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LAKE MYAKKA WATER QUALITY STUDY

PREPARED FOR

FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION

BY

priede-sedgwick, inc.
consulting engineers

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INTRODUCTION

1.1 BACKGROUND

The present water quality study of Whitaker Bayou, Sarasota Bay, and Lake Myakka (Figure 1-1) resulted from a series of events relating to the City of Sarasota's wastewater treatment facility discharge to Whitaker Bayou. During the process of satisfying Section 201 Construction Grant requirements, Sarasota County evaluated various alternatives for disposing of treated effluent from the City of Sarasota's wastewater treatment plant. The surface discharge options identified in the Facilities Plan required advanced wastewater treatment (AWT) restrictions described in the Wilson-Grizzle Amendment, since revised. The recommended alternative for wastewater disposal involved implementing a land treatment project. Specific components would include upgrading and expanding the existing wastewater treatment facility with treated effluent conveyed to a proposed spray irrigation site east of the City. The wastewater applied to the land application site would result in intermittent discharge from underdrains to Howard Creek and ultimately discharge into Lake Myakka.

During the construction grant review of the recommended plan for land application, the U.S. Environmental Protection Agency (EPA) indicated that the impacts upon water quality in Sarasota Bay from the present discharge had not been quantified. Therefore, EPA conducted that removing the entire wastewater load or any part of the wastewater load from Sarasota Bay could not be related to water quality enhancement. This finding caused construction grant funds for the land application system to be deferred until further studies were conducted and the impacts upon Lake Myakka water quality delineated. In order to properly assess impacts within the Bay/Bayou system and document predicted impacts upon Lake Myakka, a joint study was authorized by EPA. The present Florida Department of Environmental Regulation (FDER) study is a result of these evaluations and recommendations for defining impacts of implementable wastewater discharge alternatives upon the two systems.

1.2 PURPOSE

This investigation has the following three primary purposes:

A. Within Whitaker Bayou, define the discharge limits for oxygen demanding substances necessary to satisfy dissolved oxygen standards in Whitaker Bayou.

B. Define existing quality within the Lake Myakka system; determine nutrient loadings to the Lake and flushing rates within the lake system; develop allowable nutrient

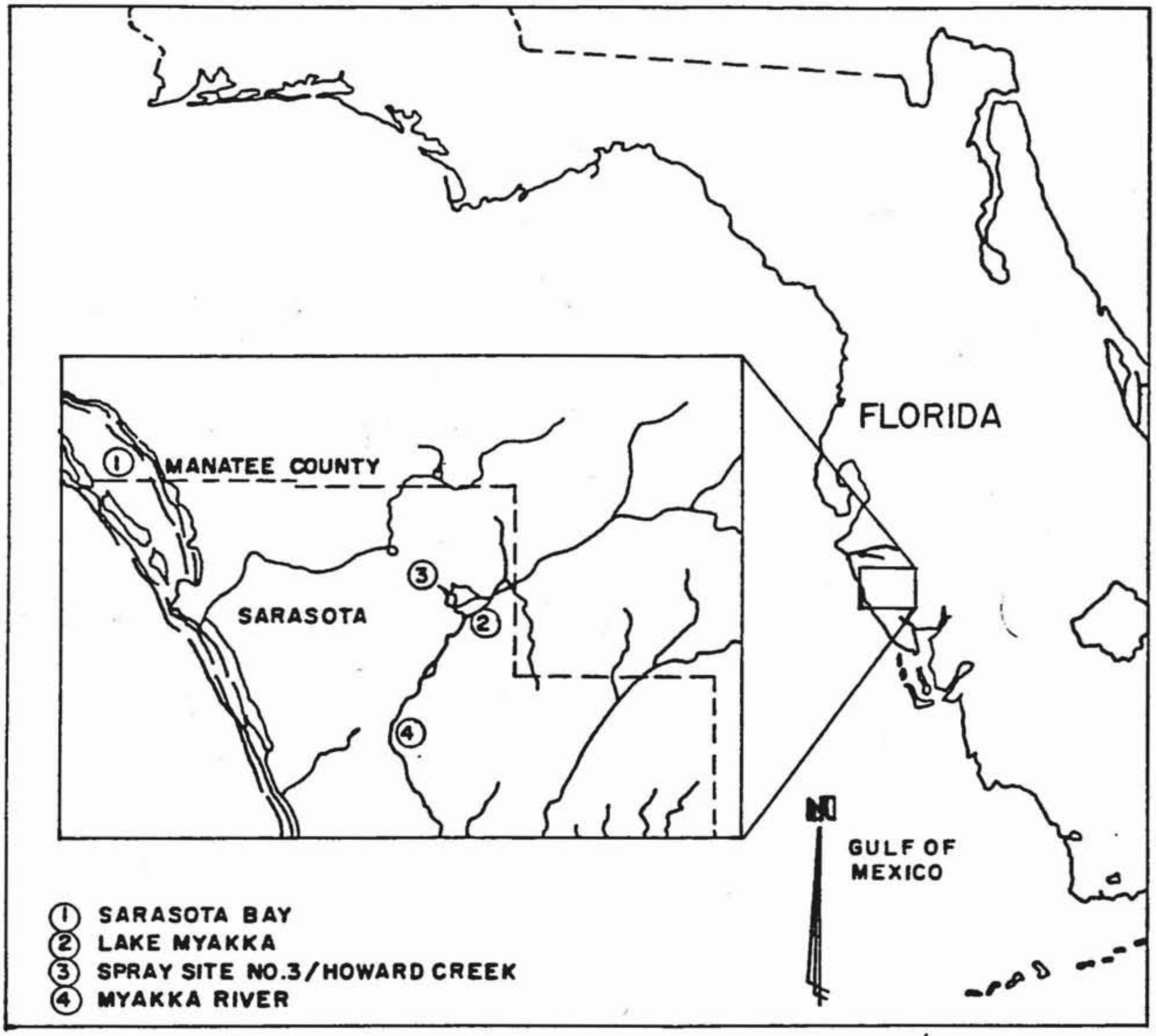

FIGURE I-1
LOCATION MAP
LAKE MYAKKA STUDY

loadings to the lake which would cause no further deterioration and possibly enhancement of water quality and determine loading limits for oxygen demanding substances.

C. Determine existing water quality in Sarasota Bay; estimate the present impact of the City of Sarasota wastewater discharge upon the Bay; and develop allowable point source loadings to the Bay for nutrients and oxygen demanding substances at various discharge locations.

1.3 SCOPE

Within the context of the previous evaluations, specific project purposes, and the EPA/FDER/City agreements, the project purposes were divided into four principal components. These components consisted of:

A. Project control documents (including quality assurance/quality control);
B. Whitaker Bayou/Sarasota Bay field studies;
C. Lake Myakka/tributaries field studies; and
D. Level I and Level II evaluations.

Each component has been completed. This document contains the results obtained from field data collection, special investigations, modelling frameworks, and assimilative capacities for Howard Creek and Lake Myakka. A companion document discusses the same elements pertaining to Whitaker Bayou and Sarasota Bay. This presentation format provides separate documentation of assimilative capacities for the physically significant study involvements.

Specific information addresses field investigations conducted between November, 1981, and August, 1982, with continuous evaluations performed on these data. The modelling framework established for Howard Creek and Lake Myakka has been developed with calibration/verification based upon field data collected during the regularly scheduled events and the information obtained from special investigations. Through calibrating/verifying the conservative parameter (total nitrogen and total phosphorus) models an adequate description of the existing conditions within the Creek and Lake were generated. Subsequent calibration/verification for non-conservative parameters (biochemical oxygen demand and dissolved oxygen) was also obtained for the same data collection events. Through utilizing these calibrated/verified models, assimilative capacities are defined for conservative and non-conservative parameters with the anticipated spray field irrigation underdrain system discharging to the Howard Creek system. The study summary addresses these specific assimilative capacities obtained for the particular parameters along with the identified impacts upon water quality related factors.

SECTION 2

LEVEL I FINDINGS

Results obtained from the first five sampling events (November, 1981 through March, 1982) were presented in the report entitled "Level I Evaluation Report, Water Quality Study of Sarasota Bay, Whitaker Bay, and Lake Myakka", June, 1982, (Ref. 1). Results displayed water quality conditions throughout Lake Myakka and the tributary streams during the cool, dry periods. Water quality violations associated with dissolved oxygen at certain stations during these sample events. Due to the extreme low flows existing in the West and East Branches of Howard Creek, preliminary modelling results were deemed questionable. However, within Lake Myakka proper, calibration/verification was obtained for both conservative and non-conservative parameters, but with qualifications.

The general status of Lake Myakka was found to be a highly disturbed ecological system with excessive nutrient concentrations in the water column and extensive growth of aquatic plants. When initial sediment oxygen demand studies were performed, extreme variations were observed in dissolved oxygen concentrations within the water column. Particularly evident was the lack of oxygen near the organic mat occurring across the lake bottom. Although the initial model segmentation provided adequate calibration/verification of sample event data sets, concerns were expressed relative to quantifying the sources of loads due to extreme low flows into the system and the extensive aquatic plant communities. However, the preliminary model evaluations indicated that the continued use of a two-dimensional, steady-state model would properly identify the existing conditions and allow impacts to be quantified relative to future loading scenarios. Particularly with the present status of the lake adequately documented with water quality/special studies, the assimilative capacity associated with conservative and non-conservative parameters could be defined.

SECTION 3

FIELD DATA COLLECTION EFFORTS

Similar to Sarasota Bay, the Lake Myakka system has never been the subject of intensive water quality studies. Special studies have been conducted regarding the flooding potential along Myakka River and first order estimates of existing plant growth have been performed by the Southwest Florida Water Management District (SWFWMD). Furthermore, variations in lake level have been managed to control excessive vegetation, but correlations with water quality and flow rate impacts have not been addressed. Other special studies relating to general life forms within the Lake system and the surrounding areas have been completed, but were not referenced directly to water quality conditions. The particular elements necessary to properly determine the system's assimilative capacity are an adequate description of the existing conditions and a proper understanding of the interrelationships within the aquatic environment.

Without the benefit of a coordinated data base describing inputs and interrelationships within the lake system, a significant portion of the project's resources was allocated to describing the existing system. Included within this data collection program were water quality characteristics, tributary flow and lake level data, meteorology relative to the study area, and additional special studies necessary to better understand the existing lake system. These data will then be used to develop specific mathematical relationships which describe the existing system and allow assimilative capacities to be generated for loads from point and non-point sources to the lake system. The following sub-sections summarize the efforts expended in collecting specific information relative to describing the existing system's condition. Detailed evaluations and analyses of this data base are presented in Section 5.

3.1 <u>Water Column Data</u>

In order to properly characterize the water quality conditions within Lake Myakka and the tributary streams, a total of ten sampling events were initially scheduled between November, 1981, and August, 1982. As the study effort progressed through the completion of Level I, one sampling event had to be eliminated due to budgetary limitations. The total events utilized for characterizing water quality involved nine discrete sampling events (every month except July, 1982) with water quality data obtained at each station. Water quality data obtained for each of the nine events at the respective stations are completely identified in Appendix A. Figure 3-1 displays the seven stations

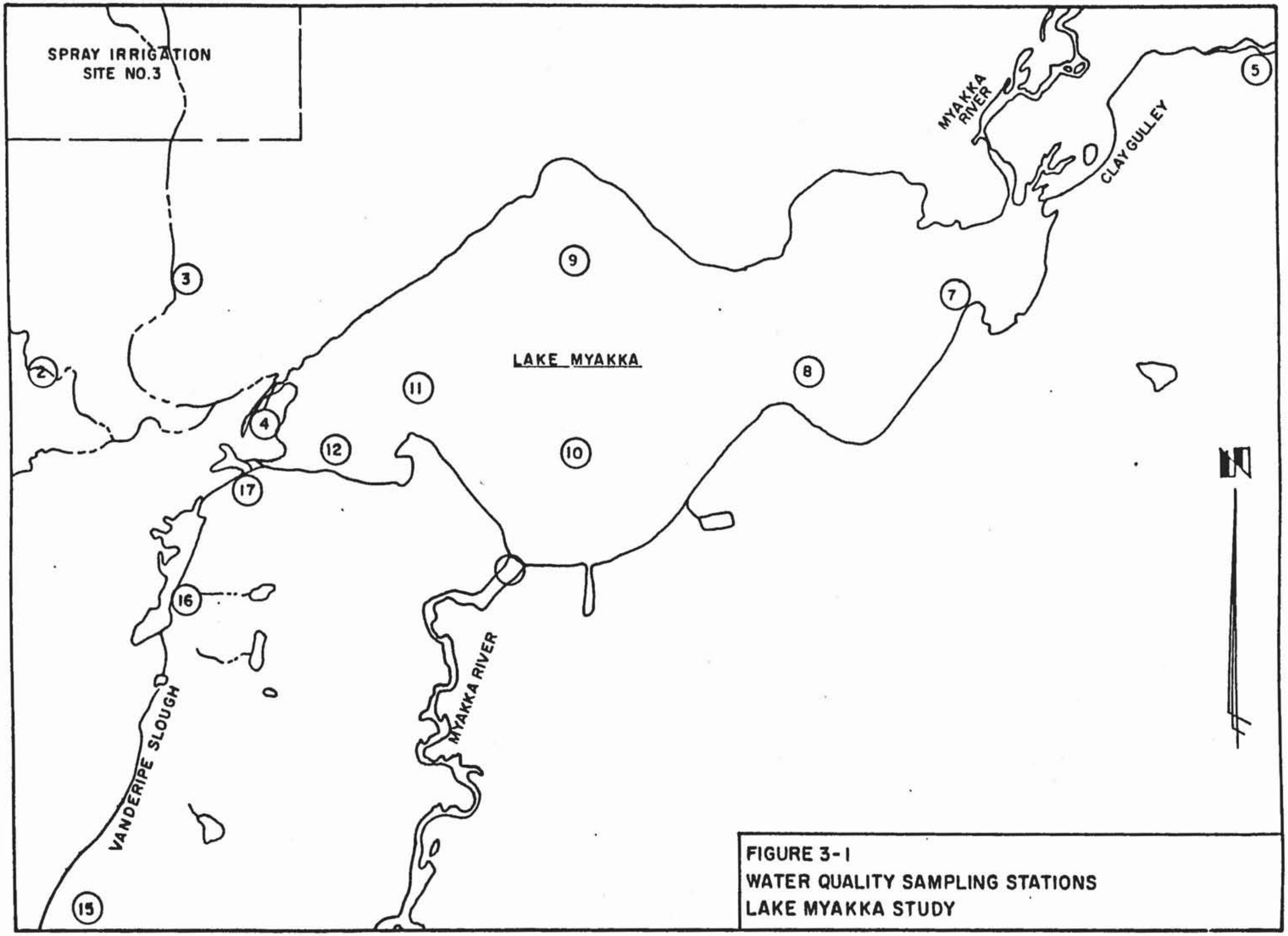

FIGURE 3-1
WATER QUALITY SAMPLING STATIONS
LAKE MYAKKA STUDY

within Lake Myakka, the other six stations on the various tributaries to the Lake, and the one station on the outflow.

3.2 Hydrologic Lake Water Level Data

Continuous records for stream flow on the lake tributaries was to be obtained through using continuous recording stage recorders and calibration curves based upon velocity meter measurements. The stage recorders produced reasonably good records with more dependability than the punch-type recorders utilized in Sarasota Bay. However, development of stage-discharge relationships for each tributary was hampered during low flows based upon extremely low velocities through large cross-sections. In addition, during the wet season portion of the study effort, extreme high flows sometimes created difficulty with the continuous reading level recorders. However, through utilizing other data collected upstream and downstream from the study area, correlations were established to allow approximate flow data to be generated for inputs to Lake Myakka and outputs to be identified from the Lake system.

A continuous record of lake levels was developed through the study period. Through obtaining daily staff gauge readings and correlating those values to a common lake elevation datum, variations in depth, area, and volume were identified. These values were established from the detailed bathymetric survey performed in the lake and characterized the lake's contours, including the organic mat existing in the bottom.

3.3 Meteorological Data

In order to account for the potentially significant differing weather patterns between Lake Myakka and the meteorological station established at Mote Marine Laboratory, an auxiliary weather station was established at the Myakka State Park. Data were recorded on a daily basis by the State Park employees, checked by project team personnel, and compiled on a monthly basis. These data were especially useful in monitoring rainfall quantities over the Myakka basin and assisted the Project Team in understanding conditions which occurred during sampling events. The specific parameters measured at this station include the following: temperature ranges, humidity, rain wind speed and direction, cloud cover and barametric pressure. The necessary information required for program evaluations has been extracted from the data record; detailed continuous records are available upon request.

3.4 Miscellaneous Data Collection

Additional data collection efforts were performed to further identify physical, biological, and chemical characteristics within the Lake system. These studies included a comprehensive bathymetric survey of bottom elevations and organic deposits, algal assays, sediment oxygen demand investigations, plant specie identification and ground truthing, and mini-studies addressing specific irregularities applicable to the data collection program. Results from these investigations are reported in Section 5 along with the respective data and interpretations. The algal assay analyses were performed by the Florida Department of Environmental Regulation on samples collected during April and August, 1982. The Environmental Protection Agency Athens Laboratory performed <u>in situ</u> benthic oxygen demand studies during August, 1981, February, 1982, and August, 1982.

SECTION 4

SPECIAL INVESTIGATIONS

Various special studies were conducted throughout the project for the purpose of gaining information needed for simulating actual conditions or in order to develop relationships which were not completely defined by other data collection activities. Many activities were innovative because of the need to develop parameter relationships which often had not been explained before in the project area. Specific study results are summarized below.

4.1 Benthic (Sediment) Oxygen Demand Studies

Through requests from FDER, personnel from the Surveillance and Analysis Division of the Environmental Protection Agency's Athens, Georgia Laboratory performed three in situ benthic oxygen demand studies in Lake Myakka. These studies were performed during August, 1981; February, 1982; and August, 1982 (references 2, 3, and 4). The purpose of these studies was to provide sediment oxygen demand (SOD) estimates for inclusion in the dissolved oxygen models. When field measurements obtained during Level I indicated that dissolved oxygen was a definite problem in Lake Myakka during particular sampling events, field activities were adjusted to obtain more information on sediment demand rates. Particular reference is made to the fact that anoxic bottom conditions were observed at certain stations.

Study results indicated patterns throughout the lake which were not easily explainable. Specific stations surveyed during the three studies are identified on Figure 4-1. Table 4-1 displays the data obtained from the three studies with the mean SOD rates converted to the 20°C standard temperature. The first disparity observed in the data results is the fact that the SOD rate decreases from February to August at station 7, while rates increase at station 12. The EPA report suggested that station 7 had a much shallower dry season depth (February, 1982), allowing light penetration to the bottom and permitting algal growth through the entire water column thus contributing to the net bottom oxygen demand. During August, 1982, the depth at station 7 increased and sunlight was fully attenuated before reaching the sediment, thus precluding algal growth and decreasing the total oxygen demand of the sediment.

However, this explanation does not apply to station 12 since water levels were never shallow enough to permit light to reach the bottom. The two indications provided by EPA relative to station 12 are that the variation possibly resulted from an error in the field replicates or suppressed metabolic activity due to

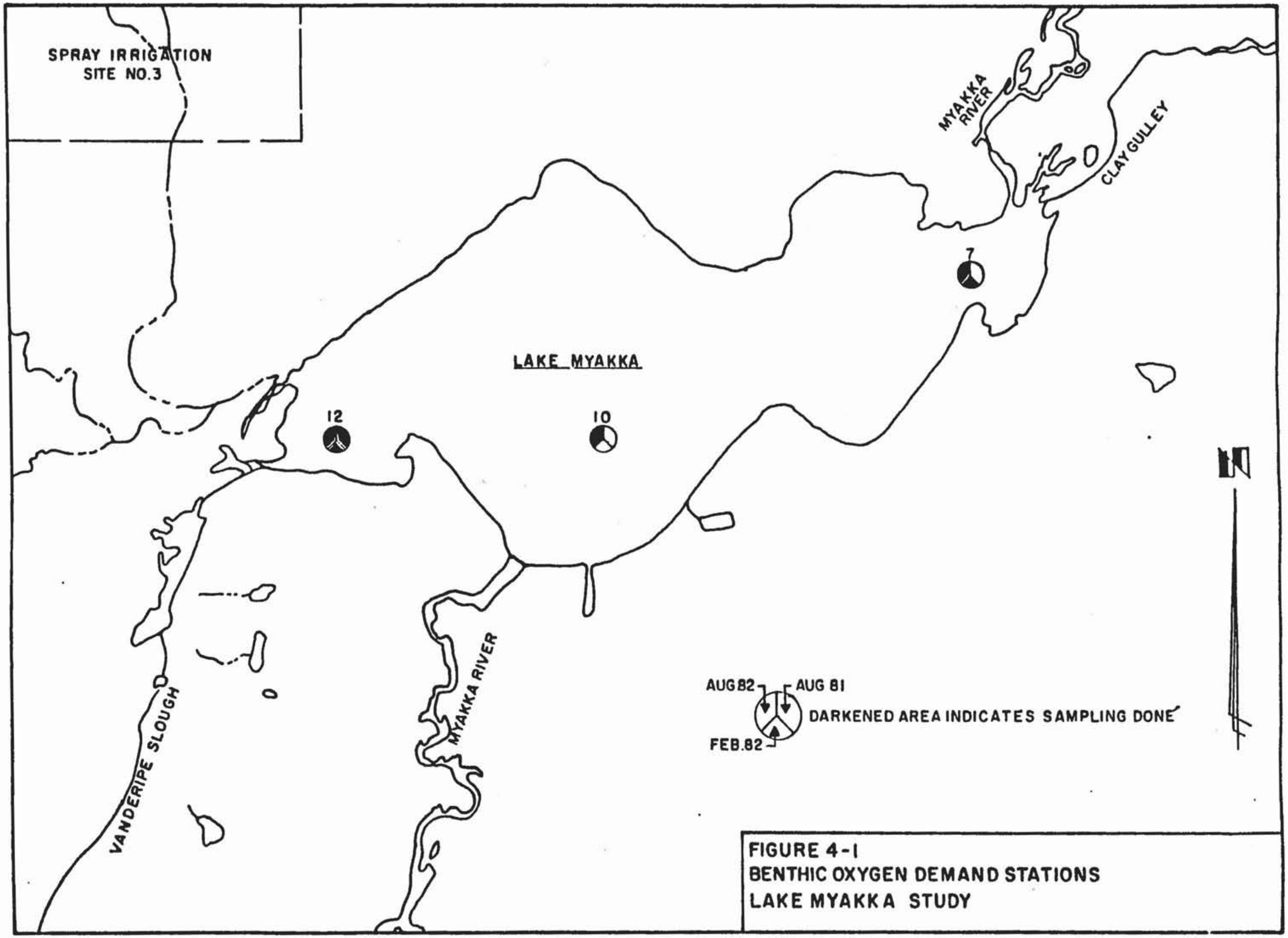

FIGURE 4-1
BENTHIC OXYGEN DEMAND STATIONS
LAKE MYAKKA STUDY

extremely low oxygen levels. Through obtaining this information and combining the results with the _in situ_ water column data, a more thorough understanding of sediment/water column relationships was obtained. Section 8 displays the analyses and evaluations compatible with utilizing these relationships in the assimilative capacity analysis.

4.2 Algal Assays

During the initial project development phase, specific information describing nutrient limitations on algal growth potential were identified as necessary information required to enable the Project Team to understand the system and predict impacts from changes. In order to develop these data, algal assays were to be performed by FDER during the study. The water samples were to be collected by Project Team personnel and shipped to the FDER Tallahassee Biology Laboratory for analysis using the standard monoculture assay technique approved by the Environmental Protection Agency.

Initial water samples collected in February, 1982, were unprocessable. The second set of water samples was transmitted to FDER in April, 1982, with results made available in early July (FDER report, _Algal Assays of Sarasota Bay and Lake Myakka_). After the results were evaluated, another request was made to repeat the analyses during the August, 1982, sampling event. During both of these samplings, three stations (April-7, 10, 12; August-2, 7, 13) in Lake Myakka were utilized for sample collection.

Assay results from the April sampling indicated that nitrogen was limiting at all three stations. Water chemistry data and nitrogen:phosphorus ratios also indicated nitrogen limitations. This finding was hardly unexpected, since the upper Myakka River basin contains some of the richest phosphate lands in Florida. In fact, mining is presently underway adjacent to Wingate Creek, a minor tributary in Manatee County. In August, 1982, the assay results were similar except for station 7. Station 7 indicated colimitation for nitrogen and phosphorus, signifying that neither nutrient is in sufficient quantity for algal growth. The specific results obtained for station 7 are displayed on Figures 4-2 and 4-3 for the April and August sample events.

As opposed to results obtained for Sarasota Bay, the Project Team anticipated that this stressed system would be nitrogen limited. The significance of this fact is associated with implications regarding the impact of further nitrogen discharges through discharge from the spray irrigation site underdrain system. With excessive growth existing within the Lake presently, any increase in nitrogen discharges will continue the growth patterns and

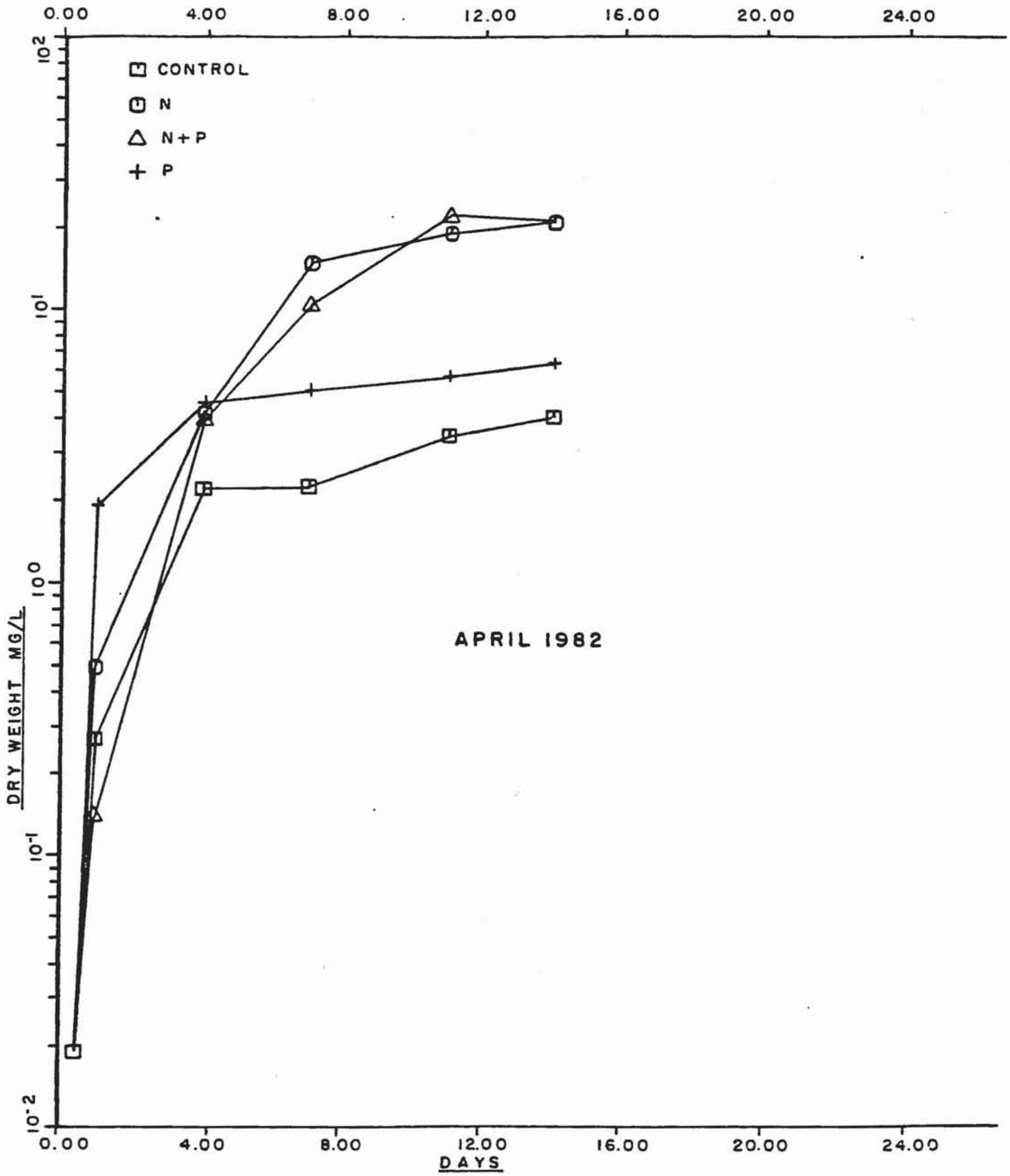

FIGURE 4-2
ALGAL ASSAY RESULTS - STATION 7
LAKE MYAKKA STUDY

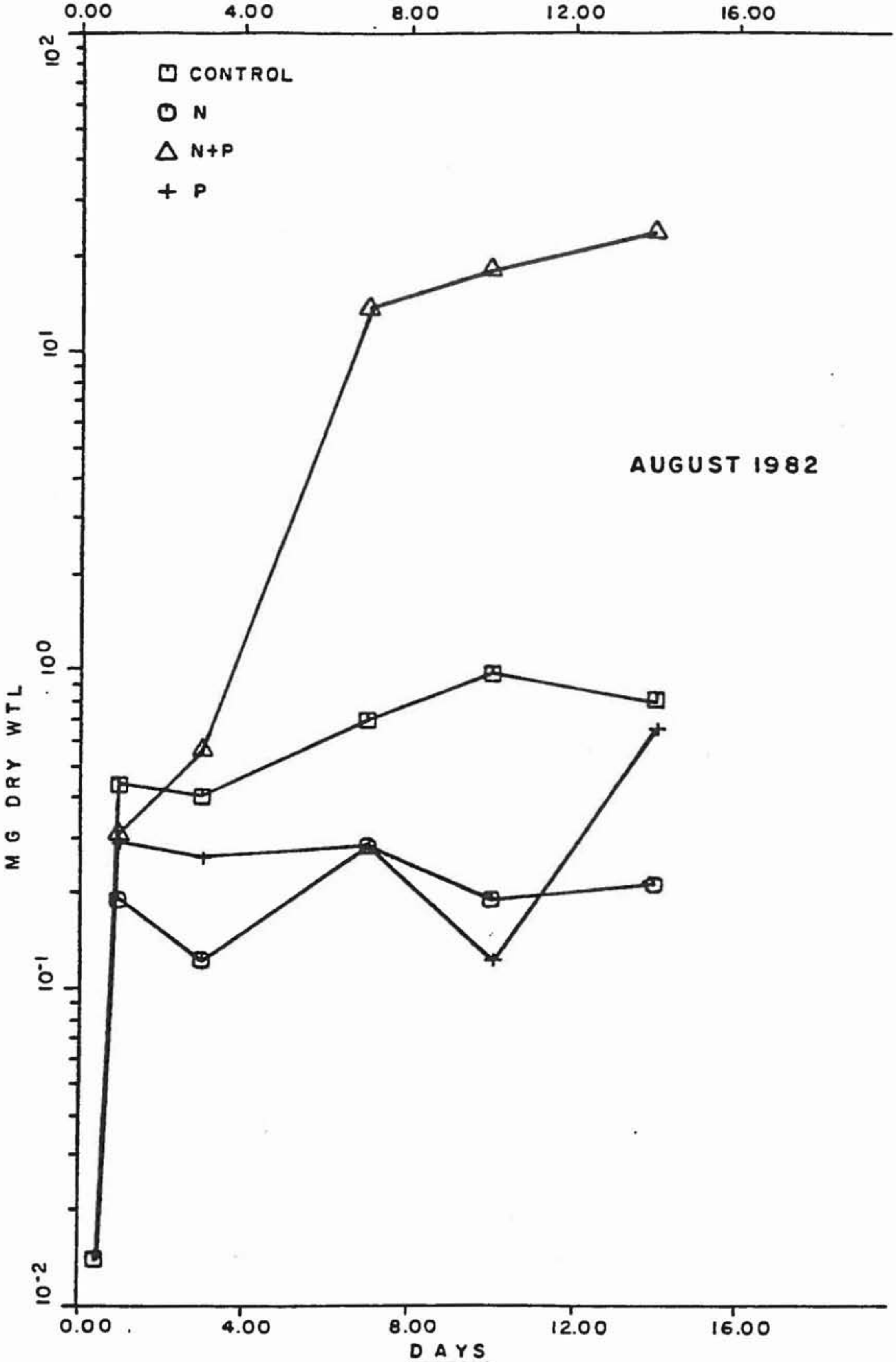

FIGURE 4-3
ALGAL ASSAY RESULTS-STATION 7
LAKE MYAKKA STUDY

cause additional eutrophication within the system. Particular relevant applications of these results are displayed in Section 8.

4.3 Elemental Composition Studies

During development of the Plan of Study, efforts were defined to relate water column chemistry to sediment composition and plant growth. In order to further understand these relationships, elemental composition analyses were necessary for both the sediment fractions on the lake bottom and the individual plant species.

Sediment samples were collected from nine stations within the Lake and tributaries for analysis of percent solids, total nitrogen, total organic carbon, and total phosphorus. Both the organic and granular fractions were analyzed separately from each location to assist in defining the nature of the materials. As displayed on Figure 4-4, variations in elemental composition throughout the lake suggest either different sources of the sediment or possibly the effect of scouring velocities under high flow conditions. The expected output from this data collection program was the distribution of nutrient loads from the sediment due to release to the water column or the converse, increased nutrient levels in the sediment due to decay and settling.

The second elemental composition analysis was conducted on Hydrilla collected from five stations (station 2, 7, 8, 10, and 11) within Lake Myakka. Hydrilla plants were segmented into upper, lower, and root sections for analysis of percent moisture, total nitrogen, total phosphorus, and total organic carbon. Although the results are meaningful relative to identifying nutrients within segments of the hydrilla plants, utilization of this data from only one sampling has not proven significantly beneficial to further understanding the complex water quality conditions existing within the lake. Additional data collection would be necessary to incorporate these results into models of appropriate macrophyte growth kinetics.

4.4 Nutrient Release Study

When program elements necessary to define the interrelationships within Lake Myakka were identified, there was sufficient reason to suspect that nutrient releases from decaying organic material deposited on the bottom may have a significant impact on water quality. Utilizing the data collected and analyzed during Level I, these hypotheses were further supported from additional data collection and early model evaluations. Impacts upon both the oxygen resource and the nutrient balance within the lake appeared to be originating from sediment related conditions. However,

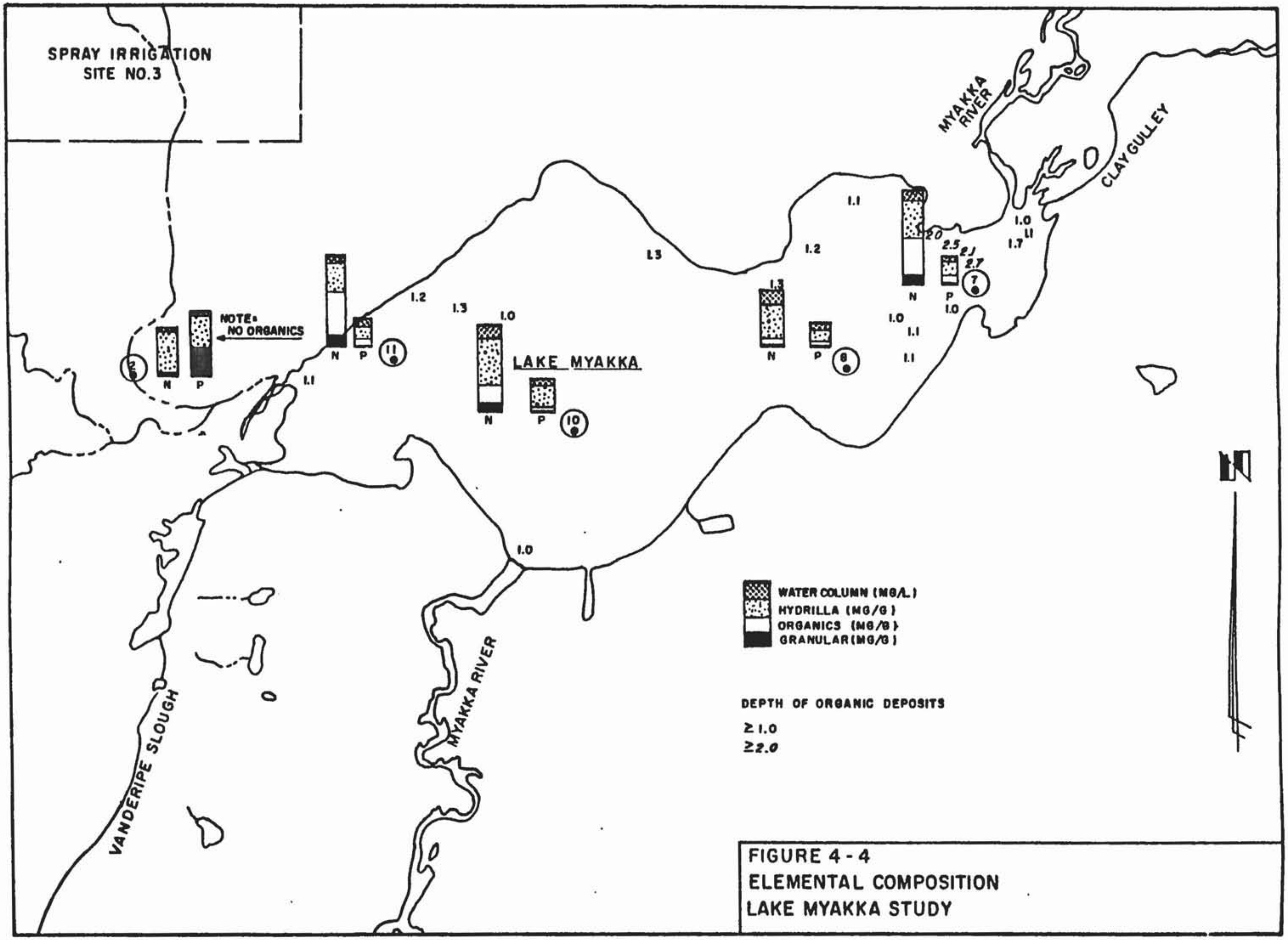

FIGURE 4-4
ELEMENTAL COMPOSITION
LAKE MYAKKA STUDY

since budgetary resources were not available when the program was initiated or as the study proceeded, _in situ_ nutrient release studies could not be performed. Therefore, _in vitro_ nutrient release studies were identified to assist in understanding the water column/sediment interrelationships.

Sediment samples were collected from two stations (stations 8, and 10), composited, and split into five series of four flasks. Each series included three flasks with sediment and a blank of filtered lake water only. The flasks were incubated in the dark at 10°C. After zero, five, twenty, fifty, and eighty five days one series of flasks was sacrificed for analysis.

The flasks were inverted, allowed to settle, filtered and analyzed for organic carbon, total phosphorus, total kjeldahl and oxidized forms of nitrogen. Results obtained from this investigation were contrary to the anticipated findings. For each nutrient analyzed (total nitrogen, total phosphorus, and total organic carbon), the laboratory results indicated a net decrease of nutrients or an actual uptake of nutrients by the sediment. These results were obtained through measuring a net decrease in water column concentration as a result of subtracting the sediment sample water column concentration from the blank (control) water column sample of the same water. Therefore, with only one series of samples collected and analyzed within the project resources, the data have proven of limited benefit in attributing loads directly to the sediment.

SECTION 5

WATER QUALITY DATA RESULTS

Previous sections have identified Level I evaluations, field data collection programs, and special investigations. Highlighted within this section are the results of these sampling programs and specific ranges and trends applicable to the data collection. Presentation of these results will establish the basis necessary for developing the evaluation frameworks presented in Section 8. Particular emphasis has been placed upon those parameters primarily associated with determining nutrient limitations within the Lake and those oxygen demanding substances affecting dissolved oxygen concentrations.

5.1 Nitrogen Series

As indicated from data results displayed in Appendix A, total nitrogen concentrations were extremely low during November, 1981, when water quality sampling began. These results may be the result of low inflows from the tributary basin or, as deemed more likely, most of the nitrogen present was tied up in algal and macrophyte cell mass. This hypothesis seems likely since the lake was overgrown with weeds following the 1981 wet season and subsequent results obtained following herbicide spraying indicate levels significantly higher than those obtained in November.

When total nitrogen values are compared over the time scale of the investigation (Figure 5-1), three significant peak values or drastic increases are evident. The first two peaks occurred approximately one month after herbicide spraying occurred within the lake. The third spike during June, 1982, seems attributable to significant increases in tributary flows from the Myakka River (i.e., 3 cfs in February, 1982, verses 100 cfs in June, 1982) and associated increases in nutrient load, probably attributable to agricultural land runoff. Similar to the results identified for Sarasota Bay, the total nitrogen values are composed of primarily total organic nitrogen. As displayed in Table 5-1, the average percentage of total nitrogen existing as total organic nitrogen for lake stations was approximately 95 percent. Ammonia nitrogen concentrations varied through time with no definable reason, while oxidized forms (nitrite and nitrate) were always observed near or below detection limits.

Samples collected from tributary streams to Lake Myakka indicated concentrations which varied approximately in the same fashion as the ambient lake values. As indicated in Section 4.4, the preliminary hypothesis describing water column concentrations resulting from sediment release may not be totally valid. As indicated

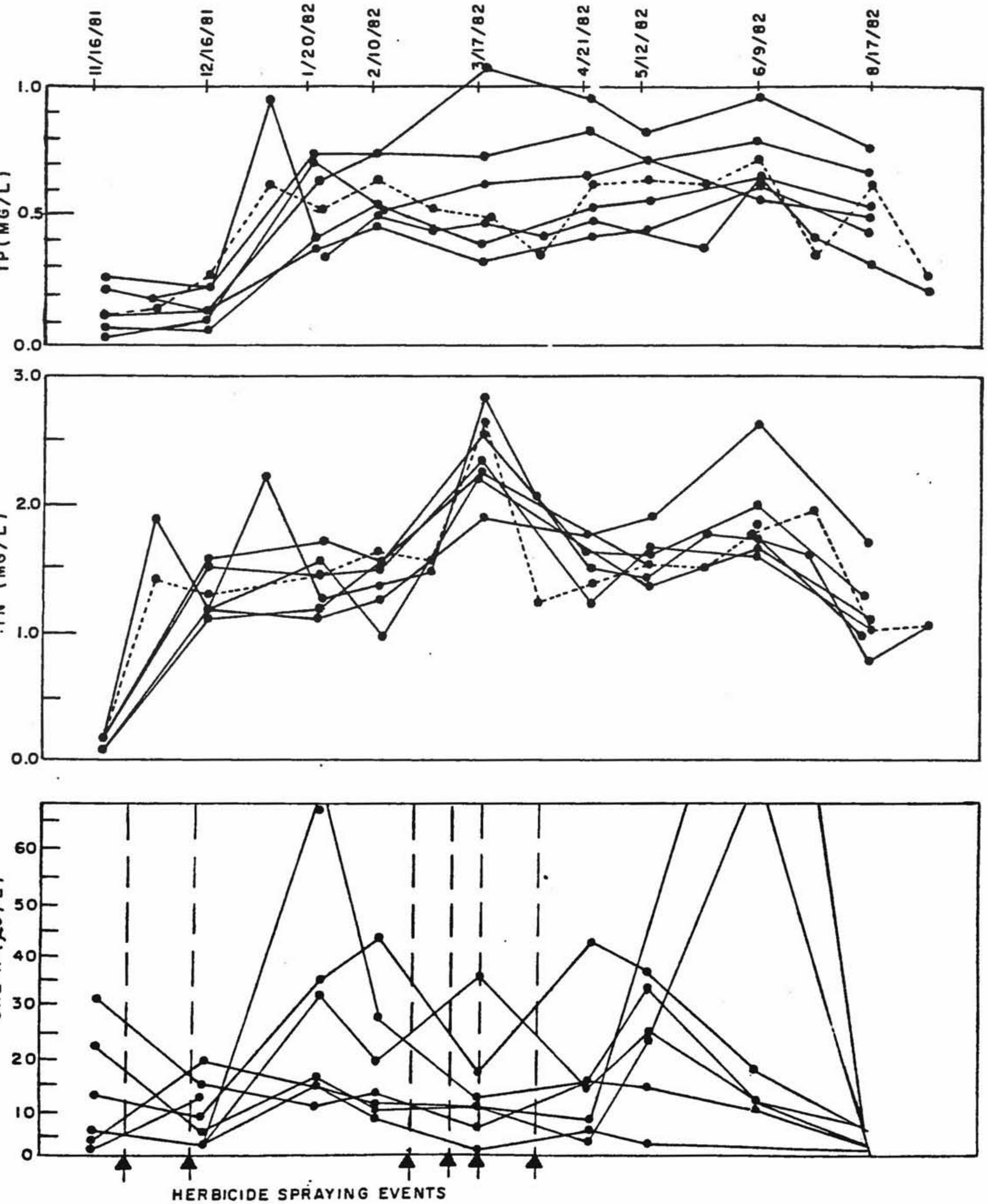

FIGURE 5-1
PARAMETER VARIATIONS
LAKE MYAKKA STUDY

from subsequent evaluations (Section 8), further review suggested that the lake is influenced primarily by tributary loadings with some nutrient uptake probably occurring during very low flow, low water level periods. Whether this loss of nutrients is to the sediment or macrophytes has not been determined.

5.2 Total Phosphorus

As indicated on Figure 5-1, total phosphorus concentrations were low during November and December, 1982, and indicated significant rises in response to herbicide spraying and possibly resultant plant die off. Although the variations in concentrations were similar to the total nitrogen results, phosphorus concentrations remained relatively constant throughout the remaining portions of the study, except for small increases during wet seasons.

During the entire sampling program, lake values averaged approximately 0.6 mg/l with only one value exceeding 1.0 mg/l. As the study progressed, total phosphorus concentrations appeared to decrease during the summer. These results could either be attributable to increased tributary flows carrying existing lake concentrations over the dam, or to the aquatic plants incorporating more phosphorus into biomass as nitrogen became more available. Phosphorus existed primarily in the ortho-phosphorus form, consistent with the observed nitrogen limitation. Based on the low nitrogen concentrations, excess ortho-phosphate would remain in solution since plant species would be unable to assimilate phosphorus due to the lack of nitrogen.

5.3 Chlorophyll"a" Results

In lake and bay environments, chlorophyll"a" concentrations are often mathematically correlatable to nutrient levels. The attempts utilized for establishing relationships from the datasets are developed and discussed in Section 8. Chlorophyll"a" levels within Lake Myakka varied widely with values ranging from less than 1 ug/l to more than 200 ug/l. Values observed at specific locations within the Lake are not uniform, but vary by ten or more units during sampling event (Figure 5-2). Normally, the highest chlorophyll values obtained during the study were from station 12 near the Howard Creek confluence with Lake Myakka. During the June and August, 1982, samplings, these stations significantly exceeded other lake concentrations. These values suggest increased algal growth due to the addition of increased nitrogen loads resulting from runoff and mixing with the otherwise nitrogen limited lake waters.

Chlorophyll concentrations observed within the tributary streams were usually less than or equal to the levels observed within the Lake. These values are not surprising since chlorophyll is a

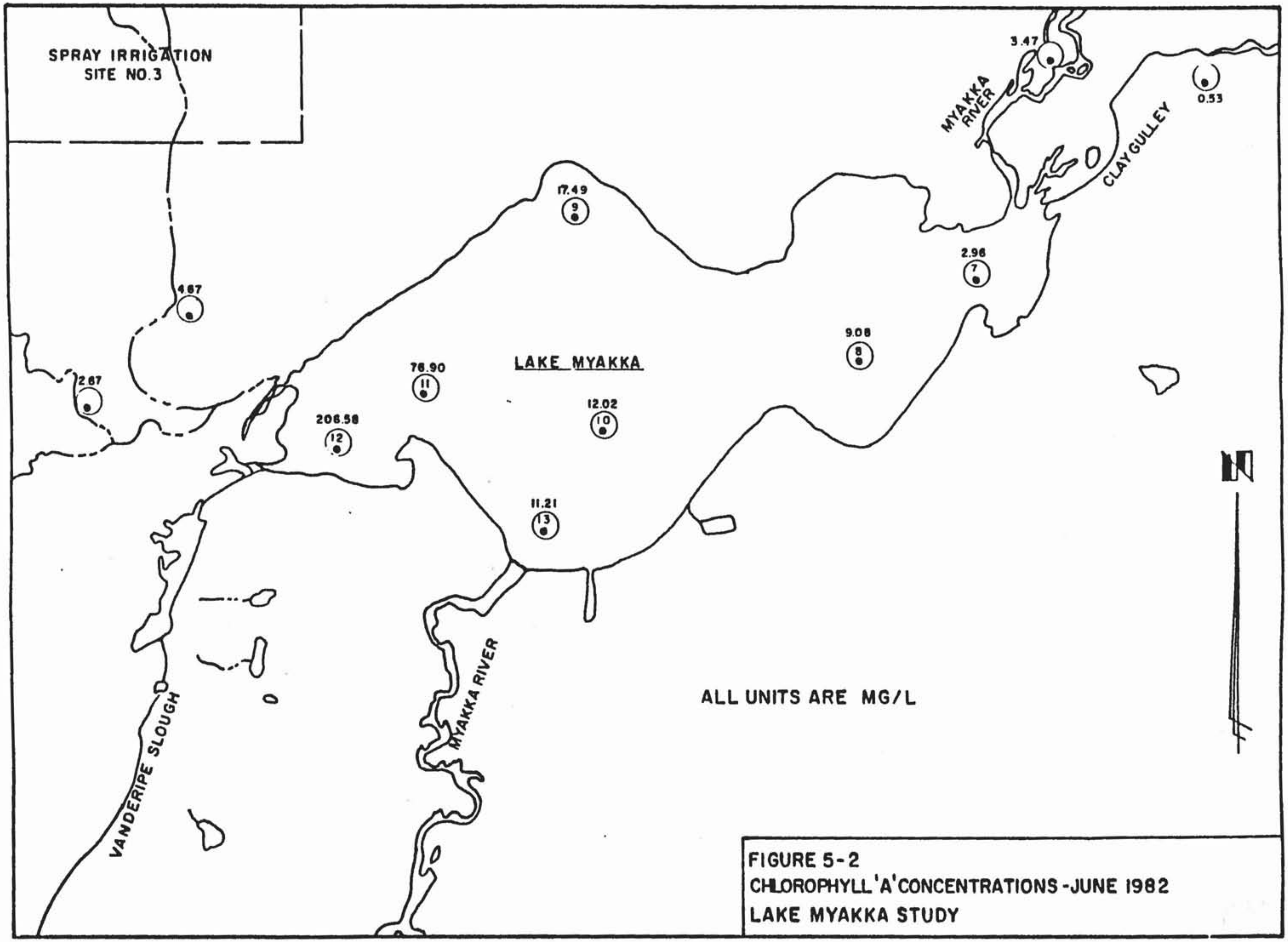

FIGURE 5-2
CHLOROPHYLL 'A' CONCENTRATIONS - JUNE 1982
LAKE MYAKKA STUDY

secondary parameter with increases resulting from other primary pollutants, particularly nitrogen and phosphorus. Since nitrogen was observed to be limiting during most of the sampling events, observing similar chlorophyll values in waters of similar characteristics would be predicted.

5.4 Biochemical Oxygen Demand Results

Biochemical Oxygen Demand (BOD) is a commonly used measurement for tracking sewage plant discharges and other organic wastewater sources. BOD values observed in Lake Myakka averaged less than 10 mg/l and were usually uniform across the lake system (Figure 5-3). Tributary BOD values were generally lower than the Lake except during the wet season; suggesting non-point source contributions (i.e., agricultural runoff). Furthermore, since lake values were usually higher than tributary concentrations, the implication is that other sources of oxygen demanding substances exist within the Lake.

5.5 Dissolved Oxygen Results

Based upon the Level I investigations, primary emphasis was placed upon quantifying oxygen resource relationships within the Lake system. During the investigation, Lake Myakka water column samples exhibited numerous violations of the 5.0 mg/l minimum freshwater dissolved oxygen (DO) standard. The calculated average of the seven lake stations for each event smooths out the DO variability, while still providing in-sight into the overall oxygen resource of the lake (Figure 5-4). Sampling results obtained during the first six months indicated a continuous increase from 5.8 to 8.9 mg/l. These results were probably caused by decreased water temperatures, concurrently increasing the solubility of oxygen in water. During these periods, BOD loads remained relatively constant signifying no additional demand placed on the DO resource.

Beginning with February, 1982, the average DO concentration trend reversed, declining initially to 5.4 mg/l and then to a low of 3.4 mg/l during April. The April average values include four individual station values below 3.0 mg/l. These changes can partially be explained by the increased ambient temperatures, but the pattern changes twice during May and June, 1982, with even warmer water temperatures. Overall average concentrations during the May sample event were 6.3 mg/l, while during June (a very high flow period) the average drops to 2.5 mg/l. During the June event, no individual station in the lake or in the four adjacent tributary inflow stations satisfied the minimum water quality standard of 5.0 mg/l.

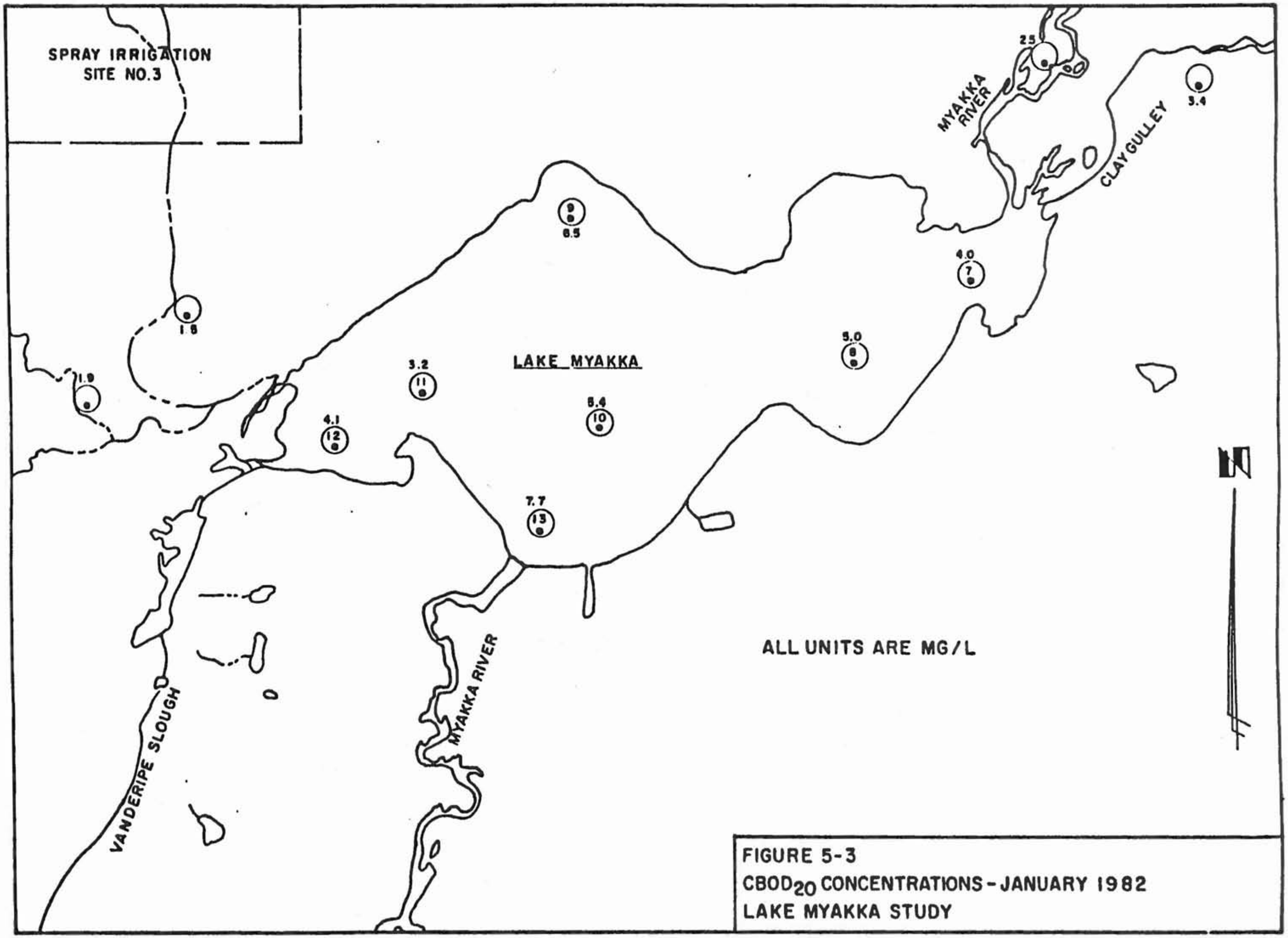

FIGURE 5-3
$CBOD_{20}$ CONCENTRATIONS - JANUARY 1982
LAKE MYAKKA STUDY

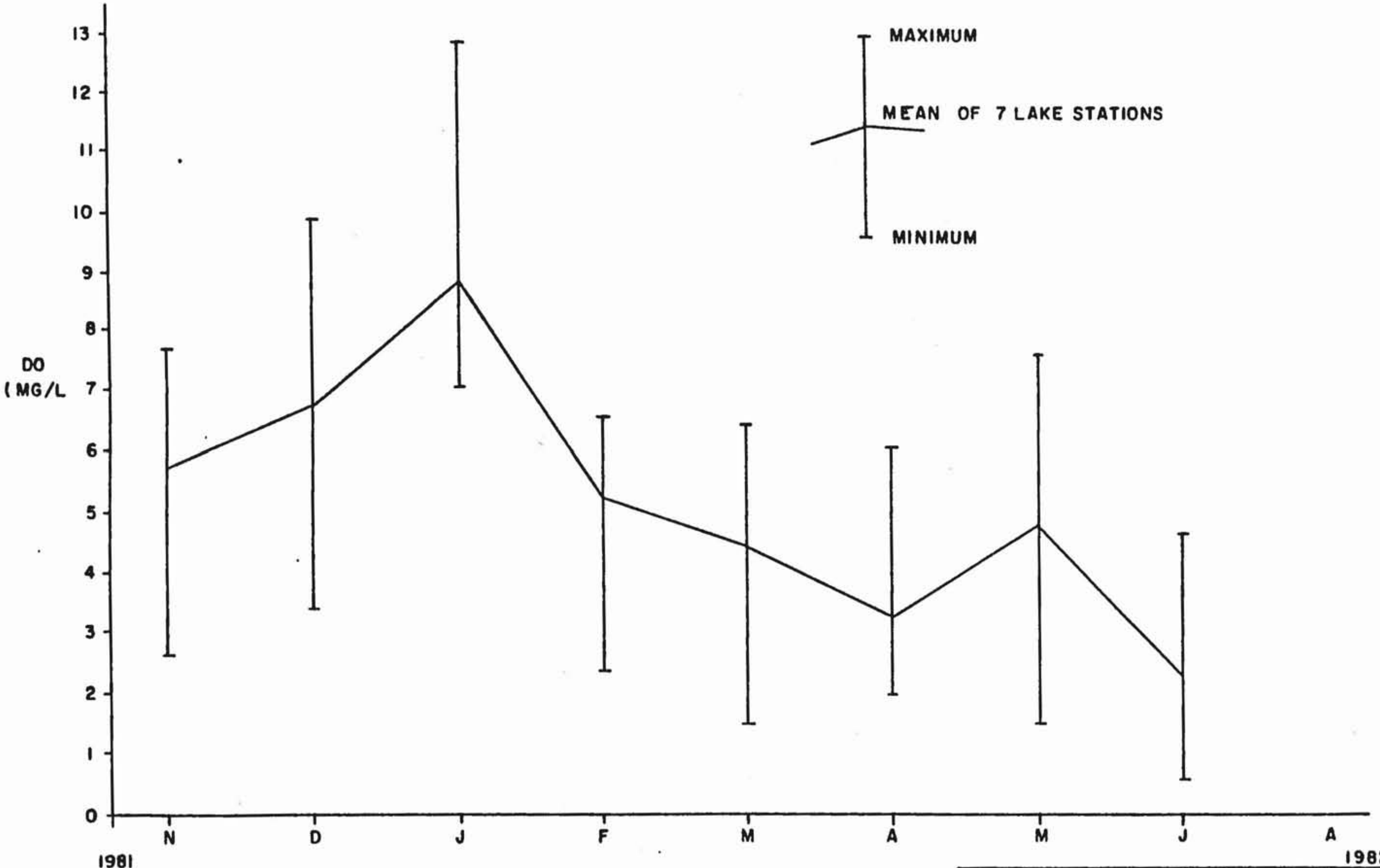

FIGURE 5-4
MEAN, MIN, MAX. DO VS TIME
LAKE MYAKKA STUDY

In order to obtain a better understanding of the DO relationships, a 24-hour DO study was conducted at three lake stations (samples analyzed every 20 minutes) during August, 1982. As indicated on Figure 5-5, the results from these stations show an unusual variability. Station 7 (near the Myakka River inflow) had a maximum DO during the study period of 4.3 mg/l with the minimum reaching a low value of 1.9 mg/l during early morning hours. Station 10 (central lake station) showed a completely different pattern with almost constant DO concentrations varying between 5.0 mg/l and 5.5 mg/l, with no evidence of the normal diurnal variation. The third station located near the mouth of Howard Creek (Station 12) reacted similarly to Station 10, but with levels closer to Station 7. The diurnal study identified an initial value of 4.8 mg/l; other data points fluctuate around this value, but never reach 5.0 mg/l. However, when the fluctuations are smoothed and averaged with time around each value, a slight diurnal variation was observed.

5.6 Bacteriological Parameter Results

The three bacteriological parameters measured during each water quality sampling event were total coliform, fecal coliform, and fecal streptococci. Total and fecal coliform levels were of particular interest due to inclusion in Florida water quality standards. Total coliform values remained relatively constant throughout the study with values ranging around 100 per 100 ml or lower at the lake stations. However, tributary stations exhibited elevated levels during wet months, suggesting influences from agricultural activities. Fecal coliform levels parallel total coliform values, but absolute numbers were near detection limits within the lake. Elevated values were observed in the tributary streams during the wet season with values ranging from less than 10 to 600 per 100 ml. Fecal streptococci values also follow the same pattern with higher values in the tributaries and lower values within the lake.

5.7 Other Parameters

Total suspended solids average concentrations in Lake Myakka vary from a low of 2.1 mg/l in March, 1982 to a high of 14.8 mg/l in May. Individual values from the lake stations range from 0 to 30 mg/l. The tributary stations have similar levels except for several slightly elevated concentrations at station 6 (Myakka River upstream of the Lake) in February, March, and April, 1982. In general, suspended solids do not appear to be a water quality problem in Lake Myakka.

Ambient water temperatures, averaged for the seven lake stations, varied from a low of 13.7°C in December to 29.7°C in June, 1982. Both May and August showed slight declines in an otherwise

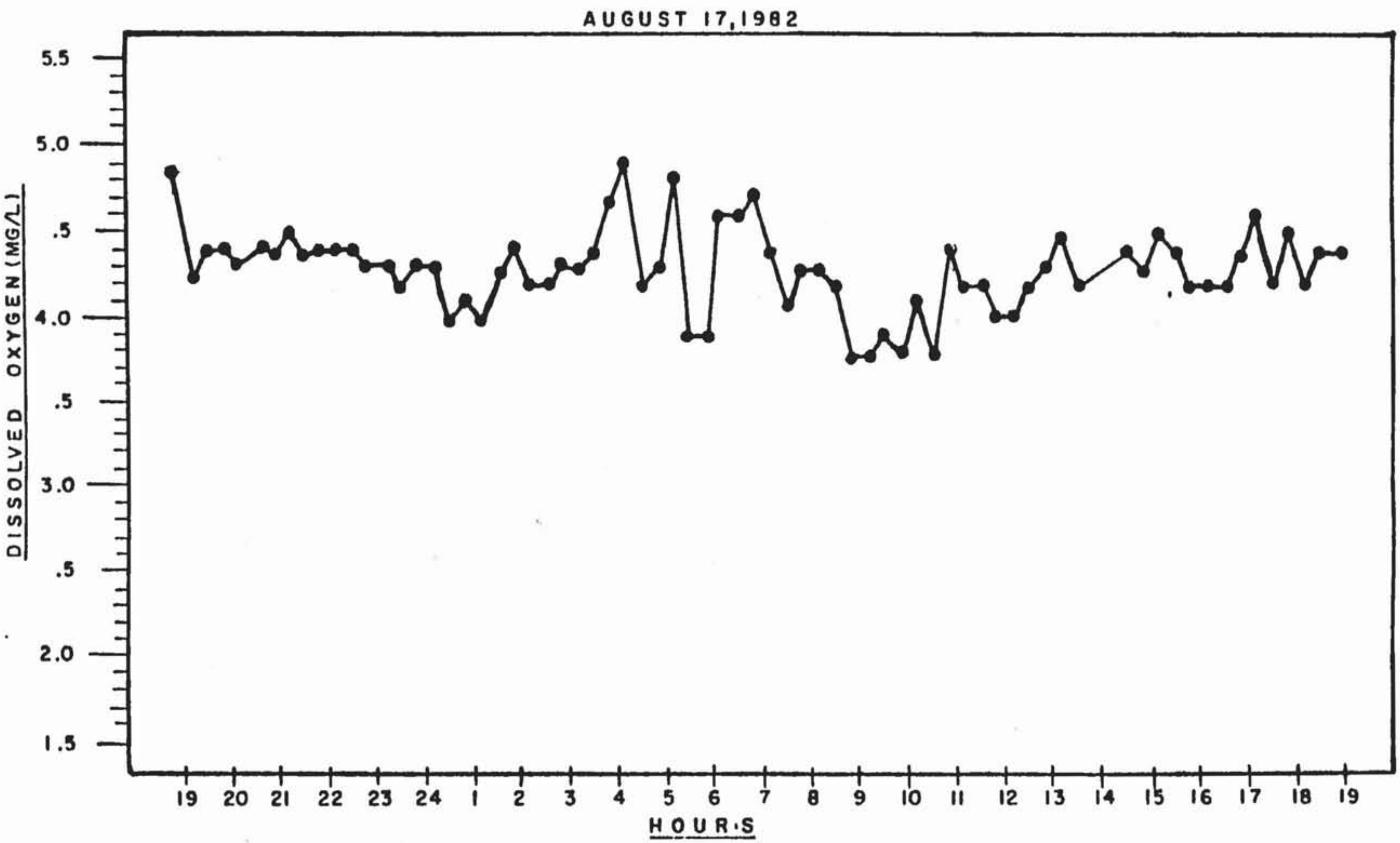

FIGURE 5-5
DIURNAL STUDY - STATION 7
LAKE MYAKKA STUDY

steadily increasing average. Tributary stations varied in a similar manner to the lake values.

Average total organic carbon concentrations varied in a narrow range from 17.6 mg/l in February to a maximum of 26.4 mg/l in April. June's average was slightly less (26.1) while the other monthly averages were clustered around 20 mg/l. Tributary station concentrations were generally lower during low flow periods and higher during the wet season, when runoff flows were high.

present, and the extra quantities of runoff containing nutrients, the lake appears to be in a eutrophic condition.

SECTION 7

NON-POINT POLLUTION SOURCES

Non-point source loads are the major contributors of pollutants to Lake Myakka. Unlike Sarasota Bay, there are presently no significant point sources of water pollution to the upper Myakka River or directly to the Lake. The stormwater runoff from agricultural, pastoural and undeveloped land uses comprises on the nutrient and oxygen demanding loadings to the Lake system.

Instead of applying various land use based estimates of pollutant loading, load estimates were generated based upon both the Lake's inflow and outflow concentrations and flows. Subsequent manipulation of these loads to match field data provided a means of developing a nutrient budget for the present lake system. This data is used in Section 9 to develop a trophic state index for Lake Myakka which can be used to predict the effect of any changes to the present Lake condition.

7.1 Non-Point Source Load Estimate

Utilizing the calibration/verification results and extrapolating them to a full calendar year, approximately 3.1 million pounds of oxygen demanding substances are discharged from the Howard Creek and Myakka River systems into Lake Myakka each year. This corresponds to a mean annual BOD loading rate of 21.2 lbs/acre/yr. Similarly, total nitrogen and total phosphorus loadings for wet and dry season months were extrapolated to yearly loadings of 1,090,000 lbs and 44,000 lbs, respectively. These values correspond to areal loading rates of 7.3 lbs/acre/year for total nitrogen and 2.9 lbs/acre/year of total phosphorus. These values are comparable with literature values from other stormwater research in Florida as indicated on the Table below.

NON-POINT POLLUTANT LOADINGS*
(lb/acre/yr)

Land Use	BOD	TN	TP
Cropland	3.56-27.6	13.4-32.9	0.16-1.44
Pasture	5.34-15.15	2.23-7.57	0.20-0.59
Forest	3.56-6.23	2.13-5.54	0.009-0.77

* Reference 7.

Other sources of non-point loads may be responsible for the elevated total phosphorus loading value as indicated below.

7.2 Other Loads

A potential major source of water pollution to the Myakka River system is the phosphate industry. At this writing only one mining operation (Beker, Inc.) is underway in the Myakka watershed. Stiff local opposition, combined with tough enforcement of local and state regulations is expected to keep the phosphate industry in Manatee County a much cleaner operation than it has been in the past in Hillsborough and Polk counties. Nevertheless, Beker already has an NPDES permit for discharge to Wingate Creek, a tributary of the Myakka River. Furthermore approximately 33,000 acres or 22 percent of the Lake Myakka watershed is scheduled for mining in the future.

Estimation of yearly loading from the existing mine or future operations is nearly impossible because of the intermittent operating schedules and discharges from mining operations. However, it is predicted that in the future unless alternate methods of process water re-use or disposal are developed, the phosphate industry will become a major source of the total phosphorus loading to Lake Myakka.

SECTION 8

EVALUATION FRAMEWORK

The framework employed to analyze existing water quality and project future conditions is identical to that utilized for Level I evaluations and consists of a two-dimensional steady-state, advective-dispersive model utilizing the finite difference solutions to basic differential equations combining flow continuity and conservation of mass. In simple terms, each segment is treated as a completely mixed volume which is subjected to advective and dispersive flows from all adjoining segments or through defined outside boundaries. A differential equation is derived for each segment; this equation is essentially a mass balance for each segment taking the effects of adjoining segments into account. The system of differential equations can be transformed into matrix arrays. The resulting matrix algebra equation has the segment concentrations as the only unknowns, and a solution is found by matrix inversion techniques.

8.1 <u>Computer Model Description</u>

Before any calculations can be performed, the various physical and chemical variables must be quantified for input to the model framework. This discussion details how these variables are calculated and then explains how the values are manipulated by the model. Appendix B details both the actual computer program coding for program SARBAY and the principal mathematical formulation used in the model.

8.1.1 Input Requirements

The actual physical description of the system to be modelled is one of the most important data inputs. Due to the segmentation used to represent the different areas of the Lake, the quantity of physical data required was increased. The required data include: volumes calculated from bathymetric and geodetic maps; areas planimetered from geodetic maps; depths measured either directly or calculated from volume and areas; vertical plane areas (the planar area between segments) determined by bathymetry; and the distance between adjacent segment centroids measured from geodetic maps. Field transects of the Lake were used to update available mapping.

The next required input information is existing and projected pollutant loads and concentrations. The loads were determined from the report on the Spray Irrigation site (Ref. 8). Flow values for existing conditions were determined using field data.

Dispersion coefficients were initially derived from previous experience and literature values. These values were later adjusted down based on various field measurements and model calibration runs. BOD reaction rates were taken from literature values and modified as necessary to fit the field data. Dissolved oxygen reaeration rates are derived from a relationship which describes says that the rate is inversely proportional to the average depth.

For BOD/DO models, two other terms reflecting sources and sinks of oxygen are also used. The source term is based on phytoplankton kinetics and is calculated from chlorophyll and nutrient concentrations, temperature, depth, secchi disk depth and light availability. The mathematical formulation is presented in Appendix B. The output values are expressed in mg/l/day and are input directly to the DO model. The last term is an oxygen sink term, which in this analysis represents the benthic oxygen demand rates determined by field measurement.

8.1.2 Model Logic

The reader is referred to Appendix B for a more detailed explanation of the actual computer program. The following summarizes the analytical procedures used to arrive at the output concentration values.

The first part of the computer program sets up the physical system by reading in all the geometric data, flows, and dispersion related terms. With this data stored in computer memory, an iterative procedure begins that formulates differential equations for each model segment based on the conservation of mass and flow continuity principles. The coefficients for each of these equations are stored in a matrix array. Once an equation has been derived for each segment, taking into account the effects of each adjacent segment, a system of N equations with N unknowns remains, where N is the number of segments. The program then uses the matrix inversion technique to evaluate the unknowns, which in this formulation are the average segment concentrations. For coupled reactions, the matrices are reformulated by adding (or subtracting) the sink and source terms and applying the reaction rates. The new matrix is also inverted and the results from both the first and second manipulations are output as concentrations by segment.

The output initially identifies a printed question asking for the average Lake temperature, followed by a segment by segment listing of BOD concentrations (first variable) and DO deficit concentrations (second variable). To obtain a DO concentration, the deficit must be subtracted from a saturation concentration.

The model is capable of handling coupled reaction equations with both advective and dispersive flows, thus simulating environmental conditions. By zeroing out the reaction rates, conservative substances like total nutrients, can be modelled (first variable only). Also non-coupled reactions like bacterial decay can also be modelled using appropriate (die off) rates.

8.2 Model Calibration and Verification

Model segments established during Level I evaluations formed the basis for initiating Level II evaluations. Figure 8-1 displays the final segmentation utilized. Water quality data collected during this study served as the basis for calibrating the model used in this project. Initial work done for Level I relied on a combination of limited field data and professional judgment. As more data were collected, the model was refined, particularly the conservative nutrient models were redone several times, until acceptable calibration was achieved. Most model manipulations involved varying dispersion terms and flow paths to fit the measured data. Table 8-1 displays a comparison of field measurement data and model predicted total nitrogen values for May, June, August, 1982. These values represent the concentration of a completely mixed segment volume. Calibration runs were continuously modified until the predicted values approximated the field measurements.

Another important consideration in model calibration was that trends seen in the water quality data also show up in the model output. Five data sets were used for calibration/verification purposes. The total nitrogen and total phosphorus data from each data set were plotted on maps of the Lake; these plots were used as a comparison with model results.

The calibration/verification procedure used several data sets. The first two were used to define coefficients and all remaining data sets were employed to compare calculated and observed water quality. The specific procedures used defined the transport coefficient for dispersion and flow field employing one conservative variable, (i.e., total nitrogen). These coefficients and patterns were then used for all other conservative and non-conservative calculations. Reaction coefficients were defined employing similar procedures.

Flows between segments and dispersion terms were adjusted to reflect water quality data. Initially, only the March and June, 1982, total nitrogen models were run so that adjustments could be made on both wet and dry condition data sets. Once satisfactory calibration of those two months was achieved, the other three months were run and all five months were subsequently used for total phosphorus models. Each output was checked against the

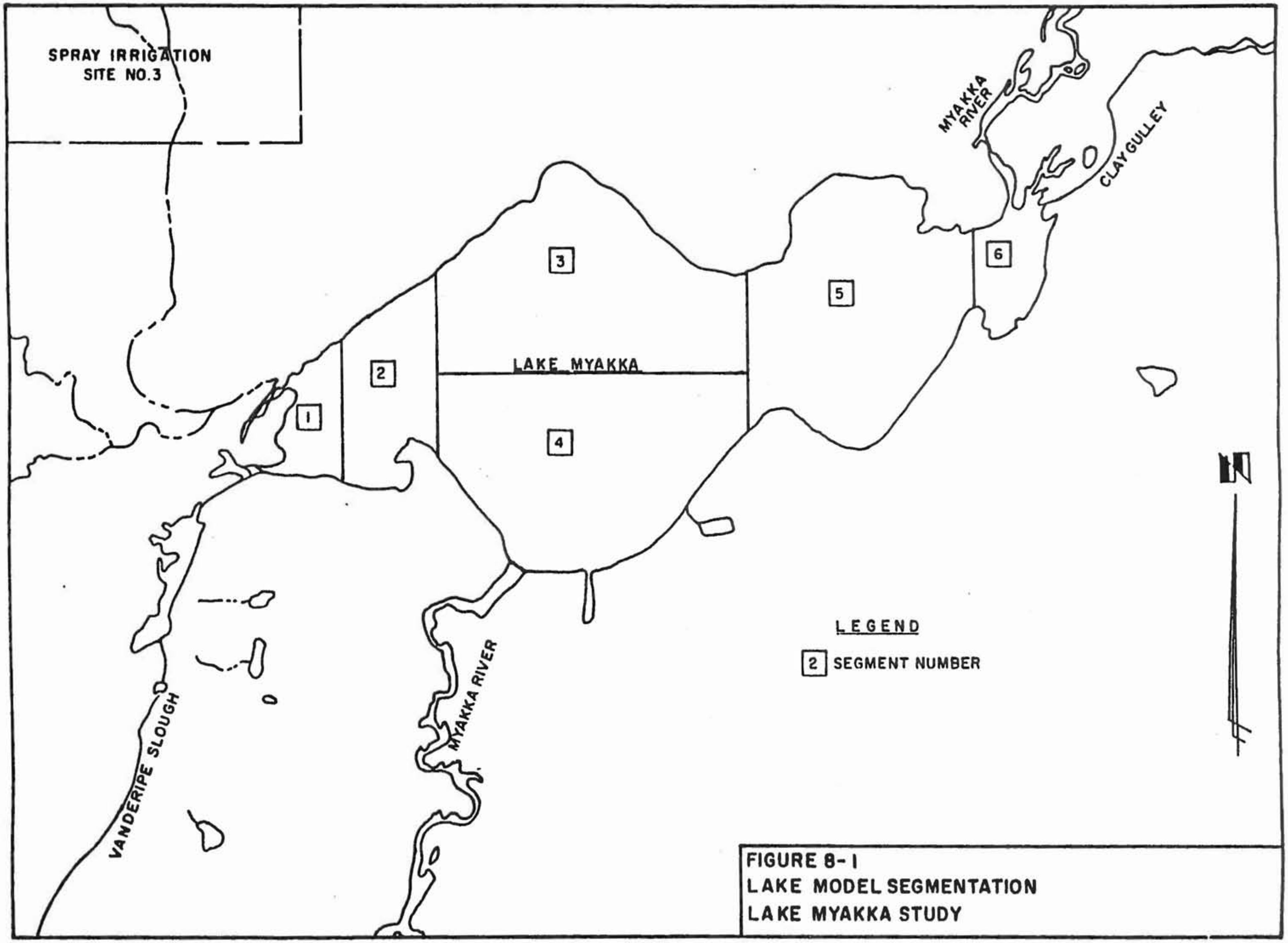

FIGURE 8-1
LAKE MODEL SEGMENTATION
LAKE MYAKKA STUDY

TABLE 8-1
MEASURED VS MODELLED TN CONCENTRATIONS
LAKE MYAKKA STUDY
(all concentrations in mg/l)

Segment	May		June		August	
	Measured	Modelled	Measured	Modelled	Measured	Modelled
1	1.93	1.87	2.66	2.46	1.66	1.33
2	1.51	1.76	2.05	2.28	1.21	1.21
3	1.38	1.54	1.65	1.76	0.97	0.95
4	1.54	1.54	1.75	1.76	1.05	0.95
5	1.64	1.37	1.63	1.55	1.12	0.79
6	1.42	1.39	1.69	1.68	0.73	0.85

plots generated from the field data to assure that adequate representation of the environmental conditions was achieved.

Operating on the assumption that the two conservative nutrient parameter models are good representations of the system, the calibrated and verified models can be used for other parameters and to make predictions regarding nutrient concentration changes. The assumption is that the physical system is well represented and changes involving flow patterns and dispersion coefficients no longer need be made. However, other variables can still be modified providing the basic transport model structure is left intact. Also, decay terms and sink/source relationships were then derived by other methods for expanding the modelling to non-conservative parameters.

By adding in various reaction rates and sink/source terms, a single model can be used to predict both the concentration of BOD, a non-conservative substance, and dissolved oxygen deficit, which is derived from both the deficit caused by the BOD and other production and respiration terms. These equations are referred to as a coupled reaction system because the second variable is at least partially dependent on the first. Reaction rates were varied during calibration to obtain the best fit for both the BOD and DO deficit results.

The two other terms used for the oxygen deficit calculations included a production minus respiration term (usually an oxygen source) and a benthic respiration term (a sink). The P-R term is derived from an equation which takes nutrient, chlorophyll, secchi disk depth, physical depth, and temperature into account to estimate net algal productivity. The benthic rates are derived from the results of the three SOD studies by EPA. Since these values were derived from field data, they were not modified during calibration except for temperature corrections to ambient temperatures.

8.3 Predictive Model Evaluations

Through utilizing the model for the Upper Lake Myakka system, the following modifications were included in model evaluations. The dispersion terms were adjusted to low values, thereby eliminating the majority of dispersive effects more representative of tidal influences as opposed to movement within a lake system. Furthermore, various volume related adjustments were necessary for the different months due to variable lake levels throughout the individual sampling events. Flows from the Howard Creek system into the western portions of Lake Myakka and from the Myakka River in the northeast segment of the lake were routed through the six lake model segments. (Figure 8-2).

Based upon the calibration/verification runs utilized for Lake Myakka, values representing the May sampling event would identify the normal critical period. During the May sampling event, higher ambient water temperatures and below average flows existed within the system and the lake levels had not returned to high elevations. With respect to wet season conditions, the values obtained for June, 1982, would be representative of wet season conditions due to the high inflows monitored. Therefore, in evaluating future impacts from additional loads to the system, the values obtained for May and June, 1982 would represent the warm dry months and the warm, wet months.

Once an understanding of the existing system was achieved through model calibration/verification, future or alternative conditions could be predicted. As with the verification procedure, the same physical and reaction rate relationships derived earlier will be maintained while concentrations and flows are altered to define proposed impacts. This assumes that physical characteristics will be essentially the same under future conditions.

In making predictions, the model requires that several assumptions be made. First, significant effluent flow changes to Howard Creek are assumed not to alter the advective/dispersive pattern presently established. This assumption may not be completely valid because of the relatively small volumes in each segment. However, the impacts upon dispersion should be offset by the increased movement of mass from the Creek into the Lake. The only likely effect in the Lake is increased dispersion in the area just beyond the Creek mouth.

SECTION 9

ASSIMILATIVE CAPACITY EVALUATION

Assimilative capacity can be defined for various constituents and conditions as the quantity of material which can be assimilated by the receiving waters without violating state water quality criteria and beneficial use designations. In order to define the appropriate quantities which can be discharged from point source and non-point source contributors, the initial system simulation must be stressed through step-wise load increases until water quality standards and use designations are just maintained.

Based upon developing calibrated/verified simulations of existing Lake Myakka and tributary conditions for both conservative and non-conservative parameters, assimilative capacity determinations can be accomplished for the following conditions: increasing flows/loads upon Howard Creek from the proposed spray field irrigation system; increasing resultant loads from Howard Creek on the Lake during periods when water quality standards were not violated; and through reducing present loads upon the system when water quality standards are violated, define the load reduction necessary to satisfy standards. Through evaluating these conditions on a step-wise basis, appropriate changes in water quality conditions can be delineated and compared with state water quality standards and use designations. Each set of loading scenarios can generate different assimilative capacities depending upon the physical/chemical/biological conditions prevalent within the receiving waters.

During the initial water quality data evaluation and model calibration/verification procedures, flows/loads representing appropriate values for each month were simulated. As indicated from the water quality data, numerous violations of the dissolved oxygen standard were observed within the lake during warm months. These particular violations indicate that the assimilative capacity for oxygen demanding substances within Lake Myakka has been exceeded during those specific periods. However, in order to properly identify the change in lake conditions under increased loadings, comparisons were developed to properly identify the degree of water quality impairment. These values would then establish the basis for comparing water quality impairment within the Lake system with other wastewater discharge options.

9.1 Spray Field Discharge to Howard Creek

Based upon identifying existing conditions within Howard Creek with the calibrated/verified model, increased flows/loads could be applied in the vicinity of proposed spray field underdrain discharges. Through step-wise increases in underdrain flows/loads, the assimilative capacity of Howard Creek could be identified for oxygen demanding materials. Once the non-conservative parameter capacity was delineated, predictions were made regarding conservative parameter levels in order to properly define impacts upon Lake Myakka.

Specific flows/loads utilized for point and non-point source values are identified in Table 9-1. Through increasing the spray field underdrain discharge by multiples of two, five, and ten times the initial loads, dissolved oxygen violations were not obtained until approximately five times the initial levels were achieved. Corresponding with these particular values, total nitrogen and total phosphorus loads discharged to Lake Myakka would be approximately 110 and 50 pounds per day.

9.2 Lake Myakka Without Water Quality Violations

Based upon the results obtained from field sampling and the calibration/verification analyses, the May, 1982, lake model simulations were used to evaluate assimilative capacities. Through incorporating the results obtained from the Howard Creek analyses as inputs to the western portion of Lake Myakka with loads identified from Myakka River and those existing within the Lake, the assimilative capacity of the Lake could be identified relative to non-conservative and conservative parameters. These evaluations proceeded until dissolved oxygen standards were violated.

The results obtained through performing the non-conservative parameter evaluations indicate that only a portion of the load discharged from Howard Creek can be assimilated by Lake Myakka during February, 1982, conditions. The amount assimilated equates to approximately two times the base concentrations utilized for the Howard Creek analyses. Furthermore, an evaluation was conducted removing the Myakka River loading to the Lake and this resulted in only a minimal increased load to be discharged from Howard Creek. When loads were reduced by fifty percent from values existing within the Lake system, the allowable capacity for Howard Creek discharges increased to approximately three times the base conditions. The range of allowable discharges into Howard Creek and subsequent impacts upon Lake Myakka range between two and three times the base discharge conditions from the spray irrigation underdrain system.

9.3 Lake Myakka With Water Quality Violations

Although water quality standards were violated during the warmer months, a comparison of resultant impacts from projected point and non-point sources were developed. Initial evaluations were performed with the same loading conditions identified as allow-

TABLE 9-1
POINT AND NON-POINT SOURCE FLOWS/LOADS
LAKE MYAKKA STUDY

Non-Point Sources	Flow (cfs)	BOD (lb/day)	TN (lb/day)	TP (lb/day)
January	3	120	20	20
February	3	130	30	10
March	14	590	210	80
April	20	1280	290	140
May	20	1390	310	140
June	100	5960	1600	800
July	100	5960	1600	800
August	50	1710	510	300
September	50	1710	510	300
October	50	1710	510	300
November	9	130	5	10
December	3	110	20	5
Point Source*				
Underdrain discharge-all months	9.2	250	107	50

* Based on 6 MGD with 5 mg/l BOD, 2.14 mg/l TN and 1.0 mg/l TP.

able capacities resulting from Howard Creek during June, 1982, lake data evaluations. These simulations indicated that dissolved oxygen concentrations would be depressed from the observed values of 2.6 mg/l to 2.1 mg/l less mg/l. When the Howard Creek discharges were reduced to the levels identified in Section 9.2 for maintaining water quality standards under February, 1982, conditions, the dissolved oxygen concentration was increased by approximately 0.4 mg/l. Through reducing the in-lake load by fifty percent, and maintaining the Howard Creek discharges at the levels satisfying February, 1982, values, dissolved oxygen concentrations were increased by 0.4 mg/l. An additional analysis was conducted identifying decreased loads from Myakka River equivalent to 25 percent of the non-conservative parameter discharges. Although these reductions would need to be accomplished on primarily agricultural land through incorporating best management practices, dissolved oxygen concentrations only increased by 0.1 mg/l

As an alternative evaluation, existing loads within Lake Myakka and the tributary systems measured in June, 1982, were reduced to satisfy water quality standards. The necessary reductions in non-conservative parameters were identified to be approximately 20 percent for Howard Creek, 40 percent for Myakka River, and 20 percent for in-lake conditions. Each one of these reductions would require increased utilization of best management practices on tributary areas and regular maintenance through removal of detritis from the Lake bottom. These reductions in load would be necessary to allow the present Lake system to maintain dissolved oxygen standards during the critical warm months.

9.4 Lake Myakka Nutrient Limitations

During the data collection program, aquatic plant conditions within Lake Myakka were identified through specific plant sampling and general observations. The extent of macrophyte growth was excessive with hyacinths covering large areas of the lake surface during almost the entire ten month period and hydrilla observed in most visible portions of the water column. As a result of the herbicide spraying and decreased lake levels during the dry season (December, 1981 - March, 1982), fluctuations in the magnitude of plant density were observed during recession caused by spraying/drying.

Judging by the extensive plant coverage and often elevated chlorophyll concentrations, the degree of eutrophication appeared excessive. In order to properly document potential changes in water quality from load increases/decreases in the future, attempts have been made to identify the quantitative change anticipated within the Lake system. Several approaches have been attempted with each based upon field data identifying input, in-lake, and output quantities pertaining to nutrients and nutrient related parameters. These attempts have been directed toward understanding the impact of nutrient loadings from existing watersheds on the Lake and methods to predict responses from changes in nutrient loading conditions.

Most approaches developed for predicting the trophic status of lakes have involved the use of simplified input-output models. These models assume that a lake is a completely-mixed reactor and that all nutrient fluxes within the Lake have achieved steady-state. Most models can be used easily with data requirements limited to morphologic and hydrologic parameters, along with areal loading rates. The primary disadvantage has been that model development has occurred on temperate zone lakes. In most of these instances, phosphorus has been the primary limiting nutrient as opposed to nitrogen.

Recent investigations performed through the Florida Water Resources Research Center, identified in "Nutrient loading - Trophic State Relationships in Florida Lakes", (Ref. 9) have addressed the critical conditions in Florida lakes. This particular report has summarized the data base established for approximately 100 lakes within Florida and concentrated on developing nutrient loading, trophic response, and critical loading rate guidelines. Particular emphasis during these investigations was placed upon transforming previous modelling techniques to applicable Florida lake situations with nitrogen limitations emphasized.

A primary output from the FWRRC study which is beneficial to the Lake Myakka evaluation was the definition of a trophic state index which allows ranking lakes along a linear gradient. This process allows comparisons between the trophic state index within a group of lakes, can be used to quantify historical changes in trophic state (thereby relating to projected changes), and provides a concise ranking system. The two relevant equations identifying the trophic state index (TSI) utilizing total phosphorus and total nitrogen are as follows:

$$TSI(TP) = 10(6 - \ln(48/(P)_1)/\ln 2).$$

$$TSI(TN) = 10(6 - \ln(1.46/(N)_1)/\ln 2).$$

Within these equations, the expression $(P)_1$ refers to the water column phosphorus concentration expressed in ug/l with TSI(TP) indicating a numerical value for the trophic state relative to total phosphorus. Within the TSI(TN) relationship, the term $(N)_1$ refers to the water column nitrogen concentration expressed in mg/l N.

Ideally, when both TSI(TP) and TSI(TN) are computed, the smaller of the two TSIs represents the limiting nutrient for the given lake. The specific values calculated for Lake Myakka based upon the field data collected during the last ten months are TSI(TP) equals 93 and TSI(TN) equals 61. These values are based upon the mean TN concentration of 1.58 mg/l and 480 ug/l for total phosphorus. These results indicate that Lake Myakka is significantly nitrogen limited since an increase of approximately 10 mg/l TN would be required to bring the two indices within the same range of values. The values cannot be explicitly utilized for defining trophic state within the categories of oligotrophic, mesotrophic, eutrophic, and hyperutrophic. However, when the Lake Myakka values are compared with the rankings utilized in the referenced study, Lake Myakka would be classified within the eutrophic and hypereutrophic ranges based upon the other lake rankings.

Through establishing nutrient loading criteria for Florida Lakes, the FWRRC lake study has developed relationships applicable to nitrogen limiting conditions. The evaluations addressed previously generated equations based upon total phosphorus and chlorophyll"a" relationships for temperate zone lakes and then were reviewed with respect to the data obtained from the 100 lakes within in the State of Florida. Through evaluating the various relationships, the following two equations were found to be statistically significant relative to identifying the trophic state of Florida lakes:

$$(MEL_n) \cdot (1 - R_n) = 1.12 \quad q_s$$

$$(MML_n) \cdot (1 - R_n) = 0.55 \quad q_s$$

Within these equations, MEL_n identifies the minimum eutrophic loading condition, while MML_n identifies the minimum mesotrophic condition. R_n refers to the nitrogen retention coefficient and is defined as follows:

$$R_n = 1 - \frac{(Q\ out)(N\ out)}{(Q\ in)(N\ in)}$$

The variable q_s refers to the hydraulic loading and is expressed as the average annual depth (meters) times the annual flow volume (cu. meter/yr) divided by the mean lake volume (cu. meter).

In order to interpret the position of a given lake within the trophic state delineation developed for Florida lakes, the above relationships were translated into Figure 9-1. In order to develop the MEL_n and MML_n envelope curves, the researchers identified the reasonable criteria for nitrogen concentrations to be 1.0 mg/l-N for minimum eutrophic conditions and 0.5 mg/l N for

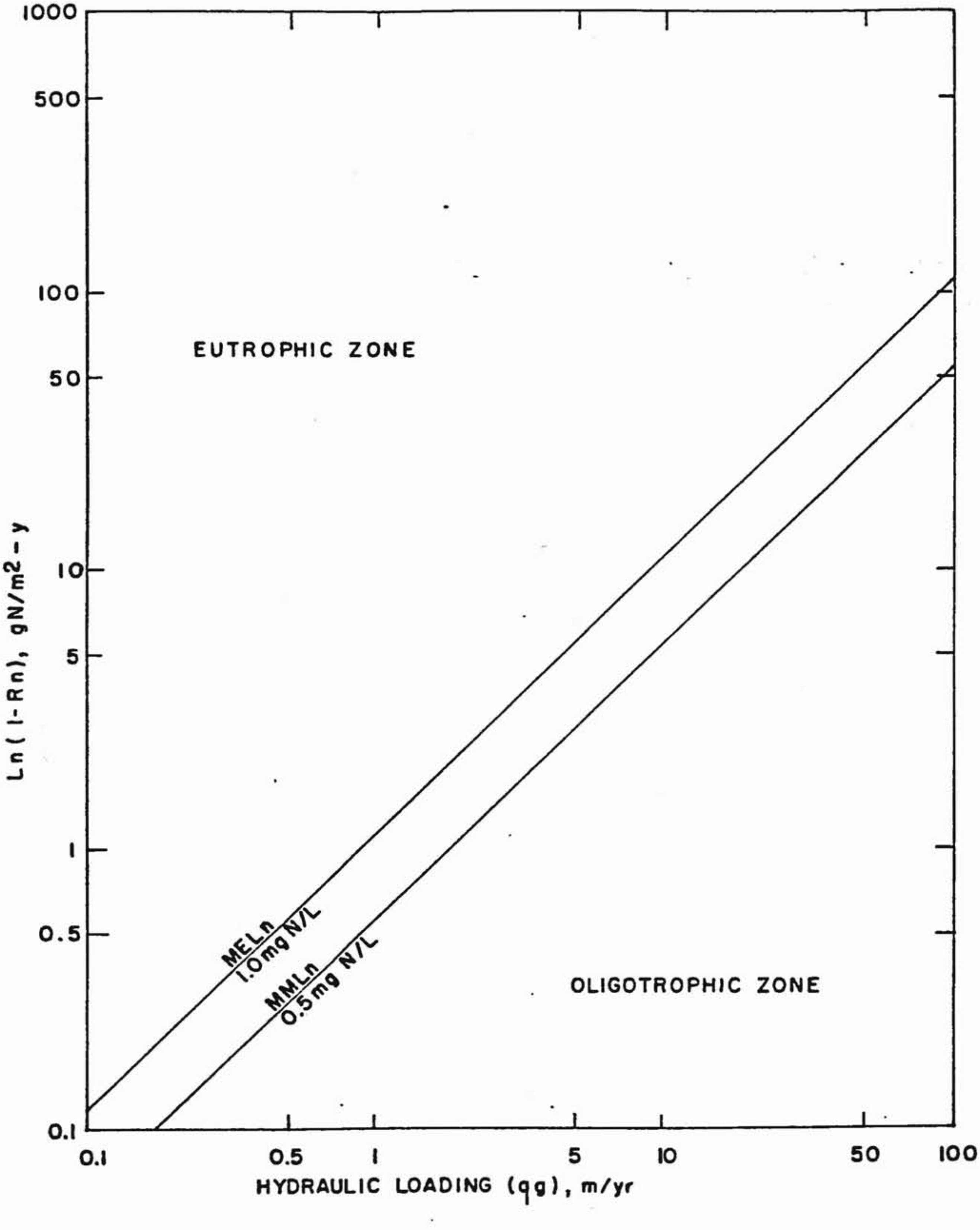

FIGURE 9-1
TROPHIC STATE DELINEATION
LAKE MYAKKA STUDY

minimum mesotrophic conditions. Utilizing those values in the above relationships, the bracket for the mesotrophic zone is identified between oligotrophic and eutrophic zones as indicated on Figure 9-1.

Placing Lake Myakka within this delineation required determining values representing L_n and average lake surface area. First, the expression $L_n(1-R_n)$ (expressed in grams N/m^2-year) must be generated. The values representing L_n were determined from the inflow nitrogen loading to Lake Myakka during the ten months of field data collection and the average lake area for the year was determined from the bathymetric contours, lake level readings, and topographic interpretations. Through evaluating the actual data collected for Lake Myakka and extrapolating similar conditions to develop a 12-month record, a total loading to the lake of 799,000 pounds-N/year or $363x(10^6)$ grams-N/year were identified. Using the average annual area of $4.17x(10^6)$ sq. meters, L_n was calculated to be 87 gm-N/m-yr. Based upon values determined for other Florida lakes, an R_n value of 0.2 was utilized to arrive at the ordinate value of 70 gm N/m^2-yr as the loading rate. Utilizing the total flow applied to Lake Myakka for the twelve month period, with an average lake depth of 5.7 feet, the hydraulic loading in meters/year was determined to be 99 meters/year. As indicated from reviewing Figure 9-1, these values placed Lake Myakka near the boundary between the mesotrophic/eutrophic curve.

Based upon the previous evaluations, Lake Myakka is nitrogen limited, is classified in the eutrophic zone, and has a hydraulic loading greater than the 40 specific lakes evaluated by the University of Florida. These independent evaluations indicate the eutrophic state of Lake Myakka and the nitrogen limitations existing within that water body. Through the above identified approaches, impacts from increased nitrogen loading, decreased nitrogen loading, and increased/decreased hydraulic loadings can be evaluated relative to whether the lake becomes more or less eutrophic. Furthermore, through the use of water column concentrations, these impacts can be translated into trophic status index changes.

Through obtaining the projected nutrient concentrations resulting from spray field underdrain discharge into Howard Creek, the resultant impact upon Lake Myakka can be evaluated. The range of values obtained from increased flows indicate water column concentrations of 1.90 mg/l-N and 540 ug/l-P with the projected discharge conditions. Through combining the increased flows and these concentrations, increased nitrogen loading, nitrogen concentrations, and phosphorus concentrations can be identified. Through utilizing the previous equations for identifying trophic state index, the TSI (TP) would become 95, while the TSI (TN) would be 64. These changes in TSIs would indicate the lake would become less nitrogen limiting, but still be significantly deficient in nitrogen limiting.

When the loading criteria calculations are utilized to identify the eutrophic state, changes in hydraulic loading also need to be included. Through utilizing projected flows and nitrogen concentrations added to the system, the new values for the ordinate ($L_n(1-R_n)$) on Figure 9-1 are gm-N/m^2-yr with a qs of 100 meters/year. These results indicate that Lake Myakka would become more eutrophic and move toward the line identifying the minimum eutrophic limit on Figure 9-6. Finally, the total nitrogen:total phosphorus ratio increased from the present annual condition of 7.3:1 to 7.8:1 with the projected water column concentrations. These numbers likewise indicate that the lake is still nitrogen limited, but less limited than under present conditions.

Based upon these evaluations, the nitrogen-limited condition of Lake Myakka can be well documented. The corresponding question relative to the impacts upon plant species or total plant growth within Lake Myakka is not as clear. Therefore, the shading and subsequent light limiting conditions within the water column indicate that light limitations are controlling the growth of biomass. Increased loads of either nitrogen or phosphorus would not allow the plant species to increase dramatically unless larger surface areas are available for providing increased light. In summary, the light limitations resulting from existing growth would not allow significant increased plant growth within the lake.

SECTION 10

SUMMARY

Field sampling events conducted between November, 1981, and August, 1982, identified water quality characteristics throughout Lake Myakka and the tributary systems. These data identified the Lake as a highly enriched system, containing large quantities of aquatic plants throughout the year. Water column data identified variations in dissolved oxygen concentrations with the 5.0 mg/l standard normally satisfied during cool months, while extensive violations were found throughout the Lake during warm months. The system is extremely complex relative to interactions between nutrient inputs, plant growth, organic deposits on the lake bottom, and fluctuating loads throughout the year.

Through developing an evaluation framework which matches the field observations, predictions were generated for non-conservative and conservative parameters. These evaluations centered upon developing assimilative capacities for Howard Creek, Lake Myakka when state standards were not violated, and impacts upon Lake Myakka when state standards were violated. Through performing step-wise loading increases on Howard Creek, the oxygen demanding substances could be increased to 30 mgd containing 5.0 mg/l UOD without violating the 5.0 mg/l dissolved oxygen state standard in Howard Creek. However, when this load was discharged to Lake Myakka, only 20 percent could be assimilated by the Lake during cool months and none of the load could be handled without further lowering the dissolved oxygen concentration in the lake during warm summer months.

When the impact of nutrient loading variations was evaluated, only comparisons identifying increased loads are possible. As a result of the heavily enriched condition of Lake Myakka, the only changes associated with increased loads are the total nitrogen and total phosphorus concentrations. Along with the representative concentrations predicted for the water column, the relationships correlating trophic state index and the trophic ranking associated with nitrogen loading are identified. In each instance, Lake Myakka can be classified nearly eutrophic to hypereutrophic. The total nitrogen:total phosphorus ratios existing and predicted with the increased spray field irrigation discharge would still fall below the necessary conditions to support a balanced nutrient system.

Any increased loads resulting from additional development within the Myakka River basin or the Howard Creek basin will result in worsening conditions within Lake Myakka. As indicated from the reductions utilized for comparing impacts from tributary loads, spray field irrigation discharge, and in-lake demands, each situation is associated with the degraded water quality. Through introducing additional nutrients from Howard Creek, the present highly enriched environment will only be further shifted towards a eutrophic classification. The results would indicate that increased nutrient loads to Lake Myakka may not directly correlate with increased plant growth since the existing condition is extremely light limited. However, when present plant communities are removed through herbicide spraying or lake level reductions, the return to healthy communities will be extremely rapid.

With conditions in Howard Creek satisfied with discharges from the spray field irrigation system for the dissolved oxygen standard, alternative means for ultimately disposing of these waters would be preferable. Preliminary investigations in a proposed study plan were identified for considering the Vanderipe Slough area for potential receipt of Howard Creek flow. This study indicated the potential for using wetlands as a biological system for incorporating the nutrients into the present plant communities. Through diverting Howard Creek flow to this area, improvements within Lake Myakka will be marginal if observable. However, the potential for degrading the present situation further would be removed. This alternative disposal mechanism needs to be reviewed and more data collected to evaluate it's feasibility.

TABLE A - 1
LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 1

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	0930	0740	0830	0800	0825	0812		0800	
Temperature, ^{o}C	16.3	12.2	15.0	22.5	23.0	26.4	22.0	29.0	
Depth, ft	0.84	0.5	0.5	0.5	1.5	1.5	1.8	1.3	
Dissolved Oxygen, mg/l	7.6	7.2	7.3	3.8	4.2	-	1.5	2.0	
pH	7.3	7.3	-	7.0	7.8	6.9	7.1	6.7	6.7
BOD_5, mg/l	0.5	0.5	1.2	1.4	1.1	1.1	-	-	-
$CBOD_5$, mg/l	0.3	0.5	1.1	1.2	0.9	1.3	-	-	-
BOD_{20}, mg/l	2.0	1.2	2.1	3.3	3.1	4.2	1.8	15.4	6.5
$CBOD_{20}$, mg/l	1.7	1.1	1.9	2.8	2.1	3.1	1.5	15.5	4.5
NO2 + NO3-N, mg/l	<.02	<.02	<.02	<.02	<.02	<.02	.033	.021	.056
Ammonia-N, mg/l	.10	<.02	<.02	.04	<.02	.05	.05	.06	.14
Organic-N, mg/l	.05	.63	.67	.35	2.23	1.59	1.30	2.76	1.90
Kjeldahl-N, mg/l	0.15	0.63	0.67	0.39	2.23	1.63	1.34	2.82	2.04
Total-N, mg/l	0.16	0.63	0.67	0.39	2.23	1.63	1.38	2.84	2.10
Ortho-P, mg/l	0.21	0.14	0.38	0.34	0.56	0.53	0.35	1.02	0.45
Total-P, mg/l	0.27	0.29	0.40	0.45	0.64	0.65	0.66	1.38	0.83
Chlorophyll A, ug/l	0	2.40	0	4.01	2.67	1.87	0.53	7.71	3.20
Total Organic Carbon mg/l	10.4	9.0	8.4	8.6	20.2	28.9	21.0	43.6	19.5
Total Susp. Solids, mg/l	9.6	3.2	1.9	3.6	1.2	4.6	5.8	6.8	24.5
Total Coliform, #/100ml	200	200	300	<100	300	1300	3900	1200	800
Fecal Coliform, #/100ml	80	30	70	40	30	560	50	130	600
Fecal Strep., #/100ml	80	300	190	30	190	3600	200	360	1700

TABLE A - 2

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 2

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1315	1020	1145	1030	1115	1042		1138	
Temperature, °C	18.9	-	17	22.0	23.4	26.8	23.3	29.0	
Depth, ft	2.0	1.5	2.0	1.5	3.5	3.5	4.0	5.0	
Dissolved Oxygen, mg/l	8.35	7.4	11.2	2.6	6.0	-	6.3	0.1	
pH	7.4	7.4	-	7.3	6.0	8.4	7.2	6.7	6.9
BOD_5, mg/l	0.4	0.5	1.1	2.0	0.9	0.7	-	-	-
$CBOD_5$, mg/l	0.2	0.5	0.8	1.4	1.0	0.4	-	-	-
BOD_{20}, mg/l	2.2	1.3	2.1	3.3	2.7	2.4	1.8	10.8	5.0
$CBOD_{20}$, mg/l	1.9	1.1	1.9	2.9	1.7	1.8	1.2	10.1	3.1
NO2 + NO3-N, mg/l	.03	<.02	<.02	0.02	.04	<.02	0.02	<.02	0.08
Ammonia-N, mg/l	.03	<.02	<.02	0.18	.04	<.02	0.02	0.03	0.10
Organic-N, mg/l	.11	0.86	0.73	0.28	1.63	1.60	1.16	2.62	2.00
Kjeldahl-N, mg/l	.14	0.86	0.73	0.45	1.67	1.60	1.19	2.65	2.11
Total-N, mg/l	.17	0.86	0.73	0.47	1.70	1.60	1.21	2.65	2.19
Ortho-P, mg/l	.36	0.37	0.52	0.53	0.73	0.42	0.39	0.68	0.46
Total-P, mg/l	.37	0.42	0.52	0.58	0.76	0.60	0.62	1.63	0.81
Chlorophyll A, ug/l	0	1.60	0.00	0.00	0.00	1.33	0.53	2.67	3.57
Total Organic Carbon mg/l	10.4	8.2	9.1	8.8	19.5	26.1	21.2	39.6	20.0
Total Susp. Solids, mg/l	1.8	0.4	0.4	0.4	0.2	6.8	3.0	19.0	4.4
Total Coliform, #/100ml	300	100	100	<100	2000	100	200	2900	300
Fecal Coliform, #/100ml	150	60	30	<10	10	10	10	270	180
Fecal Strep., #/100ml	100	50	120	30	100	6500	50	390	1000

TABLE A - 3

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 3

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1410	1110	1225	1100	1145	1108		1115	
Temperature, ^{o}C	19.5	12.8	16.8	22.3	22.9	25.6	26.8	28.0	
Depth, ft	1.0	1.5	1.0	1.0	1.0	0.8	1.0	2.0	
Dissolved Oxygen, mg/l	8.4	9.0	9.2	7.7	7.3	-	6.3	4.8	
pH	7.2	7.1	-	7.1	7.1	7.1	6.9	6.9	6.8
BOD_5, mg/l	0.3	0.5	1.0	2.3	0.8	0.5	-	-	-
$CBOD_5$, mg/l	0.4	0.3	0.8	2.5	0.5	0.4	-	-	-
BOD_{20}, mg/l	2.6	1.2	1.9	3.5	2.6	2.1	2.0	5.5	4.1
$CBOD_{20}$, mg/l	1.9	1.2	1.5	2.8	1.9	0.6	1.6	2.7	2.5
NO2 + NO3-N, mg/l	0.03	0.02	0.02	0.13	0.02	0.02	<0.02	0.02	0.04
Ammonia-N, mg/l	0.08	0.06	<.02	0.07	0.04	0.03	0.04	0.10	0.8
Organic-N, mg/l	0.22	0.87	0.82	0.46	2.87	1.48	0.76	2.21	1.10
Kjeldahl-N, mg/l	0.30	0.94	0.82	0.53	2.92	1.51	0.80	2.31	1.17
Total-N, mg/l	0.34	0.96	0.84	0.66	2.94	1.53	0.80	2.33	1.21
Ortho-P, mg/l	0.48	0.52	0.50	0.73	0.67	0.95	1.04	0.69	0.37
Total-P, mg/l	0.61	0.77	0.68	1.01	0.98	1.17	1.32	1.16	0.79
Chlorophyll A, ug/l	0	1.60	0.53	2.14	1.07	1.07	2.67	4.67	2.23
Total Organic Carbon mg/l	15.6	11.2	12.2	10.2	26.6	24.6	12.2	32.4	20.5
Total Susp. Solids, mg/l	3.8	0.8	2.6	3.6	1.57	4.0	5.2	9.0	17.5
Total Coliform, #/100ml	100	100	<100	200	<1000	200	<100	1000	400
Fecal Coliform, #/100ml	<10	30	30	27	40	10	10	110	90
Fecal Strep., #/100ml	27	60	1100	80	60	220	140	200	820

TABLE A - 4

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 4

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1450	1105	0920	0857	0930	0905			
Temperature, ^{o}C	20.5	14.0	14.5	22.0	22.0	25.5	22.5		
Depth, ft.	1.0	1.5	1.84	1.08	1.33	2.0	1.8		
Dissolved Oxygen, mg/l	5.1	7.2	5.95	2.6	3.8	4.2	3.6		
pH	7.2	6.9	-	7.2	7.1	7.1	7.1		6.7
BOD_5, mg/l	0.6	1.3	0.9	1.4	1.0	0.9	-	-	-
$CBOD_5$, mg/l	0.7	1.3	0.8	1.2	1.0	0.6	-	-	-
BOD_{20}, mg/l	3.05	3.2	2.2	3.2	3.0	2.8	2.2		4.0
$CBOD_{20}$, mg/l	2.3	2.3	1.8	2.1	1.7	2.1	1.8		2.2
NO2 + NO3-N, mg/l	0.03	0.04	0.02	0.07	0.03	0.02	<.02		0.08
Ammonia-N, mg/l	0.10	0.20	0.02	0.11	0.07	0.03	0.02		0.09
Organic-N, mg/l	0.06	0.74	0.79	0.41	2.46	1.42	1.60		1.20
Kjeldahl-N, mg/l	0.16	0.94	0.81	0.53	2.53	1.45	1.62		1.29
Total-N, mg/l	0.20	0.98	0.83	0.60	2.57	1.47	1.62		1.37
Ortho-P, mg/l	0.45	0.39	0.60	0.69	0.81	0.75	0.58		0.57
Total-P, mg/l	0.52	0.53	0.69	0.82	1.04	0.91	0.94		0.89
Chlorophyll A, ug/l	0	-	5.07	4.27	2.14	4.27	5.34		2.00
Total Organic Carbon mg/l	12.2	9.4	10.8	8.8	22.1	29.6	21.6	-	19.3
Total Susp. Solids, mg/l	4.2	2.0	2.4	2.8	2.8	2.8	12.8		15.2
Total Coliform, #/100ml	<100	700	400	180	500	200	<200		<1000
Fecal Coliform, #/100ml	40	110	60	30	40	60	30		350
Fecal Strep., #/100ml	190	120	50	20	40	130	100		490

TABLE A - 5

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 5

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1140	0855	1000	0920	0940	0921		1015	
Temperature, ^{o}C	17.4	11.7	16.0	22.3	22.9	26.0	23.2	28.0	
Depth, ft	3.5	3.0	3.4	2.0	4.5	5.0	3.7	1.5	
Dissolved Oxygen, mg/l	6.5	3.4	6.8	5.6	6.9	-	6.7	4.7	
pH	7.2	7.3	-	7.3	6.8	7.1	7.1	6.7	6.5
BOD_5, mg/l	0.8	1.4	1.6	1.7	1.1	0.6	-	-	-
$CBOD_5$, mg/l	0.9	1.3	1.3	1.6	0.8	0.8	-	-	-
BOD_{20}, mg/l	3.3	4.3	4.2	3.8	2.6	2.8	2.4	5.6	7.0
$CBOD_{20}$, mg/l	2.6	2.5	3.4	3.3	1.7	2.0	1.8	3.9	5.3
NO2 + NO3-N, mg/l	<0.02	<0.02	<0.02	<0.02	0.02	0.03	<.02	0.02	<.02
Ammonia-N, mg/l	0.10	<0.02	<0.02	0.07	0.04	0.04	0.04	0.08	0.04
Organic-N, mg/l	0.09	1.09	1.19	0.79	1.96	1.45	1.34	1.61	0.86
Kjeldahl-N, mg/l	0.18	1.09	1.19	0.85	2.00	1.49	1.39	1.69	0.90
Total-N, mg/l	0.21	1.09	1.19	0.85	2.02	1.52	1.39	1.71	0.90
Ortho-P, mg/l	0.22	0.14	0.10	0.15	0.19	0.22	0.21	0.38	0.26
Total-P, mg/l	0.21	0.30	0.24	0.25	0.33	0.49	0.57	0.77	0.57
Chlorophyll A, ug/l	4.5	20.00	14.0	8.5	2.1	2.9	1.6	0.5	2.3
Total Organic Carbon mg/l	13.8	15.4	13.0	12.6	21.8	25.2	19.6	28.4	17.5
Total Susp. Solids, mg/l	2.0	0.8	2.8	2.0	2.4	1.6	12.4	4.4	7.2
Total Coliform, #/100ml	<100	200	<100	<100	300	200	300	800	100
Fecal Coliform, #/100ml	<10	100	20	30	30	20	30	40	250
Fecal Strep., #/100ml	55	100	1700	50	180	170	40	200	950

TABLE A - 6

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 6

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1100	0830	0930	0900	0915	0858	0850	1000	
Temperature, ^{o}C	18.0	13.0	16.0	22.7	22.7	26.1	23.0	31.5	
Depth, ft	3.0	2.5	2.5	1.5	6.2	3.5	6.0	7.5	
Dissolved Oxygen, mg/l	7.6	6.6	7.3	3.4	3.9	-	4.75	1.2	
pH	6.9	7.1	-	7.0	6.7	6.8	6.9	6.4	-
BOD_5, mg/l	0.6	0.7	1.4	2.4	8.6	0.9	-	-	-
$CBOD_5$, mg/l	0.5	0.7	1.2	1.6	7.2	1.2	-	-	-
BOD_{20}, mg/l	3.1	1.7	2.8	6.1	22.2	3.5	3.1	4.4	4.4
$CBOD_{20}$, mg/l	2.7	1.4	2.5	4.1	20.4	2.0	2.0	3.8	2.9
NO2 + NO3-N, mg/l	0.03	0.02	<0.02	0.04	0.06	0.02	<0.02	<0.02	<0.02
Ammonia-N, mg/l	0.09	0.04	<0.02	0.12	0.15	0.14	0.04	0.05	0.02
Organic-N, mg/l	0.10	1.12	1.04	2.76	5.51	6.37	1.31	1.64	0.91
Kjeldahl-N, mg/l	0.18	1.16	1.04	2.88	5.65	6.51	1.34	1.69	0.94
Total-N, mg/l	0.22	1.18	1.04	2.91	5.72	6.53	1.34	1.69	0.94
Ortho-P, mg/l	0.26	0.24	0.23	0.31	0.47	0.21	0.20	0.37	0.23
Total-P, mg/l	0.27	0.31	0.24	0.50	0.68	0.91	0.55	0.70	0.49
Chlorophyll A, ug/l	1.33	2.14	4.27	26.70	-	-	11.21	3.47	2.94
Total Organic Carbon mg/l	19.0	16.0	15.0	29.8	30.8	28.4	20.4	26.8	16.5
Total Susp. Solids, mg/l	13.8	1.2	1.0	38.5	45.0	28.0	12.4	4.0	8.4
Total Coliform, #/100ml	200	270	300	300	2700	600	600	1100	400
Fecal Coliform, #/100ml	10	70	10	100	60	40	20	80	80
Fecal Strep., #/100ml	200	320	1800	70	1100	250	100	300	550

TABLE A - 7

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 7

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1422	0923	1135	1020	1110	1104		1140	
Temperature, °C	16.0	13.0	17.0	23.1	24.0	26.0	24.0	29.0	26.4
Depth, ft	3.0	1.7	1.5	1.0	2.7	3.5	3.2	4.3	
Dissolved Oxygen, mg/l	7.4	5.6	7.2	2.4	1.5	2.0	4.4	0.6	
pH	7.0	7.0	-	7.0	6.7	6.6	6.9	6.4	5.0
BOD_5, mg/l	0.7	2.7	1.7	2.1	1.9	0.8	-	-	-
$CBOD_5$, mg/l	0.7	1.7	1.4	1.9	1.3	1.1	-	-	-
BOD_{20}, mg/l	3.1	5.2	4.4	4.8	4.5	3.2	2.9	5.0	4.5
$CBOD_{20}$, mg/l	2.6	4.4	4.0	3.8	4.5	2.3	1.7	4.0	2.9
NO2 + NO3-N, mg/l	<0.2	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ammonia-N, mg/l	0.03	0.04	0.06	0.07	0.08	0.05	0.06	0.10	0.04
Organic-N, mg/l	0.11	1.21	1.22	1.26	2.76	1.45	1.36	1.59	0.69
Kjeldahl-N, mg/l	0.14	1.24	1.28	1.32	2.84	1.50	1.42	1.69	0.73
Total-N, mg/l	0.16	1.24	1.28	1.34	2.84	1.50	1.42	1.69	0.73
Ortho-P, mg/l	0.15	0.14	0.32	0.50	0.36	0.26	0.20	0.37	0.06
Total-P, mg/l	0.24	0.26	0.34	0.53	0.50	0.50	0.45	0.66	0.31
Chlorophyll A, ug/l	1.60	18.16	14.68	7.21	0.53	4.54	3.20	2.96	2.34
Total Organic Carbon mg/l	21.0	18.2	18.9	18.0	26.4	28.4	22.4	28.6	15.0
Total Susp. Solids, mg/l	11.4	10.8	14.8	4.4	2.2	4.4	11.2	1.6	10.0
Total Coliform, #/100ml	100	550	200	<100	200	100	<100	200	300
Fecal Coliform, #/100ml	<10	140	60	<10	40	<10	<10	<10	60
Fecal Strep., #/100ml	480	960	4800	10	180	330	80	80	1700

TABLE A - 8

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 8

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1357	0905	1120	1038	1125	1045		1055	
Temperature, ^{o}C	13.5	11.5	16.5	23.8	26.5	27.0	25.0	30.5	27.1
Depth, ft	3.5	2.9	2.0	2.5	3.5	4.5	3.3	5.2	
Dissolved Oxygen, mg/l	2.6	6.3	12.8	6.40	5.4	3.2	6.4	2.6	
pH	7.2	7.0	-	7.1	6.9	7.0	7.0-	6.4	6.3
BOD_5, mg/l	2.4	2.9	2.0	2.5	1.6	1.8	-	-	-
$CBOD_5$, mg/l	2.3	1.9	1.7	2.1	1.5	1.5	-	-	-
BOD_{20}, mg/l	6.6	7.2	6.1	5.2	3.7	4.9		2.7	
$CBOD_{20}$, mg/l	5.5	4.6	5.0	4.2	3.0	3.3		1.6	
NO2 + NO3-N, mg/l	<0.02	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02
Ammonia-N, mg/l	0.03	0.02	<0.02	0.07	0.05	0.06	0.05	0.08	0.13
Organic-N, mg/l	0.15	1.51	1.41	1.39	2.24	1.20	1.57	1.55	1.00
Kjeldahl-N, mg/l	0.18	1.53	1.41	1.46	2.29	1.26	1.62	1.63	1.12
Total-N, mg/l	0.20	1.53	1.41	1.49	2.29	1.28	1.64	1.63	1.12
Ortho-P, mg/l	0.08	0.04	0.35	0.47	0.22	0.30	0.22	0.34	0.25
Total-P, mg/l	0.15	0.16	0.37	0.49	0.32	0.45	0.46	0.63	0.46
Chlorophyll A, ug/l	29.64	13.62	10.95	14.15	6.39	18.16	14.95	9.08	1.53
Total Organic Carbon mg/l	20.8	26.6	21.6	23.0	21.4	26.4	23.6	23.4	16.0
Total Susp. Solids, mg/l	10.7	28.0	3.2	2.4	1.0	2.4	12.4	2.8	
Total Coliform, #/100ml	200	<100	<100	90	100	<100	<100	200	100
Fecal Coliform, #/100ml	<10	<10	<10	<10	<10	<10	<10	<10	<10
Fecal Strep., #/100ml	40	20	130	10	50	80	130	30	720

TABLE A - 9

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 9

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1244	0943	1105	1100	1030	1026		1030	
Temperature, ^{o}C	15.0	12.5	15.5	24.0	24.5	27.0	24.5	29.0	28.7
Depth, ft	2.0	2.7	1.3	2.7	2.5	3.0	4.7	4.8	
Dissolved Oxygen, mg/l	6.7	3.4	6.6	5.3	3.6	2.6	7.7	1.2	
pH	6.7	6.5	-	7.4	6.9	6.9	6.7	6.4	6.4
BOD_5, mg/l	1.6	1.1	4.0	8.2	3.0	5.3	-	-	-
$CBOD_5$, mg/l	1.9	1.0	3.8	4.8	2.7	4.1	-	-	-
BOD_{20}, mg/l	4.8	2.0	7.9	14.7	6.1	7.7			3.2
$CBOD_{20}$, mg/l	4.0	1.7	6.5	16.2	4.2	7.6		1.7	
NO2 + NO3-N, mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ammonia-N, mg/l	0.04	0.02	<0.02	0.06	0.05	0.02	0.02	0.04	0.14
Organic-N, mg/l	0.10	1.56	1.72	1.44	2.46	1.62	1.36	1.62	0.83
Kjeldahl-N, mg/l	0.13	1.58	1.72	1.50	2.51	1.64	1.38	1.65	0.97
Total-N, mg/l	0.15	1.58	1.72	1.50	2.51	1.64	1.38	1.66	0.97
Ortho-P, mg/l	0.03	0.08	0.70	0.49	0.59	0.57	0.55	0.30	0.28
Total-P, mg/l	0.09	0.13	0.74	0.53	0.63	0.66	0.69	0.59	0.49
Chlorophyll A, ug/l	11.01	6.94	33.64	42.72	16.02	41.65	36.31	17.49	4.27
Total Organic Carbon mg/l	20.0	20.2	32.4	17.8	19.6	23.8	20.8	23.0	16.5
Total Susp. Solids, mg/l	4.8	0.0	5.3	9.5	1.4	3.6	15.3	6.0	5.2
Total Coliform, #/100ml	<100	100	<100	<100	100	700	1000	200	<100
Fecal Coliform, #/100ml	<10	<100	<10	<10	<10	<10	<10	10	<10
Fecal Strep., #/100ml	1200	140	100	60	240	60	580	2000	30

TABLE A - 10

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 10

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1300	0844	1055	1115	1040	1125		1055	
Temperature, ^{o}C	16.0	13.5	17.0	24.0	26.0	27.0	24.5	29.0	28.4
Depth, ft	4.5	4.0	3.3	2.8	4.7	5.5	4.6	6.9	
Dissolved Oxygen, mg/l	3.8	6.2	9.4	5.4	6.5	4.5	7.7	2.3	
pH	6.7	6.9	-	7.1	7.0	7.0	6.7	6.5	6.5
BOD_5, mg/l	0.5	1.3	3.1	3.0	2.9	2.3	-	-	-
$CBOD_5$, mg/l	0.6	0.8	2.9	2.0	2.7	2.0	-	-	-
BOD_{20}, mg/l	2.8	1.9	6.9	7.5	6.0	3.5	5.0	5.0	3.0
$CBOD_{20}$, mg/l	2.1	1.4	5.4	5.9	4.7	3.8	3.2	2.8	1.4
NO2 + NO3-N, mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ammonia-N, mg/l	0.05	0.04	<0.02	0.16	0.04	0.05	0.05	0.12	0.14
Organic-N, mg/l	0.05	1.12	1.24	1.32	2.27	1.59	1.53	1.65	0.92
Kjeldahl-N, mg/l	0.10	1.16	1.24	1.48	2.30	1.64	1.58	1.77	1.05
Total-N, mg/l	0.12	1.16	1.24	1.48	2.30	1.64	1.58	1.77	1.05
Ortho-P, mg/l	0.08	0.07	0.33	0.52	0.31	0.40	0.32	0.38	0.29
Total-P, mg/l	0.12	0.12	0.42	0.56	0.40	0.54	0.57	0.62	0.52
Chlorophyll A, ug/l	4.0	2.14	31.38	18.02	34.98	14.15	25.63	12.02	4.54
Total Organic Carbon mg/l	19.7	20.9	18.0	17.2	23.6	26.0	18.8	19.6	16.5
Total Susp. Solids, mg/l	2.0	0.4	5.5	5.5	2.8	4.0	15.2	5.2	5.6
Total Coliform, #/100ml	100	<100	<100	<100	<100	<100	<100	100	100
Fecal Coliform, #/100ml	<10	10	10	20	<10	<10	10	<10	<10
Fecal Strep., #/100ml	20	90	10	40	80	30	80	170	90

TABLE A - 11

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 11

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1225	1000	1030	1010	1000	1008	0915	1010	
Temperature, ^{o}C	17.5	14.0	16.5	23.4	25.0	27.0	24.0	30.5	27.6
Depth, ft	4.17	3.70	2.75	2.5	4.17	4.5	4.17	6.3	
Dissolved Oxygen, mg/l	7.7	8.3	8.3	6.6	4.1	2.5	5.5	3.6	
pH	7.0	7.3	-	7.6	7.2	7.0	7.2	6.6	6.6
BOD_5, mg/l	0.2	1.1	2.2	2.5	2.4	1.5	-	-	-
$CBOD_5$, mg/l	1.1	0.9	1.5	1.8	2.0	0.7	-	-	-
BOD_{20}, mg/l	4.05	2.3	3.9	7.3	5.0	4.4			4.0
$CBOD_{20}$, mg/l	3.15	1.6	3.2	5.8	3.6	2.7			1.9
NO2 + NO3-N, mg/l	0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	0.03
Ammonia-N, mg/l	0.07	0.04	<0.02	0.12	0.03	0.20	0.04	0.06	0.18
Organic-N, mg/l	0.09	1.14	1.11	1.16	1.87	1.60	1.47	1.99	1.00
Kjeldahl-N, mg/l	0.15	1.18	1.12	1.28	1.90	1.80	1.51	2.05	1.17
Total-N, mg/l	0.18	1.18	1.12	1.28	1.90	1.83	1.51	2.05	1.21
Ortho-P, mg/l	0.21	0.14	0.62	0.77	0.65	0.83	0.50	0.52	0.42
Total-P, mg/l	0.25	0.17	0.66	0.78	0.72	0.86	0.68	0.78	0.65
Chlorophyll A, ug/l	-	2.40	13.88	10.15	11.94	2.40	23.50	76.90	0.80
Total Organic Carbon mg/l	17.4	13.8	13.0	12.0	17.8	26.0	20.2	31.2	16.5
Total Susp. Solids, mg/l	4.5	0.8	6.8	6.8	2.8	2.8	15.2	15.0	1.1
Total Coliform, #/100ml	<100	<100	<100	<100	<100	100	<100	<100	100
Fecal Coliform, #/100ml	<10	<100	10	91	<10	<10	<10	10	10
Fecal Strep., #/100ml	20	40	70	100	20	20	220	110	320

TABLE A - 12

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 12

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1151	1019	1015	0940	0955	0942			
Temperature, ^{o}C	16.0	15.0	17.0	23.2	24.5	26.0	24.0	30.5	27.6
Depth, ft	3.42	3.80	1.84	1.67	2.17	4.0	3.17	5.4	
Dissolved Oxygen, mg/l	7.1	8.2	8.6	6.1	4.2	2.5	5.5	4.7	
pH	7.2	7.3	-	7.6	7.2	7.1	6.8	6.8	6.6
BOD_5, mg/l	1.8	1.7	2.4	1.9	2.2	2.0	-	-	-
$CBOD_5$, mg/l	1.4	1.1	2.0	1.5	1.7	1.5	-	-	-
BOD_{20}, mg/l	5.2	4.0	5.7	4.6	4.5	6.4	7.5	16.0	4.2
$CBOD_{20}$, mg/l	4.1	2.2	4.1	3.6	3.3	4.3	5.8	16.3	2.3
NO2 + NO3-N, mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04
Ammonia-N, mg/l	0.09	0.07	<0.02	0.06	0.04	0.08	0.06	0.04	0.18
Organic-N, mg/l	0.04	1.09	1.58	0.93	2.13	1.61	1.87	2.62	1.44
Kjeldahl-N, mg/l	0.14	1.16	1.58	0.98	2.17	1.69	1.93	2.66	1.62
Total-N, mg/l	0.15	1.16	1.58	0.98	2.17	1.69	1.93	2.66	1.66
Ortho-P, mg/l	0.24	0.22	0.55	0.73	0.87	0.91	0.58	0.54	0.48
Total-P, mg/l	0.30	0.24	0.76	0.77	1.24	0.99	0.80	0.94	0.74
Chlorophyll A, ug/l	21.00	5.61	16.02	9.23	11.75	6.80	44.32	206.58	1.78
Total Organic Carbon mg/l	18.0	11.4	16.5	16.8	21.2	29.2	20.4	32.6	18.3
Total Susp. Solids, mg/l	8.0	3.2	29.5	4.8	4.0	3.6	16.4	18.0	5.2
Total Coliform, #/100ml	100	<100	<100	<100	300	<100	<100	700	400
Fecal Coliform, #/100ml	<10	<100	10	<10	10	<10	10	<10	100
Fecal Strep., #/100ml	100	160	560	30	70	190	2200	990	340

TABLE A - 13

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 13

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1114	1205	1045	1128	1055	1223		1115	
Temperature, °C	16.0	16.0	17.2	24.2	24.0	30.9	25.0	28.5	-
Depth, ft	3.84	-	1.07	2.0	3.0	1.5	2.3	4.0	
Dissolved Oxygen, mg/l	5.5	9.9	9.6	5.8	6.1	6.15	7.2	2.20	
pH	6.9	7.0	-	7.1	7.1	7.2	7.3	6.6	6.7
BOD_5, mg/l	0.6	4.0	5.1	4.1	1.7	2.3	-	-	-
$CBOD_5$, mg/l	0.7	3.0	4.1	2.8	1.5	2.1	-	-	-
BOD_{20}, mg/l	2.65	6.9	7.8	8.1	3.9	5.9	6.4	5.5	3.5
$CBOD_{20}$, mg/l	2.1	6.0	7.7	6.2	2.9	4.0	4.5	3.5	1.7
NO2 + NO3-N, mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04
Ammonia-N, mg/l	0.05	0.02	<0.02	0.06	0.06	0.02	0.04	0.12	0.17
Organic-N, mg/l	0.05	1.29	1.51	1.56	2.58	1.35	1.47	1.62	0.84
Kjeldahl-N, mg/l	0.11	1.31	1.51	1.62	2.64	1.38	1.51	1.74	1.00
Total-N, mg/l	0.12	1.31	1.51	1.62	2.64	1.38	1.51	1.74	1.04
Ortho-P, mg/l	0.13	0.28	0.41	0.62	0.41	0.43	0.41	0.44	0.40
Total-P, mg/l	0.16	0.30	0.57	0.67	0.51	0.62	0.66	0.74	0.61
Chlorophyll A, ug/l	1.07	12.02	70.49	26.37	10.68	12.82	33.64	11.21	6.68
Total Organic Carbon mg/l	18.0	17.6	20.0	18.2	20.2	25.6	23.6	24.0	16.0
Total Susp. Solids, mg/l	1.8	1.2	13.6	13.0	0.8	4.0	17.6	4.0	5.2
Total Coliform, #/100ml	<100	2000	200	<100	<100	<100	<100	<100	<100
Fecal Coliform, #/100ml	<10	45	20	<10	<10	<10	<10	<10	<10
Fecal Strep., #/100ml	90	80	70	<10	30	530	20	120	90

TABLE A - 14

LAKE MYAKKA WATER QUALITY DATA SUMMARY

STATION 14

	Nov. 16	Dec. 16	Jan. 20	Feb. 10	Mar. 17	Apr. 21	May 12	June 9	Aug. 17
Time	1235	0935	1110	1000	1015	1003	935	1045	
Temperature, ^{o}C	20.4	13.7	16.5	23.0	24.3	28.0	25.6	28.5	
Depth, ft	8.0	7.0	5.0	3.8	8.7	8.5	10.0	11.6	
Dissolved Oxygen, mg/l	7.1	8.5	9.8	4.2	3.6	-	4.7	0.6	
pH	7.0	7.2	-	7.4	7.0	6.8	7.1	6.5	6.4
BOD_5, mg/l	0.6	1.0	5.1	3.7	2.2	1.4	-	-	-
$CBOD_5$, mg/l	0.5	0.9	4.1	2.8	1.7	1.2	-	-	-
BOD_{20}, mg/l	2.9	2.2	8.2	8.2	5.1	3.8	4.0		4.0
$CBOD_{20}$, mg/l	2.6	1.9	7.8	5.6	3.5	2.4	2.9		2.6
NO2 + NO3-N, mg/l	0.01	<0.02	<0.02	0.04	<0.02	0.04	<0.02	<0.02	0.41
Ammonia-N, mg/l	0.06	<0.02	<0.02	0.08	0.08	0.06	0.05	0.08	0.05
Organic-N, mg/l	0.07	1.28	1.27	1.43	2.16	1.31	1.25	1.38	0.96
Kjeldahl-N, mg/l	0.13	1.28	1.27	1.51	2.24	1.37	1.30	1.45	1.01
Total-N, mg/l	0.15	1.28	1.27	1.55	2.24	1.41	1.30	1.45	1.05
Ortho-P, mg/l	0.14	0.08	0.36	0.59	0.49	0.55	0.39	0.42	0.32
Total-P, mg/l	0.16	0.20	0.43	0.63	0.56	0.66	0.62	0.67	0.57
Chlorophyll A, ug/l	4.27	4.01	0.00	32.71	13.62	2.67	1.60	10.68	2.67
Total Organic Carbon mg/l	19.8	17.8	19.6	19.4	21.2	25.8	23.4	23.6	16.0
Total Susp. Solids, mg/l	1.6	0.0	6.0	3.2	1.2	1.2	14.8	0.8	4.0
Total Coliform, #/100ml	400	180	<100	<100	100	<100	200	1100	200
Fecal Coliform, #/100ml	60	70	<10	<10	10	<10	10	<10	<10
Fecal Strep., #/100ml	270	80	4400	50	90	270	510	130	900

APPENDIX B
MODELLING FRAMEWORK

B.1 General

The framework employed to analyze existing water quality and project future conditions consists of a two-dimensional, steady-state, advective-dispersive model. The finite difference solutions to the basic differential equations (illustrated by equations A and B) for a coupled system include the following ultimate oxygen demand and dissolved oxygen deficit expressions.

Ultimate Oxygen Demand:

$$0=\frac{1}{A}\frac{d}{dx}(LQ)+\frac{1}{A}\left(\frac{d}{dx}\left(EA\frac{dL}{dx}\right)\right)-k_R L \pm S_L \qquad \text{(A)}$$

Dissolved Oxygen Deficit:

$$0=\frac{1}{A}\frac{d}{dx}(DQ)+\frac{1}{A}\left(\frac{d}{dx}\left(EA\frac{D}{dx}\right)\right)-k_d L \pm S_D \qquad \text{(B)}$$

where:

L = Ultimate oxygen demand (mg/l)

D = Dissolved oxygen deficit (mg/l)

A = Cross-sectional area (ft^2)

E = Dispersion coefficient (mi^2/day)

Q = Advective flow (cfs)

Kd = Oxidation rate of ultimate oxygen demand (l/day)

S_L = Sources or sinks of ultimate oxygen demand (mg/l/day)

X = distance (miles)

Ka = Reaeration coefficient (l/day)

Kd = Deoxygenation coefficient of ultimate oxygen demand (l/day)

Sd = Sources and sinks of dissolved oxygen deficit (mg/l/day)

Equation A is also employed to calculate the distribution of substances which can be considered conservative (i.e. total phosphorous and total nitrogen). In those instances, the reaction rate K_r is set equal to zero.

Two major sources and sinks which appear to control dissolved oxygen in Sarasota Bay and Lake Myakka are the sediment oxygen demand and the oxygen produced and used (P-R) by phytoplankton. The sediment oxygen demand has been estimated from <u>in situ</u> measurements obtained by EPA-Athens personnel. Estimates of oxygen production and respiration by phytoplankton are calculated employing equations C to H which use values developed from measurements of chlorophyll"a", inorganic nitrogen and secchi depth for each segment.

$$A_O=I_I/I_S \tag{C}$$

$$K_E=1.85/S_H \tag{D}$$

$$A_1=A_O e-k_E*H \tag{E}$$

$$R_L=\frac{2.7183*F}{k_E*H}(e^{-A_1}-ed^{A_O}) \quad \text{(E) (F)}$$

$$R_N=C_N/u_N + C_N \tag{G}$$

$$(P-R)= (k_S*T_G*R_L*R_N-R_p*T_R)*P_{P*A_S} \tag{H}$$

where:

I_I = Incident solar radiation

I_S = saturated growth rate

S_H = secchi depth

H = water depth

K_e = equivalent light extinction coefficient

f = light fraction of day

R_L = plankton growth rate reduction due to light limitations

R_N = plankton growth rate reduction due to nutrient limitations

C_N = concentration of inorganic nitrogen

U_N = nitrogen concentration at which plankton growth rate is 1/2 maximum

K_S = saturated plankton growth rate

T_G = temperature correction for plankton growth rate

T_R = Temperature correction for plankton respiration rate

R_P = Phytoplankton respiration rate

P_P = chlorophyll"a" concentration

A_S = oxygen to chlorophyll"a" ratio

The approach employed in the water quality analysis essentially consists of maximizing the use of measured information and data. The mathematical models are employed to supplement the observed data and to provide a framework for evaluation of the overall level of quantitative understanding of the factors that are currently controlling water quality. This process is concerned with: 1)identifying factors and phenomena which are understood; and 2) defining those water quality situations and observations which cannot be defined by measured phenomena or a "consistent" quantitative representation of the system.

B.2 Computer Coding Explanation

The following pages, identified as Figure B-1, display a copy of the BASIC language coding used for one of the total nitrogen model calibrations. The line numbers along the left margin will be used for reference in the following discussion.

Lines 11-40 provide information for the programmer's reference and define constants that will be used in subsequent formulations. Lines 50-80 define respectively, the number of segment interfaces, the number of segments and the number of upstream and downstream boundaries. Lines 90-120 allocate memory space for all the data arrays. Lines 140-160 and 170-230 enter first the interface information, then boundary conditions and finally other system information including volumes, reaction rates, loads and sink/source terms. Lines 161-170 and 275-285 allow a user-entered temperature to be input with subsequent conversions from equivalent 20°C values. Lines 279-510 set up the matrix equation coefficients including

```
TEST FOR VSBASIC

FILE CONTROL NOT FREED, IS NOT ALLOCATED
FILE MYPROG NOT FREED, IS NOT ALLOCATED
FILE INPUT NOT FREED, IS NOT ALLOCATED
DATE: 83-021; TIME: 14:12:24.9
RUN MYPROG SOURCE,LIST,GO,INPUT=INPUT
00000010

11 OPTION LPREC
12 REM VSBASIC MODIFICATION OF PROGRAM SARBAY/ APRIL 1982
15 REM LAKE MYAKKA MODIFICATION OF SARBAY//DSN=MYVIC
20 A9=0
30 F9=30.48**3*3600*24/1000
40 F8=160900**2*30.48/1000
50 M7=7
60 N7=6
70 N1=2
80 N2=1
90 DIM I(7),J(7),Q(7),E(7),A(7),L(7),G(6,6),H(6,6)
100 DIM F(6),C(6),K(6),B(6),W(6),D(6),P(6),S(6)
110 DIM V(6),M(2),N(1),O(2),R(1),T(2),U(1)
120 DIM X(2),Y(1),Z(2),@(1),#(6,6),$(6,6)
140 FOR I9=1 TO M7
150 READ I(I9),J(I9),Q(I9),E(I9),A(I9),L(I9)
160 NEXT I9
161 PRINT "ENTER LAKE TEMPERATURE IN DEGREES CELCIUS"
162 INPUT T4
163 T5=T4-20
164 T6=1.045**T5
165 T7=1.02**T5
166 T8=1.08**T5
170 FOR I9=1 TO N1
180 READ M(I9),O(I9),T(I9),X(I9),Z(I9)
190 NEXT I9
200 FOR I9=1 TO N2
210 READ N(I9),R(I9),U(I9),Y(I9),@(I9)
220 NEXT I9
230 MAT READ V,K,B,W,D,P,S
270 MAT V=(28.32)*V
275 MAT K=(T6)*K
280 MAT B=(T7)*B
285 MAT S=(T8)*S
290 FOR K9=1 TO M7
300 N6=I(K9)
310 N5=J(K9)
320 A7=Q(K9)*.5*F9
330 B7=E(K9)*A(K9)/L(K9)*F8
340 G(N6,N5)=A7+B7+G(N6,N5)
350 G(N6,N6)=A7-B7+G(N6,N6)
360 G(N5,N6)=-A7+B7+G(N5,N6)
370 G(N5,N5)=-A7-B7+G(N5,N5)
380 NEXT K9
390 MAT H=G
400 FOR K9=1 TO N7
410 H(K9,K9)=G(K9,K9)-V(K9)*K(K9)
420 F(K9)=-W(K9)*453590+F(K9)
430 NEXT K9
```

FIGURE B-1A
LAKE MODEL PROGRAM LISTING
LAKE MYAKKA STUDY

```
440 FOR I9=1 TO N1
450 H(M(I9),M(I9))=H(M(I9),M(I9))+(-O(I9)+T(I9)*0.5)*F9
460 F(M(I9))=F(M(I9))-(O(I9)+T(I9)*0.5)*X(I9)*F9
470 NEXT I9
480 FOR I9=1 TO N2
490 H(N(I9),N(I9))=H(N(I9),N(I9))-(R(I9)+U(I9)*1.0)*F9
500 F(N(I9))=F(N(I9))-(R(I9)-U(I9)*1.0)*Y(I9)*F9
510 NEXT I9
516 MAT H=(.0000001)*H
520 MAT S=INV(H)
521 MAT S=(.0000001)*$
522 MAT H=(10000000)*H
526 MAT #=TRN($)
530 MAT C=F*#
550 IF A9=0 THEN PRINT "FIRST VARIABLE" ELSE PRINT"SECOND VARIABLE"
560 FOR M9=1 TO N7
561 PRINT M9,C(M9)
562 NEXT M9
570 PRINT
580 FOR I9=1 TO N7
581 F(I9)=C(I9)*V(I9)*K(I9)*(-1)
592 NEXT I9
630 MAT K=B
640 FOR I9=1 TO N7
641 P(I9)=P(I9)*V(I9)
642 NEXT I9
670 MAT F=F+P
680 MAT W=D
690 FOR I9=1 TO N7
691 S(I9)=S(I9)*V(I9)
692 NEXT I9
720 MAT F=F-S
730 MAT Y=@
740 MAT X=Z
750 A9=A9+1
760 IF A9 = 2 THEN 1230 ELSE 400
770 REM BOUNDARY CONDITIONS AND SYSTEM CONFIGURATION
775 REM JUNE LAKE ELEVATION ASSUMED AT 16.5 FT
800 DATA 2,1,100.0,.10,16725,1650
810 DATA 3,2,25.0,.10,8850,3550
820 DATA 4,2,75.0,.10,9738,3100
830 DATA 4,3,325.0,.10,34425,3040
840 DATA 3,5,300.0,.10,9505,4300
850 DATA 4,5,600.0,.10,5845,4700
860 DATA 5,6,900.0,.10,6688,2400
1025 REM BOUNDARY CONDITIONS UPSTREAM
1030 DATA 1,0,0.0,0.0,0
1040 DATA 6,0,0.0,0.0,0
1055 REM DOWNSTREAM
1070 DATA 4,0,1000.0,0.0,0
1105 REM VOLUMES
1110 DATA 15995000,18016000,44872000,77212000,37319000,4112000
1120 REM REACTION RATE--ZERO FOR TOTAL NUTRIENT MODELS
1130 DATA 0,0,0,0,0,0
1140 REM NO SECOND K
1150 DATA 0,0,0,0,0,0
1160 REM FIRST VARIABLE LOAD IN LBS PER DAY
1170  DATA 1354,0,0,0,0,8286
1175 REM DEFICIT LOAD
1180 DATA 0,0,0,0,0,0
```

FIGURE B-1B
LAKE MODEL PROGRAM LISTING
LAKE MYAKKA STUDY

```
 90 REM P-R, AND SOD TERMS BOTH ZERO FOR NUTRIENT MODELS
.200 DATA 0,0,0,0,0,0
 220 DATA 0,0,0,0,0,0
 30 END

ENTER LAKE TEMPERATURE IN DEGREES CELCIUS


FIRST VARIABLE
                    2.20851775111215
                    2.09954674314853
 3                  1.78817400668532
                    1.78723588076213
                    1.65831087752755
 6                  1.73930568772035

SECOND VARIABLE
                    0
 2                  0
                    0
                    0
 5                  0
 6                  0

DATE: 83-021; TIME: 14:15:02.1; CPU TIME: 0000.2 SEC
READY
```

FIGURE B -1C
LAKE MODEL PROGRAM LISTING
LAKE MYAKKA STUDY

the advective, dispersive, loading, source/sink and boundary conditions. Lines 516-570 invert the coefficient matrix and print the solution matrix (concentrations). Lines 580-760 reformulate the existing matrices if a coupled reaction (like BOD/DO) is to be modelled. Lines 770-860 contain the segment interface information used to develop the differential equations. The variable order is flow to segment number, from segment number, advective flow across an interface, dispersion coefficient, vertical plane area between adjoining segments and the distance between their centroids. Lines 1025-1070 define the boundary conditions, including any flow outside the model, an equivalent dispersion term and the external boundary condition parameter concentrations. Lines 1105-1110 are the individual segment volumes. Lines 1120-1150 are the reaction rates. Lines 1160-1180 are the first and second equation loads by segment. Lines 1190-1270 are used as the dissolved oxygen source term, production minus respiration while lines 1478-1490 are used as the dissolved oxygen sink term, in this case, both are zero. Statement 1230 marks the end of the BASIC program coding.

REFERENCES

1. "Level I Evaluation Report, Water Quality Study of Sarasota Bay, Whitaker Bayou and Lake Myakka", June 4, 1982, Priede-Sedgwick, Inc. for FDER.

2. "Benthic Oxygen Demand Studies, Sarasota Bay, Whitaker Bayou and Lake Myakka, Florida, August 1981", updated, Surveilliance and Analysis Division - EPA - Athens, Georgia.

3. "Benthic Oxygen Demand Studies, Sarasota Bay, Whitaker Bayou and Lake Myakka, Florida, February 18-25, 1982", updated, Surveilliance and Analysis Division - EPA - Athens, Georgia.

4. "Benthic Oxygen Demand Studies, Sarasota Bay, Whitaker Bayou and Lake Myakka, Florida, August 15-18, 1982", updated, Surveilliance and Analysis Division - EPA - Athens, Georgia.

5. "Algal Assays of Sarasota Bay and Lake Myakka," July 2, 1982, FDER.

6. "Algal Assay, Lake Myakka - Sarasota Bay, October, 1982, FDER.

7. "Non-Point Source Effects", January, 1976, Martin P. Wanielista for FDER, Report No. ESEI-76-1.

8. "Report on Land Disposal Methods for Renovated Wastewater, Irigation Site No. 3, Sarasota Florida", November, 1978, Smith and Gillespie Engineers, Inc. for City of Sarasota.

9. "Nutrient Loading - Trophic State Relationship in Florida Lakes," May 21, 1981, L.A. Baker, P.L. Brezonik and C.R. Kratzer, for Florida Water Resources Research Center.