FINAL REPORT

ON

MANAGEMENT OF RUNOFF FROM HIGHWAY BRIDGES

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

Page

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 controll 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 Hypercium exhibited the highest concentration factors for Pb, Fe, Cu, Ni, Zn and Cd in Maitland Interchange site. It appears that Spirogyra and/or Hypercium

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 Amy, 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-existant 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 cojectured 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 (Malmquiest 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 constitutents 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 and 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:

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

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

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

Lazrus, et al. (1970) determined heavy metal concentrations found in precipitation collected in a nationwide network. Lead loading in precipitation (g/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 andintercept 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 metals 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 tetralkyl 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 to

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 oxyhalide, $2PbO \cdot PbClBr$ (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 Bayard, 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 mg/m^2/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 primarly 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 tendancy 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 immoblized 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 concentration 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 Edginton and Robbins, 1976). Edginton 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 occurence 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) 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 fraction, with some in the 2-6.3 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 occurence 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 wasted received from Chicago and other cities along the river and its tributaries.

In general the highest concentrations occured in sediments, and worms, then decreased through clams, onmivorous 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 occured 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 occurence 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 suspensed 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 slug 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 occurence of lead in the environment. Each section contains numerous tables and illustrations showing lead concentrations found in varying locations and mediums (Boggess 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, drain age 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

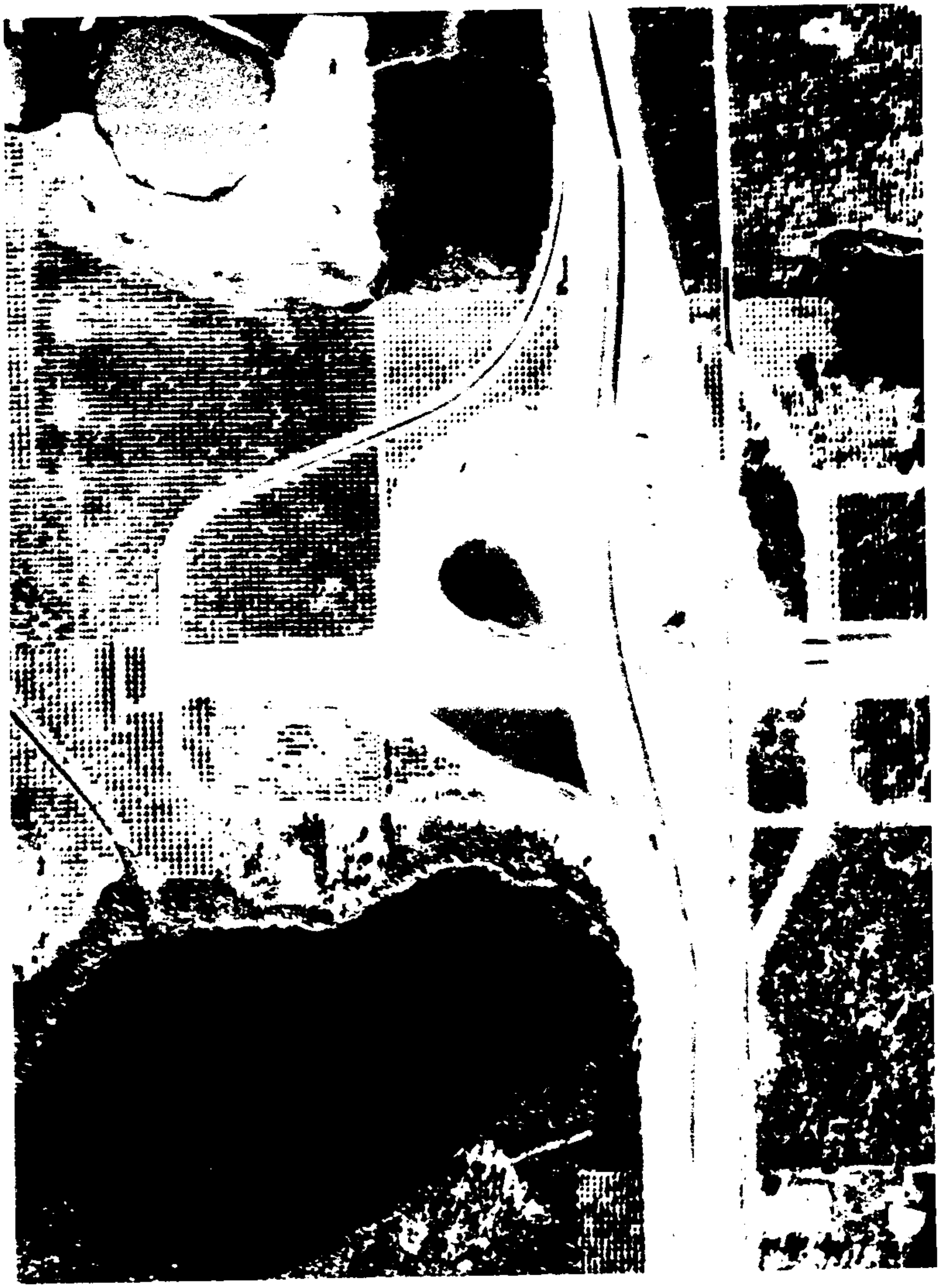

FIGURE - 3-2. AERIAL PHOTOGRAPHY OF MAITLAND INTERCHANGE AND INTERSTATE 4 SITE

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
	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
	Wymore Road	E. Bound	---	---	31642	29611	32678	32823
		W. Bound	---	---	32232	32805	32484	32454
	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

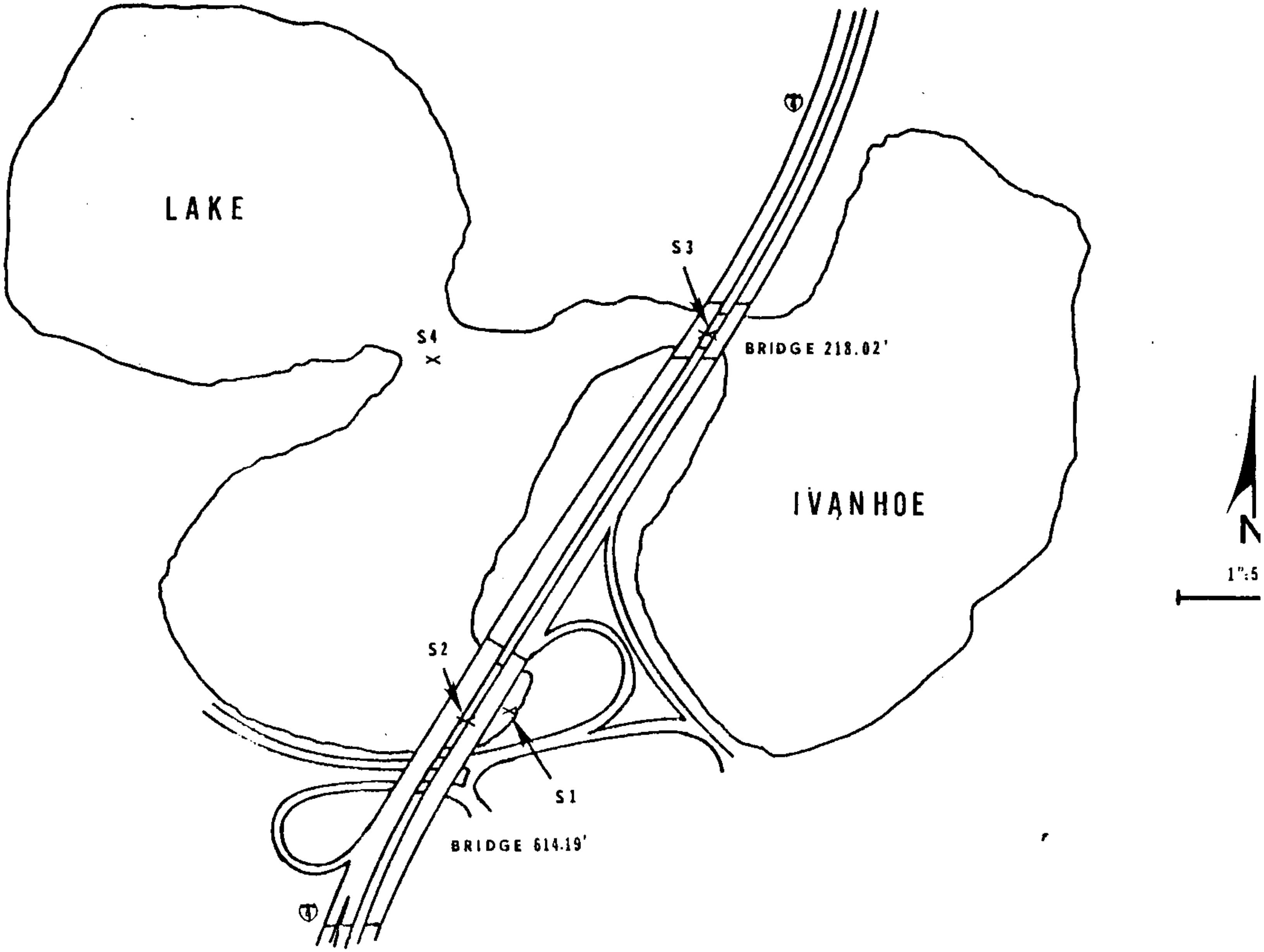

FIGURE 3-3 SAMPLING LOCATIONS FOR BRIDGE RUNOFF AT LAKE IVANHOE.

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 westen 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

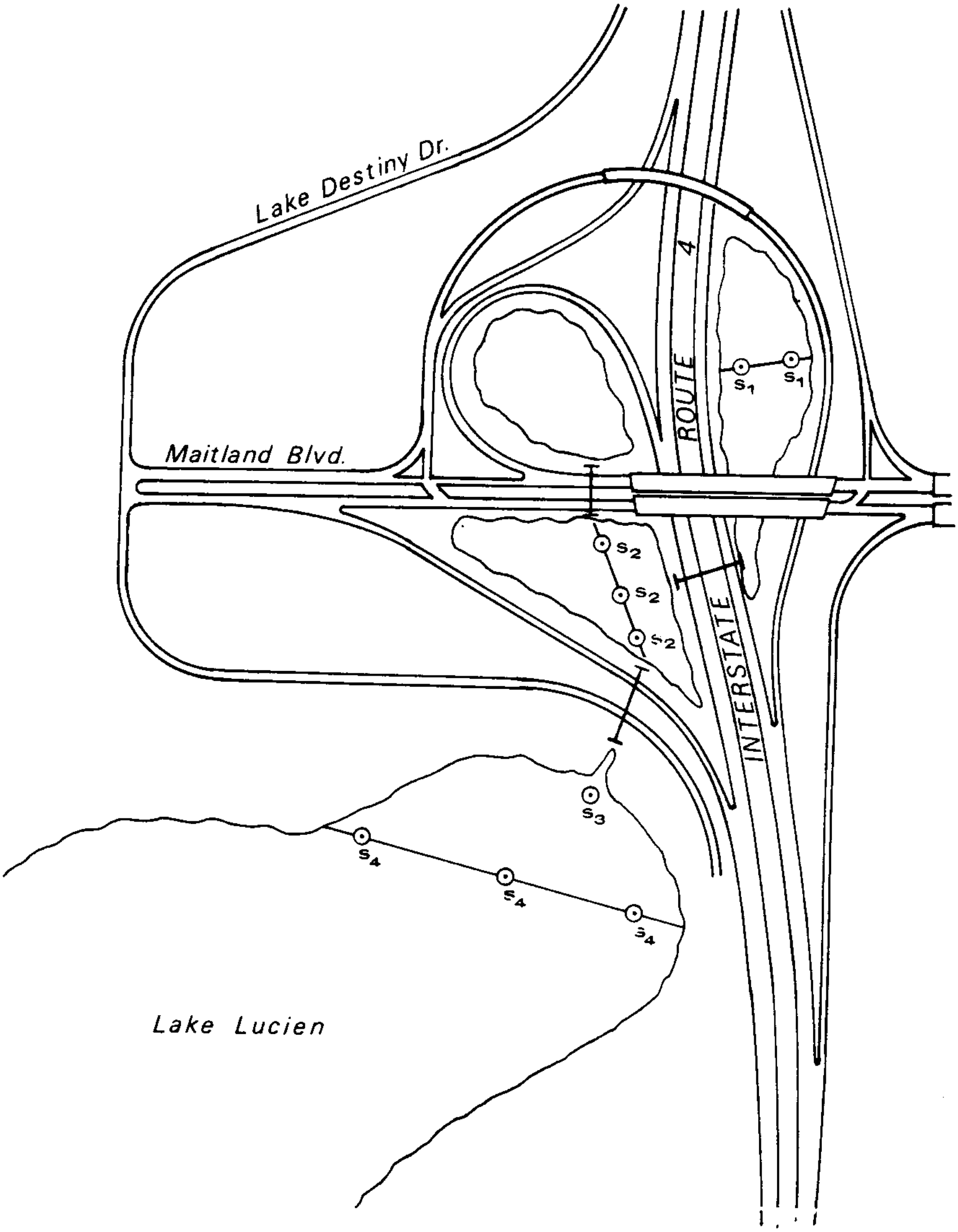

FIGURE 3-4. SAMPLING SITES AT MAITLAND INTERCHANGE AND INTERSTATE 4

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 ends 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 JTU standard supplied by the manufacturer.

Chlorophyll "a" was determined from a calibration curve, using a Turner III 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/1 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/1 per mg/1 in spiked lake water samples above 0.5 mg/1. 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/1 per mg/1 up to concentrations of 2 mg/1.

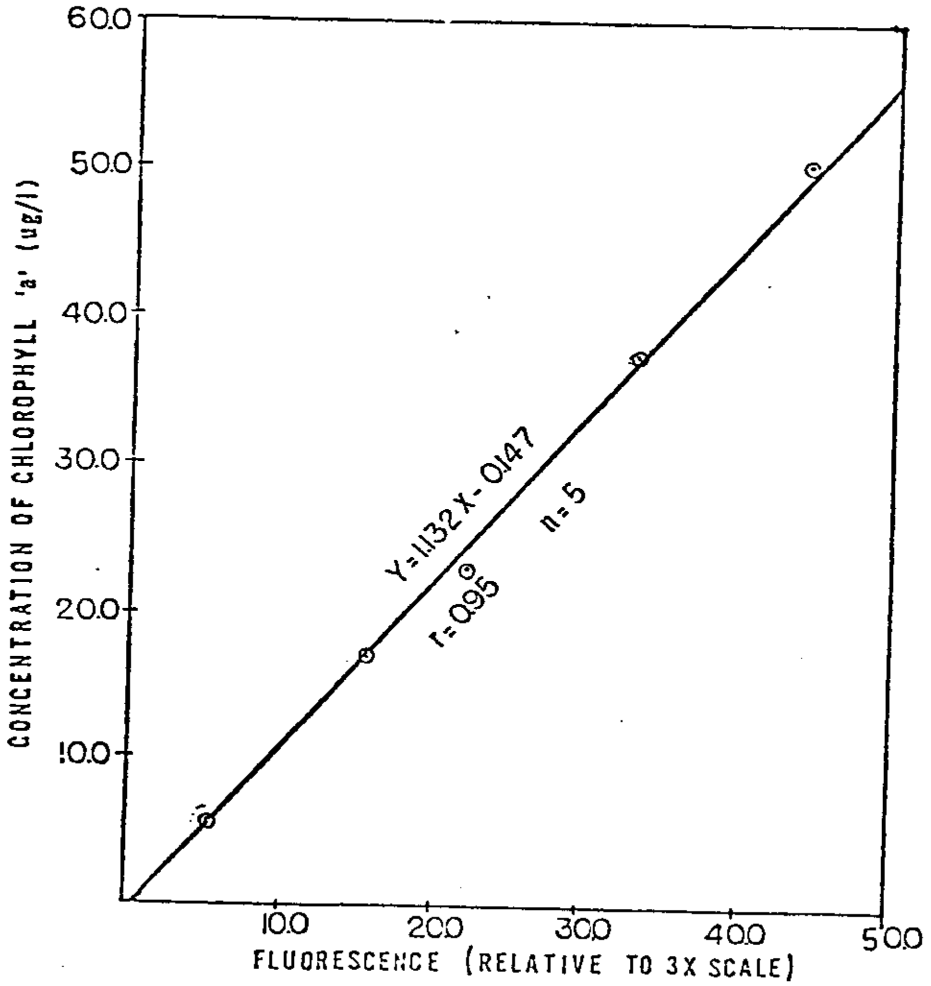

FIGURE 3-5. RELATIVE FLUORESCENCE vs. CHLOROPHYLL "a" CONCENTRATIONS FOR INDIGENOUS ALGAL SPECIES IN LAKE EOLA

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 acccording 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 Esmission 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 temperature 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/1 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/1.

Chlorophyll "a" measurements varied with sampling location and date and the values ranged from 7.80 to 28.50 g/1. The lowest average values (14 µg/1)

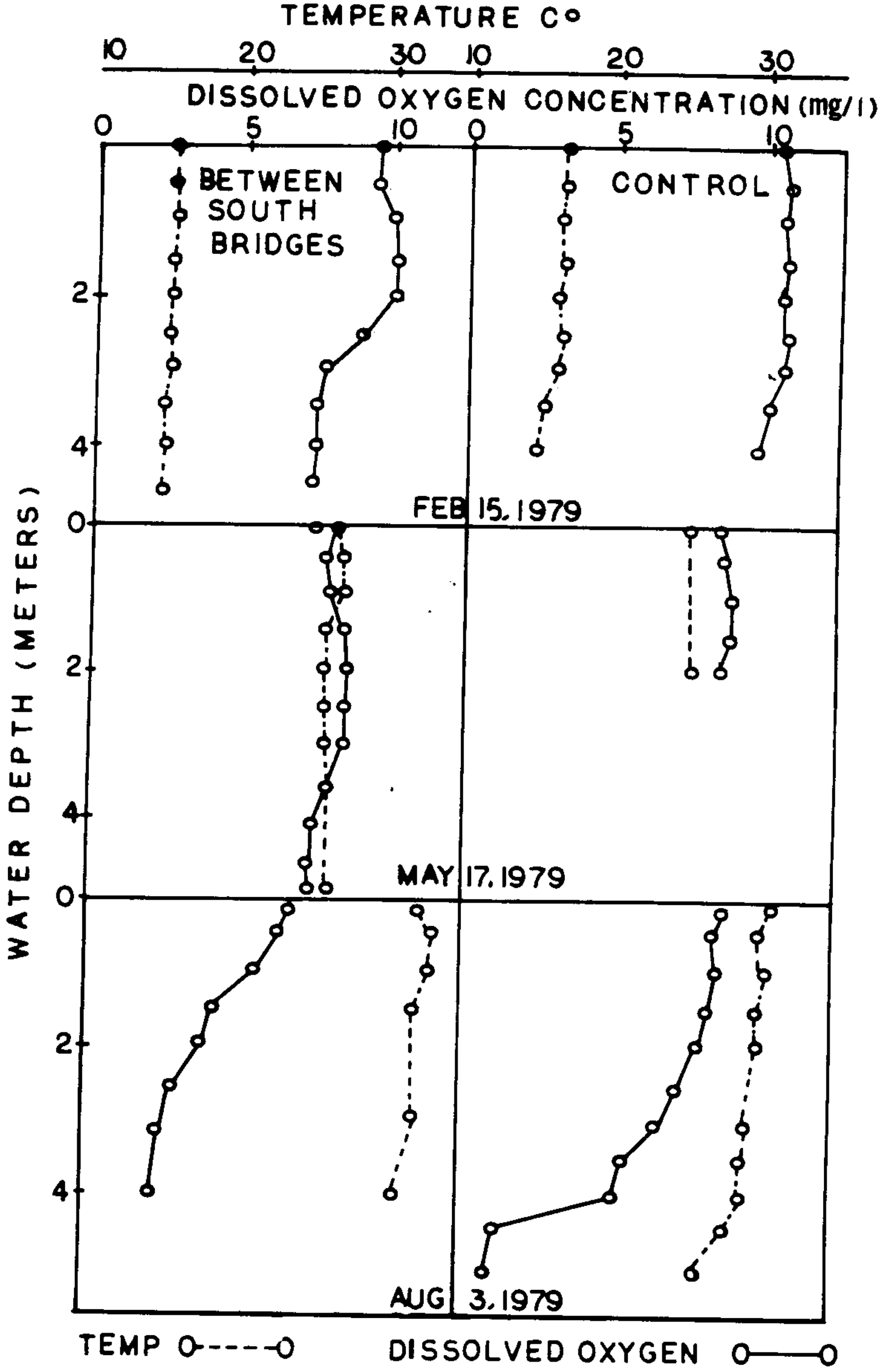

FIGURE 4-1. VARIATIONS IN DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON LAKE IVANHOE.

were found underneath the bridges, and the highest average concentration (18 µg/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 µg/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 µg/l of total As. Similarly the dissolved arsenic concentrations ranged from 23 to 70 µg/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 µg/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 µg/l for S-1 and 126 µg/l for S-2. Average dissolved zinc concentration for the four stations fell between 30 and 60 µg/l, thus accounting for approximately 52% of the total concentrations. Total iron averaged from 174 at station S-3 up to 210 µg/l at station S-2 with the dissolved metal averaging 50 to 80 µg/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 µg/l for each of the stations with 45 to 61 µg/l dissolved. Total nickel ranged from 11 µg/l at S-1 and S-2 up to 18 µg/l at S-3 and S-4. The dissolved nickel concentrations showed considerable greater variation ranging from 3 to 15 µg/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 µg/l and the dissolved fraction being 5 to 7 µg/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 mg-N/l. Also, the total phosphorus concentrations averaged 0.426 mg-P/l and the soluble fraction averaged 0.067 mg/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 μg/l-Zn and the soluble fraction averaged 67%. Total cadmium and chromium concentrations were relatively low averaging 5 μg/l for Cd and 11 μg/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 μg/l-As, and 53 μg/l-Ni, 52 μg/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 μg/l-Fe and 1558 μg/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 μg-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 g 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 g-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 μg 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 μg 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 μg 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 μg 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 μg-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 μg-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 μg 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 µg/g), almost the same for stations S-2 and S-4 (33.7 and 32.0 µg/g), and considerably lower in the sediments underneath the north bridges, S-3 (14.7 µg/g). Iron exhibited a similar trend with the highest concentration, 3900 µg/g, occurring at station S-1, intermediatee concentrations of 3191 and 3350 µg/g, being reported for stations S-2 and S-4 and the lowest concentrations appeared in the sediments underneath the north bridges, 1889 µg/g. Once again lead concentrations followed a distinctly different pattern. The highest lead concentrations of 984 µg/g and second highest lead concentration of 827 µg/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 µg/g and the lowest lead concentration was found in the control section, 355 µg/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 Typa 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 μg/g dry weight. Iron averaged 63.9 μg/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 μg/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 μg/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 μg/g, was found between the north bridges. The Cr values for this station do contain an anomalous value of 333 μg/g 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 μg/g, 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 μg/g 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 μg/g were reported for the control sections. Lowest average Fe and Cu concentrations of 862 and 29 μg/g 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 μg/g compared to 9.2 and 5.8 under the south bridges. Magnesium and calcium concentrations of 0.86 and 13.1 μg/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 μg/g for S-1 and S-2, as opposed to 21.0 μg/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 μg/g for lead and 510 and 2589 μg/g for iron. Average chromium concentration in the crustacean was lowest in the control at 25.0 μg/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 μg/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 μg/g. The lowest lead concentration of 25.1 μg/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 µg/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 Appendicies 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 stormwater 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-

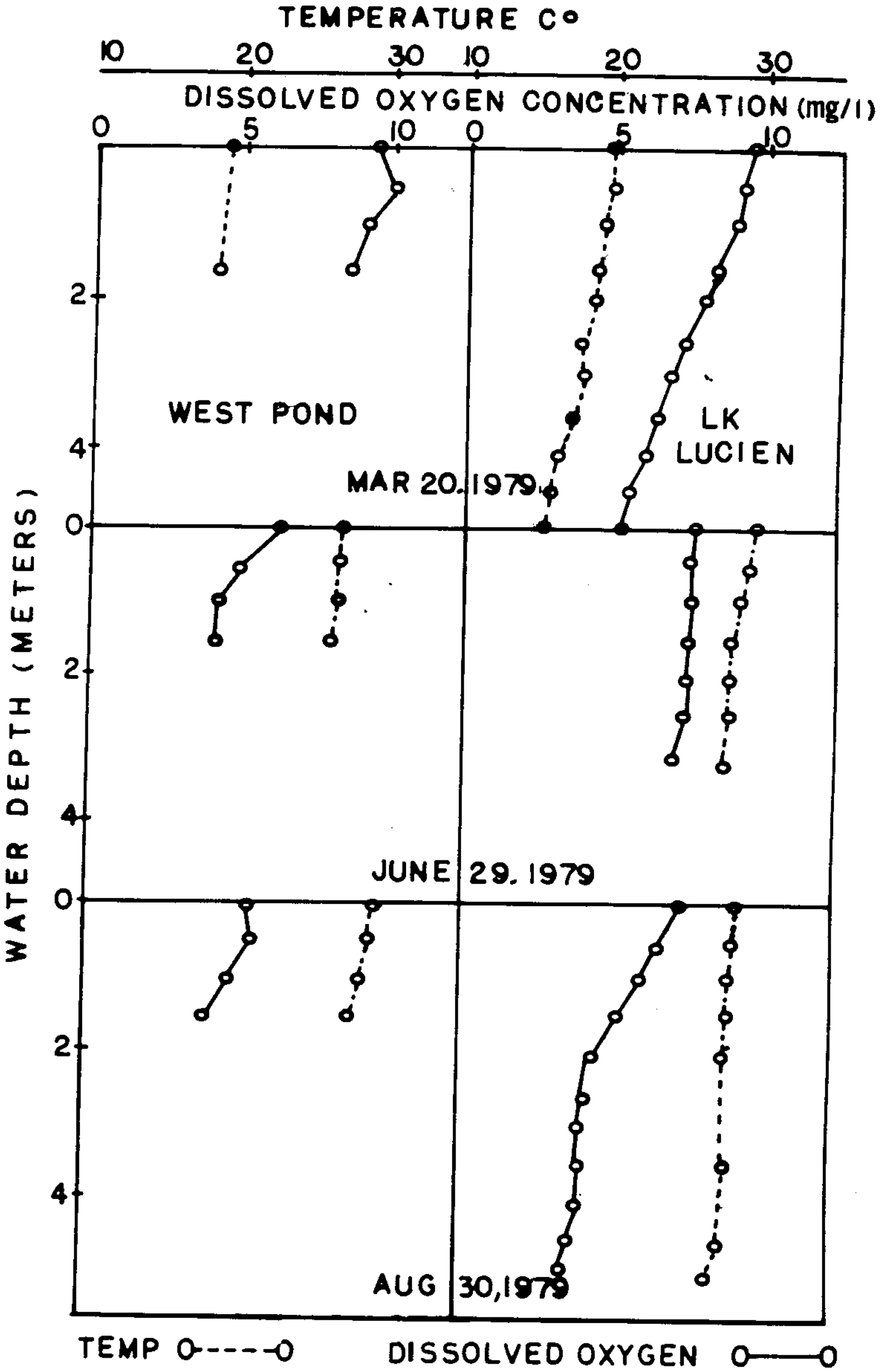

FIGURE 4-2. VARIATIONS IN DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON MAITLAND INTERCHANGE

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 be inorganic particulates such as clay, silt and sand.

Chlorophyll "a" concentrations averaged 17.2, 8.1, 4.8 and 5.4 μg/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 μg/l and also showed the greatest variability with a standard deviation of 17.30 μg/l. The chlorophyll "a" concentrations at S-2 increased significantly during July and August and the values ranged from 7.50 to 53.1 μg/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 μg/l with dissolved concentrations ranging from below detectable to 92 μg/l. The highest average total zinc was recorded for the east pond, 71 μg/l with 46% in the dissolved form followed by S-2, S-3, and S-4 reporting 64 μg/l with 67% dissolved, 57 μg/l with 60% dissolved, and 56 μg/l with 61% dissolved. Standard deviations ranged from 43 to 23 μg/l for total concentrations and 26 to 6 μg/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 μg/l was recorded for Lake Lucien with other average total cadmium levels being 2 to 3 μg/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 μg/l with 40% in the dissolved form. The other stations showed 15 μg/l of which 33% dissolved at S-2: 11 μg/l, 36% dissolved; and 7 μg/l with 43% dissolved at S-4. The highest copper concentration was reported for the west pond, S-2, at 38 μg/l with 55% dissolved followed closely by 36 μg/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 μg/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 μg/l, total lead fell between 9 and 129 μg/l and total chromium values were reported from 1 to 49 μg/l. The highest average total iron, lead and chromium concentrations of 414, 92 and 17 μg/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 μg/l for iron, lead and chromium. Concentrations in the two stations of Lake Lucien were quite similar, 140, 30 and 9 μg/l at S-3 and 182, 33 and 9 μg/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 μg/g oven dry weight for stations S-1 through S-4.

Calcium concentrations averaged 2690, 11105, 4483 and 820 μg/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 μg/g.

Average cadmium concentrations in μg/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 μg/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 μg/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 μg/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 μg/g dry weight. The concentrations in the east pond and Lake Lucien averaged 561 and 421 μg/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 seived 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 Hypercium samples were found in Lake Lucien, S-4, and the outfall from the west pod, 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%. Hypercium 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 μg/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 μg/g, Fe ranged between 854 and 1137 g/g and Pb concentrations fell between 75.0 and 96.0 μg/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 μg/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. *Hypercium* 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 μg/g, respectively. Concentrations of 257.5, 46.2, 1252 and 78.5 μg/g for Zn, Cu, Fe, and Pb in the control sections were higher than those of 223, 32.5, 837.6, and 71.1 μg/g reported for *Hypercium* 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 μg/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 μg/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 averge 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/m^2 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/m^2 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 gradiant 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 µg/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 µg/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 µg/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 µg/l and the average dissolved lead concentrations were 55 µg/l in Lake Ivanhoe water column. Also the average total lead concentration in runoff water from scupper drains was 1558 µg/l and the average dissolved lead was 187 µg/l. The lead released through scupper drains can be estimated assuming an average rainfall or runoff of 50 inches/year (1.27 m/yr) 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 Plurarg, 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 g/l in the water column of the west pond, S-2, was higher than the maximum permissible concentration of 50 μg/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 accummulated 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 µg/l				Percent Probability	
		Total		Dissolved			
		S-1 E. Pond	S-2 W. Pond	S-1 E. Pond	S-2 W. Pond	Total	Dissolved
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 µg/l				Percent Probability	
		Total		Dissolved			
		S-4 Lk Lucien	S-2 W. Pond	S-4 Lk Lucien	S-2 W. Pond	Total	Dissolved
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 μg/gm (dry wt.) S-2 With Scuppers	S-3 Without Scuppers	Percent Probability
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 µg/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 INTECHANGE (T-Test Analysis)

Element	No. of Observ.	Mean Values µg/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 µg/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 accummulation of heavy metals 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-existant. 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 setting 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 containe 423 μg-Pb/g oven dry weight which was four times in excess of the lead concentration, 98.4 μg-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:

$$N = 2.81\times10^{-6}\ CEC + 1.07\times10^{-5}\ pH - 4.93\times10^{-5}$$

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 μg/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 µg/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 µg/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 Arthropodea (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 perimenter 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 *Hypercium* 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 *Hypercium*. 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 Arthropodea (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 *Hypercium* 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

REFERENCES

Angino, E. E.; Magnuson, L. M. and Wangh, T. C., "Mineralogy of Suspended Sediment and Concentration of Fe, Mn, Ni, Zn, Cu, and Pb in Water and Fe, Mn, and Pb in Suspended Load of Selected Kansas Streams," Water Resources Research, Vol. 10, No. 6, December 1974, pp. 1187-1191.

Baretta, C., "Effetti Del Piombo Nel Settore Zootecnico," Paper presented at Centro Ceramico Problems of Lead and Fuorine Air Pollution From Industrial Sources, International Conference, Bologna, France, January 1978, p. 81.

Barkdoll, Michael P.; Overton, Donald E. and Betson, Roger P., "Some Effects of Dustfall on Urban Stormwater Quality," Journal of the Water Pollution Control Federation, Vol. 49, No. 9, September 1977, pp. 1976-1984.

Bell, John H., "Shallow Water Roadside Ditches for Stormwater Purification," M.S.E. Thesis, University of Central Florida, Orlando, Florida, 1978.

Bell, John H. and Martin P. Wanielista, "Use of Overland Flow in Stormwater Management on Interstate Highways," Transportation Research Record 736, Transportation Research Board, National Academy of Sciences, Washington D.C., 1979.

Benes, P.; Gjessing, E. T. and Steinnes, E., "Interaction Between Humus and Trace Elements in Fresh Water," Water Research, Vol. 10, No. 8, 1976, pp. 711-716.

Boggess, W. R., and Wixson, B. G. (Editors), "Lead in the Environment," Geological Survey Professional Paper 957, U.S. Government Printing Office, Washington D.C., 1976.

Bradford, Wesley L., "Urban Stormwater Pollutant Loadings: A Statistical Summary Through 1972," Journal of the Water Pollution Control Federation, Vol. 49, No. 4, April 1977, pp. 613-622.

Brosett, C., "Danger of Water Pollution Through Air," Fed. Europaiskher Gewasserchutz, Informationsblatt, 21, 1974.

Christensen, E. R., et al., "Metals from Urban Runoff in Dated Sediments of a Very Shallow Estuary," Environmental Science and Technology, Vol. 12, 1978, p. 1168.

Committee on Water Quality Criteria, Environmental Studies Board, National Academy of Sciences and National Academy of Engineering, Water Quality Criteria 1972, published by United States Environmental Protection Agency, EPA-R-3-73-033, March 1973.

Edginton, David N. and Robbins, John A., "Records of Lead Deposition in Lake Michigan Sediments Since 1800," Environmental Science and Technology, Vol. 10, No. 3, March 1976, pp. 266-274.

Enk, M. D. and Mathis, B. J., "Distribution of Cadmium and Lead in a Stream Ecosystem," Hydrobiologica, Vol. 52, No. 2-3, 1977, pp. 153-158.

Ganley, J. T. and Springer, G. S., "Physical and Chemical Characteristics of Particulates in Spark Ignition Engine Exhausts," Environmental Science and Technology, Vol. 8, No. 4, April 1974, pp. 340-347.

Gardiner, J., "Chemistry of Admium in Natural Water—2. The Adsorption of Cadmium on River Muds and Naturally Occurring Solids," Water Research Vol. 12, 1978, p. 1168.

Getz, Lowell L.; Verner, Louis and Prather, Martin, "Lead Concentrations in Small Mammals Living Near Highways," Environmental Pollution, Vol. 13, No. 2, June 1977, p. 151.

Gupta, M. K., "Constituents of Highway Runoff, An Executive Summary," U.S. Department of Transportation, Federal Highway Administration, Office of Research and Development, Washington D.C., 1978.

Guy, R. D.; Chakrabarti and McBain, D. C., "An Evaluation of Extraction Techniques for the Fractionation of Copper and Lead in Model Sediment Systems," Water Research, Vol. 12, No. 1, January 1978, pp. 21-24.

Habibi, K., "Characterization of Particulate Matter in Vehicle Exhaust," Environmental Science and Technology, Vol. 7, No. 3, March 1973, pp. 223-234.

Harrell, David, FDOT Traffic Volume, Personnel Communication, Deland, Florida, 1980.

Hassett, John J. and Miller, J. F., "Uptake of Lead by Corn from Roadside Soil Samples," Communications in Soil Science and Plant Analysis, Vol. 8, No. 1, 1977, p. 49.

Helmke, P.A., et al.,"Determination of Trace Element Contamination of Sediment by Multi-element Analysis of Clay Size Fractions," Evironmental Science and Technology, Vol. 11, P. 984, 1977.

Helsel, Dennis R.; Kim, Jung I.; Grizzard, Thomas J.; Randall, Clifford and Hoehn, Robert C., "Land Use Influences on Metals in Storm Drainage," Journal of the Water Pollution Control Federation, Vol. 51, No. 4, April 1979, p. 709.

Hirschler, D. A. and Gilbert, L. F., "Nature of Lead in Automobile Exhaust Gas," Archives of Environmental Health, Vol. 8, 1964, pp. 109-125.

Hosie, D. J.; Boggoiais A.; De Laeter, J. R. and Rosman, K. J., "The Cadmium Content in Soil at Heirisson Island, Western Australia," Search, Western Australia Institute of Technology, Vol. 9, No. 1-2, January - February 1978, p. 47.

Htun, Maung Nay and Ramachandran, P. N., "An Investigation of Blood Lead Content and Atmospheric Lead Levels in Bangkok," Water, Air, and Soil Pollution, Vol. 7, No. 1, January 1977, p. 79.

Huang, C. P.: Elliot, H. A. and Asmead, R. M., "Interfacial Reactions and the Fate of Heavy Metals in Soil-Water Systems," Journal of the Water Pollution Control Federation, Vol. 49, No. 5, May 1977, pp. 745-746.

Iskandar, K. and Keeney, Dennis R., "Concentration of Heavy Metals in Sediment Cores from Selected Wisconsin Lakes," Environmental Science and Technology, Vol. 8, No. 2, February 1974, pp. 165-170.

Johnson, R. E.; Rossano, A. T. and Sylvester, R. O., "Dustfall as a Source of Water Quality Impairment," Journal of the Sanitary Engineering Division, ASCE 4694, 1966, pp. 245-271.

Joselow, Morris M.: Tobias, Ed; Koehler, Robert; Coleman, Scott; Bogden, John and Gause, Douglas, "Manganese Pollution in the City Environment and its Relationship to Traffic Density," American Journal of Public Health, Vol. 68, No. 6, June 1978, p. 557.

Laxen, D. P. H. and Harrison, R. M., "Highway as a Source of Water Pollution: An Appraisal with the Heavy Metal Lead," Water Research, Vol. 11, No. 1, 1977, pp. 1-11.

Lazrus, A.L.: Lorange, E.: and Lodge, J.P., "Lead and Other Metal Ions in U.S. Precipitation," Environmental Science and Technology, Vol. 4, 1970, pp. 55-67.

Leland, H. V.: Luoma, S. N.; Elder, J. F. and Wilkes, D. J., "Heavy Metals and Related Trace Elements," Journal of the Water Pollution Control Federation, Vol. 50, June 1978, pp. 1469-1514.

Malmquist, Per Arne, "Atmospheric Fallout and Street Cleaning--Effects on Urban Stormwater and Snow," Prog. Water Technology, Vol. 10, No. 5, International Conference on Water Pollution Research 9th (pt. 1), Stockholm, Sweden, June 12-26, 1978, 1978, pp. 495-505.

Mathis, B. J. and Cummings, T. F., "Selected Metals in Sediments, Water, and Biota in the Illinois River," Journal of the Water Pollution Control Federation, Vol. 45, July 1973, pp. 1573-1583.

McLean, R. O. and Shields, B., "A Study of Factors Causing Changes in the Lead Levels of Crops Growing Beside Roadways," Environmental Pollution, Vol. 14, No. 4, December 1977, p. 267.

Namminga, H. and Wilhm, J., "Heavy Metals in Water, Sediments, and Chironomids," Journal of the Water Pollution Control Federation, Vol. 49, July 1977, pp. 1725-1731.

Oliver, Barry G.: Milne, John B. and LaBarre, Norman, "Chloride and Lead in Urban Snow," Journal of the Water Pollution Control Federation, Vol. 46, No. 4, April 1974, pp. 766-771.

Olson, K. W. and Skogerboe, R. K., "Identification of Soil Lead Compounds from Automotive Sources," Environmental Science and Technology, Vol. 9, No. 3, March 1975, pp. 227-230.

Pierson, William R.; McKee, Douglas E.; Brachaczek, Wanda W. and Butler, James W., "Methylcyclopentadienyl Manganese Tricarbonyl: Effect on Manganese Emissions from Vehicles on the Road," APCA Journal, Vol. 28, No. 7, July 1978, p. 692.

Pitt, R.E. and Arney, G., "Toxic Material Analysis of Street Surface Contaminants," U.S. EPA Report No. RZ-72-081, November, 1972.

Plurarg, et al., Environmental Management Strategy for the Great Lakes System, Final Report to the International Joint Commission, Windsor, Ontario, Canada, 1978.

Pope, W., et al., "Urban Runoff From a Road Surface--A Water Quality Study," Prog. Water Technology (G.B.), Vol. 10, No. 5-6, 1978, p. 553.

Randall, C. W.; Helsel, D. R.; Grizzard, T. J. and Hoehn, R. C., "The Impact of Atmospheric Contaminants on Storm Water Quality in an Urban Area," Progress in Water Technology, Vol. 10, No. 5, Internation Conference on Water Pollution Research, 9th (pt. 1), Stockholm, Sweden, June 12-26, 1978, pp. 417-431.

Rickert, D. A.; Kennedy, V. C.; McKenzie, S. W. and Hines, W. G., "A Synoptic Survey of Trace Metals in Bottom Sediments of the Willamette River, Oregon," U.S. Geological Survey Circular 715-F, Arlington, Virginia, 1977.

Rimer, A. E., et al., "Characterization and Impact of Stormwater Runoff from Various Land Cover Types," Journal of the Water Pollution Control Federation, Vol. 50, 1978, p. 252.

Sartor, James D.; Boyd, Gail B. and Agardy, Franklin J., "Water Pollution Aspects of Street Surface Contaminants," Journal of the Water Pollution Control Federation, Vol. 46, No. 3, Part 1, March 1974, pp. 458-467.

Shaheen, D. G., Contributions of Urban Roadway Usage to Water Pollution, U.S. Environmental Protection Agency Report EPA 600/2-75-004, Washington D.C., EPA, 1975.

Shuldiner, D.F., Cope and R.B. Newton, "Ecological Effects of Highway Fills on Wetlands," National Cooperative Highway Research Program Report No. 218A, Transportation Research Board, National Research Council, D.C., December, 1979.

Suzuki, Motoyuki: Yamada, Toshimasa: Miyazaki, Toshio and Kawazoe, Kunitaro, "Sorption and Accumulation of Cadmium in the Sediment of the Tama River," Water Research, Vol. 13, No. 1, 1979, p. 57.

Ter Haar, G. L. and Bayard, M. A., "Composition of Airborne Lead Particles," Nature, Vol. 232, London, 1971, pp. 553-554.

Ter Haar, G. L.; Lenane, D. L.; Hu, J. N. and Brandt, M., "Composition, Size, and Control of Automotive Exhaust Particulates," Journal of the Air Pollution Control Association, Vol. 22, No. 1, January 1972, pp. 39-46.

Uken, E. A., et al., "Distribution of Selected Trace Elements in Samples of Sediment Suspension and Water Taken Along the Isar River, Bavaria," Journal of Radioanalytical Chemistry, Vol. 37, 1977, p. 741.

Ward, Neil I.; Roberts, Edward and Boswell, Colin R., "Heavy Metal Pollution from Automotive Emissions and its Effect on Roadside Soils and Pasture Species in New Zealand," Environmental Science and Technology, Vol. 11, No. 9, September 1978, p. 917.

Whipple, W. Jr., et al., "Characterization of Urban Runoff," Water Resource Research, Vol. 14, 1978, p. 370.

Williams, L. G.; Joyce, J. C. and Monk, J. T. Jr., "Stream Velocity Effects on the Heavy Metal Concentration," Journal of the American Water Works Association, Vol. 65, April 1973, pp. 275-279.

Wong, M. H. and Tam, F. Y., "Lead Contamination of Soil and Vegetables Grown Near Motorways in Hong Kong," Journal of Environmental Science and Health--Environmental Science and Engineering, Vol. 13, No. 1, 1978, p. 13.

Zimdahl, R. L. and Skogerboe, R. K., "Behavior of Lead in Soil," Environmental Science and Technology, Vol. 11, 1977, p. 1202.

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

APPENDIX - A-4. VARIATIONS OF HEAVY METAL CONCENTRATIONS IN WATER SAMPLES FROM INBETWEEN THE NORTH BRIDGES (S3) 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	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 (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	23	99	108	113	111	319	125	67	121	87
Dissolved Zn	2	9	0	11	6	319	125	23	62	112
Total Cd	3	4	5	3	11	6	0	4	5	3
Dissolved Cd	3	0	4	3	11	0	0	4	3	4
Total As	0	0	36	67	0	28	27	121	35	42
Dissolved As	0	0	36	0	0	28	0	121	23	42
Total Ni	56	5	14	19	5	14	19	10	18	16
Dissolved Ni	56	0	6	11	2	0	19	4	12	19
Total Cu	27	164	44	27	64	171	42	71	76	58
Dissolved Cu	9	19	22	17	14	13	26	18	17	6
Total Fe	70	153	113	358	329	123	144	268	195	108
Dissolved Fe	--	4	35	178	51	3	61	21	50	60
Total Pb	82	71	81	55	84	118	67	55	77	20
Dissolved Pb	82	50	73	55	56	26	59	19	53	21
Total Cr	12	17	21	23	21	13	3	8	15	7
Dissolved Cr	--	0	--	23	2	2	0	1	5	9

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

Parameter	Concentration µg/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 INBETWEEN SOUTH BRIDGES (S2) ON LAKE IVANHOE

Parameter	Concentration µg/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	73.40	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 INBETWEEN NORTH BRIDGES (S3) ON LAKE IVANHOE

Parameter	Concentration µg/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 µg/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	μg/gm Dry Weight
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
		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
		8/24	3.23	0.30	17.6	10.5	12.4	43.8	11.8	1.39	2.15	13.2	1.41
	Average x̄		7.2	.26	21.9	1.7	11.3	53.6	22.9	2.7	1.8	14.3	1.4
	Std. Dev. σ		4.2	.27	7.5	.70	1.6	14.4	17.4	1.4	.31	4.4	.73
	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
		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
		8/24	11.6	0.26	13.5	1.37	9.62	48.2	11.7	1.46	2.54	12.8	1.76
	Average x̄		11.9	.28	22.7	2.2	10.3	178.6	24.1	3.4	1.9	16.1	1.5
	Std. Dev. σ		5.2	.16	13.2	1.6	1.8	281.4	8.8	1.6	.44	8.4	.38
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 x̄		37.7	2.0	234.7	22.0	115.7	541.3	168.3	17.4	5.7	37.3	1.8
	Std. Dev. σ		21.2	.21	22.5	16.5	11.6	160.7	74.1	6.3	1.0	22.5	.10
	S_1	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
		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
		6/20	31.6	1.44	309	27.4	122	1334	145	16.5	6.35	45.9	2.83
	Average x̄		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	50.4	1.94	21.3	2.37
		3/16	23.3	1.05	258	13.8	54	433	235	13.2	4.14	15.3	3.03

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	4/19	44.2	1.94	222	28.9	270	847	135	--	8.60	20.7	6.36
	(cont.)	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 $\bar{x}$		28.7	1.8	333.0	32.9	139.8	789.0	248.0	23.7	5.2	23.8	3.6
	Std. Dev. σ		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 $\bar{x}$		24.2	1.2	229.3	12.1	106.7	559.0	126.8	122.3	4.9	16.1	4.5
	Std. Dev. σ		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	435	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
		8/24	24.8	0.72	92.4	16.0	147	3004	131	36.1	1.67	9.2	3.27
	Average $\bar{x}$		18.3	.60	91.6	17.1	340.8	1283.5	133.8	44.8	2.0	15.1	3.0
	Std. Dev. σ		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 $\bar{x}$		16.2	1.9	188.3	25.8	238.8	1550.0	375.0	41.3	3.2	21.3	4.3
	Std. Dev. σ		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
		8/24	20.3	1.97	250	21.7	240	2203	506	61.8	2.75	9.0	7.17
	Average $\bar{x}$		14.3	1.5	188.5	21.2	261.3	1920	368.3	46.0	2.8	15.3	4.7
	Std. Dev. σ		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	.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 (Gastro-poda)	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
		8/3	0.2	0.36	355	4.6	39.9	63.5	4.4	1.8	0.45	5.7	1.2
		8/24	3.2	0	23.5	0.71	12.2	147	7.4	0.6	0.59	3.8	0.1
	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	.40	35.9	2.9
	Std. Dev. σ		14.0	11.0	131.6	46.8	287.6	1098.4	86.5	52.5	.39	27.2	2.9
MOLLUSCA (Pelecypoda)	Control	3/16	79.6	2.8	24.9	12.4	21	129	194	24.5	0.07	33.5	0.29
	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	.11	25.3	2.8
	Std. Dev. σ		26.2	1.3	15.6	6.5	7.9	--	93.6	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
	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	.11	2.2	1.4
	Std. Dev. σ		.53	.13	4.9	1.8	17.1	121.4	16.1	5.7	.02	1.0	.97
ANNELIDA (Oligochaeta - Tubifex)	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								mg/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
PLANARIA	S_3	3/16	0.00	26.3	3605	368	1737	11052	553	6.32	1.26	12.4	4.87

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

Plant	Station	Concentration Factor mg/gm (oven dry wt.) / Mg/ml							
		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 $\frac{\text{mg/g (oven dry wt.)}}{\text{mg/ml}}$							
		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	x̄	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	7.76	---
	S-3	6.97	6.65	7.39	7.45	7.52	7.52	7.06	7.45	7.13	---
	S-4	7.40	7.06	7.32	7.20	---	7.41	7.31	7.09	7.24	---
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	22.00	12.90
	S-3	2.40	1.90	5.00	2.60	3.50	2.20	2.00	2.00	2.70	1.06
	S-4	10.0	4.70	4.00	3.00	3.50	13.30	2.80	2.40	5.46	3.98
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	---	---	---	8.82	3.62
	S-3	11.50	9.30	34.90	11.50	8.50	---	---	---	15.10	11.10
	S-4	12.20	10.80	16.60	14.00	6.60	---	---	---	12.00	3.73
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	---	---	---	30.80	20.60
	S-3	5.00	3.50	9.80	11.50	4.00	---	---	---	6.76	3.64
	S-4	4.00	3.50	9.50	14.00	4.40	---	---	---	7.08	4.56
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	8.05	3.35
	S-3	4.50	5.00	6.20	4.50	3.90	5.00	5.60	3.40	4.76	.896
	S-4	5.00	7.30	5.00	5.60	2.80	9.50	3.40	4.50	5.39	2.15
Nitrates mg/l-N	S-1	---	---	0.79	---	---	1.34	---	0.89	1.01	.293
	S-2	---	---	2.11	---	---	2.59	---	1.95	2.22	.333
	S-3	---	---	0.52	---	---	0.58	---	0.39	0.497	.097
	S-4	---	---	0.70	---	---	0.07	---	0.34	0.370	.316
Phosphorus mg/l-P	S-1	---	.067	.121	.333	.065	.228	.045	.073	.133	.1076
	S-2	---	.481	.145	.540	.351	.188	.147	.630	.355	.2004
	S-3	---	.008	.075	.044	UD	.069	.070	UD	.038	.0346
	S-4	---	.046	.110	.218	UD	.159	.081	.034	.093	.0761
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	56.10	4.25
	S-3	11.00	13.00	11.40	15.50	10.00	11.60	11.50	11.70	12.00	1.66
	S-4	---	13.60	10.80	13.30	10.00	11.70	11.90	11.70	11.90	1.27
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	4.91	.801
	S-3	3.90	3.70	4.20	4.30	3.70	4.00	3.70	4.00	3.93	.221
	S-4	---	5.50	3.80	4.30	3.80	3.90	3.80	4.00	4.17	.627

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

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

Parameter	Concentration (µg/1)								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
Dissolved Zn	43	17	--	32	31	35	79	30	43	17
Total Cd	5	1	7	0	1	3	2	5	3	2
Dissolved Cd	0	0	2	0	1	3	0	5	2	2
Total As	59	31	359	201	0	66	92	237	131	123
Dissolved As	59	--	0	71	0	58	1	237	53	81
Total Ni	52	8	11	10	4	12	9	7	15	15
Dissolved Ni	0	3	9	3	0	1	5	7	5	3
Total Cu	36	23	44	24	19	31	65	48	38	15
Dissolved Cu	18	18	34	10	17	11	27	15	21	11
Total Fe	425	174	545	318	170	232	245	690	414	207
Dissolved Fe	314	174	395	42	71	29	101	39	128	144
Total Pb	83	68	129	69	118	57	97	60	92	29
Dissolved Pb	69	67	103	64	118	25	85	29	66	35
Total Cr	44	10	18	25	21	8	4	7	17	13
Dissolved 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	x̄	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 ($\mu g/l$)								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 µg/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 µg/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 µg/gm (oven dry weight)								Statistical Analysis	
	2/22	3/20	5/ 3	5/24	6/29	7/20	8/17	8/30	x̄	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 µg/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	µg/gm Dry Weight
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
Hypercium	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	3.2	0.6	0.5	0.6
		5-3	19.8	.38	18.1	6.4	9.9	166.0	25.0	2.7	1.6	9.8	2.0
		5-24	4.9	.24	3.7	2.5	7.5	95.0	14.1	3.5	1.3	18.5	1.1
		6-29	18.9	.25	16.8	1.8	9.2	59.0	25.1	3.4	1.2	17.0	1.4
		7-20	6.1	.13	26.5	1.7	6.4	65.0	19.7	2.9	2.1	15.7	1.2
		8-17	9.1	.08	21.4	4.3	2.2	39.0	9.8	1.5	1.2	10.5	1.1
		8-30	6.5	.51	18.5	2.1	6.8	60.0	24.1	3.0	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	5.4	1.0	6.2	0.7
	Lucien	5-3	0.0	.24	23.0	4.9	7.2	56.0	7.5	1.3	1.6	2.8	1.7
	Near	5-24	5.7	.13	19.2	1.9	7.2	63.0	16.0	3.3	3.0	19.0	0.7
	Outfall	6-29	15.8	.40	34.7	1.3	13.1	73.0	23.0	4.4	2.5	18.3	0.9
		7-20	12.7	.25	37.0	2.1	12.2	68.0	19.1	3.1	4.0	16.8	0.8
		8-17	11.5	.32	36.5	2.7	21.1	45.0	13.1	0.9	3.6	12.7	0.8
		8-30	5.1	.22	17.9	1.8	6.8	43.0	13.7	1.1	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	2-22	12.3	.78	89.9	11.7	16.3	579.0	23.2	10.6	4.1	11.3	1.7
	Pond	3-20	15.8	.64	75.8	6.7	29.5	793.0	90.0	11.9	2.4	15.7	.90
	Close to	5-3	38.8	.82	59.6	4.2	13.0	——	90.4	6.0	5.2	11.6	.87
	Outfall	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	3-20	17.3	.72	63.7	12.3	76.8	1212.0	142.0	18.1	2.5	14.8	.73
	WEIR	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
Hypercium	Lake Lucien (Control)	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 Near Outfall	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	7	2.3
	S-2	0	0	0	0	0	0	5	0	0.6
	S-3	0	21	43	0	0	0	0	0	8.0
	S-4	0	7	14	0	--	15	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								mg/gm		
			As	Cd	Zn	Ni	Cu	Fe	Pb	Cr	Mg	Ca	P
ANNELIDA CLASS Oligochaeta - Tubifex	Lake Lucien (Control	3/20	19.2	2.0	868.0	47.7	37.1	368.0	31.8	19.2	.32	2.1	.72
		5/3	0.0	.3	23.0	8.0	7.5	54.5	0.0	0.0	.09	1.5	0.0
		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	0.0
		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 Lucien Near Outfall	5/3	188.0	.88	43.0	5.3	12.3	0.0	6.2	14.0	.09	1.7	0.0
		5/24	0.0	0.0	1146.0	0.0	83.3	0.0	83.3	271.0	1.8	49.0	3.1
		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							mg/gm		
			As	Cd	Zn	Ni	Cu	Fe	Pb	Cr	Mg	Ca	P
MOLLUSCA CLASS Gastropoda	Lake Lucien (Control)	5/3	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 Near Outfall	3/20		1.4	294.8	10.6	33.5	128.5	141.8	17.7	0.03	62.0	0.52
		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
ANNELIDA CLASS Hirudinea	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 (Control)	3/20	0.0	6.9	12260.0	326.0	253.0	2719.0	199.0	137.0	0.56	6.6	1.2
		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	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 Near Outfall	8/17	79.3	0.0	60.5	9.7	26.4	862.0	9.0	0.70	0.43	1.9	0.57
	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 $\frac{\text{mg/gm (oven dry wt.)}}{\text{mg/ml}}$							
		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
Crustacea	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		7.5		10.0		15.0		16.0
	4.0		7.6		9.0		14.8		14.9
	5.0		7.6				14.8		
March 16/79	0	8.3	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		18.3
	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	25.0	25.5	25.0	25.0
	1.0	10.0	8.6	8.5	8.9	25.0	25.5	25.2	25.0
	1.5		8.5	7.2	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		7.8		25.0		24.5
May 17/79	0	8.2	8.4	8.5	8.5	26.5	26.7	24.0	25.0
	0.5	7.1	7.5	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	8.6	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		8.1				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	5.2	7.7	32.2	31.2	31.0	29.0
	1.0	2.1	5.6	5.1	7.3	32.0	31.3	31.0	29.5
	1.5		5.6	6.1	7.6		31.0	31.0	29.5
	2.0		5.5		7.2		31.0		28.5
	3.0		5.1		4.4		31.0		28.5
	4.0		4.6		1.5		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	31.0	30.0
	1.5		4.2	7.2	7.2		32.0	31.5	30.0
	2.0		3.9	7.3	8.2		32.0	31.5	29.5
	3.0		2.9		6.0		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	6.3	7.3	34.0	32.2	29.7	29.5
	0.5	4.6	5.0	5.3	6.7	33.0	31.0	29.7	29.0
	1.0		3.6	3.0	4.1		31.0		29.0
	1.5		2.9	3.3	3.7		31.0		29.0
	2.0		2.3	3.0	3.3		30.6		29.0
	3.0		2.3		2.9		30.0		28.7
	4.0		2.3		1.2		30.0		27.0
	5.0		1.6		0.6		29.5		26.0

Appendix C-2. DISSOLVED OXYGEN CONCENTRATIONS AND TEMPERATURE PROFILES ON MAITLAND 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	8.3	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	29.0	28.0		29.3
	2.0	3.7			6.5	28.0			29.3
	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	7.3	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	2.3	4.5	6.3	5.3	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 Solution
			Range	Mean	Std. Dev.	
Zn	Total	11	0.228-1.120	0.498	0.263	67
	Dissolved		0.028 1.120	0.336	0.300	
Cd	Total	11	0.003-0.009	0.005	0.002	20
	Dissolved		0.000-0.005	0.001	0.002	
As	Total	11	0.000-0.145	0.058	0.049	86
	Dissolved		0.000-0.145	0.050	0.055	
Ni	Total	11	0.013-0.261	0.053	0.071	92
	Dissolved		0.006-0.261	0.049	0.072	
Cu	Total	11	0.032-0.101	0.052	0.023	60
	Dissolved		0.010-0.055	0.027	0.014	
Fe	Total	11	0.510-6.850	2.429	2.290	12
	Dissolved		0.034-2.170	0.287	0.626	
Pb	Total	11	0.690-3.250	1.558	0.939	12
	Dissolved		0.063-0.504	0.187	0.136	
Cr	Total	11	0.003-0.027	0.011	0.008	20
	Dissolved		0.000-0.009	0.002	0.003	
Ca	Total	11	25.10-53.80	38.073	9.837	97
	Dissolved		21.80-53.80	36.800	11.110	
Mg	Total	11	0.493-2.790	1.062	0.673	78
	Dissolved		0.294-2.790	0.831	0.738	
P	Total	11	0.160-1.220	0.426	0.382	16
	Dissolved		0.000-0.137	0.067	0.059	