

FINAL REPORT
ON
MANAGEMENT OF RUNOFF FROM HIGHWAY BRIDGES

by

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Submitted to

FLORIDA DEPARTMENT OF TRANSPORTATION
Tallahassee, Florida

Contract No. 99700-7198

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ACKNOWLEDGEMENTS

The authors wish to acknowledge with gratitude the assistance of the many individuals who helped make this investigation possible.

Special acknowledgements are extended to FDOT personnel for their financial support and technical assistance. The interest and assistance of Messers Gary Evink, Larry Barfield and Herbert H. Zebuth are most gratefully appreciated.

Appreciation is also extended to Mr. Harvey Harper for his assistance in the field sampling and laboratory analysis. The assistance given by several UCF students in collecting samples and laboratory studies made this study possible and is deeply appreciated.

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SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This research project was conducted to investigate the impact of highway bridge runoff on adjacent receiving water bodies by researchers from the Department of Civil Engineering and Environmental Sciences at the University of Central Florida (UCF) and the Florida Department of Transportation (FDOT). Two sampling sites on Interstate-4 in Orange County, Florida were selected for this study. The Lake Ivanhoe site was ideal because of the two existing sets of bridges. The north bridges, without scupper drains, discharge the runoff water through swales to adjacent flood plains and the south bridges discharge runoff water directly to Lake Ivanhoe through scupper drains. The Ivanhoe site made it possible to examine the lake impacts due to direct discharge of bridge runoff through scupper drains. At the Maitland Interchange site, the highway runoff water is drained to detention ponds which flow through a culvert to Lake Lucien. It was possible to examine removal efficiencies of highway pollutants by detention ponds.

Four sampling locations were selected at each site. Lake Ivanhoe sampling locations included: beneath one set of scupper drains on the east side of south bridges, S-1, beneath another set of scupper drains between the two south bridges, S-2, beneath the two north bridges without scupper drains, S-3, and from the open lake as control, S-4. Maitland Interchange sampling locations included: the east pond which drains into the west pond, S-1; the west pond which flows through a culvert to Lake Lucien, S-2; the outfall of the west pond in Lake Lucien, S-3; and open Lake Lucien control section, S-4. Eight different sets of water, bottom sediments, plants and benthic organisms were collected from various sampling stations between February and August 1979. Sampling of plants and benthos was not uniform since it was impossible to sample the same species from all stations at the same sampling time. The samples

collected were processed and analyzed for physical, chemical and biological parameters at the Environmental Engineering and Sciences Laboratory at UCF, Orlando, Florida. Emphasis was given to the heavy metal content of Zn, Pb, Cu, Ni, Fe and Cr which are most often associated with highway runoff. The results were statistically analyzed to determine if significant differences existed between samples collected from various locations. The following conclusions were reached:

1. Runoff water through scupper drains contained several times higher concentrations of Zn, Pb, Ni and Fe than average concentrations in Lake Ivanhoe water. Lead and iron were mainly in particulate form and the dissolved fraction in the runoff samples accounted only for 12 percent of the total content of either lead or iron.
2. The total lead in bridge runoff released through scupper drains to Lake Ivanhoe was estimated to be 13.5 kilograms Pb/year and the dissolved fraction to be 1.6 kilograms Pb/year.
3. Heavy metal concentrations were evenly distributed throughout the west section of Lake Ivanhoe water body where sampling took place, since no significant differences existed between the stations sampled. The soluble fraction averaged 43.4% of total heavy metals tested in the water column of Lake Ivanhoe.
4. The data showed that the water column in the west pond, S-2, at Maitland Interchange contained the highest average Pb, Fe and Cr concentrations of all stations tested. Also, Pb concentrations in the west pond were higher than the concentrations in the water column of the east pond, S-1, and Lake Lucien control, S-4, by an amount that was significant at the 99% confidence level.
5. Lead associated with particulates averaged 88% of the total lead in runoff water released through scupper drains. The dense lead

particles are most likely to settle out from the water column close to the point of release and become immobilized by the bottom sediments.

6. Analysis of the sediment samples showed that there were no significant differences in concentrations of heavy metals for the two stations located underneath the scupper drains on the south bridges of Lake Ivanhoe. However, the t-test analysis showed that the concentrations of heavy metals most often associated with highway runoff, Pb, Fe, Cr, Ni and Zn were significantly higher in samples taken under the scupper drains as compared to those from beneath the north bridges without scupper drains.
7. The bottom sediments in the west pond, S-2, at Maitland Interchange showed higher concentrations Pb, Cr, Ni, Fe and Cd at confidence level better than 95%, as opposed to bottom sediments from either the east pond, S-1, or the control station in Lake Lucien, S-4.
8. Most of the heavy metals at both Lake Ivanhoe and Maitland Interchange sites were associated with the bottom sediments. For example, Pb averaged 98.7, 0.5 and 0.7 percent in the bottom sediments, dissolved fraction and particulate fraction of the water column respectively for both study sites. Similar results were detected for Fe, Cu, Zn, Ni and Cr. Also, the total mass of heavy metals associated with biota was considered insignificant and did not enter into the calculations of the relative distribution per unit area.
9. Spirogyra showed higher concentration factors for Cu, Fe and Pb than Hydrilla, Chara and Typha in Lake Ivanhoe. Also Hypericum exhibited the highest concentration factors for Pb, Fe, Cu, Ni, Zn and Cd in Maitland Interchange site. It appears that Spirogyra and/or Hypericum

could be used as indicators for detecting highway runoff pollutants.

10. Spirogyra and Hydrilla showed significantly higher concentration of heavy metals in samples taken beneath the scupper drains as opposed to those collected from the bridges without scuppers.
11. It appeared that Annelida (Oligochaeta, Tubifex) concentrated more Zn, Pb and Cr than other organisms tested in Lake Ivanhoe. Also, Annelida (Oligochaeta, Tubifex and Hirudinea) showed the highest average concentration factors for Ni, Cu, Fe, Pb and Cr in the Maitland Interchange site. The results suggest that the phylum Annelida could be used as an indicator for detecting heavy metals for highway runoff.
12. Significant differences in heavy metal concentrations in benthic organisms collected from various stations were difficult to detect due to a combination of factors including: sampling non-uniformity, number of samples taken from each station for the same organism, total weight of organisms available for analysis, and the scarcity of organisms collected from many of the stations.

RECOMMENDATIONS

When highways pass over water bodies, especially land-locked impoundments where the effects of heavy metal pollution are more localized and where high traffic volumes are encountered, it is recommended that:

1. The use of scupper drains in highway bridges should be limited as much as is feasibly possible.
2. Runoff from the bridge surface may be directed off the bridge surface toward either side so that the runoff will experience the maximum overland flow to encourage percolation and removal by the soil before reaching the receiving body.

3. Future research should be conducted to determine the extent of the required floodplain adjacent to the bridge to assimilate heavy metals without causing detrimental effects to the existing environment.

Where detention/retention systems are used in conjunction with highways for the control and storage of runoff before discharging this runoff into a receiving water body and where heavy metal removal is desired:

1. Control structures should be installed to insure that heavy metals are not released to the receiving water body during periods of no flow by leakage between the ponds and the receiving water.
2. Natural vegetative canals should be used whenever possible to convey water from the detention/retention pond to the receiving water body to provide an additional amount of settling out and adsorption of heavy metals by the sediments before introduction of the runoff into the main body of the receiving water.
3. Simple treatment units such as sand filters or limestone beds could be installed at the ponds' outfall to receiving water body to minimize the release of heavy metals into the lake or stream.
4. Further research should be conducted to develop construction practices and management schemes for these detention/retention ponds to maximize removal of heavy metals. Consideration should be given here to the types of sediments affording the greatest degree of removal and the role and best types of plants that might be introduced to increase heavy metal removal.

CHAPTER I

INTRODUCTION

Currently, there are increasing concerns, both legal and environmental, that must be considered when building highway bridges above or adjacent to water bodies. Environmental impact assessment studies are required to satisfy guidelines for State and local agencies; U.S. Army Corps of Engineers permit procedures and Section 4 (F) of the U.S. Department of Transportation Act as amended (Shuldiner and Cope, 1979). Federal, State and local authorities will intercede in any land-use decision that adversely affects regulated water bodies.

Highway bridges runoff contain large concentrations of lead, zinc, copper, iron, chromium, and cadmium which will magnify in the adjacent environment to the edge of the pavement (Pitt and Arny, 1973; Sartor and Boyd, 1972). Wanielista et al. (1978) concluded a study for Florida Department of Transportation (FDOT) which indicated that most of the metals from stormwater runoff were being retained in the soils adjacent to highway bridges.

Shuldiner and Cope (1979) developed a user's manual containing summaries of the literature review and case studies to be utilized in determining potential biological effects of highway construction activity on adjacent aquatic environment. From their manual, major and or variable impact on turbidity, sedimentation and chemical pollution results from pile supported roadway or bridging construction, maintenance and use. Also, minor impacts due to modification of circulatory patterns of surface water flows will be noticed. The biological responses resulting from these physical impacts include change in

plant species composition, change in primary and secondary productivity and in some cases, sudden mortality of aquatic species.

Available information on impact of highway bridges runoff and definition of cause and response are mainly qualitative and the FDOT has the responsibility to convince the environmental agencies with their qualitative evaluation. Quantitative data are scarce or non-existent and the environmental agencies often contest FDOT evaluations. The FDOT urgently needs better information about specific impacts of bridging to adjacent environment in order to avoid considerable project development delays. From existing work, the environment adjacent to highway bridges are conjectured to be possible sinks of metals and macro-nutrients. Thus, it is speculated that bridge runoff can be stored, treated or managed as much as possible to minimize adverse effects to surrounding water, land and biota.

OBJECTIVES

FDOT had contracted with researchers from Department of Civil Engineering and Environmental Sciences, College of Engineering, UCF at Orlando, Florida to determine the effectiveness of the aquatic environment (water, land, plant and resident animal environment) under and near highway bridges for the assimilation of highway runoff. Specific activities were designed to answer the following questions.

1. What are the concentrations and mass of metals in the environments under scupper drains?
2. Can a preliminary screening model be developed to determine water quality concentrations of metals, organics and inorganics in water quality limited river sections?
3. If water quality is limited and scupper discharges are projected to

have violated the water quality standards, what are alternative designs for stormwater management?

To answer these questions the following research activities were developed to insure a logical progression and maintenance of control to meet the objectives:

1. Two sites, namely Lake Ivanhoe and Maitland Interchange sites, were selected for sampling collection and analysis.
2. Eight separate field visits were made for each site during February August, 1979. During each visit, field analysis including turbidity DO and temperature profiles were measured. Also, samples of water, bottom sediments, plants and benthos were carried back to the Environmental Engineering and Sciences laboratory, College of Engineering UCF for physical, chemical and biological analyses.
3. Bridge runoff samples through scupper drains were collected and analyzed.
4. Comparison was made between aquatic environment beneath bridges with scupper drains and those beneath bridges without scupper drains.
5. Attempts were made to evaluate existing detention/retention ponds at the Maitland Interchange site for stormwater management.
6. Quantitative analysis of bridge runoff impacts were assessed, recommendations were developed for proper management of stormwater.

CHAPTER II

LITERATURE REVIEW

The impact of point and non-point sources of pollution on water quality parameters within receiving water bodies has attracted the attention of many investigators and planners, especially as a result of Public Law 92-500, Sections 201 and 208. Urban stormwater runoff has been identified as a major pollution source and many authors have shown that concentrations of certain constituents, such as heavy metals and nutrients, greatly exceed those found in secondary effluent discharges (Rimer, 1978; Helsel, et al., 1979; Sartor and Boyd, 1974). Heavy metals are a major constituent of urban stormwater runoff and their sources, distribution, types, modes of transport, and fate in receiving waters will be discussed here.

SOURCES OF HIGHWAY CONTAMINANTS

Pope, et al. (1978) listed several sources of roadway contaminants which include: road surface degradation, vehicle lubrication system losses, vehicle exhaust emissions, load losses from vehicles, degradation of automobile tires, road surface cleaning/deicing and rainfall. Paint used on highway markings (Bell and Wanielista, 1979) and corrosion of building materials (Malmquist 1978) were also given as possible sources of heavy metals in urban stormwater runoff. The heavy metals most often mentioned in relation to highway sources are lead, iron, zinc, chromium, copper and nickel.

The principle source of lead is the use of leaded fuels by highway vehicles. Tetramethyl and tetraethyl lead are added to gasoline as anti-knock ingredients in concentrations ranging from 550 mg/l in the U.K. to 150 mg/l in

West Germany (Laxen and Harrison, 1977). Cadmium and manganese are also receiving attention as constituents of stormwater runoff. Cadmium is thought to originate from the wearing of automobile tires (Hosie, et al., 1978). Manganese is beginning to show up in greater concentrations in highway runoff because of its use as an antiknock ingredient in gasoline in some areas instead of lead. Manganese pollution has been related to traffic density and manganese concentrations measured at two tunnels on the Pennsylvania Turnpike in 1977 showed emissions to be 0.08 mg Mn/kg fuel combusted or about 15% of the manganese in the fuel burned (Pierson, et al., 1978; Joselow, et al., 1978).

Zinc is used in high concentrations as a stabilizer in motor oil and as a filler in tires. Copper which is used to increase the mechanical strength heat dissipation properties of brake linings is deposited as a result of brake wear. Copper, nickel, and chromium result from wearing of metal plating, bearings, bushings, and moving parts within the engine. Malmquist (1978) found in a study of heavy metals in precipitation and resultant runoff that the fallout accounted for only 7% of the copper and 30% of the zinc in the runoff. He concluded that the differences in the copper and zinc could be attributed to the corrosion of building materials which may be another important source of heavy metals especially in urban runoff.

Evidence had been presented suggesting that motor vehicles and their use provide sources of heavy metal contaminants. Recent findings help to support the premise that highway activity contributes hourly to heavy metal pollution. Studies of heavy metal concentrations in snow samples taken adjacent to streets and highways had shown that concentrations were related to traffic volume. Oliver (1974) found that lead levels in snow taken from city streets were roughly proportionate to traffic volume and this was also reflected in the data presented by Malmquist (1978) as shown in Table 2-1.

TABLE 2-1. CONCENTRATIONS OF HEAVY METALS IN URBAN SNOW
(After Malmquist, 1978)

| Population Density P/ha | Sampling Site | Pb μg/l | Zn μg/l | Cu μg/l |
|----------------------------|---------------------|------------|------------|------------|
| 250 | Grass Surface | 250 | 360 | 50 |
| 250 | Street 7400 veh/day | 2610 | 1030 | 390 |
| 115 | Grass Surface | 40 | 50 | 10 |
| 115 | Street 3600 veh/day | 730 | 330 | 70 |
| 22 | Grass Surface | 40 | 60 | 10 |
| 22 | Street 1500 veh/day | 730 | 330 | 120 |

The data showed that traffic volume was not the controlling factor below a certain level (3600 veh/day) probably due to non traffic related activities and sources. Linear relationships were formulated using the data:

$$C(\text{q-Pb/l}) = 730 \mu\text{q/l} + 0.495 (\# \text{ veh/day})$$

$$C(\text{q-Zn/l}) = 330 \mu\text{q/l} + 0.271 (\# \text{ veh/day})$$

$$C(\text{q-Cr/l}) = 70 \mu\text{q/l} + 0.084 (\# \text{ veh/day})$$

Lazrus, et al. (1970) determined heavy metal concentrations found in precipitation collected in a nationwide network. Lead loading in precipitation (q/ha/cm) were correlated to sale of gasoline (10^3 dollars) in the locale of the sampling station.

The loading intensity of heavy metals as a function of traffic volume had been predicted using linear regression analysis of data collected in the Washington, D.C. metropolitan area (Shaheen, 1975). A linear relationship was derived ($Y = mX + b$) in which Y was the predicted loading intensity (lb/mile); m was the loading factor (lb/axle-mile); x was the traffic volume during the period of depositions (axles); and b represented the contribution from non-traffic related activities. The values of the slope and intercept were summarized in Table 2-2.

TABLE 2-2. CORRELATION BETWEEN HEAVY METAL LOADING INTENSITY AND TRAFFIC VOLUME (After Shaheen, 1975)

| Parameter | m (lb/axle-mile) | b lb/mile | Significance of Correlation (%) |
|-----------|-----------------------|--------------|------------------------------------|
| Pb | 2.79×10^{-5} | -.345 | 0.1 |
| Cr | 1.85×10^{-7} | .011 | 1 |
| Cu | 2.84×10^{-7} | .0121 | 1 |
| Ni | 4.40×10^{-7} | .00323 | 0.1 |
| Zn | 3.5×10^{-6} | .0341 | 0.1 |
| Cd | 3.11×10^{-8} | .000909 | 10 |

Helsel, et al. (1979), determined that a good non-linear correlation existed between concentrations of Pb, Zn and Cr and traffic volume and percent impervious cover. Indicating that vehicles are a major source of these metal and that impervious areas deliver these pollutants to the drainage systems efficiently.

CHARACTERISTICS OF HIGHWAY CONTAMINANTS

Shaheen (1975) investigated the origin of several metals related to the operation of motor vehicles. The origin and nature of lead had been investigated extensively because of its toxicity and large concentrations being found in non-point source studies. Unfortunately, the other heavy metals associated with stormwater runoffs have not been very well characterized.

Small amounts of the tetraalkyl lead compounds are lost by evaporation or pass through the exhaust system uncombusted. Ganley and Springer (1974), Habibi (1973) and Ter Haar, et al. (1972) showed that the majority of the lead was emitted in particulate form and the percentage being controlled by the speed of the engine and the driving mode. Ganley and Springer (1974) determined that the percentage of lead compounds emitted in particulate was close

45.7% by weight at normal cruise speeds, 55-60 mph, and exhaust gas temperatures of 90°F. Also, the percentage of lead emitted tended to increase with increased speed. Hirschler and Gilbert (1964) showed that great extremes in the percentage of lead emitted existed and this percentage increased during full throttle acceleration. Ter Haar, et al. (1972) concluded that the lead emission rate was 0.028 g/mi using emission data collected from a fleet of 25 cars model 1966 under the Federal Cycle conditions.

Several investigators reported three size ranges for lead particulate emissions (Ter Haar, et al., 1972; Ganley and Springer, 1974; Habibi, 1973). Particles from 0.5 - 1.5 microns diameter were derived directly from the combustion chamber. Particles from 1.5 - 5.0 microns contained a negligible amount of lead particulates. Particles in this size range were deposited within the exhaust system where they grew in size and were later reentrained. Particles greater than 5 microns were considered to be composed of those particles that were reentrained after deposition in the exhaust system, under conditions favoring reentrainment, such as rapid acceleration and high engine speed. The exact percentage of a given size that was emitted tended to vary according to changes in speed, driving mode, exhaust temperature, gasoline additives, and car mileage with the ratio of fine to coarse particles decreasing under high speed and high load conditions (Hirschler and Gilbert, 1964), similar to those experienced in city type driving. It is realized that particles less than one micron will remain suspended in the atmosphere, whereas particles greater than five microns will settle out close to the roadway due to turbulent impaction, impingement and gravitational settling.

The chemical composition of the lead particulates being emitted depended upon the length of time they spent in the exhaust system and the types of fuel additives used. The majority of the lead emitted was in the form of PbClBr and

$PbCl_2 \cdot PbClBr$ when ethylene dichloride and ethylene dibromide was added to the fuel as lead scavenging agents as was the case of commercial leaded gasoline (Ganley and Springer, 1974). The lead salt, $2PbBrCl \cdot NH_4Cl$, was mainly associated with particles less than two microns in diameter and results from the mixing and cooling of the exhaust gases in the ambient air. The larger particles that resulted from deposition and reentrainment were composed of lead in the form of the mixed oxhalide, $2PbO \cdot PbClBr$ (Habibi, 1973). Other compounds including $PbSO_4$, $Pb_2P_2O_7$, and $Pb_3(PO_4)_2 \cdot PbClBr$ occurred in small amounts when phosphorus and sulfur compounds were present in the fuel mixture. These highly soluble compounds tended to lose their halide constituents upon aging in the atmosphere and were converted into the less soluble lead oxides, carbonates, and sulfates (Laxen and Harrison, 1977; Ter Haar and Bavard, 1971). A study of soluble lead content of precipitation in the U.S. showed a large concentration of soluble salts which the authors attributed to the existence of the halide salts and the conversion of PbO_2 to the sulfate by atmospheric sulfur dioxide (Lazrus, Lorange and Lodge, 1970). Further support was given by Olson and Skogerboe (1975) who had identified the sulfate as the major component of lead in street dust and roadside soil in a discussion of the conversion of lead to the sulfate and nitrate in the atmosphere and soil (Laxen and Harrison, 1977).

HEAVY METALS TRANSPORT MECHANISMS

Heavy metals are transferred through a combination of mechanisms including airborne dispersal, dustfall, precipitation, deposition on street surfaces with subsequent washout and transport effected by stormwater during precipitation.

Dustfall is a measure of the particulate matter that falls out of the atmosphere due to gravity, typically in the 20-40 μ range. Johnson, et al. (1976) found that lead loadings ranged from 0 $mg/m^2/min$ to 70 $mg/m^2/min$ at

certain stations measuring dustfall in the Seattle, Washington area. Highest lead levels were found in industrial land use areas and adjacent to major traffic arteries with highest lead loading of $71.6 \text{ mg/m}^2/\text{min}$ being recorded next to the heaviest traffic artery (30,000 ADT). Conversely, Randall, et al. (1978) found no such correlations with respect to proximity to metropolitan areas or traffic lanes, although they proposed that metal concentrations originate primarily from inner city, especially auto, emissions.

Precipitation events which wash pollutants out of the atmosphere may be a more important contributor of heavy metals than dustfall, although significant amounts of pollutants can accumulate during long dry periods (Randall, et al., 1978; Malmquist, 1978). Pollutographs collected for precipitation indicate that there is a definite first flush effect during storm events. That is to say that seemingly all pollutants were washed out during the first few minutes of rainfall and are diluted by subsequent rainfalls (Randall, et al., 1978). Brosett (1974) found the relationship between concentration and precipitation to follow a negative exponential: $Y = a + be^{cx}$ in which Y is the concentration of a given parameter in the rainfall, x = volume of rainfall, and a, b, c are experimental coefficients.

Sartor and Boyd (1974) studied the washoff phenomenon and developed a relationship for particle removal, rainfall intensity and duration,

$$N_c = N_o(1 - e^{-krt}).$$

N_c = weight of material of a given particle size removed

N_o = initial weight of material of given particle size

t = duration of rainfall (hrs)

r = rainfall intensity in/hr

k = constant depending on street surface characteristics and independent of particle size within range of 10 to 1000 μ .

The relative contribution of the pollutants contained in precipitation to

the total pollutional load contained in stormwater runoff has not been extensively studied. One study showed that bulk precipitation approximated the concentrations of Pb and As found in stormwater, however, Fe, Mn, Mg, and Cu concentrations were underestimated by bulk precipitation alone (Barkdoll, et al., 1977). The relative concentration in precipitation and stormwater runoff is undoubtedly affected by the accumulation of solids during the antecedent dry period, soil leaching and corrosion. Higher precipitation intensity, runoff-rainfall relationships and duration of storms enhance the ability to loosen and transport particulates with which heavy metals are associated.

More attention has been directed to the role of stormwater as a contributor to receiving water bodies. In localized situations stormwater is a more important source of heavy metals than secondary effluent, and runoff from a typical city during the first hour of 0.5 inch/hr storm would contribute significantly greater pollution load than the cities sanitary waste for the same period of time (Rimer, 1978; Helsel, et al., 1979; Sartor and Boyd, 1974). Factors influencing the concentration of pollutants in stormwater runoff include: length of antecedent dry period, intensity of precipitation, duration of precipitation, rainfall-runoff relationships, surrounding land use, type of street, traffic volume, street sweeping practices, percent impervious area and ground slope. Heavy metals concentrations have been shown to increase with increased impervious area and ground slope (Helsel, 1979) and in urban and industrial areas.

A first flush effect similar to that for precipitation was reported to occur more frequently as urbanization increases, for extractable rather than soluble metals (Helsel, et al., 1979). Increasing urbanization means increased impervious area leading to greater stormwater volumes which enhance solids removal and transport. However, preliminary study by Pope, et al. (1978) in

which metals concentrations were related to flow, found lead levels to be relatively constant during a storm event. This may indicate that lead particulate have a low tendency to go metal into solutions on first flush. They have proposed that a critical flow is required for the removal of a particular particle size with which no heavy metals are associated. They indicated the critical flow to be 0.5 l/s for Zn and Pb; 0.03, 0.55, 1.0 and 1.0 l/s for Cd, Cr, Cu, and Ni, respectively. Therefore the runoff flow which is a function of % impervious area, grade slope, and intensity of rainfall may be a key variable in predicting concentrations of heavy metals in stormwater.

HEAVY METALS IMPACT

The heavy metals that have been thus produced find their way into soils and bodies of water by means of atmospheric dispersion and stormwater runoff. The means of transport is highly dependent upon the specific origin of the pollutant and the particle size with which it is associated. Particles greater than five microns in size settle on or close to the roadway and many of the particles deposited are blown off the roadway by the turbulence created by passing automobiles. These particles that settle adjacent to the roadway tend to be immobilized in the soil or incorporated into the tissues of surrounding plants and animal species.

Metal concentrations decreased with distance from the pavement and lead concentrations were found to be considerably higher in the top 2-3 cm of soil as compared to the subsurface soils. Other metals, zinc, cadmium, and chromium, were not found to be immobilized by the soil as effectively as lead (Wanielista, et al., 1978; Bell and Wanielista, 1979). They also determined that metal concentrations in soil and plants were not distinguishable from background levels

at 30-40 m from the roadway which is in good agreement with other authors. Hassett and Miller (1977) stated that the use of limestone as a road building material, causing high soil pH, reduced the plant availability of lead in roadside soils. Concentrations of Cd, Cr, Cu, Pb, Ni, and Zn in soils and pasture species along a highway in New Zealand revealed that the concentrations of all metals correlated with traffic density (Ward, et al., 1977). The source of pollutants was taken to be aerial deposition of metals from automobiles. Cadmium content of soils was investigated by Hosie, et al. (1978) who indicated that cadmium concentrations decreased markedly with distance from the roadway. They recommended that growing of crops for human consumption next to busy highways be avoided due to the accumulation rate of cadmium in soil and its high toxicity. Similar studies conducted with respect to lead show that crops grown adjacent to highways have a high degree of contamination from exhausted lead. The levels being related to the distance from the roadway and the traffic volume. Lead concentration was seen to drop from 80 ppm at one m from the road to 48 ppm at 15 m and is reduced at distances 20-50 m (McLean and Shields, 1977 Wong and Tam, 1978).

Severe localized contamination of sediments were identified at the locations of snow dumping into rivers and near the outfalls of some storm sewers (Oliver, et al., 1974). Similarly Whipple et al. (1978) found heavy metals occur mainly in the particulate form and seem to settle out in the bed of the receiving water. Heavy metals were found in high concentrations in the bottom sediments even though appreciable quantities could not be detected in the water column.

Bradford (1977) stated that particulate matter collected in stormwater from commercial areas contained the highest lead concentration. Rimer, et al. (1978) found lead levels closely correlated with suspended solids (SS) levels

in the runoff which suggested the mechanism for lead removal was connected to the solids transport functions. Also it was found that although particles less than 43 microns in size of particulate accounted for only 5.9% of the total solids they contained over half of the heavy metals. Street sweeping was found to be generally ineffective, removing only 85% of the less than 43 micron particles and 52% of the less than 246 microns (Sartor and Boyd, 1974).

Getz, et al. (1977) reported higher lead concentrations in mammals living 5-10 m from Illinois interstate highways. Similarly, the impact of particulate lead has been determined in relation to sheep grazing adjacent to major highways. Blood lead contents were 0.90 mg/ml in sheep grazing near the highway as compared to 0.20 mg/ml in a control group. Sheep that were fed uncontaminated forage and placed near the highway were shown to have an immediate rise in blood lead content. However, blood lead levels were seen to decrease rapidly after moving the animals to an uncontaminated area. Considerable accumulation of lead was found in the livers, kidneys, and bones of sheep exposed to highway contaminants (Ward, et al., 1978). Baretta (1978) studied the clinical aspects of lead poisoning in dogs, cows, goats, and horses and found that lead pollution of pastures and fodder near major highways was the main cause of animal poisoning. The average content of lead in fodder from unpolluted areas was 0-1.5 ppm whereas the lead content of plants near major roadways ranged from 100-700 ppm. The study also suggested the possible indirect lead poisoning of humans feeding on meats poisoned by lead. Air and blood lead levels were measured in Bangkok by Htun and Ramachandran (1977), who recorded similar concentrations to those measured in other cities. Air lead levels were a function of traffic volume and proximity to congested roads. High blood lead content and large respiratory intake of lead are possible for those spending large amounts of time next to roads, although high blood levels were not always a direct result of high air

lead exposures. A study by Little and Wiffen (1977) using radioactive lead to prepare labeled exhaust aerosols showed that less than 10% of the lead emitted is deposited within 30 m of the roadway. Deposition velocities were found to be greater for fresh, diffused aerosols than for older aggregated aerosols and velocities increased with higher wind speed.

SORPTION OF HEAVY METALS BY BOTTOM SEDIMENTS

Heavy metal pollutants are transported from their origin to the receiving water body through the air and within stormwater runoff. These metals are being introduced into the water column as dissolved ions and in association with the suspended solids in the water column.

Several studies have been done that help to show the distribution of heavy metals within the water and sediment columns. Angino, et al. (1974) conducted a study of the water chemistry and suspended matter in Kansas rivers. They found that the bulk of Fe and Mn existed in the suspended sediment and Pb was evenly distributed between water and suspended sediments. Suzuki et al., (1979) studied Cadmium in the Tama River and concluded that the suspended sediments could absorb large concentrations of the metal ions. Similar results were reported for chromium in the Isar River, Bavaria. It had also been reported that concentrations of Fe and Mn, Cr were similar in the sediments and suspended solids (Uken, et al., 1977). The adsorption of Cd was found to occur relatively rapidly onto suspended matter and settled solids. Concentration of heavy metals in sediments could be used to indicate levels of heavy metals in the water column and to locate sources of pollution. (Gardiner, 1974). Heavy metals introduced into the receiving water body will be adsorbed by suspended and settled sediments until some equilibrium value is reached with the water column and concurrently the suspended sediments will settle out.

increasing the concentration in the sediments.

Core samples taken from Michigan lakes, and a California estuary in three separate studies showed that increased levels of Pb and Zn corresponded to high auto traffic in the vicinity and increased use of fuels, and anthropogenic activity (Christensen, et al., 1978; Iskandar, et al., 1974; and Edgington and Robbins, 1976). Edgington and Robbins (1976) used the ratio of Pb to Pb^{210} to consider the relative contribution of atmospheric deposition and surface runoff. They found that atmospheric deposition was the most significant source offshore and runoff contributed the most lead to the sediments close to the shore.

There are a number of factors that affect the adsorptive capacity of sediments and their concentration of heavy metals. The factors include: type of solids, contact time, complexing ligands present, pH, temperature, hardness, presence of carbonates, organic material, and hydrated metal oxides present. (Zimdahl and Skogerboe, 1977 and Gardiner, 1974). Hardness and the presence of carbonates were not shown to be major factors in the fixation of heavy metals in the sediments. Benes, et al., (1976) discovered that iron was released from organic complexes at pH 2-3 and Zn adsorption by humus increased with increasing pH. Adsorption of heavy metals onto SiO_2 , Al_2O_3 , and two soils showed that adsorption capacity increased abruptly at pH 5-6 for Pb, Zn, Cu and pH 6-7 for Cd (Huang, et al., 1977). This increase in adsorption correlated with the presence of the M^{+2} species and Pb and Cd were observed to be desorbed below this pH range. The same study also suggests that the presence of certain anions, humic acid, nitrilotriacetate, tartate, phosphate, affected adsorption at lower pH through complex formation. Investigations of the chemical contents of sediments have indicated that there may be a positive correlation between the occurrence of heavy metals and the oxides of Fe and Mn. This

association has been attributed to the coprecipitation of the heavy metals with fresh oxides of Fe and Mn, which were reported to be excellent scavengers (Angino, et al., 1974) and the association with, or collection of hydrous oxides by organic matter (Zimdahl and Skogerboe, 1977).

A relationship between heavy metals and organic material in sediments may also exist. Suzuki, et al., (1979) found that Cd content was proportional to the ignition loss of the sediments which would be related to the organic content. Adsorption equilibria of cadmium was found to follow a Freundlich isotherm:

$$q_{IL} = k_{IL} C^{1/n}$$

where $n=1.5$, $q_{IL}=q/IL$, and IL =ignition loss. Benes, et al. (1976) studied complexation of heavy metals with humus and found that Zn and Co seemed to be complexed with the humus whereas, correlations for other metals were not apparent. However, other authors observed that the majority of lead immobilized by soils is associated with organic matter (Zimdahl and Skogerboe, 1977) and humic materials appeared to be the major component of mud responsible for adsorption

Finally, evidence in the literature points to the fact that the majority of heavy metals found in sediments are expressed in the fine particles. Lead concentrations (weight %) were highest in the smallest size fraction ($\leq 74 \mu$) of some soils studied (Zimdahl and Skogerboe, 1977). Uken, et al. (1977) fractionated sediments into 0-2 μ , 2-6.3 μ , 6.3-20 μ and 20-63 μ fractions and analyzed for heavy metal concentrations. Highest concentrations for Cr and Fe existed in the 0-2 μ fraction, with some in the 2-6.3 μ fraction and little in all other fractions. Comparison of the concentrations of heavy metals in the clay size fraction were relatively constant for all samples in comparison to the concentration in the total sediments. However, As, Cr, Cu, Hg, Ni, Sb, and Zn concentrations were higher in the clay size fraction, which the authors

attributed to anthropogenic inputs. Finally, a comparison of concentrations in the clay size fraction of sediments from contaminated and uncontaminated sediments whereas total concentration in the sediments did not reflect this. Therefore, it has been shown in the literature that a number of factors within the sediments and the water column above affect the concentrations of heavy metals contained in the sediments. Even so it had been suggested and reasonably well documented in the literature that the sediments do provide information about heavy metal pollution. This is important because large quantities of heavy metal pollutants may be introduced to a receiving water body, especially in the particulate form, and not manifest their presence by introduction into the receiving water column.

HEAVY METALS IN RECEIVING WATER

In the last few years attention has been drawn to the occurrence of heavy metals in the aquatic environment and the possible toxic effects that they might have upon the biota associated with these waters. Many of these surface waters provide both potable water and a source of food for man and therefore it is necessary to ascertain the levels and effects of these heavy metals upon human health also.

Mathis, et al. (1973) looked at the concentrations of Cu, Ni, Pb, Cr, Li, Zn and Cd contained in water, sediments, tubificids, clams and fish taken from the Illinois River near Peoria. They were interested in the decline in the diversity of the biota due to the industrial and domestic wastes received from Chicago and other cities along the river and its tributaries.

In general the highest concentrations occurred in sediments, and worms, then decreased through clams, omnivorous fish, carnivorous fish, with the lowest concentrations being found in the water samples. The authors note that the

concentrations in the clams and tubificids may have been increased by the bottom sediments remaining in the organisms' digestive tracts.

A similar study was conducted by Namminga, et al. in 1973 to determine the seasonal and longitudinal variations of chromium, lead, zinc and copper in water, sediments, and chironomids taken from Skeleton Creek, Oklahoma. They found that the concentration of zinc and copper in water were higher in winter than in summer and that no seasonal variation occurred for chromium. The maximum concentrations were generally found downstream from introduction of domestic and industrial wastes from various sources. The sediments produced the opposite effect showing much higher concentrations in summer than in the winter although all the values were lower than reported in other similar studies. It was also shown that higher metal contents were directly related to a greater percent loss on ignition and a greater fraction of less than 0.5mm size particles. Also, it was concluded that metals concentrations in sediment were not greatly affected by surface adsorption.

Another similar study was undertaken by Enk, et al. (1977) to determine the occurrence of Cd and Pb in water, sediments and biota taken from Jubilee Creek, Peoria County, Illinois. Cadmium showed a very small concentration in water (.02 ppm) a higher concentration in fish and sediment (0.14 ppm) and the highest concentration in aquatic insects (0.5-1.5 ppm). Lead also showed the lowest concentration in water (0.5 ppm), higher concentration in fish (2.6 ppm), concentrations around 8 ppm for sediments and aquatic insects, and the highest concentrations were found in snails (13.6 ppm).

A highly industrial area was studied by Williams, et al. (1973) in order to determine a correlation between concentrations of Cd, Cr, Cu, Fe, Mn, Hg, and Zn and stream flow. The study was conducted on the Black Warrior River near

Tuscaloosa, Alabama and focused on metals that were in a suspended rather than a dissolved form.

The study showed that the concentration of the metals in the suspended matter increased in time of increased flow and they were lower in times of low flow. Highest metal concentrations were reported after periods of heavy rain where increased flow scoured bottom sediments producing a toxic slux which moved downstream. The authors further suggested that fish kills during these periods which are normally attributed to low DO may in fact be caused by the toxic effects of high heavy metal concentrations.

Extensive studies were conducted by the USGS in September of 1973 to determine the background concentrations of heavy metals and whether any of these metals were present at levels high enough to pose an ecological threat. The study was based on 44 bottom sediment samples taken along the visual center of flow at various points along the Willamette River, Oregon. The sampling sites were chosen to reflect natural settings and pollutant source locations. The concentrations of Cd, Cr, Cu, Pb, Hg, Ag, Zn and As were plotted on log normal paper for each of the 44 samples to determine natural background concentration versus concentrations that might reflect pollution. Each curve except for mercury had a breakpoint indicating pollution levels and background levels could be differentiated. Interestingly at three points below highway bridges lead concentrations above the background levels were detected (Rickert, et al., (1977).

The USGS published a report entitled "Lead in the Environment." This publication consisted of several articles by various authors on different aspects of the occurrence of lead in the environment. Each section contains numerous tables and illustrations showing lead concentrations found in varying locations and mediums (Boqqess and Wixson, 1976).

CHAPTER III

SITE SELECTION AND METHODOLOGY

Two principle sampling sites located along Interstate 4 in Orange County Florida were selected for this study. The first site is located where Interstate 4 crosses over Lake Ivanhoe near downtown Orlando and the second site is located at the intersection of Interstate 4 and Maitland Interchange, which will be referred to as the Maitland Interchange. A total of eight sample sets were collected from each of the two locations during the period February, 1979 to August, 1979.

SELECTION CRITERIA

These sampling sites were based on the average daily traffic (ADT) volume, drainage methodology of bridge runoff and proximity to the University. The first site is located where Interstate 4 crosses over Lake Ivanhoe near downtown Orlando as shown from the aerial overview, Figure 3-1. The second site is located at the intersection of Interstate 4 and Maitland Interchange as shown in aerial overview, Figure 3-2. These sites were decided upon during meetings held between representatives of the FDOT and the UCF personnel.

The average daily traffic volume, near the study sites for the past several years, 1975 - 1980, have been supplied by FDOT (Harrell, 1980), and are presented in Table 3-1. This table shows a gradual increase in the ADT volume of over 40 percent at Lake Ivanhoe and Maitland Interchange sites between 1975 and 1980. This increased traffic volume should impact the quality of stormwater runoff from highway systems and adjacent receiving water bodies.

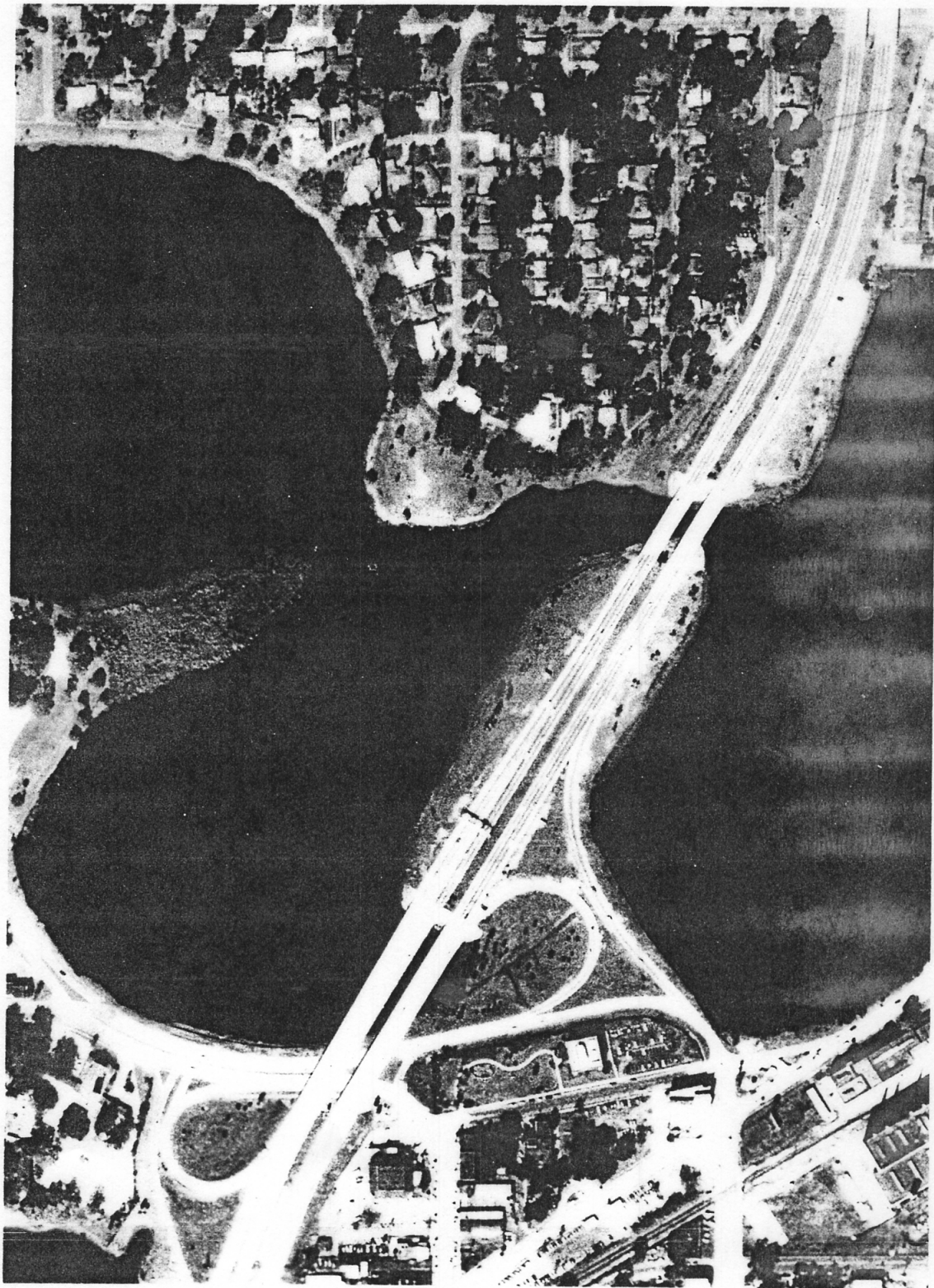


FIGURE - 3-1. AERIAL PHOTOGRAPHY OF LAKE
IVANHOE AND INTERSTATE 4 SITE

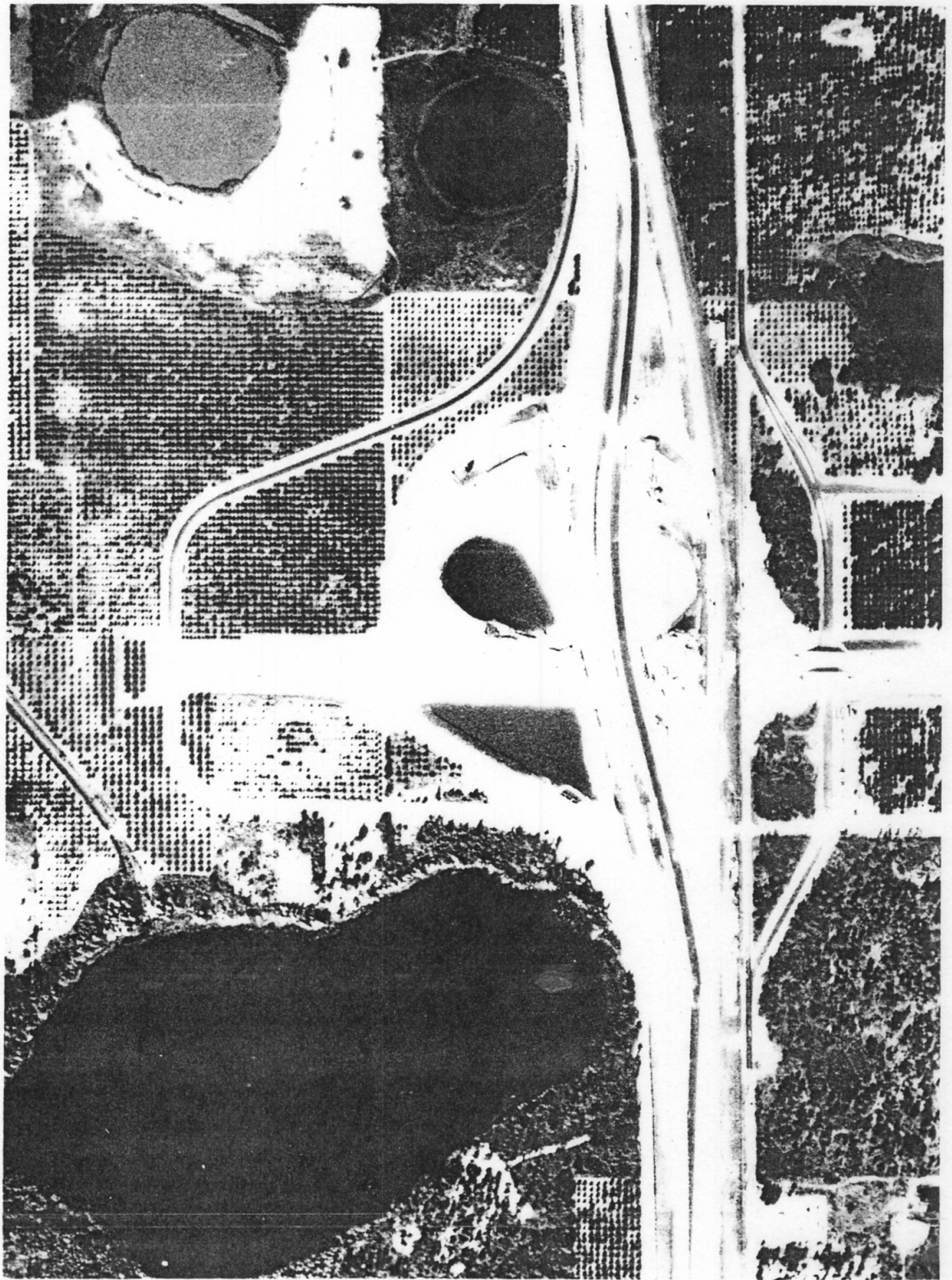


FIGURE - 3-2. AERIAL PHOTOGRAPHY OF MAITLAND INTERCHANGE AND INTERSTATE 4 SITE

TABLE 3-1. AVERAGE DAILY TRAFFIC COUNT FOR SITES
SELECTED ON INTERSTATE 4

| Sampling Station | Location | Traffic Lanes | Average Daily Traffic | | | | | |
|----------------------|---------------------|---------------|-----------------------|-------|-------|-------|-------|-------|
| | | | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
| Lake Ivanhoe | East Lake Ivanhoe | E. Bound | 39166 | 41276 | 41273 | 45860 | 44215 | 49958 |
| | | W. Bound | 37360 | 40409 | 41727 | 45502 | 47275 | 58598 |
| Maitland Interchange | West Lake Ivanhoe | E. Bound | 38191 | 40125 | 40695 | 43743 | 47455 | 51113 |
| | | W. Bound | 41515 | 53646 | 43891 | 45607 | 49518 | 48652 |
| Maitland Interchange | North Lee Road | E. Bound | 30696 | 29565 | 34938 | --- | 37793 | 43562 |
| | | W. Bound | 30027 | 30045 | 32224 | --- | 40332 | 43132 |
| Maitland Interchange | Wynore Road | E. Bound | --- | --- | 31642 | 29611 | 32678 | 32823 |
| | | W. Bound | --- | --- | 32232 | 32805 | 32484 | 32454 |
| Maitland Interchange | Maitland Blvd. #578 | E. Bound | --- | --- | --- | --- | 11105 | 10688 |
| | | W. Bound | --- | --- | --- | --- | 11378 | 9565 |

LAKE IVANHOE SITE

Lake Ivanhoe is a 125 acre (50.6 HA) freshwater lake that is located inside the City of Orlando, Florida. A section of the central portion of the lake was filled in 1965 to allow Interstate 4, then under construction, to cross it. Interstate 4 presently crosses the lake by means of two bridges that connect the central island created during construction to the northern and southern shores of the lake, thus dividing the lake into an eastern and western section. The eastern section is bordered by Orange Avenue which fronts numerous commercial and light industrial establishments. The western portion of the lake is bordered by Ivanhoe Boulevard and is surrounded by well-established single family residences. All of the perimeter area is tributary to the lake which receives direct stormwater runoff from the surrounding streets. The lake drains 3.2 square miles (828.8 HA) in the St. Johns River basin and is heavily used by the public for recreational purposes. Lake Ivanhoe is also interconnected with an adjacent Lake Concord, through a concrete culvert running under Ivanhoe Boulevard.

The north bridge at Lake Ivanhoe consists of two sections, one for west bound traffic and one for east bound traffic, each carrying three lanes of thru traffic. Both sections are 216 feet in length with a 40 foot roadway and 44 foot horizontal clearance. Water on the bridge drains toward the adjacent land on either side since there are no scupper drains located on the bridges. The section of south bridge carrying east bound traffic has three lanes of thru traffic and one exit lane. This section spans 580 feet with a 52 foot roadway and a 56 foot horizontal clearance. Drainage is facilitated by a set of 4 inch diameter plastic pipe scupper drains set on 8 foot centers running along the eastern edge of the bridge. The western section of the south bridge carrying

west bound traffic has two lanes of thru traffic and two lanes exiting onto Ivanhoe Boulevard and S. R. 50. The western bridge is 640 feet long with a 60 foot roadway and a 64 foot horizontal clearance. Two sets of scupper drains located on 8 foot centers drain this section, one set running along the eastern edge of the bridge and the other set running along the eastern edge of the exit lanes. The ADT volume, as provided by the FDOT (Harrell, 1980), is presented in Table 3.1. The table shows that traffic volume across Lake Ivanhoe was approximately 45-50,000 ADT east bound and 48-58,000 ADT west bound during the study period.

Sampling Stations on Lake Ivanhoe

The two bridges over Lake Ivanhoe were ideal for sampling because the northern bridge contained no scupper drains, whereas the southern bridge has a set of scupper drains running down the eastern edge of each section. Therefore, samples were taken from between the northern bridge sections, underneath each set of scuppers on the southern bridge sections, and in the main body of the western portion of the lake, to serve as a control as shown in Figure 3-3. Also three direct runoff sample sets were taken directly from the scupper drains during three storm events in August, 1979.

The four sampling cross sections or sampling stations were established as shown in Figure 3-3. Station 1 was located just inside the easternmost part of the south bridge and consists of two points from which samples were taken and composited. Station 2 was located in between the two sections of the south bridge and consists of three sampling points. Station 3 was located in between the two sections of the north bridge and consisted of two sampling points. At first the control section was located across the lake between the north and south bridges and consisted of three sampling points. The control section was

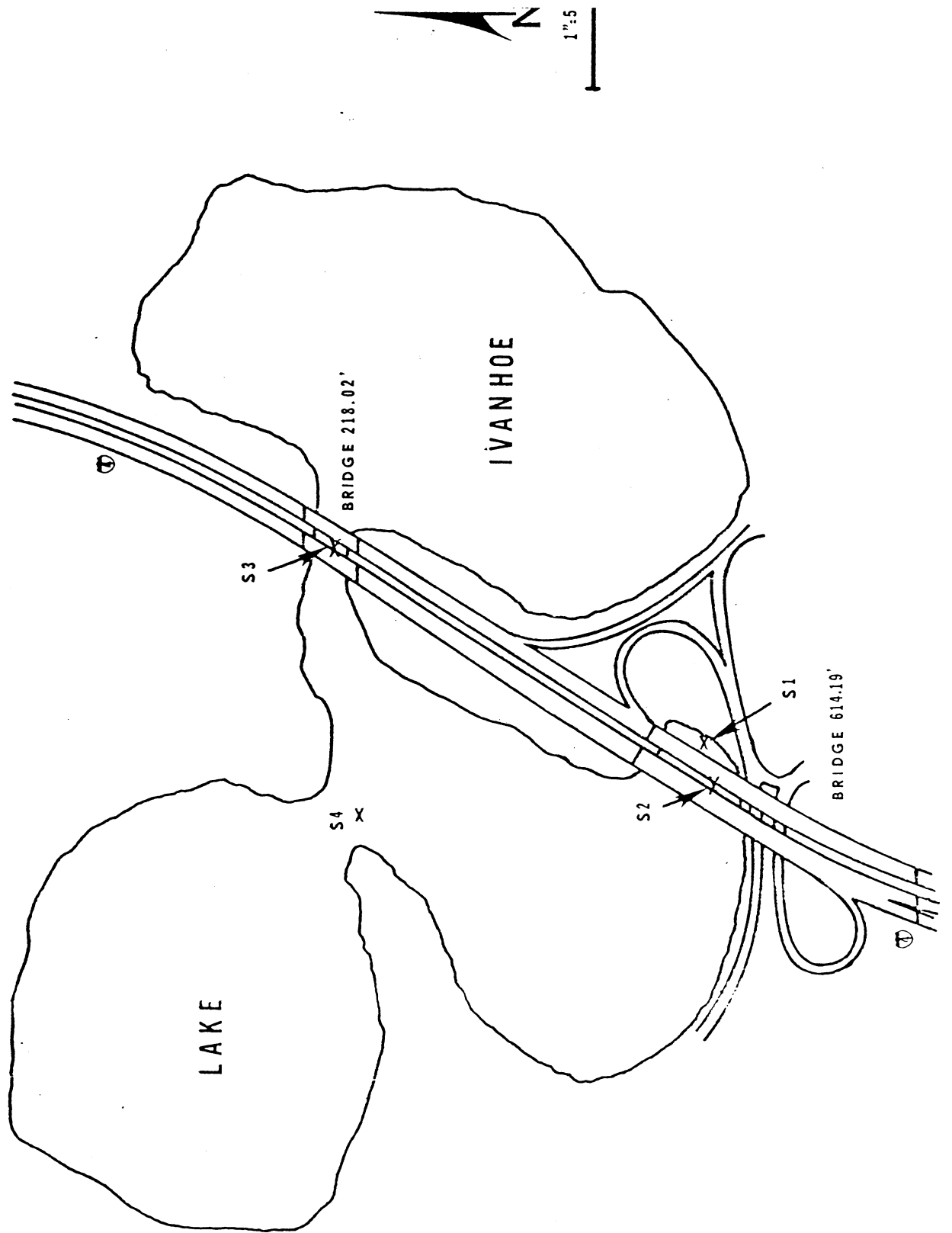


FIGURE 3-3 SAMPLING LOCATIONS FOR BRIDGE RUNOFF AT LAKE IVANHOE

then relocated so it ran parallel to the highway to try to eliminate the influence of the highway which ran very close to one of the sampling points in the original cross section. The control section was finally moved a third time to a different section of the lake for which two sampling points were established. The last change in the control section was necessitated due to the nature of the sediments in the second section and the dense layer of plant and algae covering the bottom which made sampling almost impossible.

THE MAITLAND BOULEVARD EXCHANGE SITE

The Maitland Interchange, located north of the City of Orlando, Florida, was constructed in 1976. Maitland Boulevard crosses over Interstate 4 by means of a bridge overpass created during construction of the interchange. The traffic lanes on the interstate are separated by a 20 foot grassy median, as they approach the interchange, which widens to 44 feet through the interchange. Stormwater coming off the interstate is delivered by overland flow over a good grass cover to stormdrain inlets or receiving waters. Three borrow pits were dug to provide fill for the construction of the overpass, as depicted in Figure 3-2, and remain in existence serving as stormwater detention/retention facilities. Stormwater runoff from the Maitland Boulevard bridge crossing over Interstate 4 is conveyed directly off the roadway surface through stormwater inlets to culverts that discharge directly into the ponds. The ponds are interconnected so that the two northernmost ponds flow into the southwest pond (referred to hereafter as the west pond) when they reach a certain design level. The water from the west pond flows over a wooden weir at its southern end which is connected to Lake Lucien by means of a culvert and a short, densely vegetated ditch.

The land adjacent to the Maitland Interchange is essentially undeveloped

and in the natural state with the exception of the north western side which is planted in citrus groves. These citrus groves provide little flow to the ponds but can contribute runoff to Lake Lucien by means of a canal at the northwest end of the lake. Therefore, runoff to the ponds is essentially all from the roadway environment and flow to Lake Lucien is a combination of natural, highway, and citrus runoff with the relative contributions probably governed by the antecedent conditions and magnitude of the rainfall event. Lake Lucien is a 57 acre freshwater lake and the lack of significant development on its shores has left it in a seemingly pristine condition.

The Maitland Boulevard bridge consists of two sections, one carrying two lanes of east bound traffic plus one exit lane and the other section carries two lanes of west bound traffic plus one exit lane. The section carrying west bound traffic spans 552 feet with a 52 foot roadway and 53 feet of horizontal clearance. The section carrying east bound traffic spans 534 feet also having a 52 foot roadway and 53 feet horizontal clearance. Traffic volume, as presented in Table 3-1, shows that the traffic volume on Maitland Boulevard was approximately 11,000 ADT east bound and 10,000 west bound during the study period. Interstate 4 has three lanes of thru traffic east and west bound through the Maitland Interchange. Table 3-1 shows that traffic volume on Interstate 4 through the Maitland Interchange was approximately 32-40,000 ADT east bound and west bound during the study period.

Sampling Sites at Maitland Interchange

Four sampling stations were also chosen for this site to delineate differences in water quality due to stormwater runoff as depicted in Figure 3-4. Station 1 consisted of two sampling points in the eastern drainage pond adjacent to Interstate 4. One sampling point was located next to the outfall from

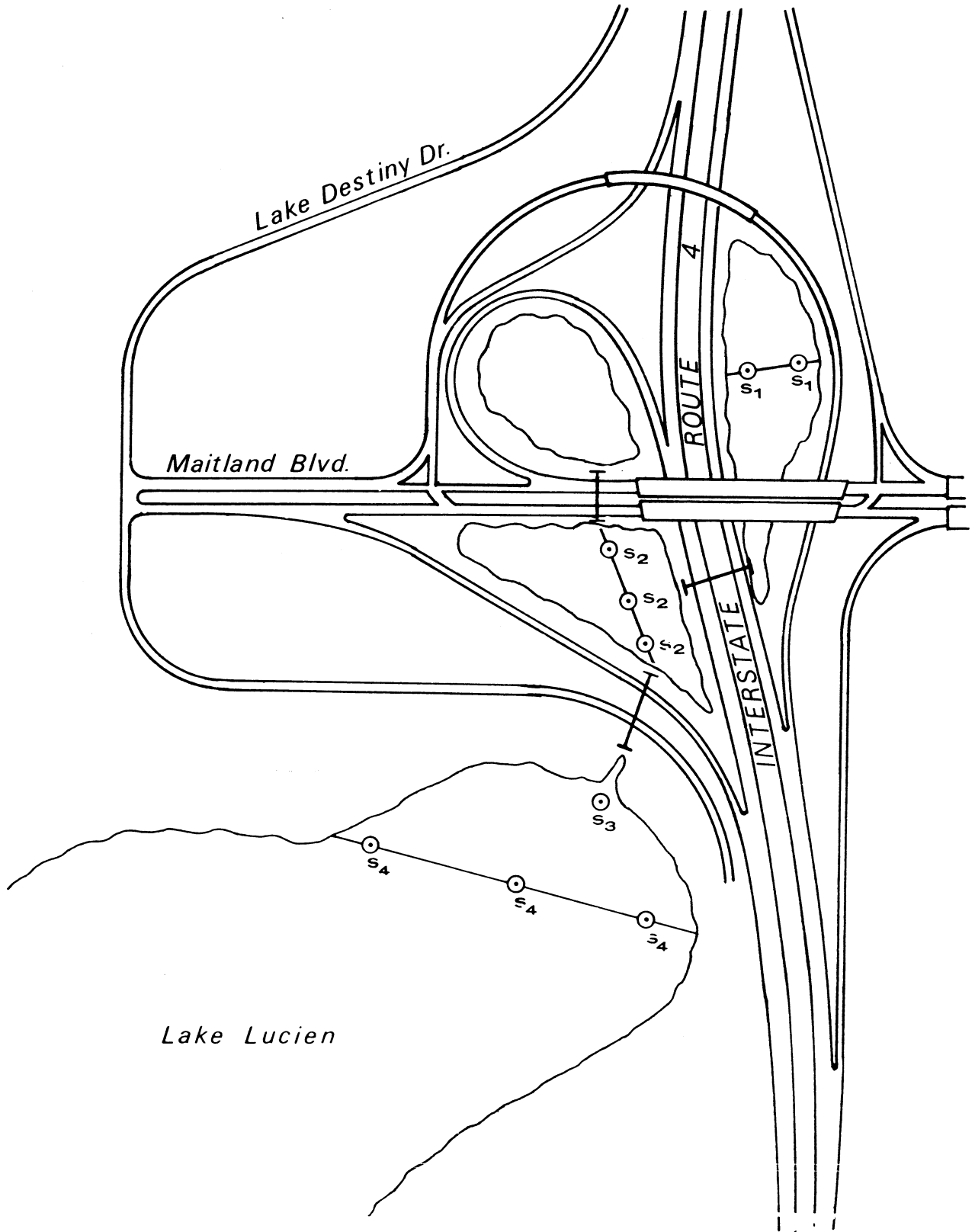


FIGURE 3-4. SAMPLING SITES AT MAITLAND INTERCHANGE AND INTERSTATE 4

another pond and the other point was located across from it next to the highway. Station 2 consisted of three sampling points in the western drainage pond. The sampling points were located along a visual line between the outfall at the north end and the control weir at the southern end of the borrow pond closest to and connected to Lake Lucien. Station 3 consisted of one sampling point on Lake Lucien next to where the canal enters from the west pond. The control section was chosen to be along a visual line connecting the northwest and southeast end of Lake Lucien in which three sampling points were established.

FIELD AND LABORATORY PROCEDURES

The broad objective of this study was to assess the impact of highway bridge runoff upon the adjacent water bodies. This required field investigation of some water quality parameters such as dissolved oxygen and temperature profiles and sampling collection for laboratory analysis.

Field Investigation

Certain water quality parameters were measured in the field at the same time the samples for laboratory analysis were being collected. A Secchi disk depth was determined for each sampling point as a measure of water clarity and light penetration. DO and temperature profiles were also measured at 0.5 m intervals from the water surface down to the bottom using a Yellow Springs Instrument Co., Inc. Model 54 Oxygen Meter, YSI 5739 DO Probe and YSI 5795 Stirrer.

A complete set of samples and field measurements were taken at each sampling point and then samples were composited for those stations having multiple sampling points. Water samples were taken 0.5 m below the surface, 0.5 m above the bottom, and at middepth for locations that were greater than 3 m deep, using

a 2.1 liter kemmerer water sampler. The water thus collected was placed in a 5 gal. plastic carboy from each sampling point and at the completion of all the points in a given station, a 1-gal. sample was withdrawn and placed in an acid washed, distilled water rinsed 1-gal. plastic container. One six by six inches bite of sediments was collected from each location using an Eckmann dredge. The sediments from each sampling point were placed in 5-gal. plastic pails and composited for each sampling station.

Benthos samples were obtained for each sampling station by taking 2-3 bites of the sediment at each sampling point and straining them through a 0.5 mm by a 0.5 mm opening sieve and placing the material collected into small plastic containers from which the organisms would be separated later. Plants were collected from each sampling point by hand or dragging the anchor along the bottom. At least 100 grams of plants were collected from each sampling point and placed in plastic bags which were tied up to keep the plants moist until they were reopened back at the laboratory.

Laboratory Procedures

Collected samples of water, bottom sediments, plants and benthos were brought back to the Environmental Engineering Sciences laboratory at the College of Engineering, UCF for preparation and analysis.

Water Samples

The water samples were analyzed to determine: pH, turbidity, chlorophyll "a", organic and inorganic carbon, nitrates, total and dissolved metals. The water samples were stored in 1.0 gal. polyethylene containers at 4° C until each analysis could be performed. Turbidity, pH, and chlorophyll "a" were

always determined upon return from the field after collection. The pH of the water samples was measured using a Corning Model 12 Research pH meter with a temperature compensation probe. The pH meter was calibrated using Scientific Products pH Reference Buffer Solution (pH 7.00-10.00) before each set of samples was measured. Turbidity was measured with a H. F. Instruments Model DRT-150 and JTI standard supplied by the manufacturer.

Chlorophyll "a" was determined from a calibration curve, using a Turner II Fluorometer. The calibration curve, which appears in Figure 3-5, was prepared by calculating chlorophyll "a" concentration in water samples by the trichromatic spectrometric acetone extraction method as described in Standard Methods for Examination of Water and Wastewater, Fourteenth edition, 1975, and comparing these to relative fluorescence values. Calibrations were made using the 1X and 3X fluorometer ranges which yielded virtually identical results. Carbon was measured using the combustion-infrared analysis technique with a Beckman Model 215A Infrared Analyzer. Both total and inorganic carbon were measured and organic carbon was taken to be the difference between the total and inorganic carbon. Ten and 50 mg/l sodium carbonate solutions were used as the standards for this determination.

The Orion Model 93-07 nitrate ion electrode in conjunction with an Orion Model 801A Digital Ionalyzer were used for the determination of nitrates in water samples. The nitrate-nitrogen levels were generally less than 1 ppm, so the low level technique as described by Orion in the ion electrode manual was used for these measurements. However, it was found that this caused an overestimate of nitrate-nitrogen of up to 0.40 mg/l per mg/l in spiked lake water samples above 0.5 mg/l. The substitution of the high level ion strength adjustor was shown to reduce the error in the same samples to less than 0.05 mg/l per mg/l up to concentrations of 2 mg/l.

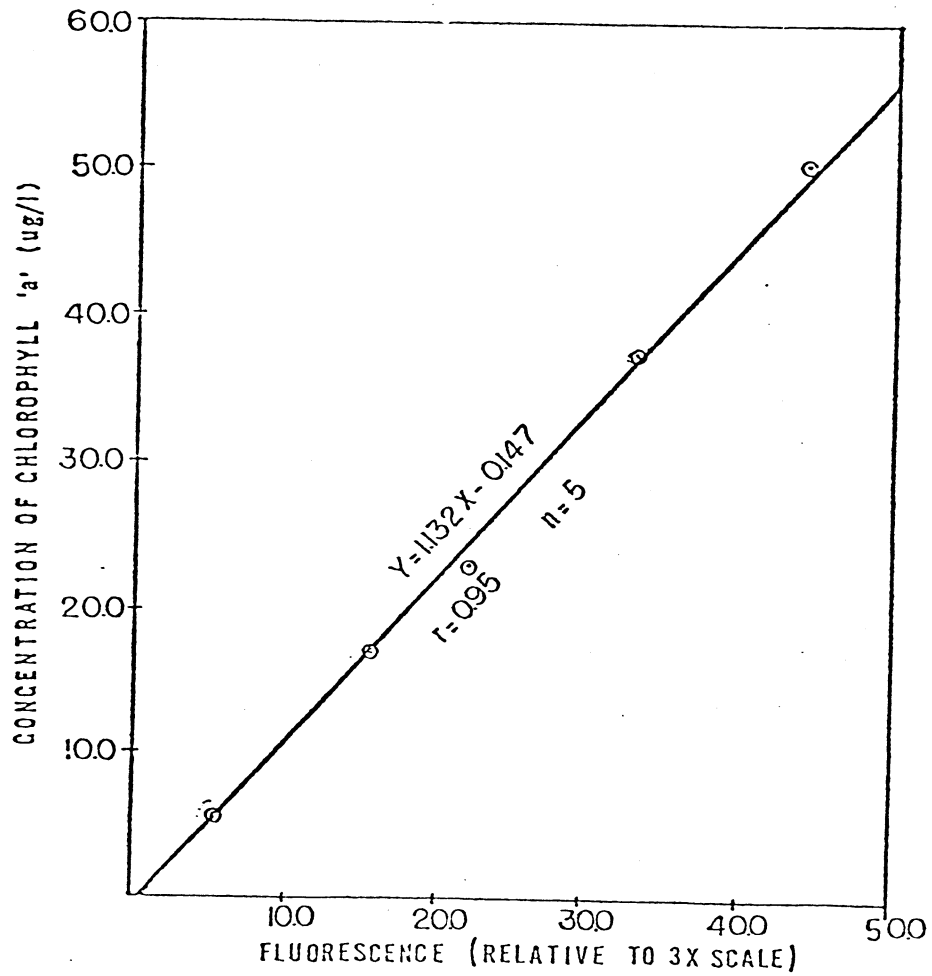


FIGURE 3-5. RELATIVE FLUORESCENCE vs. CHLOROPHYLL "a" CONCENTRATIONS FOR INDIGENOUS ALGAL SPECIES IN LAKE EOLA

The water samples were also prepared for total and dissolved metals determination in accordance with the procedures outlined in Standard Methods. A blank for each of the two determinations was also prepared using an equivalent amount of glass distilled, deionized water and nitric acid to that used in the procedure for the raw water samples. The blank readings were subtracted from each sample to obtain its proper concentration. The solutions were analyzed for using dc-argon plasma emission spectrophotometry on a Spectrometrics, Inc. Spectrospan III Plasma Emission Spectrophotometer.

Bottom Sediments

An evaporating dish was filled with the wet sediments and placed in a 103° C oven for approximately 12-18 hours. The dried samples were then weighed to determine the water content. A 40-70 g portion of the dried sediments were placed in a crucible to be ashed, at 550°C for 12 hours. The ashed sediments were removed from the furnace, cooled to room temperature and then reweighed to determine the % loss on ignition. Finally two samples of 2.5-3.5 grams of each were weighed from each crucible and placed in separate 100 ml pyrex beakers that had been washed in 20% nitric acid and rinsed four times with glass-distilled, deionized water. Ten mls. of nitric acid was added to each beaker which was refluxed with a watch glass over the top for 45 min. at 375°F. Afterwards 10-20 ml of glass distilled, deionized water was added to each beaker and the contents were filtered through a 0.45 micron filter. The filtered solution was then diluted with glass-distilled, deionized water in a volumetric flask to bring the total volume to 100 ml.

Plant Samples

Treatment of the plant samples was begun within one working day after the samples were collected. The plant samples were stored in sealed plastic bags with sufficient water in them to keep the samples fresh for several days. Approximately 100 grams of the plant material of each type and location was removed and cleaned using tap water to remove dirt and grit from the sample. The sample was then rinsed with distilled water and shaken to remove excess water. These samples were weighed and placed in an evaporating dish in a 103°C oven for drying. The samples were removed after 12-18 hours, allowed to cool and then reweighed to determine the water content. A 2.5-3.5 g sample of the dried plants was then placed in a tared crucible which was placed in a 550°C muffle furnace for 12 hours after which the ashed sample was then reweighed. The samples were then prepared for metal analysis by dissolving the ashes in 4 ml of nitric acid, to which 20-30 ml of glass distilled, deionized water was added. The resultant solution was filtered through a 0.45 micron filter and diluted to a total volume of 50 ml in a volumetric flask.

Benthic Organisms

The benthos samples from the field contained varying amounts of sediments and plant material from which the organisms needed to be separated. The use of rose bengal solution to dye the organisms helped in the separation process which was done by hand. After the organisms had all been removed from the sample, they were separated according to phylum and/or class, counted and weighed. Each different type of organism was placed in a separate crucible and ashed in the furnace as above at 550°C for a period of 8-12 hours. The ashes were then dissolved in 2 ml of nitric acid to which 10-20 ml of glass distilled,

deionized water was added and then the contents were filtered through a 0.45 micron filter. The filtered solutions were then brought to 50 ml total volume in a volumetric flask. Where mollusks and gastropods were collected, the shells were removed so that only viscera would be ashed and analyzed for metal content.

All water, sediment, plant and benthos samples that were prepared for metal analysis as described above were placed in either nalgene Tripour 100 ml beakers or plastic beakers and covered with Parafilm for storage. These solutions were stored in the dark at 4°C until the metal analysis was performed, usually less than one week elapsed between the time the samples were prepared and analyzed. All samples were analyzed to determine the concentration of the following elements: lead, chromium, zinc, cadmium, nickel, copper, arsenic, iron, phosphorus, magnesium and calcium. The analysis was done for all the elements simultaneously using the multielement cassette on a Spectrometrics, Inc. Spectrospan III Plasma Emission Spectrometer. The blank used to calibrate the spectrometer was plain glass-distilled deionized water that was used to prepare the standards. A blank was also prepared for each type of sample, water, benthos, plants, and sediments, using equal amounts of glass-distilled, deionized water and nitric acid to that used in preparing the samples. The readings from the measurement of the blank were subtracted from the sample reading to obtain the sample concentration. The standards for these determinations were prepared by diluting Scientific Products 1000 mg/l atomic adsorption standards with the desired amount of glass-distilled, deionized water.

CHAPTER IV

EXPERIMENTAL RESULTS

Data were collected from the two principle sampling sites during winter, spring, and summer of 1979 to evaluate the effects of highway bridge runoff on adjacent waterbodies and to examine the effectiveness of highway borrow pits as retention-detention ponds. Samples of water, bottom sediments, plants, and benthos were taken from several sampling points within each selected site and analyzed for numerous parameters, especially heavy metal content. The data collected from Lake Ivanhoe and Maitland exchange sites will be discussed in this chapter.

LAKE IVANHOE AND INTERSTATE 4

Four sampling stations, namely east southern bridges, S-1, in between southern bridges, S-2, in between northern bridges, S-3, and open lake control, S-4, and/or S-5, were selected as shown in Figure 3-3. The results obtained from field measurements and laboratory analysis of water samples, bottom sediments, plants and benthos are presented in Appendices A, B, and C.

Field Measurements

Dissolved oxygen and temperature profiles measured in Lake Ivanhoe are presented in Appendix C-1. The water depth varied between 1 to 3 meters at S-1, 4.0 to 5.0 meters at S-2, 1.5 to 2 meters at S-3 and 4.0 to 5.0 meters at S-4. Variations in water temperature during the study period at these stations ranged between 14.8°C during February and 35.0°C during August, 1979. Generally, a gradual decrease in temperature with depth was noticed. In most cases, typical thermocline in Lake Ivanhoe did not exist and the temper-

ature differential in the water column did not exceed 3.5°C. Selected temperature and dissolved oxygen profiles are shown in Figure 4-1. These profiles show higher water temperatures and lower dissolved oxygen (DO) content during summer months as compared with profiles measured during winter months. The increased water temperature and runoff loading of organic matter during summer months could depress the dissolved oxygen concentration in lake water.

During the month of August, the dissolved oxygen concentrations in Lake Ivanhoe dropped down below 1.0 mg/l at the water-sediment interface in the deep sections of the lake as shown in Figure 4-1. A sharp decline in DO was measured at sites deeper than 4.5 meters, however the DO content at the surface was close to or above saturation levels.

Water Quality Analysis

Water quality parameters that were measured for each water sample included: pH, turbidity, TOC, inorganic carbon, chlorophyll "a", nitrates, total phosphorous, calcium, and magnesium. The results are presented in Appendix A-1.

In general, little variations from station to station were exhibited by these water quality parameters on a given date. The pH recorded for all the stations ranged from 7.17 to 8.94 with the averages for the entire sampling period ranging from 7.23 to 8.29. Turbidity showed slightly more variations between the stations on a given date with values ranging between 4.0 and 21.0 and averaging between 5.6 and 7.9 JTU's for all stations during the study period. The average organic carbon concentration ranged between 8.6 and 9.8 and the inorganic carbon showed little variation between stations with average values ranging from 24.1 to 24.3 mg/l.

Chlorophyll "a" measurements varied with sampling location and date and the values ranged from 7.80 to 28.50 µg/l. The lowest average values (14 µg/l)

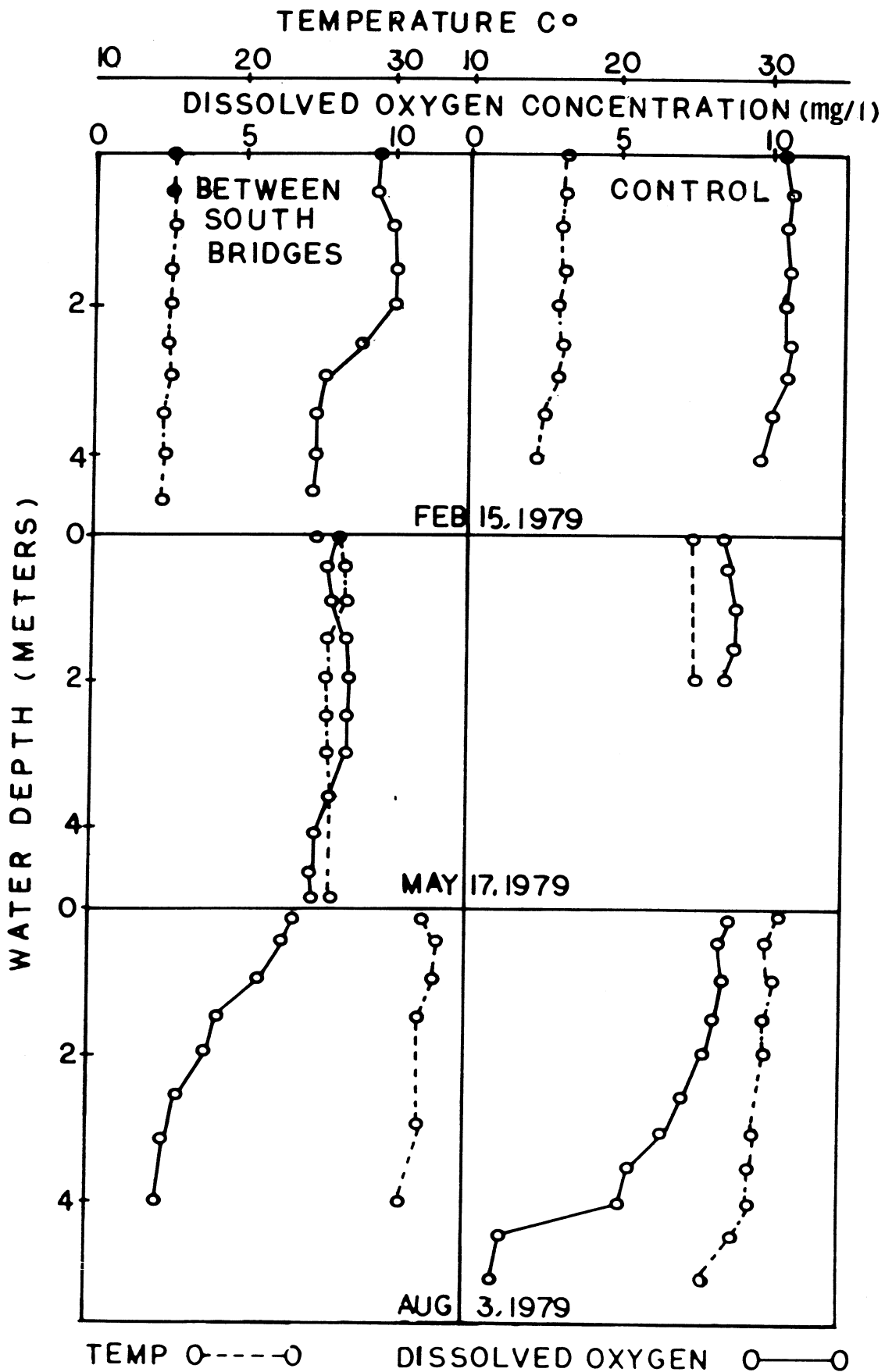


FIGURE 4-1. VARIATIONS IN DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON LAKE IVANHOE.

were found underneath the bridges, and the highest average concentration (18 $\mu\text{g}/\text{l}$) was exhibited by the control station. The decrease in average chlorophyll "a" concentrations in water samples collected from underneath the bridges could be caused by light limitations and/or toxic effects.

The nutrients measured showed large variations with nitrate concentrations ranging from .26 to 4.27 mg/l . The lowest average value of 0.64 was recorded underneath the south bridges and the highest value of 2.06 mg/l was measured for the control section. The standard deviations ranged from 0.35 to 1.93 mg/l . Average total phosphorus concentrations ranged from 0.09 for S-2 and 0.099 for S-4. The hardness ions, calcium and magnesium, showed the smallest differences between stations with the average concentrations ranging from 41.3 to 41.7 $\mu\text{g}/\text{l}$ for calcium and 4.3 to 4.4 for magnesium, respectively. The standard deviations were approximately 5.7 mg/l for calcium and .55 mg/l for magnesium.

Heavy Metals in Water

The concentrations of the various heavy metals measured are presented in tabular form in Appendices A-2 to A-5. These tables show that the average values for each of the parameters are generally of the same magnitude and they may differ slightly between various stations. Arsenic did show average values ranging from 35 up to 83 $\mu\text{g}/\text{l}$ of total As. Similarly the dissolved arsenic concentrations ranged from 23 to 70 $\mu\text{g}/\text{l}$. Cadmium concentrations were quite low and showed little variation between stations with average values ranging from 2 to 4 mg/l total Cd with the dissolved fraction accounting for approximately 65%. Copper concentrations averaged from 68 to 82 $\mu\text{g}/\text{l}$ total Cu of which an average of 34% was dissolved Cu forms.

The metals of the most interest in highway runoff are Zn, Cr, Pb, Fe and Ni. Average total zinc concentrations varied between 75 $\mu\text{g}/\text{l}$ for S-1 and 126 $\mu\text{g}/\text{l}$ for S-2. Average dissolved zinc concentration for the four stations fell between 30 and 60 $\mu\text{g}/\text{l}$, thus accounting for approximately 52% of the total concentrations. Total iron averaged from 174 at station S-3 up to 210 $\mu\text{g}/\text{l}$ at station S-2 with the dissolved metal averaging 50 to 80 $\mu\text{g}/\text{l}$ Fe. Lead, nickel, and chromium concentrations showed little, if any, real differences between each of the stations. Total lead averaged between 72 and 78 $\mu\text{g}/\text{l}$ for each of the stations with 45 to 61 $\mu\text{g}/\text{l}$ dissolved. Total nickel ranged from 11 $\mu\text{g}/\text{l}$ at S-1 and S-2 up to 18 $\mu\text{g}/\text{l}$ at S-3 and S-4. The dissolved nickel concentrations showed considerable greater variation ranging from 3 to 15 $\mu\text{g}/\text{l}$ or 27 to 83% of the total nickel in water samples. Finally, chromium concentrations varied little between stations with the average total chromium concentrations being 13 to 15 $\mu\text{g}/\text{l}$ and the dissolved fraction being 5 to 7 $\mu\text{g}/\text{l}$ Cr or roughly 44% of the total.

Runoff Water Quality

Several samples of runoff were taken directly from the scupper drains on the southern bridge at Lake Ivanhoe. A total of eleven separate runoff samples were collected from four different scupper drains during three storm events. Four samples were collected from four different scupper drains on the southern bridges for each storm event. The results of the analysis of these samples are presented in Appendices C-3 and C-4. These tables showed that the pH values varied between 6.75 and 8.80 with more than half of the readings showing pH less than 7.0. The average turbidity was 33.3 JTU and the average nitrate nitrogen was 3.87 $\text{mg-N}/\text{l}$. Also, the total phosphorus concentrations averaged 0.426 $\text{mg-P}/\text{l}$ and the soluble fraction averaged 0.067 $\text{mg}/\text{l-P}$ or approximately 16% of total phosphorus. The total calcium concentration averaged 38.07 mg/l

with 97% in solution and the total magnesium concentration averaged 1.06 mg/l with 78% in solution. The turbidity, nitrogen and phosphorus concentrations in runoff waters through scupper drains are three to five times higher than average concentrations measured in Lake Ivanhoe water.

Heavy metal concentrations in runoff water samples including Zn, Cd, As, Ni, Cu, Fe, Pb, and Cr were also measured. The total zinc concentrations averaged 498 $\mu\text{g/l}$ -Zn and the soluble fraction averaged 67%. Total cadmium and chromium concentrations were relatively low averaging 5 $\mu\text{g/l}$ for Cd and 11 $\mu\text{g/l}$ for Cr. The relative fraction in solution for both metals in all eleven runoff samples averaged 20% of the total metal. Total arsenic, nickel and copper averaged similar values showing 58 $\mu\text{g/l}$ -As, and 53 $\mu\text{g/l}$ -Ni, 52 $\mu\text{g/l}$ -Cu. The percent metal in solution averaged 86% for As, 92% for Ni, and 60% for Cu. The highest recorded values for bridge runoff water samples were recorded for Iron and Lead. The total iron and lead concentrations averaged 2429 $\mu\text{g/l}$ -Fe and 1558 $\mu\text{g/l}$ -Pb with an average of 12% in solution for both metals.

Bottom Sediments

Bottom sediments were collected from one to three sampling points at each sampling station from which a composite sample for the station was obtained. The sediments were analyzed to determine the moisture content, percent loss on ignition or volatile fraction, phosphorus content, calcium, magnesium and various heavy metal concentrations. These findings are presented in Appendices A-6 through A-11.

The specific characteristics of the sediments, namely water content and loss on ignition are shown in Appendix A-10. Values of the water content ranged from a low of 25.2% up to an extremely high value of 90.8% from the main body of the lake. The water content of the sediments below the south bridges

averaged 47.2 and 45.9% for Stations S-1 and S-2 with standard deviations of 10.4 and 8.7 indicating that these sediments were quite similar in character. The sediments below the north bridges had a water content of 38.6% with a standard deviation of 10.8. The sediments listed under station S-4, the control station, ranged in water content from 32.8% to 90.8% with an average and standard deviation of 64.8 and 21.8, respectively. It was obvious that heterogeneous sampling took place in the control section and in fact samples were taken from three distinct areas in the section of Lake Ivanhoe west of the highway bridges. The first sampling cross section was utilized on February 15 and March 16, however one sampling point was quite close to the highway and it was abandoned. The second sampling cross section was used during April and June, 1979 and then abandoned because sampling was difficult due to a thick layer of algae and detritus that covered the bottom. Also it was noted that the water content and loss on ignition were significantly different from those of the sediments found underneath the bridges and therefore might not be comparable. Subsequently a third cross section was utilized as a control for the remainder of the study. Appendix A-10 shows a station S-5 which we created for the purpose of statistical comparison by using the the data from the control section minus the three suspected values from the second cross section. The average water content of the control section S-5 was 52.80 with a standard deviation of 16.70 both of which were higher than for the other stations. Still this new sample set should be more amenable to comparison of values between stations.

The measurements of the volatile content or percent loss on ignition also varied over a wide range from 0.84 to 37.80%. These values for stations S-1 and S-2 averaged 3.65 and 3.21% loss with standard deviations of 2.81 and 1.57.

The data for the sediments collected from stations S-1 and S-2 under the south bridges were quite similar indicating their homogeneity. The percent loss on ignition for the sediments from S-3 under the north bridges averaged 2.14% with a standard deviation of 1.94. Finally, the heterogeneous nature of the sediments taken for the control section is also exhibited by the values of the percent loss on ignition. The measurements ranged from 1.42 to 37.80 averaging 12.1% with a standard deviation of 12.62. These findings show that the organic fraction of the sediments from the control section were four to five times that of the sediments beneath the bridges making any comparison of chemical parameters difficult. Therefore, the average and standard deviation of the measurements were once again computed without the use of the three values from the second cross section. The revised average and standard deviation for these values were 4.12 and 2.48 which were much closer values to those computed for the other cross sections underneath the bridges.

The chemical constituents measured in the sediments are presented in Appendices A-6 through A-9. These tables showed that the highest average phosphorus content was found in the control section, S-4. The concentration of phosphorus was 1610 for S-4 as compared to 776, 833, and 624 $\mu\text{g-P/g}$ oven dry weight for stations S-1, S-2, and S-3. Also, calcium concentrations were also highest in the control section, although the difference was not as pronounced as the phosphorus concentrations. The averages for the calcium concentrations measured for stations S-1 through S-4 were 5362, 4157, 2379, and 6770 $\mu\text{Ca/g}$ dry weight and standard deviations were 1892, 1572, 1130, and 6729 respectively. The large standard deviation of the calcium concentration for the control station, 6729, lends credence to the proposition that these sediments were very heterogeneous in nature. The highest average magnesium concentration of 970 $\mu\text{Mg/g}$ dry weight also occurred in the control section. This value was four to

five times the concentrations cited for the other stations which were 204, 182, and 93.7 for stations S-1, S-2 and S-3, respectively. The values of the concentrations of magnesium in the sediments collected below the north bridges were slightly lower than the sediments below the south bridges following the trend exhibited by phosphorus and calcium.

Heavy Metals in Bottom Sediments

The results for heavy metals associated with bottom sediments in Lake Ivanhoe are presented in Appendix A-6 to A-9. Cadmium showed the lowest relative concentrations in all cross sections ranging from a low of 0.00 to a high of 2.30 $\mu\text{g Cd/g}$ oven dry weight. The average concentrations of cadmium in the sediments were 0.502, 0.483, 0.276 and 0.887 with corresponding standard deviations of 0.390, 0.247, 0.183 and 0.809 for stations S-1 through S-4 respectively. Arsenic concentrations were an order of magnitude higher with average concentrations of 3.62, 6.02, 3.08 and 16.0 $\mu\text{g As/g}$ oven dry weight of sediments collected from S-1, S-2, S-3 and S-4, respectively. Significant copper concentrations were found in all the sediments analyzed averaging 63.7, 80.1, 29.2 and 222 $\mu\text{g Cu/g}$ dry weight for stations S-1 through S-4 with the corresponding standard deviations of 45.80, 42.1, 22.7 and 264. The standard deviations reinforced the idea that sediments in station S-4 exhibited a distinctly different amount of variation.

Nickel is frequently detected in highway runoff, however relatively small concentrations of this metal were measured in the sediments. The average concentrations of 12, 7.2, 2.8 and 12.4 $\mu\text{g Ni/g}$ dry weight of sediments were measured at stations S-1, S-2, S-3 and S-4 respectively. Zinc occurred in the sediments in greater abundance as exhibited by the concentrations which fell between 14.9 and 285 $\mu\text{g Zn/g}$ dry sediments. Zinc concentration averaged 98.80

96.90, 42.00, and 117.0 in the sediments of stations S-1 to S-4, respectively. Average chromium concentrations were determined to be 20.5 and 23.9 for S-1 and S-2, 11.0 for S-3 and 77.10 for S-4 in the control section. The corresponding standard deviations were 13.50, 8.99, 7.32 and 97.3 exhibiting the large variability in samples collected from the control section S-4.

Iron, although not toxic like some of the other heavy metals studied, is associated with urban and highway runoff. At the same time, significant amounts of iron appear naturally in the environment, especially in sedimentary materials, and is therefore not always a strict indicator of highway runoff pollution of the sediments. Nevertheless iron concentrations in the sediments were measured to determine if they were significant. These concentrations were quite high ranging between 186 and 4543 $\mu\text{g-Fe/g}$ oven dry weight of sediment. The average concentrations of iron for stations S-1 through S-4 were determined to be 1819, 814, 1689 and 825, and their corresponding standard deviations were 643, 225, 1788 and 1744. Tetraethyl lead is one of the primary additives of regular gasoline. The average lead concentrations calculated for each of the four stations were 386, 423, 132, and 206 $\mu\text{g Pb/g}$ dry weight at S-1, S-2, S-3 and S-4. Individual values of the lead concentrations ranged from a low of 20.0 in the control station to a high of 869 in between the south bridges.

In summary, the average concentrations of the parameters presented in Appendices A-6 to A-9 showed an identifiable trend for all the parameters with a few notable exceptions. Almost all of the parameters except lead and iron exhibited the highest average concentration for the control section S-4. The lowest average concentrations for all the parameters measured occurred underneath the north bridges without scuppers, S-3. This phenomenon may be due to the influence of the organic content of the sediments, as exhibited by the

moisture content and loss on ignition, upon the concentration and adsorption of these parameters. Iron deviated slightly from this pattern since the concentration for the control section falls in between the concentrations for the two stations under the south bridges, but the lowest concentration still occurs in the sediments underneath the north bridges. The more notable exception to this trend is the heavy metal, lead. Lead concentrations in the sediments from underneath the south bridges were nearly double the average for the control section and the concentration in the control section was nearly double that found underneath the north bridges without the scupper drains. It must also be realized that iron and lead collected in the runoff samples during this study were associated with particulate matter and only 12% of the total iron and lead were measured in solution. This may have limited the mobility and availability of these metals to adsorption sites.

Many investigators cited several factors that have influenced the concentration of heavy metals in the sediments. These factors included but were not limited to the size distribution of the sediments particles, the moisture content, the organic content, and the age of the sediments. Helmke, et al. (1977) showed that concentrations in the clay size fraction were fairly constant even when there was wide variance in the total sediment concentrations. They further showed that the clay size fraction could reflect the presence of contamination when the total concentration did not. Therefore, it was decided to analyze bottom sediments passing through sieve openings of 105 micron for composite sediment samples from each of the stations. The results of this analysis are shown in Appendix A-11.

Appendix A-11 showed that the same relative pattern noted earlier held true for the loss on ignition, As, Cr, Cu, Cd, As, Ca, and P concentrations in

sediment particles less than 105 micron size fraction from various sampling stations. The notable exceptions here were lead, iron, and nickel. Nickel concentration was greatest in station S-1 (41.0 $\mu\text{g}/\text{g}$), almost the same for stations S-2 and S-4 (33.7 and 32.0 $\mu\text{g}/\text{g}$), and considerably lower in the sediments underneath the north bridges, S-3 (14.7 $\mu\text{g}/\text{g}$). Iron exhibited a similar trend with the highest concentration, 3900 $\mu\text{g}/\text{g}$, occurring at station S-1, intermediate concentrations of 3191 and 3350 $\mu\text{g}/\text{g}$, being reported for stations S-2 and S-4 and the lowest concentrations appeared in the sediments underneath the north bridges, 1889 $\mu\text{g}/\text{g}$. Once again lead concentrations followed a distinctly different pattern. The highest lead concentrations of 984 $\mu\text{g}/\text{g}$ and second highest lead concentration of 827 $\mu\text{g}/\text{g}$ were found in the sediments below the south bridges with scupper drains. The concentration of lead under the north bridges without scupper drains was much less at 491 $\mu\text{g}/\text{g}$ and the lowest lead concentration was found in the control section, 355 $\mu\text{g}/\text{g}$. One further comparison may be made using this data. It can be noted from the table that the loss on ignition or organic content of the sediments collected between the south bridges with scuppers (S-2) and between the north bridges without scuppers (S-3) are quite similar at 7.6 and 6.9%. This should help to eliminate differences in concentration that occur due to the increased adsorption capacity and metal concentrations of the organic matter. The table shows that for all the parameters measured the concentrations in the sediments underneath the bridge with scuppers were higher than the sediments underneath the bridge without scuppers.

Plants In Lake Ivanhoe

Initially Hydrilla samples were collected from all four sampling stations and Typha (cattails) were collected from the control station and inside the southern bridges (S-1). Halfway through the sampling program a weed eradication

program was undertaken and the Hydrilla were eradicated. It was noted that Spirogyra, a filamentous macro-algae, dominated all segments of the lake and sampling of this species was initiated after the Hydrilla disappeared.

The percent moisture and loss on ignition are presented in Appendix Tables C-3 and C-4. The percent moisture for all plant samples collected from Lake Ivanhoe averaged 91.7%, 84.3% and 85.6% for Hydrilla, Spirogyra and Typha, respectively. Similarly, the percent loss on ignition for Hydrilla, Spirogyra and Typha averaged 77.5%, 86.0% and 89.2%, respectively. There is no significant difference in percent moisture content and percent loss on ignition between plant samples collected from various stations in Lake Ivanhoe.

The results of the metals analysis of the Typha samples were presented in Appendix A-14. Average concentrations of Mg, Ca, and P were almost identical for the two stations S-1 and S-4, averaging at 1.9, 15, and 1.5 mg/g oven dry weight. Average concentrations of the heavy metals were also quite similar for both stations, however, all the values except copper concentrations were slightly higher for the samples collected from inside the south bridges. Average concentrations of Pb, Cr, Ni and Zn for the two stations were approximately 23, 3.0, 2.0, and 22.0 $\mu\text{g/g}$ dry weight. Iron averaged 63.9 $\mu\text{g/g}$ inside the south bridge, S-1 and 55.9 in the control section, S-4.

The elemental analysis of the Hydrilla samples showed average concentration ranges of 4.9-5.7, 16.1-37.3, 1.8-4.5 mg/g oven dry weight for Mg, Ca and P, respectively in all four stations tested in Lake Ivanhoe. The average concentrations were 5.3 mg/g for magnesium, 25 mg/g for calcium and 3.4 mg/g for phosphorus. Cadmium concentrations were quite low and showed little variation falling between 1.2 and 2.0 $\mu\text{g/g}$. Concentrations of the other parameters varied more widely between stations. The highest average Zn, Ni, Cu and Pb concentrations of 333, 32.9, 140, and 248 $\mu\text{g/g}$, respectively, were found between

the south bridges. The highest Fe concentration of 798 was found between the south bridge and the highest average concentration of Cr, 122 $\mu\text{g}/\text{q}$, was found between the north bridges. The Cr values for this station do contain an anomalous value of 333 $\mu\text{g}/\text{q}$ whose elimination would make the average concentrations similar to the other stations. Lowest average concentration of Fe and Cr which were 541 and 17.4 were reported for the control station. Lowest average concentrations of Zn, Ni, Cu, and Pb were 229, 12, 107, and 127 $\mu\text{g}/\text{q}$, respectively, occurring in-between the north bridges. Examination of Appendix A-14 showed all the heavy metal concentrations, except chromium, to be higher in the Hydrilla samples collected in-between the south bridges with scupper drains (S-2) compared to those collected beneath the north bridge without scupper drains.

Spirogyra samples also showed little variations of average phosphorus and magnesium concentrations with values ranging from 2.9 to 4.7 and 1.7 to 3.2 for P and Mg, respectively. Highest concentrations of Cd, Zn, Ni, Fe, Pb, and Cr, which were 7.9, 188.5, 25.8, 1920, 375, and 46.0 $\mu\text{g}/\text{q}$ dry weight, respectively, were found in the two stations underneath the south bridges with scuppers. The lowest average concentrations of Cd, Zn, Ni, and Pb, 0.60, 91.6, 17.1, and 133.8 $\mu\text{g}/\text{q}$ were reported for the control sections. Lowest average Fe and Cu concentrations of 862 and 29 $\mu\text{g}/\text{q}$ were recorded from samples underneath the north bridges (S-3). Average concentrations of Cd, Zn, Ni, Fe, Pb and Cr in-between the south bridge with scuppers were higher and in some cases almost double the samples taken between the north bridges without scupper drains.

Benthic Organisms in Lake Ivanhoe Sediments

Data was collected to reflect both the distribution of the organisms collected and the heavy metal content of these organisms to detect the impact of the stormwater runoff on the benthic community, if any could be elucidated.

The organisms collected came from three major phyla (Molluska, Annelida, and Arthropodea) and the areal distribution of these organisms in terms of number per square meter is presented in Appendix A-15. The Mollusks averaged 11.6, 12.3, 61 and 0, the Annelids averaged 7.1, 7.3, 8.0 and 35.9 and the Arthropodea averaged 0, 2.0, 264 and 59.8 organisms per square meter of bottom sediments at stations S-1, S-2, S-3, and S-4, respectively. The results were widespread in the distribution of benthos and no distinct pattern could be observed as shown from Appendix A-15. One factor responsible was the appearance of organisms in a particular sampling station for only one sampling period. This is especially true of the control station whose location was shifted three times during the sampling program. Also there were differences in the composition of the sediments and the depth between the control portion of the lake and the area underneath the bridges. In general, the bottom of the control station was greater than two meters deep and composed of unconsolidated detrital material whereas the bottom underneath the bridges was usually less than two meters deep and sandy.

The benthic organisms collected were ashed and acid digested to determine their heavy metal content. The results are presented in Appendix A-16. The standard deviations and the ranges for the annelids and crustaceans are quite high in most cases due to the extremely small sample available for analysis. Some ashed weights were less than a milligram total weight and this produced heavy metal concentrations close to the detection limits. The error could be compounded when these values were converted to a per weight basis by dividing by the sample weight.

Mollusca class Gastropoda samples were obtained from stations S-1 through S-3. The analysis revealed that the concentrations for all the stations were

quite similar for each parameter. The samples taken underneath the south bridges did, however, vary from the samples taken under the north bridges, station S-3, in some cases. Arsenic concentration was higher under the north bridges at 26.9 $\mu\text{g}/\text{g}$ compared to 9.2 and 5.8 under the south bridges. Magnesium and calcium concentrations of 0.86 and 13.1 $\mu\text{g}/\text{g}$ were slightly higher than S-1 and S-2, also. Other parameters were somewhat higher in the organisms collected under the south bridges with the scupper drains. Most notably lead, which was 41.4 and 30.1 $\mu\text{g}/\text{g}$ for S-1 and S-2, as opposed to 21.0 $\mu\text{g}/\text{g}$ for S-3. Cadmium concentrations were also higher, averaging 0.40 and 0.39 under the south bridges and 0.18 under the north bridges.

Arthropoda class Crustacea samples were obtained from the control station, under the south bridges and under the north bridges. Concentrations of most parameters varied over a wide range and the standard deviations were high relative to average values. Average concentrations varied between 53.6 and 92.3 $\mu\text{g}/\text{g}$ for lead and 510 and 2589 $\mu\text{g}/\text{g}$ for iron. Average chromium concentration in the crustacean was lowest in the control at 25.0 $\mu\text{g}/\text{g}$ and 28.4 under the north bridges and highest at 71.4 underneath the south bridges.

Mollusca class Pelecypoda samples were limited in number. Only one sample was collected from the control station, S-4 and between south bridges, S-2. The highest concentrations for cadmium of 2.8, nickel of 12.4 lead at 194, and chromium of 24.5, were reported in the control section. It should, however, be noted here that the values represent only a single sample. The highest concentrations of zinc and iron at 39.3 and 593 $\mu\text{g}/\text{g}$, respectively, were reported from station S-1. The control section reported the lowest concentrations for these same parameters with the value of zinc being 24.9 and for iron 129 $\mu\text{g}/\text{g}$. The lowest lead concentration of 25.1 $\mu\text{g}/\text{g}$ was found in the mussels beneath the north bridges.

A limited number of Annelida class Oligochaeta, Tubifex samples were collected from each of the four sampling stations. Average zinc concentrations varied the most ranging from a low of 69.1 in the control section up to a high of 1667 reported under the north bridges. Lead concentrations also varied considerably from lower than detection limit at station S-1 up to 163 $\mu\text{g/g}$ under the north bridges. The highest concentrations of copper and iron were also detected under the north bridges. Otherwise a general trend for the concentrations of the parameters in each station is difficult to establish.

Appendix A-16 also presents results for samples of annelids, hirudineans, and planarians which were collected. Unfortunately these values represent only a single sampling at each of the stations and no average concentrations could be calculated. It seems complex and difficult to establish general trends for concentrations of heavy metals in various benthic organisms at different locations from a short term sampling period due to the mobility of organisms and the variability in available substrate from one station to another.

MAITLAND INTERCHANGE AND INTERSTATE 4

Four sampling stations, namely east pond, S-1, west pond, S-2, Lake Lucien near west pond outfall, S-3, and Lake Lucien control, S-4, were selected as shown in Figure 3-4. The results obtained from field measurements and laboratory analysis of water samples, bottom sediments, plants and benthos are presented in Appendices A, B and C.

Field Measurements

Dissolved oxygen and temperature profiles measured in various selected stations at Maitland exchange site are presented in Appendix C-2. The water depth varied between 1.0 to 3.0 meters at S-1, 1.50 to 2.0 meters at S-2, 0.5 to 2.0 meters at S-3, and 4.0 to 6.0-meters at S-4. Variations in water

temperature during the study period at these stations ranged between 16°C during February and 30°C during August 1979. Generally, a slight decrease in temperature with depth was noticed in Lake Lucien and a typical thermocline appeared to exist at a depth of 3.0 to 4.0 meters of water. The dissolved oxygen concentrations decreased with water depth and were lower during summer months than winter and spring, resulting from increased temperature and storm-water organic loading during summer. Selected temperature and DO profiles are presented in Figure 4-2 and Appendix C-2. The west pond (S-2) appeared to be turbid and lower in dissolved oxygen concentrations than other stations, particularly during the wet season and summer months. The dissolved oxygen during May to August 1979 in the west pond (S-2) varied between 6.2 mg/l at the water surface and 3.7 mg/l near the bottom sediments. The concentrations averaged about 60% of the saturation level. It must be realized that the west pond receives most of the highway runoff directly from the Maitland Interchange area and through the east pond (S-1). Lake Lucien showed 1 to 3 mg/l higher dissolved oxygen in the lake water than the west pond at all sampling times during May - August 1979.

Water Quality Analysis

Water quality characteristics, as shown in Appendix B-1, reflect wide variations among various sampling stations for all parameters tested. The pH values averaged 8.19, 7.76, 7.13 and 7.24 for stations S-1, S-2, S-3 and S-4, respectively. Turbidities were highest at the west pond station S-2. The turbidities averaged 7.4, 22.0, 2.7 and 5.5 JTU for stations S-1 to S-4 and the corresponding standard deviations were 4.9, 12.9, 1.1 and 4.0. These data reflect the large variability in turbidity measurements which ranged from 1.9 to 42.0 JTU in all sampling stations during the study period. The increased tur-

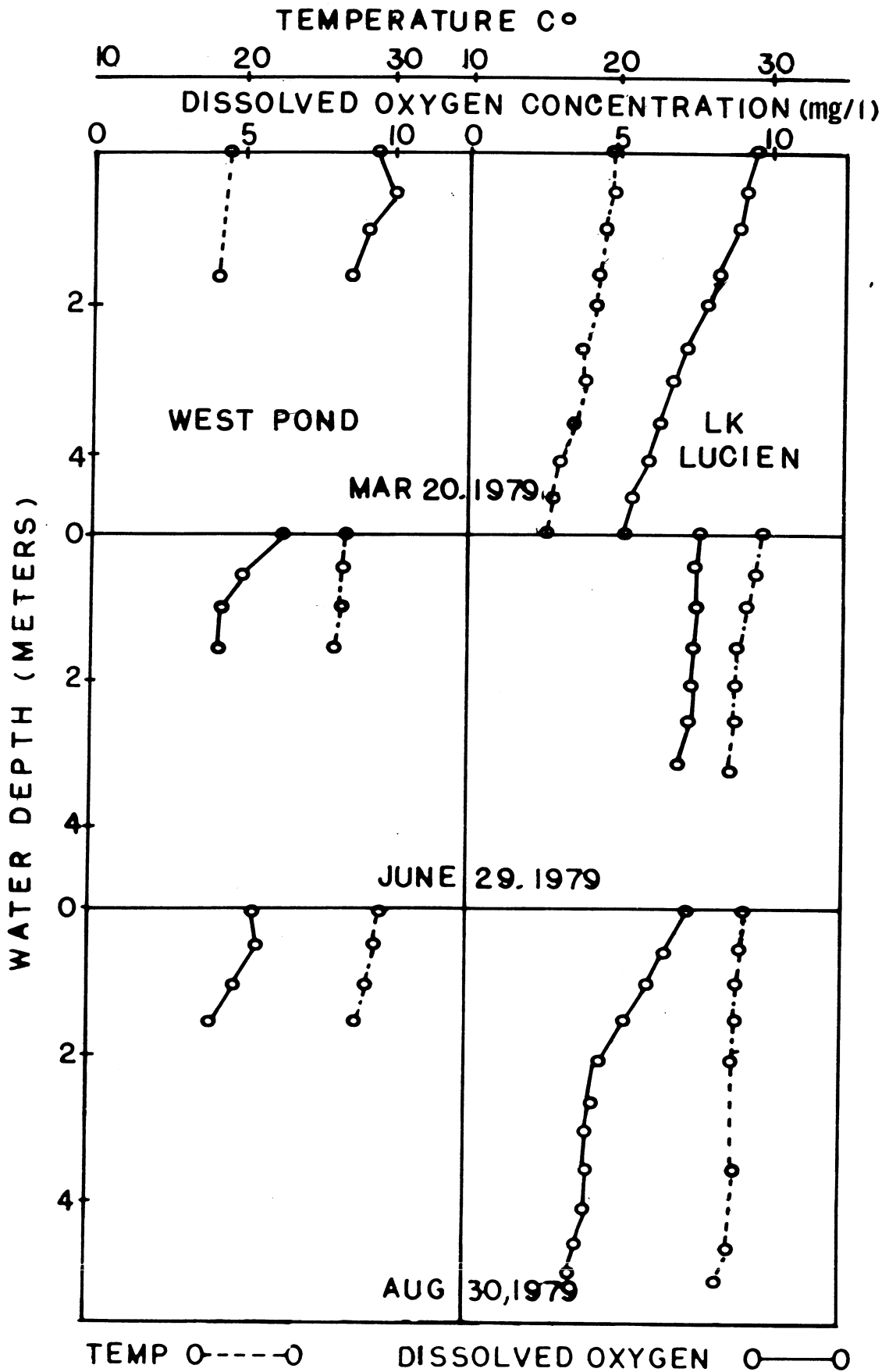


FIGURE 4-2. VARIATIONS IN DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON MAITLAND INTERCHANGE

bidity in the west pond, S-2, reflects the nature of stormwater runoff from adjacent highway bridges and from the east pond. Total organic carbon averaged 9.4, 8.8, 15.1 and 12.0 mg/l and the inorganic carbon averaged 14.3, 30.8, 6.8 and 7.1 for stations S-1, S-2, S-3 and S-4, respectively. It is obvious that the organic carbon content is higher in Lake Lucien than the drainage ponds. On the contrary, the inorganic carbon concentrations in Lake Lucien samples are lower than the drainage ponds. It may be reasonable to assume that the turbidities in Lake Lucien are caused mainly by organic particulates, while the turbidities in the east and west drainage ponds are caused mainly by inorganic particulates such as clay, silt and sand.

Chlorophyll "a" concentrations averaged 17.2, 8.1, 4.8 and 5.4 $\mu\text{g/l}$ and standard deviations were 17.3, 3.4, 0.9 and 2.2 for stations S-1, S-2, S-3 and S-4, respectively. It is interesting to notice that the chlorophyll "a" concentrations increased significantly in the east pond, S-1, during the months of July and August relative to measurements taken during February to June. The chlorophyll "a" concentrations in the west pond, S-2, decreased during the month of July and August because of the increased turbidity and/or toxic effects associated with highway runoff water. Chlorophyll "a" measurements showed that station S-1 had the highest average of 17.20 $\mu\text{g/l}$ and also showed the greatest variability with a standard deviation of 17.30 $\mu\text{g/l}$. The chlorophyll "a" concentrations at S-2 increased significantly during July and August and the values ranged from 7.50 to 53.1 $\mu\text{g/l}$ during the study period. Relatively few nitrate measurements were taken, however they show that station S-2 consistently had the highest concentration. The average concentrations for stations S-1 through S-4 were 1.01, 2.2, 0.5 and 0.4 mg-N/l, respectively, and the standard deviation close to 0.3 mg-N/l for all stations except S-3 which was 0.1. Total phosphorus concentrations recorded in this study ranged from undetectable to 0.63 mg-P/l.

Average values ranged from a high of 0.36 from station S-2 to a low of 0.04 mg/l-P at station S-3. The standard deviations were quite high relative to the average concentrations, 0.11 to 0.03 mg/l-P, reflecting the variability of concentrations with time.

The two principle hardness ions, calcium and magnesium, were also analyzed in each water sample collected. Results of these analysis showed that average calcium concentrations from stations S-1 through S-4 were 29.9, 56.1, 12.0, 11.9 mg/l and their respective standard deviations were 8.7, 4.3, 1.7, and 1.3 mg/l Ca. Magnesium concentrations showed the same type of differences between stations as calcium. Average concentration for station S-2 was once again the highest, 4.9 mg/l, and the concentrations for stations S-1, S-3, and S-4 were 1.9, 3.9, 4.2 mg/l, respectively. The standard deviations of the means were found to be 0.3, 0.8, 0.2, and 0.6 mg/l for stations S-1, S-2, S-3 and S-4.

Heavy Metals in Water

Each of the water samples collected was also analyzed to determine the concentrations of several heavy metals as presented in Appendices B-2 through B-5. Total zinc concentration ranged from below detectable limits to 138 μ g/l with dissolved concentrations ranging from below detectable to 92 μ g/l. The highest average total zinc was recorded for the east pond, 71 μ g/l with 46% in the dissolved form followed by S-2, S-3, and S-4 reporting 64 μ g/l with 67% dissolved, 57 μ g/l with 60% dissolved, and 56 μ g/l with 61% dissolved. Standard deviations ranged from 43 to 23 μ g/l for total concentrations and 26 to 6 μ g/l for the dissolved fraction. Average cadmium concentrations were extremely low with many individual measurements being below detectable limits. The average total cadmium concentration of 5 μ g/l was recorded for Lake Lucien with other average total cadmium levels being 2 to 3 μ g/l. Cadmium in Lake Lucien was all attached

to particulate matter as opposed to the other stations which averaged 50-66% in the dissolved form. Average arsenic concentrations for both the total and dissolved fractions were generally less than the standard deviation in all cases. Nickel concentrations showed that the highest concentration was found for the east pond, S-1, of 20 $\mu\text{g}/\text{l}$ with 40% in the dissolved form. The other stations showed 15 $\mu\text{g}/\text{l}$ of which 33% dissolved at S-2: 11 $\mu\text{g}/\text{l}$, 36% dissolved; and 7 $\mu\text{g}/\text{l}$ with 43% dissolved at S-4. The highest copper concentration was reported for the west pond, S-2, at 38 $\mu\text{g}/\text{l}$ with 55% dissolved followed closely by 36 $\mu\text{g}/\text{l}$ with 53% dissolved found for Lake Lucien, S-4. Levels of total copper in the east pond, S-1, and near the outfall into Lake Lucien, S-3, were 32 and 28 $\mu\text{g}/\text{l}$ of which 53% and 64% were in the dissolved form.

Three of the most important metals with respect to urban highway runoff are iron, lead and chromium. Total iron concentrations ranged between 77 and 690 $\mu\text{g}/\text{l}$, total lead fell between 9 and 129 $\mu\text{g}/\text{l}$ and total chromium values were reported from 1 to 49 $\mu\text{g}/\text{l}$. The highest average total iron, lead and chromium concentrations of 414, 92 and 17 $\mu\text{g}/\text{l}$ were found in the west pond, S-2. The next highest levels were found in the east pond, S-1, to be 241, 53, and 15 $\mu\text{g}/\text{l}$ for iron, lead and chromium. Concentrations in the two stations of Lake Lucien were quite similar, 140, 30 and 9 $\mu\text{g}/\text{l}$ at S-3 and 182, 33 and 9 $\mu\text{g}/\text{l}$ at S-4 for iron, lead and chromium, respectively. It appears that the fraction of the metal in the dissolved form increases as turbidity decreases. Station S-2 had the highest turbidity of 22.0 and showed 31% of the iron, 72% of the lead and 41% of the chromium in the dissolved form. Stations S-1 and S-3 had turbidities of 7.35 and 2.70 and showed 55% and 62% for dissolved iron, 83.0% and 83.3% for dissolved lead, and 47% and 78% for dissolved chromium for stations S-1 and S-3, respectively.

Bottom Sediments From Maitland Interchange

Samples of bottom sediments were collected and combined to obtain a composite sample for each sampling cross section. The sediment samples obtained were analyzed to determine their moisture content, % loss on ignition, calcium, magnesium and phosphorus content and heavy metal concentrations as presented in Appendices B-6 through B-11.

The moisture content of the sediments, as shown in Appendix B-6, averaged 24.4, 49.9, 76.4 and 46.2 for stations S-1 to S-4, respectively. The standard deviations were relatively low, being only 15 to 20% of the average indicating a reasonably homogenous set of samples over the sampling period. The percent loss on ignition which could be an indicator of volatile or organic content of the sediments showed a large variance between different sampling stations. Average values ranged from 1.0% at S-1 to 21.4% at the outfall to Lake Lucien, S-3. The values recorded for stations S-4 and S-2 were 3.6 and 9.2%. The standard deviations for this parameter were of the same magnitude as the averages, being 1.0 for S-1 and 20.6 for S-3. Phosphorus concentrations were 275, 3698, 1036 and 223 $\mu\text{g}/\text{g}$ oven dry weight for stations S-1 through S-4.

Calcium concentrations averaged 2690, 11105, 4483 and 820 $\mu\text{g}/\text{g}$ oven dry weight of bottom sediments for stations S-1 to S-4. Magnesium, like calcium concentrations, varied over a wide range from 27.8 to 2184.0 $\mu\text{g}/\text{g}$.

Average cadmium concentrations in $\mu\text{g}/\text{gram}$ of oven dry weight for the four stations were all very low ranging from 0.07 at S-1 to 0.59 at S-3. Arsenic content ranged from below detectable limits to 45.30. The averages for stations S-1 through S-4 were 4.27, 15.50, 11.80, and 1.49 and the standard deviations 3.95, 14.7, 12.7, and 1.48. Similarly nickel averaged 1.2, 10.6, 6.0 and 1.2 $\mu\text{g}/\text{g}$ of sediments from stations S-1, S-2, S-3 and S-4. The highest concentrations of cadmium, arsenic and nickel were detected in sediments from the west

pond, S-2, and its outfall to Lake Lucien, S-3. Copper concentrations were also lowest for S-1 and S-4 averaging 2.9 and 5 $\mu\text{g}/\text{g}$ oven dry weight of sediment. However, the highest concentration, 34.7, occurred at the outfall and was over twice that found in the west pond of 15.2.

Zinc concentrations were lowest in the east pond with a value of 9.4 and highest in the sediments from the outfall to Lake Lucien at 120.0 $\mu\text{g}/\text{g}$ dry weight. The west pond and Lake Lucien had intermediate values of 35.2 and 21.1 respectively. The concentrations reported for the outfall to Lake Lucien showed the greatest scatter with a standard deviation of 157.0 whereas the other standard deviations were 50 to 70% of the magnitude of the average. Concentrations of iron were much higher than those of zinc ranging from 127 to 7543. The outfall to Lake Lucien had the second highest average concentration of 2053 while the highest concentration of iron was found in the west pond sediments at 3265 $\mu\text{g}/\text{g}$ dry weight. The concentrations in the east pond and Lake Lucien averaged 561 and 421 $\mu\text{g}/\text{g}$ dry sediments. Low concentrations of chromium were reported for all stations. These concentrations averaged 33.9, 15.3, 3.00 and 2.51 for the west pond, outfall to Lake Lucien, east pond, and Lake Lucien. Lead in the sediments was of special interest since it has been related to highway runoff and tends to manifest itself in the sediments. The highest average concentrations were 98.40 in the west pond and 75.5 at the outfall into Lake Lucien. The concentrations of this metal averaging 13.0 and 10.7 in Lake Lucien and the east pond, were much lower than other stations and followed the same general pattern as the other heavy metals. In general, the highest concentrations of the heavy metals occurred in the west pond, S-2, and its outfall into Lake Lucien, S-3. The lowest values were consistently shown to exist in the east pond, S-1, and Lake Lucien, the control section, S-4.

Similar to Lake Ivanhoe, sediment samples from Maitland Interchange site

were dried, ground and sieved through a 105 micron openings size to test for heavy metals associated with fine fractions of the sediments. The results are presented in Appendix B-11.

The west pond and its outfall into Lake Lucien showed similar percent loss on ignition at approximately 21% which would allow easy comparison of these samples. The fine sediments from Lake Lucien showed a loss on ignition of approximately 11.9, and the fines from the east pond showed the lowest loss on ignition of only 3.2%. It can be seen from Table B-11 that the metal concentrations in the west pond, S-2, and the outfall to Lake Lucien, S-3, are higher than concentrations in other stations S-1 and S-4. Lead, chromium, nickel, copper, iron and cadmium concentrations in the fine sediments of S-2 and S-3 are several times higher than concentrations detected in S-1 and S-4.

Maitland Plants

Several different plants and macro-algae were collected from the sampling stations, however a species common to all four sampling stations could not be found. Chara samples were found only in the east pond, S-1. Water hyacinth (Eichornia) samples were taken for three different locations within the west pond, S-2. Water lily and Hydrocharis samples were found in Lake Lucien, S-4, and the outfall from the west pond, S-3. Cattails (Typha) were collected from the east pond, the west pond and the outfall for the west pond.

Data on the % moisture and % loss on ignition for each of the plant types is presented in Appendix Tables B-12 and B-13. Chara samples had a relatively low water content averaging 85.6% and % loss on ignition of 35.5%. Hydrocharis samples from S-3 and S-4 had almost identical water contents of 94.6% and loss on ignition of 82%. The average % water content of the Eichornia samples were 92-93% and the % loss on ignition averaged 81-84%. Typha samples from each

station showed a water content ranging from 85-88% and % loss on ignition between 89-91%.

Chara, a green macro-algae, exhibited the concentrations of Zn, Ni, Fe, Pb, and Cr averaging 61.5, 10.6, 609.6, 137.4, and 22.0 $\mu\text{g}/\text{g}$ dry weight. The results of the analysis of the water hyacinths showed that concentrations are similar between each of the stations with Zn, Fe, and Pb showing the most variance. Average concentrations of Zn ranged from 70.0 - 97.1 $\mu\text{g}/\text{g}$, Fe ranged between 854 and 1137 $\mu\text{g}/\text{g}$ and Pb concentrations fell between 75.0 and 96.0 $\mu\text{g}/\text{g}$.

Water lily samples are collected from the two sampling stations, S-3 and S-4, within Lake Lucien. The results in Appendix B-14 show the concentrations of the various parameters vary only slightly between stations. Concentrations of As, Zn, Ni, Cu, Fe, Cr, and Mg averaged approximately 7.4, 44.0, 2.6, 9.0, 124, 2.7, and 2.5 $\mu\text{g}/\text{g}$, respectively at both stations. Cadmium, lead and calcium concentrations in the control section, S-4 were 0.32, 21.4, and 14.5 which were higher than the concentrations of 0.17, 16.3, and 11.3 reported for the same constituents at the outfall from the west pond, S-3. Hypericum samples were also collected from these two stations within Lake Lucien. The average concentrations of As, Cd, Ni, Mg, Ca, and P for both stations were 17.0, 1.0, 5.0, 5500, 18700 and 1100 $\mu\text{g}/\text{g}$, respectively. Concentrations of 257.5, 46.2, 1252 and 78.5 $\mu\text{g}/\text{g}$ for Zn, Cu, Fe, and Pb in the control sections were higher than those of 223, 32.5, 837.6, and 71.1 $\mu\text{g}/\text{g}$ reported for Hypericum samples collected from the outfall.

Typha samples were collected from the west pond, east pond and the outfall. Concentrations of 0.25, 2.7, 12.0 and 1.0 $\mu\text{g}/\text{g}$ for Cd, Ni, Ca, and P were reported for all three stations. Samples of Typha taken from the east pond had the highest concentrations of the three stations for As, Zn, Cu, Fe, Pb, and Cr which were 11.3, 45.3, 13.0, 229, 26.6, and 4.3 $\mu\text{g}/\text{g}$ dry weight. The lowest

average concentrations of Zn, Fe, Pb, and Mg, were found in the samples taken from the west pond and samples from its outfall into Lake Lucien showed the lowest average concentration of As and Cr.

The heavy metal concentrations detected in plants collected from various sampling stations are indicative of the ability of these plants to concentrate selected metals. Lead in particular, is toxic and not required for plant growth, however higher lead concentrations than most of the metals studied were detected in all plants tested.

Benthic Organisms in Sediments From Maitland Interchange

The benthic organisms collected from the Maitland interchange sampling stations have been grouped into mollusks, annelids and arthropodeans. The averages presented for the mollusks in Appendix B-15 showed that the sampling areas were sparsely populated with these organisms. The highest population densities averaging 8 and 6 organisms per m^2 were reported from the outfall into Lake Lucien, S-3, and Lake Lucien control, S-4, respectively. The number of organisms in the borrow ponds was quite low with an average of 2 organisms/ m^2 in the east pond and less than 1 organism/ m^2 in the west pond. Organisms were collected in the control station, Lake Lucien, during four of the eight sampling periods and two or less times in each of the other locations.

The annelids, consisting primarily of Tubifex worms, were collected from all the sampling stations. The largest populations were encountered in the east pond, S-1, and Lake Lucien, S-4, in which the organisms density averaged approximately 69 organisms/ m^2 . Lower numbers were found in the west pond, S-2, and the outfall, S-3, of the west pond into Lake Lucien, the actual numbers being 26 and 21 organisms/ m^2 . Arthropodeans, which include crustaceans and insect larva, were noted in only two samples which occurred in the east pond.

21 crustacean organisms/m² were found on March 20 and subsequent samplings did not produce any of these organisms. Likewise, insect larva, or more specifically dragonfly nymphs, were only encountered in the east pond, 14 organisms/m² on July 20, 1979 as shown in Appendix 13-15.

The results of the chemical analysis of the benthic organisms collected is presented in Appendix B-16. Again, wide variations in number of organisms in various stations and sampling dates were detected and extremely small samples were collected for some organisms. The data for some of the organisms are regrettably too few for a statistical analysis or comparison between stations.

The average concentrations of metals in Gastropoda for each of the stations ranged from 7.4 to 87.8 µg-Pb/g, 84.9 to 147 µg-Fe/g, 23.5 to 2174 µg-Zn/g, 0.53 to 5.3 µg-Ni/g and 0.59 to 43.2 µg-Cr/g. For stations in which organisms were collected on more than one sampling period, the standard deviations were generally of the same magnitude as the mean or less, with a few exceptions.

Several Tubifex samples were obtained from every one of the four sampling stations. The highest concentrations of cadmium, zinc, nickel, copper, iron, lead, chromium, magnesium, and calcium were detected in the organisms taken from the west pond. The concentrations ranged from 250 to 1488 µg/g for zinc, 16.3 to 504.6 µg/g for nickel, 587 to 6178 µg/g for iron, 7.5 to 559 µg/g for lead, and 13.1 to 129.8 µg/g for chromium.

The data collected from the benthic organisms studies were widely scattered which made it extremely difficult for statistical analysis. It is interesting to notice that the lowest density of organisms per square meter occurred in the west pond bottom sediments which contained the highest concentrations of heavy metals.

CHAPTER V

STATISTICAL ANALYSIS AND DISCUSSION

During the course of this study, experimental efforts were designed to examine the impact of highway bridges runoff on the surrounding environments under and near bridge locations. Therefore, samples of water, sediment, plant and benthos from Lake Ivanhoe and Maitland Interchange sites were collected, analyzed and the results were presented in the previous chapters. Statistical analyses of results, significant differences between various sampling stations and quantification of the impact from highway bridges runoff on receiving water bodies will be discussed throughout this chapter.

WATER ANALYSIS

The heavy metals associated with the water column in study areas were statistically analyzed and significant differences between various sampling stations in Lake Ivanhoe and Maitland Interchange sites were examined.

Lake Ivanhoe

Water samples were collected from Lake Ivanhoe beneath two sets of scupper drains on the south bridges, S-1 and S-2, beneath the north bridges without scupper drains, S-3, and from open Lake Ivanhoe control section, S-4. The results, as presented in Appendix Tables A-2 to A-5, show that the average total and dissolved concentrations in the water column were quite similar. Also, from the statistical t-test analysis, using SAS program from the University of South Florida, it was concluded that water samples S-1, S-2, S-3, and S-4 did not show

significant differences in heavy metal concentrations. The total concentrations of heavy metals detected in runoff samples collected from four different scupper drains on the south bridges averaged 4.7, 20.8, 3.5 and 12.6 times higher than the average Zn, Pb, Ni and Fe concentrations in Lake Ivanhoe water, respectively as shown in Table 5-1. Minor differences were found between total Cr, Cd, and As in runoff samples and the lake water samples. The impact of the increased metals, particularly lead and iron in runoff samples over concentrations in lake water was difficult to assess because of the difficulty of isolating various pollutional sources, mixing effects by recreation activities on the east side of the lake and the continuous stream flow out of the lake. Certainly, dispersion of the soluble fraction of heavy metals throughout the lake is dependant on mechanical mixing, wind speed, density gradient and thermal gradient. A simplified approach to determine increased concentrations of heavy metals in the lake water column due to direct release through scupper drains may consider steady state conditions and completely mixed lake. However, further studies on mixing zones are needed before a satisfactory answer to this question is made. These mixing zones are currently under study for FDOT by Dr. Wanielista, et al. at the University of Central Florida.

Lead is of particular concern, since it is toxic, released in relatively higher concentrations than other elements detected in runoff water and existing dissolved lead in Lake Ivanhoe water violates the rules for maximum permissible concentrations recommended by Florida Department of Environmental Regulations, Chapter 17-3. These rules specify that surface water should not contain more than 50 $\mu\text{g}/\text{l}$. Also, the Environmental Studies Board for National Academy of Sciences and National Academy of Engineering published their report on Water Quality Criteria (1972) which stated that the concentration of lead in water should not be higher than 30 $\mu\text{g}/\text{l}$ at any time or place in order to protect the

TABLE 5-1. COMPARISON BETWEEN HEAVY METALS IN BRIDGE RUNOFF AND LAKE IVANHOE WATER SAMPLES

| Parameter | Form | Average Concentration $\mu\text{g}/\text{l}$ | | % Dissolved | | Ratio Runoff/ Lake |
|-----------|-----------|---|---------------|-------------|---------------|--------------------------|
| | | Lk Ivanhoe | Bridge Runoff | Lk Ivanhoe | Bridge Runoff | |
| Zn | Total | 104 | 498 | | | 4.7:1.0 |
| | Dissolved | 57 | 336 | 55 | 67 | 5.9:1.0 |
| Pb | Total | 75 | 1558 | | | 20.8:1.0 |
| | Dissolved | 55 | 187 | 73 | 12 | 3.4:1.0 |
| Ni | Total | 15 | 53 | | | 3.5:1.0 |
| | Dissolved | 9 | 49 | 60 | 92 | 5.4:1.0 |
| Fe | Total | 192 | 2427 | | | 12.6:1.0 |
| | Dissolved | 68 | 287 | 35 | 12 | 4.2:1.0 |
| Cu | Total | 74 | 52 | | | 0.7:1.0 |
| | Dissolved | 30 | 27 | 40 | 52 | 1.1:1.0 |
| Cr | Total | 14 | 11 | | | 0.8:1.0 |
| | Dissolved | 6 | 7 | 43 | 64 | 1.2:1.0 |
| Cd | Total | 4 | 5 | | | 1.3:1.0 |
| | Dissolved | 2 | 1 | 50 | 20 | 0.5:1.0 |
| As | Total | 57 | 58 | | | 1.0:1.0 |
| | Dissolved | 43 | 50 | 75 | 86 | 1.2:1.0 |

aquatic life. Table 5-1 indicated that the average total lead concentration was 75 $\mu\text{g}/\text{l}$ and the average dissolved lead concentrations were 55 $\mu\text{g}/\text{l}$ in Lake Ivanhoe water column. Also the average total lead concentration in runoff water from scupper drains was 1558 $\mu\text{g}/\text{l}$ and the average dissolved lead was 187 $\mu\text{g}/\text{l}$. The lead released through scupper drains can be estimated assuming an average rainfall or runoff of 50 inches/year (1.27 m/vr) on 73440 square feet (6823 sq. meter) of surface area for the south bridges and average lead concentrations detected in the runoff water during this study will hold true throughout the year. Based on these assumptions, the total and dissolved lead released can be calculated as 13.5 and 1.6 kilograms per year, respectively. This is in general

agreement with lead loadings reported by Gupta (1978). It must also be realized that these calculations do not consider contributions by dustfall or bulk precipitation. Also for comparison purposes, the amount of lead released to Lake Ivanhoe from its drainage basin of 828.8 ha, assuming loading rates for general urban areas as recommended by Pluraz, et al. (1978) of 0.14 to 0.5 kg/ha/yr, will range from 116 to 414 kg/yr. Again, lead contributions from motor boating activities and other sources to Lake Ivanhoe are disregarded. These calculations demonstrate the fact that lead contribution through scupper drains may be significant and should not be ignored. Lead concentrates in the bottom sediments close to the point of release and its fate and long term impact is not fully known. Also, the lake is divided into eastern and western sections. Bridge runoff is released to the western section which is not used for boating activities. It is also a smaller area than the eastern section and it is difficult to assess urban stormwater contribution on this western section without much detailed study.

It was also noticed from Table 5-1 that the dissolved fractions of lead concentrations were 12 percent of the average runoff water through scupper drains and 88% was associated with the particulate matter or 11.9 kg/yr of particulate lead could be released to Lake Ivanhoe. Lead compounds are generally detected in the most dense fraction of the soil (Olson and Skogerboe, 1975; Bell and Wanielista, 1979) and will settle out of the water column. The fate of this particulate metal is not fully understood. The interactions between lead in particulate matter and the water column and the sorption-desorption characteristics of lead particulates at the water sediment interface need further investigation.

Maitland Interchange Site

This site was selected to investigate the extent and fate of pollutional loads from highway bridge runoff in detention ponds. Therefore, water samples were collected from the east pond, S-1, the west pond, S-2, outfall from west pond to Lake Lucien, S-3, and Lake Lucien control section, S-4, to detect if there were significant differences in heavy metal concentrations between various sampling stations. It must be realized that the highway runoff water flows from S-1 to S-2 and to Lake Lucien through S-3. Also, the west pond, S-2, receives direct runoff from Interstate-4 and Maitland overpass.

Data presented in Appendix Tables B-2 to B-5 show that S-2 contained the highest average lead, iron and chromium concentrations in the water column of all stations tested. The average total lead concentration, 92 $\mu\text{g/l}$ in the water column of the west pond, S-2, was higher than the maximum permissible concentration of 50 $\mu\text{g/l}$ specified by the rules of Florida Department of Environmental Regulations for Surface Waters, Chapter 17-3. Also dissolved lead concentrations in the water column were 83, 72, 83 and 58% of the total lead in S-1, S-2, S-3 and S-4, respectively. Again, it appeared that most of the dense particulate lead would have settled out of the water column near the source, leaving mainly dissolved fractions and small size particles to flow through.

The statistical analysis, t-test, showed that concentrations of total lead in the water column were significantly higher in the west pond, S-2, as compared to both the east pond, S-1, and Lake Lucien, S-4, with a probability of more than 99% as shown from Tables 5-2 and 5-3. The highway runoff flows through a grassy area at the median and a thick plant growth surrounding the shore of the east pond, S-1. Also, the bottom sediment at S-1 appeared to be sandy soil with very little muck accumulated as evidenced by the percent loss on ignition. Station S-2 contained the highest Pb, Fe and Cr in the water column of all

stations tested because the west pond received direct highway runoff and the water column was relatively turbid and contained fine particles of clay and silt in suspension.

The results of this study indicate that bridge runoff contains relatively high concentrations of heavy metals, especially lead which was 12% soluble and 88% particulate. The dense particles of heavy metals settled out of the water column near the source and became immobilized by the bottom sediments.

TABLE 5-2. SIGNIFICANCE OF DIFFERENCES IN HEAVY METAL CONCENTRATIONS OF WATER SAMPLES FROM MAITLAND INTERCHANGE

| Element | No. of Observ. | Average Concentrations $\mu\text{g/l}$ | | | | Percent Probability | |
|---------|----------------|--|----------------|----------------|----------------|---------------------|-----------|
| | | Total | | Dissolved | | Total | Dissolved |
| | | S-1 E. Pond | S-2 W. Pond | S-1 E. Pond | S-2 W. Pond | | |
| Zn | 8/7* | 71 | 64 | 32 | 43 | 24.1 | 63.2 |
| Pb | 8/7 | 53 | 92 | 44 | 66 | 99.4 | 84.7 |
| Cr | 8/7 | 15 | 17 | 7 | 7 | 37.4 | — |
| Ni | 8/7 | 20 | 15 | 8 | 5 | 39.6 | 62.1 |
| Cu | 8/7 | 32 | 38 | 17 | 21 | 48.7 | 53.2 |
| Fe | 8/7 | 241 | 414 | 132 | 128 | 93.1 | 5.3 |
| Cd | 8/7 | 3 | 3 | 2 | 2 | 7.6 | 29.8 |

TABLE 5-3. SIGNIFICANCE OF DIFFERENCES IN HEAVY METAL CONCENTRATIONS OF WATER SAMPLES FROM MAITLAND INTERCHANGE

| Element | No. of Observ. | Average Concentrations $\mu\text{g/l}$ | | | | Percent Probability | |
|---------|----------------|--|----------------|------------------|----------------|---------------------|-----------|
| | | Total | | Dissolved | | Total | Dissolved |
| | | S-4 Lk Lucien | S-2 W. Pond | S-4 Lk Lucien | S-2 W. Pond | | |
| Zn | 8/7* | 56 | 64 | 34 | 43 | 45.9 | 75.6 |
| Pb | 8/7 | 33 | 92 | 19 | 66 | 99.9 | 98.6 |
| Cr | 8/7 | 9 | 17 | 5 | 7 | 84.9 | 70.4 |
| Ni | 8/7 | 7 | 15 | 3 | 5 | 80.8 | 53.6 |
| Cu | 8/7 | 36 | 38 | 19 | 21 | 29.2 | 34.9 |
| Cd | 8/7 | 5 | 3 | 0 | 2 | 32.5 | 89.6 |
| Fe | 8/7 | 182 | 414 | 82 | 128 | 98.4 | 52.4 |

* 8 Total and 7 Dissolved samples were analyzed.

BOTTOM SEDIMENTS ANALYSIS

Lake Ivanhoe Site

A sizeable fraction of heavy metals in runoff water through scupper drains was associated with particulate matter as shown from Table 5-1. Particulate and dissolved fractions will eventually be transported to the bottom sediments and quasi-equilibrium will be maintained between heavy metals in the sediments and the overlying water column. Therefore sediment samples were collected from beneath north bridges without scupper drains and south bridges with scupper drains to detect significant differences in heavy metal concentrations. The extractable heavy metals in sediments were measured as discussed in Chapter III. Again, statistical analysis, t-test, was performed to compare concentrations in the sediment from stations S-1 and S-2, both located beneath two sets of scupper drains beneath south bridges. There were no significant differences between the two stations.

Significant differences were shown to exist between bottom sediments collected from S-2 and S-3 as presented in Table 5-4. Notice that S-2 is beneath bridges with scupper drains and S-3 is beneath bridges without scupper drains. Table 5-4 showed that sediments from S-2 were significantly different in concentrations of Zn, Pb, Cr, Ni and Fe than sediment samples from S-3 with an excess of 99% probability. Lead was different with 99.99% probability. Heavy metal concentrations for Zn, Pb, Cr, Ni, Cu and Fe in sediments from S-2 were two to three times higher than sediments from S-3. These data agreed with published literature that most heavy metals from highway runoff were concentrated in the bottom sediments near the source. Also, lead released through scupper drains was generally associated with particulate matter and settled out of the water column in the vicinity of the point of release. Dissolved lead was probably

dispersed throughout the lake, but particulate lead was immobilized by the sediments. The results also suggest that sediments may be used as an indicator for types and sources of pollution since they concentrate heavy metals even when the water column contains very little.

TABLE 5-4. SIGNIFICANCE OF DIFFERENCES IN HEAVY METAL CONCENTRATIONS OF BOTTOM SEDIMENTS FROM LAKE IVANHOE

| Element | No. of Observ. | Mean Values $\mu\text{g}/\text{gm}$ (dry wt.) | | Percent Probability |
|---------|----------------|---|-------------------------|---------------------|
| | | S-2 With Scuppers | S-3 Without Scuppers | |
| Zn | 8/7 | 96.9 | 42.0 | 99.60 |
| Pb | 8/7 | 423.0 | 132.0 | 99.99 |
| Cr | 8/7 | 23.9 | 11.0 | 97.07 |
| Ni | 8/7 | 7.2 | 2.8 | 99.60 |
| Cu | 8/7 | 80.1 | 29.2 | 98.71 |
| Fe | 8/7 | 1689.0 | 643.0 | 99.85 |
| Cd | 8/7 | 0.5 | 0.3 | 91.38 |

Maitland Interchange Site

The bottom sediments from the west pond, S-2, contained extractable Zn, Pb, Cr, Ni, Cu, Fe and Cd at concentrations ranging from three to eleven times higher than concentrations detected in sediments from the east pond, S-1, as shown from Table 5-5. Also, Table 5-6 showed that similar extractable heavy metals from S-2 were two to fourteen times higher in concentrations than sediments from the control station at Lake Lucien, S-4. Much smaller differences were found between concentrations of heavy metals from S-2 and S-3 as presented in Table 5-7. The t-test analysis, Tables 5-5 and 5-6 showed that Pb, Cr, Ni, Fe and Cd concentrations were significantly higher, with a probability greater than 95%, at station S-2 than either S-1 or S-4.

Water flows directly from the west pond, S-2, over a wooden wier into a culvert discharging through a canal to S-3 in Lake Lucien. The bottom sediments

TABLE 5-5. SIGNIFICANCE OF DIFFERENCES IN HEAVY METAL CONCENTRATIONS OF BOTTOM SEDIMENTS FROM MAITLAND INTERCHANGE (T-Test Analysis)

| Element | No. of Observ. | Mean Values $\mu\text{g}/\text{gm}$ (dry wt) | | Percent Probability |
|---------|----------------|--|------------------|---------------------|
| | | S-1 East Pond | S-2 West Pond | |
| Zn | 8/7 | 9.4 | 35.2 | 96.6 |
| Pb | 8/7 | 10.7 | 98.4 | 97.8 |
| Cr | 8/7 | 3.0 | 33.9 | 98.6 |
| Ni | 8/7 | 1.2 | 10.6 | 97.7 |
| Cu | 8/7 | 2.9 | 15.2 | 96.5 |
| Fe | 8/7 | 561.0 | 3265.0 | 98.3 |
| Cd | 8/7 | 0.1 | 0.5 | 96.4 |

TABLE 5-6. SIGNIFICANCE OF DIFFERENCES IN HEAVY METAL CONCENTRATION OF BOTTOM SEDIMENTS FROM MAITLAND INTERCHANGE (T-Test Analysis)

| Element | No. of Observ. | Mean Values $\mu\text{g}/\text{gm}$ (dry wt) | | Percent Probability |
|---------|----------------|--|------------------|---------------------|
| | | S-4 Lake Lucien | S-2 West Pond | |
| Zn | 8/7 | 21.1 | 35.2 | 80.27 |
| Pb | 8/7 | 13.0 | 98.4 | 97.51 |
| Cr | 8/7 | 2.5 | 33.9 | 98.87 |
| Ni | 8/7 | 1.2 | 10.6 | 97.64 |
| Cu | 8/7 | 5.0 | 15.2 | 93.17 |
| Fe | 8/7 | 421.4 | 3264.7 | 98.62 |
| Cd | 8/7 | 0.1 | 0.5 | 96.05 |

TABLE 5-7. SIGNIFICANCE OF DIFFERENCES IN HEAVY METAL CONCENTRATIONS OF BOTTOM SEDIMENTS FROM MAITLAND INTERCHANGE (T-Test Analysis)

| Element | No. of Observ. | Mean Values $\mu\text{g}/\text{gm}$ (dry wt) | | Percent Probability |
|---------|----------------|--|------------------|---------------------|
| | | S-3 Lake Lucien | S-2 West Pond | |
| Zn | 8/7 | 119.6 | 35.2 | 82.37 |
| Pb | 8/7 | 75.5 | 98.4 | 47.76 |
| Cr | 8/7 | 15.3 | 33.9 | 92.98 |
| Ni | 8/7 | 6.0 | 10.6 | 82.49 |
| Cu | 8/7 | 34.7 | 15.2 | 76.15 |
| Fe | 8/7 | 2053.0 | 3265.0 | 76.33 |
| Cd | 8/7 | 0.6 | 0.5 | 26.87 |

from S-3 contained the highest average water content and percent loss on ignition which might have contributed to the increased accumulation of heavy metal in sediments from S-3. Also, continuous leakage through the wooden wier was noticed and flow regulation between S-2 and S-3 was non-existent. It may be possible to minimize the flow of highway pollutants from the west pond, S-2, to Lake Lucien by proper design and control of flow regime. Probably detention ponds with underdrains or natural percolation, adequate contact and settling time, control of flow through the pond exit to Lake Lucien and/or installation of a sand or limestone filter into the canal leading to Lake Lucien would improve the water quality released to Lake Lucien.

It is interesting to notice that sediments from S-2 beneath scupper drains of the south bridges of Lake Ivanhoe contain 423 $\mu\text{g-Pb/g}$ oven dry weight which was four times in excess of the lead concentration, 98.4 $\mu\text{g-Pb/g}$ oven dry weight of sediments from the west pond, S-2, at Maitland Interchange. This was understandable since the Maitland Interchange is relatively new with lower average daily traffic (ADT) as shown from Table 3-1. If the sediment characteristics of both locations are similar, it may be reasonable to assume that bottom sediments of the west pond have the capacity to retain much higher mass of lead than the existing load. Zimdahl and Skogerboe (1977) quantified the capacity of a particular soil to concentrate lead using laboratory tests. They developed the following equation:

$$N = 2.81 \times 10^{-6} \text{ CEC} + 1.07 \times 10^{-5} \text{ pH} - 4.93 \times 10^{-5}$$

where

N = moles of lead per gram of soil at saturation

CEC = Cationic exchange capacity of the soil (meq/100 g) and

pH = hydrogen ion concentration of the soil in pH units.

Soils typical of Florida were studied by Bell and Wanielista (1979). They estimated the soil capacity using the regression equation by Zimdahl and Skogerboe (1977) to range from 3.97×10^{-5} to 7.74×10^{-5} moles-Pb/g or 8218 to 16022 $\mu\text{g/g}$ of soil. If these values are correct and the soils in the west pond of Maitland Interchange behaved similar to those tested by Zimdahl and Skogerboe (1977), the bottom sediments will have an additional capacity to immobilize lead that would range from 80 to 160 times more than existing lead content. This again proves that much higher lead can be immobilized in the west pond sediments. Proper contact time, design of inlets and exits and addition of relatively inexpensive treatment filters will certainly improve the removal efficiency of heavy metals in the pond and also will improve the water quality discharged to Lake Lucien.

BIOTA ANALYSIS

Attempts were made to examine significant differences of the heavy metal concentrations in phytoplankton and zooplankton collected from various sampling locations. However, difficulties experienced with sampling common species among all stations at the same sampling time complicated the analysis. The number of samples from each station and sampling dates were not uniform, but specific conclusions were reached and will be discussed.

Lake Ivanhoe Site

The phytoplankton samples collected from Lake Ivanhoe included aquatic plants and macro-algae such as Hydrilla, Spirogyra and Typha. The benthic organisms included Arthropodea (Crustacea), Molluska (Pelecypoda and Gastropoda) and Annelida (Oligochaeta, Tubifex). The analysis revealed that there were no significant differences in heavy metal concentrations of plant and benthos collected from stations S-1 and S-2, both located beneath two sets of scupper

drains on the south bridges. However, Tables 5-8 and 5-9 showed significant differences in heavy metal concentrations of Spirogyra and Hydrilla collected from stations S-2 and S-3 beneath bridges without scuppers. Concentrations of Zn, Pb, Fe and Cd were significantly higher with a probability of more than 90% in Spirogyra collected from S-2 compared to those collected from S-3. Also, concentrations of Zn, Pb, Ni and Cd were significantly higher with a probability of greater than 80%, in Hydrilla, collected from S-2 as compared to those collected from S-3. The scarcity of data collected on benthic organisms did not allow for t-test analysis and determination of significance of differences in results.

TABLE 5-8. SIGNIFICANCE OF DIFFERENCES IN HEAVY METALS CONCENTRATION OF SPIROGYRA FROM LAKE IVANHOE (T-Test Analysis)

| Element | No. of Observ. | Mean Values $\mu\text{g}/\text{gm}$ (dry wt.) | | Percent Probability |
|---------|----------------|---|-------------------------|---------------------|
| | | S-2 With Scuppers | S-3 Without Scuppers | |
| Zn | 4/5 | 188.5 | 111.7 | 94.2 |
| Pb | 4/5 | 368.3 | 192.9 | 93.0 |
| Cr | 4/5 | 46.0 | 29.0 | 84.23 |
| Fe | 4/5 | 1920.0 | 868.2 | 95.35 |
| Cd | 4/5 | 1.54 | 0.77 | 99.1 |

TABLE 5-9. SIGNIFICANCE OF DIFFERENCES IN HEAVY METAL CONCENTRATION OF HYDRILLA FROM LAKE IVANHOE (T-Test Analysis)

| Element | Observ. | Mean Values $\mu\text{g}/\text{gm}$ (dry wt.) | | Percent Probability |
|---------|---------|---|-------------------------|---------------------|
| | | S-2 With Scuppers | S-3 Without Scuppers | |
| Zn | 5/3 | 333.0 | 229.3 | 87.24 |
| Pb | 5/3 | 248.0 | 126.8 | 81.8 |
| Ni | 5/3 | 32.8 | 12.1 | 93.59 |
| Cd | 5/3 | 1.8 | 1.2 | 83.93 |

Average concentration factors for plants and benthic organisms collected from Lake Ivanhoe were presented in Appendix A-17 and A-18. The concentration

factors were calculated as the ratio of metal concentration in mg/g of oven dry weight from selected plant or benthic organisms to the concentration of the same metal in mg/ml of the surrounding water. The maximum concentration factors calculated for iron were 3572 by Typha, 15964 by Hydrilla and 32000 by Spirogyra. Similarly, the maximum concentration factors calculated for lead were 455 by Typha, 5511 by Hydrilla, and 8184 by Spirogyra. The data indicated that Spirogyra concentrated more copper, iron and lead than Typha or Hydrilla. This is probably due to the larger surface area to weight ratio for Spirogyra than other plants. Spirogyra can be used as an indicator micro-algae for contamination with highway runoff.

In benthic organisms, it appeared that Annelida (Oligochaeta, Tubifex) concentrated more zinc, lead and chromium than other organisms tested. The highest average concentration factors for these metals were 10076, 1906, and 10825 respectively. Annelida (Hirudinea) showed the highest average concentration factors for arsenic and cadmium and Arthropoda (Crustacea) showed the highest average concentration factors for nickel, copper and iron. From these results Tubifex could be used as an indicator benthic organism for highway runoff contaminants.

Maitland Interchange Site

Again, statistical analysis to examine significant differences for selected species of phytoplankton and zooplankton collected from various sampling stations was difficult to assess. However, the data indicated that Annelida (Oligochaeta, Tubifex) in the west pond, S-2, showed significantly high concentrations of Zn and Cr than the control station S-4, with a probability in excess of 80%. Also, Typha showed significantly higher concentrations of Zn and Cr with higher than 80% probability from the east pond, S-1, as compared to the

west pond, S-2. Typha was surrounding the perimeter of the east pond and highway runoff is filtered through the plant before it is discharged to the pond which may have caused the increased concentrations of heavy metals in the plants.

The concentration factors presented in Appendices 13-17 showed that Hypericum exhibited the highest average concentration factors for Pb, Fe, Cu, Ni, Zn and Cd which amounted to 3488, 12448, 2119, 1467, 7068 and 920, respectively. Chara, Typha, Eichorina and Water Lily exhibited lower concentration factors than those shown by Hypericum. The lowest concentration factors for heavy metals were associated with Typha. Again, it appears that the surface area to weight ratio of a particular plant is important in determining their sorption capacity of heavy metals.

Similarly, the concentration factors presented in Appendices 13-18 for benthic organisms showed that the highest average concentration factors for Cd, Ni, Cu, Fe, Pb and Cr were associated with Oligochaeta (Tubifex) and Hirudinea amounted to 41500, 88922, 20897, 18670, 27116, 103937, respectively. The concentration factors for Arthropoda (Crustacea) were calculated from concentrations measured from one single sample collected from Lake Lucien control station, S-4, and may not be representative of the entire population.

The limited results collected on concentration of heavy metals by biota from Lake Ivanhoe site and Maitland Interchange site suggested that the capacity of the plant or macro-algae to concentrate heavy metals from highway runoff may be dependant on its surface area to weight ratio. Spirogyra and/or Hypericum may be good indicators for detection of highway runoff contaminants, as opposed to Typha, Water Lily, Hydrilla or Chara. Also, Annelida (Oligochaeta, Tubifex and/or Hirudinea) proved to have high capacity for concentration of heavy metals from highway runoff and may be used as indicators for detection of pollutants in benthic organisms.

The Molluska, Gastropoda and Pelecypoda exhibited the lowest concentration factors, however they are of importance as pollution indicators because it is easy to obtain large enough samples for accurate analysis and they are filter feeders ingesting the suspended matter with which heavy metal pollutants are often associated.

Biota may have shown high concentration factors for heavy metals, however their relative abundance on the basis of weight per unit area of the bottom sediments or weight per unit volume of the water column in receiving water body is very small. Therefore the total mass of heavy metals associated with biota is insignificant relative to the total mass associated with the bottom sediments and the entire water column. This was found true by many researchers (Bell and Wanielista, 1979).

Relative Distribution of Heavy Metals

The relative distribution of heavy metals between the water column and the bottom sediments in terms of the total mass per unit area were calculated. One square meter of the water column was considered and the dissolved and particulate mass of heavy metals were calculated from the average concentrations presented in Appendices A-2 to A-5 and B-2 to B-5. Also, the total weight in one square meter of bottom sediments was estimated by averaging the weight of sediments collected per one stroke of the Ekman dredge and considering each stroke to cover 6 inches x 6 inches (0.0232 sq. meter) of the bottom sediment surface area. Six strokes of sediments were collected at each sampling station, homogenized, dried, weighed, averaged and processed. From the estimated weight of bottom sediments per square meter and concentrations presented in Appendices A-6 to A-9 and B-6 to B-9 it was possible to calculate heavy metals associated

per one square meter of bottom sediments. However, it is generally assumed that all heavy metals are concentrated in the top layer of bottom sediments which is removed by the Ekman dredge.

The calculated surface distribution of the heavy metals between the water column and the bottom sediments were shown in Table 5-10 for Lake Ivanhoe site and 5-11 for Maitland Interchange site. The heavy metals Zn, Cd, As, Ni, Cu, Fe, Pb and Cr in Lake Ivanhoe bottom sediments averaged 96.6, 74.6, 86.3, 95.5, 97.9, 99.6, 99.3 and 98.8% of the total metals associated with the water column plus bottom sediments. The same heavy metals in the Maitland Interchange bottom sediments averaged 97.6, 79.5, 87.9, 95.7, 95.6, 99.7, 98.1 and 98.6%, respectively. The balance of heavy metals was divided between particulate and dissolved fractions of the water column. It is interesting to notice that each of the metals tested showed similar results in the two sites tested. In fact, all metals tested, except Cd, showed that the percent associated with bottom sediments did not differ between sites by more than plus or minus one percent from the average of the two sites. The metal Cd showed a difference of plus or minus two percent. The overall average of heavy metals associated with bottom sediments showed 93.6% at Lake Ivanhoe and 94.1% at Maitland Interchange.

The total mass of heavy metals associated with the water column is very small relative to the mass associated with the bottom sediments. The fraction associated with the water column averaged 6.4% for Lake Ivanhoe and 5.9% for the Maitland Interchange site. The mass of heavy metals in the water column was divided between dissolved and particulate fractions. The dissolved fraction averaged 43.4% of the total mass in the water column of Lake Ivanhoe and 52% of the total mass of the water column in the Maitland Interchange site. From the analysis of these data, it was concluded that bottom sediments were sinks for heavy metals released from highway bridges. The high concentration of metals may have

impacted the diversity and concentration of benthic organisms since very few organisms were detected.

TABLE 5-10. AVERAGE AREAL DISTRIBUTION OF HEAVY METALS IN LAKE IVANHOE

| Sampling Station | Fraction | Estimated Heavy Metal Concentration | | | | | | | |
|------------------|--|-------------------------------------|------|------|------|-------|--------|-------|------|
| | | Zn | Cd | As | Ni | Cu | Fe | Pb | Cr |
| S-1 | Bottom Sediments mg/m ² | 8719 | 44 | 319 | 1059 | 5622 | 160527 | 34065 | 1809 |
| S-2 | | 7432 | 37 | 462 | 548 | 6144 | 129546 | 32444 | 1833 |
| S-3 | | 2980 | 20 | 219 | 199 | 2079 | 45775 | 9397 | 783 |
| S-4 | | 9802 | 74 | 1340 | 1039 | 18599 | 149799 | 17259 | 6459 |
| Average | | 7233 | 44 | 585 | 711 | 8111 | 121412 | 23291 | 2721 |
| S-1 | Water Column (Dissolved) mg/m ² | 30 | 14 | 70 | 6 | 25 | 50 | 53 | 5 |
| S-2 | | 235 | 7 | 11 | 11 | 98 | 210 | 158 | 25 |
| S-3 | | 104 | 5 | 62 | 23 | 41 | 99 | 92 | 8 |
| S-4 | | 186 | 9 | 69 | 36 | 51 | 150 | 159 | 15 |
| Average | | 139 | 9 | 53 | 19 | 54 | 127 | 116 | 13 |
| S-1 | Water Column (Particulate) mg/m ² | 45 | 10 | 10 | 5 | 43 | 145 | 24 | 10 |
| S-2 | | 207 | 4 | 109 | 28 | 189 | 525 | 116 | 28 |
| S-3 | | 38 | 2 | 5 | 5 | 66 | 162 | 17 | 14 |
| S-4 | | 177 | 6 | 36 | 18 | 177 | 435 | 72 | 30 |
| Average | | 117 | 6 | 40 | 14 | 119 | 317 | 57 | 21 |
| PERCENT | Sediments | 96.6 | 74.6 | 86.3 | 95.6 | 97.9 | 99.6 | 99.3 | 98.8 |

TABLE 5-11. AVERAGE AREAL DISTRIBUTION OF HEAVY METALS IN MAITLAND INTERCHANGE SITE

| Sampling Station | Fraction | Estimated Heavy Metal Concentration | | | | | | | |
|------------------|--|-------------------------------------|------|------|------|------|--------|------|------|
| | | Zn | Cd | As | Ni | Cu | Fe | Pb | Cr |
| S-1 | Bottom Sediments mg/m ² | 506 | 4 | 230 | 62 | 154 | 30171 | 575 | 161 |
| S-2 | | 3252 | 47 | 1432 | 979 | 1404 | 301621 | 9090 | 3132 |
| S-3 | | 13392 | 66 | 1317 | 664 | 3873 | 229115 | 8426 | 1707 |
| S-4 | | 1501 | 6 | 106 | 88 | 357 | 29958 | 925 | 179 |
| Average | | 4663 | 31 | 771 | 448 | 1447 | 147716 | 4754 | 1295 |
| S-1 | Water Column (Dissolved) mg/m ² | 48 | 3 | 92 | 12 | 26 | 198 | 66 | 11 |
| S-2 | | 65 | 3 | 80 | 8 | 32 | 192 | 99 | 11 |
| S-3 | | 34 | 1 | 11 | 4 | 18 | 87 | 25 | 7 |
| S-4 | | 119 | 0 | 98 | 11 | 67 | 287 | 67 | 11 |
| Average | | 67 | 2 | 70 | 9 | 36 | 191 | 64 | 11 |
| S-1 | Water Column (Particulate) mg/m ² | 59 | 2 | 17 | 18 | 23 | 164 | 14 | 12 |
| S-2 | | 32 | 2 | 117 | 15 | 26 | 429 | 39 | 15 |
| S-3 | | 23 | 1 | 2 | 7 | 10 | 53 | 5 | 2 |
| S-4 | | 77 | 18 | 7 | 4 | 60 | 350 | 49 | 4 |
| Average | | 48 | 6 | 36 | 11 | 30 | 249 | 27 | 8 |
| PERCENT | Sediments | 97.6 | 79.5 | 87.9 | 95.7 | 95.6 | 99.7 | 98.1 | 98.6 |

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APPENDIX - A-1. WATER QUALITY CHARACTERISTICS IN LAKE IVANHOE

| Parameter | Station | Concentration | | | | | | | | Statistical Analysis | |
|-------------------------------|---------|---------------|-------|-------|-------|-------|-------|-------|-------|----------------------|----------|
| | | 2-15 | 3-16 | 4-19 | 5-17 | 6-20 | 7-13 | 8- 3 | 8-24 | \bar{x} | σ |
| pH | S-1 | 7.73 | 7.61 | 8.59 | 8.47 | 8.37 | --- | 8.06 | 8.00 | 7.99 | --- |
| | S-2 | 8.56 | 7.85 | 8.64 | 8.61 | 8.94 | 8.28 | 8.00 | 8.06 | 8.23 | --- |
| | S-3 | 8.81 | 8.21 | 8.80 | 8.47 | 8.37 | --- | 7.17 | 7.97 | 7.87 | --- |
| | S-4 | 8.72 | 8.08 | 8.76 | 8.76 | 7.93 | 8.84 | 8.60 | 7.95 | 8.29 | --- |
| Turbidity | S-1 | 6.60 | 6.40 | 4.50 | 8.20 | 6.70 | 4.80 | 4.70 | 3.20 | 5.64 | 1.60 |
| | S-2 | 4.00 | 6.50 | 4.30 | 6.80 | 13.00 | 4.30 | 6.00 | 4.20 | 6.14 | 2.99 |
| | S-3 | 7.20 | 4.50 | 4.10 | 5.80 | 9.20 | 4.50 | 4.40 | 7.00 | 5.84 | 1.82 |
| | S-4 | 4.90 | 5.40 | 8.00 | 7.00 | 21.00 | 4.50 | 4.60 | 8.00 | 7.93 | 5.48 |
| TOC mg/l | S-1 | 9.70 | 5.90 | 8.40 | 8.10 | 10.9 | --- | --- | --- | 8.60 | 1.88 |
| | S-2 | 8.90 | 6.00 | 9.90 | 9.20 | 12.80 | --- | --- | --- | 9.36 | 2.43 |
| | S-3 | 8.20 | 7.80 | 9.10 | 7.90 | 11.00 | --- | --- | --- | 8.80 | 1.33 |
| | S-4 | 9.20 | 7.00 | 9.00 | 9.60 | 14.4 | --- | --- | --- | 9.84 | 2.74 |
| Inorganic Carbon mg/l | S-1 | 20.30 | 21.90 | 41.60 | 20.30 | 17.40 | --- | --- | --- | 24.30 | 9.81 |
| | S-2 | 20.90 | 21.70 | 41.80 | 19.40 | 17.70 | --- | --- | --- | 24.30 | 9.90 |
| | S-3 | 21.80 | 21.30 | 41.80 | 19.20 | 16.30 | --- | --- | --- | 24.10 | 10.10 |
| | S-4 | 22.00 | 21.30 | 41.80 | 18.80 | 17.20 | --- | --- | --- | 24.20 | 10.00 |
| Chlorophyll -a µg/l | S-1 | 24.10 | 17.90 | 11.20 | 28.50 | 16.80 | 10.60 | 11.70 | 8.40 | 16.20 | 7.12 |
| | S-2 | 15.00 | 15.10 | 11.20 | 20.10 | 21.80 | 10.60 | 10.60 | 7.80 | 14.00 | 4.92 |
| | S-3 | 10.10 | 13.40 | 14.50 | 20.10 | 19.60 | 10.10 | 11.20 | 14.00 | 14.10 | 3.92 |
| | S-4 | 24.60 | 14.00 | 21.80 | 23.50 | 27.40 | 11.70 | 12.90 | 8.40 | 18.00 | 7.08 |
| Nitrates mg/l-N | S-1 | --- | --- | --- | --- | 1.68 | --- | 0.80 | 0.99 | 1.16 | .463 |
| | S-2 | --- | --- | --- | --- | 0.26 | --- | 0.71 | 0.94 | 0.637 | .346 |
| | S-3 | --- | --- | --- | --- | 2.47 | --- | 0.38 | 1.38 | 1.46 | .912 |
| | S-4 | --- | --- | --- | --- | 4.27 | --- | 0.70 | 1.20 | 2.06 | 1.93 |
| Total Phosphorus mg/l-P | S-1 | --- | .072 | .229 | --- | .106 | .107 | .086 | .077 | .113 | .0587 |
| | S-2 | --- | .097 | .028 | --- | .109 | .095 | .082 | .132 | .091 | .0349 |
| | S-3 | --- | .038 | .264 | --- | .154 | .093 | .018 | .163 | .122 | .0912 |
| | S-4 | --- | .044 | .312 | --- | .112 | .042 | .098 | .133 | .124 | .099 |
| Calcium mg/l | S-1 | 42.00 | 50.50 | 49.60 | 36.50 | 38.30 | 35.20 | 39.00 | 39.60 | 41.30 | 5.67 |
| | S-2 | 41.20 | 49.50 | 50.00 | 36.50 | 38.10 | 34.70 | 39.10 | 41.00 | 41.30 | 5.67 |
| | S-3 | 42.90 | 49.40 | 50.20 | 36.40 | 38.30 | 34.70 | 38.50 | 40.60 | 41.40 | 5.76 |
| | S-4 | 41.10 | 49.30 | 49.80 | 36.20 | 40.00 | 36.30 | 38.30 | 42.30 | 41.70 | 5.32 |
| Magnesium mg/l | S-1 | 3.50 | 5.10 | 4.40 | 3.70 | 4.10 | 4.60 | 4.60 | 5.00 | 4.30 | .53 |
| | S-2 | 3.60 | 5.00 | 4.40 | 3.70 | 4.10 | 4.70 | 4.80 | 5.00 | 4.40 | .57 |
| | S-3 | 3.50 | 5.10 | 4.30 | 3.70 | 4.20 | 4.50 | 4.50 | 5.00 | 4.40 | .55 |
| | S-4 | 3.50 | 5.10 | 4.40 | 3.70 | 4.10 | 4.60 | 4.50 | 5.10 | 4.40 | .58 |

APPENDIX - A-2. VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES
FROM EAST OF SOUTH BRIDGES (S1) ON LAKE IVANHOE

| Parameter | Concentration (µg/l) | | | | | | | | | | Statistical Analysis | |
|--------------|----------------------|------|------|------|------|------|-----|------|-----------|----------|----------------------|--|
| | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | \bar{x} | σ | | |
| Total Zn | 40 | 72 | 47 | 90 | 104 | 85 | 63 | 96 | 75 | 23 | | |
| Dissolved Zn | 16 | 8 | 2 | 16 | 10 | 85 | 54 | 50 | 30 | 29 | | |
| Total Cd | 0 | 1 | 7 | 2 | 7 | 0 | 0 | 2 | 24 | 3 | | |
| Dissolved Cd | 0 | 0 | 7 | 2 | 0 | 0 | 0 | 2 | 14 | 2 | | |
| Total As | 0 | 32 | 72 | 73 | 186 | 105 | 157 | 37 | 83 | 64 | | |
| Dissolved As | 0 | 0 | 15 | 73 | 186 | 105 | 157 | 27 | 70 | 73 | | |
| Total Ni | 5 | 10 | 13 | 14 | 15 | 6 | 10 | 18 | 11 | 4 | | |
| Dissolved Ni | 5 | 0 | 9 | 5 | 3 | 0 | 7 | 18 | 6 | 6 | | |
| Total Cu | 41 | 98 | 94 | 40 | 36 | 150 | 50 | 35 | 68 | 42 | | |
| Dissolved Cu | 9 | 21 | 72 | 19 | 11 | 18 | 25 | 27 | 25 | 20 | | |
| Total Fe | 88 | 240 | 132 | 478 | 131 | 132 | 134 | 162 | 195 | 108 | | |
| Dissolved Fe | 0 | 55 | -- | 193 | 45 | 21 | 66 | 162 | 50 | 60 | | |
| Total Pb | 75 | 70 | 101 | 65 | 76 | 78 | 74 | 38 | 77 | 20 | | |
| Dissolved Pb | 75 | 61 | 101 | 52 | 76 | 32 | 67 | 10 | 53 | 21 | | |
| Total Cr | 7 | 19 | 26 | 27 | 16 | 9 | 5 | 9 | 15 | 7 | | |
| Dissolved Cr | 0 | 1 | 26 | 17 | 12 | 7 | 3 | 1 | 5 | 9 | | |

APPENDIX - A-3. VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES
FROM INBETWEEN SOUTH BRIDGES (S2) ON LAKE IVANHOE

| Parameter | Concentration (µg/l) | | | | | | | | | | Statistical Analysis | |
|--------------------------|----------------------|-----------|-----------|------------|-----------|------------|------------|-----------|-----------|------------|----------------------|--|
| | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/ 3 | 8/24 | \bar{x} | σ | | |
| Total Zn Dissolved Zn | 37 5 | 78 0 | 40 6 | 54 16 | 199 0 | 139 139 | 336 336 | -- 32 | 126 67 | 110 118 | | |
| Total Cd Dissolved Cd | 0 0 | 7 7 | 8 2 | 0 0 | 4 4 | 1 0 | 3 2 | 0 0 | 3 2 | 3 3 | | |
| Total As Dissolved As | 0 0 | 0 0 | 100 72 | 86 0 | 75 0 | 96 96 | 98 98 | 55 0 | 64 33 | 42 47 | | |
| Total Ni Dissolved Ni | 0 0 | 11 0 | 13 5 | 7 6 | 18 2 | 11 0 | 20 6 | 9 4 | 11 3 | 6 3 | | |
| Total Cu Dissolved Cu | 44 38 | 111 18 | 100 68 | 36 15 | 56 11 | 158 18 | 72 32 | 81 26 | 82 28 | 40 18 | | |
| Total Fe Dissolved Fe | 25 0 | 225 26 | 100 30 | 415 176 | 347 47 | 92 0 | 200 171 | 276 28 | 210 60 | 134 72 | | |
| Total Pb Dissolved Pb | 83 83 | 78 43 | 95 56 | 57 47 | 91 36 | 74 15 | 89 66 | 57 21 | 78 45 | 15 23 | | |
| Total Cr Dissolved Cr | 3 3 | 17 6 | 24 8 | 19 16 | 17 5 | 11 4 | 9 4 | 17 6 | 15 7 | 7 4 | | |

APPENDIX - A-4. VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES FROM INBETWEEN THE NORTH BRIDGES (S3) ON LAKE IVANHOE

| Parameter | Concentration ($\mu\text{g/l}$) | | | | | | | | | | Statistical Analysis | |
|--------------|-----------------------------------|------|------|------|------|------|-----|------|-----------|----------|----------------------|--|
| | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | \bar{x} | σ | | |
| Total Zn | 96 | 81 | 45 | 62 | 52 | 71 | 269 | 78 | 94 | 72 | | |
| Dissolved Zn | 96 | 11 | 18 | 25 | 44 | 59 | 269 | 30 | 69 | 85 | | |
| Total Cd | 0 | 6 | 4 | 2 | 9 | 8 | 1 | 3 | 4 | 3 | | |
| Dissolved Cd | 0 | 6 | 0 | 0 | 6 | 8 | 0 | 0 | 3 | 4 | | |
| Total As | 9 | 20 | 135 | 0 | 0 | 23 | 137 | 28 | 44 | 58 | | |
| Dissolved As | 9 | 20 | 135 | 0 | 0 | 0 | 137 | 28 | 41 | 63 | | |
| Total Ni | 47 | 15 | 12 | 9 | 7 | 11 | 36 | 10 | 18 | 15 | | |
| Dissolved Ni | 47 | 15 | 1 | 8 | 7 | 4 | 36 | 4 | 15 | 17 | | |
| Total Cu | 43 | 136 | 53 | 51 | 37 | 146 | 48 | 55 | 71 | 44 | | |
| Dissolved Cu | 19 | 35 | 27 | 27 | 24 | 28 | 29 | 23 | 27 | 5 | | |
| Total Fe | 133 | 138 | 182 | 375 | 128 | 68 | 102 | 263 | 174 | 100 | | |
| Dissolved Fe | -- | 45 | 27 | 187 | 55 | 16 | 59 | 74 | 66 | 57 | | |
| Total Pb | 91 | 65 | 89 | 53 | 56 | 102 | 72 | 48 | 72 | 20 | | |
| Dissolved Pb | 91 | 65 | 51 | 52 | 56 | 93 | 60 | 22 | 61 | 23 | | |
| Total Cr | 21 | 16 | 22 | 18 | 8 | 11 | 6 | 8 | 14 | 6 | | |
| Dissolved Cr | -- | 4 | 6 | 17 | 3 | 3 | 0 | 2 | 5 | 6 | | |

APPENDIX - A-5. VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES
FROM CONTROL STATION (S4) ON LAKE IVANHOE

| Parameter | Concentration (ug/l) | | | | | | | | | | Statistical Analysis | |
|--------------------------|----------------------|-----------|-----------|------------|-----------|------------|------------|------------|-----------|-----------|----------------------|--|
| | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | \bar{x} | σ | | |
| Total Zn Dissolved Zn | 23 2 | 99 9 | 108 0 | 113 11 | 111 6 | 319 319 | 125 125 | 67 23 | 121 62 | 87 112 | | |
| Total Cd Dissolved Cd | 3 3 | 4 0 | 5 4 | 3 3 | 11 11 | 6 0 | 0 0 | 4 4 | 5 3 | 3 4 | | |
| Total As Dissolved As | 0 0 | 0 0 | 36 36 | 67 0 | 0 0 | 28 28 | 27 0 | 121 121 | 35 23 | 42 42 | | |
| Total Ni Dissolved Ni | 56 56 | 5 0 | 14 6 | 19 11 | 5 2 | 14 0 | 19 19 | 10 4 | 18 12 | 16 19 | | |
| Total Cu Dissolved Cu | 27 9 | 164 19 | 44 22 | 27 17 | 64 14 | 171 13 | 42 26 | 71 18 | 76 17 | 58 6 | | |
| Total Fe Dissolved Fe | 70 -- | 153 4 | 113 35 | 358 178 | 329 51 | 123 3 | 144 61 | 268 21 | 195 50 | 108 60 | | |
| Total Pb Dissolved Pb | 82 82 | 71 50 | 81 73 | 55 55 | 84 56 | 118 26 | 67 59 | 55 19 | 77 53 | 20 21 | | |
| Total Cr Dissolved Cr | 12 -- | 17 0 | 21 -- | 23 23 | 21 2 | 13 2 | 3 0 | 8 1 | 15 5 | 7 9 | | |

APPENDIX - A-6. ANALYSIS OF BOTTOM SEDIMENTS FROM
EAST SOUTH BRIDGES (S1) ON LAKE IVANHOE

| Parameter | Concentration $\mu\text{g}/\text{gm}$ (oven dry weight) | | | | | | | | | | Statistical Analysis | |
|-----------|---|---------|---------|---------|---------|---------|---------|---------|-----------|----------|----------------------|--|
| | 2/15 | 2/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | \bar{x} | σ | | |
| Zn | 102.00 | 74.90 | 175.00 | 91.10 | 81.30 | 158.00 | 76.20 | 31.80 | 98.80 | 46.70 | | |
| Cd | .446 | .656 | 1.36 | .172 | .498 | .462 | .321 | .103 | .502 | .390 | | |
| As | 3.40 | 2.33 | 9.43 | 5.41 | 0 | 1.44 | 4.25 | 2.68 | 3.62 | 2.87 | | |
| Ni | 6.34 | 10.60 | 18.80 | 11.90 | 11.70 | 23.40 | 10.30 | 2.87 | 12.00 | 6.51 | | |
| Cu | 59.10 | 57.10 | 164.00 | 53.70 | 34.90 | 89.50 | 32.30 | 19.00 | 63.70 | 45.80 | | |
| Fe | 1462.00 | 2143.00 | 2680.00 | 2939.00 | 1443.00 | 2177.00 | 1223.00 | 481.00 | 1819.00 | 814.00 | | |
| Pb | 368.00 | 869.00 | 597.00 | 311.00 | 168.00 | 420.00 | 151.00 | 205.00 | 386.00 | 245.00 | | |
| Cr | 23.40 | 19.10 | 51.40 | 15.10 | 11.50 | 22.40 | 10.30 | 10.40 | 20.50 | 13.50 | | |
| Ca | 2591.00 | 3831.00 | 5587.00 | 4353.00 | 7328.00 | 8461.00 | 5877.00 | 4869.00 | 5362.00 | 1892.00 | | |
| Mg | 152.00 | 140.00 | 402.00 | 209.00 | 153.00 | 300.00 | 142.00 | 136.00 | 204.00 | 97.30 | | |
| P | 1295.00 | 508.00 | 1210.00 | 704.00 | 468.00 | 732.00 | 621.00 | 666.00 | 776.00 | 309.00 | | |

APPENDIX - A-7. ANALYSIS OF BOTTOM SEDIMENTS FROM
 IN BETWEEN SOUTH BRIDGES (S2) ON LAKE IVANHOE

| Parameter | Concentration $\mu\text{g}/\text{gm}$ (oven dry weight) | | | | | | | | | | Statistical Analysis | |
|-----------|---|---------|---------|---------|---------|---------|---------|---------|-----------|----------|----------------------|--|
| | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | \bar{x} | σ | | |
| Zn | 153.00 | 126.00 | 73.10 | 109.00 | 51.70 | 84.20 | 115.00 | 62.80 | 96.90 | 34.60 | | |
| Cd | .721 | .840 | .387 | .444 | .049 | .532 | .586 | .307 | .483 | .247 | | |
| As | 4.26 | 4.63 | 2.92 | 11.60 | 12.40 | 2.60 | 4.54 | 5.24 | 6.02 | 3.80 | | |
| Ni | 12.20 | 9.84 | 4.88 | 8.46 | 3.26 | 6.28 | 7.63 | 4.66 | 7.15 | 2.97 | | |
| Cu | 103.00 | 92.60 | 164.00 | 82.70 | 26.20 | 66.40 | 58.40 | 47.10 | 80.10 | 42.10 | | |
| Fe | 1941.00 | 2367.00 | 1412.00 | 3305.00 | 819.00 | 1216.00 | 1491.00 | 962.00 | 1689.00 | 825.00 | | |
| Pb | 363.00 | 687.00 | 387.00 | 382.00 | 334.00 | 392.00 | 474.00 | 368.00 | 423.00 | 114.00 | | |
| Cr | 32.80 | 37.70 | 14.90 | 29.80 | 11.90 | 23.40 | 22.20 | 18.10 | 23.90 | 8.99 | | |
| Ca | 3905.00 | 4592.00 | 2435.00 | 3658.00 | 2144.00 | 4719.00 | 7199.00 | 4606.00 | 4157.00 | 1572.00 | | |
| Mg | 175.00 | 259.00 | 184.00 | 220.00 | 173.40 | 173.00 | 195.00 | 178.00 | 182.00 | 52.80 | | |
| P | 799.00 | 761.00 | 699.00 | 1041.00 | 460.00 | 807.00 | 1076.00 | 1020.00 | 833.00 | 207.00 | | |

APPENDIX - A-8. ANALYSIS OF BOTTOM SEDIMENTS FROM
IN BETWEEN NORTH BRIDGES (S3) ON LAKE IVANHOE

| Parameter | Concentration $\mu\text{g}/\text{gm}$ (oven dry weight) | | | | | | | | | | | Statistical Analysis | |
|-----------|---|---------|------|---------|---------|---------|---------|---------|-----------|----------|--|----------------------|--|
| | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | \bar{x} | σ | | | |
| Zn | 96.20 | 47.10 | -- | 33.30 | 17.30 | 41.00 | 27.50 | 31.90 | 42.00 | 25.70 | | | |
| Cd | .564 | .371 | -- | .054 | .083 | .262 | .198 | .401 | .276 | .183 | | | |
| As | 2.54 | 2.33 | -- | 5.05 | .345 | 2.66 | 2.82 | 5.78 | 3.08 | 1.81 | | | |
| Ni | 3.82 | 4.24 | -- | 1.82 | .833 | 3.52 | 1.62 | 3.78 | 2.80 | 1.34 | | | |
| Cu | 74.50 | 33.80 | -- | 7.84 | 8.81 | 26.60 | 34.60 | 18.20 | 29.20 | 22.70 | | | |
| Fe | 1060.00 | 779.00 | -- | 581.00 | 464.00 | 666.00 | 569.00 | 381.00 | 643.00 | 225.00 | | | |
| Pb | 223.00 | 200.00 | -- | 60.60 | 82.30 | 150.00 | 68.80 | 130.00 | 132.00 | 66.70 | | | |
| Cr | 22.60 | 19.40 | -- | 5.57 | 4.54 | 12.00 | 5.39 | 7.42 | 11.00 | 7.32 | | | |
| Ca | 1889.00 | 2426.00 | -- | 1418.00 | 2004.00 | 3010.00 | 4582.00 | 1327.00 | 2379.00 | 1130.00 | | | |
| Mg | 141.00 | 118.00 | -- | 81.10 | 50.30 | 92.40 | 92.40 | 80.90 | 93.70 | 29.00 | | | |
| P | 1748.00 | 572.00 | -- | 462.00 | 243.00 | 564.00 | 316.00 | 462.00 | 624.00 | 510.00 | | | |

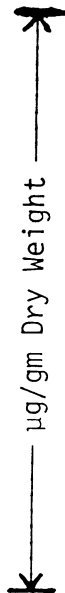
APPENDIX - A-9. ANALYSIS OF BOTTOM SEDIMENTS FROM
CONTROL STATION(S4) ON LAKE IVANHOE

| Parameter | Concentration ug/gm (oven dry weight) | | | | | | | | | | Statistical Analysis | |
|-----------|---------------------------------------|---------|---------|---------|---------|---------|---------|---------|-----------|----------|----------------------|--|
| | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/ 3 | 8/24 | \bar{x} | σ | | |
| Zn | 71.50 | 50.80 | 185.00 | 285.00 | 282.00 | 14.90 | 23.10 | 27.00 | 117.00 | 116.00 | | |
| Cd | .709 | .664 | 1.50 | 1.52 | 2.30 | .141 | 0 | .265 | .887 | .809 | | |
| As | 3.90 | 4.33 | 21.60 | 41.80 | 47.50 | 2.80 | 4.06 | 1.73 | 16.00 | 18.90 | | |
| Ni | 3.80 | 5.84 | 20.10 | 29.20 | 34.00 | 2.05 | 2.58 | 1.68 | 12.40 | 13.30 | | |
| Cu | 94.60 | 78.20 | 287.00 | 500.00 | 728.00 | 14.20 | 21.90 | 49.10 | 222.00 | 264.00 | | |
| Fe | 981.00 | 971.00 | 3858.00 | 4543.00 | 3014.00 | 186.00 | 246.00 | 507.00 | 1788.00 | 1744.00 | | |
| Pb | 51.10 | 101.00 | 206.00 | 533.00 | 670.00 | 20.00 | 24.40 | 40.90 | 206.00 | 254.00 | | |
| Cr | 16.20 | 31.50 | 84.10 | 218.00 | 240.00 | 7.31 | 7.10 | 12.20 | 77.10 | 97.30 | | |
| Ca | 3517.00 | 4952.00 | 7685.00 | 12,252 | 20,674 | 1203.00 | 1179.00 | 2700.00 | 6770.00 | 6729.00 | | |
| Mg | 227.00 | 314.00 | 2056.00 | 1437.00 | 3443.00 | 51.40 | 56.80 | 174.00 | 970.00 | 1243.00 | | |
| P | 958.00 | 730.00 | 3350.00 | 3475.00 | 2688.00 | 479.00 | 334.00 | 864.00 | 1610.00 | 1327.00 | | |

APPENDIX - A-10. CHARACTERISTICS OF BOTTOM SEDIMENTS FROM
LAKE IVANHOE

| Parameter | Station | Percent (%) | | | | | | | | | | Statistical Analysis | |
|---------------------|---------|-------------|-------|-------|-------|-------|-------|-------|-------|-----------|----------|----------------------|--|
| | | 2-15 | 3-16 | 4-19 | 5-17 | 6-20 | 7-13 | 8-3 | 8-24 | \bar{x} | σ | | |
| Water Content | S-1 | 34.00 | 44.20 | 64.70 | 45.20 | 49.50 | 59.90 | 39.00 | 41.60 | 47.20 | 10.40 | | |
| | S-2 | 52.90 | 54.70 | 29.70 | 46.50 | 42.50 | 56.20 | 41.10 | 43.60 | 45.90 | 8.70 | | |
| | S-3 | 51.50 | 49.60 | --- | 25.20 | 42.90 | 42.40 | 26.10 | 32.40 | 38.60 | 10.80 | | |
| | S-4 | 44.80 | 62.10 | 77.20 | 89.20 | 90.80 | 32.80 | 46.20 | 75.60 | 64.80 | 21.80 | | |
| | S-5 | 44.80 | 62.10 | --- | --- | --- | 32.80 | 46.20 | 75.60 | 52.30 | 16.70 | | |
| Loss On Ignition | S-1 | 5.19 | 2.11 | 9.89 | 2.11 | 2.48 | 4.03 | 1.41 | 1.98 | 3.65 | 2.81 | | |
| | S-2 | 6.34 | 4.71 | 1.72 | 3.22 | 1.99 | 2.90 | 2.32 | 2.45 | 3.21 | 1.57 | | |
| | S-3 | 6.16 | 3.09 | --- | 0.84 | 1.03 | 1.80 | 0.78 | 1.27 | 2.14 | 1.94 | | |
| | S-4 | 5.71 | 5.49 | 16.30 | 22.90 | 37.80 | 1.42 | 1.47 | 6.53 | 12.1 | 12.62 | | |
| | S-5 | 5.71 | 5.49 | --- | --- | --- | 1.42 | 1.47 | 6.53 | 4.12 | 2.48 | | |

APPENDIX - A-11. BOTTOM SEDIMENT CHARACTERISTICS
 FOR PARTICLE SIZE LESS THAN 105
 MICRON FROM LAKE IVANHOE

| Parameter | Average Concentration | | | | Units |
|----------------------|-----------------------|----------------|----------------|----------------|--|
| | S ₁ | S ₂ | S ₃ | S ₄ | |
| Loss on Ignition (%) | 9.8 | 7.6 | 6.9 | 21.8 | Percent |
| Zn | 253.0 | 244.0 | 149.0 | 245.0 |  |
| Pb | 984.0 | 827.0 | 491.0 | 335.0 | |
| Cr | 85.6 | 68.9 | 44.8 | 130.0 | |
| Ni | 41.0 | 33.7 | 14.7 | 32.0 | |
| Cu | 282.0 | 241.0 | 143.0 | --- | |
| Fe | 3900 | 3191 | 1889 | 3350 | |
| Cd | 2.1 | 1.5 | 1.0 | 2.0 | |
| As | 15.4 | 9.2 | 8.0 | 21.2 | |
| Ca | 8209.0 | 7945.0 | 6629.0 | 11695.0 | |
| P | 3869.0 | 2530.0 | 2227.0 | 4446.0 | |

APPENDIX - A-12. IVANHOE PLANTS % MOISTURE

| Form | Station | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | Statistical Analysis | |
|-----------|---------|-------|-------|-------|-------|-------|-------|-------|-------|----------------------|----------|
| | | | | | | | | | | Mean | St. Dev. |
| Hydrilla | Control | -- | -- | -- | 86.78 | 92.63 | 90.86 | -- | -- | 90.03 | 2.97 |
| | S1 | 86.95 | 94.07 | 93.12 | 86.95 | 94.17 | -- | -- | -- | 91.05 | 3.77 |
| | S2 | 89.80 | 92.97 | 91.61 | 90.80 | 93.51 | -- | -- | -- | 91.74 | 1.53 |
| | S3 | -- | 93.20 | 95.49 | 93.29 | -- | -- | -- | -- | 93.99 | 1.30 |
| Spirogyra | Control | -- | -- | -- | 91.08 | -- | 85.84 | 81.73 | 79.70 | 84.59 | 5.03 |
| | S1 | -- | -- | -- | -- | -- | 89.00 | 81.87 | 82.19 | 84.35 | 4.03 |
| | S2 | -- | -- | -- | 89.40 | -- | 87.81 | 82.55 | 80.85 | 85.15 | 4.10 |
| | S3 | -- | -- | -- | 88.88 | 80.22 | 85.50 | 80.40 | 79.63 | 82.93 | 4.08 |
| Typha | Control | -- | 89.31 | -- | 79.85 | 93.86 | 78.23 | 76.64 | 84.21 | 83.68 | 6.77 |
| | S1 | -- | 92.42 | -- | 83.26 | 95.11 | 82.22 | 83.97 | 88.10 | 87.5 | 5.31 |

APPENDIX - A-13. IVANHOE PLANTS % LOSS ON IGNITION

| Form | Station | 2/15 | 3/16 | 4/19 | 5/17 | 6/20 | 7/13 | 8/3 | 8/24 | Statistical Analysis | |
|-----------|---------|------|-------|-------|-------|-------|-------|-------|-------|----------------------|----------|
| | | | | | | | | | | Mean | St. Dev. |
| Hydrilla | Control | -- | -- | -- | 79.92 | 69.65 | -- | -- | -- | 74.79 | -- |
| | S1 | -- | 83.43 | 79.25 | 74.50 | 71.93 | -- | -- | -- | 77.28 | 5.10 |
| | S2 | -- | 84.38 | 78.96 | 77.55 | 66.86 | -- | -- | -- | 76.94 | 7.34 |
| | S3 | -- | 66.05 | 82.92 | 93.91 | -- | -- | -- | -- | 80.96 | 14.03 |
| Spirogyra | Control | -- | -- | -- | 89.44 | -- | -- | 89.31 | 72.51 | 83.75 | -- |
| | S1 | -- | -- | -- | -- | -- | -- | 84.30 | 90.66 | 87.48 | -- |
| | S2 | -- | -- | -- | 79.13 | -- | -- | 87.92 | 83.57 | 83.54 | -- |
| | S3 | -- | -- | -- | 91.46 | -- | -- | 94.85 | 81.03 | 89.11 | -- |
| Typha | Control | -- | 85.14 | -- | 91.75 | 91.17 | 92.46 | 93.73 | 91.43 | 90.95 | 2.99 |
| | S1 | -- | 80.38 | -- | 91.97 | 84.6 | 83.05 | 93.4 | 91.42 | 87.47 | 5.46 |

APPENDIX - A-14. CONCENTRATION OF HEAVY METALS
IN PLANTS FROM LAKE IVANHOE

| Form | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | |
|--------------------|--------------------|----------------|--|-------|-------|-------|-------|-------|-------|------|------|-------|------|------|
| | | | µg/gm | | | | | mg/gm | | | | | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | |
| TYPHA (Cattail) | Control | 3/16 | 3.96 | 0.76 | 31.6 | 2.33 | 9.57 | 81.4 | 48.9 | 2.16 | 1.92 | 17.5 | 2.67 | |
| | | 5/17 | 3.36 | 0.22 | 17.3 | 2.61 | 9.51 | 42.0 | 13.5 | 2.06 | 1.36 | 8.2 | 0.59 | |
| | | 6/20 | 11.6 | 0.00 | 11.8 | 0.92 | 10.6 | 50.2 | 5.60 | 1.74 | 1.54 | 11.8 | 1.67 | |
| | Average \bar{x} | 7/13 | 12.1 | 0.15 | 26.7 | 1.75 | 13.3 | 54.5 | 40.0 | 5.15 | 2.04 | 20.8 | 1.03 | |
| | | 8/3 | 8.69 | 0.10 | 26.3 | 1.25 | 12.3 | 49.6 | 17.7 | 3.43 | 1.96 | 14.4 | 0.94 | |
| | Std. Dev. σ | 8/24 | 3.23 | 0.30 | 17.6 | 10.5 | 12.4 | 43.8 | 11.8 | 1.39 | 2.15 | 13.2 | 1.41 | |
| | | | 7.2 | .26 | 21.9 | 1.7 | 11.3 | 53.6 | 22.9 | 2.7 | 1.8 | 14.3 | 1.4 | |
| | HYDRILLA | S ₁ | 3/16 | 13.0 | 0.51 | 13.1 | 0.90 | 7.69 | 45.6 | 23.5 | 1.42 | 1.52 | 9.04 | 0.97 |
| | | | 5/17 | 12.6 | 0.07 | 34.9 | 5.24 | 9.54 | 80.6 | 27.6 | 4.58 | 1.32 | 8.73 | 1.99 |
| | | | 6/20 | 20.8 | 0.40 | 12.9 | 1.44 | 11.5 | 752 | 24.8 | 3.39 | 1.97 | 30.9 | 1.78 |
| Average \bar{x} | | 7/13 | 6.22 | 0.30 | 43.4 | 2.62 | 13.0 | 82.9 | 38.0 | 5.04 | 2.09 | 20.1 | 1.33 | |
| | | 8/3 | 7.12 | 0.18 | 18.6 | 1.61 | 10.7 | 62.2 | 18.9 | 4.69 | 2.49 | 15.0 | 1.39 | |
| Std. Dev. σ | | 8/24 | 11.6 | 0.26 | 13.5 | 1.37 | 9.62 | 48.2 | 11.7 | 1.46 | 2.54 | 12.8 | 1.76 | |
| | | | 11.9 | .28 | 22.7 | 2.2 | 10.3 | 178.6 | 24.1 | 3.4 | 1.9 | 16.1 | 1.5 | |
| HYDRILLA | | Control | 5/17 | 16.8 | 1.73 | 258 | 41.0 | 108 | 433 | 111 | 10.2 | 4.50 | 11.4 | 1.90 |
| | | | 6/20 | 59.1 | 2.00 | 233 | 13.4 | 110 | 726 | 142 | 20.2 | 6.41 | 49.1 | 1.92 |
| | | | 7/13 | 37.3 | 2.15 | 213 | 11.5 | 129 | 465 | 252 | 21.9 | 6.21 | 51.5 | 1.73 |
| | Average \bar{x} | | 37.7 | 2.0 | 234.7 | 22.0 | 115.7 | 541.3 | 168.3 | 17.4 | 5.7 | 37.3 | 1.8 | |
| | | | 21.2 | .21 | 22.5 | 16.5 | 11.6 | 160.7 | 74.1 | 6.3 | 1.0 | 22.5 | .10 | |
| | Std. Dev. σ | 2/15 | 22.4 | 1.61 | 322 | 17.5 | 82 | 1400 | 427 | 22.0 | 2.05 | 19.50 | 1.46 | |
| | | 3/16 | 23.4 | 1.14 | 201 | 11.3 | 60 | 344 | 70.3 | 5.47 | 5.78 | 15.8 | 3.72 | |
| | S ₁ | 4/19 | 47.0 | 1.03 | 230 | 20.6 | 166 | 431 | 112 | 168 | 7.90 | 21.9 | 8.66 | |
| | | 5/17 | 21.0 | 0.73 | 213 | 21.0 | 113 | 482 | 126 | 13.6 | 4.98 | 11.1 | 2.36 | |
| | Average \bar{x} | 6/20 | 31.6 | 1.44 | 309 | 27.4 | 122 | 1334 | 145 | 16.5 | 6.35 | 45.9 | 2.83 | |
| | | 29.1 | 1.2 | 255.0 | 19.6 | 108.6 | 798.2 | 176.1 | 45.1 | 5.4 | 22.9 | 3.8 | | |
| Std. Dev. σ | | 10.8 | .35 | 56.4 | 5.9 | 40.5 | 522.1 | 142.9 | 69.0 | 2.2 | 13.5 | 2.8 | | |
| | S ₂ | 2/15 | 20.9 | 2.64 | 481 | 60.1 | 133 | -- | 464 | 1.94 | 21.3 | 2.37 | | |
| | 3/16 | 23.3 | 1.05 | 258 | 13.8 | 54 | 132 | 235 | 13.2 | 1.14 | 15.2 | 2.02 | | |

APPENDIX - A-14. CONCENTRATION OF HEAVY METALS
IN PLANTS FROM LAKE IVANHOE
(Continued)

| Form | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | | |
|---|---|------|--|-------|-------|-------|-------|--------|-------|-------|------|------|------|--|--|--|
| | | | µg/gm | | | | | | | mg/gm | | | | | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | | |
| HYDRILLA | S ₂ (cont.) | 4/19 | 44.2 | 1.94 | 222 | 28.9 | 270 | 847 | 135 | -- | 8.60 | 20.7 | 6.36 | | | |
| | | 5/17 | 17.5 | 1.09 | 299 | 20.4 | 123 | 797 | 193 | 12.5 | 4.27 | 13.6 | 2.55 | | | |
| | | 6/20 | 37.7 | 2.27 | 405 | 41.0 | 119 | 1079 | 213 | 18.8 | 6.90 | 48.1 | 3.58 | | | |
| | Average \bar{x} Std. Dev. σ | | 28.7 | 1.8 | 333.0 | 32.9 | 139.8 | 789.0 | 248.0 | 23.7 | 5.2 | 23.8 | 3.6 | | | |
| | | | 11.6 | 171 | 107.5 | 18.3 | 79.2 | 267.2 | 126.3 | 18.0 | 2.6 | 1.4 | 1.6 | | | |
| | | | | | | | | | | | | | | | | |
| | S ₃ | 3/16 | 22.6 | 1.13 | 307 | 8.8 | 64.4 | 525 | 190 | 17.5 | 3.33 | 15.0 | 2.67 | | | |
| | | 4/19 | 31.7 | 0.85 | 114 | 13.7 | 95.6 | 484 | 58.5 | 333 | 6.91 | 18.8 | 7.76 | | | |
| | | 5/17 | 18.4 | 1.70 | 267 | 13.8 | 160 | 668 | 132 | 16.3 | 4.45 | 14.5 | 2.96 | | | |
| | Average \bar{x} Std. Dev. σ | | 24.2 | 1.2 | 229.3 | 12.1 | 106.7 | 559.0 | 126.8 | 122.3 | 4.9 | 16.1 | 4.5 | | | |
| | | 6.8 | .43 | 101.9 | 2.9 | 48.8 | 96.6 | 65.9 | 182.5 | 1.8 | 2.4 | 2.9 | | | | |
| | | | | | | | | | | | | | | | | |
| SPIROGYRA | Control | 5/17 | 12.2 | 0.32 | 89.5 | 20.7 | 352 | 642 | 101 | 44.3 | 1.81 | 8.6 | 3.15 | | | |
| | | 7/13 | 20.7 | 0.74 | 78.3 | 14.2 | 485 | 599 | 160 | 35.8 | 1.94 | 27.8 | 2.02 | | | |
| | | 8/3 | 15.3 | 0.62 | 106 | 17.3 | 379 | 889 | 143 | 62.9 | 2.47 | 14.6 | 3.47 | | | |
| | Average \bar{x} Std. Dev. σ | | 24.8 | 0.72 | 92.4 | 16.0 | 147 | 3004 | 131 | 36.1 | 1.67 | 9.2 | 3.27 | | | |
| | | | 18.3 | .60 | 91.6 | 17.1 | 340.8 | 1283.5 | 133.8 | 44.8 | 2.0 | 15.1 | 3.0 | | | |
| | | | 5.6 | .19 | 11.4 | 2.7 | 141.3 | 1154.1 | 24.9 | 12.7 | .35 | 8.9 | .65 | | | |
| | S ₁ | 7/13 | 25.3 | 2.05 | 162 | 21.1 | 218 | 1125 | 295 | 36.0 | 3.29 | 35.9 | 2.74 | | | |
| | | 8/3 | 16.0 | 1.65 | 200 | 24.5 | 293 | 1944 | 503 | 47.3 | 3.30 | 17.8 | 4.28 | | | |
| | | 8/24 | 7.4 | 2.05 | 203 | 31.7 | 204 | 1581 | 327 | 40.5 | 2.90 | 10.3 | 6.02 | | | |
| | Average \bar{x} Std. Dev. σ | | 16.2 | 1.9 | 188.3 | 25.8 | 238.6 | 1550.0 | 375.0 | 41.3 | 3.2 | 21.3 | 4.3 | | | |
| | | 8.9 | .23 | 22.9 | 5.4 | 47.9 | 410.4 | 112.0 | 5.7 | .23 | 13.1 | 1.6 | | | | |
| | | | | | | | | | | | | | | | | |
| S ₂ | 5/17 | 8.8 | 1.17 | 135 | 21.4 | 170 | 1901 | 330 | 29.9 | 2.29 | 12.6 | 3.0 | | | | |
| | 7/13 | 19.5 | 1.55 | 201 | 23.0 | 333 | 2556 | 446 | 67.9 | 2.81 | 23.2 | 4.66 | | | | |
| | 8/3 | 8.7 | 1.47 | 168 | 18.6 | 302 | 1020 | 191 | 25.4 | 3.19 | 16.5 | 3.89 | | | | |
| Average \bar{x} Std. Dev. σ | | 20.3 | 1.97 | 250 | 21.7 | 240 | 2203 | 506 | 61.8 | 2.75 | 9.0 | 7.17 | | | | |
| | | 14.3 | 1.5 | 188.5 | 21.2 | 261.3 | 1920 | 368.3 | 46.0 | 2.8 | 15.3 | 4.7 | | | | |
| | | 6.4 | .33 | 49.1 | 1.9 | 72.1 | 657.0 | 138.9 | 22.0 | .37 | 6.1 | 1.8 | | | | |

APPENDIX - A-14. CONCENTRATION OF HEAVY METALS
 IN PLANTS FROM LAKE IVANHOE
 (Continued)

| Form | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | |
|-----------|-------------------|------|--|------|-------|------|-------|-------|-------|------|------|------|-------|--|--|
| | | | µg/gm | | | | | | | | | | mg/gm | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | |
| SPIROGYRA | S ₃ | 5/17 | 21.4 | 0.62 | 112 | 21.3 | 852 | 929 | 165 | 31.1 | 2.14 | 7.3 | 3.91 | | |
| | | 6/20 | 11.6 | 0.64 | 53.5 | 7.04 | 86.8 | 813 | 113 | 20.5 | 8.33 | 13.3 | 1.70 | | |
| | | 7/13 | 18.5 | 1.05 | 103 | 12.5 | 242 | 1166 | 234 | 28.9 | 1.90 | 25.8 | 2.28 | | |
| | | 8/3 | 6.17 | 0.40 | 94.9 | 12.2 | 639 | 699 | 92.4 | 21.0 | 1.76 | 9.6 | 2.77 | | |
| | | 8/24 | 15.1 | 1.14 | 195 | 42.5 | 205 | 734 | 360 | 43.5 | 1.99 | 10.1 | 3.60 | | |
| | Average \bar{x} | | 14.6 | 0.77 | 111.7 | 19.1 | 405.0 | 862.2 | 192.9 | 29.0 | 1.7 | 13.2 | 2.9 | | |
| | Std. Dev σ | | 5.6 | .31 | 51.7 | 14.0 | 325.0 | 188.5 | 108.3 | 9.4 | .52 | 7.4 | 0.91 | | |

APPENDIX - A-15. DISTRIBUTION OF BENTHIC ORGANISMS IN
LAKE IVANHOE BOTTOM SEDIMENTS

| Phylum | Station | #/m ² | | | | | | | | | | Average Concentration | |
|------------------------------|---------|------------------|------|------|------|------|------|-----|------|--|--|--------------------------|------|
| | | 2-15 | 3-16 | 4-19 | 5-17 | 6-20 | 7-13 | 8-3 | 8-24 | | | | |
| Mollusks | S-1 | 0 | -- | 50 | 7 | 0 | 19 | 5 | 0 | | | | 11.6 |
| | S-2 | 0 | -- | 36 | 21 | 0 | 10 | 19 | 0 | | | | 12.3 |
| | S-3 | 0 | 0 | 0 | 129 | 43 | 144 | 93 | 79 | | | | 61 |
| | S-4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 |
| Annelids | S-1 | -- | 0 | 0 | 0 | 0 | 21 | 0 | 29 | | | | 7.1 |
| | S-2 | 0 | 0 | 14 | 0 | 0 | 34 | 10 | 0 | | | | 7.3 |
| | S-3 | 0 | 0 | 14 | 0 | 0 | 36 | 14 | 0 | | | | 8.0 |
| | S-4 | 0 | 0 | 287 | 0 | 0 | 0 | 0 | 0 | | | | 35.9 |
| Arthropodea (Crustaceans) | S-1 | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 |
| | S-2 | -- | 0 | 0 | 0 | 14 | 0 | 0 | 0 | | | | 2.0 |
| | S-3 | -- | -- | 0 | 1237 | 161 | 93 | 0 | 93 | | | | 264 |
| | S-4 | -- | -- | 151 | 208 | 0 | 0 | 0 | 0 | | | | 59.8 |

APPENDIX - A-16. ANALYSIS OF BENTHIC ORGANISMS COLLECTED FROM LAKE IVANHOE BOTTOM SEDIMENTS

| Phylum & Class | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | |
|---------------------------|--------------------|------|--|-------|------|-------|-------|------|------|------|------|------|-------|--|--|
| | | | µg/gm | | | | | | | | | | mg/gm | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | |
| MOLLUSCA (Gastropoda) | S ₁ | 3/16 | 43.2 | 1.45 | 169 | 5.3 | 22.5 | 137 | 139 | 9.3 | 0.59 | 28.2 | 0.3 | | |
| | | 4/19 | 5.3 | 0.22 | 31.3 | 1.5 | 31.3 | 99.5 | .81 | 3.5 | 0.99 | 7.2 | 1.9 | | |
| | | 5/17 | 2.4 | 0.18 | 486 | 2.5 | 53.1 | 42.3 | 9.7 | 1.5 | 0.79 | 8.8 | 1.2 | | |
| | | 7/13 | 0.9 | 0.16 | 265 | 5.0 | 34.8 | 30.2 | 7.0 | 1.3 | 0.81 | 1.6 | 0.7 | | |
| | | 8/24 | 3.2 | 0 | 23.5 | 0.71 | 12.2 | 147 | 7.4 | 0.6 | 0.45 | 5.7 | 1.2 | | |
| | Average \bar{x} | 9.2 | .40 | 221.6 | 3.3 | 32.3 | 86.6 | 41.4 | 3.0 | .49 | 9.2 | .91 | | | |
| | Std. Dev. σ | 16.8 | .53 | 183.2 | 1.9 | 14.1 | 49.1 | 56.2 | 3.2 | .38 | 9.6 | .67 | | | |
| | S ₂ | 3/16 | 17.3 | 0.90 | 178 | 6.3 | 17.2 | 51.1 | 85.6 | 6.8 | 0.28 | 18.0 | 0.4 | | |
| | | 4/19 | 5.1 | 0.18 | 222 | 1.5 | 24.9 | 61.9 | 21.2 | 3.6 | 0.73 | 7.5 | 2.5 | | |
| | | 5/17 | 4.0 | 0.24 | 323 | 3.0 | 68.4 | 43.5 | 7.5 | 1.6 | 0.66 | 9.4 | 1.6 | | |
| 7/13 | | 0 | 0.48 | 350 | 4.9 | 30.5 | 62.3 | 27.9 | 4.4 | 0.81 | 8.9 | 1.2 | | | |
| 8/3 | | 2.7 | 0.12 | 256 | 1.8 | 73.2 | 73.2 | 8.51 | 1.8 | 0.69 | 6.2 | 1.1 | | | |
| Average \bar{x} | 5.8 | .39 | 265.8 | 3.5 | 42.8 | 58.4 | 30.1 | 3.6 | 0.63 | 10.0 | 1.4 | | | | |
| Std. Dev. σ | 6.7 | .32 | 70.9 | 3.1 | 26.0 | 11.4 | 32.2 | 2.1 | .21 | 4.7 | .77 | | | | |
| S ₃ | 5/17 | 6.0 | 0.27 | 237 | 1.6 | 72.8 | 37.7 | 16.3 | 1.9 | 0.85 | 4.8 | 1.3 | | | |
| | 6/20 | 95.2 | 0 | 27.7 | 7.8 | 7.8 | 3.6 | 29.1 | 2.1 | 1.58 | 39.3 | 1.6 | | | |
| | 7/13 | 3.6 | 0.20 | 168 | 1.5 | 24.0 | 29.2 | 19.8 | 1.9 | 0.54 | 2.9 | 0.9 | | | |
| | 8/3 | 2.8 | 0.27 | 467 | 1.4 | 26.1 | 88.4 | 18.7 | 2.0 | 0.48 | 5.5 | 1.0 | | | |
| | Average \bar{x} | 26.9 | .18 | 227.2 | 2.1 | 32.7 | 39.7 | 21.0 | 2.0 | .86 | 13.1 | 1.2 | | | |
| Std. Dev. σ | 45.6 | .13 | 187.3 | 3.2 | 28.0 | 35.6 | 5.6 | .11 | .51 | 17.5 | .30 | | | | |
| ARTHROPODA (Crustacea) | Control | 3/16 | 84.7 | 4.9 | 278 | 29.5 | 243 | 1349 | 179 | 35.7 | 0.61 | 53.7 | 5.9 | | |
| | | 4/19 | 0 | 4.5 | 22.2 | 25.8 | 45.5 | 180 | 92.7 | 34.8 | 0.28 | 29.1 | 4.5 | | |
| | | 5/17 | 22.9 | 1.1 | 21.8 | 4.2 | 16.2 | 1.8 | 5.3 | 4.6 | 0.22 | 19.1 | 2.0 | | |
| | Average \bar{x} | 35.9 | 3.5 | 107.3 | 29.8 | 101.6 | 510.3 | 92.3 | 25.0 | .37 | 34.0 | 4.1 | | | |
| | Std. Dev. σ | 43.8 | 2.1 | 147.8 | 27.9 | 123.4 | 731.8 | 86.9 | 17.7 | .21 | 17.8 | 2.0 | | | |
| S ₂ | 6/20 | 0 | 0 | 0 | 107 | 232 | 2589 | 53.6 | 71.4 | 2.9 | 86.6 | 4.3 | | | |

APPENDIX - A-16. ANALYSIS OF BENTHIC ORGANISMS COLLECTED FROM LAKE IVANHOE BOTTOM SEDIMENTS (Continued)

| Phylum & Class | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | |
|--------------------------------------|--------------------------|----------------|--|-------|------|-------|--------|-------|------|------|------|------|-------|------|--|
| | | | µg/gm | | | | | | | | | | mg/gm | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | |
| ARTHROPODA (Crustacea) (cont.) | S ₃ | 3/16 | 30.1 | 7.0 | 310 | 110 | 665 | 2542 | 211 | 122 | 1.1 | 73.3 | 8.0 | | |
| | | 5/17 | 24.6 | 1.0 | 23.1 | 1.8 | 21.2 | 32 | 11.7 | 2.8 | 0.2 | 15.7 | 1.6 | | |
| | | 6/20 | 0 | 9.5 | 0 | 5.7 | 43.7 | 192 | 57 | 9.5 | 0.3 | 53.8 | 2.2 | | |
| | | 7/13 | 0 | 1.5 | 26.0 | 0 | 0 | 0 | 4.9 | 0 | 0.3 | 7.7 | 1.6 | | |
| | | 8/24 | 18.1 | 2.6 | 17.3 | 38.0 | 26.8 | 146 | 18.1 | 7.8 | 0.2 | 29.0 | 1.2 | | |
| | Average \bar{x} | 14.6 | 8.3 | 75.3 | 31.1 | 151.3 | 582.3 | 60.5 | 28.4 | 28.4 | .40 | 35.9 | 2.9 | | |
| | Std. Dev. σ | 14.0 | 11.0 | 131.6 | 46.8 | 287.6 | 1098.4 | 86.5 | 52.5 | 52.5 | .39 | 27.2 | 2.9 | | |
| | Control | 3/16 | 79.6 | 2.8 | 24.9 | 12.4 | 21 | 129 | 194 | 24.5 | 0.07 | 33.5 | 0.29 | | |
| | MOLLUSCA (Pelecypoda) | S ₁ | 3/16 | 44 | 2.1 | 50.3 | 10.1 | 21 | 593 | 223 | 18.2 | 0.12 | 47.8 | 0.31 | |
| | | | 4/19 | 6.9 | 0.2 | 28.2 | 0.9 | 9.8 | -- | 90.7 | 10.3 | 0.10 | 2.7 | 5.3 | |
| Average \bar{x} | | 25.4 | 1.1 | 39.3 | 5.5 | 15.4 | 593 | 156.9 | 14.3 | 14.3 | .11 | 25.3 | 2.8 | | |
| Std. Dev. σ | | 26.2 | 1.3 | 15.6 | 6.5 | 7.9 | -- | 93.6 | 5.7 | 5.7 | .01 | 31.9 | 3.5 | | |
| S ₂ | | 8/3 | 1.4 | 0.2 | 25.5 | 1.4 | 5.1 | 191 | 42.1 | 12.3 | 0.12 | 1.4 | 2.1 | | |
| ANNELIDA (Oligochaeta - Tubifex) | S ₃ | 5/17 | 0.8 | 0.32 | 23.8 | 0.6 | 6.6 | 251 | 36.0 | 11.7 | 0.13 | 1.7 | 2.7 | | |
| | | 6/20 | 0 | 0.57 | 35.3 | 1.5 | 44.5 | 18.9 | 11.7 | 2.1 | 0.09 | 4.0 | 1.2 | | |
| | | 7/13 | 1.2 | 0.36 | 31.5 | 2.2 | 13.2 | 287 | 44.5 | 16.3 | 0.09 | 1.9 | 0.2 | | |
| | | 8/3 | 1.1 | 0.45 | 30.9 | 5.3 | 42.4 | 37.2 | 6.2 | 5.8 | 0.12 | 1.5 | 0.8 | | |
| | | 8/24 | 1.3 | 0.21 | 24.4 | 2.0 | 21.1 | 136 | 27.1 | 5.3 | 0.10 | 1.7 | 2.0 | | |
| | Average \bar{x} | .88 | .38 | 29.2 | 2.3 | 25.6 | 146.0 | 25.1 | 8.2 | 8.2 | .11 | 2.2 | 1.4 | | |
| | Std. Dev. σ | .53 | .13 | 4.9 | 1.8 | 17.1 | 121.4 | 16.1 | 5.7 | 5.7 | .02 | 1.0 | .97 | | |
| | Control | 4/19 | -- | 0.67 | 69.1 | 9.44 | 33.9 | 129 | 23.4 | 6.78 | 0.12 | 0.84 | 1.76 | | |
| | S ₁ | 7/13 | 71.4 | 0 | 679 | 62.5 | 0 | 670 | 0 | 71.4 | 1.16 | 7.96 | 1.05 | | |
| | | 8/24 | 311 | 9.43 | 31.4 | 34.6 | 53.5 | 261 | 0 | 0.0 | 0.09 | 6.82 | 0.70 | | |
| Average \bar{x} | | 191.2 | 4.7 | 355.2 | 48.6 | 26.8 | 465.5 | 0 | 35.7 | .62 | 7.4 | .87 | | | |
| Std. Dev. σ | | 169.4 | 6.7 | 457.9 | 19.7 | 37.8 | 289.2 | 0 | 50.5 | .76 | .80 | .24 | | | |
| S ₂ | | 4/19 | 0 | 6.25 | 213 | 56.3 | 87.5 | 244 | 203 | 191 | 0.18 | 1.80 | 0.34 | | |
| 7/13 | 0 | 0 | 331 | 49.3 | 0 | 732 | 84.5 | 91.5 | 0.43 | 4.32 | 1.20 | | | | |

APPENDIX - A-16. ANALYSIS OF BENTHIC ORGANISMS COLLECTED FROM LAKE IVANHOE BOTTOM SEDIMENTS (Continued)

| Phylum & Class | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | |
|---|--------------------|------|--|--------|--------|-------|--------|-------|-------|-------|------|------|------|
| | | | µg/gm | | | | | | | | | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P |
| ANNELIDA (Oligochaeta - Turbifex) (cont.) | Average \bar{x} | | 0 | 3.1 | 272.0 | 52.8 | 43.8 | 488.0 | 143.8 | 141.3 | .30 | 3.0 | .77 |
| | Std. Dev. σ | | 0 | 4.4 | 83.4 | 4.9 | 61.9 | 345.1 | 83.8 | 70.4 | .18 | 1.7 | .61 |
| | S ₃ | 3/16 | 0 | 0 | 829 | 64.3 | 979 | 2271 | 143 | 78.6 | 0.48 | 14.7 | 1.17 |
| | | 6/20 | 0 | 0 | 4125 | 938 | 469 | 297 | 344 | 31.3 | 0.45 | 21.1 | 0 |
| | | 7/13 | 17.5 | 0 | 49 | 2.3 | 0 | 137 | 3.2 | 2.8 | 0.14 | 0.5 | 1.25 |
| | Average \bar{x} | | 5.8 | 0 | 1667.8 | 334.9 | 482.7 | 901.7 | 163.4 | 37.6 | .36 | 12.1 | .81 |
| Std. Dev. σ | | 10.1 | 0 | 2163.4 | 532.2 | 489.6 | 1188.6 | 171.3 | 38.3 | .19 | 10.5 | .70 | |
| ANNELIDA (Hirudinea) | S ₂ | 7/13 | 24 | 7.72 | 125 | 15.4 | 0.00 | 208 | 37.7 | 18.9 | 0.14 | 1.0 | 0.58 |
| | S ₃ | 7/13 | 23.5 | 0.00 | 215 | 0.00 | 0.00 | 177 | 0.00 | 0.00 | 0.09 | 1.18 | 0.72 |
| | S ₃ | 3/16 | 0.00 | 26.3 | 3605 | 368 | 1737 | 11052 | 553 | 6.32 | 1.26 | 12.4 | 4.87 |
| PLANARIA | | | | | | | | | | | | | |

APPENDIX - A-17. AVERAGE CONCENTRATION FACTORS FOR HEAVY METALS IN PLANTS FROM LAKE IVANHOE

| Plant | Station | Concentration Factor $\frac{\text{mg/gm (oven dry wt.)}}{\text{Mg/m}}$ | | | | | | | | | |
|-----------|---------|--|-----|------|-------|-------|-------|-------|-------|--|--|
| | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | | |
| Typha | Control | 313 | 87 | 353 | 142 | 665 | 1072 | 432 | 540 | | |
| | S1 | 170 | 20 | 757 | 367 | 412 | 3572 | 455 | 680 | | |
| | Average | 242 | 54 | 555 | 255 | 539 | 2322 | 444 | 610 | | |
| Hydrilla | Control | 1639 | 67 | 3785 | 1375 | 6806 | 10826 | 3175 | 1933 | | |
| | S1 | 3643 | 86 | 8500 | 3267 | 4344 | 15964 | 3323 | 9020 | | |
| | S2 | 9567 | 900 | 4970 | 10967 | 4993 | 13150 | 5511 | 3386 | | |
| | S3 | 590 | 400 | 3323 | 807 | 3952 | 8470 | 2079 | 24460 | | |
| | Average | 3860 | 363 | 5145 | 4104 | 5024 | 12103 | 3522 | 9700 | | |
| Spirogyra | Control | 796 | 200 | 1477 | 1425 | 20047 | 25670 | 2525 | 8960 | | |
| | S1 | 231 | 136 | 6277 | 4300 | 9552 | 31000 | 7075 | 8260 | | |
| | S2 | 4767 | 750 | 2813 | 7067 | 9332 | 32000 | 8184 | 6571 | | |
| | S3 | 356 | 257 | 1619 | 1273 | 15000 | 13064 | 3162 | 5800 | | |
| | Average | 1538 | 336 | 3047 | 3516 | 13483 | 25434 | 52375 | 7398 | | |

APPENDIX - A-18. AVERAGE CONCENTRATION FACTORS FOR HEAVY METALS IN BENTHIC ORGANISMS FROM LAKE IVANHOE

| Phylum | Station | Concentration Factor mg/g (oven dry wt.) | | | | | | | | | |
|--|---------|---|-------|-------|-------|-------|-------|-------|-------|--|--|
| | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | | |
| MOLLUSCA (Gastropoda) | S-1 | 131 | 29 | 672 | 550 | 1292 | 1732 | 781 | 600 | | |
| | S-2 | 1933 | 195 | 3967 | 1167 | 1528 | 973 | 669 | 514 | | |
| | S-3 | 656 | 60 | 3293 | 140 | 1211 | 602 | 344 | 400 | | |
| | Average | 907 | 95 | 2644 | 619 | 1141 | 1102 | 598 | 505 | | |
| (Pelecypoda) | S-1 | 363 | 78 | 1310 | 917 | 616 | 11860 | 2960 | 2860 | | |
| | S-2 | 467 | 100 | 381 | 467 | 182 | 3183 | 936 | 1757 | | |
| | S-3 | 21 | 127 | 423 | 153 | 948 | 2212 | 411 | 1640 | | |
| | Average | 284 | 102 | 705 | 512 | 582 | 5752 | 1436 | 2086 | | |
| ARTHROPODA | Control | 1561 | 11671 | 1731 | 2483 | 5976 | 10206 | 1742 | 5000 | | |
| | S-2 | 0 | 0 | 0 | 35667 | 8286 | 43150 | 1191 | 10200 | | |
| | S-3 | 212 | 2767 | 1091 | 2073 | 5604 | 8823 | 992 | 5680 | | |
| | Average | 519 | 1311 | 941 | 13408 | 6622 | 20726 | 1308 | 6960 | | |
| ANNELIDA - OLIGOCHAETA (Tubifex) | Control | -- | 223 | 1115 | 787 | 1994 | 2580 | 442 | 1356 | | |
| | S-1 | 2731 | 336 | 11840 | 8100 | 1072 | 9310 | 0 | 7140 | | |
| | S-2 | 0 | 3125 | 3179 | 18767 | 3125 | 4067 | 4511 | 27285 | | |
| | S-3 | 141 | 0 | 24171 | 22327 | 17878 | 13662 | 2679 | 7520 | | |
| Average | 718 | 921 | 10076 | 12495 | 6017 | 7405 | 1908 | 10825 | | | |
| ANNELIDA (Hirudinea) | S-2 | 8000 | 3860 | 1866 | 5133 | 0 | 3467 | 838 | 2700 | | |
| | S-3 | 573 | 0 | 3116 | 0 | 0 | 2682 | 0 | 0 | | |
| | Average | 4287 | 1930 | 2491 | 2567 | 0 | 3075 | 419 | 1350 | | |

APPENDIX - B-1. WATER QUALITY CHARACTERISTICS IN MAITLAND INTERCHANGE

| Parameter | Station | Concentration | | | | | | | | Statistical Analysis | |
|-----------------------------|---------|---------------|-------|-------|-------|-------|-------|-------|-------|----------------------|----------|
| | | 2-22 | 3-20 | 5- 3 | 5-24 | 6-29 | 7-20 | 8-17 | 8-30 | \bar{x} | σ |
| pH | S-1 | 8.09 | 7.57 | 9.86 | 9.31 | 9.18 | 7.94 | 9.22 | 8.40 | 8.19 | --- |
| | S-2 | 7.97 | 7.43 | 7.93 | 7.85 | 7.99 | 7.85 | 7.67 | 7.70 | | |
| | S-3 | 6.97 | 6.65 | 7.39 | 7.45 | 7.52 | 7.52 | 7.06 | 7.45 | | |
| | S-4 | 7.40 | 7.06 | 7.32 | 7.20 | --- | 7.41 | 7.31 | 7.09 | | |
| Turbidity | S-1 | 17.00 | 5.50 | 5.00 | 3.30 | 4.00 | 12.50 | 4.00 | 7.50 | 7.35 | 4.89 |
| | S-2 | 25.50 | 42.00 | 15.20 | 19.00 | 11.00 | 10.80 | 11.80 | 41.00 | | |
| | S-3 | 2.40 | 1.90 | 5.00 | 2.60 | 3.50 | 2.20 | 2.00 | 2.00 | | |
| | S-4 | 10.0 | 4.70 | 4.00 | 3.00 | 3.50 | 13.30 | 2.80 | 2.40 | | |
| TOC mg/l | S-1 | 8.30 | 8.80 | 13.80 | 9.90 | 6.00 | --- | --- | --- | 9.36 | 2.86 |
| | S-2 | 6.90 | 11.90 | 13.20 | 7.60 | 4.50 | --- | --- | --- | | |
| | S-3 | 11.50 | 9.30 | 34.90 | 11.50 | 8.50 | --- | --- | --- | | |
| | S-4 | 12.20 | 10.80 | 16.60 | 14.00 | 6.60 | --- | --- | --- | | |
| Inorganic Carbon mg/l | S-1 | 21.50 | 13.70 | 16.00 | 9.90 | 10.20 | --- | --- | --- | 14.30 | 4.78 |
| | S-2 | 31.30 | 24.10 | 64.00 | 7.60 | 26.80 | --- | --- | --- | | |
| | S-3 | 5.00 | 3.50 | 9.80 | 11.50 | 4.00 | --- | --- | --- | | |
| | S-4 | 4.00 | 3.50 | 9.50 | 14.00 | 4.40 | --- | --- | --- | | |
| Chlorophyll -a mg/l | S-1 | 9.00 | 5.60 | 5.60 | 5.00 | 6.20 | 29.70 | 23.50 | 53.10 | 17.20 | 17.30 |
| | S-2 | 13.40 | 12.90 | 7.30 | 7.80 | 4.50 | 6.20 | 5.00 | 7.30 | | |
| | S-3 | 4.50 | 5.00 | 6.20 | 4.50 | 3.90 | 5.00 | 5.60 | 3.40 | | |
| | S-4 | 5.00 | 7.30 | 5.00 | 5.60 | 2.80 | 9.50 | 3.40 | 4.50 | | |
| Nitrates mg/l-N | S-1 | --- | --- | 0.79 | --- | --- | 1.34 | --- | 0.89 | 1.01 | .293 |
| | S-2 | --- | --- | 2.11 | --- | --- | 2.59 | --- | 1.95 | | |
| | S-3 | --- | --- | 0.52 | --- | --- | 0.58 | --- | 0.39 | | |
| | S-4 | --- | --- | 0.70 | --- | --- | 0.07 | --- | 0.34 | | |
| Phosphorus mg/l-P | S-1 | --- | .067 | .121 | .333 | .065 | .228 | .045 | .073 | .133 | .1076 |
| | S-2 | --- | .481 | .145 | .540 | .351 | .188 | .147 | .630 | | |
| | S-3 | --- | .008 | .075 | .044 | UD | .069 | .070 | UD | | |
| | S-4 | --- | .046 | .110 | .218 | UD | .159 | .081 | .034 | | |
| Calcium mg/l | S-1 | 39.50 | 35.00 | 18.40 | 19.80 | 21.00 | 33.80 | 33.50 | 38.20 | 29.90 | 8.69 |
| | S-2 | 57.80 | 64.20 | 52.00 | 59.90 | 52.20 | 53.60 | 54.10 | 55.10 | | |
| | S-3 | 11.00 | 13.00 | 11.40 | 15.50 | 10.00 | 11.60 | 11.50 | 11.70 | | |
| | S-4 | --- | 13.60 | 10.80 | 13.30 | 10.00 | 11.70 | 11.90 | 11.70 | | |
| Magnesium mg/l | S-1 | 2.00 | 2.10 | 1.70 | 1.60 | 1.50 | 2.00 | 1.90 | 2.40 | 1.88 | .296 |
| | S-2 | 4.60 | 3.60 | 6.20 | 5.70 | 4.60 | 5.00 | 4.60 | 5.10 | | |
| | S-3 | 3.90 | 3.70 | 4.20 | 4.30 | 3.70 | 4.00 | 3.70 | 4.00 | | |
| | S-4 | --- | 5.50 | 3.80 | 4.30 | 3.80 | 3.90 | 3.80 | 4.00 | | |

APPENDIX - B-2 . VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES
FROM EAST POND (S1) ON MAITLAND INTERCHANGE

| Parameter | Concentration (µg/l) | | | | | | | | | | Statistical Analysis | |
|--------------------------|----------------------|------------|------------|------------|-----------|-----------|-----------|-----------|------------|------------|----------------------|--|
| | 2-22 | 3-20 | 5- 3 | 5-24 | 6-29 | 7-20 | 8-17 | 8-30 | \bar{X} | σ | | |
| Total Zn Dissolved Zn | 53 33 | 43 17 | 52 52 | 138 31 | 31 26 | 124 83 | 96 4 | 27 9 | 71 32 | 43 26 | | |
| Total Cd Dissolved Cd | 6 6 | 1 0 | 2 0 | 1 1 | 1 0 | 1 1 | 5 0 | 8 8 | 3 2 | 3 3 | | |
| Total As Dissolved As | 21 0 | 31 -- | 113 113 | 247 245 | 0 0 | 0 0 | 72 0 | 93 67 | 72 61 | 82 93 | | |
| Total Ni Dissolved Ni | 62 -- | 8 3 | 23 23 | 22 6 | 14 14 | 5 3 | 16 1 | 6 4 | 20 8 | 18 8 | | |
| Total Cu Dissolved Cu | 58 24 | 23 18 | 44 41 | 39 12 | 21 12 | 32 25 | 24 0 | 17 3 | 32 17 | 14 13 | | |
| Total Fe Dissolved Fe | 453 354 | 174 174 | 428 268 | 163 62 | 125 76 | 314 53 | 107 37 | 163 33 | 241 132 | 138 121 | | |
| Total Pb Dissolved Pb | 64 64 | 68 67 | 57 28 | 40 40 | 80 80 | 34 16 | 52 36 | 31 20 | 53 44 | 17 24 | | |
| Total Cr Dissolved Cr | 49 -- | 10 5 | 15 5 | 19 17 | 18 18 | 6 2 | 1 0 | 5 2 | 15 7 | 15 7 | | |

APPENDIX - B-3. VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES
FROM WEST POND (S2) ON MAITLAND INTERCHANGE

| Parameter | Concentration (ug/l) | | | | | | | | | | Statistical Analysis | |
|--------------|----------------------|------|-----|------|------|------|------|------|-----------|----------|----------------------|--|
| | 2-22 | 3-20 | 5-3 | 5-24 | 6-29 | 7-20 | 8-17 | 8-30 | \bar{x} | σ | | |
| Total Zn | 51 | 43 | 44 | 60 | 37 | -- | 125 | 57 | 64 | 30 | | |
| Dissoived Zn | 43 | 17 | -- | 32 | 31 | 35 | 79 | 30 | 43 | 17 | | |
| Total Cd | 5 | 1 | 7 | 0 | 1 | 3 | 2 | 5 | 3 | 2 | | |
| Dissoived Cd | 0 | 0 | 2 | 0 | 1 | 3 | 0 | 5 | 2 | 2 | | |
| Total As | 59 | 31 | 359 | 201 | 0 | 66 | 92 | 237 | 131 | 123 | | |
| Dissoived As | 59 | -- | 0 | 71 | 0 | 58 | 1 | 237 | 53 | 81 | | |
| Total Ni | 52 | 8 | 11 | 10 | 4 | 12 | 9 | 7 | 15 | 15 | | |
| Dissoived Ni | 0 | 3 | 9 | 3 | 0 | 1 | 5 | 7 | 5 | 3 | | |
| Total Cu | 36 | 23 | 44 | 24 | 19 | 31 | 65 | 48 | 38 | 15 | | |
| Dissoived Cu | 18 | 18 | 34 | 10 | 17 | 11 | 27 | 15 | 21 | 11 | | |
| Total Fe | 425 | 174 | 545 | 318 | 170 | 232 | 245 | 690 | 414 | 207 | | |
| Dissoived Fe | 314 | 174 | 395 | 42 | 71 | 29 | 101 | 39 | 128 | 144 | | |
| Total Pb | 83 | 68 | 129 | 69 | 118 | 57 | 97 | 60 | 92 | 29 | | |
| Dissoived Pb | 69 | 67 | 103 | 64 | 118 | 25 | 85 | 29 | 66 | 35 | | |
| Total Cr | 44 | 10 | 18 | 25 | 21 | 8 | 4 | 7 | 17 | 13 | | |
| Dissoived Cr | -- | 5 | 16 | 2 | 21 | 3 | 4 | 1 | 7 | 36 | | |

APPENDIX - B-4 . VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES
FROM OUTFALL TO LAKE LUCIEN (S3) ON MAITLAND INTERCHANGE

| Parameter | Concentration (µg/l) | | | | | | | | | | Statistical Analysis | |
|--------------|----------------------|------|------|------|------|------|------|------|-----------|----------|----------------------|--|
| | 2-22 | 3-20 | 5- 3 | 5-24 | 6-29 | 7-20 | 8-17 | 8-30 | \bar{x} | σ | | |
| Total Zn | 43 | 43 | 56 | 57 | 33 | 92 | 95 | 35 | 57 | 24 | | |
| Dissolved Zn | 34 | 41 | 56 | 24 | 18 | 92 | 9 | 1 | 34 | 29 | | |
| Total Cd | 5 | 2 | 5 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | | |
| Dissolved Cd | 2 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | | |
| Total As | 0 | 14 | 0 | 43 | 0 | 10 | 18 | 16 | 13 | 14 | | |
| Dissolved As | 0 | 14 | 0 | 43 | 0 | 0 | 18 | 16 | 11 | 15 | | |
| Total Ni | 17 | 7 | 11 | 7 | 11 | 4 | 19 | 10 | 11 | 5 | | |
| Dissolved Ni | -- | 3 | 11 | 3 | 11 | 1 | 0 | 0 | 4 | 5 | | |
| Total Cu | 22 | 28 | 49 | 37 | 18 | 17 | 25 | 25 | 28 | 11 | | |
| Dissolved Cu | 22 | 4 | 49 | 26 | 9 | 12 | 2 | 22 | 18 | 15 | | |
| Total Fe | 157 | 83 | 289 | 125 | 97 | 179 | 77 | 113 | 140 | 70 | | |
| Dissolved Fe | 67 | 70 | 281 | 41 | 49 | 44 | 33 | 113 | 87 | 82 | | |
| Total Pb | 55 | 39 | 41 | 20 | 53 | 9 | 16 | 9 | 30 | 19 | | |
| Dissolved Pb | 55 | 39 | 31 | 15 | 53 | 5 | 3 | 0 | 25 | 22 | | |
| Total Cr | 19 | 10 | 14 | 12 | 14 | 3 | 2 | 1 | 9 | 7 | | |
| Dissolved Cr | 18 | 6 | 14 | 7 | 10 | 0 | 0 | 0 | 7 | 7 | | |

APPENDIX - B-5. VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES
FROM LAKE LUCIEN (S4) ON MAITLAND INTERCHANGE

| Parameter | Concentration (µg/l) | | | | | | | | | | Statistical Analysis | |
|--------------|----------------------|------|------|------|------|------|------|------|-----------|----------|----------------------|--|
| | 2/22 | 3/20 | 5/ 3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | \bar{x} | σ | | |
| Total Zn | 68 | 41 | 35 | 35 | 44 | 96 | 82 | 46 | 56 | 23 | | |
| Dissolved Zn | -- | 40 | 28 | 28 | 44 | 34 | 35 | 29 | 34 | 6 | | |
| Total Cd | 2 | 1 | 1 | 0 | 33 | 2 | 1 | 0 | 5 | 11 | | |
| Dissolved Cd | -- | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Total As | 0 | 16 | 115 | 0 | 0 | 2 | 110 | 0 | 30 | 51 | | |
| Dissolved As | -- | 0 | 115 | 0 | 0 | 0 | 110 | 0 | 28 | 52 | | |
| Total Ni | 16 | 5 | 7 | 8 | 6 | 6 | 5 | 6 | 7 | 4 | | |
| Dissolved Ni | 0 | -- | 4 | 8 | 4 | 3 | 0 | 5 | 3 | 3 | | |
| Total Cu | 38 | 28 | 26 | 23 | 24 | 50 | 58 | 38 | 36 | 13 | | |
| Dissolved Cu | -- | -- | 23 | 14 | 18 | 9 | 30 | 20 | 19 | 7 | | |
| Total Fe | 325 | 180 | 277 | 114 | 119 | -- | 145 | 111 | 182 | 86 | | |
| Dissolved Fe | -- | 180 | 230 | 45 | 72 | 3 | 23 | 18 | 82 | 88 | | |
| Total Pb | 30 | 39 | 30 | 27 | 62 | 30 | 24 | 19 | 33 | 13 | | |
| Dissolved Pb | -- | -- | 17 | 27 | 62 | 0 | 8 | 2 | 19 | 23 | | |
| Total Cr | 12 | 8 | 7 | 13 | 13 | 9 | 3 | 4 | 9 | 4 | | |
| Dissolved Cr | -- | 7 | 7 | 12 | 11 | 0 | 0 | 1 | 5 | 5 | | |

APPENDIX - B-6. CHARACTERISTICS OF BOTTOM SEDIMENTS FROM
MAITLAND INTERCHANGE AREA

| Parameter | Station | Percent (%) | | | | | | | | | | Statistical Analysis | |
|------------------|---------|-------------|-------|-------|-------|-------|-------|-------|------|-----------|----------|----------------------|--|
| | | 2-22 | 3-20 | 5-3 | 5-24 | 6-29 | 7-20 | 8-17 | 8-30 | \bar{x} | σ | | |
| Water Content | S-1 | --- | 26.80 | 19.50 | 24.00 | 20.80 | 27.30 | 27.90 | --- | 24.40 | 3.59 | | |
| | S-2 | --- | --- | 64.50 | 45.20 | 46.90 | 49.20 | 44.20 | --- | 49.90 | 8.31 | | |
| | S-3 | --- | 84.70 | 82.20 | 81.80 | 90.40 | 61.90 | 57.70 | --- | 76.40 | 13.30 | | |
| | S-4 | --- | 45.00 | 63.20 | 47.30 | 37.80 | 50.20 | 33.50 | --- | 46.20 | 10.40 | | |
| Loss On Ignition | S-1 | 3.33 | 0.73 | 0.54 | 1.94 | 0.32 | 0.45 | 6.14 | 0.40 | 1.04 | 1.06 | | |
| | S-2 | 20.40 | --- | 18.30 | 4.40 | 4.53 | 5.86 | 3.07 | 7.63 | 9.16 | 7.11 | | |
| | S-3 | 65.20 | 14.40 | 24.70 | 21.40 | 32.30 | 6.28 | 3.32 | 3.35 | 21.40 | 20.60 | | |
| | S-4 | 5.49 | 3.18 | 4.63 | 2.70 | 4.53 | 3.60 | 1.87 | 2.58 | 3.57 | 1.23 | | |

APPENDIX - B-7. ANALYSIS OF BOTTOM SEDIMENTS FROM
EAST POND (S-1) ON MAITLAND INTERCHANGE

| Parameter | Concentration $\mu\text{g}/\text{gm}$ (oven dry weight) | | | | | | | | | | Statistical Analysis | |
|-----------|---|---------|---------|---------|---------|---------|---------|---------|-----------|----------|----------------------|--|
| | 2/22 | 3/20 | 5/3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | \bar{x} | σ | | |
| Zn | 6.07 | 5.74 | 5.05 | 11.80 | 9.59 | 19.60 | 13.10 | 4.25 | 9.40 | 5.26 | | |
| Cd | .060 | .090 | .123 | .101 | .050 | 0 | .069 | .079 | .072 | .037 | | |
| As | 2.08 | 6.30 | 3.75 | 12.40 | 6.20 | 1.77 | .918 | .710 | 4.27 | 3.95 | | |
| Ni | .884 | .935 | .928 | 2.54 | .876 | .725 | 1.92 | .415 | 1.15 | .706 | | |
| Cu | 5.46 | 2.89 | 4.90 | 2.99 | .673 | 1.19 | 8.61 | .664 | 2.87 | 2.87 | | |
| Fe | 528.00 | 358.00 | 435.00 | 1701.00 | 183.00 | 232.00 | 871.00 | 127.00 | 561.00 | 520.00 | | |
| Pb | 11.80 | 9.84 | 6.95 | 18.00 | 6.39 | 5.13 | 22.40 | 5.43 | 10.70 | 6.36 | | |
| Cr | 2.80 | 2.56 | 2.21 | 7.13 | 2.68 | 1.13 | 4.44 | 1.05 | 3.00 | 1.98 | | |
| Ca | 3597.00 | 1714.00 | 1627.00 | 8825.00 | 1184.00 | 1961.00 | 1513.00 | 1099.00 | 2690.00 | 2598.00 | | |
| Mg | 89.90 | 66.50 | 89.40 | 273.00 | 40.40 | 43.40 | 151.00 | 27.80 | 97.70 | 80.90 | | |
| P | 209.00 | 417.00 | 278.00 | 585.00 | 121.00 | 113.00 | 393.00 | 83.60 | 275.00 | 178.00 | | |

APPENDIX - B-8. ANALYSIS OF BOTTOM SEDIMENTS FROM
WEST POND (S-2) ON MAITLAND INTERCHANGE

| Parameter | Concentration $\mu\text{g}/\text{gm}$ (oven dry weight) | | | | | | | | | | Statistical Analysis | |
|-----------|---|------|---------|---------|---------|---------|---------|---------|-----------|----------|----------------------|--|
| | 2/22 | 3/20 | 5/3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | \bar{x} | σ | | |
| Zn | 70.70 | -- | 68.00 | 16.30 | 14.90 | 38.70 | 12.10 | 25.60 | 35.20 | 25.00 | | |
| Cd | .998 | -- | 1.19 | .187 | .195 | .290 | .150 | .512 | .503 | .425 | | |
| As | 22.60 | -- | 45.30 | 8.15 | 3.53 | 10.10 | 4.31 | 14.80 | 15.50 | 14.70 | | |
| Ni | 12.70 | -- | 28.20 | 6.69 | 6.73 | 7.70 | 3.10 | 9.40 | 10.60 | 8.27 | | |
| Cu | 35.00 | -- | 29.80 | 5.90 | 6.01 | 8.40 | 9.34 | 11.80 | 15.20 | 12.00 | | |
| Fe | 4590.00 | -- | 7543.00 | 2445.00 | 2055.00 | 2406.00 | 875.00 | 2939.00 | 3265.00 | 2189.00 | | |
| Pb | 233.00 | -- | 174.00 | 43.60 | 50.30 | 61.40 | 34.60 | 91.70 | 98.40 | 76.00 | | |
| Cr | 61.60 | -- | 73.70 | 21.00 | 20.30 | 22.70 | 10.20 | 28.00 | 33.90 | 23.90 | | |
| Ca | 14640 | -- | 10278 | 12711 | 11550 | 12548 | 6096.00 | 9912.00 | 11105 | 2725.00 | | |
| Mg | 1166.00 | -- | 2184.00 | 697.00 | 573.00 | 611.00 | 283.00 | 787.00 | 900.00 | 625.00 | | |
| P | 5204.00 | -- | 6777.00 | 3494.00 | 2746.00 | 2645.00 | 1952.00 | 3070.00 | 3698.00 | 1695.00 | | |


APPENDIX - B-9. ANALYSIS OF BOTTOM SEDIMENTS FROM NEAR OUTFALL
TO LAKE LUCIEN (S-3) ON MAITLAND INTERCHANGE

| Parameter | Concentration $\mu\text{g}/\text{gm}$ (oven dry weight) | | | | | | | | | | Statistical Analysis | |
|-----------|---|---------|---------|---------|---------|---------|--------|---------|-----------|----------|----------------------|--|
| | 2/22 | 3/20 | 5/3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | \bar{x} | σ | | |
| Zn | 492.00 | 49.20 | 145.00 | 82.20 | 115.00 | 40.90 | 15.60 | 16.70 | 120.00 | 157.00 | | |
| Cd | 1.52 | .343 | 1.26 | .666 | .466 | .109 | .182 | .182 | .591 | .529 | | |
| As | 21.20 | 8.16 | 39.20 | 6.73 | 11.20 | 2.64 | .355 | 5.13 | 11.80 | 12.70 | | |
| Ni | 8.40 | 4.25 | 12.00 | 9.09 | 8.14 | 2.17 | 1.62 | 1.95 | 5.95 | 3.95 | | |
| Cu | 124.00 | 17.60 | 55.20 | 26.10 | 35.50 | 8.62 | 5.97 | 4.27 | 34.70 | 40.00 | | |
| Fe | 3141.00 | 1424.00 | 4273.00 | 3722.00 | 2576.00 | 622.00 | 363.00 | 305.00 | 2053.00 | 1582.00 | | |
| Pb | 135.00 | 78.30 | 165.00 | 62.40 | 116.00 | 19.40 | 9.30 | 18.50 | 75.50 | 58.70 | | |
| Cr | 29.60 | 10.30 | 30.40 | 23.40 | 16.60 | 4.69 | 2.91 | 4.43 | 15.30 | 11.40 | | |
| Ca | 8034.00 | 2696.00 | 4252.00 | 8288.00 | 8396.00 | 2141.00 | 938.00 | 1115.00 | 4483.00 | 3274.00 | | |
| Mg | 1220.00 | 436.00 | 1356.00 | 977.00 | 975.00 | 218.00 | 134.00 | 130.00 | 681.00 | 507.00 | | |
| P | 1664.00 | 1458.00 | 1875.00 | 1296.00 | 1351.00 | 281.00 | 169.00 | 197.00 | 1036.00 | 704.00 | | |

APPENDIX - B-10. ANALYSIS OF BOTTOM SEDIMENTS FROM LAKE LUCIEN
CONTROL STATION (S-4) ON MAITLAND INTERCHANGE

| Parameter | Concentration $\mu\text{g}/\text{gm}$ (oven dry weight) | | | | | | | | | | Statistical Analysis | |
|-----------|---|--------|---------|---------|--------|---------|--------|--------|-----------|----------|----------------------|--|
| | 2/22 | 3/20 | 5/ 3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | \bar{x} | σ | | |
| Zn | 27.40 | 16.40 | 23.50 | 21.80 | 15.70 | 38.10 | 12.80 | 13.10 | 21.10 | 8.61 | | |
| Cd | .044 | .136 | .024 | .255 | .024 | .016 | .017 | .169 | .082 | .083 | | |
| As | 1.13 | 2.73 | 4.30 | 0 | 1.73 | .141 | .213 | 1.64 | 1.49 | 1.48 | | |
| Ni | .744 | 1.39 | 1.95 | 1.28 | 1.29 | 1.36 | .845 | .970 | 1.23 | .382 | | |
| Cu | 10.50 | 4.95 | .490 | 4.79 | 3.31 | 4.45 | 7.63 | 4.05 | 5.02 | 2.97 | | |
| Fe | 479.00 | 489.00 | 845.00 | 445.00 | 351.00 | 288.00 | 230.00 | 244.00 | 421.00 | 200.00 | | |
| Pb | 11.80 | 9.84 | 20.10 | 14.00 | 10.60 | 12.60 | 9.50 | 10.40 | 13.00 | 3.42 | | |
| Cr | 2.28 | 3.66 | 3.74 | 2.37 | 2.77 | 1.99 | 1.44 | 1.81 | 2.51 | .835 | | |
| Ca | 568.00 | 637.00 | 1015.00 | 1124.00 | 853.00 | 1079.00 | 514.00 | 767.00 | 820.00 | 237.00 | | |
| Mg | 99.90 | 119.00 | 210.00 | 137.00 | 93.60 | 86.10 | 77.20 | 92.50 | 114.00 | 43.10 | | |
| P | 162.00 | 484.00 | 387.00 | 167.00 | 145.00 | 145.00 | 138.00 | 155.00 | 223.00 | 134.00 | | |

APPENDIX - B-11. BOTTOM SEDIMENT CHARACTERISTICS FOR PARTICLE SIZE LESS THAN 105 MICRON FROM MAITLAND INTERCHANGE

| Parameter | Average Concentration | | | | Units |
|----------------------|-----------------------|----------------|----------------|----------------|---|
| | S ₁ | S ₂ | S ₃ | S ₄ | |
| Loss on Ignition (%) | 3.2 | 20.8 | 22.6 | 11.9 | Percent  |
| Zn | 29.7 | 101.0 | 96.7 | 80.7 | |
| Pb | 39.7 | 205.0 | 179.0 | 58.3 | |
| Cr | 13.9 | 190.0 | 73.1 | 11.7 | |
| Ni | 4.4 | 28.3 | 24.4 | 6.0 | |
| Cu | 27.2 | 184.0 | 72.4 | 40.3 | |
| Fe | 2267.0 | 7756.0 | 6428.0 | 1739.0 | |
| Cd | 0.3 | 2.1 | 1.1 | 0.7 | |
| As | 10.1 | 41.7 | 34.3 | 5.8 | |
| Ca | 8108.0 | 14131.0 | 11936.0 | 2972.0 | |
| P | 902.0 | 8331.0 | 6834.0 | 739.0 | |

APPENDIX - B-12. MAITLAND PLANTS % MOISTURE CONTENT

| Form | Station | 2/22 | 3/20 | 5/3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | Statistical Analysis | |
|------------|--------------|-------|-------|-------|-------|-------|-------|-------|------|----------------------|-----------|
| | | | | | | | | | | Mean | Std. Dev. |
| Chara | S1 | 80.98 | 83.21 | 86.79 | 87.05 | 86.75 | 86.83 | 87.44 | -- | 85.58 | 2.48 |
| | S4 | 94.18 | 93.55 | 94.92 | 94.50 | -- | 94.8 | 95.42 | -- | 94.56 | 0.647 |
| | S3 | 94.58 | 93.52 | 94.90 | 94.29 | 95.4 | 95.35 | 94.30 | -- | 94.62 | 0.664 |
| Eichornia | Near Outfall | 93.11 | 94.21 | 93.65 | 92.61 | 91.38 | 92.93 | 93.37 | -- | 93.04 | 0.895 |
| | Near Weir | 92.68 | 94.09 | 89.97 | 92.69 | 90.35 | 92.62 | 93.89 | -- | 92.33 | 1.60 |
| | West End | 91.32 | 93.55 | 94.98 | 92.46 | 92.61 | 94.84 | 94.25 | -- | 93.43 | 1.36 |
| Typha | S1 | 89.63 | 90.10 | 86.28 | 89.73 | 89.95 | 76.79 | 91.88 | -- | 87.76 | 5.12 |
| | S2 | 91.47 | -- | 89.59 | 88.86 | 81.27 | 76.07 | 81.73 | -- | 84.83 | 6.03 |
| | S3 | -- | 90.19 | 92.30 | 86.44 | 89.95 | 76.85 | 84.13 | -- | 86.64 | 5.62 |
| Water Lily | S4 | 95.79 | -- | 89.01 | 89.92 | 87.09 | 90.34 | 88.91 | -- | 90.18 | 2.97 |
| | S3 | 91.52 | 85.84 | 94.38 | 90.31 | 86.54 | 90.43 | 91.89 | -- | 90.13 | 3.01 |

APPENDIX - B-13. MAITLAND PLANTS % LOSS ON IGNITION

| Form | Station | 2/22 | 3/20 | 5/3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | Statistical Analysis | |
|------------|--------------|------|-------|-------|-------|-------|-------|-------|-------|----------------------|----------|
| | | | | | | | | | | Mean | St. Dev. |
| Chara | S1 | -- | 28.30 | 36.80 | 30.71 | 46.13 | 24.95 | 41.09 | 40.28 | 35.47 | 7.69 |
| Hypercium | S4 | -- | 82.83 | 80.07 | 81.25 | -- | 81.7 | 82.43 | 81.88 | 81.69 | .970 |
| | S3 | -- | 85.59 | 87.36 | 83.76 | -- | 81.5 | 82.37 | 79.32 | 83.32 | 2.89 |
| Eichornia | Near Outfall | -- | 81.54 | 83.07 | 82.43 | 84.48 | 83.97 | 82.83 | 78.43 | 82.39 | 2.00 |
| | Near Weir | -- | 83.69 | 84.41 | 90.58 | 86.27 | 80.22 | 82.52 | 80.16 | 83.98 | 3.65 |
| | West End | -- | 79.62 | 83.73 | 84.07 | 82.59 | 81.16 | 79.82 | 79.02 | 81.43 | 2.06 |
| Typha | S1 | -- | 85.40 | 90.31 | 81.67 | 91.29 | 92.82 | 87.86 | 92.65 | 88.9 | 4.14 |
| | S2 | -- | -- | 87.10 | 91.34 | 93.50 | 92.49 | 92.23 | 91.16 | 91.3 | 2.23 |
| | S3 | -- | 89.99 | 89.81 | 89.87 | 91.74 | 91.34 | 92.87 | 92.79 | 91.2 | 1.34 |
| Water Lily | S4 | -- | -- | 92.54 | 87.21 | 89.79 | 88.39 | 89.78 | 91.50 | 87.87 | 1.95 |
| | S3 | -- | 92.18 | 92.30 | 90.35 | 90.52 | 89.59 | 86.25 | 88.01 | 89.89 | 2.18 |

APPENDIX - B-14. CONCENTRATION OF HEAVY METALS IN PLANTS
FROM MAITLAND INTERCHANGE

| Form | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | |
|-------|---------------|---------------|--|------|------|------|-------|--------|-------|------|------|------|-------|--|--|
| | | | µg/gm | | | | | | | | | | mg/gm | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | |
| Typha | East Pond | 2-22 | 7.6 | .20 | 40.9 | 1.6 | 8.0 | 135.0 | 7.0 | 3.9 | 1.1 | 5.4 | 1.6 | | |
| | | 3-20 | 14.6 | .32 | 88.0 | 3.6 | 20.9 | 353.0 | 26.6 | 7.1 | .74 | 10.9 | .95 | | |
| | | 5-3 | 15.8 | .24 | 22.2 | 2.9 | 9.1 | 56.1 | 21.8 | 2.1 | 1.5 | 8.9 | 1.4 | | |
| | | 5-24 | 27.3 | .55 | 92.3 | 5.6 | 16.7 | 1043.0 | 92.3 | 9.5 | 8.7 | 25.2 | 1.3 | | |
| | | 6-29 | 1.5 | .00 | 22.7 | 2.0 | 12.7 | 63.2 | 23.1 | 3.4 | 1.2 | 20.2 | 1.3 | | |
| | | 7-20 | 8.9 | .25 | 24.6 | 2.0 | 7.3 | 61.5 | 18.6 | 3.6 | 2.5 | 15.8 | .97 | | |
| | | 8-17 | 8.2 | .00 | 44.2 | 3.7 | 24.2 | 60.9 | 11.4 | 1.0 | 1.8 | 13.2 | 3.1 | | |
| | | 8-30 | 6.9 | .33 | 27.2 | 2.2 | 5.5 | 55.9 | 12.2 | 3.8 | 1.5 | 10.8 | 1.5 | | |
| | | Average | 11.3 | .24 | 45.3 | 2.9 | 13.0 | 228.6 | 26.6 | 4.3 | 2.4 | 13.8 | 1.5 | | |
| | | Standard Dev. | 7.9 | .18 | 28.9 | 1.3 | 6.9 | 344.4 | 27.4 | 2.7 | 2.6 | 6.4 | .67 | | |
| | | West Pond | 2-22 | 2.8 | 0.04 | 27.3 | 0.7 | 6.5 | 146.0 | 0.1 | 0.6 | 0.5 | 0.6 | | |
| | | | 5-3 | 19.8 | .38 | 18.1 | 6.4 | 9.9 | 166.0 | 25.0 | 1.6 | 9.8 | 2.0 | | |
| | | | 5-24 | 4.9 | .24 | 3.7 | 2.5 | 7.5 | 95.0 | 14.1 | 1.3 | 18.5 | 1.1 | | |
| | | | 6-29 | 18.9 | .25 | 16.8 | 1.8 | 9.2 | 59.0 | 25.1 | 1.2 | 17.0 | 1.4 | | |
| | | | 7-20 | 6.1 | .13 | 26.5 | 1.7 | 6.4 | 65.0 | 19.7 | 2.1 | 15.7 | 1.2 | | |
| | | 8-17 | 9.1 | .08 | 21.4 | 4.3 | 2.2 | 39.0 | 9.8 | 1.2 | 10.5 | 1.1 | | | |
| | | 8-30 | 6.5 | .51 | 18.5 | 2.1 | 6.8 | 60.0 | 24.1 | 1.0 | 11.5 | 1.3 | | | |
| | Average | 9.7 | .23 | 21.8 | 2.8 | 9.7 | 89.9 | 16.8 | 2.9 | 1.3 | 11.9 | 1.3 | | | |
| | Standard Dev. | 6.8 | .17 | 4.2 | 1.9 | 5.5 | 48.4 | 9.4 | .65 | .46 | 6.1 | .43 | | | |
| | Lake | 3-20 | 9.1 | .33 | 94.4 | 3.0 | 15.2 | 507.0 | 25.0 | 1.0 | 6.2 | 0.7 | | | |
| | Lucien | 5-3 | 0.0 | .24 | 23.0 | 4.9 | 7.2 | 56.0 | 7.5 | 1.6 | 2.8 | 1.7 | | | |
| | Near | 5-24 | 5.7 | .13 | 19.2 | 1.9 | 7.2 | 63.0 | 16.0 | 3.0 | 19.0 | 0.7 | | | |
| | Outfall | 6-29 | 15.8 | .40 | 34.7 | 1.3 | 13.1 | 73.0 | 23.0 | 2.5 | 18.3 | 0.9 | | | |
| | | 7-20 | 12.7 | .25 | 37.0 | 2.1 | 12.2 | 68.0 | 19.1 | 4.0 | 16.8 | 0.8 | | | |
| | | 8-17 | 11.5 | .32 | 36.5 | 2.7 | 21.1 | 45.0 | 13.1 | 3.6 | 12.7 | 0.8 | | | |
| | | 8-30 | 5.1 | .22 | 17.9 | 1.8 | 6.8 | 43.0 | 13.7 | 2.9 | 8.7 | 1.3 | | | |
| | Average | 8.5 | .27 | 37.5 | 2.5 | 11.8 | 122.2 | 16.8 | 2.8 | 2.7 | 12.1 | .98 | | | |
| | Standard Dev. | 5.4 | .10 | 26.4 | 1.2 | 5.3 | 170.1 | 6.1 | 1.7 | 1.1 | 6.4 | .40 | | | |

APPENDIX - B-14. CONCENTRATION OF HEAVY METALS IN PLANTS
FROM MAITLAND INTERCHANGE (Continued)

| Form | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | |
|-----------|------------------|---------------|--|------|-------|-------|-------|--------|--------|-------|------|------|-------|-----|--|
| | | | µg/gm | | | | | | | | | | mg/gm | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | |
| Eichornia | West Pond | 2-22 | 12.3 | .78 | 89.9 | 11.7 | 16.3 | 579.0 | 23.2 | 10.6 | 4.1 | 11.3 | 1.7 | | |
| | Close to Outfall | 3-20 | 15.8 | .64 | 75.8 | 6.7 | 29.5 | 793.0 | 90.0 | 11.9 | 2.4 | 15.7 | .90 | | |
| | | 5-3 | 38.8 | .82 | 59.6 | 4.2 | 13.0 | --- | 90.4 | 6.0 | 5.2 | 11.6 | .87 | | |
| | | 5-24 | 21.4 | .38 | 71.1 | 2.7 | 14.4 | 371.0 | 40.9 | 4.7 | 7.0 | 25.5 | 1.3 | | |
| | | 7-20 | 17.0 | .60 | 92.1 | 4.5 | 25.0 | 956.0 | 99.7 | 12.5 | 9.0 | 22.2 | 1.3 | | |
| | | 8-17 | 17.8 | .48 | 68.1 | 8.3 | 103.0 | 463.0 | 58.6 | 12.3 | 7.7 | 18.6 | 1.5 | | |
| | | 8-30 | 18.5 | .96 | 74.4 | 8.3 | 23.2 | 1961.0 | 122.0 | 18.9 | 7.1 | 14.7 | 2.6 | | |
| | | Average | 20.2 | .67 | 75.9 | 6.6 | 32.1 | 853.8 | 75.0 | 11.0 | 6.1 | 17.1 | 1.5 | | |
| | | Standard Dev. | 8.7 | .20 | 11.6 | 3.1 | 31.9 | 583.3 | 35.1 | 4.7 | 2.3 | 5.3 | .59 | | |
| | | West Pond | 2-22 | 14.9 | .60 | 93.5 | 6.1 | 19.3 | 1484.0 | 18.7 | 17.6 | 6.8 | 2.6 | 1.7 | |
| | | Next to WEIR | 3-20 | 17.3 | .72 | 63.7 | 12.3 | 76.8 | 1212.0 | 142.0 | 18.1 | 2.5 | 14.8 | .73 | |
| | | | 5-3 | 36.4 | 1.3 | 56.7 | 6.5 | 22.4 | --- | 99.9 | 8.0 | 5.1 | 10.9 | .93 | |
| | | | 5-24 | 5.3 | .10 | 16.9 | 2.5 | 7.7 | 130.0 | 16.8 | 4.0 | 1.4 | 18.6 | .98 | |
| | | | 6-29 | 24.7 | .44 | 40.3 | 5.2 | 36.9 | 473.0 | 67.2 | 8.6 | 8.0 | 31.2 | 1.6 | |
| | | | 7-20 | 21.8 | .75 | 146.0 | 7.6 | 31.1 | 2162.0 | 155.0 | 21.0 | 8.7 | 21.0 | 2.0 | |
| | | | 8-17 | 22.8 | 6.0 | 80.7 | 7.5 | 47.2 | 845.0 | 82.7 | 7.6 | 10.5 | 18.3 | 1.3 | |
| | | | 8-30 | 14.0 | 1.1 | 62.4 | 7.0 | 17.5 | 1650.0 | 103.0 | 14.8 | 7.3 | 16.1 | 1.9 | |
| | | Average | 19.6 | 1.4 | 70.0 | 6.8 | 32.4 | 1136.6 | 85.7 | 12.5 | 6.3 | 16.7 | 1.4 | | |
| | | Standard Dev. | 9.2 | 1.9 | 38.6 | 2.8 | 21.8 | 704.8 | 50.1 | 6.2 | 3.1 | 8.2 | .48 | | |
| | | West Pond | 2-22 | 12.9 | 1.5 | 85.8 | 5.9 | 24.7 | 1107.0 | 59.6 | 14.8 | 6.1 | 6.1 | 1.5 | |
| | West end | 3-20 | 19.0 | .64 | 140.0 | 19.7 | 29.1 | 1060.0 | 150.0 | 12.6 | 3.7 | 15.1 | .99 | | |
| | | 5-3 | 29.8 | 1.2 | 47.4 | 3.9 | 10.6 | --- | 76.3 | 5.3 | 4.2 | 11.6 | .69 | | |
| | | 5-24 | 15.2 | .26 | 47.6 | 5.8 | 22.1 | 398.0 | 40.7 | 7.1 | 7.3 | 23.8 | 1.0 | | |
| | | 6-29 | 27.9 | .53 | 45.0 | 7.3 | 24.1 | 252.0 | 56.5 | 6.8 | 9.3 | 35.7 | 1.7 | | |
| | | 7-20 | 17.4 | .38 | 77.7 | 4.8 | 30.5 | 455.0 | 78.2 | 9.9 | 10.1 | 25.4 | 1.6 | | |
| | | 8-17 | 22.9 | .95 | 225.0 | 10.0 | 60.2 | 1622.0 | 146.0 | 12.6 | 13.3 | 18.6 | 2.1 | | |
| | | 8-30 | 17.4 | 1.5 | 108.0 | 9.0 | 34.0 | 1996.0 | 161.0 | 16.1 | 8.3 | 16.2 | 2.1 | | |
| | Average | 20.3 | .88 | 97.1 | 8.3 | 29.4 | 984.3 | 96.0 | 10.6 | 7.8 | 19.1 | 1.5 | | | |
| | Standard Dev. | 6.0 | .50 | 61.5 | 5.0 | 14.3 | 659.7 | 48.2 | 4.0 | 3.2 | 9.2 | .51 | | | |

APPENDIX - B-14. CONCENTRATION OF HEAVY METALS IN PLANTS
FROM MAITLAND INTERCHANGE (Continued)

| Form | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | |
|-----------|-------------|---------------|--|-----|-------|------|------|--------|-------|------|------|------|-----|--|--|
| | | | µg/gm | | | | | | mg/gm | | | | | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | |
| Chara | East Pond | 2-22 | 34.0 | 2.2 | 79.0 | 11.9 | 10.3 | 414.0 | 105.0 | 27.3 | 8.3 | 50.8 | 1.1 | | |
| | | 3-20 | 45.1 | 1.3 | 57.3 | 10.8 | 10.8 | 454.0 | 149.0 | 18.4 | 3.4 | 38.1 | 0.7 | | |
| | | 5-3 | 97.5 | 2.4 | 48.3 | 8.8 | 23.5 | ----- | 143.0 | 20.6 | 8.6 | 16.0 | 1.9 | | |
| | | 5-24 | 47.0 | 0.8 | 49.6 | 7.3 | 42.7 | 625.0 | 120.0 | 18.2 | 10.2 | 33.4 | 2.4 | | |
| | | 6-29 | 87.3 | 1.4 | 51.6 | 10.2 | 23.9 | 533.0 | 165.0 | 25.1 | 11.7 | 71.0 | 3.3 | | |
| | | 7-20 | 57.4 | 0.9 | 71.4 | 18.6 | 26.8 | 534.0 | 203.0 | 37.4 | 8.7 | 70.4 | 1.9 | | |
| | | 8-17 | 46.5 | 1.3 | 73.7 | 10.3 | 50.5 | 1046.0 | 103.0 | 14.6 | 11.1 | 27.5 | 2.9 | | |
| | | 8-30 | 36.6 | 1.4 | 62.0 | 7.2 | 15.8 | 661.0 | 111.0 | 14.1 | 10.4 | 41.0 | 1.7 | | |
| | | Average | 56.4 | 1.5 | 61.5 | 10.6 | 25.5 | 609.6 | 137.4 | 22.0 | 9.1 | 43.5 | 2.0 | | |
| | | Standard Dev. | 23.5 | .56 | 12.0 | 3.6 | 14.5 | 211.1 | 34.8 | 7.8 | 2.6 | 19.6 | .86 | | |
| Hypericum | Lake | 2-22 | 21.8 | 2.3 | 359.0 | 5.5 | 29.3 | 1138.0 | 107.0 | 6.8 | 4.7 | 17.5 | 0.7 | | |
| | | 3-20 | 14.0 | 1.2 | 299.0 | 4.4 | 28.6 | 423.0 | 66.4 | 5.2 | 2.5 | 15.1 | 0.5 | | |
| | | 5-3 | 29.6 | 1.5 | 264.0 | 3.6 | 43.2 | ----- | 80.2 | 4.4 | 4.5 | 10.6 | 1.3 | | |
| | | 5-24 | 3.5 | 1.0 | 242.0 | 4.5 | 50.5 | 1922.0 | 71.2 | 4.8 | 5.0 | 24.0 | 1.3 | | |
| | | 6-29 | 17.7 | 0.4 | 226.0 | 4.5 | 38.3 | 579.0 | 78.3 | 7.1 | 6.3 | 29.2 | 1.5 | | |
| | | 7-20 | 15.6 | 0.7 | 238.0 | 5.0 | 38.1 | 1767.0 | 87.9 | 6.2 | 6.3 | 22.2 | 1.1 | | |
| | | 8-17 | 13.8 | 0.9 | 211.0 | 7.5 | 97.5 | 1655.0 | 60.2 | 4.6 | 6.6 | 16.2 | 1.1 | | |
| | | 8-30 | 12.9 | 2.2 | 221.0 | 4.1 | 43.9 | 1280.0 | 76.5 | 3.9 | 6.2 | 15.7 | 1.2 | | |
| | | Average | 16.1 | 1.3 | 257.5 | 4.9 | 46.2 | 1252.0 | 78.5 | 5.4 | 5.3 | 18.8 | 1.1 | | |
| | | Standard Dev. | 7.5 | .68 | 49.5 | 1.2 | 22.0 | 581.7 | 14.4 | 1.1 | 1.4 | 5.9 | .34 | | |
| | Lake Lucien | 2-22 | 22.8 | 2.1 | 292.0 | 8.4 | 26.9 | 791.0 | 98.3 | 12.4 | 5.6 | 18.3 | 1.1 | | |
| | | 3-20 | 13.8 | 0.6 | 241.0 | 5.4 | 29.5 | 364.0 | 60.3 | 7.9 | 2.3 | 13.8 | 0.7 | | |
| | | 5-3 | 27.5 | 1.0 | 210.0 | 3.7 | 25.6 | ----- | 72.9 | 5.6 | 4.0 | 10.2 | 1.0 | | |
| | | 5-24 | 12.1 | 0.4 | 186.0 | 4.8 | 28.3 | 772.0 | 56.5 | 4.8 | 5.4 | 21.6 | 1.6 | | |
| | | 6-29 | 25.7 | 0.9 | 228.0 | 4.1 | 32.1 | 744.0 | 76.4 | 8.3 | 6.7 | 29.3 | 1.2 | | |
| | | 7-20 | 14.8 | 0.7 | 220.0 | 4.7 | 34.7 | 660.0 | 73.7 | 11.8 | 7.5 | 23.4 | 1.3 | | |
| | | 8-17 | 11.2 | 0.7 | 210.0 | 6.1 | 49.9 | 97.0 | 31.8 | 2.4 | 7.8 | 16.8 | 0.2 | | |
| | | 8-30 | 15.6 | 1.0 | 198.0 | 4.9 | 33.3 | 2436.0 | 98.5 | 7.8 | 6.2 | 15.3 | 1.8 | | |
| | | Average | 17.9 | .92 | 223.1 | 5.2 | 32.5 | 837.6 | 71.1 | 7.6 | 5.7 | 18.6 | 1.1 | | |
| | | Standard Dev. | 6.4 | .52 | 32.6 | 1.5 | 7.7 | 750.0 | 22.0 | 3.4 | 1.8 | 6.0 | .50 | | |

APPENDIX - B-14. CONCENTRATION OF HEAVY METALS IN PLANTS
FROM MAITLAND INTERCHANGE (Continued)

| Form | Station | Date | Concentration Per Gram Oven Dry Weight | | | | | | | | | | | | |
|---------------|---------------|------|--|------|------|------|-------|-------|-------|------|------|------|------|--|--|
| | | | µg/gm | | | | | | mg/gm | | | | | | |
| | | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P | | |
| Water Lily | Lake | 2-22 | 11.4 | 0.42 | 66.3 | 3.1 | 5.5 | 172.0 | 17.2 | 5.8 | 2.2 | 11.8 | 2.3 | | |
| | Lucien | 5-3 | 15.4 | 0.53 | 30.1 | 2.3 | 6.7 | --- | 23.1 | 1.7 | 1.1 | 8.1 | 1.0 | | |
| | (Control) | 5-24 | 0.0 | 0.33 | 44.1 | 2.3 | 3.4 | 186.0 | 18.6 | 2.9 | 2.0 | 19.8 | 1.8 | | |
| | | 6-29 | 9.4 | 0.13 | 36.7 | 2.2 | 9.6 | 83.4 | 24.4 | 3.0 | 2.6 | 16.9 | 2.0 | | |
| | | 7-20 | 4.4 | 0.23 | 51.8 | 2.6 | 10.4 | 111.0 | 26.8 | 2.8 | 4.1 | 19.3 | 1.9 | | |
| | | 8-17 | 4.3 | 0.20 | 42.2 | 4.0 | 29.7 | 80.9 | 16.8 | 1.1 | 2.9 | 13.3 | 1.9 | | |
| | | 8-30 | 7.5 | 0.42 | 30.9 | 1.1 | 7.9 | 108.0 | 22.8 | 1.8 | 2.6 | 11.9 | 2.0 | | |
| | Average | | 7.5 | 0.32 | 43.2 | 2.5 | 10.4 | 123.6 | 21.4 | 2.7 | 2.5 | 14.5 | 1.8 | | |
| | Standard Dev. | | 5.1 | 0.14 | 12.7 | 0.91 | 10.3 | 44.9 | 3.9 | 1.6 | 0.91 | 4.4 | 0.40 | | |
| | Lake Lucien | 2-22 | 5.9 | 0.07 | 58.2 | 4.0 | 8.8 | 253.0 | 4.3 | 4.3 | 2.4 | 1.6 | 2.2 | | |
| Near | 3-20 | 7.3 | 0.23 | 43.8 | 2.8 | 9.5 | 132.0 | 21.0 | 2.4 | 0.69 | 5.8 | 8.7 | | | |
| Outfall | 5-3 | 4.4 | 0.47 | 42.1 | 0.83 | 5.7 | --- | 14.8 | 1.5 | 1.7 | 6.9 | 3.0 | | | |
| | 5-24 | 5.0 | 0.10 | 49.9 | 1.9 | 3.4 | 118.0 | 14.6 | 3.9 | 1.9 | 17.5 | 2.4 | | | |
| | 6-29 | 10.1 | 0.0 | 31.1 | 1.8 | 7.6 | 102.0 | 21.0 | 2.7 | 2.5 | 18.5 | 2.7 | | | |
| | 7-20 | 8.7 | 0.18 | 42.3 | 1.7 | 14.8 | 126.0 | 21.8 | 3.9 | 3.0 | 15.9 | 2.4 | | | |
| | 8-17 | 7.7 | 0.12 | 58.0 | 6.2 | 29.2 | 72.7 | 13.5 | 2.0 | 3.7 | 12.7 | 4.1 | | | |
| | 8-30 | 8.8 | 0.24 | 32.5 | 1.8 | 3.8 | 80.2 | 19.9 | 1.3 | 3.6 | 11.7 | 2.5 | | | |
| Average | | 7.2 | 0.17 | 44.7 | 2.6 | 8.8 | 126.3 | 16.3 | 2.7 | 2.4 | 11.3 | 2.5 | | | |
| Standard Dev. | | 2.0 | 0.14 | 10.2 | 1.7 | 8.4 | 60.2 | 5.9 | 1.2 | 1.0 | 6.0 | 0.89 | | | |

APPENDIX - B-15. DISTRIBUTION OF BENTHIC ORGANISMS IN MAITLAND INTERCHANGE BOTTOM SEDIMENTS

| Phylum | Station | #/m ² | | | | | | | | | | Average |
|---------------------------|---------|------------------|------|-----|------|------|------|------|------|------|---|---------|
| | | 2/22 | 3/20 | 5/3 | 5/24 | 6/29 | 7/20 | 8/17 | 8/30 | | | |
| MOLLUSCA (Gastropoda) | S-1 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 7 | 2.3 |
| | S-2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0.6 |
| | S-3 | 0 | 21 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.0 |
| | S-4 | 0 | 7 | 14 | 0 | -- | 15 | 0 | 0 | 0 | 5 | 5.9 |
| ANNELIDS (Oligochaeta) | S-1 | 0 | 11 | 108 | 0 | -- | 208 | 93 | 57 | 68.1 | | |
| | S-2 | 0 | 0 | 43 | 36 | -- | 57 | 7 | 36 | 25.6 | | |
| | S-3 | 0 | 0 | 65 | 43 | 0 | -- | 42 | 0 | 21.4 | | |
| | S-4 | 0 | 151 | 108 | 100 | -- | 24 | 41 | 64 | 69.7 | | |
| ARTHROPODA | S-1 | 0 | 21* | 0 | 0 | 0 | 14** | 0 | 0 | 4.4 | | |
| | S-2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | S-3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | S-4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

* Crustaceans
 ** Insect Larva

APPENDIX - B-16. CONCENTRATION OF HEAVY METALS IN BENTHIC ORGANISMS
IN MAITLAND INTERCHANGE BOTTOM SEDIMENTS

| Phylum | Station & Date | Concentration per Gram Oven Dry Weight | | | | | | | | | | |
|---|-------------------|--|--------|--------|-------|---------|--------|--------|-------|------|------|------|
| | | µg/gm | | | | | | | | | | |
| | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P |
| ANNELIDA CLASS Oligochaeta - Tubifex | Lake 3/20 | 19.2 | 2.0 | 868.0 | 47.7 | 37.1 | 368.0 | 31.8 | 19.2 | .32 | 2.1 | .72 |
| | Lucien 5/3 | 0.0 | .3 | 23.0 | 8.0 | 7.5 | 54.5 | 0.0 | 0.0 | .09 | 1.5 | 0.0 |
| | (Control) 5/24 | 0.0 | 2.6 | 97.2 | 18.8 | 16.8 | 0.0 | 8.4 | 0.0 | .13 | 3.7 | .52 |
| | 6/29 | 719.0 | 0.0 | 125.0 | 0.0 | 229.0 | 948.0 | 0.0 | 0.0 | .95 | 8.9 | .21 |
| | 7/20 | 13.6 | 0.0 | 68.6 | 2.7 | 16.3 | 783.0 | 0.0 | 3.3 | .08 | .97 | .23 |
| | 8/17 | 0.0 | 25.0 | 518.0 | 43.8 | 306.0 | 2169.0 | 12.5 | 0.0 | .80 | 1.9 | 0.0 |
| | 8/30 | 0.0 | 0.0 | 51.7 | 51.7 | 174.0 | 1121.0 | 0.0 | 69.0 | 1.3 | 13.1 | 1.3 |
| | Average | 107.4 | 4.3 | 250.2 | 24.7 | 112.4 | 777.6 | 7.5 | 13.1 | .52 | 4.6 | .43 |
| | Std. Deviation | 269.8 | 9.2 | 320.5 | 16.3 | 169.5 | 750.4 | 11.8 | 25.6 | .48 | 4.6 | .48 |
| | East Pond | 5/3 | 0.0 | 0.0 | 628.0 | 218.0 | 372.0 | 2615.0 | 167.0 | 0.0 | 2.0 | 52.6 |
| 6/29 | 0.0 | 0.0 | 165.0 | 8.1 | 65.3 | 200.0 | 21.5 | 0.0 | .22 | 5.5 | .93 | |
| 7/20 | 82.8 | 0.0 | 161.0 | 19.0 | 16.2 | 64.6 | 0.0 | 1.4 | .22 | 10.5 | .26 | |
| 8/17 | 166.0 | 0.0 | 56.6 | 10.6 | 60.1 | 242.0 | 0.0 | 3.5 | .09 | 3.1 | .49 | |
| 8/30 | 0.0 | 33.3 | 533.0 | 0.0 | 333.0 | 3600.0 | 0.0 | 133.0 | 2.7 | -- | 5.1 | |
| Average | 49.8 | 6.7 | 308.7 | 51.1 | 169.3 | 1344.3 | 37.7 | 27.6 | 1.1 | 17.9 | 1.4 | |
| Std. Deviation | 74.2 | 14.9 | 254.1 | 93.5 | 168.9 | 1648.1 | 72.9 | 58.9 | 1.2 | 23.3 | 2.1 | |
| West Pond | 5/3 | 0.0 | 0.0 | 53.2 | 51.6 | 16.1 | 0.0 | 29.0 | 4.8 | .03 | 2.4 | 0.0 |
| 5/24 | 260.0 | 6.4 | 2319.0 | 68.1 | 6.4 | 0.0 | 51.1 | 14.9 | 4.0 | 49.1 | .99 | |
| 6/29 | 250.0 | 0.0 | 1800.0 | 550.0 | 500.0 | 2900.0 | 2400.0 | 350.0 | 1.7 | 17.4 | 0.0 | |
| 7/20 | 5.5 | 5.5 | 436.0 | 21.8 | 30.9 | 1036.0 | 0.0 | 25.5 | .38 | 3.7 | 1.2 | |
| 8/17 | 0.0 | 0.0 | 448.0 | 86.2 | 405.0 | 3258.0 | 0.0 | 8.6 | .35 | 2.6 | .17 | |
| 8/30 | 0.0 | 250.0 | 3875.0 | 2250.0 | 750.0 | 29875.0 | 875.0 | 375.0 | 3.5 | 33.4 | 0.0 | |
| Average | 85.9 | 43.6 | 1488.5 | 504.6 | 284.7 | 6178.2 | 559.2 | 129.8 | 1.7 | 18.1 | .39 | |
| Std. Deviation | 131.0 | 101.1 | 1465.1 | 877.8 | 313.5 | 11692.7 | 964.7 | 180.5 | 1.7 | 19.4 | .56 | |
| Lake | 5/3 | 188.0 | .88 | 43.0 | 5.3 | 12.3 | 0.0 | 6.2 | 14.0 | .09 | 1.7 | 0.0 |
| Lucien | 5/24 | 0.0 | 0.0 | 1146.0 | 0.0 | 83.3 | 0.0 | 83.3 | 271.0 | 1.8 | 49.0 | 3.1 |
| Near Outfall | 8/17 | 1793.0 | 0.0 | 326.0 | 43.5 | 413.0 | 1761.0 | 0.0 | 32.6 | .14 | 2.6 | .92 |
| Average | 660.3 | .29 | 505.0 | 16.3 | 169.5 | 587.0 | 29.8 | 105.9 | .67 | 17.8 | 1.3 | |
| Std. Deviation | 985.4 | .51 | 572.9 | 23.7 | 213.8 | 1.0 | 46.4 | 143.3 | .95 | 27.0 | 1.6 | |

APPENDIX - B-16. CONCENTRATION OF HEAVY METALS IN BENTHIC ORGANISMS
IN MAITLAND INTERCHANGE BOTTOM SEDIMENTS (Continued)

| Phylum | Station & Date | Concentration per Gram Oven Dry Weight | | | | | | | | | | |
|---------------------------------|------------------------------|--|---------|--------|--------|---------|--------|--------|------|------|------|------|
| | | µg/gm | | | | | | | | | | |
| | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | Mg | Ca | P |
| MOLLUSCA CLASS Gastropoda | Lake Lucien 5/3 (Control) | 10.1 | 0.32 | 21.7 | 1.6 | 3.4 | 90.0 | .57 | .06 | .09 | 1.2 | .38 |
| | 7/20 | 0.0 | 0.27 | 387.0 | 1.5 | 53.0 | 99.7 | 14.0 | 1.8 | 1.1 | 11.5 | 1.1 |
| | 8/30 | 2.1 | 2.1 | 327.0 | 2.1 | 16.9 | 70.0 | 18.6 | 3.1 | 0.06 | 5.8 | 2.0 |
| | Average | 4.1 | 0.89 | 245.2 | 1.7 | 24.4 | 84.9 | 11.1 | 1.7 | 0.60 | 9.5 | 1.1 |
| | Std. Deviation | 5.3 | 1.0 | 195.9 | 0.29 | 25.6 | 14.8 | 9.4 | 1.5 | 0.50 | 7.5 | 0.76 |
| | East Pond 5/24 | | 0.0 | 4331.0 | 0.0 | 47.8 | 0.0 | 172.0 | 86.0 | 7.0 | -- | 1.5 |
| | 8/30 | 1.7 | 0.15 | 17.3 | 1.1 | 6.0 | 242.0 | 3.6 | 0.37 | 0.03 | 21.1 | 1.2 |
| | Average | 4.2 | 0.10 | 2174.2 | 0.53 | 26.9 | 121.0 | 87.8 | 43.2 | 3.6 | 21.1 | 1.4 |
| | Std. Deviation | 0.59 | 0.11 | 3050.2 | 0.74 | 29.5 | 171.1 | 119.1 | 61.0 | 4.7 | 26.9 | 0.27 |
| | West Pond 8/17 | 3.2 | 0.0 | 23.5 | 0.72 | 12.2 | 147.0 | 7.4 | 0.59 | 0.59 | 3.8 | 0.12 |
| | Lake Lucien 3/20 | | 1.4 | 294.8 | 10.6 | 33.5 | 128.5 | 141.8 | 17.7 | 0.03 | 62.0 | 0.52 |
| | Near Outfall 5/3 | | 0.32 | 479.0 | 2.0 | 68.9 | 93.4 | 14.8 | 1.1 | 1.1 | 7.2 | 0.0 |
| Average | 34.0 | 0.84 | 387.0 | 6.3 | 51.2 | 111.2 | 78.4 | 9.4 | 0.73 | 34.6 | 0.26 | |
| Std. Deviation | 23.1 | 0.74 | 130.1 | 6.1 | 25.0 | 25.2 | 90.0 | 11.8 | 0.58 | 38.7 | 0.37 | |
| East Pond 6/29 | 0.0 | 0.0 | 53.9 | 5.6 | 19.5 | 210.0 | 45.5 | 8.4 | 0.17 | 3.0 | .57 | |
| Lake Lucien 3/20 | 0.0 | 6.9 | 12260.0 | 326.0 | 253.0 | 2719.0 | 199.0 | 137.0 | 0.56 | 6.6 | 1.2 | |
| (Control) 8/17 | 56.7 | 0.4 | 56.0 | 9.8 | 23.7 | 301.0 | 5.7 | 4.5 | 0.05 | 1.6 | 0.34 | |
| Average | 28.4 | 3.6 | 6158.2 | 167.9 | 138.4 | 1510.0 | 102.4 | 70.7 | 0.30 | 4.1 | 0.78 | |
| Std. Deviation | 40.1 | 4.6 | 8629.3 | 223.6 | 162.1 | 136.7 | 136.7 | 0.70 | 0.36 | 3.5 | 0.62 | |
| East Pond 3/20 | 2333.0 | 166.0 | 14500.0 | 1667.0 | 917.0 | 2583.0 | 3333.0 | 2083.0 | 15.0 | 46.9 | 1.6 | |
| Lake Lucien 8/17 | 79.3 | 0.0 | 60.5 | 9.7 | 26.4 | 862.0 | 9.0 | 0.70 | 0.43 | 1.9 | 0.57 | |
| Near Outfall | | | | | | | | | | | | |
| East Pond 6/29 | 0.0 | 0.0 | 844.0 | 31.3 | 391.0 | 1141.0 | 203.0 | 0.0 | 2.2 | 17.2 | 14.8 | |
| 7/20 | 0.0 | 0.81 | 152.0 | 31.6 | 25.1 | 710.0 | 0.0 | 2.0 | 0.17 | 1.1 | 1.1 | |
| Average | 0.0 | 0.41 | 498.0 | 31.5 | 208.1 | 925.5 | 101.5 | 1.0 | 1.2 | 9.2 | 7.9 | |
| Std. Deviation | 0.0 | 0.57 | 489.3 | 0.21 | 258.7 | 304.8 | 143.5 | 1.4 | 1.5 | 11.4 | 9.7 | |
| East Pond 3/20 | 5231.0 | 269.0 | 6115.3 | 2230.0 | 1192.0 | 15385.0 | 2115.0 | 1428.0 | 2.4 | 31.0 | 2.6 | |

APPENDIX - B-17. AVERAGE CONCENTRATION FACTORS FOR HEAVY METALS IN PLANTS FROM LAKE MAITLAND

| Plant | Station | Concentration Factor mg/gm (oven dry wt.) | | | | | | | |
|------------|--------------|--|-----|------|------|------|-------|------|------|
| | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr |
| Typha | S-1 | 185 | 120 | 1416 | 363 | 765 | 1732 | 605 | 614 |
| | S-2 | 183 | 115 | 507 | 560 | 462 | 702 | 255 | 414 |
| | S-3 | 773 | 270 | 1103 | 625 | 656 | 1405 | 672 | 400 |
| | Average | 380 | 168 | 1009 | 516 | 628 | 1280 | 511 | 476 |
| Chara | S-1 | 925 | 750 | 1922 | 1325 | 1500 | 4618 | 3123 | 3143 |
| Hypercium | Control, S-4 | 575 | -- | 7574 | 1633 | 2432 | 15268 | 4132 | 1080 |
| | S-3 | 1627 | 920 | 6562 | 1300 | 1806 | 9628 | 2844 | 1086 |
| | Average | 1101 | 920 | 7068 | 1467 | 2119 | 12448 | 3488 | 1083 |
| Water Lily | Control, S-4 | 268 | -- | 1271 | 833 | 547 | 1507 | 1126 | 540 |
| | S-3 | 655 | 170 | 1315 | 650 | 489 | 1452 | 652 | 386 |
| | Average | 462 | 170 | 1293 | 742 | 518 | 1477 | 889 | 463 |
| Eichorina | S-2 | 299 | 335 | 1765 | 1320 | 1529 | 6670 | 1136 | 1571 |
| | S-2 | 370 | 700 | 1628 | 1360 | 1543 | 8880 | 1298 | 1786 |
| | S-2 | 383 | 440 | 2258 | 1660 | 1400 | 7690 | 1455 | 1514 |
| | Average | 351 | 492 | 1884 | 1447 | 1491 | 7747 | 1296 | 1624 |

APPENDIX - B-18. AVERAGE CONCENTRATION FACTORS FOR HEAVY METALS IN BENTHIC ORGANISMS FROM LAKE MAITLAND

| Phylum | Station | Concentration Factor $\frac{\text{mg/gm (oven dry wt.)}}{\text{mg/ml}}$ | | | | | | | | | |
|-------------------------------------|---------|---|--------|--------|--------|-------|--------|-------|--------|--|--|
| | | As | Cd | Zn | Ni | Cu | Fe | Pb | Cr | | |
| ANNELIDA- OLIGOCHAETA Tubifex | Control | 3836 | -- | 7359 | 8233 | 5916 | 9483 | 395 | 2620 | | |
| | S-1 | 816 | 3350 | 9647 | 6388 | 9959 | 10182 | 857 | 3943 | | |
| | S-2 | 1998 | 21800 | 34605 | 100920 | 13557 | 48267 | 19283 | 18543 | | |
| | S-3 | 60027 | 290 | 14853 | 4075 | 9417 | 6747 | 1192 | 15129 | | |
| | Average | 16669 | 6360 | 16616 | 29904 | 9712 | 18670 | 5432 | 10059 | | |
| Hirudinea | Control | 1014 | -- | 181124 | 55967 | 7284 | 18415 | 5389 | 14140 | | |
| | S-1 | 38246 | 83000 | 453125 | 208375 | 53941 | 19568 | 75750 | 297571 | | |
| | S-3 | 72090 | 0 | 1779 | 2425 | 1467 | 9908 | 360 | 100 | | |
| | Average | 37117 | 41500 | 212009 | 88922 | 20897 | 15964 | 27166 | 103937 | | |
| ARTHROPOD Nymph | S-1 | 0 | 205 | 15563 | 3938 | 12241 | 7011 | 2307 | 143 | | |
| | S-1 | 85754 | 134500 | 191103 | 278750 | 70118 | 116553 | 48068 | 204000 | | |
| MOLLUSCA Gastropoda | Control | 146 | -- | 7212 | 567 | 1284 | 1035 | 584 | 340 | | |
| | S-1 | 69 | 50 | 67944 | 66 | 1582 | 917 | 1995 | 6171 | | |
| | S-2 | 60 | 0 | 547 | 144 | 581 | 1148 | 112 | 84 | | |
| | S-3 | 3091 | 840 | 11382 | 1575 | 2844 | 1278 | 3136 | 1343 | | |
| | Average | 841 | 223 | 21771 | 588 | 1573 | 1095 | 1457 | 1985 | | |
| Pelecypoda | Control | 7.5 | -- | 694 | 303 | 358 | 3500 | 679 | 72 | | |

Appendix C-1. DISSOLVED OXYGEN AND TEMPERATURE
PROFILES ON LAKE IVANHOE

| Date | Depth (meter) | Dissolved Oxygen Concentration (mg/l) | | | | Temperature °C | | | |
|--------------|------------------|--|-----------------------|-----------------------|------------------------|-----------------------|-----------------------|-----------------------|------------------------|
| | | East of S. Bridges | Between S. Bridges | Between N. Bridges | Lk. Ivanhoe Control | East of S. Bridges | Between S. Bridges | Between N. Bridges | Lk. Ivanhoe Control |
| Feb. 15/79 | 0 | 10.0 | 9.7 | | 10.5 | 16.9 | 15.5 | | 16.6 |
| | 0.5 | 10.2 | 9.8 | | 10.6 | 16.3 | 15.5 | | 16.4 |
| | 1.0 | 9.8 | 9.9 | | 10.7 | 16.0 | 15.5 | | 16.3 |
| | 1.5 | | 10.0 | | 10.8 | | 15.4 | | 16.2 |
| | 2.0 | | 10.0 | | 10.8 | | 15.3 | | 16.2 |
| | 3.0 | | 7.6 | | 10.9 | | 15.0 | | 16.0 |
| | 4.0 | | 7.6 | | 9.0 | | 14.8 | | 14.9 |
| 5.0 | | 7.6 | | | | 14.8 | | | |
| March 16/79 | 0 | 8.8 | 8.7 | 9.2 | 9.0 | 20.5 | 19.7 | 18.7 | 19.0 |
| | 0.5 | 8.3 | 8.4 | 8.7 | 8.5 | 20.1 | 19.6 | 18.7 | 19.0 |
| | 1.0 | 8.3 | 8.2 | 8.5 | 7.9 | 19.5 | 19.3 | 18.7 | 19.0 |
| | 1.5 | 8.2 | 8.1 | 7.8 | 7.6 | 19.4 | 19.2 | 18.7 | 19.0 |
| | 2.0 | 8.1 | 7.3 | 7.8 | 7.4 | 19.4 | 19.1 | 18.7 | 19.0 |
| | 3.0 | | 6.8 | | 7.1 | | 19.1 | | 18.8 |
| | 4.0 | | 6.0 | | 6.6 | | 19.0 | | 18.1 |
| 5.0 | | 5.6 | | | | 19.0 | | 18.1 | |
| April 19/79 | 0 | 8.4 | 8.3 | 9.2 | 8.8 | 25.3 | 25.5 | 25.5 | 25.0 |
| | 0.5 | 10.6 | 8.3 | 8.6 | 9.0 | 25.3 | 25.5 | 25.0 | 25.0 |
| | 1.0 | 10.0 | 8.6 | 8.5 | 8.9 | 25.3 | 25.5 | 25.2 | 25.0 |
| | 1.5 | | 8.5 | 7.7 | 8.9 | | 25.5 | 25.0 | 25.0 |
| | 2.0 | | 8.2 | 7.3 | 8.6 | | 25.0 | 25.0 | 25.0 |
| | 3.0 | | 7.9 | | 8.0 | | 25.0 | | 24.7 |
| | 4.0 | | 6.5 | | 7.5 | | 25.0 | | 24.5 |
| May 17/79 | 0 | 8.2 | 8.4 | 8.5 | 8.5 | 26.5 | 25.7 | 24.0 | 25.0 |
| | 0.5 | 7.1 | 7.6 | 8.2 | 8.7 | 27.7 | 26.0 | 25.2 | 25.5 |
| | 1.0 | 7.2 | 7.6 | 8.5 | 8.9 | 26.0 | 26.0 | 25.5 | 25.7 |
| | 1.5 | 7.7 | 8.7 | 8.5 | 9.0 | 26.0 | 26.0 | 25.5 | 26.0 |
| | 2.0 | 7.9 | 8.7 | 8.3 | | 26.0 | 26.0 | 25.5 | |
| | 3.0 | | 8.4 | | | 26.0 | | | |
| | 4.0 | | 7.6 | | | 26.0 | | | |
| June 21/79 | 0 | 8.5 | 8.2 | 8.7 | 9.5 | 32.7 | 32.0 | 29.7 | 30.0 |
| | 0.5 | 8.5 | 8.4 | 6.5 | 9.5 | 33.0 | 32.0 | 29.7 | 30.0 |
| | 1.0 | 8.2 | 8.4 | 4.1 | 10.2 | 31.0 | 31.0 | 30.0 | 29.0 |
| | 1.5 | | 8.5 | 2.7 | | | 30.7 | 30.0 | |
| | 2.0 | | 8.4 | | | | 30.0 | | |
| | 3.0 | | 8.0 | | | | 30.0 | | |
| | 4.0 | | 7.2 | | | | 30.0 | | |
| July 13/79 | 0 | 5.7 | 5.9 | 6.2 | 7.7 | 32.2 | 31.0 | 31.0 | 29.0 |
| | 0.5 | 5.7 | 5.7 | 6.2 | 7.7 | 32.2 | 31.2 | 31.0 | 29.0 |
| | 1.0 | 2.1 | 5.6 | 6.1 | 7.9 | 32.0 | 31.3 | 31.0 | 29.5 |
| | 1.5 | | 5.6 | 6.1 | 7.8 | | 31.0 | 31.0 | 29.5 |
| | 2.0 | | 5.6 | | 7.3 | | 31.0 | | 28.5 |
| | 3.0 | | 5.1 | | 4.4 | | 31.0 | | 28.5 |
| | 4.0 | | 4.6 | | 0.5 | | 31.0 | | 26.5 |
| 5.0 | | 4.3 | | | | 31.0 | | | |
| August 3/79 | 0 | | 7.0 | 7.2 | 8.8 | 35.0 | 32.3 | 31.0 | 30.5 |
| | 0.5 | | 6.6 | 7.1 | 8.3 | 35.0 | 32.3 | 31.0 | 30.5 |
| | 1.0 | | 5.6 | 7.2 | 8.6 | | 33.0 | 31.2 | 30.0 |
| | 1.5 | | 4.2 | 7.2 | 8.2 | | 32.0 | 31.5 | 30.0 |
| | 2.0 | | 3.9 | 7.3 | 8.2 | | 32.0 | | 29.5 |
| | 3.0 | | 2.9 | | 6.5 | | 32.0 | | 29.5 |
| | 4.0 | | 2.4 | | 5.1 | | 31.0 | | 29.0 |
| 5.0 | | | | 1.0 | | | | | |
| August 24/79 | 0 | 6.9 | 6.4 | 6.8 | 7.3 | 34.0 | 32.2 | 29.7 | 29.5 |
| | 0.5 | 4.6 | 5.0 | 5.3 | 6.1 | 33.0 | 31.0 | 29.7 | 29.0 |
| | 1.0 | | 3.6 | 3.8 | 4.1 | | 31.0 | | 29.0 |
| | 1.5 | | 2.9 | 3.3 | 3.7 | | 31.0 | | 29.0 |
| | 2.0 | | 2.8 | 3.0 | 3.3 | | 30.6 | | 29.0 |
| | 3.0 | | 2.5 | | 2.9 | | 30.5 | | 28.7 |
| | 4.0 | | 2.3 | | 1.8 | | 30.0 | | 27.0 |
| 5.0 | | 1.6 | | 0.5 | | 29.5 | | 26.0 | |

Appendix C-2. DISSOLVED OXYGEN CONCENTRATIONS AND TEMPERATURE PROFILES ON HAITLAND INTERCHANGE

| Date | Depth (meter) | Dissolved Oxygen Concentration (mg/l) | | | | Temperature °C | | | | |
|--------------|---------------|---------------------------------------|---------|-----------------------|--------------------|----------------|---------|--------------------|--------------------|------|
| | | E. Pond | W. Pond | Outfall to Lk. Lucien | Lk. Lucien Control | E. Pond | W. Pond | Lk. Lucien Outfall | Lk. Lucien Control | |
| Feb. 22/79 | 0 | 9.3 | 9.7 | | 9.4 | 17.9 | 16.4 | | 16.0 | |
| | 0.5 | 9.0 | 9.3 | | 9.4 | 17.8 | 16.1 | | 15.5 | |
| | 1.0 | 8.8 | 8.8 | | 8.1 | 16.7 | 15.9 | | 15.4 | |
| | 1.5 | 7.5 | 7.4 | | 7.0 | 15.5 | 15.4 | | 15.1 | |
| | 2.0 | 7.0 | 7.3 | | 6.3 | 14.7 | 15.2 | | 15.0 | |
| | 3.0 | | | | 6.1 | | | | 14.6 | |
| | 4.0 | | | | 5.5 | | | | 13.5 | |
| | 5.0 | | | | 4.6 | | | | 13.0 | |
| | 6.0 | | | | 4.1 | | | | 13.0 | |
| | March 20/79 | 0 | 8.8 | 9.3 | 8.5 | 9.5 | 20.0 | 19.0 | 21.0 | 19.5 |
| 0.5 | | 8.7 | 10.5 | 8.0 | 9.5 | 20.0 | 18.7 | 21.0 | 19.2 | |
| 1.0 | | 7.5 | 9.0 | | 9.0 | 19.5 | 18.7 | | 19.0 | |
| 1.5 | | 7.3 | 8.2 | | 8.2 | 19.5 | 18.2 | | 18.5 | |
| 2.0 | | 9.0 | | | 7.8 | 19.5 | | | 18.5 | |
| 3.0 | | 5.5 | | | 6.5 | 19.0 | | | 17.5 | |
| 4.0 | | | | | 6.3 | | | | 15.7 | |
| 5.0 | | | | | 2.8 | | | | 15.0 | |
| 6.0 | | | | | | | | | | |
| May 3/79 | | 0 | 11.7 | 5.8 | | 8.2 | 24.2 | 22.0 | | 22.7 |
| | 0.5 | 12.1 | 4.9 | | 8.2 | 24.2 | 22.0 | | 22.7 | |
| | 1.0 | 10.0 | 5.3 | | 7.5 | 24.0 | 22.0 | | 22.5 | |
| | 1.5 | | 4.7 | | 7.4 | | 22.0 | | 22.2 | |
| | 2.0 | | | | 6.8 | | | | 22.0 | |
| | 3.0 | | | | 1.9 | | | | 22.0 | |
| | 4.0 | | | | 1.6 | | | | 21.0 | |
| | 5.0 | | | | 1.5 | | | | 19.0 | |
| | 6.0 | | | | 1.5 | | | | 17.0 | |
| | May 24/79 | 0 | 10.5 | 5.6 | 7.2 | 8.2 | 25.5 | 25.0 | 26.0 | 25.5 |
| 0.5 | | 11.5 | 5.7 | 6.1 | 7.9 | 26.0 | 25.0 | 26.0 | 25.5 | |
| 1.0 | | 10.0 | 5.8 | 5.4 | 7.3 | 26.0 | 25.0 | 26.0 | 25.7 | |
| 1.5 | | 10.4 | 6.1 | | 7.5 | 26.0 | 25.0 | | 25.7 | |
| 2.0 | | 4.7 | | | 7.5 | 25.0 | | | 25.7 | |
| 3.0 | | 4.9 | | | 8.7 | 25.0 | | | 26.0 | |
| 4.0 | | | | | 8.5 | | | | 24.0 | |
| 5.0 | | | | | 6.5 | | | | 23.0 | |
| June 29/79 | | 0 | 11.0 | 6.2 | 7.8 | 7.6 | 27.2 | 26.3 | 30.0 | 29.7 |
| | | 0.5 | 7.9 | 5.0 | 7.0 | 7.4 | 27.5 | 26.5 | 29.5 | 29.2 |
| | 1.0 | | 4.7 | 5.1 | 7.7 | 27.5 | 26.3 | 28.5 | 28.5 | |
| | 1.5 | | 2.9 | | 7.5 | | 26.0 | | 27.8 | |
| | 2.0 | | | | 7.3 | | | | 27.7 | |
| | 3.0 | | | | 7.0 | | | | 27.0 | |
| | 4.0 | | | | | | | | | |
| | July 20/79 | 0 | 6.3 | 4.9 | 7.3 | 7.4 | 29.0 | 28.5 | 28.5 | 29.5 |
| | | 0.5 | 5.3 | 4.8 | 5.4 | 7.1 | 28.7 | 28.0 | 29.5 | 29.5 |
| | | 1.0 | 4.2 | 4.8 | | 6.8 | 28.0 | 28.0 | | 29.5 |
| 1.5 | | 4.7 | 4.8 | | 6.7 | 28.0 | 28.0 | | 29.3 | |
| 2.0 | | 3.7 | | | 6.5 | 28.0 | | | 29.0 | |
| 3.0 | | | | | 6.7 | | | | 29.0 | |
| 4.0 | | | | | 5.6 | | | | 28.5 | |
| August 17/79 | | 0 | 14.6 | 5.4 | 9.4 | 8.0 | 27.2 | 26.7 | 29.0 | 29.6 |
| | | 0.5 | 9.8 | 5.3 | 8.7 | 7.8 | 27.2 | 26.3 | 28.5 | 29.2 |
| | | 1.0 | 7.5 | 5.6 | 7.1 | 7.8 | 27.2 | 26.0 | 27.5 | 28.3 |
| | 1.5 | | | | 7.5 | | | | 28.0 | |
| | 2.0 | | | | 7.1 | | | | 27.5 | |
| | 3.0 | | | | 4.4 | | | | 27.0 | |
| | 4.0 | | | | 3.9 | | | | 26.5 | |
| | 5.0 | | | | 4.4 | | | | 26.0 | |
| | August 30/79 | 0 | 10.0 | 5.3 | 7.4 | 7.3 | 30.0 | 28.8 | 28.5 | 28.5 |
| | | 0.5 | 5.5 | 5.5 | 7.6 | 7.1 | 28.5 | 28.7 | 28.5 | 28.3 |
| 1.0 | | 2.8 | 4.5 | 6.3 | 5.8 | 27.5 | 27.7 | 28.0 | 28.0 | |
| 1.5 | | 1.9 | 3.7 | 4.8 | 5.3 | 27.0 | | 27.5 | 28.0 | |
| 2.0 | | | | 3.6 | 5.0 | | | 27.5 | 27.5 | |
| 3.0 | | | | | 4.7 | | | | 27.5 | |
| 4.0 | | | | | 3.9 | | | | 27.0 | |
| 5.0 | | | | | 3.2 | | | | 26.5 | |
| 6.0 | | | | | 1.6 | | | | 25.0 | |

APPENDIX - C-3. WATER QUALITY ANALYSIS FOR RUNOFF WATER SAMPLES
 COLLECTED FROM SCUPPER DRAINS ON SOUTHERN BRIDGES
 ON LAKE IVANHOE

| Scupper Drain Location | Date | pH | Turbidity JTU | NO ₃ -N mg/l |
|------------------------------|---------|------|------------------|----------------------------|
| NW | 8-3-79 | 7.11 | 27.5 | 3.60 |
| NE | | 6.75 | 37.0 | 8.20 |
| SW | | 6.82 | 21.5 | 3.76 |
| SE | | 6.94 | 20.0 | 4.96 |
| NW | 8-17-79 | 7.20 | 37.5 | 3.76 |
| NE | | 6.97 | 26.5 | 3.88 |
| SW | | 6.99 | 41.0 | 2.48 |
| SE | | 7.06 | 18.0 | 4.60 |
| NW | 8-24-79 | 8.43 | 43.0 | 2.68 |
| NE | | 8.80 | 12.0 | 3.24 |
| SW | | 6.91 | 82.5 | 1.44 |
| SE | | -- | -- | -- |
| AVERAGE | | | 33.3 | 3.87 |

APPENDIX - C-4. WATER QUALITY CHARACTERISTICS FOR RUNOFF THROUGH
BRIDGE SCUPPERS ON I-4 AND LAKE IVANHOE

| Parameters | Form | Number of Samples | Concentrations (mg/l) | | | Average % In Solu |
|------------|--------------------|-------------------------|-----------------------|--------|-----------|-------------------------|
| | | | Range | Mean | Std. Dev. | |
| Zn | Total Dissolved | 11 | 0.228-1.120 | 0.498 | 0.263 | 67 |
| | | | 0.028-1.120 | 0.336 | 0.300 | |
| Cd | Total Dissolved | 11 | 0.003-0.009 | 0.005 | 0.002 | 20 |
| | | | 0.000-0.005 | 0.001 | 0.002 | |
| As | Total Dissolved | 11 | 0.000-0.145 | 0.058 | 0.049 | 86 |
| | | | 0.000-0.145 | 0.050 | 0.055 | |
| Ni | Total Dissolved | 11 | 0.013-0.261 | 0.053 | 0.071 | 92 |
| | | | 0.006-0.261 | 0.049 | 0.072 | |
| Cu | Total Dissolved | 11 | 0.032-0.101 | 0.052 | 0.023 | 60 |
| | | | 0.010-0.055 | 0.027 | 0.014 | |
| Fe | Total Dissolved | 11 | 0.510-6.850 | 2.429 | 2.290 | 12 |
| | | | 0.034-2.170 | 0.287 | 0.626 | |
| Pb | Total Dissolved | 11 | 0.690-3.250 | 1.558 | 0.939 | 12 |
| | | | 0.063-0.504 | 0.187 | 0.136 | |
| Cr | Total Dissolved | 11 | 0.003-0.027 | 0.011 | 0.008 | 20 |
| | | | 0.000-0.009 | 0.002 | 0.003 | |
| Ca | Total Dissolved | 11 | 25.10-53.80 | 38.073 | 9.837 | 97 |
| | | | 21.80-53.80 | 36.800 | 11.110 | |
| Mg | Total Dissolved | 11 | 0.493-2.790 | 1.062 | 0.673 | 78 |
| | | | 0.294-2.790 | 0.831 | 0.738 | |
| P | Total Dissolved | 11 | 0.160-1.220 | 0.426 | 0.382 | 16 |
| | | | 0.000-0.137 | 0.067 | 0.059 | |