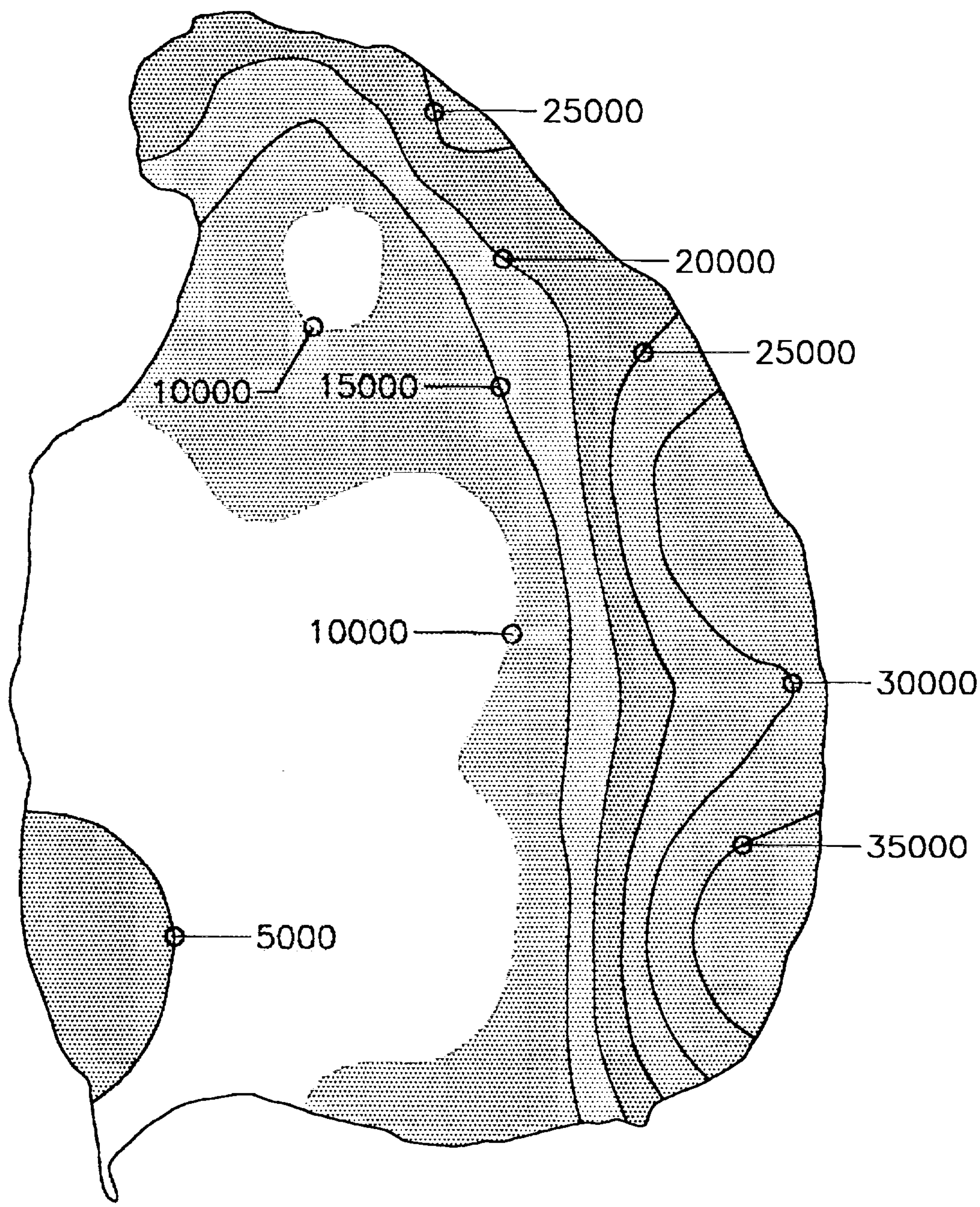


Figure 5-7. Mass Loading Isopleths for Total Nitrogen Entering Lake Hancock in Groundwater Seepage Under Wet Season Conditions.

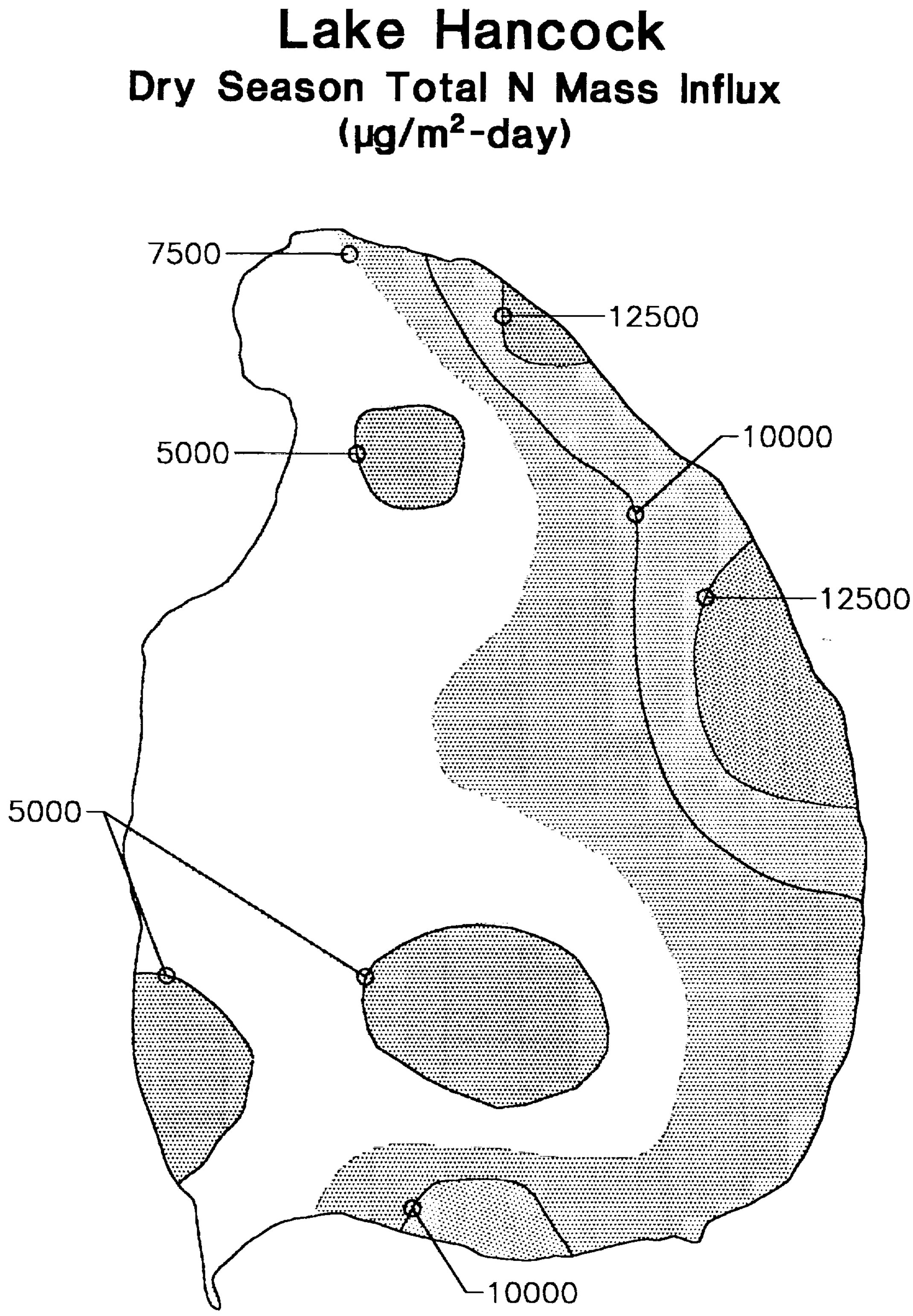


Figure 5-8. Mass Loading Isopleths for Total Nitrogen Entering Lake Hancock in Groundwater Seepage Under Dry Season Conditions.

Mass loading isopleths for total phosphorus entering Lake Hancock in groundwater seepage under wet season conditions are illustrated in Figure 5-9. The primary influx of total phosphorus during wet season conditions also appears to occur along the eastern shoreline of the lake, adjacent to the reclaimed strip mine area.

Mass loading isopleths for total phosphorus entering Lake Hancock in groundwater seepage under dry season conditions are illustrated in Figure 5-10. Similar to the trends observed under wet season conditions, influx of total phosphorus into the lake during dry season conditions is concentrated primarily along the eastern shoreline of the lake.

A summary of estimated mass loadings from groundwater seepage entering Lake Hancock is given in Table 5-16. Estimated mass loadings from total nitrogen and total phosphorus are based upon the mass loading isopleths under dry season and wet season conditions, presented previously. Mass inputs of BOD in groundwater seepage are calculated based upon the mean wet season BOD concentration of 6.5 mg/l and the mean dry season concentration of 8.4 mg/l. Each of these concentrations was multiplied times the estimated annual dry season and wet season seepage inflow, as outlined in Section 4.3.3. Seepage concentrations of TSS are assumed to be approximately zero.

TABLE 5-16

ESTIMATED MASS LOADINGS FROM GROUNDWATER SEEPAGE TO LAKE HANCOCK

PARAMETER	LOADING (kg/yr)		TOTAL LOADING (kg/yr)
	DRY SEASON	WET SEASON	
Total Nitrogen	9900	56,695	66,595
Total Phosphorus	1148	3498	4646
BOD	13,839	22,854	36,693
TSS	≈0	≈0	≈0

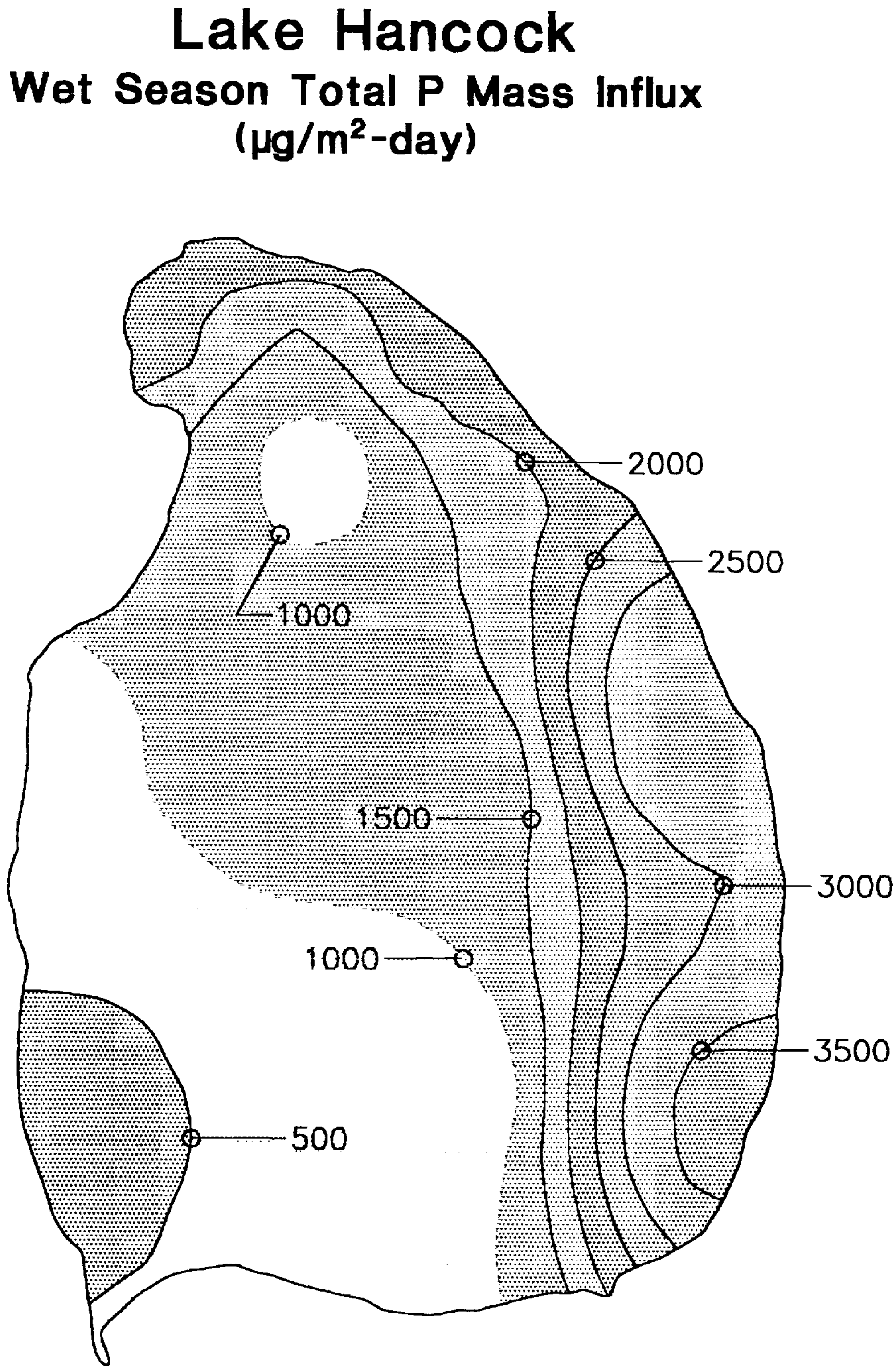


Figure 5-9. Mass Loading Isopleths for Total Phosphorus Entering Lake Hancock in Groundwater Seepage Under Wet Season Conditions.

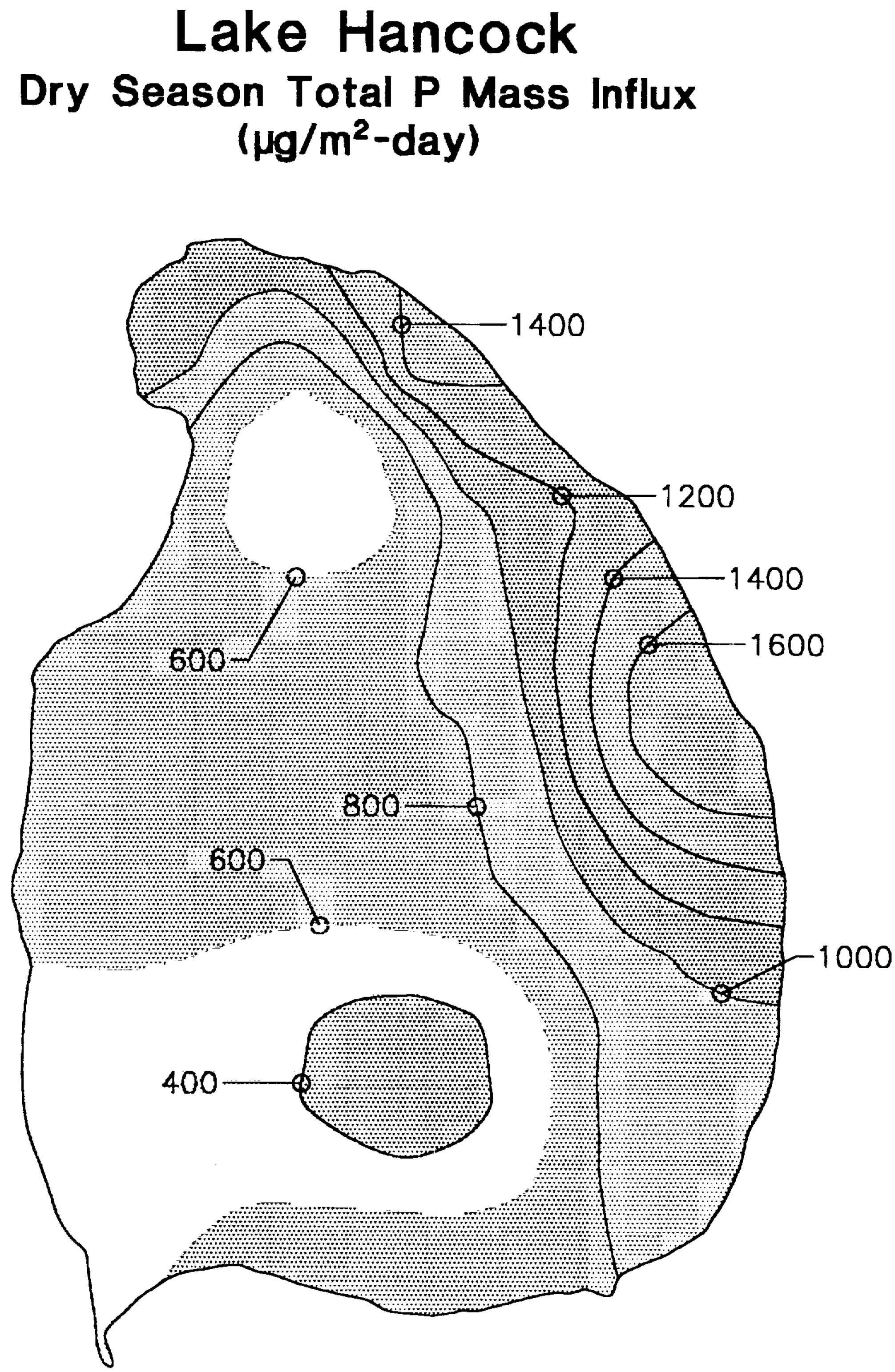


Figure 5-10. Mass Loading Isopleths for Total Phosphorus Entering Lake Hancock in Groundwater Seepage Under Dry Season Conditions.

On an annual basis, groundwater seepage is estimated to contribute approximately 66,595 kg/yr of total nitrogen, 4646 kg/yr of total phosphorus, 36,693 kg/yr of BOD, and a negligible amount of TSS. Mass loadings of total nitrogen, total phosphorus, and BOD from groundwater seepage are greater than estimated annual loadings from bulk precipitation, outlined in Table 5-13, but lower than estimated runoff generated annual mass loadings, summarized in Table 5-11.

5.4 Summary of Estimated Annual Pollutant Loadings to Lake Hancock

A detailed evaluation of pollutant inputs from stormwater runoff and baseflow, bulk precipitation, and groundwater seepage into Lake Hancock was presented in the previous sections. A summary of estimated annual pollutant loadings to Lake Hancock, based upon these evaluations, is given in Table 5-17. The annual pollutant loadings summarized in this table reflect identified pollutant inputs to Lake Hancock and do not include the effects of internal recycling or inputs from water fowl. Internal recycling within the lake is primarily a source of phosphorus to the water column, and does not necessarily impact water column concentrations of total nitrogen, BOD, or TSS.

Based upon the information presented in Table 5-17, stormwater runoff and baseflow appear to be the primary inputs of identified mass pollutant loadings to Lake Hancock. Stormwater runoff and baseflow contribute approximately 52% of the annual loadings of total nitrogen to the lake, 77% of the annual loadings of BOD, and 86% of the annual loadings of TSS. Runoff and baseflow contribute approximately 81% of the identified total phosphorus loadings to Lake Hancock, although this value does not include internal recycling of phosphorus from the sediments. The impact of internal recycling on phosphorus loading is evaluated in Section 5.6.

TABLE 5-17

ESTIMATED ANNUAL IDENTIFIED LOADINGS TO LAKE HANCOCK

INPUT SOURCE	ANNUAL LOAD (kg/yr)				PERCENT OF TOTAL			
	TOTAL N	TOTAL P[1]	BOD	TSS	TOTAL N	TOTAL P[1]	BOD	TSS
Stormwater Runoff/Baseflow	91,157	28,562	180,294	911,945	52	81	77	86
Bulk Precipitation	18,127	1878	18,473	143,168	10	6	7	14
Groundwater Seepage	66,595	4646	36,693	0	38	13	16	0
TOTALS:	175,879	35,086	235,460	1,055,113	100	100	100	100

1. Does not include additional inputs from internal recycling

The second largest contributor of annual loadings to Lake Hancock appears to be groundwater seepage which contributes approximately 38% of the total nitrogen, 13% of the total phosphorus, and 16% of the BOD. Annual loadings from bulk precipitation appear to be relatively minimal, contributing 10-15% or less of the annual mass inputs of total nitrogen, total phosphorus, BOD, and TSS entering Lake Hancock. Graphical comparisons of estimated annual loadings of total nitrogen, BOD, and TSS entering Lake Hancock are given in Figures 5-11, 5-12, and 5-13, respectively.

5.5 Evaluation of Trophic State Modeling Under Existing Nutrient Loadings

Trophic state modeling analyses were conducted to predict water quality characteristics in Lake Hancock resulting from estimated nutrient inputs into the lake from stormwater and baseflow, groundwater seepage, and bulk precipitation as presented in Table 5-17. This modeling exercise is used to predict in-lake concentrations of total phosphorus, chlorophyll-a,

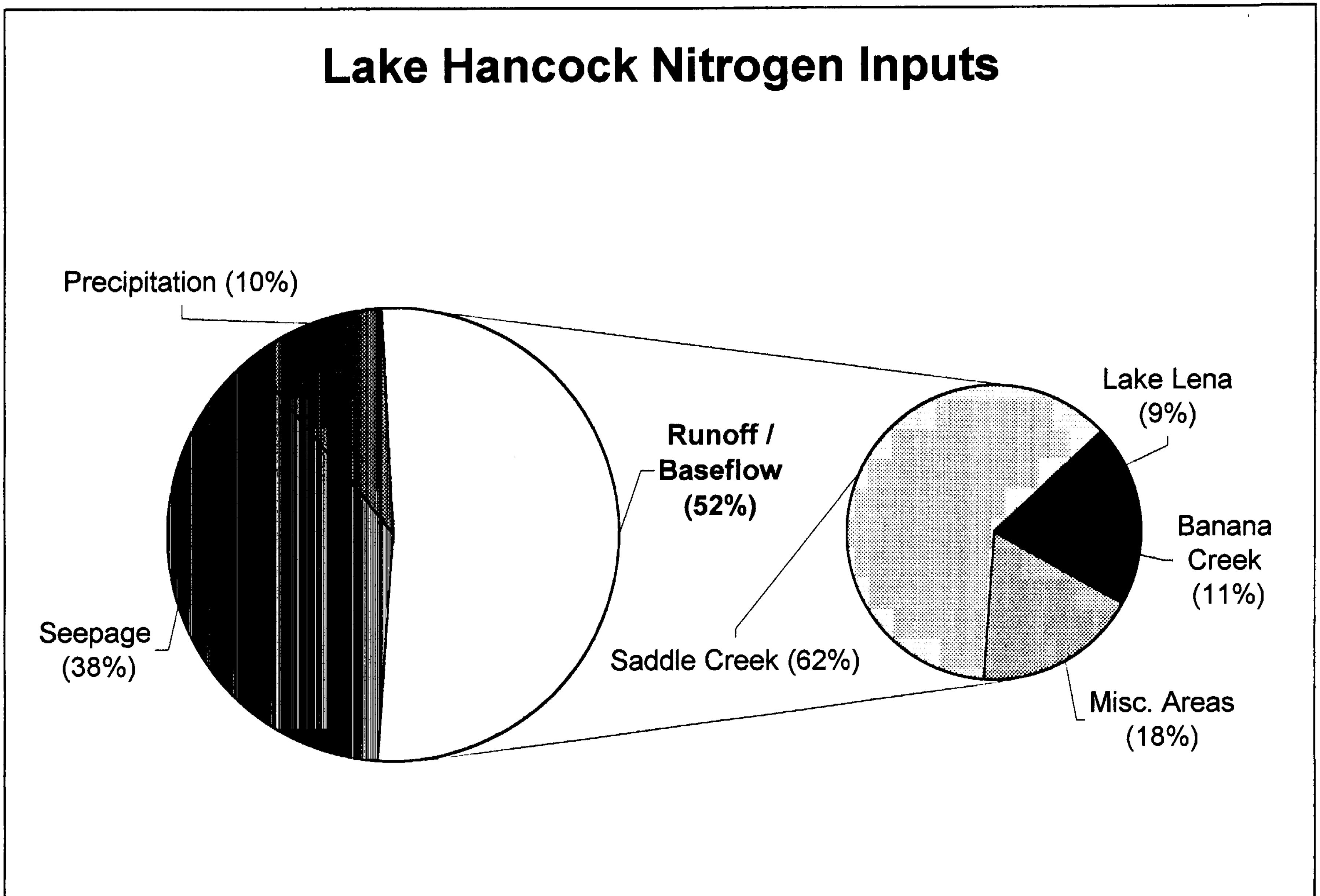


Figure 5-11. Comparison of Estimated Total Nitrogen Loadings Entering Lake Hancock.

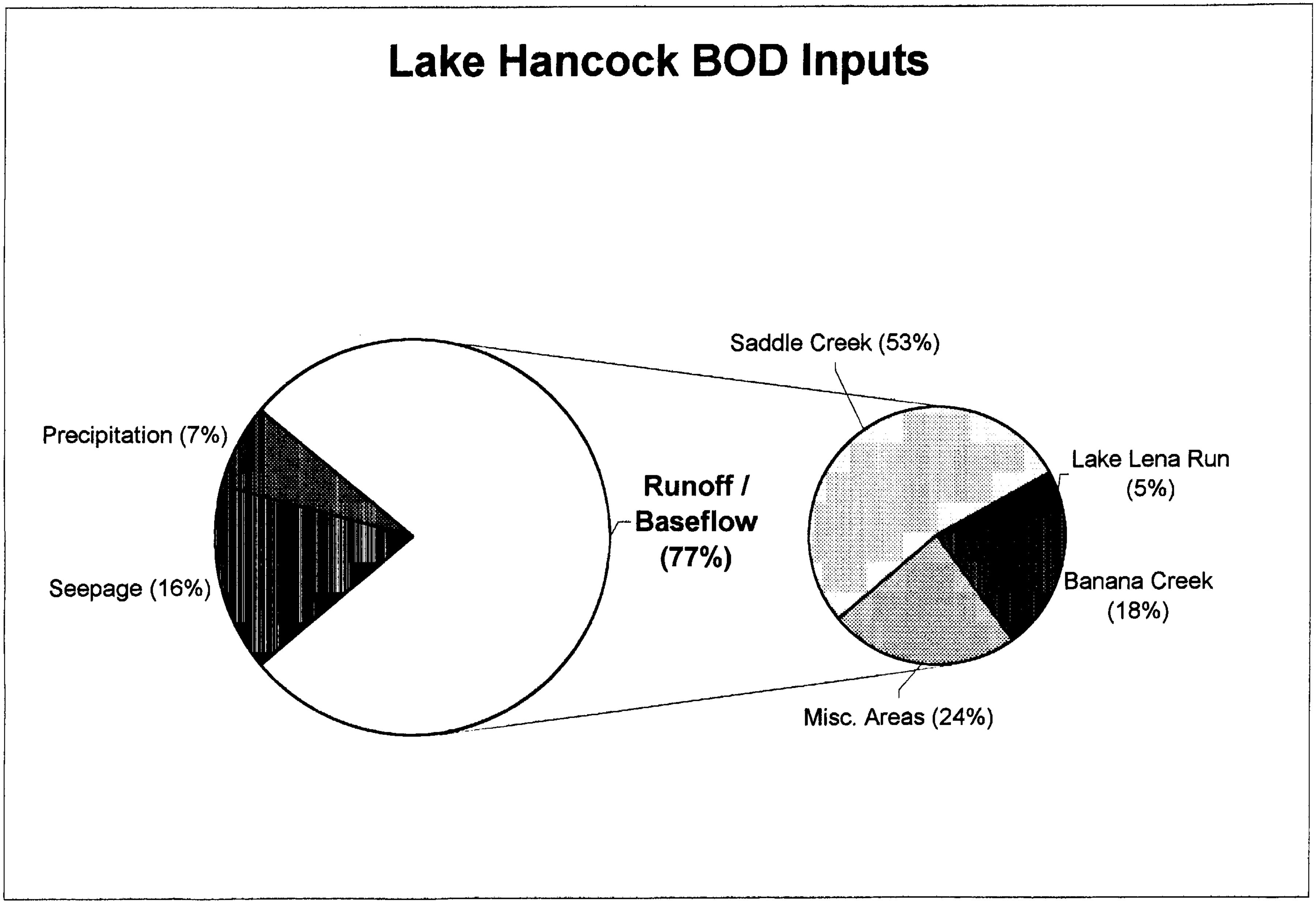


Figure 5-12. Comparison of Estimated BOD Loadings Entering Lake Hancock.

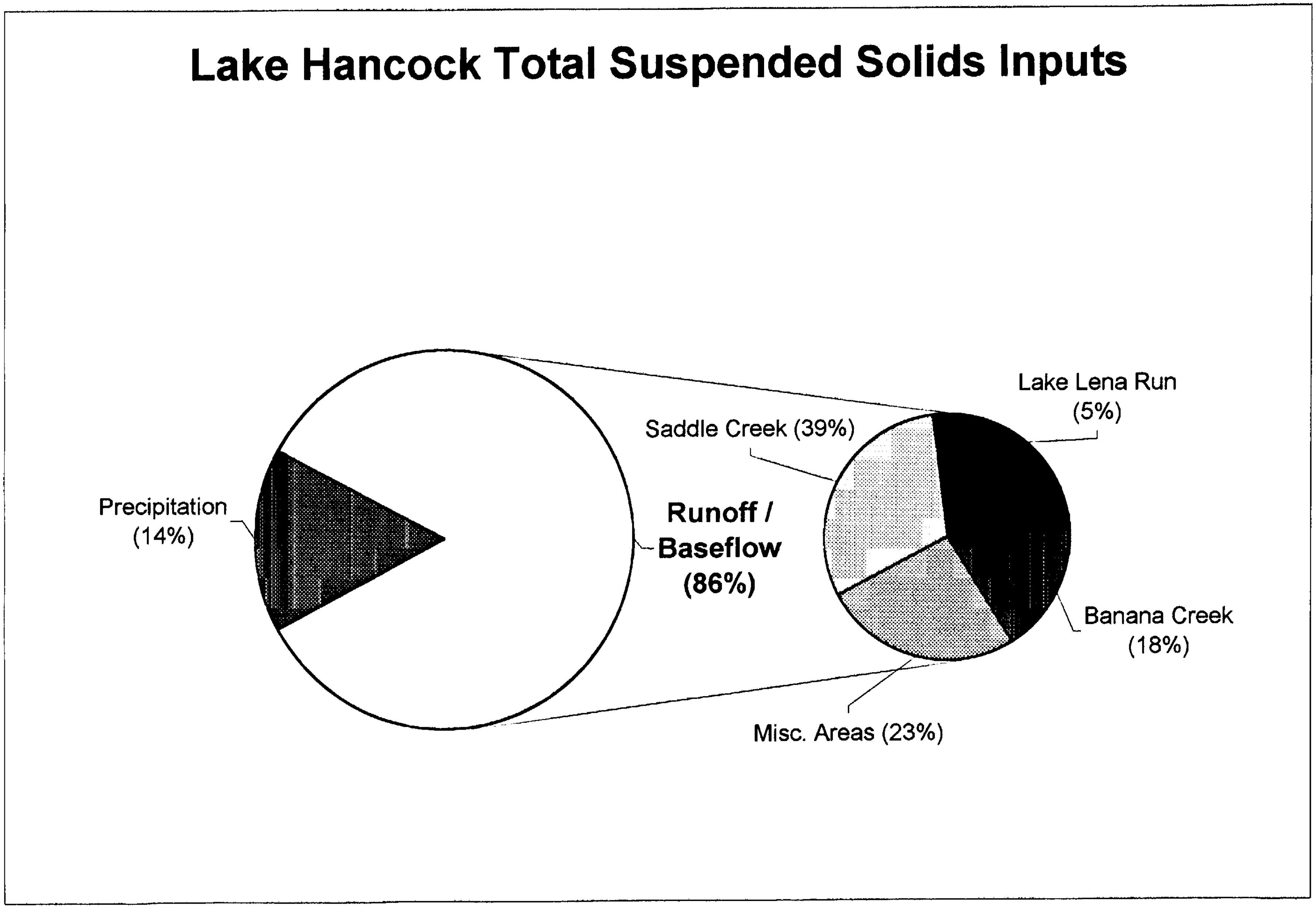


Figure 5-13. Comparison of Estimated Total Suspended Solids (TSS) Loadings Entering Lake Hancock.

and Secchi disk depth based upon existing estimated loadings. Discrepancies between predicted concentrations of total phosphorus and chlorophyll-a and values actually measured within the lake may suggest the presence of unaccounted nutrient inputs into Lake Hancock such as internal nutrient recycling.

As discussed in Section 2, calculated TN/TP ratios for Lake Hancock suggest that Lake Hancock is primarily a nutrient-balanced system with sporadic conditions of phosphorus or nitrogen limitation. However, many researchers question whether a hypereutrophic lake dominated by blue-green algae can exhibit true nitrogen-limitation due to the ability of the blue-green algae to fix atmospheric nitrogen. Under these conditions, the TN/TP ratios may be misleading and phosphorus may actually limit overall algal productivity. In addition, retrofit projects proposed to treat inflows into the lake, such as treatment ponds or marshes, will likely exhibit more removal of phosphorus than nitrogen, further reducing phosphorus loading, increasing the TN/TP ratio in the lake, and increasing the likelihood of phosphorus-limiting conditions resulting from evaluated improvements. As a result, a phosphorus-limitation model is used to predict current and future water quality in Lake Hancock.

Predicted concentrations of total phosphorus and chlorophyll-a in Lake Hancock were estimated using a modified Vollenweider phosphorus limitation model as proposed by Vollenweider (1976), Vollenweider and Dillon (1974), and Dillon and Rigler (1974). In-lake phosphorus concentrations are predicted based upon four parameters, including the estimated annual phosphorus input to the lake, a phosphorus retention coefficient which is based upon phosphorus sedimentation dynamics, the mean depth of the lake, and the mean flushing rate for the lake system.

The first step in modeling involves estimation of the phosphorus retention coefficient, R_{TP}. The phosphorus retention coefficient for a lake can be estimated based upon the lake flushing time and mean depth as proposed by Vollenweider (1976):

$$R_{TP} = \frac{10}{\rho\bar{z} + 10}$$

where:

R_{TP}	=	phosphorus retention coefficient (dimensionless)
ρ	=	lake flushing rate, Q/V (units of 1/time)
$\bar{z}$	=	lake mean depth = lake volume/surface area (m)

Estimates of equilibrium total phosphorus concentrations within the lake are developed based upon the relationship proposed by Vollenweider and Dillon (1974):

$$TP = \frac{L_p(1 - R_{TP})}{\bar{z} * \rho}$$

where:

L_p	=	annual areal total phosphorus loading (mg/m^2-yr)
R_{TP}	=	phosphorus retention coefficient (dimensionless)
ρ	=	lake flushing rate (1/time)
$\bar{z}$	=	mean depth (m)

Estimates of in-lake equilibrium chlorophyll-a concentrations are based on the empirical relationship between chlorophyll-a and total phosphorus as proposed by Dillon and Rigler (1974):

$$\log(chyl\text{-}a) = 1.449 \log TP - 1.136$$

where:

TP = mean total phosphorus concentration (µg/l)

Estimates of mean Secchi disk depth in Lake Hancock were determined based upon the empirical relationship presented by Dillon and Rigler (1974) which results in an estimated Secchi disk depth in meters, based upon a chlorophyll-a input in units of mg/m^3:

$$SD = 8.7\left(\frac{1}{1 + 0.47\ chyl\text{-}a}\right)$$

where:

SD = Secchi disk depth (m)

chyl-a = chlorophyll-a concentration (mg/m^3)

Trophic State Index (TSI) values were calculated based upon the Florida Trophic State Index proposed by Brezonik (1984) which was developed specifically for Florida lakes. The empirical equations for calculating the Florida Trophic State Index are as follows for phosphorus-limited lakes:

TSI (Chyl-a)	=	16.8 + 14.4 ln (Chyl-a)	(Chyl-a in mg/m^3)
TSI (SD)	=	60.0 - 30.0 ln (SD)	(SD in m)
TSI (TP)	=	23.6 ln (TP) - 23.8	(TP in µg/l)
TSI (Avg)	=	1/3 [TSI (Chyl-a) + TSI (SD) + TSI (TP)]	

Average trophic state values less than 50 indicate oligotrophic conditions, values between 50 and 60 indicate mesotrophic conditions, and values from 61 to 70 indicate eutrophic conditions. Values over 70 represent hypereutrophic conditions.

A modified Vollenweider model was developed for Lake Hancock on a monthly basis for a period of 36 months. Monthly evaluations were performed to examine fluctuations in water quality characteristics on a seasonal basis throughout the year. The model includes monthly hydrologic inputs to Lake Hancock from direct precipitation, stormwater runoff and baseflow, and groundwater seepage. Nutrient inputs to Lake Hancock include estimated loadings from bulk precipitation, stormwater runoff and baseflow, and groundwater seepage. Precipitation-based inputs, such as direct precipitation and stormwater runoff/baseflow, were allocated on a monthly basis based upon mean monthly rainfall in the Lakeland area over the period from 1960-1995. Inputs from groundwater seepage were allocated evenly on a seasonal basis based upon estimated seasonal inputs outlined in previous sections.

Hydrologic and mass losses from Lake Hancock were assumed to occur as a result of evaporation, discharges through the outfall structure, and loss to deep groundwater. For purposes of the model, hydrologic losses from the outfall and groundwater are combined together in a category of general losses. Hydrologic losses from these sources are assumed to also remove a corresponding mass load of pollutants. The net hydrologic inputs into the lake were used to provide an estimate of mean detention time as well as flushing rate which is utilized in calculation of the phosphorus retention coefficient and the equilibrium total phosphorus concentration. Nutrient inputs were used to generate estimates of the annual areal phosphorus loading rate and the mean in-lake phosphorus concentration. Estimates of equilibrium chlorophyll-a concentrations and Secchi disk depth in the lake were calculated based upon the predicted in-lake phosphorus concentration.

After developing the trophic state model, initial model runs were performed to examine predicted water quality characteristics in Lake Hancock based upon the estimated annual loadings of total phosphorus to the lake as outlined in Table 5-17. However, these initial model runs were found to substantially underestimate in-lake concentrations of total phosphorus and chlorophyll-a based upon the historical water quality characteristics for the lake and the results of field monitoring performed in Lake Hancock by ERD during 1998-1999. Additional inputs of phosphorus were added to the model on an incremental basis of 1 kg of phosphorus each day, and the model was rerun with each incremental addition to evaluate changes in water quality characteristics.

Predicted water quality characteristics in Lake Hancock began to closely approach actual measured water quality characteristics after the addition of 108 kg of total phosphorus to the lake on a daily basis, representing an additional loading to Lake Hancock of approximately 39,420 kg/yr over a 12-month period. This additional input is approximately 12% greater than the total estimated combined annual inputs of phosphorus from runoff/baseflow, groundwater seepage, and bulk precipitation entering the lake. This additional input is likely a combination of inputs from water fowl and other animals as well as internal recycling and resuspension of bottom sediments within the lake.

A listing of trophic state modeling performed for model verification under current conditions is given in Appendix K. Model calibration was based exclusively on water column concentration of chlorophyll-a, since total phosphorus concentrations and Secchi disk depth in Lake Hancock can be artificially impacted by resuspension of bottom sediments during periods of wind activity. Trophic state models assume that total phosphorus and Secchi disk depth are regulated exclusively by algal productivity. This is not the case in Lake Hancock, and therefore, agreement between predicted and measured values for these parameters is not anticipated. Assuming the additional phosphorus loading of 108 kg/day described previously, the trophic state model for Lake Hancock predicts an annual in-lake chlorophyll-a concentration of 170 mg/m^3 which is identical to the historical mean chlorophyll-a concentration from 1985-1999, listed in Table 2-4.

The trophic state model presented in Appendix K predicts a mean phosphorus retention coefficient of approximately 0.672 for Lake Hancock, indicating that approximately 67% of the annual phosphorus inputs into the lake are retained within the sediments throughout the year. On an annual basis, the phosphorus retention coefficient for Lake Hancock ranges from a low of 0.500 during July to a high of 0.793 during December. Phosphorus retention coefficients in this range are substantially lower than retention coefficients typically measured in lake systems in Central Florida. The relatively low phosphorus retention rate in Lake Hancock is related to a combination of relatively short detention times combined with an extremely shallow water depth.

In view of the relatively close agreement between the measured and predicted values for chlorophyll-a, the trophic state model outlined in Appendix K is assumed to be reasonably accurate for prediction of primary productivity, as measured by chlorophyll-a, in Lake Hancock. The model was subsequently modified to reflect anticipated phosphorus reductions as a result of recommended restoration options for Lake Hancock, and the output results are used to evaluate restoration options. Details of supplemental trophic state modeling for selection of potential retrofit options are described in Section 6.

5.6 Estimated Phosphorus Budget

A summary of annual phosphorus inputs to Lake Hancock is given in Table 5-18. Phosphorus inputs are included for runoff/baseflow, groundwater seepage, and bulk precipitation, as outlined previously in Table 5-17. Internal recycling/animal waste inputs are assumed to contribute approximately 39,420 kg/yr, as discussed in Section 5.6. On an overall basis, approximately 74,506 kg/yr of phosphorus is input into Lake Hancock.

TABLE 5-18

SUMMARY OF ANNUAL PHOSPHORUS INPUTS TO LAKE HANCOCK

SOURCE	ESTIMATED ANNUAL INPUT	
	kg/yr	Percent of Total
Runoff/Baseflow	28,562	38
Groundwater Seepage	4646	6
Bulk Precipitation	1878	3
Internal Recycling/Animal Waste	39,420	53
TOTAL:	74,506	100

As seen in Table 5-18, internal recycling/animal waste is the primary source of phosphorus in Lake Hancock, contributing 53% of the estimated annual input. Runoff/baseflow inputs contribute approximately 38% of the total annual input to Lake Hancock, with the majority of these inputs contributed by Saddle Creek. An additional 6% of the annual phosphorus loading is contributed by groundwater seepage, with 3% contributed by bulk precipitation. A graphical comparison of total phosphorus inputs to Lake Hancock is given in Figure 5-14.

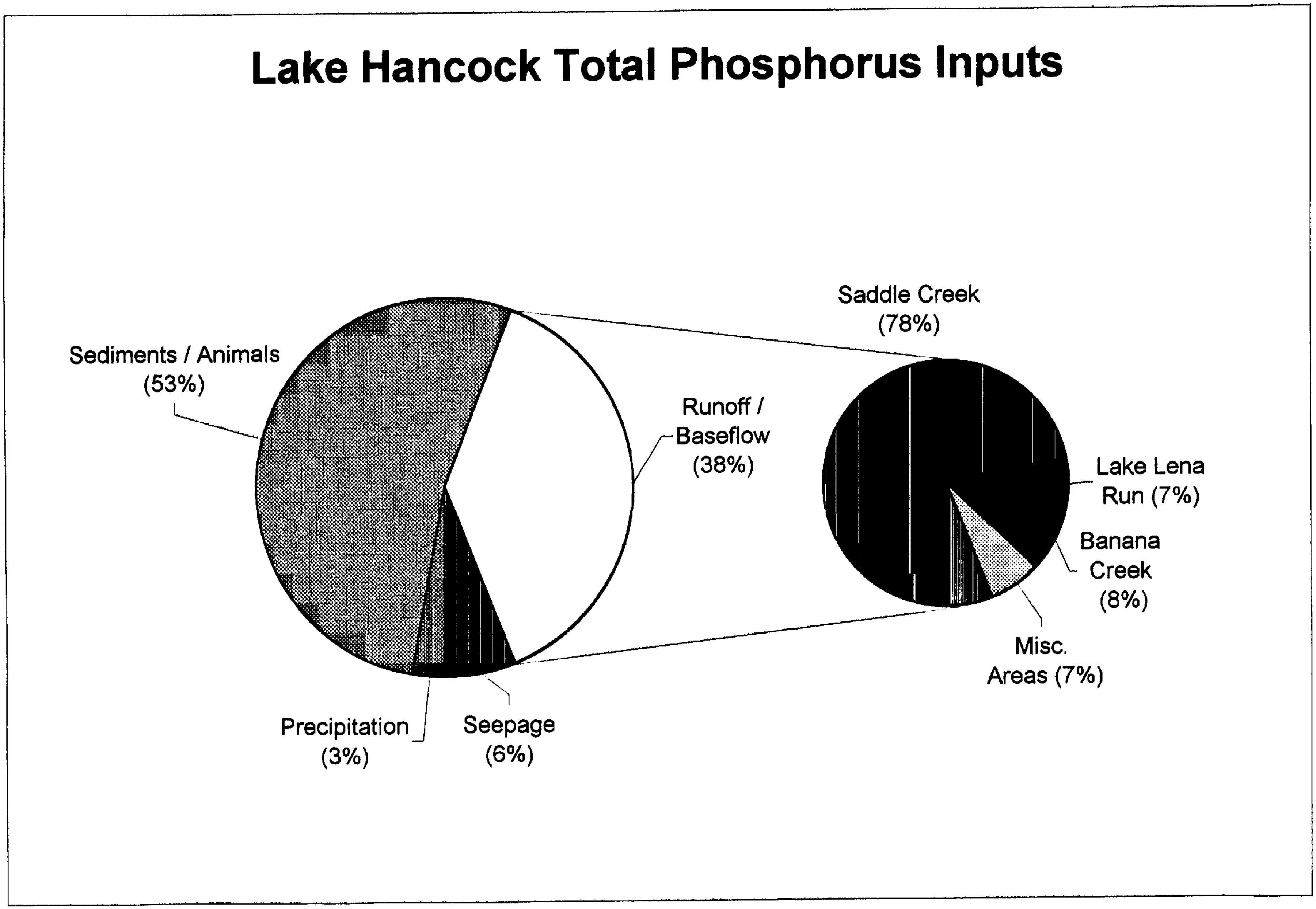


Figure 5-14. Comparison of Estimated Total Phosphorus Loadings Entering Lake Hancock.

Losses of phosphorus in Lake Hancock occur as a result of sedimentation and loss of phosphorus in discharges through the outfall at Structure P-11. Assuming an average annual discharge of 42,916 ac-ft/yr (52,976,782 m^3/yr) at Structure P-11, and assuming a historical total phosphorus concentration in Lake Hancock of 628 μg/l as outlined in Table 2-4, approximately 32,269 kg/yr of phosphorus leaves Lake Hancock through the outfall structure. The remaining phosphorus inflow, approximately 41,236 kg/yr, is deposited into the sediments of the lake. A graphical comparison of total phosphorus losses in Lake Hancock is given in Figure 5-15.

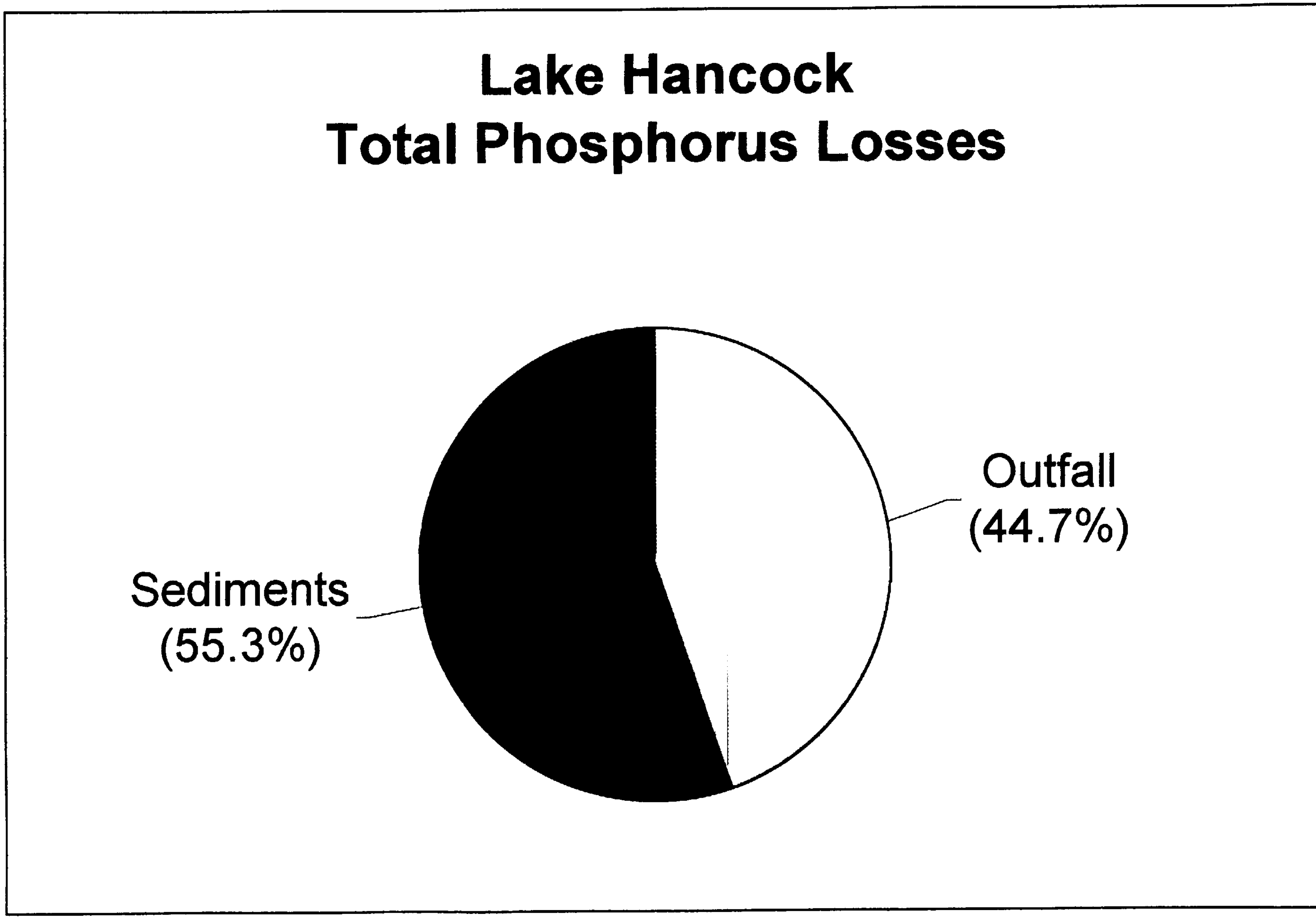


Figure 5-15. Estimated Phosphorus Losses from Lake Hancock.

6

SECTION 6

EVALUATION OF ALTERNATIVES FOR IMPROVEMENT OF WATER QUALITY DISCHARGING FROM LAKE HANCOCK

6.1 Conceptual Design Alternatives

Since discharges from Saddle Creek have a significant impact on overall water quality in the Peace River, one of the primary objectives of the Lake Hancock water quality improvement project is to evaluate water quality treatment alternatives to improve the quality of water which discharges from Lake Hancock through Saddle Creek into the Upper Peace River. This treatment alternative is important to improving water quality in the Peace River and ensuring that adequate supplies of fresh water and drinking water are available in the Lower Peace River basin.

6.1.1 General Design Philosophy

The objective of the water quality treatment project is to develop a process which would rapidly remove a significant portion of the pollutant loads discharging from Lake Hancock at Structure P-11 prior to entering the Upper Peace River. The two critical elements which must be considered in conceptualizing treatment alternatives are: (1) the rate at which water discharges from Lake Hancock; and (2) the chemical characteristics of that water at the point of treatment. Based on available USGS flow data collected at Structure P-11 from 1964-1996, historic discharges from Lake Hancock vary from 0 to approximately 700 cubic feet per second (cfs). As seen in Table 4-9, average monthly discharges at Structure P-11 vary from approximately 24 cfs in December to 76 cfs in July, increasing to more than 120 cfs duringAugust and September. As expected, the highest average monthly discharges occur during the wet months, including July, August, September and October. With the exception of August and September, all months have an average monthly discharge less than 80 cfs.

As presented in Table 2-1, during the period from 1995-1998, Lake Hancock had a minimum average annual water surface elevation of 97.61 ft MSL, a maximum average annual water surface elevation of 99.09 ft MSL and a mean average annual water surface elevation of 98.24 ft MSL. A minimum low management level of 96.00 ft MSL and a minimum flood level of 99.00 ft MSL have been established by SWFWMD for the lake. SWFWMD personnel from the Bartow office regulate flow through Structure P-11. As the lake level rises, the gates at structure P-11 are manually opened and water is allowed to discharge downstream. As lake level continues to increase, the discharge through Structure P-11 is increased. Much of the current water level control, and corresponding discharge rates, is based on visual observations.

However, based on discussions with SWFWMD operational personnel, it may be possible to more closely regulate discharges from Structure P-11 to provide a more constant discharge flow rate from the lake. By discharging at lower rates sooner, the peak discharge rates may be reduced, resulting in a more constant discharge from Lake Hancock. Minimizing the peak and average discharge rates at Structure P-11 is essential to constructing an economical water quality treatment project for the discharge from Lake Hancock.

The other important element which must be understood prior to conceptualizing a water quality treatment project is the chemical characteristics of the water to be treated. A summary of the chemical characteristics of the water discharging through Structure P-11 is provided in Table 2-9. Based on measurements performed by ERD, the water discharging from Structure P-11 has a mean total nitrogen concentration of 5100 μg/l and a particulate nitrogen concentration of 3500 μg/l. Therefore, approximately 67% of the total nitrogen is present as particulate nitrogen, primarily in the form of algal biomass. Water discharging through Structure P-11 also has a mean total phosphorus concentration of 4700 μg/l with a mean particulate phosphorus concentration of 4400 μg/l. Therefore, approximately 93% of the total phosphorus is present in the form of particulate phosphorus as algal biomass. The water discharging through Structure P-11 has an average suspended solids concentration of approximately 69 mg/l and a mean chlorophyll-a concentration of 120 mg/m^3.

The objective of the water quality improvement project is to remove total phosphorus, total nitrogen, and TSS from the water which discharges through Structure P-11. Based on the chemical analysis of water discharging through Structure P-11, a large majority of the total nitrogen and total phosphorus loads are present in the form of algal biomass. Therefore, a significant portion of the total nitrogen and total phosphorus loads can be removed if the algal biomass is removed. Based on the findings of the chemical analyses and the recognition of the relationship between pollutant loads and algal biomass, three water quality treatment alternatives were conceptualized to remove algal biomass from lake water prior to discharge through Structure P-11.

The three water quality treatment alternatives selected for evaluation include media filtration, wetlands treatment, and settling pond treatment aided by chemical coagulation. The media filtration alternative includes construction of gravity sand filters in concrete tanks similar to a traditional drinking water treatment plant. Algae would be physically removed as it passes downward through the sand media. An automated backwash system would be installed to periodically remove filtered algae from the sand filters. The wetlands treatment alternative would involve construction of multiple wetland cells using marsh vegetation to physically filter out algae from lake water, similar to the process currently being investigated at Lake Apopka. The chemical coagulation/settling pond treatment alternative would involve adding a coagulant to the water and pumping the treated water into settling pond cells for floc settling and drying.

For evaluation purposes, an average daily flow of 80 cfs was selected for conceptual design. This exceeds the mean average monthly discharge for the entire year with the exception of August and September. However, it may be possible to substantially reduce the average monthly discharge during August and September by altering the current management schedule for discharges from Structure P-11. By modifying the operation of Structure P-11 to start discharging earlier and reduce peak discharges, it is anticipated that approximately 90% of the water discharged from the lake from October to July (25,420 ac-ft) and approximately 50% of the flow during August and September (7,335 ac-ft) can be diverted into a treatment system with a capacity of 50 cfs. The total annual water volume which could be treated by such a system will be approximately 32,755 ac-ft or about 76% of the historic average annual discharge volume.

The following sections provide a detailed description of the three water quality treatment alternatives. All three water quality treatment alternatives will be designed for an average daily flow of 80 cfs and to maximize the removal of total nitrogen, total phosphorus, and total suspended solids (TSS).

6.1.2 Media Filtration

6.1.2.1 Experimental Procedures

Gravity sand filters have been used to treat drinking water in the United States for almost 100 years. Filters are typically used towards the end of the treatment process to remove any remaining solids prior to disinfection and distribution for use. To evaluate the feasibility of using a media filter for the removal of algae from Lake Hancock water, a pilot testing apparatus was constructed, as shown in Figure 6-1. The apparatus allowed for testing under gravity and pressure conditions and for the addition of chemical coagulants. Twelve inches (30 cm) of pea-sized gravel were added to the bottom of a 4 inch (10 cm) diameter clear PVC column, 6 ft (1.8 cm) in length. Twenty-four inches (61 cm) of test sand media were then added to the clear PVC column above the pea-gravel. Two different sand media were tested, including a 20/30 sand and FDOT filter sand.

Grain size distributions for the two sand media are provided in Appendix L. The 20/30 sand has a larger mean diameter, with 50% retained on a No. 20 sieve and the remaining 50% retained on a No. 40 sieve. The FDOT filter sand, commonly used for detention pond underdrain systems, has a much wider grain size distribution, ranging from a No. 10 sieve to a No. 200 sieve. Four separate treatment options were evaluated with each filter media. Three replicate tests were conducted for each treatment option to verify removal efficiency results. The four treatment options included gravity flow, pressure flow, pressure flow with alum added at a rate of 2.5 mg/l as aluminum (Al), and pressure flow with alum added at a rate of 5.0 mg/l as Al.

Prior to each experiment, 300 gallons (1135 liters) of water was collected just upstream of Structure P-11 and transported to the ERD research lab in Orlando. The water was then pumped into a 150-gallon (570 liter) HDPE tank which was used as a storage reservoir for lake water during the test experiments. Compressed air was added at the base of the tank to keep the water well mixed. A small peristaltic pump was used to feed water at a rate of approximately 4 gpm/ft^2 (160 lpm/m^2) to the test apparatus. During the gravity experiments,

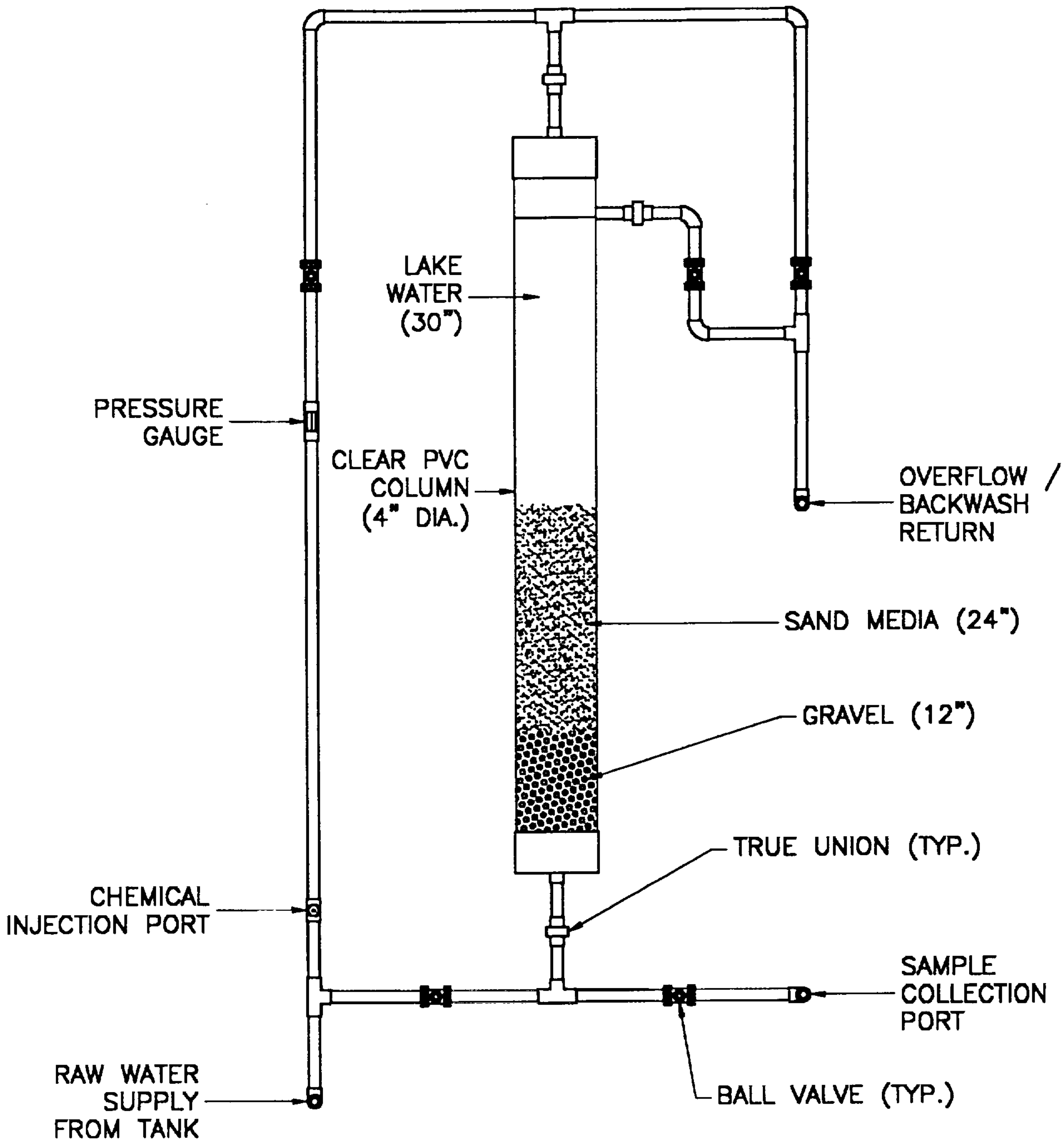


Figure 6-1. Media Filtration Test Apparatus.

excess water which could not pass through the media was returned to the 150-gallon (570 liter) HDPE tank. The experiment was continued until no water would pass through the sand filter. During the pressurized experiments, the experiments were continued until the pressure in the column exceeded 20 pounds per square inch (psi). For the experiments using alum addition, a second peristaltic pump was used to inject alum at the desired dosing rate into the inflow water prior to entering the test apparatus.

During each experiment, the flow rate through the column was measured using a clear graduated cylinder and stopwatch at the outflow point. Samples were collected multiple times throughout each experiment. Collected samples were analyzed for pH, conductivity, alkalinity, NH_3 nitrogen, NO_x nitrogen, total nitrogen, orthophosphorus, total phosphorus, sulfate, color, BOD, TSS, chlorophyll-a, and dissolved aluminum.

6.1.2.2 Experimental Results

A summary of experimental results obtained during the media filtration experiments is provided in Appendix M. Average percent removal efficiencies for total nitrogen, total phosphorus, BOD, TSS, and chlorophyll-a are provided in Table 6-1 for each experiment. The FDOT filter sand provided significantly higher removal efficiencies for all experiments. The fine-sized particles in the FDOT filter sand were more effective in removing algae than the larger-sized particles in the 20/30 sand. Under gravity conditions, the FDOT filter sand provided good removal efficiencies, including 46% for total nitrogen, 65% for total phosphorus, and 69% for TSS. Under pressure conditions, removal efficiencies of the FDOT filter sand decreased substantially. The addition of alum at 2.5 mg/l and 5 mg/l as Al provided higher removal efficiencies for the pressure condition than without alum, although no higher than the removal efficiencies for the filter sand under gravity conditions without chemical addition. Since the sand filter under gravity conditions provided removal efficiencies equal to or better than the pressure system, with or without alum addition, the gravity sand filter concept was selected for conceptual design.

TABLE 6-1

COMPARISON OF POLLUTANT REMOVAL EFFICIENCIES FOR MEDIA FILTRATION TESTING PERFORMED ON SURFACE WATER COLLECTED AT STRUCTURE P-11

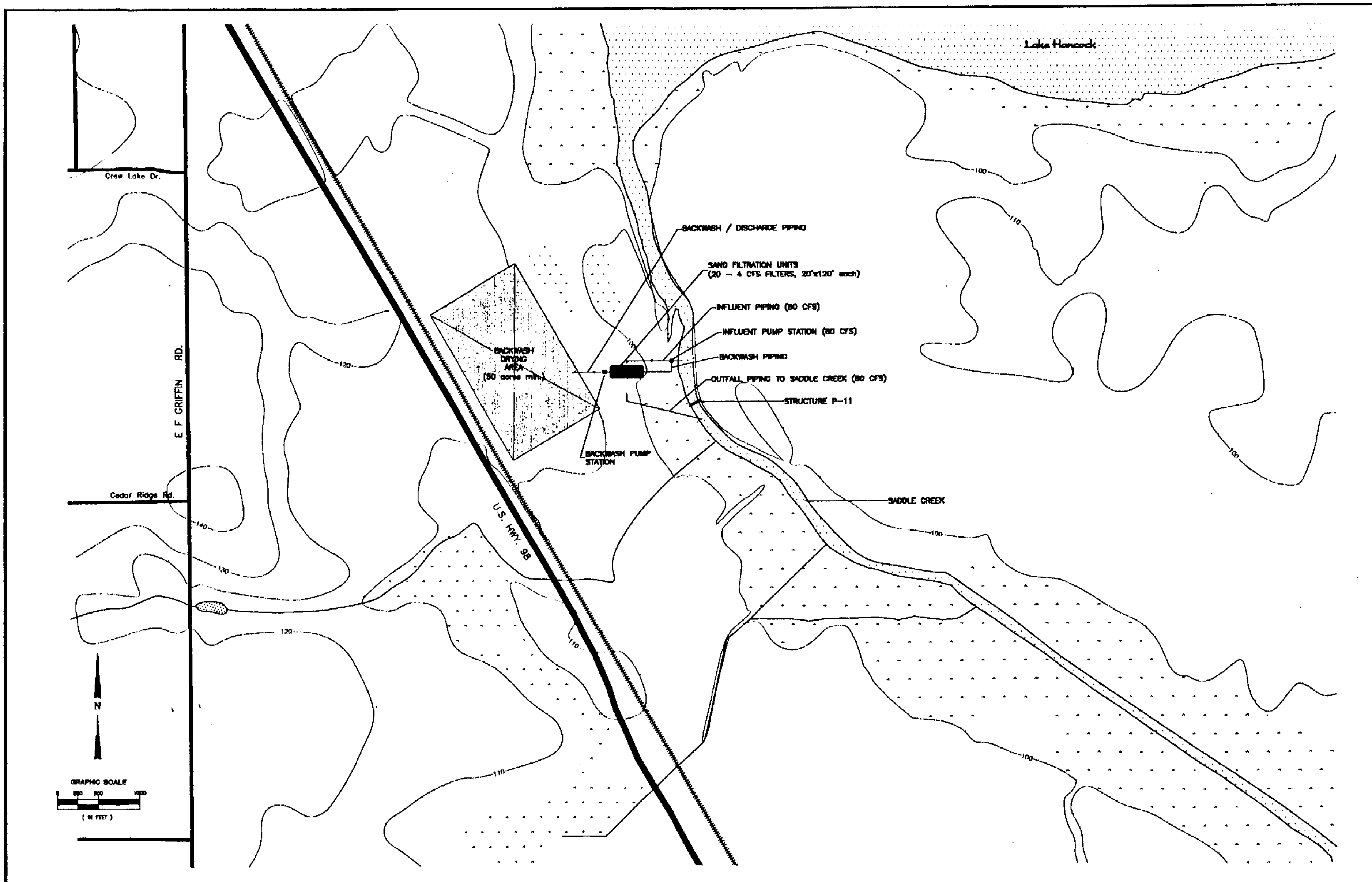
TEST	AVERAGE POLLUTANT REMOVAL (%)				
	TOTAL N	TOTAL P	BOD	TSS	CHYL-A
20/30 Sand - Gravity	23	33	30	33	38
20/30 Sand - Pressure	14	21	19	13	14
20/30 Sand - Pressure Alum = 2.5 mg/l as Al	32	50	42	59	50
20/30 Sand - Pressure Alum = 5.0 mg/l as Al	20	25	31	15	6
FDOT Filter Sand - Gravity	46	65	61	69	65
FDOT Filter Sand - Pressure	30	45	46	53	35
FDOT Filter Sand - Pressure Alum = 2.5 mg/l as Al	49	68	45	67	60
FDOT Filter Sand - Pressure Alum = 5.0 mg/l as Al	48	66	53	62	73

6.1.2.3 Conceptual Design

Heyward, Inc. (Orlando, FL) was contacted to obtain specific design and pricing information on sand filters for the removal of algae from water discharging through Structure P-11. Heyward obtained pricing information from Agency Environmental for water treatment-type gravity sand filters with an automated backwash system. Each filter unit will treat approximately 5 million gallons per day (MGD) (8 cfs) average daily flow, with two 16 ft (4.88 m) wide x 100 ft (30.5 m) long sand filters. The design loading rate will be approximately 1 gpm/ft^2. Because these filters will be primarily above-grade and will produce a 24 inch (60 cm) head loss through the filters, an influent pump station would need to be constructed adjacent to Saddle Creek upstream of Structure P-11. The inflow pump station would have a capacity of 80 cfs and would pump lake water into each of the media filters. The treated water would be applied to the top of the media and would be withdrawn below the media. The treated water would discharge through outfall piping into Saddle Creek, downstream of Structure P-11.

A backwash pump station would be constructed adjacent to the sand filtration units to pump the backwash water into a 50 acre (20.2 ha) drying area. The drying area would allow water to infiltrate into the ground and also to evaporate, leaving a dry algal material. A conceptual plan of the media filtration alternative is provided in Figure 6-2. On an annual basis, the media filtration alternative would treat approximately 32,755 ac-ft of water or 76% of the 42,916 ac-ft of water which discharges from Lake Hancock at Structure P-11. A programmable logic controller (PLC) could be used in conjunction with a water elevation sensor to control multiple pumps within the influent pump station. The higher the water elevation, the higher the water flow into the filter units.

Backwash will require approximately 5% of the treated water volume or about 1638 ac-ft/yr. It is anticipated that the backwash water would contain approximately 1% solids which could be dried to a final volume of approximately 26,460 yd^3 each year. This material will contain significant quantities of nitrogen and phosphorus and may be land spread or used as a fertilizer on local land. Removal efficiencies for this alternative will be provided in Section 6.2.



DESIGNED BY: J. L. HERR		REV.	DATE	DESCRIPTION	APP'D. BY
DRAWN BY: L. E. HEIGHT					
CHECKED BY: J. L. HERR					
APPROVED BY: H. H. HARPER					
DATE: FEB. 2000	SCALE: 1"=500'				

ERD
Environmental Research & Design, Inc.
Water Quality Engineering

LAKE HANCOCK
WATER QUALITY IMPROVEMENT PROJECT
FOR
SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
POLK COUNTY, FLORIDA

MEDIA FILTRATION
TREATMENT ALTERNATIVE
CONCEPTUAL PLAN

JEFFREY L. HERR, P.E.
REGISTERED ENGINEER NO. 38997
STATE OF FLORIDA

PROJECT No. 98-004

FIG. 6-2

SHEET 1 OF 1

6.1.3 Settling Pond Treatment Alternative

A comparison of water quality characteristics in Lake Hancock and at Structure P-11 is given in Table 2-9. Water quality in Lake Hancock appears to be somewhat different than water quality at Structure P-11. The open water of Lake Hancock is subject to extensive agitation by wind action and accelerated algal productivity due to intense solar radiation. Conversely, Saddle Creek is shaded to a significant degree and receives a smaller amount of solar radiation. In addition, the extensive vegetation on the sides of the creek limits wind action and water agitation.

Between Lake Hancock and Structure P-11, lake water turbidity decreases from 320 NTU to 43 NTU, TSS decreases from 113 mg/l to 69 mg/l, and chlorophyll-a decreases from 204 mg/m^3 to 120 mg/m^3. These values indicate that there is a reduction in algal biomass between Lake Hancock and Structure P-11. There appears to be a physical phenomenon occurring which allows a portion of the algal biomass to settle to the bottom of Saddle Creek between Lake Hancock and Structure P-11. This observation led to the selection of a settling pond treatment alternative which would allow algal biomass to settle under quiescent conditions. It may be possible to enhance this natural process by limiting the amount of sunlight reaching the surface of the water or by adding a chemical coagulant to increase algal floc size.

6.1.3.1 Experimental Procedures

A simple experiment was conducted to evaluate the feasibility of settling algal biomass and associated pollutant loads from water discharging from Structure P-11. Approximately 5 gallons (20 liters) of water was obtained just upstream of Structure P-11 on September 22, 1999. The water was transported to the ERD laboratory and poured into two 1000 ml clear PVC graduated cylinders. One of the graduated cylinders was placed in direct sunlight and one graduated cylinder was covered with an opaque black plastic container and placed in a shaded area. At intervals of three hours, six hours, and nine hours, the algal volume in the bottom of the cylinder was recorded, and a sample was carefully siphoned off the top of the cylinder for chemical analysis. The samples were analyzed for alkalinity, color, NH_3, NO_x, total nitrogen, orthophosphorus, total phosphorus, and chlorophyll-a. The results of the settling tests are provided in Table 6-2.

TABLE 6-2

RESULTS OF SETTLING TEST PERFORMED ON WATER DISCHARGING FROM STRUCTURE P-11 ON 9/22/99

SAMPLE	PARAMETER								
	Alk. (mg/l)	Color (Pt-Co)	NH_3-N (μg/l)	NO_x-N (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	Chyl-a (mg/m³)	Algal Volume (ml)
Raw	55.3	55	31	< 5	7741	< 1	638	264	0
Sun after 3 hrs	55.4	51	34	< 5	7305	< 1	543	232	0
Sun after 6 hrs	53.8	49	25	< 5	5000	< 1	324	117	15
Sun after 9 hrs	54.3	46	26	< 5	4922	< 1	314	113	25
Dark after 3 hrs	56.8	52	21	< 5	5060	< 1	334	149	30
Dark after 6 hrs	56.9	52	21	< 5	3290	< 1	153	70.3	40
Dark after 9 hrs	56.4	53	25	< 5	3047	< 1	143	57.7	45

The raw water had a total nitrogen concentration of 7700 μg/l, a total phosphorus concentration of 600 μg/l, and a chlorophyll-a concentration of 264 mg/m³. After nine hours in the cylinder under sunlight conditions, the water had a total nitrogen concentration of 4900 μg/l, a total phosphorus concentration of 300 μg/l, and a chlorophyll-a concentration of 113 mg/m^3. After nine hours in darkness, the water had a total nitrogen concentration of 3000 μg/l, a total phosphorus concentration of 100 μg/l, and a chlorophyll-a concentration of 58 mg/m^3. After nine hours in sunlight, approximately 25 ml of algae had accumulated in the bottom of the graduated cylinder, while 45 ml of algae accumulated in the graduated cylinder placed in darkness.

Pollutant removal efficiencies were calculated for total nitrogen, total phosphorus, and chlorophyll-a for the settling test results presented in Table 6-2. A summary of calculated removal efficiencies is given in Table 6-3. The settling test conducted in darkness had significantly higher removal efficiencies than the settling test conducted in sunlight. Removal efficiencies appeared to stabilize after approximately six hours of settling. Removal efficiencies at nine hours were approximately the same as at six hours.

TABLE 6-3

POLLUTANT REMOVAL EFFICIENCIES FOR SETTLING TESTS PERFORMED ON WATER DISCHARGING FROM STRUCTURE P-11 ON 9/22/99

SAMPLE	POLLUTANT REMOVAL (%)		
	Total N	Total P	Chyl-a
Sun after 3 hrs	6	15	12
Sun after 6 hrs	35	49	56
Sun after 9 hrs	36	51	57
Dark after 3 hrs	35	48	44
Dark after 6 hrs	58	76	73
Dark after 9 hrs	61	78	78

Unfortunately, the quiescent conditions within the graduated cylinders are not representative of conditions which would likely occur within a 10- or 20-acre settling pond. The settling pond will receive direct sunlight and will be affected by wind action. To maximize pollutant removal efficiencies for this alternative, it will be necessary to add a chemical coagulant to the water prior to discharging into the settling area to enhance the removal processes.

6.1.3.2 Conceptual Design

Based on the removal efficiencies summarized in Table 6-3, settling was substantially complete after approximately six hours. At a mean flow rate of 80 cfs and six hours of detention time, approximately 40 ac-ft of permanent pool volume would need to be provided for the settling pond treatment alternative. Settling processes could be substantially enhanced by the addition of a small dose of coagulant. An alum dose of approximately 2.5 mg/l as Al should be sufficient to generate large floc which should settle relatively quickly. A portion of the dissolved nutrient fractions may also be removed even at this low dose. At an alum dose of 2.5 mg/l as Al, approximately 491,325 gallons of alum will be required to treat 32,755 ac-ft of water each year. Based on the testing performed, the floc volume will be approximately 1% of the treated water volume, or approximately 328 ac-ft/yr. This material should dry to approximately 5% of its original wet volume, or approximately 16.4 ac-ft. This equates to a dry floc volume of 26,460 yd^3.

Five separate settling pond areas could be constructed, each with a capacity equal to the required detention time volume (40 ac-ft) plus one-fifth of the annual wet floc volume of 66 ac-ft, for a total capacity of 106 ac-ft. Only one of the five cells would be loaded at a time, with the remaining cells drying. Based on an overall 6 ft depth, approximately 20 acres would be required for each pond, for a total of approximately 100 acres for all five ponds.

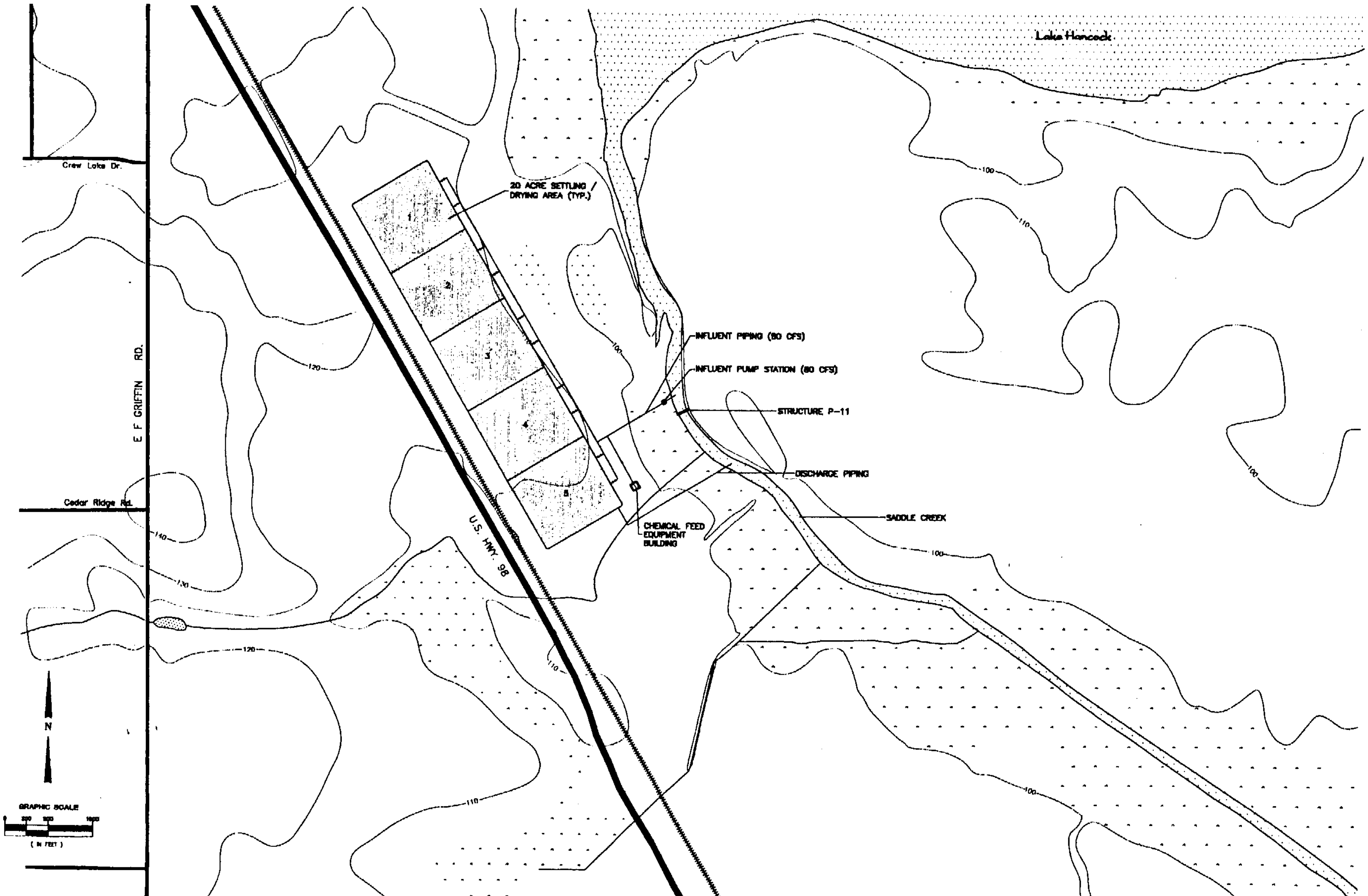
Operation of the settling ponds would generate approximately 26,460 yd^3 of floc which would need to be disposed of each year. Once each of the 20 acre cells had dried out, a grader and/or front-end loader would be used to transport the dry material to a disposal area. Based on previous work conducted by ERD, this material could be land spread almost anywhere, although it has little value as fertilizer.

The settling pond treatment alternative would involve pumping flow from Saddle Creek upstream of Structure P-11, up to the maximum design flow of 80 cfs, through influent piping and into one of the five settling/drying areas. The flow rate would be monitored and alum would be added in the influent line upstream of the settling/drying area. A conceptual plan for the settling pond treatment alternatives is provided in Figure 6-3. The treated water would discharge from the settling area through discharge piping into Saddle Creek downstream of Structure P-11. The anticipated pollutant removal effectiveness for this alternative is provided in Section 6.2.

6.1.4 Wetlands Treatment

6.1.4.1 Background

Wetlands have been used for over 40 years to remove nutrients and solids from wastewater effluent prior to reaching a receiving water. Wetland systems have been used for approximately the past 20 years to treat stormwater runoff, agricultural discharges, and, in some cases, lake water. The most similar work has been performed by the St. Johns River Water Management District on Lake Apopka in Orange County, Florida. Lake Apopka is a large



DESIGNED BY: J. L. HERR	REV.	DATE	DESCRIPTION	APP'D. BY	ERD Environmental Research & Design, Inc. Water Quality Engineering	LAKE HANCOCK WATER QUALITY IMPROVEMENT PROJECT FOR SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT	SETTLING POND TREATMENT ALTERNATIVE CONCEPTUAL PLAN
DRAWN BY: L. E. HEIGHT						POLK COUNTY, FLORIDA	JEFFREY L. HERR, P.E.
CHECKED BY: J. L. HERR							PROJECT No. 98-004
APPROVED BY: H. H. HARPER							FIG. 6-3
DATE: FEB. 2000 SCALE: 1"=500'							SHEET 1 OF 1

(30,000 acres or 125 km^2) shallow (mean depth 5.2 ft or 1.6 m) hypereutrophic lake. A wetland filter was created on flood plain farm land to physically remove algae, sediments, and particle-bound nutrients from Lake Apopka water.

The Flow-Way Demonstration Project is a pilot scale (>2 km^2) marsh flow-way constructed to evaluate efficiencies and management techniques. The project started in 1990 and was drained for the first time in 1994. The areal hydraulic loading rate for the first cell varied from 4-18 cm/day, with mean water depth ranging from 0.6-0.9 m, and residence time ranging from 4-12 days. Similar to Lake Hancock, particulate nitrogen comprised 65% of the total nitrogen in the inflow, with particulate phosphorus comprising more than 90% of the total phosphorus. The demonstration project achieved a 75-90% reduction in particulate nitrogen and a 50-90% reduction in particulate phosphorus. Overall removal efficiencies for total nitrogen and total phosphorus varied from 30-50%.

Several important lessons were learned during completion of the demonstration project, including the need for multiple parallel cells, a recommended hydraulic loading rate of 10 cm/day, the need for distributed inlet and outlet structures, the need for deep areas perpendicular to flow paths to intercept channelized flow, the need to minimize the frequency and duration of drawdowns, and the need to stabilize phosphorus in the consolidated organic material prior to re-flooding to limit leaching of soluble phosphorus. After 29 months of operation, approximately 33 cm of organic material had accumulated in the wetland cell which consolidated to approximately one-seventh its original depth after several months of drying. The specific objective of the Lake Apopka marsh flow-way system is to remove particulate nitrogen, particulate phosphorus, and TSS from the lake water.

Information was also obtained on work being conducted on the Everglades nutrient removal project. The objectives of the Everglades nutrient removal project are much different than the Lake Apopka marsh flow-way or the Lake Hancock wetland treatment alternative. The objective of the Lake Hancock wetland treatment alternative is to remove particulate nitrogen, particulate phosphorus, and TSS primarily in the form of algal biomass from lake water. The primary objective of the Everglades nutrient removal project is to remove primarily dissolved nutrients from agricultural discharges. The Everglades nutrient removal project is relying on biological treatment to achieve relatively low effluent concentrations (TP $< 50\ \mu g/l$).

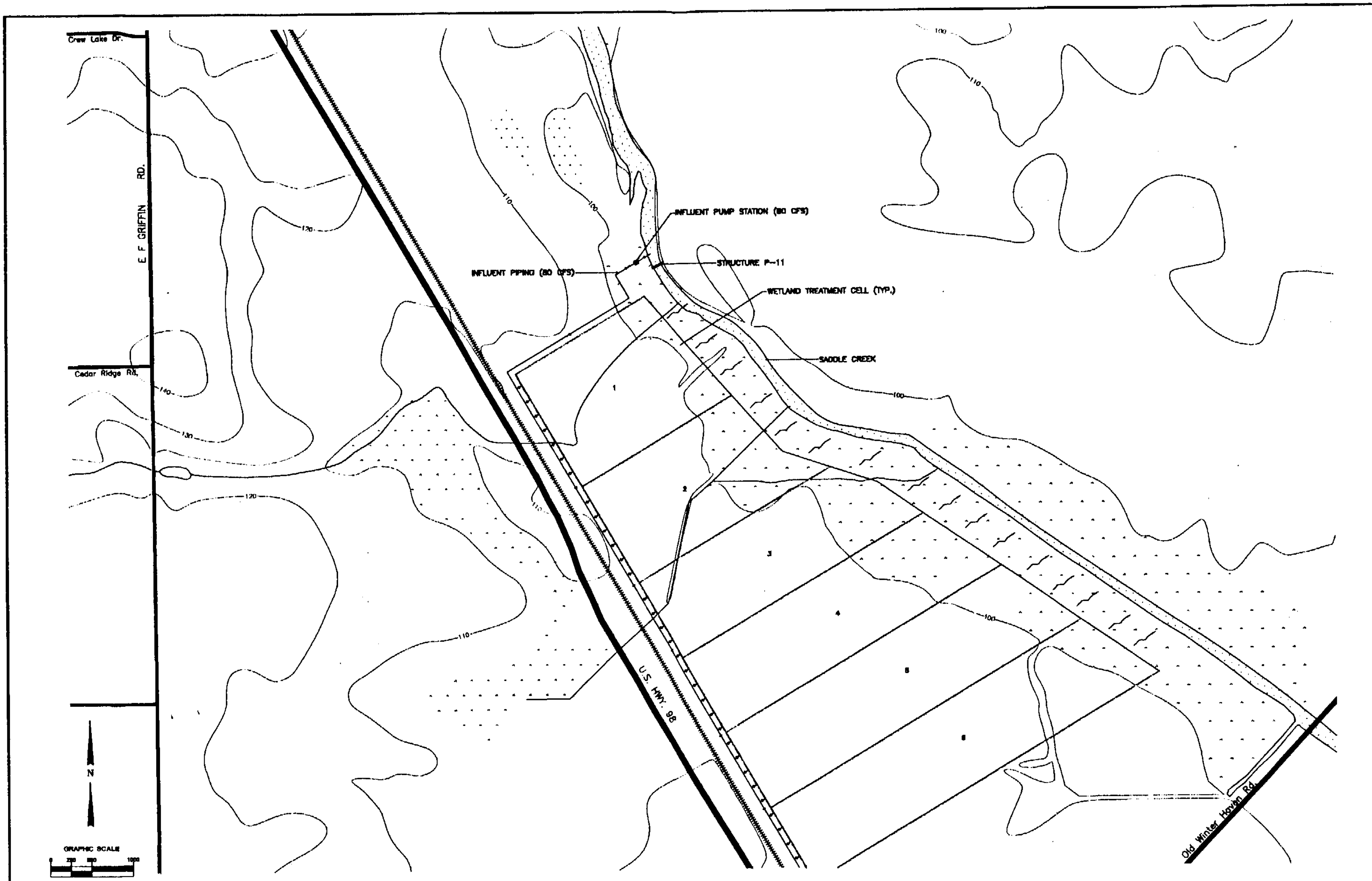
6.1.4.2 Conceptual Design

Due to its similarity, information obtained from the Lake Apopka marsh flow-way demonstration project will be used to conceptually design a wetland treatment system to treat the water which discharges at Structure P-11. The wetland treatment system will be designed to treat a peak flow of 80 cfs. A hydraulic loading rate of 10 cm/day will be used in conjunction with a normal water depth of 2 ft (0.6 m). Water will be pumped from Saddle Creek upstream of Structure P-11 into multiple wetland treatment cells. The inflow water will be distributed evenly across the front of each wetland treatment cell. Water will pass through a marsh system planted with Typha or other selected plant materials and discharge into Saddle Creek downstream of Structure P-11. The wetland cell areas adjacent to U.S. Highway 98 will be excavated due to the significantly higher existing land elevations. This material will be used to construct berms 6 ft above existing land elevations surrounding the lower portions of each treatment cell. The berms will contain a clay core to limit water passage from one cell to another. Once cell grading is completed, Typha or other selected materials will be planted at

2.5 ft on center throughout the wetland treatment cells. Water will be introduced into each cell at an initial slower rate and gradually increased over time as vegetation develops. A conceptual plan for the wetlands treatment alternative is provided in Figure 6-4.

Based on a hydraulic loading rate of 10 cm/day and a flow rate of 80 cfs, approximately 480 acres of actual wetland material will be required. This will require a total area of approximately 600 acres considering berms and grading. Based on a 2 ft water depth, the average residence time in each cell will be approximately 6.1 days at a flow rate of 80 cfs. Assuming a sediment volume equal to 1% of the treated water volume, the cells will accumulate approximately 54 cm of organic material over a two-year period. This is comparable to the 33 cm observed at Lake Apopka. Assuming the volume dries to one-seventh of its wet volume, approximately 3 inches (8 cm) will remain after two years. This equates to a dry volume of approximately 199,259 yd^3.

The management of any wetland treatment system is extremely important to maximize pollutant removal efficiency and to limit leaching of trapped pollutants. Prior to implementation of the full 600-acre system, it is highly recommended that a two-cell demonstration project be constructed on 50-100 acres of land. Various removal efficiencies could be confirmed and management strategies could be evaluated during the demonstration project. Possible management strategies include: drawdown and burning of dried wetland treatment cells followed by partial replanting with Typha; stabilization of dried organic material to limit the release of phosphorus when re-flooded; or use of a grader to remove the vegetation and approximately 3 inches of dried organic material. The collected material could be composted and then landspread. The removal efficiencies for the wetland treatment alternative are provided in the following section.



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Water Quality Engineering

LAKE HANCOCK
WATER QUALITY IMPROVEMENT PROJECT
FOR
SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
POLK COUNTY, FLORIDA

WETLAND
TREATMENT ALTERNATIVE
CONCEPTUAL PLAN

JEFFREY L. HERR, P.E.

PROJECT No. 98-004
FIG. 6-4
SHEET 1 OF 1

6.2 Estimated Annual Mass Pollutant Load Reductions

Concentration-based pollutant removal efficiencies were developed for each of the three outfall treatment alternatives outlined in Section 6.1. A summary of estimated removal efficiencies is given in Table 6-4. Concentration-based removal efficiencies for the media filtration were obtained from pilot testing, as described in Section 6.1. Pollutant removal efficiencies for the settling pond treatment alternative were obtained from settling tests, as described in Section 6.1, and from the evaluation of existing alum treatment systems with settling ponds. Pollutant removal efficiencies for the wetland treatment alternative were estimated based on the Lake Apopka marsh flow-way demonstration project and the chemical characteristics of water discharging at Structure P-11. All three alternatives have similar removal efficiencies for the four parameters of concern. The settling pond treatment alternative appears to provide slightly higher concentration-based removal efficiencies for total nitrogen and total phosphorus.

TABLE 6-4

ESTIMATED CONCENTRATION-BASED REMOVAL EFFICIENCIES FOR LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

OPTION	PERCENT POLLUTANT REMOVAL EFFICIENCY (%)			
	TOTAL N	TOTAL P	BOD	TSS
Media Filtration	45	65	60	70
Wetlands Treatment	50	60	50	90
Settling Pond Treatment	60	80	50	90

As previously discussed, each of the alternatives would treat approximately 32,755 ac-ft of water, or about 76% of the total volume of water discharged from Structure P-11. Estimated annual overall mass removal efficiencies for discharges at Structure P-11 are estimated by multiplying the pollutant concentration removal efficiency times the percent of water treated (76%). A summary of estimated overall pollutant mass removal efficiencies is given in Table 6-5. Mass removals provided in this table include the effects of the treatment systems as well as discharged water which bypasses the treatment system.

TABLE 6-5

ESTIMATED ANNUAL POLLUTANT MASS REMOVAL EFFICIENCIES FOR LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

OPTION	ANNUAL MASS REMOVAL EFFICIENCY (%)			
	TOTAL N	TOTAL P	BOD	TSS
Media Filtration	34	50	46	53
Wetlands Treatment	38	46	38	69
Settling Pond Treatment	46	61	38	69

Each of the treatment alternatives summarized in Table 6-5 provides comparable mass removal efficiencies for total nitrogen, total phosphorus, BOD, and TSS. Estimated total nitrogen mass removal efficiencies for the three treatment options vary from 34-46%, with estimated mass removal efficiencies of 50-61% for total phosphorus, 38-46% for BOD, and 53-69% for TSS. The settling pond treatment alternative provides the highest annual mass removal efficiencies for total nitrogen and total phosphorus, with media filtration providing the highest removal for BOD.

Based on an annual water discharge volume of 42,916 ac-ft and pollutant concentrations from Table 2-9, the estimated annual mass pollutant loads discharging from Structure P-11 were calculated, as provided in Table 6-6. An estimated 272,000 kg of total nitrogen, 25,000 kg of total phosphorus, and over 3,600,000 kg of TSS discharge at Structure P-11 each year. Utilizing the estimated annual mass pollutant loads from Table 6-6 and the estimated annual mass pollutant removal efficiencies from Table 6-5, the estimated annual mass pollutant load reductions for the three treatment alternatives were calculated, as provided in Table 6-7. Mass pollutant load reductions vary from 92,000-125,000 kg of total nitrogen, 12,000-15,000 kg of total phosphorus, and 2,000,000-2,500,000 kg of TSS each year.

TABLE 6-6

ESTIMATED ANNUAL MASS LOADS DISCHARGING FROM LAKE HANCOCK AT STRUCTURE P-11[1]

ESTIMATED ANNUAL MASS POLLUTANT LOADS (kg/yr)					
PARTICULATE N	TOTAL N	PARTICULATE P	TOTAL P	BOD	TSS
183,400	271,700	23,180	24,980	836,241	3,673,000

1. Based on annual discharge volume of 42,916 ac-ft and pollutant concentrations from Table 2-9

TABLE 6-7

ESTIMATED ANNUAL MASS LOAD REDUCTIONS FOR LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

OPTION	MASS POLLUTANT LOAD REDUCTIONS (kg/yr)			
	TOTAL N	TOTAL P	BOD	TSS
Media Filtration	92,380	12,490	384,670	1,946,700
Wetlands Treatment	103,250	11,490	317,770	2,534,400
Settling Pond Treatment	124,980	15,240	317,770	2,534,400

6.3 Conceptual Opinion of Probable Construction Costs

Utilizing the conceptual plans provided earlier in this section, conceptual opinions of probable construction cost were developed for each of the three alternatives. The conceptual opinions of cost include land acquisition, land preparation, construction, and a 20% contingency due to the conceptual nature of the estimate. The conceptual opinions of probable construction cost for the media filtration treatment alternative, the wetland treatment alternative, and the settling pond treatment alternative are provided in Appendix N.

A comparison of the conceptual opinions of probable construction cost for the Lake Hancock outfall treatment alternatives is provided in Table 6-8. The media filtration option has the highest conceptual cost, followed by wetland treatment and settling pond treatment. The settling pond treatment alternative has a significantly lower estimated construction cost than the other two alternatives.

TABLE 6-8

COMPARISON OF CONCEPTUAL OPINIONS OF PROBABLE CONSTRUCTION COST FOR LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

OPTION	CONCEPTUAL COST ($)
Media Filtration	13,308,300
Wetlands Treatment	11,176,800
Settling Pond Treatment	7,562,400

6.4 Estimated Annual Operation and Maintenance Cost

6.4.1 Media Filtration Treatment

The annual operation and maintenance (O&M) cost for the media filtration treatment alternative includes labor to operate the system, power to operate the influent pump station and backwash pump station, renewal and replacement for equipment, solids disposal, and a 10% contingency. The labor cost is calculated by multiplying the anticipated annual number of man-hours (2080 hours/year) times a personnel rate ($30/hour). The power cost is determined by multiplying the kilowatt (kw) motor requirement (225 kw) times the number of hours the pump will operate per year (6460 hrs) times $0.07/kw hour of operation. The renewal and replacement cost is calculated by dividing the cost of the mechanical equipment ($1,000,000) by the useful life (20 years). The solids disposal cost is calculated by multiplying the solids volume (26,460 yd^3) times $10/$yd^3$ for handling and disposal. The total estimated annual O&M cost for the media filtration alternative is $539,033.

6.4.2 Wetlands Treatment

The annual O&M cost for the wetland treatment alternative includes labor for operation, power to operate the influent pump station, renewal and replacement for equipment, solids disposal and/or management, and a 10% contingency. The labor cost is calculated by multiplying the anticipated annual number of man-hours (1872 hours/year) times a personnel rate ($30/hour). The power cost is determined by multiplying the kw motor requirement (240 kw) times the number of hours the pump will operate (6460 hrs) times $0.07/kw hour of operation. The renewal and replacement cost is calculated by dividing the cost of the mechanical equipment ($300,000) by the useful life (20 years). The solids disposal cost is calculated by multiplying the area of wetlands (480 acres) times $500/acre. The total estimated annual O&M cost for the wetlands treatment alternative is $461,696.

6.4.3 Settling Pond Treatment

Calculations for the annual O&M cost for the settling pond treatment alternative are similar to the other alternatives with the exception of chemical costs. The settling pond treatment alternative will require approximately 491,000 gallons of alum per year at a cost of $0.40/gallon. The total estimated O&M cost for the settling pond treatment alternative is $883,626. The settling pond treatment alternative O&M cost is much higher than the other alternatives due to the chemical cost. A comparison of estimated annual O&M costs for the three treatment alternatives is provided in Table 6-9.

TABLE 6-9

COMPARISON OF ESTIMATED ANNUAL OPERATION AND MAINTENANCE COSTS FOR LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

OPTION	LABOR COST ($)	POWER COST ($)	RENEWAL AND REPLACEMENT COST ($)	CHEMICAL COST ($)	SOLIDS DISPOSAL COST ($)	CONTINGENCY COST ($)	TOTAL COST ($)
Media Filtration	43,680	101,753	50,000	--	294,600	49,000	539,033
Wetlands Treatment	56,160[1]	108,536	15,000	--	240,000[2]	42,000	461,696
Settling Pond Treatment	93,680[1]	108,536	25,000	245,660	330,750	80,000	883,626

1. Includes the cost of pond mowing and general maintenance
2. Includes cost of plant and solids management

6.5 Present Worth Cost

As discussed in Section 6.4, the three treatment alternatives have different estimated construction costs and annual O&M costs. One method to compare the total cost, including construction and O&M, is to calculate the present worth cost for each alternative over a given time period. Using a 20-year period, the present worth cost for each alternative was calculated, as provided in Table 6-10. While the settling pond treatment alternative has the lowest capital cost, it has the highest overall present worth cost due to the higher annual O&M cost. The wetland treatment alternative has the lowest present worth cost at $20,410,720. The implementation of any of these three treatment alternatives would require a significant financial commitment from SWFWMD and other participating state agencies.

TABLE 6-10

ESTIMATED PRESENT WORTH COST FOR LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

OPTION	CAPITAL COST ($)	ANNUAL O&M COST ($)	PRESENT WORTH COST ($)
Media Filtration	13,308,300	539,033	24,088,960
Wetlands Treatment	11,176,800	461,696	20,410,720
Settling Pond Treatment	7,562,400	883,626	25,234,920

6.6 Comparison of Present Worth Cost per Mass Pollutant Removed

It is important to have the ability to compare the cost effectiveness of one alternative to another. This comparison should consider not only the present worth cost but also the mass of pollutants removed. The best method to compare the cost effectiveness of different treatment alternatives is to calculate the present worth cost per mass of pollutant removed. Based on the estimated mass pollutant load reductions outlined in Table 6-7, and the present worth costs outlined in Table 6-10, present worth costs per mass of pollutant removed were calculated for total nitrogen, total phosphorus, BOD, and TSS. A summary of these calculations is given in Table 6-11. The present worth cost per kg of total nitrogen removed varies from $198 for the wetland treatment alternative to $261 for the media filtration alternative. The present worth cost per kg of total phosphorus removed varies from $1656 for the settling pond alternative to $1929 for the media filtration alternative. The present worth cost per kg of TSS removed varies from $8 for wetland treatment to $12 for media filtration.

TABLE 6-11

ESTIMATED PRESENT WORTH COST PER MASS POLLUTANT REMOVED FOR LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

OPTION	PRESENT WORTH COST/MASS POLLUTANT REMOVED ($/kg)			
	TOTAL N	TOTAL P	BOD	TSS
Media Filtration	261	1929	63	12
Wetlands Treatment	198	1776	64	8
Settling Pond Treatment	202	1656	79	10

Overall, the wetlands treatment alternative has the lowest present worth cost per mass of pollutant removed for total nitrogen and TSS. The settling pond alternative has a slightly lower present worth cost per mass of pollutant removed for total phosphorus than the other alternatives, while the media filtration alternative has the lowest present worth cost per mass of pollutant removed for BOD. Based on the preceding analyses, the wetland treatment alternative appears to be the most cost-effective based on its lower present worth cost and present worth cost per mass pollutant removed for total nitrogen and TSS.

6.7 Water Quality Improvements Resulting from Supplemental Treatment Options

Treatment options have been evaluated in the preceding sections for alternate methods of improving water quality characteristics in discharges from Lake Hancock. Although improving water quality characteristics in discharges from Lake Hancock is the primary emphasis of this study, additional modeling evaluations were performed to evaluate anticipated water quality improvements which could be achieved from a series of runoff/baseflow treatment options as well as sediment removal options. These evaluations were conducted primarily for comparative purposes and also to quantify anticipated water quality improvements resulting from runoff treatment or sediment removal.

6.7.1 Runoff/Baseflow Treatment Options

Supplemental water quality modeling was performed to evaluate anticipated water quality characteristics in Lake Hancock resulting from various levels of treatment to runoff/baseflow inputs entering the lake. For evaluation purposes, generalized reductions of 25%, 50%, and 75% of existing runoff/baseflow inputs were assumed as input into the existing water quality model developed in Section 5.7.

The model input assumes an overall reduction of 25%, 50%, or 75% in runoff/baseflow inputs, but does not specify the particular tributary to be treated. Annual phosphorus inputs to Lake Hancock are assumed to be similar to the values presented in Table 5-18 under existing conditions, which assumes an annual phosphorus input of approximately 28,562 kg/yr from runoff/baseflow. Overall reductions of 25%, 50%, and 75% are assumed for this source, while estimated phosphorus inputs from groundwater seepage, bulk precipitation, and internal recycling/animal waste remain unchanged.

As seen in Figure 5-14, approximately 78% of the total phosphorus inputs from runoff/baseflow originate within the Saddle Creek watershed. Therefore, an overall reduction of 25% of the annual runoff/baseflow loadings to Lake Hancock can be achieved by a 32% reduction in total phosphorus loadings discharging to the lake through Saddle Creek. A 50% reduction in estimated annual runoff/baseflow loadings to Lake Hancock can be achieved by removal of approximately 64% of the annual phosphorus loading from Saddle Creek. Achieving an overall 75% reduction in annual runoff/baseflow loadings of total phosphorus to Lake Hancock would require removal of 96% of the total phosphorus entering the lake from Saddle Creek. A removal efficiency of this magnitude is probably not feasible, indicating that retrofit projects would be required on multiple watershed inflows to achieve a removal efficiency of this magnitude.

Additional trophic state modeling was conducted, using the procedures outlined in Section 5.6, to evaluate changes in water quality characteristics in Lake Hancock resulting from the evaluated runoff/baseflow treatment options. Separate water quality models were generated to predict impacts from removal of 25%, 50%, and 75% of the annual runoff/baseflow inputs of total phosphorus to Lake Hancock. Additional phosphorus inputs from bulk precipitation, groundwater seepage, and internal recycling are assumed to be identical to values estimated under current conditions. A complete listing of trophic state modeling used to evaluate runoff/baseflow treatment options is given in Appendix O.

A summary of anticipated TSI values in Lake Hancock based on the evaluated runoff/baseflow treatment option is given in Figure 6-5. TSI values, calculated based on estimated chlorophyll-a concentrations, are provided for each of the evaluated options on a monthly basis. Removal of 25% of the total phosphorus inputs from runoff/baseflow will improve TSI values in Lake Hancock from 91 under existing conditions to approximately 89. Removal of 50% of total phosphorus loadings from runoff/baseflow will improve the mean annual TSI value from 91 to 86, while a 75% reduction in total phosphorus loadings from runoff/baseflow will improve the mean annual TSI value to 84. Even with the 75% removal of total phosphorus, the predicted improvements in water quality characteristics are minimal for improvement options involving treatment of runoff/baseflow.

6.7.2 Sediment Removal Options

In addition to the runoff/baseflow treatment options outlined in the previous section, additional water quality modeling was performed to evaluate potential water quality improvements resulting from sediment removal in Lake Hancock. Sediment removal has the potential to substantially improve water quality characteristics within the lake since the majority of phosphorus loadings to the lake are thought to originate from the nutrient-rich sediments. For evaluation purposes, it is assumed that a sediment removal/dredging project will reduce internal recycling within the lake by approximately 80%. Complete elimination of internal recycling is not feasible since dredging operations are rarely 100% efficient. Therefore, under the sediment removal option, miscellaneous total phosphorus inputs to the lake are reduced from 108 kg/day under existing conditions to approximately 21.6 kg/day.

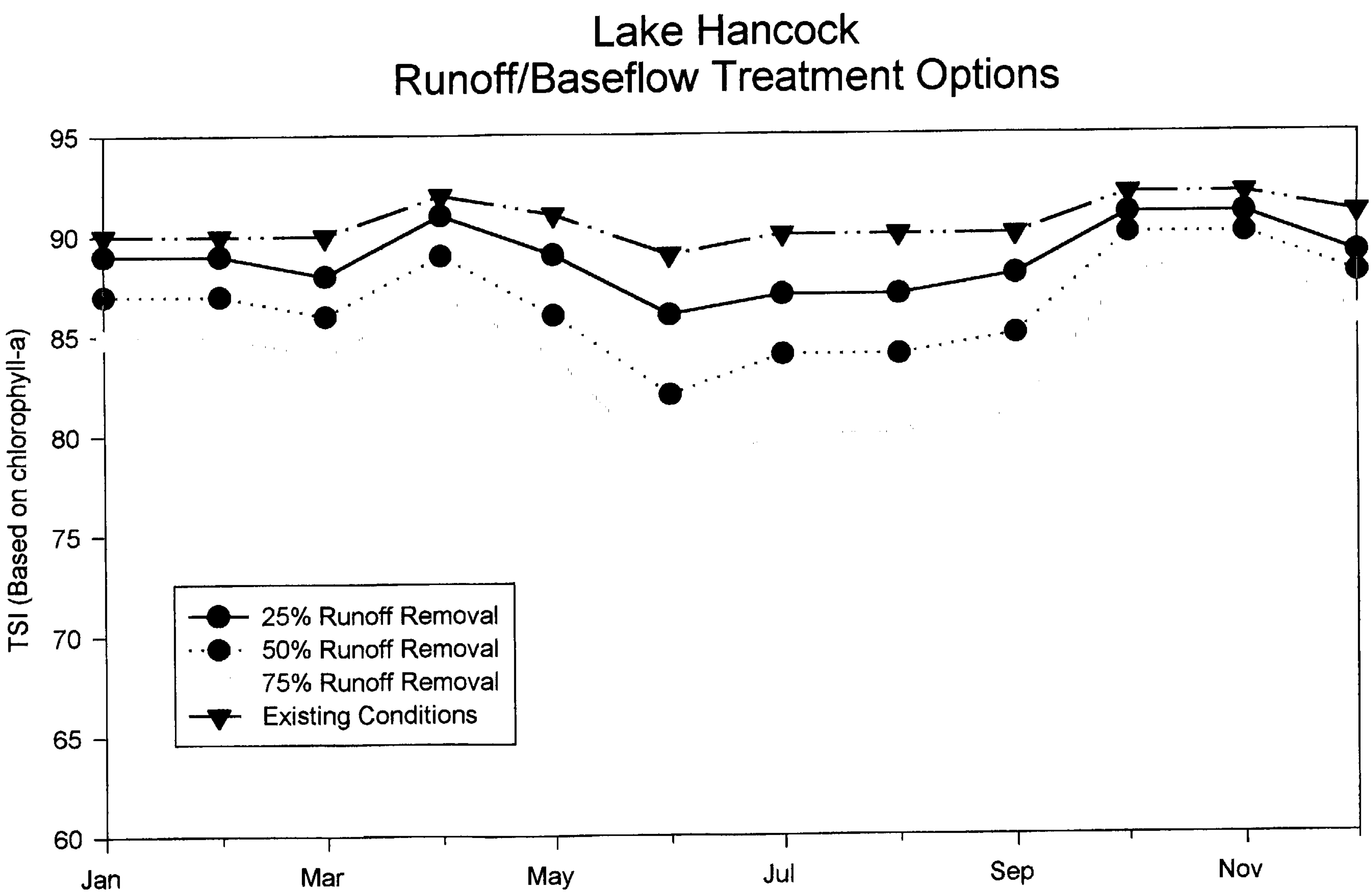

Figure 6-5. Anticipated Monthly TSI Values in Lake Hancock Based on Selected Runoff/Baseflow Treatment Options.

Additional modeling was performed to evaluate the combined water quality impacts from sediment removal and reduction of total phosphorus in runoff/baseflow inputs. For purposes of this evaluation, it is assumed that, in addition to sediment removal, 25% and 50% of the total phosphorus in runoff/baseflow inputs is also removed from the lake. A complete listing of modeling used to evaluate these options is given in Appendix P.

A graphical comparison of predicted water quality characteristics in Lake Hancock from the sediment removal options is given in Figure 6-6. Removal of sediments from Lake Hancock will result in a significant improvement in water quality characteristics, although the lake will still exist in a hypereutrophic condition. Estimated water column transparency in the lake will more than double, with estimated chlorophyll-a concentrations reduced from 170 mg/m^3 to 73 mg/m^3. Supplementing the dredging operation with inflow treatment equivalent to 25% and 50% of the total phosphorus inflow from runoff/baseflow will result in additional improvements in water quality characteristics, although the incremental improvement in water quality is relatively small. Removal of 25% of the runoff/baseflow inputs will result in mean annual TSI value of 75, compared with an estimated mean annual value of 78 with dredging alone. Removal of 50% of the phosphorus inflow from runoff/baseflow, combined with dredging, will improve the mean annual TSI value to approximately 70. Under this scenario, the lake will exist in borderline hypereutrophic/eutrophic conditions and will have substantially lower mean values for chlorophyll-a and total phosphorus. Water column clarity in the lake will improve by approximately a factor of 4. Unfortunately, no combination of treatment options appears capable of restoring Lake Hancock to mesotrophic conditions.

SECTION 7

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A

APPENDICES

APPENDIX A

HISTORICAL DATA
FOR LAKE HANCOCK

1. **Historical Lake Level Data from 1958-1999**
   (Source: Polk County)

2. **Historical Water Quality Data from 1984-1999**
   (Source: Polk County)

B

APPENDIX B

IMC-AGRICO SEDIMENT CHARACTERIZATION STUDY

(Source: IMC-Agrico, 1998)

IMC AGRICO®

Pat Fricano
Environmental Manager
Department of Environmental Protection
Mail Station 45
3900 Commonwealth Blvd,
Tallahassee, Fl 32399-3000

December 9, 1998

RE: Lake Hancock Restoration

Dear Mr. Fricano:

This is a response to your request for information concerning Lake Hancock. At Lee Thurner's direction, I am sending you all available data concerning the sediment characterization.

This data is attached and includes the following:

- A table containing the depth of water and sediment obtained from our drilling program.
- An aerial photo with depth of water contours.
- An aerial photo with contours of lake muck sediments thickness.
- A table containing chemical analysis of lake muck sediments for nutrients and metals.
- A series of grain size analysis of the sediments.

You asked for desiccation calculations. We did not do sediment drying tests. Previous work by Jacob's Engineering, indicated acceptable desiccation rates. The fatal flaw, from a mining standpoint, was the sediment's fluidity. During a high volume dewatering phase, large quantities of sediments would flow to the dewatering sump and be transported with the decanted water. An unacceptable probability for significant water quality problems in the form of suspended solids would be created.

The primary source of information used in making our mining evaluation was the "Lake Hancock Restoration Study" complete by Jacobs Engineering Inc. I assume you are familiar with this report, but if not, it is a comprehensive study completed in the late 1980's by Zellars and Williams a division of Jacob's Engineering. This study was done for the Florida Institute of Phosphate Research. The Project Number is 29-8047-00.

The purpose of our testing and prospecting was to verify the correctness of that report. All tested areas were within acceptable statistical variance so it was accepted .

I have enclosed a 3½" disk that includes the tables and the grain size analysis.

If you have any questions or would like further clarification, please feel free to call me at 941-428-2721

Sincerely,

Mike Hutchens
Superintendent Reserves and Planning

cc. Lee Thurner

Grain Size Analysis

Lake Hancock Sediments

Hole 0446
Section 8, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 mm	1.6	0.7
0.5 - 1.68 mm	4.5	2
0.25 - 0.5 mm	39.4	17.2
0.13 - 0.25 mm	23.4	10.2
0 - 0.125 mm	37.6	16.4
< 0.0025mm	122.4	53.5

228.9 gram sample

Hole 1254
Section 7, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 m	12.2	3.3
0.5 - 1.68 m	16	4.3
0.25 - 0.5 m	41.3	11.2
0.125 - 0.25 m	62.3	16.9
0.0025 - 0.125 m	62.1	16.8
< 0.0025 m	175.7	47.5

369.6 gram sample

Hole 0446
Section 16, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 mm	1.3	0.3
0.5 - 1.68 mm	9.5	2.1
0.25 - 0.5 mm	216.1	47.6
0.13 - 0.25 mm	88.6	19.5
0 - 0.125 mm	93.1	20.5
< 0.0025mm	45.5	10

454.1 gram sample

Hole 2062
Section 17, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 m	1.17	0.4
0.5 - 1.68 m	6.79	2.3
0.25 - 0.5 m	82	27.7
0.125 - 0.25 m	82.6	27.9
0.0025 - 0.125 m	75.8	25.6
< 0.0025 m	48	16.2

296.4 gram sample

Hole 1238
Section 5, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 mm	1	0.5
0.5 - 1.68 mm	9.7	4.8
0.25 - 0.5 mm	46.8	22.9
0.13 - 0.25 mm	34.2	16.8
0 - 0.125 mm	46.5	22.8
< 0.0025mm	65.9	32.3

204.1 gram sample

Hole 2854
Section 6, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 m	7.8	1.5
0.5 - 1.68 m	14.5	2.7
0.25 - 0.5 m	44.5	8.4
0.125 - 0.25 m	46.9	8.8
0.0025 - 0.125 m	64.9	12.2
< 0.0025 m	351.8	66.3

530.4 gram sample

Hole 1238
Section 17, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 mm	2.6	0.6
0.5 - 1.68 mm	7.3	1.7
0.25 - 0.5 mm	51.4	12.2
0.13 - 0.25 mm	52.1	12.4
0 - 0.125 mm	94.7	22.5
< 0.0025mm	213	50.6

421.1 gram sample

Hole 2854
Section 18, Towhship 29 South, Range 25 East

	Sieve Retention Grams	Sieve Retention %
> 1.68 m	0.74	0.7
0.5 - 1.68 m	2.36	2.2
0.25 - 0.5 m	7.88	7.5
0.125 - 0.25 m	9.38	8.9
0.0025 - 0.125 m	18.5	17.6
< 0.0025 m	66.5	63.1

105.36 gram sample

Lake Hancock

Polk County - Florida

Estimated Lake Water Depth and Lake Floor Sediment Thickness

Drill Core Location						Depth in Ft.	Thickness in Ft.
Section	Township	Range	XCOORD	YCOORD	IMCA Hole #	Lake Water	Muck Sediment
05	29	25	551615	1328145	0446	3.0	4.0
			551615	1330785	0462	2.5	3.5
			552935	1326825	1238	2.0	1.0
			552935	1329465	1254	3.0	1.0
			554255	1328145	2046	3.0	0.0
			555575	1326825	2838	2.0	0.0
06	29	25	548705	1328145	2046	5.0	0.0
			548705	1330785	2062	4.0	6.0
			550025	1326825	2838	5.0	0.0
			550025	1329465	2854	5.0	2.0
07	29	25	546165	1322875	0446	2.0	3.0
			547485	1321555	1238	5.0	0.0
			547485	1324195	1254	2.0	3.0
			548805	1322875	2046	4.0	3.5
			548805	1325515	2062	5.0	4.0
			550125	1321555	2838	3.0	3.0
			550125	1324195	2854	3.5	4.5
08	29	25	551635	1322895	0446	3.0	0.0
			551635	1325535	0462	2.5	5.5
			552955	1321575	1238	3.0	3.0
			552955	1324215	1254	2.0	5.5
			554275	1322895	2046	3.0	3.0
			554275	1325535	2062	2.5	4.5
			555595	1321575	2838	3.0	3.5
			555595	1324215	2854	4.0	0.0
09	29	25	557005	1322955	0446	4.0	0.0
			557005	1325595	0462	3.0	1.0
			558325	1321635	1238	3.0	0.0
16	29	25	556995	1317645	0446	2.0	1.0
			556995	1320285	0462	3.5	1.5
			558315	1318965	1254	3.0	2.0
17	29	25	551695	1317575	0446	2.5	2.0
			551695	1320215	0462	3.0	3.0
			553015	1316255	1238	1.5	1.0
			553015	1318895	1254	1.5	3.5
			554335	1317575	2046	2.5	3.5
			554335	1320215	2062	1.0	2.0
			555655	1316255	2838	3.0	1.0
			555655	1318895	2854	2.0	4.0
18	29	25	546265	1317545	0446	5.0	0.5
			546265	1320185	0462	2.5	1.0
			547585	1316225	1238	1.0	3.5
			547585	1318865	1254	2.0	3.0
			548905	1317545	2046	2.0	4.0
			548905	1320185	2062	2.0	2.5
			550225	1316225	2838	3.5	3.5
			550225	1318865	2854	1.5	2.0
19	29	25	548995	1314875	2062	4.0	0.0
20	29	25	551715	1314915	0462	4.0	4.0
			554355	1314915	2062	1.0	2.5
Average						2.9	2.3
Standard Deviation						1.11	1.70

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Lake Hancock Sediment Quality

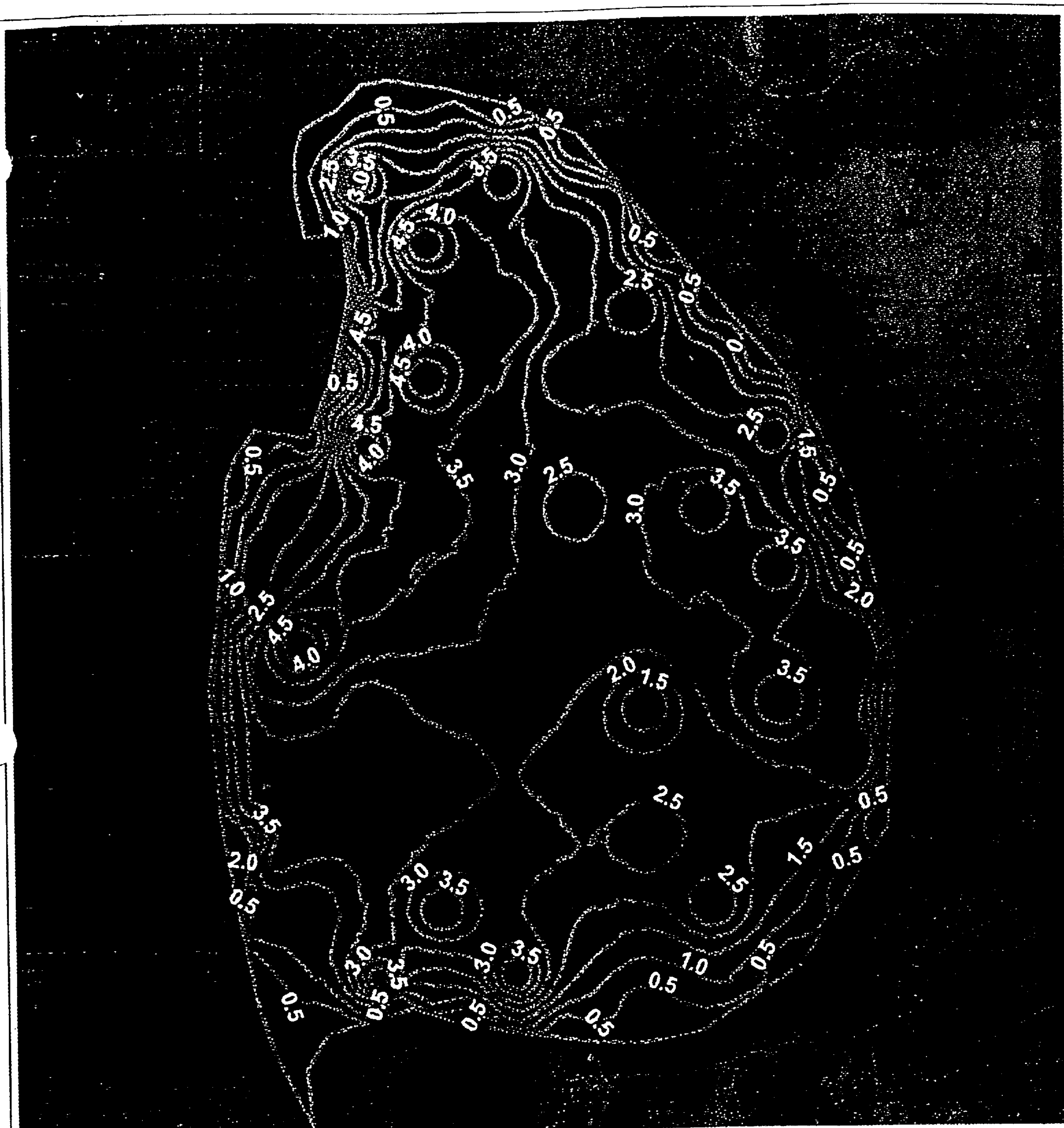
Nutrients and Metals

Hole	Section	Township	Range	Date	pH Std Units	Total Solids %	Organic Matter %	Total Phosphorus ppm	Ammonia ppm	NOX ppm	TKN ppm	Arsenic ppm
1254	6	29	25	6/17/98	8.94	41.86	11.45	0.58	325	20.55	1027	6.9
2854	7	29	25	6/17/98	9.06	55.41	8.41	0.82	368	21	787.6	3.9
2854	18	29	25	7/1/98	7.97	33.4	9.98	0.23	485	15	6000	6
1238	17	29	25	7/1/98	8.86	49.1	5.74	0.17	382	50	650	2
1238	25	29	25	6/23/98	7.90	34.5	14.5	0.46	433	35	1450	3
0446	8	29	25	6/23/98	9.19	42.9	11	0.6	570	35	1050	9
0446	16	29	25	6/25/98	9.20	49.7	4	0.21	126	30	850	* 1-U
2062	17	29	25	6/25/98	8.89	39.9	16.8	0.22	269	30	1350	1

Hole	Section	Township	Range	Date	Chromium ppm	Copper ppm	Iron %	Lead ppm	Nickel ppm	Zinc ppm	Cadmium ppm
1254	6	29	25	6/17/98	33.3	14.7	0.48	22	42.4	1.6	0.58
2854	7	29	25	6/17/98	33.2	15.4	0.82	9.7	29.3	9.6	0.38
2854	18	29	25	7/1/98	81	7	0.51	6	13	30	* 1-U
1238	17	29	25	7/1/98	31	13	0.86	11	12	45	* 1-U
1238	25	29	25	6/23/98	59	7	0.65	6	9	* 1-U	* 1-U
0446	8	29	25	6/23/98	27	12	0.91	10	12	* 1-U	* 1-U
0446	16	29	25	6/25/98	48	2	0.2	* 1-U	4	* 1-U	* 1-U
2062	17	29	25	6/25/98	69	3	0.37	2	5	* 1-U	* 1-U

* 1-U Indicates Under Detectable Limits

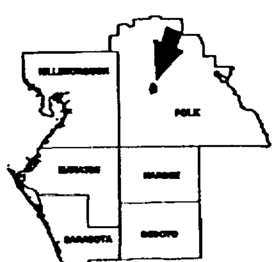
** Nutrient and metals results are on a dry weight basis.



Lake Hancock

North Clear Springs
Township 29S, Range 25E

Lake Water Depth Contour



N

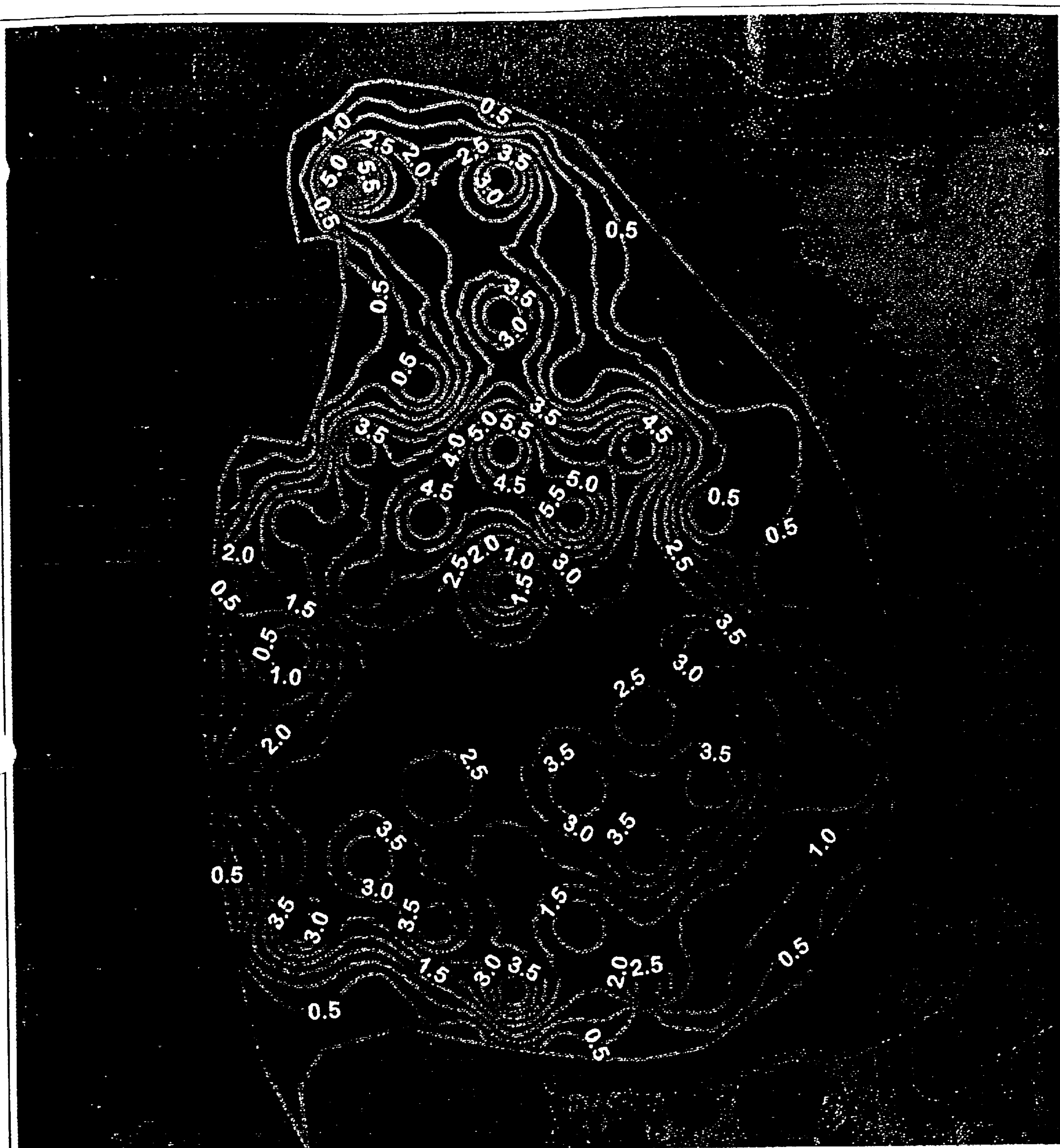
NTS

Location Key

● 1998 Prospect Hole Locations

IMC AGRICO

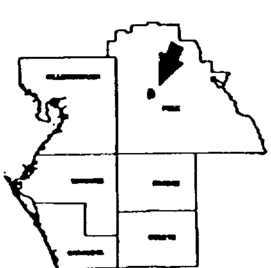
c:nor/hancock.apr - aet- 8/98



Lake Hancock

North Clear Springs
Township 29S, Range 25E

Lake Floor Muck Thickness Contour



N

NTS

Location Key

● 1998 Prospect Hole Locations

IMC AGRICO

c:nor/hancock.apr - set- 8/98

MONTHLY LAKE LEVEL MEANS
LAKE NAME: HANCOCK 0771
STATION ID # : 192 192

BASIN:
BEGINNING PERIOD OF RECORD: 11/1958
LAT/LON [S-T-R] : 275748.0/0815129.0 [18-29-25]

END OF RECORD:

YEARS/ MEAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN YEARLY	MIN YEARLY	MAX YEARLY	MEDIAN YEARLY
1958										96.85		97.03	96.94	96.85	97.03	96.94
1959	97.93		98.17	98.90	98.23		98.73	98.17	98.40	98.36	97.86	97.82	98.26	97.82	98.90	98.20
1960	97.99	98.30	98.34	98.70	97.88	98.00	98.45	99.49	100.21	98.98	97.59	97.31	98.44	97.31	100.21	98.32
1961	97.58	97.79	97.27	96.93	96.81	96.77	96.97	96.96	97.25	96.46	96.20	96.32	96.94	96.20	97.79	96.95
1962	96.78	96.90	96.86	96.95	96.66	96.94	96.97	97.19	97.34	97.03	96.89	96.81	96.94	96.66	97.34	96.92
1963	96.91	97.41	98.45	97.53	96.96	97.18	97.93	97.86	97.72	97.88	98.36	98.19	97.70	96.91	98.45	97.79
1964	98.50	98.57	97.74	97.48	97.29	96.48	96.52	97.49	98.81	97.63	96.89	97.04	97.54	96.48	98.81	97.49
1965	97.14	97.30	97.23	96.58	96.27	96.27	96.88	99.04	97.78	98.68	97.39	97.77	97.36	96.27	99.04	97.27
1966	98.70	98.15	97.87	97.97	98.09	98.18	98.48	98.17	98.22	98.60	98.48	97.87	98.23	97.87	98.70	98.18
1967	97.93	98.25	98.27	97.70	96.49	96.32	96.52	97.30	97.61	97.09	96.49	96.12	97.17	96.12	98.27	97.20
1968	95.92	95.84	95.86	95.28	94.45	96.75	99.14	99.06	98.92	98.46	98.77	98.70	97.26	94.45	99.14	97.61
1969	98.86	98.64	98.58	98.21	98.22	98.39	98.23	98.39	98.29	98.73	98.59	98.67	98.48	98.21	98.86	98.49
1970	98.72	98.34	98.89	98.57	97.79	97.87	97.65	97.81	98.20	97.73	97.77	97.85	98.10	97.65	98.89	97.86
1971	98.02	98.38	98.08	97.67	97.32	97.26	97.59	98.77	98.11	98.12	98.37	98.51	98.02	97.26	98.77	98.10
1972	98.40	98.69	98.36	98.23	97.96	97.89	97.47	97.41	97.94	98.01	97.96	98.37	98.06	97.41	98.69	97.99
1973	98.49	98.41	98.45	98.53	98.20	97.83	97.88	98.78	99.18	98.30	98.00	97.94	98.33	97.83	99.18	98.36
1974	98.06	98.03	97.84	97.54	97.09	97.04	98.50	98.88	98.16	97.64	97.29	97.12	97.77	97.04	98.88	97.74
1975	97.13	97.16	97.07	96.60	96.28	96.26	96.34	97.03	97.90	98.33	98.37	98.34	97.23	96.26	98.37	97.10
1976	98.27	98.12	97.91	97.48	97.39	97.81	97.80	97.58	97.49	97.37	96.94	97.03	97.60	96.94	98.27	97.54
1977	97.17	97.33	97.24	96.70	96.03	95.78	95.87	96.29	97.13	98.19	98.55	98.49	97.06	95.78	98.55	97.15
1978	98.24	98.22	98.02	97.34	97.24	97.40	97.72	98.45	97.96	97.71	97.58	97.48	97.78	97.24	98.45	97.72
1979	98.13	98.06	98.49	98.41	98.94	97.78	97.50	97.74	97.90	98.31	97.92	98.09	98.11	97.50	98.94	98.08
1980	98.45	98.33	98.30	97.99	97.54	97.13	96.97	96.95	97.42	97.31	97.26	97.61	97.61	96.95	98.45	97.48
1981	97.64	97.94	97.84	97.08	96.52	96.33	96.17	96.43	97.96	98.17	98.18	97.97	97.35	96.17	98.18	97.74
1982	97.90	98.07	98.29	97.77	96.75	97.69	97.99	97.89	98.24	98.33	98.33	98.24	97.96	96.75	98.33	98.03
1983	98.42	98.48	98.22	97.84	97.14	97.46	97.64	97.55	98.17	98.29	98.33	98.27	97.98	97.14	98.48	98.20
1984	97.93	97.89	97.87	97.83	97.69	97.20	97.08	97.70	97.79	97.65	97.46	97.49	97.63	97.08	97.93	97.70
1985	97.47	97.43	97.42	97.19	96.87	96.50	96.63	97.45	97.96	97.90	98.07	98.08	97.41	96.50	98.08	97.44
1986	98.38	98.27	98.28	97.94	97.52	97.41	97.92	97.91	98.42	98.15	98.19	98.31	98.06	97.41	98.42	98.17
1987	98.16	98.27	98.34	98.22	98.02	97.71	97.79	97.56	97.62	97.69	98.17	98.45	98.00	97.56	98.45	98.09
1988	98.31	98.25	98.23	97.97	97.43	97.46	97.74	98.29	98.86	98.17	98.24	98.10	98.09	97.43	98.86	98.20
1989	98.32	98.12	98.00	97.84	97.49	97.18	97.35	97.47	97.82	98.18	97.86	98.13	97.81	97.18	98.32	97.85
1990	98.24	98.24	98.18	98.00	97.79	97.36	97.59	98.12	97.98	97.74	97.48	97.28	97.83	97.28	98.24	97.89
1991	97.22	97.16	97.10	97.11	97.26	97.56	99.29	99.53	98.15	98.17	98.08	98.02	97.89	97.10	99.53	97.79
1992	97.83	97.76	97.88	97.77	97.45	97.50	98.11	98.53	98.40	98.32	98.14	98.16	97.99	97.45	98.53	98.00
1993	98.32	98.29	98.19	97.92	97.25	96.92	96.81	96.99	98.00	98.26	98.25	97.97	97.76	96.81	98.32	97.99
1994	98.16	98.22	98.16	97.65	96.88	97.36	97.76	97.78	98.34	98.37	98.60	98.43	97.98	96.88	98.60	98.16
1995	98.46	98.50	98.25	98.11	97.87	98.03	98.28	99.13	98.26	98.19	98.32	98.39	98.32	97.87	99.13	98.27
1996	98.27	98.27	98.15	97.98	98.67	98.50	98.57	98.76	98.29	98.19	98.04	98.22	98.33	97.98	98.76	98.27
1997	98.32	98.28	98.09	97.81	97.80	97.77	98.35		98.30	98.28	98.46	98.86	98.21	97.77	98.86	98.28
1998	98.70	98.59			97.80		97.20		97.89	98.53	98.00	97.92	98.08	97.20	98.70	97.96
1999	98.04	97.95	97.64	97.00		97.40	98.06	98.16	98.06	97.88		97.92	97.81	97.00	98.16	97.94

MONTHLY LAKE LEVEL MEANS
LAKE NAME: HANCOCK 0771
STATION ID #: 192 192

BASIN:
BEGINNING PERIOD OF RECORD: 11/1958
LAT/LON [S-T-R] : 275748.0/0815129.0 [18-29-25]

END OF RECORD:

YEARS/ MEAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN YEARLY	MIN YEARLY	MAX YEARLY	MEDIAN YEARLY
MEAN	97.99	98.00	97.94	97.66	97.33	97.30	97.62	97.95	98.11	98.01	97.89	97.87	97.80	97.04	98.57	97.82
NUM	41	40	40	40	40	39	41	39	41	42	40	42	42	42	42	42
MAX	98.86	98.69	98.89	98.90	98.94	98.50	99.29	99.53	100.21	98.98	98.77	98.86	98.48	98.21	100.21	98.49
MIN	95.92	95.84	95.86	95.28	94.45	95.78	95.87	96.29	97.13	96.46	96.20	96.12	96.94	94.45	97.03	96.92
PERIOD OF RECORD MEAN LEVEL :					97.81											
PERIOD OF RECORD MEDIAN LEVEL :					97.92											
PERIOD OF RECORD MAX MEAN LEVEL :					100.21											
PERIOD OF RECORD MIN MEAN LEVEL :					94.45											
SWFWMD SUMMARY																
MIN	95.86	95.74	95.66	94.86	93.98	94.86	95.72	95.98	96.62	96.24	96.18	96.02				
MAX	99.18	99.02	99.14	99.60	99.60	98.88	99.68	100.58	101.88	100.26	99.06	99.12				
DAILY MIN VALUE & YEAR			93.98	1968												
DAILY MAX VALUE & YEAR			101.88	1960												

NOTES:

ENTIRE DATABASE	JAN-FEB-MAR		APR-MAY-JUN		JUL-AUG-SEP		OCT-NOV-DEC
MEAN	97.98	MEAN	97.43	MEAN	97.89	MEAN	97.92
MAX	98.89	MAX	98.94	MAX	100.21	MAX	98.98
MIN	95.84	MIN	94.45	MIN	95.87	MIN	96.12
NUM	40	NUM	40	NUM	40	NUM	41

SiteID	Date Collected	Site Latitude	Site Longitude	Site Location	Sample Depth	Temperature	DO	pH	Conductance	Secchi Disk	Color	Turb	Nh3	TKN	NO2+3	TN	TP	Chyl a	TSI	TN/TP
Hancock1	07/31/84	275837.2	815026.4	Center Of Lake	0.50	34.3	9.9	9.00	309	0.3	45	4.3	0.040	3.460	0.030	3.490	0.650	63	77	5.4
Hancock1	08/29/84	275837.2	815026.4	Center Of Lake	0.75	27.6	7.6	9.60	271	0.2	57	39.0	0.040	5.760	0.030	5.790	1.010	208	94	5.7
Hancock1	09/26/84	275837.2	815026.4	Center Of Lake	0.90	24.5	5.1	9.40	285	0.1	48	93.0	0.040	8.240	0.050	8.290	1.650	280	98	5.0
Hancock1	10/24/84	275837.2	815026.4	Center Of Lake	0.70	26.8	11.8	9.90	334	0.2	27	86.0	0.060	10.020	0.020	10.040	1.180	235	95	8.5
Hancock1	05/23/85	275837.2	815026.4	Center Of Lake	0.55	26.5	9.7		456	0.1			0.200	15.600	0.027	15.630	2.870	331	100	5.4
Hancock1	02/18/88	275837.2	815026.4	Center Of Lake	0.80	16.0	9.2	8.90	316	0.6	58	9.2	0.030	2.284	0.010	2.280	0.154	35	68	14.8
Hancock1	03/16/88	275837.2	815026.4	Center Of Lake	0.80	15.6	8.0	7.38	351	0.8	70	13.1	0.025	1.472	0.033	1.510	0.424	34	67	3.6
Hancock1	08/18/88	275837.2	815026.4	Center Of Lake	1.00	28.6	4.7	9.15	287	0.2	48	60.0	0.027	6.436	0.010	6.440	0.704	297	99	9.1
Hancock1	04/10/89	275837.2	815026.4	Center Of Lake	0.80	23.6	10.9		319	0.2	60	53.0	0.025	6.535	0.010	6.530	0.576	210	94	11.3
Hancock1	10/11/89	275837.2	815026.4	Center Of Lake	0.80	27.0	8.4		275	0.2	60	27.0	0.025	4.480	0.010	4.480	0.423	66	77	10.6
Hancock1	05/23/90	275837.2	815026.4	Center Of Lake	0.00	25.2	6.5	9.12	315	0.2	37	46.0	0.029	6.827	0.006	6.830	0.429	176	91	15.9
Hancock1	10/04/90	275837.2	815026.4	Center Of Lake	1.30	27.4	3.2	7.84	289	0.2	48	53.0	0.031	9.725	0.000	9.730	0.879	196	93	11.1
Hancock1	04/08/91	275837.2	815026.4	Center Of Lake	0.60	27.1	10.0	9.51	313	0.1	45	104.0	0.033	12.550	0.000	12.550	0.548	240	96	22.9
Hancock1	10/03/91	275837.2	815026.4	Center Of Lake	0.80	25.1	6.8	9.66	223	0.1	45	51.0	0.057	9.871	0.003	9.870	0.534	350	101	18.5
Hancock1	04/09/92	275837.2	815026.4	Center Of Lake	0.50	23.1	10.6	9.59	294	0.2	45	92.0	0.030	11.218	0.001	11.220	0.944	311	99	11.9
Hancock1	10/07/92	275837.2	815026.4	Center Of Lake	0.70	24.2	2.5	9.03	232	0.3	75	28.0	0.018	4.064	0.006	4.070	0.366	132	87	11.1
Hancock1	03/31/93	275837.2	815026.4	Center Of Lake	0.70	25.4	0.9	9.62	261	0.1	55	100.0	0.052	12.022	0.004	12.030	0.712	173	91	16.9
Hancock1	10/07/93	275837.2	815026.4	Center Of Lake	0.70	24.2	7.1	8.26	267	0.3	70	25.0	0.016	2.033	0.005	2.040	0.198	66	77	10.3
Hancock1	12/06/93	275837.2	815026.4	Center Of Lake	0.70	18.3	11.7	9.51	305	0.3	55	28.0	0.028	4.007	0.014	4.020	0.170	88	81	23.6
Hancock1	12/20/93	275837.2	815026.4	Center Of Lake	0.70	15.8	12.5	9.29	337	0.3	55	32.0	0.013	4.291	0.012	4.300	0.201	67	77	21.4
Hancock1	04/12/94	275837.2	815026.4	Center Of Lake	0.60	24.5	9.3	9.70	299	0.1	45	70.0	0.020	4.868	0.000	4.870	0.468	205	93	10.4
Hancock1	10/05/94	275837.2	815026.4	Center Of Lake	0.90	26.8	8.6	8.35	176	0.3	100	17.7	0.023	1.707	0.007	1.710	0.355	79	80	4.8
Hancock1	04/05/95	275837.2	815026.4	Center Of Lake	0.80	22.2	11.5	10.11	219	0.1	75	43.0	0.000	3.126	0.006	3.130	0.420	159	90	7.5
Hancock1	11/08/95	275837.2	815026.4	Center Of Lake	0.80	23.1	7.3	9.03	186	0.2	100	26.0	0.000	2.556	0.004	2.560	0.487	162	90	5.3
Hancock1	05/08/96	275837.2	815026.4	Center Of Lake	0.80	27.1	7.9	9.03	237	0.1	75	5.2	0.175	4.988	0.000	4.990	0.509	187	92	9.8
Hancock1	11/13/96	275837.2	815026.4	Center Of Lake	0.80	17.8	11.3	9.36	328	0.1	75	37.0	0.027	4.413	0.003	4.420	0.415	130	87	10.7
Hancock1	05/07/97	275837.2	815026.4	Center Of Lake	0.10	26.7	15.7	10.13	254	0.1	40	29.0	0.007	4.629	0.004	4.630	0.426	152	89	10.9
Hancock1	10/30/97	275837.2	815026.4	Center Of Lake	0.70	22.0	10.9	8.75	211	0.3	50	17.3	0.014	1.984	0.000	1.980	0.105	71	78	18.9
Hancock1	05/07/98	275837.2	815026.4	Center Of Lake	0.80	28.5	11.6	9.84	170	0.3	60	24.0	0.002	1.891	0.001	1.890	0.535	87	81	3.5
Hancock1	11/09/98	275837.2	815026.4	Center Of Lake	0.60	20.7	11.9	8.19	238	0.2	100	44.0	0.000	5.153	0.000	5.150	0.487	238	96	10.6
Hancock1	05/11/99	275837.2	815026.4	Center Of Lake	0.50	23.8	4.4	9.30	237	0.1	35	74.0	0.035	9.779	0.019	9.800	0.745	288	98	13.2
Hancock1	11/09/99	275837.2	815026.4	Center Of Lake	0.49	19.5	9.1	9.60	207	0.2	50	51.0	0.067	5.484	0.005	5.489	0.529	129	87	10.4
Hancock2	07/31/84	275810.2	814908.4	Eastern Shore Of Lake	0.90	35.8	14.4	10.30	338	0.2	45	10.3	0.040	10.170	0.020	10.190	1.430	223	95	7.1
Hancock2	08/29/84	275810.2	814908.4	Eastern Shore Of Lake	1.20	26.8	10.6	9.80	285	0.2	52	26.0	0.030	4.760	0.020	4.780	0.960	191	92	5.0
Hancock2	09/26/84	275810.2	814908.4	Eastern Shore Of Lake	1.20	24.5	6.0	9.60	250	0.2	45	70.0	0.040	7.720	0.050	7.770	1.290	294	99	6.0
Hancock2	10/24/84	275810.2	814908.4	Eastern Shore Of Lake	1.00	25.6	11.2	9.90	320	0.2	24	41.0	0.060	8.040	0.020	8.060	0.790	174	91	10.2
Hancock2	05/23/85	275810.2	814908.4	Eastern Shore Of Lake	1.10	26.8			381	0.2			0.096	10.820	0.013	10.830	2.200	293	99	4.9
Hancock2	02/18/88	275810.2	814908.4	Eastern Shore Of Lake	1.10	15.9	14.9	9.23	316	0.7	58	10.5	0.030	2.655	0.010	2.660	0.195	49	73	13.6
Hancock2	03/16/88	275810.2	814908.4	Eastern Shore Of Lake	1.00	15.2	12.9	9.06	321	0.4	40	32.0	0.025	3.465	0.010	3.470	0.519	94	82	6.7
Hancock2	08/18/88	275810.2	814908.4	Eastern Shore Of Lake	0.90	29.2	4.7	9.12	306	0.2	55	42.0	0.035	6.946	0.010	6.950	0.788	236	95	8.8
Hancock2	04/10/89	275810.2	814908.4	Eastern Shore Of Lake	1.40	25.2	10.6		316	0.2	45	31.0	0.025	4.360	0.010	4.360	0.376	96	82	11.6
Hancock2	10/11/89	275810.2	814908.4	Eastern Shore Of Lake	1.30	26.6	9.7		273	0.3	60	24.0	0.025	5.030	0.010	5.030	0.462	74	79	10.9
Hancock2	05/23/90	275810.2	814908.4	Eastern Shore Of Lake	0.00	25.5	7.2	9.13	303	0.2	45	43.0	0.029	6.444	0.004	6.450	0.529	181	92	12.2
Hancock3	08/29/84	275705.4	815101.8	Southwestern Shore Of Lake	1.00	26.6	9.2	9.60	285	0.1	55	37.0	0.120	6.890	0.020	6.910	0.980	201	93	7.1
Hancock3	09/26/84	275705.4	815101.8	Southwestern Shore Of Lake	1.00	24.1	6.7	9.70	285	0.2	48	55.0	0.040	7.480	0.040	7.520	1.270	249	96	5.9
Hancock3	10/24/84	275705.4	815101.8	Southwestern Shore Of Lake	1.00		12.7	9.60		0.2	23	46.0	0.060	7.840	0.020	7.860	0.680	222	95	11.6
Hancock3	05/23/85	275705.4	815101.8	Southwestern Shore Of Lake	0.60	28.2			381	0.1			0.228	15.180	0.014	15.190	2.940	353	101	5.2
Hancock3	03/16/88	275705.4	815101.8	Southwestern Shore Of Lake	1.00	13.8	12.8	9.12	325	0.4	40	29.0	0.027	4.078	0.010	4.080	0.518	101	83	7.9
Hancock5	10/04/90	275947.4	815019.2	Northern Shore Of Lake	0.40	28.6	8.6	8.61	282	0.2	50	52.0	0.025	9.388	0.000	9.390	0.685	179	92	13.7
Hancock-Sad Crk	01/02/96											33.0								
Hancock-Sad Crk	01/02/96											64.0								
Hancock-Sad Crk	01/02/96											1070.0								

C

APPENDIX C

PHYSICAL-CHEMICAL FIELD PROFILES COLLECTED IN LAKE HANCOCK FROM OCTOBER 1998 TO JULY 1999

(Data Collected by ERD)

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON OCTOBER 9, 1998

DEPTH (m)	STATION 1 (15:47)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	29.94	9.18	196	125	10.1	133	634	25.4
0.5	29.93	9.18	195	125	9.9	130	633	26.0
1.0	29.66	8.92	191	122	7.0	92	602	100
1.3	29.03	7.32	402	257	2.9	38	539	> 1000
	SECCHI DISK DEPTH: 0.33 m							

DEPTH (m)	STATION 2 (16:03)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	30.05	9.30	195	125	11.7	155	613	35.2
0.5	30.07	9.36	197	126	11.9	157	614	31.1
1.0	30.07	9.34	196	125	10.0	133	617	48.3
1.3	28.94	7.01	344	220	4.9	64	323	> 1000
	SECCHI DISK DEPTH: 0.30 m							

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON OCTOBER 9, 1998
(Page 2)

DEPTH (m)	STATION 3 (16:53)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	29.90	9.18	196	125	10.4	138	617	17.1
0.5	29.93	9.24	196	125	10.4	138	619	18.3
1.0	29.05	8.09	230	147	2.8	37	545	679
	SECCHI DISK DEPTH: 0.38 m							

DEPTH (m)	STATION 4 (16:37)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	30.40	9.30	204	130	12.4	165	614	23.8
0.5	30.42	9.31	201	129	12.4	165	615	27.5
1.0	30.14	9.33	201	129	11.0	147	614	119
	SECCHI DISK DEPTH: 0.31 m							

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON NOVEMBER 3, 1998

DEPTH (m)	STATION 1 (16:24)							
	TEMP. (°C)	pH	SPEC. COND. (µS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	24.29	10.02	203	130	12.3	148	692	92.0
0.5	24.30	10.05	200	128	12.3	147	690	86.4
1.0	24.44	7.28	300	192	0.3	3	573	> 800
	SECCHI DISK DEPTH: 0.18 m							

DEPTH (m)	STATION 2 (16:49)							
	TEMP. (°C)	pH	SPEC. COND. (µS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	24.86	10.27	212	135	14.6	177	677	65.1
0.5	24.86	10.29	212	136	14.6	176	675	61.7
1.0	24.71	6.77	427	273	0.3	4	508	> 800
	SECCHI DISK DEPTH: 0.20 m							

DEPTH (m)	STATION 3 (17:32)							
	TEMP. (°C)	pH	SPEC. COND. (µS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	25.02	10.10	206	132	14.1	171	658	47.8
0.5	25.05	10.10	207	132	14.2	172	657	45.8
1.0	25.05	6.99	285	182	0.2	3	334	> 800
	SECCHI DISK DEPTH: 0.18 m							

DEPTH (m)	STATION 4 (17:12)							
	TEMP. (°C)	pH	SPEC. COND. (µS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	25.04	9.72	195	125	10.9	132	627	50.6
0.5	25.04	9.79	194	124	10.7	129	626	51.8
1.0	25.35	7.28	393	251	0.2	2	413	> 800
	SECCHI DISK DEPTH: 0.24 m							

WEATHER CONDITIONS: Cloudy, 84°F

HANCOCK\PC-PROF.N03

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON DECEMBER 10, 1998

DEPTH (m)	STATION 1 (15:05)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	24.31	10.27	215	138	13.8	165	689	51.9
0.5	24.31	10.30	216	138	13.8	165	685	62.6
0.9	23.52	8.94	508	325	0.4	5	542	286
	SECCHI DISK DEPTH: 0.19 m							

DEPTH (m)	STATION 2 (15:26)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	23.92	10.22	208	133	13.0	154	659	75.8
0.5	23.93	10.27	210	135	13.2	156	658	71.2
0.9	23.89	8.45	229	146	5.0	60	505	582
	SECCHI DISK DEPTH: 0.14 m							

DEPTH (m)	STATION 3 (15:52)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	24.00	10.26	209	134	12.2	145	667	50.5
0.5	24.01	10.28	210	134	12.1	144	665	44.7
0.9	24.00	10.25	208	133	11.6	138	619	123
	SECCHI DISK DEPTH: 0.18 m							

DEPTH (m)	STATION 4 (16:09)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	24.36	10.47	225	144	14.9	179	653	70.1
0.5	24.38	10.45	224	143	14.8	177	653	60.8
0.7	23.90	9.28	425	272	1.0	12	543	638
	SECCHI DISK DEPTH: 0.18 m							

WEATHER CONDITION: Mostly cloudy, wind at 10-15 mph, 80°F

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON JANUARY 19, 1999

DEPTH (m)	STATION 1 (15:51)				
	TEMP. (°C)	pH	D.O. (mg/l)	SPEC. COND. (μS/cm)	ORP (mV)
0.1	24.88	10.49	18.1	227	618
0.5	22.47	10.32	13.1	206	615
1.0	21.72	10.00	10.3	195	607
	SECCHI DISK DEPTH: 0.23 m				

DEPTH (m)	STATION 2 (16:10)				
	TEMP. (°C)	pH	D.O. (mg/l)	SPEC. COND. (μS/cm)	ORP (mV)
0.1	24.10	10.56	17.7	230	579
0.5	22.33	10.42	14.4	214	584
0.9	21.67	10.12	0.6	266	572
	SECCHI DISK DEPTH: 0.21 m				

DEPTH (m)	STATION 3 (16:40)				
	TEMP. (°C)	pH	D.O. (mg/l)	SPEC. COND. (μS/cm)	ORP (mV)
0.1	25.15	10.52	17.7	230	562
0.5	22.64	10.29	13.1	210	571
0.9	21.82	10.00	8.3	211	563
	SECCHI DISK DEPTH: 0.21 m				

DEPTH (m)	STATION 4 (16:25)				
	TEMP. (°C)	pH	D.O. (mg/l)	SPEC. COND. (μS/cm)	ORP (mV)
0.1	25.71	10.54	17.3	235	562
0.5	22.33	10.46	14.9	219	574
0.9	21.82	8.51	10.0	223	471
	SECCHI DISK DEPTH: 0.24 m				

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON FEBRUARY 27, 1999

DEPTH (m)	STATION 1 (13:22)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	20.62	10.60	201	129	17.6	196	708	67.3
0.5	20.55	10.69	201	129	17.2	192	703	62.8
1.0	18.38	9.44	223	143	10.2	108	574	32.1
	SECCHI DISK DEPTH: 0.35 m							

DEPTH (m)	STATION 2 (13:38)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	19.90	10.51	200	128	18.0	198	696	64.0
0.5	18.72	10.53	193	124	16.1	172	686	44.8
1.0	17.34	6.58	473	303	2.1	22	462	> 1000
	SECCHI DISK DEPTH: 0.27 m							

DEPTH (m)	STATION 3 (14:15)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.2	20.33	10.31	190	121	15.4	170	634	38.2
0.5	20.30	10.36	190	122	15.4	170	634	37.9
0.7	18.63	6.83	216	138	2.7	29	442	> 1000
	SECCHI DISK DEPTH: 0.24 m							

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON FEBRUARY 27, 1999
(Page 2)

DEPTH (m)	STATION 4 (14:02)							
	TEMP. (°C)	pH	SPEC. COND. (µS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	19.39	10.62	198	127	16.7	182	681	61.5
0.5	19.13	10.57	197	126	16.5	179	672	46.4
0.8	17.79	6.57	429	275	3.5	37	385	> 1000
	SECCHI DISK DEPTH: 0.22 m							

DEPTH (m)	STATION P11 (12:21)							
	TEMP. (°C)	pH	SPEC. COND. (µS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	18.82	9.71	171	110	12.9	138	691	42.6
0.5	18.33	9.72	169	108	12.0	128	683	28.3
0.9	17.80	9.58	169	108	11.1	117	678	36.8
	SECCHI DISK DEPTH: 0.29 m							

WEATHER CONDITIONS: Sunny, 75°F

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON MARCH 26, 1999

DEPTH (m)	STATION 1 (15:44)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	23.97	10.91	221	142	14.2	168	680	56.8
0.5	23.96	10.93	222	142	14.0	167	678	57.0
0.8	22.89	6.85	265	170	0.3	3	327	> 800
	SECCHI DISK DEPTH: 0.18 m							

DEPTH (m)	STATION 2 (16:11)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	23.53	10.55	195	125	12.6	149	641	79.4
0.5	23.54	10.58	196	125	12.6	149	632	81.8
0.9	22.28	6.89	343	219	1.6	18	441	> 800
	SECCHI DISK DEPTH: 0.15 m							

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON MARCH 26, 1999
(Page 2)

DEPTH (m)	STATION 3 (16:55)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	24.55	10.81	214	137	13.9	167	611	150
0.5	23.55	7.03	251	161	0.3	3	402	> 800
0.6	22.36	6.97	322	206	0.2	2	323	> 800
	SECCHI DISK DEPTH: 0.09 m							

DEPTH (m)	STATION 4 (16:35)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	23.96	10.91	222	142	13.6	162	644	62.3
0.5	23.95	10.89	216	138	12.8	152	607	130
0.8	22.93	6.84	352	225	0.6	7	396	> 800
	SECCHI DISK DEPTH: 0.14 m							

DEPTH (m)	STATION P11 (14:21)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	23.05	10.14	178	114	12.7	149	684	52.2
0.5	22.09	9.87	178	114	9.6	110	668	59.6
0.8	21.74	9.69	176	113	7.9	90	659	67.1
	SECCHI DISK DEPTH: 0.17 m							

WEATHER CONDITIONS: Mostly sunny, windy (strong winds occasionally), 80°F

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON MAY 11, 1999

DEPTH (m)	STATION 1 (19:23)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	29.00	10.22	268	172	> 20	> 200	639	47.8
0.5	27.59	9.93	236	151	10.9	138	618	245
0.8	24.97	6.82	497	318	1.2	14	507	> 800
	SECCHI DISK DEPTH: 0.18 m							

DEPTH (m)	STATION 2 (19:06)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	30.85	10.38	296	189	> 20	> 200	651	29.0
0.5	24.96	8.36	272	174	0.6	7	541	> 800
0.8	24.71	6.55	480	307	0.4	5	290	> 800
	SECCHI DISK DEPTH: 0.20 m							

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON MAY 11, 1999
(Page 2)

DEPTH (m)	STATION 3 (17:42)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	33.13	10.59	285	182	> 20	> 200	698	60.4
0.5	27.62	6.73	446	285	1.7	22	558	> 800
	SECCHI DISK DEPTH: 0.25 m							

DEPTH (m)	STATION 4 (18:45)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	33.09	10.29	290	186	> 20	> 200	665	22.1
0.6	25.82	6.48	494	316	2.2	27	481	> 800
	SECCHI DISK DEPTH: 0.24 m							

DEPTH (m)	STATION P-11 (18:07)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	31.16	9.87	231	148	> 20	> 200	655	26.6
0.5	28.88	9.65	217	139	13.9	180	674	39.7
0.8	26.97	9.23	210	134	10.7	134	663	77.6
	SECCHI DISK DEPTH: 0.23 m							

WEATHER CONDITIONS: Partly cloudy, calm, 85°F

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON JUNE 10, 1999

DEPTH (m)	STATION 1 (16:03)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	35.24	9.90	261	167	> 20	> 100	701	26.6
0.5	26.61	7.56	271	174	5.0	62	325	> 1000
0.7	26.37	6.63	408	261	2.5	31	235	> 1000
	SECCHI DISK DEPTH: 0.21 m							

DEPTH (m)	STATION 2 (16:23)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	34.60	9.94	263	168	> 20	> 100	621	40.2
0.5	26.71	8.46	282	180	5.2	65	560	936
0.7	26.35	6.48	433	277	0.7	9	242	> 1000
	SECCHI DISK DEPTH: 0.22 m							

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON JUNE 10, 1999
(Page 2)

DEPTH (m)	STATION 3 (17:12)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	30.02	9.83	249	160	14.6	194	617	72.0
0.6	26.83	6.47	477	305	0.4	5	438	> 1000
	SECCHI DISK DEPTH: 0.18 m							

DEPTH (m)	STATION 4 (16:53)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	33.24	10.11	290	186	> 20	> 100	626	52.6
0.5	27.30	6.68	496	317	1.1	14	234	> 1000
	SECCHI DISK DEPTH: 0.18 m							

DEPTH (m)	STATION P-11 (14:53)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	28.41	9.34	224	143	10.3	133	735	55.4
0.5	27.68	9.23	220	141	9.7	123	730	57.5
0.6	27.18	8.94	220	141	7.8	99	694	43.8
	SECCHI DISK DEPTH: 0.23 m							

WEATHER CONDITIONS: Mostly cloudy, 88°F

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON JULY 1, 1999

DEPTH (m)	STATION 1 (17:03)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	29.25	9.54	181	116	10.6	138	660	85.8
0.5	29.22	9.46	183	117	10.6	139	657	84.0
1.1	27.84	6.27	405	259	0.3	4	312	> 1000
	SECCHI DISK DEPTH: 0.13 m							

DEPTH (m)	STATION 2 (17:24)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN		ORP (mV)	TURBIDITY (NTU)
					(mg/l)	(% Sat.)		
0.1	29.13	9.30	179	115	10.5	137	618	80.8
0.5	29.15	9.28	179	115	10.3	135	618	77.9
1.0	28.22	6.36	397	254	0.2	3	470	> 1000
1.1	28.07	6.38	419	268	0.1	2	461	> 1000
	SECCHI DISK DEPTH: 0.12 m							

PHYSICAL-CHEMICAL PROFILES COLLECTED IN LAKE HANCOCK ON JULY 1, 1999
(Page 2)

DEPTH (m)	STATION 3 (17:39)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	28.17	9.21	172	110	7.2	92	613	74.9
0.5	28.19	9.16	174	112	7.0	90	609	86.3
1.0	28.02	6.30	281	180	0.1	2	361	> 1000
	SECCHI DISK DEPTH: 0.13 m							

DEPTH (m)	STATION 4 (16:06)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	29.95	9.50	186	119	14.0	186	670	54.4
0.5	29.98	9.48	187	120	14.4	190	666	57.5
0.9	28.41	6.36	402	257	0.2	3	405	> 1000
	SECCHI DISK DEPTH: 0.15 m							

DEPTH (m)	STATION P-11 (15:38)							
	TEMP. (°C)	pH	SPEC. COND. (μS/cm)	TDS (mg/l)	DISS. OXYGEN (mg/l)	DISS. OXYGEN (% Sat.)	ORP (mV)	TURBIDITY (NTU)
0.1	28.43	8.04	128	82	8.1	104	627	52.3
0.5	28.40	7.95	126	81	8.2	106	628	47.2
0.9	27.79	7.16	126	80	5.3	68	587	54.8
	SECCHI DISK DEPTH: 0.26 m							

WEATHER CONDITIONS: Overcast, breezy; 87°F

D

APPENDIX D

CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK FROM OCTOBER 1998 TO JULY 1999

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON OCTOBER 9, 1998

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH (field)[1]	s.u.	9.18	9.36	9.24	9.31
Spec. Cond. (field)[1]	µmho/cm	195	197	196	201
Temperature[1]	°C	29.93	30.07	29.93	30.42
Dissolved Oxygen[1]	mg/l	9.9	11.9	10.4	12.4
ORP[1]	mv	633	614	619	615
Secchi Disk Depth	m	0.33	0.30	0.38	0.31
Alkalinity	mg/l	30.7	28.0	26.1	23.8
NH_3-N	µg/l	< 10	< 10	< 10	< 10
NO_2 + NO_3-N	µg/l	17	9	< 8	13
Diss. Organic N	µg/l	2674	2169	1522	2053
Particulate N	µg/l	842	1308	1310	1202
Total N	µg/l	3538	3491	2841	3273
Diss. Ortho-P	µg/l	16	10	14	5
Particulate P	µg/l	298	294	197	256
Total P	µg/l	436	435	341	421
Turbidity	NTU	26.0	31.1	18.3	27.5
T.S.S.	mg/l	47.0	59.0	34.0	44.0
BOD	mg/l	8.0	8.9	5.9	7.3
Color	Pt-Co	92	91	89	94
Chlorophyll-a[1]	mg/m^3	81.3	86.6	63.0	66.4

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON NOVEMBER 3, 1998

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH (field)[1]	s.u.	10.05	10.29	10.10	9.79
Spec. Cond. (field)[1]	μmho/cm	200	212	207	194
Temperature[1]	°C	24.30	24.86	25.05	25.04
Dissolved Oxygen[1]	mg/l	12.3	14.6	14.2	10.7
ORP[1]	mv	690	675	657	626
Secchi Disk Depth	m	0.18	0.20	0.18	0.24
Alkalinity	mg/l	36.2	27.0	29.2	20.7
NH_3-N	μg/l	70	54	30	43
$NO_2 + NO_3$-N	μg/l	44	13	16	64
Diss. Organic N	μg/l	1023	1048	1048	1152
Particulate N	μg/l	5287	4600	3281	3092
Total N	μg/l	6424	5715	4375	4351
Diss. Ortho-P	μg/l	16	10	14	5
Particulate P	μg/l	656	532	410	363
Total P	μg/l	684	557	437	391
Turbidity	NTU	86.4	61.7	45.8	51.8
T.S.S.	mg/l	160	109	68.2	62.0
BOD	mg/l	16.6	13.0	9.9	10.6
Color	Pt-Co	45	42	45	45
Chlorophyll-a[1]	mg/m³	425	336	249	237

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON DECEMBER 10, 1998

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH (field)[1]	s.u.	10.30	10.27	10.28	10.45
Spec. Cond. (field)[1]	μmho/cm	216	210	210	224
Temperature[1]	°C	24.31	23.93	24.01	24.38
Dissolved Oxygen[1]	mg/l	13.8	13.2	12.1	14.8
ORP[1]	mv	685	658	665	653
Secchi Disk Depth	m	0.19	0.14	0.18	0.18
Alkalinity	mg/l	47.4	56.2	28.1	19.0
NH_3-N	μg/l	24	< 10	< 10	< 10
$NO_2 + NO_3$-N	μg/l	20	< 8	< 8	< 8
Diss. Organic N	μg/l	1447	1642	1577	1497
Particulate N	μg/l	4762	10,285	5353	4465
Total N	μg/l	6253	11,936	6939	5971
Diss. Ortho-P	μg/l	8	13	4	2
Particulate P	μg/l	426	1262	512	393
Total P	μg/l	456	1291	540	419
Turbidity	NTU	62.6	71.2	44.7	60.8
T.S.S.	mg/l	91.4	313	120	88.0
BOD	mg/l	14.8	23.1	15.9	12.7
Color	Pt-Co	35	37	34	38
Chlorophyll-a[1]	mg/m^3	283	333	343	238

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON JANUARY 19, 1999

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH (field)[1]	s.u.	10.32	10.42	10.29	10.46
Spec. Cond. (field)[1]	μmho/cm	206	214	210	219
Temperature[1]	°C	22.47	22.33	22.64	22.33
Dissolved Oxygen[1]	mg/l	13.1	14.4	13.1	14.9
ORP[1]	mv	615	584	571	574
Secchi Disk Depth	m	0.23	0.21	0.21	0.24
Alkalinity	mg/l	37.3	30.9	27.2	27.6
NH_3-N	μg/l	16	43	< 10	19
NO_2 + NO_3-N	μg/l	14	58	35	51
Diss. Organic N	μg/l	1234	1344	1217	1158
Particulate N	μg/l	2193	2431	1485	1499
Total N	μg/l	3457	3876	2742	2727
Diss. Ortho-P	μg/l	6	3	4	3
Particulate P	μg/l	247	197	144	139
Total P	μg/l	279	224	173	168
Turbidity	NTU	61.3	60.4	46.4	41.0
T.S.S.	mg/l	49.0	46.0	35.0	27.0
BOD	mg/l	11.9	10.5	6.1	5.1
Color	Pt-Co	35	37	38	36
Chlorophyll-a[1]	mg/m^3	157	151	114	102

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON FEBRUARY 27, 1999

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH (field)[1]	s.u.	10.69	10.53	10.36	10.57
Spec. Cond. (field)[1]	µmho/cm	201	193	190	197
Temperature[1]	°C	20.55	18.72	20.30	19.13
Dissolved Oxygen[1]	mg/l	17.2	16.1	15.4	16.5
ORP[1]	mv	703	686	634	672
Secchi Disk Depth	m	0.35	0.27	0.24	0.22
Alkalinity	mg/l	66.1	65.5	67.8	64.6
NH_3-N	µg/l	15	20	< 10	385
NO_2 + NO_3-N	µg/l	11	15	< 8	13
Diss. Organic N	µg/l	1282	1056	1328	1298
Particulate N	µg/l	2263	3772	3452	3520
Total N	µg/l	3571	4863	4789	5216
Diss. Ortho-P	µg/l	17	9	2	68
Particulate P	µg/l	217	409	398	362
Total P	µg/l	258	436	424	464
Turbidity	NTU	62.8	64.0	37.9	46.4
T.S.S.	mg/l	56.0	92.0	92.0	106
BOD	mg/l	14.2	21.4	17.6	21.8
Color	Pt-Co	36	38	35	38
Chlorophyll-a[1]	mg/m^3	77.4	200	159	127

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON MARCH 26, 1999

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH (field)[1]	s.u.	10.93	10.58	7.03	10.89
Spec. Cond. (field)[1]	μmho/cm	222	196	251	216
Temperature[1]	°C	23.96	23.54	23.55	23.95
Dissolved Oxygen[1]	mg/l	14.0	12.6	0.3	12.8
ORP[1]	mv	678	632	402	607
Secchi Disk Depth	m	0.18	0.15	0.09	0.14
Alkalinity	mg/l	71.1	71.4	69.5	70.9
NH_3-N	μg/l	< 5	< 5	25	8
$NO_2 + NO_3$-N	μg/l	< 5	< 5	9	6
Diss. Organic N	μg/l	1163	1420	2094	2012
Particulate N	μg/l	5409	6062	6575	4987
Total N	μg/l	6577	7487	8703	7013
Diss. Ortho-P	μg/l	17	18	15	17
Particulate P	μg/l	506	665	809	538
Total P	μg/l	528	696	868	573
Turbidity	NTU	57.0	81.8	> 800	130
T.S.S.	mg/l	118	176	226	143
BOD	mg/l	17.4	16.7	19.0	19.6
Color	Pt-Co	45	45	42	45
Chlorophyll-a[1]	mg/m^3	139	103	142	170

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON MAY 11, 1999

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4	P-11
pH (field)[1]	s.u.	9.93	8.36	6.73	6.48	9.65
Spec. Cond. (field)[1]	μmho/cm	236	272	446	494	217
Temperature[1]	°C	27.59	24.96	27.62	25.82	28.88
Dissolved Oxygen[1]	mg/l	10.9	0.6	1.7	2.2	13.9
ORP[1]	mv	618	541	558	481	674
Secchi Disk Depth	m	0.18	0.20	0.25	0.24	0.23
Alkalinity	mg/l	89.3	61.2	61.3	78.7	77.3
NH_3-N	μg/l	11	11	14	11	8
NO_2 + NO_3-N	μg/l	< 5	< 5	19	< 5	< 5
Diss. Organic N	μg/l	2193	2256	2224	2266	1953
Particulate N	μg/l	4679	3398	2871	2059	2136
Total N	μg/l	6886	5668	5128	4339	4100
Diss. Ortho-P	μg/l	< 1	< 1	10	< 1	< 1
Particulate P	μg/l	394	300	202	193	292
Total P	μg/l	413	320	222	212	310
Turbidity[1]	NTU	245	> 800	> 800	> 800	39.7
T.S.S.	mg/l	110	82.9	68.6	46.0	54.0
BOD	mg/l	25.1	23.6	20.3	20.2	22.7
Color	Pt-Co	50	50	53	50	62
Chlorophyll-a[1]	mg/m³	170	156	99.9	98.5	39.4

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON JUNE 10, 1999

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4	P-11
pH (field)[1]	s.u.	7.56	8.46	6.47	6.68	9.23
Spec. Cond. (field)[1]	μmho/cm	271	282	477	496	220
Temperature[1]	°C	26.61	26.71	26.83	27.30	27.68
Dissolved Oxygen[1]	mg/l	5.0	5.2	0.4	1.1	9.7
ORP[1]	mv	325	560	438	234	730
Secchi Disk Depth	m	0.21	0.22	0.18	0.18	0.23
Alkalinity	mg/l	67.3	68.6	68.4	67.0	63.8
NH_3-N	μg/l	27	26	13	33	< 5
$NO_2 + NO_3$-N	μg/l	302	< 5	< 5	< 5	16
Diss. Organic N	μg/l	1591	1944	2011	2025	1973
Particulate N	μg/l	4937	5811	7029	7290	3329
Total N	μg/l	6857	7784	9056	9351	5321
Diss. Ortho-P	μg/l	27	8	5	7	9
Particulate P	μg/l	395	465	641	700	644
Total P	μg/l	422	489	667	725	668
Turbidity[1]	NTU	> 1000	936	> 1000	> 1000	57.5
T.S.S.	mg/l	132	156	188	212	96.0
BOD	mg/l	26.5	29.3	32.3	34.0	24.3
Color	Pt-Co	65	65	62	65	73
Chlorophyll-a[1]	mg/m^3	259	236	257	283	170

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LAKE HANCOCK ON JULY 1, 1999

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH (field)[1]	s.u.	9.46	9.28	9.16	9.48
Spec. Cond. (field)[1]	μmho/cm	183	179	174	187
Temperature[1]	°C	29.22	29.15	28.19	29.98
Dissolved Oxygen[1]	mg/l	10.6	10.3	7.0	14.4
ORP[1]	mv	657	618	609	666
Secchi Disk Depth	m	0.13	0.12	0.13	0.15
Alkalinity	mg/l	52.5	52.5	52.3	53.4
NH_3-N	μg/l	14	14	< 5	< 5
$NO_2 + NO_3$-N	μg/l	206	< 5	< 5	< 5
Diss. Organic N	μg/l	1322	2184	1762	1558
Particulate N	μg/l	7893	6468	6480	5575
Total N	μg/l	9435	8669	8247	7138
Diss. Ortho-P	μg/l	22	6	5	7
Particulate P	μg/l	810	736	802	575
Total P	μg/l	865	775	834	595
Turbidity	NTU	84.0	77.9	86.3	57.5
T.S.S.	mg/l	276	200	188	168
BOD	mg/l	26.9	25.2	29.3	22.3
Color	Pt-Co	52	52	45	60
Chlorophyll-a[1]	mg/m^3	373	402	405	360

1. Measured at a depth of 0.5 m

PHYSICAL-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED AT STRUCTURE P-11 AT LAKE HANCOCK FROM FEBRUARY-JULY 1999

PARAMETER	UNITS	DATE COLLECTED								
		2/27/99	3/17/99	3/26/99	4/2/99	4/16/99	4/30/99	5/11/99	6/10/99	7/1/99
pH (field)[1]	s.u.	9.72	8.13	9.87	8.05	9.60	9.66	9.65	9.23	7.95
Spec. Cond. (field)[1]	μmho/cm	169	231	178	234	249	246	217	220	126
Temperature[1]	°C	18.33	--	22.09	--	--	--	28.88	27.68	28.40
Dissolved Oxygen[1]	mg/l	12.0	--	9.6	--	--	--	13.9	9.7	8.2
ORP[1]	mv	683	--	668	--	--	--	674	730	628
Secchi Disk Depth	m	0.29	--	0.17	--	--	--	0.23	0.23	0.26
Alkalinity	mg/l	66.3	65.5	67.1	65.7	105	82.4	61.4	63.8	37.7
NH_3-N	μg/l	< 10	56	58	45	324	13	90	< 5	16
$NO_2 + NO_3$-N	μg/l	56	< 5	< 5	< 5	< 5	< 5	< 5	16	15
Diss. Organic N	μg/l	1386	1319	1563	1570	2219	2235	1150	1973	895
Particulate N	μg/l	2321	2536	3563	2563	6346	6055	2312	3329	2165
Total N	μg/l	3768	3914	5187	4175	8892	8306	3555	5321	3091
Diss. Ortho-P	μg/l	10	7	8	3	3	8	< 1	9	61
Particulate P	μg/l	348	288	466	262	630	561	218	644	529
Total P	μg/l	384	306	507	307	643	582	239	688	594
Turbidity	NTU	28.3	27.4	59.6	29.6	51.9	49.2	39.7	57.5	47.2
T.S.S.	mg/l	62.0	48.0	86.0	52.9	85.1	76.4	54.0	96.0	64.0
BOD	mg/l	14.7	12.6	13.3	12.2	14.7	12.1	22.7	24.3	15.4
Color	Pt-Co	48	61	53	68	120	61	62	73	71
Chlorophyll-a[1]	mg/m³	116	108	110	121	146	197	39.4	170	71

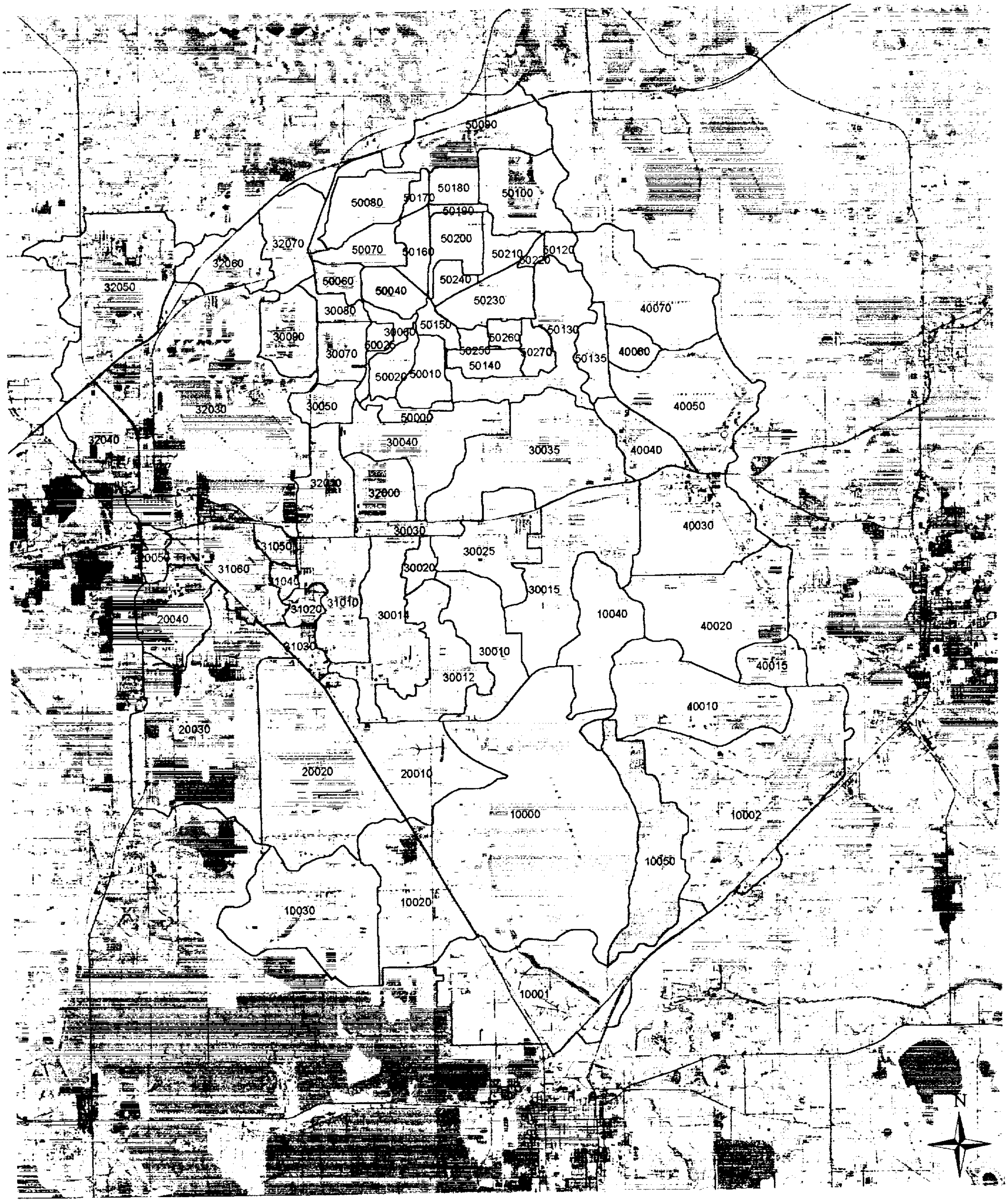
1. Measured at a depth of 0.5 m

E

APPENDIX E

DELINEATED SUB-BASIN AREAS TRIBUTARY TO LAKE HANCOCK

(SOURCE: Ardaman & Associates)



Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

Lake Hancock Water Quality Improvement Project

Watershed Map

Not to Scale

February 15, 2000

F

G

APPENDIX G

MANUAL FIELD DISCHARGE MEASUREMENTS PERFORMED IN BANANA CREEK, LAKE LENA RUN, AND SADDLE CREEK

BANANA CREEK STREAM FLOW MEASUREMENTS FROM 12/29/98

OBSERVER(S): H. Harper
METHOD: Velocity/Cross-Section

METER: Model 201
WEATHER COND: Sunny

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.00	0.00	——	——	——
4.0	0.80	0.00	0.000	1.60	0.000
6.0	1.20	0.00	0.000	2.00	0.000
8.0	1.60	0.03	0.015	2.80	0.042
10.0	1.60	0.00	0.015	3.20	0.048
12.0	1.70	0.00	0.000	3.30	0.000
14.0	1.80	0.07	0.035	3.50	0.123
16.0	1.90	0.12	0.095	3.70	0.352
18.0	2.00	0.23	0.175	3.90	0.683
20.0	1.00	0.50	0.365	3.00	1.095
22.0	0.90	0.46	0.480	1.90	0.912
24.0	0.90	0.29	0.375	1.80	0.675
26.0	0.20	0.00	0.145	1.10	0.160
28.0	0.00	0.00	0.000	0.20	0.000
			TOTALS:	32.00	4.09

BANANA CREEK STREAM FLOW MEASUREMENTS FROM 1/20/99

OBSERVER(S): H. Harper
METHOD: Velocity/Cross-Section

METER: Model 201
WEATHER COND: Sunny

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.00	0.00	——	——	——
2.0	0.30	0.00	0.000	0.30	0.000
4.0	0.75	0.00	0.000	1.05	0.000
6.0	1.20	0.00	0.000	1.95	0.000
8.0	1.25	0.00	0.000	2.45	0.000
10.0	1.50	0.00	0.000	2.75	0.000
12.0	1.70	0.00	0.000	3.20	0.000
14.0	1.30	0.07	0.035	3.00	0.105
16.0	1.90	0.20	0.135	3.20	0.432
18.0	2.00	0.40	0.300	3.90	1.170
20.0	2.10	0.63	0.515	4.10	2.112
22.0	1.80	0.52	0.575	3.90	2.243
24.0	1.20	0.25	0.385	3.00	1.155
26.0	0.65	0.00	0.260	4.90	1.274
28.0	0.00	0.00	0.000	0.65	0.000
			TOTALS:	38.35	8.49

BANANA CREEK STREAM FLOW MEASUREMENTS FROM 2/10/99

OBSERVER(S): H. Harper
METHOD: Velocity/Cross-Section

METER: Model 201
WEATHER COND: Sunny

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
8.0	0.00	0.00	------	------	------
10.0	0.20	0.00	0.000	0.20	0.000
12.0	0.70	0.00	0.000	0.90	0.000
14.0	1.10	0.00	0.000	1.80	0.000
16.0	1.50	0.00	0.000	2.60	0.000
18.0	1.60	0.01	0.005	3.10	0.016
20.0	1.80	0.03	0.020	3.40	0.068
22.0	2.00	0.02	0.025	3.80	0.095
24.0	2.10	0.08	0.050	4.10	0.205
26.0	2.20	0.40	0.240	4.30	1.032
28.0	2.30	0.61	0.505	4.50	2.273
30.0	2.20	0.65	0.630	4.50	2.835
32.0	1.80	0.16	0.405	4.00	1.620
34.0	1.30	0.00	0.080	3.10	0.248
			TOTALS:	40.30	8.39

BANANA CREEK STREAM FLOW MEASUREMENTS FROM 3/16/99

OBSERVER(S): H. Harper
METHOD: Velocity/Cross-Section

METER: Model 201
WEATHER COND: Sunny

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.00	0.00	------	------	------
1.0	0.20	0.00	0.000	0.10	0.000
2.0	0.90	0.03	0.015	0.55	0.008
3.0	1.30	0.03	0.030	1.10	0.033
4.0	1.40	0.00	0.015	1.35	0.020
5.0	1.50	0.01	0.005	1.45	0.007
6.0	1.50	0.04	0.025	1.50	0.038
7.0	1.50	0.07	0.055	1.50	0.083
8.0	1.40	0.07	0.070	1.45	0.102
9.0	1.30	0.15	0.110	1.35	0.149
10.0	1.30	0.26	0.205	1.30	0.267
12.0	1.30	0.25	0.255	2.60	0.663
14.0	1.00	0.16	0.205	2.30	0.472
16.0	0.90	0.26	0.210	1.90	0.399
18.0	0.80	0.29	0.275	1.70	0.468
20.0	0.00	0.00	0.145	0.80	0.116
			TOTALS:	20.95	2.82

LK LENA RUN STREAM FLOW MEASUREMENTS FROM 1/20/99

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
15.0	0.00	0.00	------	------	------
17.0	0.90	1.15	0.575	0.90	0.518
19.0	0.90	0.94	1.045	1.80	1.881
21.0	0.70	0.82	0.000	1.60	0.000
23.0	0.50	0.50	0.660	1.20	0.792
25.0	0.60	0.52	0.510	1.10	0.561
27.0	0.70	0.65	0.585	1.30	0.760
29.0	0.20	0.02	0.335	0.90	0.302
31.0	0.00	0.00	0.010	0.20	0.002
			TOTALS:	9.00	4.82

LK LENA RUN STREAM FLOW MEASUREMENTS FROM 2/02/99

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
6.6	0.00	0.00	------	------	------
7.8	0.40	0.22	0.110	0.24	0.026
8.8	0.40	0.73	0.475	0.40	0.190
9.8	0.50	0.95	0.000	0.45	0.000
10.8	0.40	0.72	0.000	0.45	0.000
12.8	0.20	0.62	0.000	0.60	0.000
14.8	0.40	0.82	0.000	0.60	0.000
16.8	0.70	1.00	0.000	1.10	0.000
18.8	0.80	0.98	0.965	5.85	5.645
19.8	1.00	1.12	1.050	0.90	0.945
20.8	1.10	0.79	0.955	1.05	1.003
21.8	0.55	0.13	0.460	0.83	0.380
22.0	0.00	0.00	0.065	0.05	0.004
			TOTALS:	12.52	8.19

LK LENA RUN STREAM FLOW MEASUREMENTS FROM 2/10/99

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.00	0.00	——	——	——
2.0	0.20	0.38	0.190	0.20	0.038
3.0	0.60	0.38	0.380	0.40	0.152
4.0	0.80	0.39	0.385	0.70	0.270
5.0	0.80	0.58	0.485	0.80	0.388
6.0	0.70	0.71	0.645	0.75	0.484
7.0	0.70	0.83	0.770	0.70	0.539
8.0	0.70	0.74	0.785	0.70	0.549
9.0	0.90	0.56	0.650	0.80	0.520
10.0	1.00	0.40	0.480	0.95	0.456
11.0	0.90	0.10	0.250	0.95	0.238
12.0	0.00	0.00	0.050	0.45	0.023
			TOTALS:	7.40	3.66

LK LENA RUN STREAM FLOW MEASUREMENTS FROM 3/16/99

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.00	0.00	——	——	——
1.0	0.60	0.22	0.110	0.30	0.033
2.0	0.90	0.97	0.595	0.75	0.446
3.0	0.60	0.89	0.930	0.75	0.698
4.0	0.40	0.71	0.800	0.50	0.400
5.0	0.20	0.53	0.620	0.30	0.186
6.0	0.20	0.61	0.570	0.20	0.114
8.0	0.90	0.00	0.305	1.10	0.336
9.0	0.00	0.00	0.000	0.45	0.000
			TOTALS:	4.35	2.21

LK LENA RUN STREAM FLOW MEASUREMENTS FROM 4/02/99

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.00	0.00	——	——	——
1.0	0.40	0.01	0.005	0.20	0.001
3.0	0.80	0.76	0.385	1.20	0.462
5.0	0.60	0.73	0.745	1.40	1.043
7.0	0.30	0.60	0.665	0.90	0.599
9.0	0.20	0.32	0.525	1.60	0.840
11.0	0.20	0.04	0.180	0.40	0.072
11.5	0.00	0.00	0.020	0.05	0.001
			TOTALS:	5.75	3.02

LK LENA RUN STREAM FLOW MEASUREMENTS FROM 4/30/99

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.30	0.42	——	——	——
2.0	0.60	0.46	0.440	0.90	0.396
4.0	0.70	0.50	0.480	1.30	0.624
6.0	0.60	0.75	0.625	1.30	0.812
8.0	0.40	0.60	0.675	1.00	0.675
9.0	0.20	0.30	0.450	0.30	0.135
			TOTALS:	4.80	2.64

LK LENA RUN STREAM FLOW MEASUREMENTS FROM 6/01/99

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
0.0	0.00	0.00	——	——	——
1.0	0.20	0.33	0.165	0.10	0.017
2.0	0.20	0.29	0.310	0.20	0.062
3.0	0.30	0.69	0.490	0.25	0.123
4.0	0.40	0.84	0.565	0.60	0.339
5.0	0.50	0.63	0.735	0.45	0.331
6.0	0.00	0.00	0.315	0.25	0.079
			TOTALS:	1.85	0.95

SADDLE CREEK STREAM FLOW MEASUREMENTS FROM 2/02/99

OBSERVER(S): H. Harper
METHOD: Velocity/Cross-Section

METER: Model 201
WEATHER COND: Sunny

DISTANCE FROM INITIAL POINT (ft)	WATER DEPTH (ft)	FLOW VELOCITY AT 60% DEPTH (ft/sec)	MEAN SECTION VELOCITY (fps)	SECTION AREA (ft*ft)	SECTION DISCHARGE (cfs)
9.3	0.00	0.00	——	——	——
11.3	0.30	0.00	0.000	0.30	0.000
13.3	0.70	0.00	0.000	1.00	0.000
15.3	1.10	0.00	0.000	1.80	0.000
17.3	1.50	0.00	0.000	2.60	0.000
19.3	1.60	0.01	0.005	3.10	0.016
21.3	1.75	0.00	0.005	3.35	0.017
23.3	1.90	0.05	0.025	3.65	0.091
25.3	2.00	0.37	0.210	3.90	0.819
27.3	2.00	0.64	0.505	4.00	2.020
29.3	2.20	0.72	0.680	4.20	2.856
31.3	2.20	0.43	0.575	4.40	2.530
33.3	2.20	0.24	0.335	4.40	1.474
35.3	1.30	0.00	0.120	3.50	0.420
37.3	0.00	0.00	0.215	6.60	1.419
38.3	0.00	0.00	0.000	0.00	0.000
			TOTALS:	46.80	11.66

H

APPENDIX H

FIELD MONITORING OF SEEPAGE INFLOW INTO LAKE HANCOCK FROM NOVEMBER 1998 TO JULY 1999

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock　　Date: 10/19/98

Date Installed: 10/9/98　　Chamber Diameter: 0.58 m　　Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	15:50	--	--	--	--	--	Bag installed; no sample
2	16:05	--	--	--	--	--	Bag installed; no sample
3	16:20	--	--	--	--	--	Bag installed; no sample
4	16:45	--	--	--	--	--	Bag installed; no sample
5	16:55	--	--	--	--	--	Bag installed; no sample
6	17:05	--	--	--	--	--	Bag installed; no sample
7	17:20	--	--	--	--	--	Bag installed; no sample
8	17:35	--	--	--	--	--	Bag installed; no sample
9	17:45	--	--	--	--	--	Bag installed; no sample
10	17:58	--	--	--	--	--	Bag installed; no sample

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock

Date: 11/3/98

Date Installed: 10/9/98

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	15:00	7.6	10/19/98	15:50	14.97	1.88	Sample collected; bag in good condition
2	15:15	0.6	10/19/98	16:05	14.97	0.15	Sample collected; bag in good condition
3	15:35	--	10/19/98	16:20	14.97	--	No sample; meter damaged; repaired; bag replaced
4	15:46	8.7	10/19/98	16:45	14.96	2.15	Sample collected; bag in good condition
5	16:00	6.0	10/19/98	16:55	14.96	1.49	Sample collected; bag in good condition
6	16:12	--	10/19/98	17:05	14.96	--	No sample; bag damaged; replaced
7	16:22	4.2	10/19/98	17:20	14.96	1.04	Sample collected; bag in good condition
8	16:37	1.2	10/19/98	17:35	14.96	0.30	Sample collected; bag in good condition
9	17:00	1.3	10/19/98	17:45	14.97	0.32	Sample collected; bag in good condition
10	17:15	1.2	10/19/98	17:58	14.97	0.30	Sample collected; bag in good condition

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock

Date: 11/17/98

Date Installed: 10/9/98

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	14:15	3.6	11/3/98	15:00	13.97	0.95	Sample collected; bag in good condition
2	14:30	1.1	11/3/98	15:15	13.97	0.29	Sample collected; bag in good condition
3	14:45	3.6	11/3/98	15:35	13.97	0.95	Sample collected; bag replaced
4	15:15	9.8	11/3/98	15:46	13.97	2.60	Sample collected; bag in good condition
5	15:32	4.4	11/3/98	16:00	13.98	1.17	Sample collected; bag in good condition
6	15:45	8.0	11/3/98	16:12	13.98	2.12	Sample collected; bag in good condition
7	16:05	6.0	11/3/98	16:22	13.99	1.59	Sample collected; bag in good condition
8	16:20	3.9	11/3/98	16:37	13.99	1.03	Sample collected; bag in good condition
9	16:40	4.0	11/3/98	17:00	13.99	1.06	Sample collected; bag in good condition
10	17:00	--	11/3/98	17:15	--	--	Bag damaged; no sample; bag replaced

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock　　Date: 12/10/98

Date Installed: 10/9/98　　Chamber Diameter: 0.58 m　　Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	13:50	2.0	11/17/98	14:15	22.98	0.32	Sample collected; bag in good condition
2	14:03	2.0	11/17/98	14:30	22.98	0.32	Sample collected; bag in good condition
3	14:15	1.9	11/17/98	14:45	22.98	0.31	Sample collected; bag replaced
4	14:33	11.0	11/17/98	15:15	22.97	1.77	Sample collected; bag in good condition
5	14:45	8.2	11/17/98	15:32	22.97	1.32	Sample collected; bag in good condition
6	14:55	5.9	11/17/98	15:45	22.97	0.95	Sample collected; bag in good condition
7	15:05	9.8	11/17/98	16:05	22.96	1.58	Sample collected; bag in good condition
8	15:23	1.4	11/17/98	16:20	22.96	0.23	Sample collected; bag in good condition
9	15:45	2.0	11/17/98	16:40	22.96	0.32	Sample collected; bag in good condition
10	16:10	1.2	11/17/98	17:00	22.97	0.19	Sample collected; bag in good condition

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock

Date: 12/29/98

Date Installed: 10/9/98

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	14:15	3.9	12/10/98	13:50	19.02	0.76	Sample collected; bag in good condition
2	14:32	1.0	12/10/98	14:03	19.02	0.19	Sample collected; bag in good condition
3	14:47	1.9	12/10/98	14:15	19.02	0.37	Sample collected; bag in good condition
4	14:59	4.3	12/10/98	14:33	19.02	0.84	Sample collected; bag in good condition
5	15:15	4.8	12/10/98	14:45	19.02	0.93	Sample collected; bag in good condition
6	15:25	2.5	12/10/98	14:55	19.02	0.49	Sample collected; bag in good condition
7	15:40	5.0	12/10/98	15:05	19.02	0.97	Sample collected; bag in good condition
8	15:51	2.6	12/10/98	15:23	19.02	0.51	Sample collected; bag in good condition
9	16:10	3.0	12/10/98	15:45	19.02	0.58	Sample collected; bag in good condition
10	16:25	1.2	12/10/98	16:10	19.01	0.23	Sample collected; bag in good condition

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock

Date: 1/19/99

Date Installed: 10/9/98

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	13:50	3.1	12/29/98	14:15	20.98	0.55	Sample collected; bag replaced
2	14:12	0.9	12/29/98	14:32	20.99	0.16	Sample collected; bag in good condition
3	14:22	1.9	12/29/98	14:47	20.98	0.34	Sample collected; bag in good condition
4	14:35	5.5	12/29/98	14:59	20.98	0.97	Sample collected; bag in good condition
5	14:50	6.0	12/29/98	15:15	20.98	1.06	Sample collected; bag replaced
6	15:05	9.0	12/29/98	15:25	20.99	1.59	Sample collected; bag in good condition
7	15:15	7.5	12/29/98	15:40	20.98	1.32	Sample collected; bag in good condition
8	15:30	2.1	12/29/98	15:51	20.99	0.37	Sample collected; bag in good condition
9	15:50	3.0	12/29/98	16:10	20.99	0.53	Sample collected; bag in good condition
10	16:15	--	12/29/98	16:25	20.99	--	Bag damaged; no sample; bag replaced

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock

Date: 2/27/99

Date Installed: 10/9/98

Chamber Diameter: 0.58 m

Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	12:02	2.1	1/19/99	13:50	38.93	0.20	Sample collected, bag in good condition
2	12:17	1.8	1/19/99	14:12	38.92	0.17	Sample collected, bag in good condition
3	12:28	6.6	1/19/99	14:22	38.92	0.63	Sample collected, bag in good condition
4	12:50	11.0	1/19/99	14:35	38.93	1.05	Sample collected, bag in good condition
5	13:08	3.4	1/19/99	14:50	38.93	0.32	Sample collected, bag in good condition
6	13:15	5.5	1/19/99	15:05	38.92	0.52	Sample collected, bag in good condition
7	13:35	13.0	1/19/99	15:15	38.93	1.24	Sample collected, bag in good condition
8	13:50	3.4	1/19/99	15:30	38.93	0.32	Sample collected, bag in good condition
9	14:10	2.1	1/19/99	15:50	38.93	0.20	Sample collected, bag replaced
10	14:25	2.0	1/19/99	16:15	38.92	0.19	Sample collected, bag in good condition

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock   Date: 3/26/99

Date Installed: 10/9/98   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	13:40	1.7	2/27/99	12:02	27.07	0.23	Sample collected, bag in good condition
2	13:55	3.1	2/27/99	12:17	27.07	0.42	Sample collected, bag in good condition
3	14:10	--	2/27/99	12:28	27.07	--	Bag damaged, no sample, bag replaced
4	14:30	--	2/27/99	12:50	27.07	--	Meter damaged, repaired
5	14:55	4.0	2/27/99	13:08	27.07	0.55	Sample collected, bag in good condition
6	15:17	10.3	2/27/99	13:15	27.08	1.41	Sample collected, bag in good condition
7	15:31	13.0	2/27/99	13:35	27.08	1.78	Sample collected, bag in good condition
8	15:52	3.3	2/27/99	13:50	27.08	0.45	Sample collected, bag in good condition
9	16:21	2.6	2/27/99	14:10	27.09	0.36	Sample collected, bag in good condition
10	16:40	4.0	2/27/99	14:25	27.09	0.55	Sample collected, bag in good condition

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock Date: 5/11/99 and 5/21/99

Date Installed: 10/9/98 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	16:45 (5/11)	--	3/26/99	13:40	46.13	--	No sample; bag missing; replaced
2	17:05 (5/11)	3.8	3/26/99	13:55	46.13	0.31	Sample collected; bag replaced
3	17:25 (5/11)	4.8	3/26/99	14:10	46.14	0.39	Sample collected; bag in good condition
4	14:15 (5/21)	--	3/26/99	14:30	55.99	--	Meter damaged; no sample
5	14:20 (5/21)	7.0	3/26/99	14:55	55.98	0.46	Sample collected; bag in good condition
6	14:35 (5/21)	--	3/26/99	15:17	55.97	--	Bag damaged; no sample
7	14:50 (5/21)	--	3/26/99	15:31	55.97	--	Bag damaged; no sample
8	15:05 (5/21)	4.0	3/26/99	15:52	55.97	0.26	Sample collected; bag in good condition
9	15:15 (5/21)	--	3/26/99	16:21	55.95	--	Meter missing, no sample
10	15:20 (5/21)	4.8	3/26/99	16:40	55.94	0.32	Sample collected; bag in good condition

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock　　Date: 6/10/99

Date Installed: 10/9/98　　Chamber Diameter: 0.58 m　　Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	14:02	1.1	5/11/99	16:45	30.89	0.13	Sample collected; bag replaced
2	14:25	--	5/11/99	17:05	30.89	--	Meter missing; no sample
3	14:35	2.0	5/21/99	13:45	21.03	0.35	Sample collected; bag in good condition
4	15:10	--	5/21/99	14:15	21.04	--	Meter damaged; removed
5	15:20	7.0	5/21/99	14:20	21.04	1.23	Sample collected; bag in good condition
6	15:45	--	5/21/99	14:35	21.04	--	Bag damaged; no sample; bag replaced
7	15:55	4.2	5/21/99	14:50	21.05	0.74	Sample collected; bag in good condition
8	16:15	2.6	5/21/99	15:05	21.05	0.46	Sample collected; bag in good condition
9	16:25	--	5/21/99	15:15	21.05	--	Meter missing; no sample
10	16:35	5.0	5/21/99	15:20	21.05	0.88	Sample collected; bag replaced

SEEPAGE METER FIELD MEASUREMENTS

Location: Lake Hancock   Date: 7/1/99

Date Installed: 10/9/98   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m^2

SITE/ LOCATION	TIME COLLECTED	VOLUME COLLECTED (liters)	PREVIOUS COLLECTION EVENT		SEEPAGE TIME (days)	SEEPAGE (L/m^2-day)	COMMENTS / OBSERVATIONS
			DATE	TIME			
1	14:45	--	6/11/99	14:02	20.03	--	Meter missing; no sample
2	14:55	--	6/11/99	14:25	20.02	--	Meter missing; no sample
3	15:10	--	6/11/99	14:35	20.02	--	Bag damaged; no sample; meter removed
4	16:05	--	6/11/99	15:10	20.04	--	Meter missing; no sample
5	16:15	3.0	6/11/99	15:20	20.04	0.55	Sample collected; meter removed
6	13:35	7.2	6/11/99	15:45	19.91	1.34	Sample collected; meter removed
7	16:55	3.9	6/11/99	15:55	19.96	0.72	Sample collected; meter removed
8	17:15	--	6/11/99	16:15	20.04	--	Bag damaged; no sample; meter removed
9	17:35	--	6/11/99	16:25	20.05	--	Meter missing; no sample
10	15:50	1.1	6/11/99	16:35	19.97	0.20	Sample collected; meter removed

APPENDIX I

CHEMICAL CHARACTERISTICS OF STORMWATER RUNOFF AND BASEFLOW COLLECTED AT LAKE HANCOCK MONITORING SITES FROM DECEMBER 1998 TO JUNE 1999

EVENT MEAN CHEMICAL CHARACTERISTICS OF STORMWATER RUNOFF COLLECTED AT THE BANANA CREEK MONITORING SITE FROM JANUARY TO MAY 1999

PARAMETER	UNITS	DATE OF STORM EVENT						
		1/15/99	1/17/99	1/23/99	2/3/99	3/4/99	4/29/99	5/14/99
pH	s.u.	7.99	7.98	7.71	7.20	7.78	8.13	8.21
Conductivity	μmho/cm	230	221	224	216	218	202	201
Alkalinity	mg/l	42.0	41.6	63.2	68.2	68.2	65.1	65.1
NH_3-N	μg/l	74	84	247	11	50	11	< 5
NO_x-N	μg/l	437	106	314	765	18	121	< 5
Diss. Organic N	μg/l	782	766	1210	845	927	3463	1090
Particulate N	μg/l	2212	2353	2997	1981	3690	1685	161
Total N	μg/l	3505	3309	4768	3602	4685	5280	1256
Ortho-P	μg/l	273	368	454	382	300	308	256
Particulate P	μg/l	461	445	786	957	807	586	56
Total P	μg/l	908	833	1248	1359	1110	951	336
Color	Pt-Co	--	--	--	--	--	51	--
TSS	mg/l	7.8	4.6	82.0	47.0	100	66.0	82.0
BOD	mg/l	13.4	8.1	13.1	10.2	11.3	19.3	19.5
Sulfate	mg/l	--	--	--	--	73	--	--

HANCOCK\RUNOFF.TAB

EVENT MEAN CHEMICAL CHARACTERISTICS OF STORMWATER RUNOFF COLLECTED AT THE LAKE LENA RUN MONITORING SITE FROM JANUARY TO MAY 1999

PARAMETER	UNITS	DATE OF STORM EVENT			
		1/23/99	2/3/99	3/4/99	4/29/99
pH	s.u.	7.96	7.83	8.19	7.72
Conductivity	μmho/cm	391	351	479	375
Alkalinity	mg/l	146	121	193	126
NH_3-N	μg/l	124	17	9	78
NO_x-N	μg/l	240	357	336	838
Diss. Organic N	μg/l	1076	1013	814	757
Particulate N	μg/l	279	154	87	473
Total N	μg/l	1719	1541	1246	2146
Ortho-P	μg/l	253	276	200	168
Particulate P	μg/l	68	46	1066	149
Total P	μg/l	336	351	1379	353
Color	Pt-Co	--	--	--	152
TSS	mg/l	5.7	9.1	2.6	37.0
BOD	mg/l	1.7	2.2	1.6	1.9
Sulfate	mg/l	--	--	76	--

EVENT MEAN CHEMICAL CHARACTERISTICS OF STORMWATER RUNOFF COLLECTED AT THE SADDLE CREEK MONITORING SITE FROM JANUARY TO MAY 1999

PARAMETER	UNITS	DATE OF STORM EVENT		
		3/4/99	4/29/99	5/4/99
pH	s.u.	7.82	7.52	7.66
Conductivity	μmho/cm	306	270	296
Alkalinity	mg/l	117	129	112
NH_3-N	μg/l	34	58	63
NO_x-N	μg/l	277	261	174
Diss. Organic N	μg/l	907	847	660
Particulate N	μg/l	33	294	107
Total N	μg/l	1251	1460	1004
Ortho-P	μg/l	383	323	194
Particulate P	μg/l	87	190	22
Total P	μg/l	488	567	250
Color	Pt-Co	--	133	--
TSS	mg/l	9.5	15.5	7.6
BOD	mg/l	2.1	4.5	2.1
Sulfate	mg/l	83	--	--

CHEMICAL CHARACTERISTICS OF DRY WEATHER BASEFLOW COLLECTED AT THE BANANA CREEK MONITORING SITE FROM DECEMBER 1998 TO JUNE 1999

PARAMETER	UNITS	SAMPLE COLLECTION DATES							
		12/17/98-12/21/98	12/22/98-12/29/98	12/29/98-1/5/99	1/6/99-1/11/99	1/12/99-1/14/99	1/15/99-1/19/99	1/19/99-1/23/99	1/24/99-1/29/99
pH (lab)	s.u.	7.92	8.05	7.95	7.86	7.96	7.95	7.92	7.96
Conductivity (lab)	μmho/cm	229	238	230	211	225	231	217	222
Alkalinity	mg/l	27.2	48.2	46.7	68.5	51.3	34.5	38.1	47.1
NH_3-N	μg/l	87	< 10	30	63	< 10	180	336	78
NO_x-N	μg/l	93	601	466	53	94	190	788	113
Diss. Organic N	μg/l	973	1479	1404	786	753	975	920	1082
Particulate N	μg/l	1832	1093	3336	1716	2657	3297	1916	3817
Total N	μg/l	2985	3178	5236	2618	3509	4642	3960	5090
Ortho-P	μg/l	375	406	556	336	351	409	385	409
Particulate P	μg/l	445	393	787	386	676	1030	636	1172
Total P	μg/l	870	830	1360	755	1063	1479	1052	1613
Color	Pt-Co	--	--	--	--	--	--	--	--
TSS	mg/l	40.0	36.0	86.0	37.0	81.0	101	40.0	113
BOD	mg/l	--	21.0	13.5	9.0	8.5	15.2	7.9	14.3
Sulfate	mg/l	--	--	--	--	--	--	--	--

CHEMICAL CHARACTERISTICS OF DRY WEATHER BASEFLOW COLLECTED AT THE BANANA CREEK MONITORING SITE FROM DECEMBER 1998 TO JUNE 1999

(Page 2)

PARAMETER	UNITS	SAMPLE COLLECTION DATE							
		1/29/99-2/2/99	2/2/99-2/10/99	2/10/99-2/17/99	2/17/99-3/4/99	3/5/99-3/17/99	3/17/99-3/24/99	3/24/99-4/2/99	4/2/99-4/8/99
pH (lab)	s.u.	7.95	7.47	7.80	7.73	8.02	7.84	7.95	7.18
Conductivity (lab)	μmho/cm	269	244	234	219	225	227	235	288
Alkalinity	mg/l	63.3	75.0	63.0	61.4	64.1	71.3	69.8	84.2
NH_3-N	μg/l	84	198	22	7	< 5	1204	1196	272
NO_x-N	μg/l	84	248	1065	1160	1192	156	79	1186
Diss. Organic N	μg/l	929	1021	775	762	615	1374	1440	6054
Particulate N	μg/l	4018	2957	1334	1620	2871	3242	4211	2694
Total N	μg/l	5115	4424	3196	3549	4681	5976	6926	10,206
Ortho-P	μg/l	344	381	358	352	315	260	193	525
Particulate P	μg/l	1105	576	310	714	775	748	864	956
Total P	μg/l	1491	984	811	1024	1092	1044	1087	1775
Color	Pt-Co	--	--	--	--	--	--	--	--
TSS	mg/l	57.3	60.6	36.7	47.0	65.0	66.0	78.0	106
BOD	mg/l	21.2	11.7	8.5	8.7	12.9	18.2	19.2	19.0
Sulfate	mg/l	--	--	75	72	--	--	--	--

CHEMICAL CHARACTERISTICS OF DRY WEATHER BASEFLOW COLLECTED AT THE BANANA CREEK MONITORING SITE FROM DECEMBER 1998 TO JUNE 1999

(Page 3)

PARAMETER	UNITS	SAMPLE COLLECTION DATE						
		4/8/99-4/16/99	4/16/99-4/23/99	4/30/99-5/6/99	5/6/99-5/14/99	5/14/99-5/20/99	5/20/99-5/27/99	5/27/99-6/1/99
pH (lab)	s.u.	7.13	9.35	7.36	7.30	8.84	8.95	9.52
Conductivity (lab)	µmho/cm	369	204	207	215	213	218	208
Alkalinity	mg/l	109	68.3	59.1	60.6	56.7	59.5	61.5
NH_3-N	µg/l	7093	42	21	10	< 5	11	16
NO_x-N	µg/l	247	< 5	854	1640	1147	15	< 5
Diss. Organic N	µg/l	2997	1282	1583	1272	1201	632	1521
Particulate N	µg/l	3307	4279	2675	1507	2029	1451	4145
Total N	µg/l	13,644	5606	5133	4429	4380	2109	5685
Ortho-P	µg/l	534	257	259	337	369	289	176
Particulate P	µg/l	35	779	626	533	595	606	867
Total P	µg/l	571	1059	977	953	1031	1007	1102
Color	Pt-Co	--	17	58	50	--	--	59
TSS	mg/l	80.0	86.0	70.0	56.0	47.0	48.0	132
BOD	mg/l	23.7	14.9	22.6	19.6	23.7	37.3	12.8
Sulfate	mg/l	--	15	21	20	11	12	12

CHEMICAL CHARACTERISTICS OF DRY WEATHER BASEFLOW COLLECTED AT THE LAKE LENA RUN MONITORING SITE FROM DECEMBER 1998 TO JUNE 1999

PARAMETER	UNITS	SAMPLE COLLECTION DATES							
		12/17/98-12/21/98	12/22/98-1/5/99	1/6/99-1/11/99	1/12/99-1/14/99	1/15/99-1/19/99	1/19/99-1/23/99	1/24/99-1/29/99	2/2/99-2/10/99
pH (lab)	s.u.	8.06	8.14	7.86	8.15	8.13	8.01	8.00	7.78
Conductivity (lab)	μmho/cm	330	326	331	378	410	405	415	347
Alkalinity	mg/l	73.0	78.8	118	115	128	85.7	60.7	122
NH_3-N	μg/l	34	31	246	< 10	< 10	103	124	15
NO_x-N	μg/l	382	379	355	387	215	235	258	226
Diss. Organic N	μg/l	757	849	1064	865	871	1058	1130	1059
Particulate N	μg/l	94	44	< 30	30	72	80	139	51
Total N	μg/l	1267	1303	1680	1287	1163	1476	1651	1351
Ortho-P	μg/l	208	204	220	238	205	288	256	276
Particulate P	μg/l	18	13	11	34	14	45	84	29
Total P	μg/l	267	217	280	303	321	361	371	334
Color	Pt-Co	--	--	--	--	--	--	--	--
TSS	mg/l	2.5	--	5.3	6.5	1.3	8.7	12.7	5.4
BOD	mg/l	2.2	0.6	1.2	1.3	0.8	1.9	2.2	1.8
Sulfate	mg/l	--	--	--	--	--	--	--	--

CHEMICAL CHARACTERISTICS OF DRY WEATHER BASEFLOW COLLECTED AT THE LAKE LENA RUN MONITORING SITE FROM DECEMBER 1998 TO JUNE 1999
(Page 2)

PARAMETER	UNITS	SAMPLE COLLECTION DATES						
		2/10/99-2/16/99	2/17/99-3/4/99	3/5/99-3/10/99	3/10/99-3/17/99	3/17/99-3/24/99	3/24/99-4/2/99	4/2/99-4/8/99
pH (lab)	s.u.	8.27	8.24	8.46	8.43	8.35	8.41	8.04
Conductivity (lab)	μmho/cm	450	481	434	429	438	452	464
Alkalinity	mg/l	187	197	187	180	184	201	187
NH_3-N	μg/l	13	33	207	100	22	92	16
NO_x-N	μg/l	258	331	85	248	733	356	899
Diss. Organic N	μg/l	909	829	374	463	544	406	1024
Particulate N	μg/l	< 30	126	333	230	270	455	< 30
Total N	μg/l	1195	1319	999	1041	1569	1309	1954
Ortho-P	μg/l	194	198	115	202	203	179	168
Particulate P	μg/l	252	11	40	62	60	58	31
Total P	μg/l	432	232	165	264	269	244	266
Color	Pt-Co	--	--	--	--	--	--	--
TSS	mg/l	1.6	< 0.7	2.8	1.6	8.1	6.3	13.8
BOD	mg/l	1.1	1.1	2.6	2.0	0.6	1.6	2.5
Sulfate	mg/l	76	77	--	--	--	--	--

CHEMICAL CHARACTERISTICS OF DRY WEATHER BASEFLOW COLLECTED AT THE LAKE LENA RUN MONITORING SITE FROM DECEMBER 1998 TO JUNE 1999
(Page 3)

PARAMETER	UNITS	SAMPLE COLLECTION DATES						
		4/8/99-4/16/99	4/16/99-4/23/99	4/30/99-5/6/99	5/6/99-5/14/99	5/14/99-5/20/99	5/20/99-5/27/99	5/27/99-6/1/99
pH (lab)	s.u.	8.35	8.03	8.12	8.07	8.44	8.31	8.27
Conductivity (lab)	μmho/cm	429	394	402	406	381	377	263
Alkalinity	mg/l	160	58.7	164	156	146	145	79.5
NH_3-N	μg/l	56	70	37	14	48	29	35
NO_x-N	μg/l	501	301	335	284	43	< 5	18
Diss. Organic N	μg/l	386	640	723	640	481	563	478
Particulate N	μg/l	469	83	161	145	3964	657	30
Total N	μg/l	1412	1094	1256	1083	4536	1252	561
Ortho-P	μg/l	170	229	199	146	149	2	80
Particulate P	μg/l	34	42	10	148	600	133	16
Total P	μg/l	235	309	210	338	770	308	126
Color	Pt-Co	--	64	107	111	--	--	101
TSS	mg/l	5.3	4.3	15.5	8.9	3.0	2.1	1.5
BOD	mg/l	2.6	1.7	2.5	2.4	1.9	2.2	0.8
Sulfate	mg/l	--	25	18	15	15	15	17

CHEMICAL CHARACTERISTICS OF DRY WEATHER BASEFLOW COLLECTED AT THE SADDLE CREEK MONITORING SITE FROM MARCH 1999 TO JUNE 1999

PARAMETER	UNITS	SAMPLE COLLECTION DATES									
		3/10/99-3/17/99	3/17/99-3/24/99	3/24/99-4/2/99	4/2/99-4/8/99	4/8/99-4/16/99	4/30/99-5/6/99	5/6/99-5/14/99	5/14/99-5/20/99	5/20/99-5/27/99	5/27/99-6/1/99
pH (lab)	s.u.	8.32	8.23	8.31	7.96	7.78	7.88	7.92	8.08	7.91	7.87
Conductivity (lab)	µmho/cm	326	318	334	337	336	240	236	293	289	293
Alkalinity	mg/l	141	134	149	135	144	106	106	98.5	105	115
NH_3-N	µg/l	77	105	80	< 5	< 5	30	< 5	11	162	119
NO_x-N	µg/l	196	352	95	266	513	478	539	400	< 5	91
Diss. Organic N	µg/l	397	617	374	600	382	543	572	252	879	585
Particulate N	µg/l	244	119	267	< 30	< 30	219	107	476	106	86
Total N	µg/l	914	1193	816	884	913	1270	1221	1139	1150	881
Ortho-P	µg/l	403	403	411	520	481	272	246	229	200	188
Particulate P	µg/l	71	13	65	51	90	31	30	35	79	214
Total P	µg/l	474	432	478	571	571	310	281	262	370	440
Color	Pt-Co	--	--	--	--	--	76	64	--	74	72
TSS	mg/l	2.4	2.0	5.6	3.3	4.0	9.1	6.5	1.3	5.4	16.1
BOD	mg/l	1.3	0.5	0.6	2.1	1.8	1.8	1.6	1.5	2.4	1.5
Sulfate	mg/l	--	--	--	--	--	15	14	16	12	11

J

APPENDIX J

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE ENTERING LAKE HANCOCK FROM OCTOBER 1998 TO JULY 1999

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON MARCH 26, 1999

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	7.74	8.21	--	--	8.07	8.32	8.00	7.77	7.73	7.96
Spec. Conductivity	μmho/cm	533	319	--	--	365	470	263	291	372	265
Alkalinity	mg/l	335	244	--	--	170	241	73.3	108	160	105
NH_3-N	μg/l	15,639	13,098	--	--	9514	13,054	20	768	9273	629
NO_x-N	μg/l	2456	9	--	--	34	2352	6910	513	6	13
Organic N	μg/l	1143	1880	--	--	2138	336	1383	1949	2526	1327
Total N	μg/l	19,238	14,987	--	--	11,686	15,742	8313	3230	11,805	1969
Ortho-P	μg/l	5783	1401	--	--	1096	1863	586	473	1150	28
Total P	μg/l	5931	1593	--	--	1130	1960	593	492	1173	29
BOD	mg/l	5.7	5.6	--	--	4.4	1.8	3.0	5.4	7.2	3.9
Seepage Flow	L/m²-day	0.23	0.42	--	--	0.55	1.41	1.78	0.45	0.36	0.55

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON MAY 11 AND 21, 1999

PARAMETER	UNITS	LOCATION/SITE									
		1[1]	2[1]	3[1]	4[2]	5[2]	6[2]	7[2]	8[2]	9[2]	10[2]
pH	s.u.	--	7.25	8.41	--	6.97	--	--	7.48	--	7.60
Spec. Conductivity	μmho/cm	--	421	253	--	230	--	--	333	--	266
Alkalinity	mg/l	--	188	91.2	--	413	--	--	693	--	313
NH_3-N	μg/l	--	12,690	48	--	5446	--	--	19,921	--	2484
NO_x-N	μg/l	--	9	2109	--	< 5	--	--	38	--	10
Organic N	μg/l	--	1339	1986	--	870	--	--	9569	--	2532
Total N	μg/l	--	14,038	4143	--	6319	--	--	29,528	--	5026
Ortho-P	μg/l	--	789	144	--	9	--	--	248	--	< 1
Total P	μg/l	--	1000	171	--	40	--	--	283	--	13
BOD	mg/l	--	6.2	5.4	--	11.9	--	--	19.0	--	9.3
Color	Pt-Co	--	17	18	--	56	--	--	54	--	42
Seepage Flow	L/m^2-day	--	0.31	0.39	--	0.46	--	--	0.26	--	0.32

1. Samples collected on May 11, 1999
2. Samples collected on May 21, 1999

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON JUNE 10, 1999

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	7.29	--	7.53	--	7.77	--	7.70	7.76	--	7.56
Spec. Conductivity	μmho/cm	885	--	309	--	527	--	552	459	--	357
Alkalinity	mg/l	461	--	88.7	--	231	--	192	165	--	132
NH_3-N	μg/l	19,888	--	2214	--	15,316	--	516	5738	--	4765
NO_x-N	μg/l	12	--	2396	--	321	--	18,643	809	--	9
Organic N	μg/l	26,138	--	2078	--	4945	--	17,856	2670	--	2102
Total N	μg/l	46,038	--	6688	--	20,582	--	37,015	9217	--	6876
Ortho-P	μg/l	4184	--	487	--	1566	--	2482	384	--	6
Total P	μg/l	4273	--	584	--	1635	--	2420	452	--	41
BOD	mg/l	23.8	--	12.2	--	25.4	--	25.7	25.8	--	7.7
Color	Pt-Co	118	--	70	--	91	--	112	63	--	62
Seepage Flow	L/m^2-day	0.13	--	0.35	--	1.23	--	0.74	0.46	--	0.88

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON JULY 1, 1999

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	--	--	--	--	8.10	8.36	8.06	--	--	8.01
Spec. Conductivity	µmho/cm	--	--	--	--	396	501	298	--	--	293
Alkalinity	mg/l	--	--	--	--	537	316	126	--	--	272
NH_3-N	µg/l	--	--	--	--	58,253	24,390	18,613	--	--	19,342
NO_x-N	µg/l	--	--	--	--	6	365	23,159	--	--	< 5
Organic N	µg/l	--	--	--	--	3549	3221	3530	--	--	2995
Total N	µg/l	--	--	--	--	61,808	27,976	45,302	--	--	22,340
Ortho-P	µg/l	--	--	--	--	5448	2561	3454	--	--	756
Total P	µg/l	--	--	--	--	6750	2956	3956	--	--	964
BOD	mg/l	--	--	--	--	15.4	6.1	5.2	--	--	14.6
Color	Pt-Co	--	--	--	--	145	128	118	--	--	86
Seepage Flow	L/m^2-day	--	--	--	--	0.55	1.34	0.72	--	--	0.20

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON NOVEMBER 17, 1998

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	7.24	7.18	7.63	7.78	7.20	7.92	7.71	7.11	7.22	--
Spec. Conductivity	μmho/cm	393	736	241	245	561	370	294	260	335	--
Alkalinity	mg/l	166	279	37.3	39.2	147	129	46.4	61.6	95.5	--
NH_3-N	μg/l	10,334	36,815	241	59	22,591	9144	443	2853	4675	--
NO_x-N	μg/l	105	656	2406	3536	120	141	8149	60	2222	--
Organic N	μg/l	951	5633	1310	1410	8146	580	877	2458	2123	--
Total N	μg/l	11,390	43,104	3957	5005	30,857	9865	9469	5371	9020	--
Ortho-P	μg/l	1477	4704	308	393	2633	994	1256	453	1374	--
Total P	μg/l	1587	5027	348	399	2974	1044	1280	582	1536	--
BOD	mg/l	6.2	17.2	3.2	1.6	7.2	1.4	2.6	5.2	5.3	--
Seepage Flow	L/m^2-day	0.95	0.29	0.95	2.60	1.17	2.12	1.59	1.03	1.06	--

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON NOVEMBER 3, 1998

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	7.35	7.45	--	7.86	7.46	--	7.66	7.42	7.44	7.77
Spec. Conductivity	μmho/cm	278	601	--	252	400	--	291	549	426	545
Alkalinity	mg/l	60.1	275	--	38.3	130	--	52.3	199	136	112
NH_3-N	μg/l	1511	26,699	--	1486	11,205	--	827	16,605	10,738	15,202
NO_x-N	μg/l	140	< 8	--	665	< 8	--	7643	3957	745	2758
Organic N	μg/l	4320	6483	--	1616	9638	--	962	8446	3122	2441
Total N	μg/l	5971	33,186	--	3767	20,847	--	9432	29,008	14,606	20,401
Ortho-P	μg/l	569	3687	--	270	1727	--	1206	2986	1607	2221
Total P	μg/l	772	3715	--	315	1771	--	1286	3212	1682	2300
BOD	mg/l	4.7	15.1	--	2.2	4.1	--	11.3	10.2	7.3	5.1
Color	Pt-Co	50	72	--	53	61	--	77	46	55	45
Seepage Flow	L/m^2-day	1.88	0.15	--	2.15	1.49	--	1.04	0.30	0.32	0.30

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON DECEMBER 10, 1998

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	7.39	7.79	7.68	7.76	7.61	7.74	7.79	7.75	7.82	8.08
Spec. Conductivity	μmho/cm	592	463	241	263	275	319	230	380	535	476
Alkalinity	mg/l	322	182	52.4	27.7	96.6	117	35.7	153	230	220
NH_3-N	μg/l	28,934	15,355	886	338	7609	7421	815	8795	28,983	17,725
NO_x-N	μg/l	29	4792	5576	2611	201	2188	5079	351	57	< 8
Organic N	μg/l	11,659	3135	2999	2157	2572	2613	2686	5305	77	3390
Total N	μg/l	40,622	23,282	9461	5106	10,382	12,222	8580	14,451	29,117	21,119
Ortho-P	μg/l	4588	3525	1111	310	1071	1310	1095	2166	3775	2309
Total P	μg/l	4711	3815	1235	349	1160	1338	1011	2209	3911	2465
BOD	mg/l	21.6	10.3	3.6	2.0	3.4	2.6	1.7	4.2	19.1	19.0
Seepage Flow	L/m^2-day	0.32	0.32	0.31	1.77	1.32	0.95	1.58	0.23	0.32	0.19

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON DECEMBER 29, 1998

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	7.89	8.24	8.04	8.37	8.25	8.22	8.00	8.20	8.23	8.35
Spec. Conductivity	μmho/cm	226	671	364	436	365	388	322	384	474	468
Alkalinity	mg/l	61.5	190	86.1	179	122	114	45.9	130	187	185
NH_3-N	μg/l	952	30,331	4184	12,291	11,485	4854	1859	10,492	18,511	11,156
NO_x-N	μg/l	69	2929	10,643	524	< 8	5038	9381	251	< 8	131
Organic N	μg/l	4307	5068	10,878	683	1966	2415	1856	992	915	1378
Total N	μg/l	5328	38,328	25,705	13,498	13,455	12,307	13,096	11,735	19,430	12,665
Ortho-P	μg/l	58	4813	2350	915	1021	1333	1360	997	1928	1202
Total P	μg/l	150	5152	2565	916	1278	1465	1484	1091	2007	1297
BOD	mg/l	5.9	11.0	3.2	3.1	5.7	5.4	5.0	9.6	11.8	8.1
Seepage Flow	L/m²-day	0.76	0.19	0.37	0.84	0.93	0.49	0.97	0.51	0.58	0.23

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON JANUARY 19, 1999

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	7.97	8.06	7.98	8.28	7.95	8.35	8.02	8.18	8.13	--
Spec. Conductivity	μmho/cm	255	537	289	376	278	443	300	405	314	--
Alkalinity	mg/l	76.7	201	44.4	134	67.7	170	45.2	109	80.7	--
NH_3-N	μg/l	1216	18,231	617	4798	4051	8966	1651	6854	14,003	--
NO_x-N	μg/l	< 8	521	7233	4849	34	3099	6569	2154	582	--
Organic N	μg/l	1800	2975	732	358	913	135	152	659	1055	--
Total N	μg/l	3020	21,727	8582	10,005	4998	12,200	8372	9667	15,640	--
Ortho-P	μg/l	188	3025	1508	840	387	1681	934	1458	626	--
Total P	μg/l	213	3054	1565	904	409	1689	1453	1459	628	--
BOD	mg/l	7.3	13.1	1.6	3.2	5.0	2.3	7.8	1.3	0.6	--
Seepage Flow	L/m^2-day	0.55	0.16	0.34	0.97	1.06	1.59	1.32	0.37	0.53	--

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE MEASURED AT LAKE HANCOCK ON FEBRUARY 27, 1999

PARAMETER	UNITS	LOCATION/SITE									
		1	2	3	4	5	6	7	8	9	10
pH	s.u.	8.13	7.84	7.74	8.04	7.76	7.90	7.75	7.56	7.82	8.18
Spec. Conductivity	μmho/cm	470	361	254	366	740	559	319	443	529	546
Alkalinity	mg/l	192	144	69.2	156	341	246	90.7	150	245	221
NH_3-N	μg/l	2128	8542	405	6512	18,510	14,453	2461	3549	16,003	13,861
NO_x-N	μg/l	7353	128	4046	1214	79	2428	4961	105	19	148
Organic N	μg/l	1757	639	848	591	884	1353	1603	980	3844	1651
Total N	μg/l	11,238	9309	5299	8317	19,473	18,234	9025	4634	19,866	15,660
Ortho-P	μg/l	1972	943	512	446	3505	2113	846	1247	960	955
Total P	μg/l	2132	1258	525	448	3544	2123	853	1268	2069	963
BOD	mg/l	7.4	10.8	3.2	1.6	4.2	9.5	2.4	5.7	19.2	4.3
Seepage Flow	L/m^2-day	0.20	0.17	0.63	1.05	0.32	0.52	1.24	0.32	0.20	0.19

K

APPENDIX K

TROPHIC STATE MODELING FOR MODEL VERIFICATION UNDER CURRENT CONDITIONS

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK BASED ON IDENTIFIED NUTRIENT LOADINGS UNDER CURRENT CONDITIONS

Month	Initial P Conc.	Hydrologic and Mass Inputs: Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Hydrologic and Mass: Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.230	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	2.53	953	2894	778	0
February	0.206	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	3.08	1160	3015	769	0
March	0.208	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	4.57	1721	3982	1018	0
April	0.207	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.55	2090	1479	393	0
May	0.223	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	6.18	2327	3647	976	0
June	0.210	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.59	2105	8524	2116	0
July	0.192	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.53	2083	10552	2559	0
August	0.201	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	5.23	1970	9639	2394	0
September	0.202	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.58	1725	8191	2050	0
October	0.204	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	4.02	1514	2959	789	0
November	0.228	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.91	1096	2302	649	0
December	0.229	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	2.36	889	2400	647	0
January	0.209	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	3.08	1160	2687	694	0
February	0.210	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	4.57	1721	2454	642	0
March	0.214	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	5.55	2090	3613	946	0
April	0.210	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	6.18	2327	1242	334	0
May	0.226	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.59	2105	3869	1036	0
June	0.208	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.53	2083	8547	2110	0
July	0.192	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.23	1970	10665	2583	0
August	0.200	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.58	1725	9884	2440	0
September	0.200	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.02	1514	8401	2087	0
October	0.203	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.91	1096	3377	888	0
November	0.223	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.36	889	2509	696	0
December	0.226	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	3.08	1160	2129	576	0
January	0.212	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	4.57	1721	2126	562	0
February	0.217	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	5.55	2090	2085	560	0
March	0.219	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	6.18	2327	3375	897	0
April	0.212	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.59	2105	1464	393	0
May	0.223	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.53	2083	3892	1035	0
June	0.208	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.23	1970	8660	2133	0
July	0.192	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	4.58	1725	10910	2627	0
August	0.199	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.02	1514	10095	2476	0
September	0.199	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	2.91	1096	8819	2169	0
October	0.200	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.36	889	3584	931	0
November	0.221	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	3.08	1160	2238	623	0
December	0.230	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	4.57	1721	1568	435	0
Totals:		49.72	18724		1039	56284	28562	4209	4646	39420	79216	73667		52.13	19631	59585	15138	0

Lake Surface Area (acres): 4519

Runoff/Baseflow Input (ac-ft/yr): 56284

Runoff/Baseflow Total P Input (kg/yr): 28562

Dry Season Seepage Inflow (ac-ft): 1343

Wet Season Seepage Inflow (ac-ft): 2866

Dry Season P Input (kg): 1148

Wet Seas

Misc. Total P Inputs (kg/day): 108

Inflow Mass Removal (%): 0

Losses										
nt System Losses		Total Losses		Mean Detention Time	Phosphorus Retention Coeff.	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI Value
% Removal	(kg)	(ac-ft)	(kg)	(days)		(g/m^2)	(mg/l)	(mg/m^3	(m)	
0	0	3847	778	129	0.766	0.228	0.206	165	0.11	90
0	0	4175	769	108	0.732	0.218	0.208	167	0.11	90
0	0	5703	1018	87	0.689	0.255	0.207	166	0.11	90
0	0	3569	393	135	0.774	0.237	0.223	185	0.10	92
0	0	5974	976	83	0.679	0.263	0.210	170	0.11	91
0	0	10630	2116	45	0.535	0.295	0.192	149	0.12	89
0	0	12634	2559	39	0.500	0.342	0.201	159	0.11	90
0	0	11609	2394	43	0.521	0.329	0.202	160	0.11	90
0	0	9915	2050	49	0.552	0.304	0.204	163	0.11	90
0	0	4473	789	111	0.738	0.262	0.228	191	0.10	92
0	0	3398	649	142	0.782	0.240	0.229	192	0.10	92
0	0	3289	647	151	0.793	0.223	0.209	168	0.11	91
0	0	3847	694	129	0.766	0.233	0.210	170	0.11	91
0	0	4175	642	108	0.732	0.225	0.214	174	0.10	91
0	0	5703	946	87	0.689	0.259	0.210	170	0.11	91
0	0	3569	334	135	0.774	0.241	0.226	189	0.10	92
0	0	5974	1036	83	0.679	0.260	0.208	167	0.11	90
0	0	10630	2110	45	0.535	0.296	0.192	149	0.12	89
0	0	12634	2583	39	0.500	0.340	0.200	158	0.12	90
0	0	11609	2440	43	0.521	0.326	0.200	158	0.12	90
0	0	9915	2087	49	0.552	0.302	0.203	161	0.11	90
0	0	4473	888	111	0.738	0.257	0.223	185	0.10	92
0	0	3398	696	142	0.782	0.238	0.226	189	0.10	92
0	0	3289	576	151	0.793	0.227	0.212	172	0.11	91
0	0	3847	562	129	0.766	0.240	0.217	177	0.10	91
0	0	4175	560	108	0.732	0.229	0.219	180	0.10	92
0	0	5703	897	87	0.689	0.262	0.212	172	0.11	91
0	0	3569	393	135	0.774	0.237	0.223	185	0.10	92
0	0	5974	1035	83	0.679	0.260	0.208	167	0.11	90
0	0	10630	2133	45	0.535	0.294	0.192	148	0.12	89
0	0	12634	2627	39	0.500	0.338	0.199	157	0.12	90
0	0	11609	2476	43	0.521	0.324	0.199	156	0.12	90
0	0	9915	2169	49	0.552	0.298	0.200	158	0.12	90
0	0	4473	931	111	0.738	0.255	0.221	183	0.10	92
0	0	3398	623	142	0.782	0.242	0.230	193	0.09	93
0	0	3289	435	151	0.793	0.235	0.220	181	0.10	92
	0	79216	15138	94		0.267	0.210	170	0.11	91

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 3498

L

APPENDIX L

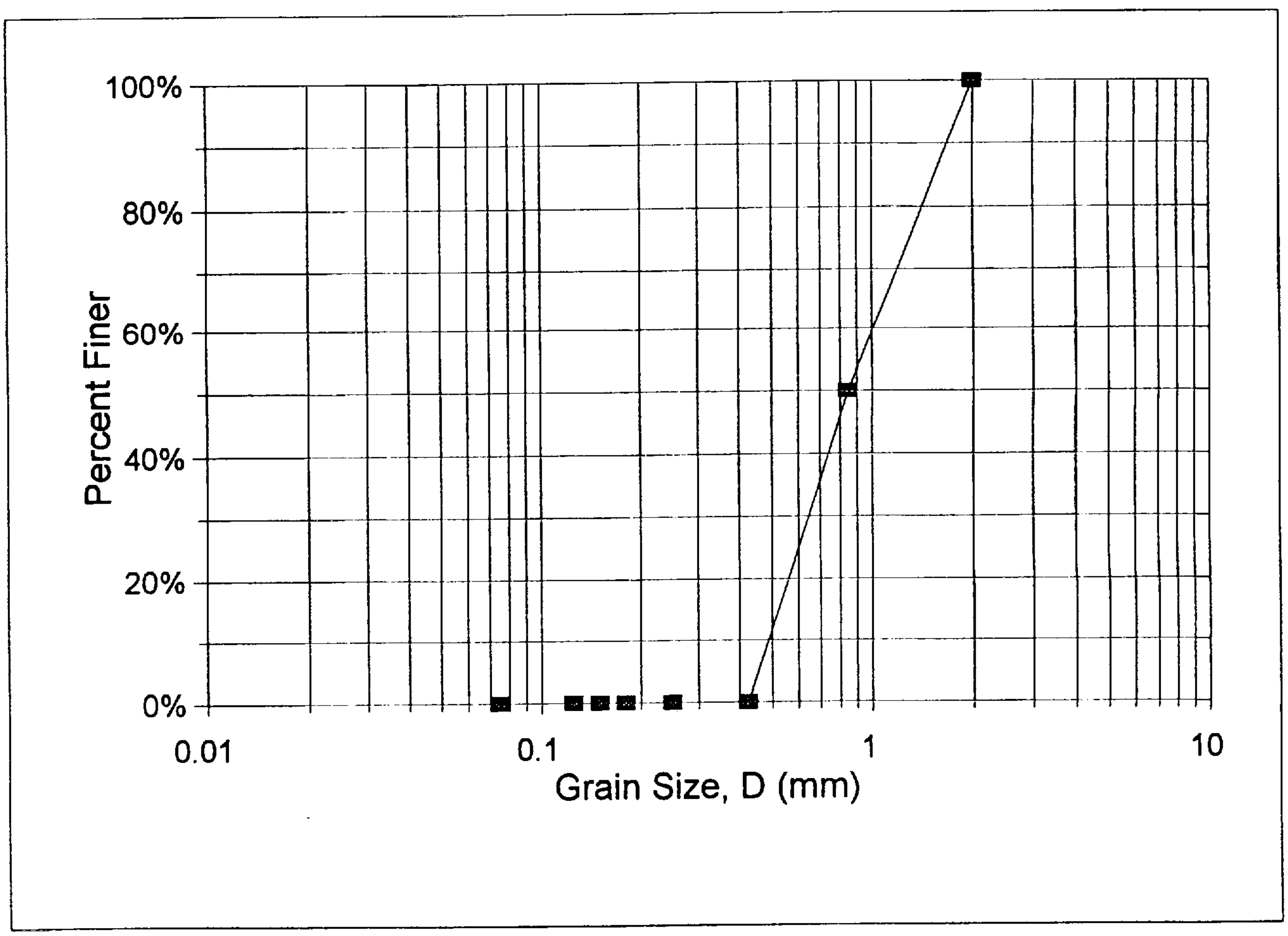
FILTER SYSTEM PILOT TESTING STANDARD SIEVE ANALYSES

Lake Hancock 20/30 Sand

Seive Number	Grain Size (mm)	Weight of Seive	Weight Seive + Sed	Weight of Sed	Percent Retained on Seive	Cummulative Percent Retained	Percent Finer
10	2	474.55	474.69	0.14	0.0%	0.0%	100.0%
20	0.850	445.72	648.32	202.60	47.6%	50.0%	50.0%
40	0.425	422.83	642.84	220.01	51.7%	100.0%	0.0%
60	0.250	393.17	395.85	2.68	0.6%	100.0%	0.0%
80	0.180	390.48	390.57	0.09	0.0%	100.0%	0.0%
100	0.150	380.48	380.48	0.00	0.0%	100.0%	0.0%
120	0.125	364.07	364.12	0.05	0.0%	100.0%	0.0%
200	0.075	375.68	375.73	0.05	0.0%	100.0%	0.0%
PAN		369.28	369.30	0.02	0.0%	100.0%	0.0%
	Total			425.50	100.0%		

D10= 0.0%
D30= 17.0%
D60= 50.0%

Uniformity Coefficient = ERR
Coefficient of Gradiation= ERR

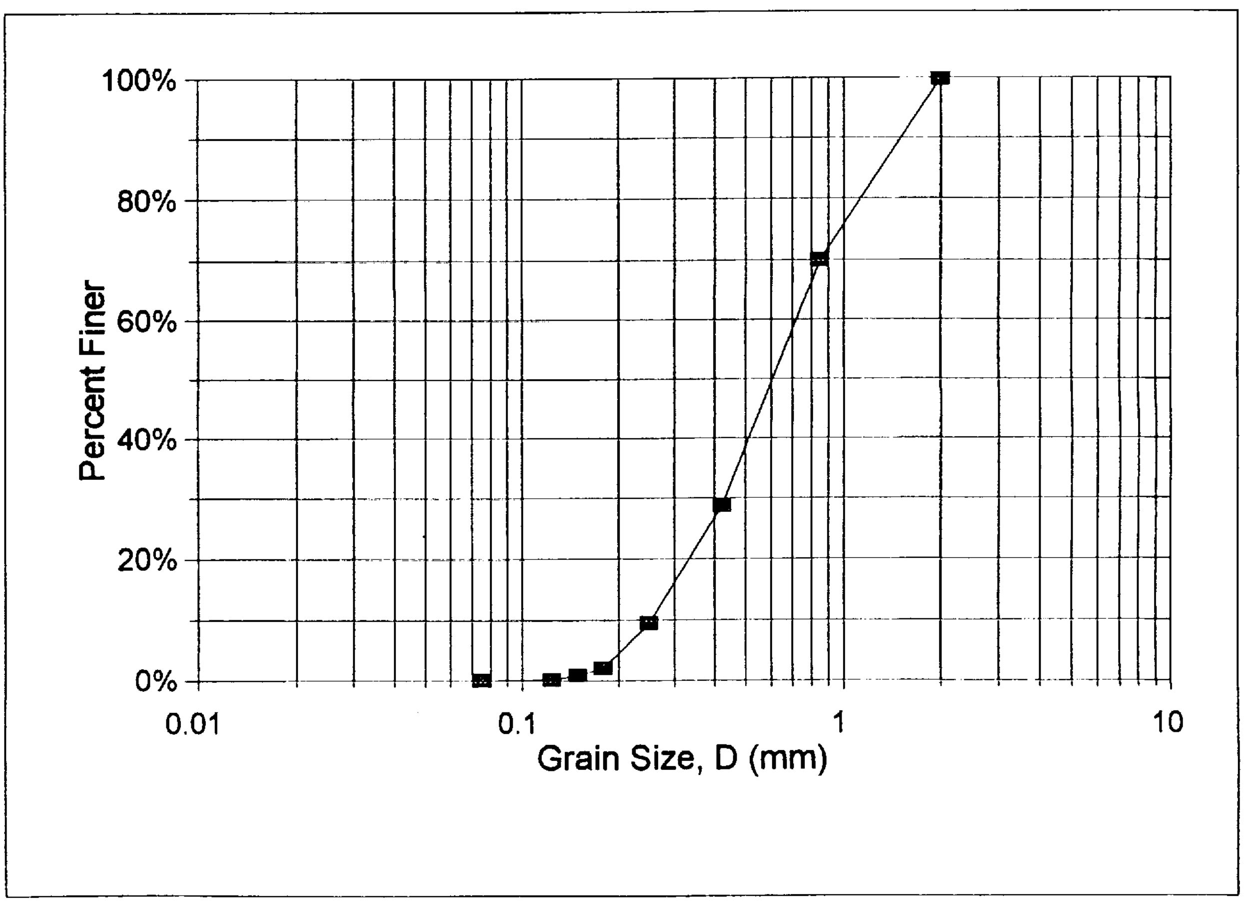


Lake Hancock FDOT Filter Sand

Seive Number	Grain Size (mm)	Weight of Seive	Weight Seive + Sed	Weight of Sed	Percent Retained on Seive	Cummulative Percent Retained	Percent Finer
10	2	474.57	475.33	0.76	0.2%	0.2%	99.8%
20	0.850	445.74	586.20	140.46	29.8%	29.9%	70.1%
40	0.425	423.25	618.02	194.77	41.3%	71.3%	28.7%
60	0.250	393.18	484.01	90.83	19.3%	90.5%	9.5%
80	0.180	390.54	425.52	34.98	7.4%	97.9%	2.1%
100	0.150	380.49	386.25	5.76	1.2%	99.2%	0.8%
120	0.125	364.12	367.27	3.15	0.7%	99.8%	0.2%
200	0.075	375.75	376.57	0.82	0.2%	100.0%	0.0%
PAN		369.32	369.33	0.01	0.0%	100.0%	0.0%
	Total			471.54	100.0%		

D10= 0.00
D30= 0.17
D60= 0.50

Uniformity Coefficient = ERR
Coefficient of Gradiation= ERR



M

APPENDIX M

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 7/30/99 **Filtration Type:** Gravity **Sand Media:** 20/30 Sand **Coagulant Added:** None

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	PARAMETERS													
			pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m³)	Diss. Al (μg/l)
1-Raw	Initial	--	9.16	217	59.7	31	< 5	7800	4	706	13	52	13.6	164	591	60
1-1	5	53.3	9.06	209	61.5	35	13	6857	4	637	14	49	11.0	148	397	408
1-2	20	12.5	8.96	209	60.1	28	< 5	6220	4	513	14	50	9.9	124	364	266
1-3	25	7.5	9.11	206	59.5	16	6	5749	4	448	14	50	6.8	100	350	279
1-4	30	5.0	8.49	205	58.6	42	13	5484	4	415	14	49	8.5	84	342	295
1-5	33	0.0														
2-Raw	Initial	--	9.16	217	59.7	31	< 5	7800	4	706	13	52	13.6	164	591	60
2-1	5	37.7	8.69	212	60.9	25	< 5	6345	4	508	14	51	10.7	132	387	351
2-2	15	17.7	8.43	213	61.2	20	9	6524	4	530	14	51	10.1	124	308	335
2-3	20	3.3	8.40	211	60.4	28	5	5460	4	398	13	50	8.6	100	353	360
2-4	25	0.0														
3-Raw	Initial	--	9.16	217	59.7	31	< 5	7800	4	706	13	52	13.6	164	591	60
3-1	5	68.6	8.14	213	62.2	25	10	6567	4	519	13	50	11.1	144	436	342
3-2	10	23.2	8.36	212	61.6	29	< 5	6074	3	452	14	50	10.3	104	394	350
3-3	15	12.7	8.09	213	61.7	35	10	5964	4	454	14	50	9.5	100	390	359
3-4	20	9.0	8.51	213	61.4	56	22	5881	4	434	14	50	9.1	84	384	366
3-5	25	4.8	8.03	212	61.6	32	< 5	5828	4	417	14	49	9.0	84	390	371
3-6	30	4.6	7.97	214	62.6	30	16	5684	4	406	14	48	9.0	76	384	370
3-7	35	3.1	8.08	213	62.2	26	< 5	5467	4	390	14	47	9.0	76	350	374
3-8	40	0.0														

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 8/2-3/99 **Filtration Type:** Pressure **Sand Media:** 20/30 Sand **Coagulant Added:** None

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	COLUMN PRESSURE (psi)	PARAMETERS													
				pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (μg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m^3)	Diss. Al (μg/l)
1-Raw	Initial	20.7	0	7.45	221	62.2	11	< 5	8301	4	688	14	44	14.3	184	509	91
1-1	12	18.2	0	7.31	222	62.9	14	< 5	6533	4	512	14	43	13.4	76	362	78
1-2	22	18.2	0	7.32	218	62.4	15	< 5	7010	3	564	14	43	13.4	156	385	85
1-3	40	18.5	4	7.35	220	62.9	24	< 5	7423	4	578	14	44	13.6	160	511	90
1-4	62	16.9	5	7.33	221	64.9	14	< 5	6738	4	540	13	44	14.3	164	468	86
1-5	90	16.9	8	7.32	220	64.3	13	< 5	7770	4	640	14	43	15.8	168	471	82
1-6	120	15.0	12	7.30	220	63.9	17	< 5	7789	4	639	13	44	17.3	176	512	82
2-Raw	Initial	18.8	0	7.56	222	59.0	26	6	4328	4	375	20	47	10.0	96	246	342
2-1	60	15.7	0	7.48	222	61.2	11	< 5	3840	4	293	20	46	9.5	92	174	273
2-2	120	15.0	17	7.38	222	59.4	15	< 5	3836	3	291	20	45	7.5	80	203	259
2-3	135	11.9	20	7.41	224	59.3	23	< 5	3676	4	282	20	44	7.0	92	190	187
3-Raw	Initial	17.5	0	7.37	221	60.3	13	< 5	4958	3	332	20	44	8.2	88	222	211
3-1	45	16.3	0	7.33	221	60.0	19	< 5	4460	3	271	21	44	7.0	88	196	184
3-2	90	15.7	12	7.32	221	58.8	11	< 5	4108	3	231	21	45	6.9	84	200	163
3-3	135	11.3	20	7.38	223	59.2	14	< 5	4083	3	245	20	44	6.3	112	218	214

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 8/4/99 **Filtration Type:** Pressure **Sand Media:** 20/30 Sand **Coagulant Added:** Alum, 2.5 mg/l

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	COLUMN PRESSURE (psi)	PARAMETERS													
				pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m³)	Diss. Al (μg/l)
1-Raw	Initial	15.0	0	9.07	217	49.5	20	< 5	4218	5	248	16	46	9.3	132	165	134
1-1	30	20.0	7	7.80	222	42.3	20	< 5	2779	4	94	28	39	4.6	80	68.2	70
1-2	60	13.8	15	7.57	228	40.8	35	13	2793	4	104	31	32	6.0	38	78.1	44
2-Raw	Initial	20.0	0	9.07	217	49.5	20	< 5	4218	5	248	16	46	9.3	132	165	134
2-1	15	20.0	0	7.60	225	40.5	24	< 5	2687	5	94	29	33	4.1	44	64.0	45
2-2	45	18.8	6	7.40	226	41.3	24	< 5	2716	5	111	29	35	4.3	40	74.6	41
2-3	105	20.0	17	7.30	226	41.6	28	< 5	3207	5	174	27	33	6.8	58	104	38
2-4	135	15.0	19	7.27	229	41.2	20	< 5	3130	4	165	31	29	6.8	62	110	37

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 8/31/99-9/1/99 **Filtration Type**: Pressure **Sand Media**: 20/30 Sand **Coagulant Added**: Alum, 5 mg/l

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	COLUMN PRESSURE (psi)	PARAMETERS													
				pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m³)	Diss. Al (μg/l)
1-Raw	Initial	33.4	0	8.90	152	55.8	38	< 5	5755	< 1	837	16	52	11.2	192	306	52
1-1	10	25.0	0	8.10	155	43.6	35	< 5	4578	< 1	512	30	49	8.0	144	165	50
1-2	30	19.4	0	7.24	176	38.8	50	5	5950	< 1	625	36	37	11.9	156	170	45
1-3	45	18.8	0	7.45	169	--	--	< 5	4628	< 1	558	--	36	9.9	152	179	42
1-4	60	17.5	5	7.37	174	35.8	23	< 5	2991	< 1	565	37	33	8.6	168	212	38
1-5	75	16.9	7	7.22	178	38.0	38	7	5870	< 1	617	36	31	8.2	160	220	34
1-6	90	16.2	10	7.12	178	34.0	32	< 5	4624	< 1	624	39	28	6.6	176	245	33
1-7	105	16.2	13	7.13	182	35.6	29	< 5	3026	< 1	636	37	29	6.8	180	116	34
1-8	120	15.0	18	7.07	187	36.9	32	< 5	2926	< 1	531	39	27	6.4	184	115	35
2-Raw	Initial	17.5	0	8.63	167	58.1	32	< 5	2813	< 1	666	17	52	11.6	196	153	67
2-1	0	17.5	0	7.17	187	38.9	54	< 5	3448	< 1	378	37	28	6.6	104	80.2	36
2-2	15	16.9	4	6.95	180	35.9	31	< 5	1892	< 1	482	38	27	5.8	144	89.3	38
2-3	30	16.9	6	6.89	179	34.6	49	< 5	4712	< 1	504	38	26	7.3	152	96.4	38
2-4	45	16.9	8	6.92	181	37.2	40	10	5158	< 1	586	36	27	8.5	168	116	39
2-5	75	17.5	10	6.80	171	38.4	40	< 5	1051	< 1	633	36	28	7.8	180	118	41
2-6	90	16.9	14	6.72	184	36.9	25	< 5	1742	< 1	868	38	26	8.9	216	228	39
2-7	105	15.0	18	6.93	178	34.9	57	9	2596	< 1	729	37	30	11.1	254	314	38
3-Raw	Initial	17.5	0	7.52	172	56.6	33	< 5	4463	< 1	852	16	52	10.4	192	142	51
3-1	15	17.5	0	7.06	178	38.6	38	< 5	2204	< 1	333	37	30	4.7	108	91.4	39
3-2	30	16.9	0	6.86	179	35.4	19	< 5	699	< 1	428	38	26	5.1	140	145	38
3-3	45	16.9	4	6.82	181	37.1	34	< 5	4078	< 1	393	37	26	5.3	144	167	39
3-4	60	16.9	6	6.89	167	38.2	26	< 5	4098	< 1	603	37	26	8.3	144	182	40
3-5	75	16.3	9	6.74	167	33.3	41	< 5	5892	< 1	635	38	25	7.1	164	187	40
3-6	90	16.3	12	6.72	182	37.7	37	5	3885	< 1	677	38	92	6.9	164	208	41
3-7	105	15.0	16	6.72	189	35.3	80	19	3708	< 1	653	39	88	7.5	172	211	42
3-8	120	13.8	18	6.73	189	35.5	39	246	4166	< 1	680	37	27	7.4	176	245	41

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 9/10/99 **Filtration Type:** Gravity **Sand Media:** FDOT Filter Sand **Coagulant Added:** None

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	PARAMETERS													
			pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m^3)	Diss. Al (μg/l
1-Raw	Initial	14.4	9.72	245	57.1	43	< 5	4766	6	580	16	50	8.5	116	172	261
1-1	10	0	9.47	219	59.6	42	< 5	2656	5	232	16	46	4.2	50	56.3	233
2-Raw	Initial	18.8	9.72	245	57.1	43	< 5	4766	6	580	16	50	8.5	116	172	261
2-1	10	9.4	9.61	223	53.9	26	< 5	2537	5	206	16	49	1.7	40	53.5	290
2-2	20	0	9.52	217	52.6	89	< 5	2372	7	181	16	49	3.2	34	49.9	291
3-Raw	Initial	18.8	9.72	245	57.1	43	< 5	4766	6	580	16	50	8.5	116	172	261
3-1	10	9.4	9.51	210	53.9	37	< 5	2735	6	225	15	48	3.9	42	78.8	266
3-2	20	5.0	9.42	211	54.8	26	< 5	2565	6	198	16	46	3.4	30	73.1	246
3-3	30	2.5	9.38	213	55.8	46	< 5	2547	5	181	16	46	3.5	18	53.5	207

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 9/10/99 **Filtration Type:** Pressure **Sand Media:** FDOT Filter Sand **Coagulant Added:** None

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	COLUMN PRESSURE (psi)	PARAMETERS													
				pH	Cond. (µmho/cm)	Alk. (mg/l)	NH_3 (µg/l)	NO_3 (µg/l)	Total N (µg/l)	Ortho-P (µg/l)	Total P (µg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m³)	Diss. Al (µg/l)
1-Raw	Initial	20.0	0	9.56	256	57.1	43	< 5	4766	6	580	16	50	8.5	116	172	261
1-1	10	16.3	5	9.12	260	55.6	41	< 5	2701	5	237	16	48	3.5	36	77.9	198
1-2	20	15.0	10	8.76	263	56.5	36	< 5	2913	5	244	16	48	4.0	36	77.9	154
1-3	30	15.0	16	8.71	271	55.2	37	< 5	3188	5	308	16	49	5.0	54	97.3	109
1-4	40	12.5	20	8.50	280	56.0	40	6	3222	4	324	16	48	4.4	48	114	147
2-Raw	Initial	17.5	0	9.56	256	57.1	43	< 5	4766	6	580	16	50	8.5	116	172	261
2-1	10	16.9	5	9.16	243	56.8	70	8	2902	8	255	16	50	3.4	50	101	139
2-2	20	15.0	8	8.50	251	56.1	33	< 5	2978	5	269	16	48	4.6	48	111	127
2-3	30	13.8	16	8.43	266	55.1	35	< 5	4325	5	478	16	48	4.0	78	146	96
2-4	37	16.3	20	8.31	271	56.7	78	6	4017	13	417	16	54	6.2	80	150	96
3-Raw	Initial	17.5	0	9.56	256	57.1	43	< 5	4766	6	580	16	50	8.5	116	172	261
3-1	10	16.9	7	8.99	247	57.3	279	5	3060	5	267	16	47	4.3	48	106	76
3-2	20	16.3	14	8.76	265	58.4	105	7	3355	9	313	16	50	5.0	54	118	76
3-3	30	15.0	20	8.50	275	57.0	61	5	3919	7	390	16	47	5.9	72	134	72

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 9/13/99 **Filtration Type:** Pressure **Sand Media:** FDOT Filter Sand **Coagulant Added:** Alum, 2.5 mg/l

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	COLUMN PRESSURE (psi)	PARAMETERS													
				pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m³)	Diss. Al (μg/l)
1-Raw	Initial	31.3	0	9.02	190	55.6	44	< 5	5105	6	590	16	45	9.1	116	174	165
1-1	10	15.0	12	8.60	190	52.6	88	8	2696	8	205	19	44	4.8	34	62.6	220
1-2	18	0	20														
2-Raw	Initial	22.5	0	9.02	190	55.6	44	< 5	5105	6	590	16	45	9.1	116	174	165
2-1	10	16.3	8	7.72	223	46.6	42	5	2547	5	182	26	33	4.4	36	65.8	68
2-2	20	16.3	16	7.34	215	45.3	59	9	2343	5	158	28	29	5.3	40	68.2	51
2-3	25	0	20														
3-Raw	Initial	31.3	0	9.02	190	55.6	44	< 5	5105	6	590	16	45	9.1	116	174	165
3-1	10	20.0	16	7.49	193	48.9	49	< 5	2782	6	211	23	36	5.6	44	84.0	60
3-2	18	0	20														

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 9/14/99 **Filtration Type**: Pressure **Sand Media**: FDOT Filter Sand **Coagulant Added**: Alum, 5 mg/l

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	COLUMN PRESSURE (psi)	PARAMETERS													
				pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m³)	Diss. Al (μg/l)
1-Raw 1-1 1-2	Initial 10 20	30.1 15.0 0	0 12 20	7.55 7.00	203 213	58.1 38.1	34 52	< 5 8	5357 2052	5 5	604 130	16 35	45 25	11.4 4.2	122 21	188 31.6	69 42
2-Raw 2-1 2-2	Initial 10 20	30.1 22.5 0	0 10 20	7.55 6.92	203 212	44.2 38.1	50 52	10 8	3040 2052	5 5	278 130	28 35	41 25	11.4 6.5	122 72	188 67.5	46 42

RESULTS OF FILTERABILITY PILOT TESTING PERFORMED ON LAKE HANCOCK SURFACE WATER COLLECTED AT STRUCTURE P-11

Test Date: 9/16/99 **Filtration Type:** Pressure **Sand Media:** FDOT Filter Sand **Coagulant Added:** None

SAMPLE RUN	TOTAL RUN TIME (minutes)	FLOW RATE (cm/min)	COLUMN PRESSURE (psi)	PARAMETERS													
				pH	Cond. (μmho/cm)	Alk. (mg/l)	NH_3 (μg/l)	NO_3 (μg/l)	Total N (μg/l)	Ortho-P (μg/l)	Total P (μg/l)	SO_4 (mg/l)	Color (Pt-Co)	BOD (mg/l)	TSS (mg/l)	Chyl-a (mg/m^3)	Diss. Al (μg/l)
1-Raw	Initial	57.6	0	7.64	185	57.3	37	5	5239	6	696	16	47	11.6	78.7	143	70
1-1	10	25.0	11	7.77	191	58.7	85	6	3711	5	364	16	44	8.4	45.3	85.8	75
1-2	20	15.0	17	7.80	200	57.7	30	< 5	3629	5	355	16	43	8.4	41.3	88.6	72
1-3	30	6.3	20	7.72	196	58.9	56	15	3363	6	322	16	44	6.8	36.0	77.7	64

N

APPENDIX N

CONCEPTUAL OPINIONS OF PROBABLE CONSTRUCTION COST FOR THE LAKE HANCOCK OUTFALL TREATMENT ALTERNATIVES

CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST FOR THE MEDIA FILTRATION TREATMENT ALTERNATIVE

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT COST ($)	TOTAL COST ($)
1.	Land Purchase	AC	100	5,000.00	500,000.00
2.	Clearing and Grubbing	AC	80	2,000.00	160,000.00
3.	Earthwork	CY	75,000	6.00	450,000.00
4.	Fencing	LF	8,500	15.00	127,500.00
5.	Entrance Road	SY	8,000	30.00	240,000.00
6.	Influent Piping	LS	--	--	500,000.00
7.	Discharge Piping	LS	--	--	300,000.00
8.	Influent Pump Station	LS	--	--	300,000.00
9.	Backwash Pump Station	LS	--	--	100,000.00
10.	Sand Filters	EA	10	700,000.00	7,000,000.00
10.	Electrical	LS	--	--	200,000.00
11.	Miscellaneous	LS	--	--	250,000.00
12.	Mobilization, Bonds, Insurance, Etc.	LS	--	--	962,750.00
				Sub-Total	$ 11,090,250.00
				20% Contingency:	2,218,050.00
				TOTAL:	**$ 13,308,300.00**

CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST FOR THE WETLAND TREATMENT ALTERNATIVE

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT COST ($)	TOTAL COST ($)
1.	Land Purchase	AC	600	5,000.00	3,000,000.00
2.	Clearing and Grubbing	AC	500	2,000.00	1,000,000.00
3.	Earthwork	CY	250,000	6.00	1,500,000.00
4.	Entrance Road	SY	5,000	30.00	150,000.00
5.	Vegetation	AC	480	3,000.00	1,440,000.00
6.	Influent Piping	LS	--	--	1,000,000.00
7.	Influent Pump Station	LS	--	--	350,000.00
8.	Electrical	LS	--	--	50,000.00
9.	Miscellaneous	LS	--	--	250,000.00
10.	Mobilization, Bonds, Insurance, Etc.	LS	--	--	574,000.00
				Sub-Total	$ 9,314,000.00
				20% Contingency:	1,862,800.00
				TOTAL:	**$ 11,176,800.00**

CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST FOR THE SETTLING POND TREATMENT ALTERNATIVE

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT COST ($)	TOTAL COST ($)
1.	Land Purchase	AC	200	5,000.00	1,000,000.00
2.	Clearing and Grubbing	AC	175	2,000.00	350,000.00
3.	Earthwork	CY	250,000	6.00	1,500,000.00
4.	Fencing	LF	13,000	15.00	195,000.00
5.	Entrance Road	SY	15,000	30.00	450,000.00
6.	Influent Piping	LS	--	--	1,000,000.00
7.	Discharge Piping	LS	--	--	250,000.00
8.	Influent Pump Station	LS	--	--	325,000.00
9.	Chemical Treatment System	LS	--	--	300,000.00
10.	Electrical	LS	--	--	150,000.00
11.	Miscellaneous	LS	--	--	300,000.00
12.	Mobilization, Bonds, Insurance, Etc.	LS	--	--	482,000.00
				Sub-Total	$ 6,302,000.00
				20% Contingency:	1,260,400.00
				TOTAL:	**$ 7,562,400.00**

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APPENDIX O

TROPHIC STATE MODELING FOR EVALUATION OF RUNOFF/ BASEFLOW TREATMENT OPTIONS

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK WITH 25 PERCENT REMOVAL OF IDENTIFIED RUNOFF/BASEFLOW INPUTS

Month	Initial P Conc.	Hydrologic and Mass Inputs: Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Hydrologic and Mass: Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.218	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	2.53	953	2894	730	0
February	0.191	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	3.08	1160	3015	711	0
March	0.191	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	4.57	1721	3982	930	0
April	0.188	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.55	2090	1479	361	0
May	0.209	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	6.18	2327	3647	896	0
June	0.190	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.59	2105	8524	1869	0
July	0.166	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.53	2083	10552	2218	0
August	0.175	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	5.23	1970	9639	2091	0
September	0.177	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.58	1725	8191	1804	0
October	0.181	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	4.02	1514	2959	720	0
November	0.214	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.91	1096	2302	611	0
December	0.217	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	2.36	889	2400	610	0
January	0.196	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	3.08	1160	2687	648	0
February	0.195	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	4.57	1721	2454	594	0
March	0.197	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	5.55	2090	3613	864	0
April	0.191	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	6.18	2327	1242	308	0
May	0.211	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.59	2105	3869	952	0
June	0.188	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.53	2083	8547	1863	0
July	0.166	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.23	1970	10665	2238	0
August	0.175	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.58	1725	9884	2131	0
September	0.175	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.02	1514	8401	1837	0
October	0.179	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.91	1096	3377	810	0
November	0.210	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.36	889	2509	658	0
December	0.214	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	3.08	1160	2129	543	0
January	0.199	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	4.57	1721	2126	525	0
February	0.201	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	5.55	2090	2085	517	0
March	0.201	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	6.18	2327	3375	819	0
April	0.193	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.59	2105	1464	362	0
May	0.208	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.53	2083	3892	950	0
June	0.188	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.23	1970	8660	1883	0
July	0.165	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	4.58	1725	10910	2277	0
August	0.173	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.02	1514	10095	2163	0
September	0.174	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	2.91	1096	8819	1909	0
October	0.177	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.36	889	3584	850	0
November	0.208	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	3.08	1160	2238	587	0
December	0.218	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	4.57	1721	1568	410	0
Totals:		49.72	18724		1039	56284	28562	4209	4646	39420	79216	73667		52.13	19631	59585	13550	0

Lake Surface Area (acres):	4519	Runoff/Baseflow Input (ac-ft/yr):	56284	Runoff/Baseflow Total P Input (kg/yr):	28562
Dry Season Seepage Inflow (ac-ft):	1343	Wet Season Seepage Inflow (ac-ft):	2866	Dry Season P Input (kg):	1148
Misc. Total P Inputs (kg/day):	108	Inflow Mass Removal (%):	-25		

Wet Seas

Losses										
nt System Losses		Total Losses		Mean Detention Time	Phosphorus Retention Coeff.	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI Value
% Removal	(kg)	(ac-ft)	(kg)	(days)		(g/m^2)	(mg/l)	(mg/m^3	(m)	
-25	348	3847	1078	129	0.766	0.212	0.191	148	0.12	89
-25	381	4175	1091	108	0.732	0.200	0.191	148	0.12	89
-25	524	5703	1454	87	0.689	0.231	0.188	144	0.13	88
-25	322	3569	683	135	0.774	0.221	0.209	168	0.11	91
-25	550	5974	1446	83	0.679	0.238	0.190	146	0.12	89
-25	994	10630	2863	45	0.535	0.255	0.166	120	0.15	86
-25	1147	12634	3365	39	0.500	0.298	0.175	130	0.14	87
-25	1050	11609	3140	43	0.521	0.288	0.177	132	0.14	87
-25	890	9915	2694	49	0.552	0.269	0.181	136	0.13	88
-25	371	4473	1090	111	0.738	0.246	0.214	174	0.11	91
-25	270	3398	881	142	0.782	0.228	0.217	177	0.10	91
-25	294	3289	904	151	0.793	0.209	0.196	153	0.12	89
-25	348	3847	995	129	0.766	0.216	0.195	153	0.12	89
-25	381	4175	974	108	0.732	0.207	0.197	154	0.12	89
-25	524	5703	1388	87	0.689	0.235	0.191	147	0.12	89
-25	322	3569	629	135	0.774	0.224	0.211	171	0.11	91
-25	550	5974	1502	83	0.679	0.235	0.188	144	0.13	88
-25	994	10630	2856	45	0.535	0.255	0.166	120	0.15	86
-25	1147	12634	3386	39	0.500	0.297	0.175	130	0.14	87
-25	1050	11609	3181	43	0.521	0.286	0.175	130	0.14	87
-25	890	9915	2728	49	0.552	0.267	0.179	135	0.14	87
-25	371	4473	1181	111	0.738	0.241	0.210	169	0.11	91
-25	270	3398	926	142	0.782	0.225	0.214	174	0.10	91
-25	294	3289	837	151	0.793	0.213	0.199	157	0.12	90
-25	348	3847	872	129	0.766	0.223	0.201	159	0.11	90
-25	381	4175	898	108	0.732	0.211	0.201	159	0.11	90
-25	524	5703	1343	87	0.689	0.237	0.193	149	0.12	89
-25	322	3569	684	135	0.774	0.221	0.208	168	0.11	91
-25	550	5974	1501	83	0.679	0.235	0.188	144	0.13	88
-25	994	10630	2877	45	0.535	0.254	0.165	120	0.15	86
-25	1147	12634	3424	39	0.500	0.295	0.173	128	0.14	87
-25	1050	11609	3212	43	0.521	0.284	0.174	129	0.14	87
-25	890	9915	2799	49	0.552	0.263	0.177	132	0.14	87
-25	371	4473	1220	111	0.738	0.239	0.208	167	0.11	90
-25	270	3398	857	142	0.782	0.229	0.218	179	0.10	91
-25	294	3289	704	151	0.793	0.220	0.206	165	0.11	90
	7141	79216	20691	94		0.241	0.191	148	0.13	89

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 3498

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK WITH 50 PERCENT REMOVAL OF IDENTIFIED RUNOFF/BASEFLOW INPUTS

Month	Initial P Conc.	Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.206	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	2.53	953	2894	682	0
February	0.177	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	3.08	1160	3015	652	0
March	0.174	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	4.57	1721	3982	841	0
April	0.168	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.55	2090	1479	330	0
May	0.194	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	6.18	2327	3647	816	0
June	0.169	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.59	2105	8524	1622	0
July	0.139	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.53	2083	10552	1876	0
August	0.149	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	5.23	1970	9639	1788	0
September	0.152	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.58	1725	8191	1558	0
October	0.157	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	4.02	1514	2959	651	0
November	0.200	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.91	1096	2302	574	0
December	0.204	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	2.36	889	2400	573	0
January	0.182	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	3.08	1160	2687	601	0
February	0.180	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	4.57	1721	2454	545	0
March	0.180	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	5.55	2090	3613	781	0
April	0.171	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	6.18	2327	1242	281	0
May	0.196	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.59	2105	3869	867	0
June	0.167	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.53	2083	8547	1616	0
July	0.139	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.23	1970	10665	1894	0
August	0.149	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.58	1725	9884	1823	0
September	0.150	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.02	1514	8401	1587	0
October	0.156	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.91	1096	3377	732	0
November	0.196	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.36	889	2509	616	0
December	0.202	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	3.08	1160	2129	509	0
January	0.186	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	4.57	1721	2126	487	0
February	0.186	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	5.55	2090	2085	475	0
March	0.183	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	6.18	2327	3375	741	0
April	0.173	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.59	2105	1464	331	0
May	0.194	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.53	2083	3892	866	0
June	0.167	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.23	1970	8660	1634	0
July	0.139	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	4.58	1725	10910	1926	0
August	0.148	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.02	1514	10095	1849	0
September	0.149	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	2.91	1096	8819	1648	0
October	0.154	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.36	889	3584	768	0
November	0.194	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	3.08	1160	2238	552	0
December	0.206	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	4.57	1721	1568	385	0
Totals:		49.72	18724		1039	56284	28562	4209	4646	39420	79216	73667		52.13	19631	59585	11962	0

Lake Surface Area (acres): 4519
Runoff/Baseflow Input (ac-ft/yr): 56284
Runoff/Baseflow Total P Input (kg/yr): 28562

Dry Season Seepage Inflow (ac-ft): 1343
Wet Season Seepage Inflow (ac-ft): 2866
Dry Season P Input (kg): 1148
Wet Seas

Misc. Total P Inputs (kg/day): 108
Inflow Mass Removal (%): -50

Losses				Mean Detention Time	Phosphorus Retention Coeff.	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI Value
nt System Losses		Total Losses								
% Removal	(kg)	(ac-ft)	(kg)	(days)		(g/m^2)	(mg/l)	(mg/m^3	(m)	
-50	695	3847	1377	129	0.766	0.196	0.177	132	0.14	87
-50	761	4175	1413	108	0.732	0.183	0.174	129	0.14	87
-50	1048	5703	1889	87	0.689	0.208	0.168	123	0.15	86
-50	643	3569	974	135	0.774	0.206	0.194	151	0.12	89
-50	1100	5974	1916	83	0.679	0.212	0.169	124	0.15	86
-50	1988	10630	3609	45	0.535	0.214	0.139	93	0.19	82
-50	2295	12634	4171	39	0.500	0.254	0.149	103	0.18	84
-50	2100	11609	3887	43	0.521	0.247	0.152	106	0.17	84
-50	1781	9915	3339	49	0.552	0.234	0.157	111	0.16	85
-50	741	4473	1392	111	0.738	0.230	0.200	157	0.12	90
-50	540	3398	1114	142	0.782	0.215	0.204	163	0.11	90
-50	589	3289	1162	151	0.793	0.195	0.182	138	0.13	88
-50	695	3847	1296	129	0.766	0.200	0.180	136	0.13	88
-50	761	4175	1306	108	0.732	0.188	0.180	135	0.13	87
-50	1048	5703	1830	87	0.689	0.211	0.171	126	0.14	86
-50	643	3569	925	135	0.774	0.208	0.196	153	0.12	89
-50	1100	5974	1967	83	0.679	0.209	0.167	122	0.15	86
-50	1988	10630	3603	45	0.535	0.214	0.139	93	0.19	82
-50	2295	12634	4189	39	0.500	0.253	0.149	103	0.18	84
-50	2100	11609	3922	43	0.521	0.245	0.150	104	0.17	84
-50	1781	9915	3368	49	0.552	0.232	0.156	110	0.17	84
-50	741	4473	1473	111	0.738	0.225	0.196	153	0.12	89
-50	540	3398	1156	142	0.782	0.213	0.202	160	0.11	90
-50	589	3289	1098	151	0.793	0.199	0.186	142	0.13	88
-50	695	3847	1183	129	0.766	0.206	0.186	142	0.13	88
-50	761	4175	1236	108	0.732	0.192	0.183	139	0.13	88
-50	1048	5703	1790	87	0.689	0.213	0.173	128	0.14	87
-50	643	3569	974	135	0.774	0.206	0.194	151	0.12	89
-50	1100	5974	1966	83	0.679	0.209	0.167	122	0.15	86
-50	1988	10630	3621	45	0.535	0.213	0.139	93	0.19	82
-50	2295	12634	4221	39	0.500	0.251	0.148	102	0.18	83
-50	2100	11609	3949	43	0.521	0.244	0.149	103	0.18	84
-50	1781	9915	3429	49	0.552	0.229	0.154	108	0.17	84
-50	741	4473	1509	111	0.738	0.223	0.194	151	0.12	89
-50	540	3398	1092	142	0.782	0.216	0.206	164	0.11	90
-50	589	3289	973	151	0.793	0.206	0.192	149	0.12	89
	14281	79216	26243	94		0.216	0.172	127	0.15	86

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 3498

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK WITH 75 PERCENT REMOVAL OF IDENTIFIED RUNOFF/BASEFLOW INPUTS

Month	Initial P Conc.	Hydrologic and Mass Inputs												Hydrologic and Mass				
		Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.193	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	2.53	953	2894	634	0
February	0.162	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	3.08	1160	3015	593	0
March	0.157	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	4.57	1721	3982	752	0
April	0.149	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.55	2090	1479	299	0
May	0.179	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	6.18	2327	3647	737	0
June	0.149	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.59	2105	8524	1374	0
July	0.113	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.53	2083	10552	1535	0
August	0.123	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	5.23	1970	9639	1485	0
September	0.126	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.58	1725	8191	1312	0
October	0.133	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	4.02	1514	2959	581	0
November	0.185	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.91	1096	2302	536	0
December	0.192	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	2.36	889	2400	535	0
January	0.169	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	3.08	1160	2687	555	0
February	0.166	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	4.57	1721	2454	496	0
March	0.162	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	5.55	2090	3613	699	0
April	0.151	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	6.18	2327	1242	255	0
May	0.181	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.59	2105	3869	782	0
June	0.147	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.53	2083	8547	1369	0
July	0.113	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	5.23	1970	10665	1550	0
August	0.123	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.58	1725	9884	1514	0
September	0.126	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	4.02	1514	8401	1336	0
October	0.132	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.91	1096	3377	654	0
November	0.182	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	2.36	889	2509	576	0
December	0.190	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	3.08	1160	2129	476	0
January	0.172	2.42	911	0.045	50.6	2739	1390	196	168	3348	3847	4957	1.045	4.57	1721	2126	450	0
February	0.171	2.65	998	0.045	55.4	3000	1522	177	152	3024	4175	4753	0.923	5.55	2090	2085	433	0
March	0.166	3.65	1375	0.045	76.3	4132	2097	196	168	3348	5703	5689	0.809	6.18	2327	3375	663	0
April	0.153	2.24	844	0.045	46.8	2536	1287	190	162	3240	3569	4736	1.076	5.59	2105	1464	299	0
May	0.179	3.83	1442	0.045	80.0	4336	2200	196	168	3348	5974	5796	0.787	5.53	2083	3892	781	0
June	0.147	6.92	2606	0.045	144.6	7834	3975	190	162	3240	10630	7522	0.574	5.23	1970	8660	1384	0
July	0.112	7.99	3009	0.045	167.0	9045	4590	581	709	3348	12634	8814	0.566	4.58	1725	10910	1576	0
August	0.122	7.31	2753	0.045	152.8	8275	4199	581	709	3348	11609	8409	0.587	4.02	1514	10095	1536	0
September	0.125	6.20	2335	0.045	129.6	7019	3562	562	686	3240	9915	7617	0.623	2.91	1096	8819	1388	0
October	0.131	2.58	972	0.045	53.9	2921	1482	581	709	3348	4473	5593	1.014	2.36	889	3584	687	0
November	0.180	1.88	708	0.045	39.3	2128	1080	562	686	3240	3398	5045	1.204	3.08	1160	2238	516	0
December	0.193	2.05	772	0.045	42.8	2321	1178	196	168	3348	3289	4736	1.168	4.57	1721	1568	359	0
Totals:		49.72	18724		1039	56284	28562	4209	4646	39420	79216	73667		52.13	19631	59585	10374	0

Lake Surface Area (acres): 4519

Runoff/Baseflow Input (ac-ft/yr): 56284

Runoff/Baseflow Total P Input (kg/yr): 28562

Dry Season Seepage Inflow (ac-ft): 1343

Wet Season Seepage Inflow (ac-ft): 2866

Dry Season P Input (kg): 1148

Wet Seas

Misc. Total P Inputs (kg/day): 108

Inflow Mass Removal (%): -75

Losses										
nt System Losses		Total Losses		Mean Detention Time	Phosphorus Retention Coeff.	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI Value
% Removal	(kg)	(ac-ft)	(kg)	(days)		(g/m^2)	(mg/l)	(mg/m^3	(m)	
-75	1043	3847	1677	129	0.766	0.179	0.162	116	0.16	85
-75	1142	4175	1735	108	0.732	0.165	0.157	112	0.16	85
-75	1573	5703	2325	87	0.689	0.184	0.149	103	0.18	84
-75	965	3569	1264	135	0.774	0.190	0.179	134	0.14	87
-75	1650	5974	2387	83	0.679	0.186	0.149	103	0.18	84
-75	2981	10630	4356	45	0.535	0.173	0.113	69	0.26	78
-75	3442	12634	4977	39	0.500	0.210	0.123	78	0.23	80
-75	3149	11609	4634	43	0.521	0.206	0.126	81	0.22	80
-75	2671	9915	3983	49	0.552	0.199	0.133	88	0.21	81
-75	1112	4473	1693	111	0.738	0.213	0.185	141	0.13	88
-75	810	3398	1346	142	0.782	0.202	0.192	149	0.12	89
-75	883	3289	1419	151	0.793	0.181	0.169	124	0.15	86
-75	1043	3847	1598	129	0.766	0.184	0.166	120	0.15	86
-75	1142	4175	1638	108	0.732	0.170	0.162	117	0.16	85
-75	1573	5703	2272	87	0.689	0.187	0.151	105	0.17	84
-75	965	3569	1220	135	0.774	0.192	0.181	136	0.13	88
-75	1650	5974	2432	83	0.679	0.184	0.147	101	0.18	83
-75	2981	10630	4350	45	0.535	0.173	0.113	69	0.26	78
-75	3442	12634	4992	39	0.500	0.209	0.123	78	0.23	80
-75	3149	11609	4663	43	0.521	0.205	0.126	80	0.22	80
-75	2671	9915	4008	49	0.552	0.197	0.132	87	0.21	81
-75	1112	4473	1766	111	0.738	0.209	0.182	137	0.13	88
-75	810	3398	1386	142	0.782	0.200	0.190	147	0.12	89
-75	883	3289	1359	151	0.793	0.185	0.172	127	0.14	87
-75	1043	3847	1493	129	0.766	0.189	0.171	126	0.14	86
-75	1142	4175	1574	108	0.732	0.174	0.166	120	0.15	86
-75	1573	5703	2236	87	0.689	0.189	0.153	107	0.17	84
-75	965	3569	1264	135	0.774	0.190	0.179	134	0.14	87
-75	1650	5974	2431	83	0.679	0.184	0.147	101	0.18	83
-75	2981	10630	4365	45	0.535	0.173	0.112	68	0.26	78
-75	3442	12634	5018	39	0.500	0.207	0.122	77	0.23	79
-75	3149	11609	4686	43	0.521	0.203	0.125	80	0.23	80
-75	2671	9915	4060	49	0.552	0.194	0.131	85	0.21	81
-75	1112	4473	1798	111	0.738	0.207	0.180	136	0.13	88
-75	810	3398	1326	142	0.782	0.203	0.193	150	0.12	89
-75	883	3289	1243	151	0.793	0.191	0.178	134	0.14	87
	21422	79216	31796	94		0.191	0.153	107	0.18	84

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 3498

P

APPENDIX P

TROPHIC STATE MODELING FOR EVALUATION OF SEDIMENT REMOVAL OPTIONS

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK WITH SEDIMENT DREDGING/REMOVAL

Month	Initial P Conc.	Hydrologic and Mass Inputs: Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Hydrologic and Mass: Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.111	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	2.53	953	2894	367	0
February	0.094	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	3.08	1160	3015	366	0
March	0.103	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	4.57	1721	3982	523	0
April	0.110	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	5.55	2090	1479	192	0
May	0.100	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	6.18	2327	3647	484	0
June	0.115	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.59	2105	8524	1285	0
July	0.130	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	5.53	2083	10552	1759	0
August	0.141	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	5.23	1970	9639	1649	0
September	0.137	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	4.58	1725	8191	1368	0
October	0.134	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	4.02	1514	2959	458	0
November	0.117	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	2.91	1096	2302	323	0
December	0.111	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	2.36	889	2400	297	0
January	0.090	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	3.08	1160	2687	310	0
February	0.097	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	4.57	1721	2454	307	0
March	0.106	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	5.55	2090	3613	485	0
April	0.112	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	6.18	2327	1242	164	0
May	0.102	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	5.59	2105	3869	514	0
June	0.114	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.53	2083	8547	1283	0
July	0.130	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	5.23	1970	10665	1775	0
August	0.140	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	4.58	1725	9884	1681	0
September	0.136	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	4.02	1514	8401	1393	0
October	0.133	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	2.91	1096	3377	515	0
November	0.114	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	2.36	889	2509	346	0
December	0.110	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	3.08	1160	2129	264	0
January	0.092	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	4.57	1721	2126	251	0
February	0.100	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	5.55	2090	2085	267	0
March	0.108	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	6.18	2327	3375	460	0
April	0.113	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	5.59	2105	1464	193	0
May	0.100	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	5.53	2083	3892	514	0
June	0.114	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.23	1970	8660	1297	0
July	0.129	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	4.58	1725	10910	1805	0
August	0.139	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	4.02	1514	10095	1706	0
September	0.135	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	2.91	1096	8819	1447	0
October	0.131	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	2.36	889	3584	539	0
November	0.113	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	3.08	1160	2238	310	0
December	0.111	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	4.57	1721	1568	200	0
Totals:		49.72	18724		1039	56284	28562	4209	4646	7884	79216	42131		52.13	19631	59585	9072	0

Lake Surface Area (acres): 4519

Runoff/Baseflow Input (ac-ft/yr): 56284

Runoff/Baseflow Total P Input (kg/yr): 28562

Dry Season Seepage Inflow (ac-ft): 1343

Wet Season Seepage Inflow (ac-ft): 2866

Dry Season P Input (kg): 1148

Wet Seas

Misc. Total P Inputs (kg/day): 21.6

Inflow Mass Removal (%): 0

Losses										
nt System Losses		Total Losses		Mean Detention Time	Phosphorus Retention Coeff.	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI
% Removal	(kg)	(ac-ft)	(kg)	(days)		(g/m^2)	(mg/l)	(mg/m^3	(m)	Value
0	0	3847	367	129	0.766	0.104	0.094	53	0.34	74
0	0	4175	366	108	0.732	0.108	0.103	60	0.30	76
0	0	5703	523	87	0.689	0.136	0.110	67	0.27	77
0	0	3569	192	135	0.774	0.107	0.100	58	0.31	75
0	0	5974	484	83	0.679	0.144	0.115	71	0.25	78
0	0	10630	1285	45	0.535	0.199	0.130	84	0.21	81
0	0	12634	1759	39	0.500	0.239	0.141	95	0.19	82
0	0	11609	1649	43	0.521	0.223	0.137	91	0.20	82
0	0	9915	1368	49	0.552	0.200	0.134	89	0.20	81
0	0	4473	458	111	0.738	0.134	0.117	72	0.25	78
0	0	3398	323	142	0.782	0.116	0.111	67	0.27	77
0	0	3289	297	151	0.793	0.096	0.090	50	0.36	73
0	0	3847	310	129	0.766	0.108	0.097	55	0.32	75
0	0	4175	307	108	0.732	0.111	0.106	63	0.29	76
0	0	5703	485	87	0.689	0.138	0.112	68	0.26	78
0	0	3569	164	135	0.774	0.108	0.102	59	0.30	76
0	0	5974	514	83	0.679	0.142	0.114	70	0.26	78
0	0	10630	1283	45	0.535	0.199	0.130	84	0.21	81
0	0	12634	1775	39	0.500	0.238	0.140	94	0.19	82
0	0	11609	1681	43	0.521	0.221	0.136	90	0.20	82
0	0	9915	1393	49	0.552	0.198	0.133	88	0.21	81
0	0	4473	515	111	0.738	0.131	0.114	70	0.26	78
0	0	3398	346	142	0.782	0.115	0.110	66	0.27	77
0	0	3289	264	151	0.793	0.098	0.092	51	0.35	73
0	0	3847	251	129	0.766	0.111	0.100	58	0.31	75
0	0	4175	267	108	0.732	0.113	0.108	64	0.28	77
0	0	5703	460	87	0.689	0.139	0.113	69	0.26	78
0	0	3569	193	135	0.774	0.107	0.100	58	0.31	75
0	0	5974	514	83	0.679	0.142	0.114	70	0.26	78
0	0	10630	1297	45	0.535	0.199	0.129	84	0.22	81
0	0	12634	1805	39	0.500	0.237	0.139	93	0.19	82
0	0	11609	1706	43	0.521	0.220	0.135	89	0.20	81
0	0	9915	1447	49	0.552	0.196	0.131	86	0.21	81
0	0	4473	539	111	0.738	0.130	0.113	69	0.26	78
0	0	3398	310	142	0.782	0.117	0.111	68	0.27	77
0	0	3289	200	151	0.793	0.102	0.095	54	0.33	74
	0	79216	9072	94		0.151	0.115	73	0.26	78

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 3498

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK WITH SEDIMENT DREDGING/REMOVAL AND REMOVAL OF 25 PERCENT OF RUNOFF/BASEFLOW INPUTS

Month	Initial P Conc.	Hydrologic and Mass Inputs: Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Hydrologic and Mass: Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.099	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	2.53	953	2894	319	0
February	0.079	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	3.08	1160	3015	307	0
March	0.086	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	4.57	1721	3982	434	0
April	0.091	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	5.55	2090	1479	161	0
May	0.085	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	6.18	2327	3647	405	0
June	0.094	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.59	2105	8524	1038	0
July	0.103	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	5.53	2083	10552	1417	0
August	0.115	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	5.23	1970	9639	1346	0
September	0.112	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	4.58	1725	8191	1123	0
October	0.111	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	4.02	1514	2959	388	0
November	0.102	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	2.91	1096	2302	285	0
December	0.099	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	2.36	889	2400	260	0
January	0.077	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	3.08	1160	2687	263	0
February	0.082	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	4.57	1721	2454	258	0
March	0.088	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	5.55	2090	3613	403	0
April	0.092	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	6.18	2327	1242	137	0
May	0.087	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	5.59	2105	3869	430	0
June	0.093	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.53	2083	8547	1036	0
July	0.103	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	5.23	1970	10665	1430	0
August	0.114	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	4.58	1725	9884	1373	0
September	0.111	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	4.02	1514	8401	1143	0
October	0.110	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	2.91	1096	3377	437	0
November	0.100	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	2.36	889	2509	306	0
December	0.098	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	3.08	1160	2129	231	0
January	0.078	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	4.57	1721	2126	214	0
February	0.085	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	5.55	2090	2085	225	0
March	0.090	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	6.18	2327	3375	382	0
April	0.093	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	5.59	2105	1464	161	0
May	0.085	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	5.53	2083	3892	429	0
June	0.093	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.23	1970	8660	1047	0
July	0.103	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	4.58	1725	10910	1455	0
August	0.114	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	4.02	1514	10095	1393	0
September	0.110	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	2.91	1096	8819	1187	0
October	0.108	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	2.36	889	3584	458	0
November	0.099	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	3.08	1160	2238	274	0
December	0.099	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	4.57	1721	1568	174	0
Totals:		49.72	18724		1039	56284	28562	4209	4646	7884	79216	42131		52.13	19631	59585	7484	0

Lake Surface Area (acres):	4519	Runoff/Baseflow Input (ac-ft/yr):	56284	Runoff/Baseflow Total P Input (kg/yr):	28562
Dry Season Seepage Inflow (ac-ft):	1343	Wet Season Seepage Inflow (ac-ft):	2866	Dry Season P Input (kg):	1148
Misc. Total P Inputs (kg/day):	21.6	Inflow Mass Removal (%):	-25		

Wet Seas

Losses											
nt System Losses		Total Losses		Mean Detention Time	Phosphorus Retention Coeff.	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI Value
% Removal	(kg)	(ac-ft)	(kg)	(days)		(g/m^2)	(mg/l)	(mg/m^3	(m)	
-25	348	3847	667	129	0.766	0.088	0.079	41	0.42	70
-25	381	4175	688	108	0.732	0.090	0.086	46	0.38	72
-25	524	5703	958	87	0.689	0.112	0.091	50	0.35	73
-25	322	3569	483	135	0.774	0.091	0.085	46	0.38	72
-25	550	5974	955	83	0.679	0.118	0.094	53	0.33	74
-25	994	10630	2032	45	0.535	0.158	0.103	60	0.30	76
-25	1147	12634	2565	39	0.500	0.195	0.115	71	0.25	78
-25	1050	11609	2396	43	0.521	0.182	0.112	68	0.26	78
-25	890	9915	2013	49	0.552	0.165	0.111	67	0.27	77
-25	371	4473	759	111	0.738	0.118	0.102	60	0.30	76
-25	270	3398	555	142	0.782	0.104	0.099	57	0.31	75
-25	294	3289	554	151	0.793	0.082	0.077	39	0.45	70
-25	348	3847	611	129	0.766	0.091	0.082	44	0.41	71
-25	381	4175	639	108	0.732	0.093	0.088	48	0.37	73
-25	524	5703	927	87	0.689	0.114	0.092	52	0.35	74
-25	322	3569	459	135	0.774	0.092	0.087	47	0.38	72
-25	550	5974	980	83	0.679	0.117	0.093	52	0.34	74
-25	994	10630	2029	45	0.535	0.159	0.103	60	0.30	76
-25	1147	12634	2578	39	0.500	0.194	0.114	70	0.26	78
-25	1050	11609	2423	43	0.521	0.181	0.111	67	0.27	77
-25	890	9915	2033	49	0.552	0.163	0.110	66	0.27	77
-25	371	4473	808	111	0.738	0.115	0.100	58	0.31	75
-25	270	3398	576	142	0.782	0.103	0.098	56	0.32	75
-25	294	3289	525	151	0.793	0.084	0.078	40	0.43	70
-25	348	3847	561	129	0.766	0.094	0.085	45	0.39	72
-25	381	4175	605	108	0.732	0.094	0.090	50	0.36	73
-25	524	5703	906	87	0.689	0.115	0.093	52	0.34	74
-25	322	3569	483	135	0.774	0.091	0.085	46	0.38	72
-25	550	5974	979	83	0.679	0.117	0.093	52	0.34	74
-25	994	10630	2041	45	0.535	0.158	0.103	60	0.30	76
-25	1147	12634	2603	39	0.500	0.193	0.114	70	0.26	78
-25	1050	11609	2443	43	0.521	0.180	0.110	67	0.27	77
-25	890	9915	2078	49	0.552	0.161	0.108	65	0.28	77
-25	371	4473	829	111	0.738	0.114	0.099	57	0.31	75
-25	270	3398	544	142	0.782	0.104	0.099	57	0.31	75
-25	294	3289	469	151	0.793	0.087	0.081	43	0.41	71
	7141	79216	14625	94		0.125	0.096	56	0.33	75

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 3498

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK WITH SEDIMENT DREDGING/REMOVAL AND REMOVAL OF 50 PERCENT OF RUNOFF/BASEFLOW INPUTS

Month	Initial P Conc.	Hydrologic and Mass Inputs													Hydrologic and Mass				
		Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.087	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	2.53	953	2894	271	0
February	0.065	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	3.08	1160	3015	249	0
March	0.069	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	4.57	1721	3982	345	0
April	0.072	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	5.55	2090	1479	130	0
May	0.071	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	6.18	2327	3647	325	0
June	0.074	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.59	2105	8524	791	0
July	0.076	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	5.53	2083	10552	1076	0
August	0.089	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	5.23	1970	9639	1044	0
September	0.087	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	4.58	1725	8191	877	0
October	0.087	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	4.02	1514	2959	319	0
November	0.088	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	2.91	1096	2302	248	0
December	0.087	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	2.36	889	2400	222	0
January	0.064	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	3.08	1160	2687	217	0
February	0.067	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	4.57	1721	2454	210	0
March	0.071	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	5.55	2090	3613	320	0
April	0.073	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	6.18	2327	1242	110	0
May	0.072	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	5.59	2105	3869	345	0
June	0.073	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.53	2083	8547	789	0
July	0.077	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	5.23	1970	10665	1086	0
August	0.089	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	4.58	1725	9884	1064	0
September	0.086	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	4.02	1514	8401	893	0
October	0.086	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	2.91	1096	3377	359	0
November	0.086	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	2.36	889	2509	266	0
December	0.086	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	3.08	1160	2129	198	0
January	0.065	2.42	911	0.045	50.6	2739	1390	196	168	670	3847	2278	0.480	4.57	1721	2126	176	0
February	0.069	2.65	998	0.045	55.4	3000	1522	177	152	605	4175	2334	0.453	5.55	2090	2085	182	0
March	0.072	3.65	1375	0.045	76.3	4132	2097	196	168	670	5703	3011	0.428	6.18	2327	3375	304	0
April	0.073	2.24	844	0.045	46.8	2536	1287	190	162	648	3569	2144	0.487	5.59	2105	1464	130	0
May	0.071	3.83	1442	0.045	80.0	4336	2200	196	168	670	5974	3118	0.423	5.53	2083	3892	345	0
June	0.073	6.92	2606	0.045	144.6	7834	3975	190	162	648	10630	4930	0.376	5.23	1970	8660	797	0
July	0.076	7.99	3009	0.045	167.0	9045	4590	581	709	670	12634	6135	0.394	4.58	1725	10910	1105	0
August	0.088	7.31	2753	0.045	152.8	8275	4199	581	709	670	11609	5730	0.400	4.02	1514	10095	1080	0
September	0.085	6.20	2335	0.045	129.6	7019	3562	562	686	648	9915	5025	0.411	2.91	1096	8819	927	0
October	0.085	2.58	972	0.045	53.9	2921	1482	581	709	670	4473	2914	0.528	2.36	889	3584	377	0
November	0.085	1.88	708	0.045	39.3	2128	1080	562	686	648	3398	2453	0.585	3.08	1160	2238	238	0
December	0.087	2.05	772	0.045	42.8	2321	1178	196	168	670	3289	2058	0.507	4.57	1721	1568	149	0
Totals:		49.72	18724		1039	56284	28562	4209	4646	7884	79216	42131		52.13	19631	59585	5896	0

Lake Surface Area (acres): 4519

Runoff/Baseflow Input (ac-ft/yr): 56284

Runoff/Baseflow Total P Input (kg/yr): 28562

Dry Season Seepage Inflow (ac-ft): 1343

Wet Season Seepage Inflow (ac-ft): 2866

Dry Season P Input (kg): 1148

Wet Seas

Misc. Total P Inputs (kg/day): 21.6

Inflow Mass Removal (%): -50

Losses										
nt System Losses		Total Losses		Mean Detention Time	Phosphorus Retention	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI
% Removal	(kg)	(ac-ft)	(kg)	(days)	Coeff.	(g/m ^ 2)	(mg/l)	(mg/m ^ 3	(m)	Value
-50	695	3847	966	129	0.766	0.072	0.065	31	0.56	66
-50	761	4175	1010	108	0.732	0.072	0.069	34	0.52	67
-50	1048	5703	1394	87	0.689	0.088	0.072	36	0.49	68
-50	643	3569	773	135	0.774	0.075	0.071	35	0.50	68
-50	1100	5974	1425	83	0.679	0.092	0.074	37	0.47	69
-50	1988	10630	2778	45	0.535	0.118	0.076	39	0.45	70
-50	2295	12634	3371	39	0.500	0.151	0.089	49	0.36	73
-50	2100	11609	3143	43	0.521	0.141	0.087	47	0.38	72
-50	1781	9915	2657	49	0.552	0.129	0.087	47	0.38	72
-50	741	4473	1060	111	0.738	0.101	0.088	48	0.37	73
-50	540	3398	788	142	0.782	0.091	0.087	47	0.38	72
-50	589	3289	811	151	0.793	0.068	0.064	30	0.58	66
-50	695	3847	912	129	0.766	0.075	0.067	33	0.53	67
-50	761	4175	971	108	0.732	0.075	0.071	35	0.50	68
-50	1048	5703	1369	87	0.689	0.090	0.073	36	0.48	69
-50	643	3569	754	135	0.774	0.076	0.072	36	0.49	68
-50	1100	5974	1445	83	0.679	0.091	0.073	37	0.48	69
-50	1988	10630	2776	45	0.535	0.118	0.077	39	0.45	70
-50	2295	12634	3381	39	0.500	0.151	0.089	48	0.37	73
-50	2100	11609	3164	43	0.521	0.140	0.086	46	0.38	72
-50	1781	9915	2673	49	0.552	0.129	0.086	47	0.38	72
-50	741	4473	1100	111	0.738	0.099	0.086	47	0.38	72
-50	540	3398	806	142	0.782	0.090	0.086	46	0.38	72
-50	589	3289	786	151	0.793	0.069	0.065	31	0.56	66
-50	695	3847	871	129	0.766	0.077	0.069	34	0.51	68
-50	761	4175	944	108	0.732	0.076	0.072	36	0.48	69
-50	1048	5703	1352	87	0.689	0.091	0.073	37	0.47	69
-50	643	3569	773	135	0.774	0.075	0.071	35	0.50	68
-50	1100	5974	1445	83	0.679	0.091	0.073	37	0.48	69
-50	1988	10630	2785	45	0.535	0.117	0.076	39	0.45	70
-50	2295	12634	3400	39	0.500	0.149	0.088	48	0.37	73
-50	2100	11609	3179	43	0.521	0.139	0.085	46	0.38	72
-50	1781	9915	2708	49	0.552	0.127	0.085	46	0.39	72
-50	741	4473	1118	111	0.738	0.098	0.085	46	0.38	72
-50	540	3398	778	142	0.782	0.092	0.087	47	0.37	72
-50	589	3289	738	151	0.793	0.072	0.067	33	0.53	67
	14281	79216	20177	94		0.100	0.077	41	0.44	70

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 3498

04105

REPORT NAME:
LAKE HANCOCK WATER & NUTRIENT

AUTHOR & REPORT DATE:
ENVIROMENTAL RESEARCH & DESIGN

KEY WORD:
WATER QUALITY IMPROVEMENT PRJ

CART #/PG #: 313 pgs.

215.1/REPORTS AND PUBLICATIONS

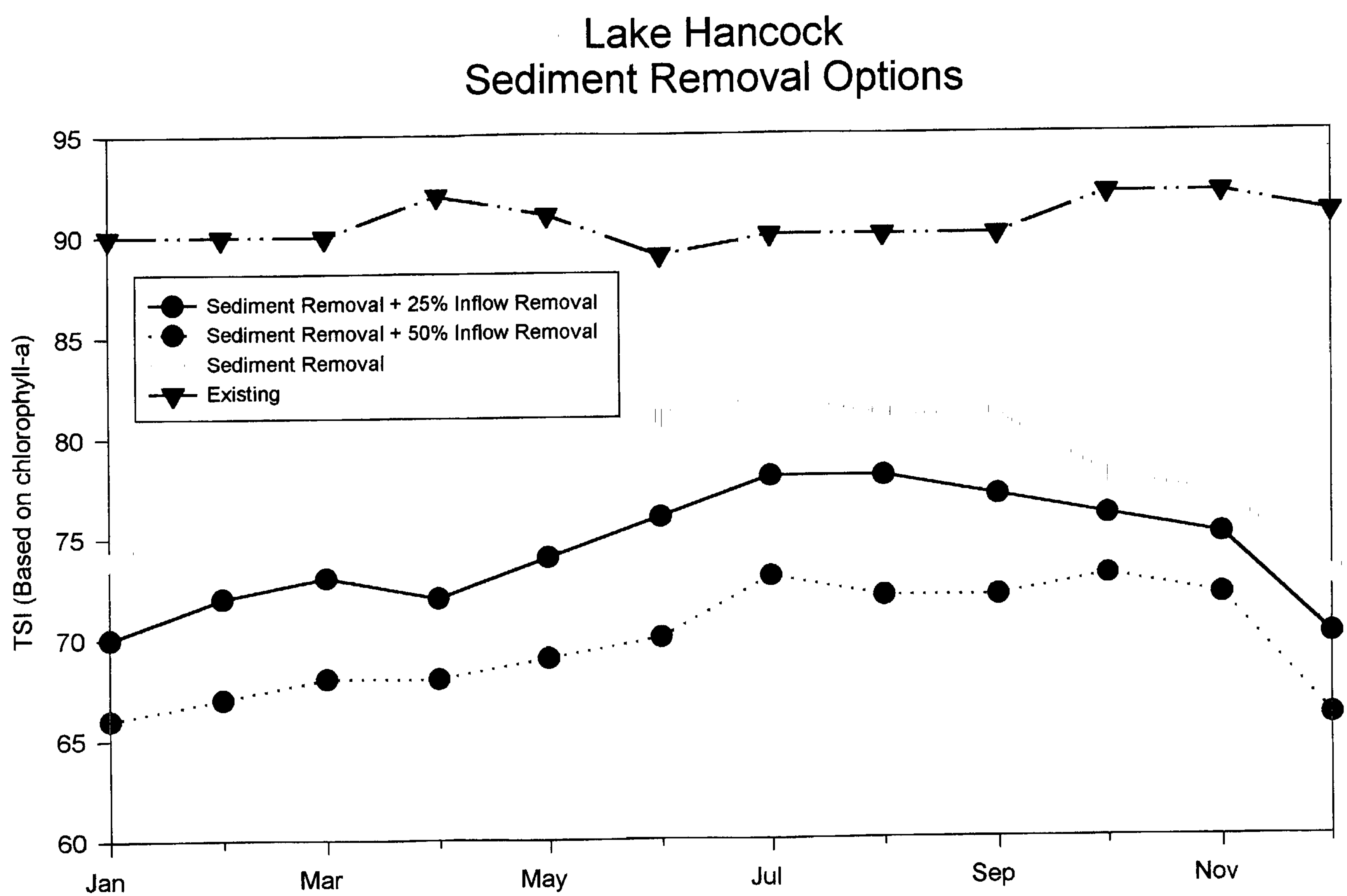

Figure 6-6. Anticipated Monthly TSI Values in Lake Hancock for Selected Dredging and Inflow Treatment Options.

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