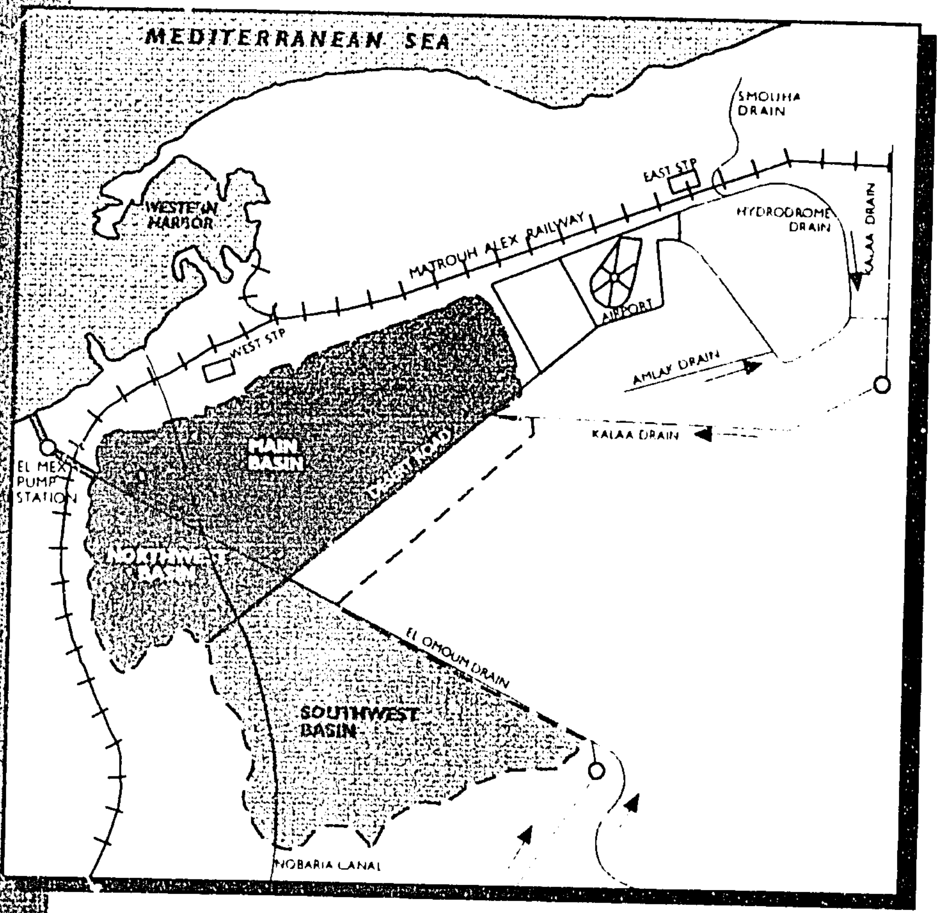
Report on Preliminary Investigations of Lake Maryout Water Quality: Past, Present, and Future

Prepared for:
U.S. Agency for International Development



Prepared by:
Waste Water Consultant Group

October 1993

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Acknowledgements

We would like to acknowledge Dr. Samia Galal Saad, PhD., Dr. Mona gamal El Din, PhD., and the laboratory and field staff at the High Institute of Public Health for their assistance in sampling and analyses throughout the 1992/93 year of monitoring.

Section 1
Introduction

1.1 General Purpose of Study

This study was commissioned by the U.S. Agency for International Development (US AID) as part of its ongoing wastewater management support for the City of Alexandria, Egypt. The intent of the study was to use primarily in-country resources and capabilities to provide a survey level documentation of existing water quality and biological conditions in Lake Maryout (the Lake).

The information collected during the study is presented in this report and is used to address several issues. The overall health of the Lake, prior to the discharge of primary effluent from the newly constructed East and West Wastewater Treatment Plants, is discussed. The relative contribution of various existing pollution sources is evaluated. The data generated are also used to construct a simplified mathematical model of the system which, in turn, is used to estimate future conditions under various wastewater management scenarios. This investigation provides information to identify issues and additional investigations which must be performed to fully evaluate various roles Lake Maryout could play in the long-term Alexandria wastewater management system. By using in-country resources, the study also allows an assessment of capabilities and strengths of local laboratories for the future scientific investigations of wastewater disposal options.

1.2 Background

To improve public health and environmental conditions in the City of Alexandria, the Alexandria Wastewater Program (the Program) was established in 1978 to provide planning, engineering, construction, and operations training of an upgraded wastewater collection and treatment system in the City.

Funded jointly by the US AID and the government of Egypt, the goals of the Alexandria Wastewater Program include the following:

- To eliminate the ponding and flooding of wastewater throughout the City and the discharge of untreated wastewater to the beaches, by providing appropriate systems to collect and convey wastewater to treatment facilities

- To provide basic wastewater treatment and safe disposal of treated effluent

- To provide facilities for the treatment and safe disposal of wastewater sludges

- To expand the collection, treatment, and disposal systems systematically to keep pace with development and population increases

- To upgrade the level of wastewater treatment or to provide an alternative method of effluent disposal that is environmentally acceptable to the community and to US AID

The Program's focus is on the collection and conveyance of the City's wastewater to one of two primary wastewater treatment facilities recently constructed and on the disposal of wastewater effluent and sludge. The wastewater treatment plants began operating in the late summer of 1993. US AID has undertaken facilities planning and environmental review for the portions of the program involving effluent disposal, sludge management, expansion of the two primary treatment plants, expansion of the collection and conveyance systems (including pump stations), and potential future upgrading of the plants to provide secondary treatment.

Implementation of the Alexandria Wastewater Program has followed a phased approach. During Phase I of the Program (represented by completion of the primary wastewater treatment plants), flows of 410 and 175 million liters per day (Ml/day) of wastewater will receive primary treatment by the East Treatment Plant (ETP) and the West Treatment Plant (WTP), respectively, and will be discharged to Lake Maryout. Although potentially subject to change, there are plans for Phase II of the program to involve the primary treatment of 544 and 475 Ml/day of wastewater by the ETP and WTP, respectively. The final discharge location(s) for Phase II effluent is undecided and could involve continued discharge to Lake Maryout or other locations. The upgrading of the treatment facilities during Phase II from primary to secondary treatment is also under consideration. Specific design-related information related to the Alexandria Wastewater Program is available in the Alexandria Wastewater Program Master Plan Update—1992 (Waste Water Consultant Group, 1992).

1.3 General Description of Lake Maryout

Lake Maryout is a large, shallow freshwater lake located directly south of western Alexandria, Egypt. The Lake is comprised of four basins: Main, Northwest, Southwest, and Fishery. These basins are divided by the Alexandria-Cairo Desert Road, the Omoum Agricultural Drain, and the Noubaria Canal (Figure 1-1) but are hydraulically connected by the numerous breaches in the dikes of the Omoum Drain and Noubaria Canal.

Although the areal extent of Lake Maryout is more than 5,000 hectares, only one-half of the Lake consists of wet surfaces. Numerous islands and periphery banks exist

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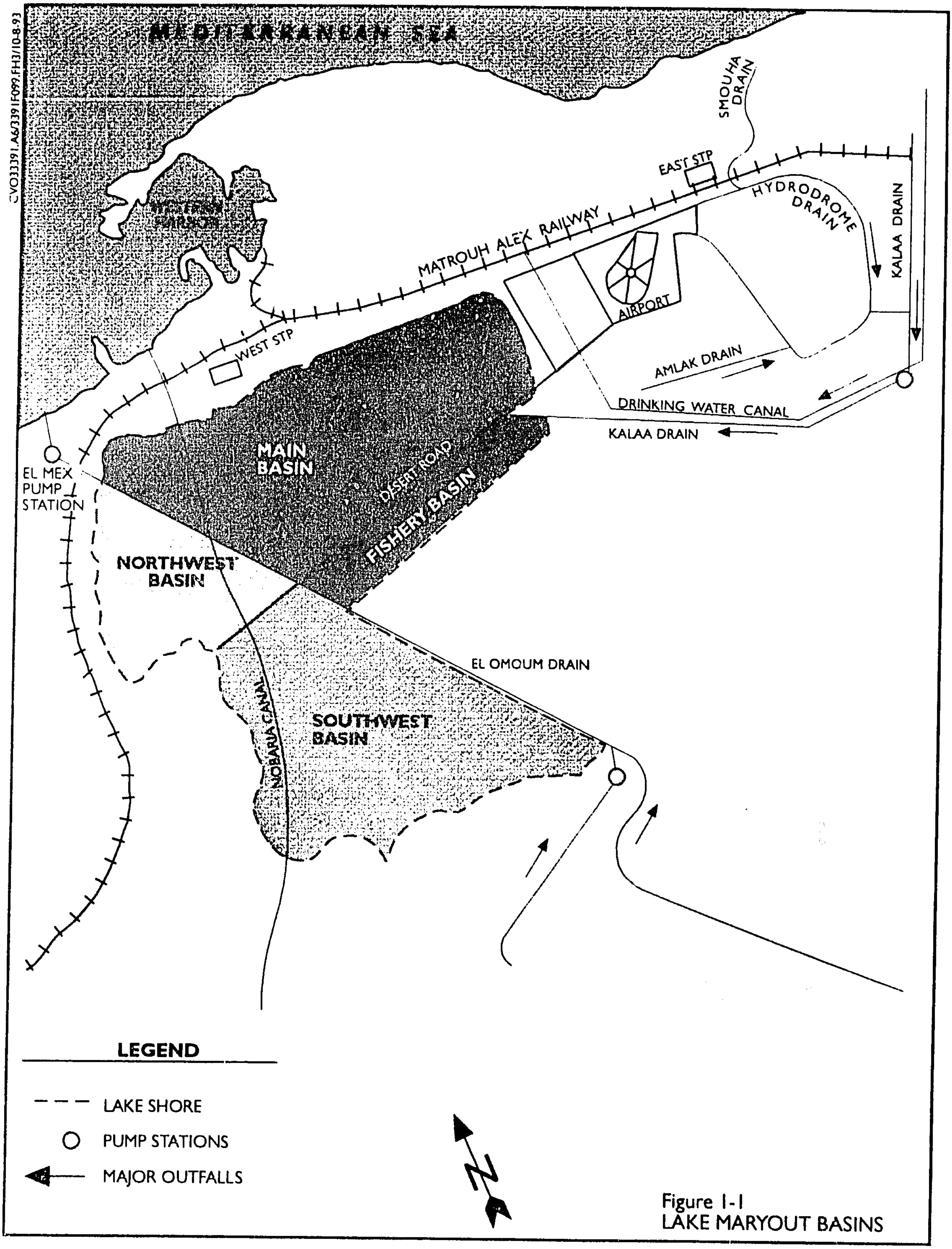

Figure 1-1
LAKE MARYOUT BASINS

within the lake's limits. Estimated areas of each basin are presented below. The Omoum Drain and Noubaria Canal account for an additional 450 hectares of wet area (Table 1-1).

Table 1-1
Size of Lake Maryout Basins

Basin	Total Area (hectares)	Wet Area (hectares)
Main	2,193	1,212
Northwest	723	641
Southwest	1,603	95
Fishery	485	288
Total	**5,004**	**2,236**

Historically, untreated domestic and industrial wastewater from the city of Alexandria and agricultural runoff have been discharged to Lake Maryout. In particular, the Main Basin receives much of the raw wastewater from Alexandria and substantial input from irrigation drains. In addition, its eastern shore is being filled by solid waste. The Northwest and Southwest Basins are not directly influenced by domestic sewage but they do receive waters from industrial discharges and agricultural runoff, respectively.

Characteristics of the Lake include excessive organic and toxic chemical loads; anaerobic conditions; and unpleasant odors, believed to be produced by current pollutant loads, accumulated organic sediments and layers of scum floating on the Lake.

Flows into Lake Maryout, for which there exists at least limited information, include outfall and drain discharges, and precipitation. Estimated or measured discharges to the Lake are shown in Table 1-2.

Table 1-2
Flows into Lake Maryout

Stations	Discharge
Industries Outfall (Station 6)	60.2 Ml/day
Gheit El Enab Outfall (Station 7)	45.2 Ml/day
Forn El Gereya Outfall (Station 8)	34.8 Ml/day
Elmetras Outfall (Station 9)	34.8 Ml/day
Kalaa Drain (Station 5)	608.0 Ml/day
Pump Stations discharging to Omoum Drain	6,621.0 Ml/day
Total	**7,404.0 Ml/day**

Locations of these discharges are indicated on Figure 1-1. Values of flow to the Lake were made from limited measurements and are thus only rough estimates.

The lake level is maintained below sea level by the El Mex Pump Station at the mouth of the Omoum Drain. Prior to the sampling period for this study, the lake level was maintained at about 2.0 to 2.2 meters below sea level. However, in early 1992, just after sampling was initiated for this study, regulation of the Lake was modified, and the level was maintained at about 2.5 meters below sea level (Figure 1-2). The level dropped gradually for late March (-2.2 meters) to mid May (-2.4 meters) and remained at about -2.5 meters through June 1993.

Flows leaving the Lake include flows pumped out El Mex Pump Station and by evaporation. The average flow at El Mex Pump Station is 6,811 Ml/day. The discharge from the El Mex Pump Station is monitored and thus calculated average outflow is more accurate than the estimated inflow to the Lake. The Lake's evaporation rate has been estimated to be approximately 5 millimeters per day (mm/day), or 72 inches per year. In comparison, the 1985 total annual rainfall in the area was only 100 millimeters, or less than 4 inches. No information is available to characterize flows associated with surface water runoff, groundwater recharge, groundwater discharge, refinery or industrial discharges to the Northwest Basin, or hydraulic exchanges between basins.

The biological conditions in Lake Maryout reflect the flow manipulation and degraded water quality. Prior to about 1970, the Lake was extremely productive because of the input of nutrients and warm temperatures. The Lake supported primary production of more than 7 grams of carbon per meter squared per day ($7 \text{ g C m}^{-2} \text{ d}^{-1}$), which is among the highest recorded lake production worldwide

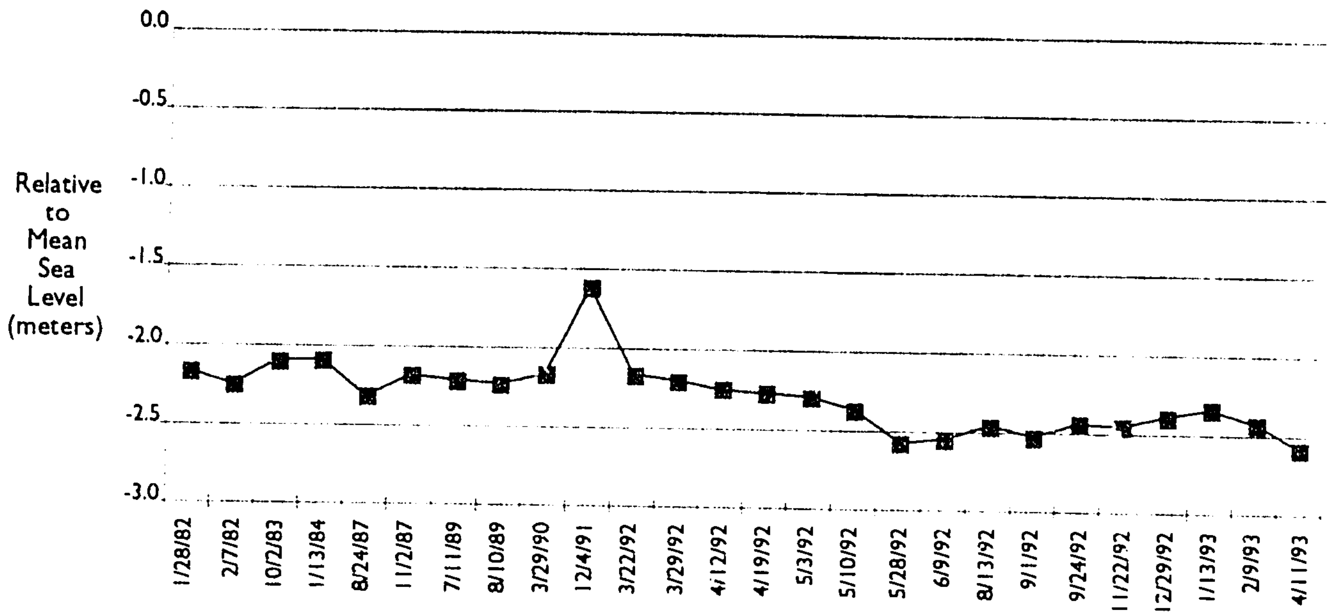

Figure 1-2
LAKE MARYOUT
SURFACE ELEVATIONS

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(Serruya and Pollingher, 1983). This high production and organic input resulted in high fisheries production as well as portions of the Lake being overstressed and anoxic. Prior to 1970, much of the Lake supported marine benthic fauna, such as the marine worm (*Nereis sp.*), barnacles (*Balanus sp.*), and the marine amphipod (*Corophimu sp.*). The more polluted areas of the Lake were dominated by freshwater, pollution tolerant midge larvae (*Chironomus sp.*) (Serruya and Pollingher, 1983). The Lake supported a productive fisheries during the period with recorded catches of more than 450 kilograms per hectare per year (450 kg $ha^{-1}y^{-1}$). As described in this report, the biological condition in the Lake has significantly deteriorated compared to the conditions prior to 1970 described by Serruya and Pollingher (1983).

Section 2
Report Contents

2.1 Scope and Purpose

The discharge of treated effluent from the Alexandria wastewater system has been a continuing and difficult issue since initial master planning in the late 1970s. Discharge to the Mediterranean with minimal treatment was initially considered but subsequently found in the Environmental Impact Statement (EIS) process to be potentially unacceptable. Land application of effluent was evaluated, but costs and availability of land were identified as serious constraints. Similarly, costs, construction implications, and institutional issues (for example, discharge to international waters) precluded simultaneous and immediate construction of both treatment facilities and a sea outfall. Consequently, the decision was made to phase the management of the Alexandria wastewater system and to construct first the elements which produced the greatest benefit for the least cost and in the shortest timeframe. This approach resulted in significant improvements in the collection system and construction of two primary wastewater treatment plants. These actions were needed immediately and are required components of any long-term solution to wastewater management. As an interim measure during the first phase, both treatment plants would discharge primary effluent to Lake Maryout. A final discharge method and location was designated as a critical element for evaluation during a subsequent phase.

As the engineering of the wastewater plants was completed and construction was well underway, it was clear that there would be no decision on implementation of the long-term treatment and discharge of effluent when treatment plant construction was completed. Consequently, the interim solution of discharging primary effluent from both plants to the Lake could be used for a number of years. Because it was only intended as an interim measure, the discharge of primary effluent over a long period potentially could have locally significant effects on the Lake's water quality and biota. Additional investigation of Lake Maryout was considered necessary because inclusion of some form of lake discharge in the long-term solution may be a viable option.

The Lake had been studied in 1983 but the investigation was cancelled after only 3 months because of a number of factors, including the uncertainty of the permanent method of effluent discharge. Also, collection system improvements had diverted additional untreated wastewater flow to the Lake since the 1983 study. Additionally, the increased development in the City and the increased agricultural activity in the area draining to the Lake had resulted in significantly increased pollution loads to the Lake. Lake level manipulation has also occurred since 1983, which has potentially affected water quality. Consequently, the conditions measured in 1983 did not truly represent the condition of the Lake immediately prior to operation of the two primary wastewater plants. If subsequent lake studies compared post-plant operation conditions to 1983 data, any degradation of water quality might incorrectly be attributed to the primary plants, when the plants actually reduced the total pollution load to the Lake. Consequently, a primary purpose of this Lake Maryout investigation is to provide survey level information on the condition of lake for parameters which are affected by primary treatment (for example, biochemical oxygen demand, bacteria, and suspended solids) before the treatment plants begin operation. Because such parameters have relatively short holding times and laboratories in Alexandria have a history of measuring these wastewater constituents, the laboratory at the University of Alexandria High Institute of Public Health was tasked with conducting the investigation.

Although the primary purpose of the investigation was to identify parameters related to primary treatment, it was broadened for several reasons. While the field work was being conducted, additional sampling for other parameters, such as metals and nutrients, added minimal effort, yet could make a significant contribution to the data record and full understanding of the lake system. Also, a complete and thorough examination of Lake Maryout may ultimately be required, if diversion of flows or other use of the Lake was eventually part of the long-term wastewater treatment and discharge solution for Alexandria. This initial study was designed to provide input to the design of any long-term study by identifying significant issues and data gaps. By using an in-country laboratory, this survey level study also provided training for the laboratory personnel and an assessment of their capabilities. The study was intentionally not broadened in several areas because of the level of effort required and possible lack of need for such information, if the Lake was not part of the permanent solution. Such areas included sophisticated analysis of organic pollutants, research level metals analysis, and complete hydrodynamic characterization of the system.

2.2 Investigation Limitations

This investigation was limited by a relatively narrow primary purpose. Although it was broadened to efficiently collect supplemental investigations and to identify issues, much of the additional information is survey quality only. Such information is adequate for general assessment but not for detailed identification and evaluation of small scale spacial and temporal trends. The purpose of the investigation also dictated that the study focus on the Main Basin, which is the portion of the Lake receiving the wastewater discharges both now and after startup of the wastewater treatment plants.

The investigation was limited in the areas of hydrodynamic characterization, some laboratory analyses, and field methods. The evaluation of flows and loads included in this report was based on input flow estimates made years apart but, because they were all that were available, they were treated as simultaneous. Also, the depth estimates were based on a few spot measurements and only gross estimates of areal extent were available.

As described in Section 3, several of the laboratory methods, particularly for the measurement of bacteria, were limited by availability of equipment. Also, general conditions in Alexandria make contamination of samples, equipment, and the laboratory a concern when measurements in the microgram range are attempted.

Field collections were made difficult by logistics. Most of the Lake is extremely shallow and when a power boat approaches a station there is unavoidable disturbance of the sediments. Although attempts were made to minimize the disturbance and wait until the particles settled, it was impossible to totally avoid the variability resulting from sediment resuspension. At several stations, small fishing boats were used, which minimized the disturbance but created additional complications such as unsteady platform and potential contamination from the boat.

Finally, the results from this study are inherently limited, compared to USA research or hazardous waste type investigations, by using in-country resources. The relatively recent concepts in the USA of quality assurance and quality control (QA/QC) have not been fully adopted in Egypt. Practices, such as split samples and data validation, have not been implemented in Alexandria. Although they were introduced in this study and much progress was made, the laboratory could not be expected to perfect a full QA/QC system in a short time when more than a decade was necessary to develop the system in the USA.

2.3 Report Organization

This report is comprised of two basic sections. The first is the reporting, description, and discussion of the sampling results, and the second is evaluation of future conditions under various wastewater discharge scenarios. The sampling results are presented by first summarizing and discussing the methods used for the 1992/93 and, to a lesser extent, for the 1983 investigation (Section 3). Full details of the 1992/93 methods are included as Appendix A. The full description of the 1983 program is given in a separate report (WWCG, 1983a). Section 4 is a summary presentation and discussion of the 1983 and 1992/93 data. The chapter focuses on the parameters potentially affected by wastewater management. They are grouped according to lake quality implications:

- Enrichment—Dissolved Oxygen, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Solids

- Nutrients—Ammonia, Nitrate, and Phosphate

- Metals—Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), and Zinc (Zn)

- Bacteria

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- Biological Characteristics—Algae, Benthos, and Fisheries

Except for biological characteristics, the discussion of the parameters is by major areas of the Lake (central lake and shore areas) and inputs to the Lake (agricultural drains and sanitary discharges). The chapter also includes a comparison of 1993 to 1983 conditions and an evaluation of major inputs to the Lake.

After one continuous year of monitoring, an additional month of data (June 1993) was collected to measure organic pollutants and other parameters not included in the year long monitoring. This collection also included analysis of split samples for several parameters as a QA/QC evaluation. The results of the additional month sampling are presented in Section 5.

All of the data generated by this investigation are included in the Appendices. Appendix B contains summary tables and graphics of the major parameters of concern grouped by lake areas for both the 1983 and 1992/93 sampling periods. The seasonal variability for selected parameters and areas is also given for the 1992/93 data in Appendix B. All of the raw data, as reported by the laboratory for 1992/93, are given in Appendix C. The raw 1983 data are in a separate report (WWCG, 1983b). Appendix D contains the data from the June 1993 effort and documentation of the validation effort.

The second part of the report is the prediction of future conditions and a discussion of the conclusions reached. Section 6 describes the evaluation of future conditions, including an overview of the model, calibration results, and estimation of water quality conditions under various wastewater management scenarios. The complete details of the model used are presented in Appendix E. The conclusions of the investigations are discussed in Section 7. A list of references appears in Section 8.

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Section 3
Study Methods

3.1 Overview of 1983 Study Methods

In 1983, a study of Lake Maryout was conducted to determine conditions in the Lake and to predict future conditions with projected waste loads (WWCG in association with WARITH/ECG, April 1983). The focus of the 1983 sampling effort was on in-lake water quality, with lake inputs monitored at only a few locations. Sampling was conducted monthly between February and April of 1983, with water samples collected at 56 stations. Most water samples were analyzed for chemical constituents, bacteria, and algae on two or three dates. Concentrations of metals and certain chemical constituents were analyzed in grab samples collected from each station on a single date. These included metals concentrations which were measured in samples collected in February 1983.

Water samples were collected at three types of stations in 1983. They included mid-lake and lake outlet stations, near shore stations, and lake input stations, including several locations in the Kalaa Drain system. Sampling was conducted in the Main, Northwest, Southwest, and Fishery Basins, although only water quality data in the Main and Northwest Basins will be discussed in Section 4.1 for purposes of comparison with 1992/93 conditions.

Water samples collected from the lake and drains were analyzed for the following parameters on two or three dates:

- Dissolved Oxygen
- Total Solids
- Suspended Solids
- Total Dissolved Solids
- Fixed Dissolved Solids
- Chemical Oxygen Demand
- Nitrate-Nitrogen
- Phosphate-Phosphorus
- Alkalinity
- Sulfates
- Conductivity
- Fecal Coliform
- pH
- Settleable Solids
- Volatile Suspended Solids
- Volatile Dissolved Solids
- Biochemical Oxygen Demand
- Ammonia-Nitrogen
- Nitrite-Nitrogen
- Chlorides
- Hardness
- Oil and Grease
- Total Coliform
- Fecal Streptococcus

Water samples were analyzed for the following parameters on a single date:

- Salinity
- Carbonate
- Chromium
- Sulfides
- Bicarbonate
- Copper

- Zinc
- Mercury
- Lead
- Turbidity
- Magnesium
- Iron
- Nickel
- Cadmium
- Calcium

Chemical analyses were performed at the University of Alexandria High Institute of Public Health. The laboratory protocol called for analysis and sampling methodologies to follow *Standard Methods for the Examination of Water and Wastewater*, Fourteenth Edition.

3.2 Overview of 1992/93 Study Methods

The parameters most useful in characterizing lake conditions related to primary treatment of sanitary waste are discussed in Section 4.1. A summary of data from the 1983 sampling program is included in Appendix B.

Between March 1992 and February 1993, a sampling program was conducted involving the collection and analysis of water samples for chemical parameters, algae, and bacteria. Samples were collected from nine land-based drains discharging agricultural irrigation water and untreated industrial and domestic wastewater to Lake Maryout, nine receiving water stations in the Lake, and at the lake outlet. Throughout this report, the term outfall is used interchangeably with drain because both discharge to the Lake. The land-based and receiving water stations were selected for sampling so that the effects of current discharges could be characterized and so that the effects of the future east and west treatment plant discharges could be predicted. Sediment was sampled at the receiving water stations in the Lake. The location of 1992/93 sampling stations is shown in Figure 3-1. Table 3-1 correlates these stations to stations monitored at the same or similar locations in 1983.

Water quality and sediment were monitored monthly so that temporal trends could be identified and, if present, could be used to enhance an understanding of conditions in Lake Maryout.

The 1992-1993 sampling program provides information that can be used to characterize the existing conditions of the lake and the discharges. Those parameters most useful in characterizing existing conditions of the Lake and discharges related to sanitary waste are discussed in Section 4.2. Field and laboratory methods for the 1992/93 sampling program generally followed *Standard Methods for the Examination of Water and Wastewater*, Seventeenth Edition, and are presented in Appendix A of this report. Summary results are presented in detail in Appendix B, and complete results are presented in Appendix C.

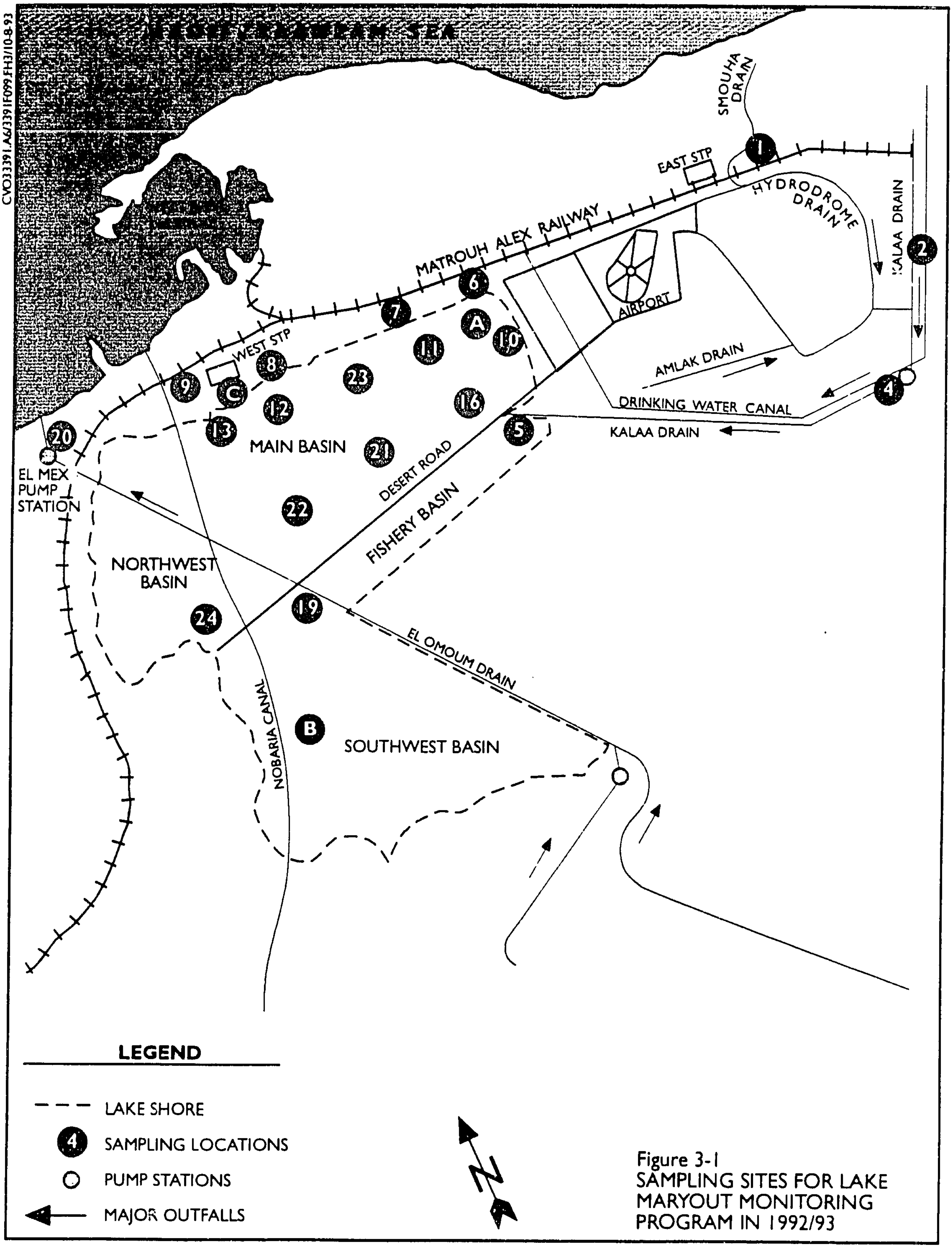

Figure 3-1
SAMPLING SITES FOR LAKE MARYOUT MONITORING PROGRAM IN 1992/93

Table 3-1
Station Comparison for 1983 and 1992/93 Lake Maryout Monitoring

Station Name	Station Number 1983	Station Number 1993
Kalaa Drain		
Smouha Drain	–	1
Upstream Kalaa	3	2
Kalaa Pump Station	4	4
Input Stations		
Industries Drain	-	6
East Central Drain	–	7
West Central Drain	–	8
West Drain	–	9
Kalaa Mouth	5	5
Omoum Drain	7	19
Lake Shore Stations		
East Central Lake	–	11
West Central Lake	–	12
West Lake	–	13
North Shore	17, 18, 25, 26, 32	23
East Lake	10, 11, 12, 13	10
Lake at Kalaa	14	16
Mid-Lake and Outlet		
Main Basin - Central Lake	23, 24, 27, 28	21, 22
Northwest Basin	39, 40, 41	24
El Mex Outlet	9	20

Water samples were analyzed monthly for the following parameters:

- Dissolved Oxygen
- Biochemical Oxygen Demand
- Total Solids
- Dissolved Solids
- Alkalinity
- Magnesium Hardness
- Ammonia-Nitrogen
- Nitrate-Nitrogen
- Sulfates
- Conductivity
- Cadmium
- Copper
- Nickel
- Zinc
- Temperature
- pH
- Chemical Oxygen Demand
- Volatile Solids
- Fixed Solids
- Calcium Hardness
- Total Hardness
- Nitrite-Nitrogen
- Phosphate-Phosphorus
- Chloride
- Oil and Grease
- Chromium
- Iron
- Lead
- Fecal Coliform

Sediments were analyzed for the following parameters:

- pH
- Fixed Solids
- Sulfates
- Chromium
- Iron
- Lead
- Volatile Solids
- Phosphate-Phosphorus
- Cadmium
- Copper
- Nickel
- Zinc

3.3 1992/93 Investigation Methods Limitations

The High Institute of Public Health developed a QA/QC plan for this investigation (Appendix A) modeled after a typical plan for a hazardous waste investigation in the USA. Development of the plan was an important step in training and development for the laboratory and set forth ambitious goals. It also identified the methods to be used, which were ones specified in *Standard Methods for the Examination of Water and Wastewater (Standard Methods).* However, because the QA/QC procedures described in the plan were not all standard practice for the laboratory, strict adherence to all requirements was not always achieved the first time they were used. Because of equipment and reagent availability, some variations to *Standard Methods* were unavoidable. Most of the variations were minor and did not affect the quality of the data for the intended uses. However, as described below, there were some aspects of the bacterial analyses which could have affected the coliform data.

Several important elements of the QA/QC plan were followed and proved to be very useful. For example, review of the sediment metals data pointed to what appeared to be extreme variability. Frozen sample alloquots were reanalyzed and yielded similar results, thus the QA/QC procedures functioned as intended. Similarly, review of data indicated anomalously high BOD and COD values for the outlet to the Lake (Station 20), and review of laboratory sheets by the director identified incorrect data reporting. Correct values were determined.

For the bacterial analyses during the continuous 12 months of monitoring, there were unavoidable deviations from *Standard Methods*. These deviations were addressed, to the extent possible, during the June 1993 evaluation of methods by providing additional equipment and by using a WWCG laboratory specialist to personally conduct the tests on a duplicate set of samples in the High Institute of Public Health Laboratory. This approach was selected because of the uncertainty in delivering the samples to a laboratory in the USA within the holding time for bacteria samples. The variations from *Standard Methods* noted for the 12 continuous months of monitoring and the approach for addressing them during the June 1993 effort include the following:

- MacConkey's media was all that was locally available and was used for all analyses performed by the High Institute for Public Health. Standard Methods specifies Lauryl Sulfate Broth for presumptive tests, Brilliant Green Bile Broth for confirmed test, and EC media for fecal coliform tests. For the June 1993 additional sampling effort, the three types of media specified by *Standard Methods* were shipped to Alexandria and were used for a complete set of samples.

- Because of equipment limitations, temperature control of fecal coliform tests was difficult and could have varied for tests on the continuous 1992/93 monthly samples. For the June 1993 evaluation, an incubation temperature of 44.5°C was strictly maintained for the duplicate set of samples.

- Only 5 ml of media were used instead of the 10 ml called for in Standard Methods. The full amount was available and was used for analysis of the June 1993 duplicate samples.

- Dilution water was not buffered or pH checked. This constraint was addressed to the extent possible for the June 1993 duplicates, but could not be rectified fully with available resources.

- Only cotton plugs were available for test tubes. Normal practice is to use metal or autoclavable plastic caps. It was not possible to eliminate this problem for the analysis of June 1993 duplicates.

- The autoclave did not have a temperature or timing check, which could have potentially affected sterilization procedures. This could not have been remedied for the June 1993 duplicates.

- Because of equipment limitations, used cultures from previous tests were not sterilized before discarding, thus contaminated sinks and work areas could have occurred. This, in combination with the lack of disinfection of bench tops, work areas, and floors could have produced contamination of samples. It was not possible to eliminate this potential concern for the June 1993 evaluation.

- There was a general shortage of sterilized glassware in the laboratory. Lack of funds for replacing broken items had a cumulative effect which could have affected data quality. There was a limited number of milk bottles for making dilutions, and volumetric flasks and graduated cylinders were also not plentiful. This could not have been totally overcome for the June 1993 evaluations but care was taken to minimize the effect. For example, to overcome the shortage of pipets, it was necessary to use a pipet for multiple transfers of a single sample. However, in all cases, transfers started at the highest dilution and worked to lowest dilution.

- Calibration weights were not available to check the balance accuracy, and this could not have been addressed by the WWCG Laboratory Specialist during the June 1993 evaluation. Although this may not have been critical for the bacterial analyses, it could have implications for other parameters.

- As is true in much of Alexandria, there is no air conditioning in the laboratory building. Because of the high temperature the windows were opened during the laboratory procedures. Wind carried dust inside from the opened windows. That could have caused contamination problems. This could not have been corrected for the duplicate sample evaluation.

- *Standard Methods* calls for inoculation of appropriate decimal dilutions of water samples in laurel tryptose broth in tubes with 10 ml or more of the media. The procedure calls for five tubes per dilution with at least three dilutions of sample. Any tube showing gas is considered as a presumptive positive tube. This procedure was followed for the June 1993 duplicate sample. However, an alternative procedure (described in *Standard Methods* for wastewater but to be used only with caution) was used for the continuous 12 months of sampling. Under the alternative method, if all presumptive tubes are positive in two or more consecutive dilutions within 24 hours, only the tubes of the highest dilution in which all tubes are positive and any positive tubes in still higher dilutions are submitted to the confirmed test. The positive tubes are submitted to the confirmed test only after 48 hours. This alternative method was used because the lake water was expected to be highly contaminated and because of limited laboratory facilities (for example, glassware and water bath).

Sediment disturbance during sample collection was another area of unavoidable variation. The sediments in the Lake were disturbed naturally by gasses rising to the surface, periodic high wind velocities, and because the shallow depth sampling, including the boat propeller, can suspend large volumes of sediments. They are not equally dispersed in the water column and inclusion of recently suspended bottom sediments in the sample can affect analytical results.

Several of the limitations pointed out for the bacterial analyses also apply to other parameters. For example, the availability of glassware can sometimes affect results. Similarly, the unavailability of sample containers prevented what is now standard practice of using new, virgin bottles for each discrete sample. Alternatively, all water was collected in a single marked container and was drawn within the laboratory for individual analyses. The container was thoroughly cleaned prior to the next sampling event but it was reused. Containers were dedicated to a specific station, which did minimize potential for cross contamination. The potential for contamination from dust entering through open windows could have contaminated samples and could have resulted in dirty glassware.

Another unavoidable complication that could have affected results is the strength of the waste which could have multiple implications. First, high dilutions were required, which increased the chance for measurement, calculation, and contamination error. Because of the high dilution, variability was often in the hundreds of milligrams (mg) range, and thus significant. For cleaner situations, the natural variability would be in the milligram range and not significant. The strong and complex waste also produced interferences and other complications for analytical methods and could have affected the results of several analyses.

Based on the above qualification in methods, there are some limitations on use of the resulting data. The combination of variability because of the Lake conditions and methods resulted in significant "noise" in the data. Consequently, month-to-month or station-to-station differences had to be above the background noise to be detected. Also, significant inclusion of resuspended bottom sediments in water samples, recent disturbance prior to sample collection, or other variables produced "data point outliers". Such events made detailed evaluation of small scale trends unproductive but did not significantly alter the consideration of the larger picture when averages were used.

Perhaps the greatest limitations related to bacterial data. Because of the extremely high concentrations (MPN's of up to 10^9 per 100 ml) and laboratory limitations, the evaluation of conditions is probably most useful at the order of magnitude level. Because the Lake receives approximately 500 megaliters of raw domestic sewage a day, supports extensive bird populations, and is used extensively for livestock watering and grazing, an order of magnitude consideration of bacterial concentrations is generally sufficient.

Section 4
Existing Lake Maryout Conditions

4.1 Water Quality Results of 1983 Study

The 1983 sampling program provides a snapshot of conditions in Lake Maryout and a baseline against which current conditions can be compared. To conduct a meaningful assessment of trends between 1983 and 1993, data from stations monitored in 1983 were grouped for comparison to the same or similar stations monitored in 1992/93. Only water quality data from 1983 stations that were also monitored in 1993 are discussed below. Table 3-1 correlates 1983 stations to 1993 stations and shows how stations were grouped. To simplify the discussion that follows, stations are referred to by name or by 1993 station number. For example, the Omoum Drain is referred to by name or as Station 19. The locations of the 1993 stations are shown on Figure 3-1.

Prior to directly comparing 1983 data to 1992/93 data, 1992/93 data were reviewed for potential temporal trends. After reviewing the data for each parameter at each station, no obvious temporal trends were not identified. Therefore, 1983 data collected from February through April were compared to annual data collected in 1992/93.

In the following sections, water quality conditions in Lake Maryout are described and then related to various inputs. Conditions in the Lake are described in Section 4.1.1. and are followed by a description of conditions in shoreline portions of the Lake (Main Basin only, because those were the only near shore areas monitored in 1993) in Section 4.1.2. The water quality of lake inputs is described in Section 4.1.3.

Throughout this section, reported concentrations of phosphate are measurements of phosphate as phosphorus. Reported concentrations of nitrate and ammonia are measurements of the nitrogen component of each.

4.1.1 Mid-Lake and Outlet Stations

Water quality data from four stations in the central portion of the Main Basin are used to represent conditions in the Main Basin, and data from three stations in the Northwest Basin are used to represent conditions in that basin.

Nutrients and Enrichment

The water quality data indicate that in 1983, the Main and Northwest Basins had high concentrations of organic matter and, on the average, biochemical and chemical oxygen demands were comparable to concentrations found in "weak to medium" strength untreated wastewater (Table 4-1). Average volatile solids concentrations were comparable to "weak to strong" untreated wastewater, and average suspended solids concentrations were higher than those found in "strong" untreated wastewater. Generally, BOD and COD concentrations were highest in the Northwest Basin and lowest at the El Mex pump station, suggesting that chemical and biological processes in Lake Maryout are consuming organic material (Figure 4-1).

Table 4-1
Water Quality of Mid-Lake and Outlet Stations – 1983
(Average Concentration in mg/l)

Parameter	Main Basin	Northwest Basin	El Mex Outlet	Typical Composition of Untreated Wastewater[a]	
				Weak	Strong
BOD	182	221	111	110	400
COD	562	594	340	250	1,000
Total Suspended Solids	564	1,096	515	100	350
Volatile Suspended Solids	106	373	61	80	275
Ammonia-N	9.1	2.7	6.1	12	50
Nitrate-N	6.3	3.5	4.2	0	0
Phosphate-N	1.6	0.8	1.1	3	10

[a]Source: Metcalf & Eddy, 1991.

Nutrient concentrations in Lake Maryout showed similar evidence of enrichment and indicate that Lake Maryout's trophic state was eutrophic. Trophic state is a lake classification system based on the concentration of plant nutrients and the resulting level of biological productivity. The two most widely recognized lake trophic states are oligotrophy and eutrophy, although the boundary between the two is vague.

Biological productivity (and the trophic state), depends on a variety of materials, including phosphorus, nitrogen, carbon, iron, manganese and trace minerals. Biological growth is limited by the substance that is present in minimal quantities with respect to the needs of algae or macrophytes. Nitrogen and phosphorus are usually the elements in least relative supply, and usually are the ones responsible for causing the shift from oligotrophy to a more productive state. Typically, algae and macrophytes contain phosphorus and nitrogen in the approximate ratios of 1 gram of phosphorus for every 7 grams of nitrogen. If one type of nutrient is depleted before the other, it is the limiting nutrient. Where the ratio of nitrogen to phosphorus is greater than 7:1, phosphorus is the nutrient that limits plant growth, and the nutrient that, if controlled, will limit biological productivity.

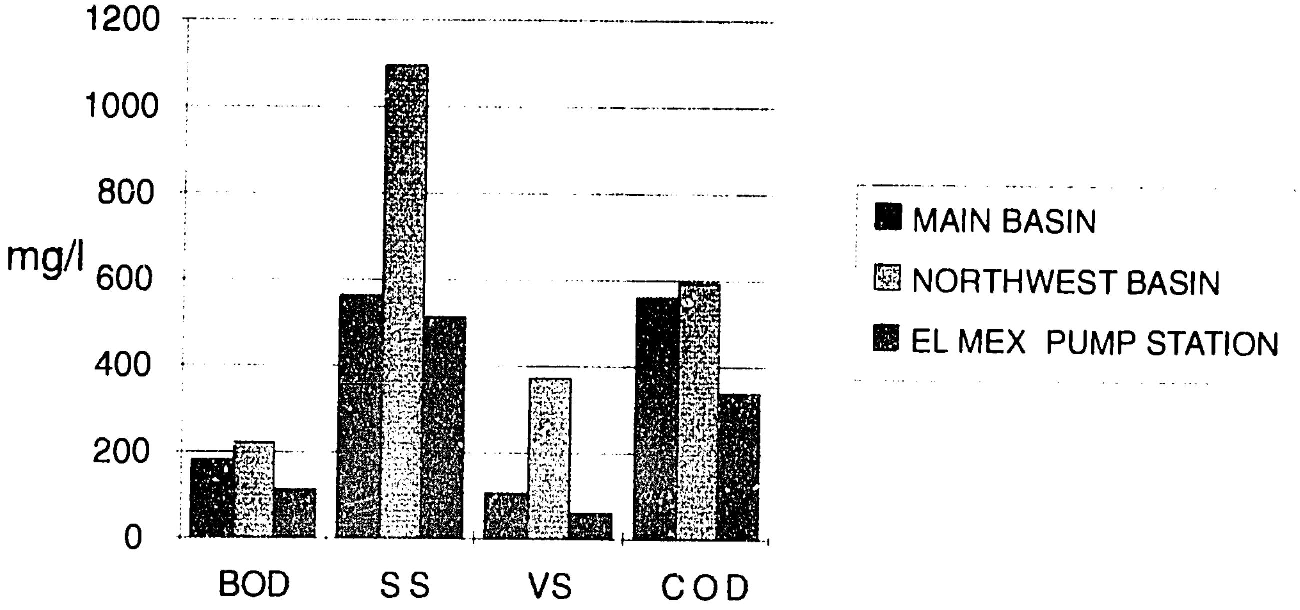

Figure 4-1
LAKE AND OUTLET ENRICHMENT CHARACTERISTICS - 1983

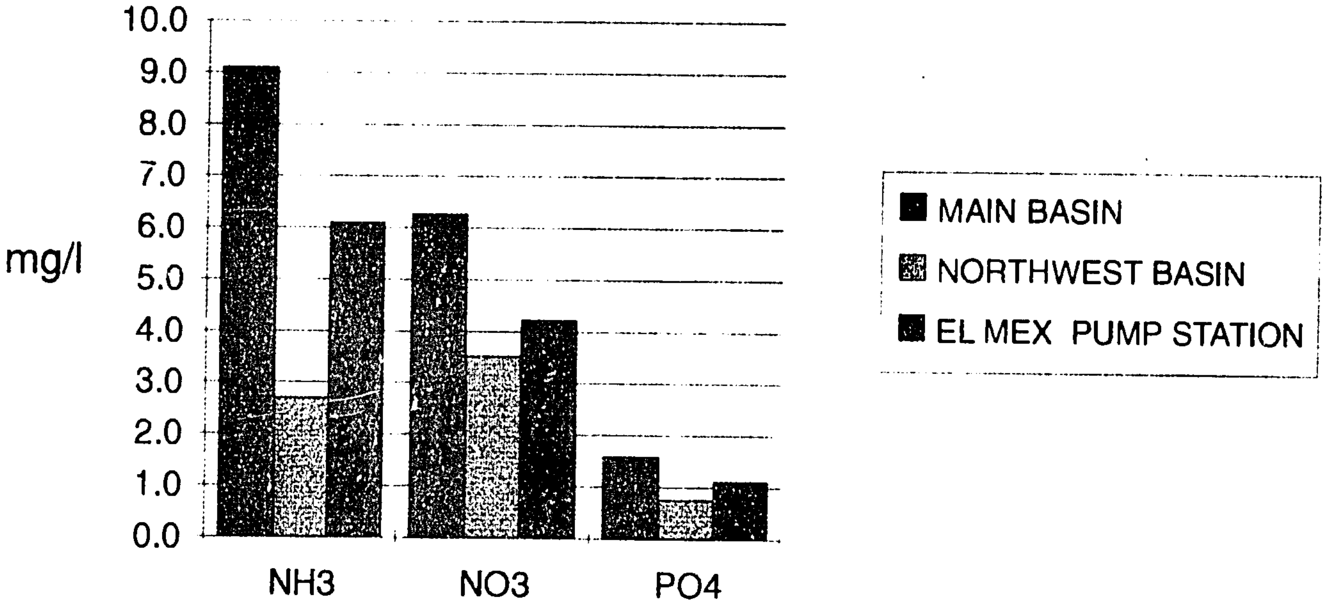

Figure 4-2
LAKE AND OUTLET NUTRIENT CHARACTERISTICS - 1983

Oligotrophic lakes have low nutrient concentrations, low algal biomass, and low productivity. Eutrophic lakes have high nutrient levels, high phytoplankton biomass, and low water clarity because of the phytoplankton density. During the spring, summer, and fall, a eutrophic lake usually has algal blooms or excessive growth of aquatic plants. When the algae die and decompose, oxygen is consumed, frequently resulting in anoxic conditions in the bottom waters of the lake. Oligotrophic lakes typically have total phosphorus concentrations in the winter that are less than or equal to 10 to 15 μg/l.

Eutrophic lakes have total phosphorus concentrations in the winter that are greater than or equal to 20 to 30 μg/l. In Lake Maryout, concentrations of phosphate as phosporus (which is the only form of phosphorus that was measured) were always higher and, on the average, were approximately two orders of magnitude greater than the threshold for eutrophic lakes. Average phosphate concentrations in the Main and Northwest Basins and the El Mex Pump Station ranged from 760 to 1,583 μg/l, with total phosphorus concentrations expected to be even greater than the phosphate concentrations measured.

Oxygen concentrations in the Lake varied considerably from February to March. In February, dissolved oxygen concentrations in the Main and Northwest Basins ranged from approximately 8 to 16 mg/l, in March they ranged from approximately 7 to 19 mg/l, and in April they ranged from zero to 15 mg/l. These values indicate that oxygen conditions in the Lake ranged from being supersaturated to depleted. High oxygen concentrations were likely the result of plant productivity, while low concentrations likely resulted from high concentrations of organic material, which consumes oxygen as it decomposes. In the United States, a minimum dissolved oxygen concentration of 5 mg/l is typically required for warm waters designated, at a minimum, as suitable habitats for wildlife and fish. In April, conditions at three of the seven stations in the Main and Northwest Basin were below 5 mg/l.

In contrast to enrichment parameters (BOD, COD, volatile solids and suspended solids), average nutrient concentrations (phosphate, nitrate and ammonia) were higher in the Main Basin than those in the Northwest Basin, with concentrations in the Northwest Basin approximately one-third to one-half those in the Main Basin (Figure 4-2). Nutrient concentrations may have been higher in the Main Basin because of runoff from agricultural activities.

On the average, nutrient concentrations at the El Mex Pump Station were lower than those in the Main or Northwest Basin, suggesting that biological processes were taking up nutrients. Most stations exhibited this trend.

Metals

The U.S. Environmental Protection Agency (USEPA) has established criteria for the protection of sensitive aquatic species against acute (short-term) and chronic (long-

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term) effects, and for the protection of human health from effects associated with eating fish. These criteria are guidelines to evaluate the potential impact to aquatic biota and human health.

The bioavailability of certain metals varies with the hardness of the water. Therefore, the water quality criteria were adjusted to reflect typical hardness conditions observed in Lake Maryout. The hardness-dependent criteria were calculated using a minimum hardness of 550 mg/l as calcium carbonate and a maximum hardness of 1,330 mg/l as calcium carbonate which represents the range measured in the Lake.

In 1983, the concentrations of some heavy metals were at an acceptable level compared to USEPA aquatic life water quality criteria, while concentrations of other metals exceeded the criteria. In the Main and Northwest Basins and the outlet station, average chromium, nickel, and zinc concentrations were below the acute and chronic water quality criteria as indicated by ratios of less than one. The ratios are calculated by dividing the average concentration measured by the chronic and acute water quality criteria. Ratios greater than or equal to one indicated that the criteria were exceeded.

In the Main Basin, the average concentration of cadmium exceeded the USEPA's chronic and acute water quality criteria by a factor of 1 to 21. In the Northwest Basin, average cadmium concentrations exceeded the chronic water quality criteria by a factor of 2 to 4 and were below the acute criteria. Average cadmium concentrations were highest at the El Mex Pump Station and exceeded the chronic and acute water quality criteria by a factor of 2 to 40 (Table 4-2).

Copper concentrations were similar in the Main and Northwest Basins, and exceeded the chronic and acute water quality criteria by a factor of 2 to 8. Average copper concentrations at the El Mex Pump Station exceeded chronic and acute water quality criteria by a factor of 1 to 5.

Average lead concentrations followed a trend similar to that for cadmium. Concentrations were highest at the El Mex Pump Station, where they exceeded the chronic water quality criteria by a factor of 9 to 27, and had a ratio ranging from 1 to 0.34 compared to the acute water quality criteria. Lead concentrations were lowest in the Northeast Basin, where they exceeded chronic water quality criteria by a factor of 3 to 8, and had a ratio ranging from 0.11 to 0.31 compared to the acute water quality criteria. In the Main Basin, average lead concentrations exceeded chronic and acute water quality criteria by a factor of zero to 27.

Average mercury concentrations were high at all locations (80 to 165 μg/l): However the June 1993 analyses showed mercury levels less than 10 μg/l. This indicates either a significant decline in mercury concentrations or laboratory variability in 1983.

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Table 4-2
Comparison of 1983 Metals Concentrations to USEPA Water Quality Criteria for Lake and Outlet Stations (Average Concentration in μg/l)

Parameter	Avg.	U.S. EPA Water Quality Criteria				Ratio of Average:			
		Chronic		Acute		Chronic		Acute	
		Min	Max	Min	Max	Min	Max	Min	Max
Cadmium		4	9	27	73				
Various Main Basin	85					21	9	3	1
Various NW Basin	15					4	2	0.56	0.21
El Mex Outlet	160					40	18	6	2
Chromium		836	1,723	7,015	14,458				
Various Main Basin	17					0.02	0.01	0.002	0.001
Various NW Basin	ND					-	-	--	--
El Mex Outlet	150					0.18	0.09	0.02	0.01
Copper		51	108	108	203				
Various Main Basin	400					8	4	4	2
Various NW Basin	339					7	3	3	2
El Mex Outlet	260					5	2	2	1
Lead		28	86	715	2,201				
Various Main Basin	747					27	9	1	0.34
Various NW Basin	233					8	3	0.31	0.11
El Mex Outlet	812					29	9	1	0.37
Nickel		667	1,408	5,999	12,663				
Various Main Basin	20					0.03	0.01	0.003	0.002
Various NW Basin	15					0.02	0.01	0.002	0.001
El Mex Outlet	12					0.02	0.01	0.002	0.001
Zinc		449	950	496	1,048				
Various Main Basin	196					0.44	0.21	0.40	0.18
Various NW Basin	178					0.40	0.19	0.36	0.17
El Mex Outlet	120					0.27	0.13	0.24	0.11
Mercury[a]		.15		2.4					
Various Main Basin	165						13,750		69
Various NW Basin	94						7,833		39
El Mex Outlet	80						6,667		33

ND = Not detected
(a) = Not Hardness dependent

The actual toxicity of individual metals is dependent on more than just the concentration in the water or sediment. The bioavailability and interactions with other toxic compounds present in the environment can also be significant factors. In Lake Maryout the bioavailability may be reduced because of binding with the high concentration of dissolved and particulate organic matter. The high concentrations of sulfide in the water and sediment may also bind at least some of the metals (Cd, Ni, and Hg, particularly) and limit their availability. In contrast the additive, or perhaps even synergistic effects of high concentrations of multiple metals, may result in even greater toxicity than discussed above. Where metal concentrations are near the criteria, these factors are critical in determining the actual toxicity. However, where concentrations are an order of magnitude above levels known to be harmful such factors may reduce but probably do not eliminate toxic effects.

4.1.2 Lake Shore Stations

Lake shore stations fall into three categories: stations along the north shore of the Main Basin (five stations), stations along the east shore of the Main Basin (four stations distributed evenly), and a station near the mouth of the Kalaa Drain (in the lake near Desert Road and the drain).

Nutrients and Enrichment

The average concentrations of BOD, COD, total suspended solids, and volatile suspended solids are similar between the north shore, east shore, and lake at Kalaa stations (Table 4-3). BOD, COD, and volatile suspended solids are present at concentrations comparable to "medium to strong" untreated wastewater, and total suspended solids are present at concentrations greater than "strong" untreated wastewater. On the average near shore and lake stations have similar concentrations of these parameters.

Somewhat different trends are observed in nutrient parameters. The average ammonia and phosphate concentrations are slightly higher at each category of shoreline stations than at mid-lake, suggesting that nutrients are being input from outside sources and are consumed by chemical or biological processes. Average nitrate concentrations are similar at shoreline and mid-lake stations (Figure 4-3). Phosphate concentrations in lake shore areas are indicative of highly eutrophic conditions. Average phosphate concentrations at individual stations range from 1,200 μg/l to 2,900 μg/l, with total phosphorus concentrations expected to be even greater.

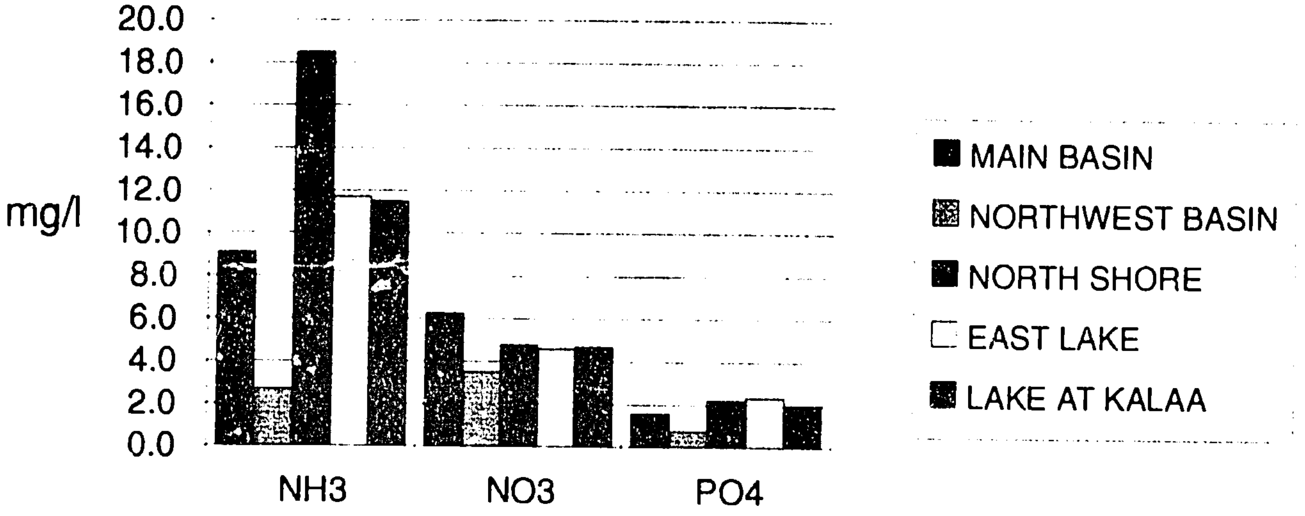

Figure 4-3
COMPARISON OF NUTRIENTS AT
LAKE SHORE AND MID-LAKE STATIONS - 1983

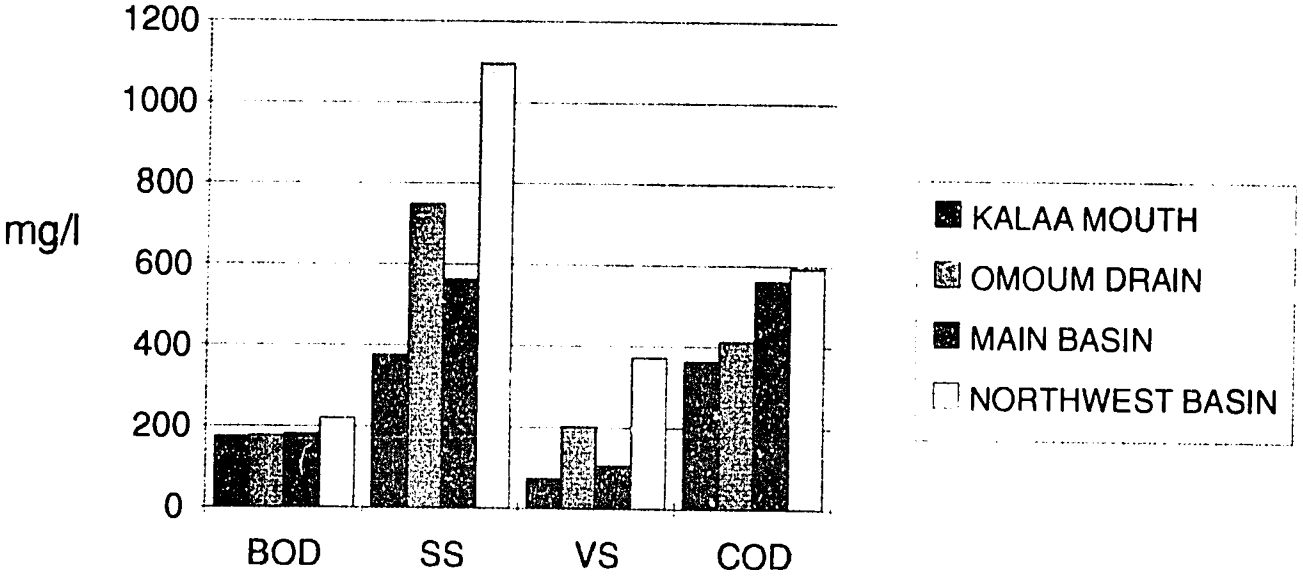

Figure 4-4
COMPARISON OF ENRICHMENT
CHARACTERISTICS AT LAKE INPUT
AND MID-LAKE STATIONS - 1983

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Table 4-3
Water Quality of Lake Shore Stations – 1983
(Average Annual Concentration in mg/l)

Parameter	North Shore	East Lake	Lake Near Kalaa Mouth	Typical Concentration of Untreated Wastewater[a]	
				Weak	Strong
BOD	277	308	288	110	400
COD	479	634	407	250	1,000
Total Suspended Solids	628	493	467	100	350
Volatile Suspended Solids	218	165	218	80	275
Ammonia-N	18.5	11.7	11.5	12	50
Nitrate-N	4.8	4.6	4.7	0	0
Phosphate-P	2.2	2.3	2.0	3	10

[a]Source: Metcalf & Eddy, 1991.

Dissolved oxygen concentrations at lake shore stations were lower than at mid-lake stations and also are indicative of highly eutrophic conditions. At the east lake and Kalaa stations, dissolved oxygen concentrations were low throughout the sampling period, ranging from zero to a high of approximately 4 mg/l. At the north shore stations, dissolved oxygen concentrations ranged from zero to almost 21 mg/l, supersaturated conditions that are likely the result of high biological productivity.

Although average nitrate and phosphate concentrations were similar for each category of shoreline station (north shore, east lake, and near the mouth of the Kalaa Drain), average ammonia concentrations were higher at north shore stations. In addition, there was considerable variability in nutrient concentrations at individual stations and at different times at the same station. For example, average ammonia concentrations were highest at the north shore Stations 17 and 32, average nitrate concentrations were highest at the north shore Stations 25 and 26, and average phosphate concentrations were highest at the north shore Stations 18 and 25.

Between individual sampling events, nitrate concentrations were highly variable (greater than an order of magnitude difference) at all north shore and east shore stations, and phosphate concentrations were highly variable at Stations 18 and 32 (north shore), Station 10 (east shore), and Station 14 (Lake at Kalaa). Ammonia concentrations were variable at Stations 26 and 32 (north shore).

Metals

For the most part, the lake shore stations had metals concentrations that were the same order of magnitude as those of the mid-lake stations in the Main Basin. As in the mid-lake stations, the lake shore stations had average chromium, nickel, and zinc concentrations below the USEPA acute and chronic water quality criteria (Table 4-4). However, chromium concentrations at the Kalaa Station were much higher than those at the north or east shore stations.

Average concentrations of cadmium at the North Shore, East Lake, and Lake at Kalaa stations exceeded the USEPA's chronic water quality criterion by ratios of 5 to 11, 7 to 15, and 9 to 20, respectively. The average cadmium concentrations at the North Shore, East Lake and Lake at Kalaa Stations had ratios compared to the acute water quality criteria of 2 to 0.62, 2 to 0.84, and 3 to 1, respectively. The average copper concentrations at the North Shore and East Lake stations exceeded chronic and acute water quality criteria by a factor of 2 to 6, and at the Lake at Kalaa Station, exceeded the chronic criteria by a factor of 1 to 3. Lead concentrations exceeded chronic water quality criteria at lake shore stations by approximately a factor of 2 to 15. Lead concentrations were below the acute water quality criteria by factors of 0.61 to 0.09.

As with nutrients, average concentrations of metals varied between stations. The average cadmium and lead concentrations at Stations 25 and 32 were approximately five times higher than those found at other stations, and the highest average copper and zinc concentrations were found at Station 17. Each of these stations had high concentrations of certain nutrients.

Average mercury concentrations were high at all locations (75 to 150 µg/l), although they were greatest at the Lake at Kalaa Station. As with mid-lake stations, the June 1993 analyses showed much lower mercury levels. This indicates either a significant decline in mercury concentrations or laboratory variability in 1983.

4.1.3 Lake Input Stations

In 1983, two lake input stations were monitored: the mouth of the Kalaa Drain system, and the Omoum Drain, just south of the Main Basin. In addition, two stations in the Kalaa Drain system were monitored: Station 2, located upstream of the Hydrodrome Drain, and Station 4, located downstream of the Hydrodrome Drain, near the Kalaa Drain Pump Station.

Although there were inputs to Lake Maryout other than the Kalaa and Omoum Drain systems, these two systems carried a large portion of the flow to the Lake, and provided information on potential sources of enrichment.

Table 4-4
Comparison of 1983 Metals Concentrations to USEPA Water Quality Criteria for Lake Shore Stations (Average Concentration in μg/l)

Parameter	Avg.	U.S. EPA Water Quality Criteria				Ratio of Average:			
		Chronic		Acute		Chronic		Acute	
		Min	Max	Min	Max	Min	Max	Min	Max
Cadmium		4	9	27	73				
North Shore	45					11	5	2	0.62
East Lake	61					15	7	2	0.84
Lake at Kalaa	80					20	9	3	1
Chromium		836	1,723	7,015	14,458				
North Shore	25					0.03	0.01	0.004	0.002
East Lake	11					0.01	0.01	0.002	0.001
Lake at Kalaa	120					0.14	0.07	0.02	0.01
Copper		51	108	108	203				
North Shore	313					6	3	3	2
East Lake	320					6	3	3	2
Lake at Kalaa	160					3	1	1	0.79
Lead		28	86	715	2,201				
North Shore	348					12	4	0.49	0.16
East Lake	433					15	5	0.61	0.20
Lake at Kalaa	200					7	2	0.28	0.09
Nickel		667	1,408	5,999	12,663				
North Shore	10					0.01	0.01	0.002	0.001
East Lake	23					0.03	0.02	0.004	0.002
Lake at Kalaa	10					0.01	0.01	0.002	0.001
Zinc		449	950	496	1,048				
North Shore	235					0.52	0.25	0.47	0.22
East Lake	303					0.67	0.32	0.61	0.29
Lake at Kalaa	25					0.06	0.03	0.05	0.02
Mercury[a]		.15		2.4					
North Shore	108						9,000		45
East Lake	75						6,250		31
Lake at Kalaa	150						12,500		63

[a] Not hardness dependent

Nutrients and Enrichment

Of the two drain systems, the Omoum Drain carried higher concentrations of organic material than that of the Kalaa Drain, with average total suspended and volatile solids concentrations approximately two to three times greater than those found at the mouth of the Kalaa Drain. Concentrations of volatile solids in the Kalaa Drain were comparable to "weak" untreated wastewater, and those of total suspended solids were comparable to "strong" wastewater. Average BOD and COD concentrations were similar at the mouth of the Kalaa Drain and in the Omoum Drain, and were comparable to concentrations found in "weak to medium" untreated wastewater (Table 4-5).

Table 4-5
Water Quality of Lake Input Stations – 1983
(Average Concentration in mg/l)

Parameter	Station 5 Mouth of Kalaa Drain	Station 7 Omoum Drain	Typical Concentration of Untreated Wastewater[a]	
			Weak	Strong
BOD	173	177	110	400
COD	363	413	250	1,000
Total Suspended Solids	377	750	100	350
Volatile Suspended Solids	74	203	80	275
Ammonia-N	22.4	11.2	12	50
Nitrate-N	4.4	4.4	0	0
Phosphate-P	0.8	1.0	3	10

[a]Source: Metcalf & Eddy, 1991.

Generally, average concentrations of BOD in the Omoum and at the mouth of the Kalaa Drain systems were similar to those observed in the Northwest and Main Basins of Lake Maryout (Figure 4-4). However, average concentrations of COD, suspended solids, and volatile suspended solids were slightly higher in the Lake than in these drains, suggesting other sources of organic material. These sources could have been inputs from other drains, organic material in the water column from decomposing algae, or lake bottom sediments. The most likely cause of high suspended solids concentrations was shallow conditions in the Lake and wind induced turbulence, which resuspended bottom sediments.

On the average, nitrate and phosphate concentrations at the mouth of the Kalaa Drain system and those in the Omoum Drain were similar to each other and to concentrations found in the Lake. Average ammonia concentrations were higher at the mouth of the Kalaa system than those in the Omoum Drain, with concentrations in the Kalaa Drain system similar to those found in the Lake. With each nutrient, however, concentrations at a single location were highly variable over the 3-month sampling period.

Within the Kalaa Drain system, there was a general trend for the average concentrations of BOD, total suspended solids, and volatile solids to decrease as water in the drain flows downstream from Station 2 to Station 4 to Station 5, with average concentrations of total suspended solids and volatile solids being two to three times higher at Station 2, upstream of the Hydrodrome Drain, than at Station 5, at the mouth of the Kalaa Drain system (Table 4-6). These drops may have been associated with the uptake of organic material or settling of suspended solids. In contrast, the average COD concentrations increased at Station 4, when flows from the Hydrodrome Drain entered the Kalaa Drain system, then dropped by Station 5. Station 4 had COD concentrations comparable to "strong" untreated wastewater.

Table 4-6
Water Quality of Kalaa Drain System—1983
(Average Concentration in mg/l)

Parameter	Station 2 Upstream Kalaa	Station 4 Kalaa Pump Station	Typical Concentration of Untreated Wastewater[a]	
			Weak	Strong
BOD	210	237	110	400
COD	500	1,017	250	1,000
Total Suspended Solids	764	569	100	350
Volatile Suspended Solids	226	138	80	275
Ammonia-N	28.5	12.6	12	50
Nitrate-N	3.7	3.7	0	0
Phosphate-P	5.6	5.3	3	10

[a] Source: Metcalf & Eddy, 1991.

Phosphate and ammonia concentrations followed a similar trend with average phosphate concentrations dropping by a factor of seven from Station 2 to Station 5, and average ammonia concentrations dropping by a factor of approximately 10. Nitrate concentrations remained relatively constant. This trend suggests that nutrients are being consumed by biological activity in the drain, although ammonia and nitrate concentrations were variable from month to month at Stations 2, 4, and 5, and phosphate was highly variable at Station 2.

Metals

The average concentration of lead in the Omoum Drain was more than an order of magnitude greater than that at the mouth of the Kalaa Drain. These concentrations were comparable to those found in Lake Maryout, suggesting that the Omoum Drain is a dominant contributor of lead (Table 4-7).

Table 4-7
Metal Concentrations in Lake Input and Kalaa Drain System – 1983
(Average Concentration in ug/l)

Parameter	**Omoum Drain**	**Mouth of Kalaa Drain**	**Upstream Kalaa – Station 2**	**Kalaa Pump Station – Station 4**
Cadmium	30	160	5	2
Chromium	12	15	J320	20
Copper	480	865	380	650
Lead	800	15	620	580
Nickel	10	10	20	20
Zinc	385	293	520	440
Mercury	150	70	80	100

J = estimated

Concentrations of cadmium and copper were somewhat greater at the mouth of the Kalaa Drain than those in the Omoum Drain, with in-lake concentrations of cadmium being greater than those of the Omoum Drain and less than those at the mouth of the Kalaa Drain. Copper concentrations in the Lake were comparable to those found at the Omoum Drain and less than those found at the mouth of the Kalaa Drain system.

The average chromium concentrations were similar at the two lake input stations as well as being similar to those found at the north shore and east shore lake stations. Generally, lake input and lake shore stations had similar average concentrations of cadmium, nickel, mercury, and zinc.

Within the Kalaa Drain system, the Hydrodrome Drain appeared to have little effect on metals concentrations. Levels measured upstream and downstream of the Hydrodrome Drain were similar. Chromium was the one exception to this, with much higher concentrations being found upstream of the Hydrodrome Drain than those found downstream.

4.1.4 Bacteria

Bacterial analyses were conducted on samples from mid-lake, lake shore, and lake input stations. Despite variability between total coliform levels on each of the three sampling dates, these data indicated that the untreated wastewater discharged by the drains consistently exceeded the effluent discharge limit for unfresh waters (Egyptian Law No. 48) of 5,000 MPN/100 ml total coliform.

Total coliform concentrations in the Main Basin averaged 192,000 MPN/100 ml, or almost 40 times the effluent discharge limit (Table 4-8). Total coliform concentrations in the Northwest Basin averaged almost an order of magnitude lower than those in the Main Basin.

Table 4-8
Total Coliform Concentrations in Lake Maryout–1983

Station	Geometric Mean (MPN/100 ml)
Kalaa Drain System	
Upstream Kalaa-Station 2	813,000
Pump Station-Station 4	916,000
Average of Kalaa Stations	863,000
Inputs	
Mouth of Kalaa-Station 5	88,000
Omoum Drain-Station 19	50,000
Average of Inputs	66,000
Shore	
North Shore	861,000
East Shore	1,039,000
Kalaa	556,000
Mid-Lake and Outlet	
Main Basin	192,000
Northwest Basin	13,000
El Mex Outlet	96,000

Source: WWCG, 1983.

On the average, lake shore areas had total coliform concentrations the same order of magnitude or greater than mid-lake levels. Of the lake shore stations, the east lake stations had the highest average concentration (1,039,000 MPN/100 ml, followed by the north shore stations (861,000 MPN/100 ml) and the Kalaa mouth station (556,000 MPN/100 ml).

Of the lake input stations, total coliform levels were the same order of magnitude in the Omoum and Kalaa Drains (88,000 and 50,000 MPN/100 ml, respectively) and were an order of magnitude lower than levels in the Main Basin, suggesting that other inputs were contributing to total coliform concentrations in the Lake or that die-off of coliform was occurring within the drain system before the bacteria reach the Lake. This is supported by higher total coliform concentrations at the upstream Kalaa (Station 2) and Kalaa Pump Stations (Station 4) than at the mouth of the Kalaa Drain system (Station 5). Total coliform levels in the Omoum Drain reflect agricultural runoff which was discharged to the lake, and levels in the Kalaa Drain reflected flows of raw wastewater.

4.1.5 Summary of Conditions in 1983

The water quality and biological characteristics of a lake generally fall into one of three categories. The first category, a clean lake, has a healthy biological assemblage and an orderly, well-buffered oscillation of conditions based on seasonal, water balance, or internal (for example, nutrient recycling) processes.

A lake subject to significant stress (the second category) generally supports excessive, but out of balance biological conditions alternating with wide and abrupt abiotic (demise of biological community) conditions. The massive oscillations in such systems produce fish kills, growth of excessive algal populations, and then the demise and decay of the algal population. The fish kills and dying algal assemblages produce anoxia, odors, and a strong impression of a highly polluted system.

The third category is a lake that is generally abiotic (without flora and fauna) the entire year. In such cases, the pollution and other sources of stress are so severe that biological processes rarely get started. Consequently, the lake system always appears to be degraded, but there is no punctuation of obvious periods of degradation as seen in the second category of lake, where periods of die-off of flora and fauna are highly visible.

In 1983, Lake Maryout fell into the second category of lake. The lake possessed high concentrations of organic matter, comparable to those present in untreated wastewater, and nutrients were present at concentrations typical of highly eutrophic conditions. Generally, nutrients and enrichment parameters were lower at the El Mex outlet than those at mid-lake stations, indicating that chemical and biological processes in Lake Maryout were functioning and were consuming organic material. Concentrations of organic material were generally higher in the Northwest Basin, and nutrient concentrations were generally higher in the Main Basin. Dissolved oxygen concentrations in the Lake fluctuated widely, indicating periods of high plant productivity which generated oxygen, followed by periods of plant decay that consumed oxygen and led to anoxic conditions. In addition to monthly variations in dissolved oxygen concentrations, diurnal variations probably occurred. It is likely that dissolved oxygen concentrations were high in the daytime when photosynthesis was occurring and dropped at night, when lake respiration dominated. Some metals were present at acceptable levels (chromium, nickel, and zinc), but cadmium, copper, lead, and mercury were present at levels that stress lake biota.

Conditions at the lake shore were comparable or worse than those observed mid-lake. Where conditions were worse (for example, higher pollutant levels and lower dissolved oxygen) they could be attributed to the direct effect of lake inputs.

4.2 Water Quality Results of 1992/93 Study

As discussed in Section 3.2, survey level monitoring was conducted from March 1992 to February 1993 to characterize the general condition of Lake Maryout and to allow for an identification of temporal trends. For the most part, seasonal variability in the data did not occur and, where variability was present, it could not be attributed to seasonal changes, such as higher temperatures in the summer. Where a marked month-to-month change in concentration was observed, it often was not associated with season, suggesting that some other type of lake, sampling or laboratory phenomenon was causing the deviation. Within the Lake, some of the variability may be due to wind and resuspension of bottom sediments. However wind action would not account for some of the variability which occurred at lake and lake input stations.

Usually, a peak (or drop) in concentration occurred during a single month (for example, ammonia concentrations peaked at all stations in April 1993), with no evidence of elevated (or decreased) concentrations in the months immediately before or after the peak (or drop). Nitrate concentrations dropped approximately two orders of magnitude in April and June 1993, but concentrations present in May were comparable to those measured the rest of the year, reducing the likelihood that the low concentrations were seasonally related.

In the case of metals, the summary graphs in Appendix B suggest seasonal variations for categories of stations, but when the raw data were examined at individual stations, variations did not appear to be attributable to in-lake processes or seasonal trends, but rather tied to sampling and laboratory variability.

Metal levels in the sediments also were examined to assess temporal variations in metals content. Although somewhat higher concentrations of metals were observed from April to July, the variation appeared to be more a result of spatial and data variability than of a seasonal variation. For example, sampling locations were unmarked, resulting in sample collection at close but not identical locations from month to month. When higher concentrations were observed, often the higher concentration occurred on only one or two dates in this period; it occurred at different times for different parameters; and it was a relatively small increase in magnitude. These factors made it unlikely that the variability was due to seasonal factors.

In the following discussion, 1993 conditions are described and then compared to conditions in 1983. Differences in metals concentrations in the water column and sediments between 1983 and 1993 were identified as potential trends where the average concentration had varied by approximately a factor of four or more. Smaller differences are not discussed because metals concentrations in the water column and sediment were measured only once in the 1983 study, and for the reasons discussed in Sections 3.1 and 3.2, the Overview of 1983 and 1992/93 Study Methods, and in Section 5, Data Quality and Priority Pollutants.

4.2.1 Mid-Lake and Outlet Stations

During the 1992 to 1993 sampling period, water quality samples were collected and analyzed from two mid-lake stations in the Main Basin, one station in the Northwest Basin, and at the El Mex Pump Station. The stations in the Main Basin, Stations 21 and 22, were located in open water areas removed from the shoreline and the direct influence of any drains or discharges. Station 24 in the Northwest Basin was located approximately 300 meters north of Desert Road. Although the Northwest Basin does not receive any known drain discharges, its shoreline is developed and wastewater from the developed area enters the basin.

Nutrients and Enrichment

Water quality in Lake Maryout has deteriorated substantially since 1983. On the average, BOD and volatile solids concentrations in the Main and Northwest Basins increased by factors of two or more during the 10-year period. In the Main Basin, concentrations of COD and total suspended solids were approximately 30 to 60 perçent higher in 1993 concentrations then those recorded in 1983. In the Northwest Basin, average COD concentrations more than doubled (Figure 4-5). The mid-lake stations had average annual concentrations of enrichment parameters (BOD, COD, total suspended solids, and volatile solids) that exceeded the concentrations found in "strong" untreated wastewater (Table 4-9).

At the El Mex Pump Station, BOD concentrations have remained approximately the same during the 10 years and were approximately one-third to one-seventh of those measured in the Main and Northwest Basins. COD concentrations have dropped since 1983, and were approximately one-fourth to one-seventh of those measured in the Main and Northwest Basins. As in 1983, concentrations of BOD and COD were lower at the El Mex pump station than those at mid-lake stations, suggesting that the

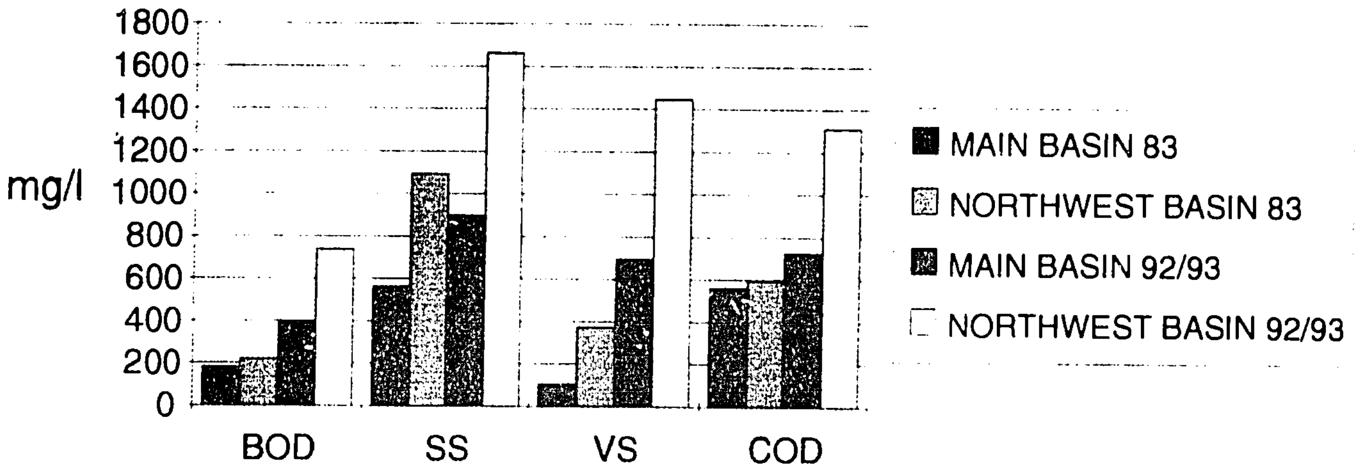

Figure 4-5
COMPARISON OF ENRICHMENT CHARACTERISTICS AT MID-LAKE STATIONS BETWEEN 1983 AND 1992/93

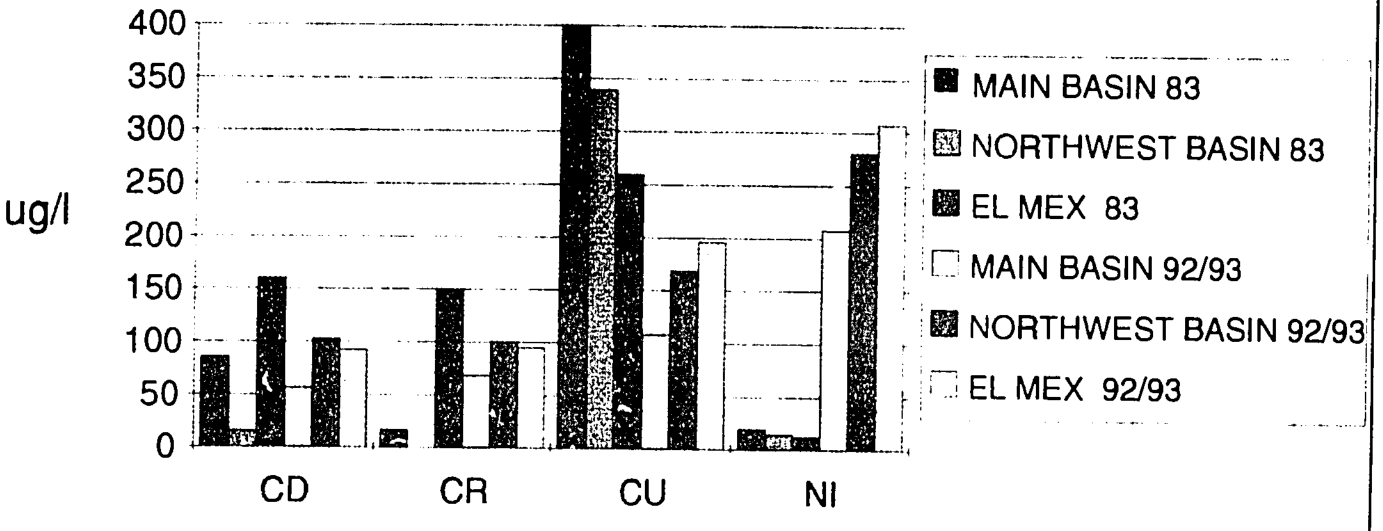

Figure 4-6
COMPARISON OF SELECTED METALS AT MID-LAKE AND OUTLET STATIONS BETWEEN 1983 AND 1992/93

Table 4-9
Water Quality of Mid-Lake and Outlet Stations—1992/93
(Average Concentration in mg/l)

Parameter	Station 21 Main Basin	Station 22 Main Basin	Northwest Basin	El Mex Outlet	Typical Composition of Untreated Wastewater[a]	
					Weak	Strong
BOD	336	454	738	111	110	400
COD	689	760	1,311	180	250	1,000
Total Suspended Solids	748	1,050	1,662	2,146	100	350
Volatile Suspended Solids	572	820	1,445	2,326	80	275
Ammonia-N	1.5	1.5	0.7	1.1	12	50
Nitrate-N	6.9	4.7	4.1	3.0	0	0
Phosphate-P	3.7	3.6	2.9	2.8	3	10

[a] Source: Metcalf & Eddy, 1991.

Lake continued to respire, to accumulate organic material in the sediments, or to take it up as biomass. However, as discussed in Chapter 3, there were some data reporting concerns with data from the El Mex Pump Station.

The average annual concentration of all enrichment parameters was higher in the Northwest Basin than that in the Main Basin. Industry present on the edge of the Northwest Basin is the likely source.

Within the Main Basin, concentrations of enrichment parameters were greater at Station 22 than those at Station 21, which may be due to the proximity of Station 22 to the Omoum Drain. As discussed below, the Omoum Drain had high concentrations of enrichment parameters relative to the Main Basin's mid-lake stations.

Eutrophic conditions in Lake Maryout also increased substantially since 1983 Average annual phosphate concentrations in 1993 (Table 4-9) were more than double those present in 1983. Phosphate concentrations in the Lake were comparable to those present in "weak" untreated wastewater. In addition, average dissolved oxygen concentrations dropped. Low oxygen and anoxic conditions persist much of the year in the Main Basin, while oxygen concentrations in the Northwest Basin fluctuated between acceptable and low levels. In the Main Basin, dissolved oxygen concentrations ranged from zero to 8 mg/l with anoxic conditions prevailing most of the year. The highest measured levels were present in the fall and winter. In the Northwest Basin, dissolved oxygen concentrations ranged from approximately 2 to 9 mg/l, with low oxygen conditions in approximately one-half of the samples.

In contrast to phosphorus, average annual concentrations of nitrate and ammonia in the water column have not shown a dramatic increase since 1983. Nitrate concentrations in the Main and Northwest Basins were similar, with concentrations in both basins comparable to 1983 levels.

Ammonia concentrations in the Main and Northwest Basins have dropped to 15 and 25 percent of their 1983 levels, respectively. Average annual ammonia concentrations in the Northwest Basin were lower than those measured in the Main Basin, and most of the time, were approximately 30 to 50 percent of those in the Main Basin. This drop in ammonia concentrations may have been due to a variety of factors, including the following: denitrification and diffusion into the atmosphere as nitrogen gas; sequestering nitrogen in the sediments; sorption of ammonia to particulate and colloidal particles under conditions that are alkaline with high concentrations of dissolved organic matter; and laboratory variability.

Metals

On the average, concentrations of all metals (cadmium, chromium, copper, lead, nickel, and zinc) were the same order of magnitude in the Main and Northwest

Basins and at the El Mex outlet. In the Main and Northwest Basins and El Mex outlet station, average annual chromium, nickel, and zinc concentrations were below the acute and chronic water quality criteria as indicated by ratios less than 1 (Table 4-10).

In the Main Basin, the average concentration of cadmium exceeded the USEPA's chronic and acute water quality criteria by a factor of 1 to 14. In the Northwest Basin, average cadmium concentrations exceeded the chronic and acute water quality criteria by a factor of 1 to 26. Average cadmium concentrations at the El Mex outlet exceeded the chronic and acute water quality criteria by a factor of 1 to 23.

Average copper concentrations at the lake and outlet stations exceeded the chronic water quality criteria by a factor of 1 to 4. The ratio of average copper concentrations to the acute water quality criteria ranged from 1 to 0.54 in the Main Basin, 2 to 0.83 in the Northwest Basin, and 2 to 0.97 at the El Mex outlet.

In the Main Basin, average lead concentrations were similar to those at the outlet. and they exceeded the chronic water quality criteria by a factor of 4 to 14. Average concentrations in the Northwest Basin exceeded the chronic water quality criteria by a factor of 8 to 23. The ratio of average lead concentrations to the acute water quality criteria ranged from 0.17 to 0.91.

Compared to 1983 (which was based on one sampling event), the average zinc and lead concentrations in the water column have shown little change.

Chromium and nickel, which were present at concentrations below the acute and chronic water quality criteria, have increased in the water column compared to 1983 concentrations (Figure 4-6). The average chromium concentrations increased by a factor of four in the Main Basin, and went from an undetectable level to an average concentration of 100.3 *u*g/l in the Northwest Basin. Average nickel concentrations increased by more than an order of magnitude in the Main and Northwest Basins and the El Mex outlet.

Other increases in average metal concentrations since 1983 included a seven-fold increase in cadmium in the Northwest Basin and a four-fold increase in copper concentrations in the Main Basin.

Sediments

Enriched lake sediments are typically comprised of between 5 and 6 g/100g volatile solids, with 10 g/100g being considered a high concentration. In the Main Basin, volatile solids or the organic content of fixed solids, ranged from 18 to 44 g/100 g, with an average of 29 g/100 g. In the Northwest Basin, volatile solids ranged from 12 to 31 g/100 g, with an average of 22 g/100 g. Thus, the average volatile solids

Table 4-10
Comparison of 1993 Concentrations of Metals at Lake and Outlet Stations to USEPA Water Quality Criteria (Average Concentration in µg/l)

Parameter	Avg.	USEPA Water Quality Criteria				Ratio of Average			
		Chronic		Acute		Chronic		Acute	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Cadmium		4	9	27	73				
Main Basin	56.4					14	6	2	1
NW Basin	103.0					26	11	4	1
El Mex Outlet	92.6					23	10	3	1
Chromium		836	1,723	7,015	14,458				
Main Basin	68.9					0.08	0.04	0.01	0.005
NW Basin	100.3					0.12	0.06	0.01	0.01
El Mex Outlet	95.1					0.11	0.06	0.01	0.01
Copper		51	108	108	203				
Main Basin	108.8					2	1	1	0.54
NW Basin	168.8					3	2	2	0.83
El Mex Outlet	196.0					4	2	2	0.97
Lead		28	86	715	2,201				
Main Basin	392.6					14	5	0.55	0.18
NW Basin	651.4					23	8	0.91	0.30
El Mex Outlet	373.2					13	4	0.52	0.17
Nickel		667	1,408	5,999	12,663				
Main Basin	207.6					0.31	0.15	0.03	0.02
NW Basin	281.0					0.42	0.20	0.05	0.02
El Mex Outlet	307.8					0.46	0.22	0.05	0.02
Zinc		449	950	496	1,048				
Main Basin	244.7					0.54	0.26	0.49	0.23
NW Basin	413.2					0.92	0.43	0.83	0.39
El Mex Outlet	157.8					0.35	0.17	0.32	0.15

concentration in the Main Basin was three times greater than this "high" of 10 g/100 g, and in the Northwest Basin was more than twice as high (Table 4-11).

The pH of lake bottom sediment remained close to neutral throughout the year, ranging from a minimum of 6.1 to a maximum of 8.0.

Concentrations of heavy metals detected in the Lake Maryout sediments were compared to benchmark values established by observing effects on biota (Long and Morgan, 1990). These values are based on an effects range associated with a specific heavy metal and include a Low Effects Range (ER-L), a concentration at the low end of the range in which effects had been observed, and a Median Effects Range (ER-M), a concentration approximately midway in the range of reported values associated with biological effects. Although the marine organisms discussed by Long and Morgan and presented in the following section are not known to be present in Lake Maryout, they are the best available data.

Cadmium. The concentration of cadmium ranged from 1.3 to 75 μg/g in the sediments of the Main Basin and from 4 to 140 μg/g in the sediments of the Northwest Basin. The average concentrations in the sediments were 30 μg/g and 45 μg/g in the Main Basin and Northwest Basin, respectively. Concentrations in both basins were much higher than the ER-L of 5 ug/g and the ER-M of 9 μg/g (Table 4-11). Similarly, concentrations of cadmium in the water column were above the chronic and acute water quality criteria.

Sediments with concentrations of cadmium similar to those collected from Lake Maryout have been associated with high mortality in a variety of species, such as the amphiphods *Rhepoxynius abronius* and *Grandidierella japonica*, the fish *Pimepheles affinis*, the freshwater flea *Daphnia magna*, and the clam *Macoma balthica* (Long and Morgan, 1990). In addition, Eisler (1985) summarized available toxicological data for cadmium and concluded that concentrations in sediments exceeding 10 μg/g are associated with high mortality, reduced growth, inhibited reproduction, and other adverse effects. Therefore, cadmium concentrations in the sediment of Lake Maryout were expected to contribute to mortality and altered life-cycles in a variety of species.

Chromium. The average concentration of chromium in the sediments of the Main Basins was 27 μg/g, with concentrations ranging from 5 to 43 μg/g. In the Northwest Basin the average concentration of chromium was 16 μg/g, with concentrations ranging from 2 to 40 μg/g (Table 4-11). In both basins, average chromium concentrations were less than the ER-L of 80 μg/g and the ER-M of 145 μg/g, although concentrations of individual samples approached the ER-L in both basins. Overall, these concentrations were not expected to affect the biota. In Massachusetts Bay, for example, sediments with a mean chromium content of 27 μg/g had high species richness (Long and Morgan, 1990). These results corresponded to chromium concentrations in the water column, which were below the chronic and acute water quality criteria.

Table 4-11
Characteristics of Sediment in Mid-Lake Samples 1992/93

Parameter	Units	Main Basin		Northwest Basin		Effects Range *ug/g*[a]	
		Average	Range	Average	Range	Low	Median
Fixed Solids	g/100g	71	56-82	78	69-89	ND	ND
Volatile Solids	g/100g	29	18-44	22	12-31	ND	ND
Cadmium	*ug/g*	30	1-75	45	4-140	5	9
Chromium	*ug/g*	27	5-43	16	2-40	80	145
Copper	*ug/g*	688	109-7,510	204	4-812	70	390
Lead	*ug/g*	845	110-3,200	292	50-679	35	110
Nickel	*ug/g*	249	106-600	168	85-400	30	50
Zinc	*ug/g*	1,989	430-8,200	657	130-1,648	120	270

ND-Not Determined
[a] Source: Long and Morgan, 1980.

Copper. In the Main Basin, copper concentrations in the sediment ranged from 109 µg/g to 7,510 µg/g with an average concentration of 688 µg/g (Table 4-11). These concentrations were significantly higher than the ER-L and ER-M levels of 70 and 390 µg/g. In the Northwest Basin, copper concentrations were lower. They ranged from 4 to 812 µg/g and averaged 204 µg/g, a value within the range of the ER-L and ER-M. Similarly, concentrations of copper in the water column were above chronic and acute water quality criteria.

High copper concentrations have been associated with adverse effects of several species. These include the following: depressed diversity of benthic taxa in sediments with 200 µg/g copper; a decreased burrowing rate for the littleneck clam *Protothaca staminea* (a sublethal behavior) in sediment concentrations exceeding 17.8 µg/g; and toxicity of *R. abronius* at concentrations of 810 µg/g and oyster larva, *C. gigas*, at concentrations of 390 µg/g. Based on these results, copper levels in the Main and Northwest Basins in Lake Maryout may have caused toxicity in various species and a depressed diversity of benthic fauna.

Lead. Average lead concentrations were higher in the sediments of the Main Basin (845 µg/g) than those of the Northwest Basin (292 µg/g) of Lake Maryout. Concentrations in both basins were greater than the ER-L and ER-M of 35 and 110 µg/g, respectively (Table 4-11). Lead concentrations ranged from 110 to 3,200 µg/g in the Main Basin and from 50 to 679 µg/g in the Northwest Basin.

High concentrations of lead are associated with low species diversity, low species richness, and toxicity. Depressed benthic diversity in areas with high concentrations of lead in sediment was observed in Norwegian fjords (35 µg/g) and Los Angeles Harbor (41.3 µg/g). Low species richness because of lead concentrations was observed in Massachusetts Bay where the mean concentration was 42 µg/g. In addition, significant increases in burrowing time of *M. balthica* were seen with lead concentrations of 35 µg/g. Other toxicity tests were performed on *R. abronius* (threshold of 660 µg/g) and oyster larvae *C. gigas* (660 µg/g). These data indicate lead concentrations found in the sediment of Lake Maryout will likely contribute to low species diversity, low species richness, and toxicity to a variety of species.

Nickel. In Lake Maryout, the average nickel concentrations of 249 µg/g in the Main Basin and 168 µg/g in the Northwest Basin, were significantly higher than the ER-L of 30 µg/g and the ER-M of 50 µg/g (Table 4-11). Nickel concentrations ranged from 106 to 600 µg/g in the Main Basin, and from 85 to 400 µg/g in the Northwest Basin.

Lower species richness in both Massachusetts Bay (21 µg/g) and Puget Sound (28 µg/g), and high oyster larvae toxicity in Commencement Bay (30 µg/g) are examples of the effects of elevated lead concentrations. In addition, toxicity of *R. abronius* (>120 µg/g) and *C. gigas* (9 µg/g) are other examples of effects thresholds. The high concentrations of nickel in Lake Maryout sediments are expected to contribute to low species richness and toxic effects on a variety of species. Despite elevated levels of nickel in the sediments, concentrations in the water column were below the chronic and acute water quality criteria.

Zinc. The average zinc concentration was 1,989 µg/g in the sediment of the Main Basin and 657 µg/g in the sediment of the Northwest Basin, significantly higher than ER-L of 120 µg/g and the ER-M of 270 µg/g (Table 4-11). Zinc concentrations in the Main Basin ranged from 430 to 8,200 µg/g. Available data on zinc concentrations in sediments supported observations of low species richness among Massachusetts Bay benthos (117 µg/g), significant mortality among *D. magna* exposed to Trinity River sediments (121 µg/g), high mortality among *H. azteca* exposed to Waukegan Harbor sediments (127 µg/g), and apparent effects thresholds in San Francisco Bay bivalve larvae (130 µg/g). Therefore, zinc concentrations in Lake Maryout would also contribute to low species richness and mortality in a variety of species. As with nickel, despite elevated concentrations of zinc in the sediments, concentrations in the water column were below the chronic and acute water quality criteria.

In summary, the average sediment concentrations of copper, lead, and zinc were higher at the mid-lake stations in the Main Basin than those of the Northwest Basin; cadmium, chromium, and nickel concentrations were comparable in each basin. With the exception of chromium, all of the heavy metals analyzed in Lake Maryout sediments exhibited concentrations that were at or higher than the benchmark values, indicating that they would contribute to low species diversity, low species richness, and toxicity to a variety of species. Average sediment concentrations of cadmium, copper, lead, nickel and zinc were approximately one order of magnitude higher than the standard effects levels as determined by Long and Morgan (1990).

4.2.2 Lake Shore Stations

Six lake shore stations were sampled during the 1992 to 1993 sampling period. Stations 11, 12, 13, and 23 were located along the north shore of the Main Basin. Of these, Stations 11, 12, and 13 were located near discharge drains. Station 16, the Lake at Kalaa Station, was located in the Lake at the mouth of the Kalaa Drain. Station 10 was located at the east end of Lake Maryout, between the discharge of the Industries Drain and the Kalaa Drain.

Nutrients and Enrichment

For the most part, lake shore stations have concentrations of enrichment parameters similar to those found in the Lake (Figure 4-7). The exceptions to this trend were Station 11 (East Central Lake), which had the highest average concentrations of COD, total suspended solids and volatile solids; and north shore Stations 11 (East Central Lake) and 13 (West Lake), which had average BOD concentrations higher than those of mid-lake stations (Table 4-12). COD concentrations at Station 13 were also elevated over mid-lake levels. Station 11 was located near the discharge drain at Station 7 (East Central Drain), and Station 13 was located near the discharge drain

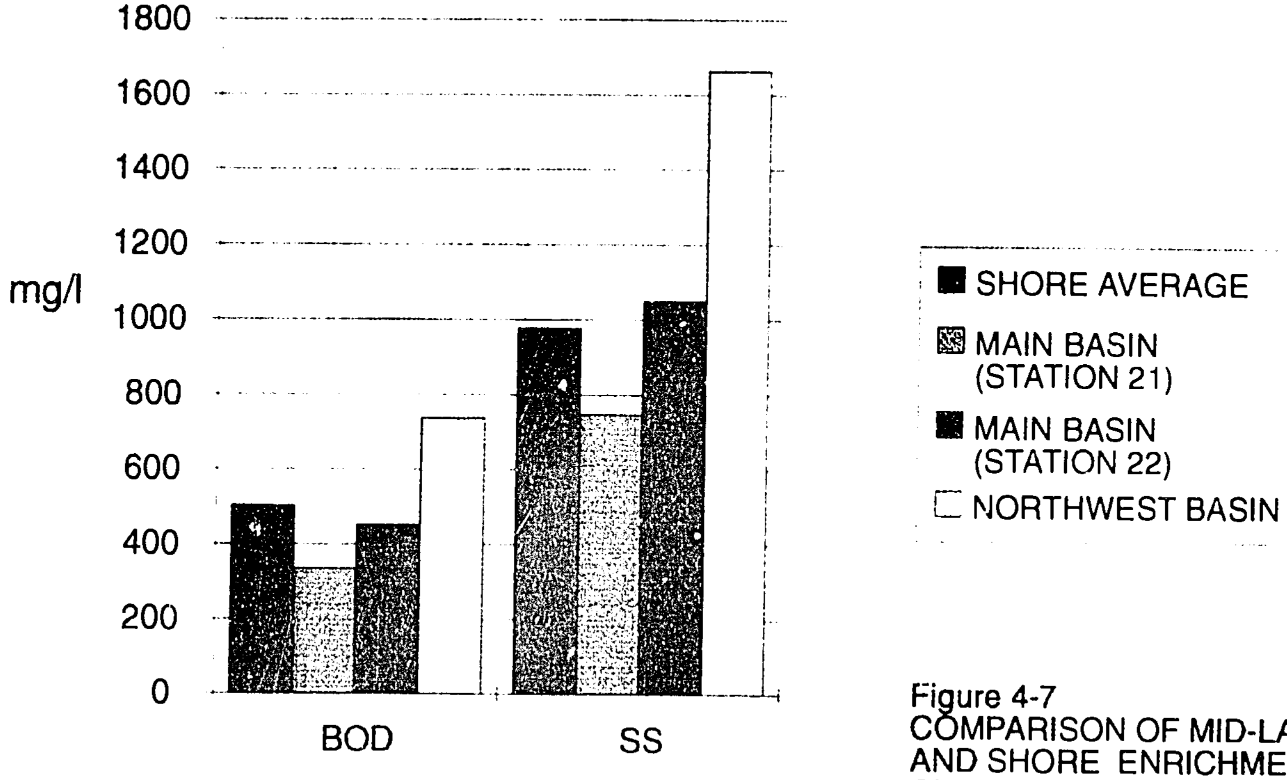

Figure 4-7
COMPARISON OF MID-LAKE AND SHORE ENRICHMENT CHARACTERISTICS - 1992/93

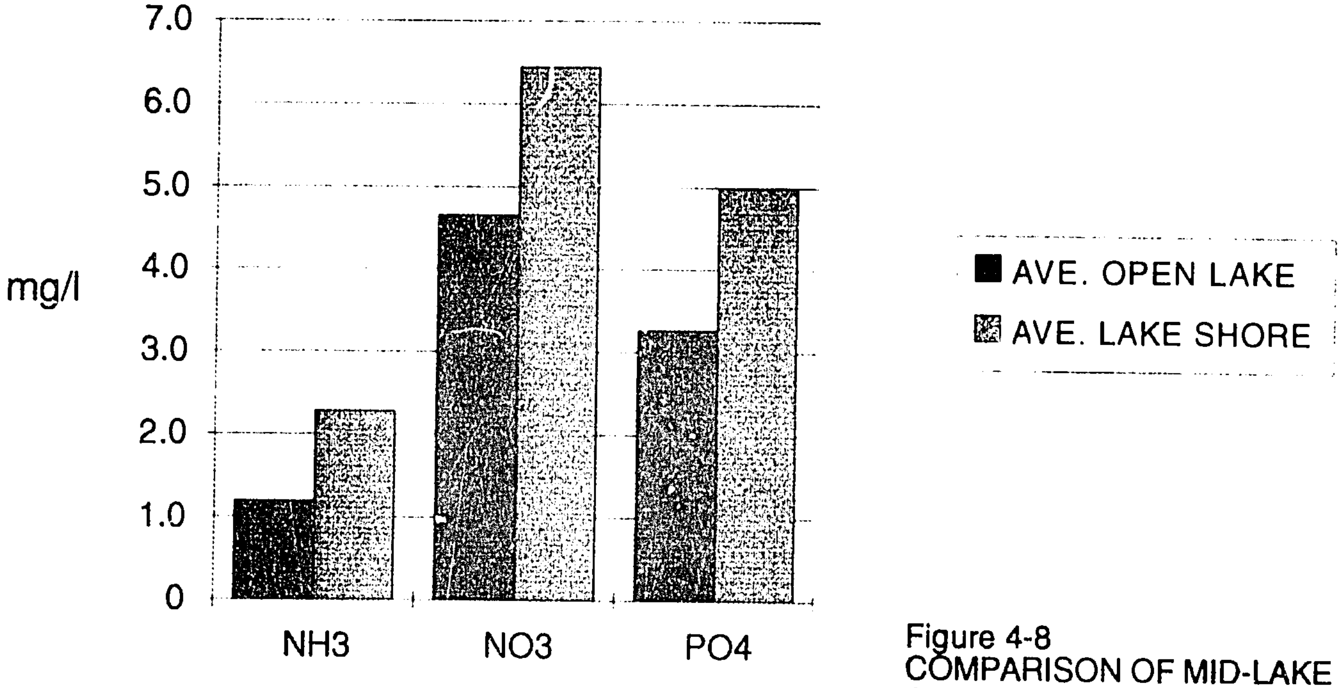

Figure 4-8
COMPARISON OF MID-LAKE AND SHORE NUTRIENT CHARACTERISTICS - 1992/93

Table 4-12
Water Quality of Lake Shore Stations–1992/93
(Average Annual Concentration in mg/l)

Parameter	Station 11 East Central Lake	Station 12 West Central Lake	Station 13 West Lake	Station 23 North Shore	Station 10 East Lake	Station 16 Lake at Kalaa	Typical Concentration of Untreated Wastewater[a]	
							Weak	Strong
BOD	803	465	550	461	347	396	110	400
COD	1,367	796	951	740	601	709	250	1,000
Total Suspended Solids	1,427	858	1,041	891	936	709	100	350
Volatile Suspended Solids	1,201	634	863	772	589	616	80	275
Ammonia-N	2.6	2.4	2.6	1.4	1.9	2.9	12	50
Nitrate-N	13.8	4.7	4.7	6.4	3.3	6.0	0	0
Phosphate-P	3.6	7.2	6.2	3.9	4.0	5.1	3	10

[a] Source: Metcalf & Eddy, 1991.

near Station 9 (West Drain), suggesting that these discharge drains were influencing water quality at Stations 11 and 13.

Similar trends were observed with nitrate and phosphate concentrations. Levels at lake shore and mid-lake stations were comparable (Figure 4-8), except for the lake shore Station 11, which had higher concentrations of nitrate than those at mid-lake locations, and Stations 11 and 12, which had higher phosphate concentrations. These data also suggest that discharge drains are influencing water quality in near shore areas. Average ammonia levels were higher at all lake shore stations compared to those at mid-lake (and higher at lake shore stations compared to those at lake inputs, as discussed later), suggesting that shoreline areas reflected the discharge of ammonia associated with lake inputs.

Concentrations of enrichment parameters at the near shore lake stations followed trends similar to those at the mid-lake stations from 1983 to 1993 (Figure 4-9). Average BOD concentrations increased to those at concentrations approximately equal to or greater than those measured in "strong" untreated wastewater, with the greatest increases observed at stations along the north shore of the Lake. The greatest average COD concentrations also were observed at north shore stations, with average annual concentrations comparable to those present in "medium to strong" untreated wastewater. Average total suspended solids and volatile solids concentrations were two to four times those found in "strong" untreated wastewater, with 1993 concentrations higher at all stations than those found in 1983.

From 1983 to 1993, nutrient levels at near shore stations followed trends similar to those observed at mid-lake stations. Average ammonia concentrations dropped by approximately 15 to 25 percent and average phosphate concentrations approximately doubled. Trends in nitrate concentrations varied with location. Average nitrate concentrations increased from 1983 to 1993 at the Lake at Kalaa Station, and at the north shore stations, primarily because of the elevated concentrations measured at Station 11, East Central Lake.

Dissolved oxygen concentrations paralleled trends observed with enrichment and nutrient parameters, with higher levels of enrichment and nutrient parameters being reflected in lower dissolved oxygen concentrations. Concentrations were lower at lake shore than at mid-lake stations and significantly lower than those found in 1983. Stations 11 and 16 were anoxic throughout the year. Stations 10 and 12 had dissolved oxygen concentrations ranging from zero to approximately 2 mg/l, with anoxic conditions prevailing most of the year. The highest concentrations were measured at Station 23 where they ranged from zero to 6 mg/l, with acceptable conditions (≥ 5 mg/l) occurring only during 3 months. As discussed in Section 4.1, which follows, diurnal variations were observed in dissolved oxygen concentrations.

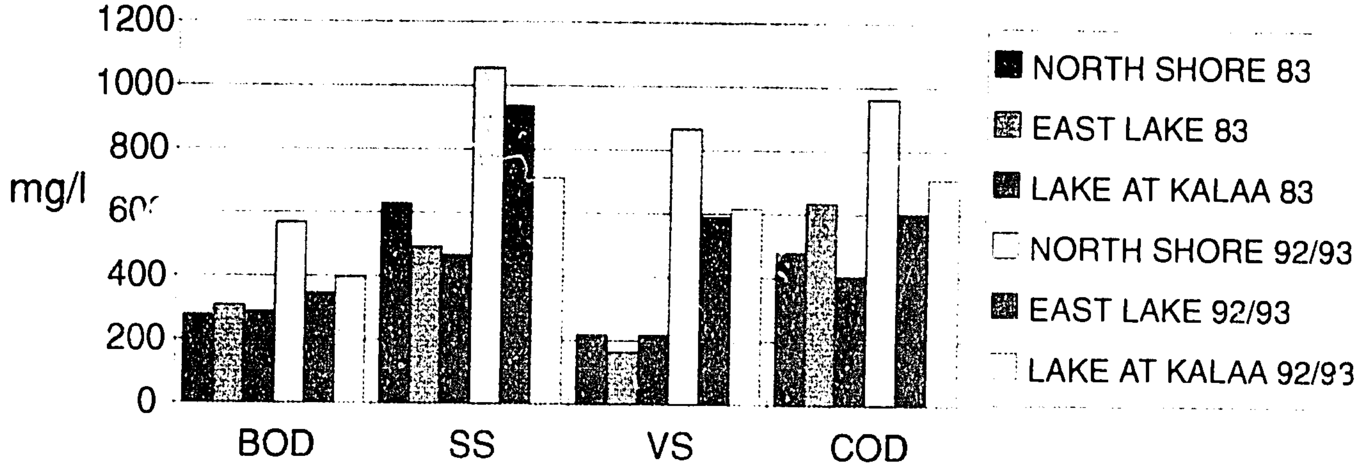

Figure 4-9
COMPARISON OF ENRICHMENT CHARACTERISTICS AT LAKE SHORE STATIONS BETWEEN 1983 AND 1992/93

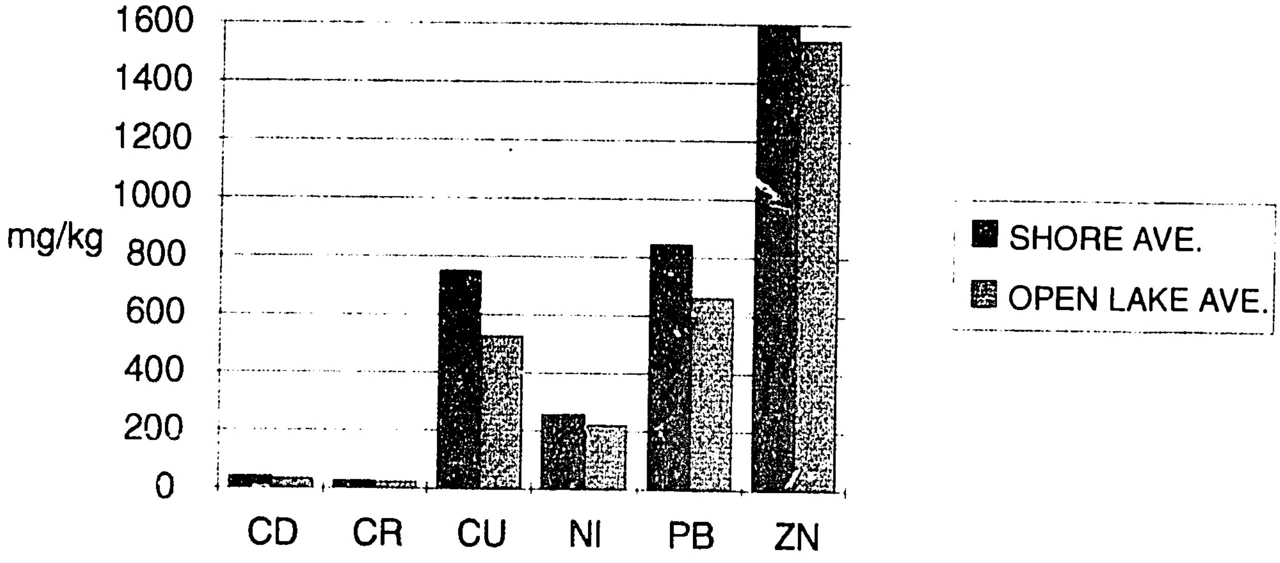

Figure 4-10
COMPARISON OF MID-LAKE AND SHORE SEDIMENT CHARACTERISTICS - 1992/93

Metals

With the exception of average annual copper and zinc concentrations, which were marginally higher at the Lake at Kalaa Station (Station 16) than at other stations, concentrations of metals at all near shore stations were comparable.

Overall, conditions at the near shore stations were similar to those observed mid-lake with average concentrations of metals at near shore and mid-lake stations being the same order of magnitude. As with mid-lake stations, average annual chromium, nickel, and zinc concentrations were below the acute and chronic water quality criteria (Table 4-13).

The average concentration of cadmium at the North Shore, East Lake, and Lake at Kalaa Stations exceeded the USEPA's chronic and acute water quality criteria by a factor of 1 to 14 (Table 4-12). Average concentrations of copper at the North Shore and East Lake Stations exceeded chronic, and acute water quality criteria by a factor of 1 to 4, and at the Lake at Kalaa station, exceeded the criteria by a factor of 2 to 8 (Table 4-13). Average lead concentrations at the North Shore, East Lake, and Lake at Kalaa Stations exceeded the chronic water quality criteria by a factor of 1 to 16, and were less than the acute water quality criteria (Table 4-13).

Compared to 1983, the average cadmium, copper, and lead concentrations at near shore stations have shown little change. Average chromium concentrations at the east lake stations increased by a factor of 4. Average nickel concentrations at near shore stations showed an increase from those found in 1983. The average concentrations at the North Shore, East Lake, and Lake at Kalaa Stations increased by factors of 20, 6, and 17, respectively.

Average zinc concentrations remained approximately the same at the North Shore and East Lake stations, but increased at the Lake at Kalaa station by more than an order of magnitude.

Sediments

Volatile solids, or the organic content of fixed solids, ranged from 17 to 65 g/100 g, with an average of 37 g/100 g. Thus, the average volatile solids concentration in near shore areas of the Main Basin was four times greater than the "high" of 10 g/100g, and was greater than those at mid-lake stations. Of the near shore stations, average volatile solids levels were highest at the East Central Lake Station (Station 11) at 59 g/100 g and lowest at the North Shore Station (Station 23) at 27 g/100 g.

The pH of near shore sediments remained close to neutral throughout the year, ranging from a minimum of 6.0 to a maximum of 8.0.

Table 4-13
Comparison of 1993 Concentrations of Metals at Lake Shore Stations to USEPA Water Quality Criteria (Average Concentration in µg/l)

Parameter	Avg.	USEPA Water Quality Criteria				Ratio of Average			
		Chronic		Acute		Chronic		Acute	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Cadmium		4	9	27	73				
North Shore	57.0					14	6	2	0.78
East Lake	49.3					12	5	2	0.68
Lake at Kalaa	39.4					10	4	1	0.54
Chromium		836	1,723	7,015	14,458				
North Shore	55.5					0.07	0.03	0.01	0.004
East Lake	47.6					0.06	0.03	0.01	0.003
Lake at Kalaa	40.3					0.05	0.02	0.01	0.003
Copper		51	108	108	203				
North Shore	151.2					3	1	1	0.74
East Lake	190.4					4	2	2	1
Lake at Kalaa	387.1					8	4	4	2
Lead		28	86	715	2,201				
North Shore	396.9					14	5	0.56	0.18
East Lake	436.5					16	5	0.61	0.20
Lake at Kalaa	404.5					14	5	0.57	0.18
Nickel		667	1,408	5,999	12,663				
North Shore	203.2					0.30	0.14	0.03	0.016
East Lake	152.5					0.23	0.11	0.03	0.012
Lake at Kalaa	168.4					0.25	0.12	0.03	0.013
Zinc		449	950	496	1,048				
North Shore	307.5					0.68	0.32	0.62	0.29
East Lake	191.2					0.43	0.20	0.39	0.18
Lake at Kalaa	460.3					1	0.48	0.93	0.44

Cadmium. The concentration of cadmium ranged from 6 to 140 μg/g in the lake shore sediments of the Main Basin. The average concentration of cadmium was similar at each of the lake shore stations, with averages ranging from 37 to 49 μg/g, and an average at all shore stations of 41 μg/g, slightly higher than the averages at mid-lake stations (Table 4-14 and Figure 4-10). Average concentrations at each lake shore station were much higher than the ER-L of 5 μg/g and the ER-M of 9 μg/g. Therefore, cadmium concentrations in near shore sediments are expected to contribute to mortality and altered life-cycles of a variety of species.

Chromium. The concentration of chromium in the lake shore sediments ranged from 4 to 95 μg/g. The average concentration of chromium was similar at each of the lake shore stations, with averages ranging from 22 to 33 μg/g, and an average at all lake shore stations of 28 μg/l (Table 4-14). Average concentrations of chromium were higher at most of the lake shore stations than those at the mid-lake stations (Figure 4-10). Average chromium concentrations were less than the ER-L of 80 μg/g and the ER-M of 145 μg/g, although concentrations of individual samples were greater than the ER-L.

At locations where chromium concentrations approached or exceeded 80 μg/g, there may have been detrimental effects. In Massachusetts Bay, for example, sediments with low species richness had a mean chromium content of 81 μg/g, as compared to a mean of 27 μg/g in samples that had high species richness (Long and Morgan, 1990). Similarly, significant toxic effects were observed in *D. magna* when *Daphnia* were exposed to sediments with mean chromium levels of 72.6 μg/g and in *G. japonica* when they were exposed to samples with mean chromium levels of 81.4 μg/g. Therefore, species in areas of Lake Maryout with sediment chromium concentrations greater than 80 μg/g can be expected to exhibit toxic effects.

Copper. The concentration of copper in the lake shore sediments ranged from 98 μg/g to 7,110 μg/g (Table 4-14). The average concentration of copper ranged from lows of 430 μg/g at Station 23 (North Shore Station) and 544 μg/g at Station 16 (Lake at Kalaa) to a high of 1,105 μg/g at Station 10 (East Lake Station). Compared to copper concentrations measured at mid-lake stations, higher concentrations are present at Station 10 (East Lake) and lower concentrations are present at Stations 16 and 23 (Lake at Kalaa and North Shore, respectively), resulting in a higher average concentration at shore than at mid-lake stations (Figure 4-10). On the average, however, lead concentrations were higher at near shore than those at mid-lake stations. Average concentrations at all lake shore stations were higher than the ER-L and ER-M levels of 70 and 390 μg/g, and were likely to cause toxicity in various species and lower diversity of benthic organisms.

Lead. The concentration of lead in the lake shore sediments ranged from 60 to 7,000 μg/g, with average concentrations of lead at lake shore stations ranging from a low of 469 μg/g at Station 16 (Lake at Kalaa) to a high of 1,398 μg/g at Station 23 (North Shore) (Table 4-14). With the exception of Station 23, lead concentrations at near shore stations were comparable to those at mid-lake stations in the Main Basin.

Table 4-14
Characteristics of Sediment at Lake Shore Stations—1992/93

Parameter	Units	Main Basin Lake Shore		Effects Range (*ug*/g)[a]	
		Average	Range	Low	Median
Fixed Solids	g/100g	63	35-83	ND	ND
Volatile Solids	g/100g	37	17-65	ND	ND
Cadmium	*ug*/g	41	6-140	5	9
Chromium	*ug*/g	28	4-95	80	145
Copper	*ug*/g	748	98-7,110	70	390
Lead	*ug*/g	843	60-7,000	35	110
Nickel	*ug*/g	259	1-830	30	50
Zinc	*ug*/g	1,593	130-13,200	120	270

ND-Not Determined

[a] Source: Long and Morgan, 1990.

On the average, however, lead concentrations were higher at the near shore than those at mid-lake stations. Average concentrations at all near shore stations were significantly higher than the ER-L and ER-M of 35 and 110 μg/g, respectively. These data indicated lead concentrations found in the sediment along the shore of Lake Maryout would likely contribute to low species diversity, low species richness, and toxicity to a variety of species.

Nickel. Nickel concentrations in lake shore sediments ranged from 1 to 830 μg/g. Average nickel concentrations at lake shore stations ranged from 163 to 328 μg/g, with concentrations comparable to those present at mid-lake stations (Table 4-14 and Figure 4-10). Average nickel concentrations were significantly higher than the ER-L of 30 μg/g and the ER-M of 50 μg/g. Consequently, the sediments were expected to contribute to low species richness and toxic effects on a variety of species.

Zinc. The zinc concentration in the lake shore sediments ranged from 130 to 13,200 μg/g, with average concentrations of zinc at lake shore stations ranging from a low of 1,071 μg/g at Station 16 (Lake at Kalaa) to a high of 2,125 μg/g at Station 13 (West Lake) (Table 4-13). Zinc concentrations at lake shore stations were comparable to those present at mid-lake stations, and were significantly higher than ER-L of 120 μg/g and the ER-M of 270 μg/g (Figure 4-10). These zinc concentrations would also contribute to low species richness and mortality in a variety of species.

In summary, lake shore sediments had metals concentrations that were comparable to or higher than those measured at mid-lake stations (Figure 4-10). As with the mid-lake sediments, all of the heavy metals analyzed in lake shore sediments exhibited concentrations that were close to or higher than the benchmark values. Average sediment concentrations of cadmium, copper, lead, nickel, and zinc in lake shore sediments of Lake Maryout were at least one order of magnitude higher than the low effects range and, in some cases, were an order of magnitude higher than the median effects levels as determined by Long and Morgan (1990). In addition, the range of chromium concentrations contained levels that were higher than the standard effects levels for this metal. These levels indicate that metals in the sediments contributed to low species diversity, low species richness, and toxicity to a variety of species.

4.2.3 Lake Input Stations

The following stations are lake input stations:

- Station 6–Industries Drain
- Station 7–East Central Drain
- Station 8–West Central Drain
- Station 9–West Drain
- Station 5–Mouth of the Kalaa Drain
- Station 19–El Omoum Drain

Stations 6, 7, 8, and 9 were drains directly entering the north shore of Lake Maryout, with Station 6 receiving flows from industrial sources. Stations 5 and 19 were located at the mouths of the Kalaa and El Omoum Drains, respectively, and are major inputs to the Lake. Station 5 was on the Kalaa Drain at Desert Road, immediately prior to the drain's discharge to the Lake.

The Kalaa Drain system, which enters the lake at Station 5, consists of three stations: Station 2, which was located upstream of the Hydrodrome Drain; Station 4, which was located downstream of the Hydrodrome Drain near the Kalaa Drain Pump Station; and Station 5. Station 1, which flowed to the Kalaa Drain System, was located on the Smouha Drain. The Smouha Drain carries the sewage that will ultimately be diverted to the East Sewage Treatment Plant (STP). Station 5 carried flows from the Smouha, Kalaa and Hydrodrome Drains.

Nutrients and Enrichment

Generally, the average concentration of enrichment parameters ranged from a high at the Industries Drain, followed by the Omoum Drain and then the Mouth of the Kalaa Drain, to a low at the West Drain (Figure 4-11). Although flow associated with the Industries Drain (Station 6) was only approximately 0.5 percent of the total flows entering the lake, this drain carrie the highest average annual concentrations of all enrichment parameters (BOD, COD, total suspended solids, and volatile solids) (Table 4-15). Average annual concentrations of enrichment parameters were approximately two to three times those measured in the Main Basin (Figure 4-12).

The next highest concentrations were measured in the Omoum Drain (Table 4-15). Although average annual concentrations in the Omoum Drain were approximately one-half those measured in the Industries Drain, the Omoum Drain still had average annual BOD and COD concentrations comparable to "strong" untreated wastewater, and total suspended solids and volatile solids concentrations approximately four times those found in "strong" untreated wastewater. The Omoum Drain carries approximately 90 percent of the flows to the lake; therefore, it contributes a substantial load of BOD, COD, total suspended solids, and volatile solids to the lake. Average annual concentrations of enrichment parameters were higher in the Omoum Drain than in the Main Basin, and lower than in the Northwest Basin (Figure 4-12). This suggests that developed land around the Northwest Basin was a major contributor of enrichment parameters.

The Kalaa Drain, which carries approximately 8 percent of the flow to Lake Maryout, had the third highest concentrations of enrichment parameters. BOD and COD concentrations were comparable to "medium to strong" untreated wastewater, and total suspended solids and volatile solids concentrations were almost twice as strong as those found in "strong" untreated wastewater. Concentrations of enrichment parameters measured at the mouth of the Kalaa Drain were comparable to or lower than those at mid-lake stations.

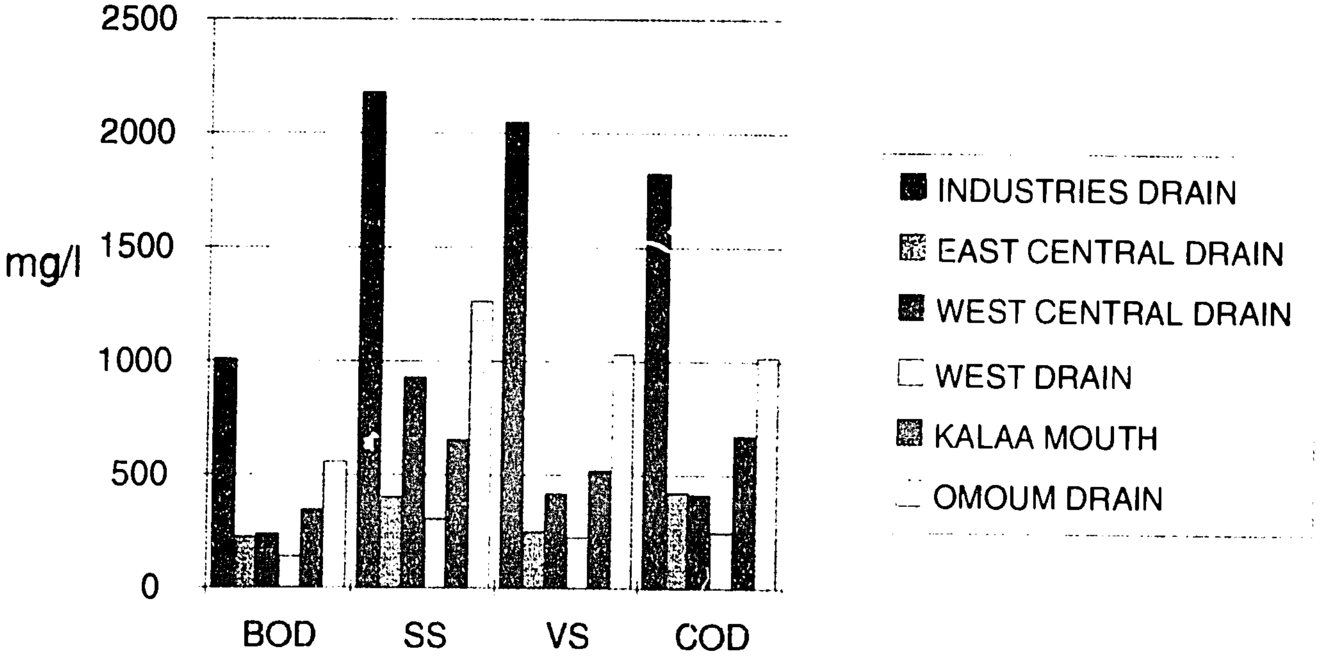

Figure 4-11
LAKE INPUT ENRICHMENT
CHARACTERISTICS -1992/93

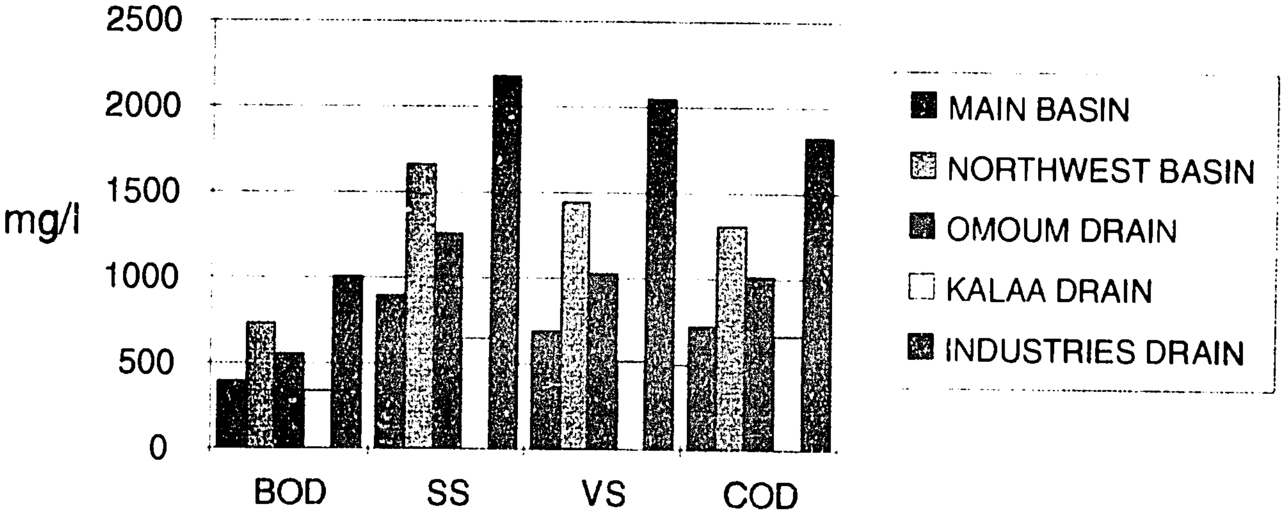

Figure 4-12
COMPARISON OF ENRICHMENT
CHARACTERISTICS OF MAJOR LAKE INPUTS
TO MID-LAKE CONDITIONS IN 1992/93

Table 4-15
Water Quality of Lake Input Stations—1992/93
(Average Annual Concentration in mg/l)

Parameter	Station 6 Industries Drain	Station 7 East Central Drain	Station 8 West Central Drain	Station 9 West Drain	Station 5 Kalaa Mouth	Station 19 Omoum Drain	Typical Concentration of Untreated Wastewater[a]	
							Weak	Strong
BOD	1,009	225	236	139	344	557	110	400
COD	1,825	422	415	249	670	1,017	250	1,000
Total Suspended Solids	2,178	402	927	306	653	1,262	100	350
Volatile Suspended Solids	2,047	250	418	224	519	1,030	80	275
Ammonia-N	2.7	1.9	2.0	2.3	1.1	0.8	12	50
Nitrate-N	9.4	5.2	5.1	4.7	3.5	3.23	0	0
Phosphate-P	2.9	6.0	9.2	8.5	3.9	4.1	3	10

[a] Source: Metcalf & Eddy, 1991.

Within the Kalaa Drain system, the lowest concentrations of enrichment parameters are found in the Smouha Drain (Station 1) (Table 4-16 and Figure 4-13). Station 1 represents flows that will eventually be diverted to the East Treatment Plant. Average annual BOD and COD concentrations were comparable to "weak" untreated wastewater, and total suspended solids and volatile solids concentrations were comparable to "medium to strong" wastewater (Table 4-16). The highest concentrations of enrichment parameters were observed upstream of the Hydrodrome Drain (Station 2), which drains an agricultural area. The Kalaa Pump Station (Station 4), which reflected the aggregate quality of the Smouha, Hydrodrome, and Kalaa Drains, had concentrations of enrichment parameters higher than those at Station 1 and slightly lower than those at Station 2.

During most months of the 1992/93 sampling period, nutrient concentrations (ammonia, nitrate, and phosphate) at lake input stations were higher than concentrations observed at in-lake and lake outlet stations, although not to the extent observed with enrichment parameters. Average annual nutrient concentrations at the mouth of the Kalaa Drain (Station 5) and in the Omoum Drain (Station 19), which have the greatest flows, were similar to or lower than those found at mid-lake stations.

The greatest nitrate levels were observed at the Industries Drain, Station 6, and the highest phosphate concentrations were observed at Stations 8 and 9 (the West Central and West Drains) (Figure 4-14). These elevated concentrations may account for the higher concentrations observed at stations in the Main Basin relative to the Northwest Basin.

Within the Kalaa Drain system, the average annual concentrations of nutrients are generally low, and were less than those found in "strong" municipal wastewater. Average annual ammonia and nitrate concentrations were similar at all stations. However, on a monthly basis, ammonia concentrations were usually higher in the Smouha Drain (Station 1) than those at the upstream Kalaa Station (2). Inputs from the Smouha and Hydrodrome Drains raised ammonia and nitrate concentrations at Station 4. These concentrations dropped somewhat by the time Station 5 was reached. Average annual phosphate concentrations followed similar trends and were higher at Station 4.

Dissolved oxygen concentrations in the lake inputs were lower than those at lake shore and mid-lake stations, with most lake inputs being anoxic most or all of the year. The few times that low levels of dissolved oxygen were present occurred in the winter or early spring. The highest concentrations were measured in the Omoum Drain (Station 19), where dissolved oxygen concentrations ranged from zero to 4 mg/l, never reaching the U.S. criteria for warm waters designated for fish and wildlife habitat.

The increased levels of enrichment parameters observed in the lake from 1983 to 1993 corresponded to increased concentrations observed in lake inputs (Figure 4-15).

Table 4-16
Water Quality of Kalaa Drain System–1992/93
(Average Concentration in mg/l)

Parameter	Station 1 Smouha Drain	Station 2 Upstream Kalaa	Station 4 Kalaa Pump Station	Typical Concentration of Untreated Wastewater[a]	
				Weak	Strong
BOD	129	404	313	110	400
COD	202	642	604	250	1,000
Total Suspended Solids	300	946	641	100	350
Volatile Suspended Solids	169	695	591	80	275
Ammonia-N	1.7	1.1	1.5	12	50
Nitrate-N	3.3	3.0	3.4	0	0
Phosphate-P	3.1	3.0	4.5	3	10

[a] Source: Metcalf & Eddy, 1991.

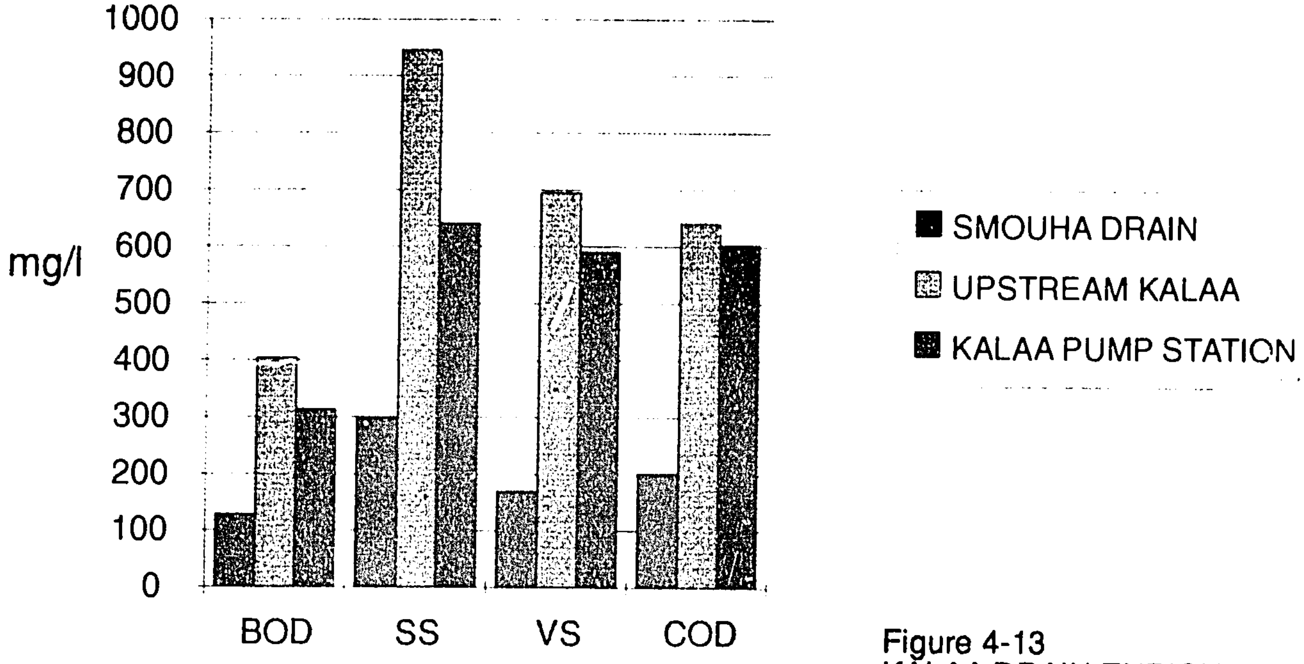

Figure 4-13
KALAA DRAIN ENRICHMENT
CHARACTERISTICS - 1992/93

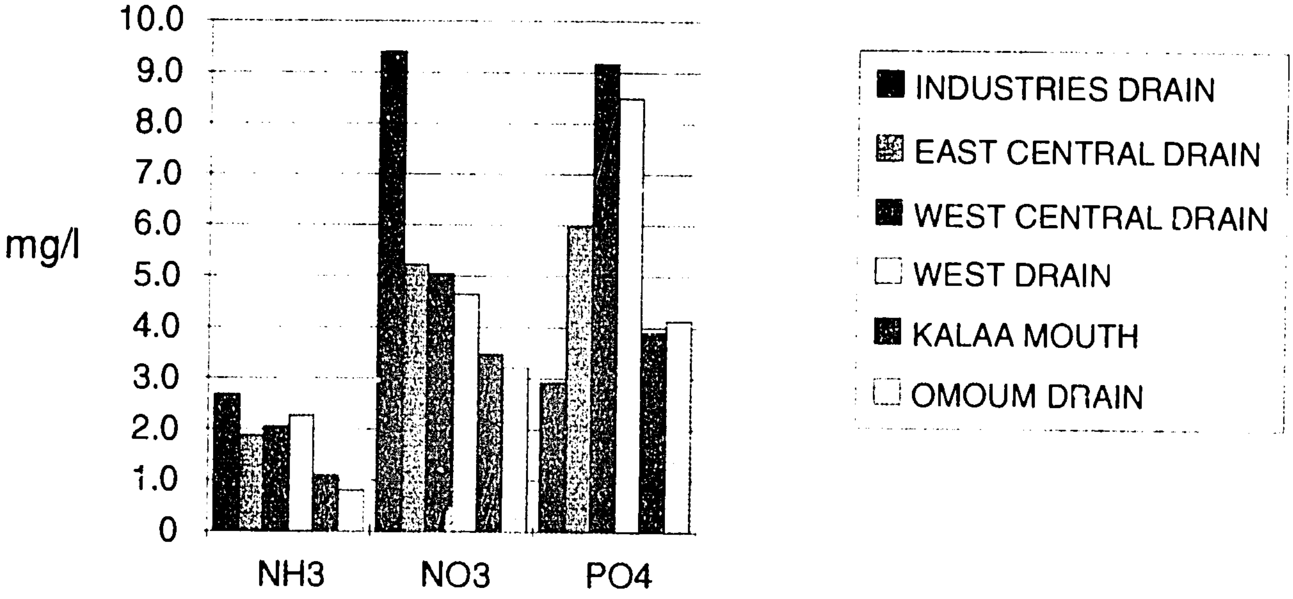

Figure 4-14
LAKE INPUT NUTRIENT
CHARACTERISTICS - 1992/93

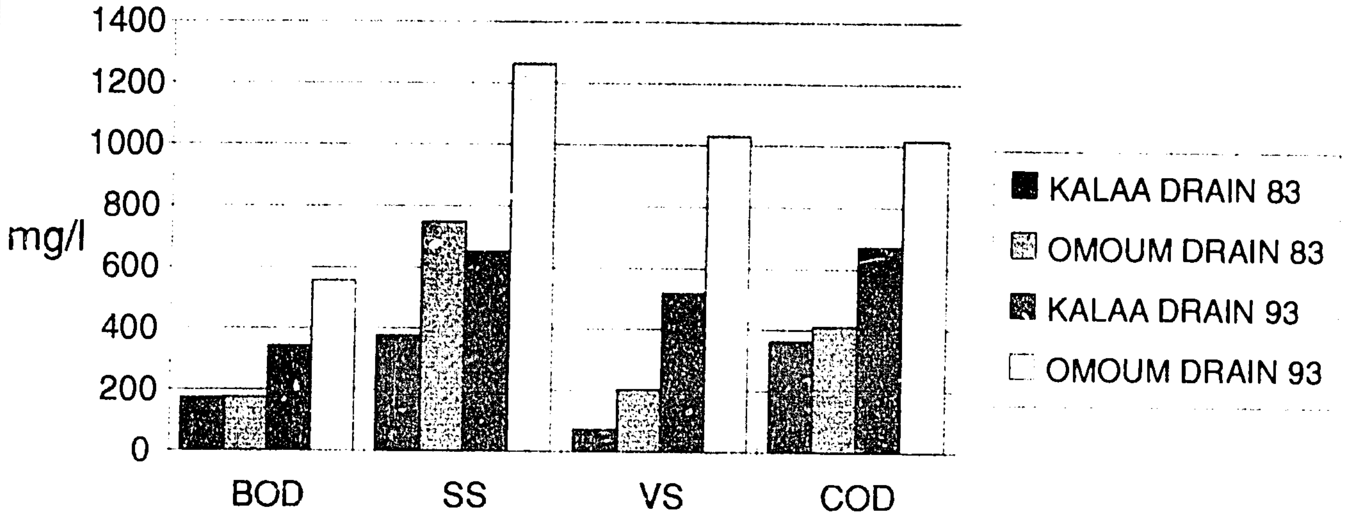

Figure 4-15
COMPARISON OF ENRICHMENT CHARACTERISTICS OF MAJOR LAKE INPUTS BETWEEN 1983 AND 1992/93

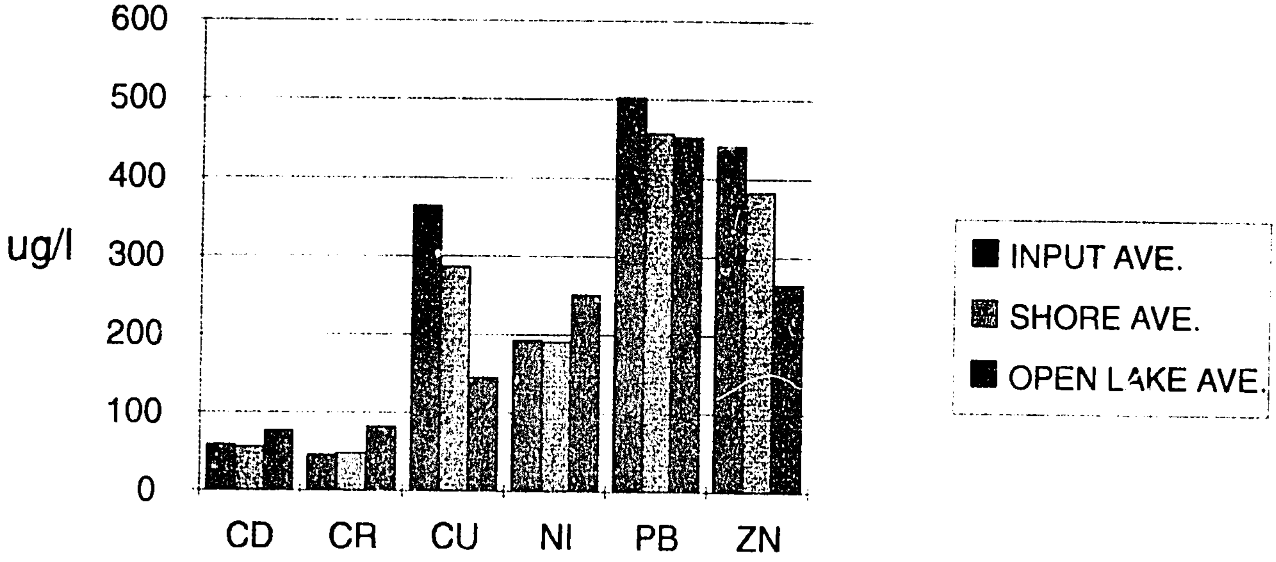

Figure 4-16
COMPARISONS OF METAL CONCENTRATIONS AT LAKE AND INPUT STATIONS - 1992/93

Average concentrations of BOD and COD in the Omoum Drain increased by factors of approximately 3 and 2.5, respectively, during the 10-year period, and total suspended solids and volatile solids concentrations increased by factors of approximately 2 and 5, respectively. Concentrations of BOD, COD, and total suspended solids at the mouth of the Kalaa Drain increased approximately two-fold and volatile solids concentrations increased by a factor of approximately 7.

Within the Kalaa Drain system (Stations 2 and 4), the increase in enrichment concentrations during the 10-year period was less dramatic. BOD concentrations increased by factors ranging from 1.3 to 2; COD concentrations remained the same or dropped; total suspended solids concentrations remained the same or showed a small increase; and volatile solids concentrations increased by factors of 3 to 4.

From 1983 to 1993, nutrient concentrations at lake input stations followed trends similar to those observed at the near shore and mid-lake stations. The increase in both nutrient and enrichment concentrations can be attributed, in part, to greater population densities, to increased industrial activity, and to increased development in the city and outlying areas.

During this period, phosphorus inputs increased, and ammonia inputs dropped dramatically. As discussed earlier, the drop in ammonia concentrations may have been due to high concentrations of dissolved organic matter, resulting in ammonia strongly sorbing to particulate and colloidal particles.

Average ammonia concentrations at the mouth of the Kalaa Drain (Station 5), the upstream Kalaa Station (2), the Kalaa Pump Station (4), and the Omoum Drain (Station 19) dropped by an order of magnitude or more from 1983 levels. The magnitude of the drop can be attributed to the extreme variability in ammonia concentrations at Stations 2, 4, 5, and 19 in 1983 (concentrations were an order of magnitude or more higher at each station on one sampling date).

Average annual nitrate concentrations at Stations 2, 4, 5, and 19 remained approximately the same, although in 1993 higher nitrate concentrations were observed more frequently in individual samples taken at Station 2 than those taken in 1983.

From 1983 to 1992/93, average phosphate concentrations increased three-fold at Station 5 and increased four-fold at Station 19. Average phosphate concentrations dropped from 1983 to 1993 at Stations 2 and 4, although this trend was due to one sample in 1983 with very high phosphate concentrations that raised the average concentration. In 1993, higher phosphate concentrations were observed more frequently at these stations than in 1983.

Given the magnitude of change in ammonia concentrations at Stations 2, 4, 5, and 19, and in phosphate concentrations at Stations 5 and 19, it is likely that similar trends (decrease in ammonia and increase nitrate concentrations) have occurred at other input stations.

Metals

Overall, the average concentrations of cadmium, chromium, nickel, lead, and zinc measured at lake input and Kalaa Drain stations, lake shore, and lake stations were similar (Figure 4-16). However, concentrations of copper differ between stations. The average concentration of copper at lake input stations was approximately double that at lake shore and mid-lake stations. Differences were also observed between lake input stations. Copper concentrations at the mouth of the Kalaa Drain Station (Station 5) and the near shore Lake at Kalaa Station (Station 16) were approximately two to seven times higher than those at other stations (Table 4-17). However, because of the variability of copper concentrations at stations in the Kalaa Drain system on different dates, the source of the elevated copper concentrations (Smouha, Hydrodrome, or Kalaa Drains) was not clear. Of the lake input stations, the Omoum Drain had the lowest average concentration of copper.

In addition to copper, cadmium and lead were at concentrations above chronic and acute water quality criteria in Lake Maryout. Although average cadmium concentrations were similar at all lake input stations, the high concentrations were observed on individual dates at the Industries Drain (Station 6) and the Omoum Drain (Station 19), suggesting that pulses of cadmium from these drains contributed to elevated cadmium concentrations.

Lead inputs also appeared to be intermittent. Although average lead concentrations were similar at all stations, elevated concentrations were measured on individual dates at the Industries, East Central, and West Central Drains (Stations 6, 7, and 8). This suggests that episodic lead inputs from these stations may have been responsible for in-lake concentrations above the water quality criteria.

Although comparison to 1983 conditions was limited by a single metal sample in 1983, increases in concentrations of several metals by more than an order of magnitude were observed at lake input stations. Nickel concentrations at the mouth of the Kalaa Drain and the Omoum Drain (Stations 5 and 19) and lead concentrations at the mouth of the Kalaa Drain (Station 5) increased by more than an order of magnitude. This increase in concentrations at lake input stations may be responsible for the increase in nickel concentrations measured at mid-lake and near shore stations. Despite the increase in lead inputs at Station 5, average lead concentrations at mid-lake and near shore stations have remained approximately the same.

Smaller changes were also observed between 1983 and 1993, including an increase in chromium concentrations in the Omoum Drain by a factor of approximately 5, and an decrease in copper concentrations in the Omoum Drain, which dropped by a factor of 5. Increased chromium concentrations were also observed in the Lake during this period. Copper concentrations increased in the Main Basin and remained approximately the same at near shore stations during this period.

Table 4-17
Metals Concentrations at Lake Input Stations–1992/93
(Average Annual Concentration in *u*g/l)

Parameter	Station 6 Industries Drain	Station 7 East Central Drain	Station 8 West Central Drain	Station 9 West Drain	Station 5 Kalaa Mouth	Station 19 Omoum Drain
Cadmium	89	36	59	48	50	72
Chromium	65	33	60	25	38	59
Copper	380	398	330	278	700	95
Nickel	248	129	244	126	185	228
Lead	616	560	541	411	471	420
Zinc	297	257	583	618	563	329

4.3 Bacteria

Although, as described in Section 3, there were several limitations on use of coliform data because of equipment availability and other unavoidable factors, the data do reveal significant trends. These trends are discussed below for the various lake areas. Little consistent seasonal trends were identifiable, thus yearly averages are used in the discussion. Also, the fecal coliform trends generally followed the total coliform trends (most measurements positive for total coliform were also positive of fecal coliforms). and, although both fecal and total are presented in Appendix C and summarized in Appendix B, the discussion in this section focuses on the total coliform measurements.

The coliform measurements in the Kalaa Drain system reflected expected results. The upstream station had a yearly geometric mean of 1 x 10^9 per 100 ml and the Smouha Drain had a concentration approximately four times higher. This resulted in a concentration of total coliform bacteria in the Kalaa Drain as it entered the Lake of between 4 and 5 x 10^9 per 100 ml.

The other discharges to the Lake reflected a similar pattern. The shore discharges (Stations 11, 12, 13, 23, 10, and 16) had an average of 5 up to almost 8 x 10^9 per 100 ml. The highest of these were the West Central (Station 8) and West (Station 9) Drains. The north shore discharges were generally higher than those of the east shore. The Omoum Drain (Station 19), which is primarily an agricultural drainage, had a significantly lower concentration (7 x 10^3 per 100 ml).

The lake shore stations showed extreme spacial and temporal variability but generally ranged from 10^5 per 100 ml to 10^8 per 100 ml. In contrast, the open lake and outlet (Stations 21, 22, 24, and 20) had lower concentrations, with yearly averages ranging from 10^2 per 100 ml to 10^4 per 100 ml.

Although the individual measurements may be affected by data quality limitations, a discernable trend seems apparent (Figure 4-17). The sanitary discharges to the Lake were the major sources of bacteria, with concentrations generally at 10^9 per 100 ml. The agriculture drains had concentrations generally 4 to 6 orders of magnitude lower. The shore stations, which were most heavily influenced by the sanitary discharges, had the highest lake concentrations. The open lake stations reflected die-off and dilution with the agricultural drains and had concentrations almost 4 orders of magnitude lower. However, even the relatively low concentrations in the open lake, and even the agricultural drains, represented a significant public health risk from even secondary contact.

As described in Section 3, duplicate sets of bacteria samples were taken in June 1993. One set was analyzed at the University of Alexandria High Institute for Public Health using the procedures used during the 12 continuous months of monitoring. The other set was analyzed by a WWCG laboratory specialist at the High Institute using supplemental equipment. The results of the two methods are presented in

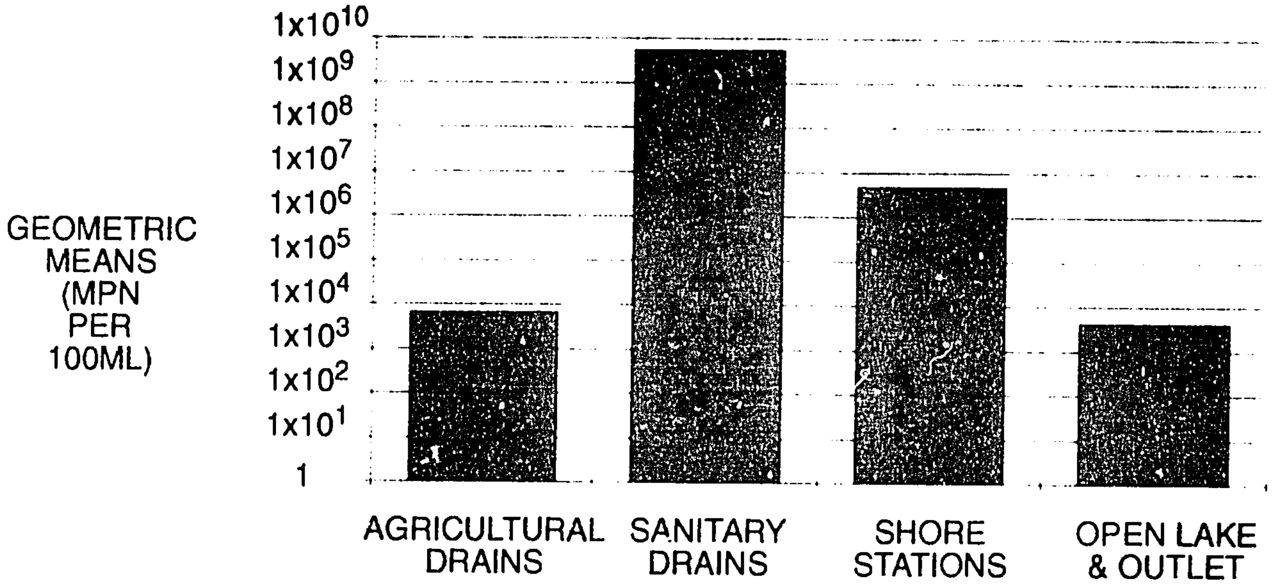

Figure 4-17
TOTAL COLIFORM
CONCENTRATIONS - 1992/93

Table 4-18. In general, the June 1993 results follow the trends observed during the 12 consecutive months of monitoring. The sanitary drains had concentrations of 10^8 per 100 ml to 10^9 per 100 ml, and the agricultural drains were several orders of magnitude lower. The shore stations had lower concentrations than those of the sanitary drains but considerably higher than those of the central lake.

The comparison of duplicate samples showed large variations. The High Institute data were generally 2 or more orders of magnitude lower. However, the split sample analyzed by the WWCG laboratory specialist (Station A) showed an order of magnitude variation. The variation was pronounced because of the large dilutions which had to be made and also the extreme variability of the lake water, particularly the solids in the water column. Even with the limitations in the data and the variability between duplicate samples, the trends were clear, and there was no question concerning the presence of a significant public health risk.

4.4 Biological Resources

4.4.1 Algal Populations

Algae were sampled from March through June and from October through December 1992 in Lake Maryout. Algae were analyzed for their abundance and were identified to the genus level. Changes in the abundance and diversity of genera are described below.

Algal Abundance

The total number of algae per sampling date was reported. The total number of algae identified ranged from 200 to 2,800,000 organisms/liter (o/l). It is difficult to judge the algal density in the Lake on a biomass basis because algal counts included single-celled, colonial, and chain forming organisms and did not specify the abundances of each genus or species.

Analysis of the data at each sampling site revealed changes in algal abundance during different months. In March, Station 8 (West Central Drain) showed the highest algal abundance, 2,664,000 o/l (Figure 4-18). During this month, Stations 10, the East Lake Station (1,034,000 o/l), and 11, East Central Lake Station (756,000 o/l) also showed high algal counts.

Algal counts were much lower until July. In April, the highest algal counts were at Stations 4, Kalaa Pump Station (806,000 o/l), and 13, West Lake Station (975,000 o/l) (Figure 4-19). In May, the highest counts were at Stations 21, Central Lake (700,000 o/l), and 23, North Shore (1,092,000 o/l), (Figure 4-20). In June, only Station 10, the East Lake Station (56,000 o/l), had relatively high algal counts (Figure 4-21). In July the number of algae increased. At mid-lake Stations 22 and 21 (Main Basin) algal

Table 4-18
Summary of Lake and Input Station Bacteria
June 1993

Station No.	Description	Coliform (MPN per 100 ML)			
		U Alex Analysis		Duplicate Analysis	
		Total	Fecal	Total	Fecal
1	Smouha Drain	1.7 x 10^{9}	1.7 x 10^{9}	1.6 x 10^{9}	1.6 x 10^{9}
2	Upstream Kalaa	8.3 x 10^{6}	3.7 x 10^{6}	1.6 x 10^{9}	1.6 x 10^{9}
4	Kalaa Pump Station	1.1 x 10^{8}	6.8 x 10^{7}	1.6 x 10^{9}	1.6 x 10^{9}
6	Industries Drain	5.4 x 10^{9}	2.4 x 10^{9}	1.6 x 10^{9}	1.6 x 10^{9}
8	West Central Drain	9.2 x 10^{9}	3.5 x 10^{9}	1.6 x 10^{9}	1.6 x 10^{9}
5	Kalaa Mouth	2.2 x 10^{7}	9.3 x 10^{6}	1.6 x 10^{9}	1.6 x 10^{9}
19	Omoum Drain	1.6 x 10^{5}	5.4 x 10^{4}	4.0 x 10^{6}	4.0 x 10^{6}
C	West STP	2.4 x 10^{10}	2.4 x 10^{10}	1.6 x 10^{9}	1.6 x 10^{9}
	Geomean of Lake Inputs	3.4 x 10^{8}	1.6 x 10^{8}	4.8 x 10^{8}	4.8 x 10^{8}
11	East Central Lake	6.8 x 10^{5}	1.8 x 10^{5}	1.6 x 10^{9}	1.6 x 10^{9}
12	West Central Lake	1.3 x 10^{2}	4.0 x 10^{1}	1.2 x 10^{7}	1.2 x 10^{7}
13	West Lake	2.4 x 10^{7}	2.4 x 10^{7}	1.6 x 10^{9}	1.6 x 10^{9}
23	North Shore	6.8 x 10^{2}	2.0 x 10^{2}	2.0 x 10^{6}	2.0 x 10^{6}
10	East Lake	7.0 x 10^{5}	1.7 x 10^{5}	3.5 x 10^{8}	3.5 x 10^{8}
16	Lake at Kalaa	1.3 x 10^{8}	1.3 x 10^{8}	1.6 x 10^{9}	1.6 x 10^{9}
A	East Central	1.6 x 10^{5}	3.5 x 10^{4}	5.4 x 10^{9}	5.4 x 10^{9}
A Duplicate				3.0 x 10^{8}	3.0 x 10^{8}
	Geomean of Shore Area	2.2 x 10^{5}	8.3 x 10^{4}	2.9 x 10^{8}	2.9 x 10^{8}
Lake 21	Central Lake	2.8 x 10^{4}	1.1 x 10^{3}	2.0 x 10^{6}	2.0 x 10^{6}
22	Central Lake	2.6 x 10^{3}	2.0 x 10^{2}	1.7 x 10^{8}	1.7 x 10^{8}
NW Basin 24	Northwest Basin	4.0 x 10^{1}	4.0 x 10^{1}	3.0 x 10^{8}	3.0 x 10^{8}
Outlet 20	El Mex Pump Station	2.4 x 10^{4}	2.5 x 10^{3}	9.2 x 10^{8}	9.2 x 10^{8}
B	Southwest Basin	2.3 x 10^{3}	1.3 x 10^{3}	2.0 x 10^{6}	2.0 x 10^{6}
	Geomean of Open Lake	2.8 x 10^{3}	4.9 x 10^{2}	4.5 x 10^{7}	4.5 x 10^{7}

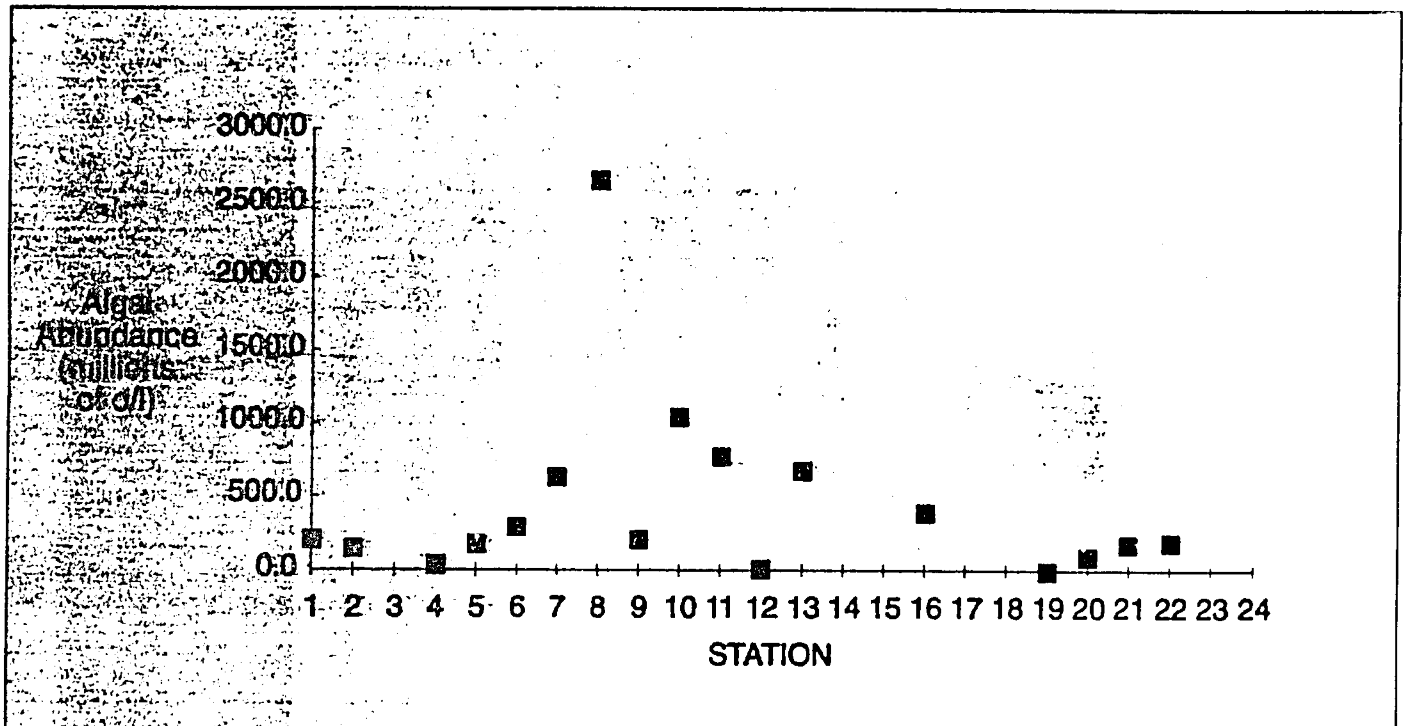

Figure 4-18
ALGAL COUNTS IN
LAKE MARYOUT - MARCH 1992

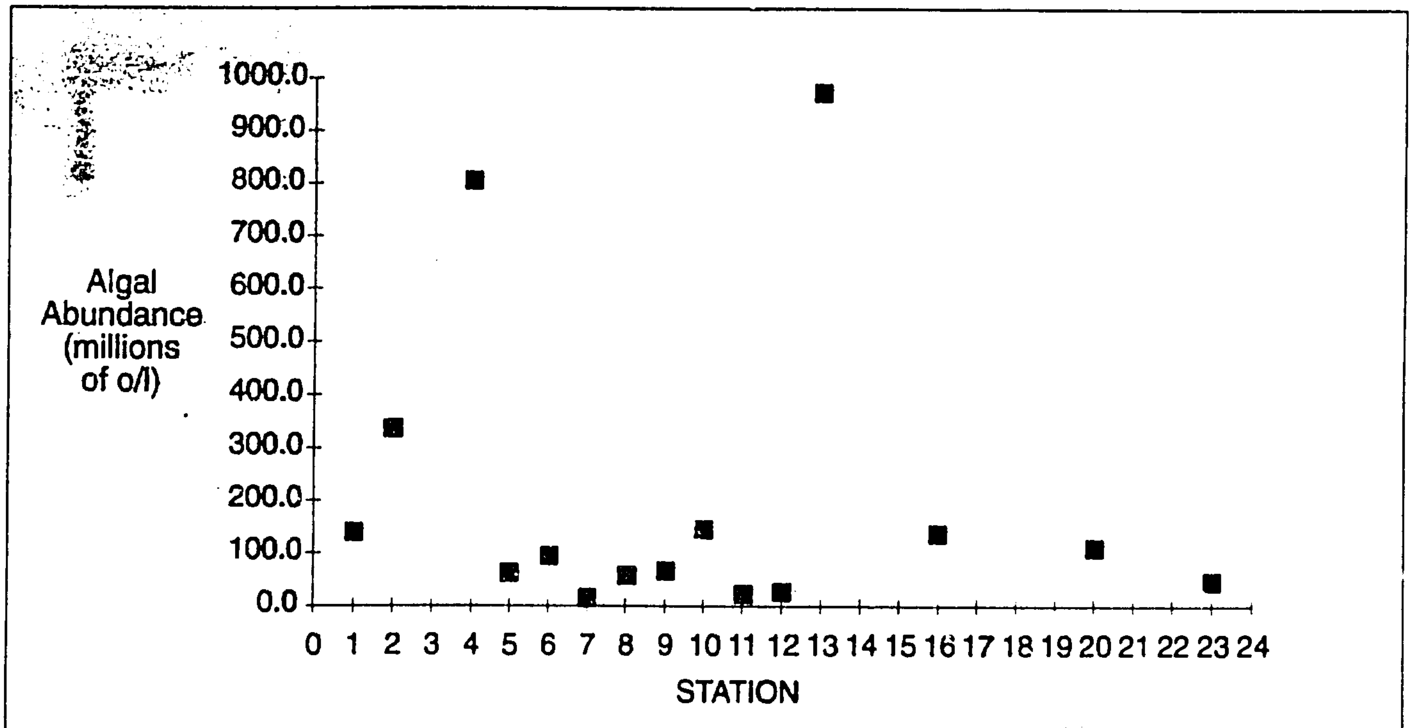

Figure 4-19
ALGAL COUNTS IN
LAKE MARYOUT - APRIL 1992

3391013 13

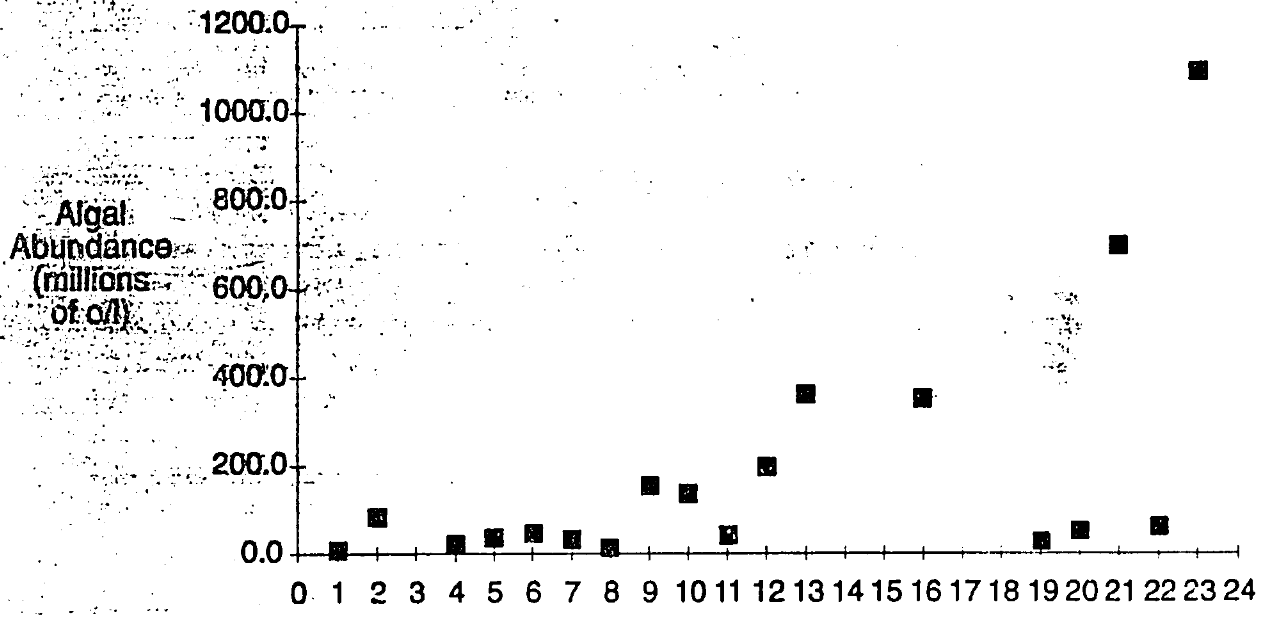

Figure 4-20
ALGAL COUNTS IN
LAKE MARYOUT - MAY 1992

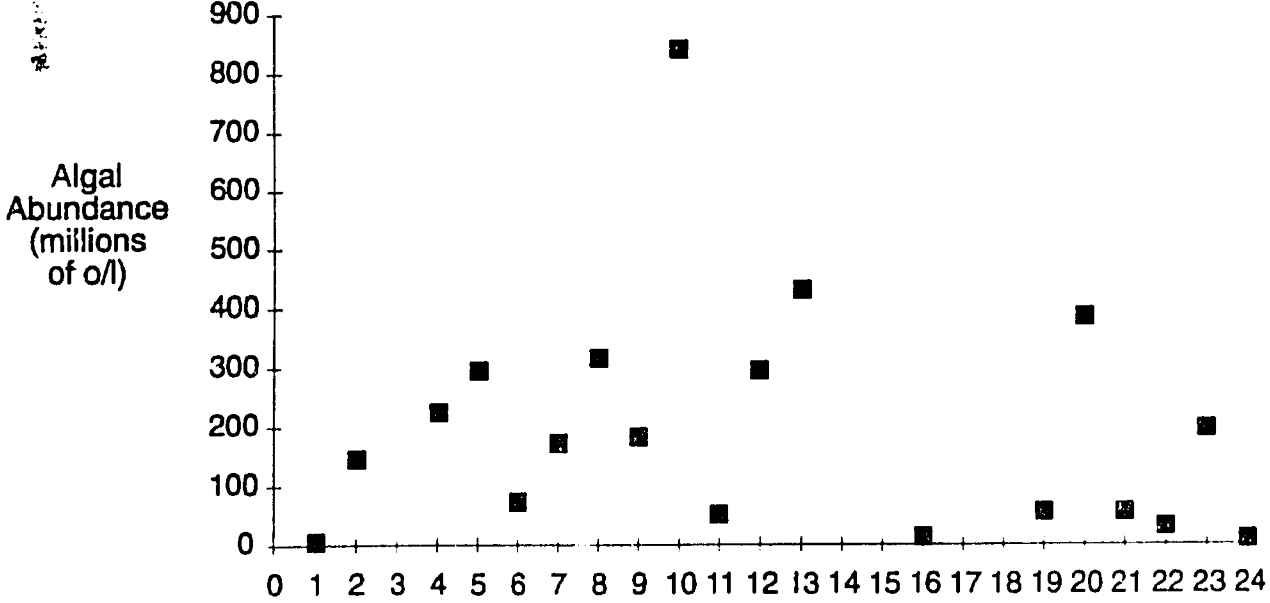

Figure 4-21
ALGAL COUNTS IN
LAKE MARYOUT - JUNE 1992

counts increased to 1,620,000 o/l and 750,000 o/l, respectively and at Station 23 (North Shore) increased to 1,020,000 o/l (Figure 4-22). In August, the highest algal counts of the year, 5,000,000 o/l, were observed at Station 23 (North Shore) (Figure 4-23). In October algal counts dropped and only Station 23 (871,200 o/l) had high algal counts (Figure 4-24).

In November, the number of algae increased again. The greatest number of algae were counted at Stations 13, West Lake, (2,800,000 o/l), 22, Central Lake, (1,650,000 o/l), and 23, North Shore, (1,750,000 o/l) (Figure 4-25). Algae counts in December were relatively low at all sites (less than 400,000 o/l) (Figure 4-26).

Throughout the year, the highest counts generally occurred at lake shore stations. The stations that had relatively low algal densities (less than 400,000 o/l) throughout the sampling period included Stations 1, 2, 5, 6, 9, 16, 19, and 20. These low counts generally reflect stations at drain locations as opposed to open lake conditions. Stations 1, 2, and 5 were part of the Kalaa Drain system; Stations 6, 9, and 19 were the Industries Drain, West Drain, and Omoum Drain, respectively; Station 16 is the Lake at Kalaa Station; and Station 20 was the El Mex outlet.

Algal Diversity

The dominant phyla identified throughout the sampling period included Chlorophyta (green algae) and Euglenophyta (euglena) and the sub-phylum, Bacillariophycaea (diatoms). In March 1992, algae were identified broadly as Chlorophyta, Diatoms, and Euglenophyta. In the following months, algae were identified to the generic level. Dominant algae included *Euglena*, *Chlorella*, *Cyclotella*, *Ulothrix*, *Zygnema*, and protozoa species.

The composition of algae in Lake Maryout changed when sampling was performed in May 1992. In addition to *Euglena*, *Chlorella*, and *Cyclotella* identified in the April samples, *Melosira*, *Spirulina*, *Tabelaria*, *Agmenellum*, *Phytoconies*, and diatom species were present in the water column.

In June 1992, most of these genera remained in the water column. Three genera present in the May sample, *Chlorella*, *Agmenellum*, and *Phytoconies*, disappeared in June, and were replaced by *Pediastrum*, *Actinastrum*, and *Stephanodescus*.

In July, *Actinastrum* remained and was accompanied primarily by *Melosira*, *Euglena*, and *Spirulina*. In August, the dominant algal species was *Spirulina*, which was accompanied by *Euglena*, *Melosira*, *Phytoconies* and *Cyclotella*.

Algal data were not available in September 1992. Analysis of data collected in October 1992 indicated the presence of the dominant genera, *Tabelaria*. In addition, *Chlorella*, previously in the May sample, reappeared and two new genera, *Fragilaria* and *Scenedsmus*, appeared.

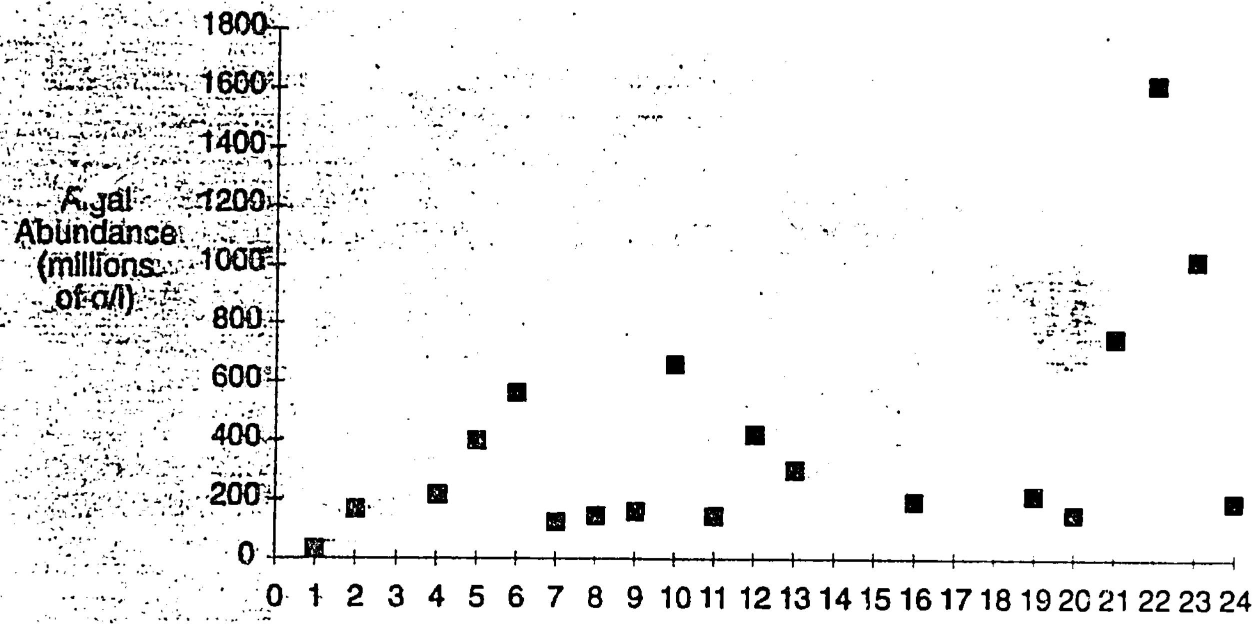

Figure 4-22
ALGAL COUNTS IN
LAKE MARYOUT - JULY 1992

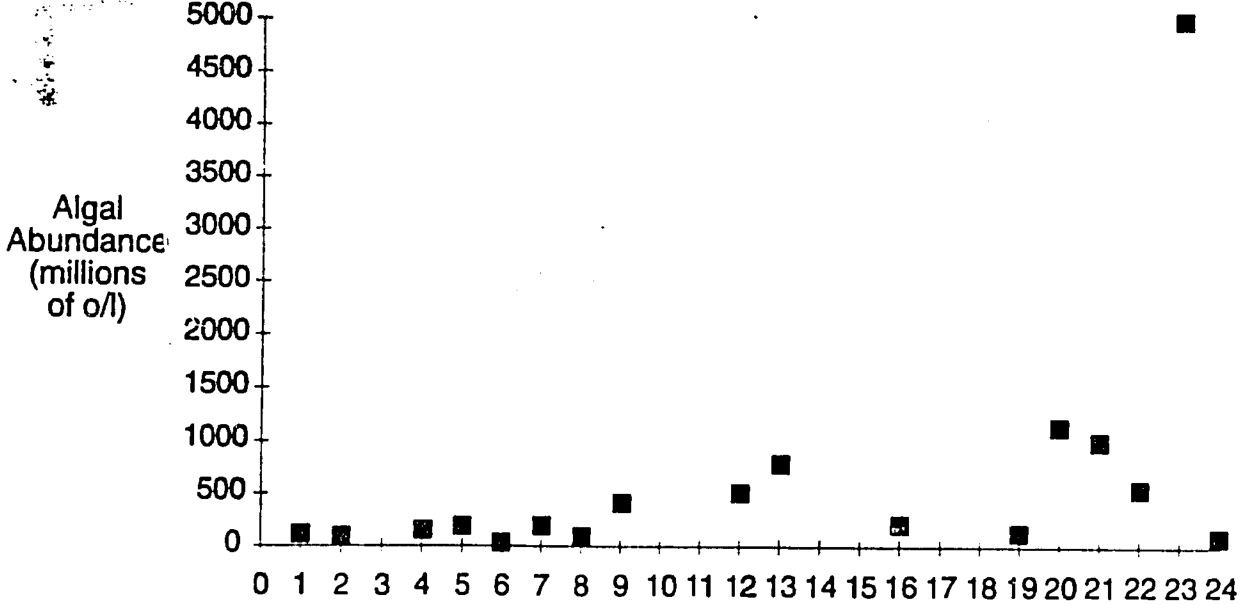

Figure 4-23
ALGAL COUNTS IN
LAKE MARYOUT - AUGUST 1992

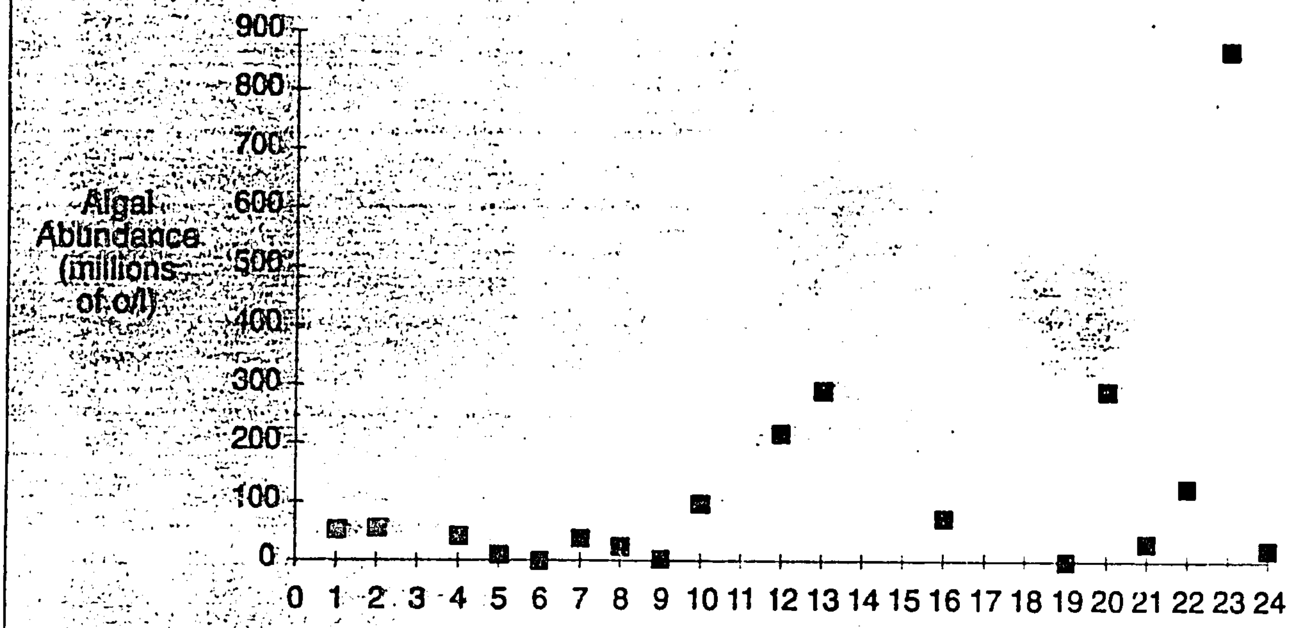

Figure 4-24
ALGAL COUNTS IN
LAKE MARYOUT - OCTOBER 1992

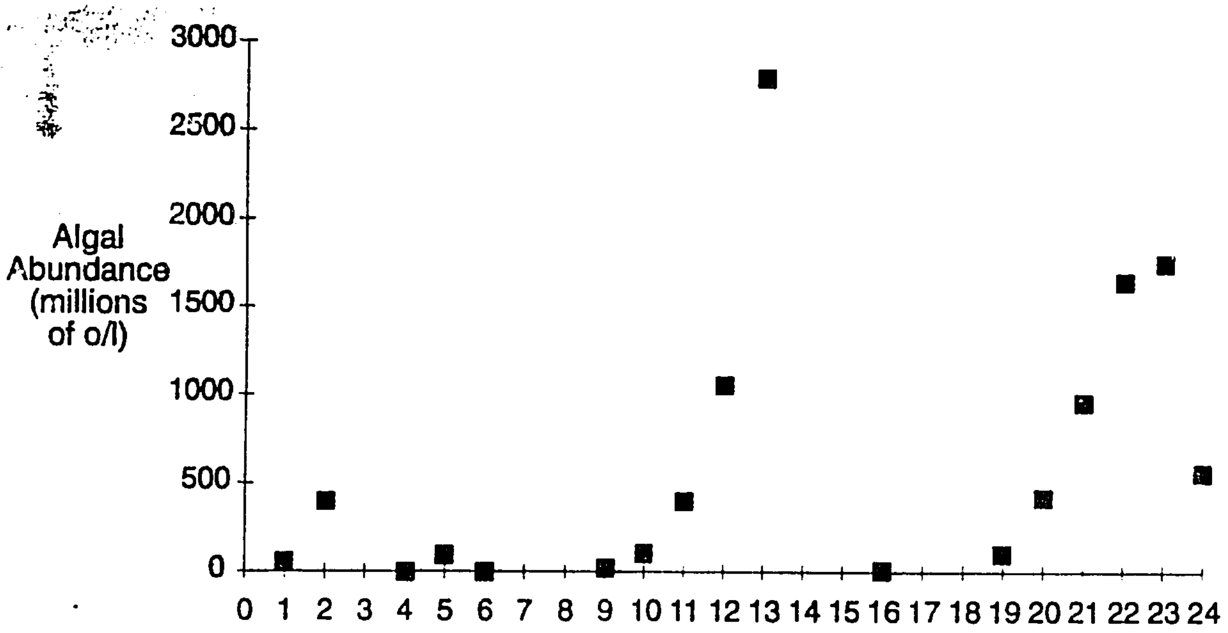

Figure 4-25
ALGAL COUNTS IN
LAKE MARYOUT - NOVEMBER 1992

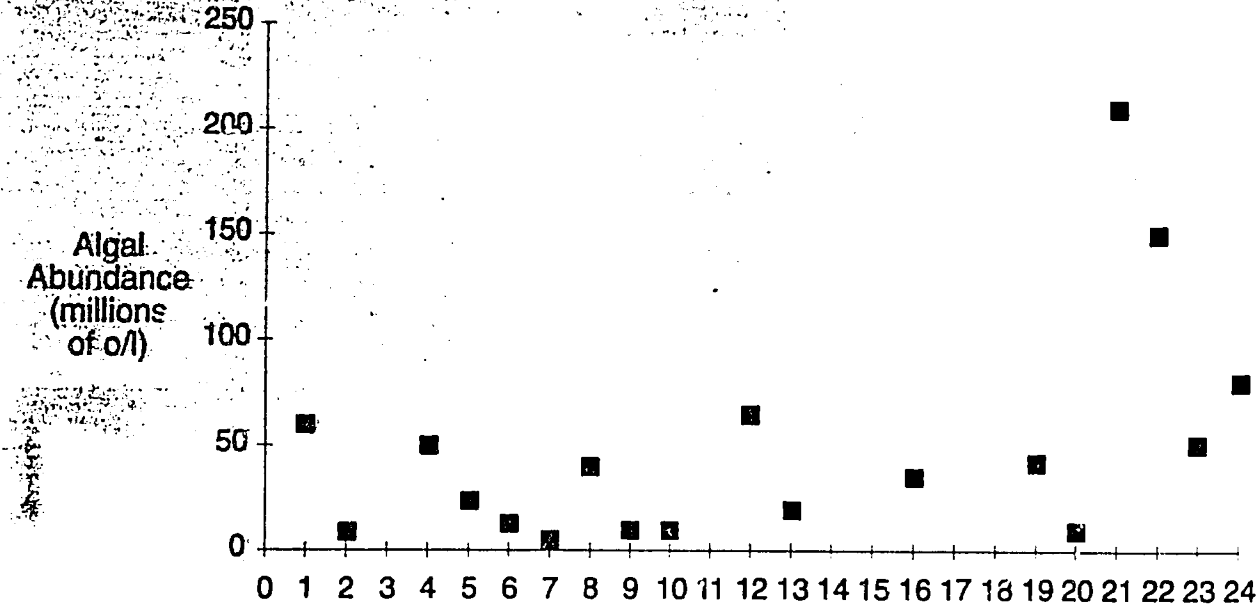

Figure 4-26
ALGAL COUNTS IN
LAKE MARYOUT - DECEMBER 1992

In November 1992, one genera, *Actinastrum*, dominated the water column. *Actinastrum* was replaced by *Gomphonosphera* as the dominant genera in December. Other genera identified in the December 1992 sample included *Euglena*, *Tabelaria*, *Pediastrum*, *Melosira*, and *Ulothrix*.

The genus of algae in Lake Maryout demonstrate that water quality is exceedingly poor. Most of the genera identified have been associated with different aspects of poor water quality (Table 4-19). For example, *Chlorella*, *Euglena*, and *Agmenellum* are algae usually found in polluted water (APHA, 1989). According to Lee (1980), *Euglena* are usually found in waters contaminated by animal pollution or decaying organic matter. The diatom, *Fragilaria*, is almost always present in "sewage fungus", a characteristic indication of organic discharges (Hellawell, 1986). Furthermore, according to Hellawell, other filamentous algae present in "sewage fungus" include *Cladophora*, *Spirogyra*, and *Ulothrix*. Hellawell also notes that diatoms are often associated with "sewage fungus", and the genera *Fragilaria*, *Melosira*, and *Diatoma* are commonly present. The following genera of algae are indicators of pollution:

- *Euglena* is found in Polysaprobic waters (grossly polluted)
- *Ulothrix* is found in alpha-Mesosaprobic water (polluted)
- *Cladophora*, *Pediastrum*, and *Scenedesmus* are found in beta-Mesosaprobic water (mildly polluted)

Thus, the majority of algae identified in samples from Lake Maryout have been associated with polluted water in other studies, and are another indication that Lake Maryout has poor water quality.

Productivity

Primary production in a lake is associated with algae and macrophytes. To estimate in-lake primary production from both these sources, oxygen concentrations were measured for a 24-hour period in the Northwest and Main Basins. For this gross estimate of production, the simplifying assumption was made that the change in concentration over the period is the net result of oxygen generated by photosynthesis and oxygen consumed by total lake respiration. This simplification ignores other sources of oxygen generation, such as diffusion from the atmosphere, and other sources of oxygen depletion, such as sediment oxygen demand.

In both basins, the oxygen concentration decreased by approximately 0.5 mg/l per hour during the dark period, indicating the rate of lake respiration. During light hours, the oxygen concentration increased by approximately 0.5 mg/l per hour, which indicated a net production (gross production minus respiration) of approximately 0.5 mg/l per hour. Combining the net production and respiration yielded a gross primary production, expressed as oxygen, of approximately 1 mg/l per hour for daylight hours.

Table 4-19
Description of Algae in Lake Maryout (March - December, 1992)

Algae	Colonial	Chain	Single Cell	Pollution Indicator	Algal Group				
					Blue/Green	Green	Red	Flagellate	Diatoms
Euglenophyta			✓	Yes				✓	
Chlorella			✓	Yes and filter clogging		✓			
Cyclotella			✓	Depends on species type					✓
Melosira		✓		Yes and filter clogging					✓
Spirulina		✓		Yes and associated with pond sewage		✓			
Ulothrix		✓		No, clean water algae		✓			
Zygnema		✓				✓			
Pediastrum	✓					✓			
Tabelaria		✓		Taste and odor causing					✓
Actinastrum	✓					✓			
Stephanodescus		✓							✓
Gomphosphaeria	✓			Taste and odor causing	✓				
Agmenellum	✓			Depends on species type	✓				
Scenedesmus	✓			Associated with pond sewage		✓			
Diatoms			✓	Filter clogging					✓
Phytoconies			✓						
Protozoa			✓						

Source: C.M. Palmer, 1977.

This rate was high and reflected the relatively warm temperatures, nutrient rich waters, and high intensity sunlight.

The estimated gross oxygen production rate of 1 mg/l per hour would result in a total lake production of approximately 300,000 kilograms of oxygen per day or almost 10 g C per m^2 per day, which ranks with the most productive systems in the world. The BOD exerted by the decay of the organic matter resulting from this production would be a similar value, which was approximately 8 percent of the total BOD load to the Lake.

The effects of the production on dissolved oxygen and other water quality and biological parameters in the lake were highly variable on a seasonal and diurnal basis. During periods of high productivity, more oxygen was generated than was consumed, but at other times respiration and decay of the production would contribute significantly to anoxic conditions. There were also times when the excess production accumulated in the sediments, producing high hydrogen sulfide concentrations. The excessive production would also result in export, via the El Mex pump station, of significant BOD to coastal waters, potentially affecting dissolved oxygen in the near shore area.

4.4.2 Benthos

In June 1993, benthic samples were collected from four lake shore stations in the Main Basin, the two mid-lake stations in the Main Basin, and one station in the Southwest Basin (Station B) (See Figure 3-1). The lake shore stations included Station A, which is near the Industries Drain, Station 11 (East Central Lake), Station 23 (North Shore), and Station 16 (Lake at Kalaa).

At each station, three samples were collected and inventoried. Shells or other evidence of freshwater and marine fauna from four classes were present in the 21 samples: Polychaeta (tube worms), Crustacea (barnacles), Lamellibranchia (*Cardium* sp. and *Lucina* sp.), and Gastropoda (*Melanoid* sp., *Pirenilla* sp., *Planorbula* sp., and *Neretina* sp.). The biological examination found dead bottom fauna at all of the stations in the Main Basin, and two specimens of *Planorbula* sp. (snail) at the station in the Southwest Basin. These data are included in Appendix C.

These results contrast with conditions prior to 1970. In polluted areas, *Chironomus* (midge) larvae and *Gammarus* (scud or sideswimmers) were common. Non-polluted areas of the lake were populated with the marine worm, *Nereis diversicolor*; *Melania tuberculata*; the marine amphipod, *Corophium* sp.; *Gammarus* and *Chironomus* larvae (Serruya and Pollingher, 1983). Shell debris from *Balanus* sp. (barnacles) and *Mercierella enigmatica* were also present.

4.4.3 Fisheries

In 1992, the most recent year for which fish catch data are available, the fish catch in Lake Maryout was dominated by pollution-tolerant species capable of surviving under conditions of low dissolved oxygen and high vegetative productivity. Approximately 77 percent of the catch in Lake Maryout consisted of grass carp (*Tilapia* sp.), 20 percent consisted of catfish (*Clarias Lazera*), and the remainder consisted of species such as suckers (*Mugil* sp.), carp (*Cyprinus* sp.), and eel (*Anguilla* sp.) (Table 4-20). Grass carp are omnivorous, relying largely on vegetation for food. Catfish and suckers are bottom feeders that are opportunistic and will eat carrion, if available.

Table 4-20
Fish Catch in Lake Maryout in 1992

Species	Metric Tons	Percentage
Tilapia	2,379.0	76.9
Mugil—Mullet	56.5	1.8
Clarias Lazera	609.2	19.7
Cyprinus	34.5	1.1
Anguilla	13.5	.4
Total	3,092.7	99.9

Source: National Fishery Authority, 1993.

Although comparable information on historic species composition in Lake Maryout was not available, data on the Hydrodrome Lake reported that 84 percent of the commercial catch consisted of grass carp, catfish, and eel.

Annual fisheries data in Lake Maryout and nearby water bodies showed a significant decline in the fish catch in the Lake during the past 12 years (Figure 4-27). During the same period, the annual fish catch in the Hydrodrome Lake and Alexandria lands from the Mediterranean Sea fluctuated up and down. Through 1985, the annual reported catch was greater in Alexandria landings from the Mediterranean Sea than that in Lake Maryout. After 1985, the annual catch in Lake Maryout dropped to a fraction of that landed in Alexandria from the Mediterranean.

In Lake Maryout, this trend was a continuation of a long-term trend, with the annual fisheries catch in Lake Maryout declining from a peak of 17,058 metric tons in 1975 to a low of 1,706 metric tons in 1990, the lowest catch in more than 20 years.

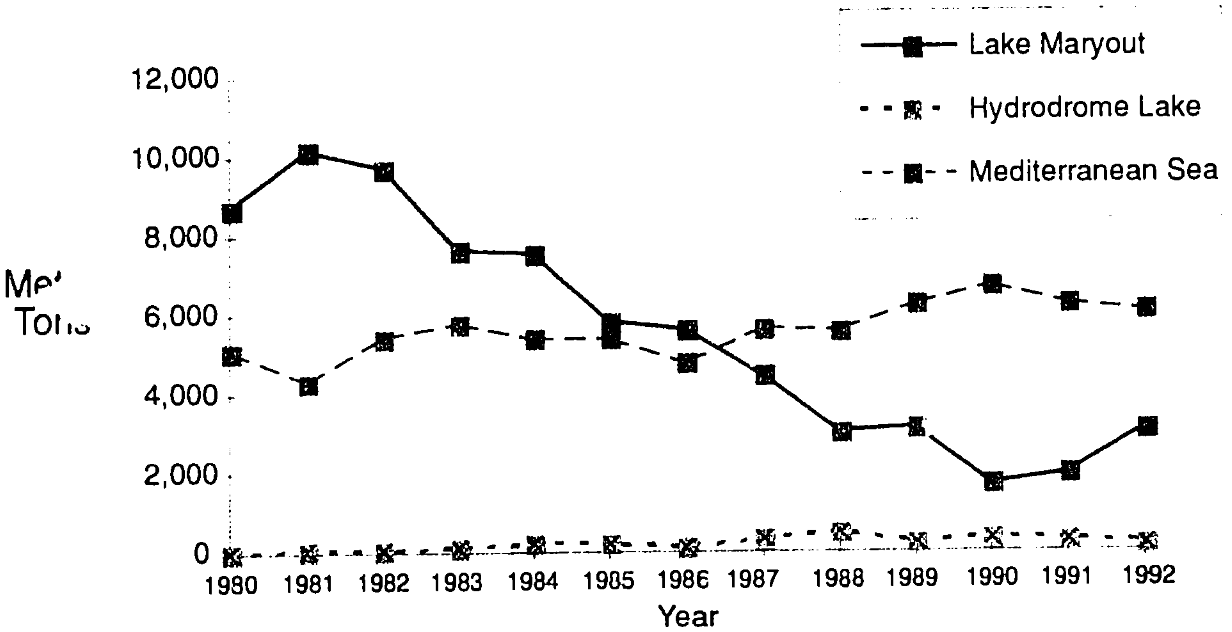

Figure 4-27
ANNUAL FISHERIES CATCH
IN LAKE MARYOUT AND
NEARBY WATERBODIES

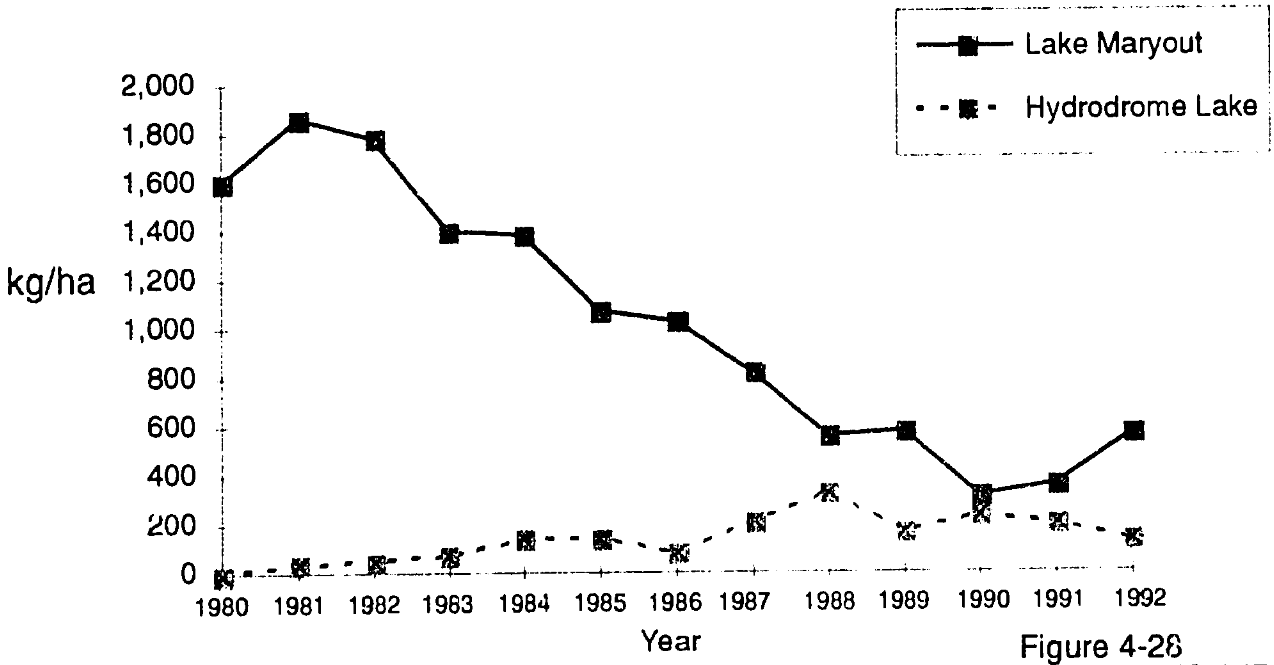

Figure 4-28
ANNUAL FISHERIES
PRODUCTION

Annual fisheries production (weight of fish caught on an areal basis) in Lake Maryout followed a similar trend. For the past 12 years, the annual fisheries production in Lake Maryout declined from a peak in 1981 of almost 1,900 kg/ha to a low point in 1990 of approximately 300 kg/ha (Figure 4-28). During the same period, fisheries production in the Hydrodrome Lake fluctuated from a low in 1980 of less than 1 kg/ha to a high in 1988 of approximately 330 kg/ha.

A variety of factors were likely to have been responsible for the overall decline in annual fisheries catch and production. These included frequent anoxic conditions; high concentrations of pollutants, including heavy metals; excessive bacterial concentrations, which indicate the presence of other disease-causing organisms; and low levels of benthic organisms. Lake Maryout's depth may also be a contributing factor. The decrease in lake depth reduces available habitat area and may increase water temperature.

4.5 Summary of Conditions in 1992/93

In the 1992/93 monitoring period, Lake Maryout exhibited conditions most typical of an abiotic lake. Pollution and other sources of stress were so severe that the Lake always appeared to be degraded, without the obvious periods of die-off and decay of flora and fauna.

In the Lake, the concentrations of enrichment factors increased in the Main and Northwest Basins from 1983, often exceeding the concentrations found in "strong", untreated wastewater. Phosphate concentrations more than doubled during the same period and were comparable to levels present in "weak", untreated wastewater. The phosphate levels, as well as the drop in dissolved oxygen concentrations, indicated that eutrophic conditions have worsened. Low oxygen and anoxic conditions persisted much of the year in the Main Basin, while oxygen concentrations in the Northwest Basin fluctuated between acceptable and unacceptable levels.

Metals concentrations in the water column also increased from 1983, and concentrations in the water column and the sediments posed a stress on aquatic biota. Although chromium, nickel, and zinc concentrations in the water column remained less than the water quality criteria levels, their levels increased substantially from 1983, in some cases by more than an order of magnitude. Cadmium and copper concentrations, which were above the water quality criteria levels in 1983, were present at even higher concentrations. Average metals concentrations in the Main Basin were comparable to or higher than those in the Northwest Basin.

Sediment levels of cadmium, copper, lead, nickel, and zinc were similarly high, and were expected to contribute to altered life cycles, depressed diversity, low species richness, and mortality. Chromium, which had average concentrations below the low effects range, occurred at concentrations approaching the low effects range at specific locations.

Overall, conditions at the lake shore were generally worse than conditions at mid-lake stations. Where conditions were worse, they were likely the result of the direct effect of inputs to the Lake. Stations where selected enrichment and nutrient levels were higher than at mid-lake included Stations 11, 12, and 13, all of which are located along the Lake's north shore. Dissolved oxygen concentrations at lake shore stations were lower than those at mid-lake stations and were significantly lower than those found in 1983. At most shoreline stations, anoxic or very low oxygen conditions prevailed for most of the year. The bacterial concentrations were also significantly greater at shore stations.

Metals levels in the water column at lake shore stations were comparable to those at mid-lake stations. In the sediments, metals levels were comparable to or higher than those at mid-lake stations. In both cases (water and sediment), they were comparable to or higher than levels measured in 1983, with chromium, nickel, and zinc (in the water column) increasing over levels measured in 1983. Heavy metals in the lake shore sediments were present at concentrations close to or higher than the benchmark values for aquatic effects, and will contribute to low species diversity and richness, toxicity, and mortality to a variety of species. Cadmium, copper, lead, nickel, and zinc were at least one order of magnitude higher than the low effects range and, in some cases, were an order of magnitude higher than the median effects range. At certain locations, chromium was present at levels that would also contribute to impacts to aquatic organisms.

The effects of pollutant levels in the water column and sediments of Lake Maryout was clearly seen in the bacterial, algal, benthic, and fisheries communities. Total coliform concentrations at lake input stations influenced by sanitary discharges had geometric means of approximately 10^9 bacteria per 100 ml. Concentrations were lower in the Omoum Drain, which is primarily agricultural drainage, and in the lake, because of die-off and dilution. However, these "lower" concentrations (for example, 10^3 to 10^5 bacteria per 100 ml) were still high. Algal communities were at relatively low densities and were comprised of pollution tolerant genera, such as *Chlorella*, *Euglena*, *Agmenellum*, *Fragilaria*, and *Cladophera*. Live benthic organisms were virtually absent from the stations sampled and the commercial fish catch, which has dropped significantly during the past few decades, consists primarily of pollution-tolerant fish, such as grass carp, catfish, and suckers.

The causes of high in-lake pollution levels and low biological diversity and abundance in 1993 compared to 1983 can be attributed to a number of factors. The lake level has dropped 0.3 to 0.6 meters and in a lake that averages less than 2 meters total depth, the drop is significant. The effects have been a decrease in available dilution, alteration of hydrodynamics and a decrease in total assimilative capacity. There has also been a substantial increase in the pollution load from the Omoum agricultural drain, which is the primary input to the Lake. Although all of the other agricultural drainage to the Lake was not measured directly, it is likely that the pollutant concentrations increased from 1983 to 1993 in a manner similar to that seen for the Omoum Drain. There have also been increases in flow from some of the north shore sanitary drains. Based on a comparison of 1983 and 1993 near shore measured concentrations of pollutants, it also appears that the strength of the north shore sanitary and industrial discharges has increased between 1983 and 1993. The increases in flow and concentrations in the north shore sources are most likely related to a near doubling of the population between 1983 and 1993.

Concentrations of enrichment parameters, ranged from a high at the Industries Drain (which had average concentrations approximately two to three times those of the Main Basin), followed by the Omoum and Kalaa Drains (each of which had average concentrations of enrichment parameters equal to or stronger than "medium to strong" untreated wastewater). The Omoum Drain, which carried approximately 90 percent of the flows to the Lake, and the Kalaa Drain, which carried approximately 8 percent of the flows, were responsible for a large percentage of the enrichment loads. Concentrations at the Omoum Drain and mouth of the Kalaa increased over 1983 levels.

Within the Kalaa Drain system, the lowest concentrations were measured in the Smouha Drain, and the highest were measured upstream of the Hydrodrome Drain, which drains an agricultural area. Compared to 1983, concentrations in the Kalaa Drain did not increase as much as those at other lake inputs.

Corresponding to high enrichment levels were low dissolved oxygen concentrations, with most lake input stations being anoxic most or all of the year.

During most months of the year, nutrient concentrations were lower in the Omoum and Kalaa Drains, which carried the largest volumes of flow, than those at in-lake stations. Other lake input stations had concentrations of nutrients that were comparable to or higher than in-lake stations. Under anoxic conditions, particulate forms of phosphorus were likely to be solubilized from lake sediments, resulting in another source of phosphorus to the water column. Concentrations in the Kalaa Drain system were generally low, and were less than those found in "strong" untreated wastewater.

Lake inputs were also responsible for elevated metals levels in the water column and sediments of the lake. For the most part, average metals concentrations were comparable at lake input and in-lake stations. However, the variability in concentrations of some metals on different dates suggested that "pulses" of elevated metals concentrations may be significant sources to control. For example, cadmium concentrations peaked on individual dates at the Industries Drain (Station 6) and the Omoum Drain (Station 19), and lead concentrations were occasionally elevated at the Industries, East Central, and West Central Drains (Stations 6, 7, and 8).

Section 5
Data Quality and Priority Pollutants

5.1 Objectives of the June 1993 Investigation

This pre-discharge supplemental Lake Maryout investigation had three primary objectives relative to data quality and priority pollutants:

- Provide an indication of background concentrations of contaminants which could not be measured at the University of Alexandria High Institute of Public Health Laboratory (High Institute) or other Egyptian laboratories.

- Perform data quality assessment for the 1992/1993 High Institute data by splitting samples during the supplemental sampling program between The High Institute's laboratory and CH2M HILL's USA laboratories.

- Collect and analyze water and sediments samples at the study sample locations for priority pollutants (metals, pesticides and PCBs, volatiles, and semi-volatiles).

5.2 Methods and Procedures of the June 1993 Investigation

Sampling methods and analytical procedures used during the June 1993 supplemental sampling program are detailed in the Lake Maryout Supplemental Sampling Program Sampling & Analysis Work Plan. A copy has been included in Appendix D.

The work plan includes a discussion of approach and rationale used to achieve the above stated objectives. In brief, CH2M HILL used sample collection methods, sampling handling procedures, preservation methods, analytical procedures, and field and laboratory documentation that are congruent with USEPA and the USA environmental laboratory industry standards of good practice.

The High Institute used sampling methods and analytical procedures that were identical to those used in previous rounds of sampling and analysis. By design, this permitted a quality control check of the High Institute's sampling techniques, sampling handling methods, and analytical work.

5.2.1 Sampling Techniques

Observations relevant to the field sampling portion of this supplemental sampling program included the following.

Surface Water Samples

In the collection of surface water samples, the High Institute's dip bucket method was used to retrieve samples from drains and waterways. Samples splits for analysis by each laboratory were obtained directly from the dip bucket by filling containers supplied by CH2M HILL and the High Institute. Good representiveness in split samples would be expected in samples obtained by the dip bucket method.

Lake Water Samples

All lake water samples were collected from a boat. The sample containers were filled by dipping each container below the water surface. To the extent possible, floating surface matter was avoided. However, at some locations, particularly those sampling sites on the north shore, the inclusion of septic floating matter in the samples was unavoidable. The comparability of results obtained from split samples at these locations may reflect the bias associated with inclusion of floating matter.

Lake Sediment Samples

Lake sediment samples were obtained by using a mini Ponar sediment sampler. One or two grabs of bottom sediments were collected with the Ponar sampler at each sample location. Upon retrieval, the free water was allowed to drain from the Ponar sampler before releasing the sediments into a plastic bucket. In instances where two sediment grabs were made, the sediments were composited and mixed in the plastic bucket. Both CH2M HILL and the High Institute filled sample containers by dipping sediments from the plastic bucket. Sample splits obtained by this method would be comparable.

5.2.2 Sampling Handling Procedures

Sample handling and preservation procedures can have a significant effect on the useful life of a sample. In most cases, the handling procedure was both sample matrix and parameter specific. Some relevant observations are included below.

High Institute's Procedures

Samples collected by the High Institute were generally not preserved in the field. The lack of field preservation would not have a significant effect on the sample integrity, provided the analyses were performed immediately or within the period of time where the integrity of a particular constituent was not significantly altered.

CH2M HILL's Procedure

In the collection of samples, CH2M HILL immediately places the sample containers on ice. At the end of each day's sampling event, samples were preserved as prescribed in the Work Plan. On the same day of sampling, samples were packaged and shipped via TNT express service to CH2M HILL's Gainesville, Florida laboratory. Three separate shipments were made. Each shipment experienced extended delays in delivery by TNT. Shipping time between Alexandria and Gainesville was as much as 17 days.

Delays in the analysis created by shipping could have significantly altered those analyses which were subject to biological and chemical change, particularly BOD, COD, and coliform analyses. As such, coliform analyses were not performed, and results of BOD and COD should not be used to evaluate intra-laboratory comparability.

Samples for USEPA priority pollutants were preserved according to USEPA specifications, as prescribed in the Work Plan. With the exception of volatile organic hydrocarbons, shipping delays should not have affected the integrity of the samples for analysis. Volatile organic samples exceeded USEPA's recommended holding times and were not cooled during shipping.

5.2.3 Analytical Procedures

Analytical methods utilized by the High Institute's laboratory and CH2M HILL's laboratory are specified in the following documents:

> Quality Assurance and Quality Control Document For Lake Maryout Study. Dr. Samia Galal Saad, Alexandria University High Institute of Public Health. September 1992 (Appendix A).
>
> Lake Maryout Supplemental Sampling Program Quality Assurance Plan. CH2M HILL, June, 1993 (Appendix D).

Both laboratories are employing methods that are recognized as standards in the USA environmental laboratory industry. The High Institute references the Seventeenth Edition of *Standard Methods of Water and Wastewater Analysis* (1987) as a source of analytical methods. CH2M HILL's laboratories references methods are primarily those of USEPA, including *Methods for Chemical Analysis of Water and Wastes*, EPA 600/4-79-020, and *Test Methods for Evaluating Solid Wastes, Physical Chemical Methods* (Third Edition).

Analytical methods cited by both laboratories were in many regards inter-changeable. The results, if each laboratory performed the analyses according to the published protocols, should yield comparable outcomes.

Data packages produced by CH2M HILL's laboratory allowed for data validation of the priority pollutant analyses. No attempt was made to validate the data from the

High Institute other than to compare the results, as discussed in Section 5.4, to those reported by CH2M HILL's laboratory.

5.3 Priority Pollutant Results

Samples analyzed for priority pollutants (metals, pesticides and PCBs, volatiles, and semi-volatiles) showed a wide variation in levels of detected compounds (data are presented in Appendix D). When concentrations reported for inorganic and organic analyses compared against USEPA water quality criteria to assess the relative pollutant levels, several samples exceed recommended concentrations for continuous (chronic) exposure for metals (for example copper, lead and zinc). Organic compounds are detected at levels below recommended limits in water samples, but still present at easily quantifiable amounts. The sediment samples showed elevated levels of metals, polynuclear aromatics (PAHs), DDT and its breakdown products, and other organic compounds in trace amounts. No evidence of PCBs is detected in the sediment at the dilutions analyzed. Many of the analyts could not be evaluated either because water quality and sediment criteria do not exist. The elevated detection limits reported by the laboratory were associated with the sample matrix and will always tend to be a complicating factor. Achieving lower limits of measurement on the samples is difficult because of to matrix interferences and the high amounts of organic background in these samples.

Information provided in data package case narratives by CH2M HILL's laboratories indicates that holding time limits, as established by USEPA, were not appropriate for these samples. An independent review of the data packages found that the conventional holding time for most parameters was met. However, the water samples for volatile organics were not analyzed within USEPA's holding time criteria and may have been potentially affected by delays caused during shipping and analysis. It should be noted that water samples were preserved in the field by acidification and refrigerated while in residence at the laboratory. Given this, the laboratory's data for volatile organics should, as a minimum, provide an indication of the type and relative abundance of volatile organics in the water samples. Using USEPA's conventional guidelines, data from analyses that are analyzed outside of holding times are normally qualified as estimated values. Many of the samples are reported at higher detection limits because of matrix interferences. No blank problems are noted for these analyses. The data are complete for the requested parameters. No exceptions or rejections are noted and the data are considered acceptable for its intended use.

5.4 Comparison of High Institute and CH2M HILL Findings

Parameters used for comparison were metals and some general chemical parameters. For comparison of numeric values, the results of water and sediment samples analyzed by the two laboratories are aligned in Table 5-1. The data have been

Table 5-1
Comparison of Water and Sediment Sample Analyses-June 1993
Alexandria, Egypt
Lake Maryout Samples

WATER SAMPLES
Parameters as mg/l

HI=High Institute
CH=CH2M HILL

	BOD			TS			Cd			Cr			Cu			Pb			Ni			Zn			COD	
Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH
21	220	9	1	1416	1100	B	0.00816	0.00	B	0.0041	0.00	20	0.0133	0.00238	A	0.0155	0.00	B	0.03575	0.00	23	0.0305	0.0031	19	640	42
12	230	12	6	8159	1500	4	0.0025	0.00	21	0.0027	0.00	19	0.01595	0.00351	21	0.0185	0.00	11	0.01825	0.00	B	0.0175	0.005	20	600	53
11	190	14	19	5125	1520	6	0.01015	0.00	22	0.00235	0.00	23	0.0108	0.00389	23	0.0245	0.00	12	0.0255	0.00	22	0.019	0.007	A	200	63
10	180	15	4	2542	1760	8	0.0045	0.00	23	0.0026	0.00	A	0.01015	0.00409	10	0.024	0.0022	19	0.0347	0.00	20	0.0165	0.008	B	240	63
4	330	21	8	1660	2150	13	0.01205	0.00	24	0.0059	0.00	B	0.00545	0.00581	11	0.019	0.0029	20	0.0435	0.00	21	0.0185	0.008	24	320	74
A	100	27	2	2860	2280	19	0.0082	0.00	10	0.0024	0.00012	10	0.0281	0.007	24	0.0305	0.0031	21	0.018	0.00	24	0.025	0.008	10	280	95
23	200	28	C	2840	2450	20	0.0085	0.00	11	0.00255	0.00038	22	0.0055	0.012	13	0.0775	0.0048	22	0.02275	0.00	10	0.061	0.011	23	320	99
2	110	33	20	7894	3880	21	0.0032	0.00	A	0.00285	0.00129	24	0.0152	0.014	4	0.016	0.007	24	0.0321	0.00	19	0.0545	0.012	22	440	106
22	250	33	5	2114	5490	24	0.00515	0.00	20	0.00505	0.00172	13	0.0775	0.016	20	0.032	0.0093	8	0.0239	0.00283	A	0.0565	0.016	11	320	117
16	100	37	A	1930		2	0.00335	0.00018	13	0.0038	0.00245	21	0.0081	0.016	12	0.0205	0.0102	23	0.025	0.00315	11	0.061	0.018	21	400	134
5	140	37	B	4788		5	0.0027	0.00034	2	0.00285	0.0031	4	0.02225	0.02	22	0.023	0.0114	16	0.0196	0.0033	4	0.0665	0.042	4	520	144
1	140	81	10	2084		1	0.0023	0.0005	19	0.0056	0.00356	2	0.0218	0.021	19	0.0345	0.0139	5	0.0204	0.00418	12	0.043	0.058	2	160	164
13	680	90	11	2696		23	0.0031	0.00063	12	0.00275	0.00432	12	0.0101	0.021	1	0.027	0.0148	13	0.03205	0.00424	13	0.365	0.07	12	360	168
8	240	225	12	3084		11	0.003	0.00067	4	0.00335	0.006	16	0.0334	0.037	B	0.0295	0.0159	10	0.0234	0.00427	16	0.08	0.095	5	240	220
6	1200	248	13	3266		10	0.0059	0.00089	16	0.00325	0.00767	5	0.0502	0.044	5	0.0345	0.0225	2	0.0264	0.0047	2	0.054	0.098	1	240	278
C	250	874	16	2096		12	0.00585	0.00154	1	0.0033	0.014	C	0.07485	0.076	16	0.031	0.0282	4	0.01925	0.00519	5	0.182	0.102	16	160	310
B	140		21	2701		A	0.00515	0.00171	5	0.00305	0.014	6	0.06915	0.088	2	0.028	0.0345	A	0.0207	0.00661	1	0.25	0.161	13	1120	362
24	140		22	3562		C	0.0071	0.00185	8	0.0055	0.027	8	0.09095	0.095	8	0.0695	0.0394	C	0.0344	0.00818	8	0.292	0.239	8	400	861
20	340		23	3092		16	0.0027	0.0019	C	0.0052	0.031	11	0.01535	0.124	6	0.051	0.0576	1	0.01455	0.0095	C	0.337	0.279	C	400	874
19	530		24	7496		22	0.0028	0.00269	6	0.0087	0.045	1	0.10545	0.146	C	0.091	0.088	6	0.0519	0.0118	6	0.254	0.288	6	2100	1350

5-5

SEDIMENT SAMPLES
Parameters as mg/kg (Dry Basis)

	Cd			Cr			Cu			Pb			Ni			Zn	
Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH	Site	HI	CH
13	0.68	0	24	3.0	14.2	24	8.80	23.9	B	11.2	3.82	24	11.05	10.3	24	17.3	32.6
24	2.00	0.43	B	2.79	21.2	B	5.28	27.2	24	11.9	3.9	B	12.5	19.9	16	133	103
22	0.94	0.62	21	2.57	34.2	16	8.24	51.1	21	24.4	33.2	21	17.22	30.7	21	74.4	120
B	1.44	1.27	16	2.45	35.8	21	12.33	57.2	16	24.9	34.7	16	11.35	37.9	22	143	121
21	1.72	1.8	22	2.95	46.2	22	14.55	63.1	22	28.6	38	22	17.20	49.2	23	118	202
11	1.42	1.91	23	4.2	53.8	23	18.93	96.7	23	43.1	58.9	23	20.79	53.5	B	17.7	316
16	1.10	2.08	12	7.63	77	A	130.8	204	A	103.2	129	12	32.48	60.1	A	328.2	453
A	1.60	2.79	13	4.41	83.1	12	121.6	210	13	96.7	209	13	22.14	70.4	12	329.2	674
23	1.23	3.23	A	7.20	98.1	13	60.91	309	12	104.4	240	A	14	76.2	11	345.4	882
10	2.53	4.34	10	8.75	114	11	115.6	371	11	116.1	257	11	24.5	93	13	422.6	908
12	1.61	5.67	11	11.69	210	10	215.4	445	10	144.4	263	10	45	107	10	699	1000

arranged from low to high values (using CH2M HILL data) and are graphically presented in Figures 5-1 to 5-5. Statistical analysis using correlation coefficient showed good correlation between the two laboratories for most parameters. Similar coefficients could be expected between any two USEPA certified laboratories. Many of the differences in the numbers can probably be attributed to sample handling, analytical techniques, methodologies, and matrix. These sample matrices were complex, with high levels of potentially interfering constituents. Taking into account the nature of the samples, logistics, and level of the constituent measured, the data reported by the two laboratories were reasonably comparable.

5.4.1 General Chemistry Parameters

Biochemical Oxygen Demand

The BOD test is by its nature an empirical analysis which is subject to many variables associated with a bioassay type analysis. Not only is it subject to the skill of the analyst but the specific sample flora and fauna also have a big impact on the results of the test. Because these samples were preserved, essentially eliminating all the native flora and fauna, it is not surprising to see wide differences in comparison data. Samples of this nature usually require an acclimated seed to produce accurate results reflecting actual conditions.

Total Solids

Solids testing is another analysis which was also affected by the preservations employed. The limited comparison data tracked well except for two outliers, which threw the correlation coefficient off.

Chemical Oxygen Demand

COD testing can be subject to wide variations and is especially sensitive to different methodologies. A good correlation between the data was shown.

5.4.2 Metals

Generally speaking, the High Institute reported higher values for most of the water tests and CH2M HILL reported higher values for most of the sediment analyses. These differences can be explained by different laboratory procedures, especially a more rigorous digestion procedure for the sediment samples. Other effects can be attributed to equipment differences, such as flame atomic absorption versus inductively coupled plasma versus graphite furnace atomic absorption. Each has advantages and disadvantages for individual analyses and matrices, and will invariably produce different values depending on the situation.

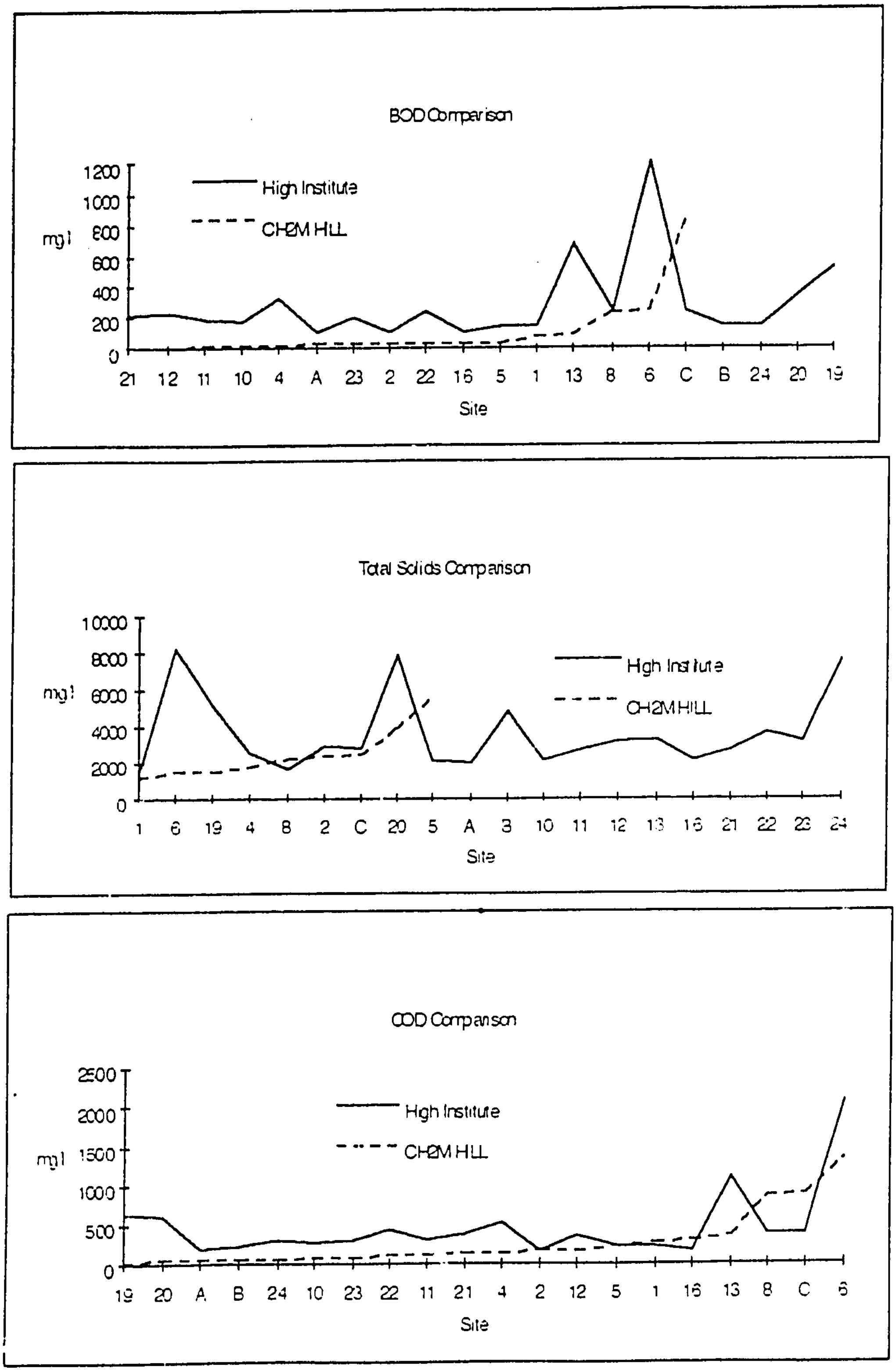

Figure 5-1
COMPARISON OF THE HIGH INSTITUTE AND CH2M HILL ANALYSES OF BOD, TOTAL SOLIDS AND COD

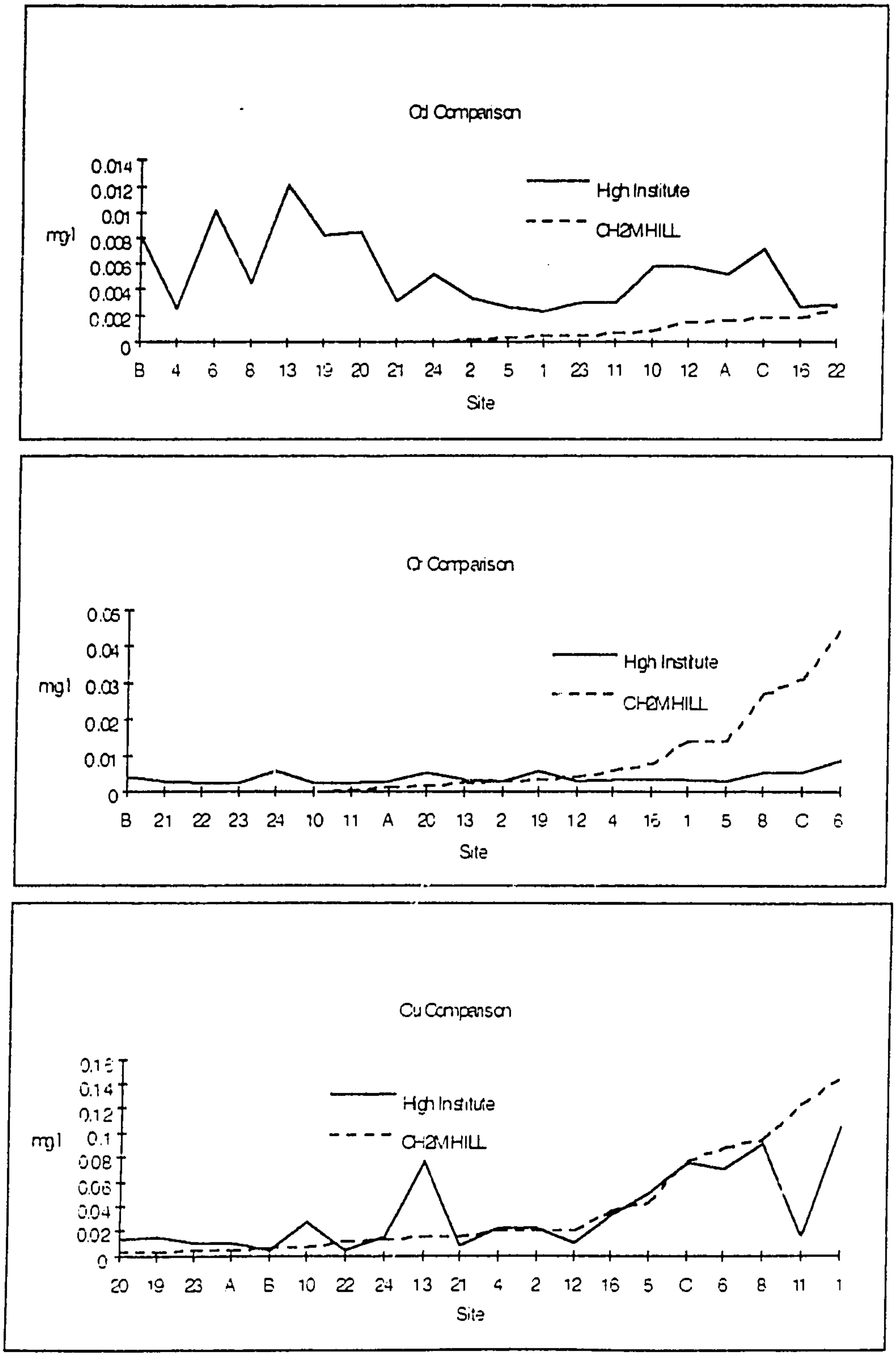

Figure 5-[illegible]
COMPARISON OF THE HIGH INSTITUTE
AND CH2M HILL ANALYSES OF CADMIUM,
CHROMIUM, AND COPPER IN WATER SAMPLES

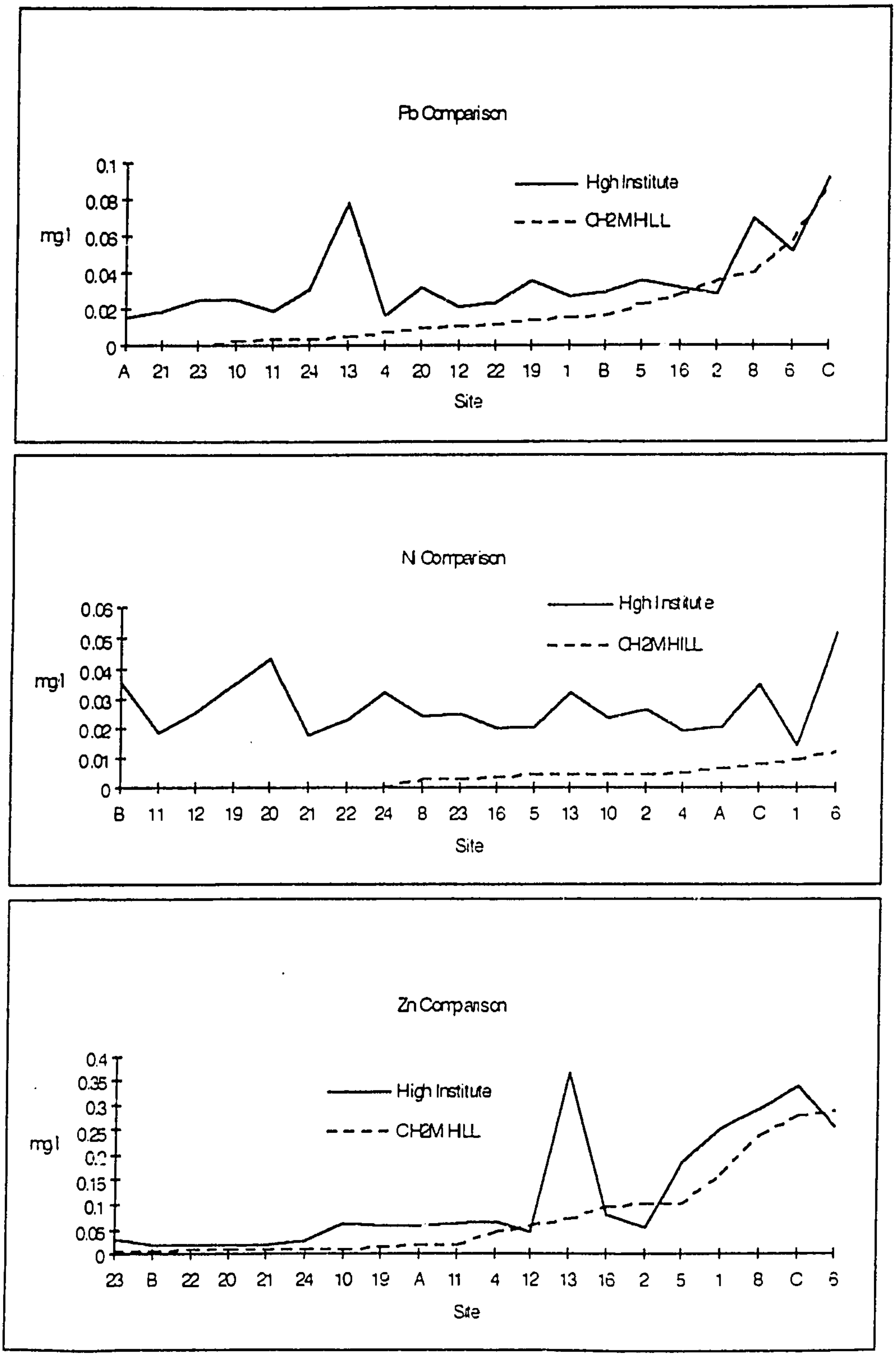

Figure 5-3
COMPARISON OF THE HIGH INSTITUTE
AND CH2M HILL ANALYSES OF LEAD,
NICKEL, AND ZINC IN WATER SAMPLES

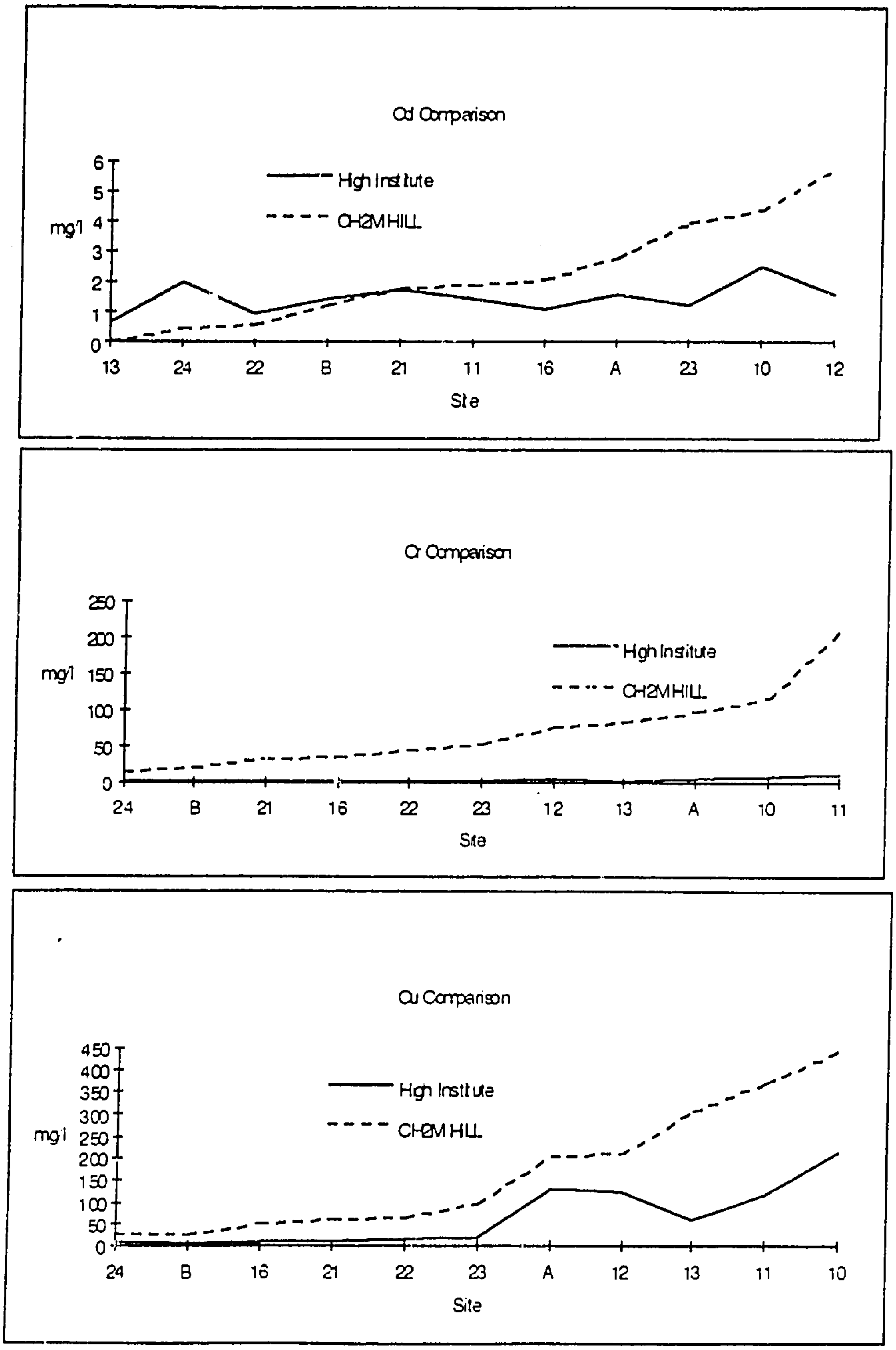

Figure 5-4
COMPARISON OF THE HIGH INSTITUTE
AND CH2M HILL ANALYSES OF CADMIUM,
CHROMIUM, AND COPPER IN SEDIMENT SAMPLES

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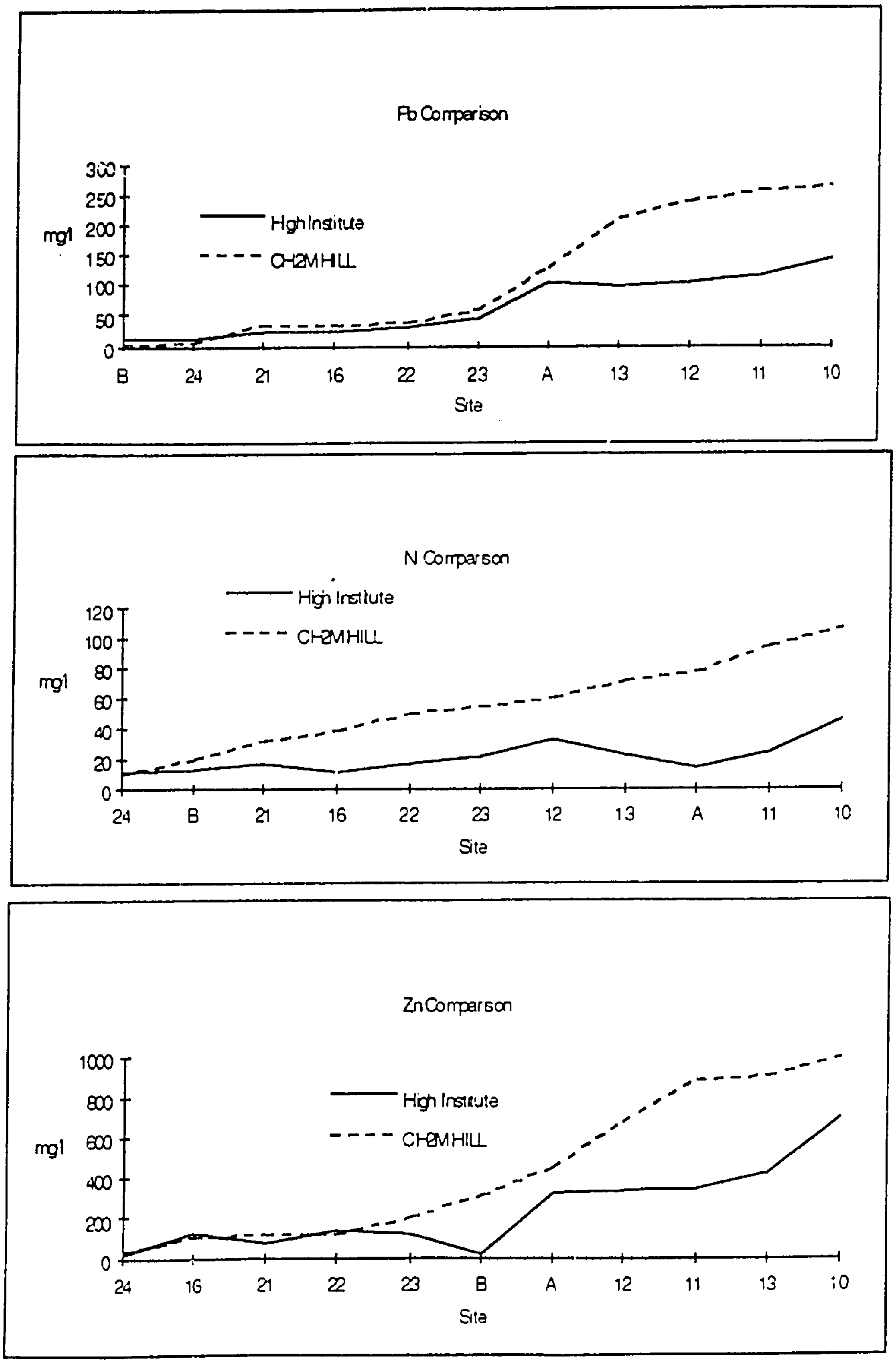

Figure 5-5
COMPARISON OF THE HIGH INSTITUTE
AND CH2M HILL ANALYSES OF LEAD,
NICKEL, AND ZINC IN SEDIMENT SAMPLES

Cadmium

Cadmium had the lowest correlation of the metals evaluated. Much of this can be attributed to the low levels reported and to the inherent variation encountered when working at very low detection limits.

Chromium

Although a good correlation was demonstrated for this metal, the values reported were the most widely separated of the metals. This can easily be caused by the different methodologies.

Copper

Copper had good agreement, with a few outliers apparent in the data.

Lead

Lead also had good agreement and the occasional outlier.

Nickel

The nickel data had poor correlation on water samples, probably because of the low levels present but the sediment numbers followed each other nicely.

Zinc

Zinc had the best correlation of all the metals. A few outliers were also present in this data.

5.5 Data Quality and Usability

A normal measure of data quality involves the evaluation of a data package. This package includes the evaluation of laboratory spikes, duplicates, and control samples. In this case, the measure of quality was its comparability to data from sample splits analyzed by CH2M HILL's laboratory. As a starting point, for data generated by the High Institute's laboratory, the data from CH2M HILL was examined closely for completeness, adherence to method protocols, sample handling, precision, accuracy and reporting. Then a comparison was performed for the parameters analyzed by both laboratories. For the most part, the two sets of data showed good agreement. Where anomalies occurred, these can usually be explained by the analytical complexity associated with the matrices and by the potential differences associated with minor differences in the actual analytical procedures of each laboratory.

The overall quality of the High Institute data was consistent with its end use, that being a broad assessment of the predischarge sediment and water quality. Given the year long or greater duration of the study and frequency at which sampling analyses have occurred, the data generated by the High Institute would support a broad spatial sediment quality assessment and long-term water quality assessment. Variability in the High Institute data from one sampling event to the next can be expected, given the complexity associated with a study of this magnitude. The inherent variability in sediment samples and ever changing water quality conditions at both the Lake and land-based water sampling sites were evident in the High Institute's laboratory data. This variability generally precludes the use of the data for interpreting short term trends in water and sediment quality of Lake Maryout.

Section 6
Estimation of Future Conditions

6.1 Computer Model

A simple computer model of Lake Maryout was created to simulate existing and future hydraulic conditions and concentrations of BOD and dissolved oxygen. A description of the model and assumptions used are presented in Appendix E. The model predicted dissolved oxygen concentrations at or near zero for all conditions in all locations, so looking at just oxygen did not result in a meaningful comparison of alternatives. As an alternative, BOD concentrations and changes in BOD were modeled and used to compare alternative treatment scenarios.

None of the wastewater treatment scenarios (that is, Phase I primary, Phase II primary, or secondary) are expected to significantly alter the nutrient or metal concentrations in the Lake. This is due to a number of factors, including: the large concentration of nutrients entering the Lake from sources other than sewage; the large mass of metals stored in the sediments; the excessive concentration of metals currently in the water; and the relatively low removal rates for metals and nutrients achieved by primary or secondary treatment. Consequently, the conditions following implementation of any of the wastewater scenarios are not expected to change significantly from existing conditions with relation to water and sediment toxicity or eutrophication.

For the model, the lake was split into subareas within which approximately homogeneous conditions were assumed to prevail and the exchange of flows and pollutants between the areas could be simulated. Figures 6-1a and 6-1b are schematic representations of Lake Maryout illustrating how the system was segmented into subareas for the model simulation. The subareas were defined using physical characteristics, such as the Desert Road and the Omoum Drain, and using water quality characteristics, observed in the basins. For example, the Main Basin was split into four subareas, based on the locations of present and future discharges and on existing pollutant concentrations in the basin. The Southwest Basin was modeled as a point source to the Lake because the 1992-1993 sampling program focused on data collection in the Main and Northwest Basins. It was assumed that no net hydraulic movement occurs between the Fishery Basin and the rest of the lake.

The model used a water budget approach in which the flows into the Lake (and subareas) were balanced with the flows out of the Lake (and other subareas). Sources of inflow included wastewater outfalls and drains while outflow included evaporation and the El Mex Pump Station. Precipitation was neglected in the model because of its small magnitude. Runoff was also neglected because there was no data describing this and it is believed to be small in magnitude. It was assumed that groundwater infiltration was

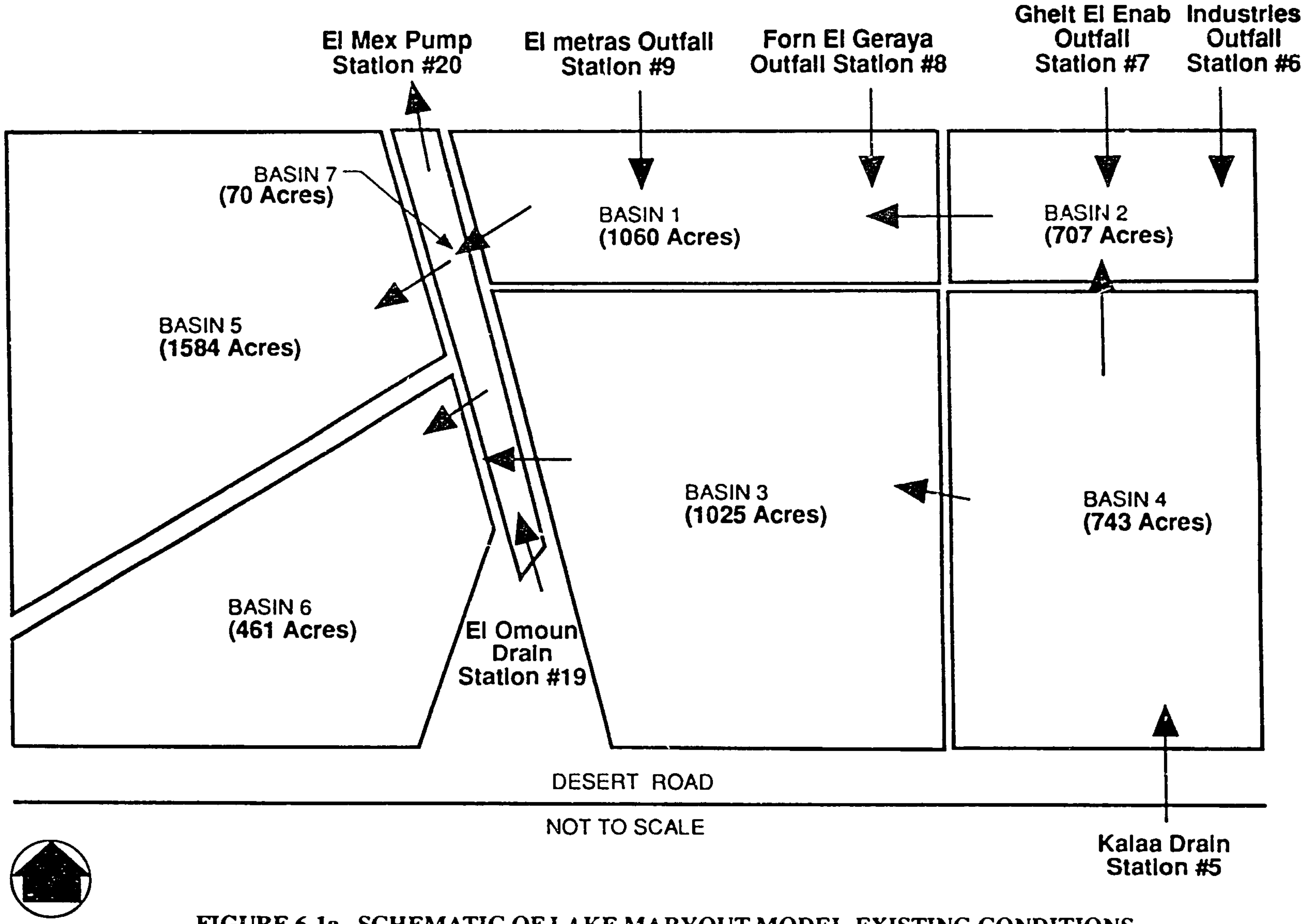

FIGURE 6-1a. SCHEMATIC OF LAKE MARYOUT MODEL-EXISTING CONDITIONS

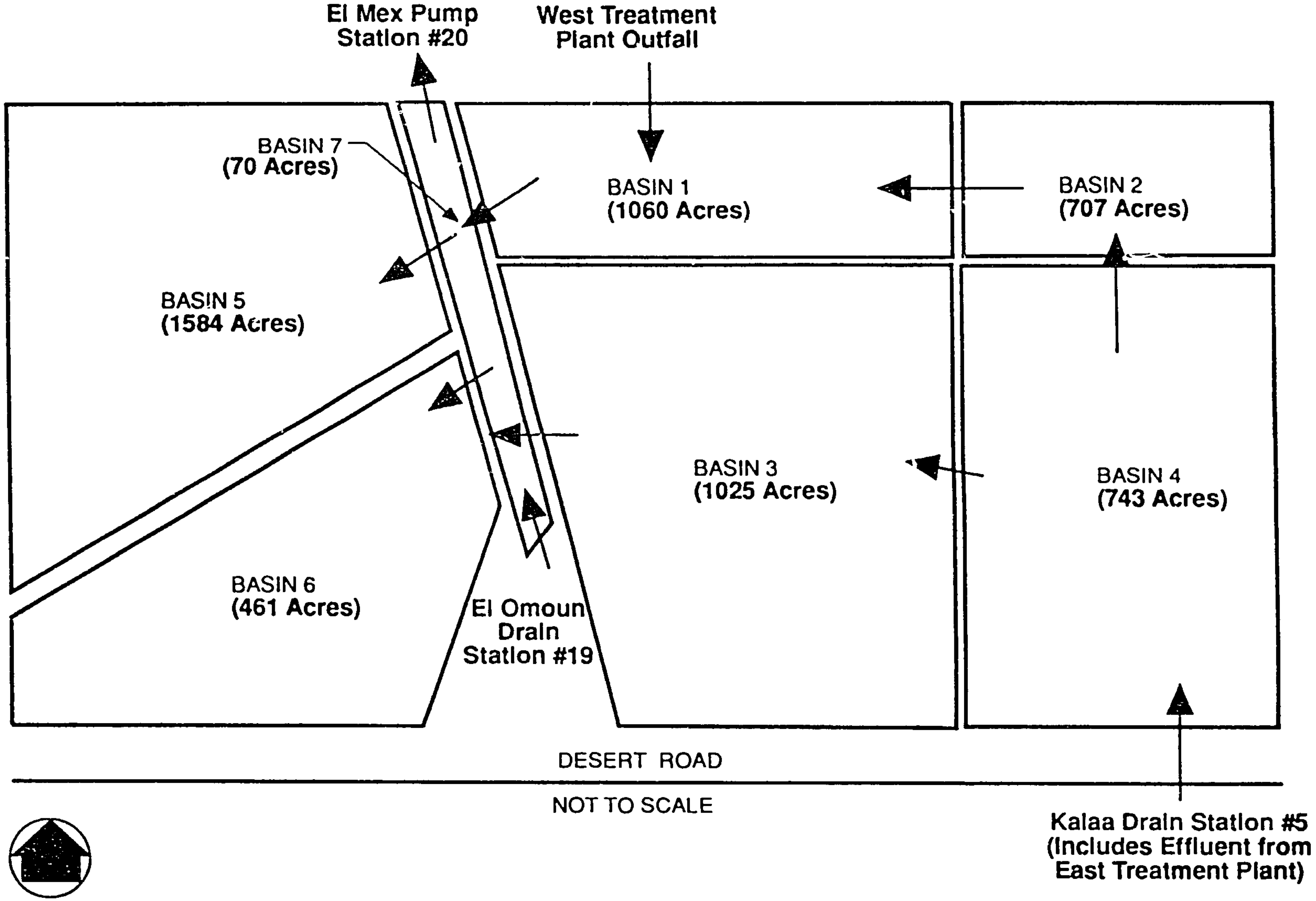

FIGURE 6-1b. SCHEMATIC OF LAKE MARYOUT MODEL-FUTURE CONDITIONS

equal to the difference between inflow to the Lake and outflow at El Mex Pump Station. Where water from one subarea was expected to flow into multiple subareas, such as from Basin 4 to Basins 2 and 3, certain assumptions were made to reflect the exchange of water. These assumptions were based on factors such as the direction of currents and the presence of physical barriers. Table 6-1 presents the hydraulic characteristics of the lake model by subarea, including: area of water, sources and magnitudes of inflow, locations and magnitudes of outflow, percent of flow assumed to move from one subarea to another, direction of net flow from one subarea to another, and evaporation losses. Evaporation losses were calculated based on the total wet area of each subarea.

The most recent data available were used to create the model of Lake Maryout. Model inputs included: flows proportional to those estimated in 1983 and equal to expected Phase I−design flow of 175 Ml/day for the drains which discharge to the northern shore of the Main Basin, flows estimated in 1990 for the Omoum and Kalaa Drains, July 1990 to June 1993 flow data at El Mex Pump Station, and BOD and dissolved oxygen data from the 1992/93 sampling program.

The flow and BOD concentrations input to the model for the treatment scenarios are summarized in Table 6-2. The flows were from the 1992 Master Plan Update and the effluent BOD concentrations were calculated from design (primary) or estimated (secondary at 80%) removals and measured influent concentrations.

6.2 Modeling Results

Based on the loads shown in Table 6-2, and the inputs from other sources measured during the 1992/93 Lake Maryout study, the BOD input to the Lake would be as shown in Table 6-3. It is predicted that implementation of Phase I primary treatment will result in less than a 2 percent reduction in BOD load over existing conditions. When Phase II flows are added to the treatment plants, the BOD load from primary treatment will almost double, but because the additional flows are derived from areas not now tributary to Lake Maryout, the total load to the lake will increase by about 4%. Implementation of secondary treatment would increase BOD removal at the plants from about 25% to 80% with the effect of decreasing BOD load to the Lake, compared to primary treatment levels, to a total BOD load 5% less than existing conditions. Consequently, on a lakewide basis, discharge of Phase I design flows with primary treatment or Phase II flows with secondary treatment would result in BOD loads similar to or less than existing conditions. Phase II flows with primary treatment would increase loads and result in additional water quality deterioration in the Lake.

Table 6-1
Hydraulic Characteristics

Basin	Description	Wet Area (acres)	Inflows		Outflows		Evaporation (loss=area *5 mm/day)	Groundwater Infiltration
			Location	Flow (m3/d)	Location	Flow (m3/d)		
1	Northwest portion of Main Basin, Northeast portion of Northwest Basin	1,060	Basin 2	248,516	Basin 7	-296,667	-21,449	0
			Elmetras #9	34,800				
			Forn El Geraya #8	34,800				
2	Northeast portion of Main Basin	707	Gheit El Enab #7	45,200	Basin 1	-248,516	-14,306	0
			Industries #6	60,200				
			30% Basin 4	157,422				
3	Southwest portion of Main Basin	1,025	70% Basin 4	367,319	Basin 7	-63,463	-20,741	-283,115
4	Southeast portion of Main Basin	743	Kalaa Drain	745,000	Basin 2, 30%	-157,422	-15,035	-205,224
					Basin 3, 70%	-367,319		
5	North portion of Northwest Basin	1,584	Industrial Drain #1	0			-32,052	0
			Basin 7	32,052				
6	South portion of Northwest Basin	461	Industrial Drain #2	0			-9,328	-127,333
			Basin 7	136,661				
7	North portion of El Omoun Drain	70	Basin 1	296,667	El Mex PS	-6,811,000	-1,416	0
			Basin 3	63,463	Basin 5	-32,052		
			El Omoun South	6,621,000	Basin 6	-136,661		
Totals		5,650		8,843,101		-8,113,102	-114,327	-615,672

Table 6-2
Wastewater Treatment Plant Inputs Used in Lake Maryout BOD Model

Treatment Scenario	Flow (Ml/day)		BOD (mg/l)	
	Influent	Effluent	Influent	Effluent
Phase I-Primary Treatment				
East Plant	410	399(a)	520	401
West Plant	175	186(a)	520	424
Phase II Primary Treatment				
East Plant	544	544	520	390
West Plant	475	475	520	390
Phase II Secondary Treatment				
East Plant	544	544	520	104
West Plant	475	475	520	104

(a) Assume 11 Ml/day sludge by-pass from ETP to WTP for Phase I - Primary.

Table 6-3
Summary of Input BOD Loads to Lake Maryout

Treatment Scenario	Load (kg/day)		
	Wastewater Effluent	Other Sources	Total
Existing Conditions	297,162	3,731,112	4,028,274
Phase I–Primary Treatment	238,810	3,731,112	3,969,922
Phase II–Primary Treatment	397,410	3,731,112	4,128,522
Phase II–Secondary Treatment	105,976	3,731,112	3,837,088

Although there is little change from existing conditions on a total system basis, the different treatment scenarios do produce changes in the various areas or basins of the Lake. These are shown in Figure 6-2 and Table 6-4. As would be expected from the lakewide evaluation, the outlet from the Lake (Basin 7) and the basins across the Omoum Drain from the existing discharges (Basins 5 and 6) would show little change in BOD concentrations with implementation of any of the treatment scenarios. Concentrations of BOD in the western portion of the Main Basin (Basins 1 and 3) are expected to increase, except with implementation of secondary treatment when they will decrease to concentrations lower than existing conditions. In the eastern portion of the Main Basin (Basins 2 and 4), BOD concentrations are expected to decrease with implementation of treatment, compared to existing conditions. With secondary treatment, the BOD concentrations in the Main Basin would be reduced 4% to 41%, compared to existing concentrations. The effect of reduced BOD concentrations in these areas, particularly over time when the reduction in contribution of solids has decreased the buildup in the sediments, could reduce odors and support a more diverse aquatic biological community.

Table 6-4
Measured and Predicted Concentrations of BOD in Lake Maryout (In mg/l)

Basin Number	Measured	Model Predictions Existing Conditions	 Phase I Primary	 Phase II Primary	 Phase II Secondary
Basin 1	492	443	506	540	333
Basin 2	537	509	439	466	372
Basin 3	395	240	258	300	230
Basin 4	359	299	281	314	176
Basins 5, 6	738	788	790	796	783
Basin 7	111	788	790	796	783

At certain times of the year, these reductions could, in localized areas, have a beneficial effect on dissolved oxygen and other water quality parameters. It is unclear, however, whether there are seasonal trends which would affect water quality. BOD and suspended solids concentrations measured during the 1992-1993 sampling program were examined by model basin for seasonal trends (Figures 6-3 and 6-4). Although concentrations of BOD and suspended solids varied monthly, it is unclear whether these variations resulted from seasonal conditions or from some other factors, such as sampling or analytical procedures. Seasonal BOD and suspended solids concentrations were input to the lake

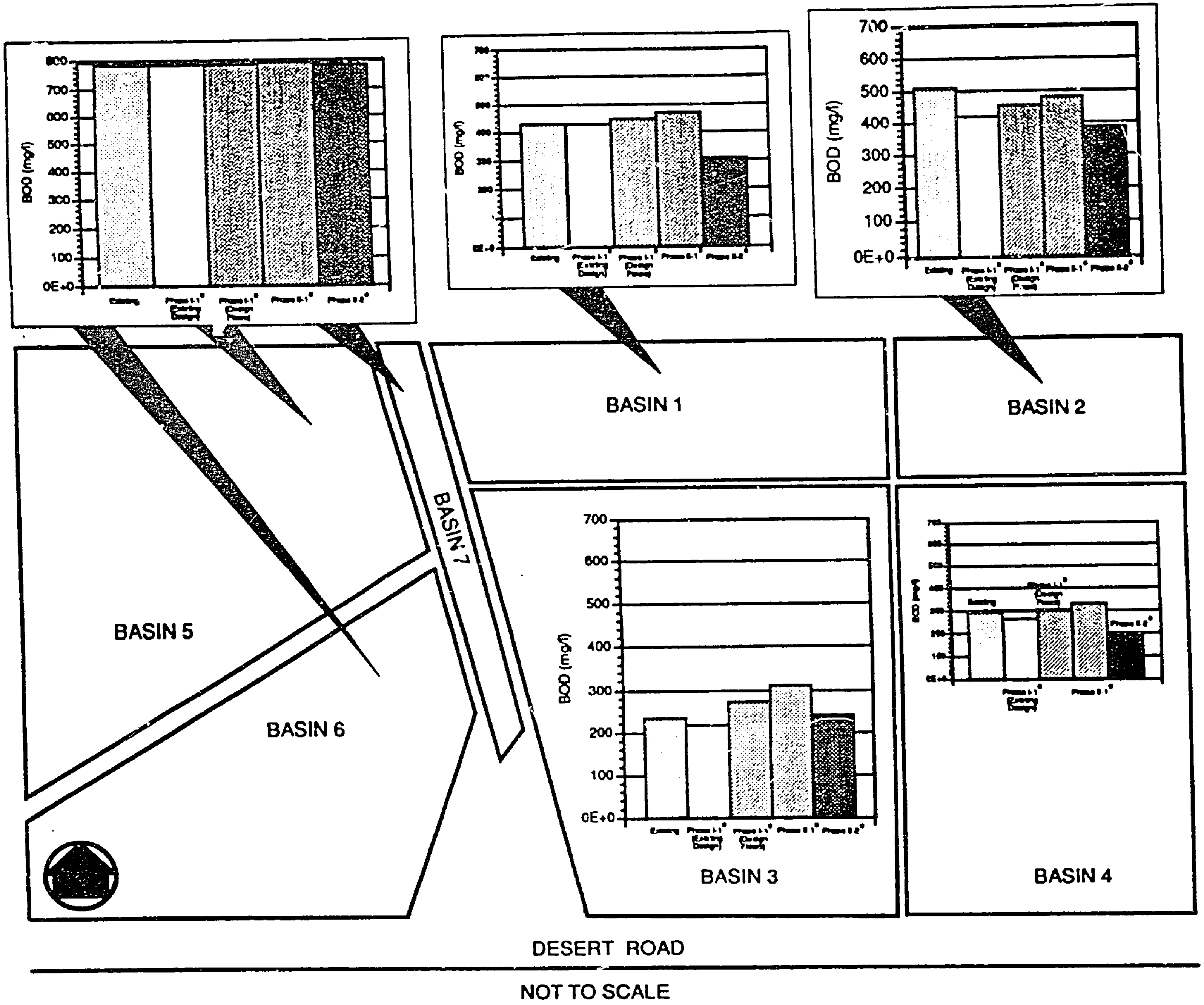

FIGURE 6-2. SUMMARY OF MODEL PREDICTED BOD CONCENTRATIONS FOR LAKE MARYOUT

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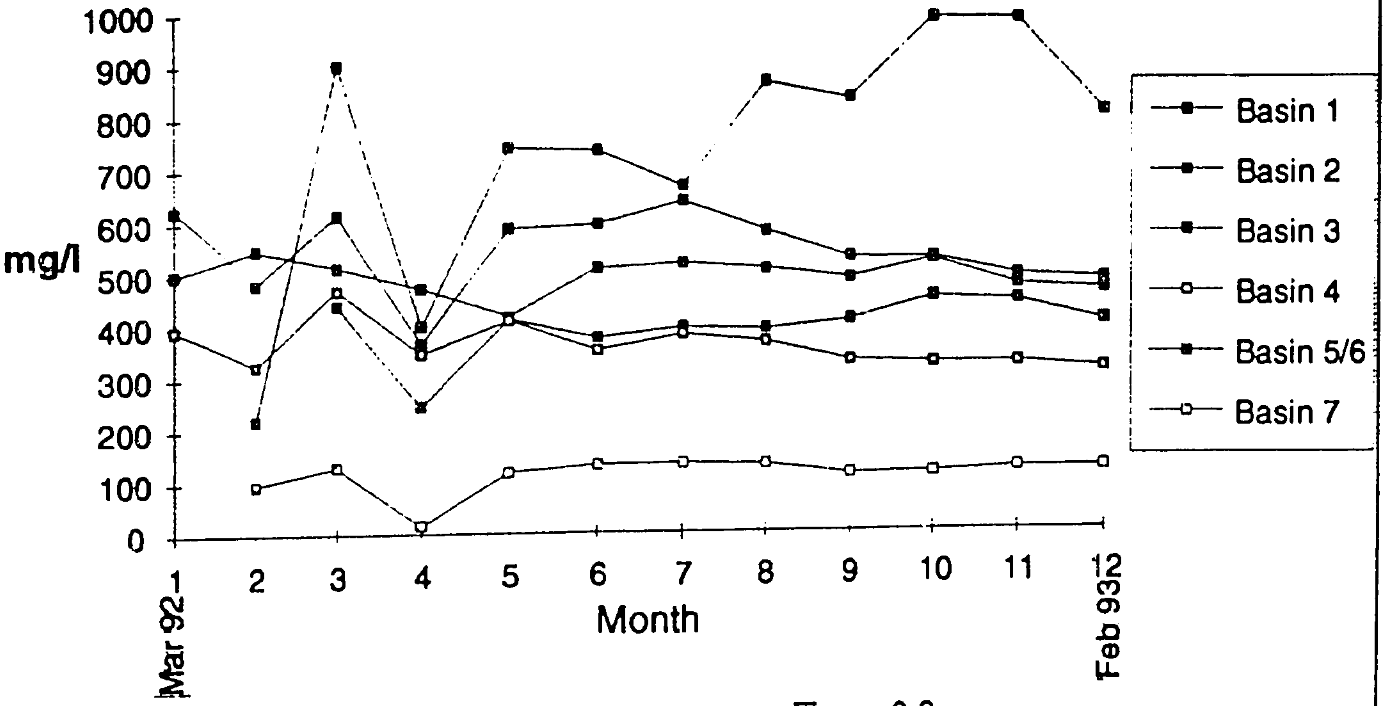

Figure 6-3
MONTHLY MEASURED BOD
CONCENTRATIONS BY MODEL BASIN

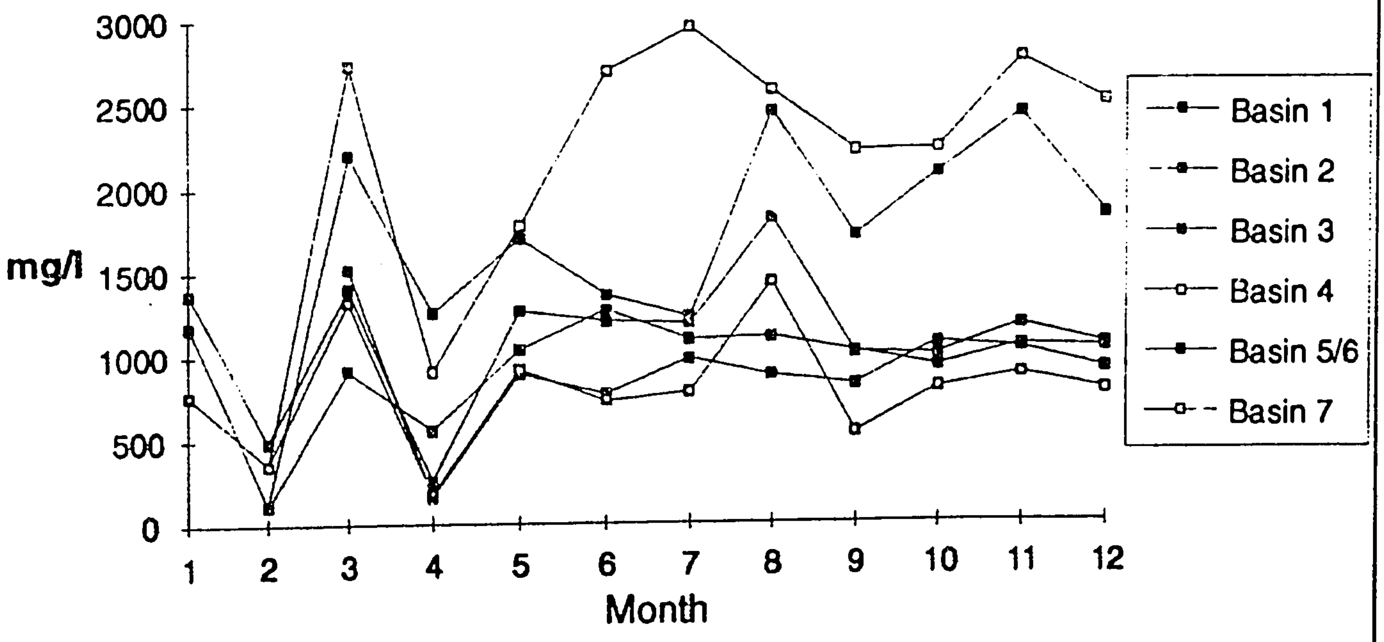

Figure 6-4
MONTHLY MEASURED SUSPENDED
SOLIDS CONCENTRATIONS BY MODEL BASIN

model of existing conditions. While the predicted concentration of BOD increased in some basins during some seasons, concentrations in other basins decreased under the same conditions. Thus, annual average conditions were used to simulate the Lake and to predict future BOD concentrations in the Lake under various wastewater treatment scenarios.

The bacterial concentrations were not modeled for several reasons. The bacterial data from the 12-month monitoring period were highly variable as discussed in Sections 3 and 4. Also, because disinfection is not part of the newly constructed primary treatment plants, the bacterial removal rate is unknown and extremely difficult to predict. Similarly the die-off rate in the Lake is unknown and there is little information available to predict coliform die-off in lakes like Maryout.

Even without modeling, it is possible to qualitatively discuss coliform bacteria concentrations following implementation of wastewater treatment. Probably the most significant change from existing conditions resulting from the first phase of the wastewater management program will be to significantly reduce coliform concentrations in lake shore areas. By removing the direct discharges of untreated wastewater from the northern shore, the concentrations in the near shore water, which are currently elevated, should decrease to levels more typical of the open water areas. Also, by removing approximately half the solids in the raw wastewater, the primary treatment plants should also significantly reduce total bacterial loading to the Lake.

Although implementation of Phase I will reduce bacterial concentrations in some near shore areas and total loads to the Lake, conditions in some localized areas may not improve. Concentrations in the Kalaa Drain could be similar to or even higher than currently exists due to the East Treatment Plant discharge. Similarly the concentrations on the western end of the north shore could be comparable to existing concentrations due to West Treatment Plant effluent. Inclusion of Phase II flows would be expected to increase bacterial concentrations, compared to Phase I conditions in these localized areas. Secondary treatment of all flows may result in concentrations similar to those seen during Phase I, which represents reduced flows but only primary treatment.

The changes in coliform bacteria concentrations resulting from Phase I, II, or secondary treatment would be relatively small compared to the magnitude of the existing problem. The significant concentrations in the lake input water (generally over 10^3 per 100 ml) and many of the numerous local sources of coliform bacteria would not be altered by the treatment plants. Consequently, the conditions in Lake Maryout would continue to pose a public health risk for both primary and secondary contact.

Section 7
Conclusions

1. Lake Maryout has been in a highly degraded condition over the past 20 years. The poor quality is evident in very low dissolved oxygen concentrations and a significantly degraded biological community. The stress on the Lake's biota is seen in a much reduced fishery. There is also an apparent absence of benthic organisms, which should be a significant component in the biological community in a lake such as Maryout and they were 20 years ago (Serruya and Pollingher, 1983). The impact on the lake system stems from excessive loading of organic matter, which consumes oxygen, and nutrients which stimulate plant growth and ultimately consume oxygen. The Lake is also significantly stressed by concentrations of toxic chemicals (particularly metals) much greater than levels known to be harmful to biota. The Lake continues to represent a significant public health threat as indicated by levels of coliform bacteria one hundred or more time those of concentrations considered safe for even secondary human contact.

    a. The conditions throughout the Lake are not uniform. The shoreline water quality, particularly along the north shore, is significantly worse for most measures of pollution. The close proximity to sanitary discharges and shoreline activities, including garbage disposal in the Lake, produced the extremely poor conditions along the shore.

    b. The deterioration in lake conditions over the last 20 years reflects several trends in the Alexandria area. The population, agricultural activity, and industrial development have increased substantially. Each of these activities resulted in an incremental increase in pollutant load to Lake Maryout which is the receiving water for much of the Alexandria area. Lake deterioration has also been influenced by a drop in lake level of 0.3 and 0.6 meters which, in a lake that averages less than 2 meters total depth, is significant, The effects have been a decrease in available dilution, alteration of hydrodynamics and decrease in total assimilative capacity.

    c. The effort during the past 10 years to eliminate sewage from Mediterranean beaches and other areas of the City has resulted in significantly improved beach and City conditions. However, it has also resulted in increased discharges to Lake Maryout. The increased discharges have contributed to some of the locally poor conditions, such as those observed at the north shore of the Lake in 1993.

2. The situation will improve when the Phase I wastewater treatment facilities are operational. At this writing, both plants have been in shakedown operation for three months.

a. The West Zone interceptor will intercept raw wastewater discharge presently discharged to the Lake and provide primary treatment. Primary effluent will be discharged to the Lake at the plant.

b. The East Plant will receive flows from the eastern portion of the City. Primary effluent will be discharged to the Lake by way of the Hydrodrome and Kalaa drains.

3. The following removals of pollutants to the Lake from domestic and industrial wastewater will take place under various flows.

	Flow ML/D	Kg/d BOD Influent	Kg/d BOD Effluent to Lake	Kg/d TSS Influent	Kg/d TSS Effluent to Lake
Existing	585	297,162	304,200	404,494	310,050
Ph I (PRIM)	585	304,200	238,810	310,050	167,480
Ph II (PRIM)	1019	529,880	397,410	540,070	244,860
Ph II (SEC)	1019	529,880	105,976	540,070	135,000

The Phase I construction has removed raw wastewater discharges from streets and beaches, a significant public health improvement.

4. The effluent form the treatment plants will be discharged to the Lake on an interim basis. This will result in important water quality improvement, particularly along the North Shore by eliminating raw wastewater discharges. However, much of the Lake will remain in a significantly degraded condition and a long term effluent discharge solution will be needed.

5. While the Phase I program will reduce the wastewater impacts on the Lake by reducing BOD and wastewater solids, a larger nutrient contribution will continue to enter the Lake via the agricultural drains.

6. Under current, preoperation of the treatment plant conditions, there are three major sources of pollutants to the lake: sanitary waste, industrial waste, and agricultural activities. The sanitary waste, particularly as represented by the discharges on the north shore of the Lake, is a major source of bacterial contamination. Although the discharges represent a relatively small portion of the flow to the Lake, the extremely high bacterial concentration results in lake concentrations 10 to 100 times those in the drains. The industrial discharges, as represented by the Industries Drain, contributed extremely high concentrations of metals and other toxic chemicals. The other sources were also significant contributors, but this was likely due to industrial discharges to the other drains.

The agricultural drains, (primarily Omoum Drain) are the major sources of water to the system and were heavily loaded with organic matter and nutrients.

7. Conditions in the Omoum agricultural drain, which is the major pollutant input to the Lake, showed increases between 1983 and 1993 comparable to the increases seen in the Main Basin of the Lake. North shore conditions, which reflect sanitary discharges and shoreline activities, such as solid waste disposal, also showed similar deterioration in 1993 compared to 1983. Although other agricultural and land use related pollution sources were not measured in both 1983, and 1993, it is likely that loads from such sources increased during the period similar to the increases seen at the north shore and Omoum Drain.

8. Use of in-country sampling and analysis resources allowed for training opportunities and evaluation of available equipment and other resources. Important training, particularly in the area of QA/QC, was achieved by this program. Although all data may not be adequate to fully evaluate small scale spacial and temporal trends, the analyses did produce information to characterize the condition of the Lake and make future predictions. Also, the evaluation of resources indicated that the capabilities were definitely in place to conduct analyses of the Lake and other systems. There were, however, some equipment and other limitations which must be addressed to bring the in-country laboratories up to the QA/QC approach used in the USA. In addition to equipment, hands-on training of staff in the areas of data verification and other procedures would be important items in subsequent work.

9. A simplified model was constructed from historic and 1993 data to predict conditions resulting from various wastewater treatment scenarios. Dissolved oxygen, which is essential to aquatic life is currently near zero in most of the lake and would continue to be under most future conditions. Consequently modeling dissolved oxygen provided little information. As a substitute biochemical oxygen demand (BOD) which is the major consumer of oxygen was modeled. Predicted BOD concentrations in the basins used for modeling at and adjacent to the north shore would be up to 18 percent lower with implementation of Phase I primary conditions. With Phase II flows and primary treatment, BOD shoreline conditions would be worse than existing, However, secondary treatment of Phase II flows could result in up to 30 percent reduction in shoreline BOD concentrations. Although bacterial conditions were not modeled, improvement in shoreline concentrations of coliform bacteria under the various wastewater treatment scenarios should be at least as great as those modeled for BOD. However, other bacterial sources would most likely continue to represent potential public health risks, even in near shore areas.

Section 8
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Appendix A

Sampling and Quality Assurance Plan for 1992/93 Lake Maryout Investigation

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1 Introduction and Project Description

1.1 Introduction

This document outlines the chemical, physical, and biological data quality assurance standards by which the sampling and analysis efforts shall be conducted at the Laboratories of the High Institute of Public Health, Environmental Health Department.

This document presents the detailed site-specific field and laboratory procedures to be followed, to insure the quality and integrity of the sampling and the analytical procedures adopted during the conduct of the Lake Maryout Study. The data will be further used in the environmental impact assessment of the treated waste discharge to the lake, which will be the final recipient of the primary treated combined industrial and domestic wastewater effluent.

This document is prepared to assure that the collection and analysis of the samples are both performed in the highest quality manner and the results will closely represent the status of pollution in the lake. Sediment and water samples will be collected and preserved according to the EPA standards of sampling and preservation. Sample analysis will be conducted according to Standard Methods of Water and Wastewater Analysis.

1.2 Site Location and Description

Lake Maryout is a brackish water lake receiving its water from agricultural drains, which collect drainage water from the Delta region and flow by gravity to El Omoum Drain. Omoum Drain, in turn, discharges to the southwest corner of the lake's main basin, the basin of concern in this study. The second drain is El Kalaa Drain which discharges at the southeast corner of the basin under study. In addition, Noubaria Canal is considered the fresh water source for the lake, yet its water by the time it reaches the lake is saline and polluted. Industrial waste effluents are also mixed with domestic effluents and are discharged into the north side of the lake at Moharrem Bey, at Ghiet El Enab, and at Karmous.

During Phase I, the East Treatment Plant, after primary treating 410 ML/D, will discharge its effluent into an agricultural drain leading to El Kalaa Drain and finally into Lake Maryout. The West Treatment plant, after primary treatment of the combined domestic and industrial effluents, will discharge 175 ML/D into the northwest corner of the lake. According to the Alexandria Master Plan, the three north sewage industrial outfalls will be diverted to the collection system, and their discharges will then flow to the West Treatment Plant.

The lake site is about 3,000 feddans, with a very shallow bottom reaching 150 cm at its deepest location and a depth of 50 cm at shore locations around the lake periphery. The east side of the basin is presently being filled with solid wastes and garbage collected from the City. Solid waste leachate from this side is an added nonpoint source of pollutional load to the lake basin.

Excessive weed growth around the periphery and on isolated small islands in the lake hinders the process of natural reaeration in the basin. The excessive organic and toxic chemical loads reaching the basin, in addition to low natural reaeration rate, contribute severely to the lake's continuous anaerobic state. The lake water level is maintained at a relatively constant level by means of the El Mex pumping station where water is discharged through a dug canal to the Mediterranean Sea.

1.3 Site Background

Lake Maryout used to be a highly productive fishing lake as well as a recreational lake for wild duck hunting. The lake was divided into four basins upon the construction of the highway connecting Alexandria with the desert areas around it and with Cairo. As the area around the lake became more developed, the cleanest east basin, used as a fishery basin, was filled with garbage and used as a garden. The eastern side of the main basin is in the process of also being filled with domestic and industrial solid wastes.

Industrial development has occupied a relatively wide stretch around the lake with various industrial activities dumping their untreated wastes directly into the lake. Domestic and industrial wastes generated and collected in the sewer system in the eastern part of the Governorate are also discharged to the lake without any treatment either.

Domestic sewage, mixed with agricultural drainage water, find its way to the main basin of the lake through Gheit El Enab and Karmous drains. At the farthest southwest corner of the main basin, petroleum companies discharge their cooling and processing water, which is laden with oils and petroleum derivatives.

1.4 Project Objectives

Lake Maryout monitoring has been carried several times during the past years. Since the pollutional status of the lake is ever escalating, it was determined by USAID that an evaluation was now needed of the main basin condition, ahead of its use as the final recipient of the primary treated combined industrial and domestic effluents, discharged by the East and West Treatment Plants. Any environmental adverse impacts, and any possible remedial alternatives, could be determined through the generation of data collected during this study.

The major part of the present land base sources of pollution will be collected in the sewer system and diverted to the two treatment plants for primary treatment and discharged to the lake at two points. The effect of this waste concentration can be evaluated if the background status of the lake's main basin is documented. Any remedial actions needed can be assessed.

Biological analyses of the lake water samples will give a clear indication of the lake's self-cleaning capabilities. To achieve this, water samples for chemical, bacterial, and algal analyses will be collected in proper containers with preservatives to maintain the samples in their original form. Heavy metal analyses will also be performed on these samples.

Sediment samples will be collected for analyses of their heavy metals, as well as their organic and inorganic constituents. Water samples from the land base sources will be collected and analyzed for their physical and physiochemical parameters in addition to their heavy metal contents.

1.5 Sampling Schedule

A reconnaissance survey of the lake's land base sources of pollution, as well as Kalaa and Smouha Drains, was started in March 1992. The sampling schedule will be repeated for 12 months to cover seasonal variations encountered in the lake. Sampling will be carried out on two consecutive days. During the first day, samples from drains and landbase outfalls will be collected. On the second day, water and bottom sediments samples from the main basin will be gathered and sent to the laboratory within half an hour from sampling termination. Usually, lake sampling takes about 1.5-2 hours. A similar time is expected for land base samples.

1.6 Data Usage

The organic and inorganic analyses of the water and bottom sediments in the lake will provide background information, which will be compared with the similar estimated parameters for the lake after receiving the Phase I wastewater effluents. This will allow for identification of important factors affecting the self-purification process of the lake. Bottom sediment analyses will allow the estimation of the organic and heavy metal loads that may be released from the bottom to the lake, and which would add to the lake's total pollution loading.

2 Quality Assurance Objective

2.1 General

The comprehensive Quality Assurance (QA) objectives for the Lake Maryout study is to provide guidelines for all field and laboratory procedures to be followed in this study and in any future surveys of the main basin of the lake in order to assess the Phase I impacts on the lake.

The intention of the sampling and analysis effort is to produce data of acceptable quality to allow for an accurate evaluation of the chemical, biological, and ecological impacts of the present and future sources of pollution. An additional effort will be to provide a basis for any remedial restoration of the lake in order to accommodate the future discharges.

The main QA objective for this study is to obtain all measurements as representable as possible for the actual site conditions and all data resulting from sampling and analysis activities to be comparable. The use of accepted, published, sampling, and analysis methods, as well as the use of standardized units, shall assure the comparability of the data.

The major characteristics of data quality to be addressed, during development and presentation of the sampling and analytical plan, are defined hereinafter.

2.2 Accuracy

Accuracy is defined as the degree of agreement of a measurement (or measurement average) with an accepted reference or true value. It is a measure of system bias and is usually expressed as a percentage of the true value.

Accuracy will be determined in the laboratory through the use of spike and duplicate analysis. The head team shall select a spike sample every five samples to be analyzed and measured following the same parameter scheme under investigation. A frozen volume of each sample will be preserved till the finalization of the monthly analysis program, in case any sample needs to be rechecked. In this way, a fresh sample can be obtained upon thawing. Algal analysis will be maintained by preserving the samples with iodine solution and refrigeration, as freezing can alter its quality. Spiked samples of known chemical concentration will be prepared under the direct supervision of the team leader by another lab chemist not involved with the study and without revealing the name of chemicals being used, just referring to them as chemical A, B, etc.

Enough volume of both water (liters) and sediment samples (500 cc) will be collected at each sampling station in the lake basin. Sterile glass bottles will be used for bacterial analysis, and will be sent to the laboratory in an ice chest surrounded with plastic bags filled with ice.

Sampling accuracy shall be maintained by adhering strictly to the procedural protocol agreed upon by the team and WWCG, in order to achieve the goals of the study.

2.3 Precision

Precision is a measure of the amount agreement among individual measurements of the same parameter under similar conditions. It is expressed in terms of relative percent difference (RPD) between replicates or in terms of the standard deviation when three or more replicate analyses are performed.

Precision shall be determined through the use of duplicate analyses for the same sample. The RPD between the two results shall be calculated as a measure of analytical precision.

2.4 Comparability

Comparability expresses the confidence with which one data set can be compared to another. To achieve comparability in this study, the data generated will be reported using units of ug/l, ug/kg, and mg/kg. Securely prepared standard reference samples will be locally prepared to ensure data validation.

2.5 Procedures for Data Assessment

The precision values will be presented in a table showing the variability for replicate measurements of the same parameter, and are expressed in terms of relative percent difference for duplicate measurements made on samples. Accuracy values include components of both random error (i.e., variability due to imprecision and systematic error, (i.e., bias)), and thus reflect the total error for a given measurement.

3 Sampling

3.1 Sampling Objectives

WWCG will conduct the survey of the lake's main basin, its contributing drains, and the sewer outfalls discharging to the lake. A representative sample of the water column and the bottom sediment at each lake site will be collected using a bottom sampler and a BOD sampler at three levels identified at 30 cm from the bottom, middle depth, and 30 cm below the water surface. The three samples will be equally mixed for each site sample.

For the drain sampling, water samples will be collected using the previous technique, to give a clear indication about the current status of the drains pollution load and to assess the impact of primary treated wastewater effluent discharged by these drains. The effect of the industrial effluents discharged from Moharrem Bey Industrial Complex will be also assessed by sampling the outfalls ahead of their discharge into the lake.

3.2 Sampling Location

Sampling locations are shown in Figure 1 and described below.

Land Based Stations

Station 1	Smouha Drain upstream of East Treatment Plant discharge. This station was selected to represent the sewage which will eventually be diverted to the East Treatment Plant. On the days of sampling (as during the 92/93 sampling program) flows were going directly to the Smouha drain and not diverted to the East Treatment Plant.
Station 2	Kalaa Drain upstream of the Hydrodrome Drain. The water quality at this station represents the ambient quality of the receiving waters upstream of the confluence with the Hydrodrome Drain. The Hydrodrome Drain will contain the East Treatment Plant effluent once the plant begins operation and currently contains the raw sewage from the east zone.
Station 4	Kalaa Drain downstream of the Hydrodrome Drain. The station is at the Kalaa Drain Pump Station and represents the combined water quality of the Kalaa and Hydrodrome drains.
Station 5	Mouth of Kalaa Drain. Station 5 is on the Kalaa Drain at the Desert Road immediately prior to the drain's discharge to the lake. The water quality at this location represents one of the major inputs to Lake Maryout.

Station 6	Industries Drain. This is the easternmost drain along the north shore of Lake Maryout. It receives a heavy contribution of industrial flow. On the day of sampling the flow was being diverted to the West Treatment Plant, but we were able to sample upstream of the diversion.
Station 7	Central Discharge Drain—East. This is one of two drains entering the central north shore of the lake. On the day of sampling the sewage was being diverted to the West Treatment Plant and it was not sampled. We did collect a sample designated as 7, but this was a duplicate of Station 20.
Station 8	Central Discharge Drain—West. Station 8 is the second drain entering the central north shore of the lake. Although the flows were being diverted to the treatment plant on the day of sampling we were able to collect a sample upstream of the diversion.
Station 9	Westernmost drain on the north shore. This drain was diverted to the treatment plant and no sample was collected.
Station C	West Treatment Plant. The sample was collected from the effluent channel at the West Treatment Plant. On the day of sampling the influent was being diverted directly to the effluent channel, thus no removal was being achieved in the clarifiers, and the sample represented influent quality.
Station C	Mouth of the Omoum Drain. The Omoum Drain is the major input to the lake, and Station 19 represents the point of discharge to the lake.
Station 20	El Mex Pump Station. Station 20 is located on the discharge channel of the El Mex Pump Station approximately 300 meters downstream of the pump station and 100 meters upstream from the confluence with the Mediterranean. The pump station is the only significant discharge from Lake Maryout, thus all inflow to the lake must leave via the pump station or evaporation. The discharge channel from the pump station enters a channel which flows through an industrialized (e.g., oil refinery) and highly developed residential area before discharging to the Mediterranean.

Lake Stations

Station 10	East End of Lake Maryout. This station is between the discharge of the Industries Drain and the discharge of Kalaa Drain.
Station 16	Lake Maryout at Kalaa Drain. Station 16 is the mouth of the Kalaa Drain. Although it is accessible from the lake, the drain currents are detectable.

Station A	Northern Shore of Lake Maryout. This station is one of four on the north shore of the lake directly opposite drain discharge points. Station A is opposite the Industries Drain (sample Station 6).
Station 11	Northern Shore of Lake Maryout. Station 11 is opposite Station 7.
Station 12	Northern Shore of Lake Maryout. Station 12 is opposite Station 8.
Station 13	Northern Shore of Lake Maryout. Station 13 is opposite Station 9.
Station 23	Northern Shore of Lake Maryout. Station 23 is in an area similar to Stations 11, 12, and 13 at about the midpoint along the north shore except it is not directly opposite any drain.
Station 21	Lake Center—Middle. The station represents the open water area of the lake removed from the shore or any immediate influence of drains or discharges entering the lake.
Station 22	Lake Center—West. The station is similar to Station 21 (open water, away from drains or discharges) in the western portion of the Main Basin.
Station 24	Northwest Basin. A sample was taken in the Northwest Basin approximately 300 meters north of the Desert Road. The basin does not receive any known drain discharges, however, the shore of the basin is developed, and wastewater from the developed area enters the basin.
Station B	Southwest Basin. Station B is located approximately 300 meters south of the desert road and 100 meters west of the Noubaria Canal. Discharges from local development are the only known wastewater inputs to the Southwest Basin.

3.4 Field Quality Control for Sampling

To assure a true presentation of the water quality sampled, water samples will be collected from three depths at each site, and will be further mixed in a plastic container, clearly marked with a non-flowing black marker on both sides of the container. Only one container will be used for each sampling site. Bottom samples will be collected by mixing three bottom catches from the bottom sampler and then taking one quarter of the total amount at random.

Temperature readings will be taken as the average of two thermometer readings measured at each site. Depth will be measured twice and averaged at each site. Dissolved Oxygen is measured at the laboratory after fixing it at the sampling site. The BOD bottle will be filled with minimal disturbance at the three depths at each site. Samples from land base polluted water sources will be collected at a middle point of the source, with the BOD sampler to achieve proper mixing of the sampled water at all depths. To collect the volume of at least 12 liters from each site, the BOD sampler will be filled at each site at least 11 times and emptied in the container, which will result in good sample representation of the water at each location.

Bacteriological samples will be collected in sterilized glass bottles from the water samples collected at each site.

Disturbance effect of the water in the lake, due to the mixing action of the boat propeller will be minimized by shutting down the motor 50 meters away from the sampling location and allowing the boat to move under its own inertia towards the sampling site.

3.5 Sample Containers and Preservation

Table 1 lists the type of containers and sample preservatives required, and the maximum holding time allotted for each analysis. Plastic containers were purchased from a local supplier from the type used for storage of drinking water. Thorough washing will be carried on each container after and ahead of its use, with hot water and a pure liquid detergent concentrate free of phosphates. Further rinsing with cold water for three times with at least two liters of tap water followed by 500 ml distilled water will be part of the sample container preparation.

Glass containers will be of good quality glass for water sample collection for biological and bacteriological analysis. Bottles with narrow mouth and a capacity of 250 ml will be used after autoclaving for the bacterial analysis.

Acid digested water samples and bottom sediments will be sent to the heavy metals analysis laboratory in 50 ml capacity medical grade tight plastic containers labeled with the sample number and type of sample whether water or bottom sediment.

Samples collected for biological analysis will be taken in high quality dark glass to minimize the light effect on algal growth. The collected sample from variable depths will be stored in these bottles at each site.

3.6 Analytical Procedures

Table 2 summarizes the analytical parameters measured and the analytical techniques to be used during this study. All analysis will be carried according to the Standard Methods of Water and Wastewater Analysis published in 1987.

Table 1
Sampling and Preservation of Samples According to Measurement

Measurement	Vol. Req. (ml)	Container	Preservative	Holding Time
Acidity	100	P, G	Cool, 4°C	24 Hrs.
Alkalinity	100	P, G	Cool, 4°C	24 Hrs.
BOD	1,000	P, G	Cool, 4°C	6 Hrs.
COD	50	P, G	H_2SO_4 to $pH < 2$	7 Days
Chloride	50	P, G	None Req.	7 Days
Color	50	P, G	Cool, 4°C	24 Hrs.
Dissolved Oxygen Probe	300	G only	Det. on site	No Holding
Winkler	300	G only	Fix on site	No Holding
Hardness	100	P, G	Cool, 4°C	7 Days
Metals Dissolved	200	P, G	Filter on site HNO_3 to $pH < 2$	6 Mos.
Suspended			Filter on site	6 Mos.
Total	100	P, G	HNO_3 to $pH < 2$	6 Mos.
Nitrogen Ammonia	400	P, G	Cool, 4°C H_2SO_4 to $pH < 2$	24 Hrs.
Kjeldahl	500	P, G	Cool, 4°C H_2SO_4 to $pH < 2$	24 Hrs.
Nitrate	100	P, G	Cool. 4°C H_2SO_4 to $pH < 2$	24 Hrs.
Nitrite	50	P, G	Cool, 4°C	24 Hrs.
Oil & Grease	1,000	G only	Cool, 4°C H_2SO_4 to $pH < 2$	24 Hrs.
pH	25	P, G	Cool, 4°C Det. on site	6 Hrs.
Phosphorus Orthophosphate, Dissolved	50	P, G	Filter on site Cool, 4°C	24 Hrs.
Sulfide	50	P, G	2 ml zinc acetate	24 Hrs.
Temperature	1,000	P, G	Det. on site	No Holding
Turbidity	100	P, G	Cool, 4°C	7 Days

4 Sample Custody

4.1 General

Special consideration has been given for the validation of the environmental measurement data to demonstrate that samples have been obtained from the location stated and that they have reached the laboratory without alteration.

The field team leader is responsible for overseeing and supervising the implementation of proper sample delivery at the laboratory, as well as securing them in the lab in a restricted area where nobody other than the authorized personnel can deal with them. Samples while not in use will be kept in refrigerators in order to minimize any possible changes in their water quality.

Once the samples arrive at the lab, a volume of 500 ml is kept frozen in the deep freezing section of the lab refrigerators to be thawed and analyzed in case the data for any physical or chemical parameter needs to be rechecked. The team leader will assure this step is carried out upon sample arrival at the laboratory.

4.2 Laboratory Sample Custody Procedure

Upon sample arrival, the chief chemist is responsible for accepting the samples and checking with the team leader to insure that the sample numbers, locations, and tags are all accounted for in case any sample is damaged during shipment and transportation.

Chief chemist must verify that samples are preserved and collected in proper containers. In case of mistakes, immediate corrective action is required. The chief chemist will also record the general information of the samples, including the project name, sample number, date of sampling, and source of samples, in a log-in book.

Project supervisor is responsible for the different analytical task appointments within the specialized staff. Chemical and physiochemical analyses are carried by a group of five analysts to insure accurate results. Each analyst has been assigned certain parameters in order to minimize variations in the results due to personal variability.

Bottom sediment analysis will be carried out by one expert during the project duration. Bacterial and biological analysis will also be performed by one specialist. Heavy metals analysis for both water and bottom sediments will be acid digested and analyzed by atomic absorption spectrophotometry by another specialist.

Overall supervision on the samples is the responsibility of the chief chemist, double checked by the project supervisor.

BOD bottles will be kept in a wooden rack which holds 30 bottles at one time. Bacterial analysis bottles will also be transported in wooden racks to prevent their spillage. Same procedures will be maintained for the biological samples using a wider rack with smaller number. Special racks will be used for keeping the DO fixing solutions, thermometers, and preservative solutions, to prevent breakage or spillage.

4.3 Photographs

The team leader will document, through the use of color photography, various on-site environmental conditions of the different sampling locations as deemed necessary. Examples of items that may require such photographic documentation include:

- General site pollutional conditions
- Exact sample locations
- Physical appearance of environmental samples

4.4 Field Logbooks

A field logbook will be maintained by the field team leader and a record of each sample site, depth, and water temperature will be recorded. Observations regarding the visible status of pollution in the lake sites will also be recorded.

The field team leader has the responsibility of emphasizing the logbook completeness and accuracy. Entries into the logbook shall include :

- Weather conditions, sampling date and time
- pH, water clarity, and temperature
- Description of the sampling sites landmarks
- List of any changes from standard operation procedures, decisions made in the field, and other pertinent information
- Comments relative to any problem areas that occurred during the day's activities, their final resolution, and any anticipated impact on the outcome of the field investigation

5 Calibration Procedures and Frequencies of Analytical Instruments

5.1 Laboratory Instrumentation

Instruments used in the laboratories of the High Institute of Public Health, Department of Environmental Health are all subject to continuous calibration before they are used. The manner in which various instruments are calibrated is dependent on the particular type of instrument and its intended use.

All sample measurements are made within the calibrated range of the instrument. Preparation of all reference materials will be documented in a standards preparation notebook.

Instrument calibration typically consists of two types:

- Initial calibration
- Continuing calibration

Initial calibration procedures establish the calibration range of the instrument and determine the instrument response over that range. Usually the calibration is carried out with three concentrations, having low, medium, and high concentrations. The instrument response over the range is absorbance, or transition, which can be expressed as a linear model with a response factor, or as an amount vs. response plot.

Continuing calibration may be used within an analytical sequence to verify stable calibration throughout the sequence and/or to demonstrate that the instrument response did not drift during a period of non-use of the instrument. Calibration is further ensured by the periodic analysis of quality control samples during the course of instrumental analysis of field collected samples.

The following analytical instruments shall be used to analyze samples according to The Standard Methods for Examination of Water and Wastewater, the fourteenth Edition, and EPA Methods for Chemical Analysis of Water and Wastes.

- pH meter
- Conductivity meter
- Spectrophotometer
- Atomic absorption Spectrophotometer

5.2 Field Test Equipment

Prior to the use of any field test equipment, proper calibration shall be ensured. Specific calibration of certain instruments is described as follows:

pH Calibration

A field digital pH meter shall be used throughout this investigation in order to determine the pH of various water samples. All pH buffer solutions used to calibrate the pH meter are purchased from Fisher Scientific Co. USA.

DO Fixation

A BOD bottle will be filled with the composite water sample from the three depths collected by the DO sampler. Fixation using manganous sulphate solution and alkaline azide solution will be done immediately after the sample collection in the field.

6 Analytical Procedures

6.1 General

The analytical methods specified for the collected samples during this study are summarized in the following table:

Table 2
Analytical Parameters and Procedures in Lake Maryout Study

Parameter	Analytical Procedure	Units of Measurements
Temperature	Glass Thermometer	Degrees Centigrade
Conductivity	Conductivity Meter	umhos/cm
Total Solids	Drying at 103-105°C	mg/L
Dissolved Solids	Filtrable Solids dried at 103-105°C	mg/L
Volatile and Fixed Solids in Water Samples	Ignition at 550°C	mg/L
Volatile and Fixed Solids in Solid and Bottom Sediments	Ignition of Dry Weight at 550°C	mg/L
Heavy Metals	Acid Digestion followed by Atomic Absorption	mg/L
Alkalinity	Titrimetric Analysis	mg/L $CaCo_3$
Chlorides	Argentometric Titration	mg/L Cl^-
Hardness Total	EDTA Titration	mg/L $CaCo_3$
Calcium Hardness	EDTA Titration using Murexide Indicator	mg/L $CaCo_3$
Magnesium Hardness	By Difference	mg/L $CaCo_3$
Ammonia (Nitrogen)	Distillation followed by Nesslerization	mg/L NH_4
Nitrate (Nitrogen)	Chronotropic Acid Calorimetric Determination	mg/L NO_3
Nitrate (Nitrogen)	Deoxidization Method	mg/L NO_2
Dissolved Oxygen	Audiometric Method Azide Modification	mg/L O_2
pH	Glass Electrode	
Phosphates	Stannous Chloride Method	mg/L PO_4
Sulfates	Turbidimetric Method after Filtration	mg/L SO_4
Grease and Oil	Wet Extraction by Petroleum Either after Acidification	mg/L
Oxygen Demand Biochemical BOD	Winkler Modified Azide	mg/L O_2
Oxygen Demand Chemical COD	Dichromate Reflux Method	mg/L O_2

6.2 Laboratory Standards and Reagents

Laboratory standards and reagents are obtained from a local supplier who imports them from Fisher And Coli Parmer Chemicals in Europe. They are all Analytical Grade.

All standards and laboratory reagents and common laboratory solvents are dated upon receipt. The preparation and use of all standards are recorded in bound laboratory notebooks to document their traceability.

Additional information recorded includes the date of preparation, concentration of the prepared solution, and name of preparer.

6.3 Laboratory Generated QC Samples

6.3.1 Calibrated Check Sample

One calibration check sample (CCS) shall be analyzed for every 10 samples analyzed sequentially for all project-specified parameters. A CCS is chosen as one of the mid-range working calibration standards that is reanalyzed periodically throughout the sample analysis to verify that the original calibration is still valid. A composite CCS of known concentrations of chlorides, sulfates, phosphates, and nitrates will be analyzed to determine the recovery of each parameter in the presence of the others (spiked sample).

6.3.2 Method/Reagent Blank

One method/reagent blank shall be analyzed with each sample batch tested. A method blank is comprised of laboratory-pure, analyte-free water carried through the entire sample preparation and analysis procedure. Analysis of the method blank provides a check of the background contamination due to sample preparation procedures.

6.3.3 Laboratory Replicates

One sample per monthly batch of samples will be analyzed in replicate. A replicate sample is produced by dividing a single collected sample into two equal parts for the purpose of determining analytical precision.

6.3.4 Matrix Spike/Matrix Spike Duplicates

A spiked sample analysis will be performed with each parameter determination, using a multi-chemical spiked sample. If the recovery is not within the acceptable criteria limits as specified in the Standard Methods for Water and Wastewater Analysis, the data of those samples and the spike must be repeated.

6.4 Biological Analysis

Water samples collected from the three depths of the lake, as well as those collected from land base sources, will be kept in wide mouth glass bottles in ice chests and after the addition of preservative solution. All water samples will be concentrated by means of Schedwick rafter funnel. The concentrated volume is counted under the microscope using the standard Schedwick cell for algal species identification, and counting. All counts will be presented as counts/liter.

6.5 Bacterial Analysis

The collected samples for bacterial analysis will be subject to serial dilution with sterile water to get the proper dilution of samples that can be cultured and counted on the agar plates.

The MPN technique will be followed to determine the fecal coliform bacterial counts. The presumptive test will confirm the presence of the fecal coliform bacteria. All data will be presented as counts/100 ml.

6.6 Data Presentation

Data of all sample analysis will be presented in monthly cumulative data tables. Each parameter will be presented in a separate table over the different sites for the consecutive 13 months of sampling.

Appendix B

Summary Lake Maryout Water Quality Data 1983 and 1992/93

Appendix B

Summary Lake Maryout Water Quality Data 1983 and 1992/93

In order to assist in data interpretation several summary tables and graphics for some of the parameters potentially affected by sanitary sewage and primary treatment were developed. These data summaries were taken directly from the 1983 data report (WWCG 1983) or the complete 1992/93 data set (Appendix C this Report). They are averages of monthly data for a station or averages of stations from similar areas.

The following summaries are provided in this Appendix:

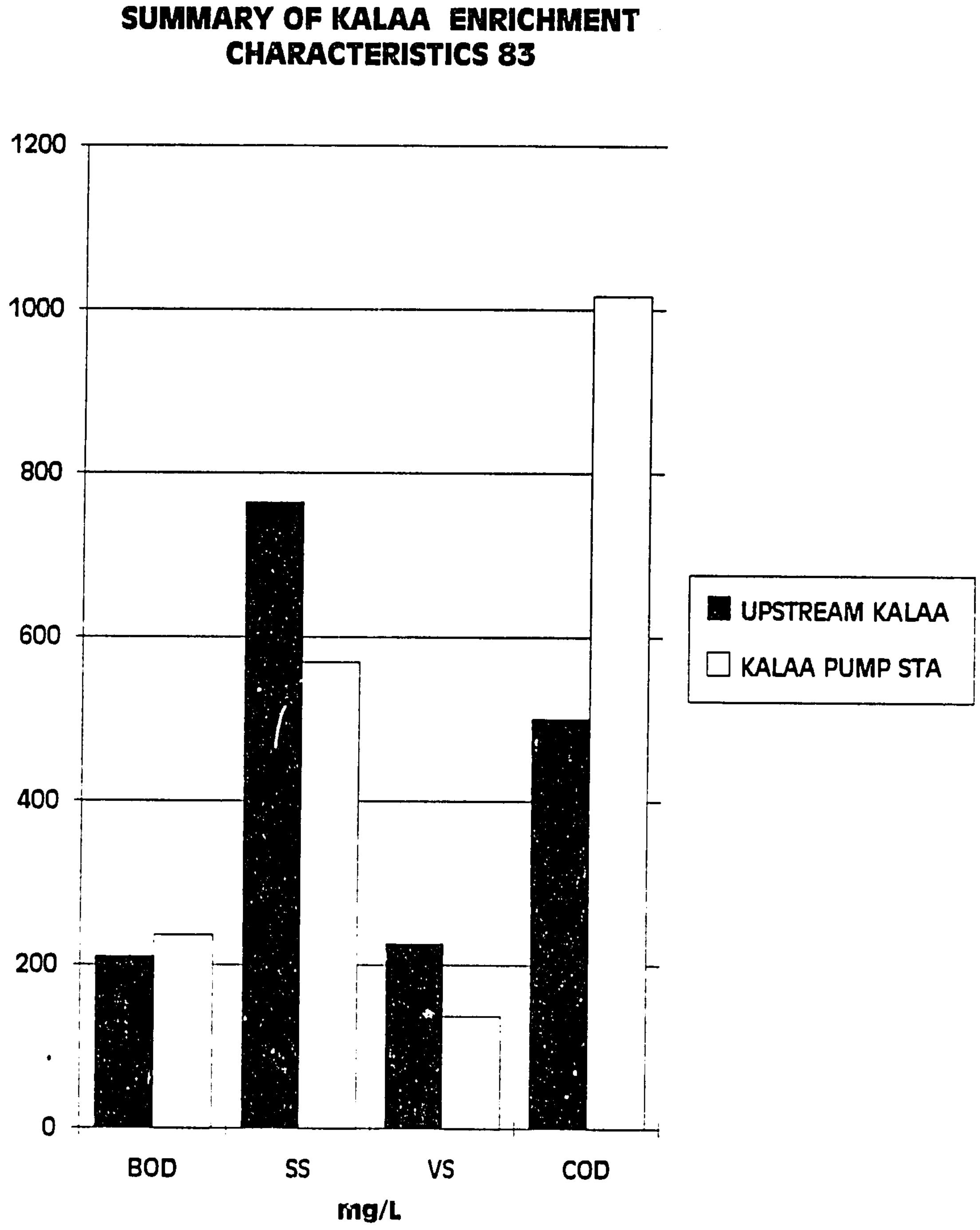
Title	Stations	Parameters
1983		
Summary of Kalaa Enrichment Characteristics	Upstream Kalaa Kalaa Pump Station	Average BOD, SS, VS, COD
Summary of Lake Input Enrichment Characteristics	Kalaa Mouth Omoum Drain	Average BOD, SS, VS, COD
Summary of Shore Enrichment Characteristics	North Shore Stations East Lake Lake at Kalaa	Average BOD, SS, VS, COD
Summary of Lake and Outlet Enrichment Characteristics	Central Lake NW Basin El Mex Pump Station	Average BOD, SS, VS, COD
Summary of Kalaa Nutrient Characteristics	Upstream Kalaa Kalaa Pump Station	Average NH_3, NO_3, PO_4
Summary of Lake Input Nutrient Characteristics	Kalaa Mouth Omoum Drain	Average NH_3, NO_3, PO_4
Summary of Shore Nutrient Characteristics	North Shore Stations East Lake Lake at Kalaa	Average NH_3, NO_3, PO_4
Summary of Lake and Outlet Nutrient Characteristics	Central Lake NW Basin El Mex Pump Station	NH_3, NO_3, PO_4

Title	Stations	Parameters
Summary of Kalaa Metal Concentrations	Upstream Kalaa Kalaa Pump Station	One-month data Cd, Cr, Cu, Ni, Pb, Zn, Hg
Summary of Lake Input Metal Concentrations	Kalaa Mouth Omoum Drain	One-month data Cd, Cr, Cu, Ni, Pb, Zn, Hg
Summary of Shore Metal Concentrations	North Shore Stations East Lake Lake at Kalaa	One-month data Cd, Cr, Cu, Ni, Pb, Zn, Hg
Summary of Lake and Outlet Metal Concentrations	Central Lake NW Basin El Mex Pump Station	One-month data Cd, Cr, Cu, Ni, Pb, Zn, Hg
1992/93		
Seasonal Summary of Enrichment Characteristics (1 Fig. each Parameter)	Kalaa, Inputs, Shore, Lake and Outlet, All Stations	BOD, SS, VS, COD
Seasonal Summary of Nutrient Characteristics (1 Fig. each Parameter)	Kalaa, Inputs, Shore, Lake and Outlet, All Stations	NH_3, NO_3, PO_4
Seasonal Summary of Metal Concentrations (1 Fig. each Parameter)	Kalaa, Inputs, Shore, Lake and Outlet, All Stations	Cd, Cr, Cu, Ni, Pb, Zn, Total Metals
Seasonal Summary of Sediment Metals (1 Fig. each Parameter)	Shore, Lake and Outlet, All Stations	Cd, Cr, Cu, Ni, Pb, Zn, Total Metals
Seasonal Summary of Lake Shore Sediment Volatile Solids	Shore Stations	VS
Seasonal Summary of Open Lake Sediment Volatile Solids	Open Lake Stations	VS
Seasonal Summary of All Sediment Volatile Solids	Shore, Lake and Outlet, All Stations	VS
Summary of Kalaa Enrichment Characteristics	Upstream Kalaa Kalaa Pump Station Smouha Drain	Yearly Average BOD, SS, VS, COD

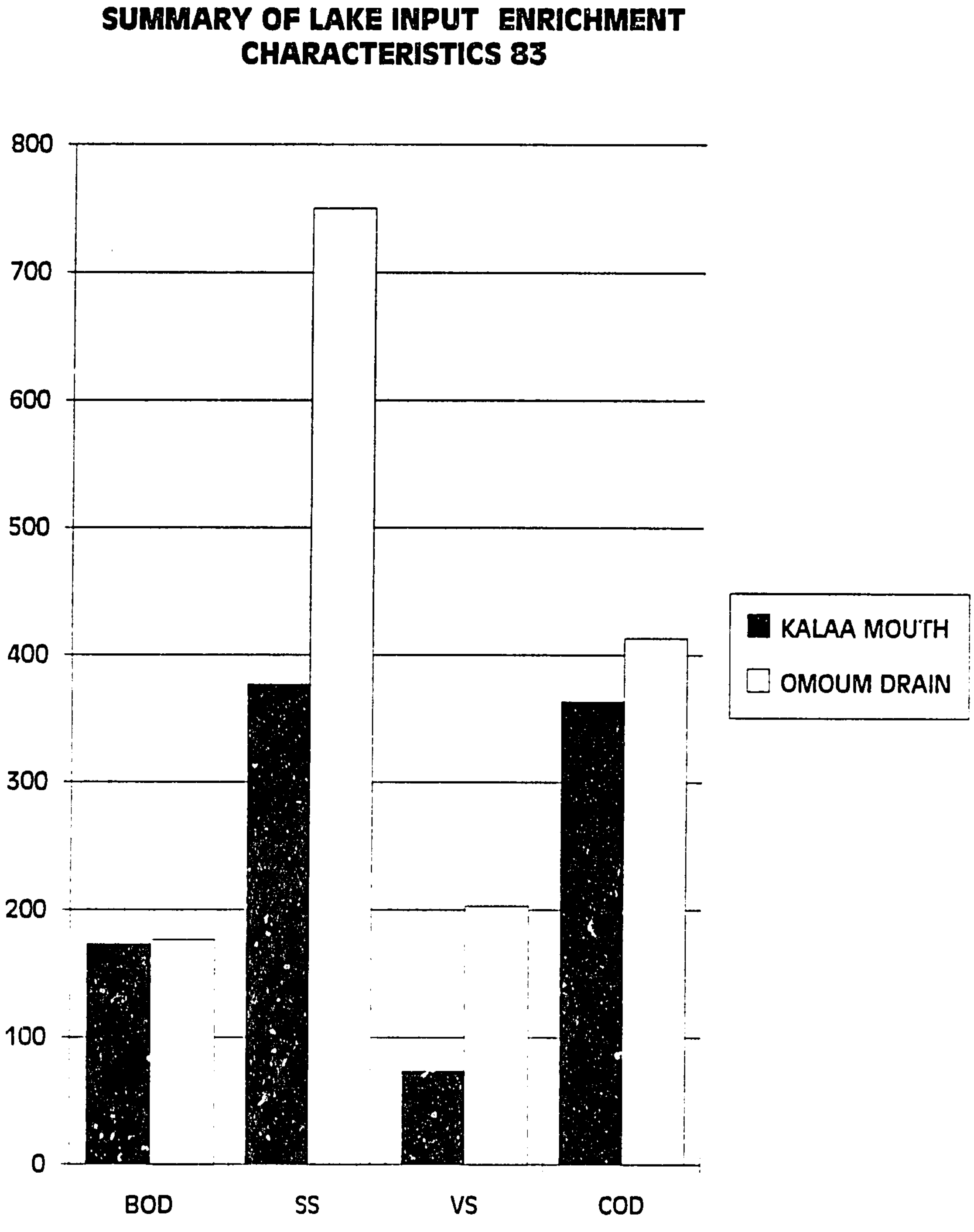
Title	Stations	Parameters
Summary of Lake Input Enrichment Characteristics	Kalaa Mouth Omoum Drain North Shore Drains	Yearly Average BOD, SS, VS, COD
Summary of Shore Enrichment Characteristics	North Shore East Lake Lake at Kalaa	Yearly Average BOD, SS, VS, COD
Summary of Lake and Outlet Enrichment Characteristics	Central Lake NW Basin El Mex Pump Station	Yearly Average BOD, SS, VS, COD
Summary of Kalaa Nutrient Characteristics	Upstream Kalaa Kalaa Pump Station Smouha Drain	Yearly Average NH_3, NO_3, PO_4
Summary of Lake Input Nutrient Characteristics	Kalaa Mouth Omoum Drain North Shore Drains	Yearly Average NH_3, NO_3, PO_4
Summary of Shore Nutrient Characteristics	North Shore Stations East Lake Lake at Kalaa	Yearly Average NH_3, NO_3, PO_4
Summary of Lake and Outlet Nutrient Characteristics	Central Lake NW Basin El Mex Pump Station	Yearly Average NH_3, NO_3, PO_4
Summary of Kalaa Metal Concentrations	Upstream Kalaa Kalaa Pump Station Smouha Drain	Yearly Average Cd, Cr, Cu, Ni, Pb, Zn, Total
Summary of Lake Input Metal Concentrations	Kalaa Mouth Omoum Drain North Shore Drains	Yearly Average Cd. Cr, Cu, Ni, Pb, Zn, Total
Summary of Shore Metal Concentrations	North Shore East Lake Lake at Kalaa	Yearly Average Cd, Cr, Cu, Ni, Pb, Zn, Total
Summary of Lake and Outlet Metal Concentrations	Central Lake NW Basin El Mex Pump Station	Yearly Average Cd, Cr, Cu, Ni, Pb, Zn, Total

Title	Stations	Parameters
Summary of Lake Shore Sediment Metal Concentrations	Shore Stations	Yearly Average Cd, Cr, Cu, Ni, Pb, Zn
Summary of Open Lake Sediment Metal Concentrations	Open Lake Stations	Yearly Average Cd, Cr, Cu, Ni, Pb, Zn
Summary of Kalaa Total Coliform	Upstream Kalaa Kalaa Pump Station Smouha Drain	Geometric Mean
Summary of Lake Input Total Coliform	Industries Drain East Central Drain West Central Drain West Drain Kalaa Mouth Omoum Drain	Geometric Mean
Summary of Lake Shore Total Coliform	North Shore Stations East Lake Lake at Kalaa	Geometric Mean
Summary of Lake and Outlet Total Coliform	Central Lake Northwest Basin El Mex Pump Station	Geometric Mean

	SUMMARY OF KALLA DRAIN ENRICHMENT CHARACTERISTICS 83						
			mg/l				
STA #	DESCRIPTION	BOD	SS	VS	COD		
2	UPSTREAM KALAA	210	764	226	500		
4	KALAA PUMP STA	237	569	138	1017		

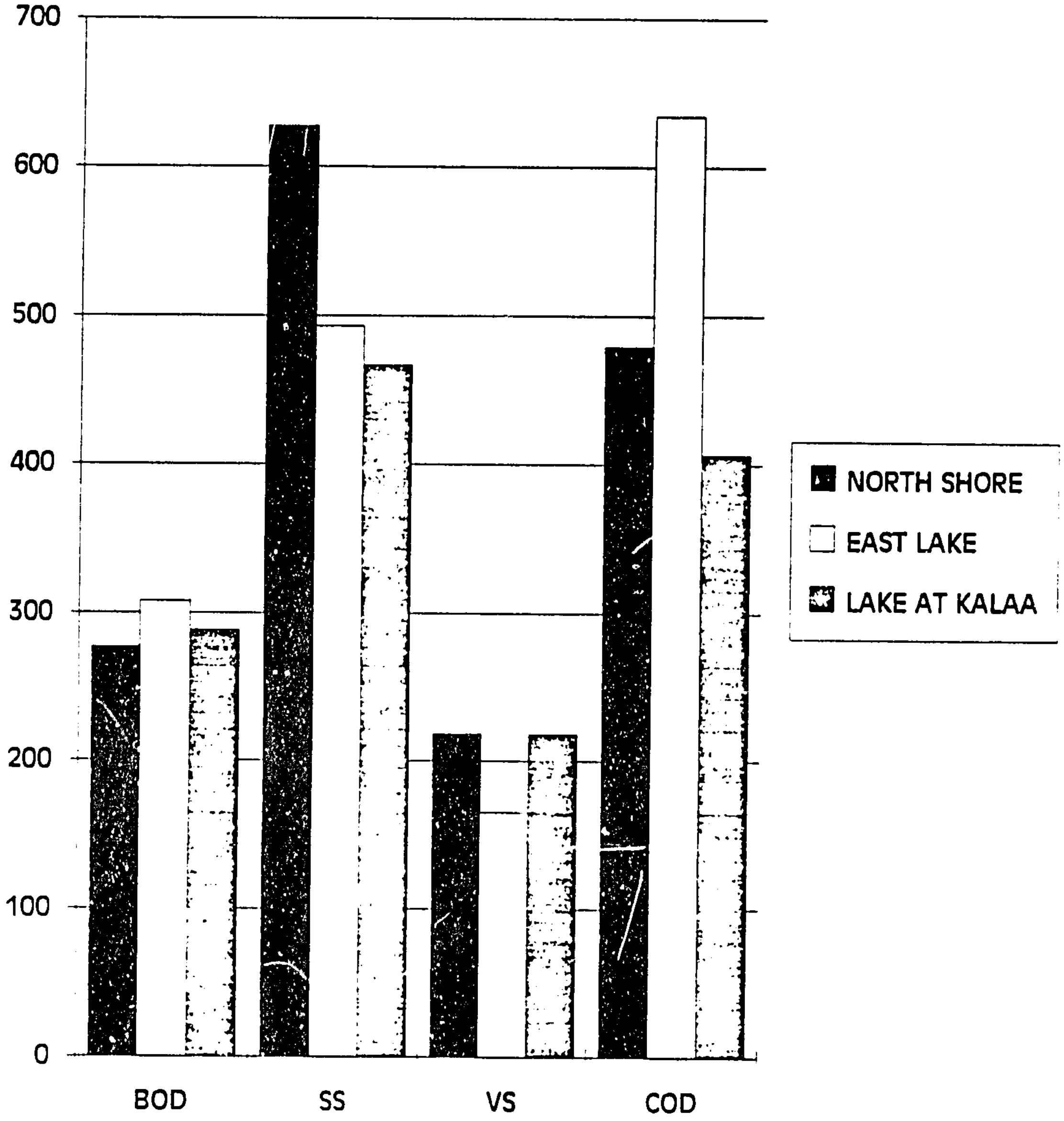


	SUMMARY OF LAKE INPUT ENRICHMENT CHARACTERISTICS 83				
			mg/l		
STA #	DESCRIPTION	BOD	SS	VS	COD
5	KALAA MOUTH	173	377	74	363
19	OMOUM DRAIN	177	750	203	413



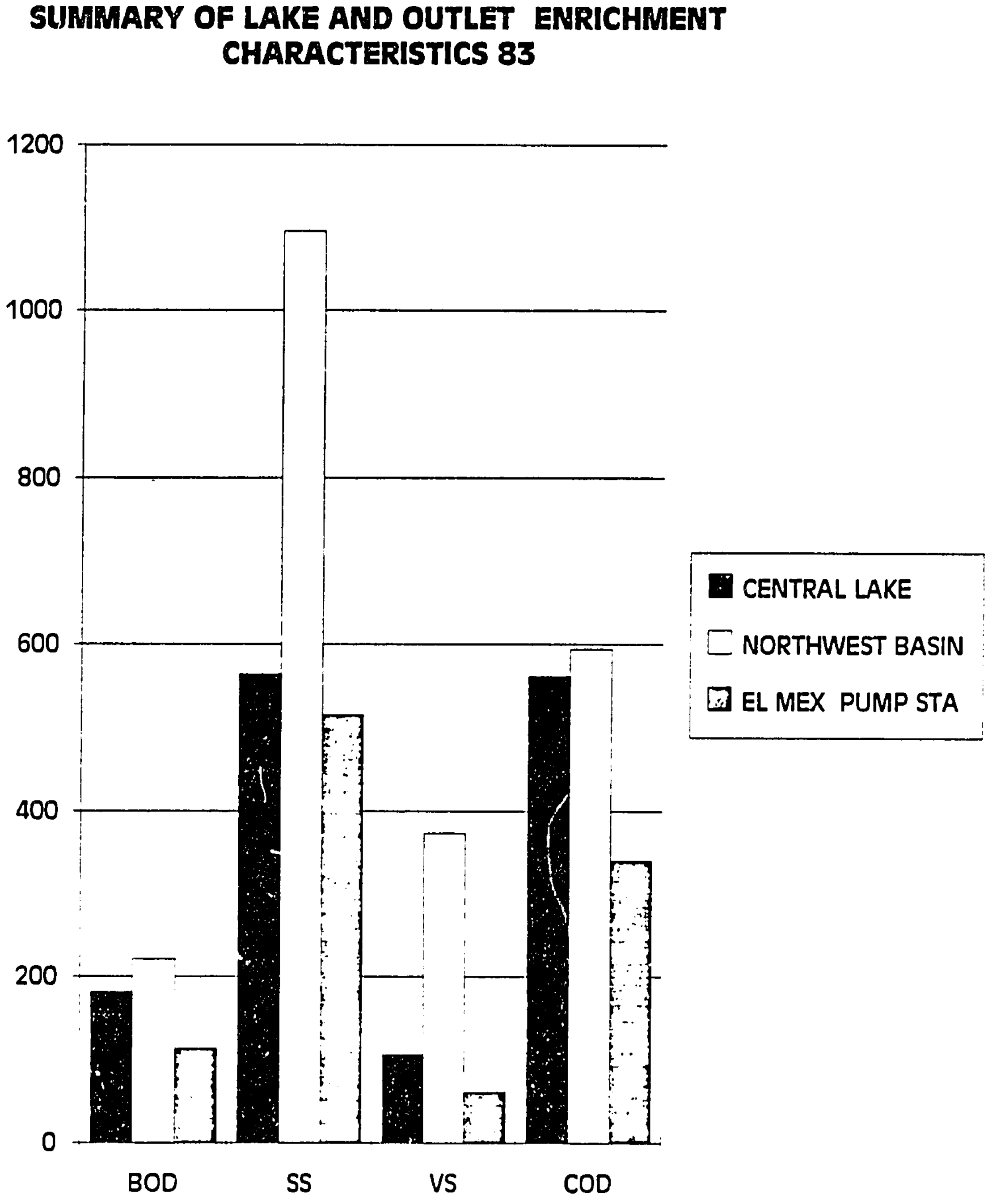
	SUMMARY OF SHORE ENRICHMENT CHARACTERISTICS 83						
			mg/l				
STA #	DESCRIPTION	BOD	SS	VS	COD		
VARIOUS	NORTH SHORE	277	627	218	479		
VARIOUS	EAST LAKE	308	493	165	634		
16	LAKE AT KALAA	288	467	218	407		

SUMMARY OF SHORE ENRICHMENT CHARACTERISTICS 83

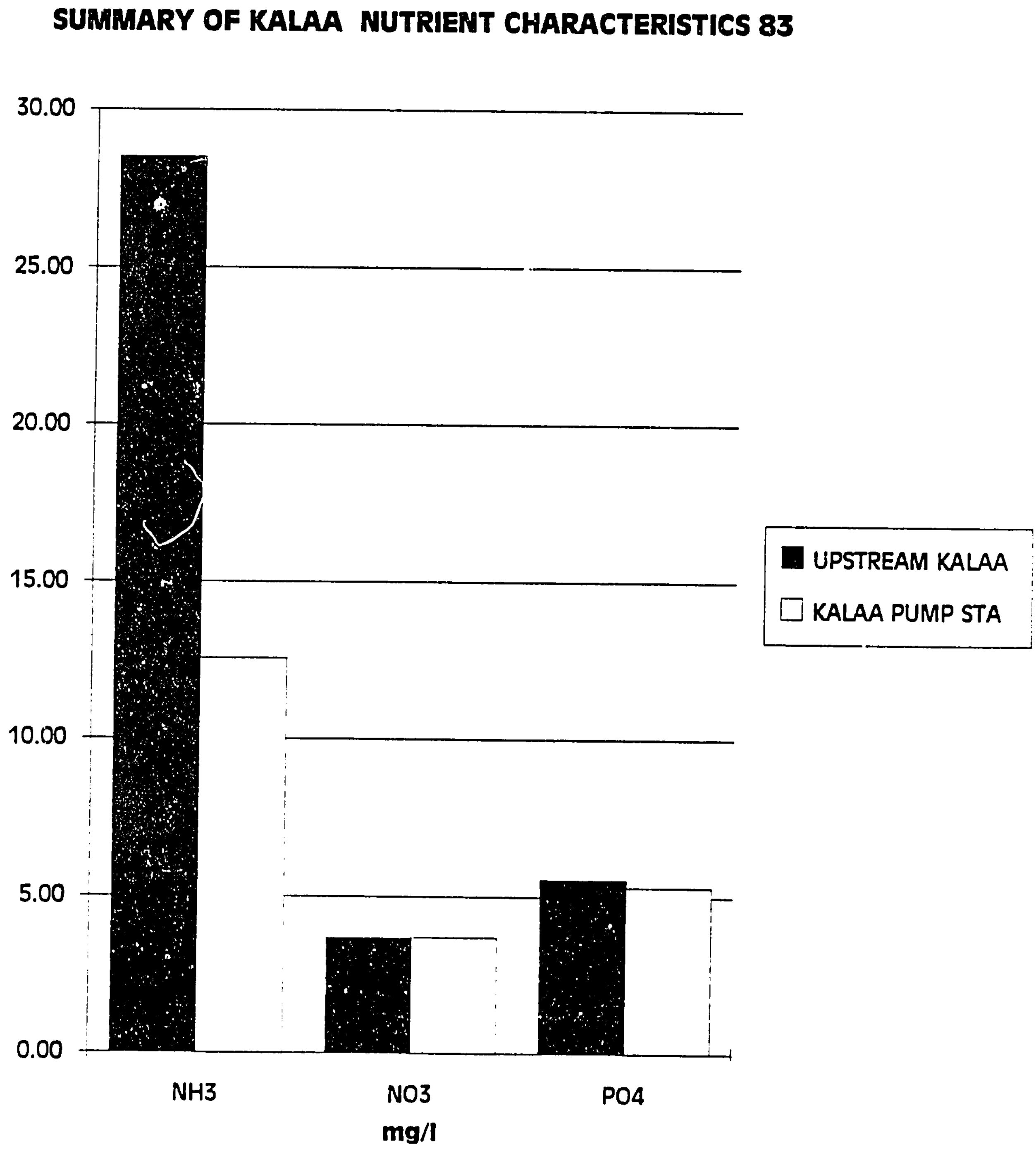


SUMMARY OF LAKE AND OUTLET ENRICHMENT CHARACTERISTICS 83

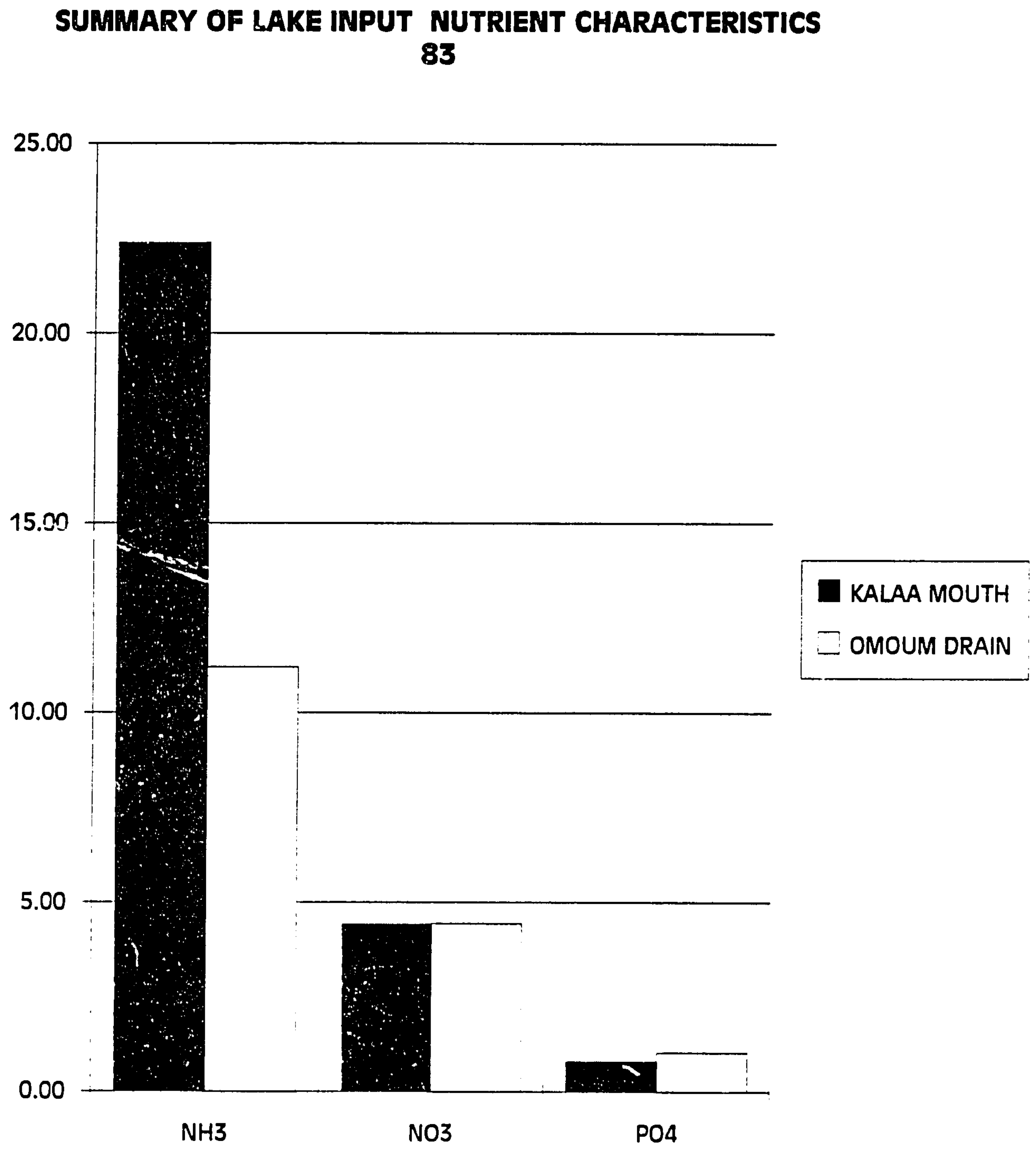
			mg/l		
STA #	DESCRIPTION	BOD	SS	VS	COD
VARIOUS	CENTRAL LAKE	182	564	106	562
VARIOUS	NORTHWEST BASIN	221	1096	373	594
20	EL MEX PUMP STA	113	515	61	340



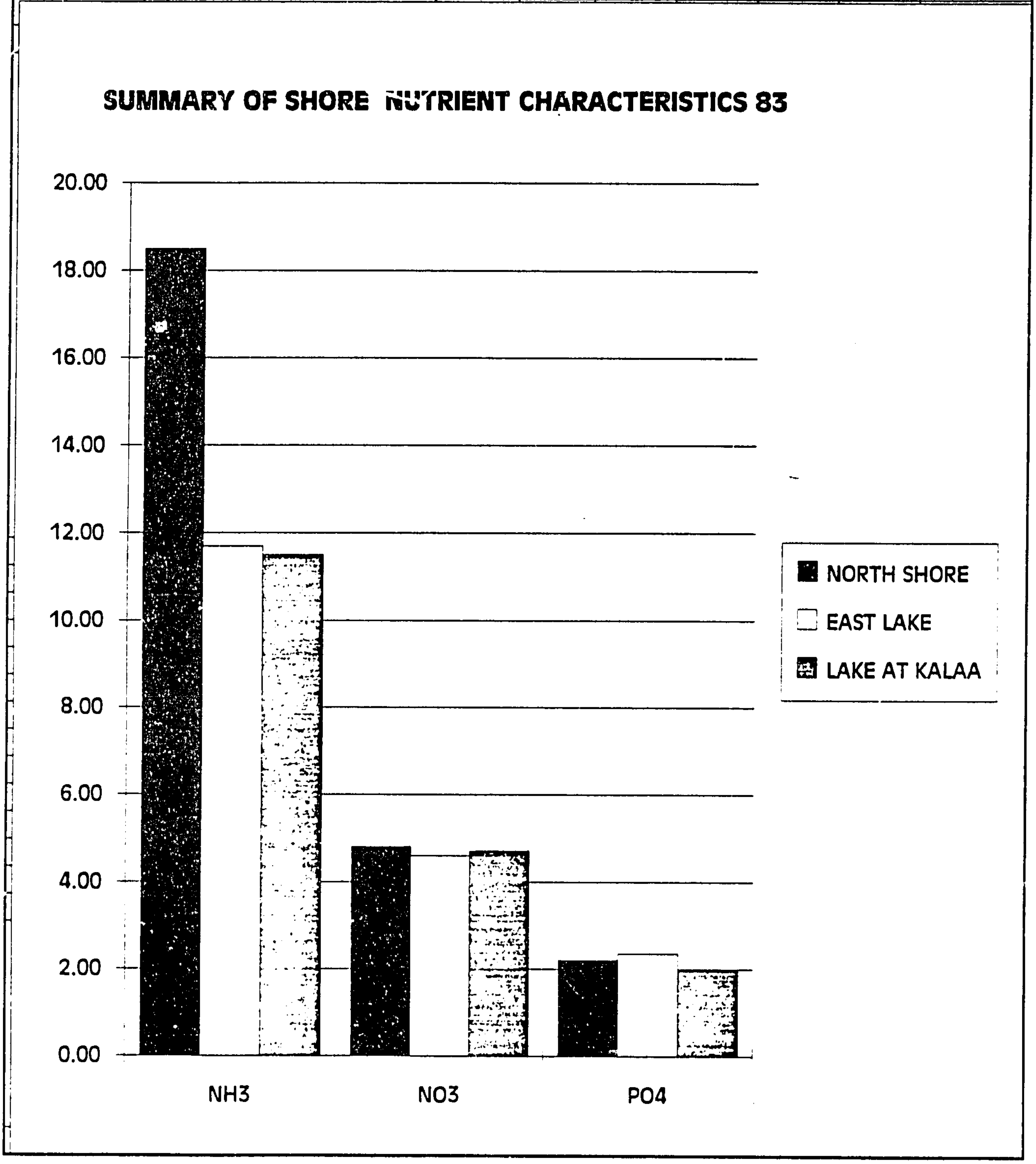
	SUMMARY OF KALLA DRAIN NUTRIENT CHARACTERISTICS 83			
			mg/l	
STA #	DESCRIPTION	NH3	NO3	PO4
2	UPSTREAM KALAA	28.52	3.68	5.55
5	KALAA PUMP STA	12.57	3.70	5.32



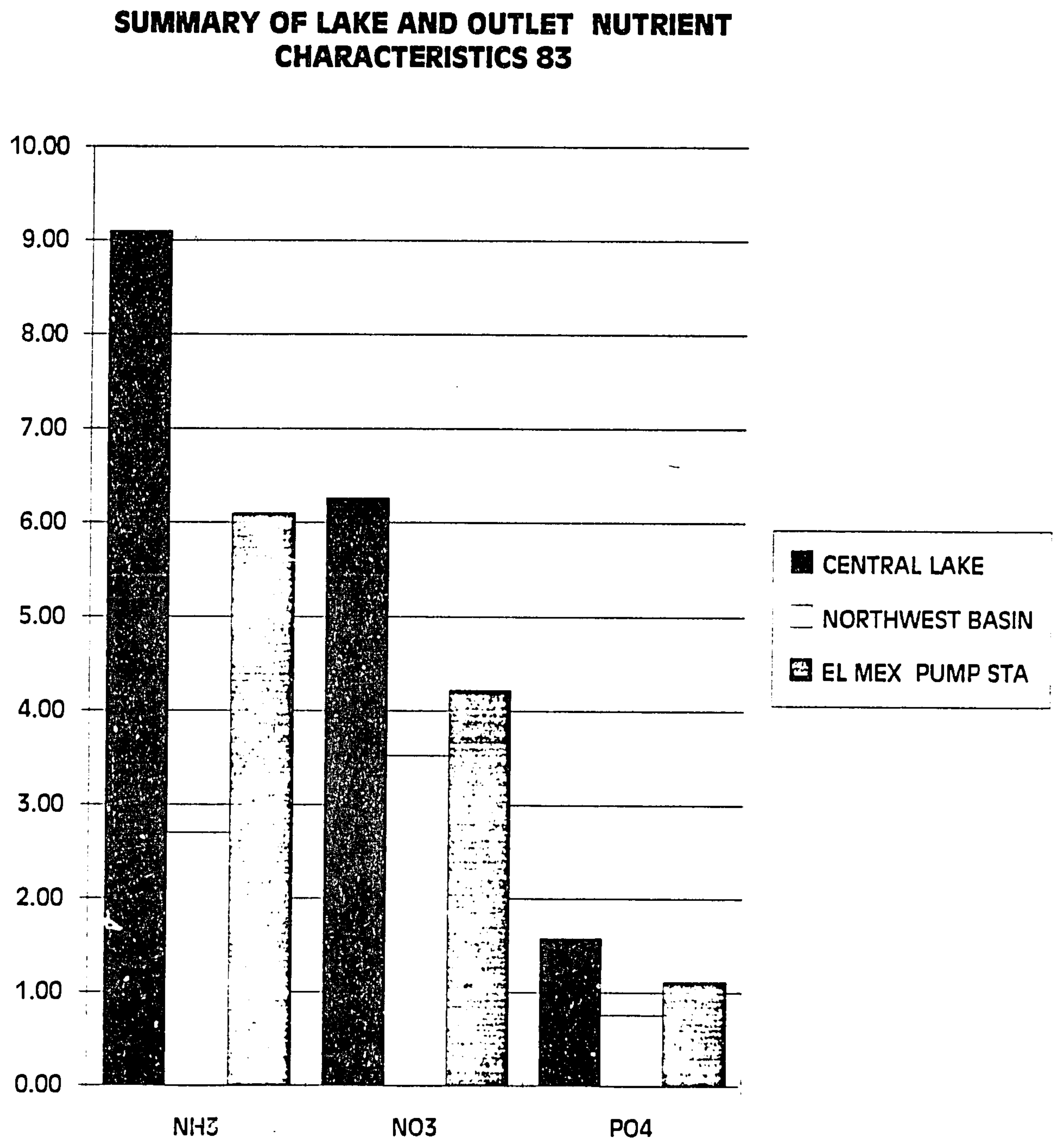
	SUMMARY OF LAKE INPUT NUTRIENT CHARACTERISTICS 83			
			mg/l	
STA #	DESCRIPTION	NH3	NO3	PO4
5	KALAA MOUTH	22.40	4.42	0.81
19	OMOUM DRAIN	11.20	4.44	1.04



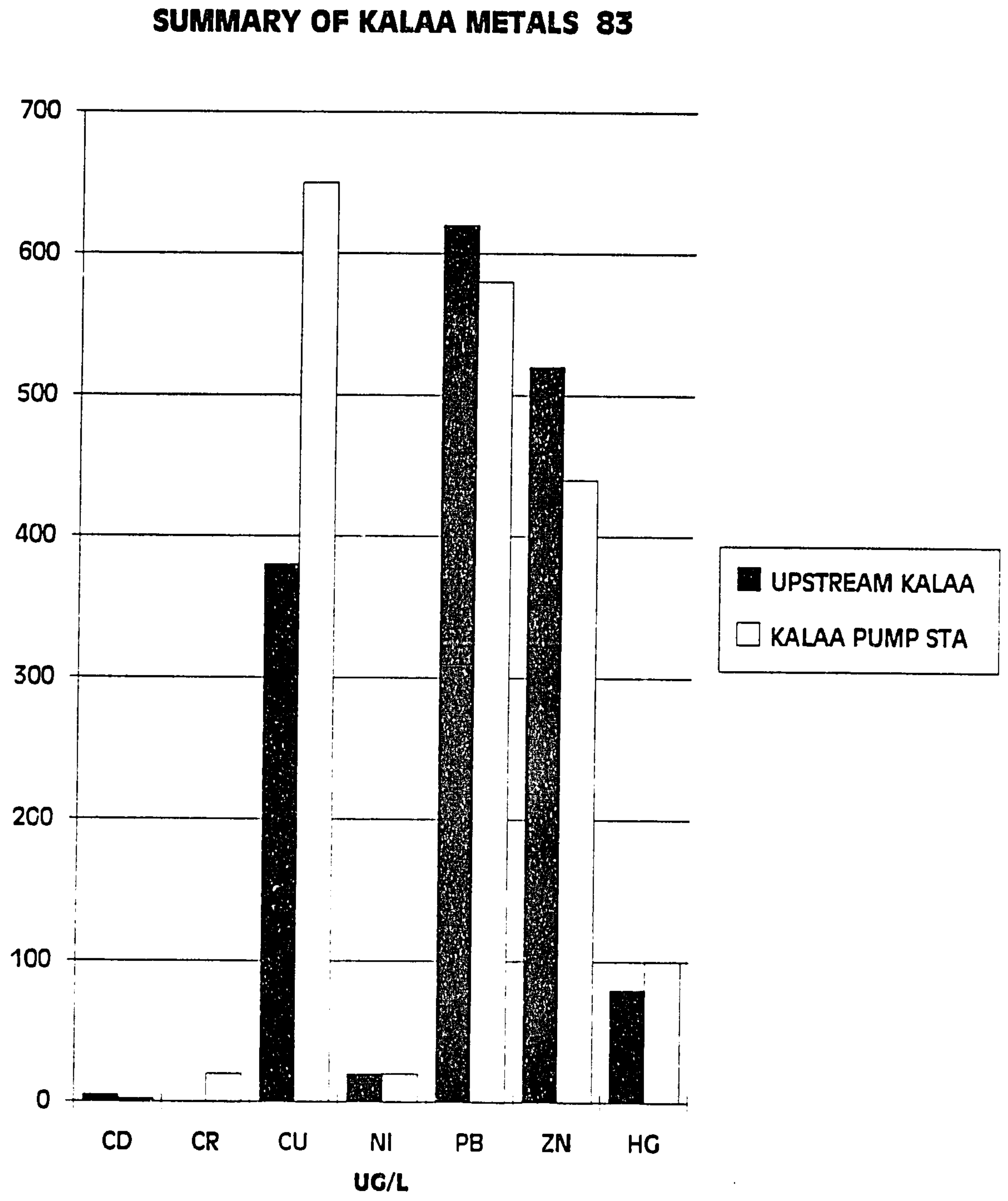
	SUMMARY OF SHORE NUTRIENT CHARACTERISTICS 83			
			mg/l	
STA #	DESCRIPTION	NH3	NO3	PO4
VARIOUS	NORTH SHORE	18.50	4.81	2.20
VARIOUS	EAST LAKE	11.70	4.60	2.35
16	LAKE AT KALAA	11.50	4.71	1.98



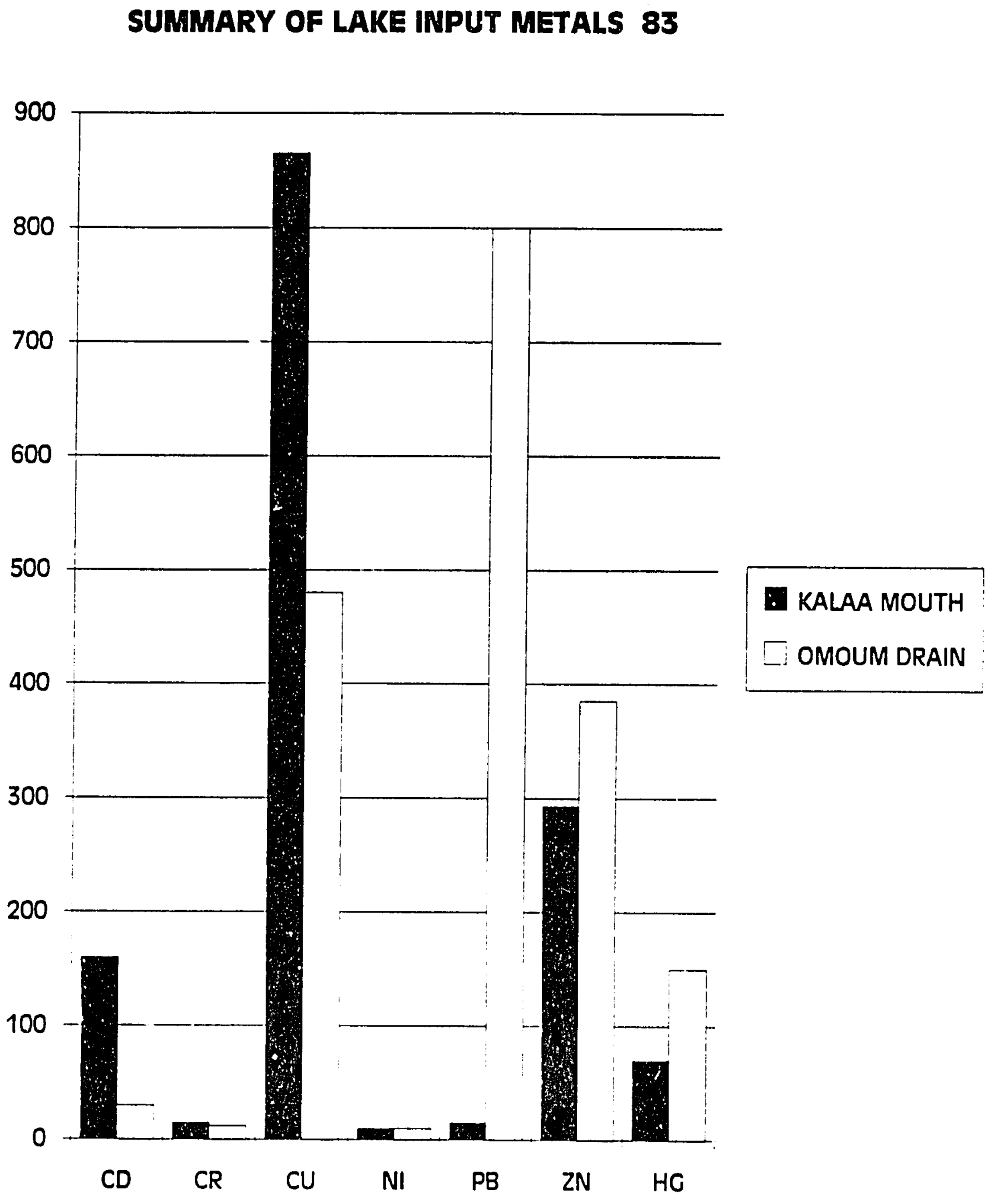
	SUMMARY OF LAKE AND OUTLET NUTRIENT CHARACTERISTICS 83			
			mg/l	
STA #	DESCRIPTION	NH3	NO3	PO4
VARIOUS	CENTRAL LAKE	9.10	6.26	1.58
VARIOUS	NORTHWEST BASIN	2.70	3.52	0.76
20	EL MEX PUMP STA	6.10	4.22	1.11



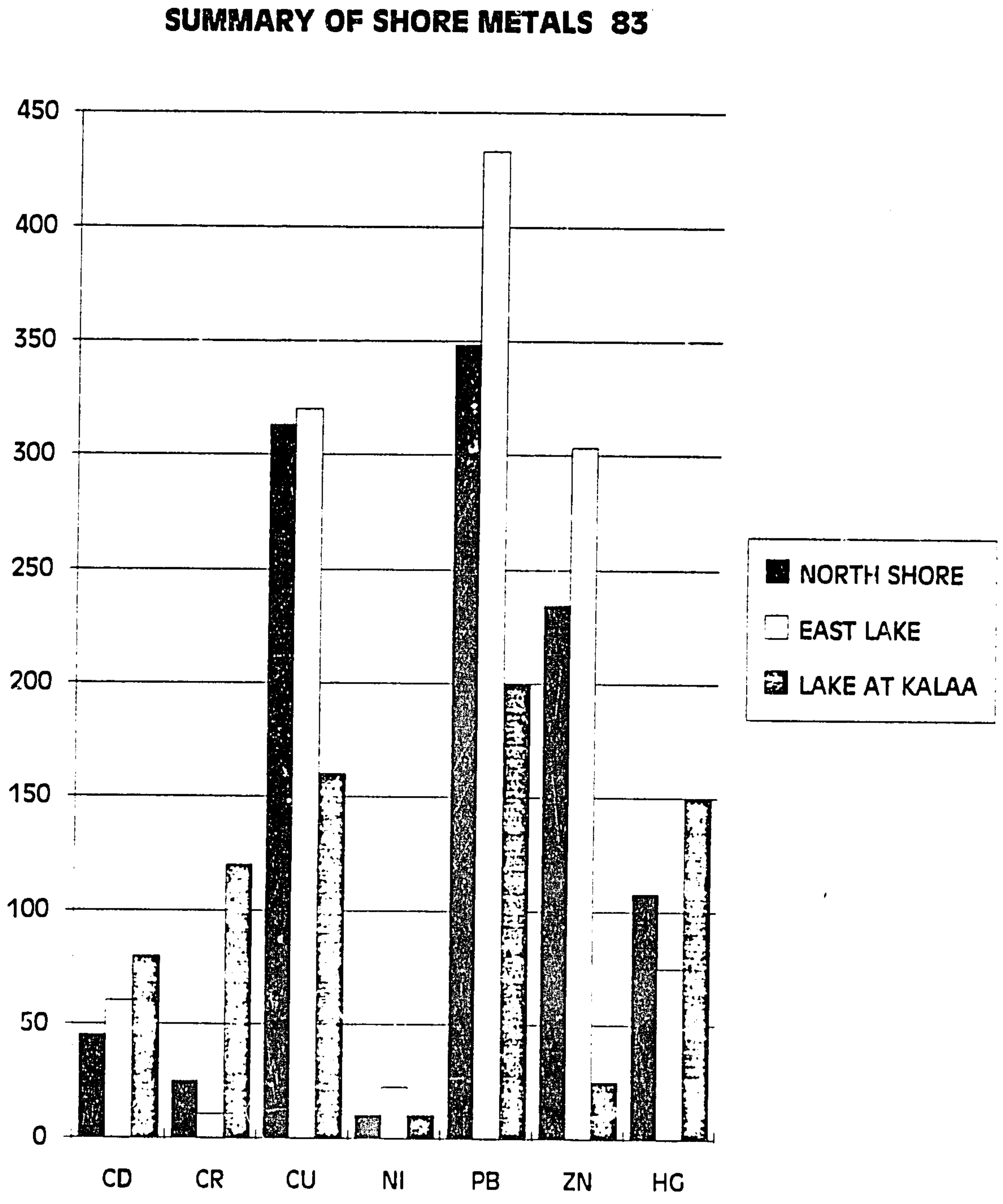
	SUMMARY OF KALLA DRAIN METAL CONCENTRATIONS 83							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	HG
2	UPSTREAM KALAA	5	J320	380	20	620	520	80
4	KALAA PUMP STA	2	20	650	20	580	440	100



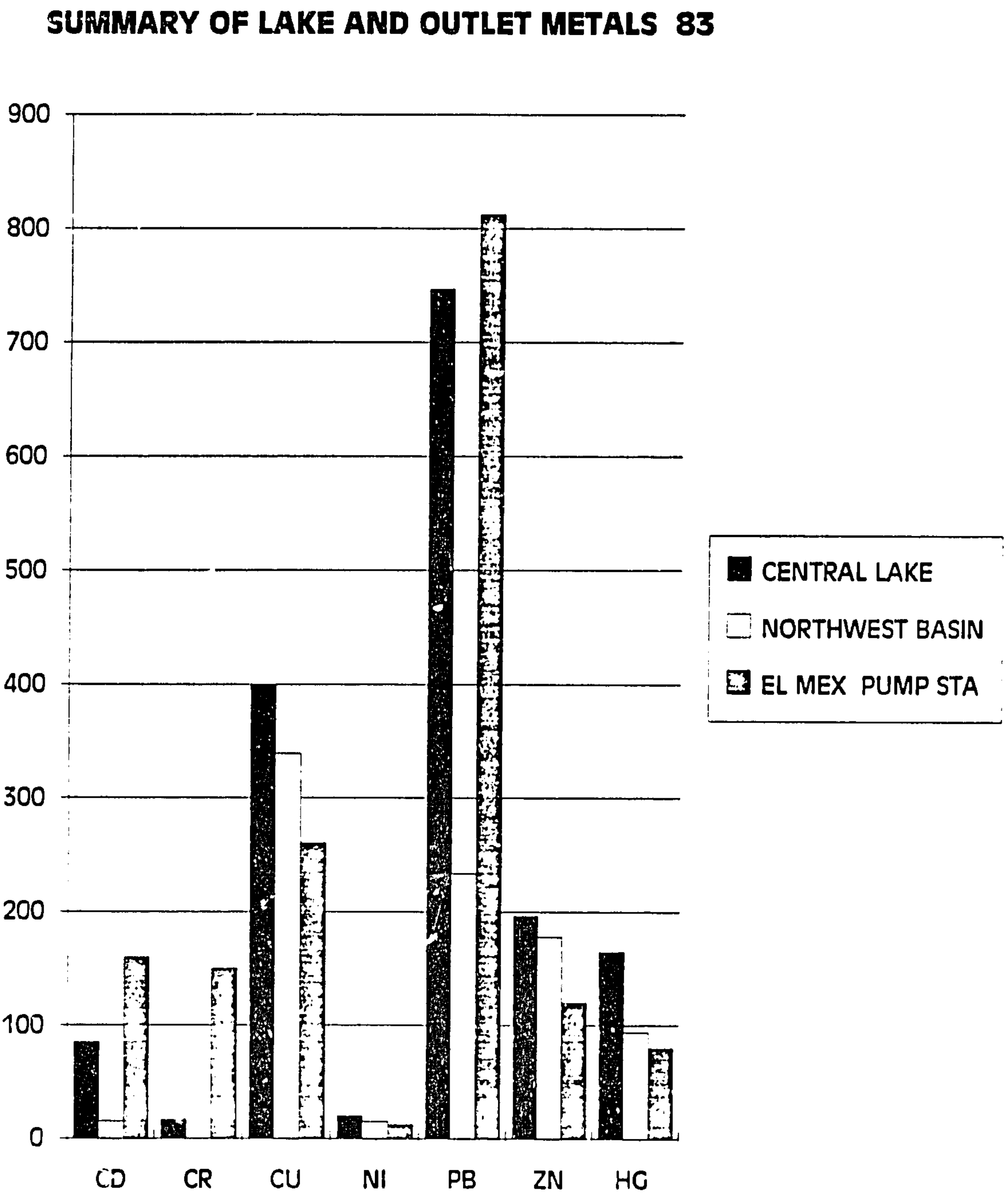
	SUMMARY OF LAKE INPUT METAL CONCENTRATIONS 83							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	HG
5	KALAA MOUTH	160	15	865	10	15	293	70
19	OMOUM DRAIN	30	12	480	10	800	385	150



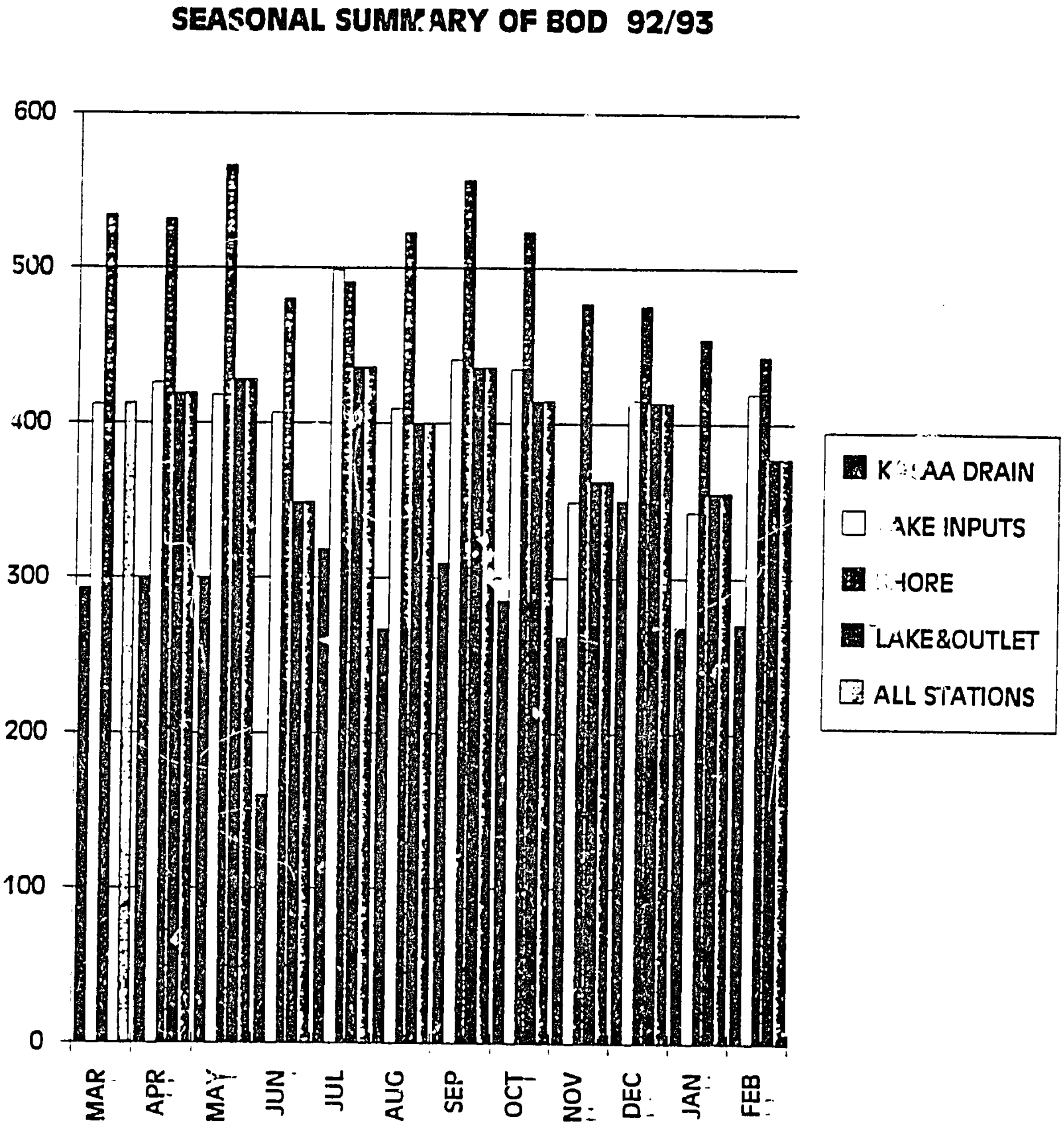
	SUMMARY OF LAKE SHORE METAL CONCENTRATIONS 83							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	HG
VARIOUS	NORTH SHORE	45	25	313	10	348	235	108
VARIOUS	EAST LAKE	61	11	320	23	433	303	75
16	LAKE AT KALAA	80	120	160	10	200	25	150



	SUMMARY OF LAKE AND OUTLET METAL CONCENTRATIONS 83							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	HG
VARIOUS	CENTRAL LAKE	85	17	400	20	747	196	165
VARIOUS	NORTHWEST BASIN	15	ND	339	15	233	178	94
20	EL MEX PUMP STA	160	150	260	12	812	120	80

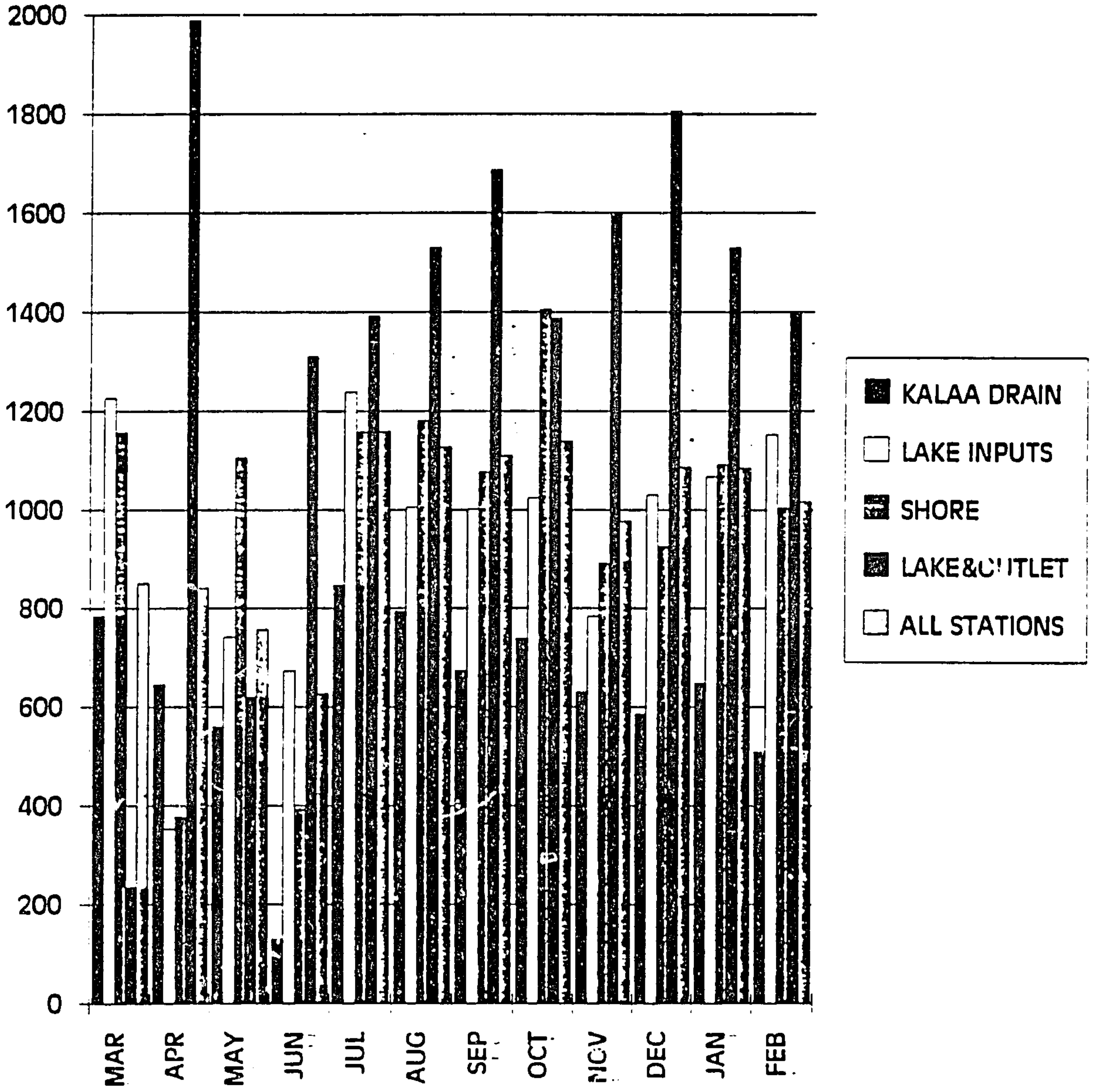


SEASONAL SUMMARY OF ENRICHMENT CHARACTERISTICS 92/93												
				BOD IN mg/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	293	300	300	160	319	267	310	285	262	350	269	271
LAKE INPUTS	412	426	418	407	499	409	441	435	349	415	343	419
SHORE	534	532	566	480	491	523	557	523	477	476	455	443
LAKE&OUTLET	NA	419.2	428.1	348.9	436.1	399.7	435.8	414.6	362.9	413.6	355.4	377.8
ALL STATIONS	413	419	428	349	436	400	436	415	363	414	355	378


SEASONAL SUMMARY OF BOD 92/93

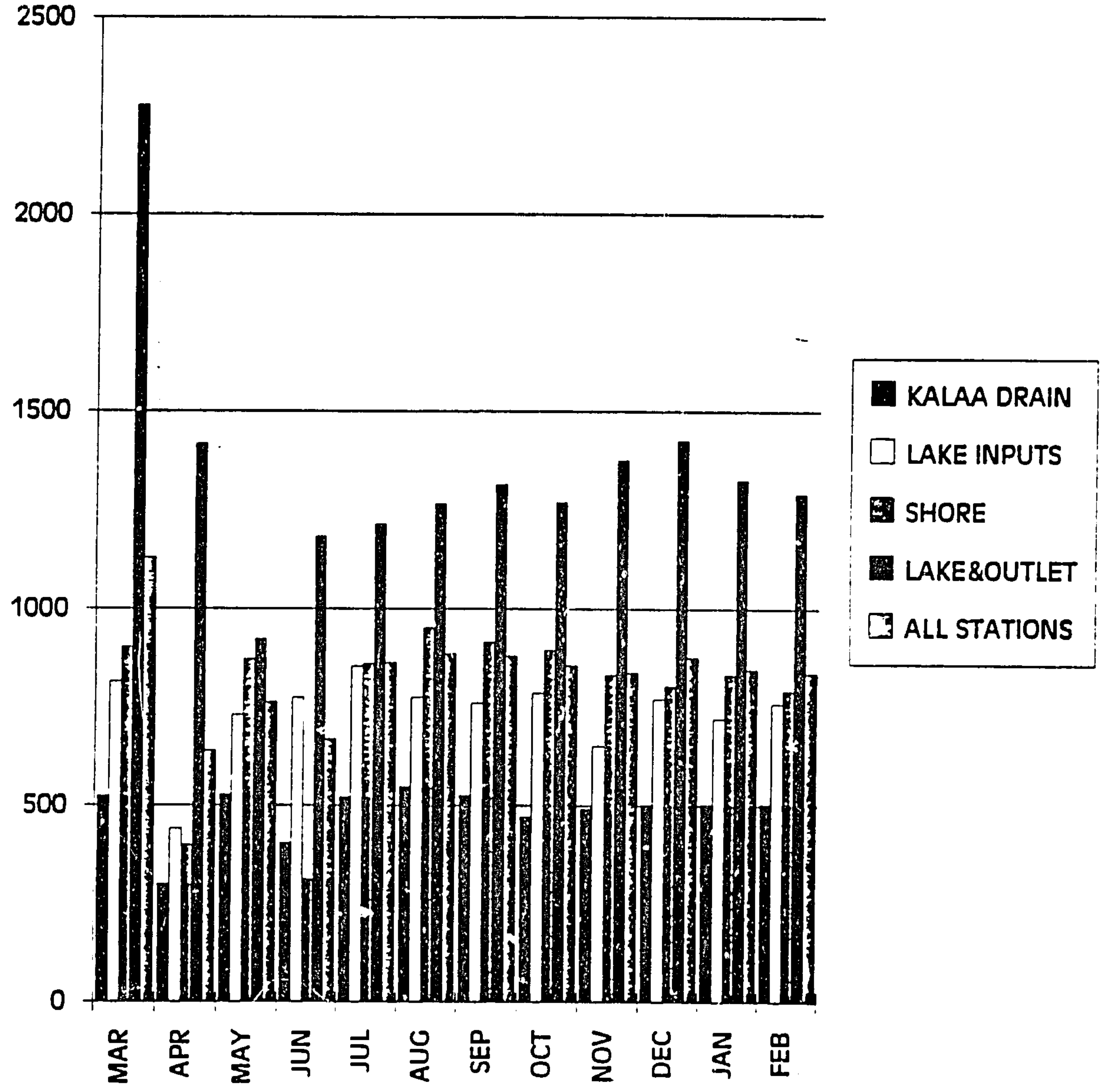
				SS IN mg/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	784	646	560	130	847	794	674	739	631	586	648	509
LAKE INPUTS	1226	353	742	673	1238	1006	1002	1025	784	1030	1068	1153
SHORE	1157	377	1106	393	1158	1181	1078	1406	891	925	1093	1005
LAKE&OUTLET	236	1989	620	1310	1392	1530	1687	1388	1601	1806	1530	1402
ALL STATIONS	851	841	757	626	1159	1128	1110	1139	977	1087	1084	1017

SEASONAL SUMMARY OF SS 92/93



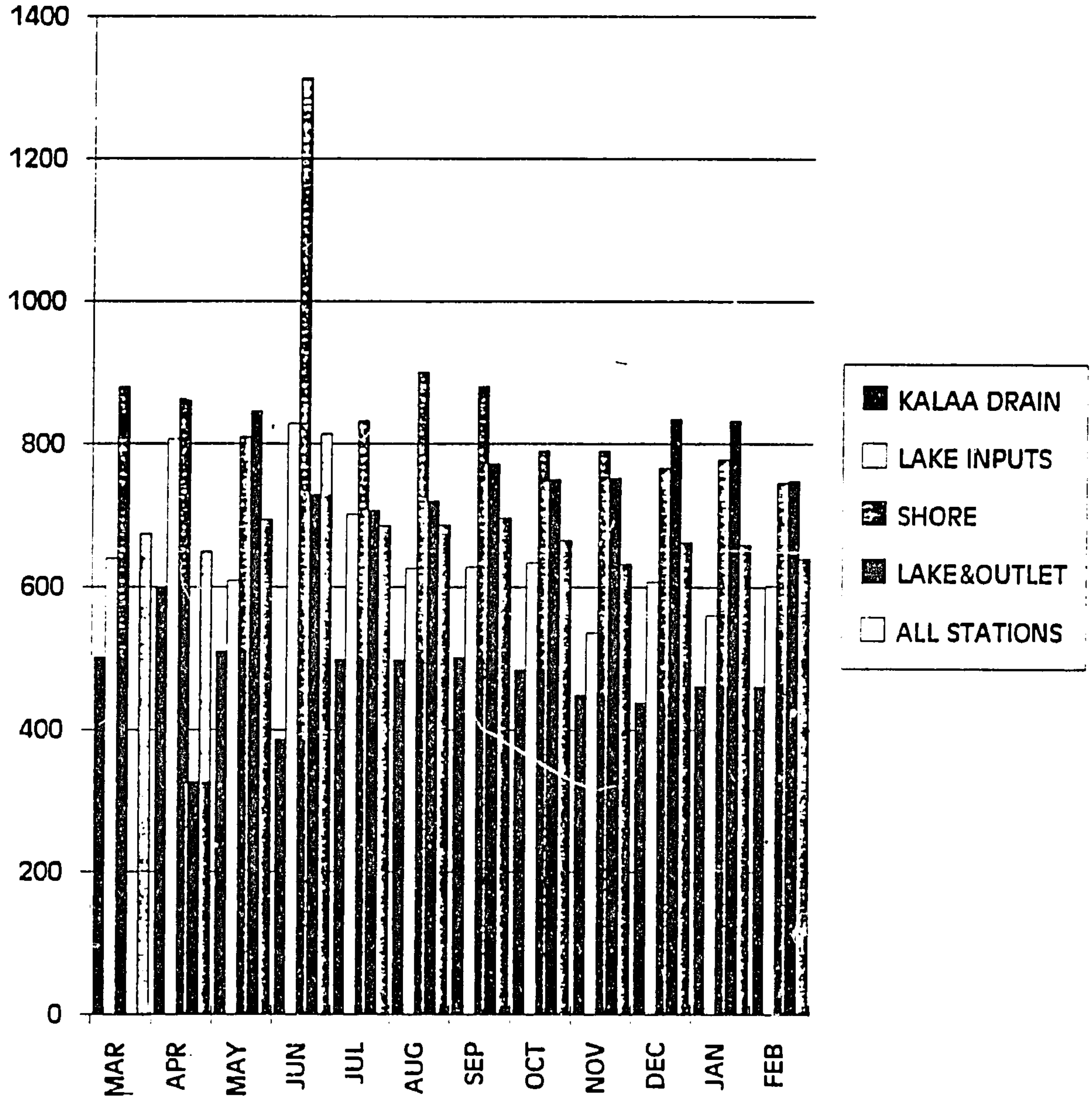
				VS mg/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	523	300	527	405	520	547	525	471	493	502	503	504
LAKE INPUTS	814	441	731	775	853	775	761	786	652	772	722	760
SHORE	903	400	871	312	861	952	915	895	833	805	833	792
LAKE&OUTLET	2276	1418	923	1183	1215	1266	1314	1270	1375	1425	1325	1291
ALL STATIONS	1129	640	763	669	862	885	879	855	838	876	846	837

SEASONAL SUMMARY OF VS 92/93

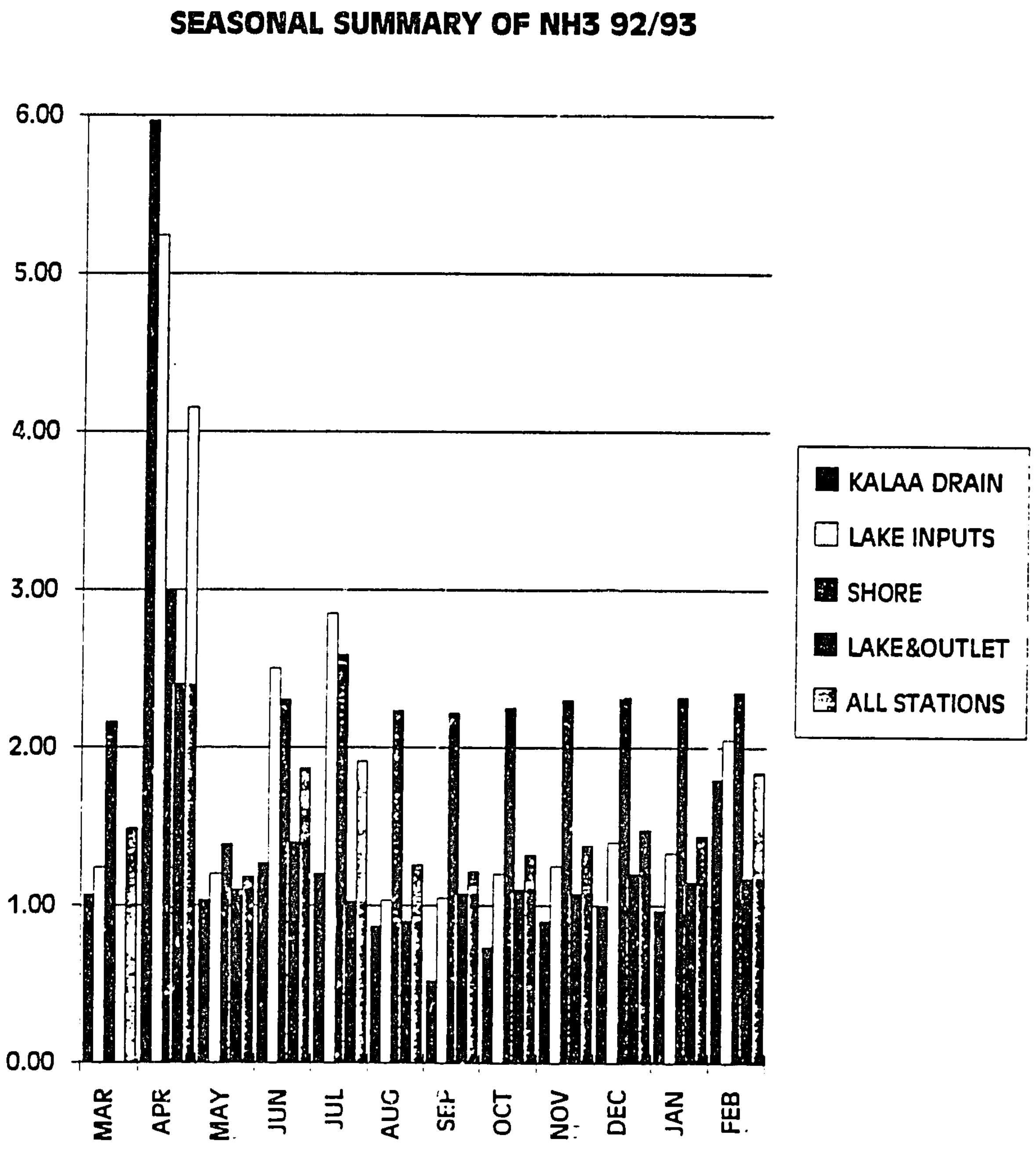


				COD mg/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	502	600	510	387	499	498	502	484	449	438	461	461
LAKE INPUTS	639	807	609	828	701	625	628	633	536	607	561	601
SHORE	880	863	810	1313	832	900	881	790	790	767	778	746
LAKE&OUTLET	NA	327	846	729	706	720	772	750	752	834	832	749
ALL STATIONS	674	649	694	814	685	686	696	664	632	662	658	639

SEASONAL SUMMARY OF COD 92/93

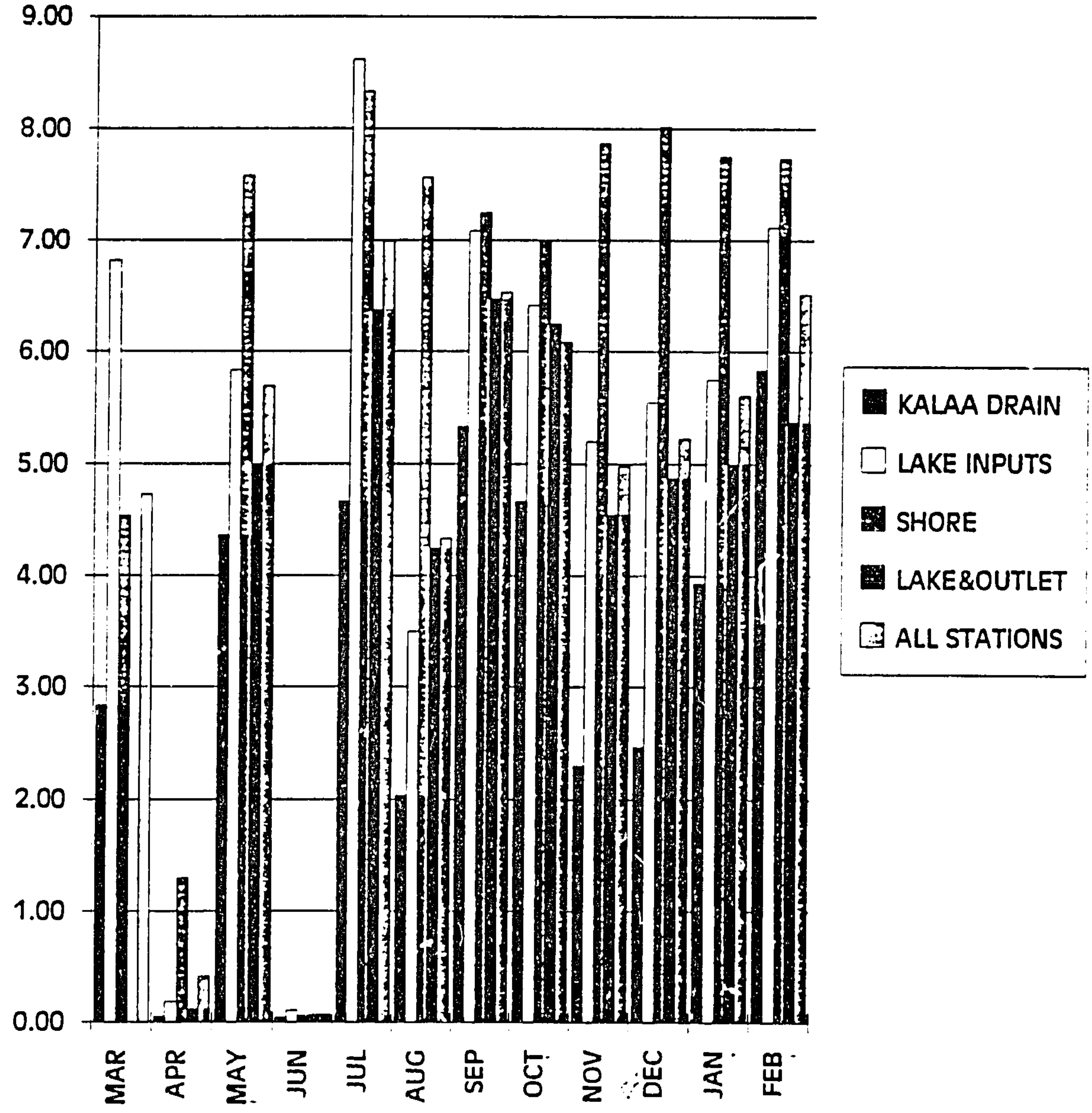


SEASONAL SUMMARY OF NUTRIENTS CHARACTERISTICS 92/93												
				NH3 mg/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	1.07	5.97	1.03	1.27	1.20	0.87	0.52	0.73	0.90	1.00	0.97	1.80
LAKE INPUTS	1.24	5.24	1.20	2.50	2.85	1.03	1.05	1.20	1.25	1.40	1.33	2.05
SHORE	2.16	3.00	1.39	2.30	2.58	2.23	2.22	2.25	2.30	2.32	2.32	2.35
LAKE&OUTLET	NA	2.40	1.10	1.40	1.03	0.90	1.08	1.10	1.08	1.20	1.15	1.18
ALL STATIONS	1.49	4.15	1.18	1.87	1.91	1.26	1.21	1.32	1.38	1.48	1.44	1.84


SEASONAL SUMMARY OF NH3 92/93

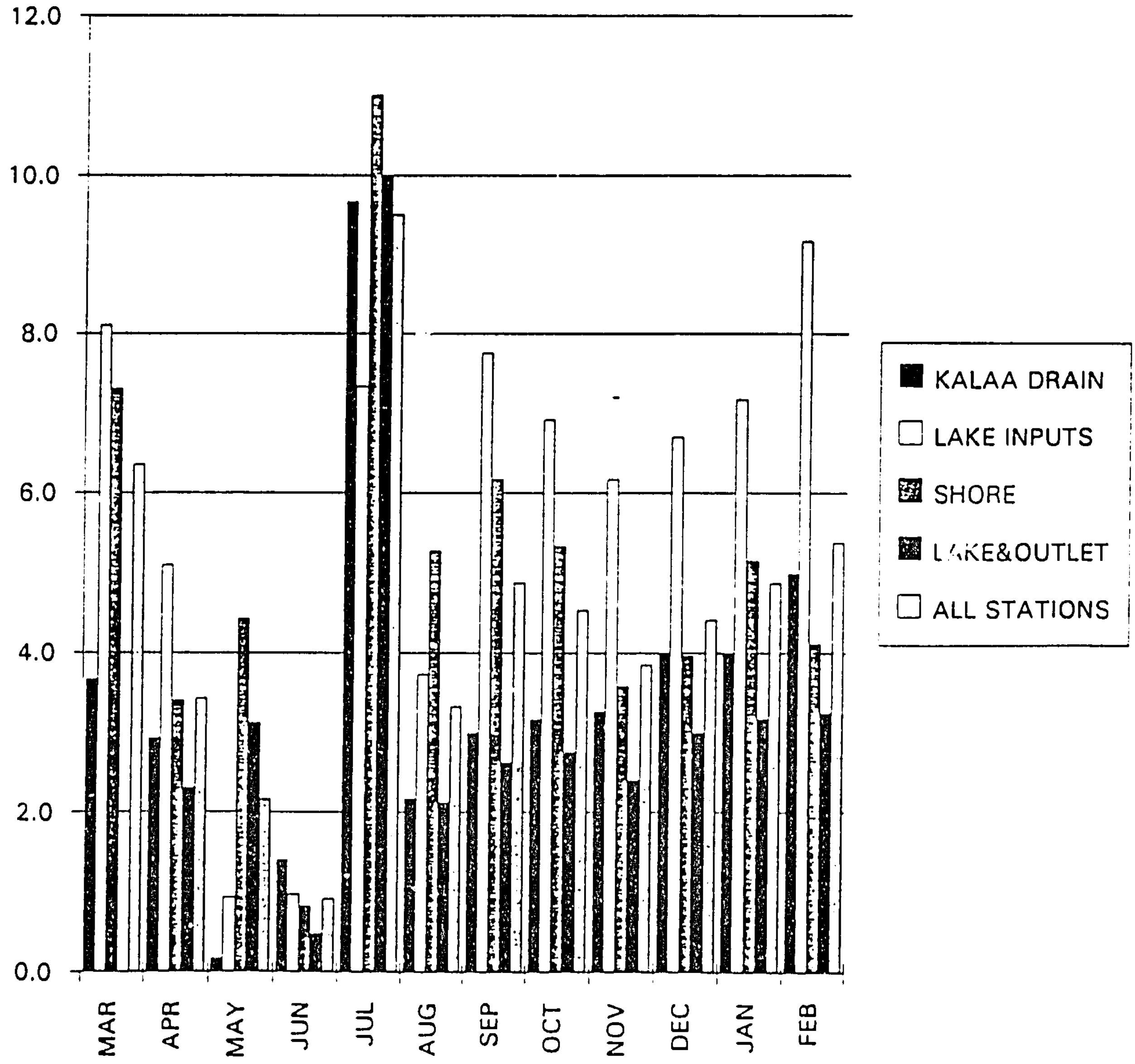
				NO3 mg/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	2.83	0.05	4.37	0.04	4.67	2.03	5.33	4.67	2.30	2.47	3.93	5.83
LAKE INPUTS	6.82	0.18	5.83	0.11	8.62	3.50	7.08	6.42	5.20	5.55	5.75	7.12
SHORE	4.54	1.30	7.58	0.06	8.33	7.57	7.25	7.00	7.87	8.02	7.75	7.73
LAKE&OUTLET	NA	0.12	5.00	0.07	6.38	4.25	6.48	6.25	4.55	4.88	5.00	5.38
ALL STATIONS	4.73	0.41	5.70	0.07	7.00	4.34	6.54	6.08	4.98	5.23	5.61	6.51

SEASONAL SUMMARY OF NO3 92/93



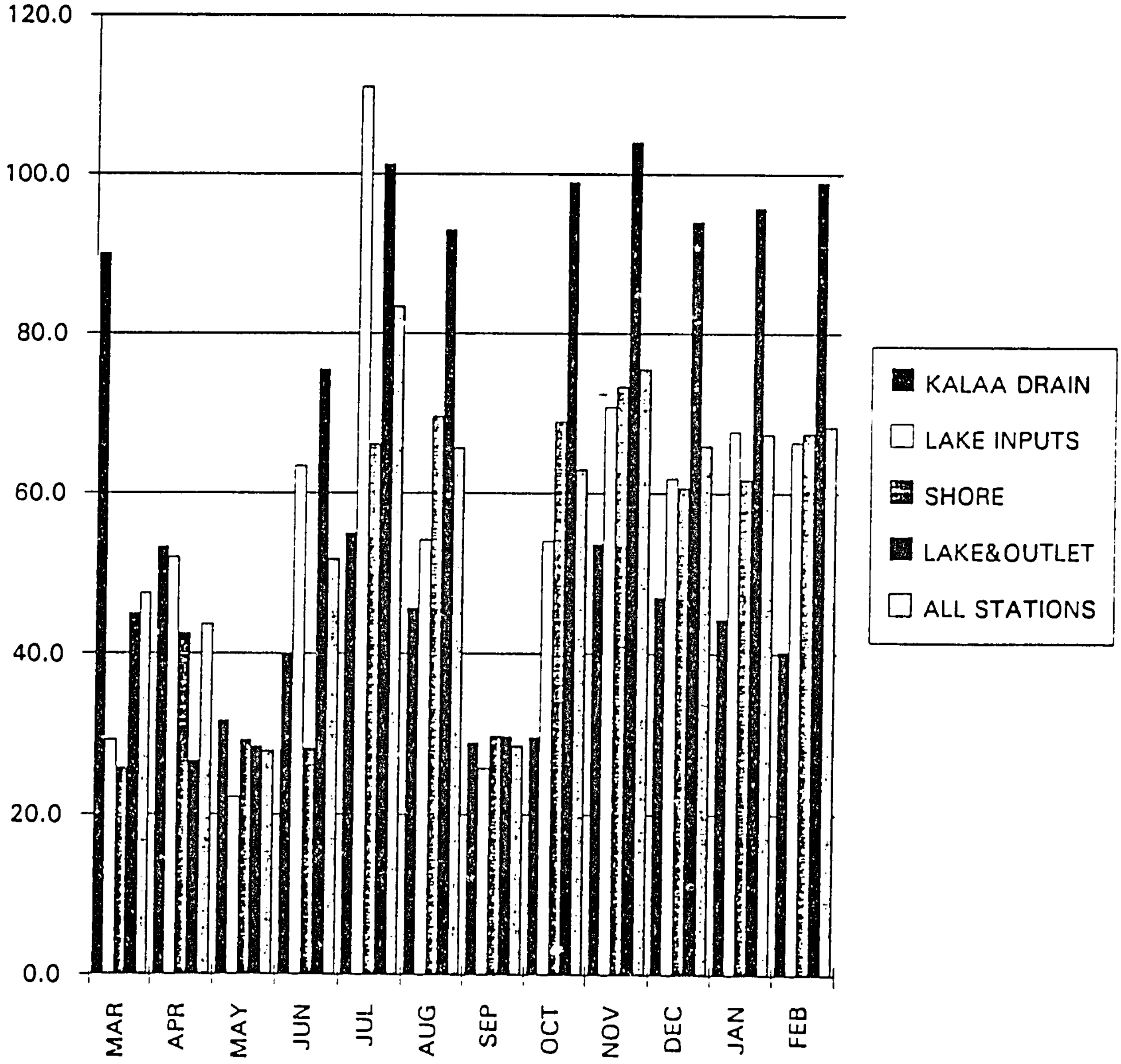
				PO4 mg/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	3.7	2.9	0.2	1.4	9.7	2.2	3.0	3.2	3.3	4.0	4.0	5.0
LAKE INPUTS	8.1	5.1	0.9	1.0	7.3	3.7	7.8	6.9	6.2	6.7	7.2	9.2
SHORE	7.30	3.40	4.42	0.82	11.00	5.28	6.17	5.33	3.58	3.97	5.15	4.12
LAKE&OUTLET	NA	2.30	3.13	0.48	10.00	2.13	2.63	2.75	2.40	3.00	3.18	3.25
ALL STATIONS	6.4	3.4	2.2	0.9	9.5	3.3	4.9	4.5	3.9	4.4	4.9	5.4

SEASONAL SUMMARY OF PO4 92/93



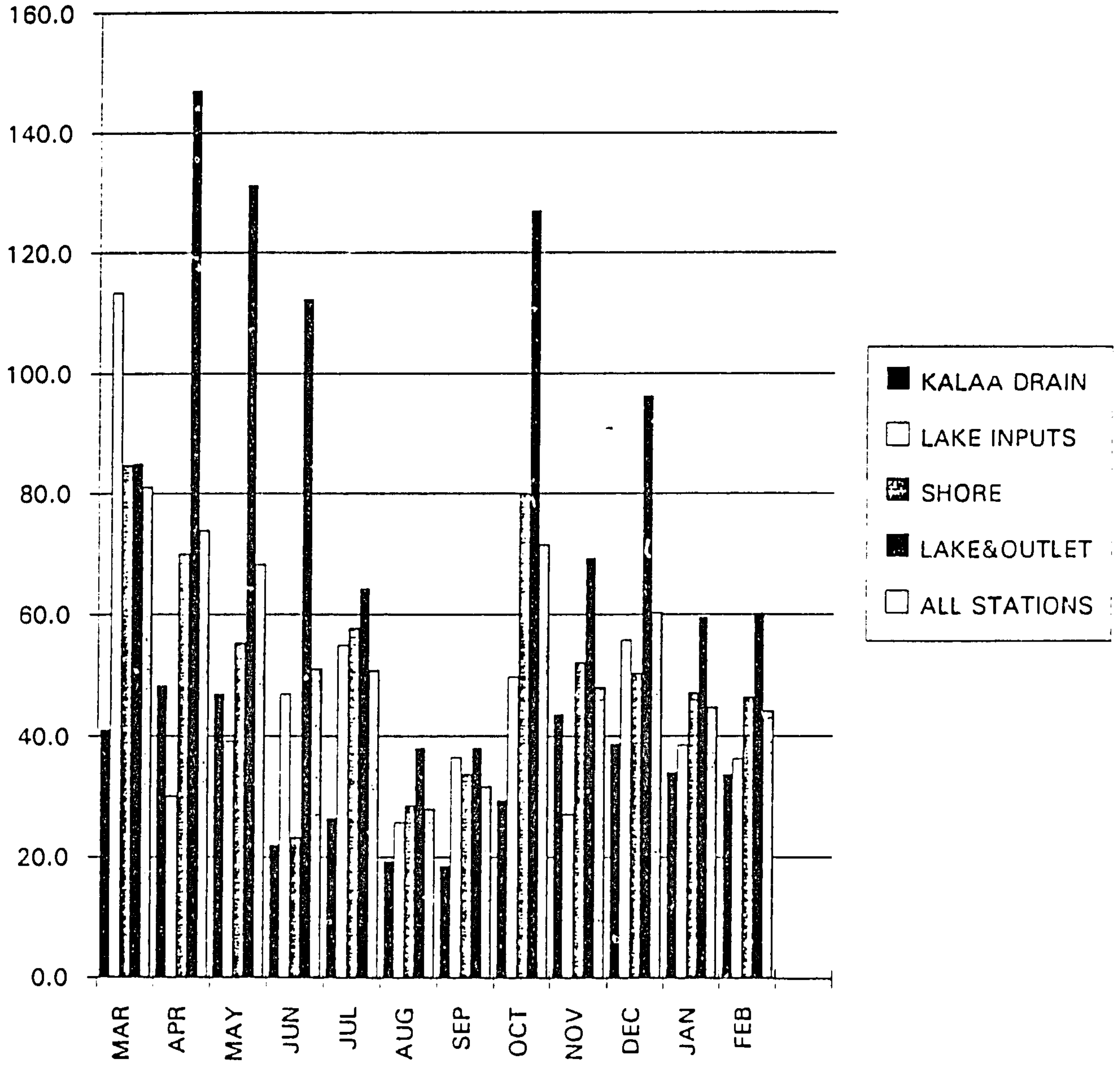
	SEASONAL SUMMARY OF LAKE MARYOUT METALS 92/93										
				CD IN ug/l							
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	90.0	53.3	31.7	40.0	55.0	45.7	29.0	29.7	53.7	47.0	44.3	40.3
LAKE INPUTS	29.3	52.0	22.2	63.3	111.0	54.2	25.8	54.0	70.8	61.8	67.7	66.3
SHORE	25.8	42.5	29.3	28.2	66.2	69.7	29.8	69.0	73.3	60.7	61.7	67.5
LAKE&OUTLET	45.0	26.7	28.5	75.5	101.3	93.0	29.8	99.0	104.0	94.0	95.8	99.0
ALL STATIONS	47.5	43.6	27.9	51.8	83.4	65.6	28.6	62.9	75.5	65.9	67.4	68.3

SEASONAL SUMMARY OF CD 92/93

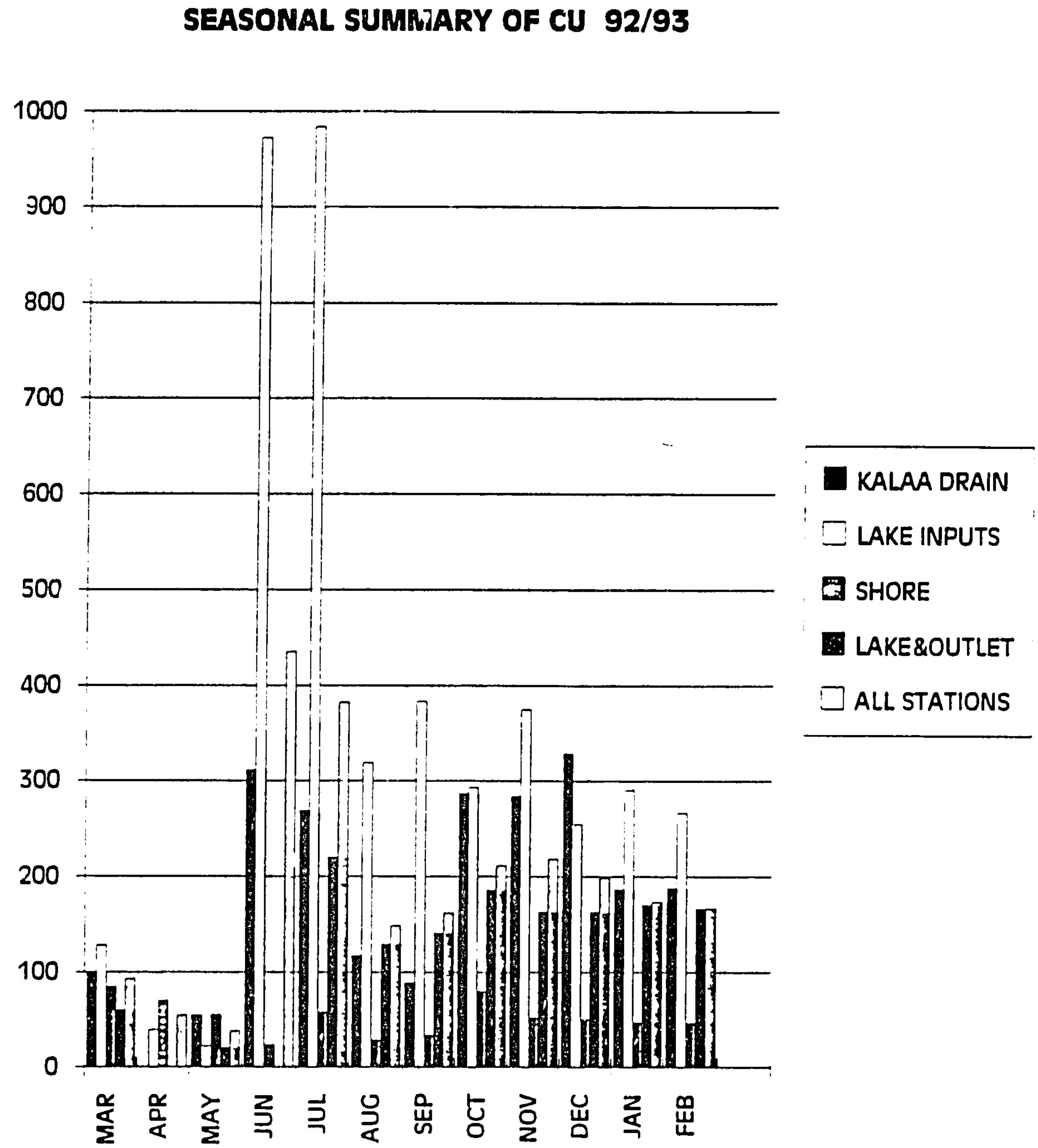


				CR IN ug/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	41.0	48.3	47.0	22.0	26.3	19.3	18.5	29.3	43.7	38.7	34.0	33.7
LAKE INPUTS	113.3	30.0	39.2	47.0	55.0	25.7	36.5	49.8	27.1	55.8	38.5	36.3
SHORE	84.8	70.0	55.3	23.3	57.8	28.5	33.7	80.0	52.2	50.3	47.2	46.5
LAKE&OUTLET	85.0	147.0	131.3	112.3	64.3	38.0	38.0	127.0	69.3	96.3	59.5	60.3
ALL STATIONS	81.0	73.8	68.2	51.1	50.9	27.9	31.7	71.5	48.0	60.3	44.8	44.2

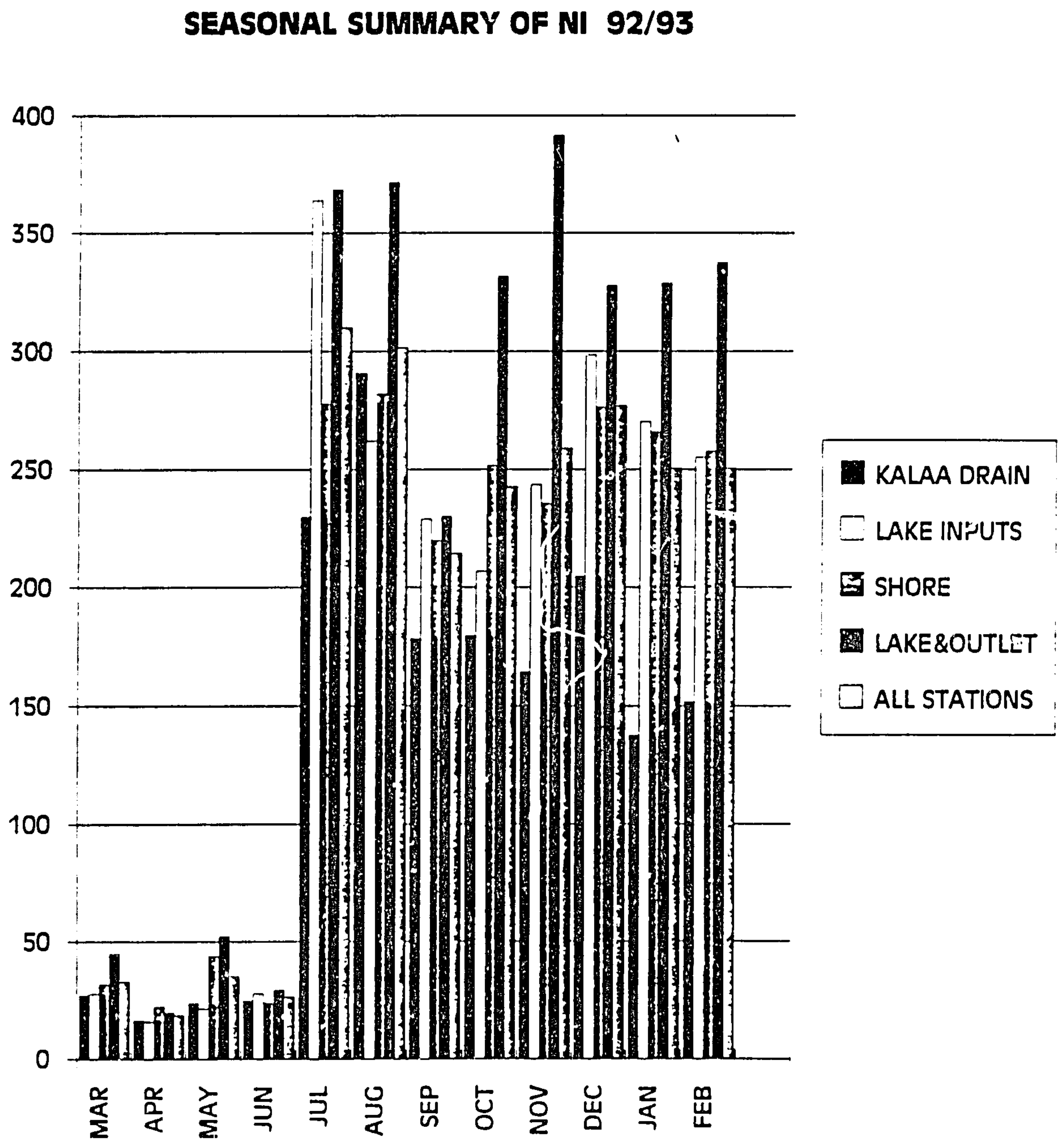
SEASONAL SUMMARY OF CR 92/93



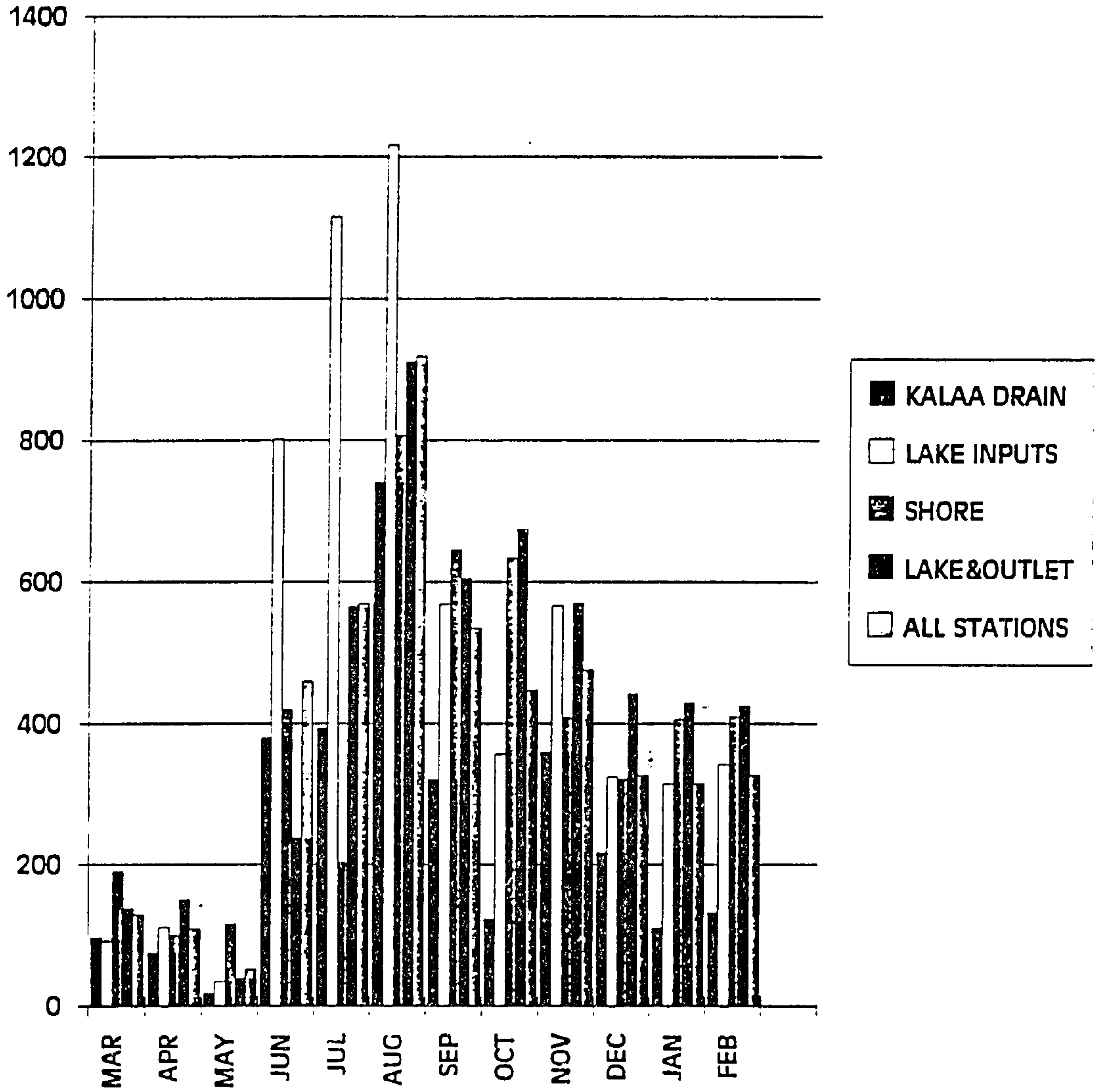
				CU IN ug/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	100	ND	55	311	268	117	89	287	284	329	186	188
LAKE INPUTS	128	39	22	973	984	319	383	293	375	254	290	266
SHORE	85	70	55	23	58	29	34	80	52	50	47	47
LAKE&OUTLET	60	ND	20	ND	220	129	141	186	163	163	170	166
ALL STATIONS	93	55	38	436	382	148	162	211	218	199	173	167


SEASONAL SUMMARY OF CU 92/93

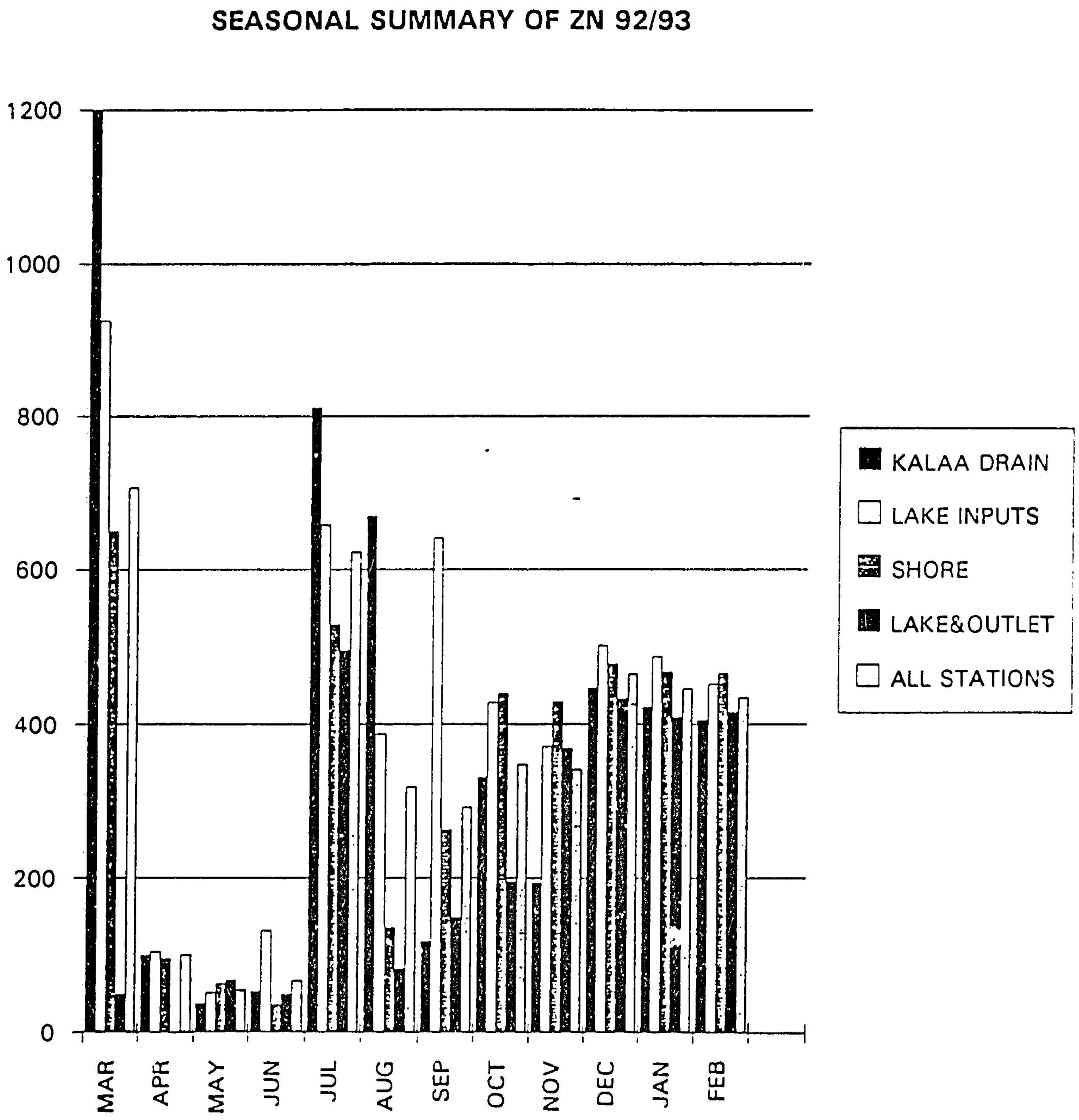
				NI IN ug/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	27	17	24	25	230	291	178	180	164	205	137	152
LAKE INPUTS	28	16	22	28	364	262	229	207	244	298	270	255
SHORE	32	23	44	24	278	282	220	252	236	276	266	258
LAKE&OUTLET	45	20	52	30	369	372	230	332	392	328	329	338
ALL STATIONS	33	19	35	27	310	301	214	242	259	277	250	250



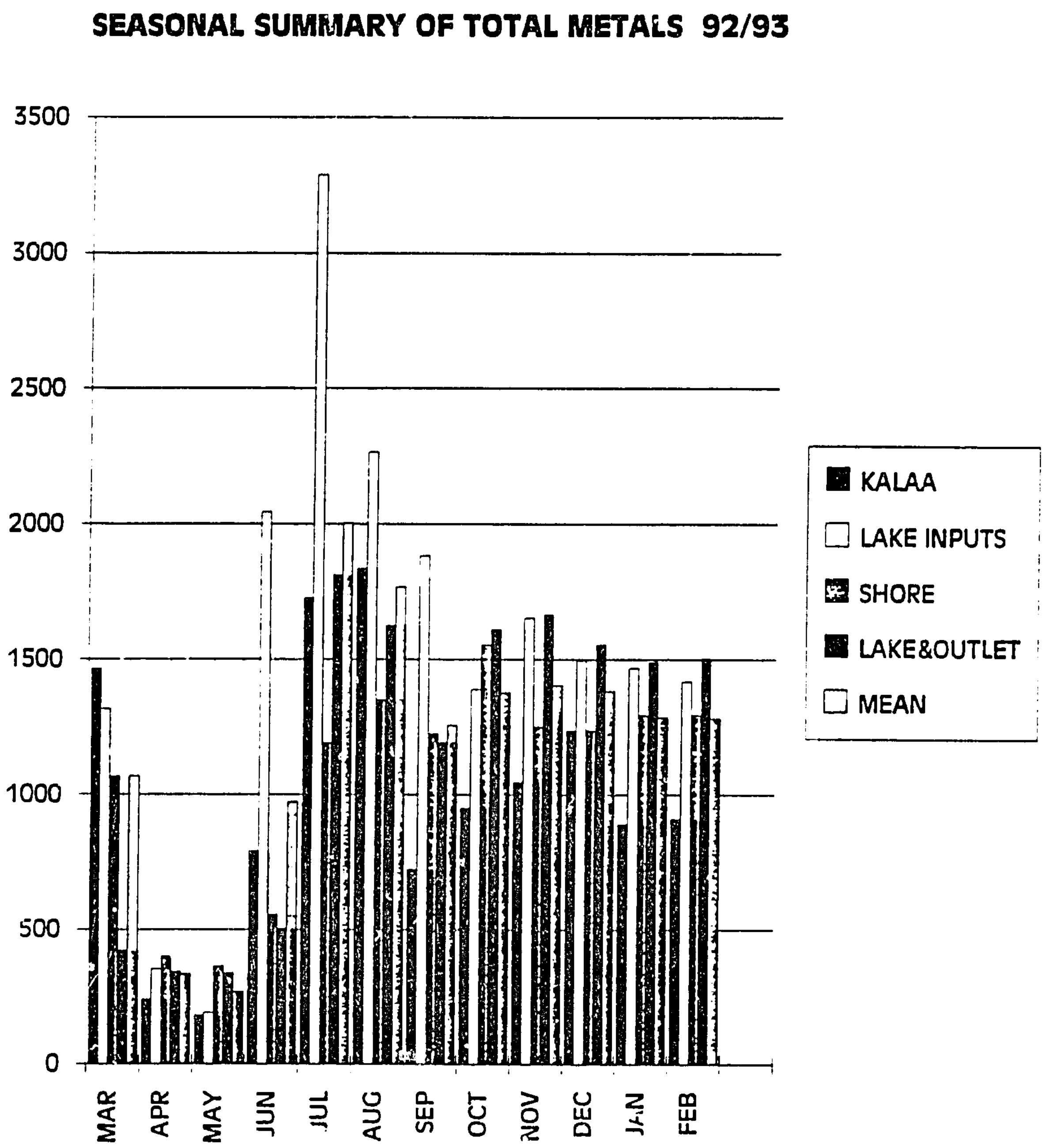
				PB IN ug/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	97	75	17	380	393	740	321	123	360	217	110	132
LAKE INPUTS	92	112	35	802	1115	1217	569	357	567	325	315	343
SHORE	190	100	116	420	203	807	645	633	408	322	406	410
LAKE&OUTLET	138	150	39	238	565	911	605	674	570	443	429	426
ALL STATIONS	129	109	52	460	569	919	535	447	476	326	315	328


SEASONAL SUMMARY OF PB 92/93

				ZN IN ug/l								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA DRAIN	1200	100	37	53	811	670	118	331	194	447	422	405
LAKE INPUTS	925	105	52	132	658	387	641	428	371	502	487	452
SHORE	650	95	63	36	529	135	262	440	430	478	467	466
LAKE&OUTLET	50	ND	68	50	495	83	148	195	369	433	409	416
ALL STATIONS	706	100	55	68	623	319	292	348	341	465	446	435

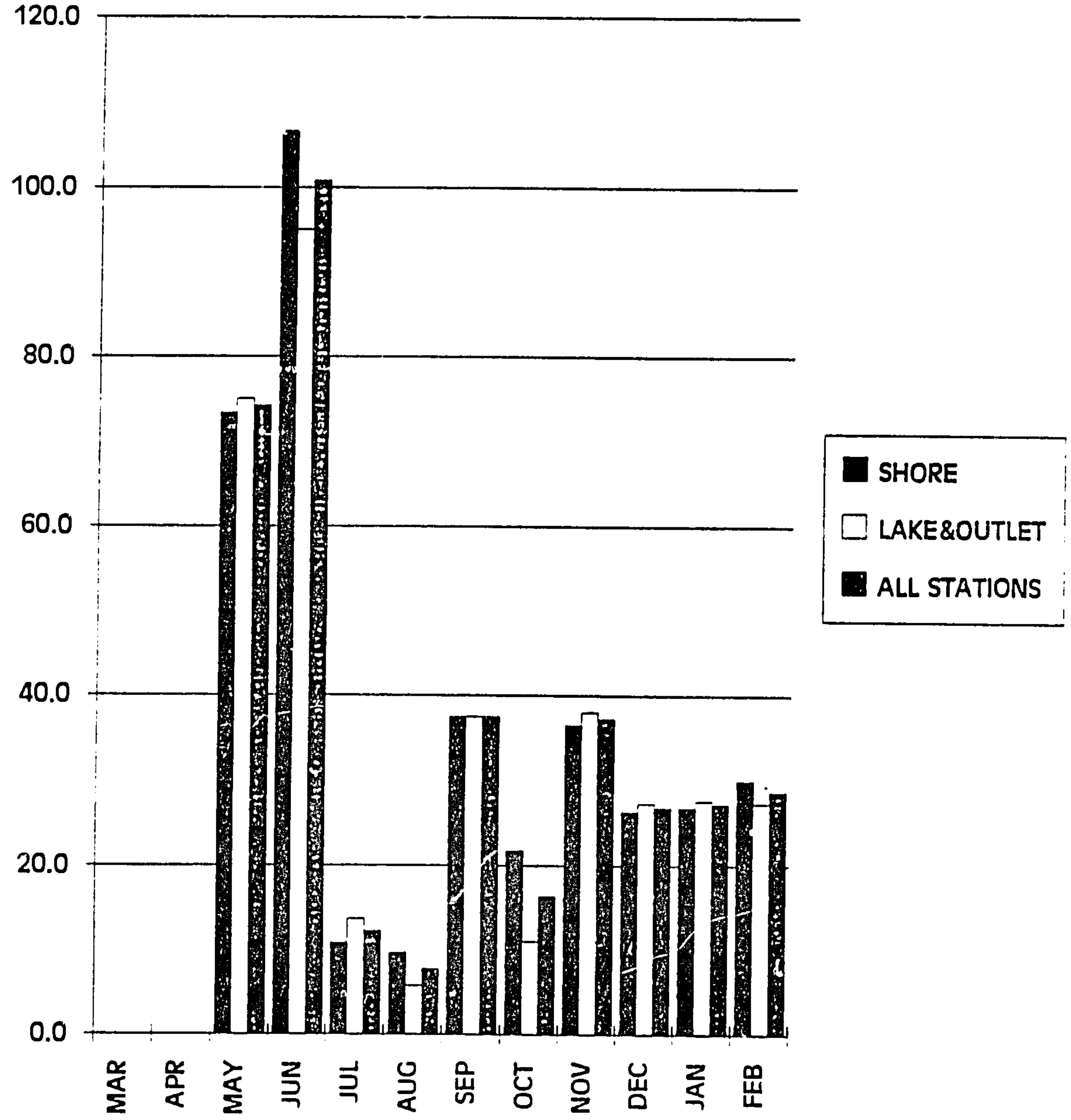


			TOTAL METALS FOR ALL AREAS IN ug/l									
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
KALAA	1465	240	181	791	1728	1837	724	949	1046	1236	890	910
LAKE INPUTS	1316	354	192	2044	3287	2264	1884	1389	1654	1497	1469	1418
SHORE	1067	400	363	555	1191	1350	1224	1554	1251	1237	1295	1294
LAKE&OUTLET	423	344	338	505	1814	1626	1191	1612	1667	1556	1492	1504
MEAN	1068	334	268	974	2005	1769	1256	1376	1404	1381	1286	1282

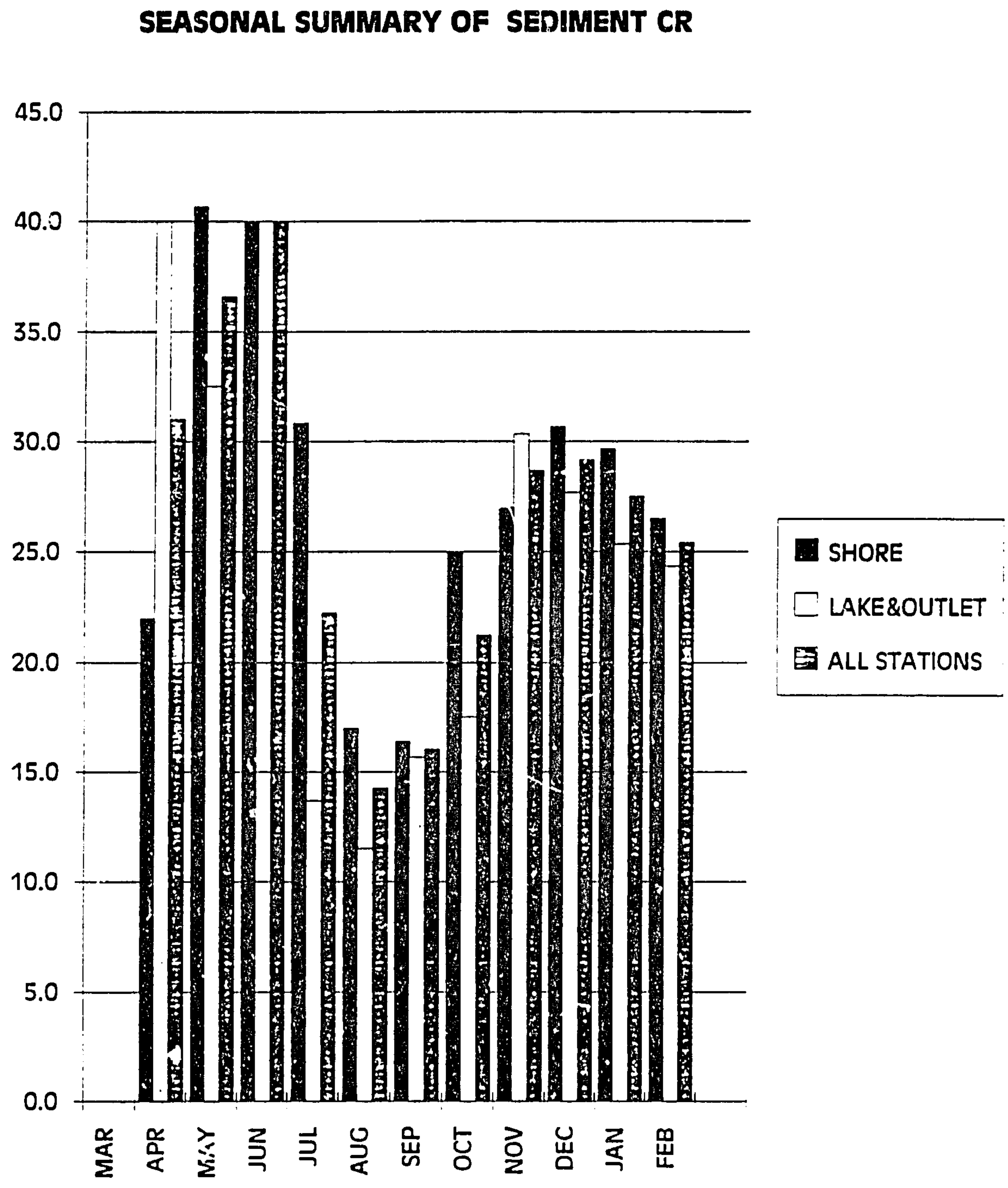


		SEASONAL SUMMARY OF 1992/93 SEDIMENT METALS										
				CD IN mg/kg								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
SHORE	NA	NA	73.3	106.7	10.8	9.7	37.5	21.8	36.5	26.3	26.8	30.0
LAKE&OUTLET	NA	NA	75.0	95.0	13.7	5.8	37.5	11.0	38.0	27.3	27.7	27.3
ALL STATIONS	NA	NA	74.2	101	12.2	7.72	37.5	16.4	37.3	26.8	27.3	28.7

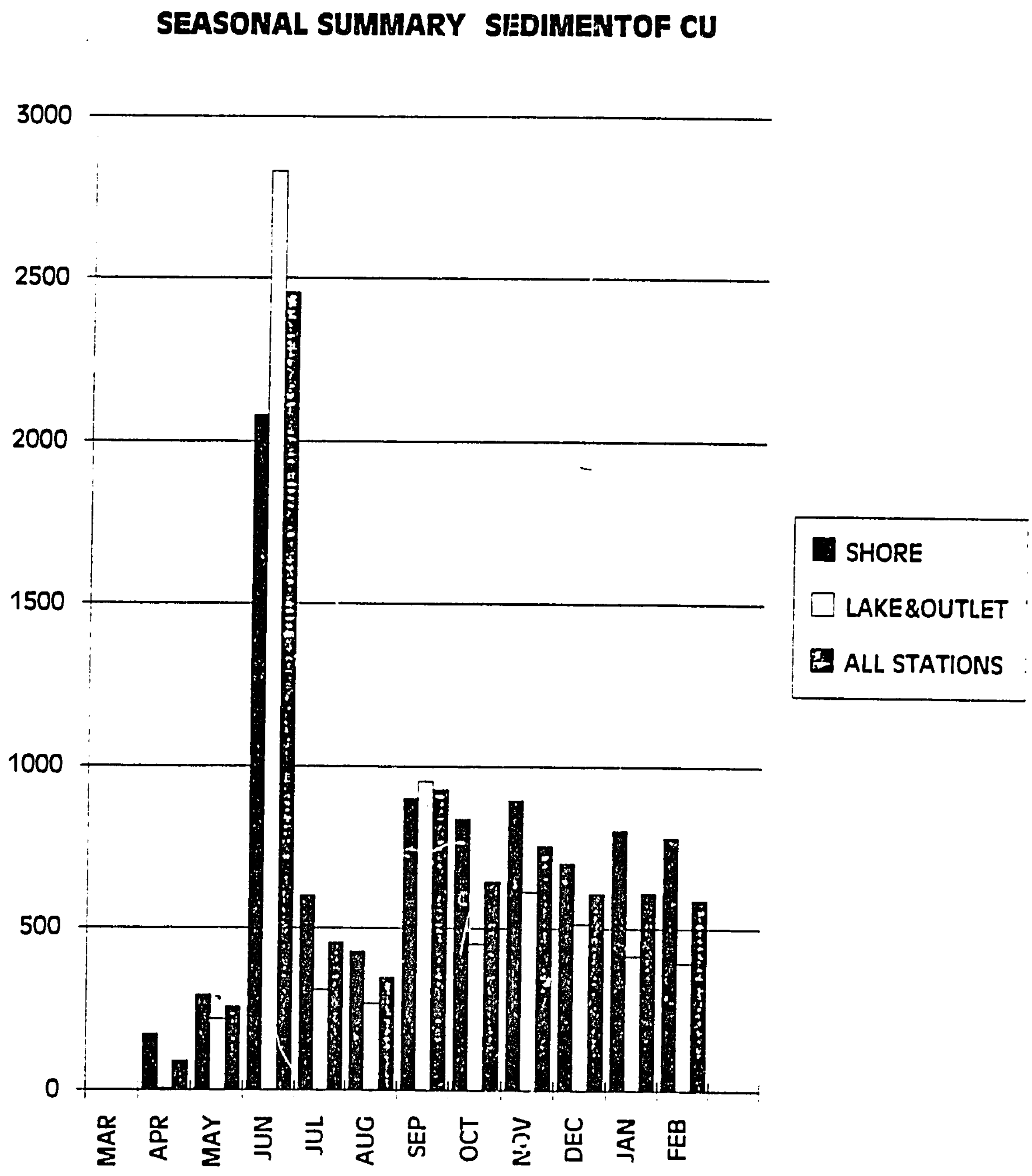
SEASONAL SUMMARY OF SEDIMENT CD



				CR mg/kg								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
SHORE	NA	22.0	40.7	40.0	30.8	17.0	16.4	25.0	27.0	30.7	29.7	26.5
LAKE&OUTLET	NA	40.0	32.5	NA	13.7	11.5	15.7	17.5	30.3	27.7	25.3	24.3
ALL STATIONS	NA	31.0	36.6	40.0	22.3	14.3	16.0	21.3	28.7	29.2	27.5	25.4

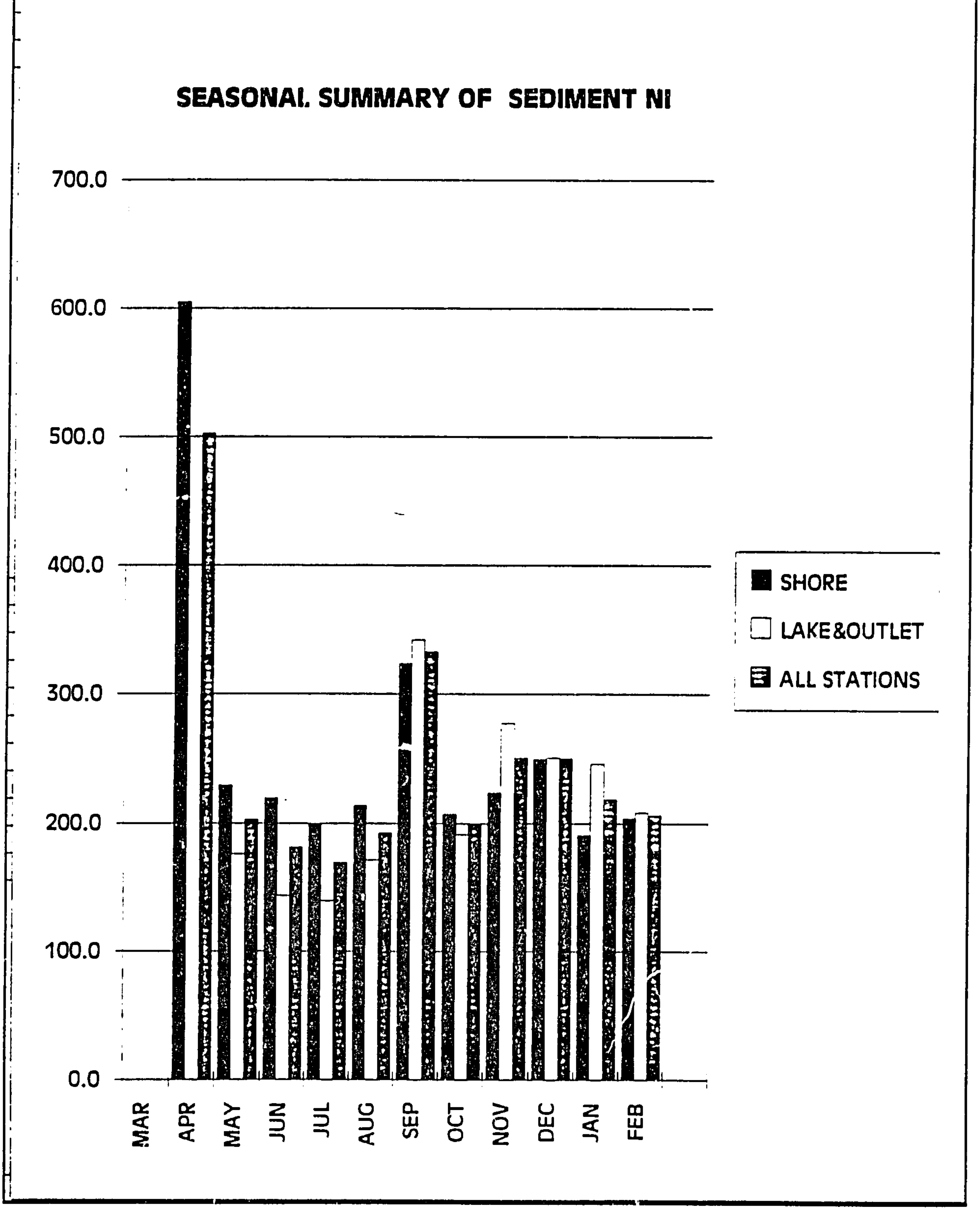


				CU IN mg/kg								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
SHORE	NA	173	295	2080	601	430	902	838	896	702	804	781
LAKE&OUTLET	NA	4	220	2830	311	269	954	452	612	513	416	395
ALL STATIONS	NA	89	258	2455	456	349	928	645	754	608	610	588

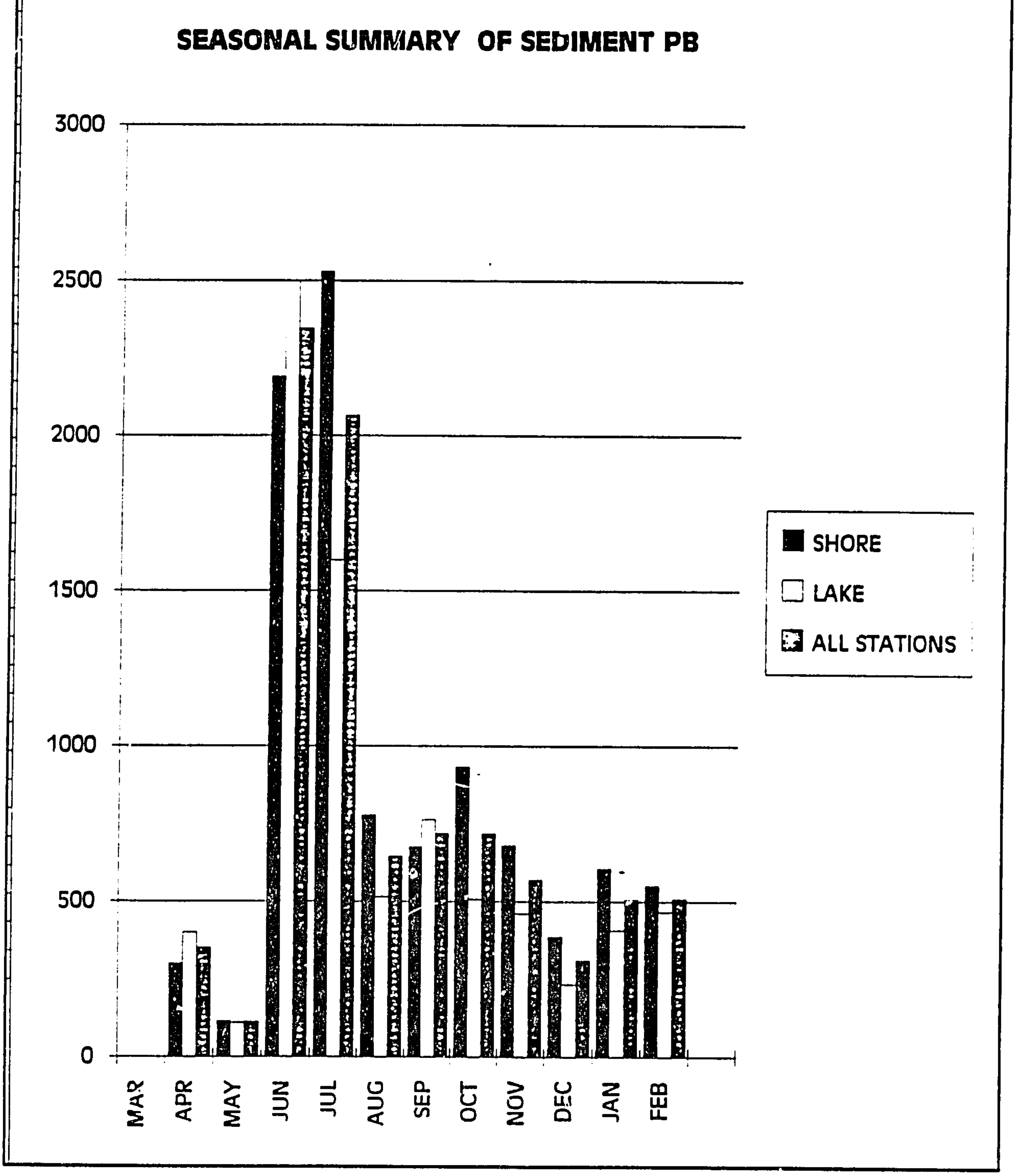


SEASONAL SUMMARY SEDIMENTOF CU

				NI mg/kg								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
SHORE	NA	605.0	229.5	219.5	199.5	213.8	323.5	207.2	223.8	249.7	190.7	203.8
LAKE&OUTLET	NA	400.0	176.0	143.3	139.3	171.3	341.7	191.3	277.7	251.0	246.3	208.3
ALL STATIONS	NA	502.5	202.8	181.4	169.4	192.6	332.6	199.3	250.8	250.3	218.5	206.1

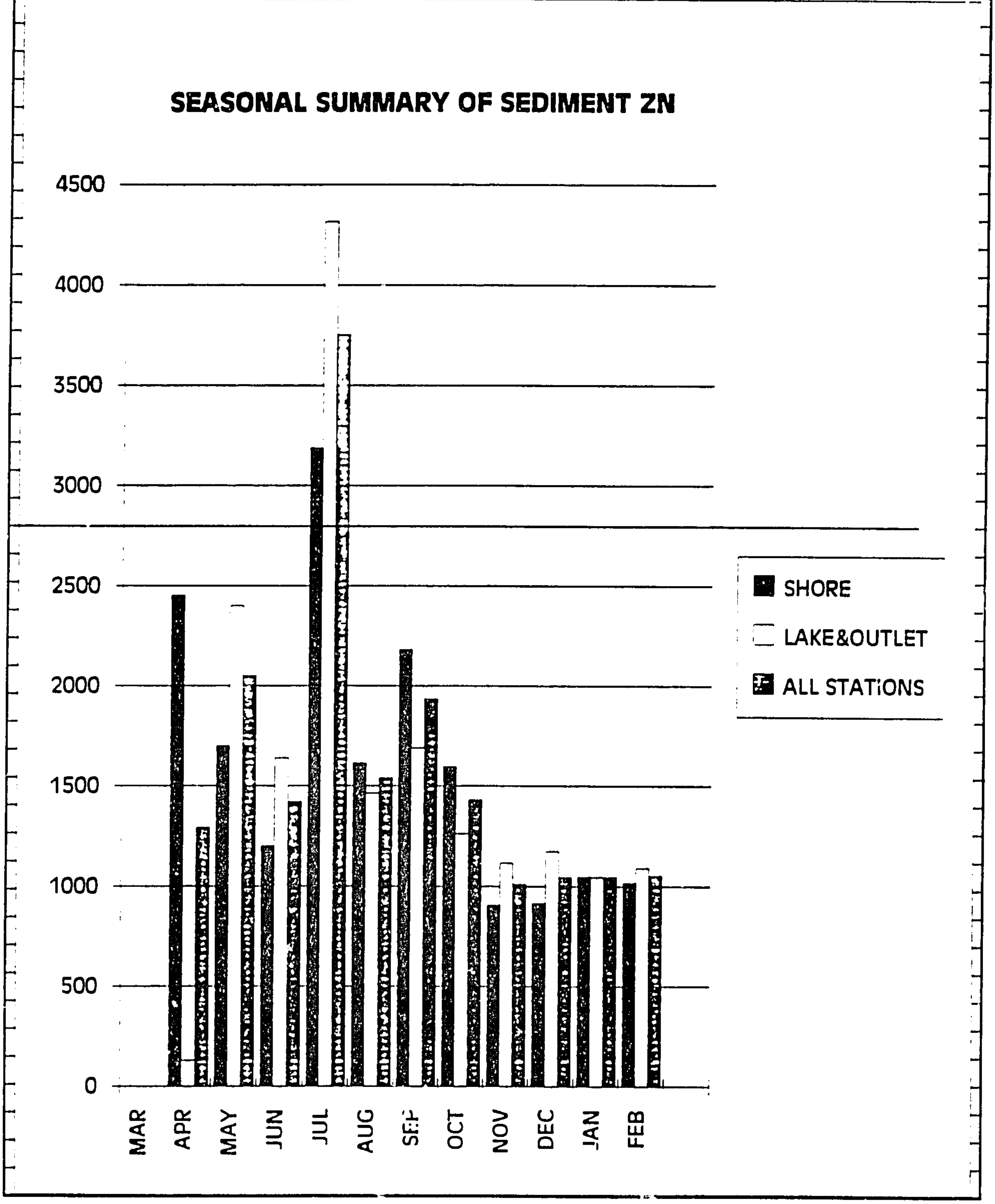


				PB mg/kg								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
SHORE	NA	300	115	2190	2530	778	677	933	682	387	608	552
LAKE	NA	400	110	2500	1600	515	763	507	460	233	407	467
ALL STATIONS	NA	350	113	2345	2065	647	720	720	571	310	507	509



SEASONAL SUMMARY OF SEDIMENT PB

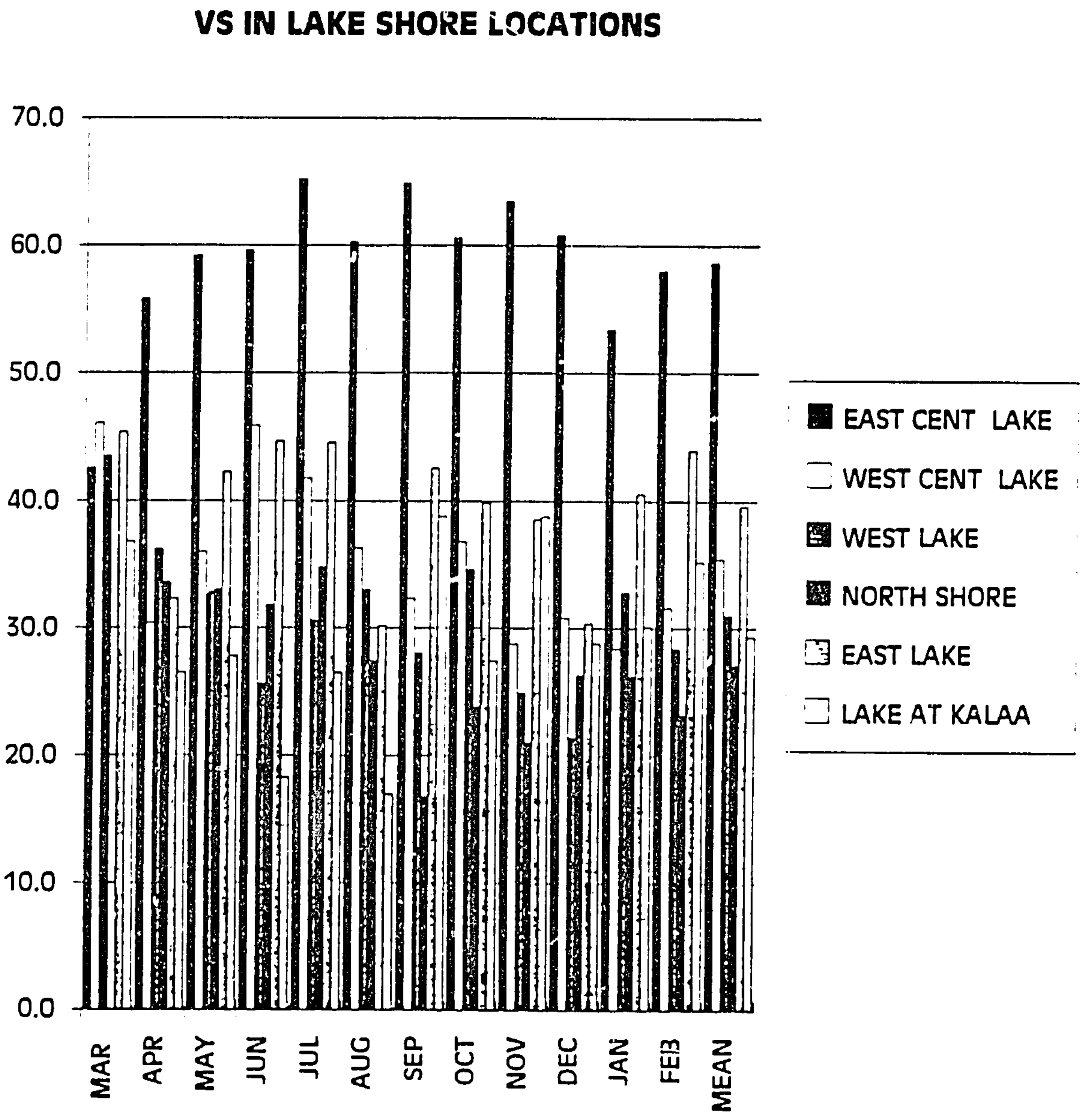
				ZN mg/kg								
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
SHORE	NA	2452	1700	1200	3188	1616	2182	1598	906	918	1049	1019
LAKE&OUTLET	NA	130	2400	1640	4315	1463	1688	1261	1116	1175	1047	1091
ALL STATIONS	NA	1291	2050	1420	3752	1539	1935	1429	1011	1046	1048	1055


SEASONAL SUMMARY OF SEDIMENT ZN

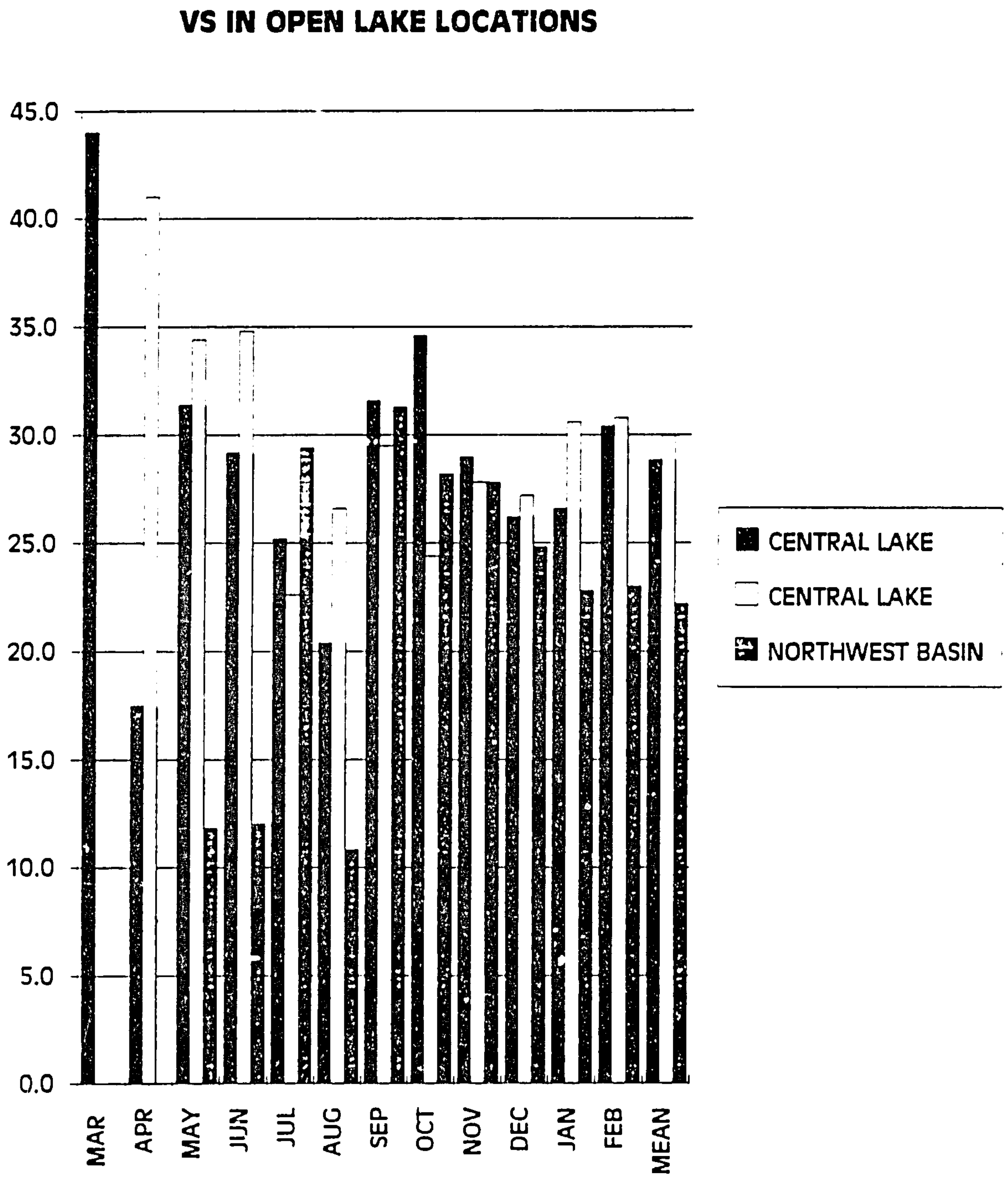
SEASONAL SUMMARY OF 1992/93 LAKE SHORE SEDIMENT VS

g/100g SOLIDS

STA	DESCRIPTION	AR	APR	MA	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MEA
11	EAST CENT LAKE	42.6	55.8	59.2	59.6	65.2	60.3	64.9	60.6	63.5	60.8	53.4	58.0	58.7
12	WEST CENT LAKE	46.1	30.4	36.0	45.9	41.8	36.3	32.3	36.8	28.8	30.8	28.4	31.6	35.4
13	WEST LAKE	43.5	36.2	32.8	25.6	30.6	33.0	28.0	34.6	24.9	21.4	32.8	28.4	31.0
23	NORTH SHORE		33.6	33.0	31.8	34.8	27.4	16.8	23.8	21.0	26.3	26.2	23.2	27.1
10	EAST LAKE	45.4	32.3	42.3	44.7	44.6	30.2	42.6	39.9	38.6	30.4	40.6	44.0	39.6
16	LAKE AT KALAA	36.8	26.5	27.8	18.3	26.5	17.0	38.8	27.4	38.8	28.8	30.1	35.2	29.3


VS IN LAKE SHORE LOCATIONS

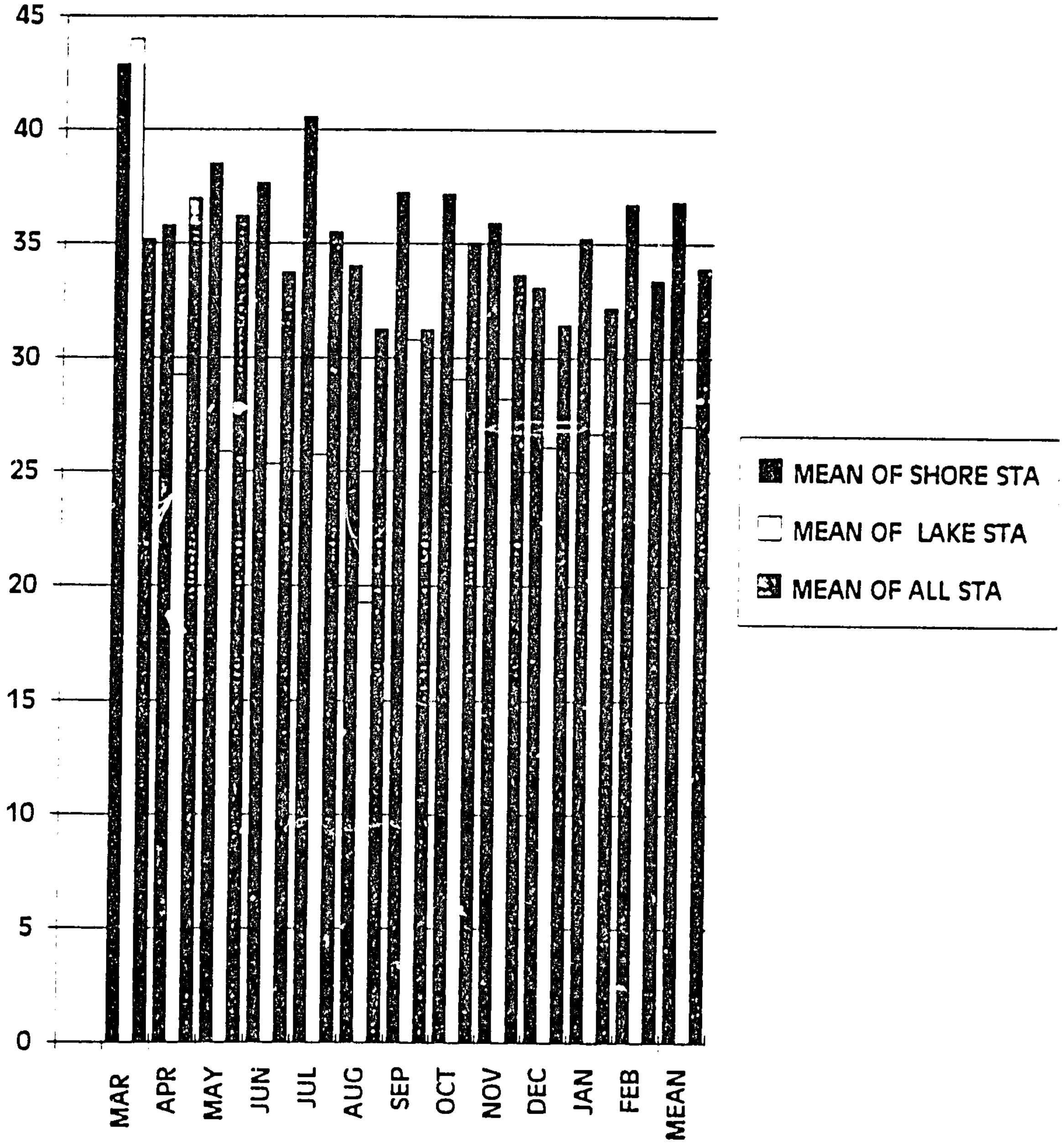
	SEASONAL SUMMARY OF 1992/93 OPEN LAKE SEDIMENT VS													
STA	DESCRIPTION	AR	APR	MA	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MEA
21	CENTRAL LAKE	44.0	17.5	31.4	29.2	25.2	20.4	31.6	34.6	29.0	26.2	26.6	30.4	28.8
22	CENTRAL LAKE		41.0	34.4	34.8	22.6	26.6	29.5	24.4	27.8	27.2	30.6	30.8	30.0
24	NORTHWEST BASIN			11.8	12.0	29.4	10.8	31.3	28.2	27.8	24.8	22.8	23.0	22.2



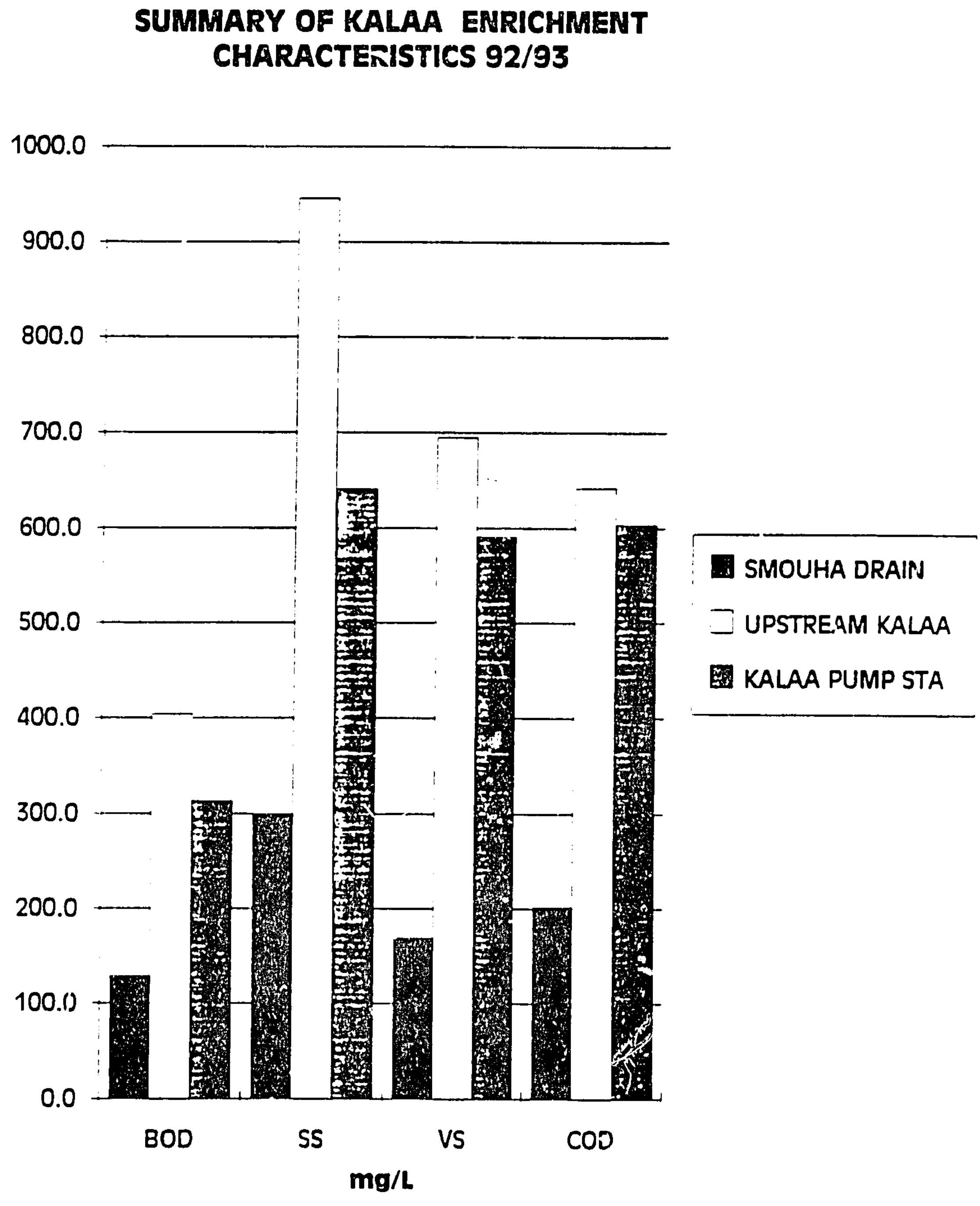
SEASONAL SUMMARY OF ALL 1992/93 SEDIMENT VS

STA #	MAR	APR	MA	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MEA
MEAN OF SHORE STA	42.9	35.8	38.5	37.7	40.6	34.0	37.2	37.2	35.9	33.1	35.3	36.7	36.9
MEAN OF LAKE STA	44.0	29.3	25.9	25.3	25.7	19.3	30.8	29.1	28.2	26.1	26.7	28.1	27.0
MEAN OF ALL STA	35.2	37.0	36.2	33.7	35.5	31.3	31.2	35.1	33.6	31.5	32.2	33.4	33.9

VS IN ALL STATIONS

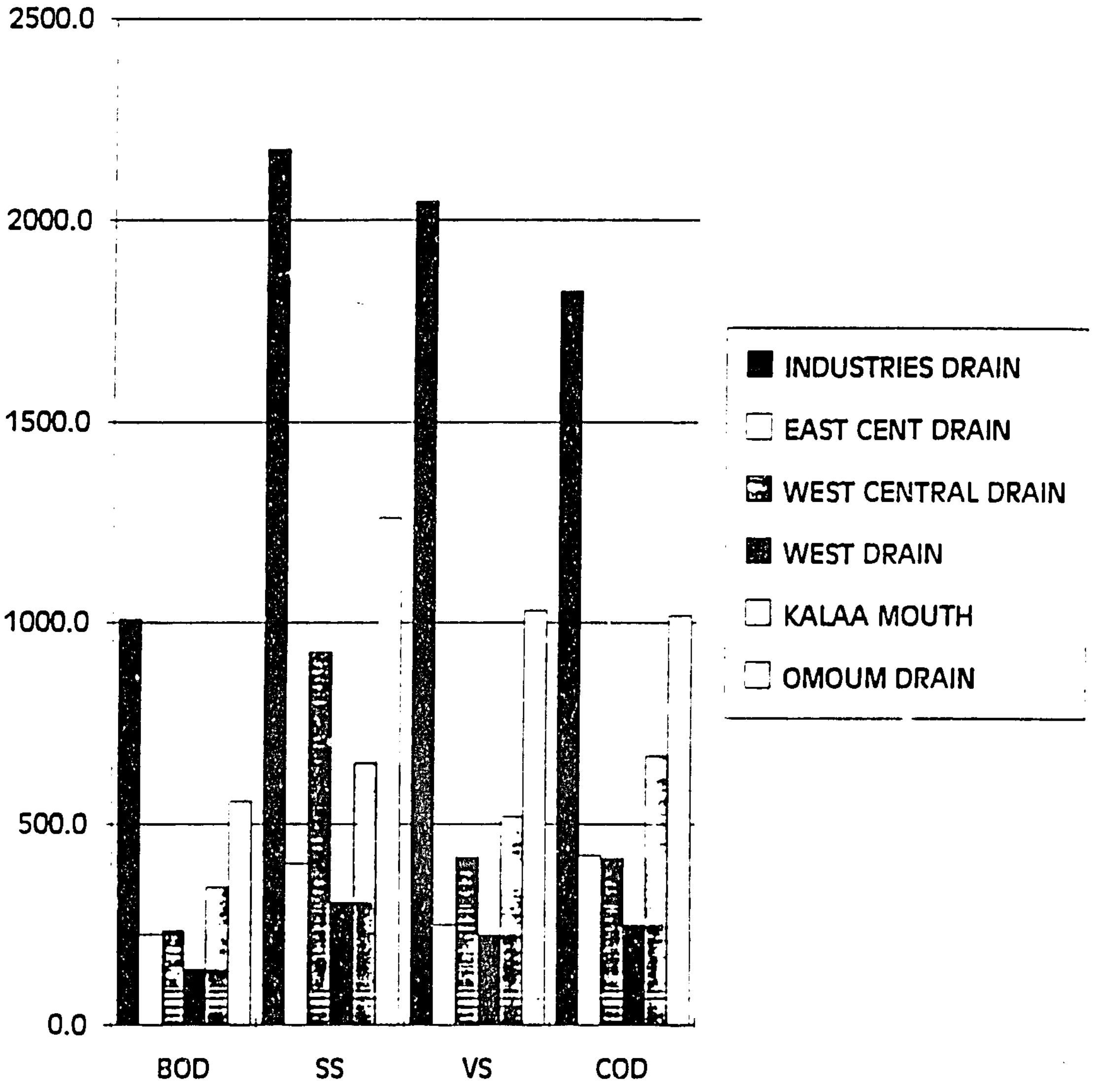


	SUMMARY OF KALLA DRAIN ENRICHMENT CHARACTERISTICS 92/93						
			mg/l				
STA #	DESCRIPTION	BOD	SS	VS	COD		
1	SMOUHA DRAIN	128.9	299.8	169.3	201.8		
2	UPSTREAM KALAA	404.0	945.8	694.8	641.8		
4	KALAA PUMP STA	313.3	641.0	591.1	603.7		

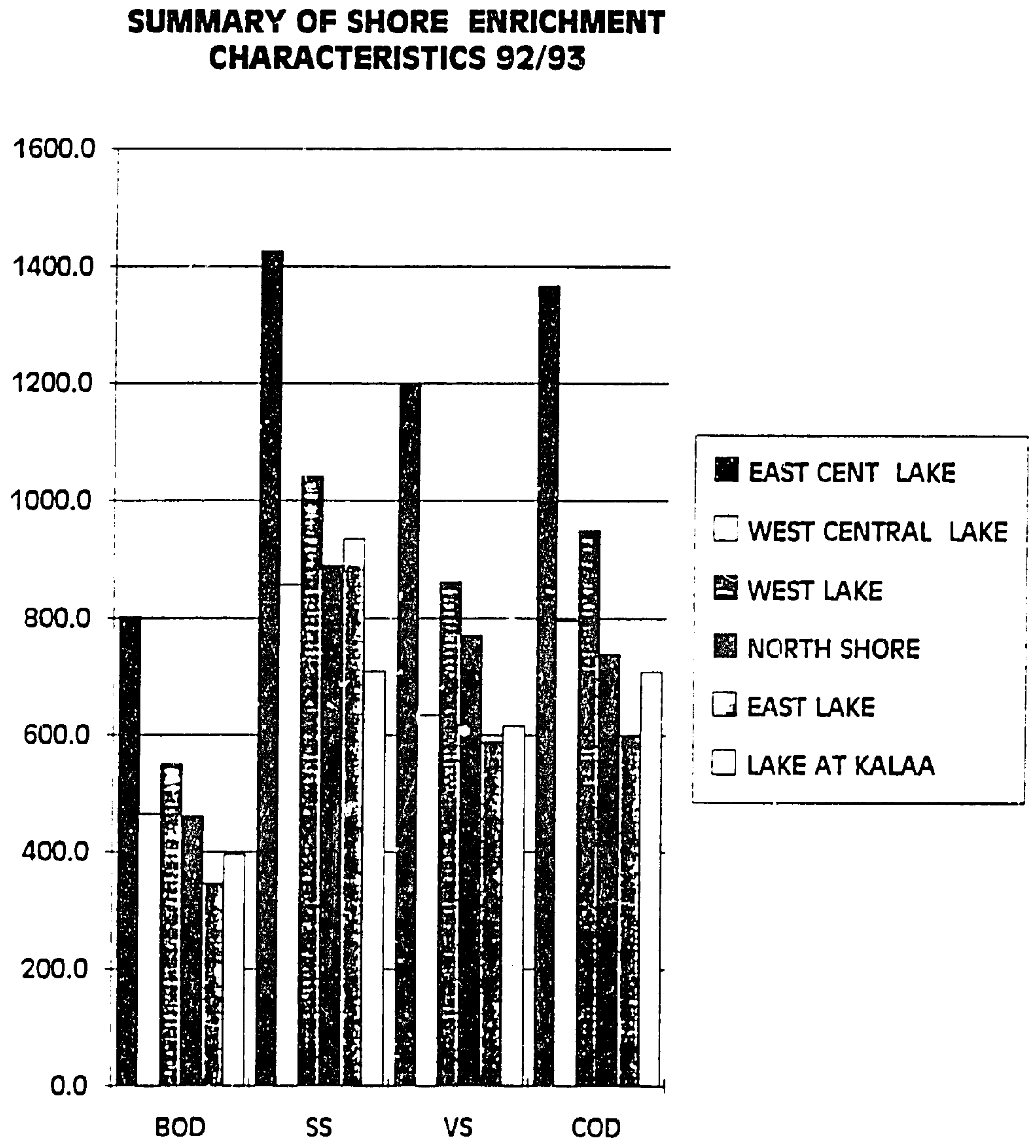


	SUMMARY OF LAKE INPUT ENRICHMENT CHARACTERISTICS 92/93						
			mg/l				
STA #	DESCRIPTION	BOD	SS	VS	COD		
6	INDUSTRIES DRAIN	1008.5	2177.8	2047.4	1825.2		
7	EAST CENT DRAIN	225.2	402.3	249.7	422.2		
8	WEST CENTRAL DRAIN	236.0	926.8	417.8	415.2		
9	WEST DRAIN	139.3	306.4	224.1	249.3		
5	KALAA MOUTH	343.7	652.7	519.3	670.3		
19	OMOUM DRAIN	557.0	1261.7	1029.5	1017.4		

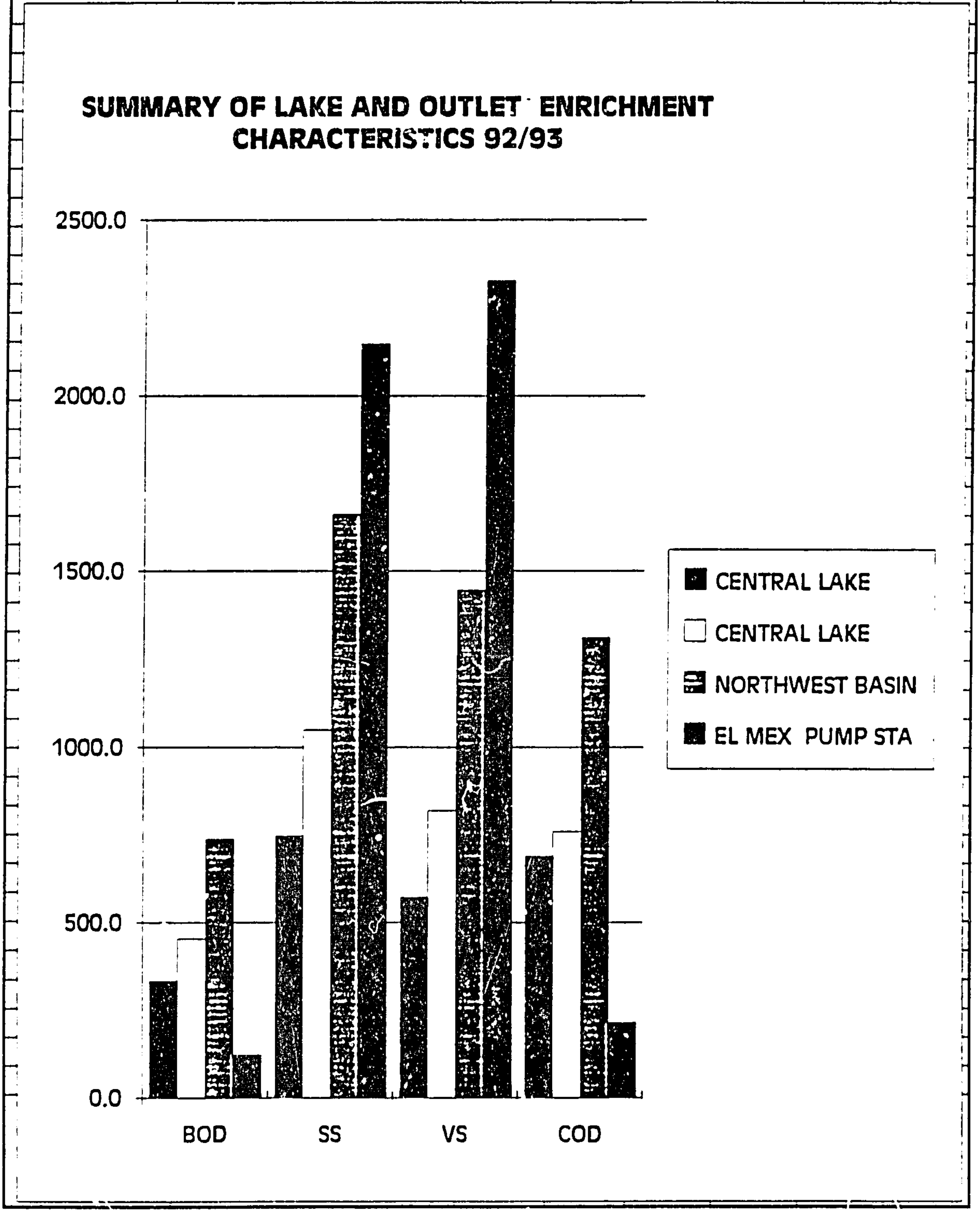
SUMMARY OF LAKE INPUT ENRICHMENT CHARACTERISTICS 92/93



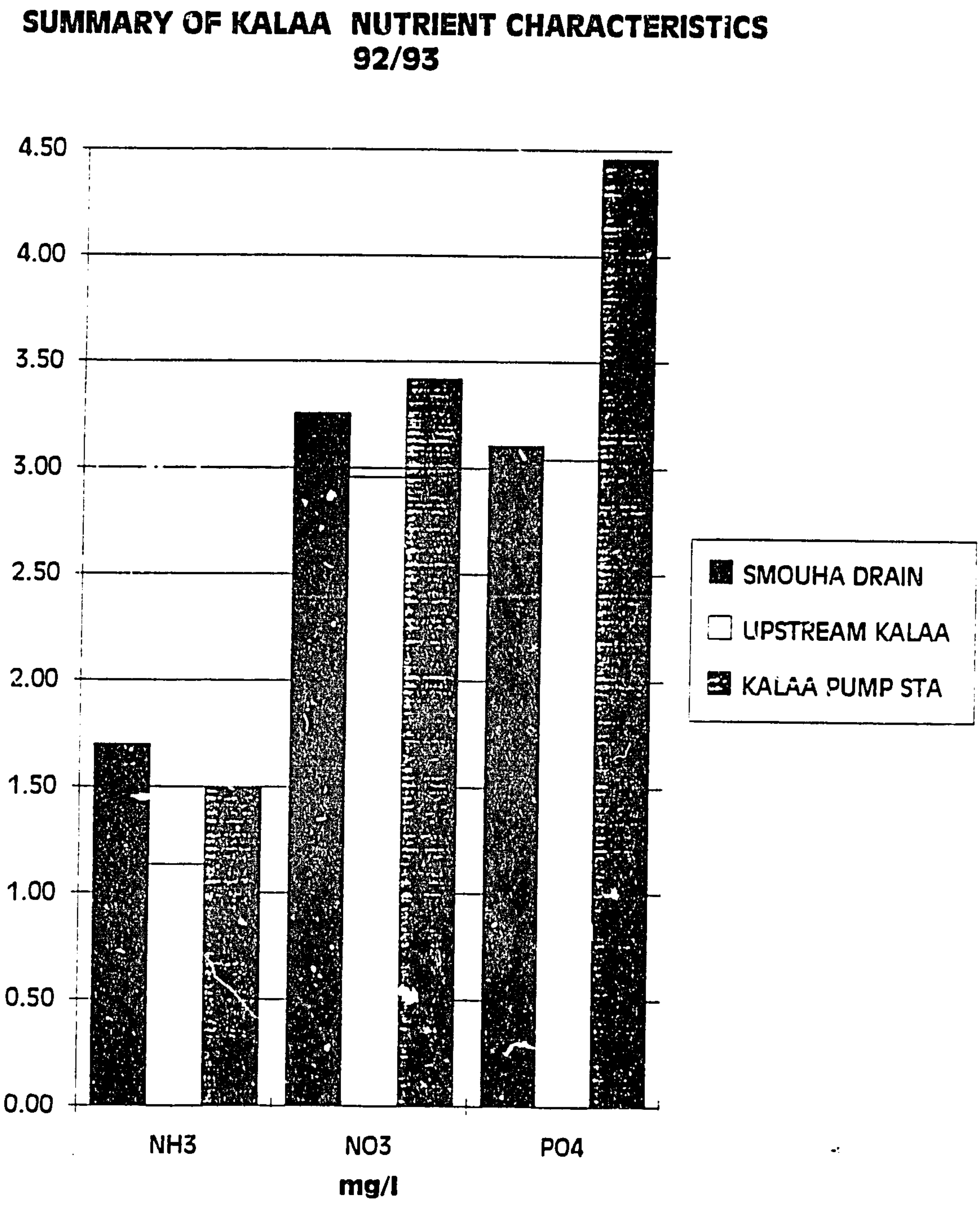
	SUMMARY OF SHORE ENRICHMENT CHARACTERISTICS 92/93				
			mg/l		
STA #	DESCRIPTION	BOD	SS	VS	COD
11	EAST CENT LAKE	803.2	1426.6	1200.8	1366.6
12	WEST CENTRAL LAKE	464.8	858.0	634.4	796.3
13	WEST LAKE	550.3	1040.8	863.0	950.8
23	NORTH SHORE	461.2	891.2	771.6	739.8
10	EAST LAKE	346.8	936.2	588.8	601.2
16	LAKE AT KALAA	396.1	709.4	615.8	708.8



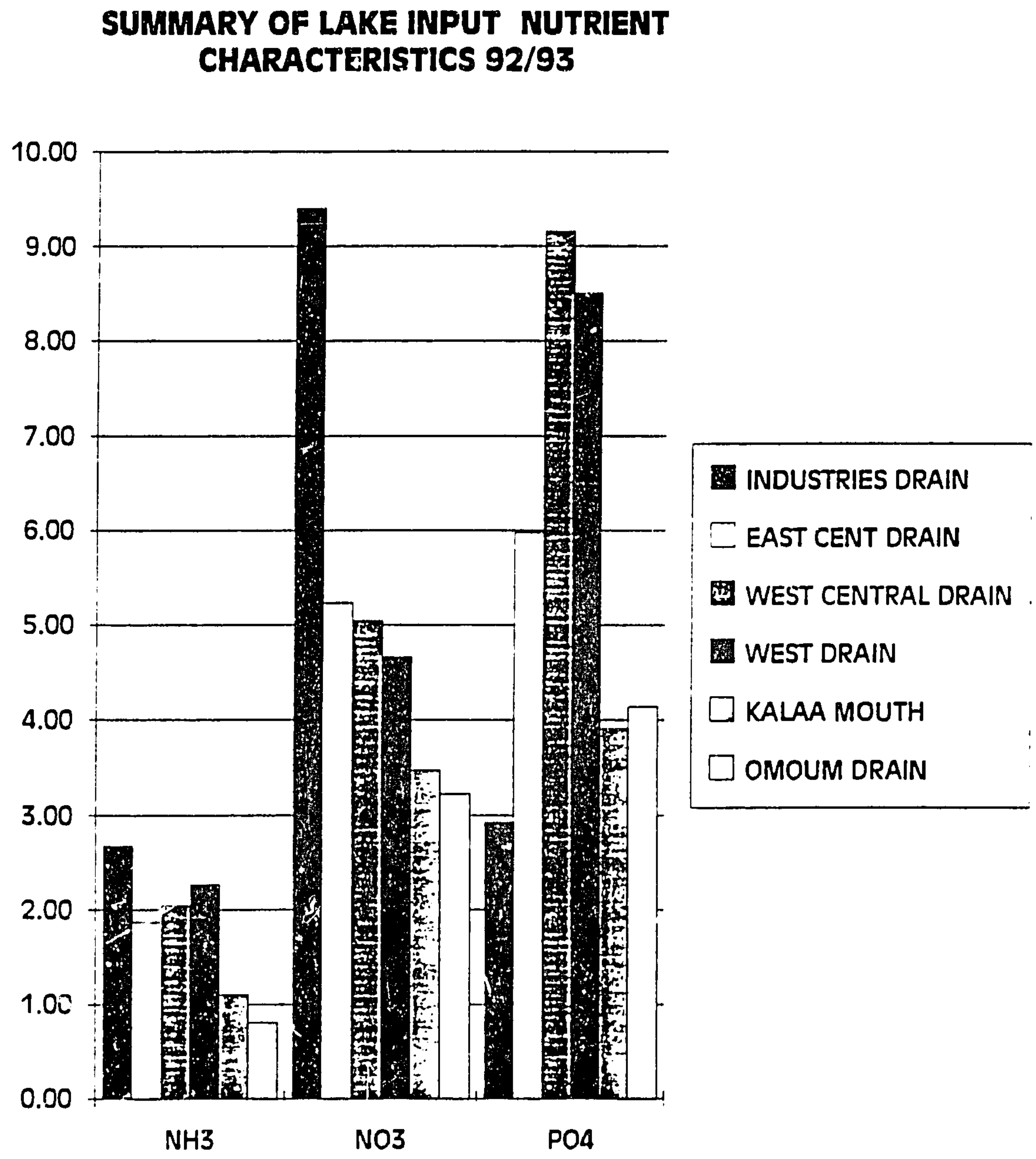
SUMMARY OF LAKE AND OUTLET ENRICHMENT CHARACTERISTICS 92/93						
				mg/l		
STA #		DESCRIPTION	BOD	SS	VS	COD
LAKE	21	CENTRAL LAKE	335.7	747.6	571.8	688.6
	22	CENTRAL LAKE	454.2	1050.3	819.5	760.0
NW BASIN	24	NORTHWEST BASIN	737.5	1662.3	1445.3	1311.4
OUTLET	20	EL MEX PUMP STA	123.8	2146.3	2326.4	216.7



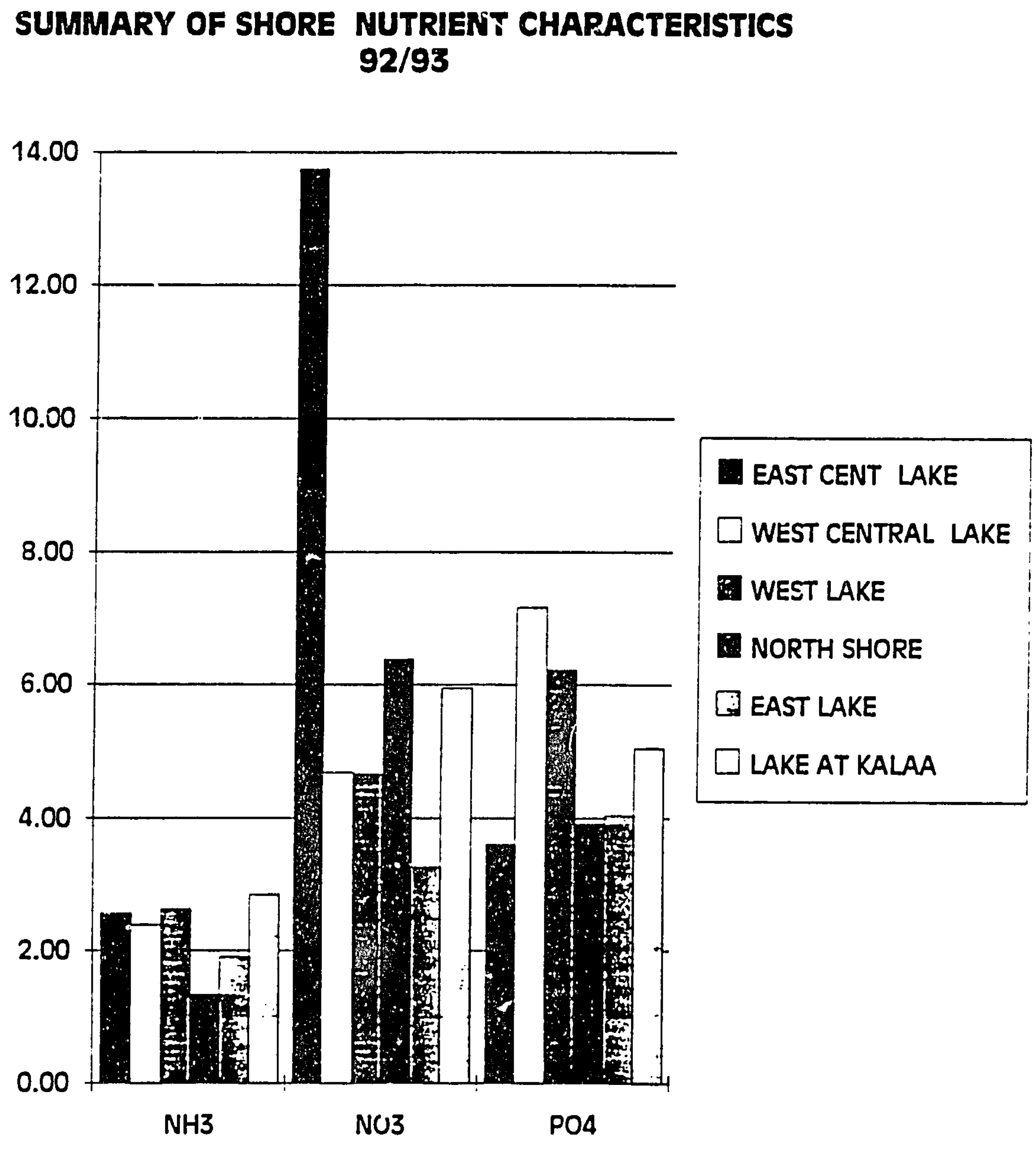
	SUMMARY OF KALLA DRAIN NUTRIENT CHARACTERISTICS 92/93			
			mg/l	
STA #	DESCRIPTION	NH3	NO3	PO4
1	SMOUHA DRAIN	1.70	3.26	3.11
2	UPSTREAM KALAA	1.13	2.96	3.04
4	KALAA PUMP STA	1.50	3.42	4.46



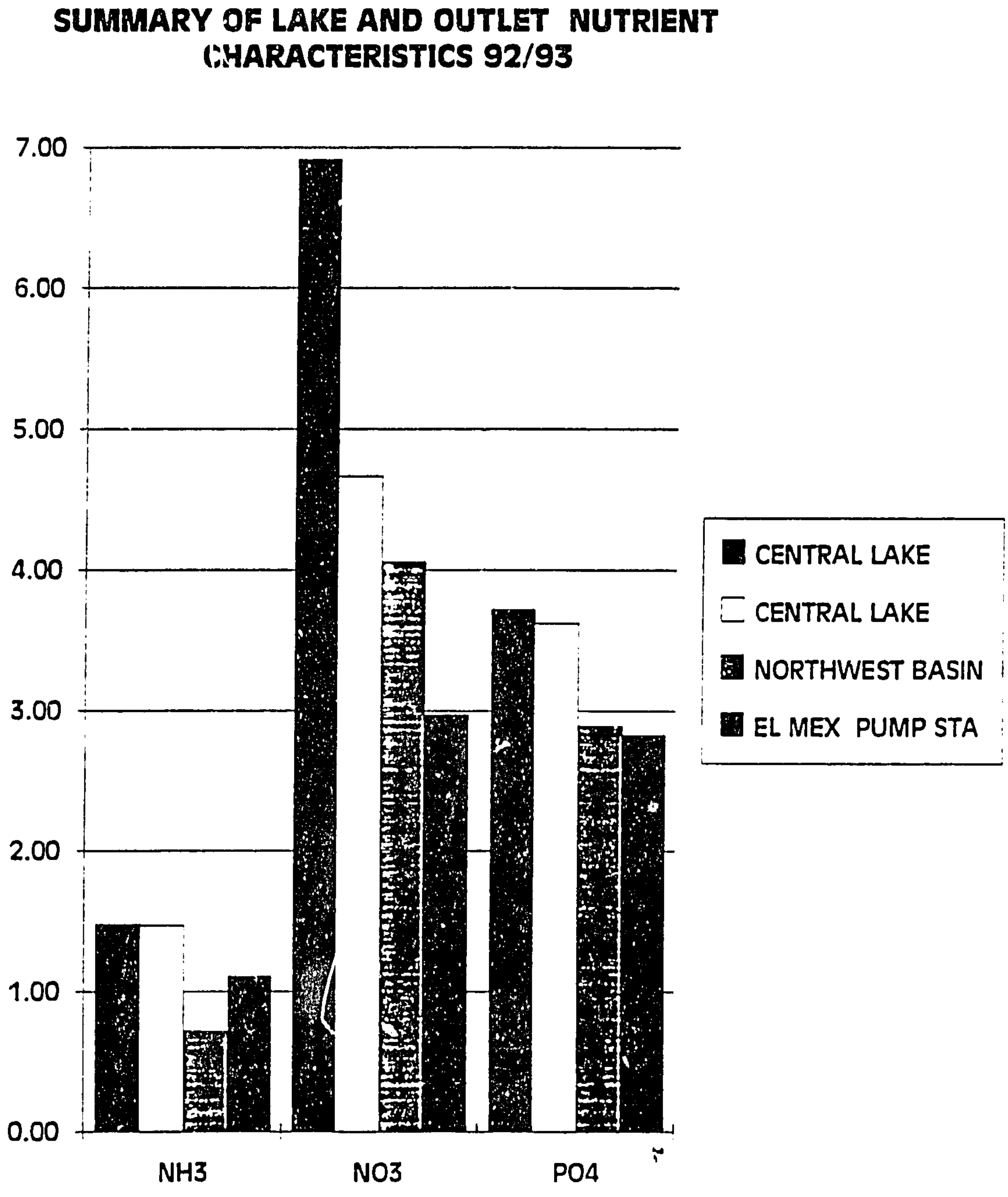
	SUMMARY OF LAKE INPUT NUTRIENT CHARACTERISTICS 92/93			
			mg/l	
STA #	DESCRIPTION	NH3	NO3	PO4
6	INDUSTRIES DRAIN	2.68	9.40	2.93
7	EAST CENT DRAIN	1.87	5.23	5.98
8	WEST CENTRAL DRAIN	2.05	5.05	9.16
9	WEST DRAIN	2.27	4.66	8.50
5	KALAA MOUTH	1.10	3.47	3.91
19	OMOUM DRAIN	0.81	3.23	4.14



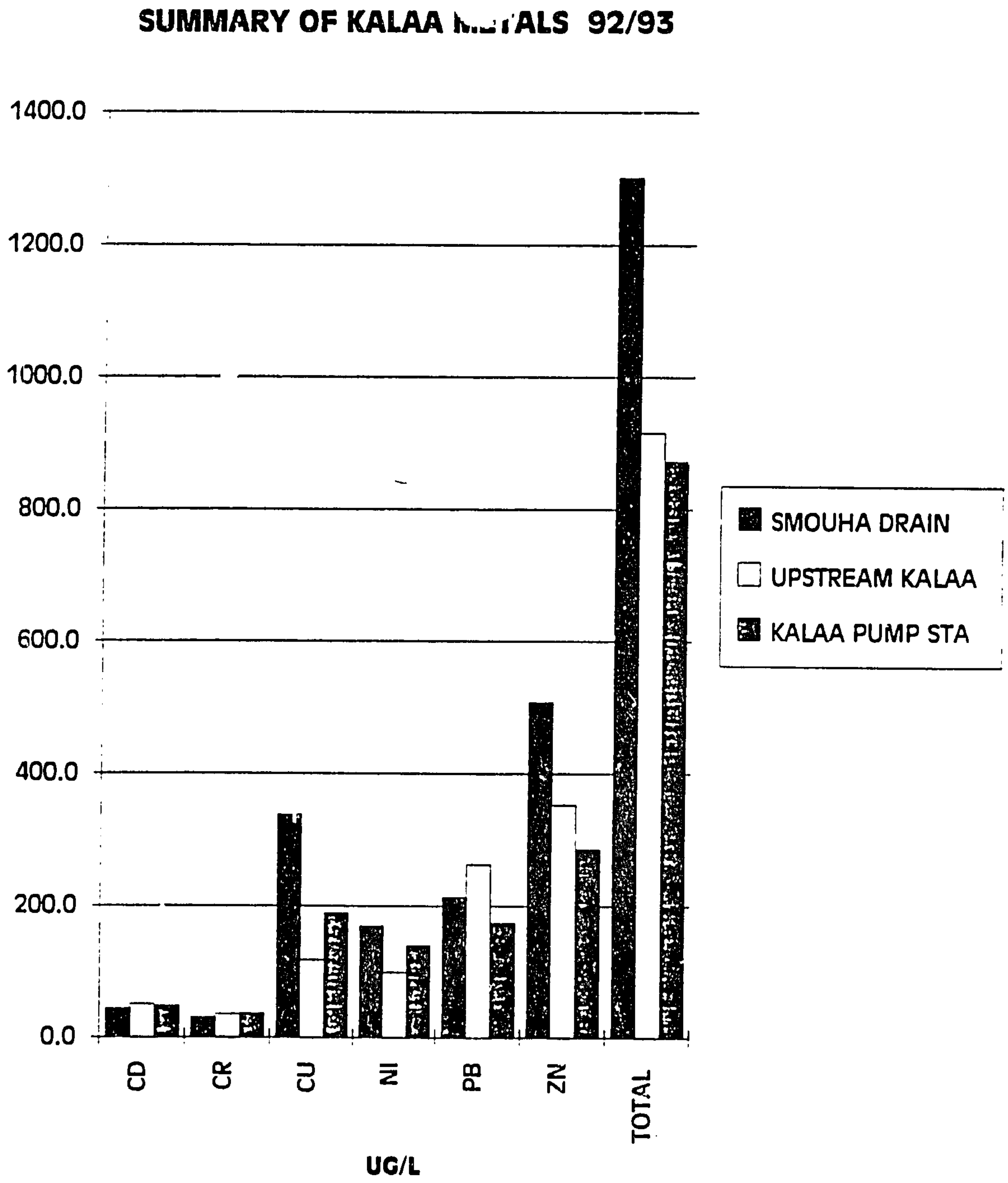
	SUMMARY OF SHORE NUTRIENT CHARACTERISTICS 92/93			
			mg/l	
STA #	DESCRIPTION	NH3	NO3	PO4
11	EAST CENT LAKE	2.57	13.75	3.61
12	WEST CENTRAL LAKE	2.39	4.68	7.17
13	WEST LAKE	2.63	4.66	6.22
23	NORTH SHORE	1.35	6.39	3.92
10	EAST LAKE	1.91	3.27	4.04
16	LAKE AT KALAA	2.85	5.95	5.05



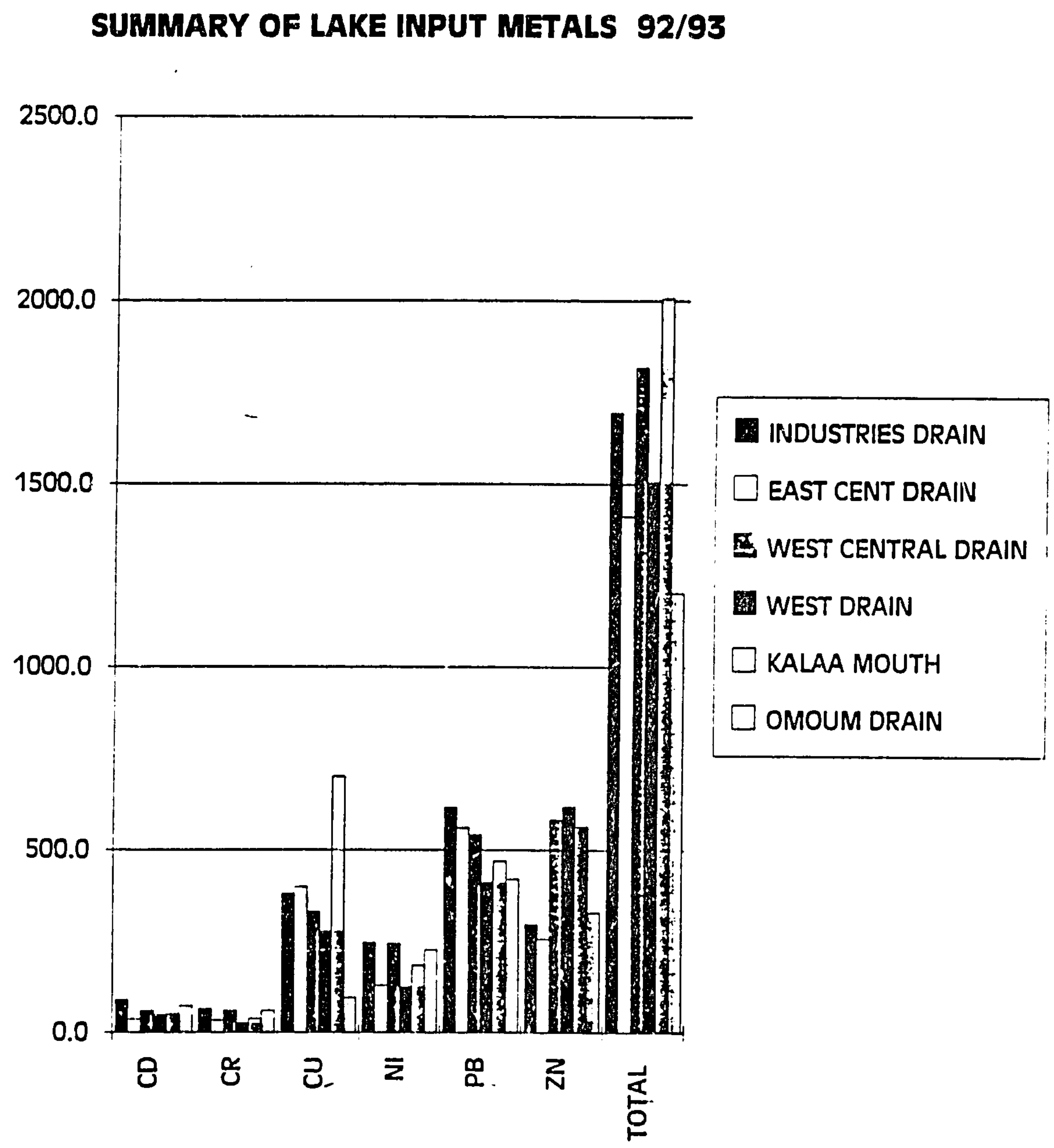
		SUMMARY OF LAKE AND OUTLET NUTRIENT CHARACTERISTICS 92/93			
				mg/l	
STA #		DESCRIPTION	NH3	NO3	PO4
LAKE	21	CENTRAL LAKE	1.48	6.92	3.72
	22	CENTRAL LAKE	1.47	4.66	3.62
NW BASIN	24	NORTHWEST BASIN	0.72	4.06	2.89
OUTLET	20	EL MEX PUMP STA	1.11	2.97	2.83



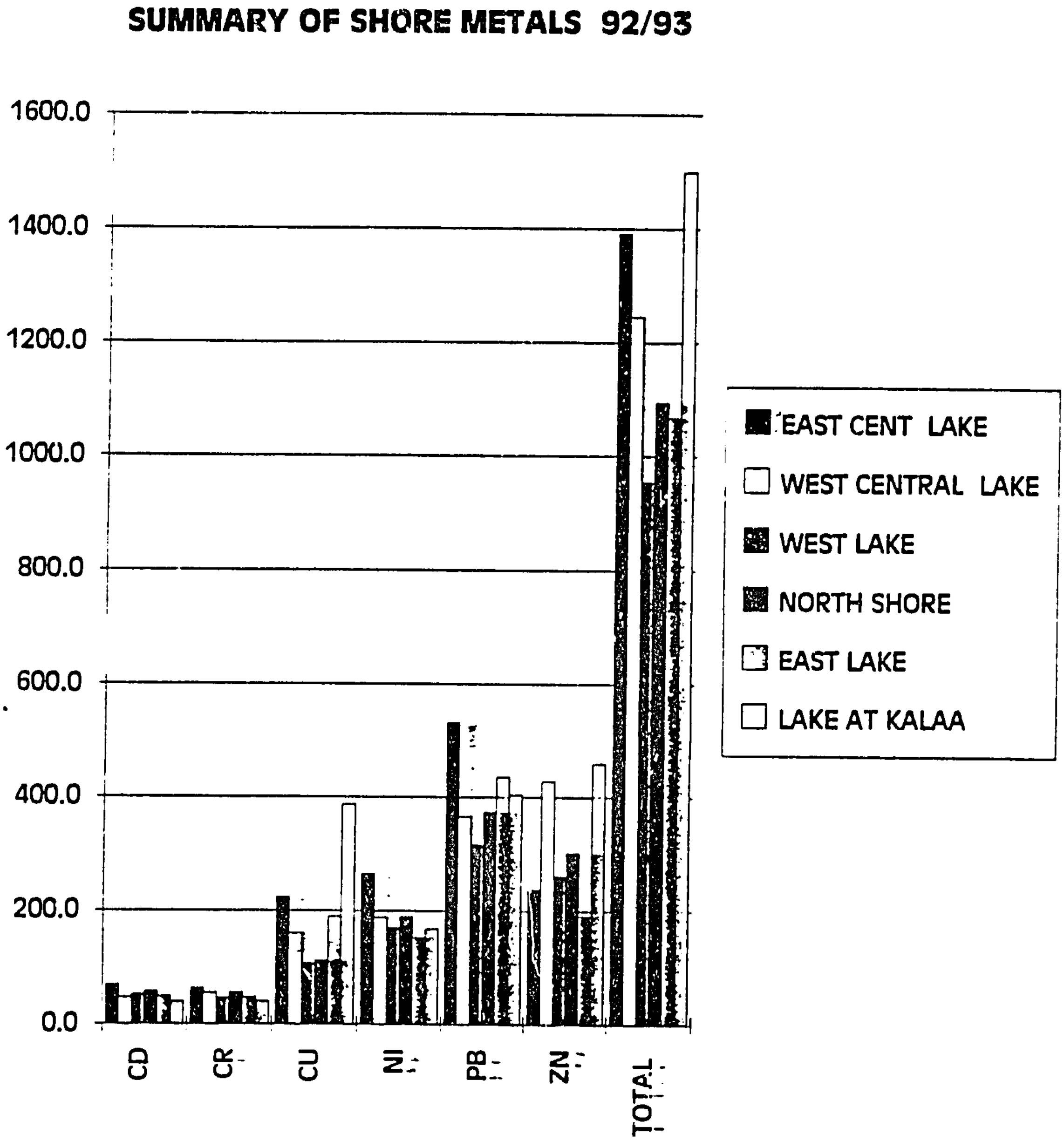
	SUMMARY OF KALLA DRAIN METAL CONCENTRATIONS 92/93							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	TOTAL
1	SMOUHA DRAIN	43.1	30.5	337.6	169.3	213.5	507.6	1301.6
2	UPSTREAM KALAA	49.8	35.0	117.5	98.3	262.1	352.6	915.3
4	KALAA PUMP STA	47.0	36.5	189.0	139.7	174.5	285.6	872.1



	SUMMARY OF LAKE INPUT METAL CONCENTRATIONS 92/93							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	TOTAL
6	INDUSTRIES DRAIN	88.9	64.6	380.4	247.6	615.9	296.9	1694.3
7	EAST CENT DRAIN	36.0	32.8	398.0	128.8	559.7	256.7	1411.8
8	WEST CENTRAL DRAIN	58.7	59.7	329.7	244.2	541.3	583.1	1816.7
9	WEST DRAIN	47.9	25.3	277.5	125.8	410.6	618.4	1505.6
5	KALAA MOUTH	49.8	37.5	700.3	184.8	470.5	563.4	2006.3
19	OMOUM DRAIN	71.8	59.4	95.3	227.5	420.3	329.0	1203.3

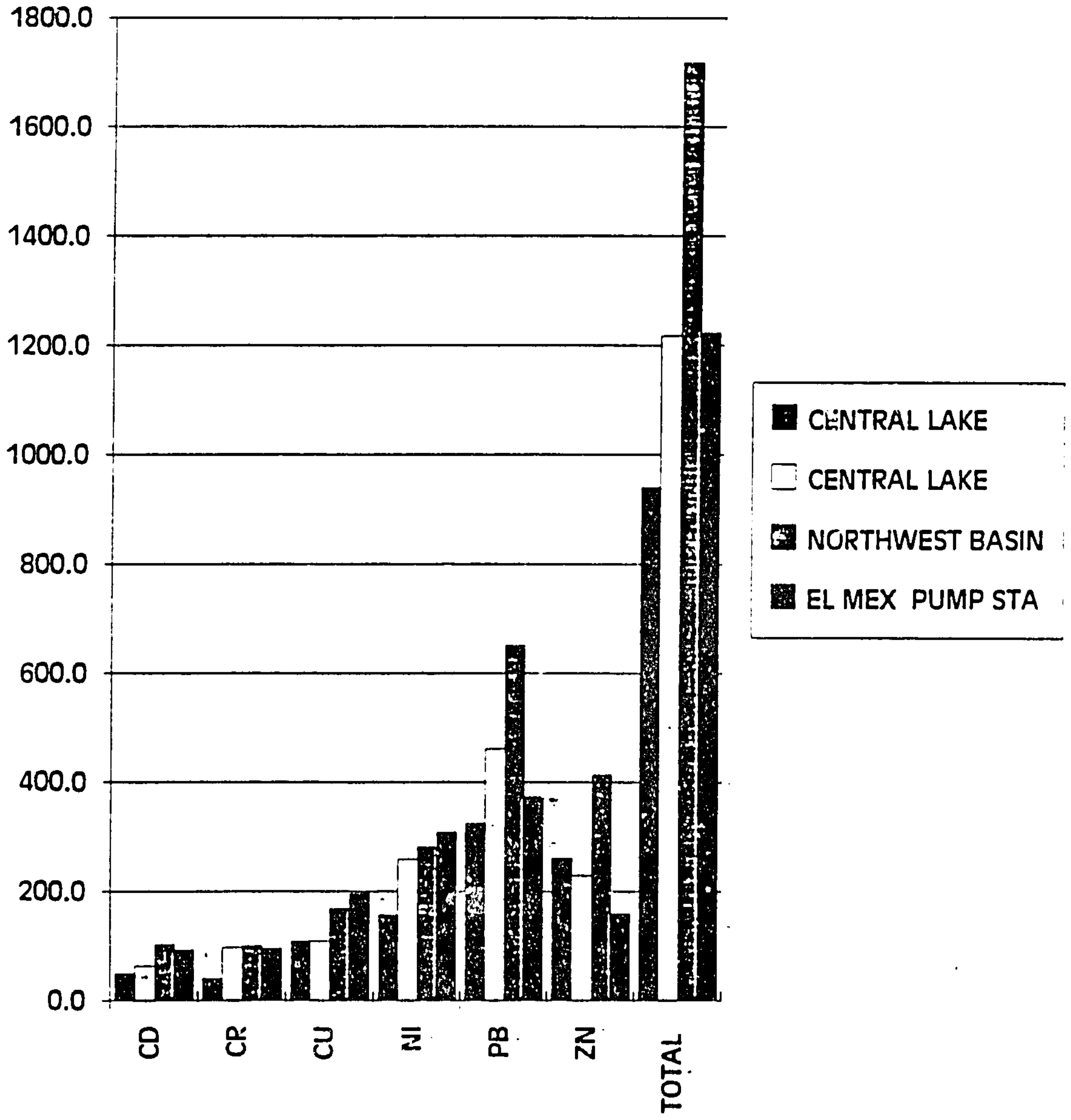


	SUMMARY OF LAKE SHORE METAL CONCENTRATIONS 92/93							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	TOTAL
11	EAST CENT LAKE	69.5	63.8	224.1	264.7	532.2	237.6	1391.9
12	WEST CENTRAL LAKE	47.3	55.1	160.5	188.2	365.2	428.6	1244.8
13	WEST LAKE	53.1	46.3	107.4	170.0	316.1	261.5	954.4
23	NORTH SHORE	58.1	56.9	112.8	189.9	373.9	302.4	1094.0
10	EAST LAKE	49.3	47.6	190.4	152.5	436.5	191.2	1067.5
16	LAKE AT KALAA	39.4	40.3	387.1	168.4	404.5	460.3	1500.0

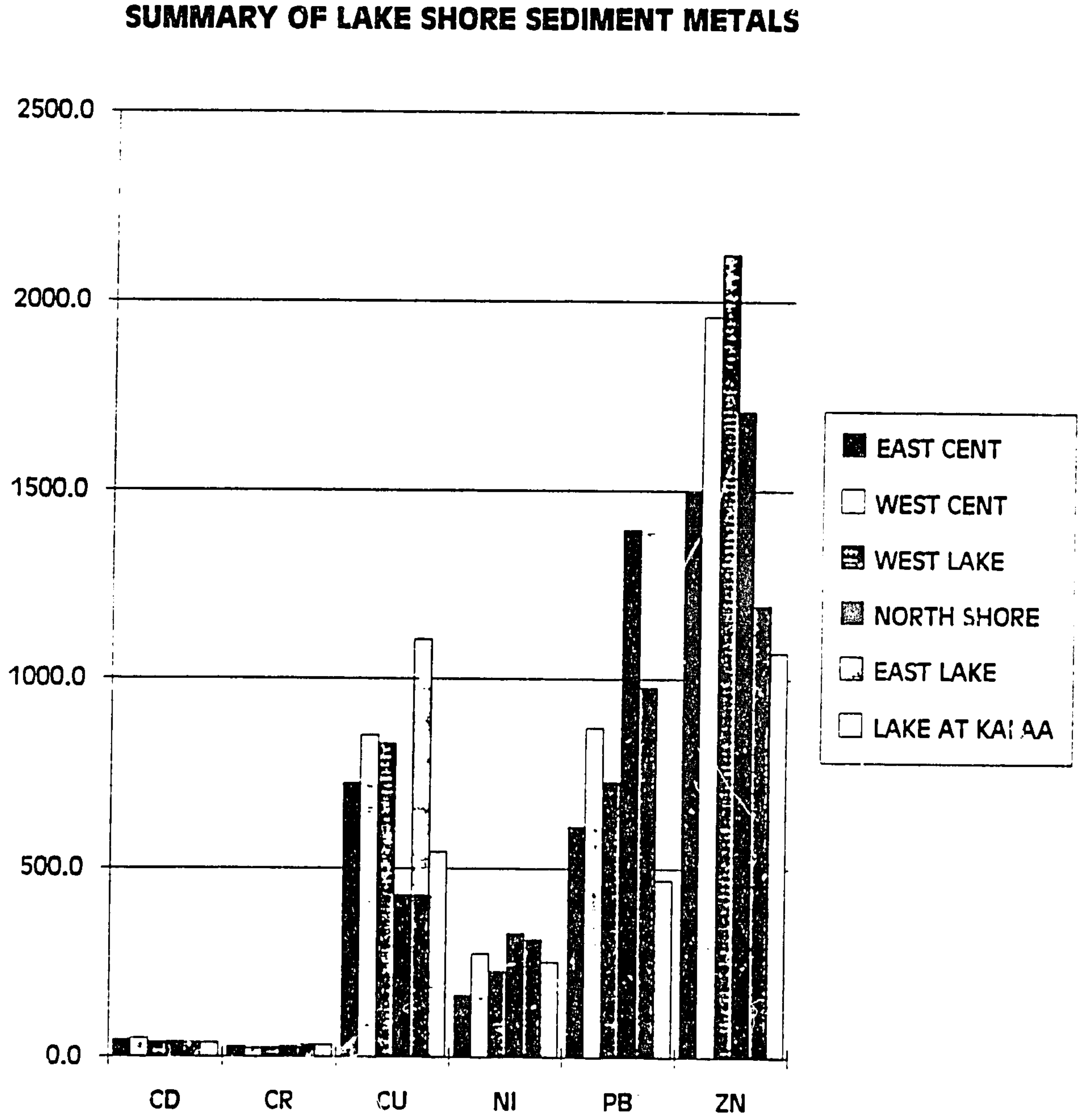


	SUMMARY OF LAKE AND OUTLET METAL CONCENTRATIONS 92/93							
			ug/l					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	TOTAL
21	CENTRAL LAKE	49.4	40.6	108.4	156.8	323.9	260.7	939.7
22	CENTRAL LAKE	63.3	97.2	109.1	258.4	461.2	228.6	1217.8
NW BASIN 24	NORTHWEST BASIN	103.0	100.3	168.8	281.0	651.4	413.2	1717.6
OUTLET 20	EL MEX PUMP STA	92.6	95.1	196.0	307.8	373.2	158.8	1223.5

SUMMARY OF LAKE AND OUTLET METALS 92/93

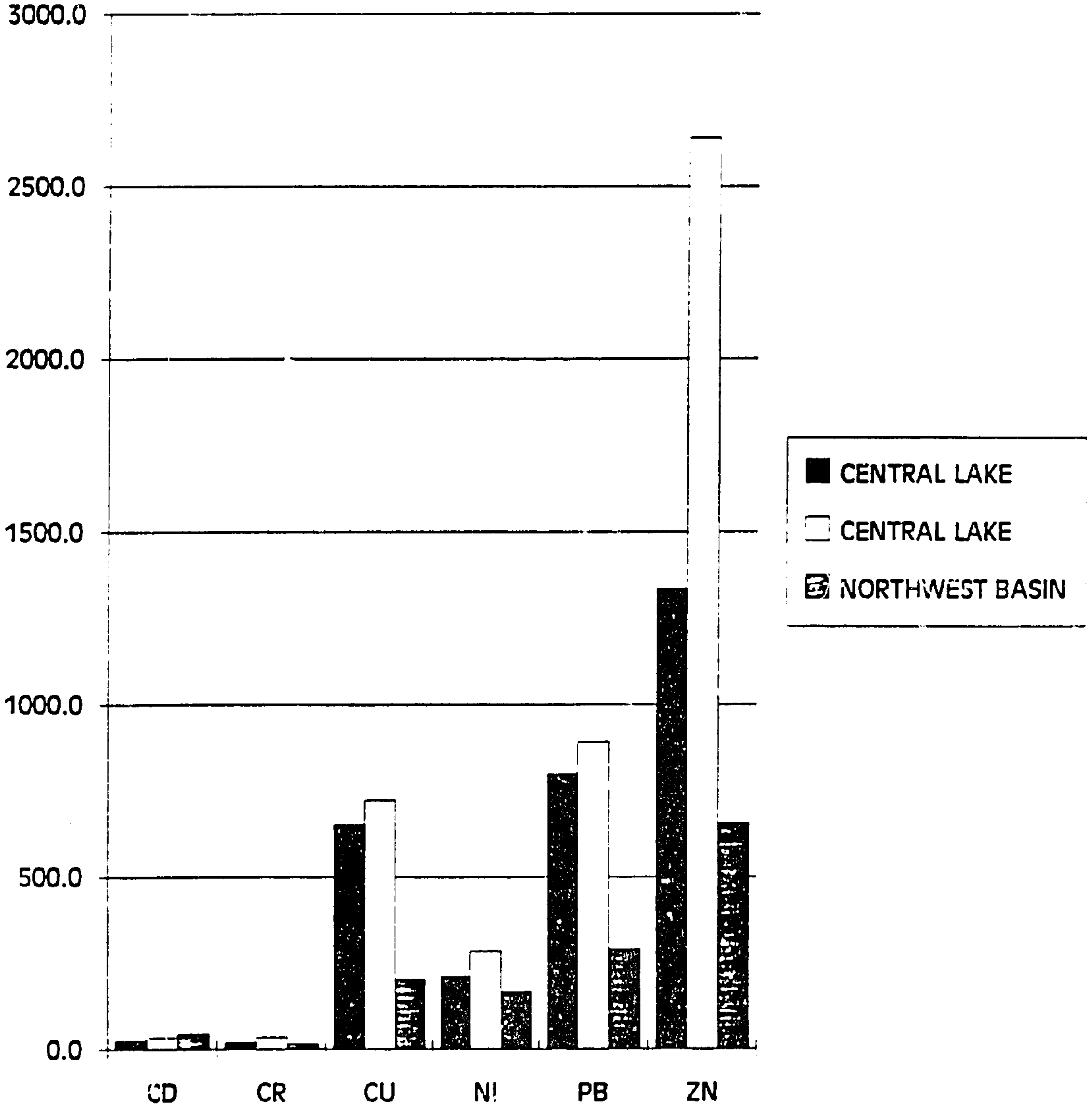


	SUMMARY OF 1992/93 LAKE SHORE SEDIMENT METAL CONCENTRATIONS						
			mg/kg				
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN
11	EAST CENT	44.4	27.8	725.3	163.2	610.7	1495.1
12	WEST CENT	48.9	21.6	852.3	274.0	872.9	1958.9
13	WEST LAKE	38.6	24.8	829.8	227.6	730.0	2124.7
23	NORTH SHORE	40.3	28.7	430.1	328.1	1397.5	1710.2
10	EAST LAKE	37.6	33.1	1,105.5	310.5	978.2	1195.7
16	LAKE AT KALAA	37.2	32.3	543.5	252.5	469.3	1071.1



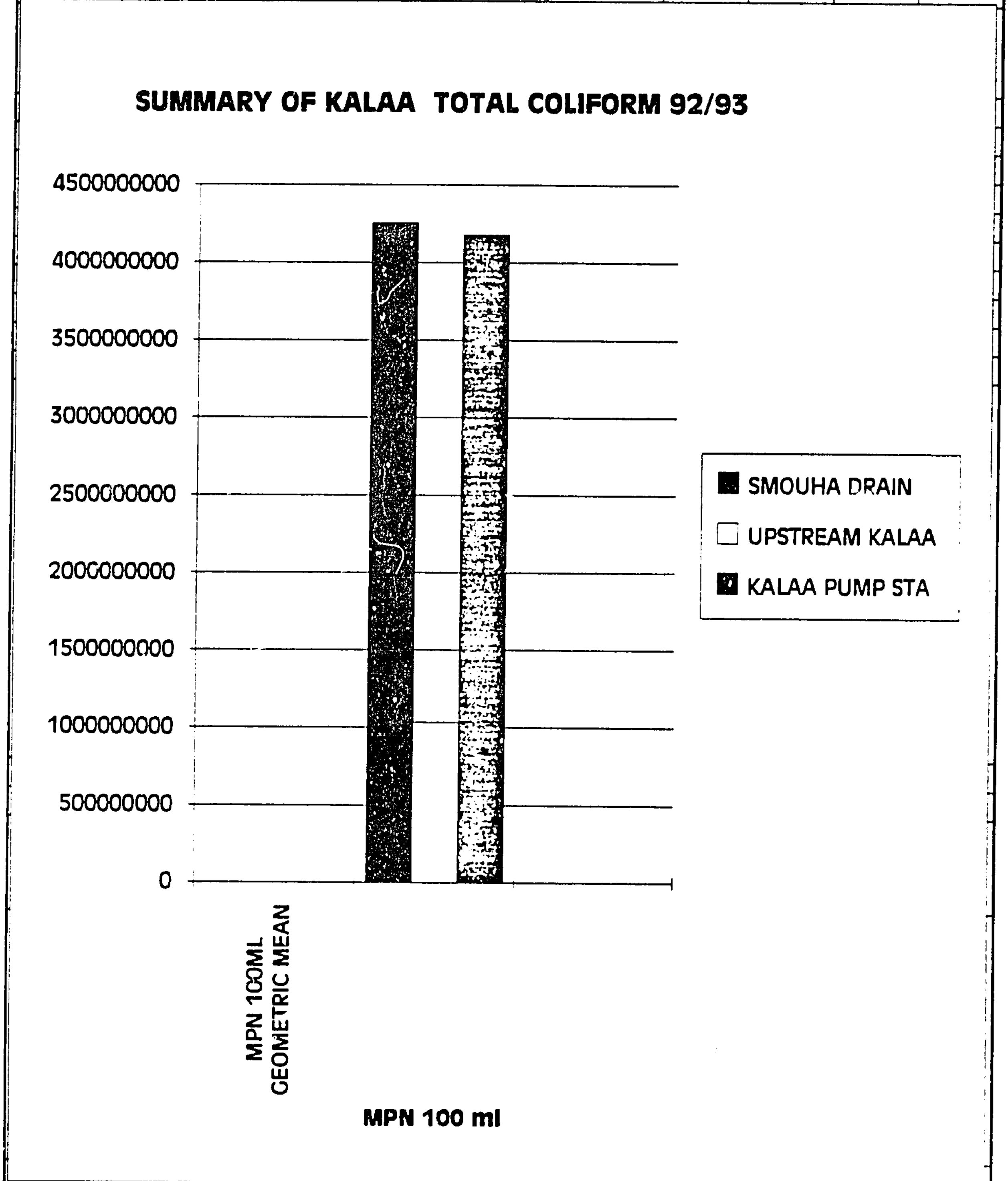
	SUMMARY OF1992/93 OPEN LAKE SEDIMENT METAL CONCENTRATIONS							
			mg/kg					
STA #	DESCRIPTION	CD	CR	CU	NI	PB	ZN	TOTAL
21	CENTRAL LAKE	25.8	19.7	653.0	212.5	798.2	1337.5	
22	CENTRAL LAKE	33.3	34.0	722.2	286.2	890.8	2641.3	
24	NORTHWEST BASIN	44.7	15.6	203.8	167.6	292.4	657.0	

SUMMARY OF OPEN LAKE SEDIMENT METALS



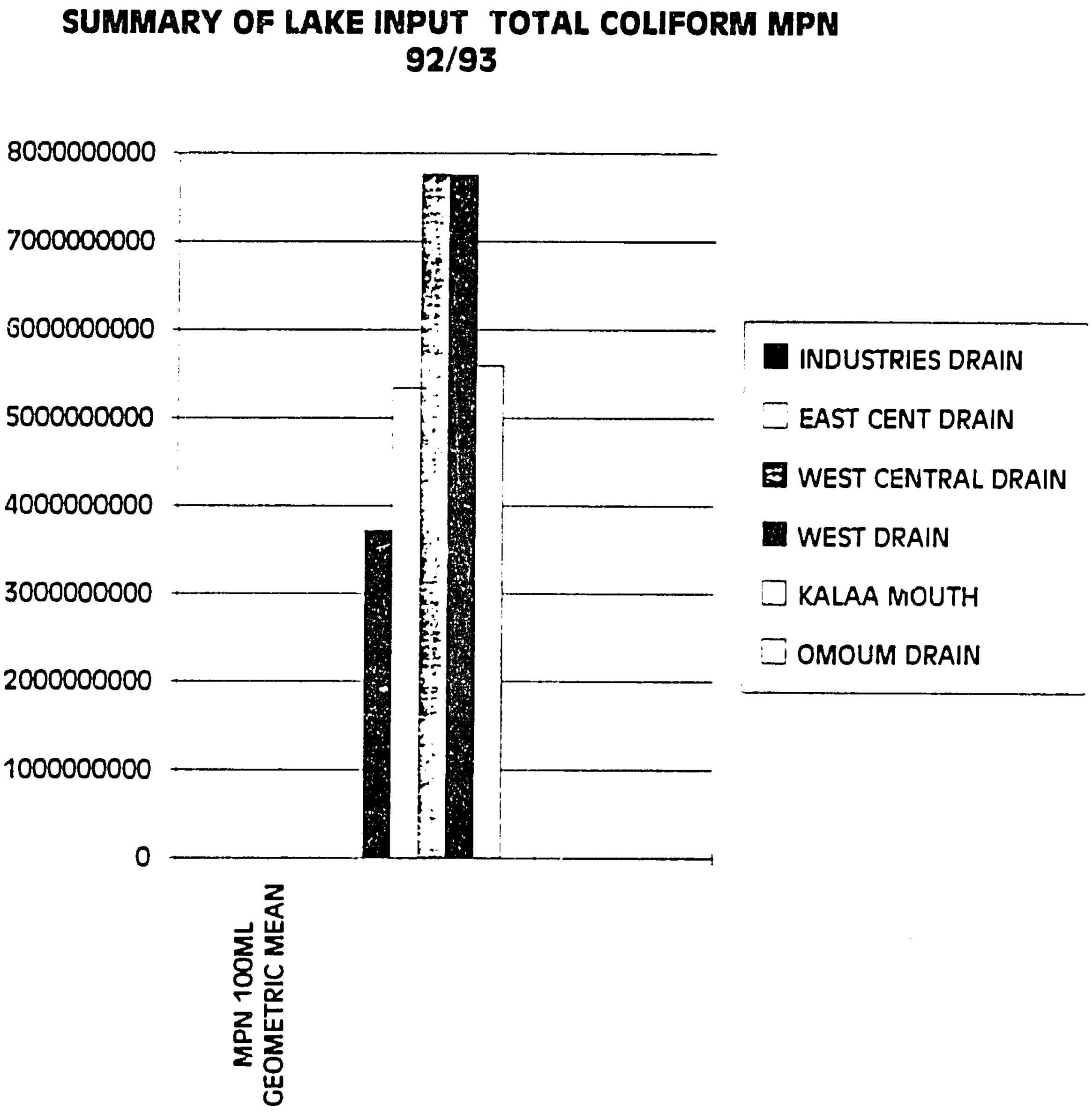
SUMMARY OF KALAA DRAIN TOTAL COLIFORM CHARACTERISTICS 92/93

STA #	DESCRIPTION	MPN 100ML GEOMETRIC MEAN
1	SMOUHA DRAIN	4.26E+09
2	UPSTREAM KALAA	1.03E+09
4	KALAA PUMP STA	4.18E+09



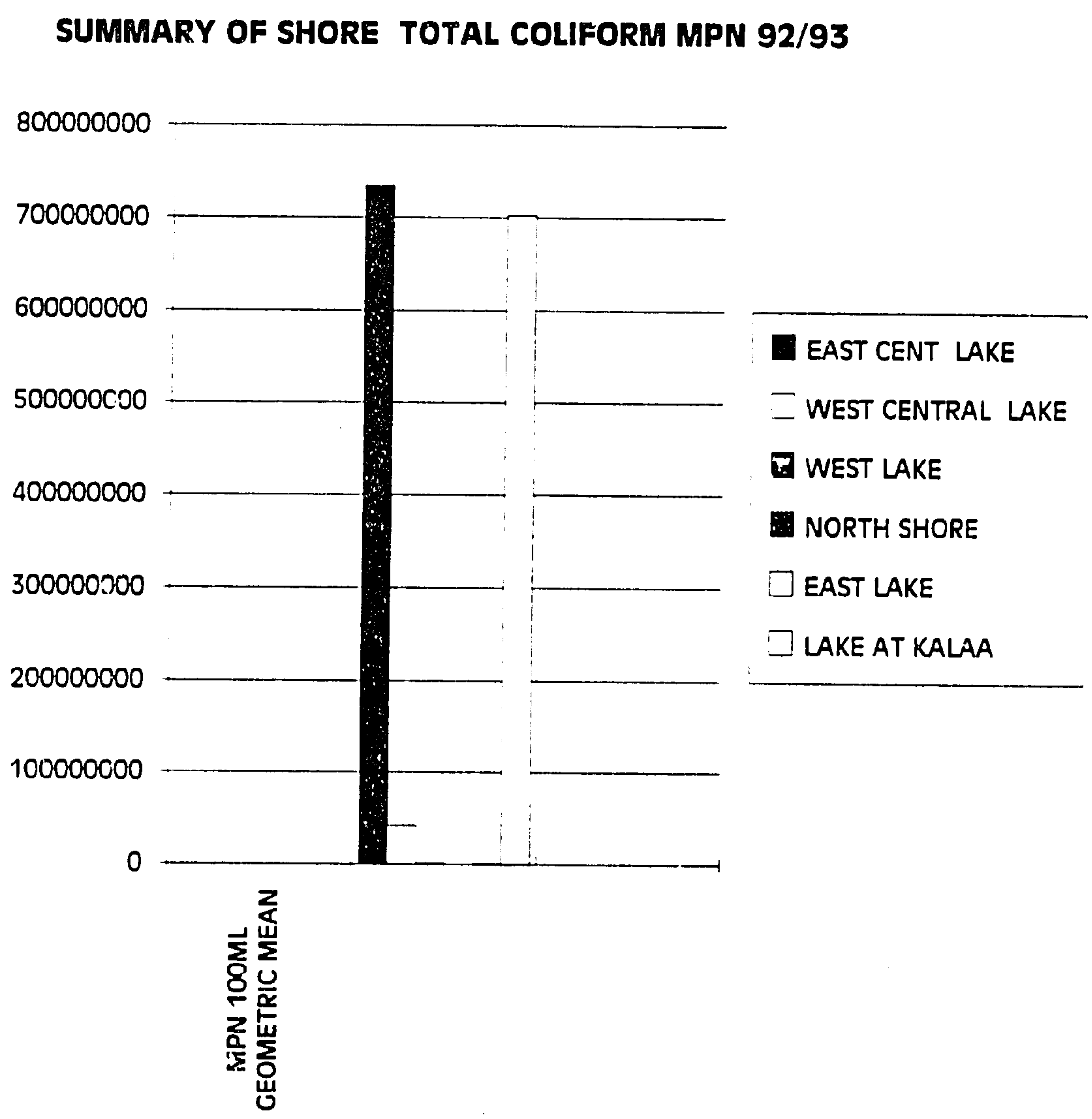
SUMMARY OF LAKE INPUT TOTAL COLIFORM CHARACTERISTICS 92/93

STA #	DESCRIPTION	MPN 100ML GEOMETRIC MEAN
6	INDUSTRIES DRAIN	3.72E+09
7	EAST CENT DRAIN	5.34E+09
8	WEST CENTRAL DRAIN	7.76E+09
9	WEST DRAIN	7.76E+09
5	KALAA MOUTH	5.59E+09
19	OMOUM DRAIN	6.70E+03

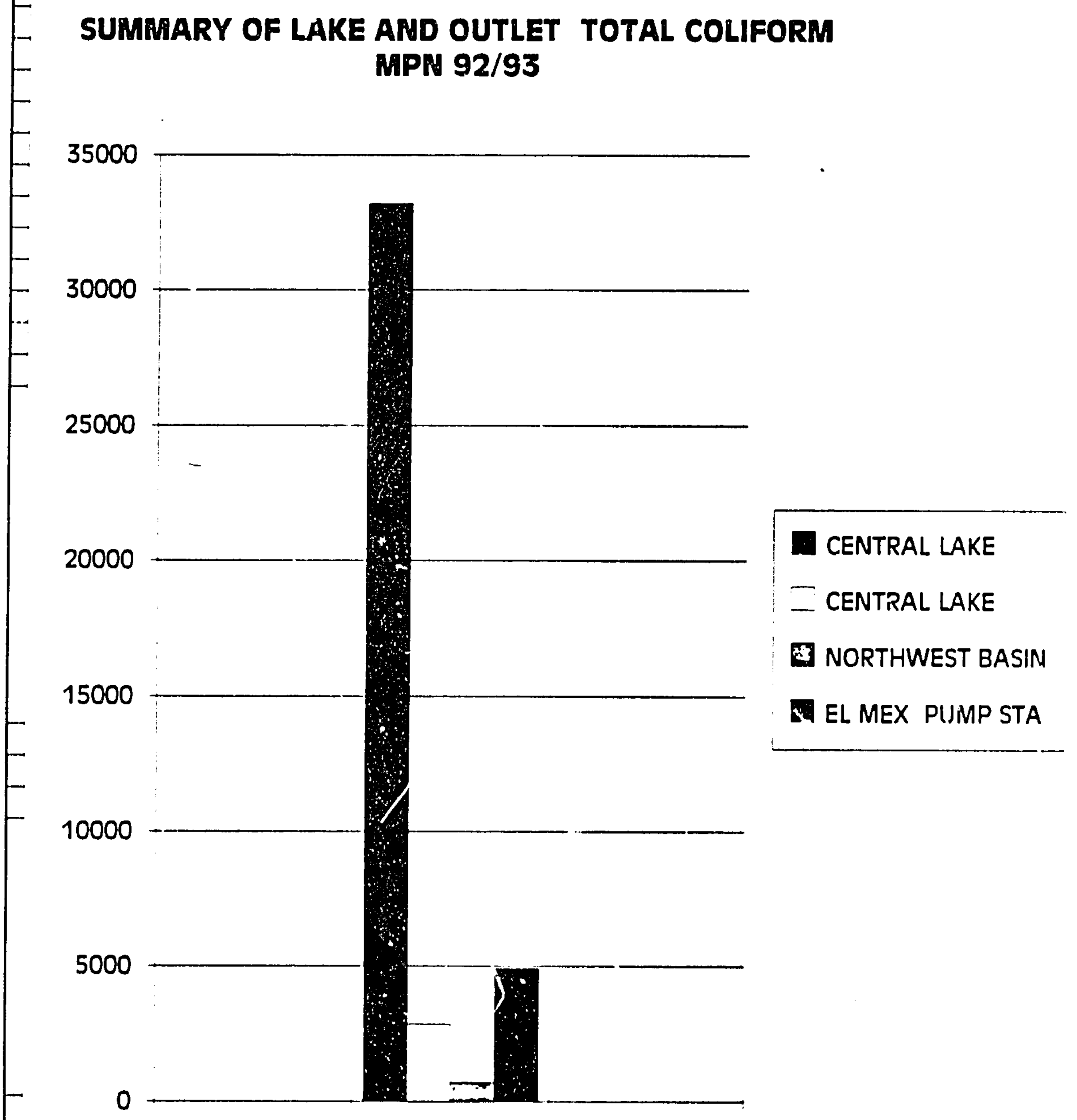

SUMMARY OF LAKE INPUT TOTAL COLIFORM MPN 92/93

SUMMARY OF SHORE TOTAL COLIFORM CHARACTERISTICS 92/93

STA #	DESCRIPTION	MPN 100ML GEOMETRIC MEAN
11	EAST CENT LAKE	7.34E+08
12	WEST CENTRAL LAKE	4.23E+07
13	WEST LAKE	1.25E+06
23	NORTH SHORE	9.36E+02
10	EAST LAKE	4.17E+05
16	LAKE AT KALAA	7.03E+08



	SUMMARY OF LAKE AND OUTLET TOTAL COLIFORM CHARACTERISTICS 92/93		
		MPN 100ML GEOMETRIC MEAN	
STA #	DESCRIPTION		
LAKE 21	CENTRAL LAKE		3.32E+04
22	CENTRAL LAKE		2.87E+03
NW BASIN 24	NORTHWEST BASIN		7.05E+02
OUTLET 20	EL MEX PUMP STA		4.93E+03



Appendix C
Lake Maryout 1992/93 Water Quality Data

Appendix C

Lake Maryout 1992/93 Water Quality Data

Table (1) D.O. Changes In The Lake Water Samples During 92/93

Data expressed in mg O2 /l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	0.0	2.4	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	4.0	0.0	0.0	
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20		0.0	3.1	1.2	0.0	3.3	0.0	3.5	0.0	2.0	2.0	2.0	
21			1.5	0.8	0.0	0.0	0.0	0.0	0.0	8.0	2.0	2.0	
22			2.5	0.0	1.0	3.0	7.0	7.0	4.0	8.0	6.0	4.0	
23		0.0	2.5	0.0	1.0	3.0	5.5	6.0	1.0	0.0	6.0	2.0	
24		8.8	1.6	5.6	4.2	3.1	5.0	6.0	4.0	6.0	4.0	4.0	

Table (2) pH Changes In The Lake Water Samples During 92/93

~~Data expressed in mg/l~~

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	8.0	7.6	7.6	8.8	7.6	7.2	8.0	7.7	7.8	8.0	8.2	8.1	
11	8.0	6.9	7.0	8.0	7.0	6.5	7.5	7.4	7.2	7.6	7.7	7.8	
12	8.0	7.6	7.3	8.3	7.2	7.0	7.7	8.3	8.1	7.9	8.0	8.1	
13	8.4	7.8	7.7	8.8	7.8	7.3	8.0	8.0	8.0	8.1	8.0	7.9	
16	8.2	7.5	7.5	8.6	7.5	7.0	8.0	7.7	7.6	7.9	7.9	7.8	
20		7.9	8.0	7.9	8.0	7.1	8.2	8.2	7.8	8.1	8.1	8.0	
21			8.0	8.8	8.1	7.4	8.0	8.1	7.9	8.3	8.1	8.1	
22			8.5	8.7	8.5	7.7	8.3	8.7	8.0	8.0	8.2	8.1	
23		7.5	8.6	9.0	8.5	8.0	8.5	8.0	7.9	8.0	8.0	8.0	
24		7.7	9.4	7.5	8.7	7.9	8.3	8.3	8.3	8.1	8.3	8.3	

[redacted]

Table (3) BOD In Lake Water Samples During 92/93

Data expressed In mg O2 / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	370.0	330.0	582.0	140.0	384.0	331.0	372.0	352.0	354.0	316.0	320.0	310.0	
11	880.0	900.0	762.0	720.0	886.0	884.0	982.0	852.0	750.0	672.0	680.0	670.0	
12	420.0	560.0	444.0	800.0	362.0	418.0	434.0	430.0	462.0	418.0	420.0	410.0	
13	580.0	860.0	600.0	380.0	402.0	541.0	569.0	558.0	526.0	558.0	520.0	510.0	
16	420.0	320.0	510.0	600.0	422.0	402.0	431.0	418.0	300.0	310.0	320.0	300.0	
20		96.0	130.0	160.0	118.0	131.0	134.0	130.0	11.2	11.6	120.0	120.0	
21			320.0	300.0	424.0	321.0	340.0	328.0	332.0	342.0	330.0	320.0	
22			560.0	190.0	400.0	428.0	450.0	452.0	480.0	552.0	550.0	480.0	
23		220.0	500.0	240.0	489.0	561.0	552.0	530.0	472.0	581.0	468.0	460.0	
24		220.0	900.0	400.0	740.0	734.0	664.0	862.0	830.0	982.0	980.0	800.0	

Table (4) COD in Lake Water Samples During 92/93

Data expressed in mg 02 / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	600.0	480.0	660.0	768.0	622.0	620.0	602.0	582.0	582.0	532.0	580.0	586.0	
11	1400.0	1200.0	1260.0	2400.0	1460.0	1510.0	1448.0	1260.0	1260.0	1101.0	1100.0	1000.0	
12	740.0	800.0	360.0	2048.0	582.0	730.0	712.0	736.0	736.0	702.0	700.0	710.0	
13	960.0	1800.0	940.0	544.0	862.0	922.0	932.0	860.0	860.0	940.0	910.0	880.0	
16	700.0	500.0	820.0	1800.0	684.0	700.0	690.0	492.0	492.0	528.0	580.0	520.0	
23		400.0	820.0	320.0	782.0	920.0	900.0	810.0	810.0	796.0	800	780.0	
21			570.0	1800.0	680.0	560.0	592.0	540.0	540.0	564.0	540.0	500.0	
22			880.0	240.0	662.0	720.0	748.0	820.0	820.0	910.0	920.0	880.0	
20		200.0	200.0	448.0	188.0	200.0	221.0	181.0	181.0	182.0	200.0	183.0	
24		380.0	1760.0	835.0	1220.0	1200.0	1400.0	1400.0	1410.0	1720.0	1700.0	1400.0	

Table (5) TS Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	3140.0	2837.0	2912.0	1817.0	3210.0	2847.0	2800.0	2920.0	2936.0	2648.0	2310.0	3020.0	
11	4692.0	2478.0	3744.0	2373.0	5260.0	4832.0	4810.0	4540.0	4459.0	4085.0	4202.0	4430.0	
12	3080.0	2014.0	2022.0	2221.0	2582.0	2722.0	2888.0	3140.0	3226.0	2944.0	2989.0	3134.0	
13	3806.0	3045.0	3314.0	2174.0	3390.0	3850.0	3475.0	3662.0	3688	3594.0	3602.0	3708.0	
16	2782.0	2055.0	2509.0	1231.0	3030.0	2842.0	2876.0	2821.0	2223.0	2366.0	2862.0	2582.0	
20		6460.0	7092.0	6528.0	7260.0	7720.0	7944.0	6930.0	6710.0	6237.0	7310.0	7012.0	
21			3374.0	1754.0	3520.0	2989.0	3201.0	3186.0	3252.0	3594.0	3522.0	3382.0	
22			3796.0	2316.0	3645.0	3950.0	3981.0	3593.0	3910.0	3963.0	3922.0	3830.0	
23		2932.0	3423.0	2061.0	3845.0	3883.0	4020.0	4030.0	3790.0	3214.0	3719.0	3621.0	
24		3194.0	8380.0	6394.0	7660.0	8153.0	7342.0	7540.0	6680.0	6050.0	7542.0	6981.0	

Table (6) VS Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	620.0	450.0	690.0	355.0	660.0	667.0	620.0	610.0	616.0	548.0	620.0	610.0	
11	1500.0	152.0	1399.0	421.0	1520.0	1600.0	1510.0	1480.0	1297.0	1199.0	1211.0	1120.0	
12	790.0	406.0	420.0	151.0	620.0	762.0	766.0	720.0	794.0	732.0	730.0	722.0	
13	984.0	551.0	960.0	399.0	840.0	1010.0	960.0	950.0	906.0	972.0	914.0	910.0	
16	620.0	455.0	899.0	291.0	720.0	722.0	716.0	700.0	503.0	564.0	620.0	580.0	
20		4120.0	2300.0	1539.0	2000.0	2310.0	2500.0	2320.0	2000.0	2001.0	2300.0	2200.0	
21			610.0	352.0	710.0	577.0	591.0	566.0	560.0	612.0	560.0	560.0	
22			940.0	452.0	682.0	738.0	761.0	760.0	960.0	1002.0	980.0	920.0	
23		386.0	860.0	256.0	803.0	951.0	920.0	910.0	880.0	812.0	900.0	810.0	
24		431.0	1820.0	1348.0	1340.0	1233.0	1210.0	1610.0	1560.0	1886.0	1840.0	1620.0	

Table (7) DS Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	2284.0	2633.0	1393.0	1436.0	2312.0	2069.0	2118.0	232.0	2228.0	1844.0	2066.0	2128.0	
11	2800.0	1248.0	2461.0	2178.0	3323.0	3089.0	3056.0	2922.0	3162.0	2712.0	2591.0	3144.0	
12	1882.0	1865.0	1869.0	878.0	1812.0	1780.0	1810.0	2096.0	2292.0	2146.0	2010.0	2226.0	
13	2647.0	2893.0	2122.0	2027.0	2016.0	2093.0	2406.0	2510.0	2584.0	2520.0	2500.0	2500.0	
16	2102.0	1550.0	1406.0	1124.0	2010.0	2051.0	2110.0	2001.0	1926.0	1664.0	1896.0	1826.0	
20		6108.0	4363.0	5623.0	5460.0	5034.0	5002.0	4368.0	4500.0	4022.0	4562.0	4522.0	
21			2041.0	1713.0	2687.0	2360.0	2322.0	2412.0	2660.0	2721.0	2700.0	2682.0	
22			2099.0	2039.0	2702.0	3050.0	2906.0	2622.0	2860.0	2714.0	2688.0	2723.0	
23		2912.0	2037.0	1876.0	2897.0	2787.0	2904.0	2916.0	2782.0	2314.0	2662.0 ~~2660.0~~	2644.0	
24		3075.0	6135.0	5139.0	5966.0	6800.0	6120.0	5100.0	4982.0	3982.0	5122.0	5160.0	

DSLK XLS

4/21/93

Table (8) FS Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	2520.0	2387.0	2222.0	1462.0	2550.0	2180.0	2180.0	2310.0	2320.0	2100.0	2290.0	2410.0	
11	3192.0		2345.0	1952.0	3740.0	3232.0	3300.0	3060.0	3223.0	2886.0	2991.0	3310.0	
12	2290.0	1608.0	1602.0	2070.0	1962.0	1960.0	2122.0	2420.0	2432.0	2212.0	2259.0	2412.0	
13	2822.0	2494.0	2354.0	1775.0	2330.0	2840.0	2515.0	2712.0	2782.0	2622.0	2688.0	2798.0	
16	2162.0	1600.0	1610.0	740.0	2310.0	2120.0	2160.0	2121.0	1720.0	1802.0	2242.0	2002.0	
20		2340.0	4792.0	4989.0	5260.0	5410.0	5444.0	4610.0	4710.0	4236.0	5010.0	4812.0	
21			2764.0	1402.0	2810.0	2412.0	2610.0	2620.0	2692.0	2982.0	2942.0	2822.0	
22			2856.0	1864.0	2963.0	3212.0	3220.0	2833.0	2950.0	2961.0	2960.0	2910.0	
23		2546.0	2563.0	1805.0	3042.0	2932.0	3100.0	3120.0	2910.0	2402.0	2819.0	2811.0	
24		2763.0	6560.0	5046.0	6320.0	6920.0	6132.0	5930.0	5120.0	4164.0	5702.0	5361.0	

FSLK.XLS

4/20/93

Table (9) ALK Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	520.0	500.0	500.0	220.0	500.0	520.0	420.0	500.0	520.0	540.0	520.0	520.0	
11	520.0		700.0	1280.0	900.0	720.0	750.0	700.0	740.0	700.0	700.0	720.0	
12	520.0	480.0	520.0	700.0	660.0	520.0	600.0	600.0	600.0	640.0	600.0	620.0	
13	540.0	450.0	480.0	400.0	540.0	560.0	500.0	560.0	560.0	580.0	560.0	580.0	
16	540.0	380.0	440.0	400.0	500.0	500.0	440.0	500.0	500.0	520.0	500.0	520.0	
20		470.0	440.0	320.0	340.0	400.0	480.0	460.0	480.0	480.0	460.0	480.0	
21			500.0	360.0	500.0	500.0	540.0	520.0	520.0	540.0	540.0	520.0	
22			460.0	440.0	420.0	520.0	540.0	540.0	540.0	540.0	540.0	520.0	
23		450.0	440.0	440.0	460.0	480.0	560.0	560.0	580.0	580.0	560.0	580.0	
24		420.0	460.0	260.0	380.0	320.0	460.0	440.0	440.0	460.0	460.0	460.0	

ALKLK.XLS

4/15/93

Table (10) CaH Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	250.0	220.0	240.0	180.0	240.0	160.0	210.0	220.0	240.0	250.0	240.0	240.0	
11	280.0		280.0	140.0	220.0	250.0	400.0	260.0	250.0	220.0	250.0	230.0	
12	270.0	280.0	230.0	160.0	180.0	170.0	200.0	210.0	220.0	250.0	240.0	250.0	
13	310.0	280.0	310.0	300.0	220.0	250.0	330.0	300.0	250.0	330.0	280.0	300.0	
16	210.0	160.0	210.0	180.0	170.0	160.0	200.0	200.0	200.0	220.0	220.0	210.0	
20		400.0	500.0	340.0	460.0	420.0	460.0	430.0	460.0	510.0	500.0	310.0	
21			300.0	200.0	280.0	140.0	210.0	220.0	300.0	330.0	320.0	300.0	
22			360.0	200.0	290.0	360.0	350.0	350.0	360.0	350.0	360.0	350.0	
23		260.0	360.0	300.0	260.0	250.0	360.0	350.0	260.0	375.0	350.0	360.0	
24		260.0	650.0	340.0	450.0	360.0	650.0	400.0	500.0	340.0	520.0	540.0	

CALK.XLS

4/20/93

Table (11) MgH Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	400.00	620.00	430.00	380.00	660.00	290.00	290.00	380.00	380.00	400.00	360.00	410.00	
11	570.00		330.00	700.00	1110.00	500.00	520.00	510.00	550.00	400.00	530.00	670.00	
12	410.00	340.00	350.00	340.00	400.00	250.00	400.00	450.00	460.00	320.00	410.00	430.00	
13	490.00	420.00	550.00	400.00	600.00	370.00	310.00	410.00	470.00	420.00	470.00	450.00	
16	410.00	580.00	390.00	320.00	630.00	290.00	400.00	360.00	330.00	280.00	320.00	290.00	
20		1440.00	1400.00	1040.00	1850.00	730.00	900.00	970.00	880.00	690.00	700.00	890.00	
21			500.00	340.00	870.00	490.00	540.00	540.00	480.00	470.00	500.00	550.00	
22			590.00	540.00	810.00	340.00	500.00	500.00	500.00	520.00	490.00	540.00	
23		560.00	520.00	420.00	840.00	410.00	490.00	500.00	590.00	445.00	470.00	490.00	
24		1000.00	1650.00	1060.00	2230.00	940.00	950.00	300.00	800.00	780.00	880.00	860.00	

MGHLK.XLS

4/20/93

Table (12) TH Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	650.0	840.0	670.0	560.0	900.0	450.0	500.0	600.0	620.0	650.0	600.0	650.0	
11	850.0		810.0	840.0	1330.0	750.0	920.0	770.0	800.0	620.0	720.0	900.0	
12	680.0	620.0	580.0	500.0	580.0	420.0	600.0	660.0	680.0	550.0	650.0	680.0	
13	800.0	700.0	860.0	800.0	820.0	620.0	640.0	710.0	720.0	750.0	750.0	750.0	
16	620.0	760.0	600.0	500.0	600.0	450.0	600.0	560.0	530.0	500.0	540.0	500.0	
20		1840.0	1400.0	1480.0	2310.0	1150.0	1360.0	1400.0	1340.0	1200.0	1200.0	1400.0	
21			800.0	540.0	1150.0	630.0	750.0	760.0	780.0	800.0	820.0	850.0	
22			950.0	740.0	950.0	700.0	850.0	850.0	860.0	900.0	850.0	900.0	
23		820.0	880.0	720.0	850.0	650.0	850.0	850.0	850.0	820.0	820.0	850.0	
24		1260.0	1300.0	1400.0	1680.0	1300.0	1600.0	1300.0	1300.0	1320.0	1400.0	1400.0	

THLK.XLS

4/20/93

Table (13) NH3 Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	2.00	2.40	0.25	1.60	2.40	2.00	2.00	2.00	2.00	2.20	2.00	2.10	
11	2.00			3.60	2.50	2.40	2.50	2.50	2.50	2.60	2.50	2.60	
12	2.20	2.80	0.00	4.00	2.60	2.50	2.50	2.50	2.60	2.00	2.50	2.50	
13	2.40	4.00	2.40	1.40	4.00	2.40	2.40	2.40	2.50	2.60	2.60	2.50	
16	2.20	3.20	3.00	2.20	2.50	3.00	2.80	3.00	3.00	3.20	3.00	3.10	
20		2.20	0.80	2.00	0.60	0.60	1.20	1.20	0.70	0.90	1.00	1.00	
21			1.50	1.60	1.50	1.30	1.30	1.30	1.50	1.70	1.50	1.60	
22			1.50	1.60	1.50	1.30	1.40	1.50	1.50	1.50	1.50 ~~1.20~~	1.40	
23		2.60	1.30	1.00	1.50	1.10	1.10	1.10	1.20	1.30	1.30	1.30	
24		2.60	0.60	0.40	0.50	0.40	0.40	0.40	0.60	0.70	0.60	0.70	

NH3LK.XLS

4/20/93

Table (14) NO2 Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	0.10	0.00	0.12	0.00	0.12	0.04	0.20	0.10	0.05	0.06	0.05	0.06	
11	0.10		0.65	0.00	0.10	0.10	0.08	0.10	0.10	0.10	0.10	0.10	
12	0.10	0.00	0.03	0.00	0.08	0.09	0.12	0.12	0.10	0.10	0.10	0.12	
13	0.10	0.00	0.10	0.00	0.10	0.16	0.20	0.20	0.20	0.22	0.20	0.20	
16	0.10	0.00	0.20	0.00	0.22	0.08	0.20	0.20	0.09	0.10	0.10	0.10	
20		0.00	0.16	0.00	0.20	0.09	0.11	0.11	0.09	0.09	0.09	0.10	
21			0.10	0.00	0.10	0.05	0.20	0.20	0.06	0.07	0.07	0.07	
22			0.10	0.00	0.20	0.10	0.18	0.18	0.10	0.10	0.10	0.10	
23		0.00	0.10	0.00	0.18	0.16	0.10	0.10	0.20	0.20	0.20	0.20	
24		0.00	0.12	0.00	0.14	0.07	0.11	0.10	0.40	0.40	0.20	0.30	

Table (15) NO3 Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	3.10	0.06	1.50	0.04	4.00	4.50	4.00	4.00	4.80	4.50	4.50	4.20	
11	3.10		16.00	0.16	16.00	16.00	20.00	16.00	16.00	16.00	16.00	16.00	
12	3.50	0.16	7.00	0.04	7.00	4.50	6.00	6.00	5.00	5.50	6.00	5.50	
13	7.00	0.08	7.00	0.04	7.00	5.00	4.00	5.00	5.20	5.50	5.00	5.10	
16	6.00	6.00	6.00	0.04	7.00	6.90	4.50	6.00	7.20	7.60	7.00	7.10	
20		0.16	3.00	0.04	5.00	2.00	4.50	5.00	2.50	3.00	4.00	3.50	
21			7.00	0.16	10.00	6.00	10.00	10.00	6.00	6.00	6.00	8.00	
22			5.00	0.04	6.00	5.00	4.90	5.00	5.20	5.50	5.00	5.00	
23		0.20	8.00	0.04	9.00	8.50	5.00	5.00	9.00	9.00	8.00	8.50	
24		0.08	5.00	0.04	4.50	4.00	6.50	5.00	4.50	5.00	5.00	5.00	

NO3LK.XLS

4/20/93

Table (16) PO4 Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	9.00	3.40	3.00	1.80	10.00	3.00	3.00	3.00	3.00	3.30	3.00	3.00	
11	3.50		0.04	2.20	12.00	3.00	3.00	3.00	3.00	3.40	3.40	3.20	
12	10.50	2.80	10.00	0.30	12.00	10.00	12.00	10.00	3.00	3.4	8.00	4.00	
13	7.50	2.40	6.50	0.16	7.00	7.50	10.00	8.00	5.60	6.00	8.00	6.00	
16	6.00	4.60	3.50	0.38	12.00	6.00	5.00	5.00	3.90	4.20	5.00	5.00 ~~3.00~~	
20		2.00	3.00	1.80	4.00	2.80	3.00	3.00	2.50	3.00	3.00	3.00	
21			3.00	0.01	13.00	2.50	2.50	3.00	3.00	3.50	3.20	3.50	
22			3.50	0.01	13.00	2.20	2.00	2.00	3.00	3.50	3.50 ~~3.20~~	3.50	
23		3.80	3.50	0.10	13.00	2.20	4.00	3.00	3.00	3.50	3.50	3.50	
24		2.60	3.00	0.10	10.00	1.00	3.00	3.00	1.10	2.00	3.00	3.00	

PO4LK.XLS

4/20/93

Table (17) SO4 Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	140.0	488.0	160.0	72.0	140.0	130.0	130.0	140.0	140.0	140.0	135.0	130.0	
11	300.0		175.0	80.0	175.0	300.0	300.0	170.0	225.0	220.0	230.0	225.0	
12	180.0	468.0	125.0	80.0	100.0	150.0	100.0	150.0	180.0	180.0	180.0	180.0	
13	280.0	800.0	250.0	64.0	175.0	280.0	275.0	275.0	225.0	220.0	230.0	225.0	
16	150.0	220.0	100.0	64.0	100.0	100.0	150.0	116.0	115.0	100.0	110.0	100.0	
20		1250.0	550.0	320.0	600.0	750.0	600.0	600.0	560.0	550.0	600.0	600.0	
21			225.0	128.0	240.0	175.0	160.0	200.0	210.0	200.0	210.0	200.0	
22			300.0	136.0	260.0	350.0	400.0	300.0	300.0	280.0	300.0	300.0	
23		580.0	275.0	144.0	225.0	300.0	350.0	280.0	280.0	250.0	280.0	260.0	
24		420.0	750.0	375.0	600.0	750.0	800.0	600.0	550.0	300.0	600.0	550.0	

SO4LK.XLS

4/20/93

Table (18) CL Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	900.0	1000.0	450.0	800.0	850.0	950.0	900.0	1000.0	950.0	750.0	920.0	1000.0	
11	1100.0		1000.0	1020.0	1200.0	1250.0	1300.0	1400.0	1400.0	1200.0	1200.0	1400.0	
12	700.0	650.0	560.0	290.0	500.0	750.0	700.0	750.0	800.0	720.0	750.0	800.0	
13	980.0	1100.0	560.0	900.0	1100.0	1120.0	1100.0	1100.0	1210.0	1000.0	1000.0	1150.0	
16	820.0	615.0	690.0	550.0	700.0	850.0	840.0	860.0	700.0	620.0	800.0	780.0	
20		3000.0	1950.0	270.0	2250.0	2300.0	2400.0	2300.0	2250.0	1900.0	2200.0	2100.0	
21			1020.0	700.0	1000.0	1060.0	1100.0	1102.0	1100.0	1200.0	1150.0	1180.0	
22			960.0	930.0	1000.0	1050.0	1000.0	1100.0	1100.0	1100.0	1100.0	1000.0	
23		1065.0	1100.0	940.0	1050.0	1140.0	1080.0	1110.0	1150.0	900.0	1100.0	1100.0	
24		1200.0	1950.0	2670.0	2450.0	2250.0	2700.0	2500.0	2750.0	1900.0	2800.0	2700.0	

Table (19) Cond Changes In The Lake Water Samples During 92/93

Data expressed in µ mohs

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	3600.0	4200.0	2980.0	2700.0	3500.0	2400.0	2600.0	2700.0	2800.0	2500.0	3000.0	3100.0	
11	5500.0	7000.0	4000.0	3500.0	5000.0	5000.0	4200.0	4000.0	4500.0	4000.0	4000.0	4000.0	
12	3200.0	2600.0	2200.0	1400.0	2600.0	2800.0	2700.0	3200.0	3300.0	2800.0	2600.0	3300.0	
13	4000.0	5400.0	4000.0	2800.0	3000.0	4000.0	3300.0	3500.0	3500.0	3600.0	3700.0	3400.0	
16	4000.0	2100.0	2800.0	2050.0	3000.0	2900.0	2500.0	2800.0	2050.0	2400.0	3000.0	2100.0	
20		8000.0	9000.0	5700.0	7100.0	7800.0	8500.0	7000.0	6100.0	6000.0	8500.0	7500.0	
21			3900.0	2450.0	4000.0	3000.0	3000.0	3100.0	3500.0	4000.0	4000.0	4000.0	
22			4000.0	2900.0	4000.0	4000.0	4000.0	4100.0	4100.0	4000.0	4100.0	4000.0	
23		3400.0	3900.0	3200.0	4000.0	4000.0	3800.0	3800.0	3500.0	3000.0	3200.0	3700.0	
24		3800.0	11700.0	5700.0	8000.0	8000.0	7500.0	8000.0	6000.0	6000.0	8000.0	6100.0	

CONDLK XLS

4/21/93

Table (20) O&G Changes In The Lake Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	32.00	8.00	30.00	8.00	8.00	33.00	30.00	22.00	36.00	34.00	26.00	30.00	
11	30.00		34.00	65.00	26.00	69.00	62.00	30.00	72.00	76.00	60.00	70.00	
12	22.00	32.00	22.00	14.00	26.00	35.00	32.00	22.00	38.00	40.00	35.00	35.00	
13	15.00	60.00	20.00	5.00	26.00	19.00	20.00	28.00	23.00	26.00	24.00	28.00	
16	18.00	53.00	18.00	3.00	20.00	13.00	14.00	10.00	16.00	18.00	16.00	18.00	
20		47.00	30.00	10.00	nd	60.00	56.00	56.00	64.00	68.00	60.00	58.00	
21			22.00	39.00	22.00	33.00	32.00	20.00	36.00	40.00	36.00	32.00	
22			22.00	26.00	14.00	26.00	24.00	16.00	30.00	32.00	26.00	26.00	
23		32.00	12.00	4.00	10.00	14.00	12.00	10.00	16.00	18.00	18.00	18.00	
24		40.00	20.00	9.00	20.00	18.00	20.00	16.00	20.00	22.00	20.00	20.00	

Table (21) pH Changes In The Lake Bottom Sediment Samples During 92/93

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	7.5	6.5	6.2	6.6	7.3	7.3	7.5	7.1	7.9	7.2	7.7	7.5	
11	7.1	6.3	6.0	6.5	7.8	7.5	7.2	7.0	6.8	7.0	7.5	7.5	
12	7.0	6.5	6.5	6.8	7.5	7.6	7.3	7.5	7.0	7.6	7.8	7.6	
13	7.6	6.6	6.2	6.7	7.4	7.9	7.5	7.0	7.1	7.7	7.7	7.5	
16	7.3	6.6	6.5	7.2	8.0	7.5	7.7	7.7	7.2	7.5	8.1	8.0	
21	7.3	6.9	6.7	7.2	7.9	7.5	7.2	7.4	7.0	7.4	8.0	8.3	
22	7.2	6.4	6.1	6.8	8.0	7.7	7.4	7.2	7.1	7.6	7.8	8.0	
23		6.8	6.8	7.0	8.0	7.8	7.5	7.8	7.5	7.1	7.8	8.1	
24			7.0	6.5	7.8	7.7	7.5	7.5	7.0	7.0	7.8	8.0	

PHBS.XLS

4/15/93

Table (22) VS Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in gm/100 gm solid

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	45.4	32.3	42.3	44.7	44.6	30.2	42.6	39.9	38.6	30.4	40.6	44.0	
11	42.6	55.8	59.2	59.6	65.2	60.3	64.9	60.6	63.5	60.8	53.4	58.0	
12	46.1	30.4	36.0	45.9	41.8	36.3	32.3	36.8	28.8	30.8	28.4	31.6	
13	43.5	36.2	32.8	25.6	30.6	33.0	28.0	34.6	24.9	21.4	32.8	28.4	
16	36.8	26.5	27.8	18.3	26.5	17.0	38.8	27.4	38.8	28.8	30.1	35.2	
21	44.0	17.5	31.4	29.2	25.2	20.4	31.6	34.6	29.0	26.2	26.6	30.4	
22		41.0	34.4	34.8	22.6	26.6	29.5	24.1	27.8	27.2	30.6	30.8	
23		33.6	33.0	31.8	34.8	27.4	16.8	23.8	21.0	26.3	26.2	23.2	
24			11.8	12.0	29.4	10.8	31.3	28.2	27.8	24.8	22.8	23.0	

Table (23) FS Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in gm/100 gm solid

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	54.6	67.7	57.7	55.3	55.4	69.8	57.4	60.1	61.4	69.6	59.4	56.0	
11	57.4	44.2	40.8	40.4	34.8	39.7	35.1	39.4	36.5	39.2	46.6	42.0	
12	53.9	69.6	64.0	54.1	58.2	63.7	67.7	63.2	71.2	69.2	71.6	68.4	
13	56.5	63.8	67.2	74.4	69.4	67.0	72.0	65.4	75.1	78.6	67.2	71.6	
16	63.2	73.5	72.2	81.7	73.5	83.0	61.2	72.6	61.2	71.2	69.9	64.8	
21	56.0	82.5	68.6	70.8	74.8	79.6	68.4	65.4	71.0	73.8	73.4	69.6	
22		59.0	65.6	65.2	77.4	73.4	70.5	75.6	72.2	72.8	69.4	69.2	
23		66.4	67.0	68.2	65.2	72.6	83.2	76.2	79.0	73.7	73.8	76.8	
24			88.2	88.0	70.6	89.2	68.7	71.8	72.2	75.2	77.3	77.0	

Table (24) PO4 Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in mg/gm

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10	5.3	9.4	9.2	14.0	24.0	26.0	26.0	20.0	38.0	24.0	20.0	30.0	
11	5.3	7.6	6.0	16.0	30.0	24.0	28.0	30.0	40.0	20.0	24.0	24.0	
12	12.2	11.2	5.2	18.0	36.0	32.0	38.0	30.0	36.0	18.0	18.0	34.0	
13	1.7	9.4	6.0	10.0	24.0	22.0	18.0	22.0	38.0	10.0	16.0	16.0	
16	3.2	6.0	7.2	6.0	18.0	20.0	26.0	20.0	30.0	14.0	16.0	24.0	
21		6.4	6.0	12.0	22.0	26.0	24.0	28.0	36.0	24.0	22.0	28.0	
22		4.0	8.8	14.0	16.0	12.0	22.0	24.0	36.0	18.0	18.0	26.0	
23		16.0	9.6	12.0	34.0	24.0	24.0	20.0	36.0	26.0	22.0	10.0	
24			4.8	6.0	8.0	14.0	10.0	8.0	12.0	6.0	6.0	10.0	

Table(25)SO4 Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in mg/gm

Site No.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 92
10	480.0	480.0	600.0	680.0	800.0	720.0	800.0	880.0	960.0	640.0	960.0	920.0	
11	640.0	600.0	360.0	500.0	460.0	800.0	920.0	980.0	800.0	480.0	800.0	960.0	
12	480.0	480.0	800.0	620.0	800.0	800.0	920.0	800.0	600.0	560.0	920.0	920.0	
13	600.0	680.0	600.0	960.0	960.0	800.0	480.0	720.0	560.0	560.0	960.0	800.0	
16	720.0	600.0	720.0	720.0	960.0	640.0	400.0	420.0	480.0	360.0	600.0	800.0	
21		200.0	920.0	880.0	976.0	640.0	400.0	600.0	720.0	480.0	720.0	920.0	
22		120.0	480.0	920.0	880.0	800.0	480.0	600.0	800.0	360.0	920.0	920.0	
23		480.0	800.0	960.0	920.0	560.0	200.0	320.0	600.0	360.0	880.0	560.0	
24			600.0	952.0	800.0	800.0	480.0	480.0	560.0	240.0	600.0	640.0	

Table (26) Cd Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in µg ~~l~~ gm-1

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10		nd	60.0	100.0	9.0	10.0	nd	21.0	37.0	28.0	38.0	35.0	
11		nd	75.0	130.0	6.0	nd	nd	nd	33.0	16.0	26.0	25.0	
12		nd	75.0	100.0		nd	65.0	40.0	29.0	29.0	24.0	29.0	
13		nd	75.0	80.0	12.0	nd	nd	13.0	33.0	34.0	30.0	32.0	
16		nd	75.0	140.0	13.0	10.0	10.0	13.0	40.0	27.0	20.0	24.0	
21			75.0	50.0	3.0	1.3	3.0	nd	26.0	26.0	25.0	23.0	
22			75.0	nd	13.0	12.0	72.0	11.0	43.0	24.0	28.0	22.0	
23		nd	80.0	90.0	14.0	9.0	nd	nd	47	24.0	23.0	35.0	
24		nd		140.0	25.0	4.0	nd	nd	45.0	32.0	30.0	37.0 ~~39.0~~	

d = not detected

Table (27) Cr Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in µg /gm

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10		40.0	33.0	25.0	14.0	nd	17.0	29.0	39.0	59.0	40.0	35.0 ~~25.0~~	
11		4.0	40.0	65.0	3.0	30.0	8.0	37.0	38.0	15.0	36.0	30.0	
12		4.0	24.0	nd	15.0	nd	16.0	30.0	18.0	44.0	23.0	20.0	
13		nd	24.0	30.0	41.0	nd	23.0	nd	17.0	17.0	24.0	22.0	
16		40.0	52.0	nd	95.0	8.0	18.0	4.0	26.0	22.0	30.0	28.0	
21			41.0		5.0	12.0	11.0	24.0	19.0	23.0	20.0	22.0	
22			24.0		31.0	11.0	34.0	nd	42.0	47.0	43.0 ~~42.0~~	40.0	
23		nd	71.0	nd	17.0	13.0	nd	nd	24.0	27.0	25.0	24.0	
24		40.0		nd	5.0	nd	2.0	11.0	30.0	13.0	13.0	11.0	

nd = not detected

CRBS.XLS

4/21/93

Table (28) Cu Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in µg/gm

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10		160.0	260.0	2014.0	376.0	78.0	1290.0	1841.0	1941.0	1315.0	1,620.0	1,266.0	
11		200.0	310.0	1260.0	638.0	607.0	750.0	697.0	984.0	680.0	922.0	930.0	
12		120.0	310.0	1655.0	112.0	394.0	1150.0	1316.0	1057.0	1074.0	1,067.0	1,120.0	
13		160.0	320.0	4200.0	897.0	425.0	439.0	788.0	525.0	374.0	450.0 ~~950.0~~	550.0	
16		200.0	310.0	1270.0	1123.0	387.0	1452.0	286.0	240.0	251.0	260.0	200.0	
21			310.0	7510.0	256.0	641.0	828.0	928.0	772.0	707.0	720.0	715.0	
22			130.0	2830.0	365.0	109.0	1222.0	323.0	894.0	601.0	388.0	360.0	
23		200.0	260.0	7110.0	457.0	686.0	330.0	98.0	629.0	518.0	503.0	620.0	
24		4.0		nd	nd	57.0	812.0	104.0	171.0	231.0	140.0	111.0	

nd = not detected

Table (29) Fe Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in µg/gm

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10		1200.0	3530.0	6040.0	12090.0	8746.0	19780.0	7892.0	5221.0	8442.0	8588.0	8719.0	
11		16000.0	4746.0	4902.0	20440.0	3330.0	13780.0	4254.0	3350	4654.0	39350.0	4552.0	
12		13000.0	5078.0	10205.0	9395.0	1728.0	2561.0	8442.0	3301.0	4197.0	4290.0	4600.0	
13		13200.0	8140.0	45540.0	16970.0	3122.0	31020.0	8446.0	3155.0	4723.0	3915.0	4094.0	
16		15000.0	11050.0	51880.0	27560.0	7556.0	24880.0	3176.0	2144.0	3052.0	3156.0	3167.0	
21			7428.0	64640.0	21590.0	3720.0	26900.0	9130.0	5304.0	9312.0	8754.0	9231.0	
22			1884.0	34040.0	39050.0	1666.0	6021.0	7532.0	11024.0	5512.0	6520.0	6701.0	
23		13100.0	11650.0	53060.0	14510.0	4828.0	16820.0	6110.0	6966.0	6498.0	6500.0	6803.0	
24		8200.0		36360.0	17660.0	2238.0	22980.0	3628.0	3900.0	4078.0	4000.0	3978.0	

nd = not detected

FEBS.XLS

4/21/93

Table (30) Ni Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in µg /gm

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10		400.0	156.0	411.0	79.0	415.0	280.0	426.0	340.0	420.0	220.0	269.0	
11		400.0	108.0	301.0	44.0	113.0	135.0	155.0	150.0	170.0	110.0	109.0	
12		400.0	600.0	128.0	1.0	166.0	276.0	229.0	231.0	262.0	220.0	228.0	
13		800.0	108.0	119.0	202.0	113.0	200.0	183.0	179.0	220.0	180.0	200.0	
16		820.0	165.0	157.0	380.0	219.0	220.0	127.0	171.0	176.0	175.0 ~~125.0~~	167.0	
21			240.0	205.0	106.0	237.0	190.0	300.0	229.0	188.0	220.0	210.0	
22			112.0	115.0	226.0	192.0	600.0	170.0	452.0	385.0	350.0	260.0	
23		810.0	240.0	201.0	137.0	257.0	830.0	123.0	272.0	250.0	239.0	250.0	
24		400.0	0.0	110.0	86.0	85.0	235.0	104.0	152.0	180.0	169.0	155.0	

nd = not detected

Table (31) Pb Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in µg /gm

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10		400.0	112.0	1380.0		1240.0	909.0	1670.0	1280.0	940.0	950.0	901.0	
11		400.0	150.0	1300.0	380.0	770.0	598.0	570.0	690.0	600.0	670.0	590.0	
12		400.0	112.0	1760.0		690.0	1213.0	1690.0	930.0	103.0	920.0	911.0	
13		400.0	101.0	1400.0	2000.0	760.0	419.0	1000.0	380.0	60.0	450.0	390.0	
16		100.0	112.0	1400.0	740.0	220.0	820.0	540.0	290.0	110.0	480.0	350.0	
21			110.0	3200.0		790.0	514.0	790.0	360.0	210.0	520.0	690.0	
22				1800.0	1600.0		1096.0	510.0	750.0	440.0	480.0	450.0	
23		100.0	104.0	5900.0	7000.0	990.0	104.0	130.0	520.0	180.0	175.0	170.0	
24		400.0				240.0	679.0	220.0	270.0	50.0	220.0 ~~22.0~~	260.0	

PBBS.XLS

5/10/93

Table (32) Zn Changes In The Lake Bottom Sediment Samples During 92/93

Data expressed in µg /gm

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
10		132.0	1200.0	200.0	2700.0	3098.0	2737.0	952.0	482.0	598.0	564.0	490.0	
11		4000.0	1200.0	300.0	1940.0	1731.0	1741.0	1726.0	948.0	946.0	964.0	950.0	
12		3000.0	1200.0	1000.0	7500.0	1249.0	3096.0	962.0	203.0	985.0	1223.0	1130.0	
13		5000.0	3600.0	2500.0	1520.0	1291.0	1036.0	2366.0	1674.0	1181.0	1684.0	1520.0	
16		13200.0	1500.0	2000.0	1070.0	860.0	2299.0	671.0	613.0	537.0	560.0	601.0	
21			1200.0		430.0	1468.0	1241.0	1958.0	1591.0	1501.0	1225.0	1422.0	
22			3600.0		8200.0	2610.0	2176.0	1486.0	1340.0	1445.0	1465.0	1450.0	
23		130.0	1500.0	1200.0	4400.0	1464.0		2910.0	1518.0	1259.0	1300.0	1421.0	
24		130.0		1640.0		310.0	1648.0	339.0	418.0	578.0	450.0	400.0	

nd = not detected

Table (33) D.O. Changes In The Land Base Water Samples During 92/93

Data expressed in mg O2 /l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	0.0	2.4	0.0	0.0	2.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	
7	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	
19			0.0	1.5	1.0	2.0	0.0	2.5	1.0	4.0	2.0	2.0	

Table (34) pH Changes In The Land Base Samples During 92/93

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	7.7	7.6	8.0	7.5	7.8	7.1	7.5	7.8	7.3	7.6	8.0	7.8	
2	7.8	7.6	8.1	7.5	7.9	7.0	7.6	7.9	7.6	7.8	7.5	7.6	
4	7.5	7.5	8.0	7.5	8.0	7.0	7.9	8.1	7.5	7.7	7.5	7.7	
5	8.0	7.6	8.2	7.5	8.1	6.7	7.4	7.5	7.5	8.0	8.0	8.0	
6	7.4	7.7	7.2	6.0	7.1	6.3	7.0	7.4	7.7	7.6	7.0	7.4	
7	8.1	7.8	7.4	7.2	7.4	6.5	7.7	8.0	7.5	7.8	7.5	7.6	
8	9.0	7.6	8.7	7.5	8.0	6.4	8.2	8.0	8.0	7.8	8.2	8.0	
9	8.6	7.6	7.3	7.8	7.1	6.5	7.7	8.0	7.6	9.9	8.0	8.0	
19			8.5	9.0	8.3	7.5	8.0	8.2	8.0	8.2	8.2	8.0	

Table (35) BOD Changes In The Land Base Water Samples During 92/93

Data expressed in mg O2 / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	118.0	420.0	110.0	100.0	112.0	103.0	112.0	100.0	92.0	102.0	96.0	82.0	
2	400.0	260.0	420.0	280.0	460.0	366.0	442.0	386.0	392.0	632.0	400.0	410.0	
4	360.0	220.0	370.0	100.0	384.0	332.0	375.0	370.0	302.0	316.0	310.0	320.0	
5	300.0	420.0	304.0	460.0	496.0	300.0	324.0	300.0	332.0	304.0	300.0	284.0	
6	1160.0	360.0	1206.0	120.0	1200.0	1158.0	1300.0	1272.0	940.0	1006.0	960.0	1420.0	
7	110.0	920.0	114.0	520.0	212.0	124.0	114.0	130.0	132.0	116.0	110.0	100.0	
8	388.0	220.0	102.0	630.0	460.0	102.0	104.0	102.0	100.0	412.0	104.0	108.0	
9	102.0	210.0	100.0	410.0	160.0	114.0	120.0	108.0	90.0	80.0	84.0	94.0	
19			682.0	300.0	464.0	658.0	684.0	698.0	502.0	572.0	500.0	510.0	

BODLB.XLS

4/15/93

Table (36) COD Changes In The Land Base Water Samples During 92/93

Data expressed in mg O2 / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	175.0	600.0	180.0	160.0	166.0	180.0	175.0	152.0	162.0	166.0	164.0	142.0	
2	720.0	400.0	730.0	400.0	720.0	692.0	716.0	688.0	664.0	632.0	680.0	660.0	
4	610.0	800.0	620.0	600.0 60.0	610.0	622.0	614.0	612.0	520.0	516.0	540.0	580.0	
5	530.0	1000.0	550.0	1664.0	702.0	550.0	532.0	508.0	530.0	518.0	500.0	460.0	
6	2000.0	1100.0	1860.0	1600.0	1996.0	1980.0	2002.0	2100.0	1610.0	1634.0	1820.0	2200.0	
7	214.0	210 2100.0	196.0	188. 768.0	344.0	210.0	196.0	212.0	210.0	204.0	200.0	212.0	
8	820.0	300.0	160.0	928.0	800.0	200.0	182.0	180.0	172.0	860.0	180.0	200.0	
9	184.0	360.0	162.0	736.0	362.0	200.0	198.0	186.0	160.0	140.0	144.0	160.0	
19			1120.0	1040.0	812.0	1122.0	1160.0	1210.0	886.0	964.0	920.0	940.0	

Table (37) TS Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	1650.0	1115.0	1504.0	928.0	1570.0	1520.0	1518.0	1640.0	1520.0	1491.0	1662.0	1737.0	
2	2823.0	1682.0	2500.0	2354.0	3161.0	3122.0	2933.0	2646.0	2880.0	2468.0	2624.0	2669.0	
4	2740.0	2120.0	2336.0	1566.0	2940.0	3080.0	2870.0	2770.0	2582.0	2172.0	2644.0	2237.0	
5	2470.0	1797.0	2382.0	1462.0	2859.0	2660.0	2751.0	2720.0	2480.0	2406.0	2406.0	2500.0	
6	6472.0	5514.0	4520.0	7185.0	7820.0	7220.0	7030.0	7054.0	6042.0	6231.0	6450.0	9322.0	
7	1699.0	1113.0	1502.0	950.0	1500.0	1760.0	1792.0	1660.0	1472.0	1446.0	1622.0	1737.0	
8	4351.0	1403.0	1820.0	1934.0	5760.0	1620.0	1932.0	1820.0	1902.0	5842.0	1866.0	2042.0	
9	1426.0	811.0	1400.0	936.0	1200.0	1222.0	1400.0	1422.0	1380.0	1475.0	1366.0	1594.0	
19			5026.0	3334.0	4950.0	5443.0	5320.0	4730.0	5016.0	4594.0	5210.0	4621.0	

Table (38) VS Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	190.0	197.0	190.0	92.0	180.0	210.0	196.0	60.0	178.0	189.0	190.0	160.0	
2	740.0	260.0	760.0	715.0	751.0	760.0	740.0	712.0	700.0	746.0	720.0	733.0	
4	640.0	442.0	630.0	407.0	630.0	672.0	640.0	640.0	600.0	572.0	600.0	620.0	
5	560.0	308.0	530.0	349.0	720.0	591.0	551.0	520.0	570.0	522.0	510.0	500.0	
6	2110.0	915.0	1998.0	2760.0	2100.0	2110.0	2200.0	2234.0	1820.0	1822.0	2100.0	2400.0	
7	238.0	352.0	210.0	208.0	360.0	222.0	210.0	240.0	250.0	230.0	240.0	236.0	
8	960.0	440.0	200.0	421.0	820.0	230.0	200.0	200.0	192.0	910.0	200.0	240.0	
9	204.0	191.0	200.0	485.0	290.0	208.0	204.0	200.0	180.0	163.0	180.0	164.0	
19			1250.0	425.0	830.0	1288.0	1200.0	1320.0	900.0	982.0	1100.0	1000.0	

Table (39) DS Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	1322.0	924.0	1209.0	819.0	1009.0	1163.0	1299.0	1234.0	1280.0	1262.0	1310.0	1422.0	
2	1523.0	1484.0	1616.0	2154.0	2110.0	2177.0	2001.0	1636.0	2000.0	1610.0	1810.0	1746.0	
4	2016.0	1871.0	1836.0	1481.0	2012.0	2001.0	1999.0	1969.0	1810.0	1502.0	1920.0	1948.0	
5	2100.0	1592.0	1844.0	1044.0	1872.0	2002.0	2001.0	1992.0	1864.0	1710.0	1320.0	1720.0	
6	4212.0	4823.0	4010.0	5527.0	5261.0	4695.0	4266.0	4410.0	4010.0	4202.0	4100.0	5230.0	
7	1102.0	837.0	1200.0	699.0	910.0	1343.0	1366.0	1210.0	1196.0	1103.0	1100.0	1410.0	
8	1651.0	910.0	1024.0	1806.0	4002.0	1217.0	1610.0	1410.0	1560.0	3982.0	1422.0	1711.0	
9	798.0	463.0	1002.0	672.0	790.0	810.0	1002.0	1069.0	1040.0	1314	1002.0	1320.0	
19			3120.0	3150.0	3824.0	3824.0	3969.0	3188.0	3920.0	3502.0	3620.0	3510.0	

Table (40) FS Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	1460.0	918.0	1314.0	736.0	1390.0	1310.0	1322.0	1480.0	1342.0	1302.0	1472.0	1577.0	
2	2083.0	1422.0	1740.0	1639.0	2410.0	2362.0	2193.0	1934.0	2182.0	1722.0	1904.0	1936.0	
4	2100.0	1678.0	1706.0	1159.0	2310.0	2408.0	2230.0	2130.0	1982.0	1600.0	2044.0	2237.0	
5	1910.0	1489.0	1852.0	1113.0	2139.0	2069.0	2200.0	2200.0	1910.0	1834.0	1896.0	2000.0	
6	4362.0	4599.0	2522.0	4425.0	5720.0	5110.0	4830.0	4820.0	4222.0	4409.0	4350.0	6922.0	
7	1461.0	761.0	1292.0	742.0	1140.0	1538.0	1582.0	1420.0	1222.0	1216.0	1382.0	1501.0	
8	3391.0	963.0	1620.0	1493.0	4940.0	1390.0	1732.0	1620.0	1710.0	4932.0	1666.0	1802.0	
9	1222.0	620.0	1200.0	451.0	910.0	1014.0	1196.0	1222.0	1200.0	1312.0	1181.0	1410.0	
19			3746.0	2909.0	4120.0	4155.0	4120.0	3410.0	4110.0	3612.0	4110.0	3621.0	

Table (41) ALK Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	440.0	480.0	460.0	380.0	440.0	360.0	350.0	400.0	440.0	460.0	440.0	460.0	
2	440.0	450.0	440.0	380.0	460.0	420.0	400.0	400.0	440.0	480.0	460.0	440.0	
4	520.0	470.0	440.0	380.0	420.0	500.0	540.0	520.0	480.0	440.0	480.0	460.0	
5	520.0	600.0	460.0	380.0	400.0	460.0	380.0	460.0	460.0	520.0	500.0	520.0	
6	520.0	800.0	540.0	720.0	500.0	520.0	540.0	540.0	600.0	680.0	600.0	620.0	
7	540.0	650.0	500.0	540.0	500.0	600.0	660.0	600.0	540.0	560.0	560.0	540.0	
8	660.0	700.0	700.0	760.0	740.0	620.0	760.0	700.0	700.0	740.0	700.0	720.0	
9	600.0	570.0	560.0	640.0	400.0	520.0	640.0	600.0	600.0	600.0	600.0	620.0	
19			420.0	360.0	400.0	440.0	460.0	460.0	460.0	500.0	460.0	480.0	

Table (42) CaH Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	220.0	280.0	180.0	180.0	100.0	120.0	140.0	160.0	160.0	200.0	160.0	200.0	
2	210.0	200.0	210.0	300.0	160.0	160.0	180.0	190.0	200.0	220.0	190.0	200.0	
4	230.0	200.0	210.0	180.0	170.0	200.0	210.0	200.0	210.0	230.0	200.0	240.0	
5	220.0	200.0	200.0	140.0	160.0	160.0	220.0	220.0	210.0	220.0	210.0	220.0	
6	360.0	280.0	290.0	140.0	400.0	300.0	360.0	400.0	320.0	460.0	340.0	600.0	
7	150.0	140.0	150.0	200.0	110.0	110.0	120.0	130.0	140.0	160.0	140.0	200.0	
8	550.0	200.0	180.0	140.0	240.0	110.0	130.0	140.0	160.0	500.0	160.0	180.0	
9	110.0	140.0	160.0	140.0	100.0	110.0	100.0	130.0	140.0	160.0	140.0	150.0	
19			470.0	240.0	450.0	360.0	380.0	380.0	200.0	520.0	380.0	360.0	

Table (43) MgH Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	180.0 ~~150.0~~	120.0	170.0	200.0	320.0	200.0	220.0	260.0	200.0	180.0	240.0	350.0	
2	350.0	420.0	400.0	280.0	660.0	340.0	340.0	310.0	360.0	330.0	370.0	300.0	
4	310.0	460.0	340.0	360.0	560.0	270.0	290.0	210.0	340.0	200.0	270.0	310.0	
5	340.0	460.0	360.0	360.0	540.0	330.0	530.0	380.0	350.0	360.0	370.0	380.0	
6	740.0	160.0	560.0	1060.0	780.0	650.0	740.0	800.0	460.0	640.0	660.0	900.0	
7	210.0	320.0	170.0	140.0	170.0	240.0	240.0	232.0	200.0	140.0	240.0	250.0	
8	300.0	280.0	220.0	200.0	1390.0	240.0	230.0	220.0	240.0	450.0	200.0	200.0	
9	260.0	160.0	120.0	140.0	180.0	120.0	140.0	150.0	160.0	240.0	160.0	230.0	
19			670.0	660.0	870.0	540.0	620.0	750.0	810.0	530.0	700.0	640.0	

Table (44) TH Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	400.0	400.0	350.0	380.0	420.0	320.0	360.0	420.0	360.0	380.0	400.0	450.0	
2	560.0	620.0	610.0	680.0	820.0	500.0	520.0	500.0	560.0	550.0	560.0	500.0	
4	540.0	660.0	550.0	540.0	730.0	470.0	500.0	410.0	550.0	430.0	470.0	550.0	
5	560.0	660.0	560.0	480.0	700.0	490.0	750.0	600.0	560.0	580.0	580.0	600.0	
6	1100.0	440.0	850.0	1200.0	1180.0	950.0	1100.0	1200.0	780.0	1100.0	1000.0	1500.0	
7	360.0	460.0	320.0	340.0	280.0	350.0	360.0	362.0	340.0	300.0	360.0	450.0 ~~440.0~~	
8	850.0	480.0	400.0	340.0	1650.0	350.0	360.0	360.0	400.0	950.0	360.0	380.0	
9	370.0	300.0	280.0	280.0	280.0	230.0	240.0	280.0	300.0	400.0	300.0	380.0	
19			1140.0	900.0	1320.0	900.0	1000.0	1130.0	1210.0	1050.0	1050.0	1000.0	

Table (45) NH3 Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	1.0	8.4	1.0	2.0	1.20	0.70	0.90	0.90	0.70	0.80	0.80	2.00	
2	0.9	4.0	0.9	0.8	1.40	0.80	0.30	0.30	0.80	0.90	0.90	1.60	
4	1.3	5.5	1.2	1.0	1.00	1.10	0.36	1.00	1.20	1.30	1.20	1.80	
5	0.9	5.4	0.9	0.8	0.50	0.10	0.42	0.50	0.90	1.00	0.90 0.40	0.90	
6	2.0	2.0	1.6	1.4	6.00	2.40	2.40	2.50	2.50	2.80	2.50	4.00	
7	0.9	3.6	1.0	2.6	7.00	0.84	0.20	0.80	0.90	1.00	1.00	2.60	
8	1.0	7.2	1.3	4.8	1.20	1.26	0.70	1.00	1.30	1.40	1.40	2.00	
9	1.4	8.0	1.4	4.4	1.40	1.20	1,80	1.40	1.30	1.40	1.40	2.10	
19			1.0	1.0	1.00	0.40	0.76	1.00	0.60	0.80	0.80	0.70	

Table (46) NO2 Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	0.10	0.00	0.01	0.00	0.01	0.07	0.11	0.08	0.08	0.10	0.10	0.20	
2	0.10	0.00	0.01	0.00	0.01	0.06	0.11	0.09	0.07	0.08	0.08	0.10	
4	0.10	0.00	0.04	0.00	0.04	0.06	0.12	0.12	0.06	0.07	0.07	0.10	
5	0.10	0.00	0.03	0.00	0.04	0.07	0.14	0.14	0.08	0.09	0.08	0.08	
6	0.10	0.00	0.01	0.00	0.02	0.07	0.16	0.12	0.07	0.08	0.08	0.10	
7	0.10	0.00	0.02	0.00	0.02	0.01	0.11	0.11	0.10	0.10	0.10	0.15	
8	0.10	0.00	0.02	0.00	0.02	0.06	0.10	0.10	0.07	0.08	0.08	0.10	
9	0.10	0.00	0.01	0.00	0.02	0.06	0.12	0.09	0.06	0.07	0.07	0.10	
19			0.03	0.00	0.03	0.07	0.11	0.10	0.08	0.09	0.09	0.09	

Table (47) NO3 Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	2.40	0.04	5.00	0.04	6.00	2.40	5.00	5.00	2.60	2.80	2.80	5.00	
2	3.10	0.04	4.00	0.04	3.00	1.50	6.00	4.00	1.80	2.00	4.00	6.00	
4	3.00	0.08	4.10	0.05	5.00	2.20	5.00	5.00	2.50	2.60	5.00	6.50	
5	4.60	0.04	5.00	0.05	6.50	2.00	6.00	6.00	2.50	2.80	3.00	3.20	
6	14.00	0.40	8.00	0.04	12.00	5.40	16.00	12.00	10.00	10.00	10.00	15.00	
7	3.50	0.20	7.00	0.08	12.00	5.00	5.00	5.00	5.50	6.00	6.00	7.50	
8	7.00	0.16	5.00	0.19	10.00	2.70	6.00	6.00	5.00	5.50	6.00	7.00	
9	5.00	0.12	8.00	0.12	9.00	4.00	5.00	5.00	4.20	4.50	5.00	6.00	
19			2.00	0.16	2.20	1.90	4.50	4.50	4.00	4.50	4.50	4.00	

Table (48) PO4 Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	3.0	3.2	0.5	0.4	12.0	2.5	1.5	1.5	2.7	3.0	3.0	4.0	
2	2.0	2.9	0.0	2.0	12.0	2.0	1.5	2.0	2.1	3.0	3.0	4.0	
4	6.0	2.7	0.0	1.8	5.0	2.0	6.0	6.0	5.0	6.0	6.0	7.0	
5	6.3	3.4	0.0	1.2	4.0	3.5	6.0	5.0	3.5	4.0	5.0	5.0	
6	2.0	2.7	1.7	1.0	6.0	1.2	1.5	1.5	1.5	2.0	2.0	12.0	
7	6.0	3.7	0.0	2.5	4.0	7.5	6.0	6.0	8.0	10.0	8.0	10.0	
8	13.2	8.5	1.4	0.8	12.0	5.0	13.0	12.0	10.0	10.0	12.0	12.0	
9	13.0	7.2	2.5	0.1	12.0	4.2	12.0	11.0	10.0	10.0	10.0	10.0	
19			0.0	0.2	6.0	1.0	8.0	6.0	4.0	4.2	6.0	6.0	

Table (49) SO4 Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	100.0	132.0	90.0	56.0	80.0	90.0	110.0	110.0	100.0	100.0	10.0	120.0	
2	140.0	148.0	100.0	84.0	120.0	130.0	150.0	110.0	100.0	100.0	120.0	130.0	
4	150.0	228.0	115.0	80.0	150.0	150.0	150.0	160.0	150.0	150.0	160.0	160.0	
5	100.0	156.0	95.0	56.0	80.0	125.0	140.0	120.0	120.0	120.0	125.0	130.0	
6	500.0	980.0	325.0	144.0	500.0	500.0	520.0	550.0	500.0	450.0	500.0	1000.0	
7	130.0	116.0	80.0	56.0	70.0	90.0	80.0	100.0	100.0	110.0	100.0	110.0	
8	240.0	128.0	80.0	40.0	300.0	80.0	75.0	150.0	120.0	300.0	160.0	240.0	
9	120.0	92.0	45.0	30.0	50.0	45.0	50.0	100.0	70.0	75.0	75.0	100.0	
19			400.0	340.0	550.0	750.0	560.0	450.0	500.0	450.0	460.0 560.0	500.0	

Table (50) CL Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	480.0	300.0	320.0	280.0	320.0	450.0	460.0	480.0	420.0	320.0	440.0	480.0	
2	670.0	590.0	680.0	900.0	750.0	1000.0	900.0	900.0	900.0	550.0	750.0	780.0	
4	960.0	730.0	600.0	600.0	670.0	1000.0	980.0	1000.0	780.0	500.0	900.0	950.0	
5	600.0	640.0	620.0	500.0	642.0	900.0	900.0	910.0	710.0	600.0	600.0	620.0	
6	2200.0	2070.0	2000.0	2170.0	2120.0	2250.0	2300.0	2250.0	2200.0	2100.0	2150.0	3500.0 ~~3280.0~~	
7	320.0	200.0	180.0	170.0	190.0	480.0	420.0	320.0	190.0	210.0	320.0	350.0	
8	420.0	250.0	400.0	610.0	1400.0	400.0	410.0	400.0	400.0	1600.0	400.0	430.0	
9	200.0	140.0	200.0	140.0	180.0	200.0	410.0	210.0	180.0	200.0	200.0	250.0	
19			680.0	1200.0	1250.0	1800.0	1840.0	1200.0	1840.0	1520.0	1600.0	1500.0	

Table (51) Cond Changes In The Land Base Water Samples During 92/93

Data expressed in µ mohs

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	2000.0	6600.0	1500.0	1400.0	1400.0	1500.0	1400.0	1500.0	1400.0	1500.0	2000.0	1400.0	
2	3000.0	2000.0	3900.0	2700.0	3000.0	3100.0	3000.0	2600.0	2700.0	2500.0	2300.0	2000.0	
4	3000.0	2500.0	3000.0	2000.0	2900.0	3000.0	2800.0	2900.0	2100.0	1700.0	2700.0	2200.0	
5	2900.0	2300.0	2900.0	2000.0	2800.0	2500.0	2600.0	2500.0	2400.0	2100.0	2400.0	2200.0	
6	7000.0	5000.0	4900.0	5500.0	7500.0	7600.0	7000.0	7600.0	6000.0	7000.0	6000.0	8500.0	
7	1650.0	1400.0	1200.0	1200.0	1100.0	1710.0	1700.0	1600.0	1100.0	1200.0	1600.0	1150.0	
8	4000.0	1500.0	1400.0	2300.0	6100.0	1560.0	1600.0	1700.0	1500.0	6100.0	1800.0	1700.0	
9	1500.0	1100.0	1150.0	1200.0	1000.0	1000.0	1200.0	1100.0	1100.0	1200.0	1300.0	1100.0	
19			5000.0	3700.0	5000.0	5500.0	5000.0	5200.0	5000.0	3000.0	5500.0	5500.0	

Table (52) O&G Changes In The Land Base Water Samples During 92/93

Data expressed in mg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	8.0	63.0	8.0	62.0	8.0	8.0	8.0	8.0	6.0	8.0	8.0	8.0	
2	21.0	65.0	8.0	73.0	0.0	8.0	12.0	8.0	10.0	12.0	10.0	12.0	
4	20.0	81.0	8.0	42.0	8.0	16.0	16.0	16.0	20.0	24.0	20.0	24.0	
5	10.0	54.0	8.0	7.2	8.0	6.0	8.0	8.0	8.0	10.0	8.0	8.0	
6	8.0	32.0	8.0	50.0	16.0	30.0	15.0	15.0	34.0	36.0	34.0	¿ 64.0 64~~0~~.0	
7	18.0	32.0	18.0	14.0	14.0	17.0	18.0	18.0	18.0	20.0	18.0	20.0	
8	8.0	24.0	0.0	46.0	8.0	44.0	48.0	44.0	46.0	48.0	46.0	48.0	
9	16.0	60.0	18.0	40.0	2.0	24.0	22.0	24.0	30.0	32.0	30.0	32.0	
19			8.0	9.0	8.0	8.0	8.0	7.0	12.0	14.0	12.0	12.0	

Table (53) Cd Changes In The Land Base & Lake Water Samples During 92/93

Data expressed in µg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	20.0	50.0	35.0	32.0	51.0	45.0	47.0	42.0	62.0	51.0	43.0	39.0	
2	120.0	50.0	35.0	58.0	49.0	50.0	18.0	24.0	63.0	45.0	42.0	44.0	
4	130.0	60.0	25.0	30.0	65.0	42.0	22.0	23.0	36.0	45.0	48.0	38.0	
5	nd	50.0	28.0	48.0	70.0	57.0		47.0	48.0	56.0	50.0	44.0	
6	400.0	60.0	25.0	168.0	146.0	76.0	34.0	44.0	118.0	77.0	110.0	120.0	
7	30.0	50.0	20.0	37.0	55.0	41.0	32.0	20.0	39.0	33.0	38.0	37.0	
8	30.0	50.0	15.0	58.0	184.0	34.0	11.0	61.0	52.0	89.0	61.0	59.0	
9	28.0	50.0	20.0	30.0	89.0	63.0	12.0	56.0	80.0	34.0	55.0	58.0	
10	40.0	50.0	30.0	21.0	40.0	68.0	14.0	79.0	76.0	52.0	53.0	69.0	
19			25.0	39.0	122.0	54.0	40.0	96.0	88.0	82.0	92.0	80.0	
11	10.0	10.0	28.0	53.0	97.0	99.0	11.0	172.0	91.0	81.0	90.0	92.0	
12	34.0	50.0	35.0	17.0	54.0	58.0	34.0	36.0	91.0	48.0	56.0	54.0	
13	35.0		28.0	43.0	61.0	75.0	52.0	51.0	36.0	74.0	62.0	67.0	
16	10.0	60.0	30.0	8.0	69.0	45.0	32.0	41.0	76.0	24.0	37.0	41.0	
20	20.0	20.0	22.0	115.0	131.0	146.0	22.0	129.0	137.0	106.0	132.0	131.0	
21	80.0	50.0	28.0	48.0	49.0	67.0	34.0	51.0	58.0	30.0	48.0	50.0	
22	35.0	10.0	35.0	62.0	77.0	59.0	48.0	90.0	87.0	89.0	83.0	85.0	
23			25.0	27.0	76.0	73.0	36.0	35.0	70.0	85.0	72.0	82.0	
24			29.0	77.0	148.0	100.0	15.0	126.0	134.0	151.0	120.0	130.0	

nd= not detected

Table (54) Cr Changes In The Land Base & Lake Water Samples During 92/93

Data expressed in µg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	80.0	10.0	44.0	13.0	21.0	24.0	18.0	27.0	30.0	34.0	32.0	33.0	
2	20.0	60.0	61.0	24.0	35.0	15.0	19.0	53.0	31.0	40.0	30.0	32.0	
4	23.0	75.0	36.0	29.0	23.0	19.0	nd	8.0	70.0	42.0	40.0	36.0	
5	nd	40.0	29.0	34.0	31.0	17.0	33.0	76.0	28.0	49.0	39.0	37.0	
6	160.0	30.0	50.0	118.0	85.0	37.0	61.0	17.0	29.3	66.0	60.0	62.0	
7	100.0	40.0	55.0	40.0	31.0	15.0	18.0	30.0	13.0	22.0	15.0	14.0	
8	80.0	10.0	19.0	32.0	274.0	38.0	36.0	46.0	27.0	81.0	37.0	36.0	
9	nd	nd	5.0	31.0	37.0	28.0	22.0	52.0	16.0	20.0	22.0	20.0	
10	78.0	60.0	78.0	13.0	59.0	18.0	26.0	nd	68.0	41.0	40.0	43.0	
19			77.0	27.0	91.0	19.0	49.0	78.0	49.0	97.0	58.0	49.0	
11	100.0	75.0	21.0	41.0	84.0	59.0	53.0	101.0	57.0	67.0	55.0	53.0	
12	76.0	80.0	62.0	nd	50.0	18.0	9.0	77.0	76.0	50.0	56.0	52.0	
13	85.0	65.0	67.0	17.0	51.0	33.0	35.0	51.0	19.0	49.0	45.0	39.0	
16	350.0	40.0	5.0	nd	45.0	14.0	43.0	80.0	48.0	41.0	42.0	45.0	
20	85.0	200.0	151.0	68.0	66.0	23.0	27.0	184.0	78.0	113.0	77.0	69.0	
21			94.0	25.0	60.0	32.0	24.0	25.0	63.0	30.0	28.0	25.0	
22			95.0	290.0	67.0	nd	62.0	123.0	54.0	71.0	53.0	60.0	
23		100.0	99.0	22.0	58.0	29.0	36.0	91.0	45.0	54.0	45.0	47.0	
24		94.0	185.0	66.0	64.0	59.0	39.0	176.0	82.0	171.0	80.0	87.0	

nd= not detected

CR XLS

4/21/93

Table (55) Cu Changes In The Land Base & Lake Water Samples During 92/93

Data expressed in µg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	120.0	nd	60.0	500.0	395.0	3155.0	114.0	366.0	376.0	770.0	335.0	340.0	
2	nd	nd	50.0	214.0	125.0	117.0	45.0	115.0	167.0	110.0	115.0	117.0	
4	80.0	nd	nd	220.0	285.0	1312.0	107.0	379.0	309.0	106.0	108.0	107.0	
5	50.0	125.0		1197.0	1251.0	750.0	973.0	683.0	561.0	728.0	650.0	635.0	
6	170.0	nd	9.0	1159.0	1337.0	180.0	336.0	135.0	381.0	162.0	170.0	145.0	
7	220.0	30.0	7.0	898.0	1491.0	1431.0	23.0	539.0	334.0	176.0	320.0	340.0	
8	130.0	1.0	75.0	872.0	892.0	1442.0	620.0	197.0	215.0	192.0	220.0	~~219.0~~ 213.0	
9	70.0	1.0	10.0	737.0	852.0	1578.0	285.0	110.0	522.0	118.0	228.0	120.0	
10	850.0	nd	20.0	232.0	28.0	123.0	183.0	67.0	350.0	349.0	232.0	320.0	
19	—		10.0	nd	81.0	26.0	63.0	94.0	135.0	150.0	154.0	145.0	
11	80.0	50.0	95.0	582.0	2500.0	297.0	89.0	313.0	276.0	215.0	248.0	220.0	
12	80.0	nd	75.0	206.0	2383.0	[illegible]	265.0	121.0	175.0	220.0	172.0	169.0	
13	85.0		30.0	nd	47.0	75.0	123.0	158.0	70.0	175.0	152.0	159.0	
16	nd	nd	60.0	304.0	334.0	269.0	622.0	742.0	644.0	242.0	334.0	320.0	
20	80.0	nd	30.0	nd	708.0	204.0	17.0	180.0	204.0	132.0	205.0	200.0	
21	40.0	nd	10.0	nd	27.0	163.0	240.0	184.0	104.0	107.0	105.0	104.0	
22		nd	30.0	nd	47.0	30.0	133.0	149.0	122.0	167.0	169.0	135.0	
23			20.0	nd	78.0	150.0	73.0	172.0	117.0	172.0	113.0	120.0	
24			10.0	nd	97.0	120.0	172.0	229.0	221.0	244.0	201.0	225.0	

nd= not detected

CU.XLS

4/21/93

Table (56) Fe Changes In The Land Base & Lake Water Samples During 92/93

Data expressed in µg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	180.0	0.0	337.0	5160.0	4871.0	9495.0	1350.0	5026.0	8622.0	2564.0	1772.0 ~~1775.0~~	1893.0	
2	nd	80.0	387.0	1270.0	3060.0	2287.0	619.0	5657.0	4509.0	3981.0	4500.0	(3900.0)	
4	nd	230.0	133.0	1886.0	4052.0	5075.0		1316.0	4523.0	3058.0	3240.0	2852.0	
5	6200.0	310.0	605.0	4368.0	8400.0	3181.0	2951.0	7487.0	4180.0	1590.0	[illegible]	3351.0	
6	9200.0	110.0	224.0	2048.0	10880.0	1655.0	1828.0	2422.0	5256.0	2685.0	2750.0	5772.0	
7	130.0	230.0	453.0	1230.0	24220.0	3070.0		1574.0	5806.0	3748.0	3804.0	3232.0	
8	200.0	0.0	28.0	1368.0	8610.0	5154.0	5974.0	840.0	3949.0	2746.0	3385.0	3823.0	
9	110.0	0.0	173.0	3390.0	9380.0	3771.0	2411.0	3104.0	1538.0	3196.0	3198.0	3920.0	
10	60.0	110.0	214.0	nd	15200.0	552.0	513.0	2281.0	575.0	4323.0	4421.0	4644.0	
19			471.0	6728.0	2121.0	696.0	151.0	1388.0	4818.0	7170.0	4742.0	4915.0	
11	130.0	230.0	414.0	1160.0	34050.0	1353.0		6826.0	4609.0	6628.0	6062.0	4901.0	
12	1700.0	230.0	109.0	3400.0	81000.0	1013.0	3015.0	2463.0	2854.0	3475.0	2633.0	2481.0	
13	120.0		240.0	5120.0	840.0	601.0	277.0	267.0	237.0	2527.0	397.0	488.0	
16	70.0	160.0	214.0	1646.0	6080.0	866.0	1726.0	664.0	1515.0	2544.0	2422.0	2153.0	
20	nd	450.0	441.0	1658.0	1568.0	1655.0		2134.0	2292.0	1071.0	1978.0 ~~1928.0~~	2100.0	
21	180.0	450.0	218.0	709.0	800.0	737.0	1041.0	2856.0	1078.0	840.0	1177.0	1208.0	
22	40.0	450.0	120.0	689.0	850.0		1400.0	2075.0	1061.0	2599.0	2350.0	2877.0	
23			177.0	723.0	981.0	193.0	51.0	2003.0	1451.0	1619.0	1815.0	2232.0	
24			572.0	820.0	760.0	133.0	528.0	2228.0	914.0	2480.0	2422.0	2323.0	

nd= not detected

Table (57) Ni Changes In The Land Base & Lake Water Samples During 92/93

Data expressed in µg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	50.0	10.0	29.0	20.0	293.0	354.0	162.0	192.0	204.0	346.0	182.0	190.0	
2	2.0	20.0	28.0	35.0	156.0	215.0	156.0	178.0	133.0	82.0	80.0	95.0	
4	30.0	20.0	15.0	20.0	240.0	303.0	217.0	169.0	156.0	186.0	150.0	170.0	
5	50.0	20.0		30.0	299.0	300.0	237.0	309.0	98.0	225.0	230.0	235.0	
6	20.0	30.0	10.0	60.0	657.0	313.0	313.0	171.0	334.0	372.0	376.0	315.0	
7	20.0	20.0	28.0	18.0	244.0	223.0	108.0	77.0	156.0	221.0	235.0	195.0	
8	30.0	10.0	28.0	26.0	447.0	250.0	220.0	242.0	440.0	427.0	420.0	390.0	
9	20.0	0.0	15.0	15.0	167.0	287.0	155.0	209.0	137.0	205.0	135.0	165.0	
10	50.0	20.0	29.0	77.0	176.0	273.0	227.0	84.0	220.0	229.0	220.0	225.0	
19			27.0	19.0	369.0	198.0	340.0	232.0	296.0	340.0	224.0	230.0	
11	30.0	20.0	60.0	14.0	495.0	370.0	220.0	376.0	355.0	486.0	400.0	350.0	
12	20.0	20.0	60.0	17.0	332.0	226.0	152.0	238.0	300.0	300.0	301.0	292.0	
13	40.0		60.0	7.0	220.0	283.0	242.0	278.0	70.0	220.0	210.0	240.0	
16	20.0	30.0	26.0	19.0	218.0	255.0	213.0	276.0	282.0	213.0	250.0	219.0	
20	50.0	30.0	60.0	46.0	449.0	552.0	310.0	418.0	502.0	440.0	417.0	420.0	
21	40.0	10.0	60.0	17.0	292.0	306.0	88.0	287.0	218.0	166.0	182.0	215.0	
22		20.0	29.0	26.0	298.0	278.0	282.0	394.0	386.0	360.0	396.0	373.0	
23			29.0	10.0	225.0	284.0	264.0	258.0	186.0	210.0	212.0	220.0	
24			60.0	29.0	435.0	350.0	240.0	228.0	461.0	345.0	320.0	342.0	

nd= not detected

Table (58) Pb Changes In The Land Base & Lake Water Samples During 92/93

Data expressed in µg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	130.0	50.0	26.0	380.0	280.0	1200.0	234.0	280.0	600.0	130.0	120.0	118.0	
2	30.0	75.0	25.0	590.0	470.0	740.0	560.0	38.0	270.0	240.0	50.0	57.0	
4	130.0	100.0	1.0	170.0	430.0	1050.0	168.0	50.0	210.0	280.0	160.0	220.0	
5	25.0	220.0		750.0	560.0	740.0	591.0	740.0	340.0	420.0	400.0	390.0	
6	25.0	100.0	40.0	1290.0	1300.0	910.0	901.0	380.0	1590.0	290.0	265.0	300.0	
7	250.0	200.0	55.0	1170.0	2070.0	2120.0	94.0	119.0	240.0	140.0	123.0	135.0	
8	130.0	0.0	26.0	690.0	1480.0	1480.0	720.0	520.0	200.0	400.0	420.0	430.0	
9	30.0	50.0	1.0	810.0	580.0	1100.0	337.0	340.0	520.0	210.0	240.0	300.0	
10	210.0		550.0	900.0	180.0	770.0	526.0	400.0	530.0	260.0	225.0	250.0	
19		100.0	18.0	100.0	700.0	950.0	770.0	45.0	510.0	490.0	440.0	500.0	
11	250.0	100.0	40.0	710.0	3110.0	950.0	583.0	900.0	610.0	520.0	611.0	580.0	
12	140.0	100.0	28.0	100.0	2790.0	640.0	819.0	450.0	520.0	350.0	420.0	450.0	
13	250.0		25.0	230.0	80.0	850.0	612.0	580.0	30.0	270.0	290.0	260.0	
16	100.0	100.0	26.0	160.0	180.0	840.0	617.0	750.0	640.0	250.0	590.0	601.0	
20	138.0	200.0	38.0	530.0	700.0	1450.0	354.0	115.0	720.0	480.0	390.0	440.0	
21			55.0	160.0	270.0	850.0	637.0	650.0	310.0	90.0	97.0	120.0	
22			25.0	50.0	420.0	870.0	837.0	760.0	480.0	310.0	440.0	420.0	
23		100.0	26.0	nd	370.0	790.0	713.0	720.0	120.0	280.0	300.0	320.0	
24		100.0	37.0	210.0	870.0	1014.0	591.0	1170.0	770.0	890.0	790.0	723.0	

nd= not detected

Table (59) Zn Changes In The Land Base & Lake Water Samples During 92/93

Data expressed in µg / l

Site No.	MAR 92	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR 93
1	1200.0	0.0	60.0	80.0	1365.0	21281.0	122.0	460.0	194.0	555.0	550.0	490.0	
2	nd	0.0	15.0	25.0	956.0	365.0	113.0	425.0	nd	429.0	420.0	425.0	
4	nd	100.0	37.0	nd	111.1	974.0		107.3	nd	357.0	297.0	301.0	
5	1200.0	300.0		250.0	327.0	372.0	794.0	785.0	673.0	100.0	706.0	690.0	
6	8800.0	10.0	60.0	197.0	299.0	44.0	569.0	366.0	209.0	796.0	386.0	330.0	
7	300.0	100.0	37.0	60.0	373.0	385.9		214.6	219.0	644.0	240.0	250.0	
8	1000.0	0.0	50.0	20.0	2710.0	356.2	1400.0	742.0	nd	540.0	620.0	520.0	
9	1200.0	10.0	2.0	5.0	1780.0	779.0	347.0	423.0	248.0	527.0	450.0	420.0	
10	nd	30.0	60.0	25.0	840.0	100.0	98.0	280.0	191.0	89.0	200.0	190.0	
19			60.0	nd	510.0		93.0	39.0	505.0	403.0	522.0	500.0	
11	100.0	40.0	60.0	30.0	7000.0	419.0		123.0	280.0	454.0	420.0	450.0	
12	1200.0	300.0	50.0	25.0	8650.0	150.0	482.0	403.0	546.0	677.0	462.0	420.0	
13	nd		60.0	50.0	217.0	32.0	102.0	509.0	280.0	422.0	440.0	503.0	
16	nd	10.0	90.0	36.0	3600.0	59.0	497.0	916.0	872.0	453.0	850.0	820.0	
20	50.0	0.0	90.0	nd	90.0	94.0		83.0	82.0	318.0	300.0	322.0	
21	nd	0.0	60.0	35.0		132.0	222.0	559.0	377.0	276.0	325.0	360.0	
22		1.0	60.0	nd	95.0	16.0	98.0	42.0	421.0	445.0	460.0	420.0	
23			60.0	50.0		50.0	131.3	409.0	408.0	770.0	430.0	413.0	
24			60.0	65.0	1300.0	90.0	125.0	95.0	595.0	692.0	550.0	560.0	

nd= not detected

Table (60) Changes of Algal Counts & Species in Lake & Landbase Water Samples During 92/93

Data expressed in cells/l X 10³

Site No.	MAR 92		APRIL		MAY		JUNE		JULY		AUGUST	
	Count	Species	Count	Species	Count	Species	Count	Species	Count	Species	Count	Species
1	208 0	Euglenophyta	142 0	Euglena Chlorella Cyclotella	8 8	Melosira Cyclotella	6 5	Cyclotella Spirulina				
2	148 0	Euglenophyta	338 0	Euglena Chlorella Cyclotella	84 0	Melosira	147 0	Melosira Spirulina				
4	39 6	Euglenophyta& Diatoms	806 0	Chlorella Ulothrix Cyclotella	21 6	Chlorella Cyclotella	224 0	Melosira spirulina				
5	176 0	Euglenophyta& Chlorophyta	63 6	Chlorella Zygnema	39 2	Spirulina	294 0	Melosira,spirulina,pediastrum				
6	292.4	Euglenophyta& Chlorophyta	92 4	Cyclotella Ulothrex	48 0	Cuclotella	72 0	Euglena,Cyclotella				
7	630 0	Euglenophyta &Chlorophyta& Diatoms	16 4	Cyclotella Zygnema	33 8	Cyclotella	170 0	Cyclotella Spirulina				
8	2664 0	Chlorophyta&Diatoms	60 0	Cyclotella Euglena	16 0	Cyclotella	315 0	Cyclotella				
9	210 8	Euglenophyta& Chlorophyta	65 0	Cyclotella, Large No of Protozoa	156 0	Cyclotella, Euglina	180 0	Cyclotella				
10	1034 0	Euglenophyta& Chlorophyta	144 0	Euglena	138 0	Cyclotella, Tabelana	840 4	Actinastrum Stephanodescus				
19	0 0				30 0	Cyclotella	56 0	Euglina,Tabelana				
11	765 6	Euglenophyta& Chlorophyta&Diatoms	24 0	Cyclotella	40 8	Chlorella	51 3	Melosira				
12	12 0	Euglenophyta& Diatoms	28 8	Euglena Cyclotella	198 0	Diatoms Chlorella	292 8	Melosira				
13	664 0	Euglenophyta& Chlorophyta	975 0	Euglena Cyclotella	351 8	Cyclotella Agmenellum	432 0	Euglina,Tabelana				
16	386 4	Euglenophyta& Chlorophyta	136 8	Cyclotella	350 0	Melosira, Cyclotella	15 0	Euglina				
20	92 0	Euglenophyta& Chlorophyta	108 8	Cyclotella Chlorella	50 0	Cyclotella	385 0	Spirulina Actinastrum Stephanodescus				
21	176 6	Euglenophyta			700 0	Cyclotella, Tabelana, Phytoconies	54 0	Spirulina				
22	186 0	Euglenophyta			60 0	Tabelana	30 0	Spirulina				
23			45 0	Cyclotella Ulothrix Ex. Protozoa	1092 0	Cyclotella, Tabellana	196 0	Spirulina,Actinastrum				
24			168 0	Cyclotella Chlorella	300 0	Cyclotella, Tabelana	10 0	Melosira				

e ( ) Changes of Algal Counts & Species in Lake & Landbase Water Samples During 92/93

Data expressed in cells/l x10³

.	MAR 92		APRIL		MAY		JUNE		JULY		AUGUST	
	Count	Species	Count	Species	Count	Species	Count	Species	Count	Species	Count	Species
	208.0	Euglenophyta	142.0	Euglena Chlorella Cyclotella	8.8	Melosira,Cyclotella	6.5	Cyclotella, Spirulina	36	Melosina cyclotella	120	spirulina
2	148.0	Euglenophyta	338.0	Euglena Chlorella Cyclotella	84.0	Melosira	147.0	Melosira,Spirulina	171	Melosina cyclotella phytoconios	90	stephanodescu
4	39.6	Euglenophyta&Diatoms	806.0	Chlorella Ulothrix Cyclotella	21.6	Chlorella,Cyclotella	224.0	Melosira,spirulina	220	phytoconios Zygnema	150	Euglena
5	176.0	Euglenophyta&Chlorophyta	63.6	Chlorella Zygnema	39.2	Spirulina	294.0	Melosira,spirulina,pediastrum	400	oocystis sphaerocystis staurastrum	200	spirulina stephanodescus
	292.4	Euglenophyta&Chlorophyta	92.4	Cyclotella Ulothrex	48.0	Cudotella	72.0	Euglena,Cyclotella	560	Euglena	30	cc
7	630.0	hyta&Chlorophyta&Diatoms	16.4	Cyclotella Zygnema	33.8	Cyclotella	170.0	Cyclotella, Spirulina	126	Euglena cyclotella	200	spirulina ulothrix
	2664.0	Chlorophyta&Diatoms	60.0	Cyclotella Euglena	16.0	Cyclotella	315.0	Cyclotella	144	Euglena	100	Spirogina spirulina
9	210.8	Euglenophyta&Chlorophyta	65.0	Large No.of Protozoa.	156.0	Cyclotella, Euglina	180.0	Cyclotella	160	Euglena scendesmus	400	spirulina Melosira
0	1034.0	Euglenophyta&Chlorophyta	144.0	Euglena	138.0	Cyclotella, Tabelaria	840.4	Actinastrum,Stephanodescus	660	Actinastrum spirulina		
9	0.0				30.0	Cyclotella	56.0	Euglina,Tabelaria	216	spirulina	1400	spirulina
1	765.6	yta&Chlorophyta&Diatoms		24.0 Cyclotella	40.8	Colorella	51.3	Melosira	150	spirulina c Actinastrum	~~500~~	
2	12.0	Euglenophyta&Diatoms	28.8	Euglena Cyclotella	198.0	Diatoms,Chlorella	292.8	Melosira	420	chlorella spirulina Actinastrum	500	spirulina chlorella
3	664.0	Euglenophyta&Chlorophyta	975.0	Euglena Cyclotella	361.8	Cyclotella, Agmenellum	432.0	Euglina,Tabelaria	300	Euglena Melosira	780	spirulina phytoconios
6	386.4	Euglenophyta&Chlorophyta	136.8	Cyclotella	350.0	Massive,Cyclotella	15.0	Euglina	200	Euglena	210	spirulina
0	92.0	Euglenophyta&Chlorophyta	108.8	Cyclotella Chlorella	50.0	Cyclotella	385.0	Sprulina,Actinastrum, Stephanodescus	153	Melosira spirulina Actinastrum	1140	cc
1	176.8	Euglenophyta			700.0	Cyclotella, Tabelaria, Phytoconies	54.0	Spirulina	750	Actinastrum spirulina	1000	cc
2	186.0	Euglenophyta			60.0	Tabelaria	30.0	Spirulina	1620	cc c.	550	cc cyclotella
3			45.0	Cyclotella Ulothrix Ex. Protozoa	1092.0	Cyclotella, Tabellaria	196.0	Spirulina,Actinastrum	1020	cc c	5000	spirulina

Table (60) Changes of Algal Counts & Species in Lake & Landbase Water Samples During 92/93

Data expressed in cells/l X 10³

Site No.	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY	
	Count	Species	Count	Species	Count	Species	Count	Species	Count	Species	Count	Species
1			53.2	Spirulina	60.0	Actinastrum	60.0	Melosira, Coelastrum	20.0	Melosira Scendesmus	165.0	Cyclotclla Cynara
2			54.5	Spirulina	400.0	Actinastrum	9.0	Ulothnx, Pediastrum	15.0	Melosira Scenaesmus+Euglena	450.0	Melo Sira Cyclotella
4			41.1	Melosira, Tablena	3.5	Actinastrum	50.0	Gomphonosphera	4.0	Phytocomies Protegoa	250.0	Melo Sira
5			9.7	Melosira, Ulthonx	90.0	Actinastrum	24.0	Gomphonosphera	8.4	Scendesmus	450.0	Melo Sira Cyclotella
6			Zero	Protozoa	0.3	Spirulina	12.5	nosphera, protozoa	17.5	Phytocenies	400.0	Melo Sira Cyclotella
7			36.3	Cholorella		Euglena + Protozoa	5.0	Gomphonosphera	17.5	Phytocenies Spirulina	200.0	Melo Sira Cyclotella
8			24.2	Cholorella, Protozoa		Euglena + Protozoa	40.0	Gomphonosphera	125.0	Melosim	200.0	Melo Sira Cyclotella
9			1.2	Melosira	25.0	Spirulina, Protozoa	10.0	Euglena, Pediastrum	20.0	Ankistrodesmus	150.0	Melo Sira Cyclotella
10			96.8	Tabelana, Stephandisus	100.0	Spirulina, Actinastrum	10.0	nosphera, Protozoa	85.0	Ankistrodesmus	300.0	Melo Sira Cyclatella
19			0.2	Stephpnd Discus Fngiralia	100.0	Actinastrum	42.0	Gomphonosphera	50.0	Cyelotcllu Tabelewa	500.0	Sira+Syndra Cyclotella
11					400.0	Actinastrum		Euglena	125.0	Ankistrodesmus	300.0	Melo Sira Cyclotella
12			217.8	Spirulina, Tablena	1050.0	Actinastrum	65.0	Gomphonosphera, Tablena	50.0	Spirulina Tabelana	200.0	Melo Sira Cyclotella
13			290.4	mus, Stephanodiscus	2800.0	Actinastrum	20.0	Gomphonosphera, Tablena	50.0	Tabelana	400.0	Phytoconies Mela Sira
16			72.6	Spirulina	15.0	Actinastrum	35.0	Gombhoneisphera Tablena	22.5	Tabelana Cyclotella,	350.0	Melo Sira
20			290.4	Diatcma, Tablena	420.0	Actinastrum	10.0	Melosira, Ulthonx	250	Tabelana Cyclotella	700.0	Melo Sira Phytoconies
21			30.3	Stephonodiscus, Tablena	960.0	Actinastrum	210.0	Gomphonosphera	500.0	Tabelana Cyclotella	400.0	MiloSira Syndra+Cyclotella
22			125.9	Spirulina, Stephanodiscus	1650.0	Actinastrum	150.0	Tabelana	250.0	Tabelana Cyclotella	135.0	Tetra Spora+Syndra Melo Sira
23			871.2	Tabelana, scendesmus	1750.0	Actinastrum	51.0	Gomphonosphera	40.0	Tabelana Cyclotella	550.0	Melo Sira Phytoconies
24			20.6	Frigiralia	560.0	Actinastrum	80.0	Chrololla, Gomphonoshepra	75.0	Tabelana Cyclotella	550.0	Spora+Syndra Melo Sira

Table (61) Changes of Bacterial Counts Lake & Landbase Water Samples During 92/93

Data expressed in MPN/100 ml

Site No.	MAR 92		APRIL		MAY		JUNE		JULY		AUGUST	
	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform
1	>24E+8	>24E+8	11*10E9	46*10E8	>24*10E8	>24*10E8	46'10E8	24'10E8	93'10E7	43'10E7	93'10E8	43'10E8
2	>24E+8	>24E+8	24*10E9	11*10E9	>24*10E8	>24*10E8	24'10E8	24'10E8	24'10E8	24'10E8	46'10E5	46'10E5
4	>24E+8	>24E+8	93*10E7	91*10E6	>24*10E8	>24*10E8	46'10E8	46'10E8	11'10E9	11'10E9	15'10E9	15'10E9
5	>24E+8	15E+7	46*10E8	46*10E8	>24*10E8	>24*10E8	46'10E8	24'10E8	93'10E7	93'10E7	15'10E9	15'10E9
6	>24E+8	>24E+8	24*10E8	93*10E7	>24*10E8	>24*10E8	46'10E8	46'10E8	>24'10E9	>24'10E9	46'10E9	46'10E9
7	>24E+8	>24E+8	24*10E9	11*10E9	>24*10E8	>24*10E8	43'10E8	24'10E8	>24'10E9	>24'10E9	>24'10E10	>24'10E10
8	>24E+8	>24E+8	24*10E8	46*10E6	>24*10E8	>24*10E8	46'10E8	46'10E8	>24'10E9	>24'10E9	>24'10E10	>24'10E10
9	>24E+8	>24E+8	24*10E9	46*10E8	>24*10E8	>24*10E8	46'10E8	24'10E8	46'10E8	46'10E8	11'10E10	18'10E10
10	43E+6	43E+6	21*10E4	43*10E3	4600.0	4600.0	4600.0	2400.0	2400 0	2400 0	24'10E4	24'10E2
19					91*10E5	91*10E5	24000.0	21000 0	21000 0	21000 0	1100 0	1100.0
11	4600.0	1500.0	24*10E4	15*10E8	>24*10E8	>24*10E8	46'10E8	46'10E8	11'10E9	11'10E9	>24'10E10	>24'10E10
12	>24E+8	>24E+8	24*10E8	24*10E8	>24*10E8	>24*10E8	24'10E8	24'10E8	24'10E8	24'10E8	46'10E10	46'10E10
13	2400.0	1500.0	11*10E3	11*10E3	43.0	23.0	43'10E8	24'10E8	46'10E8	46'10E8	2'10E7	2'10E7
16	1500.0	1500 0	23*10E7	91*10E6	21*10E9	15*10E9	46'10E8	24'10E8	24'10E8	24'10E8	23'10E8	23'10E8
20	230 0	230 0	11*10E2	35 0	23 0	23.0	21000 0	11000 0	11000 0	11000 0	1100 0	1100 0
21					2400 0	2400 0	2400 0	2400.0	460 0	460 0	46'10E4	46'10E4
22					2400 0	150 0	2400 0	2400.0	2400 0	2400 0	2400 0	2400 0
23					93 0	15 0	46 0	46 0	43 0	43 0	460 0	460 0
24			24*10E2	460 0	0 0	0 0	23 0	23.0	23 0	23 0	460 0	460 0

Table (61) Changes of Bacterial Counts Lake & Landbase Water Samples During 92/93

Data expressed in MPN/100 ml

Site No.	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH 93	
	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Coliform	Presumptive Coliform	Fecal Colifor
1	11*10E10	11*10E10	43*10E8	43*10E8	39*10E8	39*10E8	91*10E7	91*10E7	24'10E8	91'10E6	24'10E8	43'10E7		
2	24*10E6	24*10E6	11*10E8	11*10E6	46*10E9	46*10E9	91*10E7	91*10E7	46'10E8	36'10E6	24'10E9	23'10E7		
4	93*10E7	93*10E7	11*10E10	93*10E8	43*10E8	43*10E8	91*10E7	91*10E7	24'10E8	93'10E7	24'10E8	43'10E7		
5	24*10E8	24*10E8	75*10E8	39*10E8	93*10E8	93*10E8	23*10E8	23*10E8	11'10E10	15'10E9	2'10E8	15'10E7		
6	27*10E8	27*10E8	11*10E10	46*10E9	93*10E8	93*10E8	43*10E8	43*10E8	15'10E7	15'10E7	24'10E9	21'10E7		
7	15*10E9	15*10E9	43*10E8	43*10E8	24*10E9	24*10E9	39*10E8	39*10E8	23'10E8	36'10E7	46'10E8	15'10E8		
8	15*10E9	15*10E9	24*10E10	24*10E10	43*10E8	43*10E8	39*10E8	39*10E8	43'10E8	43'10E8	46'10E8	75'10E7		
9	15*10E9	15*10E9	46*10E8	24*10E8	46*10E9	46*10E9	24*10E9	24*10E9	93'10E7	43'10E7	24'10E8	43'10E7		
10	15*10E4	15*10E4	11*10E5	11*10E5	24*10E5	24*10E5	24*10E6	24*10E6	24'10E5	93'10E4	11'10E6	23'10E5		
1R	2400.0	2400.0	24000.0	1500.0	24*10E3	9300.0	3900.0	3900.0	75.0	15.0	4300.0	1500.0		
11	43*10E8	43*10E8	93*10E8	93*10E8	46*10E9	46*10E9	43*10E8	43*10E8	43'10E8	91'10E7	24'10E9	24'10E9		
12	46*10E6	46*10E6	23000.0	9100.0	11*10E5	11*10E5	24*10E5	24*10E5	43000.0	7300.0	24'10E5	39'10E4		
13	91*10E4	91*10E4	23*10E5	91*10E4	24*10E5	24*10E5	11*10E5	46*10E4	24'10E4	46000.0	24'10E6	46'10E5		
16	91*10E7	91*10E7	21*10E8	21*10E8	91*10E7	91*10E7	43*10E8	43*10E8	23'10E8	91'10E7	46'10E8	91'10E6		
20	24000.0	24000.0	11000.0	11000.0	24000.0	24000.0	11*10E4	11*10E4	4300.0	1500.0	46000.0	9300.0		
21	46*10E5	46*10E5	24*10E5	24*10E5	24*10E6	24*10E6	240.0	240.0	4600.0	2400.0	4600.0	4600.0		
22	2400.0	2400.0	38.0	0.0	11000.0	2400.0	4600.0	4600.0	24000.0	24000.0	11000.0	11000.0		
23	930.0	930.0	430.0	91.0	2400.0	2400.0	24000.0	24000.0	24000.0	24000.0	11000.0	11000.0		
24	930.0	930.0	430.0	150.0	1500.0	1500.0	24000.0	11000.0	2400.0	430.0	150.0	91.0		
B			43'10E4	43'10E4	11'10E5	11'10E5								
B2			24'10E7	24'10E7	2400.0	2400.0								

Table (62) Lake & LandbaseTemperature

Data expressed in degrees C

Site No.	Mar-92	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	Mar-93
1	21	24	27	31	29	31	31	28.5	27	21	19	17.5	
2	21	24	25	25	28	29	30	28	26	21	19	18	
3													
4	21	22	25	29	27	31	30	27	24	12	19	15	
5	19	24	25		28	30	32	27	24	20	18	16	
6	23	24	25	25	32	32	33	31	25	23	24		
7	19	24	25	27	31	30	30	27	26	21	24	19	
8	18	22	25	27	30	28	28	28	25	19	18	15.5	
9	19	22	25	27	28	29	29	27	25	19	18	16	

Table (62) Lake & Landbase Temperature

Data expressed in degrees C

Site No.	Mar-92	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	Mar-93
10	12		26	25	29	29	30	25	22	18	15	13	
11	14		25	30	30	31	30	29	28	18	21	12	
12	16		24	26	30	28	28	25	21	18	15	12	
13	15			26	27	27	28	26	21	16	17	11	
14	15												
15	16	22											
16	12		24	27	29	29	29	26	24	20	13	16	
21			25	27	28	28	28	25	22	17	14	13	
22			24	25	29	28	28	26	21	17	15	12	
23			28	24	28	28	29	26	21	17	15	12	
24			26	26	34	29	29	31	25	22	20	19	

Data expressed in cm

Site No.	Mar-92	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	Mar-93
10	150	120	84	80	70	80	85	95	75	90	95		
11	170	70	100	45	40	30	35	50	45	40	60		
12	150	110	55	40	25	60	65	50	50	40	90		
13	150	100		50	60	100	105	70	70	70	105		
14	200												
15	120	150											
16	200	150	55	100	100	60	65	80	80	95	100		
21		140	160	140	120	150	155	120	110	95	150		
22			80	110	120	140	145	105	100	100	160		
23		140	45	80	60	110	115	100	95	105	120		
24			90	80	90	120	120	75	60	60	40		

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Appendix D

June 1993 Work Plan, Quality Assurance Plan, and Data

Appendix D consists of three sections. The first section is the Sampling and Analysis Work Plan, which describes the objectives and scope of the supplemental sampling program conducted in June 1993. The second section is a Quality Assurance Plan for the June 1993 sampling, which describes the protocols for sampling; field measurements; sample splitting, preservation, holding time and shipping; laboratory analyses; and reporting. The final section consists of CH2M HILL and High Institute data.

Sampling and Analysis Work Plan

Supplemental Sampling Program
Lake Maryout, Alexandria, Egypt

Revision 1

Prepared by

WWCG

June 1993
CVO33391.A6

Contents

Tables

1.0 Introduction

As a supplement to the ongoing Lake Maryout baseline study and environmental assessment a sampling and analysis program will be undertaken. This supplemental program will include:

- Benthic invertebrate examination of lake bottom sediments.
- Priority pollutant analysis of lake water and bottom sediments.
- Quality assessment for sampling and analysis work provided to the WWCG by the University of Alexandria High Institute of Public Health (UAHIPH).

This sampling and analysis work plan (SAP), in conjunction with the "Lake Maryout Supplemental Sampling Quality Assurance Plan (QAP), provides the overview of work to be performed, a plan for conducting the work and a quality assurance plan. The anticipated approach, procedures, and equipment are fully described. Due to shipment difficulties or other logistic conditions inherent in Third World countries some modifications to this Plan may be necessary once sampling is initiated. Any modifications will be fully documented and the potential consequences evaluated.

2.0 Project Objectives

This supplemental sampling and analysis program has three primary objectives:

- To Document the current biological conditions in Lake Maryout by collecting sediment from selected locations and identify benthic invertebrate animals in the samples
- To provide an indication of background concentration of priority pollutants which to date has not been measured by the Egyptians
- To perform quality assurance/quality control procedures for the 1992/1993 UAHIPH data by splitting samples for analysis between a USA laboratory and the UAHIPH lab.

3.0 Approach and Rationale

The objectives of the Lake Maryout supplemental sampling and analysis program will be accomplished by conducting another round of sampling at all previously sampled stations. In addition, samples will be collected at the east end of the lake near the industrial discharge points and also at an area within the Southwest Basin that is not directly impacted by dischargers. In doing so, the impact of the industrial discharges can be assessed.

Lake water samples for water quality analysis and bottom sediment samples for sediment quality analysis will be collected. Sample collections and sample splits will be made for the lists of parameters displayed in Table 3-1.

Table 3-1
Lake Maryout Sample List

			Sample Splits	
	Lake Water	**Lake Sediment**	**WWCG**	**UAHIPH**
EPA Priority Pollutants				
Volatile Organics (EPA 624)	X	X	X	
Semi-Volatile Organics (EPA 625)	X	X	X	
Pesticides & PCBs (EPA 8080)	X	X	X	
Metals (EPA 23 TAL Elements)	X	X	X	X
Total and Fecal Coliform Bacteria	X		TBD	X
Total Suspended Solids	X			X
Total and Volatile Solids	X	X		X
Nutrients (ammonia and O-phosphates)	X	X		X
Biochemical Oxygen Demand (BODs)	X	X	X	X
Chemical Oxygen Demand	X	X	X	X
Benthic Invertebrate Examination		X		X

Note: Lake water sampling sites will also include in-situ measurements for pH, temperature, dissolved oxygen, and conductivity.

TBD = To be determined

To assure representativeness, sample splits will be generated at the sampling sites and handled in an identical manner up to the point of shipment to the laboratories. One set of duplicate samples obtained from the sample split will be shipped by express air service to CH2M HILL's Gainsville, Florida laboratory. The other set of duplicates will be surrendered to the UAHIPH lab.

Priority pollutant analysis will be performed by CH2M HILL's lab. This will provide a pre-discharge (baseline) measurement of lake water and lake sediment quality for EPA's target priority pollutant analyte list.

Creation of duplicate samples for metals and other selected parameters and subsequent analysis by CH2M HILL's lab and the UAHIPH lab will provide a measure of quality for previous work performed at the UAHIPH lab. CH2M HILL's lab maintains EPA accreditation by active participation in EPA's analytical performance evaluation program. Additionally CH2M HILL's lab has State certification and an ongoing quality assurance program from which the lab's precision and accuracy can be determined at any time. CH2M HILL's data will serve as the reference point to compare results obtained from the UAHIPH lab. In addition, a visit to the UAHIPH lab will evaluate the staff, equipment and procedures used to perform previous Lake Maryout sample analyses. A statement of reliability concerning previous UAHIPH test data will be made.

Benthic invertebrate examination will also be performed by UAHIPH scientists who are familiar with the local aquatic fauna. This taxonomic examination will be overseen by WWCG scientists. The benthic examination will provide a pre-discharge biological record of the lake's water and sediment quality and overall condition of the lakes aquatic habitat.

4.0 Project Staff and Responsibilities

4.1 Dr. James Maughan, CH2M HILL, Senior Project Scientist

- Project Management & Coordination
- Planning
- Senior Project Scientist
- Staffing
- Scheduling
- Benthic invertebrate oversite
- Report completion

4.2 Mark Boedigheimer, CH2M HILL, Environmental Chemist

- Prepare SAP
- Prepare QAPP
- Lab services coordination
- Sampling oversite
- In-field measurements
- UAHIPH Lab review

4.3 Thurman Dickens, CH2M HILL, Laboratory Director

- USA lab analysis
- Lab QA/QCs
- Lab data deliverables

4.4 Barry Patterson, CH2M HILL, Laboratory Customer Service

- USA sampling kits
- Sample shipping
- Customs coordination

4.4 Andrew Beliveau, Metcalf & Eddy, Senior Chemist

- Data review
- Consultation

4.5 AHIPH Scientists

- Benthic invertebrates examination

4.6 AHIPH Lab Staff

- Chemical and microbiological analyses

5.0 Work Tasks

5.1 Sampling Equipment and Supplies

This sections details the sampling equipment and supplies required to collect samples of lake water and sediments for testing described under Section 3.0, Approach and Rationale. Table 5-1 identifies the required materials for sample collection and identifies the provider of the materials.

Table 5-1
Lake Maryout Sampling Equipment and Supplies

Item	Provided By
Boat and motor	UAHIPH
Safety equipment, on-water	UAHIPH
Water sampler	UAHIPH
Water sampler, dipper	UAHIPH
Sediment sampler	UAHIPH
Sample composite buckets, 5 gal.	UAHIPH
Stirring paddle for mixing composite	UAHIPH
Sample containers for UAHIPH analyses for USA analyses	 UAHIPH CH2M HILL's Lab

Table 5-1
Lake Maryout Sampling Equipment and Supplies
(Continued)

Item	Provided By
Sample preservation reagents 10% sulfuric acid solution 10% hydrochloric acid solution packaged ice, for USA samples	 UAHIPH UAHIPH CH2M HILL's Lab
Sample tags, markers, log book, etc.	UAHIPH & CH2M HILL
Chain of custody forms	CH2M HILL
Shipping containers, for USA samples	CH2M HILL's Lab
Shipping and Customs forms, for USA samples	CH2M HILL's Lab/Fed. Exp.
pH meter	CH2M HILL's equip. pool
Dissolved oxygen meter	CH2M HILL's equip. pool
Conductivity meter	CH2M HILL's equip. pool
Thermometer(s)	UAHIPH & CH2M HILL
Camera, 35 mm w/date	CH2M HILL
Labware, (eye dropper, litmus paper, etc)	CH2M HILL
Misc. sampling supplies (rope, ice, etc.)	UAHIPH & CH2M HILL

5.2 Sampling Events

Tentatively, this Lake Maryout supplemental sampling program is being planned as two separate sampling activities. It is quite likely that lake water sampling and lake sediment sampling will be conducted as two separate activities on different days. This is based on the logistics associated with sample collection, packaging, shipping, and oversite.

At the time of this writing, it appears as though the lake bottom sediment sampling activities will be conducted prior to water sampling to facilitates the USA scientist's oversite of the benthic invertebrate examinations by UAHIPH scientists. In doing so, an aliquot of lake bottom sediment from each sampling site will be retained for benthic invertebrate examination. Another aliquot of bottom sediment will be collected and mixed to create a homogenous sample, then split for analysis by the UAHIPH lab and CH2M HILL's lab.

Samples for total and fecal coliforms may also be collected during the first sample event, again for the purposes of allowing the USA scientist to observe the UAHIPH lab's microbiological procedures and techniques for measuring coliform bacteria.

Lake water samples will be collected no later than three (3) days after the bottom sediment sampling activity.

5.3 Sampling Locations

Samples will be collected from all 1992/1993 survey sites, plus one lake station opposite the industries discharge and one site in the southwest basin.

5.4 In-Field Measurements

pH. pH will be measured at each sample location on an aliquot of lake water taken immediately after collection. pH measurements will be performed using a portable Orion, model SA250, pH meter and combination pH electrode, or equal.

Temperature and Dissolved Oxygen. In-situ measurements for temperature and dissolved oxygen concentration of the lake water will be measured at each sample location. A YSI, model 51, portable dissolved oxygen meter and dissolved oxygen field probe, or equal, will be used.

Conductivity. In-situ conductivity measurements will be made in the lake water at each sample location. Direct measurement of lake water electrolytic conductivity will be made with a YSI model 33 portable conductivity meter.

All field measurements will be recorded in a field log book, along with the sample location, date, time, photographs, and other field observations (e.g., weather or unusual conditions). Field instrument calibration will be documented daily.

5.5 Sampling Procedures

Sampling Equipment Cleaning

All equipment, apparatus, or implements that come into contact with the sample will be precleaned as follows:

- Remove any visible residue
- Scrub with soap and clean water using a bottle brush and sponge
- Rinse thoroughly with clean water
- Inspect
- Air dry

All sample collection equipment will be flushed with onsite water at each station.

All sample containers used for samples to be analyzed by CH2M HILL's lab will be provided by CH2M HILL's lab. The containers used for collection of priority pollutants will be acquired as preclean according to EPA CLP specifications. Containers used for conventional chemical parameters will be precleaned and sterilized by the lab.

Lake Water Samples

In instances where sample locations are along the bank of the lake or in drains, samples will be collected from the shore. For open water samples, a boat outfitted for sampling, will be used to reach each sample location. Lake water samples at open water locations will be collected with an appropriate sampling bottle. All lake water will be sampled at a depth of half-way between the surface and the lake bottom.

At each sample location sufficient sample will be collected to satisfy the sample volume requirements listed in Table 5-6. In cases where multiple grabs are required to generate sufficient sample volume, the grabs will be composited and thoroughly mixed prior to each sample container filling and preservation addition. An exception to this procedure will be made for samples collected for volatile organic constituents (VOCs). To prevent loss of VOCs, a sample will be collected directly from the sampler or dipper without compositing or mixing.

Where possible samples will be collected directly, using the sample container to minimize potential for cross-contamination among samples.

Lake Bottom Sediment Samples

Sediment will be collected for identification and enumeration of benthic invertebrate animals. The sediment will be collected using an Eckman-type dredge and sieved in the field, to the extent possible, using a No. 30 mesh sieve (opening of approximately 0.5 mm). The samples will be fully sieved, sorted, and microscopically examined in the laboratory.

5.6 Sample Handling and Preservation

Labels, all sample containers will be labeled at the time of collection with stick-on labels and indelible ink or felt tip.

Chain-of-Custody

At the end of each sampling activity, or at the end of each day, chain of custody forms will be completed for all samples collected. A chain of custody form will accompany each sample shipment (cooler) and it will be signed by all parties who have possessed the samples. The lab will return the chain of custody to the project manager as part of their data deliverable

Sample Preservation

Samples will be persevered at the time of collection by the methods shown in Table 5-6. These preservation methods deviate somewhat from methods recommended by EPA. However, for many parameters EPA recommends sample refrigeration and next day receipt by a lab. Samples generated in Egypt will require a minimum of 72 hours to reach CH2M HILL's laboratory in Gainesville, Florida. In this instance sample refrigeration is not a viable preservation method. The preservation methods shown in Table 5-6 are intended to halt biological activity, disinfect, and maintain the samples integrity during the shipping period without adverse affect on the subsequent chemical analysis.

5.7 Sample Splitting

To achieve the objective of assessing the quality of previous data generated by the UAHIPH lab, samples will be split for analysis by the UAHIPH lab and CH2M HILL's lab for selected parameters. Samples will be collected as described under Section 5.5, Sampling Procedures, composited (if required), thoroughly mixed, and aliquots placed in appropriate containers. The specifications for sample size, container type, preservation method and holding time for samples to be analyzed by CH2M HILL's lab is shown in Table 5.6. Sample splits produced for analysis by the UAHIPH lab will be handled in a manner identical to that used for previous rounds of Lake Maryout sampling. In doing so, the UAHIPH sample handling techniques and lab procedures will be evaluated.

Table 5-6
Sample Size, Containers, Preservation and Holding Time

	Minimum Sample Size and Containers		Preservation Method and Holding Time[a]
	Water	Sediment	
EPA Priority Pollutants			
Volatile Organics	3x40 ml G-TLC	3x40 ml G-TLC	Cool, acidify <2 w/HCL 14 days
Semi-Volatile Organics	2.5 L G-TLC	16 oz. G-TLC	Cool, acidify <2 w/H_2SO_4 14 days
Pesticides and PCBs	2.5 L G-TLC	16 oz. G-TLC	Cool, acidify <2 w/H_2SO_4 14 days
Metals	1 L Plastic	100 gms Plastic	acidify <2 w/NHO_3 28 days
All Solids, Nutrients			
BOD and COD	1 L Plastic	16 oz. Plastic	Cool, acidify to 3.0 w/HCl 7 days[a]
Total and Fecal Coliform		1 L	Ethanol or formalin
Benthic Invertebrates		Plastic	

[a] Holding times are project-specific and most are more stringent than EPA criteria.

G = glass; TLC = teflon-lined cap; NHO_3 = Nitric acid; HCl = Hydrochloric acid; H_2O_4= sulfuric acid.

5.8 Sample Shipping

Once samples for analysis in the United States have been prepared as described under 5.6, Sample Preservation, they will be packed in coolers. The samples along with packaged ice will be carefully arranged in the shipping coolers. Packing materials and bottle sleeves will be used to cushion the glass sample containers. A chain of custody form will be placed in each cooler to describe its contents. Coolers will be sealed with strapping tape and custody seals. Shippers labels (Federal Express), USA Custom's forms and the address of CH2M HILL's Gainesville lab will be attached to the outside of the shipping cooler.

Samples for analysis by UAHIPH will be handled as during the 1992/1993 program.

6.0 Sample Management and Residuals

Having received the samples, the laboratories will have assumed responsible for management of the sample in accordance with "good laboratory practice".

Upon receipt of the samples, the lab should immediately report any anomalies concerning the integrity of the shipment. And if during the course of the analysis any abnormal conditions are encountered the lab should provide a status report to the project manager.

Any unused portion of the sample will be retained by the lab for 30 days after the delivery of the lab's final report. Disposal of the samples and all lab waste generated during the analysis will be handle in accordance with Federal, Country, State, and local regulations.

7.0 Health and Safety

No significant or unusual health or safety hazards should be encountered with the Lake Maryout supplemental sampling program. However, the following precautions should be observed:

- Operation of the boat in a safe manner

- Handle sample preservation chemicals (dilute acids) with care, never pipet by mouth, always wear safety glasses, immediately wash skin if contacted by acid, clean up any spills immediately.

8.0 Quality Control and Lab Performance Review

One of the objectives of the supplemental Lake Maryout sampling program is to evaluate the quality and reliability of data generated by UAHIPH during previous sampling rounds. This evaluation will be based on two findings: (1) the comparability of lab results obtained from sample splits, and (2) observations concerning the UAHIPH sampling techniques, sample handling methods, and laboratory procedures.

Quality assurance for this supplemental sampling program is described in the "*Lake Maryout Supplemental Sampling Program Quality Assurance Project Plan.*"

The evaluation of quality associated with the AHIPH procedures will be based on guidance provided in:

- "*Handbook for Sampling and Sample Preservation of Water and Wastewater,*" EPA-600/4-82-029

- "*Standard Guide for General Criteria Used for Evaluating Laboratory Competence*"," ASTM E548-91

9.0 Project Deliverables

Three sets of data will be obtained form the Lake Maryout supplemental sampling program. Those are:

- Benthic invertebrate analysis of the lake sediments
- Priority pollutant analyses of the lake water and bottom sediments
- Duplicate analyses from sample splits analyzed by the UAHIPH lab and CH2M HILL's Gainesville lab

Technical memorandums will be produced for each of the above and the results summarized for the Lake Maryout Study Report. The content of each technical memorandum is briefly described below.

In addition, the laboratory analysis will generated an extensive lab deliverable, particularly the priority pollutant analyses. As such, the laboratory data packages will be delivered as addenda to the technical memorandums.

Technical Memorandum No. 1 - Benthic Invertebrate Examination

The Benthic Invertebrate Technical Memorandum will present the results of the benthic sampling. The lake benthic fauna will be described in terms of diversity, community composition, and density. Where possible the data will be compared to other systems and Lake Maryout historic data. The presence of pollution-tolerant and sensitive species will be noted and spacial variation of the benthic community within the lake evaluated.

Technical Memorandum No. 2 - Priority Pollutant Results

The priority pollutant results will be presented to document pre-discharge conditions. The data will be discussed in terms of appropriate criteria and other environmental bench marks. The spacial variation within the lake and potential sources of various contaminants will also be evaluated.

Technical Memorandum No. 3 - AHIPH Data Quality

This technical memo will present the outcome from a QA/QC review of the UAHIPH's sampling and analysis procedures and compare the data obtained from sample splits.

Observations concerning UAHIPH's sampling techniques, sample handling, and laboratory procedures will be discussed in terms of data reliability.

Data obtained from duplicate chemical analysis of sample splits will be examined for comparability. For this purpose, we will assume that CH2M HILL's lab, because of it's stringent QA/QC program, has provided a true measure of each constituents concentration. Routine quality control samples analyzed in conjunction with Lake Maryout samples by CH2M HILL's lab will establish the lab's 95 percent confidence limits (upper and lower limits of confidence). Duplicate data obtained from the UAHIPH lab will be examined for conformance with CH2M HILL's lab data. In addition UAHIPH's test data will be compared to commonly achieved goals of precision and accuracy for these tests by the environmental testing laboratory industry.

10.0 Schedule

Sampling is scheduled for the week of June 14, 1993.

QUALITY ASSURANCE PLAN

SUPPLEMENTAL SAMPLING PROGRAM
LAKE MARYOUT, ALEXANDRIA, EGYPT

Revision 1

Prepared By

CH2M HILL, Inc.

June 1993

Project No. : CVO33391.A6

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Tables

1.0 Quality Assurance Objectives

This quality assurance plan (QAP) provides the frame work for quality control and quality assurance for the Lake Maryout supplemental sampling program. Quality assurance objectives for the Lake Maryout supplemental sampling program are:

- To assure representativeness in the collection of Lake Maryout water and bottom sediment samples,
- To assure that the sample integrity is maintained,
- To assure that the data collection is adequately documented,
- To assure that the chemical constituents and other parameters are correctly identified,
- To assure numerical accuracy in the reported data, and
- To assure that the quality of work performed is consistent with the project objectives.

This QAP is a companion to the "Lake Maryout Supplemental Sampling Program Sampling & Analysis Plan".

2.0 Sampling Methods

2.1 Lake Water Sampling Protocol

Lake Maryout is shallow, the average depth is about 1 meter and ranges from .25 to 2 meters deep. For sample sites that are at or near the shallow margins of the lake, water sampling by hand will be performed. For open water sampling sites, depth sampling will be performed with a weighted water sampling bottle. Samples for microbiological tests will require special handling. A brief overview of the sampling protocols for each type of sample being collected is described in this section along with a schedule for the frequency of field QA samples. In addition, important information about the lake water and sediment sampling is also presented in Section 5 of the SAP.

2.1.1 Surface Water, Hand Sampling

Collect a grab sample directly into a container that can capturing a volume of water sufficient enough to allow for sample splitting and to adequately fill all sample containers. The grab sample container should be made of materials that will not contaminate the sample and cleaned (see SAP Section 5.5.1) prior to use. A 10 liter bucket constructed of high density plastic is suitable.

To acquire a sample the collector should carefully approach the desired sampling location. In reaching the sample site the collector avoid stirring up bottom sediments to the extent it is possible. Once in position, grasp the buckets handle and base. Tip the bucket slightly upwards and gently sweep the bucket away from the shoreline and legs of the collector at a depth of 15 to 30 cm below the water surface. Be sure to not penetrate the lake bottom sediments in the process and avoid collecting surface scum or sediments which may have become suspended while approach the sample site. Carefully examine the sample for extraneous matter or sediments. Re-collect any sample which appear different in any way than the water being sampled.

Immediately upon returning to shore, collected samples for volatile organics by filling 3 VOA vials. Gently mix the contents of the bucket and fill the other sample containers.

2.1.2 Open Water, Depth Sampling

Depth sampling will be performed such that a water sample is obtained at a point mid-way between the surface and the lake bottom. To do so requires that the water depth at each sample location be determined and the mid-point depth clearly marked on the line used to lower the sampler. The depth sampler should be made of materials that will not contaminate the sample and cleaned (see SAP Section 5.5.1) prior to use.

Owing to the shallowness of the lake, it is important that bottom sediments are not disturbed or resuspended by movement of the boat. As such, care should be taken when approaching each sample site.

The lake water sample volume requirements for this program are several times larger than the volume to the typical weighted depth sampling bottle. This dictates several grabs with the depth sampler and compositing into a bucket such as the one described in Section 2.1.1.

During one of the grabs, fill 3 VOA vials directly from the depth sampler.

Collect as many lake water grab samples at the mid-point as is needed to satisfy the volume requirements for sample splitting and to adequately fill each sample container. Gently mix the sample and fill each container.

2.1.3 Microbiological Sampling

Collection of samples for total and fecal coliform analysis requires special precautions. First and foremost is the requirement that aseptic handling techniques must always be used. The samples bottles are sterile and must remain so prior to sampling. At the surface water sampling sites, precautions should be taken to avoid surface scum.

Irrespective of observable scum, the surface film is known to contain microbiological populations that are several orders of magnitude greater than the bulk water itself. Therefore, it is important that a consistent sampling procedure be employed for collection of water samples at the shallow surface water sample sites.

Total and fecal coliform samples will be collected in a sterile bottle provided by the UAHIPH. Remove the bottle cap and protect it from contamination. Avoid touching the inside surfaces of the bottle and its cap. Grasp the bottle securely at the base and plunge it mouth down into the water. In a sweeping motion move the bottle horizontally away tipping it slightly upward to allow air to exit and the bottle to fill. Immediately replace the cap onto the sample bottle and tighten.

At open water sampling locations which employ a weighted depth sampling bottle, coliform samples will be collected directly from the depth sampling bottle.

2.2 Lake Bottom Sediment Sampling

Bottom sediments will be collected with an Ekman style grab sampler. Prior to use the sediment sampler will be cleaned (see SAP Section 5.5.1).

Secure the line of the sampler to the boat. Open the hinged spring loaded flaps such that the sampler is cocked for sampling. Slowly lower the sampler overboard until it rests on the bottom. Attach the sender (sampler trip weight) to the line. While holding the sampler retrieval line in a vertical position drop the sender to trip the flaps of the sampler.

Carefully retrieve the sampler. As it rises above the water surface momentary allow excess water to drain from the sampler. Bring the sampler on-board by placing it in a bucket for unloading. Unload the sampler and inspect the sediments. Determine if an adequate sediment sample has been collected.

Repeat the sampling process as needed to collect a quantity of sediment sufficient for sample splitting and to fill all sample containers.

Once sufficient sediment has been obtained the entire quantity should be thoroughly mixed. Fill each sample container.

2.3 Frequency of Field QA Samples

In general, the frequency of quality assurance samples collected in connection with the sampling program will be 1 in 10 for duplicates and 1 in 10 for field (equipment) blanks. For each sampling day at least one field duplicate and one field blank will be collected.

In addition CH2M HILL's lab will include several travel blanks to monitor the sample integrity during shipping to the USA.

For the overall sampling program, the minimum number of field QA samples to be collected will be:

- 3 field duplicates
- 3 field blanks
- 2 trip blanks

3.0 In-Field Measurements

Quality assurance procedures associated with in-field measurements is shown in Table 3-1. In addition, information concerning the use of portable meters for in-field measurements is provided in Section 5.4 of the SAP. Always record the make, model, serial or equipment ID number for the equipment in use in the field log book.

Table 3-1
Quality Assurance For In-Field Measurements

Parameter	**Daily QA Procedure**
pH	1. Calib. the system according to the manufacturer's instructions using a series of standard buffers, nominal pH 4, 7, & 10. Record the results of calib. in the field log book. 2. Periodically check the buffer during the sampling activities and record the data in the field log book. 3. Rinse the electrode thoroughly between samples or after calib. 4. Always inspect the meter and probe prior to each use. Check the battery charge and cable connections, etc.
Temperature	1. Check the thermistor or sensing device for response and operation according to the manufacture's instructions. 2. Check the thermistor reading against a mercury-in-glass thermometer. 3. Always inspect the meter and sensor prior to use.

Table 3-1
Quality Assurance For In-Field Measurements

Dissolved Oxygen

1. Check the membrane for air bubbles. Change the membrane and KCl solution if necessary.

2. Check the meters battery charge, cable connections, etc. prior to each use.

3. Calibrate the meter using the manufactures instructions, air calibration procedure or Winkler-Azide method.

Conductivity

1. Standardize with KCl standards having similar specific conductance values close to those anticipated in the samples.

2. Rinse the cell after each sample or calibration to prevent carry over.

3. Inspect the meter and cell prior to each use.

4.0 Field Records and Documentation

4.1 Field Log Book

A field log book will be keep by the leader of the sampling team. The field log book will be a complete diary of field activities. Entries will include, but not limited to, the following:

- Date
- Sample team members
- Start and end time for major activities or significant events
- Field equipment identity and calibration information
- Weather conditions (temp., wind speed, humidity, rainfall, weather pattern throughout the day).
- A log of samples collected
- Any problems encountered

4.2 Sample Identification

Samples will be identified at the time collection using the follow example sample coding system:

LM-BS-22-6/16-GL

LM = Lake Maryout
BS = Bottom sediment, or WS for water sample
22 = Sample site, use numerical value previously used to identify sample locations
6/16 = Month and date the sample was collected, use the actual date
GL = Gainesville lab, or UAL for Univ. of Alex. High Inst. Public Health Lab

Each sample container will be individually labeled. Labeling will be by use of stick-on labels for bottles and rigid plastic containers. Wire tags or water proof felt tip marking pen will be used to label collapsible plastic containers. Only indelible ink or water proof felt tip will be used to mark labels. tags and containers. An example of the label to be used for sample identification is shown in Exhibit 1.

At the time of collection the liquid level of each container will be recorded by placing the container on a level surface and scribing the liquid level on the exterior of the container using the water proof felt marker.

All sample containers will be inspected for leaks and cleaned prior to packaging or before being relinquished to another party.

4.3 Chain-of-Custody

To maintain and document sample possession, chain-of-custody procedures will be followed. The chain-of-custody form shown in Exhibit 2 will be used. This form will be used for each batch of samples collected or one for each shipping cooler, which ever is more appropriate or as conditions dictate.

By definition, the sample is under custody if:

1. It is in your possession, or
2. It is in your view, after being in your possession, or
3. You locked it up to prevent tampering, or
4. It is in a designated secure area.

All persons having custody of the samples will sign for custody and relinquish custody to another party by use of the chain-of-custody form to sign over custody to that party.

During shipment, the original record will accompany the shipment, a copy will be retained by the project coordinator. The lab will return the final original record to the project manager as part of their final data deliverable.

5.0 Sample Splitting, Preservation, and Holding Time

5.1 Sample Splitting

Samples of lake water and bottom sediments will be split for the purpose of measuring the reliability of previous sampling and sample analysis performed for WWCG by the UAHIPH. One portion of the split will be provided to the UAHIPH lab and the other portion preserved and packaged for shipment and analysis by CH2M HILL's Gainesville, Florida lab. It is therefore imperative that the sample splitting process creates true duplicates from the original sample.

Upon collection of the original grab sample or multiple grabs, special attention must be given to the process of mixing such that a homogenous blend is achieved. This step is perhaps more important than any other in determining the outcome of comparability between the two labs performing the analysis. Data agreement between the two labs can be no better than the representativeness of the sample splits they are given.

Creation of truly duplicate samples from the original sample depends solely on the attentiveness of the person mixing the sample and creating the splits. To facilitate sample mixing and splitting, a large wide bucket should be used. Mixing should be performed with a spatula, or similar wide bladed utensil, made of non-contaminating materials. Water samples should be mixed for 30 seconds or more, sediment samples should be mixed for 1 minute or more.

Immediately fill the containers for each analysis type (i.e. metals) splitting between the containers provided by for the UAHIPH lab and CH2M HILL's lab for that analysis type. Table 5-6 of the SAP lists the containers and required sample volume for the sample that will be analyzed by CH2M HILL's lab.

Always keep the original sample well mixed to prevent the settling of suspended solids in the water samples or liquefaction in the sediments samples.

5.2 Sample Preservation

Table 5-6 of the SAP lists the preservation method that will be used for samples collected by CH2M HILL staff and shipped to CH2M HILL's lab. Collection and preservation of sample for analysis by the UAHIPH lab will be the responsibility of the UAHIPH. Preservation (if any) will be performed by the same means as has been used by UAHIPH for other rounds of Lake Maryout sampling.

5.3 Sample Holding Time and Handling

Table 5-1 lists the sample holding times that are desired for this program. Because this program is using alternative method of sample preservation, the holding times indicated are considered appropriate. In most cases the specified holding time are equal to or more stringent than criteria established by EPA. The following sample handling procedures will be followed:

Table 5-1
Sample Size, Containers, Preservation, and Holding Time

	Minimum Sample Size and Containers		Preservation Method and Holding Time[a]
	Water	**Sediment**	
EPA Priority Pollutants			
Volatile Organics	3x40 ml G-TLC	3x40 ml G-TLC	Cool, acidify <2 w/HCL 14 days
Semi-Volatile Organics	2.5 L G-TLC	16 oz. G-TLC	Cool, acidify <2 w/H_2SO_4 14 days
Pesticides and PCBs	2.5 L G-TLC	16 oz. G-TLC	Cool, acidify <2 w/H_2SO_4 14 days
Metals	1 L Plastic	100 gms Plastic	acidify <2 w/NHO_3 28 days
All Solids, Nutrients			
BOD and COD	1 L Plastic	16 oz. Plastic	Cool, acidify to 3.0 w/HCl 7 days[a]
Total and Fecal Coliform		1 L	Ethanol or formalin
Benthic Invertebrates		Plastic	

[a] Holding times are project-specific and most are more stringent than EPA criteria.

G = glass; TLC = teflon-lined cap; NHO_3 = Nitric acid; HCl = Hydrochloric acid; H_2O_4= sulfuric acid.

- In the field, samples will be retained on ice when ever it is possible to do so.
- For shipment to the USA, samples will be chilled with packaged ice.
- At CH2M HILL's Gainesville lab, the samples will be stored at 4 degrees centigrade.
- At the UAHIPH lab, it is presumed that the samples will also stored under refrigeration.

6.0 Sample Shipping

Samples for shipment to CH2M HILL's Gainesville lab will be shipped by express air freight, either Federal Express or TNT. Based on information obtained from Federal Express, shipments between Alexandria and USA require approximately 4 days to arrive.

Packing materials and bottle sleeves will be used to cushion the glass sample containers. A chain of custody form will be placed in each cooler to describe its contents. Coolers will be sealed with strapping tape and custody seals. USA Customs forms and the address of CH2M HILL's Gainesville lab will be attached to the outside of the shipping container.

7.0 Laboratory Analysis and Reporting

7.1 UAHIPH Lab Services

Analytical services that are required by the UAHIPH for this supplemental sampling program are listed in Table 3-1 of the SAP. To evaluate the reliability of data previously generated by the UAHIPH lab, it is important that the lab utilize lab methods, sampling, techniques, and reporting identical to that used for previous rounds of Lake Maryout sampling and analysis. This matter will be verified by a WWCG scientist as part of this supplemental sampling program. Also a copy of the UAHIPH lab's QA/QC program wiil be obtained and the lab's conformance to it's policy and procedures evaluated.

7.2 CH2M HILL Lab Services

CH2M HILL's lab located in Gainesville, Florida will analyzes samples for the constituents listed in Table 3-1 of the SAP. This list includes EPA's priority pollutant constituent list and several parameters that will be analyzed on sample splits to evaluated the reliability of the UAHIPH lab's data.

7.2.1 Analytical Methods

The analytical methods that will be used by CH2M HILL's lab are listed in the Tables included in Exhibit 5. In all cases these methods are those published by EPA.

7.2.2 Data Quality Objectives

Data quality assurance objectives (QAOs) for analytical work performed by CH2M HILL's lab are presented in Exhibit 5. Included in these QAOs are target values for detection limits, precision, and accuracy. In addition the lab has a target for data completion of 90%. The QAOs listed in Exhibit 3 are associated with clean water and sediments. Actual lab performance may vary from the stated QAOs for highly contaminated samples requiring dilution or cause matrix effects.

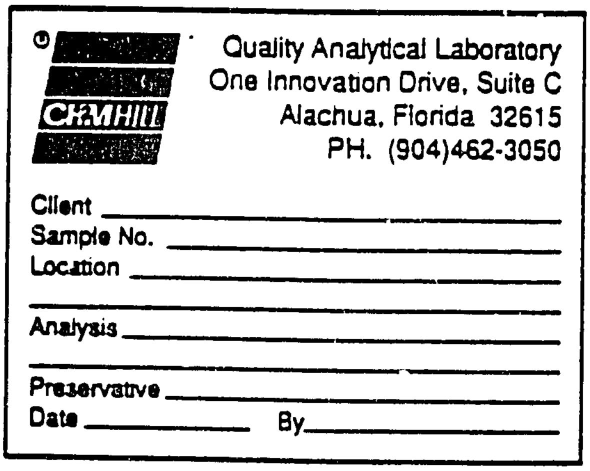
7.2.3 Data Reporting and Deliverables

CH2M HILL's lab will provide data packages as a final deliverable which are commonly referred to as EPA level 3 data packages. A level 3 data package will be submitted for each sample analyzed. The data package will include data reports, hard copies of raw data, QC data, chain-of-custody, and sample logs. If data validation is required at some future date, these data packages will suitable for formal validation according to EPAs functional guidelines for validation of chemical data.

Examples of CH2M HILL's lab data report forms are provided in Exhibits 3 and 4.

8.0 Exhibits

Exhibit 1

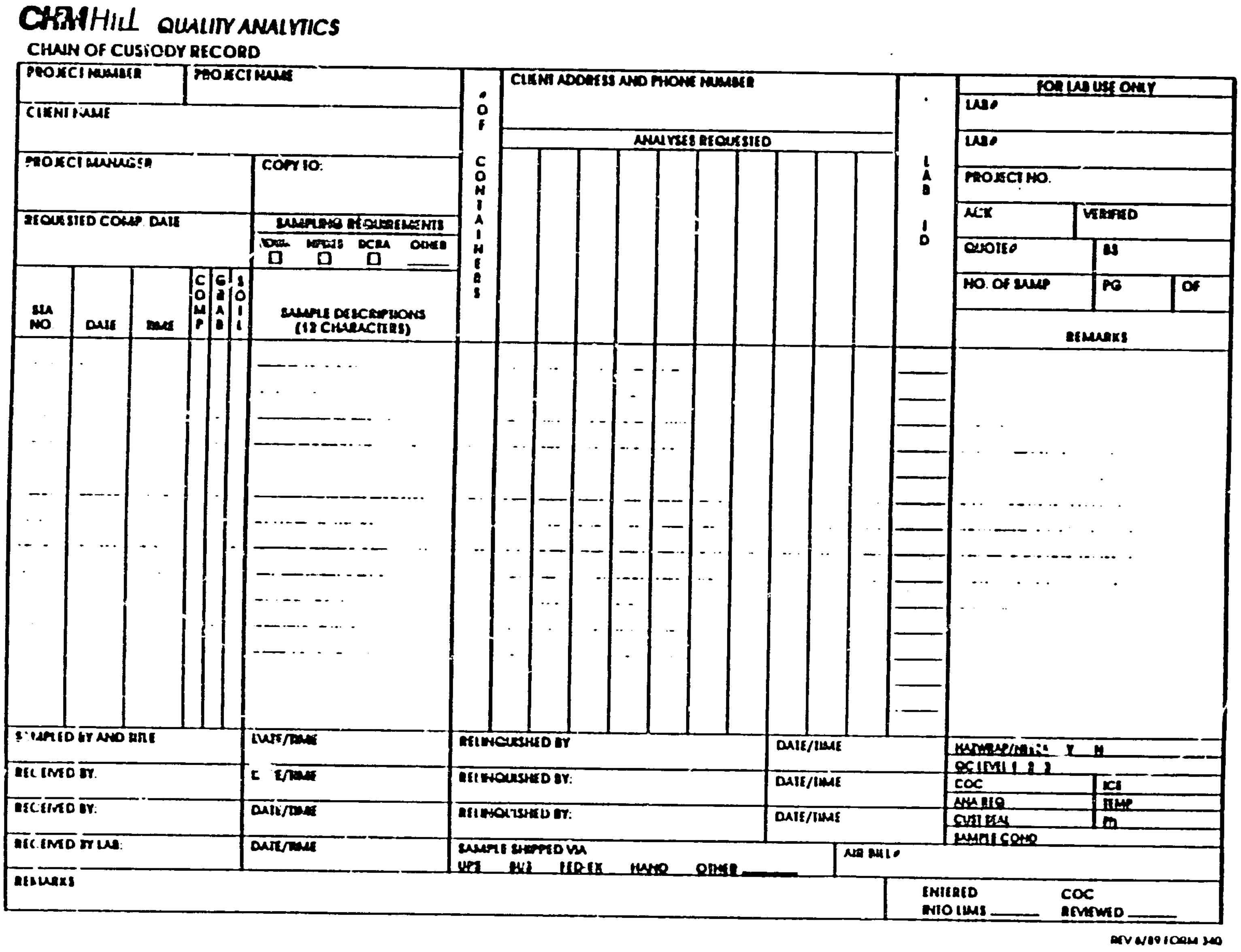


Quality Analytical Laboratory
One Innovation Drive, Suite C
Alachua, Florida 32615
PH. (904)462-3050

Client ____________________
Sample No. ____________________
Location ____________________
____
Analysis ____________________
____
Preservative ____________________
Date __________ By __________

Example of Labels for Sample Containers

Exhibit 2



CH2M HILL QUALITY ANALYTICS

CHAIN OF CUSTODY RECORD

PROJECT NUMBER

PROJECT NAME

CLIENT NAME

PROJECT MANAGER

COPY TO:

REQUESTED COMP. DATE

SAMPLING REQUIREMENTS

SDWA ☐ NPDES ☐ RCRA ☐ OTHER ____

STA NO	DATE	TIME	COMP	GRAB	SOIL	SAMPLE DESCRIPTIONS (12 CHARACTERS)	# OF CONTAINERS	ANALYSES REQUESTED	LAB ID

CLIENT ADDRESS AND PHONE NUMBER

FOR LAB USE ONLY

LAB #

LAB #

PROJECT NO.

ACK

VERIFIED

QUOTE #

BS

NO. OF SAMP

PG

OF

REMARKS

SAMPLED BY AND TITLE

DATE/TIME

RECEIVED BY:

DATE/TIME

RECEIVED BY:

DATE/TIME

RECEIVED BY LAB:

DATE/TIME

RELINQUISHED BY

DATE/TIME

RELINQUISHED BY:

DATE/TIME

RELINQUISHED BY:

DATE/TIME

SAMPLE SHIPPED VIA

UPS BUS FED-EX HAND OTHER ____

AIR BILL #

HAZWRAP/NEESA Y N

QC LEVEL 1 2 3

COC

ICE

ANA REQ

TEMP

CUST SEAL

PH

SAMPLE COND

REMARKS

ENTERED INTO LIMS ____

COC REVIEWED ____

REV 6/89 FORM 340

Example of Chain of Custody

Exhibit 3

CLIENT SAMPLE ID

TEST

REPORT OF ANALYTICAL RESULTS
PURGEABLE HALOCARBONS/AROMATICS

Date collected: DATE COLLECTED –
Date extracted: TEST
Date analyzed: TEST
Matrix: TEST
Method: TEST METHOD –
% Moisture: TEST

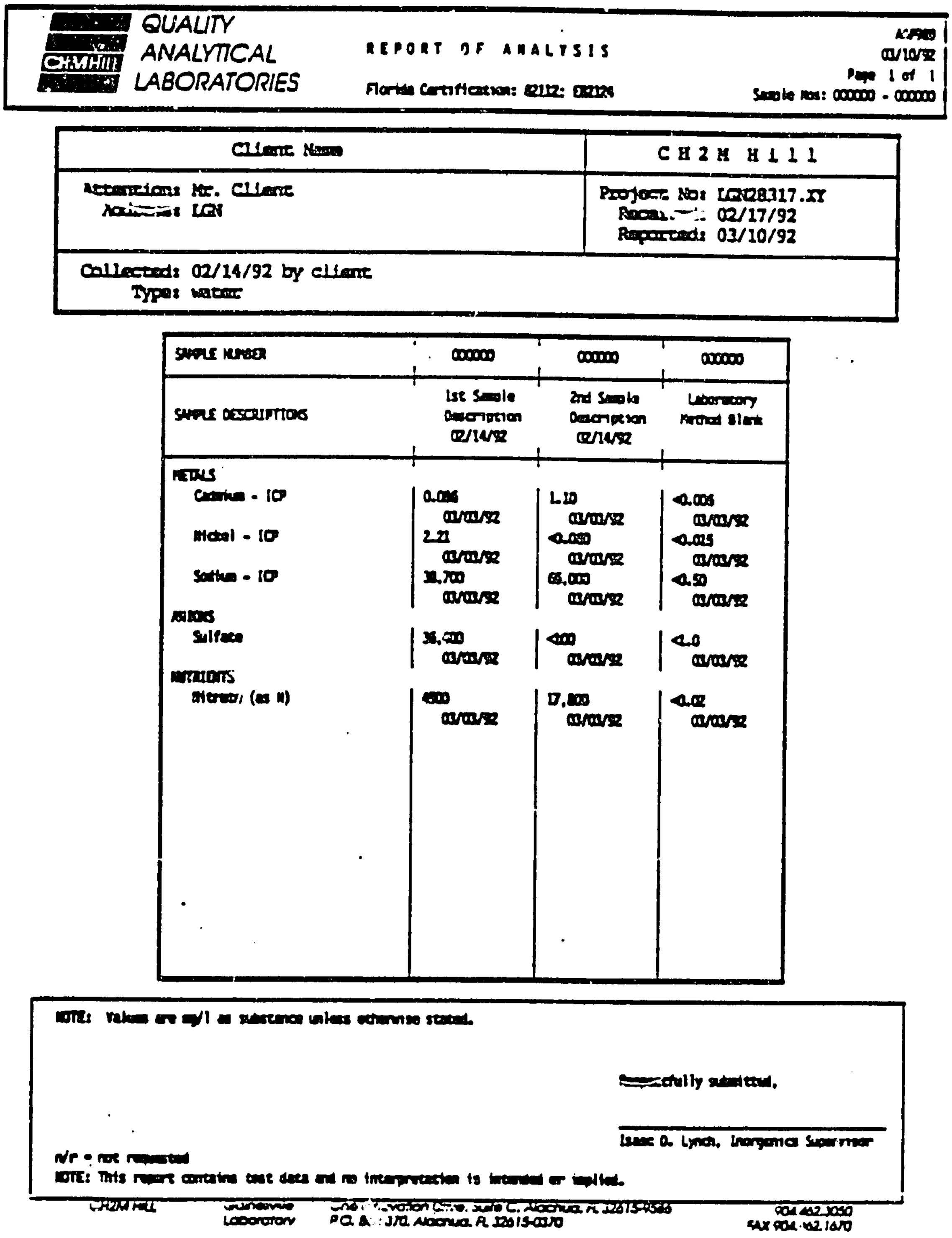
Sample Group: SAMPLE GROUP –
Lab Sample ID: TEST
Lab file 1 ID: TEST
Lab file 2 ID: TEST
Dilution Factor: 1.0
Reporting Units: UG/L

CAS NUMBER	COMPOUND NAME	REPORTING LIMIT	RESULT	
75-71-8	Dichlorodifluoromethane	1.0	U	
74-87-3	Chloromethane	1.0	U	
75-01-4	Vinyl Chloride	1.0	U	
74-83-9	Bromomethane	1.0	U	
75-00-3	Chloroethane	1.0	U	
75-69-4	Trichlorofluoromethane	1.0	U	
75-35-4	1,1-Dichloroethene	1.0	U	
75-09-2	Dichloromethane	1.0	U	
156-60-5	trans-1,2-Dichloroethene	1.0	U	
75-34-3	1,1-Dichloroethane	1.0	U	
156-59-2	cis-1,2-Dichloroethene	1.0	U	
67-66-3	Chloroform	1.0	U	
71-55-6	1,1,1-Trichloroethane	1.0	U	
56-23-5	Carbon Tetrachloride	1.0	U	
107-06-2	1,2-Dichloroethane	1.0	U	
79-01-6	Trichloroethene	1.0	U	
78-87-5	1,2-Dichloropropane	1.0	U	
75-27-4	Bromodichloromethane	1.0	U	
110-75-8	2-Chloroethyl vinyl ether	1.0	U	
10061-01-5	cis-1,3-Dichloropropene	1.0	U	
10061-02-6	trans-1,3-Dichloropropene	1.0	U	
79-00-5	1,1,2-Trichloroethane	1.0	U	
127-18-4	Tetrachloroethene	1.0	U	
124-48-1	Dibromochloromethane	1.0	U	
108-90-7	Chlorobenzene	1.0	U	
75-25-2	Bromoform	1.0	U	
79-34-5	1,1,2,2-Tetrachloroethane	1.0	U	
541-73-1	1,3-Dichlorobenzene	1.0	U	
106-46-7	1,4-Dichlorobenzene	1.0	U	
95-50-1	1,2-Dichlorobenzene	1.0	U	
1634-04-4	tert-Butyl methyl ether	1.0	U	
71-43-2	Benzene	1.0	U	
108-88-3	Toluene	1.0	U	
100-41-4	Ethylbenzene	1.0	U	
N/A	Total Xylenes	1.0	U	
74-97-5	Bromochloromethane-SURROGATE		100	% Rec.
98-08-8	a,a,a-Trifluorotoluene-SURROGATE		100	% Rec.

FORM I OC

Example of Organics Report Form

Exhibit 4



QUALITY
ANALYTICAL
LABORATORIES

REPORT OF ANALYSIS

Florida Certification: 82112; E82124

ACF980
03/10/92
Page 1 of 1
Sample Nos: 000000 - 000000

Client Name	CH2M Hill
Attention: Mr. Client Address: LGN	Project No: LGN28317.XY Received: 02/17/92 Reported: 03/10/92
Collected: 02/14/92 by client Type: water	

SAMPLE NUMBER	000000	000000	000000
SAMPLE DESCRIPTIONS	1st Sample Description 02/14/92	2nd Sample Description 02/14/92	Laboratory Method Blank
METALS			
Cadmium - ICP	0.086 03/03/92	1.10 03/03/92	<0.006 03/03/92
Nickel - ICP	2.21 03/03/92	<0.030 03/03/92	<0.015 03/03/92
Sodium - ICP	38,700 03/03/92	65,000 03/03/92	<0.50 03/03/92
ANIONS			
Sulfate	36,400 03/03/92	<100 03/03/92	<1.0 03/03/92
NUTRIENTS			
Nitrate (as N)	4800 03/03/92	17,800 03/03/92	<0.02 03/03/92

NOTE: Values are mg/l as substance unless otherwise stated.

Respectfully submitted,

Isaac D. Lynch, Inorganics Supervisor

n/r = not requested

NOTE: This report contains test data and no interpretation is intended or implied.

CH2M HILL
Gainesville Laboratory
One Innovation Drive, Suite C, Alachua, FL 32615-9586
P.O. Box 370, Alachua, FL 32615-0370
904.462.3050
FAX 904.462.1670

Example of Inorganics Report Form

Exhibit 5-1

General Wet Chemistry
QUALITY ASSURANCE OBJECTIVES
Lake Water Samples

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (RPD)	Accuracy[3] (% Rec.)	Source[4]
GENERAL ANALYSES					
pH (units)	0.05	305.1	0-5.0	---	H
Conductivity	5	120.1/9050	0-5.0	---	H
Solids, total dissolved	1,000	160.1	0-10(H) 0-17(L)	---	H
Solids, total suspended	1,000	160.2	0-9.0(H) 0-40(L)	---	H
Solids, volatile	1,000	160.4	0-15	---	H
Solids, total	1,000	160.3	0-20	---	H
NUTRIENTS					
Ammonia (as N)	40	350.2	0-5.0(H) 0-40(L)	72-120	H
Nitrate and Nitrite (as N) (Cd Red.)	20	353.2	0-5.0	90-110	H
Total Kjeldahl Nitrogen (as N)	40	351.3	0-18	86-103	H
Phosphorus, all forms (as P) ortho	10	365.2	0-8.0	85-117	H
BOD$_5$, total	1,000	405.1	0-10(H) 0-66(L)	---	H
COD	1,000	410.4	0-15	70-130	H
Dissolved Oxygen	100	360.1	0-15	---	H

[1] METHODS:

Methods are EPA methods except as noted. EPA references are:

Methods for Chemical Analysis of Water and Wastes, US EPA, PB 84-128677, March 1983.

Test Methods for Evaluation Solid Wastes, US EPA, SW 846, Third Edition, November, 1986.

(And Proposed Update Package, 1989.)

Code of Federal Register, Protection of the Environment, 40 CFR, App. A to Part 136, July, 1988

(M) EPA procedure modified for Contract Laboratory Program.

SM Standard Methods for the Examination of Water and Wastewater, APHA et al, 16th Edition, 1985.

[2] Precision defined as Relative Percent Difference (RPD). Where two RPDs are given, there is a lower and an upper concentration range.

[3] Accuracy define as Percent Recovery of known spike sample.

[4] Source of QA Objectives data:

H = from historical laboratory data
M = from published method
D = default values where sufficient data are not available

ID Insufficient Data
(H) High concentration range for duplicate samples
(L) Low concentration range for duplicate samples

Exhibit 5-2

General Wet Chemistry
QUALITY ASSURANCE OBJECTIVES
Lake Bottom Sediments

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (RPD)	Accuracy[3] (% Rec.)	Source[4]
GENERAL ANALYSES					
Solids, total (% Solids)	0.05	9045	0-10	---	H
NUTRIENTS					
Ammonia (as N)	40	350.2	0-40	72-120	H
Nitrate and Nitrite (as N) (Cd Red.)	20	353.2	0-10	85-115	H
Total Kjeldahl Nitrogen (as N)	40	351.3	0-35	60-130	H
Phosphorus, all forms (as P)	10	365.2	0-20	80-120	H
BOD$_5$, total	1,000	405.1	0-30	---	H
COD	1,000	508 (SM)	0-20	70-130	H

[1] METHODS:
Methods are EPA methods except as noted. EPA references are:
Methods for Chemical Analysis of Water and Wastes, US EPA, PB 84-128677, March 1983.
Test Methods for Evaluation Solid Wastes, US EPA, SW 846, Third Edition, November, 1986.
(And Proposed Update Package, 1989.)
Code of Federal Register, Protection of the Environment, 40 CFR, App. A to Part 136, July, 1988
(M) EPA procedure modified for Contract Laboratory Program.
SM Standard Methods for the Examination of Water and Wastewater, APHA st al, 16th Edition, 1985.

[2] Precision defined as Relative Percent Difference (RPD). Where two RPDs are given, there is a lower and an upper concentration range.

[3] Accuracy define as Percent Recovery of known spike sample.

[4] Source of QA Objectives data:
H = from historical laboratory data
M = from published method
D = default values where sufficient data are not available

ID Insufficient Data
(H) High concentration range for duplicate samples
(L) Low concentration range for duplicate samples

Exhibit 5-3

Cations (ICP)
QUALITY ASSURANCE OBJECTIVES
Lake Water Samples

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
ICP METALS		200.7/6010			
Aluminum	50		5.3	81-112	H
Antimony	30		11	63-125	H
Arsenic	60		10	70-130	H
Barium	1		3.7	80-120	H
Beryllium	1		4.9	84-114	H
Cadmium	6		5.9	78-112	H
Calcium	500		6.0	78-112	H
Chromium	6		4.2	85-110	H
Cobalt	10		8.1	75-123	H
Copper	6		4.0	80-120	H
Iron	20		6.6	79-118	H
Lead	40		6.6	76-114	H
Magnesium	50		1.7	80-120	H
Manganese	[illegible]		4.5	85-111	H
Molybdenum	60		10	70-130	H
Nickel	15		3.9	86-109	H
Potassium	1000		4.0	80-120	H
Selenium	75		10	70-130	H
Silver	5		7.7	72-115	H
Sodium	500		6.0	80-115	H
Thallium	25		10	70-130	H
Vanadium	5		3.4	80-120	H
Zinc	5		5.3	83-114	H

[1] METHODS:

Methods are EPA methods except as noted. EPA references are:

Methods for Chemical Analysis of Water and Wastes, US EPA, PB 84-128677, March 1983.

Test Methods for Evaluation Solid Wastes, US EPA, SW 846, Third Edition, November, 1986. (And Proposed Update Package, 1989.)

Code of Federal Register, Protection of the Environment, 40 CFR, App. A to Part 136, July, 1988

(M) EPA procedure modified for Contract Laboratory Program.

SM Standard Methods for the Examination of Water and Wastewater, APHA st al, 16th Edition, 1985.

[2] Precision defined as Relative Standard Deviation (% RSD).

[3] Accuracy define as Percent Recovery of known spike sample.

[4] Source of QA Objectives data:

H = from historical laboratory data
M = from published method
D = default values where sufficient data are not available

Exhibit 5-4

Cations (ICP)
QUALITY ASSURANCE OBJECTIVES
Lake Bottom Sediments

Parameter	Method Detection Limit (PPB)[5]	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
ICP METALS		6010			
Aluminum	200		5.3	81-112	H
Antimony	60		11	63-125	H
Arsenic	60		10	70-130	H
Barium	200		3.7	80-120	H
Beryllium	5		4.9	84-114	H
Cadmium	5		5.9	78-112	H
Calcium	5000		6.0	78-112	H
Chromium	10		4.2	85-110	H
Cobalt	50		8.1	75-123	H
Copper	25		4.0	80-120	H
Iron	100		6.6	79-118	H
Lead	100		6.6	76-114	H
Magnesium	5000		1.7	80-120	H
Manganese	15		4.5	85-111	H
Molybdenum	60		10	70-130	H
Nickel	40		3.9	86-109	H
Potassium	5000		4.0	80-120	H
Selenium	75		10	70-130	H
Silver	10		7.7	72-115	H
Sodium	5000		6.0	80-115	H
Thallium	25		10	70-130	H
Vanadium	50		3.4	80-120	H
Zinc	20		5.3	83-114	H

[1] METHODS:

Methods are EPA methods except as noted. EPA references are:

Methods for Chemical Analysis of Water and Wastes, US EPA, PB 84-128677, March 1983.

Test Methods for Evaluation Solid Wastes, US EPA, SW 846, Third Edition, November, 1986. (And Proposed Update Package, 1989.)

Code of Federal Register, Protection of the Environment, 40 CFR, App. A to Part 136, July, 1988

(M) EPA procedure modified for Contract Laboratory Program.

SM Standard Methods for the Examination of Water and Wastewater, APHA st al, 16th Edition, 1985.

[2] Precision defined as Relative Standard Deviation (% RSD).

[3] Accuracy define as Percent Recovery of known spike sample.

[4] Source of QA Objectives data:

H = from historical laboratory data
M = from published method
D = default values where sufficient data are not available

[5] Method Detection (MDL) is detection limit on liquid digestate; MDL varies depending on percent moisture content, sample volume, etc.

Exhibit 5-5

GC/MS Volatiles
QUALITY ASSURANCE OBJECTIVES
Lake Water Samples

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
VOLATILE COMPOUNDS		8240/8260			
Chloromethane	10		0-15	70-130	D
Bromomethane	10		0-15	70-130	D
Vinyl chloride	10		0-15	70-130	D
Chloroethane	10		0-15	70-130	D
Methylene chloride	5		0-15	70-130	D
Acetone	10		0-15	70-130	D
Carbon disulfide	5		0-15	70-130	D
Trichlorofluoromethane	5		0-15	70-130	D
1,1-dichloroethene	5		0-15	70-130	D
1,1-Dichloroethane	5		0-15	70-130	D
1,2-Dichloroethene	5		0-15	70-130	D
Chloroform	5		0-15	70-130	D
1,2-Dichloroethane	5		0-15	70-130	D
2-Butanone	10		0-15	70-130	D
1,1,1-Trichloroethane	5		0-15	70-130	D
Carbon tetrachloride	10		0-15	70-130	D
Bromodichloromethane	5		0-15	70-130	D
1,2-Dichloropropane	5		0-15	70-130	D
cis-1,3-Dichloropropene	5		0-15	70-130	D
Trichloroethene	5		0-15	70-130	D
Benzene	5		0-15	70-130	D
Dibromochloromethane	5		0-15	70-130	D
1,1,2-Trichloroethane	5		0-15	70-130	D
trans-1,3-Dichloropropene	5		0-15	70-130	D
2-Chloroethylvinylether	10		0-15	70-130	D
Bromoform	5		0-15	70-130	D
2-Hexanone	10		0-15	70-130	D
Tetrachloroethene	5		0-15	70-130	D
1,1,2,2-Tetrachloroethane	5		0-15	70-130	D
Toluene	5		0-15	70-130	D
Chlorobenzene	5		0-15	70-130	D
Ethyl benzene	5		0-15	70-130	D
Styrene	5		0-15	70-130	D
Xylenes (total)	5		0-15	70-130	D
4-Methyl-2-pentanone	10		0-15	70-130	D
1,3-Dichlorobenzene	5		0-15	70-130	D
1,4-Dichlorobenzene	5		0-15	70-130	D
1,2-Dichlorobenzene	5		0-15	70-130	D

Exhibit 5-6

GC/MS Volatiles
QUALITY ASSURANCE OBJECTIVES
Lake Water Samples

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]

[1] METHODS:

Methods are EPA methods except as noted. EPA references are:

Methods for Chemical Analysis of Water and Wastes, US EPA, PB 84-128677, March 1983.

Test Methods for Evaluation Solid Wastes, US EPA, SW 846, Third Edition, November, 1986. (And Proposed Update Package, 1989.)

Code of Federal Register, Protection of the Environment, 40 CFR, App. A to Part 136, July, 1988

(M) EPA procedure modified for Contract Laboratory Program.

SM Standard Methods for the Examination of Water and Wastewater, APHA st al, 16th Edition, 1985.

[2] Precision defined as Relative Standard Deviation (% RSD).

[3] Accuracy define as Percent Recovery of known spike sample.

[4] Source of QA Objectives data:

H = from historical laboratory data
M = from published method
D = default values where sufficient data are not available

2

Exhibit 5-7

GC/MS Volatiles
QUALITY ASSURANCE OBJECTIVES
Lake Bottom Sediments

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
VOLATILE COMPOUNDS		624/8240/8260			
Chloromethane	10		0-15	70-130	D
Bromomethane	10		0-15	70-130	D
Vinyl chloride	10		0-15	70-130	D
Chloroethane	10		0-15	70-130	D
Methylene chloride	5		0-15	70-130	D
Acetone	10		0-15	70-130	D
Carbon disulfide	5		0-15	70-130	D
Trichlorofluoromethane	5		0-15	70-130	D
1,1-dichloroethene	5		0-15	70-130	D
1,1-Dichloroethane	5		0-15	70-130	D
1,2-Dichloroethene	5		0-15	70-130	D
Chloroform	5		0-15	70-130	D
1,2-Dichloroethane	5		0-15	70-130	D
2-Butanone	10		0-15	70-130	D
1,1,1-Trichloroethane	5		0-15	70-130	D
Carbon tetrachloride	10		0-15	70-130	D
Bromodichloromethane	5		0-15	70-130	D
1,2-Dichloropropane	5		0-15	70-130	D
cis-1,3-Dichloropropene	5		0-15	70-130	D
Trichloroethene	5		0-15	70-130	D
Benzene	5		0-15	70-130	D
Dibromochloromethane	5		0-15	70-130	D
1,1,2-Trichloroethane	5		0-15	70-130	D
trans-1,3-Dichloropropene	5		0-15	70-130	D
2-Chloroethylvinylether	10		0-15	70-130	D
Bromoform	5		0-15	70-130	D
2-Hexanone	10		0-15	70-130	D
Tetrachloroethene	5		0-15	70-130	D
1,1,2,2-Tetrachloroethane	5		0-15	70-130	D
Toluene	5		0-15	70-130	D
Chlorobenzene	5		0-15	70-130	D
Ethyl benzene	5		0-15	70-130	D
Styrene	5		0-15	70-130	D
Xylenes (total)	5		0-15	70-130	D
4-Methyl-2-pentanone	10		0-15	70-130	D
1,3-Dichlorobenzene	5		0-15	70-130	D
1,4-Dichlorobenzene	5		0-15	70-130	D

Exhibit 5-8

GC/MS Volatiles
QUALITY ASSURANCE OBJECTIVES
Lake Bottom Sediments

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
1,2-Dichlorobenzene	5		0-15	70-130	D

[1] METHODS:

Methods are EPA methods except as noted. EPA references are:

Methods for Chemical Analysis of Water and Wastes, US EPA, PB 84-128677, March 1983.

Test Methods for Evaluation Solid Wastes, US EPA, SW 846, Third Edition, November, 1986. (And Proposed Update Package, 1989.)

Code of Federal Register, Protection of the Environment, 40 CFR, App. A to Part 136, July, 1988

(M) EPA procedure modified for Contract Laboratory Program.

SM Standard Methods for the Examination of Water and Wastewater, APHA st al, 16th Edition, 1985.

[2] Precision defined as Relative Standard Deviation (% RSD).

[3] Accuracy define as Percent Recovery of known spike sample.

[4] Source of QA Objectives data:

H = from historical laboratory data
M = from published method
D = default values where sufficient data are not available

Exhibit 5-9

GC/MS Semivolatiles
QUALITY ASSURANCE OBJECTIVES
Lake Water Samples

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
ACID EXTRACTABLES		625/8270			
Phenol	10		0-15	70-130	D
2-Chlorophenol	10		0-15	70-130	D
2-Methylphenol	10		0-15	70-130	D
4-Methylphenol	10		0-15	70-130	D
2-Nitrophenol	10		0-15	70-130	D
2,4-Dimethylphenol	10		0-15	70-130	D
2,4-Dichlorophenol	10		0-15	70-130	D
4-Chloro-3-methylphenol	10		0-15	70-130	D
2,4,6-Trichlorophenol	10		0-15	70-130	D
2,4,5-Trichlorophenol	10		0-15	70-130	D
2,4-Dinitrophenol	10		0-15	70-130	D
4-Nitrophanol	10		0-15	70-130	D
2-Methyl-4,6-dinitrophenol	10		0-15	70-130	D
Pentachlorophenol	10		0-15	70-130	D
Benzoic Acid	10		0-15	70-130	D
BASE-NEUTRAL COMPOUNDS		625/8270			
1,3-Dichlorobenzene	10		0-15	70-130	D
1,4-Dichlorobenzene	10		0-15	70-130	D
1,2-Dichlorobenzene	10		0-15	70-130	D
Hexachloroethane	10		0-15	70-130	D
1,2,4-Trichlorobenzene	10		0-15	70-130	D
Napthalene	10		0-15	70-130	D
Hexachlorobutadiene	10		0-15	70-130	D
Hexachlorocyclopentadiene	10		0-15	70-130	D
2-Chloronaphthalene	10		0-15	70-130	D
Acenaphthylene	10		0-15	70-130	D
Acenaphthene	10		0-15	70-130	D
Dibenzofuran	10		0-15	70-130	D
Fluorane	10		0-15	70-130	D
4-Chlorophenyl-phenylether	10		0-15	70-130	D
4-Bromophenyl-pheylether	10		0-15	70-130	D
Hexacholobenzene	10		0-15	70-130	D
Phenanthrene	10		0-15	70-130	D
Anthracene	10		0-15	70-130	D
Fluoranthene	10		0-15	70-130	D
Pyrene	10		0-15	70-130	D
Benzo(a)anthracene	10		0-15	70-130	D

Exhibit 5-10

GC/MS Semivolatiles
QUALITY ASSURANCE OBJECTIVES
Lake Water Samples

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
Cyrysene	10		0-15	70-130	D
Benzo(b)fluoranthene	10		0-15	70-130	D
Benzo(k)fluoranthene	10		0-15	70-130	D
Benzo(a)perylene	10		0-15	70-130	D
Indeno(1,2,3-ch)pyrene	10		0-15	70-130	D
Dibenzo(a,h)arahracene	10		0-15	70-130	D
Benzo(g,h,i)perylene	10		0-15	70-130	D
bis(2-Chloroethyl)ether	10		0-15	70-130	D
n-Nitroso-di-n-propylamine	10		0-15	70-130	D
Notrobenzene	10		0-15	70-130	D
Isophorona	10		0-15	70-130	D
bis(2-Chloroethoxy)methane	10		0-15	70-130	D
Dimethyl phthalate	10		0-15	70-130	D
2,6-Dinitrotoluene	10		0-15	70-130	D
2,4-Dinitrotoluene	10		0-15	70-130	D
Diethyl phthalate	10		0-15	70-130	D
n-Nitrosodiphenylamine	10		0-15	70-130	D
di-n-Butylphthalate	10		0-15	70-130	D
Butylbenzylphthalate	10		0-15	70-130	D
3,3'-Dichlorobenzidine	10		0-15	70-130	D
bis(2-Ethylhexyl)phthalate	10		0-15	70-130	D
di-n-Octylphthalate	10		0-15	70-130	D
n-Nitrosodimethylamine	10		0-15	70-130	D
2-Picoline	10		0-15	70-130	D
Diphenylamine	10		0-15	70-130	D
PNA	10		0-15	70-130	D
Acenaphthene	10		0-15	70-130	D
Acenaphthalene	10		0-15	70-130	D
Anthracene	10		0-15	70-130	D
Benzo(a)anthracen	10		0-15	70-130	D
Benzo(b)fluoranthene	10		0-15	70-130	D
Benzo(k)fluoranthene	10		0-15	70-130	D
Benzo(a)pyrene	10		0-15	70-130	D
Benzo(g,h,i)perylene	10		0-15	70-130	D
Chrysene	10		0-15	70-130	D
Dibenzo(a,h)anthracene	10		0-15	70-130	D
Fluoranthene	10		0-15	70-130	D
Fluorene	10		0-15	70-130	D
Indeno(1,2,3-cd)pyrene	10		0-15	70-130	D

Exhibit 5-11

GC/MS Semivolatiles
QUALITY ASSURANCE OBJECTIVES
Lake Water Samples

Parameter	Method Detection Limit (PPB)	Analytical Method[1]	Precision[2] (% RSD)	Accuracy[3] (% Rec.)	Source[4]
Naphthalene	10		0-15	70-130	D
Phenanthrene	10		0-15	70-130	D
Pyrene	10		0-15	70-130	D

[1] METHODS:

Methods are EPA methods except as noted. EPA references are:

Methods for Chemical Analysis of Water and Wastes, US EPA, PB 84-128677, March 1983.

Test Methods for Evaluation Solid Wastes, US EPA, SW 846, Third Edition, November, 1986. (And Proposed Update Package, 1989.)

Code of Federal Register, Protection of the Environment, 40 CFR, App. A to Part 136, July, 1988

(M) EPA procedure modified for Contract Laboratory Program.

SM Standard Methods for the Examination of Water and Wastewater, APHA et al. 16th Edition, 1985.

[2] Precision defined as Relative Standard Deviation (% RSD).

[3] Accuracy define as Percent Recovery of known spike sample.

[4] Source of QA Objectives data:

H = from historical laboratory data

M = from published method

D = default values where sufficient data are not available

CH2M HILL DATA
AND
HIGH INSTITUTE DATA

7.00

Alexandria Egypt, Lake Maryout
High Institute Data
Metals in Bottom Soil
mg/kg (dry basis)

Sample Site Number	Fe	Zn	Cu	Ni	Pb	Cd	Cr
A	10774	328.2	130.8	14.0	103.2	1.50	7.20
B	4867	17.7	5.28	12.50	11.2	1.44	2.79
10	8970	699	215.4	45.0	144.4	2.53	8.75
11	1869	345.4	115.5	24.5	115.10	1.42	11.59
12	7928	329.2	121.5	32.48	100.4	1.51	7.53
13	7496	422.6	60.91	22.14	95.7	0.58	4.41
15	3326	133	8.24	11.35	24.9	1.10	2.45
21	16164	74.4	12.33	17.22	24.4	1.72	2.57
22	8114	143	14.55	17.20	28.6	0.94	2.95
23	8308	1180	18.93	20.79	43.1	1.23	4.2
24	5219	17.3	8.80	11.05	11.9	2.00	3.00

Alexandria Egypt, Lake Maryout
High Institute Data
Bottom Sediment Analysis

Sample Site Number	V.S. gm/100	Fixed gm/100gm	SO4 mg/gm	Phosphate mg/gm
10	48.6	51.6	1120	28
11	55.6	45.4	1120	30
12	40	60	1120	30
13	55.4	44.6	1360	30
16	15.9	85.1	560	14
21	51.6	48.3	640	20
22	19.3	80.7	640	20
23	51.3	48.7	800	38
24	8.5	91.5	320	8
A	16	84	480	50
B	14.6	85.4	560	20

Data of Lake Water Samples
Analysis by HIPH
20/6/1993

Parameter		Sample Stations										
		A	B	10	11	12	13	16	21	22	23	24
pH		7.1	7.4	7.4	7.3	7.5	7	7.3	7.3	7.6	7.6	7.6
D.O.		2.5	9	0	2.5	2.2	0	0	6	8	7	4
Conductivity	µmhos/cm	2000	5000	2100	2900	3100	3000	2100	3000	3800	3100	7500
C.O.D.	mg/l	200	240	280	320	360	1120	160	400	440	320	320
B.O.D.	mg/l	100	150	180	190	230	680	100	220	250	200	140
Total Solids	mg/l	1930	4788	2084	2696	3084	3266	2096	2701	3562	3042	7496
Dissolved Solids	mg/l	1610	4410	1720	2702	2343	2002	1700	2210	3612	2510	7110
Volatile Solids	mg/l	220	300	320	356	424	1166	186	440	522	360	352
Fixed Solids	mg/l	1710	4488	1764	2340	2660	2100	1910	2261	3040	2733	7144
Sulphate	mg/l	70	450	75	70	150	175	80	152	150	145	550
Chloride	mg/l	610	1800	600	650	880	840	580	900	950	880	7600
Alkalinity	mg/l	500	520	550	520	550	400	500	500	520	520	550
Total Hardness, as CaCO3	mg/l	480	1050	450	540	620	520	450	630	650	620	1500

Data of Land Base Water Samples
Analysis by HIPH
17/6/1993

Parameter		Sample Stations								
		1	2	4	5	6	19	C	8	20
pH		7.3	7.7	7.8	7.5	7.4	8	7.3	7.3	7.9
D.O.		0	0	0	0	0	4	4	0	3.5
Conductivity	µmhos/cm	1300	3100	2700	2200	6000	5500	2400	1550	8000
C.O.D.	mg/l	240	160	520	240	2100	640	400	400	600
B.O.D.	mg/l	140	110	330	140	1200	530	250	240	340
Total Solids	mg/l	1410	2860	2542	2114	8159	5125	2840	1660	7894
Dissolved Solids	mg/l	1012	2486	1822	1741	5757	4134	2242	1146	7190
Volatile Solids	mg/l	280	220	562	249	2207	803	444	460	634
Fixed Solids	mg/l	1130	2640	1980	1865	5952	4322	2396	1200	7260
Sulphate	mg/l	100	145	100	92	400	400	110	75	500
Chloride	mg/l	200	350	710	550	2850	1600	800	250	2750
Alkalinity	mg/l	400	500	440	440	500	520	560	500	500
Total Hardness, as CaCO3	mg/l	250	550	460	450	1350	1050	450	260	1570

WATER SAMPLES

	BOD		TS		Cd		Cr		Cu		Pb		Ni		Zn		COD	
Site Location	HI	CH	HI	CH	HI	CH	HI	CH	HI	CH	HI	CH	HI	CH	HI	CH	HI	CH
A	100	27	1930	-----	0.00515	< 0.005	0.00285	< 0.006	0.01015	< 0.006	0.0155	< 0.02	0.0207	< 0.015	0.0565	0.016	200	63
B	140	< 4	4788	-----	0.00816	0.005	0.0041	0.006	0.00545	0.006	0.0295	0.02	0.03575	0.015	0.0175	0.005	240	63
C	250	874	2840	2450	0.0071	< 0.005	0.0052	0.031	0.07485	0.076	0.091	0.088	0.0344	< 0.015	0.337	0.279	400	874
1	140	81	1410	1100	0.0023	< 0.005	0.0033	0.014	0.10545	0.146	0.027	< 0.04	0.01455	< 0.015	0.25	0.161	240	278
2	110	33	2860	2280	0.00335	0.005	0.00285	< 0.006	0.0218	0.021	0.028	0.04	0.0264	0.015	0.054	0.098	160	164
4	330	21	2542	1760	0.0025	0.005	0.00335	0.006	0.02225	0.02	0.016	0.04	0.01925	0.015	0.0665	0.042	520	144
5	140	37	2114	5490	0.0027	0.005	0.00305	0.014	0.0502	0.044	0.0345	0.04	0.0204	0.015	0.182	0.102	240	220
6	1200	248	8159	1500	0.01015	0.005	0.0087	0.045	0.06915	0.088	0.051	0.04	0.0519	0.015	0.254	0.288	2100	1350
8	240	225	1660	2150	0.0045	0.005	0.0055	0.027	0.09095	0.095	0.0695	0.04	0.0239	0.015	0.292	0.239	400	861
10	180	15	2084	-----	0.0059	0.005	0.0024	< 0.006	0.0281	0.007	0.024	< 0.02	0.0234	0.015	0.061	0.011	280	95
11	190	14	2696	-----	0.003	0.005	0.00255	0.006	0.01535	0.124	0.019	0.02	0.01825	0.015	0.061	0.018	320	117
12	230	12	3064	-----	0.00585	0.005	0.00275	0.006	0.0101	0.021	0.0205	0.02	0.0255	0.015	0.043	0.058	360	168
13	680	90	3266	-----	0.01205	0.005	0.0038	0.006	0.0775	0.016	0.0775	0.02	0.03205	0.015	0.365	0.07	1120	362
16	100	37	2096	-----	0.0027	0.005	0.00325	0.006	0.0334	0.037	0.031	0.02	0.0196	0.015	0.08	0.095	160	310
19	530	< 4	5125	1520	0.0082	< 0.005	0.0056	< 0.006	0.01595	< 0.006	0.0345	< 0.04	0.0347	< 0.015	0.0545	0.012	640	42
20	340	< 4	7894	3880	0.0085	0.005	0.00505	0.006	0.0133	0.006	0.032	0.04	0.0435	0.015	0.0165	0.008	600	53
21	220	9	2701	----	0.0032	0.005	0.0027	0.006	0.0081	0.016	0.0185	< 0.02	0.018	0.015	0.0185	0.008	400	134
22	250	33	3562	----	0.0028	0.005	0.00235	0.006	0.0055	0.012	0.023	0.02	0.02275	0.015	0.019	0.007	440	106
23	200	28	3092	----	0.0031	0.005	0.0026	0.006	0.0108	< 0.006	0.0245	0.02	0.025	0.015	0.0305	< 0.005	320	99
24	140	< 4	7496	----	0.00515	0.005	0.0059	0.006	0.0152	0.014	0.0305	0.02	0.0321	0.015	0.025	0.008	320	74

SEDIMENT SAMPLES

		% Solids														
A		11.6	1.60	< 8.6	7.20	98.1	130.8	204	103.2	129	14	598	328.2	753	
B		29.8	1.44	< 3.4	2.79	21.2	5.28	27.2	11.2	< 27.3	12.5	36.1	17.7	43.3	
10		9.9	2.53	< 10.1	8.75	114	215.4	----	144.4	263	45	94.1	699	1000	
11		11.4	1.42	< 3.5	11.69	184	115.6	-----	116.1	257	24.5	< 35.3	345.4	882	
12		8.5	1.61	< 11.8	7.63	77	121.6	210	104.4	240	32.48	75.5	329.2	674	
13		9.3	0.68	< 10.8	4.41	83.1	60.91	309	96.7	209	22.14	82.7	422.6	908	
16		29.7	1.10	< 3.4	2.45	35.8	8.24	51.1	24.9	37.4	11.35	35.1	133	103	
21		22.1	1.72	< 4.5	2.57	34.2	12.33	57.2	24.4	< 36.2	17.22	35.1	74.4	120	
22		20.8	0.94	< 4.8	2.95	46.2	14.55	63.1	28.6	< 38.5	17.20	40.4	143	121	
23		21.7	1.23	< 4.6	4.2	53.8	18.93	96.7	43.1	58.9	20.79	43.0	118	202	
24		45.6	2.00	< 2.2	3.0	14.2	8.80	23.9	11.9	< 17.5	11.05	9.5	17.3	32.6	

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Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Volatiles in Sediment

Compounds **mg/kg (dry weight)**	**Sample Locations** **A**	**B**	**10**	**11**	**12**	**13**	**16**	**21**	**22**	**23**	**24**
Chloromethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Bromomethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Vinly Chloride	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Chloroethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Methylene Chloride	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
1,1-Dichloroethene	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
1,1-Dichloroethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
1,2-Dichloroethene (total)	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Chloroform	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
1,2 Dichloroethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
1,1,1-Trichloroethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Carbon Tetrachloride	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Bromodichloromethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
1,2-Dichloropropane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
cis-1,3-Dichloropropene	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Trichloroethene	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Dibromochloromethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
1,1,2-Trichloroethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Benzene	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
trans-1,3-Dichloropropene	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
2-Chloroethylvinylether	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Bromoform	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Tetrachloroethene	29 J	8 J	18 J	10 J	15 J	17 J	9 J	19 J	13 J	14 J	22 U
1,1,2,2-Tetrachloroethane	83 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Toluene	38 J	33 U	100 U	91 U	120 U	110 U	33 U	83 U	16 J	45 U	22 U
Chlorobenzene	15 U	33 U	100 U	91 U	120 U	110 U	33 U	83 U	48 U	45 U	22 U
Ethylbenzene	30 U	33 U	36 U	91 U	120 U	110 U	7 J	83 U	48 U	45 U	22 U
Acrolein	830 U	330 U	1000 U	910 U	1200 U	1100 U	330 U	830 U	480 U	450 U	220 U
Acrylonitrile	830 U	330 U	1000 U	910 U	1200 U	1100 U	330 U	830 U	480 U	450 U	220 U

U = Compound analyzed for but not detected
B = Compound was detected in QC blank
J = Reported value less than quantitation limit

Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Volatiles in Water

Compounds, as ug/l	Sample Locations																			
	A	B	C	1	2	4	5	6	8	10	11	12	13	16	19	20	21	22	23	24
Chloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinly Chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	2 J	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	10 U	10 U	2 J	2 J	2 J	2 J	3 J	10 U	3 J	10 U	10 U	10 U	2 J	3 J	10 U	1 J	10 U	10 U	10 U	10 U
1,1-Dichloroethene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	8 J	10 U	10 U	10 U	10 U
1,2-Dichloroethene (total)	10 U	1 J	10 U	10 U	10 U	2 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroform	10 U	10 U	15	10	3 J	4 J	2 J	18	10	10 U	10 U	10 U	3 J	2 J	10 U	34	10 U	10 U	10 U	3 J
1,2-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	3 J	10 U	10 U	10 U	10 U	1 J	10 U	10 U	480	10 U	10 U	10 U	61
1,1,1-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon Tetrachloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	10 U	10 U	3 J	4 J	10 U	10 U	10 U	5 J	4 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloropropane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	10 U	10 U	8 J	10 U	10 U	2 J	1 J	10 U	10 U	1 J	10 U	10 U	10 U	2 J	1 J	3 J	10 U	10 U	10 U	10 U
Dibromochloromethane	10 U	10 U	10 U	2 J	10 U	10 U	10 U	2 J	1 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	5 J	10 U	10 U	10 U	10 U
Benzene	10 U	10 U	2 J	10 U	10 U	10 U	10 U	10 U	4 J	10 U	10 U	10 U	1 J	10 U	10 U	10 U	10 U	10 U	10 U	280
trans-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromoform	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	10 U	10 U	2 J	10 U	3 J	1 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	1 J	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	1 J	10 U	17	15	10	13	15	10	37	3 J	4 J	10 U	12 U	17	10 U	10 U	10 U	10 U	10 U	87
Chlorobenzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Ethylbenzene	10 U	10 U	3 J	2 J	1 J	2 J	2 J	2 J	3 J	10 U	10 U	10 U	1 J	2 J	10 U	10 U	10 U	10 U	10 U	10 U
Acrolein	14 BJ	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	16 BJ	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U
Acrylonitrile	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U

U = Compound analyzed for but not detected
B = Compound was detected in QC blank
J = Reported value less than quantitation limit

Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Metals in Sediment

Parameters as mg/kg (dry weight)

Sample Locations	Sb	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Tl	Zn
A	< 51.7	8.62	< 3.4	< 8.6	98.1	204	129	1.05	76.2	< 8.62	< 8.6	< 43.1	453
B	< 20.5	4.99	< 1.3	< 3.4	21.2	27.2	< 27.3	< 0.14	19.4	< 3.36	< 3.4	< 37.6	316
10	< 60.6	15.7	< 4.0	< 10.1	114	445	263	1.77	107	< 10.1	< 10.1	< 50.5	1,000
11	< 53.1	< 8.85	< 4.7	< 11.8	210	371	257	0.84	93	< 8.85	< 8.8	< 44.2	882
12	< 70.6	< 11.8	< 4.7	< 11.8	77.0	210	240	0.82	60.1	< 11.8	< 11.8	< 58.8	674
13	< 64.6	13.4	< 4.3	< 10.8	83.1	309	209	0.89	70.4	< 10.8	< 10.8	< 53.8	908
16	< 20.2	3.88	< 1.3	< 3.4	35.8	51.1	34.7	0.20	37.9	< 3.37	< 3.4	< 16.8	103
21	< 27.1	< 4.52	< 1.8	< 4.5	34.2	57.2	< 36.2	0.18	30.7	< 4.52	< 4.5	< 22.6	120
22	< 28.8	< 4.81	< 1.9	< 4.8	46.2	63.1	< 38.5	< 0.19	49.2	< 4.81	< 4.8	< 24.0	121
23	< 27.6	< 4.61	< 1.8	< 4.6	53.8	96.7	58.9	0.32	53.5	< 4.61	< 4.6	< 23.0	202
24	< 13.2	3.33	< 0.88	< 2.2	14.2	23.9	< 17.5	0.15	10.3	< 2.19	< 2.2	< 11.0	32.6

< Indicates "less than"

Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Metals in Water

Parameters as mg/l

Sample Locations	TSS	VSS	TS	BOD	COD	Sb Total *(Soluble)*	As Total *(Soluble)*	Be Total *(Soluble)*	Cd Total *(Soluble)*	Cr Total *(Soluble)*	Cu Total *(Soluble)*	Pb Total *(Soluble)*	Hg Total *(Soluble)*	Ni Total *(Soluble)*	Se Total *(Soluble)*	Ag Total *(Soluble)*	Tl Total *(Soluble)*	Zn Total *(Soluble)*
A	58	58		27	63	< 0.03 *(< 0.03)*	< 0.005 *(< 0.005)*	< 0.002 *(< 0.002)*	< 0.005 *(< 0.005)*	< 0.006 *(< 0.006)*	< 0.006 *(< 0.006)*	< 0.02 *(< 0.02)*	< 0.0002 *(< 0.0002)*	< 0.015 *(< 0.015)*	< 0.025 *(< 0.005)*	< 0.005 *(< 0.005)*	< 0.04 *(< 0.04)*	0.016 *(< 0.005)*
B	8	8		< 4	63	< 0.03	< 0.005	< 0.002	< 0.005	< 0.006	< 0.006	< 0.02	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.005
C	343		2450	283	874	< 0.03	0.007	< 0.002	< 0.005	0.031	0.076	0.088	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.279
1	104		1100	81	278	< 0.03	0.007	< 0.002	< 0.005	0.014	0.146	< 0.04	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.161
2	94		2280	33	164	< 0.03	0.006	< 0.002	< 0.005	< 0.006	0.021	< 0.04	0.0018	< 0.015	< 0.025	< 0.005	< 0.04	0.098
4	53		1760	21	144	< 0.03	< 0.005	< 0.002	< 0.005	0.006	0.020	< 0.04	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.042
5	56		5490	37	220	< 0.03	0.006	< 0.002	< 0.005	0.014	0.044	< 0.04	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.102
6	79		1500	248	1350	< 0.03	0.010	< 0.002	< 0.005	0.045	0.088	0.058	0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.288
8	244		2150	225	861	< 0.03	< 0.005	< 0.002	< 0.005	0.027	0.095	< 0.04	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.239
10	44	40		15	95	< 0.03	< 0.005	< 0.002	< 0.005	< 0.006	0.007	< 0.02	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.011
11	64	64		14	117	< 0.03 *(< 0.03)*	< 0.005 *(< 0.005)*	< 0.002 *(< 0.002)*	< 0.005 *(< 0.005)*	< 0.006 *(< 0.006)*	0.124 *(< 0.006)*	< 0.02 *(< 0.02)*	< 0.0002 *(< 0.0002)*	< 0.015 *(< 0.015)*	< 0.025 *(< 0.005)*	< 0.005 *(< 0.005)*	< 0.04 *(< 0.04)*	0.018 *(0.007)*
12	114	86		12	168	< 0.03 *(< 0.03)*	< 0.005 *(< 0.005)*	< 0.002 *(< 0.002)*	< 0.005 *(< 0.005)*	< 0.006 *(< 0.006)*	0.021 *(< 0.006)*	< 0.02 *(< 0.02)*	< 0.0002 *(< 0.0002)*	< 0.015 *(< 0.015)*	< 0.025 *(< 0.005)*	< 0.005 *(< 0.005)*	< 0.04 *(< 0.04)*	0.058 *(< 0.005)*
13	160	148		90	362	< 0.03 *(< 0.03)*	< 0.005 *(< 0.005)*	< 0.002 *(< 0.002)*	< 0.005 *(< 0.005)*	< 0.006 *(< 0.005)*	0.016 *(0.006)*	< 0.02 *(< 0.02)*	0.0014 *(0.00033)*	< 0.015 *(< 0.015)*	< 0.025 *(< 0.005)*	< 0.005 *(< 0.005)*	< 0.04 *(< 0.04)*	0.070 *(0.017)*
16	82	64		37	310	< 0.03	< 0.005	< 0.002	< 0.005	< 0.006	0.037	< 0.02	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.095
19	28		1520	< 4	42	< 0.03	0.011	< 0.002	< 0.005	< 0.006	< 0.006	< 0.02	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.012
20	21		3880	< 4	53	< 0.03	0.011	< 0.002	< 0.005	< 0.006	< 0.006	< 0.02	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.008
21	33	30		9	134	< 0.03 *(< 0.03)*	< 0.005 *(< 0.005)*	< 0.002 *(< 0.002)*	< 0.005 *(< 0.005)*	< 0.006 *(< 0.006)*	0.016 *(0.012)*	< 0.02 *(< 0.02)*	< 0.0002 *(< 0.0002)*	< 0.015 *(< 0.015)*	< 0.025 *(< 0.005)*	< 0.005 *(< 0.005)*	< 0.04 *(< 0.04)*	0.008 *(< 0.005)*
22	45	45		33	106	< 0.03	< 0.005	< 0.002	< 0.005	< 0.006	0.012	< 0.02 *(0.02)*	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	0.007
23	68	68		28	99	< 0.03 *(< 0.03)*	< 0.005 *(< 0.005)*	< 0.002 *(< 0.002)*	< 0.005 *(< 0.005)*	< 0.006 *(< 0.006)*	< 0.006 *(< 0.006)*	< 0.02 *(< 0.02)*	< 0.0002 *(0.00033)*	< 0.015 *(< 0.015)*	< 0.025 *(< 0.005)*	< 0.005 *(< 0.005)*	< 0.04 *(< 0.04)*	< 0.005 *(< 0.005)*
24	9	5		< 4	74	< 0.03	< 0.005	< 0.002	< 0.005	< 0.006	0.014	< 0.02	< 0.0002	< 0.015	< 0.025	< 0.005	< 0.04	< 0.005

< Indicates "less than"

Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Pesticides/PCBs in Sediments

Compound, as ug/kg (dry weight)	Sample Locations										
	A	B	10	11	12	13	16	21	22	23	24
alpha-BHC	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
beta-BHC	65 U	12 U	72 U	54 U	73 U	94 U	11 U	13 U	16 U	32 U	5.7 U
delta-BHC	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
gamma-BHC (Lindane)	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
Heptachlor	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
Aldrin	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
Heptachlor Epoxide	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
Endosulfan I	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
Dieldrin	34 U	6.5 U	38 U	28 U	48 U	31 U	5.7 U	6.8 U	8.5 U	17 U	3.0 U
4,4'-DDE	130	6.5 U	174	200	190	240	23	26	12	67	3.0 U
Endrin	65 U	12 U	72 U	54 U	93 U	59 U	11 U	13 U	16 U	32 U	5.7 U
Endosulfan II	65 U	12 U	72 U	54 U	93 U	59 U	11 U	13 U	16 U	32 U	5.7 U
4,4'-DDD	65 U	12 U	72 U	120	93 U	59 U	15	40	16 U	32 U	5.7 U
Endorsulfan Sulfate	65 U	12 U	72 U	54 U	93 U	59 U	11 U	13 U	16 U	32 U	5.7 U
4,4'-DDT	65 U	12 U	72 U	120	93 U	59 U	11 U	13 U	16 U	32 U	5.7 U
Methoxychlor	140 U	26 U	160 U	120 U	200 U	130 U	23 U	27 U	34 U	68 U	12 U
Endrin Aldehyde	65 U	12 U	72 U	54 U	93 U	59 U	11 U	13 U	16 U	32 U	5.7 U
Chlordane	340 U	65 U	380 U	280 U	480 U	310 U	57 U	68 U	85 U	170 U	30 U
Toxaphene	1600 U	320 U	1800 U	1300 U	2300 U	1400 U	270 U	330 U	410 U	820 U	150 U
Aroclor-1016	1600 U	320 U	1800 U	1300 U	2300 U	1400 U	270 U	330 U	410 U	820 U	150 U
Aroclor-1221	3400 U	650 U	3800 U	2800 U	4800 U	3100 U	570 U	680 U	850 U	1700 U	300 U
Aroclor-1232	3400 U	650 U	3800 U	2800 U	4800 U	3100 U	570 U	680 U	850 U	1700 U	300 U
Aroclor-1242	1600 U	320 U	1800 U	1300 U	2300 U	1400 U	270 U	330 U	410 U	820 U	150 U
Aroclor-1248	1600 U	320 U	1800 U	1300 U	2300 U	1400 U	270 U	330 U	410 U	820 U	150 U
Aroclor-1254	850 U	160 U	940 U	710 U	1200 U	770 U	140 U	170 U	210 U	420 U	75 U
Aroclor-1260	850 U	160 U	940 U	710 U	1200 U	770 U	140 U	170 U	210 U	420 U	75 U

U = Compound analyzed for but not detected

Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Pesticides/PCBs in Water

Compound, as ug/l	Sample Locations																		
	A	B	C	1	2	4	5	6	8	10	11	12	13	16	19	20	21	22	23	24
alpha-BHC	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
beta-BHC	0.04 U	0.04 U	0.2 U	0.08 U	0.08 U	0.04 U	0.04 U	0.1 U	0.2 U	0.04 U	0.08 U	0.04 U	0.16 U	0.08 U	0.04 U	0.04 U	0.04 U	0.08 U	0.04 U	0.04 U
delta-BHC	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
gamma-BHC (Lindane)	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
Heptachlor	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
Aldrin	0.02 U	0.02 U	0.4 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.2 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
Heptachlor Epoxide	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
Endosulfan I	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
Dieldrin	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
4,4'-DDE	0.02 U	0.02 U	0.1 U	0.04 U	0.04 U	0.02 U	0.02 U	0.05 U	0.1 U	0.02 U	0.04 U	0.02 U	0.08 U	0.04 U	0.02 U	0.02 U	0.02 U	0.04 U	0.02 U	0.02 U
Endrin	0.02 U	0.02 U	0.2 U	0.08 U	0.08 U	0.02 U	0.02 U	0.1 U	0.2 U	0.02 U	0.08 U	0.02 U	0.16 U	0.08 U	0.02 U	0.02 U	0.02 U	0.08 U	0.02 U	0.02 U
Endosulfan II	0.04 U	0.04 U	0.2 U	0.08 U	0.08 U	0.04 U	0.04 U	0.1 U	0.2 U	0.04 U	0.08 U	0.04 U	0.16 U	0.08 U	0.04 U	0.04 U	0.04 U	0.08 U	0.04 U	0.04 U
4,4'-DDD	0.04 U	0.04 U	0.2 U	0.08 U	0.08 U	0.04 U	0.04 U	0.1 U	0.2 U	0.04 U	0.08 U	0.04 U	0.16 U	0.08 U	0.04 U	0.04 U	0.04 U	0.08 U	0.04 U	0.04 U
Endorsulfan Sulfate	0.04 U	0.04 U	0.2 U	0.08 U	0.08 U	0.04 U	0.04 U	0.1 U	0.2 U	0.04 U	0.08 U	0.04 U	0.16 U	0.08 U	0.04 U	0.04 U	0.04 U	0.08 U	0.04 U	0.04 U
4,4'-DDT	0.04 U	0.04 U	0.2 U	0.08 U	0.08 U	0.04 U	0.04 U	0.1 U	0.2 U	0.04 U	0.08 U	0.04 U	0.16 U	0.08 U	0.04 U	0.04 U	0.04 U	0.08 U	0.04 U	0.04 U
Methoxychlor	0.08 U	0.08 U	0.4 U	0.16 U	0.16 U	0.08 U	0.08 U	0.2 U	0.4 U	0.08 U	0.16 U	0.08 U	0.32 U	0.16 U	0.08 U	0.08 U	0.08 U	0.16 U	0.08 U	0.08 U
Endrin Aldehyde	0.04 U	0.04 U	0.2 U	0.08 U	0.08 U	0.04 U	0.04 U	0.1 U	0.2 U	0.04 U	0.08 U	0.04 U	0.16 U	0.08 U	0.04 U	0.04 U	0.04 U	0.08 U	0.04 U	0.04 U
Chlordane	0.2 U	0.2 U	1.0 U	0.4 U	0.4 U	0.2 U	0.2 U	0.5 U	1.0 U	0.2 U	0.4 U	0.2 U	0.8 U	0.4 U	0.2 U	0.2 U	0.2 U	0.4 U	0.2 U	0.2 U
Toxaphene	1.0 U	1.0 U	5.0 U	2.0 U	2.0 U	1.0 U	1.0 U	2.5 U	5.0 U	1.0 U	2.0 U	1.0 U	4.0 U	2.0 U	1.0 U	1.0 U	1.0 U	2.0 U	1.0 U	1.0 U
Aroclor-1016	1.0 U	1.0 U	10 U	2.0 U	2.0 U	1.0 U	1.0 U	2.5 U	10 U	1.0 U	2.0 U	1.0 U	4.0 U	2.0 U	1.0 U	1.0 U	1.0 U	2.0 U	1.0 U	1.0 U
Aroclor-1221	2.0 U	2.0 U	20 U	4.0 U	4.0 U	2.0 U	2.0 U	5.0 U	20 U	2.0 U	4.0 U	2.0 U	8.0 U	4.0 U	2.0 U	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U
Aroclor-1232	2.0 U	2.0 U	20 U	4.0 U	4.0 U	2.0 U	2.0 U	5.0 U	20 U	2.0 U	4.0 U	2.0 U	8.0 U	4.0 U	2.0 U	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U
Aroclor-1242	1.0 U	1.0 U	10 U	2.0 U	2.0 U	1.0 U	1.0 U	2.5 U	10 U	1.0 U	2.0 U	1.0 U	4.0 U	2.0 U	1.0 U	1.0 U	1.0 U	2.0 U	1.0 U	1.0 U
Aroclor-1248	1.0 U	1.0 U	10 U	2.0 U	2.0 U	1.0 U	1.0 U	2.5 U	10 U	1.0 U	2.0 U	1.0 U	4.0 U	2.0 U	1.0 U	1.0 U	1.0 U	2.0 U	1.0 U	1.0 U
Aroclor-1254	0.5 U	0.5 U	2.5 U	1.0 U	1.0 U	0.5 U	0.5 U	1.2 U	2.5 U	0.5 U	1.0 U	0.5 U	2.0 U	1.0 U	0.5 U	0.5 U	0.5 U	1.0 U	0.5 U	0.5 U
Aroclor-1260	0.5 U	0.5 U	2.5 U	1.0 U	1.0 U	0.5 U	0.5 U	1.2 U	2.5 U	0.5 U	1.0 U	0.5 U	2.0 U	1.0 U	0.5 U	0.5 U	0.5 U	1.0 U	0.5 U	0.5 U

U = Compound analyzed for but not detected

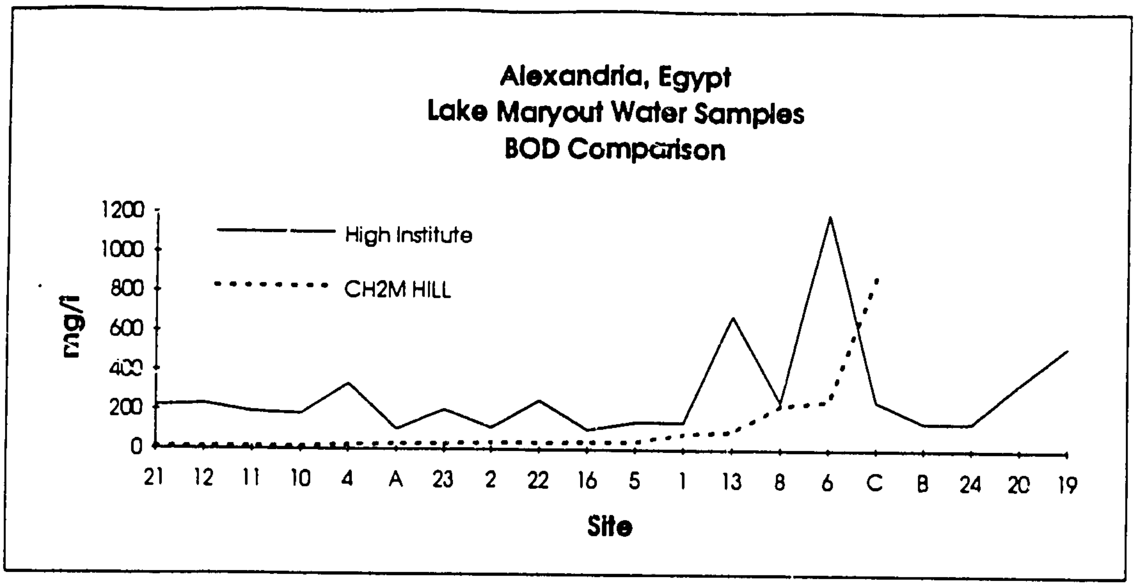
Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Semi-Volatiles in Water

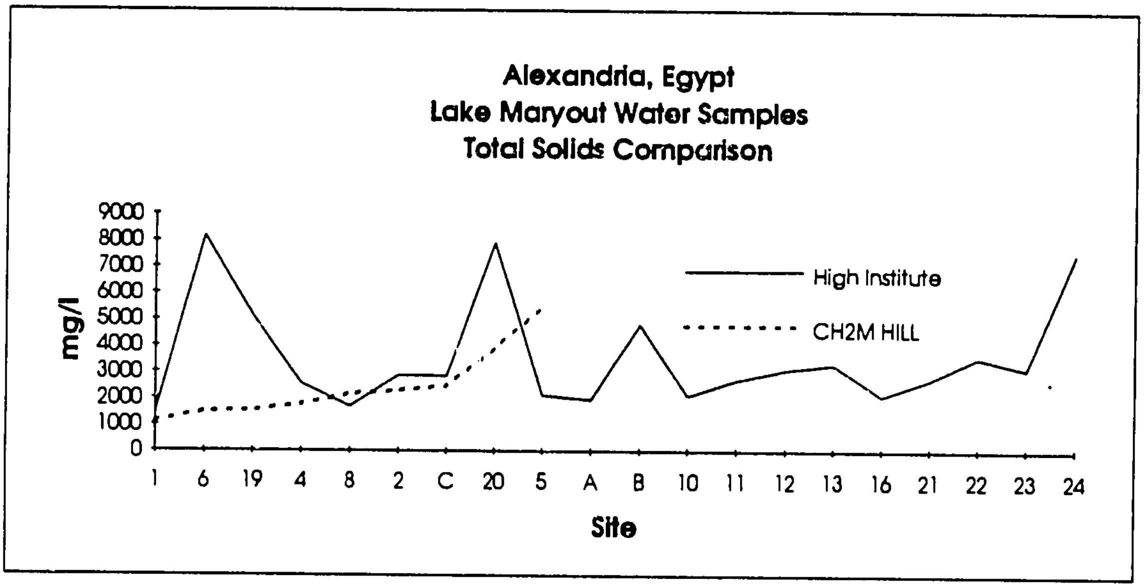
310

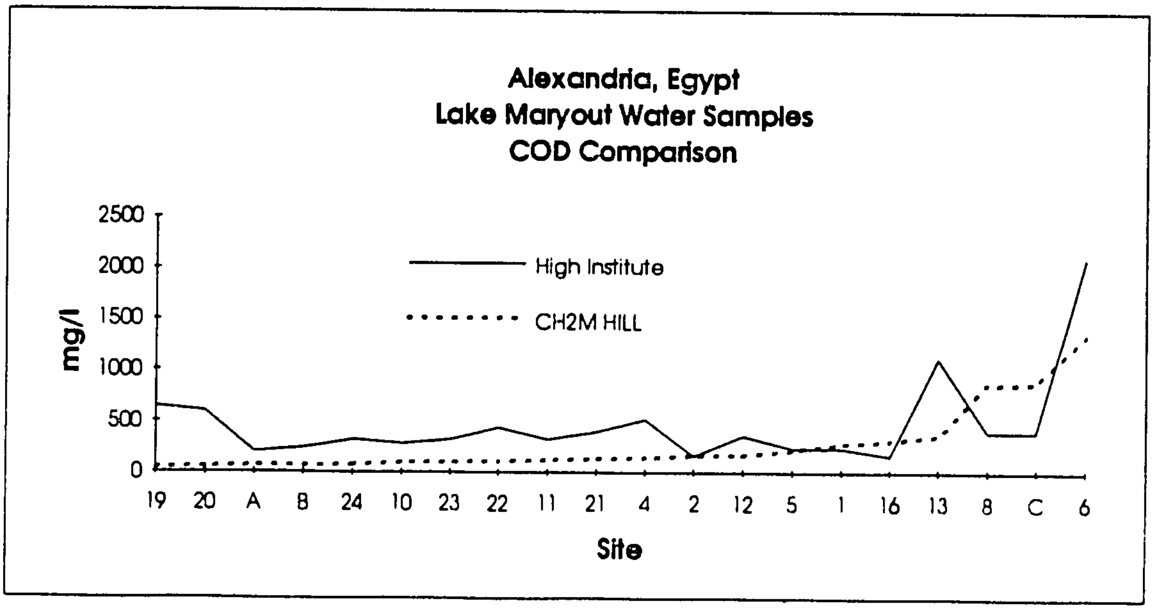
Compound, as ug/l	Sample Location																			
	A	B	C	1	2	4	5	6	8	10	11	12	13	16	19	20	21	22	23	24
N-Nitrosodimethylamine	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Phenol	10 U	10 U	47 J	14	3 J	12	16	19	530	10 U	10 U	3 J	20	20	10 U	10 U	10 U	10 U	6 J	6 J
bis(2-Chloroethyl)Ether	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bis(2-Chiroisopropyl)Ether	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-Chloroethoxy)Methane	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	50 U	9 J	4 J	8 J	11	6 J	42 J	3 J	10 U	10 U	10	13	10 U	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Chloronaphthalene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Dimethylphthalate	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acenaphthene	10 U	10 U	50 U	5 J	3 J	5 J	6 J	10 U	16 J	10 U	10 U	10 U	4 J	6 J	10 U	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
4-Nitophenol	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
2,4-Dinitrotoluene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	3 J	10 U	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	50 U	10 U	10 U	10 U	4 J	10 U	50 U	10 U	10 U	10 U	10 U	3 J	10 U	10 U	10 U	10 U	10 U	10 U
4,6-Dinitro-2-Methyphenol	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
N-Nitosodiphenylamine	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Diphenylhydrizine	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Pentachlrophenol	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	120 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Phenanthrene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	4 J	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	16 U	10 U	10 U	10 U	10 U	8 J	50 U	10 U	3 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzidine	50 U	50 U	250 U	50 U	50 U	50 U	50 U	50 U	250 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Pyrene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzo(a)Anthracene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chrysene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	50 U	10 U	10 U	10 U	18	10 U	50 U	10 U	10 U	10 U	31	15	10 U	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U

Alexandria, Egypt - Lake Maryout
CH2M HILL Laboratory Data
Semi-Volatiles in Sediments

Compound, as µg/kg	Sample Location										
	A	B	10	11	12	13	16	21	22	23	24
N-Nitrosodimethylamine	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Phenol	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
bis(2-Chloroethyl)Ether	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
2-Chlorophenol	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
1,3-Dichlorobenzene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
1,4-Dichlorobenzene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
1,2-Dichlorobenzene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Bis(2-Chlroisopropyl)Ether	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
N-Nitroso-Di-n-Propylamine	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Hexachloroethane	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Nitrobenzene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Isophorone	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
2-Nitrophenol	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
2,4-Dimethylphenol	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
bis(2-Chloroethoxy)Methane	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
2,4-Dichlorophenol	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
1,2,4-Trichlorobenzene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Naphthalene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Hexachlorobutadiene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
4-Chloro-3-Methylphenol	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Hexachlorocyclopentadiene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
2,4,6-Trichlorophenol	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
2-Chloronaphthalene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Dimethylphthalate	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Acenaphthylene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	520 J	1400 U	1400 U	690 U
2,6-Dinitrotoluene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Acenaphthene	960 J	1100 U	2200 J	17000 J	3300 U	3300 U	870 U	220 J	1400 U	260 J	690 U
2,4-Dinitrophenol	5700 U	2600 U	16000 U	62000 U	8000 U	8000 U	2100 U	3500 U	3300 U	3500 U	1700 U
4-Nitophenol	5700 U	2600 U	16000 U	62000 U	8000 U	8000 U	2100 U	3500 U	3300 U	3500 U	1700 U
2,4-Dinitrotoluene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Diethylphthalate	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
4-Chlorophenyl-phenylether	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Fluorene	560 J	1100 U	930 J	5700 J	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
4,6-Dinitro-2-Methyphenol	5700 U	2600 U	16000 U	62000 U	8000 U	8000 U	2100 U	3500 U	3300 U	3500 U	1700 U
N-Nitosodiphenylamine	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
1,2-Diphenylhydrazine	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
4-Bromophenyl-phenylether	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Hexachlorobenzene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Pentachlrophenol	5700 U	2600 U	16000 U	62000 U	8000 U	8000 U	2100 U	3500 U	3300 U	3500 U	1700 U
Phenanthrene	2800	1100 U	6900	41000	3300 U	3300 U	320 J	720 J	720 J	1400 U	140 J
Anthracene	770 J	1100 U	6600 U	8500 J	3300 U	3300 U	870 U	1400 U	1400 U	290 J	690 U
Di-n-Butylphthalate	2400 U	400 J	3900 BJ	25000 U	3300 U	3300 U	330 BJ	650 BJ	620 J	580 J	270 J
Fluoranthene	3700	1100 U	12000	34000	3300 U	3300 U	850 J	2900	480 J	1500	180 J
Benzidine	11000 U	5200 U	32000 U	120000 U	16000 U	16000 U	4200 U	7000 U	6700 U	7000 U	3300 U
Pyrene	5100	1100 U	20000	51000	580 J	530 J	960	4500	690 J	2200	190 J
Butylbenzylphthalate	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
3,3'-Dichlorobenzidine	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Benzo(a)Anthracene	2400 U	1100 U	6600 U	12000 J	3300 U	3300 U	510 J	2400	1400 U	700 J	690 U
Chrysene	1600 J	1100 U	5400 J	14000 J	3300 U	3300 U	560 J	2700	380 J	880 J	110 J
bis(2-Ethylhexyl)Phthalate	2900	1100 U	14000	25000 U	13000	18000	870 U	4500	650 J	910 J	690 U
Di-n-Octyl Phthalate	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Benzo(b)Fluoranthene	1500 J	1100 U	6700	11000 J	3300 U	3300 U	680 J	4600	440 J	860 J	160 J
Benzo(k)Fluoranthene	2000 J	1100 U	6600	16000 J	3300 U	3300 U	740 J	5500	470 J	1100 J	690 U
Benzo(a)Pyrene	1700 J	1100 U	8200	23000 J	3300 U	3300 U	570 J	4600	470 J	1000 J	690 U
Indeno(1,2,3-cd)Pyrene	2400 U	1100 U	6600 U	7300 J	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Dibenz(a,h)Anthracene	2400 U	1100 U	6600 U	25000 U	3300 U	3300 U	870 U	1400 U	1400 U	1400 U	690 U
Benzo(g,h,i)Perylene	2400 U	1100 U	6600 U	9000 J	3300 U	3300 U	870 U	1400 U	1400 U	230 J	690 U


Alexandria, Egypt
Lake Maryout Water Samples
BOD Comparison
mg/l
1200
1000
800
600
400
200
0
High Institute
CH2M HILL
21
12
11
10
4
A
23
2
22
16
5
1
13
8
6
C
B
24
20
19
Site


Alexandria, Egypt
Lake Maryout Water Samples
Total Solids Comparison
mg/l
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
High Institute
CH2M HILL
1
6
19
4
8
2
C
20
5
A
B
10
11
12
13
16
21
22
23
24
Site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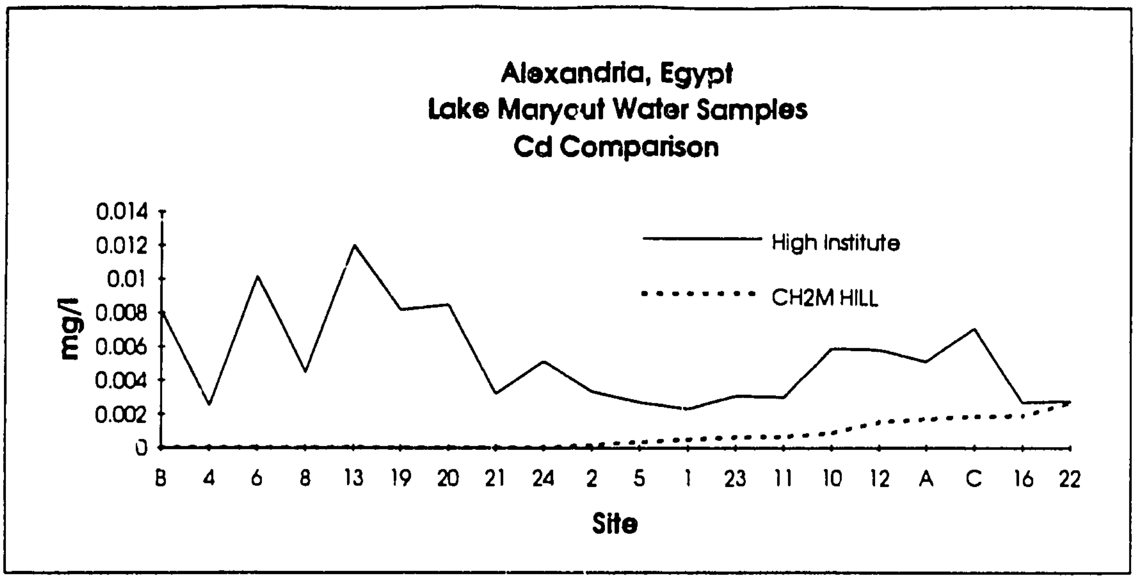
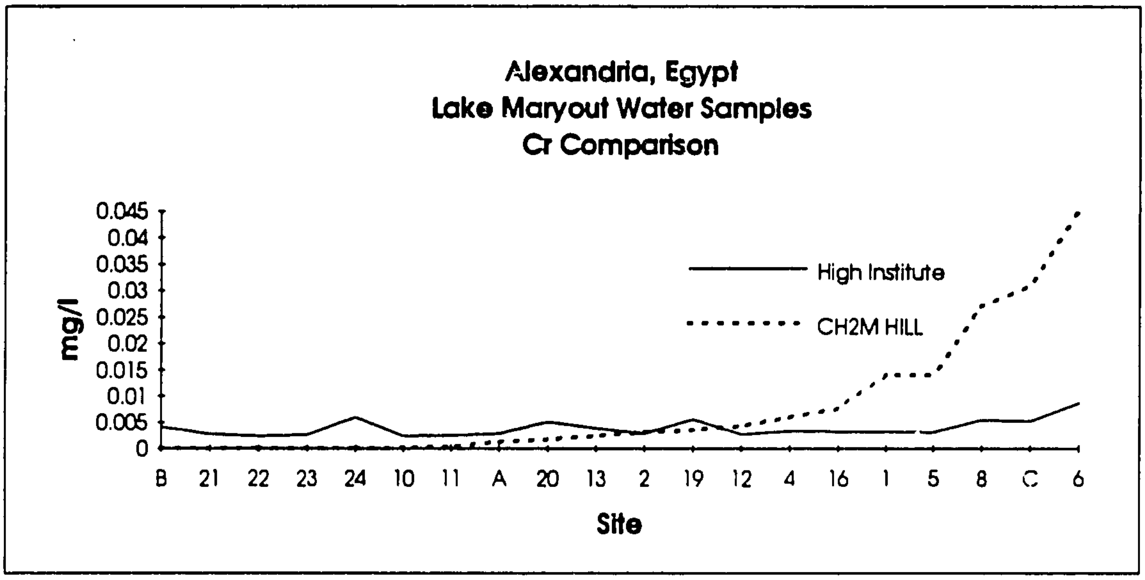
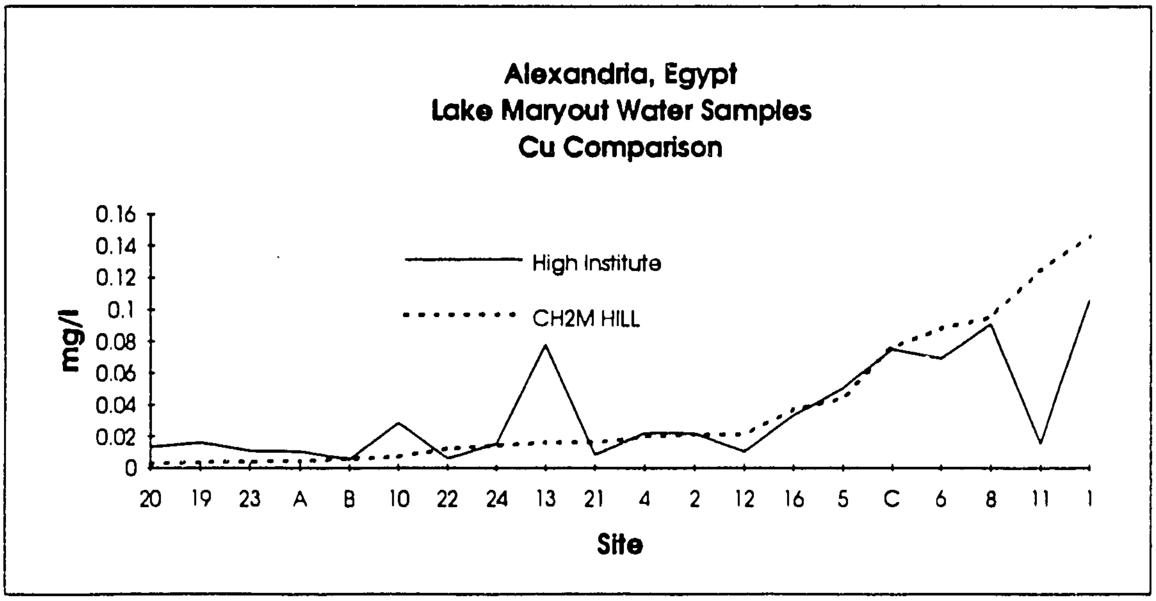
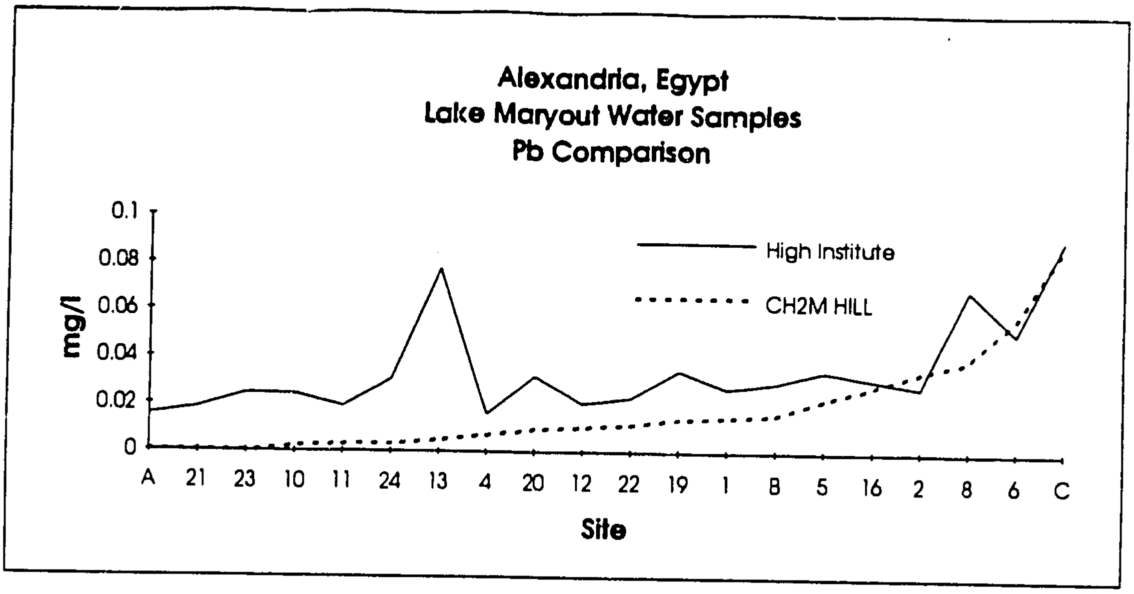
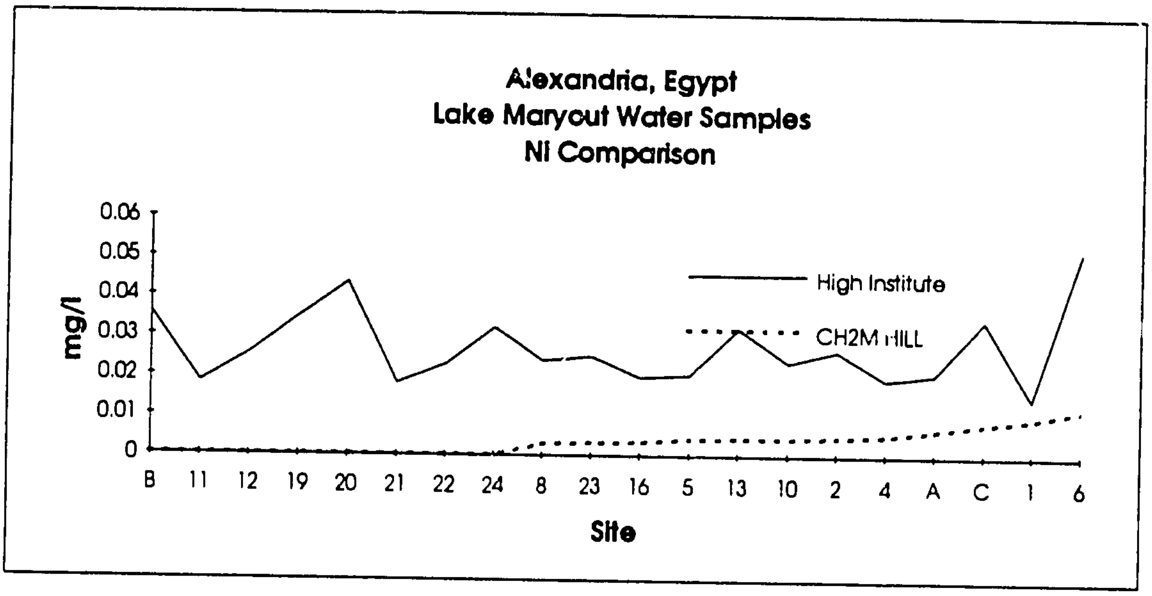
Lake Maryout Water Samples
COD Comparison
mg/l
2500
2000
1500
1000
500
0
High Institute
CH2M HILL
19
20
A
B
24
10
23
22
11
21
4
2
12
5
1
16
13
8
C
6
Site

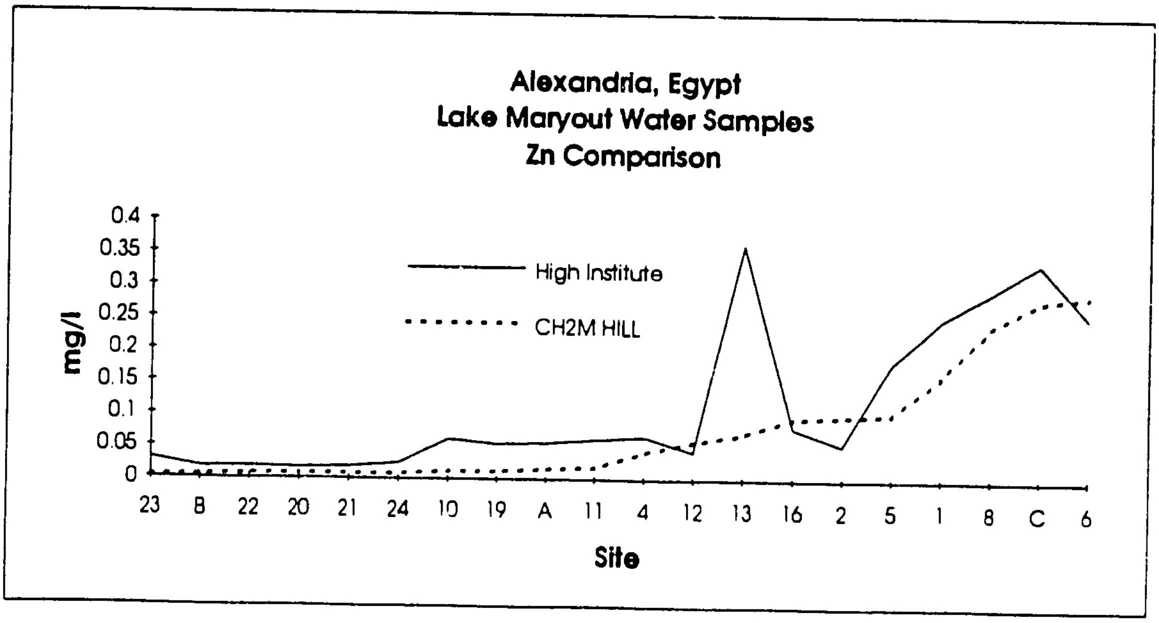

Alexandria, Egypt
Lake Maryout Water Samples
Cd Comparison
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
mg/l
High Institute
CH2M HILL
B 4 6 8 13 19 20 21 24 2 5 1 23 11 10 12 A C 16 22
Site

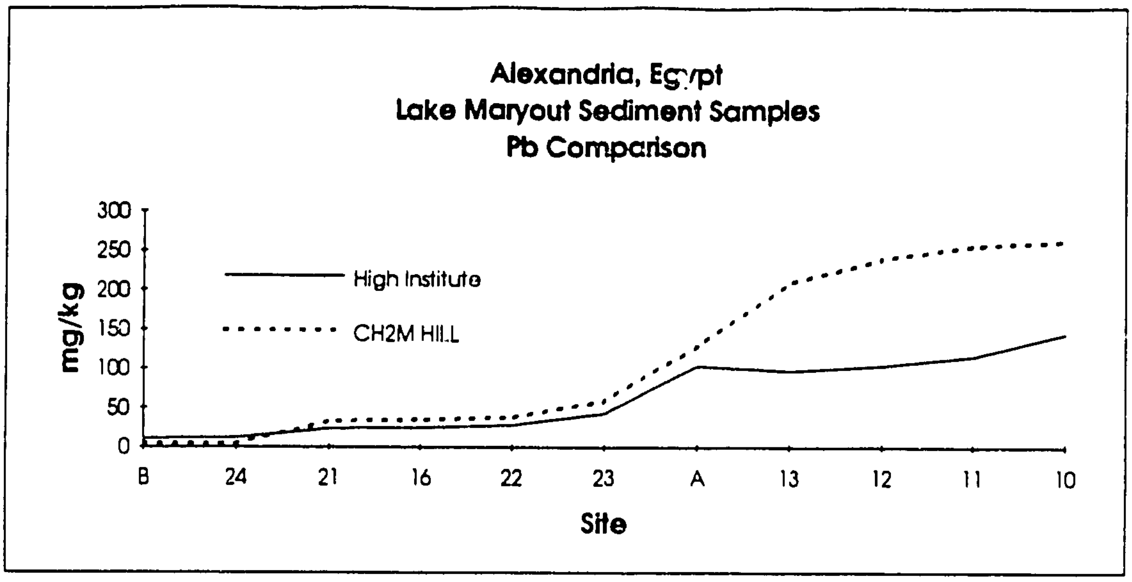

Alexandria, Egypt
Lake Maryout Water Samples
Cr Comparison
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
mg/l
High Institute
CH2M HILL
B 21 22 23 24 10 11 A 20 13 2 19 12 4 16 1 5 8 C 6
Site


Alexandria, Egypt
Lake Maryout Water Samples
Cu Comparison
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/l
High Institute
CH2M HILL
20 19 23 A B 10 22 24 13 21 4 2 12 16 5 C 6 8 11 1
Site

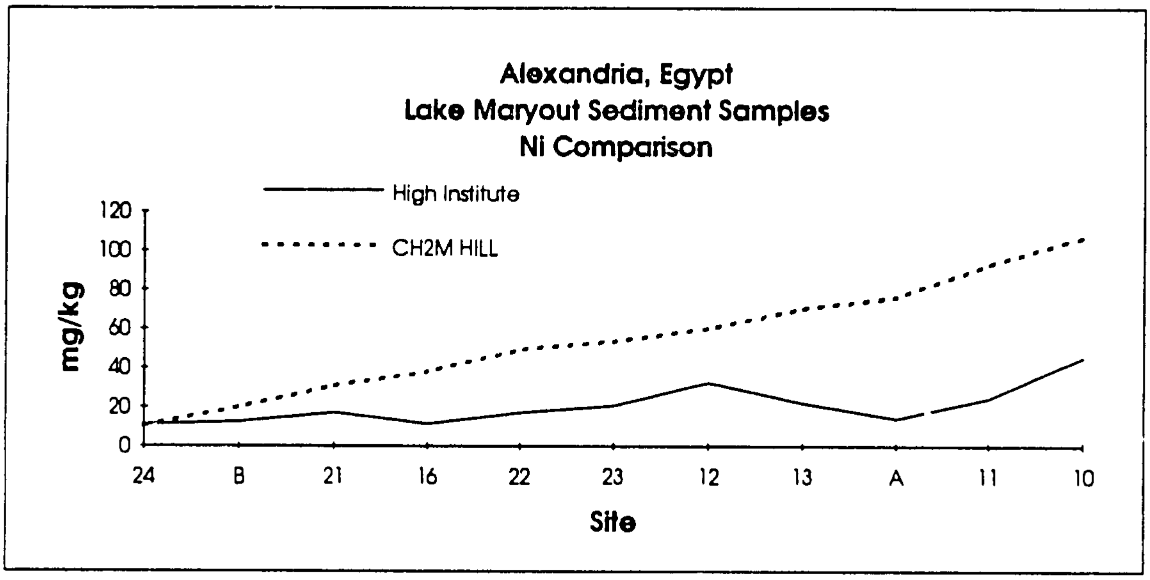

Alexandria, Egypt
Lake Maryout Water Samples
Pb Comparison


Alexandria, Egypt
Lake Maryout Water Samples
Ni Comparison

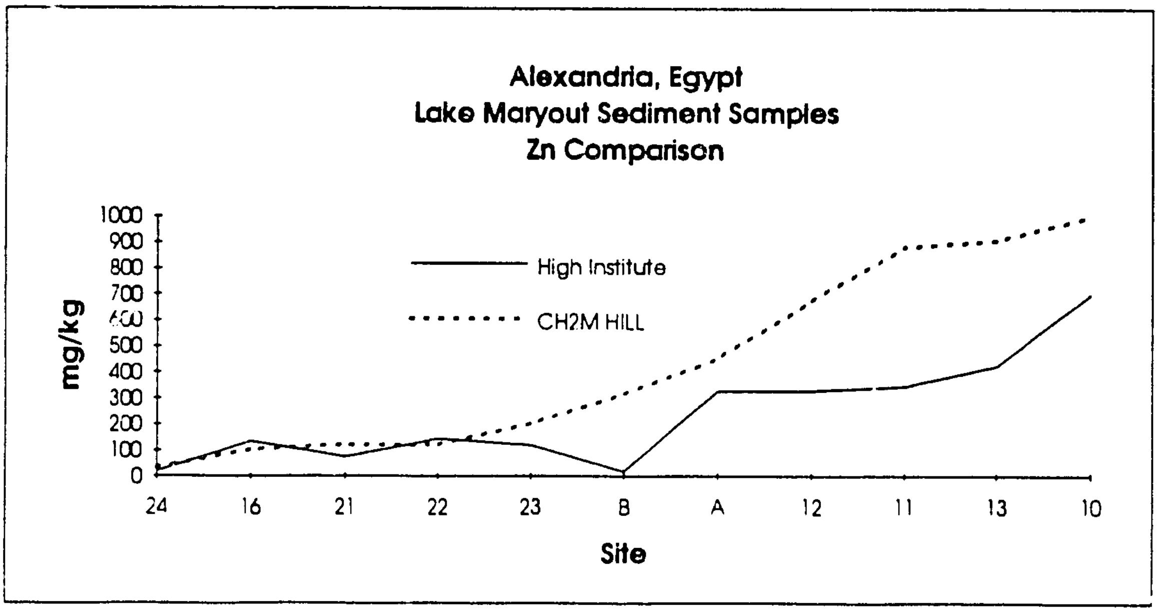

Alexandria, Egypt
Lake Maryout Water Samples
Zn Comparison



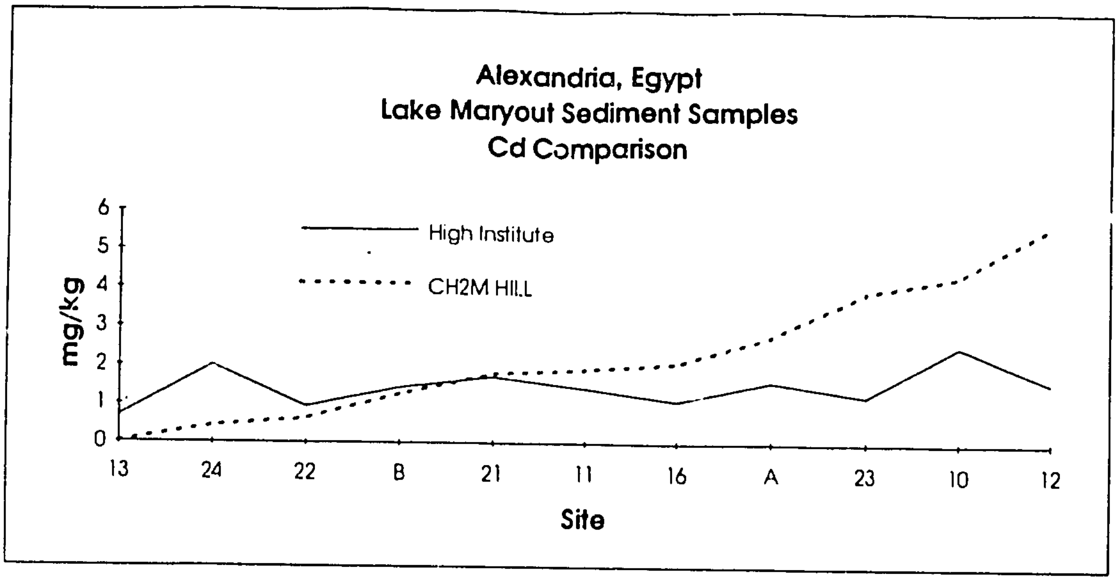
Alexandria, Egypt
Lake Maryout Sediment Samples
Pb Comparison

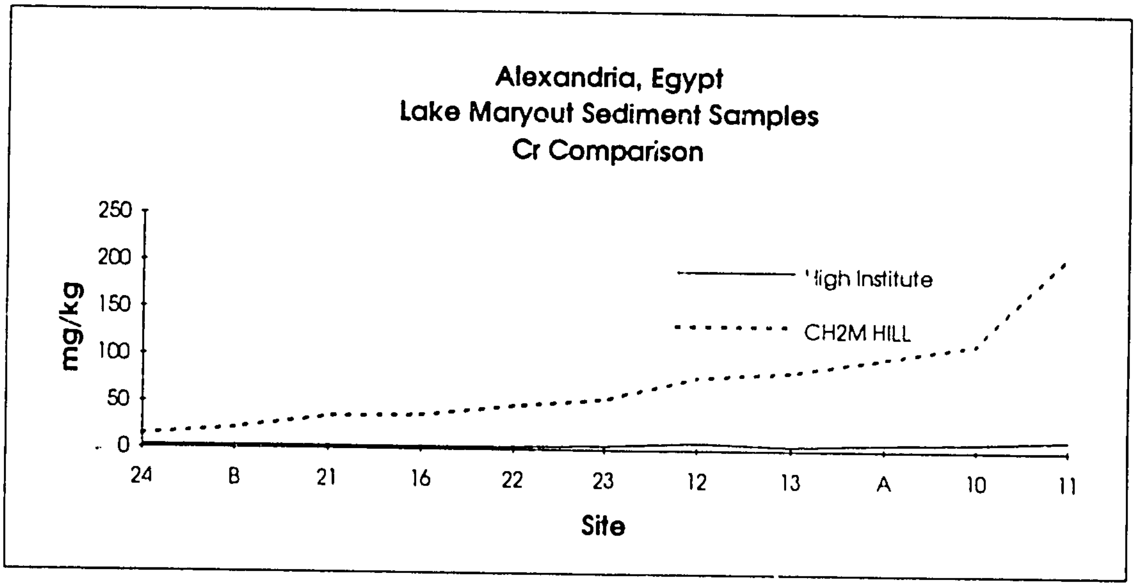


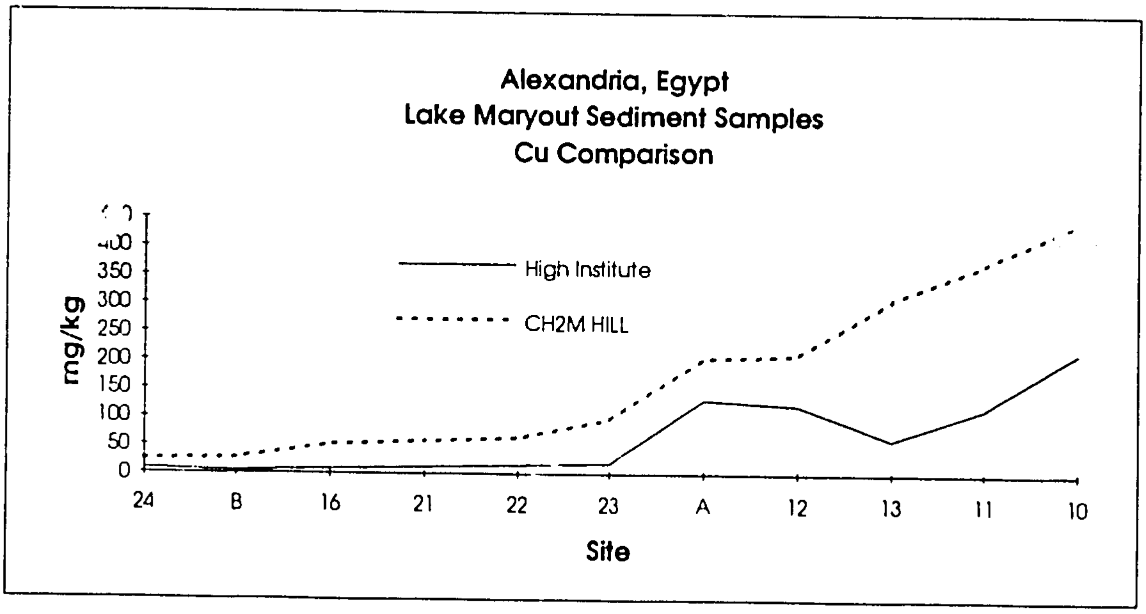
Alexandria, Egypt
Lake Maryout Sediment Samples
Ni Comparison



Alexandria, Egypt
Lake Maryout Sediment Samples
Zn Comparison


Alexandria, Egypt
Lake Maryout Sediment Samples
Cd Comparison
High Institute
CH2M HILL
mg/kg
0
1
2
3
4
5
6
13
24
22
B
21
11
16
A
23
10
12
Site


Alexandria, Egypt
Lake Maryout Sediment Samples
Cr Comparison
High Institute
CH2M HILL
mg/kg
0
50
100
150
200
250
24
B
21
16
22
23
12
13
A
10
11
Site


Alexandria, Egypt
Lake Maryout Sediment Samples
Cu Comparison
High Institute
CH2M HILL
mg/kg
0
50
100
150
200
250
300
350
400
24
B
16
21
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23
A
12
13
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Site

APPENDIX E
COMPUTER MODEL OF LAKE MARYOUT

APPENDIX E

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APPENDIX E - COMPUTER MODEL OF LAKE MARYOUT

Using the most recent data available, a computer model was created to simulate existing and future hydraulic conditions and concentrations of biochemical oxygen demand (BOD) in Lake Maryout. Model inputs included: flows proportional to those in 1983 and totalling equal to the design flow for the drains which discharge to the northern shore of the Main Basin (175 Ml/day), flows estimated in 1990 for the Omoun and Kalaa Drains, July 1990 - June 1993 flow data at El Mex pump station, and BOD and dissolved oxygen data from the 1992-1993 sampling program. This appendix provides a description of the Lake Maryout model. Model results are discussed in Chapter 6 of this report.

E.1 Hydraulics

To simulate the movement or exchange of flows and pollutant loads within Lake Maryout, the lake was divided into seven subareas (see Figures 6-1a and 6-1b). The subareas were defined using physical characteristics such as the Desert Road, the Noubaria Canal, and the Omoun Drain; locations of present and future discharges; and existing pollutant concentrations in the basin.

E.1.1 Model Structure

To keep the model simple, only the portion of the lake north of the Desert Road, where the wastewater discharges are located, was simulated. This area, consisting of the Main and Northwest Basins, was the focus of the 1992-1993 sample collection program. The Main Basin was split into four subareas, with an east-west division separating flows and loads of the northern wastewater outfalls from those of the Kalaa Drain. A north-south division in the Main Basin separates the Elmetras and Forn El Geraya outfalls from the Gheit El Enab and Industries outfalls. These divisions also isolate Basins 1 and 4, which will be the receiving waters for the West Treatment Plant (WTP) and East Treatment Plant (ETP) effluents, from Basins 2 and 3 which will not be receiving direct discharge of wastewater with the operation of the treatment plants. The Industrial drain, which bisects the Northwest Basin from southwest to northeast, divides the hydraulically distinct areas, Basins 5 and 6. Basin 7 is defined as the portion of the Noubaria Canal north of the intersection with the Omoun Drain. It was assumed that all flow from the Southwest Basin and the Omoun Drain enters the lake as a single point source. It was also assumed that no net hydraulic movement occurs between the Fishery Basin and the rest of the lake.

The model uses a water budget approach in which the flows into the lake (and subareas) were balanced with the flows out of the lake (and other subareas). Sources of inflow include wastewater outfalls and drains while outflow included evaporation, groundwater infiltration, and the El Mex pump station. Precipitation is neglected in the model because of its small magnitude. Runoff is also neglected because there is no data describing this and it is believed to be small in magnitude. Table 6-1 of this report presented the hydraulic characteristics of the lake model by subarea including: wet area, sources and magnitudes of inflow, locations and magnitudes of outflow, percent of flow assumed to move from one subarea to another, direction of net flow from one subarea to another, evaporation losses and groundwater infiltration losses. Evaporation losses were calculated based on the total wet area of each subarea, assuming an evaporation rate of 5 mm/day. Groundwater infiltration was assumed to occur in the basins farthest from the Mediterranean Sea (Basins 3, 4 and 6) at a rate proportional to each basin's surface area. Total groundwater infiltration was assumed to equal the difference between inflows to and outflows from the lake.

Where water from one subarea was expected to flow into multiple subareas, such as from Basin 4 to Basins 2 and 3, assumptions were made to reflect the exchange of water based on factors such as the direction of currents and the presence of physical barriers. It was assumed that all water from the Main Basin (Basins 1 through 4) ultimately flows west to the Noubaria Canal (Basin 7). Because higher flows are entering Basin 4 via the Kalaa Drain than are entering the northern portion of the Main Basin (Basins 1 and 2), it was also assumed that 30% of the flow from Basin 4 flow into Basin 2 while the remaining flow enters Basin 3. While these flows balance the overall water budget to the lake, they do not balance the large amounts of water lost from Basins 5 and 6 due to evaporation. Thus, it was also assumed that Basins 5 and 6 receive flow from the Noubaria Canal (Basin 7) and that all flow leaving Basins 5 and 6 occurs through evaporation.

E.1.2 Model Application

Simulation of Lake Maryout hydraulics was conducted for the cases of: existing flows, Phase I treatment plant flows with primary treatment, and Phase II treatment plant flows with primary and secondary treatment. Input flows associated with these scenarios are presented in Table E-1. Model predictions are presented in Tables E-2 through E-4. These tables present the flows which enter and exit the lake through point sources, flows lost due to evaporation, and exchange of flow with other basins. Positive values represent flows entering the system while negative values represent flows leaving the system. The major difference between the existing conditions (Table E-2) and Phase I design flows (Table E-3) is the elimination of raw wastewater outfalls discharging to Basins 1, 2 and 4, and the addition of primary effluent discharges to Basins 1 and 4. Table E-4 reflects the increased effluent discharges of Phase II to Basins 1 and 4.

E.2 BOD Concentrations

Current and future concentrations of BOD in the lake were simulated by another model which was interactive with the hydraulic model described above. A discussion of model results is presented in Chapter 6 of this report. It should be noted that because only limited water quality data was available and the validity of using 1983 flow data is suspect, the model provides order-of-magnitude predictions of BOD concentrations.

E.2.1 Model Structure

BOD concentrations in the seven model basins were simulated by calculating each component of the BOD load in a basin and dividing the sum of the components by the basin's outflow.

TABLE E-1. FLOWS AND POLLUTANT CONCENTRATIONS OF EXISTING AND FUTURE DISCHARGES TO LAKE MARYOUT

Scenario / Outfall	5	6	7	8	9	19
<u>Existing Conditions</u>						
Flow (Ml/day)	745[a]	60.2	45.2	34.8	34.8	6,621
BOD Conc. (mg/l)	344	1,009	225	236	139	557
TSS Conc. (mg/l)	653	2,178	402	927	306	1,262
<u>Phase I - Primary Treatment - Design</u>						
Flow (Ml/day)	734[b]	0	0	0	186[c]	6,621
BOD Conc. (mg/l)	277[d]	0	0	0	424[e]	557
TSS Conc. (mg/l)	515[f]	0	0	0	316[g]	1,262
<u>Phase II - Primary Treatment</u>						
Flow (Ml/day)	879[h]	0	0	0	475	6,621
BOD Conc. (mg/l)	291[i]	0	0	0	390[j]	557
TSS Conc. (mg/l)	470[k]	0	0	0	212[l]	1,262
<u>Phase II - Secondary Treatment</u>						
Flow (Ml/day)	879	0	0	0	475	6,621
BOD Conc. (mg/l)	114[m]	0	0	0	104[n]	557
TSS Conc. (mg/l)	372[o]	0	0	0	106[n]	1,262

Notes:

[a] Wastewater (410 Ml/day) estimated to be 55% of total flow; remaining flow (335 Ml/day) is agricultural (WWCG, 1992).
[b] Flow consists of ETP Phase I design flow of 410 Ml/day and 335 Ml day of agricultural flow minus 11 Ml/day sludge by-pass from ETP to WTP.
[c] Flow consists of WTP flow of 175 Ml/day and 11 Ml/day sludge by-pass from ETP to WTP.
[d] Flow-weight composite of ETP flow of 410 Ml day minus 11 Ml day (conc. of 401 mg/l) and agricultural flow of 335 Ml/day (conc. of 129 mg/l).
[e] Removal rates of 25% for WTP flow and 80% for ETP flow assumed.
[f] Flow-weight composite of ETP flow of 410 Ml/day minus 11 Ml/day (conc. of 272 mg/l) and agricultural flow of 335 Ml/day (conc. 804 mg/l); 50% removal of TSS.
[g] Removal rates of 60% for WTP flow and 50% for ETP flow assumed.
[h] Flow consists of ETP Phase II design flow of 544 Ml/day and 335 Ml/day of agricultural flow.
[i] Flow-weight composite of ETP flow of 544 Ml/day (conc. of 390 mg/l) and agricultural flow of 335 Ml/day (conc. of 129 mg/l).
[j] Removal rate of 25%.
[k] Flow-weight composite of ETP flow of 544 Ml/day (conc. of 265 mg/l) and agricultural flow of 335 Ml/day (conc. of 804 mg/l).
[l] Removal rate of 60%.
[m] Flow-weight composite of ETP flow of 544 Ml/day (conc. of 106 mg/l or 20% of 530 mg/l) and agricultural flow of 335 Ml/day (conc. of 129 mg/l).
[n] Existing flow-weighted concentration with removal rate of 80% applied.
[o] Flow-weight composite of ETP flow of 544 Ml/day (conc. of 106 mg/l or 20% of 530 mg/l) and agricultural flow of 335 Ml/day (conc. of 804 mg/l).

TABLE E-2. LAKE MARYOUT WATER BUDGET MODEL - EXISTING CONDITIONS

Basin	Inflow/ Outflow (m^3/day)	Evaporation (m^3/day)	Exchanges with Basins (m^3/day)							
			1	2	3	4	5	6	7	Subtotal
1	69,600	-21,449	0	248,516	0	0	0	0	-296,667	-48,151
2	105,400	-14,306	-248,516	0	0	157,422	0	0	0	-91,094
3	220,116	-20,741	0	0	0	367,319	0	0	-63,463	303,856
4	448,443	-15,035	0	-157,422	-367,319	0	0	0	0	-524,741
5	0	-32,052	0	0	0	0	0	0	32,052	32,052
6	-98,999	-9,328	0	0	0	0	0	0	136,661	136,661
7	-190,000	-1,416	296,667	0	63,463	0	-32,052	-136,661	0	191,417
Total	114,328	-114,328	48,151	91,094	-303,856	524,741	-32,052	-136,661	-191,417	0

TABLE E-3. LAKE MARYOUT WATER BUDGET MODEL - PHASE I PRIMARY TREATMENT - DESIGN FLOWS

Basin	Inflow/ Outflow (m^3/day)	Evaporation (m^3/day)	Exchanges with Basins (m^3/day)							
			1	2	3	4	5	6	7	Subtotal
1	186,000	-21,449	0	153,516	0	0	0	0	-318,067	-164,551
2	0	-14,306	-153,516	0	0	167,822	0	0	0	14,306
3	-220,116	-20,741	0	0	0	391,586	0	0	-150,729	240,857
4	574,443	-15,035	0	-167,822	-391,586	0	0	0	0	-559,408
5	0	-32,052	0	0	0	0	0	0	32,052	32,052
6	-98,999	-9,328	0	0	0	0	0	0	108,327	108,327
7	-327,000	-1,416	318,067	0	150,729	0	-32,052	-108,327	0	328,417
Total	114,328	-114,328	164,551	-14,306	-240,857	569,408	-32,052	-108,327	-327,417	0

TABLE E-4. LAKE MARYOUT WATER BUDGET MODEL - PHASE II PRIMARY AND SECONDARY TREATMENT

Basin	Inflow/ Outflow (m^3/day)	Evaporation (m^3/day)	Exchanges with Basins (m^3/day)							
			1	2	3	4	5	6	7	Subtotal
1	475,000	-21,449	0	197,016	0	0	0	0	-650,567	-453,551
2	0	-14,306	-197,016	0	0	211,322	0	0	0	14,306
3	-220,116	-20,741	0	0	0	493,086	0	0	-252,229	240,857
4	719,443	-15,035	0	-211,322	-493,086	0	0	0	0	-704,408
5	0	-32,052	0	0	0	0	0	0	32,052	32,052
6	-98,999	-9,328	0	0	0	0	0	0	108,327	108,327
7	-761,000	-1,416	650,567	0	252,229	0	32,052	-108,327	0	762,417
Total	114,328	-114,328	453,551	-14,306	-240,857	704,408	-32,052	-108,327	-762,417	0

The model included those components which contribute to the total BOD load:

- Input BOD loads
- Sediment resuspension
- Sediment oxygen demand (SOD)

and those which counteract the effects of BOD:

- Surface reaeration
- Input dissolved oxygen (DO) loads

Assumptions used to calculate the components of BOD are described below.

Input BOD Load - The total BOD loads entering each basin were calculated by summing the products of flows entering the basin and BOD concentrations associated with each flow:

$$\text{Input BOD Load} = \Sigma Q_{in} * L_{in}$$

where:
Q_{in} = flow entering the basin
L_{in} = concentration of BOD in the flow

Input flows included wastewater outfalls and agricultural drains as well as net movement of flow from one basin to another.

Sediment Resuspension - Sediment resuspension was included in the BOD model to help account for the discrepancy between input and output pollutant loads (discussed in detail in Chapter 2 of this report). The amount of BOD exerted as a result of resuspension of sediments was calculated using the following expression:

$$\text{Sediment Resuspension} = K_1 * BOD_{sed} * V$$

where: K_l = resuspension rate = B ÷ period of decay
= oxidizable organic content of suspended solids (assumed to be 0.6) * stoichiometric ratio of oxygen to sediment (equal to 1.07) * decay coefficient (assumed to be equal to 1/3 of BOD deoxygenation rate, or 0.08/day)
= 0.05136/day
BOD_{sed} = concentration of BOD in sediment
V = volume of overlying water

Sediment Oxygen Demand - The exertion of sediment oxygen demand on the overlying waters was simulated by the equation:

$$\text{Sediment Oxygen Demand} = K_s * A$$

where: K_s = sediment oxygen uptake rate
A = area over which SOD is exerted

Because most of the raw wastewater solids discharged to the lake have likely settled and accumulated at the lake's bottom, the sediment oxygen demand of Lake Maryout is probably higher than the demand of typical lake sediments. It is unlikely that the full impact of the sediment's oxygen demand is realized, however, since the lake's anoxic conditions probably inhibit full exertion of the SOD. Therefore, an sediment oxygen uptake rate of 0.2 g/m^2/day was input to the model. This value was obtained by examining several methods for calculating SOD rates under conditions of low dissolved oxygen concentrations (U.S. EPA, 1985).

Surface Reaeration - The net flux of oxygen from the atmosphere to the water was calculated by:

$$\text{Surface Reaeration} = (DO_{sat} - DO) * K_2 * V$$

where: DO_{sat} = saturation dissolved oxygen concentration
DO = measured dissolved oxygen concentration
K_2 = reaeration flux rate
V = volume

An assumed reaeration flux rate of K_2 of 4/day (obtained from literature review, U.S. EPA, 1985) was input to the equation.

Input Dissolved Oxygen Load - The total dissolved oxygen loads entering each basin were calculated by summing the products of flows entering the basin and DO concentrations associated with each flow:

$$\text{Input Dissolved Oxygen Load} = \Sigma\, Q_{in} * DO_{in}$$

where:

Q_{in} = flow entering the basin

DO_{in} = concentration of dissolved oxygen in the flow

Input flows included point sources and net movement of flow between basins. In all cases, contribution of oxygen to the system from input DO loads was minimal since measured DO concentrations in the lake were often close to zero mg/l.

The Lake Maryout BOD model simulates concentrations of soluble BOD, however, BOD concentrations measured during the 1992-1993 sampling program include both soluble and particulate BOD. The relationship between measured 5-day BOD and soluble BOD concentrations can be expressed as:

$$BOD_5 = (A * L_{sol}) + (B * TSS)$$

where:

BOD_5 = 5-day measured BOD concentration

A = ratio of BOD_5 concentration to ultimate BOD concentration (BOD_{ult}) = 0.6329 (assuming temperature = 17 degrees C and K_D = 0.23/day)

L_{sol} = concentration of soluble BOD

B = oxidizable organic content of suspended solids (assumed to be 0.6) * stoichiometric ratio of oxygen to sediment (equal to 1.07) * decay coefficient (assumed to be equal to 1/3 of BOD deoxygenation rate, or 0.08/day) * period of decay (5 days) = 0.2568

TSS = concentration of total suspended solids

Thus, to be compatible with the other components of predicted BOD load, measured 5-day BOD concentrations were converted to soluble BOD prior to being used to calculate input BOD loads. Although analysis of suspended solids was not included in the 1992-1993 sampling program, concentrations of suspended solids were obtained by calculating the difference between total solids and dissolved solids concentrations. Then, once the components of the BOD loads were calculated and summed, the model-predicted soluble BOD was converted to soluble and particulate BOD, to allow comparison of measured and predicted BOD concentrations.

E.2.2 Model Application

The Lake Maryout BOD model was calibrated by comparing predicted BOD concentrations for existing flows and loads to measured BOD concentrations in the lake. Input BOD concentrations, measured in samples collected from the wastewater and agricultural discharges, are presented in Table E-1. BOD concentrations used to simulate future conditions are also presented in Table E-1. Results of the simulation of existing and future concentrations of BOD in Lake Maryout are presented in Tables E-5 through E-8. These tables present predicted BOD concentrations for each model basin as well as the loads of oxygen demand or supply contributed to the system by each of the components discussed above.

Comparison of measured and simulated BOD concentrations for existing conditions indicates that the concentrations are in close agreement in the Main Basin (Basins 1 through 4) and in the Northwest Basin (Basins 5 and 6) (Table E-5). BOD concentrations are over-predicted in Basin 7 in comparison to the El Mex pump station measurements. The reason for this discrepancy may be that the measurements were conducted on samples collected some distance downstream from the pumping station. Indeed, the outlet BOD concentration should be comparable to the BOD concentration in the lake itself. The total BOD load to the lake is expected to be similar for existing, Phase I - primary treatment and Phase II - primary treatment conditions. Thus, little or no change in lake BOD concentrations is expected to occur with the implementation of either Phase I (Table E-6) or Phase II (Table E-7) with primary treatment. Some improvement in lake BOD concentrations could be expected with the implementation of secondary treatment, however, the improvement would likely be minimal (Table E-8). Implementation of wastewater treatment will not affect the flows or loads discharging to the Fishery and Southwest Basins, water quality is not predicted to be affected in these areas.

TABLE E-5. RESULTS OF LAKE MARYOUT BOD MODEL - EXISTING CONDITIONS

Basin	Measured BOD (mg/l)	Predicted BOD (mg/l)	Components of BOD					Outflow (m^3/day)
			Input BOD Loads (kg/day)	Resuspen (kg/day)	Surface Reaerate (kg/day)	SOD Exertion (kg/day)	Input DO Loads (kg/day)	
1	492	433	129,680	131,547	-166,445	858	-17	296,667
2	537	509	98,608	102,331	-111,016	572	-36	248,516
3	395	240	42,082	122,964	-160,949	830	0	346,578
4	359	299	146,086	79,087	-116,669	601	0	729,965
5	738	788						0
6	738	788						127,333
7	111	788	2,600,316	20,046	-10,992	57	0	6,981,130

TABLE E-6. RESULTS OF LAKE MARYOUT BOD MODEL - PHASE I PRIMARY TREATMENT - DESIGN FLOWS

Basin	Predicted BOD (mg/l)	Components of BOD					Outflow (m^3/day)
		Input BOD Loads (kg/day)	Resuspen (kg/day)	Surface Reaerate (kg/day)	SOD Exertion (kg/day)	Input DO Loads (kg/day)	
1	506	168,194	131,547	-166,445	858	-88	318,067
2	439	47,098	102,331	-111,016	572	0	153,516
3	258	53,093	122,964	-160,949	830	0	370,845
4	281	123,091	79,087	-116,669	601	0	718,965
5	790						0
6	790						98,999
7	790	2,663,665	20,046	-10,992	57	0	7,089,796

TABLE E-7. RESULTS OF LAKE MARYOUT BOD MODEL - PHASE II PRIMARY TREATMENT

Basin	Predicted BOD (mg/l)	Components of BOD					Outflow (m^3/day)
		Input BOD Loads (kg/day)	Resuspen (kg/day)	Surface Reaerate (kg/day)	SOD Exertion (kg/day)	Input DO Loads (kg/day)	
1	540	343,619	131,547	-166,445	858	-238	650,567
2	466	66,415	102,331	-111,016	572	0	197,016
3	300	88,893	122,964	-160,949	830	0	472,345
4	314	186,380	79,087	-116,669	601	0	863,965
5	796						0
6	796						98,999
7	796	2,905,296	20,046	-10,992	57	0	7,523,796

TABLE E-8. RESULTS OF LAKE MARYOUT BOD MODEL - PHASE II SECONDARY TREATMENT

Basin	Predicted BOD (mg/l)	Components of BOD					Outflow (m^3/day)
		Input BOD Loads (kg/day)	Resuspen (kg/day)	Surface Reaerate (kg/day)	SOD Exertion (kg/day)	Input DO Loads (kg/day)	
1	333	130,903	131,547	-166,445	858	-238	650,567
2	372	37,187	102,331	-111,016	572	0	197,016
3	239	36,227	122,964	-160,949	830	0	472,345
4	176	-2,425	79,087	-116,669	601	0	863,965
5	783						0
6	783						98,999
7	783	2,746,986	20,046	-10,992	57	0	7,523,796

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Waste Water Consultant Group, 1992. Alexandria Wastewater Program Master Plan Update-1992, prepared for the Alexandria General Organization for Sanitary Drainage.