CHARACTERIZATION OF STORMWATER POND SEDIMENTS
FINAL PROJECT REPORT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The stormwater pond is a common management practice to control and/or treat urban stormwater discharges. Ponds are popular for a number of reasons including the fact that they provide open space and wildlife habitat, can be aesthetically pleasing, and require little maintenance. However, the sediment, which accumulates in the ponds, must periodically be removed. Reported sediment accumulation rates vary widely. Sediment yields during the construction phase of urban developments can be extremely high but even after build out the rate can be on the order of 1,000 kg/ha/yr.

Pond sediments have been characterized for several heavy metals, nitrogen, phosphorus, and polychlorinated biphenyls (PCB). The reported nutrient concentrations vary by a factor of 10 and the metal concentrations typically vary by a factor of 100. In recent years, several investigators have demonstrated that a number of polycyclic aromatic hydrocarbons (PAH) are associated with the particulate material collected from street surfaces.

The purpose of this project was to quantify the physical and chemical characteristics of stormwater pond sediments generated in the Minneapolis and St Paul metropolitan area. The sites were not limited to ponds specifically designed and constructed to treat stormwater. Storm sewers discharge to many of the natural ponds and lakes in the metro area – with and without treatment. These water bodies were included in the project because they represent a typical approach for handling stormwater. Samples were collected at a total of 10 sites located in five metro area counties – Anoka, Dakota, Hennepin, Ramsey, and Washington.

The sampling and analytical program included replication of samples and analyses. Two sediment samples were collected from each of five locations in each pond yielding a total of 100 sediment samples. A total of four top soil samples were also collected for comparison purposes. The GPS coordinates for all of the samples were recorded. Replicate analyses for each sample were conducted for volatile solids, chemical oxygen demand, nitrogen and phosphorus, and 15 metals.♠ PCB and PAH analyses along with specific gravity and particle size distribution were conducted on one sample from each location. In addition, one sample from each location was subjected to the toxicity characteristic leach procedure (TCLP) and subsequent analyses for the eight metals addressed in the hazardous waste rules. In total, approximately 5,000 analyses were conducted to quantify the physical and chemical characteristics of the sediments.

When the particle size distributions were averaged for the individual ponds, the sand content (> 200 sieve) varied from 45% to 90%. The volatile content of the sediments varied from approximately 2% to approximately 37%. Based on the relationship between volatile content and specific gravity, it appears that the specific gravity of the mineral material was approximately 2.65.

♠ A mild acid digestion procedure was used for metals analysis and the reported concentrations represent the metal that is likely to environmentally available.

The total Kjeldahl nitrogen of the sediments varied in the approximate range of 300 to 7,300 mg/kg on a dry weight basis and averaged approximately 3,000 mg/kg. The total Kjeldahl nitrogen concentration for the top soils averaged approximately 1,600 mg/kg. The total phosphorus concentration was relatively constant at approximately 530 mg/kg and the concentration of the top soils was only slightly higher.

The mercury concentration in the sediments and top soils varied in the range of approximately 5 ug/kg to 150 ug/kg. Although there was considerable variation in the mercury concentrations within and between ponds, it appears that the average concentration for each pond is not significantly different than the average for the top soils.

The average metal concentrations for the individual ponds fell in the low end of the ranges reported in the literature. In general, the ratio of the pond to top soil concentrations varied in the range of 0.8 to 6. The ratio of pond to parent soil concentrations for metals are reported to fall in the range of 5 to 30 for metals. The low ratios found in this project may mean that a lower mass of metal is entering and captured in the ponds, or it may be related to the fact that the project did not analyze for total metals. It does appear that the metal content of the sediments is related to land use in the watershed. Concentrations increase as the percentage of paved area in the watershed increases.

The metal concentrations in the 50 sediment and 4 soil extracts were all well below the limits which are used by the Minnesota Pollution Control Agency (MPCA) to characterize a material as hazardous.

The PCB concentration of the sediments was low. A total of 40 of the 50 sediment samples, as well as the four soil samples, had concentrations below the detection limit of approximately 20 ug/kg.

The PAH protocol addressed a total of 43 individual compounds. State and federal agencies sum a variety of the individual compounds to define the total PAH concentration. The MPCA currently uses a suite of 13 compounds to define total PAH concentration (Σ PAH_{13}). The values for Σ PAH_{13} for the individual samples fell in the range of 0.2 mg/kg to 65.8 mg/kg with an average of 11.0 mg/kg. Total PAH is alternatively reported as an equivalent concentration of benzo(a)pyrene (BAP). The average equivalent BPA concentrations for the ponds fell in the range of 0.19 to 7.28 mg/kg.

Several approaches are used to put the sediment data into perspective – in addition to comparison with the top soil samples. The sediment metals are compared to published soil metals data for the US and Minnesota and to sediment data generated from reference (unimpacted) lakes in Minnesota.

The MPCA has developed a series of soil reference values (SRV) as part of a risk-based approach for decision making during site investigations and remedial action related to the state's Voluntary Investigation Cleanup and Superfund Programs. The SRV are used in a three-tiered evaluation approach to evaluate health effects from several exposure pathways – ingestion, dermal, and inhalation. The MPCA is currently developing guidance for managing dredged materials (including pond sediment) using the SRV approach. The tier 1 exposure scenario is based on residential property use. The current SRV values for 100+ constituents are available on the MPCA web site. MPCA recommends that, if one or more of the tier 1 SRV values is exceeded, additional site investigation is warranted. Although the SRV were not intended to make judgements on where to place sediments, they appear to be useful tools to determine the suitability of sediment placement in upland areas. It must be remembered, however, that the SRV values are targets for cleanup and not upper limits for land application.

When average concentrations are calculated for each pond, all the sediment averages exceed the tier 1 SRV for copper and 9 of 10 exceed the tier 1 SRV for iron. At the same time, the average concentration in the sediments from the reference lakes also exceed the copper SRV. Half of the ponds fail to meet the tier 1 SRV for equivalent BAP.

Much of the raw data and summaries of all the data generated during the project are presented in this report. Note, however, all of the raw data along with several related reports are accessible on the following web site.
http://www.metrocouncil.org/environment/sediment

SECTION I. INTRODUCTION

A. General

The U. S. Environmental Protection Agency (EPA), in the most recent evaluation of the nations water bodies, reports that 35% of stream miles and 45% of lake area are impaired. Although agricultural activities were found to be the major source of impairment, urban runoff accounted for approximately 32,000 miles of stream and 930,000 acres of lake impairment.[1] It is clear that, although urban runoff is not the major source of water quality impairment from a national perspective, it certainly does produce local impacts. As a result, communities use a variety of management practices to mitigate the impacts of urban runoff.

The stormwater pond is perhaps the most common structural management practice used to control and/or treat urban stormwater discharges. Although a pond and its associated buffer can require 2% to 4% of the area available for development, it is popular with both developers and governmental agencies for a number of reasons. Ponds provide open space, aesthetic quality, wildlife habitat, and require little maintenance. In fact, EPA has identified a number of case studies were properties, located near or within sight of a wet pond, generated rent/sell premiums of 10% to 150%.[2]

Removal of accumulated sediment is the primary long-term maintenance activity for stormwater ponds. Relatively high sediment loads are expected during the period required for build-out of a typical development (reported sediment yields in the range of 7 to 500 ton/acre/year).[3] After removing this initial sediment load, solids may accumulate in the pond for many years. Minton estimates that the long-term accumulation rate to be on the order of 0.25 to 0.5 inch/yr.[4] In 2000, the Minnesota Pollution Control Agency (MPCA) recommended that ponds should be constructed with approximately 25 years of sediment storage.[5] In the new Minnesota Stormwater Manual, however, it is *HIGHLY RECOMMENDED that sediment removal in the forebay occur every 2 to 7 years or after 50% of total forebay capacity has been lost*.[6] This recent recommendation is consistent with that of the Wisconsin Department of Natural resources (WNDR), which recommends that sediment should be removed every 5 to 10 years.[7] In any case, pond cleaning is conducted on an infrequent basis and there is a dearth of local data on the quantity and quality of the sediment that is removed. In fact, WNDR found that the long-term accountability for pond maintenance was often difficult to determine.[7]

From a theoretical standpoint, as significant sediment accumulates in a pond the TSS removal efficiency decreases because of a decrease in the hydraulic detention time and an increase in scour potential. The goal is, of course, to maximize the removal of TSS and the associated pollutants. However, an increased TSS removal efficiency results in a more rapid accumulation of sediment, which decreases efficiency. Sediment removal at the appropriate times is thus the key to addressing this apparent dichotomy. Although the timing of sediment removal is thus important from a pond performance perspective, it is also important from a regional sediment handling and disposal perspective as described below.

General observations over the past 25-30 years suggest that most of the stormwater ponds in the Twin Cities metropolitan area are located in the newer suburban areas and have been constructed in the past 15 to 20 years. If [a] the above observation is correct and [b] local municipalities and/or developers are following the 2000 MPCA recommendation on sediment storage, then most of the existing ponds have never been dredged (after build out) and the inventory of sediment is high. Unfortunately the magnitude of the inventory is unknown. Note, however, that well over one million people live in the suburban area surrounding the core cities. If half of these people live in communities/developments served by stormwater ponds, the sediment inventory is likely very high. In addition, the chemical and biological characteristics of the sediments are largely unknown.

Given their age and history, it is quite likely that many of the existing ponds will need to be dredged in the next 10 years. Some municipalities may periodically monitor sediment inventory and plan for disposal. It is more likely, however, that the need for dredging will become apparent only when a delta appears and/or pond performance significantly degrades.

B. Sediment Quantity

EPA reports that soil erosion is the largest source of sediment in urban communities under development with sediment yields as high as 500 tons/acre/year. Yields from construction sites are reported to be 100 to 500 times those from stabilized urban areas.[8] After build out, typical values for solids loads in urban runoff (excluding highways) fall in the range of approximately 400 to 1000 kg/hectare/year (360 to 890 lb/acre/yr).[9] This is equivalent to 115 to 285 tons solids per square mile per year.

The Metropolitan Council Environmental Services (MCES) previously funded a small study to estimate sediment accumulation in five stormwater ponds in the metropolitan area.[10] Sediment accumulation was measured over a period of 3.5 years by means of sediment traps and a trace layer, however, only the data generated by the trace layer technique were used to estimate accumulation rate. The results of the project are summarized in TABLE 1. Note that, in order to generate estimates of sediment mass yield, a dry bulk density of 2,000 lb/yd^3 was assumed.

TABLE 1. OBSERVED SEDIMENT ACCUMULATION IN METRO PONDS

Watershed		Sediment		
Land Use	Area – acres	Cubic Yards	lb/acre/yr	kg/ha/yr
LD* residential/park	47	11	134	119
LD residential	7.5	22	1,676	1,495
Industrial	17.3	90	2,973	2,652
Commercial	67	144	1,228	1,096
Commercial	26	27	593	529

* LD = low density

The Minnehaha Creek Watershed District recently reported on sediment excavation from four large impoundments serving drainage areas in the range of 633 – 1,900 acres.[11]

Again assuming a dry bulk density of 2,000 lb/yd^3, sediment accumulation fell in the range of 200 to 1,450 kg/ha/yr. It is clear from the above that sediment accumulation rates in stormwater ponds vary substantially depending on local conditions. The rate will depend on both the sediment yield for the watershed and the capture efficiency of the pond.

Barrett reviewed the database maintained by the American Society of Civil Engineers (ASCE) and found a total of 12 sites that had sufficient data to calculate event mean concentrations for both pond influent and effluent.[12] Note that three of the 12 sites are located in local suburban communities – Maplewood, Roseville, and Woodbury. It was reported that an effluent concentration of total suspended solids (TSS) of 20 mg/l could be expected for influent concentrations as high as 200 mg/l.

The MPCA reports that wet extended detention ponds typically remove 80% of influent suspended solids.[6] The MPCA estimate is based on data compiled and published by the Center for Watershed Protection.[13] The data set includes information from a total of 53 ponds (44 wet ponds and 9 dry ponds). The median suspended solids removal efficiencies for the ponds were 80% and 47% for the wet and dry ponds respectively. Since wet ponds are more efficient in removing solids and most new ponds use that approach, a TSS removal efficiency of 80% is used to estimate sediment quantity in the following example. Note, however, that the use of modified overflow devices can increase capture to 90% and above.[8]

Consider a small city of 10,000 with a population density of 1,500/mi^2 (approximate density for New Ulm in 1990[14]). If the average sediment yield for this city is 1,000 kg/ha/yr and if all of the surface runoff in this city of 6.7 mi^2 is routed through ponds, this city will generate approximately 1,500 tons of sediment per year assuming an 80% capture rate. Given that actual sediment yields will be a function of impervious area, soil type and slope, commercial and industrial development, etc., it is acknowledged that this estimating approach is not appropriate for planning purposes. It does, however, illustrate the order of magnitude of sediment accumulation in stormwater ponds.

In order to put the quantity of pond sediment into perspective it may be of value to compare it to the quantity of sewage sludge generated for the same population. Approximately 2.0 lb/1,000 gal is a reasonable estimate for sludge generation for an activated sludge treatment plant[15] At a typical sewage generation rate of 100 gal/capita/day, a city of 10,000 would then generate approximately 365 tons of sewage sludge per year. For this hypothetical community, pond sediment would accumulate at approximately four times the rate of sewage sludge.

If sediment removal is scheduled every five years for the example above, approximately 7,500 tons of material (dry weight basis) would have to be removed and disposed of. From a materials handling perspective alone, dredging and disposing of pond sediments appears to be a significant maintenance requirement (albeit conducted infrequently).

C. Sediment Quality

Sediment data were found for well over 100 ponds in a number of references. However, the descriptions of the ponds were not always complete and it is quite possible that some data were used in more than one of the references. In addition, the drainage characteristics were described in varying detail and the list of metals and organics analyzed varied considerably as did the method of data presentation - raw data, averages, and ranges. For these reasons, the data summary in TABLE 2 is limited to concentration ranges. The resulting concentration ranges are quite wide (up to three orders of magnitude) and provide little help in predicting sediment quality for any specific community or source.

As an alternative to collecting sediment samples and analyzing them, typical pond loadings and removal efficiencies can be used to calculate pollutant concentration ranges in the accumulated sediment. Polta used this approach to estimate sediment characteristics and the results are summarized in TABLE 3.[16] Note that the estimated concentrations are similar to the literature observations summarized in TABLE 2.

TABLE 2. SUMMARY OF REPORTED POND SEDIMENT DATA

Constituent	**Concentration Range* – mg/kg dry**
Arsenic	1.3 – 75
Cadmium	0.4 – 30
Chromium	7 – 817
Copper	2 – 310
Lead	2 – 1,280
Nickel	3 – 300
Zinc	29 – 3,170
Mercury	0.03 – 8
PCB	0.04 – 1
Total Phosphorus (TP)	725 - 1,790
Total Kjeldahl Nitrogen (TKN)	1,370 – 13,990

* from references number 17, 18, 19, 20, 21, 22, 23, 24, 25, and 26

TABLE 3. ESTIMATED QUALITY OF POND SEDIMENT

Constituent	**Concentration Range – mg/kg dry**
Cadmium	2 – 25
Chromium	6 – 50
Copper	95 – 770
Lead	400 – 5,600
Zinc	625 – 7,140
TKN	1,400 – 10,700
TP	450 – 4,900

Starzec et al, recently collected sediments from 15 wet detention ponds which received highway and road runoff in Sweden.[27] In all cases, the traffic intensity was classified as low or medium. The samples were extracted by acid digestion via microwave (ASTM D5258-92) prior to analysis. Summary plots for six metals were presented Because of the scale of the plots, the minimum values were difficult to interpret but the approximate maximum values were as follows; cadmium – 0.65 mg/kg, chromium – 45 mg/kg, copper – 50 mg/kg, lead – 75 mg/l, nickel 30 mg/l, and zinc – 200 mg/kg. In most cases, the sediment metal concentrations were not significantly higher than metal concentrations for soils collected in the immediate vicinity.

Lau and Stenstrom collected particulate material from paved streets (paving material not reported) at 18 sites in the city of Santa Monica, California and determined the concentration of metals and PAHs as a function of land use and four particle size fractions (< 43um, 43 – 100 um, 100 – 250 um, and 250 – 841 um).[28] The samples were collected one week after the last street sweeping or rain event. The published data were presented as metal and polycyclic aromatic hydrocarbons (PAH) yields –mass metal or PAH per street area per week. The 100 – 250 um size fraction was the most important for metals with approximately 40% of the total metal mass. The approximate concentration ranges over all sizes and land uses are summarized in TABLE 4.

TABLE 4. PARTICULATE MATERIAL FROM STREETS

Constituent	**Concentration Range – mg/kg**
Cadmium	1 – 6
Chromium	8 – 60
Copper	20 – 320
Lead	30 – 350
Nickel	10 – 500
Zinc	50 – 1,100
Total PAH (sum of 15)	0.4 – 4.6

Road debris and leaking motor oil can be a source of PAH. The PAH concentration of road dusts in Tokyo were reported to fall in the range of 3.2 to 8.2 mg/kg (sum of 63 individual compounds) with 30% to 45% identified as products of combustion.[29] More recent sampling in California found the PAH concentration of road dust to be approximately 59 mg/kg (sum of 23 individual compounds).[30] The researchers found tire wear and brake lining particles to have a PAH concentration of approximately 226 mg/kg and 16 mg/kg respectively. The PAH concentration of used motor oil (gasoline engines) is reported to be approximately 3,000 mg/kg.[31]

USGS used data collected in Marquette, Michigan in 1993 and 1994 to demonstrate that parking lots can be significant sources of PAH. Total PAH was characterized as the sum of 16 individual compounds. Although the parking lots made up 4.6% of the study area, they generated 64% of the PAH load generated in the study area.[32]

More recently, USGS and the City of Austin, Texas collaborated on a project to determine the impact that seal coating asphalt paved parking lots has on the PAH concentration in subsequent runoff.[33, 34] Two common seal coat materials were tested [1] a coal-tar-pitch-based emulsion and [2] an asphalt-based emulsion. Runoff, generated by simulated rainfall, was collected from both parking lots and special test sections. Total particulate PAH concentration was computed as the sum of 13 compounds. The data reported for parking lots are summarized in TABLE 5**.** It is clear that the sealcoat material has a significant impact. For the watersheds involved, it was reported that the estimated Σ PAH loads from the seal coated parking lots were similar to the measured stream loads even though the parking lots were only 1% to 2% of the watershed area.

USGS published the results of a study that demonstrated the relationship between vehicular traffic, which is related to urban sprawl, and sediment quality.[35] The study evaluated PAH trends in sediment cores from 10 reservoirs and lakes in six U. S. metropolitan areas including two lakes in the Minneapolis and St Paul metropolitan area (Lake Harriet in Minneapolis and Palmer Lake in Brooklyn Center). In all cases the increase in sediment ΣPAH appeared to be correlated with increased traffic for the particular metropolitan area. A subsequent paper by the same investigators provided the data which are summarized in TABLE 6.[36] Note that the sum of 13 specific PAH compounds were used to characterize total PAH (Σ PAH_{13}). The changes over the 20+ year period seems to be reasonable given that the area around Lake Harriet was fully urbanized long before 1970 while the area around Palmer Lake was just being urbanized.

TABLE 5. PARKING LOT RUNOFF PAH

Sealcoat Material	**Average ΣPAH* - mg/kg**
Coal-tar-based emulsion	3,450
Asphalt-based-emulsion	617
Unsealed asphalt	36
Unsealed concrete	72

* sum of 11 PAH

TABLE 6. PAH CONCENTRATIONS IN LOCAL LAKES

Lake	**1970 Σ PAH_{13} mg/kg**	**1990's Σ PAH_{13} mg/kg**
Harriet	19.5	15.2
Palmer	1.19	16.1

In 2005, the National Research Council published its review of the scientific information on the ecological effects of road density.[37] The report focused on all classes of hard surfaced roads and included approximately 300 references. Although numerous reports relating traffic to water quality were cited, only one citation addressed sediment quality. Stream and lake sediments, collected in the city of Burnaby, British Columbia, which is highly urbanized, contained a number of hydrocarbons that were indicative of petroleum sources. The total hydrocarbon concentration in the surficial sediment taken from Burnaby Lake was on the order of 7,500 mg/kg. Streambed sediments fell in the range of 0.055 to 4,800 mg/kg. The hydrocarbon content of street surface sediments are summarized in TABLE 7. Note that the parking lots included two classified as commercial and two classified as open space.[38]

TABLE 7. HYDROCARBON CONCENTRATIONS IN SURFACE SEDIMENTS

Land Use	N	Average – mg/kg	Std Dev – mg/kg
Residential	3	4,300	900
Commercial	4	4,900	294
Industrial	8	5,800	1,537
Parking Lots	4	7,800	3,039

D. Comparison to Biosolids

It may be of interest to compare the residuals generated by typical stormwater treatment systems with the residuals generated by typical municipal wastewater treatment systems (now termed biosolids but previously called sewage sludge). In 1996 the Association of Metropolitan Sewerage Agencies (AMSA) conducted a sludge survey. A total of 124 AMSA members provided data for more than 200 wastewater treatment plants. [39] The data are summarized in TABLE 8. With the exception of TKN and TP, the range of pollutant concentrations in pond sediments includes the average for sewage sludge.

Given this similarity and Schueler's recommendation that sediments may be valuable as a soil amendment,[24] it may be interesting to discuss sediment disposal in terms of the MPCA regulations for biosolids. In addition to the limits summarized in TABLE 9, sewage sludge applied to agricultural land in Minnesota must, at a minimum, meet class B pathogen reduction criteria as well as vector attraction criteria. The pathogen reduction criteria can be accomplished via several treatment processes or by demonstrating fecal coliform densities of less than 2,000,000 per gram of dry solids. The vector attraction requirements can be obtained by volatile solids reduction processes, chemical addition, obtaining very high solids content (> 90%), and injection into the soil.[40] Note that Zanoni reported fecal coliform concentrations in the range of approximately 150,000 to 3,000,000 organisms per gram of stormwater residuals.[18]

When the observed concentration ranges summarized in TABLE 2 and TABLE 3 are compared to the ceiling concentrations of TABLE 9 it appears that only lead has some significant likelihood of exceeding the limits. Note however that, since the metal concentrations can be significant, the annual loadings and cumulative loadings would be limited. Also note that Minnesota Rules chapter 7041.0300 limits the PCB concentration to land applied sludges to less than 50 mg/kg .

TABLE 8. CONCENTRATION DATA FOR SEWAGE SLUDGE

Pollutant*	Mean – mg/kg	Median – mg/kg
Arsenic (203)	11.5	5.4
Cadmium (207)	6.4	4.4
Chromium (201	103	62
Copper (207)	103	62
Lead (208)	111	76
Mercury (199)	2.1	1.8
Molybdenum (190)	15	12
Nickel (210)	57	35
Selenium (194)	5.7	4.1
Zinc (207)	830	744
TKN (155)	43,195	44,400
TP (149)	20,300	20,100

* (n) = number of treatment plants

TABLE 9. MPCA LIMITS FOR LAND APPLICATION OF SLUDGE

Pollutant	Ceiling – mg/kg	Cumulative – lb/ac	Annual – lb/ac
Arsenic	75	37	1.8
Cadmium	85	35	1.7
Copper	4,300	1,339	67
Lead	840	268	13
Mercury	57	15	0.76
Molybdenum	75	NA	NA
Nickel	420	375	19
Nitrogen – available	NA	NA	Meet crop needs
Selenium	100	89	4.5
Zinc	7,500	2,500	125

E. Project Description

The purpose of this project was to quantify the physical and chemical characteristics of stormwater pond sediments generated in the Minneapolis and St Paul metropolitan area. A total of 100 sediment samples were collected from 10 sites. A total of approximately 5,000 analyses were conducted to quantify the physical and chemical characteristics of the sediments. In addition, a survey of state and provincial agencies was conducted to determine the extent to which criteria or regulations have been developed to control the use and disposal of pond sediments. Note that the results of the survey have been previously published.[41]

SECTION II. METHODS

A. Site Selection

This project was not limited to collecting sediment from ponds specifically designed and constructed to treat stormwater. Storm sewers discharge to many of the natural ponds and lakes in the metro area – with and without treatment. These water bodies were included in the project because they represent a typical approach for handling stormwater.

Several approaches were used to contact communities that might be interested in participating in the project. In addition to contacting 20 communities directly, all of the watershed districts, and watershed management organizations in the State of Minnesota were notified of the project. The criteria for participation were simple and consisted of [a] operation for at least five years since the pond was last dredged, [b] relatively easy access to the pond, and [c] some knowledge of the pond drainage area.

As a result of the contacts that were made, a total of 26 ponds were eventually considered for the project. After a community expressed an interest in participating, an initial visit was made to determine how to access the site for sampling. If access was not considered to be limiting, a second visit was made to locate the pond inlets and outlets. In addition, water depth was determined in 20 to 30 locations to identify sediment deposits and to ensure that the available sampling equipment would be suitable. The preliminary information provided by the community and that obtained during the first and second site visits was sufficient to characterize the drainage area in general terms (residential, commercial, highway, etc.).

Finally, because of the wide variety of soils and drainage characteristics in the metropolitan area, participating communities were chosen to ensure a wide geographical distribution of the pond sites. The location of the ponds and the top soil samples that were collected as reference materials are illustrated on Figure 1.

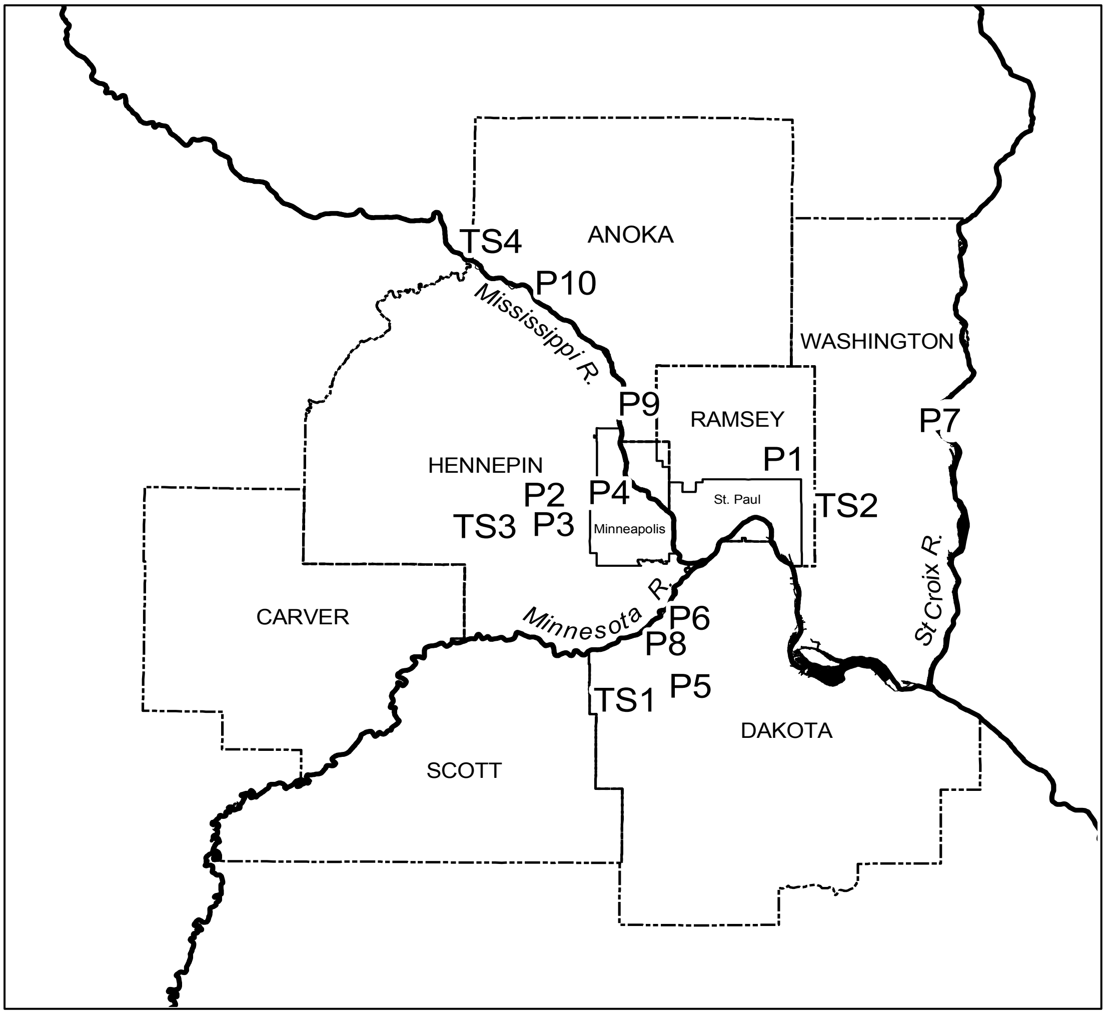
Although the initial site visits did provide basic information on the drainage area, a more thorough characterization was warranted. For six of the ponds the detailed characterization was provided by the community or their representative. For the remaining four ponds, the communities provided electronic versions of their drainage maps. This information was combined with available land use maps (electronic format) to estimate the characteristics of the individual pond watersheds.

B. Sampling

[1] <u>Location</u>

For each pond, two sediment samples were collected from each of five locations. For the ideal plug flow pond, the five sample locations would be on a line between the inlet and outlet. Unfortunately the ideal situation is rare. Most ponds have multiple inlets and are not configured to provide plug flow. In all cases, the goal was to collect samples that reasonably represented the sediment in the entire pond. After the second field visit (see Section II.A. above) the general location of the samples was selected. The actual sample locations were determined with a GPS unit in the field (Garmin model GPSmap 76S). along with the location of the pond inlet(s) and outlet(s).

Figure 1. Seven county metro area with locations of ponds (P) and top soil (TS) samples.



In those cases where the pond boundary was not defined in the available GIS files, the GPS unit was used to map the boundary. As a result, maps showing the pond boundaries, water depth, inlet(s), outlet(s) and the location of all samples are provided for each of the 10 ponds. (Details provided in section III).

[2] <u>Collection</u>

For nine of the ponds, the work platform consisted of two canoes lashed together and secured with two anchors – see Figure 2. The sediment samples were collected using a 36-inch Ogeechee™ sand corer (Wildlife Supply Company) constructed of stainless steel and equipped with a stainless steel liner. The diameter of the corer was 2 inches. The corer head has a tight closing valve that keeps the sediment from falling out of the core when the device is lifted up and out of the water. A number of extension handles of various lengths were used to lower the corer to the surface of the sediment, push it into the sediment bed, and raise it back onto the work platform. The coring device is illustrated on Figure 3. One of the ponds was dewatered because of a berm failure and a stainless steel auger was used to collect the sediment samples.

Figure 2. Loading work platform

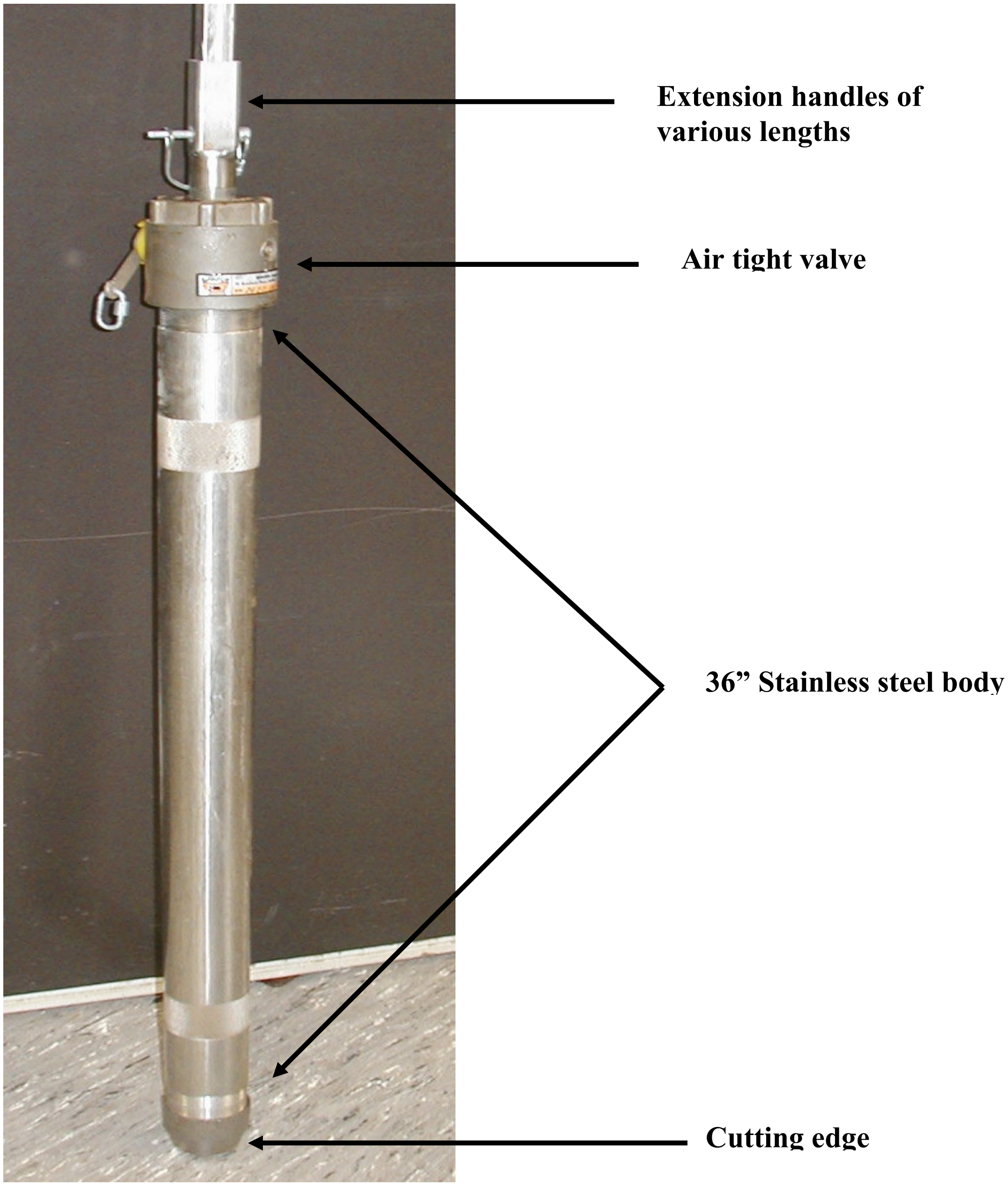
Prior to each of the 10 sampling trips, all of the sampling equipment, except the extension handles, was subjected to the following cleaning procedure.

- wash with phosphorus-free detergent
- triple rinse with distilled water
- rinse with acetone
- rinse with reagent grade hexane
- air dry

Between samples the equipment was rinsed with pond water.

Immediately after collection, the sediment samples were transferred into 2-liter wide-mouth borosilicate glass jars with Teflon lined covers. Core samples were directly discharged into the jars – see Figure 4. The depth of the individual samples varied in the range of approximately 6 to 18 inches depending on the resistance provided by the sediment. In many cases two individual samples (cores) were collected and placed into the same jar. This was done to assure sufficient sample for the scheduled analyses.

Figure 3. Sample coring device.



For the samples collected with an auger, a stainless steel scoop (subjected to the same cleaning procedure as the sampling equipment) was used to transfer the sample into the jars. Prior to taking sample jars into the field they were subjected to the following cleaning procedure.

- wash with phosphorus –free detergent
- rinse with HCl
- triple with distilled water

- rinse with acetone
- rinse with reagent grade hexane
- air dry

After the jars were cleaned, waterproof labels with the sample identification numbers were applied to the jars and caps.

Figure 4. Transferring sediment to glass bottle.

On a separate occasion, after the sediment samples had been collected from the 10 ponds, sediment was again collected from two of the ponds for use in toxicity tests. In both cases, the GPS mapping allowed collection of sediment grabs from the previous sampling locations.

In addition to pond sediments, a total of four top-soil samples were collected from retail landscaping companies in clean 5-gallon plastic containers. A subsample of each soil was transferred to one of the previously cleaned 2-liter glass jars. From this point forward, the soil samples were treated similar to the sediment samples.

All samples were labeled using an alpha-numeric code and that code is used throughout this report. The first element of the code is the pond number (1 through 10). The second element is the sample location within the pond (A through E). The third element is the number of the core at each location (1 or 2). The last element identifies the analytical replicates (blank or a). The code 3B2a thus means pond number 3, location B, second core at that location, and second analysis of the sample. The code for top soil samples was limited to sample location and analytical replicate. Thus TS 2a is interpreted as the second top soil sample and the second analysis.

[3] Transport and Storage
Within 30 minutes of collection, the filled sample jars were buried in ice. After the final sample was collected and the equipment secured, the samples were transported to the R&D laboratory, which is located at the Metropolitan Wastewater Treatment Plant (Metro), and stored in a refrigerator maintained a temperature of less than 4 ^{o}C. In most cases, the samples were stored for only one night with sample splitting the day after collection.

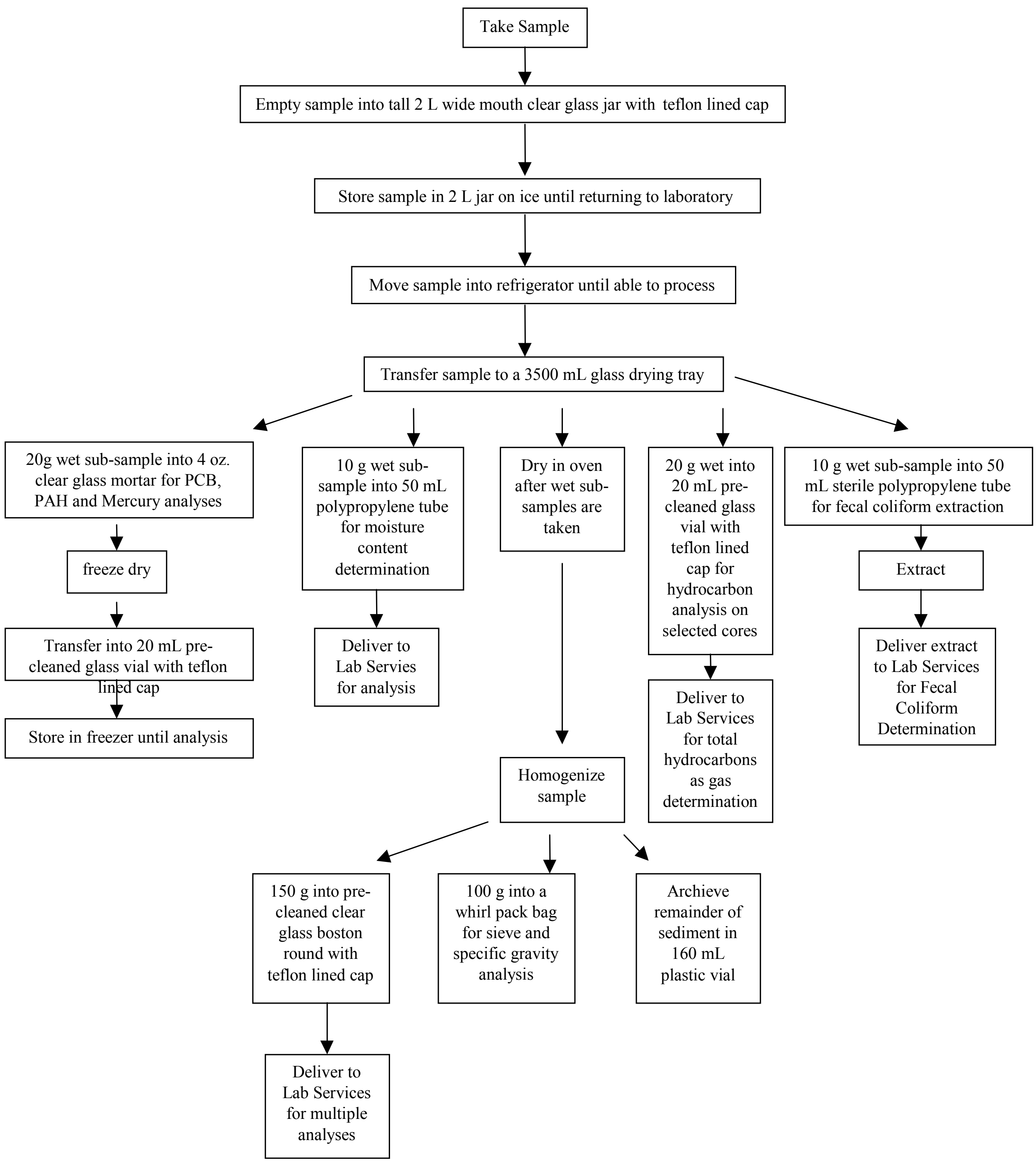
Figure 5. Preparing to measure DO and temperature.

[4] Splitting and Distribution
After a sample jar was removed from the refrigerator, free water was decanted, the sediment was transferred to a glass cake pan (9.5”x13.5”x2”), the sediment was mixed and a subsample was taken (stainless steel scoop) for those analyses using wet samples, a second subsample was taken and freeze dried (Ultra-Dry Model FZRDRY01) for

subsequent mercury, PCB, and PAH analyses, and the remaining sediment was oven dried in the cake pan. The entire process is described in detail on Figure 6.

For the samples that were used in the toxicity tests, the free water was decanted and all of the samples (for an individual pond) were mixed in a large stainless steel bowl. The composite sample was then delivered to the bioassay laboratory.

Figure 6. Sample splitting protocol.



C. Field Data Collection

Immediately after the anchors were deployed, the location was determined with the GPS unit. The dissolved oxygen (DO) concentration and temperature were determined at the sediment-water interface using a WTW 340i monitor, which was calibrated prior to use – see Figure 5 . Finally, the pH of the sediment/water mixture was determined using an Orion 290A meter and combination electrode, which had been calibrated with pH buffers of 4, 7, and 10. The DO, temperature, and pH data were recorded in the field notebook.

D. Sample Analyses

[1] Schedule

The initial analytical schedule for the 100 sediment core samples is summarized in TABLE 10. After the project was initiated the plan was modified to include the four top soil samples

[2] Physical

Because hard particle aggregates formed when the sediment was oven dried, it was necessary to de-aggregate the material prior to subsampling and analysis. For ponds 1 – 4 (sampled in 2004) the material was manually ground using a glass mortar and pestle. This material was then subsampled for a number of analyses. Subsequent analysis of the analytical data demonstrated precision problems, which appeared to be related to remaining particle aggregates. As a result, a ball mill (Fritsch Planetary Mono Mill Pulverisette 6) was used to grind the oven-dried sediments for ponds 5 – 10.

The specific gravity of the dried sediment was determined using glass pycnometers as per ASTM D854.[42] The particle size distribution of the dried sediment was determined by dry sieving (number 10, 16, 35, 50, 100, and 200 sieves) using a Ro-Tap model B sieve shaker. The volatile solids content of each of the sediment and soil samples was determined using the method listed in TABLE 11.

[3] Chemical

Most of the analyses were conducted using standard procedures as summarized in TABLE 11.

Mercury analyses were conducted as follows. Sediment samples were digested with a mixture of HNO_3, H_2SO_4, $KMnO_4$, and $K_2S_2O_8$ and total Hg was determined by cold vapor atomic fluorescence spectrometry with a single gold trap amalgamation.[43]

PAH in the sediment were extracted with methylene chloride followed by extraction with hexane in an ultra-sonicating water bath. The extracts were cleaned using glass wool and powdered activated copper followed by injection onto an Agilent Model 6890 GC with an Agilent 5973 MS in selective ion monitoring mode. A 30 meter 0.25 mm HP 190915-433 HP-5MS column was used with helium as the carrier gas. The samples were quantified using internal standards. [44, 45]

TABLE 10. INITIAL ANALYTICAL SCHEDULE

Parameter(s)	**Analyses/Core**	**Total Analyses[d]**
Part. Size & Specific Gravity	Note a	50
Toxicity bioassay	Note b	2
Volatile solids	2	200
COD	2	200
TKN and TP	2	200
NH_3-N	2	200
NO_2-N & NO_3-N	2	200
Aluminum	2	200
Arsenic	2	200
Cadmium	2	200
Chromium	2	200
Copper	2	200
Fecal Coliform	1	100
Iron	2	200
Lead	2	200
Manganese	2	200
Mercury	2	200
Molybdenum	2	200
Nickel	2	200
PAH	Note c	60
PCB	Note c	60
Selenium	2	200
TCLP – metals	Note a	50
Total petroleum hydrocarbons	Note e	10
Titanium	2	200
Vanadium	2	200
Zinc	2	200

Notes:
[a] only one of replicate cores at each location
[b] limited to two cores,
[c] one of replicate cores at each location plus 10 replicate analyses
[d] total number of analyses may be lower if dredge samples rather than cores collected
[e] total petroleum hydrocarbons (as gasoline) defined as BETX plus methyl tertiary butyl ether plus total petroleum hydrocarbons as gasoline (using Wisconsin DNR Modified Method for Determining Gasoline Range Organics)[46,] - one core per pond.

TABLE 11. ROUTINE ANALYTICAL METHODS

Parameter	Method & Reference
Volatile Solids	209G; APHA[47]
COD	410.4; EPA[48]
NH_3-N	350.1; EPA
NO_2-N, NO_3-N	300.0; EPA
TKN	351.2; EPA
TP	365.4; EPA
Metals	6020 with 3050B digestion[49]
Toxic Characteristic Leach Procedure	1311
PCB	608; EPA[50]

The analysis for gasoline range organics (GRO) was conducted by a contract laboratory using the Wisconsin DNR's modified method. Note that the plan was to analyze one sediment sample from each pond and that was done for ponds 1 – 4 during 2004. Because of oversight, when samples were collected from ponds 5 – 10 in 2005 no GRO analyses were done.

With the exception of the GRO analyses, it was initially planned to conduct all of the analytical work at MCES facilities. However, in late 2005, the MCES central laboratory began to experience problems with their ICP-MS instrumentation. As a result, arrangements were made in late March of 2006 to have a laboratory at the University of Minnesota (UM) complete some of the analyses for metals. Note, however, that MCES did complete all of the sample digestions.

[4] Biological
The original plan was to use the membrane filtration method for determining the fecal Coliform count and that procedure was used for the samples collected from pond #1. However, because of problems with fines on the filters, the most probable number technique [51] was used to quantify fecal coliform bacteria for each of the 90 sediment and four top soil samples remaining.

Two protocols were used to conduct toxicity bioassays as follows: [1] *Hyalella azteca* 10-Day Survival Test for Sediments and [2] *Chironomus tentans* 10-Day Survival and Growth Test for Sediments.[52] Lethal effects (survival) were measured as an end-point in both tests and sublethal effect (growth) was measured at the end of the C. tentans test. Survival and growth end-points were compared to organisms that were exposed to a control sediment (fine silica sand) and a reference sediment (SC 25.8).

The tests were conducted in MCES' Water Quality Toxicity Testing Laboratory (WQTTL) using a Benoit diluter system. The *C. tentans* larvae used for this test were 11 days old and the *H. azteca* were 8-10 days old at the start of the test. Test organisms were supplied by Aquatic Biosystems of Ft. Collins, CO. The supplier conducts monthly reference toxicant tests on *C. tentans* and *H. azteca*. These tests indicated that the test organisms were healthy and suitable for conducting sediment toxicity-tests.

The control sediment was fine silica sand that was thoroughly washed with filtered tap water before being used. It was obtained from Cemstone Inc, located in North St. Paul, MN. The reference sediment was obtained from the St Croix River at mile SC 25.8 which is located about two miles upstream from Stillwater, MN. This site was chosen as a reference site because it was considered to be an unimpacted site.

Five sediment samples were collected from ponds number 3 and 8 and transported to the R&D laboratory using the procedures described above. These samples were collected from the same locations previously sampled to generate the physical and chemical characteristics of the sediments. The GIS coordinates were used to determine the previous sample locations. The individual samples were decanted and a composite sediment sample was constructed for each of the two ponds.

Before the start of the test, the composite sediment samples were thoroughly mixed by hand, and 100 ml of each sediment type was added to each test beaker. Approximately 100 ml of charcoal filtered tap water was added to each beaker and the sediments were allowed to settle before adding test organisms. Each sediment sample, including control and reference samples, was set up with six replicates (beakers) of C. tentans and six replicates of H. azteca. Ten test organisms were placed in each of the six beakers in a random manor.

Overlying water used for all tests was charcoal-filtered tap water, which was obtained from a duel-filter carbon filtration system located in the WQTTL. Three volume additions of charcoal filtered tap water were exchanged in each test chamber each day of the 10-Day Sediment Toxicity-Test. The Benoit diluter system was set to exchange approximately one volume addition every 8 hours. Daily observations of the operation of the diluter system and of the appearance of the sediments and test organisms were recorded.

At the end of the test, sediments from each beaker were sieved through an eight-inch diameter, number 40 sieve, and the sieved material was searched for test organisms. If necessary, the sieved material was also spread out in a shallow white enamel pan, where it was further sorted to find organisms. Final organism counts were taken and missing organisms were presumed dead. Surviving C. tentans were preserved in an 8% formalin/glucose solution and were weighed at a later date.

E. Quality Assurance

As stated earlier, the purpose of this project was to quantify the physical and chemical characteristics of stormwater pond sediments generated in the Minneapolis and St Paul metropolitan area. It was anticipated that the data could also be used by state and local government agencies to initiate discussions on the potential risks associated with the handling, use, and/or disposal of the material. It was not anticipated that the data could be used to determine the suitability of the individual pond sediments for use and/or disposal because there were no criteria for making such judgements except for the limits for the TCLP metals. It was not anticipated that any of the sediments would exceed the criteria for classification as a hazardous waste.

Given the above, it was not possible (or necessary) to generate explicit data quality objectives (DQO). It was thus decided to use DQO (precision and accuracy) generated by EPA[53] and the US Army Corp of Engineers (USACE)[54] for separate sediment evaluation projects – see TABLE 12. Most of the analyses were duplicated and the relative percent difference (RPD) was used as a measure of precision. If the precision criterion was not obtained for a particular sample analysis, one additional analysis was conducted. When three or more replicate analyses were conducted, the percent coefficient of variation (COV) was used.

The accuracy of the methods used for determining metals, mercury, and PAH was characterized via the use of standard reference materials (SRM) provided by the National Institute of Standards and Technology (NIST). Initially, SRM 2704 (Buffalo River Sediment) was used for all metals and mercury. When that standard was no longer available, SRM 8704 (also Buffalo River Sediment) was used for metals. However SRM 8704 was not certified for mercury. As a result BCR 320 (Trace Elements in River Sediment), prepared by the Commission of the European Communities, was used for mercury. SRM 1944 (New York/New Jersey Waterway Sediment) was used for PAH. A sample of the appropriate SRM was submitted to the laboratory with each set of sediment samples.

The certified values for SRM 2704 are based on a total digestion of the material. The digestion method used in this project, however, is less rigorous and represents material that is "environmentally available". This problem was resolved because a number of researchers have determined "total recoverable" metals for this specific SRM. A total of five published reports, which contain values for the mean "total recoverable" elemental composition of SRM 2704 as determined following extraction of the sediment with either HNO_3, HNO_3 plus H_2O_2, HNO_3 plus HCl, or HNO_3 plus HCl and H_2O_2, were reviewed.[55, 56, 57, 58, 59] These published data were used to calculate the weighted overall mean elemental concentrations, using the number of determinations as the weighting factor. Weighted overall standard deviations were calculated as the square root of the weighted mean of the variances from the individual studies, again using the number of determinations as the weighting factor. Some elements were only determined in one study, so the mean value from that study is taken as the expected value. Some elements were not determined in any of the studies cited, so no expected value is given. The results of the analysis are summarized in TABLE 13. Note that the COV reported for selenium was very high.

TABLE 12. REQUIRED PRECISION AND ACCURACY

Measurement	Reference	Precision[A]	Accuracy[B]
Part size and sp. gr.	EPA	20%	NA
Volatile solids	EPA	20%	NA
COD			
TKN and TP			
NH_3-N	EPA/USACE	20%	15%
NO_2-N & NO_3-N			
Arsenic	EPA/USACE	20%	15%
Aluminum	EPA	20%	20%
Cadmium	EPA/USACE	20%	15%
Chromium	EPA	20%	20%
Copper	EPA/USACE	20%	15%
Fecal Coliform			
Iron	EPA	20%	20%
Lead	EPA/USACE	20%	15%
Manganese	EPA	20%	20%
Mercury – total	EPA/USACE	20%	15%
Molybdenum	EPA	20%	20%
Nickel	EPA/USACE	20%	15%
PCB	EPA/USACE	25%	30%
PAH	EPA/USACE	25%	30%
Selenium	EPA	20%	20%
TCLP – metals [C]		20%	NA
Titanium	EPA	20%	20%
Total petroleum hydrocarbons	EPA/USACE	20%	15%
Vanadium	EPA	20%	20%
Zinc	EPA	20%	20%

Notes:
A. less than or equal to stated precision for analytical replicates
B. accuracy within +/- of known or certified value
C. run duplicate metals analysis only (not leach)

It was originally planned to use SRM 2704 throughout the project and it was assumed that it would continue to be available. Unfortunately it was not available after January of 2005 and SRM 8704 was used in its place. However, SRM 8704 was collected at the same time and location as SRM 2704.[60]

TABLE 13. TOTAL RECOVERABLE METALS IN SRM 2704

Element	Weighted Mean (mg/kg)	Weighted Std. Dev. (mg/kg)	COV (%)	Number of Determinations	Number of Studies
Cu	94.1	2.6	2.8	19	4
Ni	40.4	2.9	7.2	24	5
Pb	153.0	10.0	6.5	24	5
Zn	408.3	18.1	4.4	19	4
Cd	3.4	0.1	4.1	19	4
Cr	82.7	6.6	8.0	21	4
Al	13500	851	6.3	8	1
As	19.1	0.4	2.2	11	2
Fe	33300	566	1.7	8	1
Mn	467	16	3.5	8	1
Se	0.26	0.09	34.0	8	1
Mo	2.88	0.26	9.2	8	1
V				0	0
Ti				0	0

SECTION III. POND DESCRIPTIONS

A. Location and General Description

[1] Pond Number 1

Markham Pond is located in Maplewood, approximately one block south of the intersection of Kennard Street and Beam Avenue. This natural shallow impoundment receives drainage from Maplewood Mall, Beam Avenue and Kohlman Creek.[61] In September, 2004 approximately two weeks before the sediment samples were collected, the average water depth was approximately 2 feet. One inlet and one outlet were located. The land use information was provided by the Ramsey Washington Metro Watershed District via Barr Engineering Company.

[2] Pond Number 2

The East Ring Pond is located in Golden Valley at the intersection of Laurel and Jersey Avenues. Based on the sewer maps provided, this pond receives flow from West Ring Pond and three storm sewers. In September 2004, one day before the sediment samples were collected, the average water depth was approximately 4.5 feet. Land use was extracted from GIS shape files provided by the City of Golden Valley via Barr Engineering Company.

[3] Pond Number 3.

The MNDOT Pond is located in Golden Valley just northeast of the intersection of Interstate Highway 394 and Highway 100. The pond can be accessed via Gleenwood Avenue, Lawn Terrace, and Colonial Drive. One inlet and one outlet were identified although the storm sewer map indicates a total of three inlets. In September 2004, one week before the sediment samples were collected, the average water depth was approximately 1.75 feet. Land use was extracted from GIS shape files provided by the City of Golden Valley via Barr Engineering Company.

[4] Pond Number 4

The pond is directly adjacent to Wirth Lake and is near the intersection of Olson Memorial Highway (55) and Theodore Wirth Parkway in Golden Valley. The pond is separated from the lake by a berm, which failed several years ago. When the sediment samples were collected (2004) stormwater flowed through the pond area in a small channel and discharged directly into the west side of the lake. Land use information was provided by the Bassett Creek Watershed Management Commission via Barr Engineering Company.

[5] Pond Number 5

Long Lake is located in Apple Valley, approximately 0.5 mile south of the intersection of Pilot Knob Road and McAndrews Road. Long Lake is west of Pilot Knob directly across from Farquar Lake. The sewer map indicates that Long Lake has six inlets (two were located) and one outlet to Farquar lake. In July of 2005, approximately two weeks before the sediment samples sere collected the average water depth was 3 feet. Land use information was provided by staff from the City of Apple Valley.

[6] Pond Number 6

Fish Lake is located in Eagan, east of Pilot Knob Road and approximately 0.5 mile north of the intersection of Pilot Knob Road and Wescott Road. A small section of the Lake on the east side was separated from the main water body with a shallow berm to form a stormwater pond. The pond can be accessed through Fish Lake Park, located on Denmark Avenue approximately 0.5 mile north of Wescott Road. Land use information was provided by staff of the City of Eagan.

In addition to the direct drainage to this pond, approximately 3,000 acres drain to the Fish Lake Pond through a series of upstream ponds. The land use for this upstream area is approximately 60% low density residential 4% medium & high density residential, 24% open, 4% commercial and 8% public.[62] The City of Eagan added alum to the flow coming from this area from 1998 to 2000. This was done to demonstrate that the phosphorus load to Fish Lake could be reduced. After alum addition, the flow passed through another small pond prior to discharging to the Fish Lake Pond.[63]

Note that the land use statistics for Fish Lake Pond summarized in TABLE 14 are for the direct discharge only. In July 2005, the average water depth was approximately 4 feet. At that time the top of the berm was completely visible. When the sediment samples were collected approximately three weeks later, the berm was completely submerged.

[7] Pond Number 7

Market Place Pond is located in Stillwater on Stillwater Boulevard approximately 0.25 mile north of the intersection of Highway 36 and Highway 5. A total of four inlets were located along with one outlet. Approximately 30% of the drainage area is located south of Highway 36 and the flow from the southern portion of the drainage area passes through Menards Pond prior to discharge to Market Place Pond.[64] In July 2005, approximately one month before the sediment samples were collected, the average water depth was approximately 6 feet. Land use information was provided by the Brown's Creek Watershed District via Emmons & Olivier Resources, Inc.

[8] Pond Number 8

Cedar Pond is located in Eagan on Diffley Road approximately 0.5 mile east of Highway 77. The sewer map indicates that two storm sewers discharge to the pond and there is one outlet – all structures were located. In July 2005, approximately one month before the sediment samples were collected, the average water depth was approximately 5.75 feet. Land use information was provided by staff of the City of Eagan.

[9] Pond Number 9

Locke Lake, which is located in Fridley, receives input from Rice Creek just before it discharges to the Mississippi River approximately 0.25 mile to the west. The west end of the lake is located just north of the intersection of East River Road and Rice Creek Way. A sediment basin was excavated at the east end of the lake in 1996/97. The sediment basin can be accessed through Fridley parkland at the intersection of Rice Creek Way and Ashton Avenue. In July 2005, one month before the sediment samples were collected from the sediment basin, the average water depth was approximately 4 feet. Land use was extracted from GIS shape files provided by the Rice Creek Watershed District via Emmons & Olivier Resources, Inc.

[10] Pond Number 10
This pond is located in Anoka between McKinley Street and the Burlington Northern railroad tracks just west of Shasta Avenue. It is identified locally as pond number 62. As per the sewer map, a total of three inlets and one outlet were located. In July 2005, five weeks before collecting the sediment samples, the average water depth was approximately 3.5 feet. A significant delta was observed near the southwest inlet. Land use was extracted from GIS shape files provided by the City of Anoka.

B. Land Use in Drainage Areas
The land use information for each of the sewer-sheds is summarized in TABLE 14. Although residential use it the most common, the reported land use varies significantly for the 10 sewer-sheds.

TABLE 14. LAND USE SUMMARY FOR POND DRAINIAGE AREAS.

Pond Number/Name	**1 – Markham Lake**	**2 - East Ring Pond***	**3 – MNDOT Pond**	**4 - Wirth Lake Pond**	**5 - Long Lake**	**6 - Fish Lake Pond (direct discharge only)**	**7 - Market Place Pond**	**8 - Cedar Pond**	**9 - Locke Lake Pond**	**10 – Anoka Pond 62**
Drainage Area – acres	3,557	366/45	100	348	996	94	817	1,317	115,299	152
% Low Density Residential	50	50/20	16	34	81	25	35	46	22	10
% Medium/High Density Residential	7	2	3	2		60	5	11	1	
% Commercial & Industrial	14	23/64	30	4		10	44	21	5	14
% Open & Undeveloped	20	1	5	44	14	5	9	22	54	20
% Institutional & Public Facility	6	4/1	1		5				2	16
% Roads & Railroads	1	4	45	5			7		3	19
% Open Water	2	2/5		11						21
% Agricultural									13	
% park, recreational, or preserve		14/10								

*Stormwater flows from West Ring Pond to East Ring Pond.
The tabulated values are for (total watershed)/(East Ring watershed).

SECTION IV. RESULTS

A. General

All of the data collected and generated during this project are presented in this section or in a series of appendices. Data summaries will generally be presented in the following paragraphs, except where an entire data set can be presented on a single page. All of the analytical data are summarized by pond in Appendix A. Note that all of the raw data can be accessed at the MCES web site. http://www.metrocouncil.org/environment/sediment

B. Field Data

The water temperature, pH of the sediment/water mixture, and the dissolved oxygen (DO) concentration at the sediment/water interface were determined in the field. All of these data are summarized in TABLE 15. Because the Wirth Lake Pond had been dewatered, no field data were available. Note that the pH meter malfunctioned on the first sampling trip (Markham Lake) and WTW monitor used to measure DO and temperature malfunctioned when Cedar Pond was being sampled and the temperatures could not be determined.

The field data do not appear to be unusual. The water temperatures reflect the season. The pH values fell in the 6 – 9 range which is not unusual for productive waters. The lower pH values were generally associated with lower DO values.

The locations of the sediment samples for each pond are illustrated in Figure 7 through Figure 16.

C. Physical Data

The concentration of volatile material in the sediments varied in the range of approximately 1% to 40% and the specific gravity varied in the range of 2.04 to 2.72. All of the sediment data are summarized in TABLE 16. The volatile content and specific gravity of the top soil samples fell within the ranges for the sediment samples. It appears that the specific gravity of the mineral material in all the sediment samples is approximately 2.65 – see Figure 17.

For most of the sites, the particle size distributions for the individual sediment samples varied significantly. All of the sieve data are summarized in Appendix B. The average particle size distributions for the 10 pond sites and the four top soil samples are presented in Figure 18. With the exception of Fish Lake Pond (number 6), the average pond sediments were all finer than the average top soil.

Based on the USGS particle size classification system, approximately 60% to 90% of the sediment material is sand. (0.05 to 2.00 mm). No attempt was made to characterize solids finer than a 200 sieve (0.074mm).

TABLE 15. FIELD DATA SUMMARY.

Pond & Date	Sample ID	GPS Coordinates	Temp – ^{o}C	pH	DO - mg/l
Markham Lake	1A	N45 01.471 W93 01.918	22.2		10.8
Sept 22, 2004	1B	N45 01.505 W93 01.922	21.8		10.9
	1C	N45 01.596 W93 01.889	21.7		14.2
	1D	N45 01.559 W93 01.961	21.9		10.9
	1E	N45 01.547 W93 02.032	22.0		9.4
East Ring Pond	2A	N44 58.521 W93 22.192	15.2	6.7	6.5
Sept 30, 2004	2B	N44 58.514 W93 22.172	15.6	6.8	7.4
	2C	N44 58.514 W93 22.150	15.2	6.9	7.3
	2D	N44 58.514 W93 22.125	15.8	6.9	6
	2E	N44 58.509 W93 22.097	15.8	6.7	6.8
MNDOT Pond	3A	N44 58.405 W93 20.561	12.4	6.8	11.4
Oct 6, 2004	3B	N44 58.408 W93 20.531	12.6	7.0	15.8
	3C	N44 58.370 W93 20.556	13.4	7.0	14.3
	3D	N44 58.361 W93 20.535	12.9	7.1	9.1
	3E	N44 58.428 W93 20.539	13.1	7.1	11.1
Wirth Lake Pond	4A	N44 58.850 W93 19.605			
Nov 3, 2004	4B	N44 58.851 W93 19.618			
	4C	N44 58.855 W93 19.629			
	4D	N44 58.858 W93 19.644			
	4E	N44 58.861 W93 19.661			
Long Lake	5A	N44 45.285 W93 10.477	22.1	7.0	7.2
July 19, 2005	5B	N44 45.375 W93 10.618	25.1	6.7	3.7
	5C	N44 45.431 W93 10.740	24.4	7.0	6.3
	5D	N44 45.384 W93 10.519	24.8	6.7	1.5
	5E	N44 45.405 W93 10.311	25.0	6.7	2.5
Fish Lake Pond	6A	N44 49.318 W93 09.627	23.6	7.0	4.0
July 26, 2005	6B	N44 49.294 W93 09.649	23.1	7.2	2.3
	6C	N44 49.310 W93 09.661	23.0	6.9	3.0
	6D	N44 49.321 W93 09.657	23.7	6.8	1.3
	6E	N44 49.307 W93 09.672	23.9	6.9	3.0
Market Place Pond	7A	N45 02.259 W92 50.562	21.4	7.1	0.3
Aug 2, 2005	7B	N45 02.294 W92 50.561	22.6	7.3	0.3
	7C	N45 02.305 W92 50.610	23.5	7.6	3.3
	7D	N45 02.322 W92 50.588	23.2	7.6	1.6
	7E	N45 02.352 W92 50.573	28.4	7.5	2.4
Cedar Pond	8A	N44 48.352 W93 12.749		7.1	1.4
Aug 9, 2005	8B	N44 48.344 W93 12.788		6.8	0.15
	8C	N44 48.330 W93 12.803		6.9	0.35
	8D	N44 48.322 W93 12.764		6.8	0.11
	8E	N44 48.313 W93 12.739		6.8	0.14
Locke Lake Pond	9A	N45 05.461 W93 16.218	20.8	7.7	2.5
Aug 16, 2005	9B	N45 05.473 W93 16.236	21.2	7.8	7.0
	9C	N45 05.493 W93 16.231	21.3	7.3	7.4
	9D	N45 05.516 W93 16.238	21.1	7.0	7.2
	9E	N45 05.493 W93 16.266	21.3	7.2	6.0
Anoka Pond 62	10A	N45 12.935 W93 24.330	22.0	9.3	11.8
Aug 30, 2005	10B	N45 12.945 W93 24.369	22.1	8.2	10.0
	10C	N45 12.930 W93 24.374	22.2	8.7	11.9
	10D	N45 12.910 W93 24.344	21.9	8.4	1.9
	10E	N45 12.898 W93 24.312	21.9	8.3	6.3

Figure 7. Sample Locations for Site Number 1 – Markham Lake

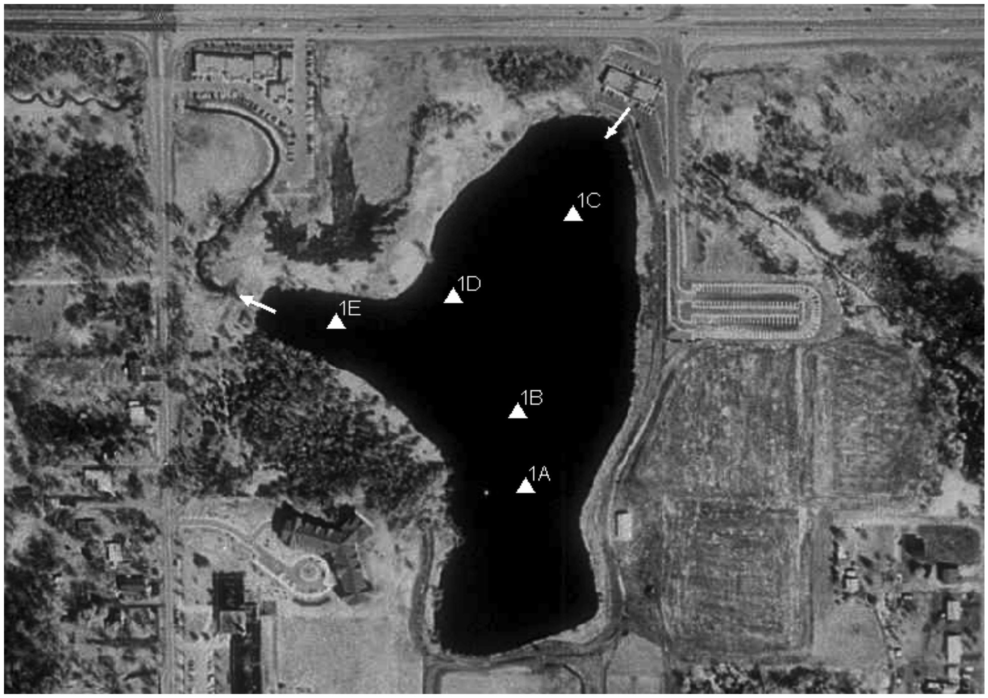


Figure 8. Sample Locations for Site Number 2 – East Ring Pond

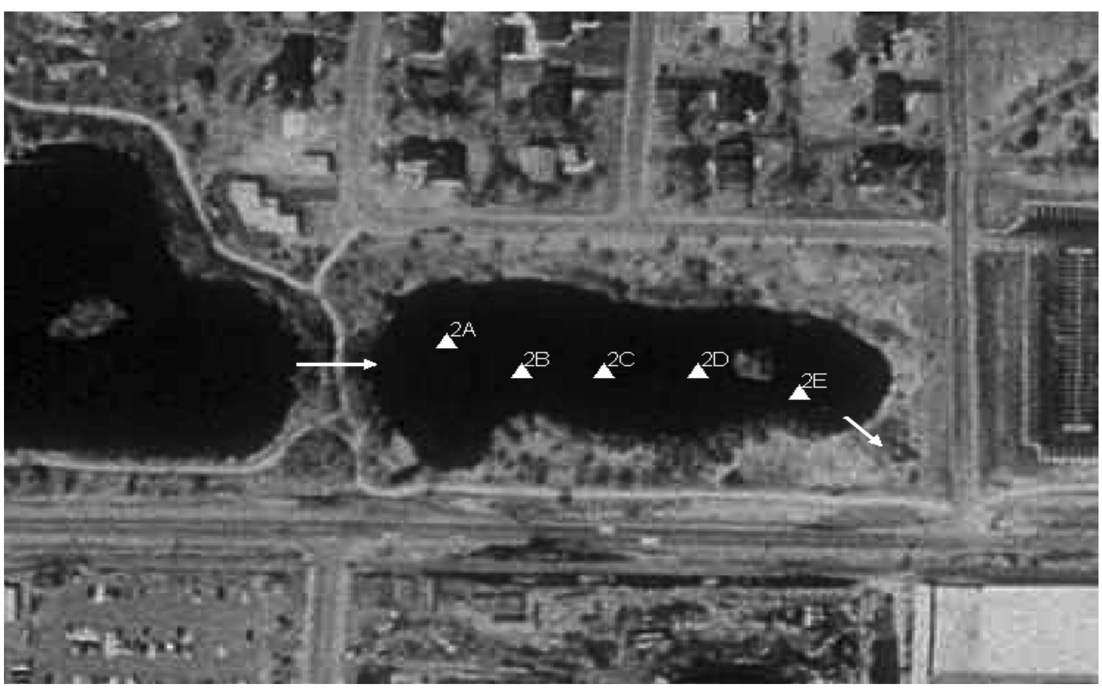


Figure 9. Sample Locations for Site Number 3 – MNDOT Pond

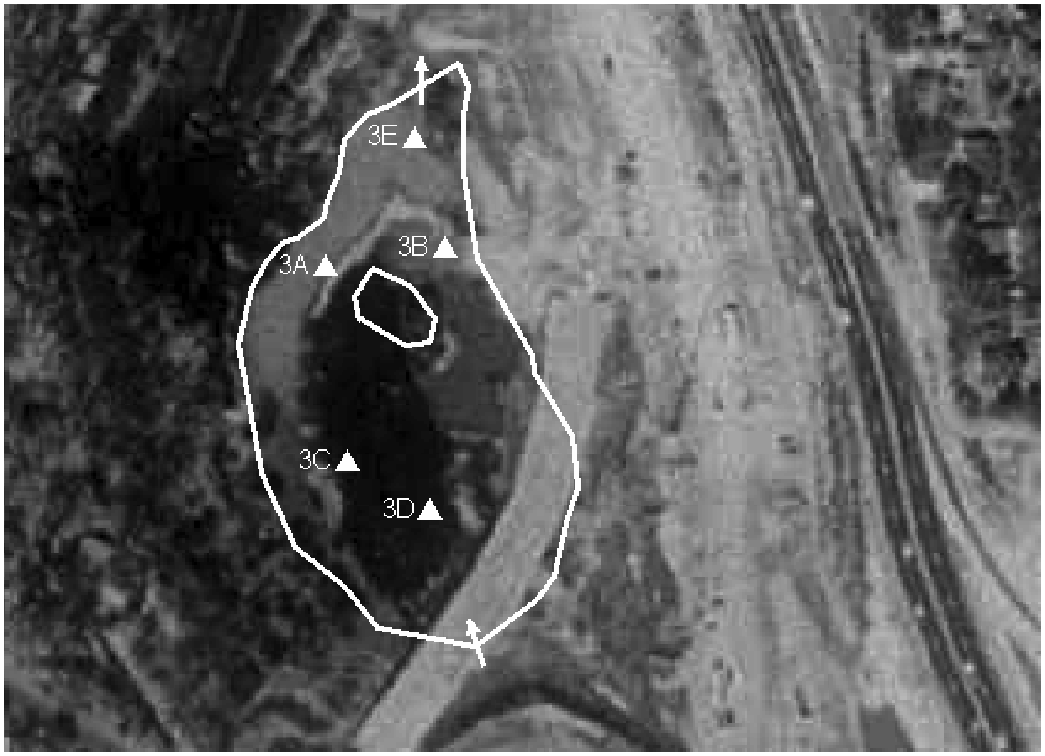


Figure 10. Sample Locations for Site Number 4 - Wirth Lake Pond

Figure 11. Sample Locations for Site Number 5 – Long Lake

Figure 12. Sample Locations for Site Number 6 – Fish Lake Pond

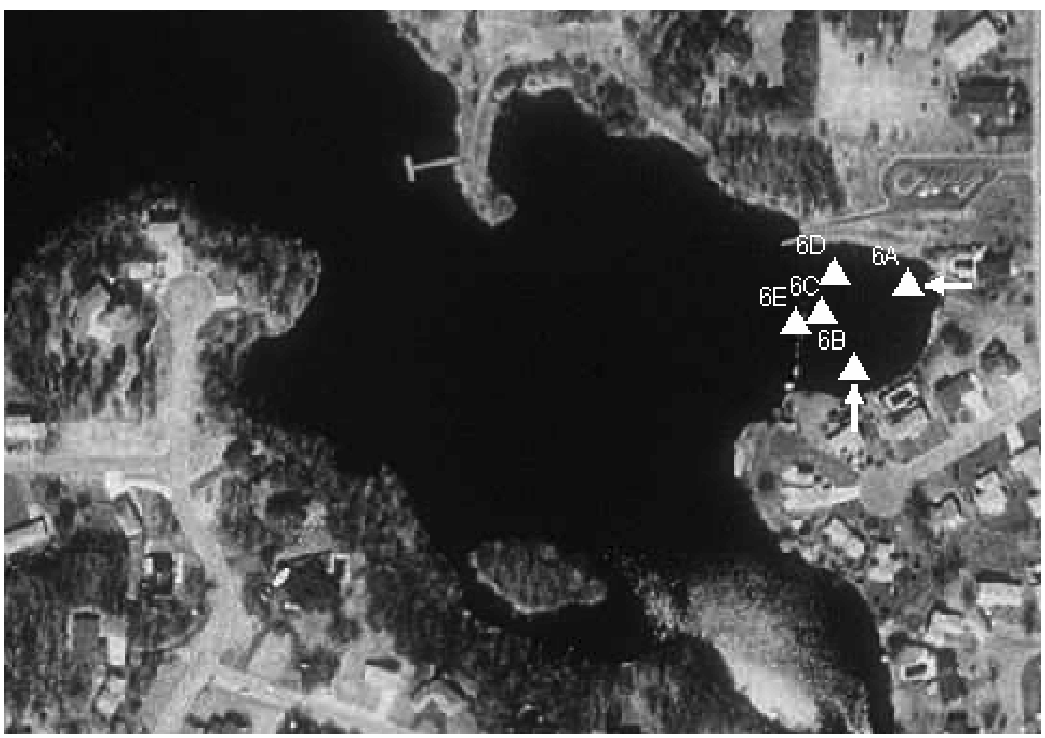


Figure 13. Sample Locations for Site #7 – Market Place Pond

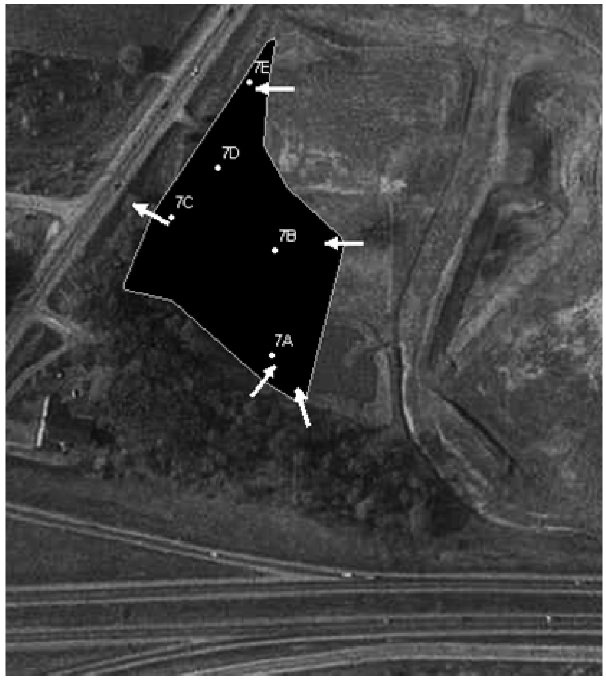


Figure 14. Sample Locations for Site #8 – Cedar Pond

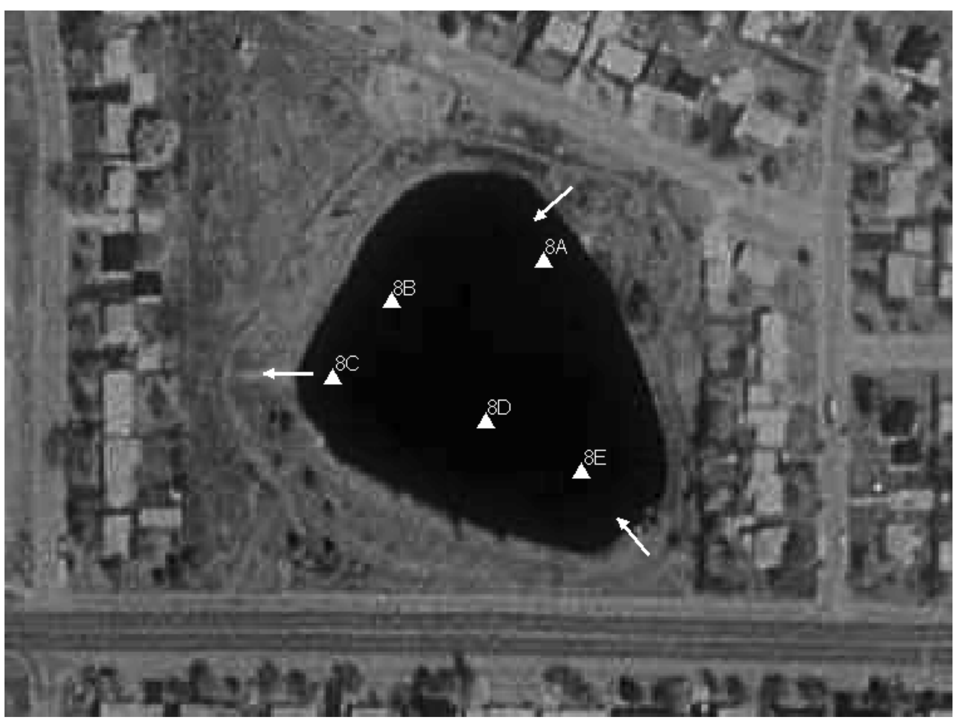


Figure 15. Sample Locations for Site #9 – Locke Lake

Figure 16. Sample Locations for Site #10 – Anoka Pond 62

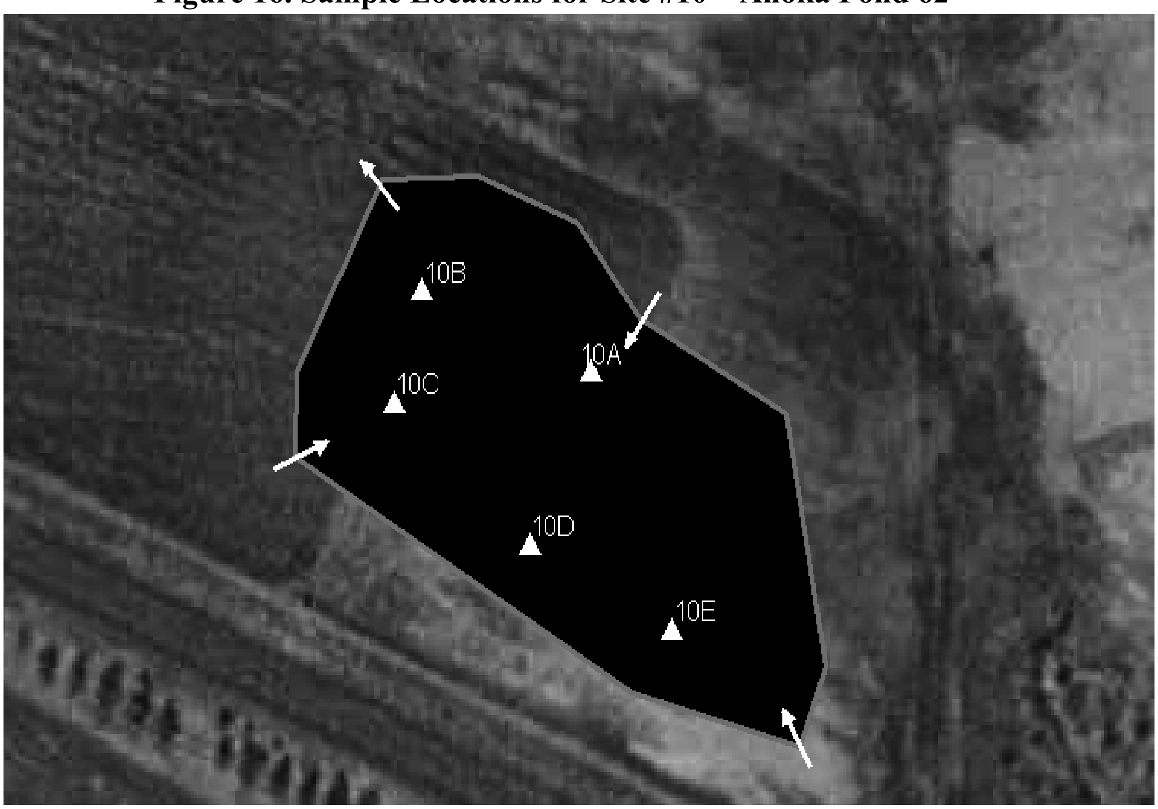


TABLE 16. PHYSICAL DATA SUMMARY

Pond	Core ID	TVS - %	SpG	Pond	Core ID	TVS - %	SpG
Markham Lake	1A1	2.9	2.45	Fish Lake Pond	6A1	2.4	2.68
	1A2	6.4			6A2	1.9	
	1B1	4.7	2.52		6B1	1.1	2.72
	1B2	2.9			6B2	1.3	
	1C1	7.7	2.47		6C1	7.6	2.60
	1C2	8.5			6C2	9.2	
	1D1	7.7	2.47		6D1	6.4	2.63
	1D2	5.0			6D2	5.1	
	1 E1	13.4	2.29		6 E1	7.4	2.59
	1 E2	11.2			6 E2	9.4	
East Ring Pond	2A1	33.9	2.04	Market Place Pond	7A1	5.3	2.63
	2A2	36.0			7A2	5.1	
	2B1	21.5	2.29		7B1	5.6	2.64
	2B2	20.5			7B2	3.7	
	2C1	35.8	2.06		7C1	6.0	2.60
	2C2	40.5			7C2	6.7	
	2D1	14.8	2.31		7D1	8.8	2.66
	2D2	11.3			7D2	6.7	
	2 E1	23.1	2.20		7 E1	8.0	2.57
	2 E2	23.9			7 E2	3.7	
MNDOT Pond	3A1	35.3	2.12	Cedar Pond	8A1	4.0	2.63
	3A2	32.5			8A2	4.7	
	3B1	23.0	2.37		8B1	11.2	2.48
	3B2	23.4			8B2	11.8	
	3C1	33.3	2.13		8C1	5.8	2.58
	3C2	37.1			8C2	3.2	
	3D1	31.3	2.20		8D1	11.2	2.51
	3D2	38.7			8D2	11.3	
	3 E1	19.1	2.21		8 E1	8.9	2.54
	3 E2	12.9			8 E2	8.0	
Wirth Lake Pond	4A1	14.7	2.49	Locke Lake Pond	9A1	0.6	2.65
	4A2	15.3			9A2	0.7	
	4B1	14.8	2.52		9B1	0.8	2.65
	4B2	17.5			9B2	0.9	
	4C1	18.1	2.47		9C1	11.1	2.50
	4C2	19.2			9C2	5.9	
	4D1	10.6	2.53		9D1	10.7	2.41
	4D2	9.2			9D2	10.6	
	4 E1	3.9	2.62		9 E1	3.2	2.64
	4 E2	5.5			9 E2	2.6	
Long Lake	5A1	11.2	2.44	Anoka Pond 62	10A1	0.9	2.64
	5A2	8.9			10A2	1.2	
	5B1	13.9	2.43		10B1	1.3	2.60
	5B2	14.2			10B2	0.9	
	5C1	4.5	2.58		10C1	1.7	2.64
	5C2	3.7			10C2	1.8	
	5D1	26.8	2.17		10D1	1.5	2.27
	5D2	18.6			10D2	2.0	
	5 E1	15.3	2.38		10 E1	1.5	2.62
	5 E2	15.1			10 E2	1.1	

Figure 17. Impact of Volatile Content on Specific Gravity of Sediments

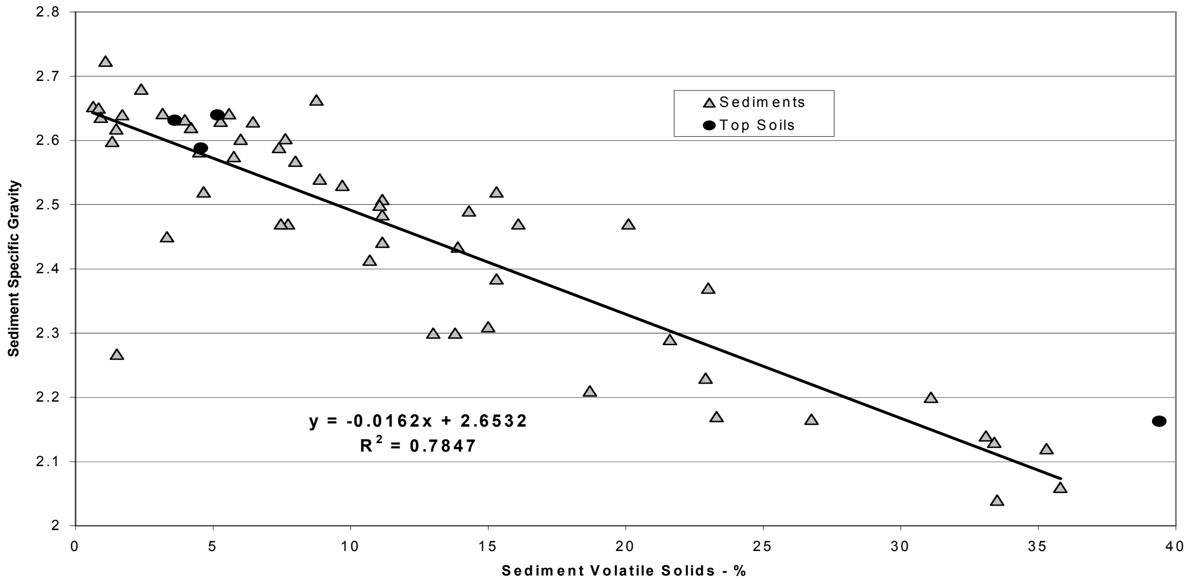
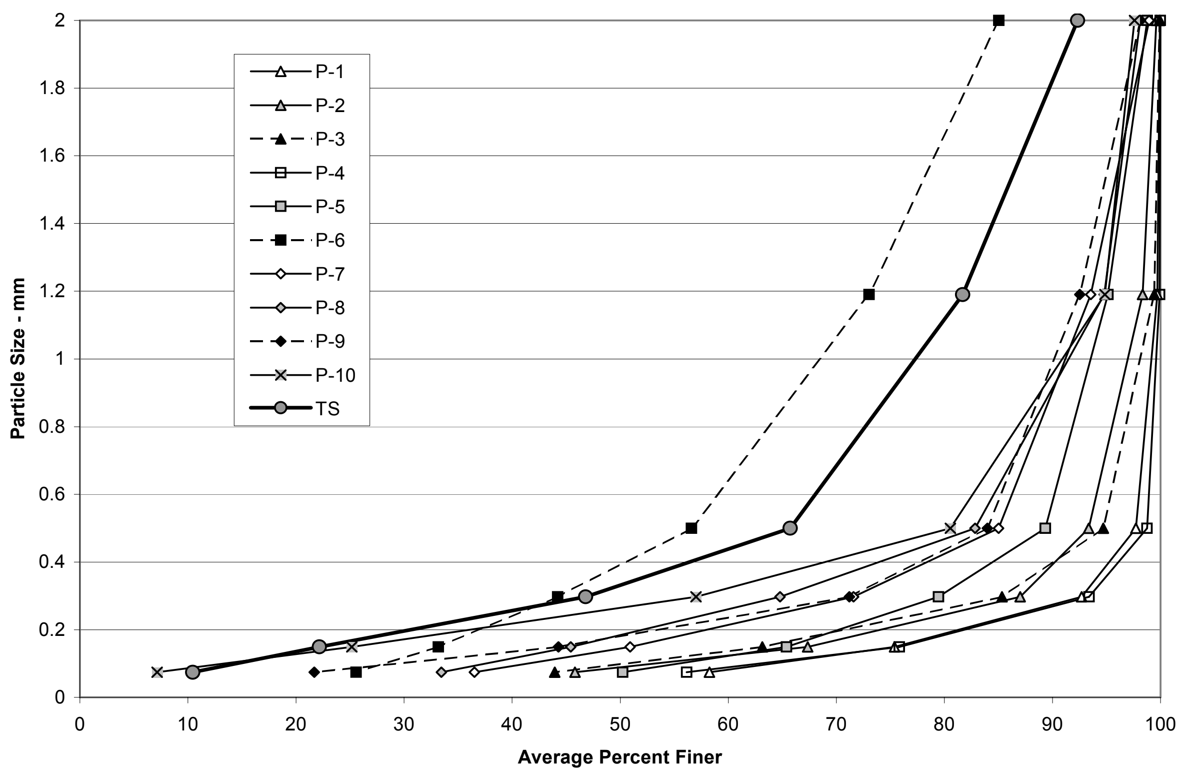


Figure 18. Average Particle Size Distributions



C. Chemical Analyses

[1] Nutrients

All of the nutrient data are presented in Appendix C and are summarized in TABLE 17. The nutrient content of the sediments collected from nine of the ten sites fell within the expected range but on the low end of the range (see TABLE 2 and TABLE 3 for ranges). For the last site (Anoka Pond 62) the concentrations were significantly lower.

TABLE 17. AVERAGE NUTRIENT CONCENTRATIONS*

Sample	TKN	TP	NH_3-N	NO_3-N	NO_2-N
Markham Lake	1,326	405	62	<0.65	<0.65
East Ring Pond	7,275	467	133	0.97	<0.65
MNDOT Pond	4,928	519	201	1.17	<0.65
Wirth Lake Pond	2,342	601	66	1.29	<0.65
Long Lake	5,176	495	184	<0.65	<0.65
Fish Lake Pond	1,385	470	63	<0.65	<0.65
Market Place Pond	1,089	588	84	<0.65	<0.65
Cedar Pond	2,753	776	211	<0.65	<0.65
Locke Lake Pond	2,300	568	116	<0.65	<0.65
Anoka Pond 62	285	328	25	<0.65	<0.65
Top Soil 1	1,800	500	26	15.6	<0.65
Top Soil 2	1,750	420	32	3.0	<0.65
Top Soil 3	1,400	520	25	18.3	<0.65
Top Soil 4	12,500	585	46	33.3	<0.65
All Sediments	2,963	534	116		<0.65
All Top soils	1,607	565	109	17.6	<0.65

* mg/kg

[2] Metals & TCLP

The mercury concentration in the sediments and top soils varied in the range of approximately 5 ug/kg to150 ug/kg. All of the data are presented in TABLE 18. Although there was considerable variation in the mercury concentrations within and between ponds, it appears that the average concentration for each pond is not significantly different than the average for the top soils – see Figure 19.

The average metal concentrations for the ponds and top soils are summarized in TABLE 19. In general, the ratio of the pond to top soil concentrations varied in the range of 0.8 to 6. Only manganese, molybdenum, and selenium fell outside this range. Schueler found that the ratio of pond to parent soil concentrations fell in the range of 5 to 30 for metals.[24] In addition, the average concentrations fall on the low end of the ranges presented in

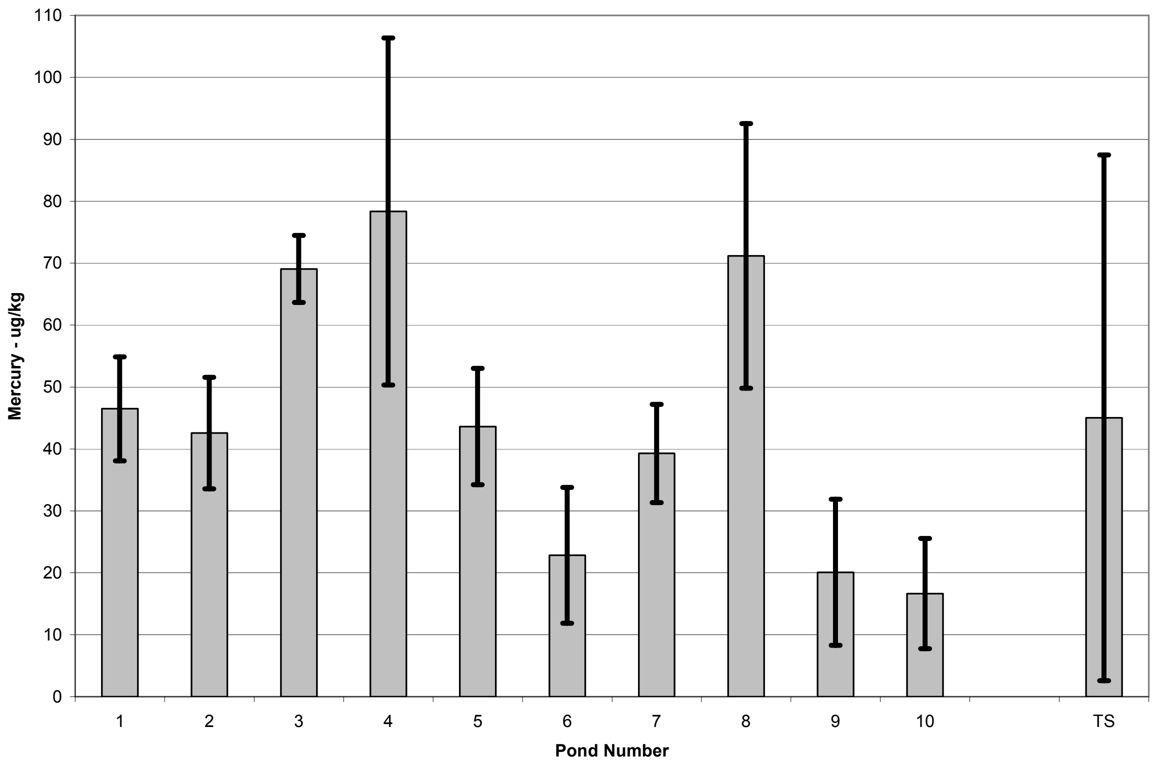
TABLE 2 and TABLE 3. Figure 20 through Figure 32 illustrate the within and between pond variability for the individual metals.

TABLE 18. MERCURY CONCENTRATION DATA*

Sample ID	Hg	Sample ID	Hg	Sample ID	Hg
Markham Lake A1	20	Long Lake A1	37	Locke Lake Pond A1	4
A2	48	A2	34	A2	4
B1	43	B1	40	B1	4
B2	28	B2	39	B2	5
C1	51	C1	29	C1	50
C2	44	C2	27	C2	26
D1	38	D1	76	D1	46
D2	42	D2	63	D2	41
E1	68	E1	45	E1	11
E2	56	E2	46	E2	10
East Ring Pond A1	54	Fish Lake Pond A1	13	Anoka Pond 62 A1	6
A2	47	A2	7	A2	6
B1	45	B1	3	B1	7
B2	25	B2	3	B2	8
C1	59	C1	55	C1	22
C2	61	C2	27	C2	28
D1	23	D1	41	D1	25
D2	22	D2	34	D2	29
E1	45	E1	13	E1	24
E2	44	E2	31	E2	11
MNDOT Pond A1	65	Market Place Pond A1	32	Top Soil 1	24
A2	61	A2	30	Top Soil 2	22
B1	75	B1	38	Top Soil 3	110
B2	70	B2	33	Top Soil 4	24
C1	88	C1	56		
C2	74	C2	55		
D1	69	D1	56		
D2	56	D2	36		
E1	68	E1	38		
E2	64	E2	18		
Wirth Lake Pond A1	146	Cedar Pond A1	18		
A2	146	A2	91		
B1	87	B1	102		
B2	89	B2	100		
C1	70	C1	33		
C2	106	C2	19		
D1	48	D1	103		
D2	47	D2	92		
E1	18	E1	76		
E2	25	E2	76		

* ug/kg

Figure 19. Mercury Concentrations – Averages and 95% Confidence Intervals



In its hazardous waste rules, the MPCA defines a waste as toxic if, when extracted using the prescribed method, the concentration of any of 40 constituents (8 metals and 32 organic compounds) meets or exceeds the limits set forth in Minnesota Rule 7045.0131 subpart 8. The extraction procedure is commonly called the toxicity characteristic leaching procedure (TCLP). The limits for the eight metals are as follows.

- Arsenic – 5 mg/l
- Barium – 100 mg/l
- Cadmium - 1 mg/l
- Chromium – 5 mg/l
- Lead – 5 mg/l
- Mercury – 0.2 mg/l
- Selenium – 1 mg/l
- Silver – 5 mg/l

The metal concentration in the 50 sediment extracts and four soil extracts were all well below the limits.

TABLE 19. AVERAGE METAL CONCENTRATIONS FOR PONDS AND TOP SOILS*

Pond	Cu	Ni	Pb	Zn	Cd	Cr	Al	As	Fe	Mn	Mo	Se**	Ti	V
1	23.6	15.3	52.7	104	1.04	17.7	6,521	3.9	15,367	670	0.99	<2.0	374	25.6
2	19.6	14.1	36.9	143	1.42	10.5	4,542	11.1	15,375	1165	3.74	2.61	292	18.8
3	43.1	22.3	69.4	200	1.40	24.9	9,804	12.0	38,406	1432	1.83	3.30	306	36.2
4	24.7	20.3	88.6	123	0.99	18.3	7,024	6.0	13,181	1169	0.59	4.84	382	29.5
5	30.1	19.4	14.7	84.3	0.74	24.2	13,095	3.9	15,907	308	0.30	<2.0	461	43.6
6	20.1	16.5	19.3	73.9	0.58	18.7	8,870	2.9	15,443	303	< 0.4	<2.0	434	36.6
7	33.7	23.5	26.7	112	0.76	31.8	15,760	3.8	21,391	213	<0.4	<2.0	683	55.4
8	26.5	24.5	79.9	128	0.94	27.0	15,799	7.2	17,211	252	0.370	<2.0	419	47.3
9	13.3	9.0	12.9	84.1	0.47	12.1	4,716	3.3	9,209	387	<0.4	<2.0	311	21.9
10	18.8	28.0	7.6	68.2	0.51	9.7	6,167	2.4	8,934	847	<0.4	<2.0	283	21.2
TS	9.8	10.6	7.5	63.4	0.43	9.6	5,581	2.0	9,358	395	1.72	0.27	222	21.0

* mg/kg
** all selenium data are suspect

Figure 20. Copper Concentrations – Averages and 95% Confidence Intervals

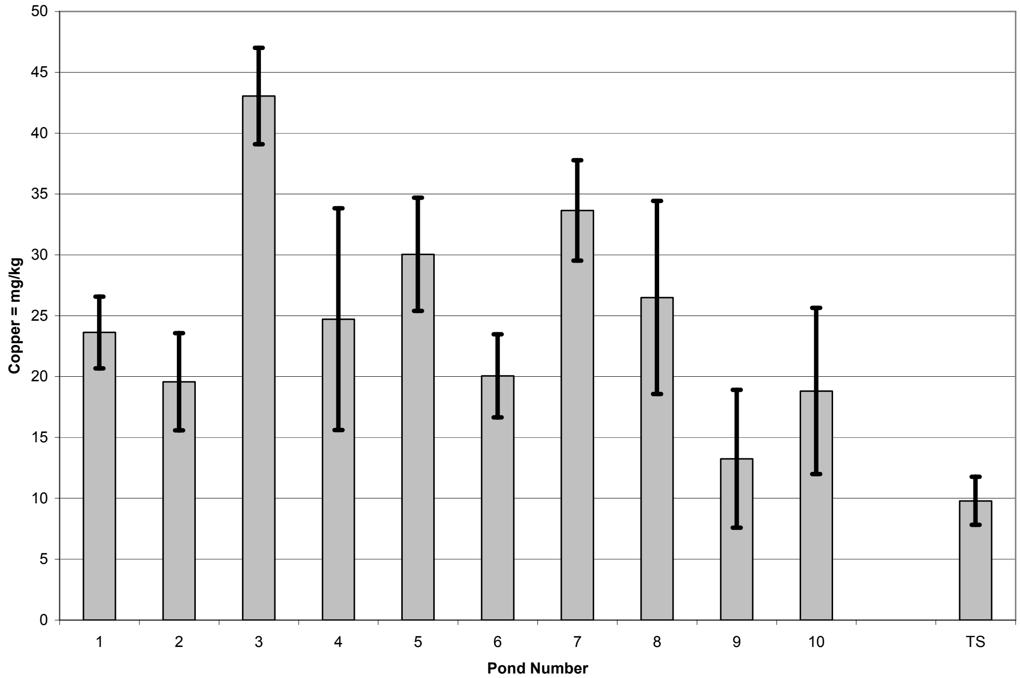


Figure 21. Nickel Concentrations - Averages and 95% Confidence Interval

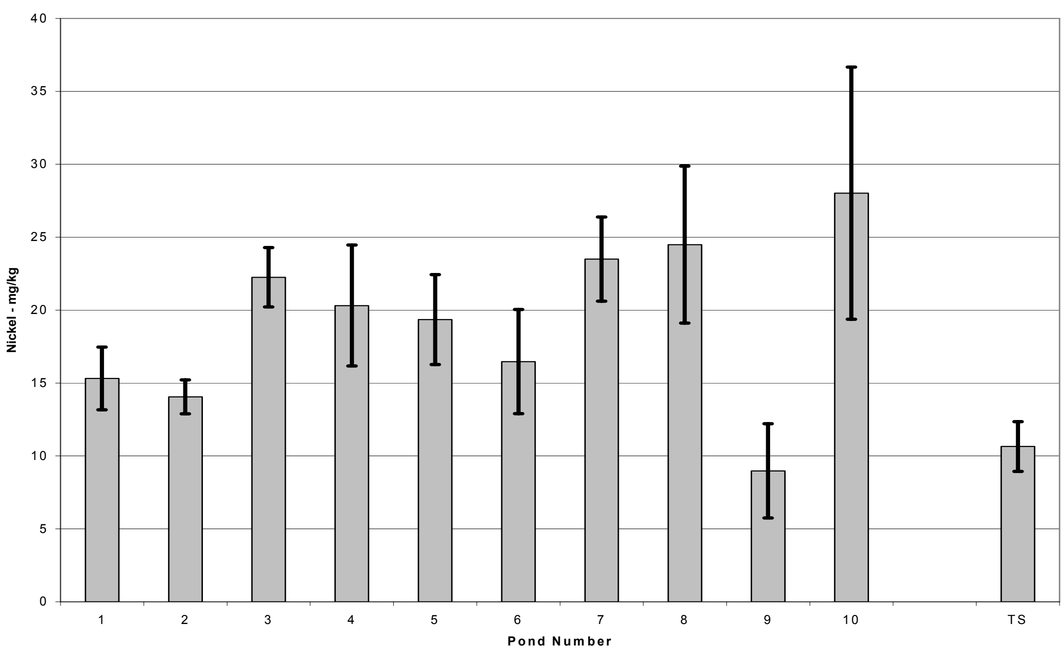


Figure 22. Lead Concentrations– Averages and 95% Confidence Intervals

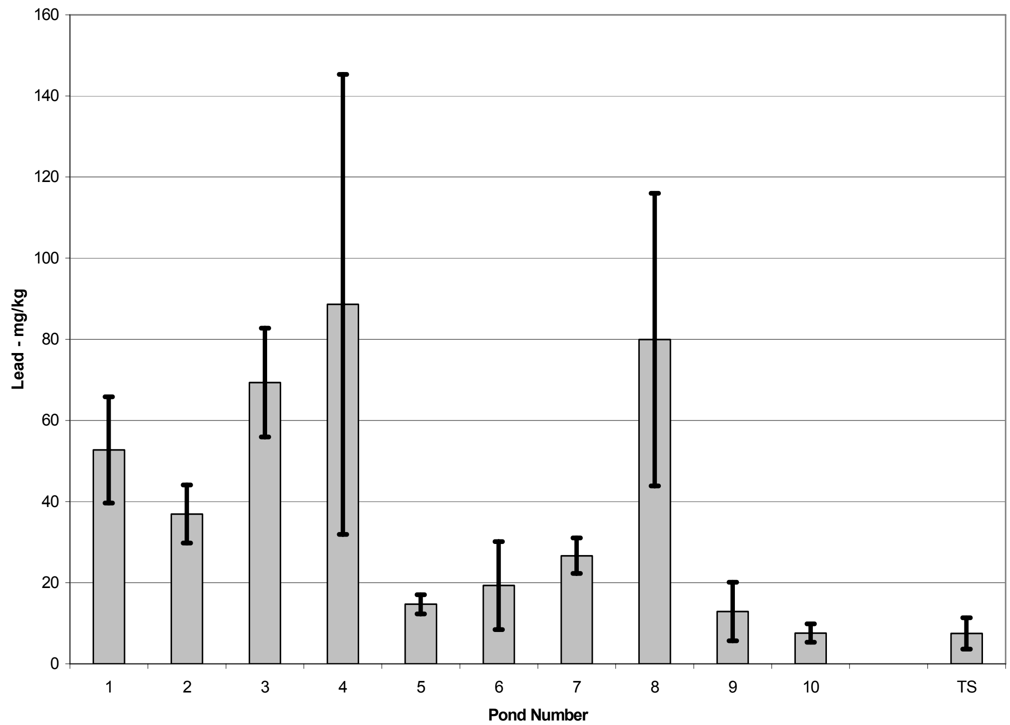


Figure 23. Zinc Concentrations - Averages and 95% Confidence Intervals

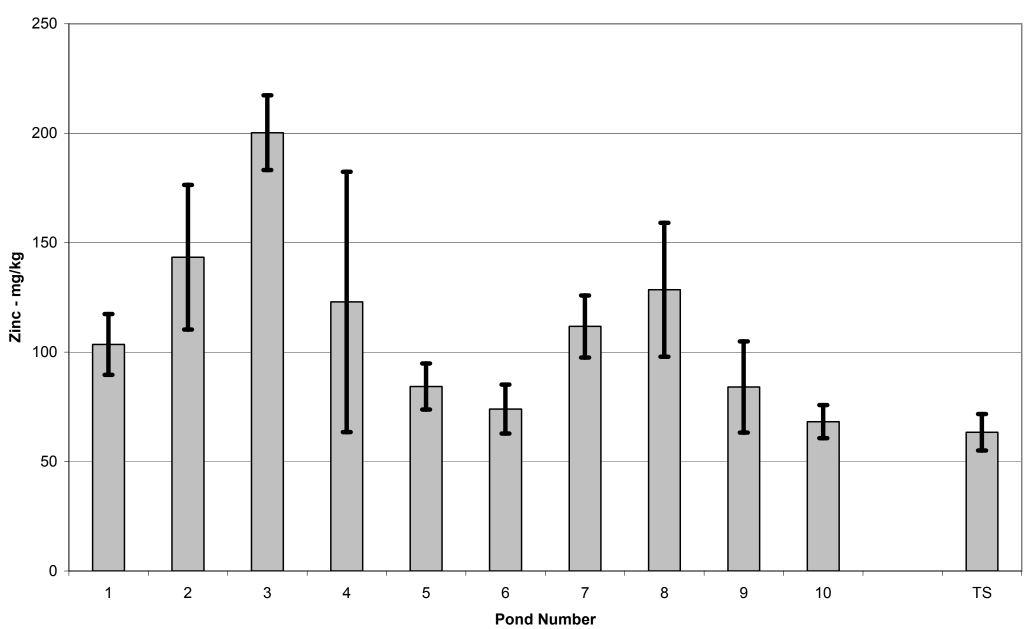


Figure 24. Cadmium Concentrations – Averages and 95% Confidence Intervals

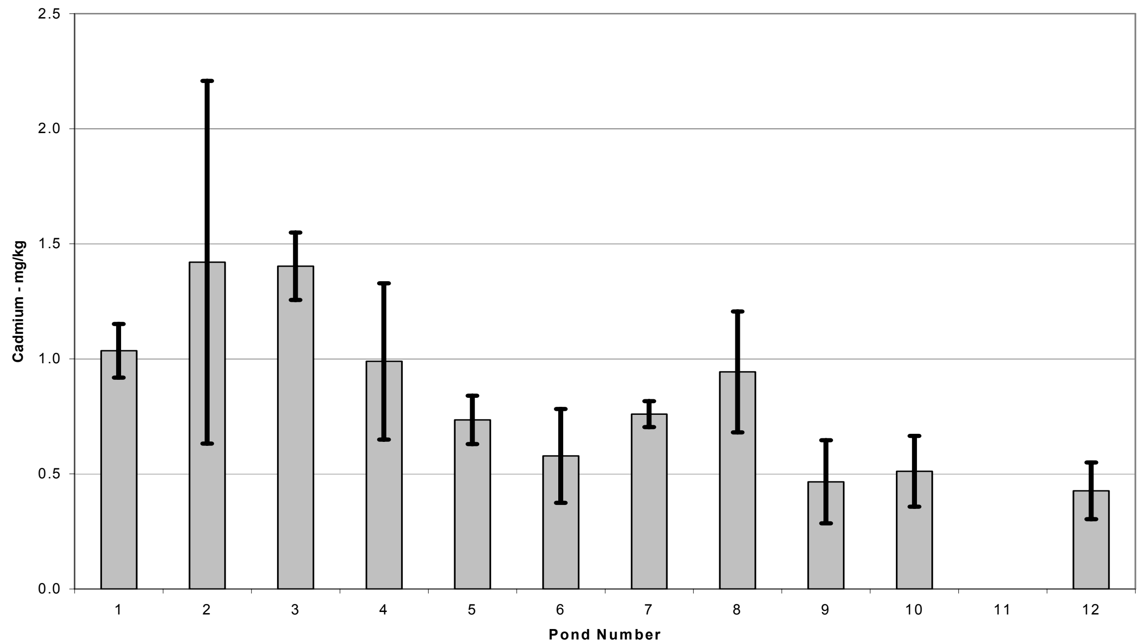


Figure 25. Chromium Concentrations – Averages and 95% Confidence Intervals

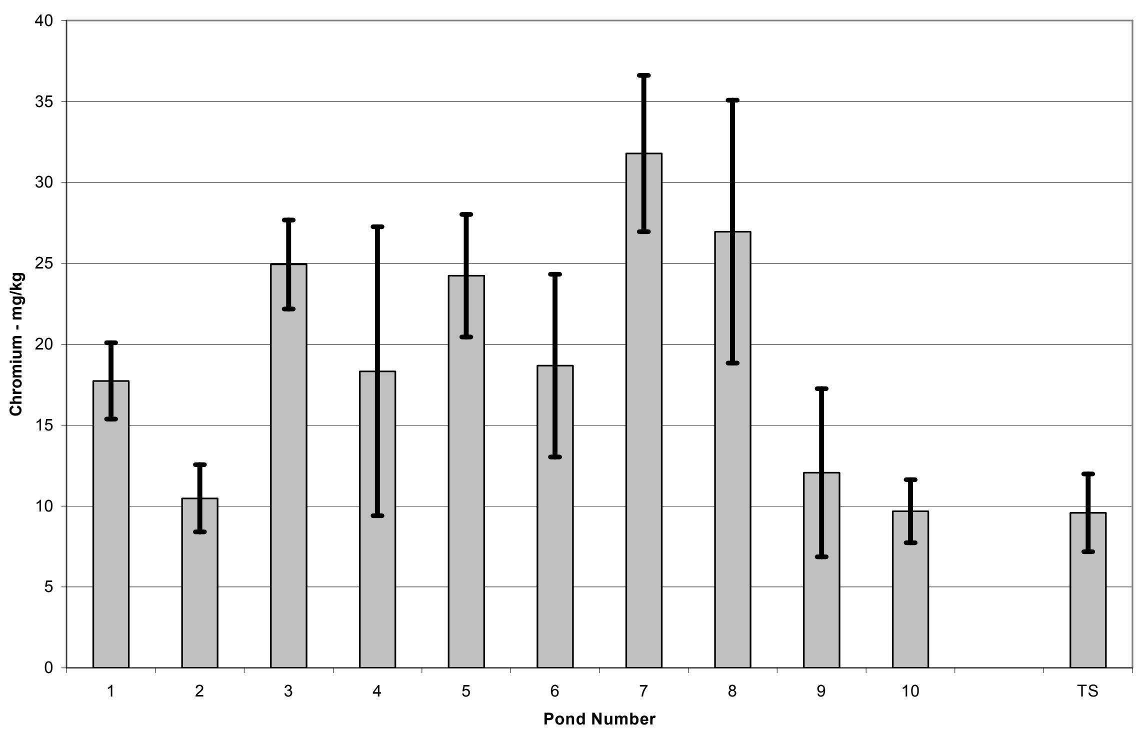


Figure 26. Aluminum Concentrations – Averages and 95% Confidence Intervals

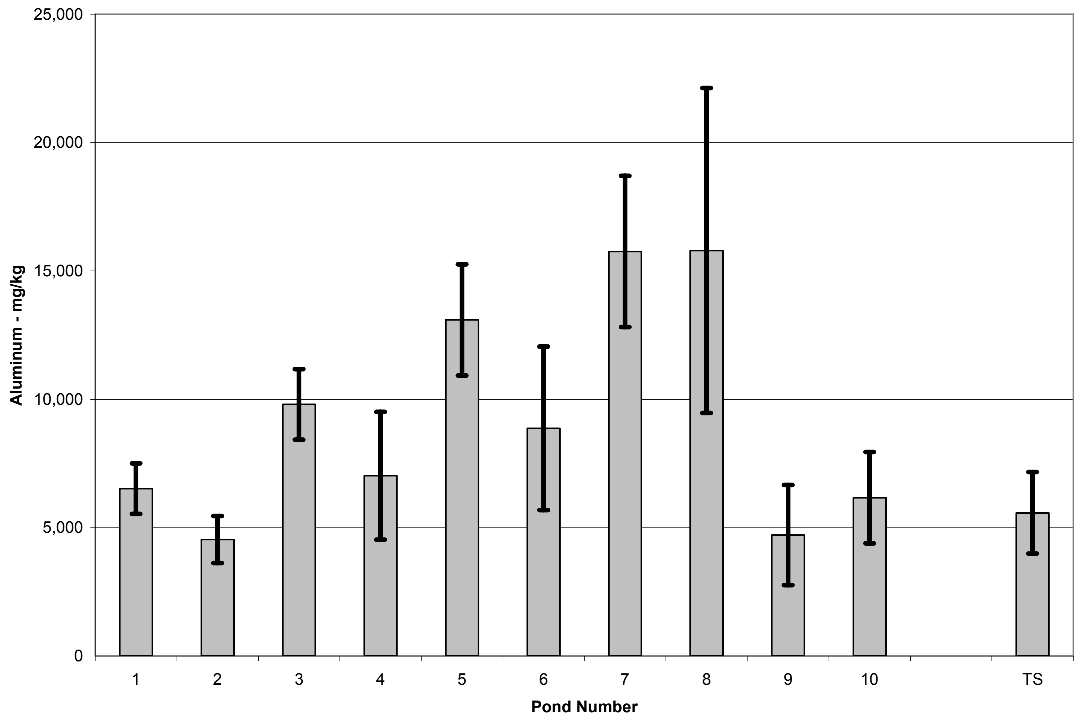


Figure 27. Arsenic Concentrations – Averages and 95% Confidence Intervals

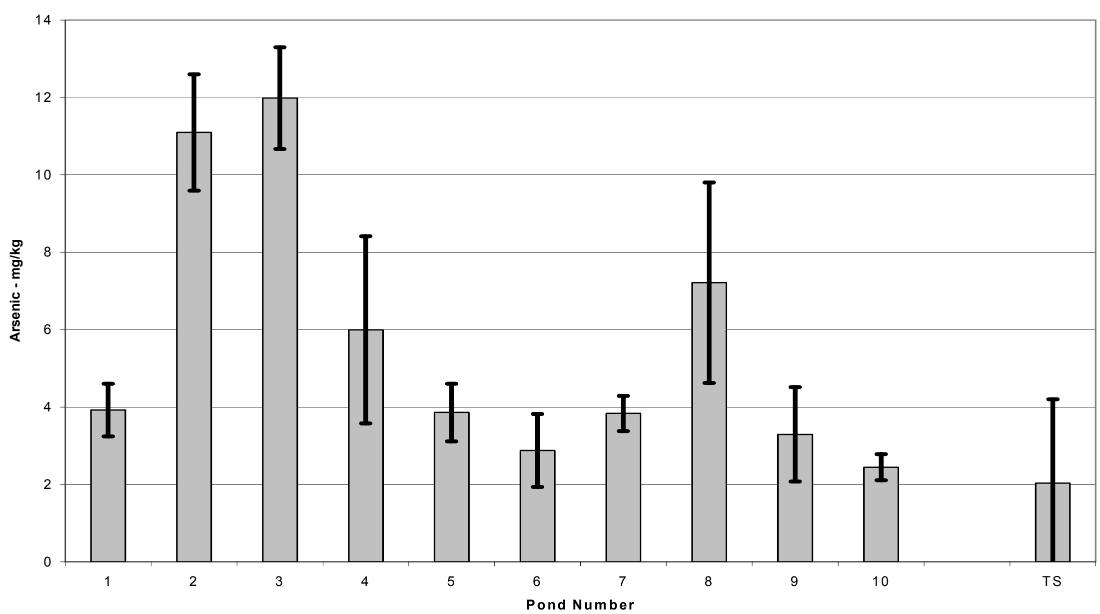


Figure 28. Iron Concentrations – Averages and 95% Confidence Intervals

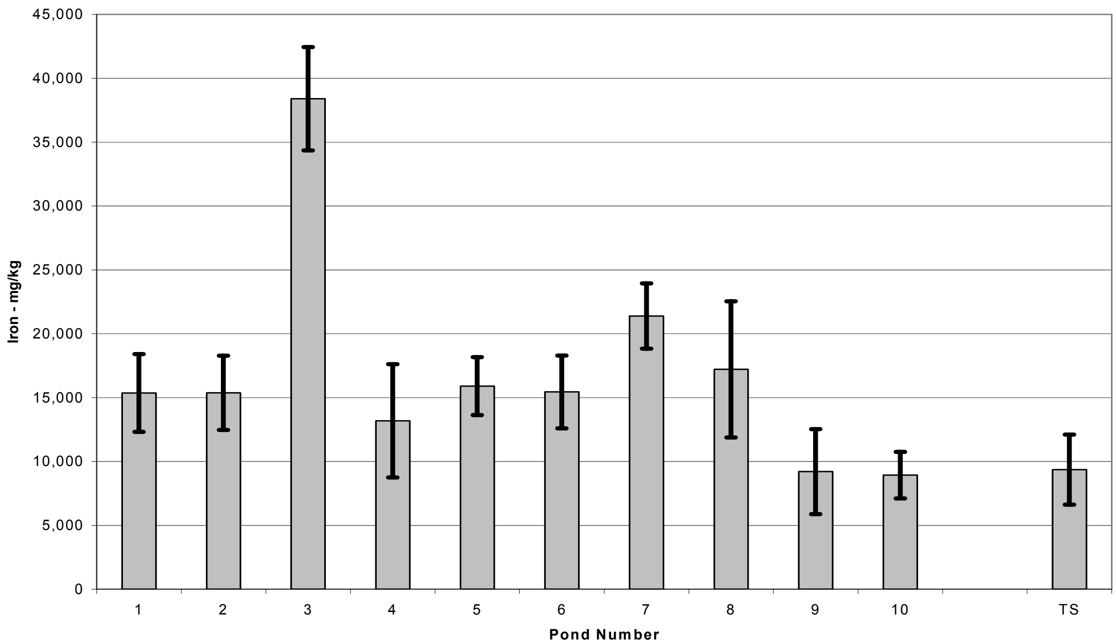


Figure 29. Manganese Concentrations – Averages and 95% Confidence Intervals

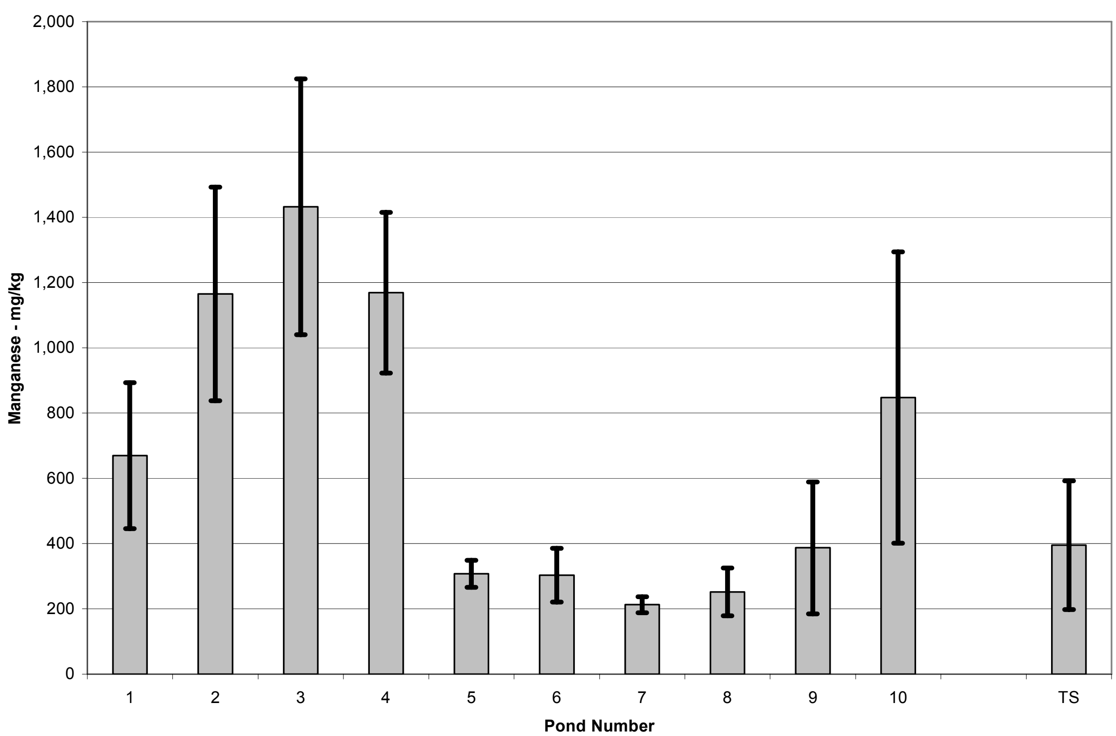


Figure 30. Molybdenum Concentrations – Averages and 95%b Confidence Intervals

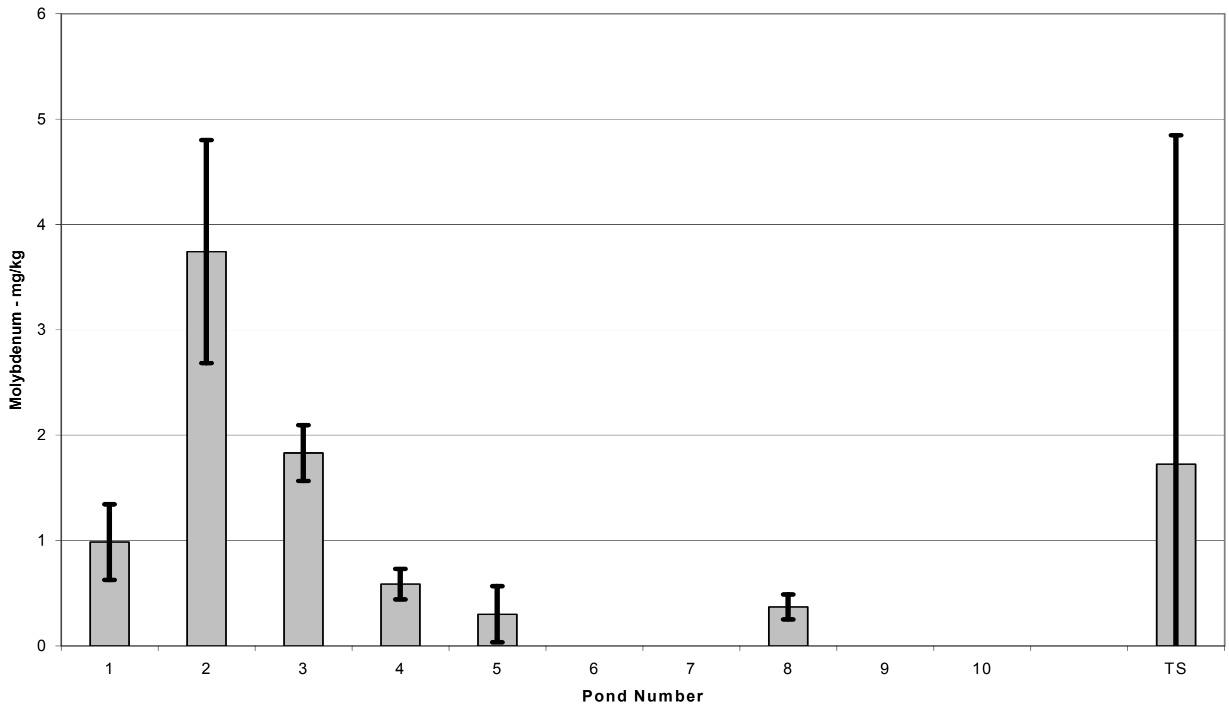


Figure 31. Titanium Concentrations – Averages and 95% Confidence Intervals

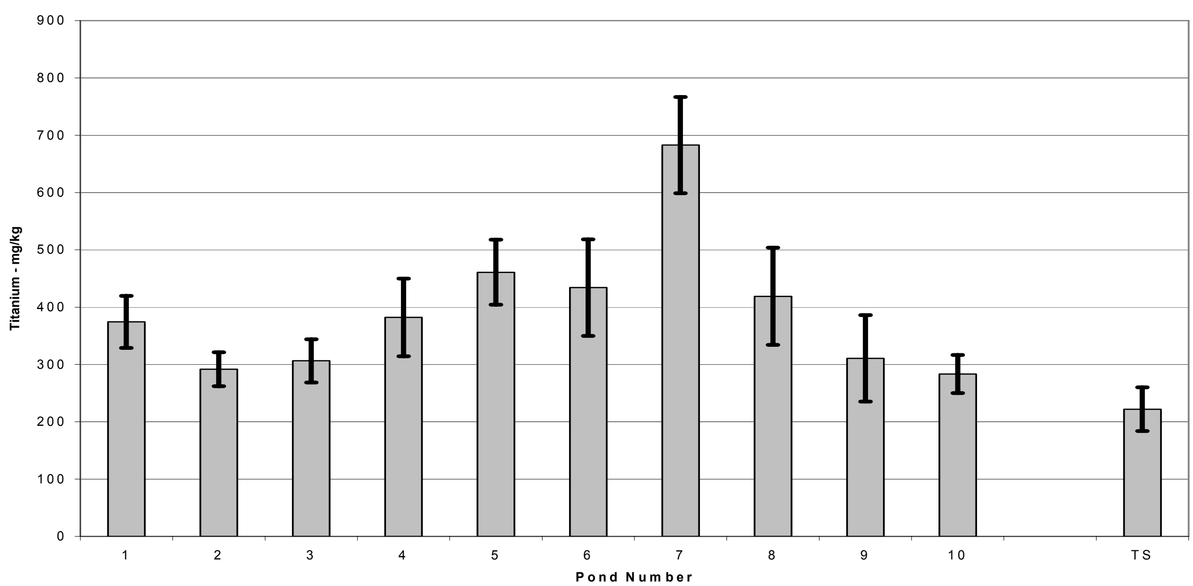
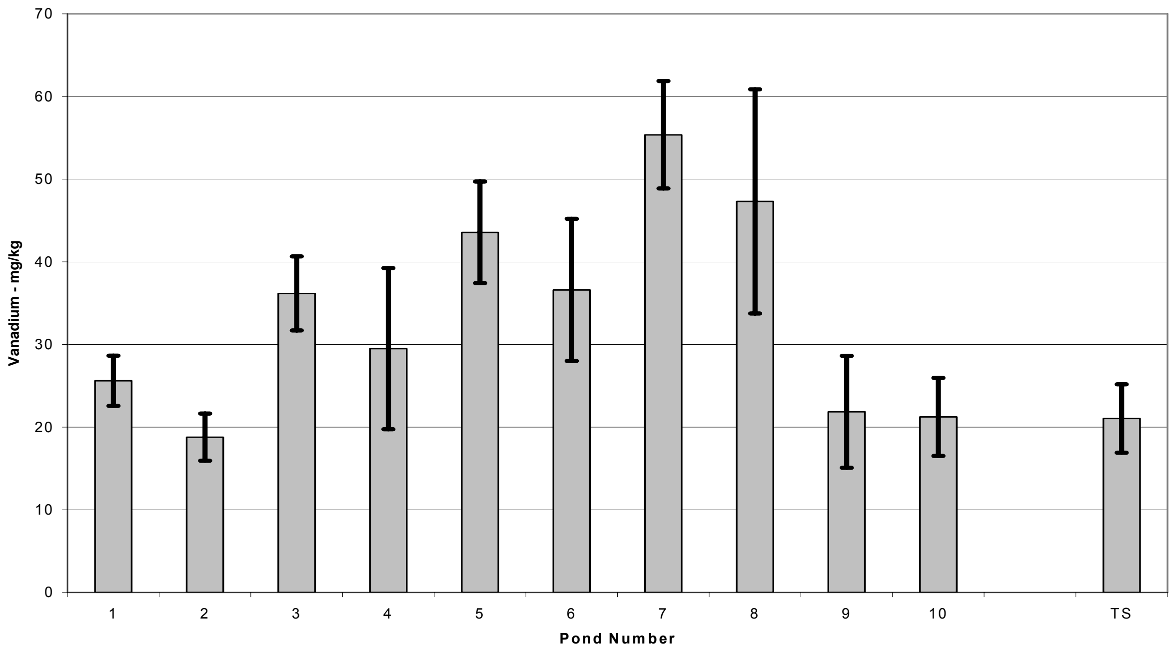


Figure 32. Vanadium Concentrations – Averages and 95% Confidence Intervals



[3] Organics

[a] Total Polychlorinated Biphenyls

The PCB concentration of the sediments was generally low – see TABLE 20. A total of 40 of the 50 sediment samples, as well as the four soil samples, had concentrations below the detection limit of approximately 20 ug/kg.

[b] Polycylic Aromatic Hydrocarbons

The PAH analytical protocol addressed a total of 43 compounds and all of the data are presented in Appendix D. However, the summary information presented here is focused on the 13 compounds for which the MPCA has developed sediment quality targets.[67] It is, however, interesting to note that the Σ PAH_{43} and Σ PAH_{13} are highly correlated – see Figure 33. Also note that the USGS work on parking lot runoff used this same set of 13 compounds - see TABLE 5.

The average value for Σ PAH_{43} and Σ PAH_{13} for each pond and top soil was determined and the results are summarized in TABLE 22. For the sediments, four compounds (fluoranthene, pyrene, benzo(a)anthracene, and chrysene) on average accounted for approximately 67% of the Σ PAH_{13}. The minimum and maximum values for Σ PAH_{13} were 121 ug/kg (core 5A1) and 65,764 ug/kg (core 8A1) respectively. The average value for Σ PAH_{13} for all of the sediments was 11,013 ug/kg.

TABLE 20. PCB DATA

Pond	Core	Total PCB - mg/kg	Pond	Core	Total PCB - mg/kg
Markham Lake	1A1	<0.017	Market Place Pond	7A1	<0.019
	1B1	<0.017		7B1	<0.019
	1C1	0.019		7C1	<0.020
	1D1	<0.017		7D1	<0.019
	1E1	<0.017		7E1	<0.020
East Ring Pond	2A1	<0.020	Cedar Pond	8A1	<0.020
	2B1	<0.021		8B1	0.099
	2C1	<0.021		8C1	<0.019
	2D1	<0.020		8D1	0.096
	2E1	<0.020		8E1	0.107
MNDOT Pond	3A1	<0.022	Locke Lake Pond	9A1	<0.020
	3B1	<0.021		9B1	<0.020
	3C1	<0.044		9C1	0.0735
	3D1	<0.021		9D1	0.081
	3E1	<0.021		9E1	0.023
Wirth Lake Pond	4A1	0.073	Anoka Pond 62	10A1	<0.004
	4B1	0.025		10B1	<0.020
	4C1	0.123		10C1	<0.019
	4D1	<0.021		10D1	<0.018
	4E1	<0.038		10E1	<0.016
Long Lake	5A1	<0.015	Top Soils	1	<0.018
	5B1	<0.016		2	<0.019
	5C1	<0.016		3	<0.019
	5D1	<0.017		4	<0.019
	5E1	<0.016			
Fish Lake Pond	6A1	<0.004			
	6B1	<0.004			
	6C1	<0.020			
	6D1	<0.018			
	6E1	<0.020			

[c] Gasoline Range Organics

As previously discussed, only four of the 10 planned GRO analyses were conducted – one sediment sample from each of the first four ponds sampled. The data are summarized in TABLE 21. It appears that the detection limits were relatively high because the moisture content of the samples submitted varied between 48% and 87%.

TABLE 21. GASOLINE RANGE ORGANICS - SUMMARY

Pond	Core ID	GRO – mg/kg
Markham Lake	1D1	19.7
East Ring Pond	2E2	<27.5
MNDOT Pond	3D1	<40.7
Wirth Lake Pond	4B1	<11.7

Figure 33. Relationship of Σ PAH_{13} and Σ PAH_{43}

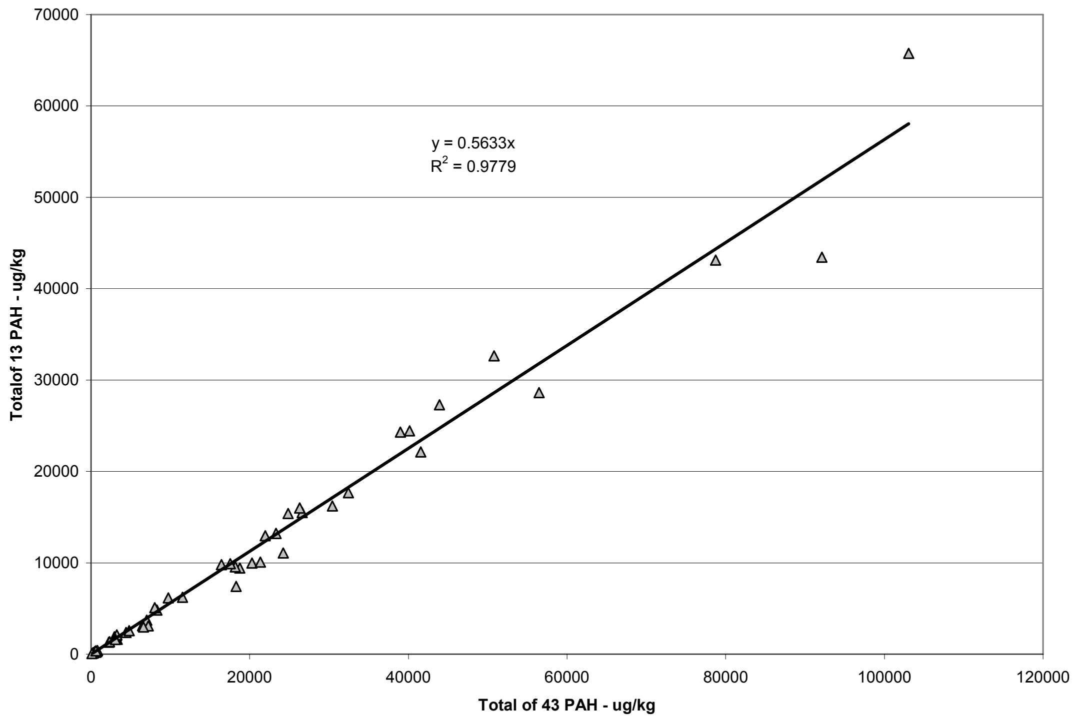


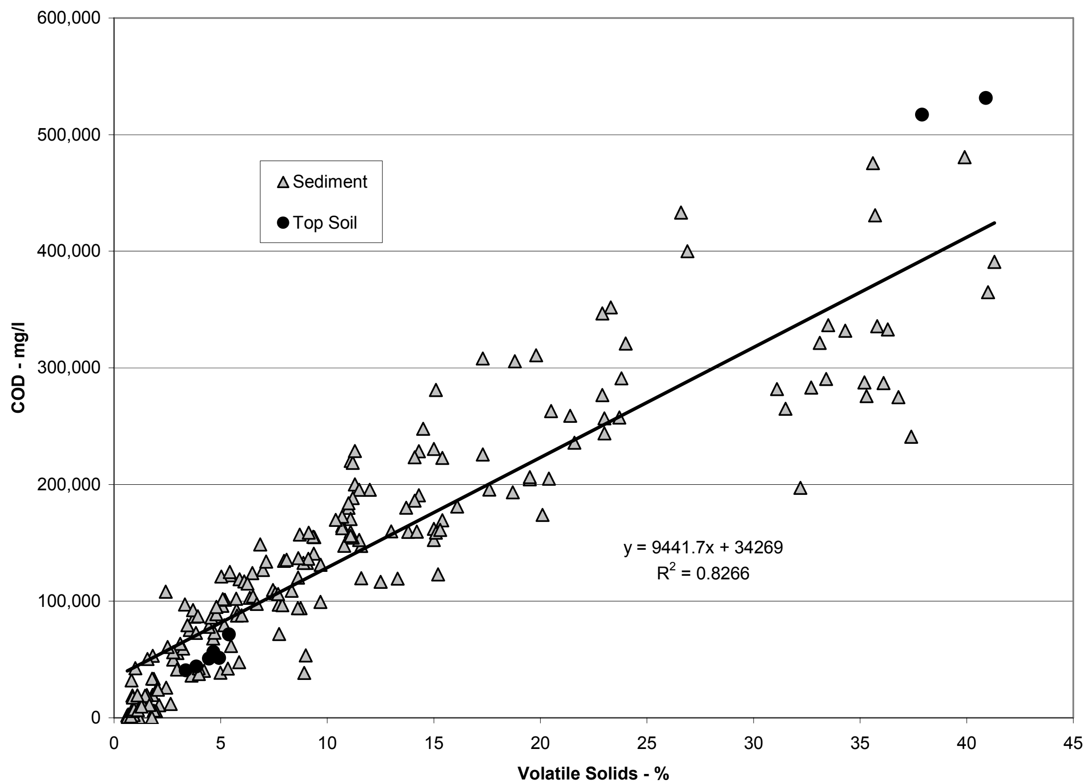
TABLE 22. PAH DATA SUMMARY

Sediment/Soil	Average Σ PAH_{43} – ug/kg	Average Σ PAH_{13} – ug/kg
Markham Lake	6,549	3,414
East Ring Pond	10,347	5,007
MNDOT Pond	38,477	19,077
Wirth Lake Pond	23,266	12,772
Long Lake	565	227
Fish Lake Pond	26,460	16,611
Market Place Pond	36,536	20,465
Cedar Pond	44,001	26,230
Locke Lake Pond	10,205	5,809
Anoka Pond 62	916	513
Top Soils	1,012	549

[4] Chemical Oxygen Demand

The COD concentration of the sediments averaged approximately 141,500 mg/kg (14.15%) and varied in the range of approximately 125 mg/kg (0%) to 481,000 mg/kg (48.1%). The concentration in the top soils averaged approximately 17% and varied in the range of 4% to 53%. The COD and volatile content of the sediments and tops soils are compared on Figure 34 and, as expected, a high correlation is observed. It appears that, at least in terms of organic content, the sediments and top soils are related.

Figure 34. Relationship Between Volatile Content and COD



[5] Biological

[a] Fecal Coliform

The fecal Coliform concentrations varied by two orders of magnitude both within and between ponds. However, 85 of the 100 sediment samples had MPN values less than 1,000/gm which is the MPCA's requirement for a class A sewage sludge. Five of the ten ponds did not exceed this limit in any of the samples. All of the data are presented in TABLE 23.

[b] Bioassay

The overlying water of the test beakers for this test was monitored daily for pH, temperature, and dissolved oxygen, and on the first and last days of the test for conductivity. In addition, alkalinity, hardness, and ammonia samples were obtained from the overlying water on the first and last days of each test. All of these data are presented in Appendix E.

The pH fluctuations for all of the treatments were within acceptable limits since none of them varied more than 50% within each treatment The temperatures of all of the treatments in this test were within the acceptable limits of plus or minus 1 ^{o}C of the recommended test temperature of 23 ^{o}C.

Minimum dissolved oxygen concentrations in the H. azteca test were above 40% saturation in all treatments. In the C. tentans test, dissolved oxygen concentrations dropped below 40% saturation in the pond 3 sediments on day numbers 5, 6, 7, and 9 of the test. This did not appear to have an adverse affect on the test organisms because C. tentans can tolerate very low dissolved oxygen levels. The recommended dissolved oxygen concentration for these tests is 40% saturation or greater

Test results for both test organisms were acceptable because they met the required performance criteria. Survival of C. tentans (93%) in the Control sediment was greater than the performance criteria of 70% survival, and the average weight of C. tentans (1.386 mg) in the Control sediment was greater than the performance criteria of 0.600 mg. Survival of H.azteca (95%) in the control sediment was greater than the performance criteria of 80% survival.

The biological results of this test indicate that the sediments from both sample sites were not toxic to Chironomus tentans and only slightly to moderately toxic to Hyalella azteca for pond 3. C. tentans survival rates of 87% for pond 3 and 88% for pond 8, as well as, average dry weights per test organism of 1.381 mg for pond 3 and 1.839 mg for pond 8 indicate little or no toxicity to C. tentans. The H. azteca survival rate of 90% for pond 8 indicates that this site is not toxic, however, the survival rate of 75% for pond 3 indicates slight to moderate toxicity to H. azteca. Survival rates of only 62% for C. tentans and 63% for H. azteca in the Reference Site (SC 25.8) were unexpected, but can be disregarded because performance criteria were met in the Controls (silica sand).

E. Quality Assurance

[1] Metals

Two subsamples of the SRM were submitted to the laboratory with each batch of pond sediments. SRM 2704 was submitted for ponds 1 – 5 and SRM 8704 for ponds 6 – 10. The MCES laboratory analyzed a total of 18 SRM samples and the UM laboratory a total of three. The data are summarized in TABLE 24, however, all of the data are presented in Appendix F. With the exceptions of selenium and titanium, all of the analyses either met or fell within one percentage point of the accuracy and precision criteria presented in TABLE 12. Both laboratories had problems with selenium and it is recommended that these data not be used for any purpose.

TABLE 23. FECAL COLIFORM CONCENTATIONS

Sample ID	MPN/gm	Sample ID	MPN/gm	Sample ID	MPN/gm
Markham Lake A1	10	Long Lake A1	2	Locke Lake Pond A1	38
A2	13	A2	5	A2	38
B1	11	B1	12	B1	30
B2	8	B2	42	B2	112
C1	49	C1	34	C1	106
C2	60	C2	13	C2	44
D1	14	D1	9	D1	27
D2	< 6	D2	<1	D2	53
E1	30	E1	10	E1	19
E2	12	E2	91	E2	21
East Ring Pond A1	1,300	Fish Lake Pond A1	1,162	Anoka Pond 62 A1	2
A2	520	A2	>2069	A2	10
B1	94	B1	>1872	B1	<1
B2	150	B2	>1908	B2	15
C1	360	C1	816	C1	11
C2	360	C2	3,383	C2	<1
D1	200	D1	3,670	D1	1
D2	69	D2	955	D2	1
E1	18	E1	1,873	E1	2
E2	450	E2	>3608	E2	<1
MNDOT Pond A1	65	Market Place Pond A1	73	Top Soil 1	59
A2	95	A2	100	Top Soil 2	278
B1	140	B1	11	Top Soil 3	100
B2	150	B2	21	Top Soil 4	29
C1	52	C1	31		
C2	47	C2	41		
D1	40	D1	20		
D2	310	D2	80		
E1	1,300	E1	>465		
E2	3,100	E2	87		
Wirth Lake Pond A1	5,000	Cedar Pond A1	1,230		
A2	109	A2	208		
B1	449	B1	132		
B2	625	B2	137		
C1	5,882	C1	53		
C2	4,706	C2	59		
D1	236	D1	61		
D2	404	D2	133		
E1	5	E1	72		
E2	5	E2	50		

TABLE 24. ACCURACY & PRECISION DATA SUMMARY FOR METALS

Metal	MCES % Recovery	COV %		UM % Recovery	COV %
Cu	94.4	7.5		91.1	3.9
Ni	92.1	4.2		100.7	3.4
Pb	97.2	8.1		94.3	5.6
Zn	100.2	8.3		91.7	3.3
Cd	103.4	12.8		88.3	2.9
Cr	92.0	8.4		88.1	2.8
Al	99.4	13.9		108.0	3.4
As	84.6	20.6[A]		91.4	3.2
Fe	94.4	4.8		97.1	2.4
Mn	102.2	4.3		101.5	2.2
V	NA	9.4		NA	4.9
Ti	NA	37.1[A]		NA	2.1
Se	818[B]	87.7[A]		581[B]	5.6
Mo	96.1	20.9[A]		121.0[B]	5.7

Notes:
A - Failed to meet 20% precision criterion – see TABLE 12
B – Failed to meet 20% accuracy criterion – see TABLE 12.

For mercury analysis, each set of 20 pond sediment samples was accompanied by the analysis of two spiked samples and two standard reference material samples. The mean spike recovery was 99% (CV=4%; n=20). The mean recovery for standard reference material SRM 2704 Buffalo River Sediment was 98% (CV=3%; n=8). The mean recovery for standard reference material BCR-320 Trace Elements in River Sediment was 98% (CV=8%; n=12).

Each of the sediment samples submitted for analysis of metals was subjected to two complete extractions and analyses. As previously discussed, relative percent difference (RPD) was used as the measure of precision for duplicate analyses. The RPD statistic is determined as follows: $RPD = (A – B) \div ((A + B) / 2)) \times 100$, where A is the larger of the two duplicate sample values and B is the smaller value.

The precision of these replicate tests for each metal is summarized in TABLE 25. With the exception of molybdenum and selenium, the average RPD for the individual metals was less than the established criterion of 20% - see TABLE 12. However, a large proportion of the replicate analyses did fail the criterion and, in those cases, an additional analysis was conducted. It is hypothesized that, because the sediment samples were coarse grained, it was difficult to obtain a truly representative subsample.

TABLE 25. RPD FOR REPLICATE METAL ANALYSES

Metal	Average RPD	% > RPD Criterion
Copper	12.4	17.5
Nickel	8.9	8.7
Lead	11.0	9.7
Zinc	9.7	15.5
Cadmium	20.0	36.1
Chromium	14.4	24.3
Mercury	8.6	8.7
Aluminum	14.3	22.3
Arsenic	9.6	20.4
Iron	7.9	4.9
Manganese	8.2	7.8
Molybdenum	22.1	33.3
Selenium		
Titanium	15.7	29.1
Vanadium	11.3	15.5

[2] Organics

The National Institute of Standards & Technology reports a total of 24 certified PAH values and 32 reference PAH values for SRM 1944.[65] During this project analyses were conducted for a total of 23 of the 56 compounds addressed in SRM 1944.The SRM was analyzed during each of eight sample runs. The COV averaged 13.3% for the 23 PAH compounds and all met the established precision criterion of 25%. The recovery averaged 98% but four of the compounds (2-Methyl-Naphthalene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, and Dibenzo(a,h)anthracene) often failed the accuracy criterion of 30% - the first was low and the remaining three were high. All of the data are presented in Appendix G

In addition to analysis of SRM 1944, replicate sample analyses were conducted a total of seven times. The average RPD for $\sum PAH_{13}$ was 5 with a maximum of 10.5. The average RPD for Benzo(a)pyrene was 7.1 with a maximum of 12.3.

The PCB analyses of the sediment samples were conducted along with other routine PCB analyses. The routine quality assurance protocol was as follows.

- One duplicate and one spike for every 10 samples.
- One blank and one fortified blank for every 10 samples.
- One check standard injected into GC for every 10 samples.

The RPD for the duplicates averaged 7.24 and the blanks were <0.01 ug/l. Recoveries for the spike, check standard, and fortified blank averaged 76.4%, 105.2% and 89.5% respectively.

[3] Nutrients
The precision of the replicate nutrient analyses are summarized in Table 26. The nitrite nitrogen analyses were all below detection and only ammonia nitrogen had a precision criterion.

TABLE 26. RPD FOR REPLICATE NUTRIENT ANALYSES

Nutrient	Average RPD	% > RPD Criterion
Total Kjeldahl Nitrogen	12.8	
Total Phosphorus	14.4	
Ammonia Nitrogen	6.3	5.8
Nitrate Nitrogen	7.6	
Nitrite Nitrogen		

SECTION V. DISCUSSION

A. MPCA Sediment Criteria

Although the MPCA has not adopted sediment quality standards, it uses the sediment quality targets (SQT), which were developed for the St Louis River area, *as state benchmark values for making comparisons to surficial sediment chemistry measurements*.[66] The SQT, summarized in TABLE 27 were developed for the protection of sediment-dwelling organisms. The level I SQT identify concentrations below which harmful effects on sediment dwelling organisms are unlikely to occur whereas harmful effects are likely to occur for concentrations above the level II SQT.[67]

TABLE 27. MPCA SEDIMENT QUALITY TARGETS

Metals	**Units**[A]	**Level I SQT**[B]	**Level II SQT**[B]
Arsenic	mg/kg	9.8	33
Cadmium	mg/kg	0.99	5.0
Chromium	mg/kg	43	110
Copper	mg/kg	32	150
Lead	mg/kg	36	130
Mercury	mg/kg	0.18	1.1
Nickel	mg/kg	23	49
Zinc	mg/kg	120	460
Organics			
2-Methylnaphthalene	ug/kg	20	200
Acenaphthene	ug/kg	7	89
Acenaphthylene	ug/kg	6	130
Anthracene	ug/kg	57	850
Fluorene	ug/kg	77	540
Naphthalene	ug/kg	180	560
Phenanthrene	ug/kg	200	1,200
Benzo(a)anthracene	ug/kg	110	1,100
Benzo(a)pyrene	ug/kg	150	1,500
Chrysene	ug/kg	170	1,300
Dibenzo(a,h)anthracene	ug/kg	33	140
Fluoranthene	ug/kg	420	2,200
Pyrene	ug/kg	200	1,500
Total PAH[C]	ug/kg	1,600	23,000
Total PCBs	ug/kg	60	680

Note A: concentrations on dry weight basis
Note B: concentration of total metal
Note C: sum of 13 listed PAH

As part of the St Louis River study, the MPCA also adopted SQT for protection of wildlife and human health. The single wildlife SQT is 1,400 ug/kg of organic carbon for total PCB. The human health SQT's are 0.8 ug/kg of organic carbon for total PCB and 1,300 ug/kg of organic carbon for Benzo(a)pyrene. The wildlife and human health SQT are designed to protect against contaminant bioaccumulation in fish and other aquatic organisms and are values developed by the New York State Department of Environmental Conservation (NYSDEC). A review of the NYSDEC document demonstrates that these SQT are based on the risk associated with consumption of [a]edible resident biota for human health issues and [b] contaminated prey for wildlife.[68] Although these SQT may be relevant when the sediments remain in the ponds (especially natural impoundments) they are not related to the risk, if any, of using and/or disposing of sediments on upland areas

Finally, the following statement was included in the MPCA report. *As a caveat to this study, the authors wish to emphasize that the SQTs developed for the St. Louis river AOC are most applicable for soft sediments. These SQTs should not be applied to assessments of upland soils, land-applied sludge, or other land-based materials (e.g. gravel).These SQTs should be used with care for any sediments containing large amounts of gravel, coarse sand, tar, slag, metal ore (e.g. taconite pellets) paint chips, coal chunks, fly ash, or wood chips. The presence of the aforementioned materials may bind up some chemicals so that they are not bioavailable to aquatic organisms.* [67]

Although it is unclear how the above SQT might be used to determine the suitability of sediment placement on upland areas, they are used as reference values in the subsequent discussion.

The MPCA has developed a series of soil reference values (SRV) as part of a risk-based approach for decision making during site investigations and remedial action related to the state's Voluntary Investigation Cleanup and Superfund Programs. The SRV are used in a three-tiered evaluation approach to evaluate health effects from several exposure pathways – ingestion, dermal, and inhalation.[69] The discussion here is limited to the tier 1 SRV which are used for initial site evaluations. The tier 1 SRV values for the metals and organics monitored in this project are summarized in TABLE 28. Based on MPCA's draft guidance for managing dredged materials, the SRV metals are determined using the same digestion procedure used in this project – see TABLE 11.

The tier 1 exposure scenario is based on residential property use. The current SRV values for 100+ constituents are available on the MPCA web site.[70] MPCA recommends that, if one or more of the tier 1 SRV values are exceeded, additional site investigation is warranted. Although the SRV were not intended to make judgements on where to place sediments, they appear to be useful tools to determine the suitability of sediment placement in upland areas. It must be remembered, however, that the SRV values are targets for cleanup and not upper limits for land application. As such, the SRV should not be used to manage pristine sites.

TABLE 28. TIER 1 SOIL REFERENCE VALUES*

Copper	11
Nickel	560
Lead	300
Zinc	8,700
Cadmium	25
Chromium	44,000
Aluminum	30,000
Arsenic	5
Iron	9,000
Manganese	3,600
Molybdenum	NA
Selenium	160
Titanium	100,000
Vanadium	30
PCBs	1.2
Acenaphthene	1,200
Anthracene	7,880
Benzo[a]pyrene equivalent	2.0
Fluoranthene	1,080
Fluorene	850
2-Methyl naphthalene	100
Naphthalene	10
Pyrene	890

* mg/kg

B. Reference Materials

[1] Soils

The U. S. Geological Survey (USGS) reported on the metal concentration found in 1,318 soil samples collected throughout the United States.[71] The data for the metals of interest in this project are summarized in TABLE 29. USGS characterized the data as east and west of the 96th meridian, which is just east of the western border of Minnesota. The samples were collected approximately 20 cm below the surface of the deposits and the analytical technique for the metals is described as a semiquantitative six-step emission spectrographic method. Note that the tabulated values are geometric means.

Although the analytical techniques are not identical, it is interesting to note that all of the reported values for aluminum, copper, iron, and vanadium for these soils exceed the tier 1 SRV values.

TABLE 29. GEOMETRIC MEAN METAL CONCENTRATION IN US SOILS

Metal	Units	Total US	West US	East US
Aluminum	%	4.7	5.8	3.3
Arsenic	mg/kg	5.2	5.5	4.8
Cadmium	mg/kg	NA	NA	NA
Chromium	mg/kg	37	41	33
Copper	mg/kg	17	21	13
Iron	%	1.8	2.1	1.4
Lead	mg/kg	16	17	14
Manganese	mg/kg	330	380	260
Mercury	mg/kg	0.058	0.046	0.081
Molybdenum	mg/kg	0.59	0.85	0.32
Nickel	mg/kg	13	15	11
Selenium	mg/kg	0.26	0.23	0.3
Titanium	%	0.24	0.22	0.28
Vanadium	mg/kg	58	70	43
Zinc	mg/kg	48	55	40

At about the time the USGS was completing the above project, researchers at the University of Minnesota determined the concentration of trace metals in some major Minnesota soils.[72] Samples (surface, subsoil, parent material) were collected from soils developed from six parent materials. Several digestion methods were used to characterize the metal content including HNO_3 and a mixture of HCl, HNO_3, and HF to characterize available metals and total metals respectively. The data resulting from these two digestion methods for surface soils are summarized in TABLE 30. Note that the weak acid extract of one of the parent materials (Lacustrine) exceeded the tier 1 SRV value for copper.

[2] <u>Sediment</u>
In 1992 and 1993, MPCA collected surficial sediment from a total of 28 reference (unimpacted) lakes and analyzed them for a number of constituents as summarized in TABLE 31.[73] Unfortunately the report does not identify the digestion method used for the analysis of metals. Note, however, that the mean copper concentration exceeds the tier 1 SRV value. PCB analysis was conducted on sediments from 11 of the 28 lakes. The average total PCB concentration was 346 ug/kg with a range of 212 to 435 ug/kg.

TABLE 30. MEAN METAL CONTENT OF MINNESOTA SURFACE SOILS

	HNO$_3$ Extractable Metals mg/kg					
Parent Material	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
Loess	0.15	3.4	3.6	5.6	7.8	10
Superior Lobe Till	0.32	4.9	4.4	5.6	6.5	23.9
Rainy Lobe Till	0.33	6	6.4	6.1	7.5	12.3
Lacustrine	0.56	4.1	11.9	13	9.4	23.3
Wadena Lobe Till	0.15	3.3	2.7	3.3	5	14.1
Percy Till	0.09	4.1	5.7	6	3.8	15.2
Des Moines Lobe Till - prairie	0.28	3.7	7.5	10.8	7.9	15.5
Des Moines Lobe Till - forest	0.18	3.1	2.4	2.8	6.3	15.9
	Total Metals mg/kg					
Loess	0.32	14	19	18		59
Superior Lobe Till	0.33	36	27	20		74
Rainy Lobe Till	0.42	104	28	39		70
Lacustrine	0.68	48	27	19		74
Wadena Lobe Till	0.24	15	22	9		40
Percy Till	0.25	28	22	10		55
Des Moines Lobe Till - prairie	0.6	40	22	21		68
Des Moines Lobe Till - forest	0.26	28	16	7		42

TABLE 31. REFERENCE LAKE SEDIMENT DATA – 1992 & 1993

Parameter	Mean	Median	25th %	75th %
Volatile - %	2	18	15	21
Mercury – mg/kg	0.08	0.08	0.07	0.09
Cadmium – mg/kg	1.8	1.7	0.5	2.9
Chromium – mg/kg	30	33	13	45
Lead – mg/kg	48	56	30	66
Copper – mg/kg	26	20	17	31
Total P – mg/kg	1,051	944	734	1,160

In May of 1996, MPCA collected surficial sediment samples from nine reference (unimpacted) lakes and analyzed them for a suite of seven metals.[74] Although the report did not describe the sample digestion procedure, it appears that the data generated, and summarized in TABLE 32, are for total metals using standard analytical methods. The mean copper concentration again exceeded the tier 1 SRV values.

TABLE 32. REFERENCE LAKE SEDIMENT DATA - 1996

Metal	Mean	Min	Max
Cadmium	1.66	0.61	2.36
Chromium	13.3	9.5	54
Copper	25.6	7.8	86
Mercury	0.10	0.03	0.35
Nickel	15.3	7.2	39
Lead	27.4	10	66
Selenium	0.88	0.25	1.8

C. Metals

Because of the problems with the quality of the selenium data, they will not be addressed in this section.

With the exception of manganese, mercury, and molybdenum, the average metal concentration for the pond sediments was almost always greater than the average concentration for the top soils - see TABLE 21. However, the sediment concentrations were not always significantly higher - see Figure 19 through Figure 32. Regardless of the relationship between the sediment and top soil concentrations, it will be difficult to define concentrations that should trigger environmental and/or health concerns. For example, all of the sediment averages exceed the tier 1 SRV for copper (11 mg/kg) and 9 of 10 exceed the tier 1 SRV for iron. At the same time, the average concentration in the sediments from reference lakes also exceed the copper SRV (see TABLES 35 and 36).

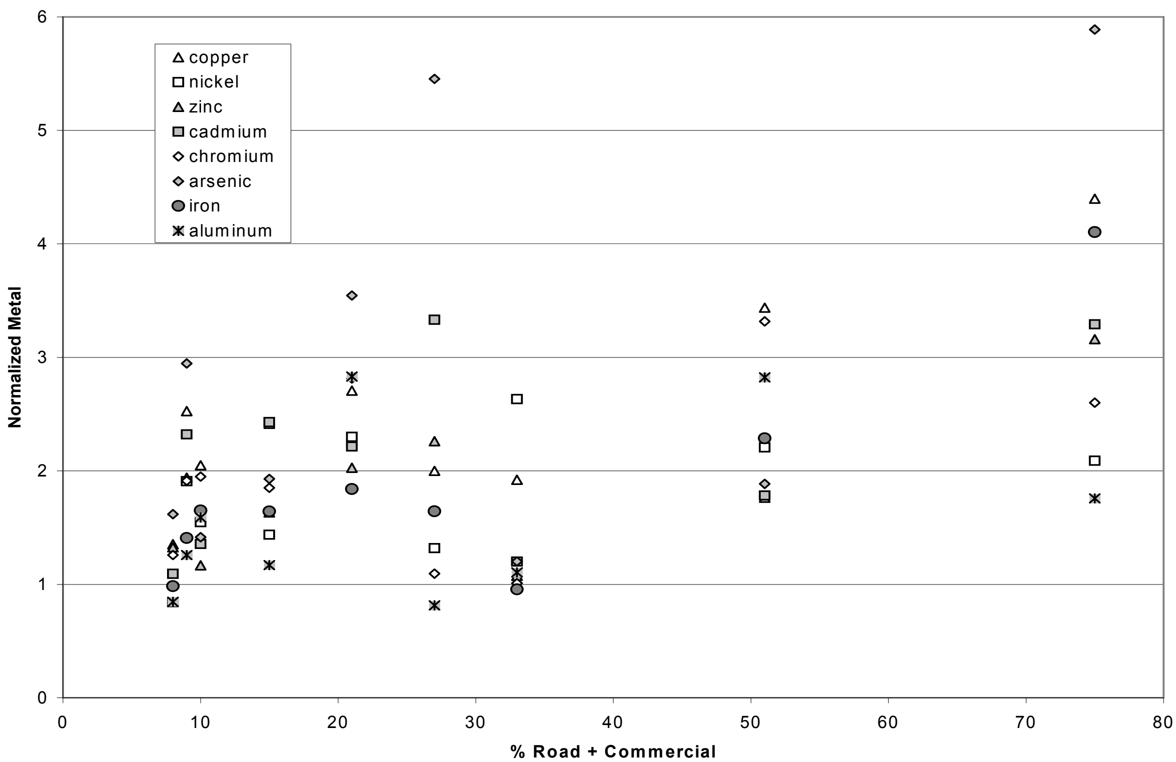
The highest average concentration for five of the 14 metals addressed (copper, zinc, arsenic, iron, and manganese) was found in pond #3 (MNDOT) and it appears that the concentration of copper, zinc, and iron were significantly higher in this pond. Relatively high concentrations of lead, cadmium, chromium, and molybdenum were also observed in pond #3. The watershed for pond #3 is 45% roads and highway. EPA has identified the sources of pollutants in highway runoff for a number of constituents and the information for metals is presented in TABLE 33.[75]

TABLE 33. SOURCE OF METALS IN HIGHWAY RUNOFF

Cadmium	Tire wear and insecticide application
Chromium	Metal plating, moving engine parts and brake lining wear
Copper	Metal plating, bearing and brushing wear, moving engine parts, brake lining wear, fungicides & insecticides
Iron	Auto body rust, steel highway structures such as bridges and guardrails, and moving engine parts
Lead	Leaded gasoline from auto exhausts and tire wear
Manganese	Moving engine parts
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear and asphalt paving
Zinc	Tire wear, motor oil and grease

The above information suggests that metal concentrations may be correlated with the roadway area in a watershed. In order to check this hypothesis, the average sediment metal concentrations were normalized by dividing by the average top soil metal concentration. The normalized values for eight of the metals are plotted against the percent of the watershed land used for roads and commercial uses – see Figure 35. The commercial uses are added because they include the large paved parking areas. It appears that, on average, the metal concentration increases as the paved area in the watershed increases.

Figure 35. Impact of Paved Area on Normalized Metal Concentration



D. Organics

[1] <u>PCB</u>

Concentrations above detection limits were found in a total of nine sediment samples with three each from Wirth Lake Pond, Cedar Pond, and Locke Lake Pond – see TABLE 20. The maximum PCB concentration was 0.123 mg/kg dry sediment and seven of the nine values fell between the level I and level II SQT for the protection of sediment dwelling organisms presented in TABLE 27. If the detection limit is used as the concentration for values reported as less than detection, the average PCB concentration for the three sites is 0.056, 0.068, and 0.044 mg/kg. Given that Minnesota Rule 7041.0300 Subpart 2. D allows sewage sludge to be land applied if the PCB concentration does not exceed 50 mg/kg, the concentrations found in the sediments do not appear to be significant if the material is deposited on upland areas.

[2] PAH

The average of each of the 13 compounds was determined for each pond and the top soils. These averages are compared to the SQT values in TABLE 34. A quick review indicates that, 8 of the 10 ponds exceed the SQT I value for Σ $PAH_{13.}$ Although only pond number 8 exceeds the SQT II value for Σ PAH_{13}**,** the individual SQT II values are often exceeded for ponds number 3, 4, 6, 7, and 8 (72 % exceed the individual SQT II values). Based on the data and the level II SQT values, it is likely that the sediment dwelling organisms in these five ponds have been subjected to harmful effects. However, as previously addressed, the SQT values are not directly relevant to the use and/or disposal of sediments in upland areas.

Note that the most recent values (1990's) for Σ PAH_{13} for local lakes were the same order of magnitude as half of the ponds and substantially higher than some ponds – see TABLE 6. This should not be unexpected. It is likely that most lakes in the urban and suburban metropolitan area receive substantial stormwater runoff. This implies that the quality of the sediment in typical area lakes will likely be similar to the material found in stormwater ponds when the characteristics of the drainage areas are similar.

The tier 1 SRV for PAH is 2.0 mg/kg and is based on the equivalent concentration of Benzo[a]pyrene. The equivalent Benzo[a]pyrene concentration is determined using the relative potency factors provided by MPCA – see TABLE 35. The equivalent Benzo[a]pyrene concentration was calculated for each pond based on the averages of the individual compounds identified in Appendix D. The results of the calculations are summarized in TABLE 36. Based on the average of PAH concentrations in the individual ponds, half of the sediments fail to meet the MPCA tier1 SRV of 2.0.

The Canadian Council of Ministers of the Environment developed soil quality guidelines for the protection of environmental and human health which includes values for Benzo[a]pyrene.[76,] The guideline value is 100 ug/kg for agricultural land uses and increases to 700 ug/kg for residential/parkland, commercial, and industrial land uses.[77] Only two ponds, and the top soil, met the 100 ug/kg guideline and four ponds met the 700 ug/kg guideline. As with the MPCA's SRV values, these guidelines are "clean down to levels" rather than "pollute up to levels".[76]

TABLE 34. PAH DATA FOR PONDS AND TOP SOILS COMPARED TO SQT VALUES*

Compound	1	2	3	4	5	6	7	8	9	10	TS	SQT - I	SQT - II
Napthalene	15	27	75	57	3	15	34	40	14	3	8	180	560
Acenapthylene	31	60	484	521	3	45	227	175	24	1	6	6	130
Acenaphthene	20	28	97	140	5	179	128	161	39	2	6	7	89
Fluorene	38	34	148	150	9	229	186	213	50	6	9	77	540
Phenanthrene	394	272	5,760	1,791	32	3,016	2,550	3,592	694	21	77	200	1,200
Anthracene	47	26	442	436	3	356	366	480	108	14	16	57	850
2-Methylphenanthrene	38	32	1,870	248	3	207	226	275	52	5	4	20	200
Fluoranthene	822	1,095	2,414	2,404	54	3,455	5,251	6,515	1,416	72	112	420	2,200
Pyrene	807	1,303	2,649	2,171	44	3,301	4,036	5,488	1,112	88	125	200	1,500
Benzo(a)anthracene	254	691	1,375	1,393	15	1,540	1,674	2,277	583	46	56	110	1,100
Chrysene	496	750	1,778	1,289	30	2,180	2,888	3,457	812	12	65	170	1,300
Benzo(a)pyrene	374	603	1,635	1,921	21	1,795	2,415	3,160	747	30	59	150	1,500
Dibenzo(a,h)anthracene	79	86	350	250	4	293	483	398	158	1	6	33	140
ΣPAH_{13}	3,414	5,007	19,077	12,772	227	16,611	20,465	26,230	5,809	301	548	1,600	23,000

* ug/kg

TABLE 35. PAH RELATIVE POTENCY FACTORS

Compound	CAS No.	Relative Potency Factor
Benz[a]anthracene	56-55-3	0.10
Benzo[b]fluoranthene	205-99-2	0.10
Benzo[j]fluoranthene	205-82-3	0.10
Benzo[k]fluoranthene	207-08-9	0.10
Benzo[a]pyrene (1)	50-32-8	1.00
Chrysene	218-01-9	0.01
Dibenz[a,j]acridine	224-42-0	0.10
Dibenz[a,h]acridine	226-36-8	0.10
Dibenz(a,h)anthracene (2)	53-70-3	0.56
7H-Dibenzo[c,g]carbazole	194-59-2	1.00
Dibenzo[a,e]pyrene	192-65-4	1.00
Dibenzo[a,h]pyrene	189-64-0	10.00
Dibenzo[a,i]pyrene	189-55-9	10.00
Dibenzo[a,l]pyrene	191-30-0	10.00
7,12-Dimethylbenzanthracene (2)	57-97-6	34.25
1,6-Dinitropyrene	42397-64-8	10.00
1,8-Dinitropyrene	42397-65-9	1.00
Indeno[1,2,3,-c,d]pyrene	193-39-5	0.10
3-Methylcholanthrene (2)	56-49-5	3.01
5-Methylchrysene	3351-31-3	1.00
5-Nitroacenaphthene (2)	602-87-9	0.02
1-Nitropyrene	5522-43-0	0.10
4-Nitropyrene	57835-92-4	0.10
6-Nitrochrysene	7496-02-8	10.00
2-Nitrofluorene	607-57-8	0.01

The Washington State Department of Ecology (WSDE) has developed a Model Toxics Control Act (MTCA) cleanup regulation. *The MTCA regulation is not intended to be directly applied to setting contaminant concentration levels for land application proposals. However, they may provide human health and environmental threat information and a useful framework for such decisions, when used in conjunction with other health and environmental decisions.*[78] The MTCA regulation addresses a total of seven PAH which are considered to be carcinogenic and criteria have been established for the sum of their toxic equivalence. The compounds and their toxicity equivalence factors are summarized in TABLE 37. The MTCA criterion for unrestricted land use is 100 ug/kg and the criterion for source cleanup for industrial sites is 2,000 ug/kg.

TABLE 36. EQUIVALENT BENZO[A]PYRENE CONCENTRATION

Sample Location	Average – mg/kg
Markham Lake	1.13
East Ring Pond	1.77
MNDOT Pond	4.24
Wirth Lake Pond	4.34
Long lake	0.07
Fish Lake Pond	3.47
Market Place Pond	5.00
Cedar Pond	7.28
Locke lake Pond	1.50
Anoka Pond 62	0.19
Top Soils	0.19

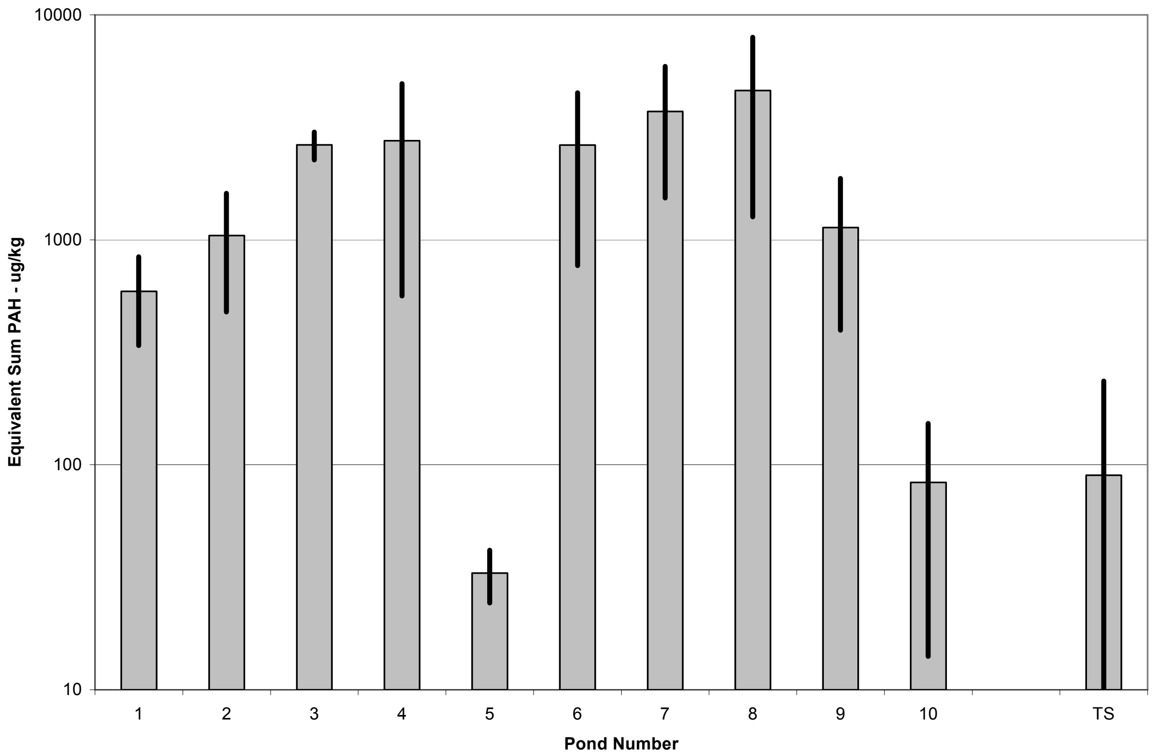
TABLE 37. WASHINGTON PAH TOXICITY EQUIVALENCY FACTORS[79]

Compound	Toxicity Equivalence Factor
Benzo(a)anthracene	0.1
Chrysene	0.01
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Benzo(a)pyrene	1.0
Indeno(1,2,3-cd)pyrene	0.1
Dibenzo(a,h)anthracene	0.4

The toxic equivalences for each of the seven PAH were summed for each core analyzed. The average and 95% confidence interval for each of the 10 ponds and top soils was calculated and the values are summarized in Figure 36. Only ponds number 5 and 10 along with the top soils met the unrestricted land use criterion. Ponds number 1, 2 and 9 did, however, meet the less restrictive cleanup criterion. Note that both criteria are based on cancer risk via direct contact with the contaminated material and that WSDE suggests that local health departments may permit higher levels if they determine that the proposed use poses little risk of direct human contact or ingestion. [78]

Given the data collected and the WSDE risk based regulations, it may be prudent to determine the source of elevated PAH concentrations in pond sediments. It should be noted here that the city of Austin, Texas banned the use of coal-tar based seal coats as of January 1, 2006 because the material appeared to the source of elevated PAH concentrations in stream sediments.[80]

Figure 36. Average and 95% Confidence Interval for Sum of 7 PAH



The data summarized in TABLE 5 demonstrate that asphalt seal coat materials can be a significant source of PAH. The 2005 edition of the Minnesota Department of Transportation (MNDOT) Standard Specifications for Construction requires the use of asphalt binders for seal coating roadway surfaces - see specification number 3151.[81] It is assumed that metro area communities use the MNDOT specification for seal coating materials. Although the PAH content of asphalt seal coating materials is much lower than for coal tar based materials, it can be a significant source of PAH. The following example will illustrate how typical street seal coating could impact the PAH content of stormwater pond sediment.

Asphalt emulsions, which are approximately 60% asphalt cement (AC)[82], have a specific gravity of approximately 1.03, and are applied at rates on the order of 0.3 gallons/yd^2. [83] This results in an AC application rate of approximately 1.5 lb/yd^2. Mahler, et al analyzed three asphalt based seal coat materials and reported total PAH concentrations of 300, 1,300, and 6,600 mg/kg dry material. [34] Using this range, the PAH application rate falls in the range of approximately 0.2 to 4.6 gm/yd^2. Applying a seal coat to all the roads (all assumed to be asphalt) in a 100 acre watershed with 10 acres of roadway will result in the application of approximately 10 to 224 kg of PAH. If it is assumed that [1] the sediment accumulation rate for the watershed is 1,000 lb/acre/yr, and [2] between 0.5% and 5% of the seal coat material is lost to stormwater ponds each year, the total PAH concentration in the sediment will fall in the range of approximately 1 to 250 mg/kg. Figure 37 illustrates the impact of the assumptions on the estimated PAH concentration. Although it does appear that asphalt seal coat materials can be a significant source of PAH for pond sediments, the characteristics of the specific asphalt material need to be determined.

Based on visits to two big box home improvement centers in Apple Valley (May 9, 2006), at least three types of driveway sealer are sold locally – coal tar based, asphalt based, and acrylic based. Material Safety Data Sheets (MSDS) were available on the manufactures' web sites for the asphalt and acrylic based materials. The product labels and MSDS did not, however, provide information on ingredient proportions. The smallest available container of each product (5 gallons for coal tar and asphalt based and 1 gallon for acrylic based) was purchased. Samples were extracted from each container after mixing. Note that the acrylic and asphalt based materials were relatively homogeneous but the coal tar based material had to be mixed for > 30 minutes before what appeared to be a representative sample could be collected. The approximate specific gravity, solids content, and ΣPAH_{13} of the materials were determined – see TABLE 38. Based on the recommended application rates for the materials, the resulting application rate for ΣPAH_{13} would be as follows: acrylic – 0.0003 gm/yd^2, asphalt – 0.0009 gm/yd^2, coal tar – 2.8 gm/yd^2.

TABLE 38. DRIVEWAY SEAL COAT CHARACTERISTICS

Seal Coat Type	Specific Gravity*	% Solids	Sum PAH_{13} mg/kg dry solids **	Application Rate ft^2/gallon***
acrylic	1.16	30.7	6.5	240
asphalt	1.19	28.5	5.5	70
coal tar	1.04	16.8	42,840	90

* determined using 25 ml graduated cylinder
** PAH concentrations not corrected for surrogate recovery
*** Label recommendations

The area of suburban driveways can be a substantial fraction of the area of suburban streets.♣ If a significant proportion of the asphalt driveways are treated with the coal tar material, it is possible that driveway seal coating material can be a significant source of PAH. Consider the previous example (100 acre watershed with 10% streets). If 80% of the driveways are asphalt and 1/3 of the asphalt driveways are treated with each of the above seal coat materials, the total application of ΣPAH_{13} would be approximately 24.5 kg per seal coat application. Although this is on the low end of the range estimated for street seal coating, it can be a significant source of PAH in pond sediments.

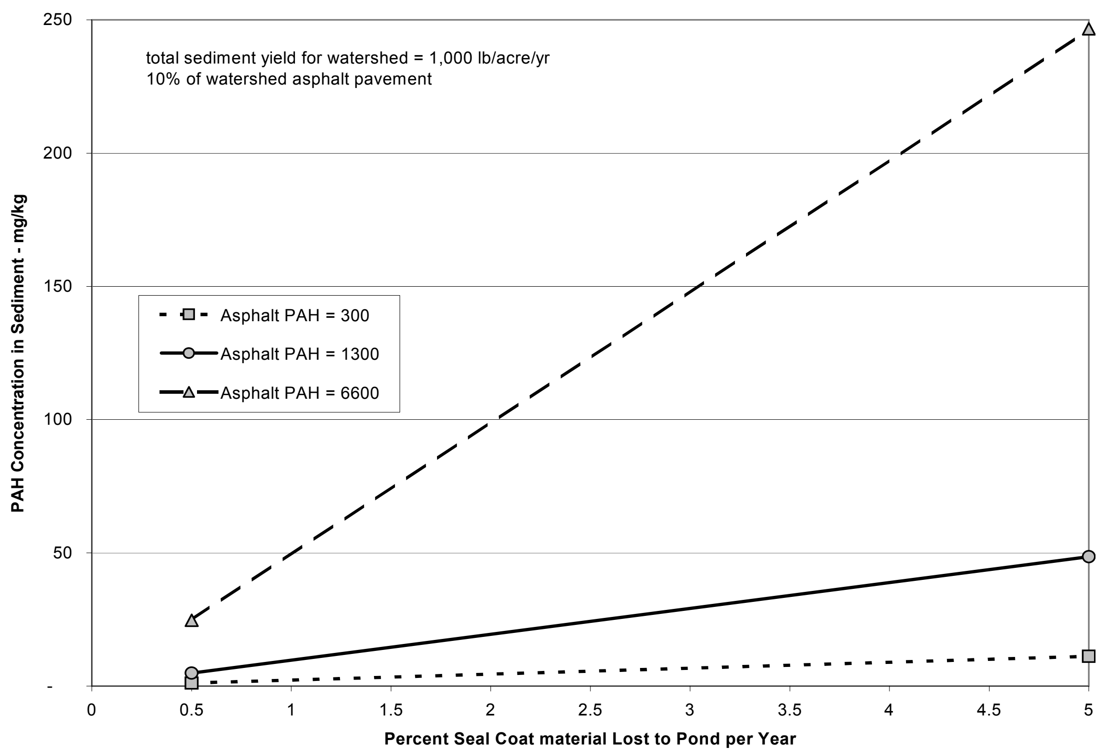
In addition to road building and maintenance materials, sites formerly used for the manufacture of coal gas and the production and use of creosote are potential sources of PAH. Hatheway estimates that there are between 30,000 and 50,000 coal tar sites in the US.[84] If one of these abandoned sites is known to be in the drainage area of a stormwater

♣ For lot width of 75 feet, street width of 30 feet, and driveway area of 750 square feet, the driveway area (both sides of street) is approximately 67% of the street area.

pond, it may be prudent to determine the PAH concentration of the sediment prior to planning any dredging operations.

Finally, the data summarized in Figure 36 and Appendix D demonstrate considerable variation in the PAH concentrations throughout the ponds. Within pond variation as high as 20:1 was observed. When excavating pond sediment, it may be prudent to separate the materials based on distance from an inlet, especially an inlet from which high concentrations are likely.

Figure 37. Sediment PAH for Hypothetical Watershed.



[3] Gasoline Range Organics

The MPCA has developed guidance addressing the excavation of petroleum contaminated soil.[85] Although the guidance was not developed for the excavation and use of aquatic sediments, it appears that if the sediment is deposited on land, at least 25 feet above the water table, no further action is required if the GRO concentration does not exceed 50 mg/kg for sand/gravel and 100 mg/kg for silt/clay. The data presented in TABLE 21 demonstrate that the GRO values were all below 50 mg/kg. Unless there was a significant spill in the watershed, it is unlikely that pond sediments would contain sufficient GRO to trigger the need for further site investigation.

E. DESIGN OF MONITORING PROGRAMS

The sampling and analytical scheme was designed to generate information on the components of variability with duplicate samples and duplicate analyses. A nested analysis of variance (ANOVA) can be used to estimate the magnitude of the several sources of variability. This information can then be used to help design effective monitoring schemes when stormwater ponds are scheduled for dredging. The following example uses the sediment mercury data. As per TABLE 10, a total of 200 mercury analyses were conducted (2 analyses per core, 2 cores per location, 5 locations per pond, 10 ponds). The nested ANOVA was conducted using Minitab and the results are summarized in TABLE 39.

TABLE 39. NESTED ANOVA: TOTAL HG (NG/G) VERSUS POND, LOC_NUM, CORE_

Analysis of Variance for Total Hg (ng/g)

Source	DF	SS	MS	F	P
pond	9	86699.0192	9633.2244	5.099	0.000
loc_num	40	75564.0440	1889.1011	7.877	0.000
core_	50	11991.2750	239.8255	2.523	0.000
Error	100	9507.1600	95.0716		
Total	199	183761.4982			

Variance Components

Source	Var Comp.	% of Total	StDev
pond	387.206	40.04	19.678
loc_num	412.319	42.64	20.306
core_	72.377	7.48	8.507
Error	95.072	9.83	9.750
Total	966.974		31.096

It appears that the variability between locations within ponds is similar to the variation between ponds – both with standard deviations of approximately 20. The variability between cores is approximately the same as the determination error – both with standard deviations of approximately 10. Given that the sampling and analysis budget is fixed, the most effective scheme to determine the average and maximum concentrations of mercury would be to collect individual cores from as many locations as possible and conduct one analysis per core.

REFERENCES

[1] EPA, *National Water Quality Inventory: 1998 Report to Congress* (Washington, DC: U. S. Environmental Protection Agency, 2000).

[2] EPA, *Economic Benefits of Runoff Controls EPA- 841-S-95-002* (Washington, DC: Environmental Protection Agency, 1995).

[3] EPA, *National Management Measures to Control Nonpoint Source Pollution from Urban Areas EPA-841-B-05-004* (Washington, DC: Environmental Protection Agency, 2005).

[4] Minton, G. R. "Revisiting Design Criteria for Stormwater Treatment Systems – Basins", *Stormwater* 5 (2004): 20 – 43.

[5] MPCA, *Protection Water Quality in Urban Areas: Best Management Practices for Dealing with Storm Water Runoff from Urban, Suburban and Developing Areas in Minnesota* (St. Paul, MN: Minnesota Pollution Control Agency, 2000).

[6] MPCA, *2005 Minnesota Stormwater Manual, Version 1.0* (St. Paul, MN: Minnesota Pollution Control Agency, 2000) only available at http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual.

[7] Donovan, T., *The Wisconsin Storm Water Manual: Wet Detention Basins* (Madison, WI: Wisconsin Department of Natural Resources, 2000).

[8] USEPA, *National Management Measures to Control Nonpoint Source Pollution from Urban Areas*, EPA-841-B-05-004 (Washington DC: Environmental Protection Agency, 2005).

[9] Novotny, V, and H. Olem, Water Quality Prevention Identification and Management for Diffuse Pollution (New York, NY: Van Nostrand Reinhold, 1994).

[10] Hubmer, T. E., *Gun Club Lake Watershed Organization Storm Water Basin Sedimentation Rate and Composition Study* (Minneapolis, MN: WSB & Associates, Inc., 2002).

[11] Hafner, J. and M. Panzer, "Stormwater Retention Ponds: Maintenance vs Efficiency", Presented at the 37th Annual Water Resources Conference, October 26, 2004. Brooklyn Center, MN.

[12] Barrett, M. "BMP Performance Comparisons: Examples From the International Stormwater BMP Database", *WEFTEC.05 Conference Proceedings* (2005) 4910 – 4922.

[13] Winer, R. *National Pollutant Removal Performance Database for Stormwater Treatment Practices – 2nd Edition* (Ellicot city, MD: Center for Watershed Protection, 2000).

[14] Yax, L. K., Land Area, Population, and Density for Metropolitan Areas: 1990 http://www.census.gov/population/www/censusdata/density.html (U.S. Census Bureau, Population Division, Population & Housing Programs Branch, 1999).

[15] Metcalf & Eddy, Inc., *Wastewater Engineering: Treatment, Disposal and Reuse*, 3rd ed., (New York, NY: McGraw-Hill book Company, 1991).

[16] Polta, R. C. , *Fate and Environmental Impact of Sediments Removed from Stormwater Ponds- A Review* (St. Paul, MN: Metropolitan Council Environmental Services, 2001).

[17] Karouna-Renier, N.K. and D.W. Sparling, "Relationships Between Ambient Geochemistry, Watershed Land-Use and Trace Metal Concentrations in Aquatic Invertebrates Living in Stormwater Treatment Ponds", *Environmental Pollution* 112 (2001)

[18] Zanoni, A. E., "Characteristics and Treatability of Urban Runoff Residuals", *Water Research* Volume 20 (1986), 651-659.

[19] Environment Canada, *Trace Metals Contamination of Urban Streams and Stormwater Detention Ponds*, see at http://www.on.ec.gc.ca/glimr/data/trace-metals-urban/intro.html

[20] Livingston, E.H. and J.H. Cox, "Stormwater Sediments: Hazardous Waste of Dirty Dirt?" *Proceedings of the 4th Biennial Stormwater Research Conference* (Brooksville, Fl:Southwest Florida Water Management District, 1995)

[21] Baker, D.M. and Y.A. Yousef, "Metal Accumulation and Impacts on Benthic Organisms in Detgention Pond Sediments" Proceedings of the 4th Biennial Stormwater Research Conference (Brooksville, Fl: Southwest Florida Water Management District, 1995.)

[22] Wren, C.D., C.A. Bishop, D.L. Stewart, and G.C. Barrett. *Wildlife and Contaminants in Constructed Wetlands and Stormwater Ponds: Current State of Knowledge and Protocol for Monitoring Contaminant Levels and Effects in Wildlife – Technical Report Series No. 269* (Burlington, Ontario: Canadian Wildlife Service, 1997).

[23] Schueler, T. R., "Performance of Stormwater Ponds in Central Texas", *Watershed Protection Techniques*, Volume 3, Number 3 (2000), 717 - 720

[24] Schueler, T. R. "Pollutant Dynamics of Pond Muck", *Watershed Protection Techniques*, Volume 1, Number 2 (1994), 39 – 46.

[25] Bishop, C.A., J. Struger, L.J. Shirose, L. Dunn, and G.D. Campbell, "Contamination and Wildlife Communities in Stormwater Detention Ponds in Guelph and the Greater Toronto Area, Ontario, 1997 and 1998. Part II-Contamination and Biological Effects of Contamination", *Water Quality Research Journal of Canada,* Volume 35 (2000) 437 - 474.

[26] Rochfort, Q., L. Grapentine, J. Marsalek, B. Brownlee, T. Reynoldson, S. Thompson, D. Milani, and C. Logan, "Using Benthic Assessment Techniques to Determine Combined Sewer Overflow and Stormwater Impacts in the Aquatic Ecosystem", *Water Quality Research Journal of Canada,* Volume 35 (2000) 365-397.

[27] Starzec, P., B. Lind, A. Lanngrem, A. Lindgren, and T. Svenson, "Technical and Environmental Functioning of Detention Ponds for the Treatment of Highway and Road Runoff", *Water, Air, and Soil Pollution* 163 (2005): 153-167.

[28] Lau, S. L. and M. K. Stenstrom, "Metal and PAHs Adsorbed to Street Particles", *Water Research* 39 (2005): 4083 – 4092.

[29] Takata, H. T. Onda, and N. Ogura, "Determination of Polycyclic Aromatic Hydrocarbons in Urban Street Dusts and Their Source Materials by Capillary Gas Chromatography", *Environmental Science & Technology* 24 (1990) 1179 – 1186.

[30] Rogge, W. F., L. M. Hildermann, M. A. Mazurek, G. R. Cass, and B. R. T. Ssimoneit, "Sources of Organic Aerosol: 3, Road Dust, Tire Debris, and Organometallic Brake Lining Dust: Roads as Sources and Sinks" *Environmental Science & Technology* 27 (1993) 1892 – 1904.

[31] Grimmer, G., J. Jacob, K. W. Naujack, and G. Dettbarn, "Profile of the Polycyclic Aromatic Hydrocarbons from Used Engine Oil – Inventory of GCGC/MS-PAH in Environmental Materials, Part 2", *Analytische Chemie* 309 (1981) 13 – 19.

[32] Steuer, J. W. Selbig, N. Hornewer, and J. Prey, *Sources of Contamination in an Urban Basin in Marquette, Michigan and an Analysis of Concentrations, Loads, and Data Quality USGS Water-Resources Investigations Report 97-4242* (Middleton, WI: U. S. Geological Survey, 1997).

[33] Mahler, B. J, P. C. Van Metre, and J. T. Wilson, *Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) and Major and Trace Elements in Simulated Rainfall Runoff From Parking Lots, Austin, Texas, 2003 Open-File Report 2004-1208, version 2*(Austin, TX: U. S. Geological Survey, 2004).

[34] Mahler, B. J., P. C. Van Metre, T. J. Bashara, J. T.m Wilson, and D. A. Johns, "Parking Lot Sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons", *Environmental Science & Technology*, 39 (2005) 5560 – 5566.

[35] Van Metre, O. C., B. J. Mahler, and E. T. Furlong, "Urban Sprawl Leaves Its PAH Signature,", *Environmental Science & Technology* 34 (2000):4064-4070.

[36] Van Metre, P. C. and B J. Mahler, "Trends in Hydrophobic Organic Contamination in Urban and Reference lake Sediments Across the United States, 1970 – 2001, *Environmental Science & Technology*, 39 (2005): 5567 – 5574.

[37] National Research Council, *Assessing and Managing the Ecological Impacts of Paved Roads* (Washington DC: The National Academies Press, 2005).

[38] Larkin, G. A. and K. J. Hall, "Hydrocarbon Pollution in the Burnette River Watershed", *Water Quality Research Journal of Canada*, 33 (1998) 73 – 94.

[39] Lue-Hing, C., P. Tata, T. A. Granato, R. Sustich, R. Johnson, and R. I. Pietz, *Sewage Sludge Survey* (Washington, DC: Association of Metropo0litan Sewerage Agencies, 1998).

[40] State of Minnesota, "Chapter 7041 Minnesota Pollution Control Agency Sewage Sludge Management", available at http://www.revisor.leg.state.mn.us/arule/7041/ .

[41] Polta, R. C. , *A Survey of Regulations used to Control the Use and Disposal of Stormwater Pond Sediments in the United States and Canada* (St. Paul, MN: Metropolitan Council Environmental Services, 2004).

[42] ASTM, "Specific Gravity of Soils", *1985 Annual Book of ASTM Standards Volume 04.08 Soil and Rock; Building Stones* (Philadelphia, PA, American Society for Testing and Materials, 1985).

[43] Balogh, S. J., D. R. Engstrom, J. E. Almendinger, M. L. Meyer, and D. K. Johnson, "A History of Mercury Loading in the Upper Mississippi River Reconstructed from Sediments of Lake Pepin" *Environmental Science and Technology* 33 (1999) 3297-3302.

[44] Franz, T. P. and A. Craft-Reardon, *Analysis of Polychlorinated Biphenyls (PCBs) in River Water* (St Paul, MN: Metropolitan Council Environmental Services, 2001).

[45] NOAA, *Gas Chromatography Mass Spectrometry (GC-MS) Analysis for Organic Contaminates in Marine Sediments* (Silver Spring, MD: National Oceanic and Atmospheric Administration, 1998).

[46] Minnesota Rules, Chapter 7037.0500, Subpart 2 and Chapter 7037.3100, Subpart 2.

[47] American Public Health Association, American Water Works Association, and Water Environment Federation, *Standard Methods for the Examination of Water and Wastewater, 15th ed.* (Washington, DC: APHA, 1980).

[48] EPA, *Methods for Chemical Analysis of Water and Wastes* (Cincinnati, OH: EPA, 1983)

[49] EPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* available at http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm.

[50] 40CFR, Part 136, Appendix A

[51] EPA, "Appendix F Sample Preparation for Fecal Coliform Tests and *Salmonella* sp." *Control of Pathogens and Vector Attraction in Sewage Sludge EPA/625/R-92/013 Revised October 1999* (Washington, DC: United States Environmental Protection Agency, 1999).

[52] USEPA, *Methods for Measuring the Toxicity and Bioaccumulation of Sediment–Associated Contaminants with Freshwater Invertebrates, EPA/600/R-94/024* (Duluth, MN: Office of Research and Development, 1994).

[53] EPA, *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual* (Washington, DC: U. S. Environmental Protection Agency, 2001).

[54] Boone, P. M. and J. A. Miller, *Great Lakes Dredged Material Testing and Evaluation Manual: Appendix E Quality Assurance Guidance* (Chicago. IL:U. S. Environmental Protection Agency, 1998).

[55] Chen M and Ma LQ. Comparison of four USEPA digestion methods for trace metal analysis using certified and Florida soils. *J. Environ. Qual.* **27** 1294-1300 (1998).

[56] Wei Y-L, Shyu H-M, and Joehuang K-L. Comparison of microwave vs. hot-plate digestion for nine real-world river sediments. *J. Environ. Qual.* **26** 764-768 (1997).

[57] Hewitt AD and Reynolds CM. Microwave digestion of soils and sediments for assessing contamination by hazardous waste metals. Special Report 90-19, US Army Corps of Engineers, Cold Regions Research & Engineering Laboratory (1990).

[58] USEPA. Method 3050B, Acid digestion of sediments, sludges, and soils. US Environmental Protection Agency (1996).

[59] USEPA. Method 3051A, Microwave assisted acid digestion of sediments, sludges, soils, and oils. US Environmental Protection Agency (1998)

[60] NIST, Report of Investigation Reference Material 8704 Buffalo River Sediment (Gaithersburg, MD: Natinonal Institute of Standards & Gtechnology, 2000)

[61] Lee, J., personal communication.

[62] Storland, J. personal communication.

[63] Macbeth, E, and J. Storland, *Project Implementation Final Report Fish Lake Clean Water partnership Grant City of Eagan, Dakota County, Minnesota* (Eagan: MN: City of Eagan, 2002).

[64] EOR, *Brown's Creek Watershed District Hydrologic & Hydraulic Study* (Oakdale, MN: Emmons & Olivier Resources, Inc., 2004).

[65] NIST, *Certificate of Analysis – Standard Reference Material 1944 New York/New jersey Waterway Sediment* (Gaithersburg, MD: National Institute of Standards & Technology, 1999).

[66] Minnesota Stormwater Steering Committee, *Minnesota Stormwater Manual Version 1.0* (St. Paul, MN: Minnesota Pollution Control Agency, 2005). Available at http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html.

[67] Crane, J. L., D. D. McDonald, C. G. Ingersoll, D. E. Smorong, R. A. Lindskoog, C. G. Severn, T. A. Berger, and L. J. Field, *Development of a Framework for Evaluating Numerical Sediment Quality Targets and Sediment Contamination in the St. Louis River Area of Concern* (Chicago, IL: U. S. Environmental Protection Agency, 2000).

[68] NYSDEC, Technical Guidance for Screening Contaminated Sediments (Albany, NY: New York State Department of Environmental Conservation, revised 1999).

[69] MPCA, *Draft Guidelines Risk-Based Guidance for the Soil – Human Health Pathway Volume 2. Technical Support Document* (St. Paul. MN: Minnesota Pollution Control Agency, 1999).

[70] http://www.pca.state.mn.us/publications/risk-tier1srv.xls

[71] Shacklette, H. T. and J. G. Boerngen, *Element Concentration in Soils and Other Surficial Materials of the Conterminous United States – USGS Professional Paper 1270* (Washington, DC: U. S. Government Printing Office, 1984).

[72] Pierce, F. J., R. H. Dowdy, and D. F. Grigal, "Concentrations of Six Trace Metals in some Major Minnesota Soil Series", *Journal of Environmental Quality* 11 (1982) 416 – 422.

[73] Heiskary, S., *Lake Sediment Contaminant Levels in Minnesota* (St. Paul, MN: Minnesota Pollution Control Agency, 1996).

[74] MPCA, Trace Metal Concentrations in Surface Sediments of Nine Minnesota Northern Lakes and Forests Ecoregions Reference Lakes (St. Paul, MN: Minnesota Pollution Control Agency, 2000).

[75] EPA, Erosion, Sediment and Runoff Control for Roads and Highways – available at http://www.epa.gov/nps/education/runoff.html

[76] Canadian Council of Ministers of the Environment, *Summary of A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines (CCME 1996a)*, available at http://www.ccme.ca/assets/pdf/sqg_summary_table.pdf.

[77] Canadian Council of Ministers of the Environment, *Canadian Soil Quality Guidelines for the Protection of Environmental and Human health Summary Tables – Update 2004*. Available at http://www.ccme.ca/assets/pdf/sqg_protocol_sum.pdf.

[78] WSDE, Stormwater Management Manual for Western Washington Volume IV – Source Control BMPs (Olympia, WA: Washington State Department of Ecology, 2001).

[79] Assessing the Carcinogenic Risk of Mixtures Using Toxicity Equivalence Factors – available at http://fortress.wa.gov/ecq.clarc/FocusSheet/tef.pdf

[80] Richardson, D. C., "Parking Lot Sealants", *Stormwater*, Volume 7, Number 3 (2006), 40 – 46.

[81] MNDOT, *Standard Specifications for Construction 2005 ed*. Available at http://www.dot.state.mn.us/tecsup/spec/

[82] MNDOT staff personal communication, may 19, 2006.

[83] MNDOT, *Minnesota Seal Coat Handbook* (Maplewood, MN: Minnesota Department of Transportation, 1998).

[84] , Hatheway, A. W., Locations of Gas Plants and Other Coal-tar Sites in the U.S., available at http://www.hatheway.net/28_locations_of_gas_plants.htm

[85] MPCA, Excavation of Petroleum Contaminated Soil: Guidance Document 3-01 (St. Paul, MN: Minnesota Pollution Control Agency, 2005).

APPENDIX A – DATA SUMMARY FOR PONDS & TOP SOILS

POND NUMBER 1 – MARKHAM LAKE SAMPLED SEPTEMBER 22, 2004

Core	1A1	1A2	1B1	1B2	1C1	1C2	1D1	1D2	1E1	1E2	Average
Temp (^oC)	22.2		21.8		21.7		21.9		22		21.85
pH**	8.5		8.5		8.3		6.9		6.9		7.6
DO @ sed surface (mg/l)	10.8		10.9		14.2		10.9		9.4		11.4
TS %*	76.4	46.3	52.4	59.7	39.9	42.7	45.8	51.6	31.9	33.6	44.9
VS %*	2.9	6.4	4.7	2.9	7.7	8.5	7.7	5.0	13.4	11.2	7.5
Specific Gravity	2.45		2.52		2.47		2.47		2.29		2.44
% passing # 10 sieve	96.2		100.0		99.9		99.8		99.9		99.9
% passing # 16 sieve	94.4		100.0		99.9		99.2		99.7		99.7
% passing # 35 sieve	83.9		99.9		98.9		93.8		98.3		97.7
% passing # 50 sieve	67.8		99.5		93.1		83.6		94.6		92.7
% passing # 100 sieve	44.3		90.6		67.8		61.9		81.3		75.4
% passing # 200 sieve	31.4		76.4		44.5		44.7		67.4		58.3
Fecal Coliform (mpn/g)	10	13	11	8	49	60	14	< 6	30	12	25
TKN (mg/kg)*	1,450		1,400	965	1,300	1,650	1,567	950	3,333	2,900	1758
TP (mg/kg)*	245		515	355	550	525	380	265	557	543	461
NH3-N (mg/kg)*	31		61	40	56	85	81	82	123	102	79
COD (mg/kg)*	102,614		70,445	52,621	83,623	101,424	103,039	83,042	159,662	147,427	100,160
NO3-N (mg/kg)*	<0.65		<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	0.66	<0.65	<0.65
NO2-N (mg/kg)*	<0.65		<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.017		<0.017		0.019		<0.017		<0.017		<0.019
PAH - sum of 13 (ug/kg)		3,098		1,623		6,158		2,349		3,686	3,383
Benzo(a)pyrene (ug/kg)		376		200		637		243		413	374

Core	1A1	1A2	1B1	1B2	1C1	1C2	1D1	1D2	1E1	1E2	Average
Equivalent B(a)P (mg/kg)***		1.08		0.53		1.63		1.18		1.24	1.13
GRO (mg/kg)							19.7				19.7
Total Hg (ng/g)*	20.2	48.1	43.1	28.0	51.1	44.4	37.9	41.6	67.8	56.4	46.5
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	24.5		21.0	16.0	21.0	25.0	25.5	21.0	31.0	28.5	23.6
Nickel (mg/kg)*	16.0		15.5	10.5	13.0	15.0	15.5	12.5	21.0	19.5	15.3
Lead (mg/kg)*	34.5		34.0	19.5	55.5	90.0	57.0	51.3	57.0	57.5	52.7
Zinc (mg/kg)*	96.5		88.0	65.0	102.4	119.7	115.5	85.0	131.5	121.0	103.5
Cadmium (mg/kg)*	0.90		0.95	1.20	0.90	1.03	0.95	0.75	1.30	1.20	1.04
Chromium (mg/kg)*	16.0		17.5	12.0	15.0	20.0	18.5	14.3	23.5	21.0	17.7
Aluminum (mg/kg)*	7,126		7,184	4,934	4,775	6,289	6,554	5,084	9,107	8,243	6,521
Arsenic (mg/kg)*	4.0		3.2	<2.0	2.8	3.9	4.0	2.9	5.4	5.5	3.9
Iron (mg/kg)*	13,907		11,402	7,583	22,571	18,754	15,155	11,271	18,485	17,712	15,367
Manganese (mg/kg)*	382		314	189	1338	804	826	539	686	664	670
Molybdenum (mg/kg)*	0.60		0.47	<0.4	0.73	0.65	0.90	0.55	1.75	1.85	0.99
Selenium (mg/kg)*	<2.0		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	383		429	287	307	358	368	314	501	432	374
Vanadium (mg/kg)*	27.5		27.0	19.7	21.0	25.5	26.5	21.0	33.5	30.7	25.6

* average of duplicates

** pH meter was not working correctly; results suspect

*** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

POND NUMBER 2 – EAST RING POND SAMPLED SEPTEMBER 30, 2004

Core	2A1	2A2	2B1	2B2	2C1	2C2	2D1	2D2	2E1	2E2	Average
Temp (^oC)	15.2		15.6		15.2		15.8		15.8		15.52
pH**	6.7		6.8		6.9		6.9		6.7		6.8
DO @ sed surface (mg/l)	6.5		7.4		7.3		6		6.8		6.8
TS %*	13.9	10.7	19.9	17.9	15.5	15.1	27.3	27.1	18.3	19.5	18.5
VS %*	33.9	36.0	21.5	20.5	35.8	40.5	14.8	11.3	23.1	23.9	26.1
Specific Gravity	2.04		2.29		2.06		2.31		2.20		2.18
% passing # 10 sieve	100.0		100.0		100.0		98.3		99.8		99.61
% passing # 16 sieve	99.3		99.9		99.0		96.9		96.6		98.4
% passing # 35 sieve	94.4		99.1		93.1		91.9		88.2		93.3
% passing # 50 sieve	87.2		96.5		85.9		83.8		81.7		87.0
% passing # 100 sieve	66.1		77.7		65.0		61.6		66.4		67.3
% passing # 200 sieve	43.1		51.5		44.5		41.2		48.7		45.8
Fecal Coliform (mpn/g)	1300	520	94	150	360	360	200	69	18	450	352
TKN (mg/kg)*	9,000	9,450	6,900	6,800	10,250	8,100	4,200	3,000	6,250	8,800	7275
TP (mg/kg)*	480	475	460	370	573	500	280	230	540	757	466.5
NH3-N (mg/kg)*	140	129	116	64	178	185	80	49	192	198	133
COD (mg/kg)*	334,249	420,309	247,392	253,408	397,262	409,881	203,402	155,929	349,291	305,875	307,700
NO3-N (mg/kg)*	1.12	0.69	1.07	0.945	1.36	0.99	0.87	0.865	0.88	0.89	0.97
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.020		<0.021		<0.021		<0.020		<0.020		<0.021
PAH - sum of 13(ug/kg)		9,740		3,106		7,417		1,720		2,953	4,987

Core	2A1	2A2	2B1	2B2	2C1	2C2	2D1	2D2	2E1	2E2	Average
Benzo(a)pyrene (ug/kg)		989		475		1,001		205		345	603
Equivalent B(a)P (mg/kg)***		2.5		1.5		3.1		0.5		1.1	1.8
GRO (mg/kg)										< 27.5	< 27.5
Total Hg (ng/g)*	53.6	47.3	44.6	25.1	59.2	61.1	22.9	21.9	45.3	44.4	42.6
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	26.0	22.0	20.5	13.0	26.5	25.0	10.6	9.1	19.5	23.5	19.6
Nickel (mg/kg)*	14.5	14.0	13.5	10.5	15.5	15.0	12.5	12.5	15.5	17.0	14.1
Lead (mg/kg)*	37.5	42.5	49.5	21.0	53.0	47.0	25.0	21.0	35.0	37.5	36.9
Zinc (mg/kg)*	224.0	176.0	156.0	97.0	182.0	191.5	73.0	61.0	133.5	139.5	143.4
Cadmium (mg/kg)*	1.20	1.10	5.00	0.85	1.08	1.15	0.67	0.80	1.20	1.15	1.42
Chromium (mg/kg)*	12.5	11.0	10.5	6.2	13.0	14.5	7.3	4.6	11.7	13.5	10.5
Aluminum (mg/kg)*	4,489	4,476	4,447	2,291	5,936	5,683	3,508	2,380	5,522	6,693	4,542
Arsenic (mg/kg)*	13.0	12.5	9.5	9.3	13.0	13.0	7.0	8.7	10.5	14.5	11.1
Iron (mg/kg)*	15,157	13,238	16,593	14,996	16,221	14,910	8,788	10,026	17,906	25,911	15,375
Manganese (mg/kg)*	907	957	1,336	1,707	685	482	681	2,197	1,431	1,275	1,165
Molybdenum (mg/kg)*	3.1	2.9	2.3	2.3	4.4	4.1	2.3	2.8	6.1	7.2	3.7
Selenium (mg/kg)*	2.5	3.3	2.8	1.9	2.5	2.4	3.6	2.0	2.4	2.7	2.6
Titanium (mg/kg)*	277	287	327	312	257	210	355	364	266	263	292
Vanadium (mg/kg)*	18.7	17.5	18.0	11.3	22.0	22.1	17.0	13.0	21.3	27.0	18.8

* average of duplicates

** pH meter was not working correctly; results suspect

*** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

POND NUMBER 3 – MNDOT POND SAMPLED OCTOBER 6, 2004

Core	3A1	3A2	3B1	3B2	3C1	3C2	3D1	3D2	3 E1	3 E2	Average
Temp (^oC)	12.4		12.6		13.4		12.9		13.1		12.9
pH	6.8		7		7		7.1		7.1		7
DO @ sed surface (mg/l)	11.4		15.8		14.3		9.1		11.1		12.3
TS %*	13.85	14.7	20.25	19.85	11.55	10.75	12.6	9.785	21.8	28.75	16.4
VS %*	35.25	32.45	22.95	23.35	33.25	37.1	31.3	38.7	19.1	12.9	28.6
Specific Gravity	2.12		2.37		2.13		2.20		2.21		2.21
% passing # 10 sieve	100.0		100.0		100.0		100.0		99.6		99.9
% passing # 16 sieve	99.8		100.0		98.7		99.8		98.8		99.4
% passing # 35 sieve	97.9		98.5		90.7		94.1		92.4		94.7
% passing # 50 sieve	92.0		92.6		80.8		81.3		79.8		85.3
% passing # 100 sieve	69.4		75.1		57.3		57.0		56.9		63.2
% passing # 200 sieve	48.6		57.4		36.9		36.8		40.1		43.9
Fecal Coliform (mpn/g)	65	95	140	150	52	47	40	310	1300	3100	530
TKN (mg/kg)*	6,933	6,850	4,300	3,250	5,400	5,750	5,933	5,800	3,000	2,067	4,928
TP (mg/kg)*	570	576.6667	610	570	545	460	420	375	485	573.3333	518.5
NH3-N (mg/kg)*	171	166.5	306.5	287	162	155	179.5	166.5	180.5	239.5	201
COD (mg/kg)*	281,696	254,647	266,693	250,769	305,952	257,912	273,462	322,861	198,871	118,012	253,087
NO3-N (mg/kg)*	0.995	1.29	0.785	1.12	1	1.04	1.695	1.445	1.15	<0.65	1.17
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.022		<0.021		<0.044		<0.021		<0.021		<0.044
PAH - sum of 13 (ug/kg)		13,215		43,452		17,554		10,887		9,883	18,998
Benzo(a)pyrene (ug/kg)		1,466		1,194		2,170		1,753		1,593	1,635
Equivalent B(a)P (mg/kg)**		3.8		2.5		6.1		4.5		3.8	4.2

Core	3A1	3A2	3B1	3B2	3C1	3C2	3D1	3D2	3 E1	3 E2	Average
GRO (mg/kg)							< 40.7				< 40.7
Total Hg (ng/g)*	65.5	61.5	74.8	69.6	88.3	73.9	69.5	56.4	67.5	63.8	69.1
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	36.5	40.5	53.0	51.5	43.5	46.5	48.0	38.0	36.0	37.0	43.1
Nickel (mg/kg)*	17.5	18.0	26.5	23.5	22.5	21.5	27.5	21.5	20.0	24.0	22.3
Lead (mg/kg)*	54.5	52.0	65.5	65.0	111.0	103.5	76.0	64.0	52.0	50.0	69.4
Zinc (mg/kg)*	170	198	235	220	192	253	182	203	181	172	200
Cadmium (mg/kg)*	1.23	1.26	1.70	1.50	1.75	1.70	1.20	1.15	1.30	1.24	1.40
Chromium (mg/kg)*	18.5	21.0	32.0	26.5	24.5	25.5	31.0	26.5	19.7	24.1	24.9
Aluminum (mg/kg)*	7,343	7,367	13,040	10,047	9,341	8,721	12,676	9,472	7,552	12,478	9,804
Arsenic (mg/kg)*	12.0	10.2	14.0	13.0	14.5	14.5	13.0	8.9	9.8	10.0	12.0
Iron (mg/kg)*	34,553	35,594	49,699	47,175	42,242	41,410	36,815	29,138	34,343	33,091	38,406
Manganese (mg/kg)*	1,348	1,548	2,426	2,118	948	902	823	593	2,161	1,460	1,432
Molybdenum (mg/kg)*	1.85	1.65	1.80	1.55	2.00	2.25	2.10	2.50	1.67	0.94	1.83
Selenium (mg/kg)*	3.29	2.55	<2.0	2.65	4.25	3.47	3.56	<2.0	2.50	4.10	3.30
Titanium (mg/kg)*	302	267	431	276	330	324	366	251	218	299	306
Vanadium (mg/kg)*	27.5	28.0	47.0	36.5	36.0	33.0	45.5	35.2	29.0	44.1	36.2
* average of duplicates											
** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA											
When duplicates were both reported < x, the highest x was reported as the average											
For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit											
and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).											

POND NUMBER 4 - WIRTH LAKE POND SAMPLED NOVEMBER 3, 2004

Core	4A1	4A2	4B1	4B2	4C1	4C2	4D1	4D2	4 E1	4 E2
Temp (^{o}C)										
pH										
DO @ sed surface (mg/l)										
TS %*	48.25	46.2	48.95	47.55	50.9	51.15	55	56.7	62.9	61.1
VS %*	14.65	15.25	14.75	17.45	18.1	19.15	10.645	9.15	3.925	5.465
Specific Gravity	2.49		2.52		2.47		2.53		2.62	
% passing # 10 sieve	100.0		100.0			100.0	100.0		100.0	
% passing # 16 sieve	99.9		99.8			99.9	100.0		99.9	
% passing # 35 sieve	98.2		98.9			98.1	99.6		98.9	
% passing # 50 sieve	88.8		96.3			89.8	95.8		96.3	
% passing # 100 sieve	71.0		73.1			69.8	81.9		83.4	
% passing # 200 sieve	57.5		43.8			52.7	65.3		61.5	
Fecal Coliform (mpn/g)	5000	109	449	625	5882	4706	236	404	5	5
TKN (mg/kg)*	1,700	1,850	2,250	3,000	4,500	3,400	2,567	2,150	855	1,150
TP (mg/kg)*	475	440	665	800	1260	835	653.3333	485	165	235
NH3-N (mg/kg)*	96	110.5	66.2	76.4	74.95	77.3	50.5	43.95	30.4	33.5
COD (mg/kg)*	180,096	164,051	160,366	210,825	177,494	249,650	125,481	96,661	38,217	81,819
NO3-N (mg/kg)*	0.955	0.76	1.085	1.225	3.425	1.515	1.29	<0.65	0.795	1.515
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	0.073		0.025		0.123		<0.021		<0.038	
PAH - sum of 13 (ug/kg)		27,956		12,806		15,349		4,767		1,876
Benzo(a)pyrene (ug/kg)		4,561		1,720		2,418		699		207

Core	4A1	4A2	4B1	4B2	4C1	4C2	4D1	4D2	4 E1	4 E2
Equivalent B(a)P (mg/kg)**		10.82		3.74		5.40		1.32		0.42
GRO (mg/kg)			<11.7							
Total Hg (ng/g)*	146.0	145.6	87.4	89.3	70.5	105.6	48.5	46.9	18.4	25.3
TCLP metals	all values below limits established for classification as hazardous waste									
Copper (mg/kg)*	49.0	46.0	24.0	25.5	26.0	31.5	19.0	14.5	5.4	6.3
Nickel (mg/kg)*	29.0	27.5	20.5	22.5	23.5	26.5	17.0	15.0	9.7	12.0
Lead (mg/kg)*	294	211	73.0	82.0	44.0	58.0	55.5	47.0	10.0	11.5
Zinc (mg/kg)*	296	290	121	131	78.4	103	87.5	70.5	27.0	26.5
Cadmium (mg/kg)*	2.10	1.65	1.30	1.00	0.75	0.90	0.74	0.65	0.40	0.41
Chromium (mg/kg)*	50.0	36.5	15.7	16.0	15.2	19.5	12.5	8.5	2.7	6.8
Aluminum (mg/kg)*	15,139	12,172	6,492	6,526	7,718	6,696	6,295	4,682	1,872	2,650
Arsenic (mg/kg)*	12.0	12.0	9.4	9.6	4.7	4.0	3.3	3.0	<2.0	<2.0
Iron (mg/kg)*	25,983	22,216	12,575	14,063	14,193	15,860	10,850	8,570	3,030	4,475
Manganese (mg/kg)*	549	606	1,280	1,723	1,012	844	1,300	1,475	1,410	1,490
Molybdenum (mg/kg)*	1.00	0.85	0.65	1.07	0.60	0.40	<0.4	0.70	<0.4	<0.4
Selenium (mg/kg)*	5.00	6.95	13.00	11.00	12.00	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	622	374	400	380	235	223	428	384	375	402
Vanadium (mg/kg)*	56.0	45.0	28.5	31.0	36.2	41.0	24.5	16.3	6.9	9.6

* average of duplicates

** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

POND NUMBER 5 – LONG LAKE SAMPLED JULY 19, 2005

Core	5A1	5A2	5B1	5B2	5C1	5C2	5D1	5D2	5 E1	5 E2	Average
Temp (^oC)	22.1		25.1		24.4		24.8		25		24.3
pH	6.95		6.73		6.97		6.67		6.71		6.8
DO @ sed surface (mg/l)	7.2		3.7		6.3		1.5		2.5		4.2
TS %*	48.6	47.2	25.5	30.6	38.35	61.1	15.45	23.65	21.6	26.3	33.8
VS %*	11.15	8.85	13.9	14.2	4.5	3.735	26.75	18.55	15.3	15.05	13.2
Specific Gravity	2.44		2.43		2.58		2.17		2.38		2.40
% passing # 10 sieve	100.0		95.7		98.79		99.7		99.71		98.8
% passing # 16 sieve	99.7		85.7		97.84		97.8		94.61		95.1
% passing # 35 sieve	97.7		76.3		95.03		85.7		91.90		89.3
% passing # 50 sieve	90.9		64.0		89.10		69.3		83.96		79.4
% passing # 100 sieve	80.5		43.8		82.12		49.6		70.86		65.4
% passing # 200 sieve	65.3		27.2		73.59		32.4		52.63		50.2
Fecal Coliform (mpn/g)	2	5	12	42	34	13	9	<1	10	91	24
TKN (mg/kg)*	4,250	3,200	5,250	5,900	1,200	805	10,100	8,400	6,550	6,100	5176
TP (mg/kg)*	425	385	440	490	450	450	623.3333	645	535	505	495
NH3-N (mg/kg)*	113.5	118	168	188	103.5	116.5	279	366	193.5	189.5	184
COD (mg/kg)*	155,207	117,666	183,140	226,024	81,983	89,528	416,713	309,408	193,732	255,815	202,921
NO3-N (mg/kg)*	<0.65	<0.65	<0.65	0.75	<0.65	<0.65	0.735	<0.65	<0.65	0.73	0.45
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.015		<0.016		<0.016		<0.017		<0.016		<0.017
PAH - sum of 13 (ug/kg)	119		224		234		306		194		215
Benzo(a)pyrene (ug/kg)	12		15		27		21		13		18
Equivalent B(a)P (mg/kg)**	0.04		0.07		0.10		0.10		0.06		0.07

Core	5A1	5A2	5B1	5B2	5C1	5C2	5D1	5D2	5 E1	5 E2	Average
GRO (mg/kg)											
Total Hg (ng/g)*	36.7	34.4	40.3	38.7	28.5	27.4	75.7	62.9	45.5	46.1	44
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	23.5	25.0	30.0	32.5	28.7	19.0	40.0	44.3	28.0	29.5	30.1
Nickel (mg/kg)*	18.0	18.0	15.5	15.5	16.0	16.5	28.0	29.0	18.0	19.0	19.4
Lead (mg/kg)*	12.0	13.0	15.5	15.5	11.0	9.6	19.0	22.5	13.5	15.0	14.7
Zinc (mg/kg)*	71.5	77.0	73.5	73.5	73.0	73.0	116.5	113.0	86.5	85.5	84.3
Cadmium (mg/kg)*	0.90	0.90	0.65	0.60	0.65	0.55	0.90	1.00	0.65	0.55	0.73
Chromium (mg/kg)*	17.0	19.5	20.5	19.3	23.5	21.0	33.5	35.0	26.0	27.0	24.2
Aluminum (mg/kg)*	9,875	11,436	9,757	10,354	12,393	10,706	18,940	18,991	13,708	14,788	13,095
Arsenic (mg/kg)*	2.6	2.7	3.7	3.7	3.0	3.4	6.0	6.0	3.6	4.1	3.9
Iron (mg/kg)*	11,912	13,562	12,613	12,924	17,221	16,170	21,888	22,224	14,763	15,794	15,907
Manganese (mg/kg)*	218	227	273	293	296	428	388	359	289	306	308
Molybdenum (mg/kg)*	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.01	0.40	<0.4	<0.4	0.3
Selenium (mg/kg)*	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	283	404	435	401	601	485	504	421	525	551	461
Vanadium (mg/kg)*	33.0	38.0	36.0	38.0	43.0	39.0	66.0	54.7	42.5	45.5	43.6

* average of duplicates

** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

POND NUMBER 6 – FISH LAKE POND SAMPLED JULY 26, 2005

Core	6A1	6A2	6B1	6B2	6C1	6C2	6D1	6D2	6 E1	6 E2	Average
Temp (^oC)	23.6		23.1		23		23.7		23.9		23.5
pH	7.01		7.15		6.91		6.76		6.89		6.9
DO @ sed surface (mg/l)	4		2.3		2.95		1.3		3		2.7
TS %*	77.5	77.4	85.5	83.9	29.4	47.3	43.6	52.4	26.7	44.4	56.8
VS %*	2.4	1.9	1.1	1.3	7.6	9.2	6.4	5.1	7.4	9.4	5.2
Specific Gravity	2.68		2.72		2.60		2.63		2.59		2.6
% passing # 10 sieve	67.3		72.6		99.70		99.8		85.8		85.0
% passing # 16 sieve	49.2		47.6		95.37		95.7		77.4		73.0
% passing # 35 sieve	28.5		14.8		86.01		89.4		64.3		56.6
% passing # 50 sieve	13.5		2.3		74.49		80.4		50.5		44.2
% passing # 100 sieve	4.2		0.1		62.22		64.6		34.7		33.2
% passing # 200 sieve	1.3		0.0		50.22		49.9		26.3		25.6
Fecal Coliform (mpn/g)	1162	>2069	>1872	>1908	816	3383	3670	955	1873	>3608	1,977
TKN (mg/kg)*	285	330	26	44	2,000	3,300	1,567	1,500	1,100	3,700	1,385
TP (mg/kg)*	203.3333	570	141.3333	175	835	500	660	660	375	585	470
NH3-N (mg/kg)*	13.75	12.9	11.36667	10.31667	141.5	81.55	139.5	118	36.9	62.95	63
COD (mg/kg)*	11,359	5,999	400	219	106,471	136,865	103,460	98,600	40,816	155,035	65,922
NO3-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	0.4925	0.34
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.004		<0.004		<0.020		<0.018		<0.020		<0.02
PAH - sum of 13 (ug/kg)	32,217		5,042		26,989		15,810		1,994		16,410
Benzo(a)pyrene (ug/kg)	3,731		522		2,728		1,758		237		1,795
Equivalent B(a)P (mg/kg)**	8.11		1.70		4.30		2.80		0.46		3.47

Core	6A1	6A2	6B1	6B2	6C1	6C2	6D1	6D2	6 E1	6 E2	Average
GRO (mg/kg)											
Total Hg (ng/g)*	13.1	6.9	3.2	2.9	55.2	27.2	40.9	34.5	13.5	31.0	23
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	20.0	15.1	11.5	17.0	28.5	18.0	26.5	23.0	16.0	25.0	20.1
Nickel (mg/kg)*	10.4	9.6	10.7	11.4	25.0	17.0	22.5	21.0	15.5	21.5	16.5
Lead (mg/kg)*	19.8	8.0	4.3	2.5	57.0	10.0	36.5	31.0	6.4	17.5	19.3
Zinc (mg/kg)*	74.0	70.4	56.2	58.9	108.5	70.0	93.5	74.5	48.5	85.0	73.9
Cadmium (mg/kg)*	0.20	0.21	0.36	0.19	1.15	0.75	0.72	0.80	0.55	0.85	0.58
Chromium (mg/kg)*	11.5	8.6	9.2	9.9	29.0	21.0	29.0	24.0	13.7	31.0	18.7
Aluminum (mg/kg)*	3,665	3,706	2,986	3,799	15,838	10,587	14,884	12,639	7,328	13,272	8,870
Arsenic (mg/kg)*	1.5	1.7	2.0	1.2	5.7	3.2	4.9	3.9	1.9	3.0	2.9
Iron (mg/kg)*	9,235	10,324	14,736	11,614	22,742	14,685	21,037	18,607	12,992	18,463	15,443
Manganese (mg/kg)*	162	168	146	188	524	302	449	392	355	347	303
Molybdenum (mg/kg)*	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	< 0.4
Selenium (mg/kg)*	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	335	303	274	275	466	516	622	551	394	608	434
Vanadium (mg/kg)*	19.5	19.5	26.5	21.5	52.5	42.0	51.5	47.0	35.0	51.0	36.6
* average of duplicates											
** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA											
When duplicates were both reported < x, the highest x was reported as the average											
For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit											
and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).											

POND NUMBER 7 – MARKET PLACE POND SAMPLED AUGUST 2, 2005

Core	7A1	7A2	7B1	7B2	7C1	7C2	7D1	7D2	7 E1	7 E2	Average
Temp (^oC)	21.4		22.6		23.5		23.2		28.4		23.8
pH	7.14		7.25		7.64		7.58		7.51		7.4
DO @ sed surface (mg/l)	0.3		0.3		3.3		1.6		2.4		1.6
TS %*	40.9	49.9	43.9	63.0	42.6	31.5	11.2	16.3	34.4	57.2	39.1
VS %*	5.3	5.1	5.6	3.7	6.0	6.7	8.8	6.7	8.0	3.7	5.9
Specific Gravity	2.63		2.64		2.60		2.66		2.57		2.6
% passing # 10 sieve	99.9		97.0		98.39		99.9		99.5		98.9
% passing # 16 sieve	97.3		83.1		88.85		99.4		99.1		93.5
% passing # 35 sieve	90.0		68.8		78.56		94.0		93.6		85.0
% passing # 50 sieve	79.0		55.8		65.71		76.2		81.2		71.6
% passing # 100 sieve	59.5		38.7		41.41		50.1		64.8		50.9
% passing # 200 sieve	42.5		26.8		29.60		35.7		48.0		36.5
Fecal Coliform (mpn/g)	73	100	11	21	31	41	20	80	>465	87	52
TKN (mg/kg)*	1,150	1,150	1,150	735	1,350	1,400	795	780	1,650	730	1,089
TP (mg/kg)*	550	460	645	500	720	790	555	545	585	525	588
NH3-N (mg/kg)*	99.2	80.4	93.7	79.2	111.5	122.5	57.0	65.8	64.6	61.5	84
COD (mg/kg)*	90,615	111,445	110,799	74,062	117,845	125,487	126,471	124,504	153,604	83,236	111,807
NO3-N (mg/kg)*	<0.65	0.925	<0.65	<0.65	<0.65	<0.65	0.8	1.325	0.96	0.79	0.64
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.019		<0.019		<0.020		<0.019		<0.020		<0.02
PAH - sum of 13 (ug/kg)	17,179		21,074		9,986		9,335		42,698		20,054
Benzo(a)pyrene (ug/kg)	1,689		2,494		1,605		1,307		4,879		2,395
Equivalent B(a)P (mg/kg)**	3,815.7		5,297.2		3,850.8		3,705.7		8,342.3		5,002.4

Core	7A1	7A2	7B1	7B2	7C1	7C2	7D1	7D2	7 E1	7 E2	Average
GRO (mg/kg)											
Total Hg (ng/g)*	32.2	29.6	38.3	32.6	56.2	55.0	56.4	36.0	38.3	18.0	39.3
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	28.0	25.5	33.5	29.0	39.5	42.0	31.0	32.0	46.0	30.0	33.7
Nickel (mg/kg)*	20.0	16.0	24.5	21.5	30.0	31.0	23.5	24.5	25.0	19.0	23.5
Lead (mg/kg)*	27.5	31.5	37.5	25.5	30.5	34.5	22.5	20.0	22.5	14.5	26.7
Zinc (mg/kg)*	94.0	109	112	90.0	121	124	94.0	92.5	167	115	112
Cadmium (mg/kg)*	0.70	0.75	0.80	0.65	0.90	0.90	0.75	0.70	0.80	0.65	0.76
Chromium (mg/kg)*	23.7	21.0	40.2	27.5	41.0	42.5	31.0	31.5	35.5	24.0	31.8
Aluminum (mg/kg)*	12,360	10,303	15,758	14,568	22,910	24,153	16,563	17,572	12,696	10,719	15,760
Arsenic (mg/kg)*	3.7	3.4	4.3	3.8	4.7	5.1	4.0	3.8	3.2	2.6	4
Iron (mg/kg)*	18,704	14,569	22,418	21,112	26,822	28,363	21,883	22,708	19,906	17,427	21,391
Manganese (mg/kg)*	235	168	220	207	266	281	198	199	203	151	213
Molybdenum (mg/kg)*	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Selenium (mg/kg)*	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	492	483	671	693	792	887	742	790	730	549	683
Vanadium (mg/kg)*	42.7	41.5	58.0	54.0	69.0	73.0	58.5	59.5	51.5	46.0	55.4

* average of duplicates

** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit
and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

POND NUMBER 8 – CEDAR POND SAMPLED AUGUST 9, 2005

Core	8A1	8A2	8B1	8B2	8C1	8C2	8D1	8D2	8 E1	8 E2	Average
Temp (^{o}C)	temperature probe not functioning properly in field										NA
pH	7.12		6.8		6.92		6.79		6.81		6.9
DO @ sed surface (mg/l)	1.4		0.15		0.35		0.11		0.14		0.4
TS %*	24	24	38	37	42	19	38	38	42	44	34.5
VS %*	4.0	4.7	11.2	11.8	5.8	3.2	11.2	11.3	8.9	8.0	8.0
Specific Gravity	2.63		2.48		2.58		2.51		2.54		2.5
% passing # 10 sieve	94.7		99.8		99.33		99.8		97.1		98.1
% passing # 16 sieve	90.7		99.0		98.58		98.4		87.4		94.8
% passing # 35 sieve	75.2		91.7		85.48		87.7		74.1		82.8
% passing # 50 sieve	52.5		77.0		61.44		70.8		62.2		64.8
% passing # 100 sieve	19.7		61.6		42.14		54.9		48.7		45.4
% passing # 200 sieve	6.9		49.8		30.25		43.6		36.7		33.4
Fecal Coliform (mpn/g)	1230	208	132	137	53	59	61	133	72	50	214
TKN (mg/kg)*	810	1,973	4,150	4,400	1,500	800	4,300	4,500	2,700	2,400	2753
TP (mg/kg)*	235	530	975	1050	410	205	1300	1300	895	860	776
NH3-N (mg/kg)*	19.5	25.55	347.5	334	68.1	13.3	413.5	398.5	245	248.5	211
COD (mg/kg)*	40,002	42,365	189,995	195,492	96,351	31,393	219,510	208,583	136,591	134,967	129,525
NO3-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	1.655	<0.65	<0.65	0.5025	<0.65	<0.65	0.48
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.020		0.099		<0.019		0.096		0.107		0.0624
PAH - sum of 13 (ug/kg)	65,033		21,941		2,554		24,290		16,049		12,456
Benzo(a)pyrene (ug/kg)	7,513		3,439		356		2,389		2,102		1,586
Equivalent B(a)P (mg/kg)**	16.45		7.41		0.80		6.15		5.60		3.83

Core	8A1	8A2	8B1	8B2	8C1	8C2	8D1	8D2	8 E1	8 E2	Average
GRO (mg/kg)											
Total Hg (ng/g)*	18.3	91.3	102.2	100.4	32.9	19.3	103.2	91.8	76.0	76.3	71.2
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	11.0	12.9	40.0	37.0	15.5	9.8	42.5	33.8	32.5	30.0	26.5
Nickel (mg/kg)*	11.5	12.5	31.5	30.0	13.0	29.4	34.5	28.5	28.0	26.0	24.5
Lead (mg/kg)*	8.3	11.5	143	93.5	20.5	19.0	147	133	111	113	79.9
Zinc (mg/kg)*	79	76	184	172	84	55	178	162	153	143	128.5
Cadmium (mg/kg)*	0.30	0.40	1.40	1.17	0.55	0.67	1.40	1.30	1.20	1.05	0.94
Chromium (mg/kg)*	14.7	16.0	38.5	37.0	15.0	5.6	45.5	33.3	33.5	30.5	27.0
Aluminum (mg/kg)*	2,925	3,064	24,005	24,805	9,494	3,109	29,764	21,935	20,445	18,449	15,799
Arsenic (mg/kg)*	2.2	2.5	9.8	8.5	3.6	2.2	13.0	12.0	9.3	9.1	7.2
Iron (mg/kg)*	6,866	7,593	23,848	23,756	10,372	5,503	28,479	23,100	22,269	20,331	17,211
Manganese (mg/kg)*	112	118	299	315	177	79	403	333	352	331	252
Molybdenum (mg/kg)*	<0.4	<0.4	0.35	0.30	0.40	<0.4	0.74	0.71	0.40	<0.4	0.4
Selenium (mg/kg)*	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	295	295	581	555	377	208	575	324	531	452	419
Vanadium (mg/kg)*	21.0	25.5	66.0	66.0	30.0	17.5	79.0	52.5	59.0	56.5	47.3

* average of duplicates

** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

POND NUMBER 9 – LOCKE LAKE POND SAMPLED AUGUST 16, 2005

Core	9A1	9A2	9B1	9B2	9C1	9C2	9D1	9D2	9 E1	9 E2	Average
Temp (^oC)	20.8		21.2		21.3		21.1		21.3		21.1
pH	7.66		7.83		7.28		6.96		7.22		7.4
DO @ sed surface (mg/l)	2.5		7		7.4		7.2		6		6.0
TS %*	79.1	78.2	79.95	80.25	28.4	38.75	25.65	24.25	58.3	61.7	55.5
VS %*	0.645	0.69	0.84	0.855	11.05	5.88	10.7	10.55	3.17	2.64	4.7
Specific Gravity	2.65		2.65		2.50		2.41		2.64		2.57
% passing # 10 sieve	98.6		93.1		99.5		99.6		99.9		98.15
% passing # 16 sieve	94.7		79.5		96.3		96.8		95.3		92.52
% passing # 35 sieve	80.0		61.2		91.3		92.4		95.0		83.98
% passing # 50 sieve	51.9		41.1		83.7		85.6		93.8		71.21
% passing # 100 sieve	11.4		10.0		69.0		68.7		62.2		44.28
% passing # 200 sieve	1.5		2.5		49.0		46.2		9.3		21.70
Fecal Coliform (mpn/g)	38	38	30	112	106	44	27	53	19	21	49
TKN (mg/kg)*	170	123	193	210	5,700	3,000	5,750	5,400	1,350	1,100	2300
TP (mg/kg)*	200	190	166.6667	206.6667	1100	705	1150	1200	390	370	568
NH3-N (mg/kg)*	11.91667	5.365	10.31667	11.22	290	148	295.5	268	58.9	59.8	116
COD (mg/kg)*	2,924	1,823	4,520	3,270	177,217	87,707	163,570	171,156	61,391	58,397	73,197
NO3-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	1.73	<0.65	1.355	1.05	<0.65	0.64
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.020		<0.020		0.0735		0.081		0.023		0.0375
PAH - sum of 17 (mg/kg)	1281		2090		9468		9825		6145		5,088
Benzo(a)pyrene (mg/kg)	178		241		1294		1236		787		664

Core	9A1	9A2	9B1	9B2	9C1	9C2	9D1	9D2	9 E1	9 E2	Average
Equivalent B(a)P (mg/kg)**	0.37		0.47		2.18		2.91		1.55		1.33
GRO (mg/kg)											
Total Hg (ng/g)*	3.8	3.7	4.5	4.7	50.2	26.2	46.0	41.0	10.8	9.8	20.1
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	4.7	4.1	4.9	8.1	26.5	16.0	26.0	24.0	10.3	8.1	13.3
Nickel (mg/kg)*	4.2	5.3	5.0	5.3	17.0	11.0	15.5	15.5	5.6	5.4	9.0
Lead (mg/kg)*	2.7	2.5	3.3	2.9	29.5	19.0	27.5	27.5	7.0	6.9	12.9
Zinc (mg/kg)*	47.5	54.5	57.0	56.5	135	91.5	129	123	78.0	68.5	84.1
Cadmium (mg/kg)*	0.20	0.20	0.30	0.19	0.90	0.60	0.80	0.85	0.27	0.34	0.47
Chromium (mg/kg)*	3.9	5.8	4.5	4.7	23.0	19.5	22.0	22.0	8.3	7.0	12.1
Aluminum (mg/kg)*	1,721	1,914	1,919	2,065	8,178	6,497	8,843	9,349	3,547	3,126	4,716
Arsenic (mg/kg)*	<2.0	<2.0	2.3	2.1	6.2	4.4	6.3	5.6	2.05	2	3.3
Iron (mg/kg)*	5,014	4,456	5,131	4,908	16,429	11,236	16,640	16,328	6,192	5,754	9,209
Manganese (mg/kg)*	167	119	146	142	811	471	885	810	152	168	387
Molybdenum (mg/kg)*	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.5	<0.4	<0.4	<0.4
Selenium (mg/kg)*	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	206	200	187	159	399	394	458	495	332	281	311
Vanadium (mg/kg)*	13.0	14.1	13.0	11.5	34.0	28.0	37.0	37.5	16.5	14.0	21.9

* average of duplicates

** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

POND NUMBER 10 – ANOKA POND 62 SAMPLED AUGUST 30, 2005

Core	10A1	10A2	10B1	10B2	10C1	10C2	10D1	10D2	10 E1	10 E2	Average
Temp (^oC)	22		22.1		22.2		21.9		21.9		22.0
pH	9.25		8.23		8.65		8.36		8.31		8.6
DO @ sed surface (mg/l)	11.8		10		11.9		1.9		6.25		8.4
TS %*	74.6	78.35	70.6	71.45	65.45	63.85	66.4	63.3	65	73.4	69.2
VS %*	0.915	1.22	1.335	0.85	1.695	1.83	1.5	2.045	1.475	1.05	1.4
Specific Gravity	2.64		2.60		2.64		2.27		2.62		2.55
% passing # 10 sieve	99.4		100.0		92.0		99.8		96.8		97.59
% passing # 16 sieve	92.9		99.7		90.6		98.7		92.4		94.84
% passing # 35 sieve	70.2		99.0		74.7		86.6		72.3		80.55
% passing # 50 sieve	44.2		95.7		43.4		57.8		44.0		57.01
% passing # 100 sieve	15.2		61.1		18.2		17.9		13.4		25.16
% passing # 200 sieve	3.7		8.1		10.4		7.3		6.3		7.15
Fecal Coliform (mpn/g)	2	10	<1	15	11	<1	1	1	2	<1	4
TKN (mg/kg)*	150	350	175	355	393	340	275	300	293	220	285.2
TP (mg/kg)*	250	210	325	375	380	400	395	365	290	290	328.0
NH3-N (mg/kg)*	12.85	13.3	22.8	23.7	30.05	26.75	26.2	30.3	27.8	31.35	24.5
COD (mg/kg)*	6,596	12,610	19,413	21,418	51,709	33,444	19,193	24,638	10,305	29,187	22,851
NO3-N (mg/kg)*	<0.65	0.6625	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.004		<0.020		<0.019		<0.018		<0.016		0.019
PAH - sum of 13 (ug/kg)	1350		160		337		292		394		507
Benzo(a)pyrene (ug/kg)	157		18.1		35.8		16.6		48.0		55.0

Core	10A1	10A2	10B1	10B2	10C1	10C2	10D1	10D2	10 E1	10 E2	Average
Equivalent B(a)P (mg/kg)**	0.63		0.04		0.11		0.03		0.12		0.19
GRO (mg/kg)											
Total Hg (ng/g)*	5.8	6.0	7.2	8.3	22.4	27.5	25.4	28.9	23.5	11.3	16.6
TCLP metals	all values below limits established for classification as hazardous waste										
Copper (mg/kg)*	27.5	43.5	6.6	7.5	17.0	19.0	15.0	16.0	11.0	25.1	18.8
Nickel (mg/kg)*	13.0	14.0	12.0	14.5	42.0	50.0	36.0	40.0	29.5	29.2	28.0
Lead (mg/kg)*	3.1	5.4	3.4	3.9	12.0	13.5	9.1	10.0	6.9	8.7	7.6
Zinc (mg/kg)*	79.5	93.0	58.5	56.5	65.0	74.0	53.6	76.0	63.5	62.4	68.2
Cadmium (mg/kg)*	0.198	0.269	0.258	0.500	0.850	0.950	0.600	0.600	0.400	0.491	0.512
Chromium (mg/kg)*	6.2	8.5	5.5	6.4	12.0	12.5	12.0	13.0	7.6	13.3	9.7
Aluminum (mg/kg)*	2,328	3,016	3,406	4,024	7,980	7,850	9,059	9,989	5,158	8,858	6,167
Arsenic (mg/kg)*	<2.0	<2.0	<2.0	2.2	3.1	3.5	3.25	3.75	2.5	3.15	2.4
Iron (mg/kg)*	5,352	6,702	5,118	5,792	10,900	11,609	11,494	12,870	8,965	10,542	8,934
Manganese (mg/kg)*	134	173	183	231	1,733	2,167	1,179	1,277	787	612	847
Molybdenum (mg/kg)*	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Selenium (mg/kg)*	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (mg/kg)*	188	254	262	278	334	301	293	339	227	361	283
Vanadium (mg/kg)*	10.5	12.0	14.5	17.0	28.0	27.5	28.0	30.0	17.5	27.3	21.2

* average of duplicates

** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA

When duplicates were both reported < x, the highest x was reported as the average

For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).

TOP SOIL SAMPLES

Sample Number	1	2	3	4	Average
TS %*	84.6	86.3	89.85	48.2	77.2
VS %*	5.16	4.555	3.61	39.4	13.2
Specific Gravity	2.64	2.59	2.63	2.16	2.5
% passing # 10 sieve	88.1	98.5	83.4	99.4	92.3
% passing # 16 sieve	77.6	90.3	66.1	92.7	81.7
% passing # 35 sieve	64.5	74.7	44.6	79.2	65.7
% passing # 50 sieve	47.1	56.1	24.9	59.1	46.8
% passing # 100 sieve	23.2	29.5	10.6	25.3	22.2
% passing # 200 sieve	10.7	14.0	6.0	11.0	10.4
Fecal Coliform (mpn/g)	59	278	100	29	117
TKN (mg/kg)*	1,800	1,750	1,400	12,500	4,363
TP (mg/kg)*	500	420	520	585	506
NH3-N (mg/kg)*	26.4	32.45	24.95	46.15	32.5
COD (mg/kg)*	61,442	53,615	42,349	524,272	170,419
NO3-N (mg/kg)*	15.76	2.965	18.3	33.32	17.6
NO2-N (mg/kg)*	<0.65	<0.65	<0.65	<0.65	<0.65
Total PCB (mg/kg)	<0.018	<0.019	<0.019	<0.019	<0.019
PAH - sum of 13 (ug/kg)	145	75	1,612	364	549
Benzo(a)pyrene (ug/kg)	2.0	1.7	230	4.0	59
Equivalent B(a)P (mg/kg)**	0.032	0.009	0.704	0.020	0.191
GRO (mg/kg)					
Total Hg (ng/g)*	24.0	22.0	110.0	24.2	45.0
TCLP metals	all values below limits established for classification as hazardous waste				

Sample Number	1	2	3	4	Average
Copper (mg/kg)*	11.0	10.4	11.0	6.8	9.8
Nickel (mg/kg)*	13.1	10.0	10.5	9.0	10.6
Lead (mg/kg)*	6.2	7.1	13.0	3.7	7.5
Zinc (mg/kg)*	63.0	66.5	72.0	52.0	63.4
Cadmium (mg/kg)*	0.60	0.41	0.40	0.30	0.43
Chromium (mg/kg)*	10.2	12.5	9.2	6.6	9.6
Aluminum (mg/kg)*	4,487	7,876	5,569	4,392	5,581
Arsenic (mg/kg)*	3.4	3.4	3.7	7.9	2.0
Iron (mg/kg)*	11,062	10,680	10,517	5,174	9,358
Manganese (mg/kg)*	580	336	527	138	395
Molybdenum (mg/kg)*	1.00	<0.4	<0.4	5.50	1.72
Selenium (mg/kg)*	2.15	<2.0	<2.0	<2.0	0.27
Titanium (mg/kg)*	228	230	262	169	222
Vanadium (mg/kg)*	20.0	26.2	22.0	16.0	21.0
* average of duplicates					
When duplicates were both reported < x, the highest x was reported as the average					
For averages, if one duplicate was < detection limit and one was > detection limit, the average of the value > detection limit					
and half of the detection limit was reported. (eg. Duplicates = 14 and <5.0; average = (14 + 5/2)/2 = 8.2).					
** Equivalent B(a)P = equivalent concentration of Benzo(a)pyrene using relative potency factors suggested by MPCA					

APPENDIX B – PARTICLE SIZE DISTRIBUTIONS

Figure A-1. Particle Size Distribution for Markham Lake Sediments

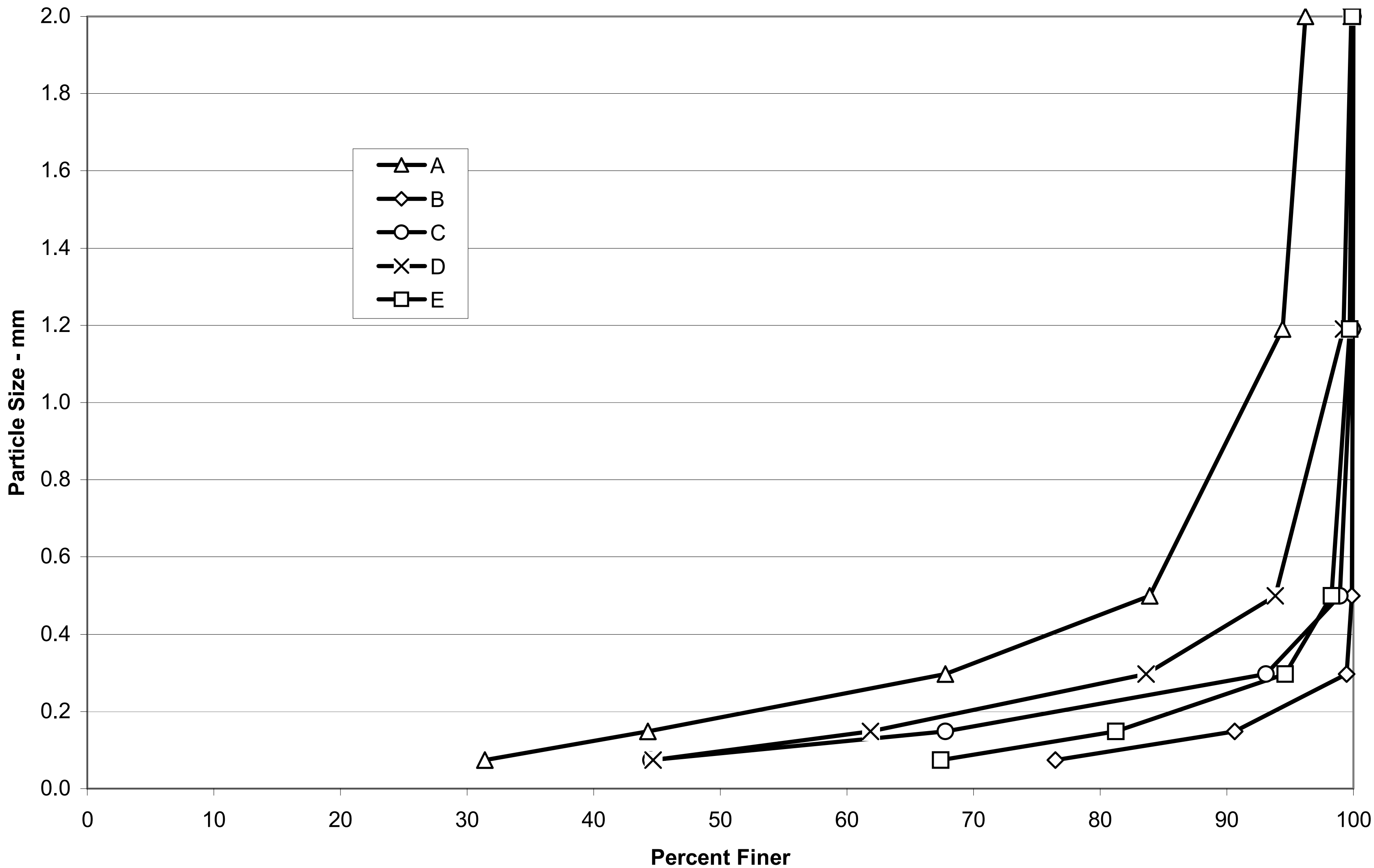


Figure A-2. Particle Size Distribution for East Ring Pond Sediments

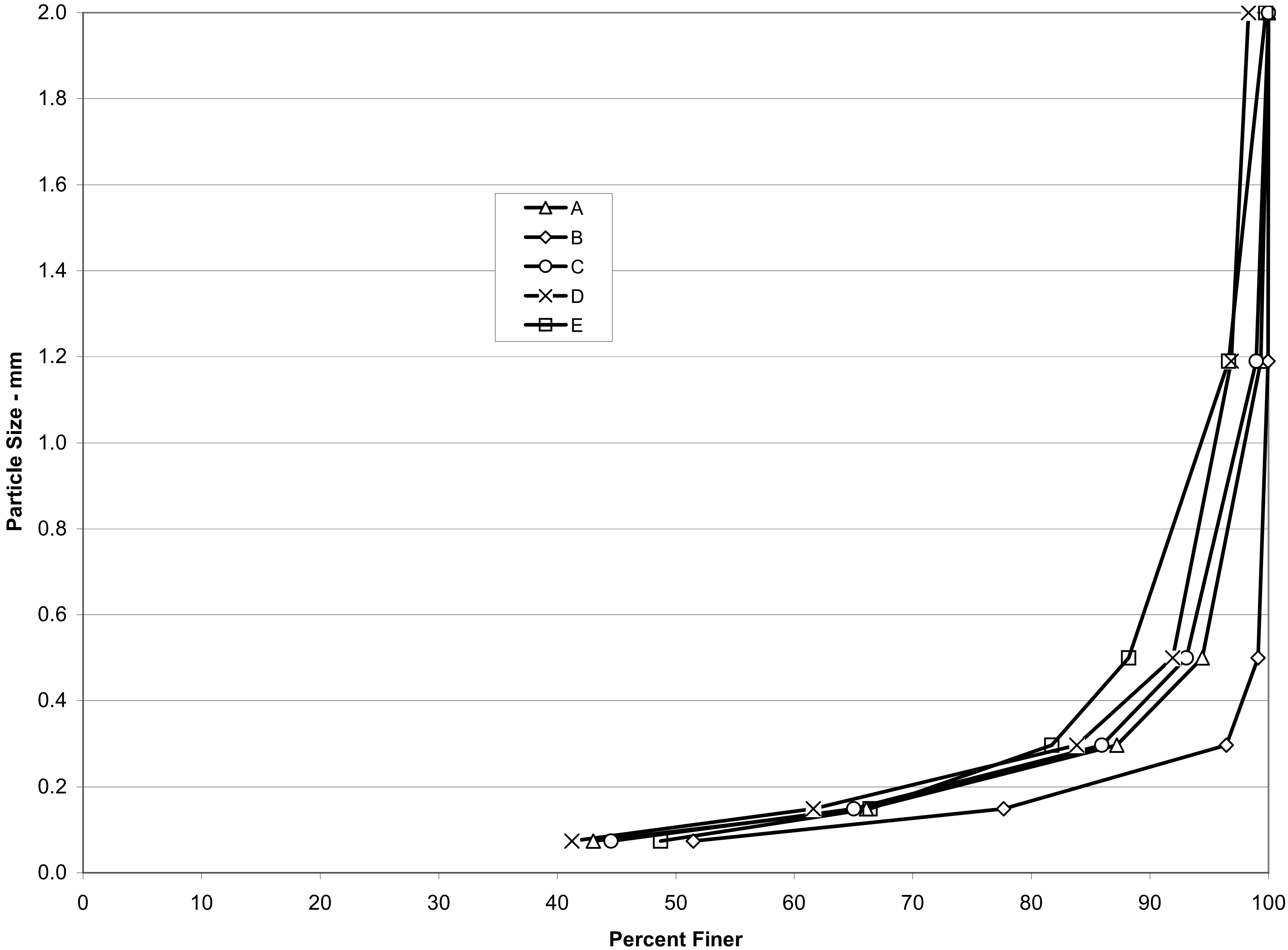


Figure A-3. Particle Size Distribution for MNDOT Pond Sediments

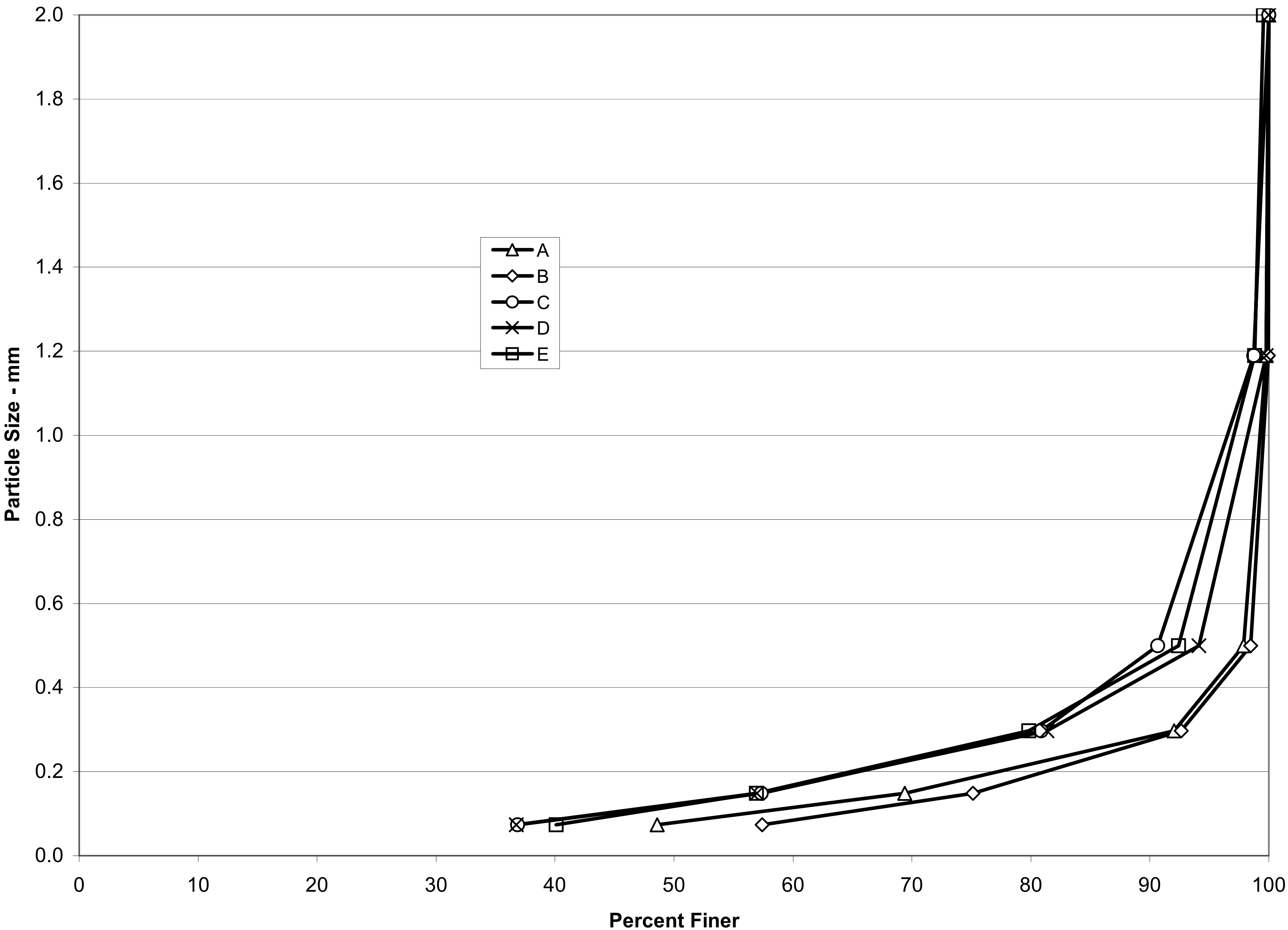


Figure A-4. Particle Size Distribution for Wirth Lake Pond Sediments

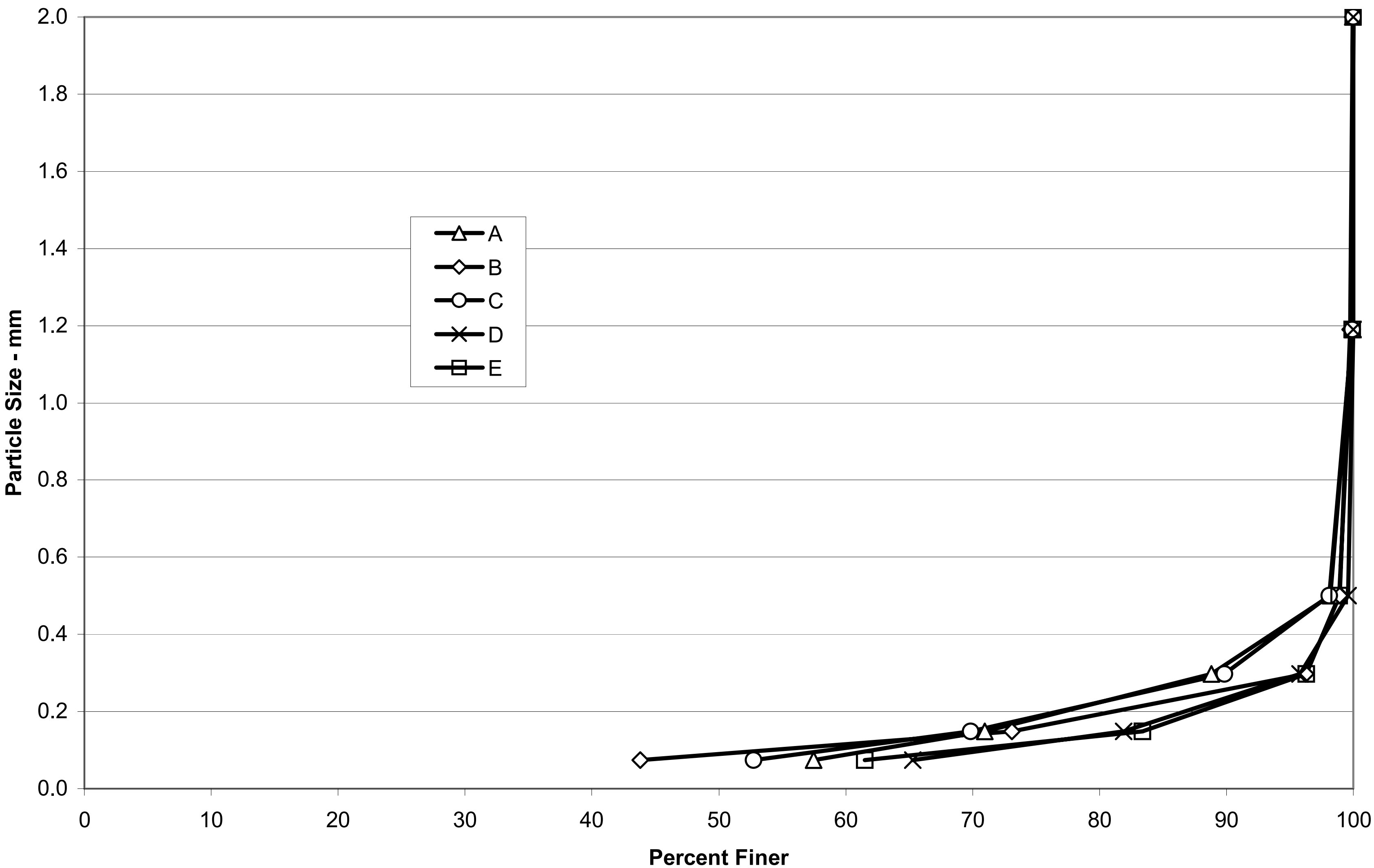


Figure A-5. Particle Size Distribution for Long Lake Sediments

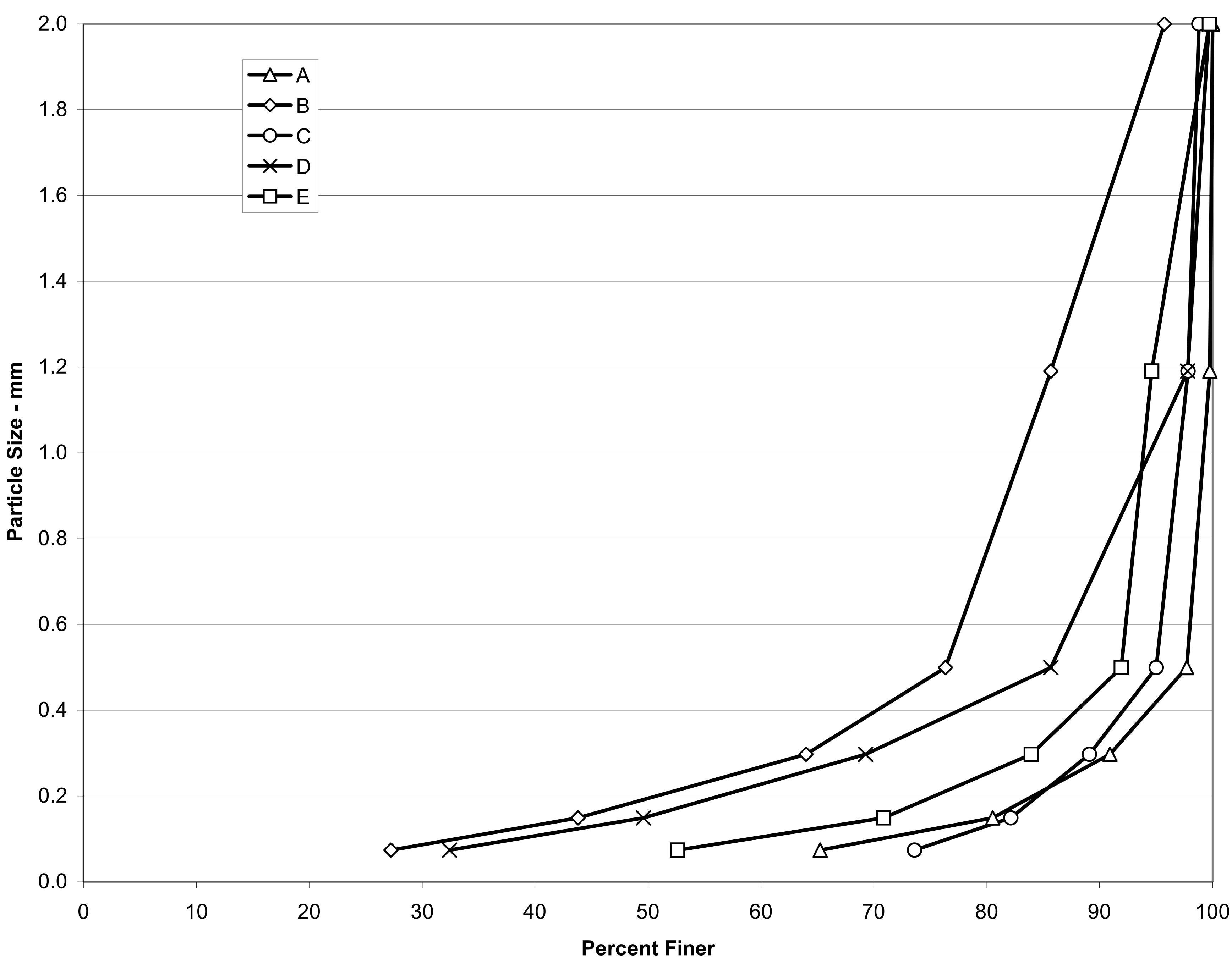


Figure A-6. Particle Size Distribution for Fish Lake Pond Sediments

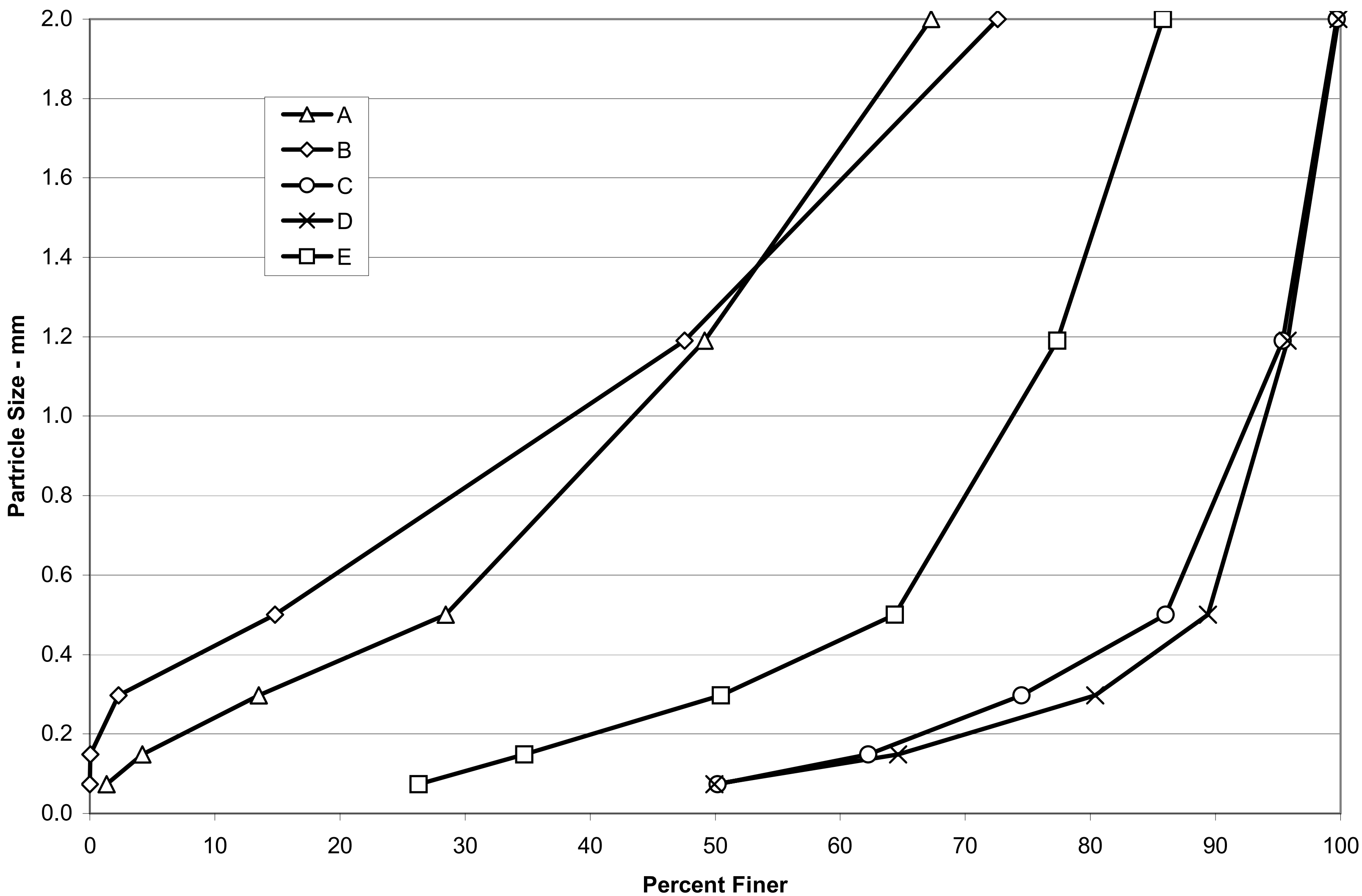


Figure A-7. Particle Size Distribution for Market Place Pond Sediments

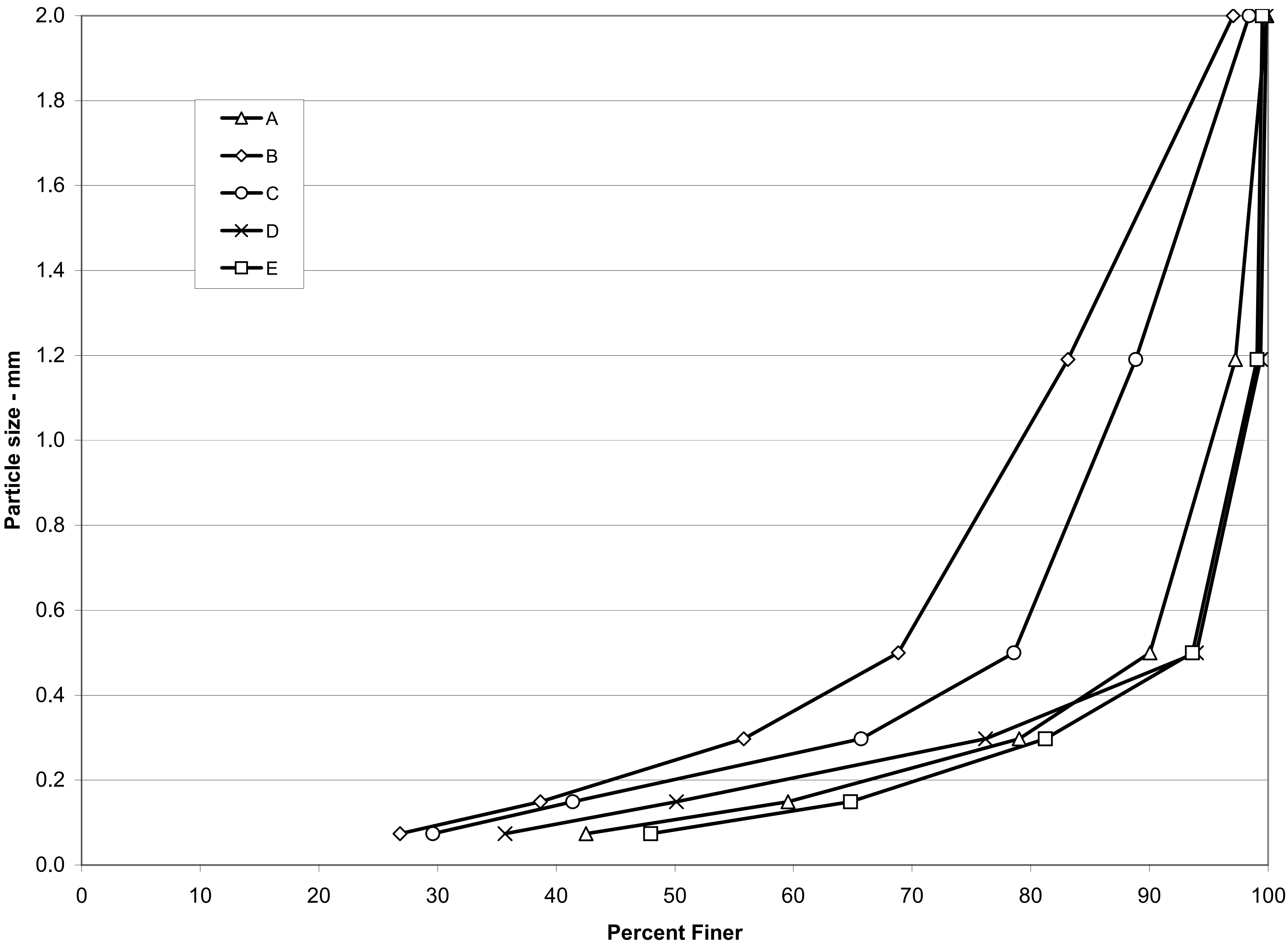


Figure A-8. Particle Size Distribution for Cedar Pond Sediments

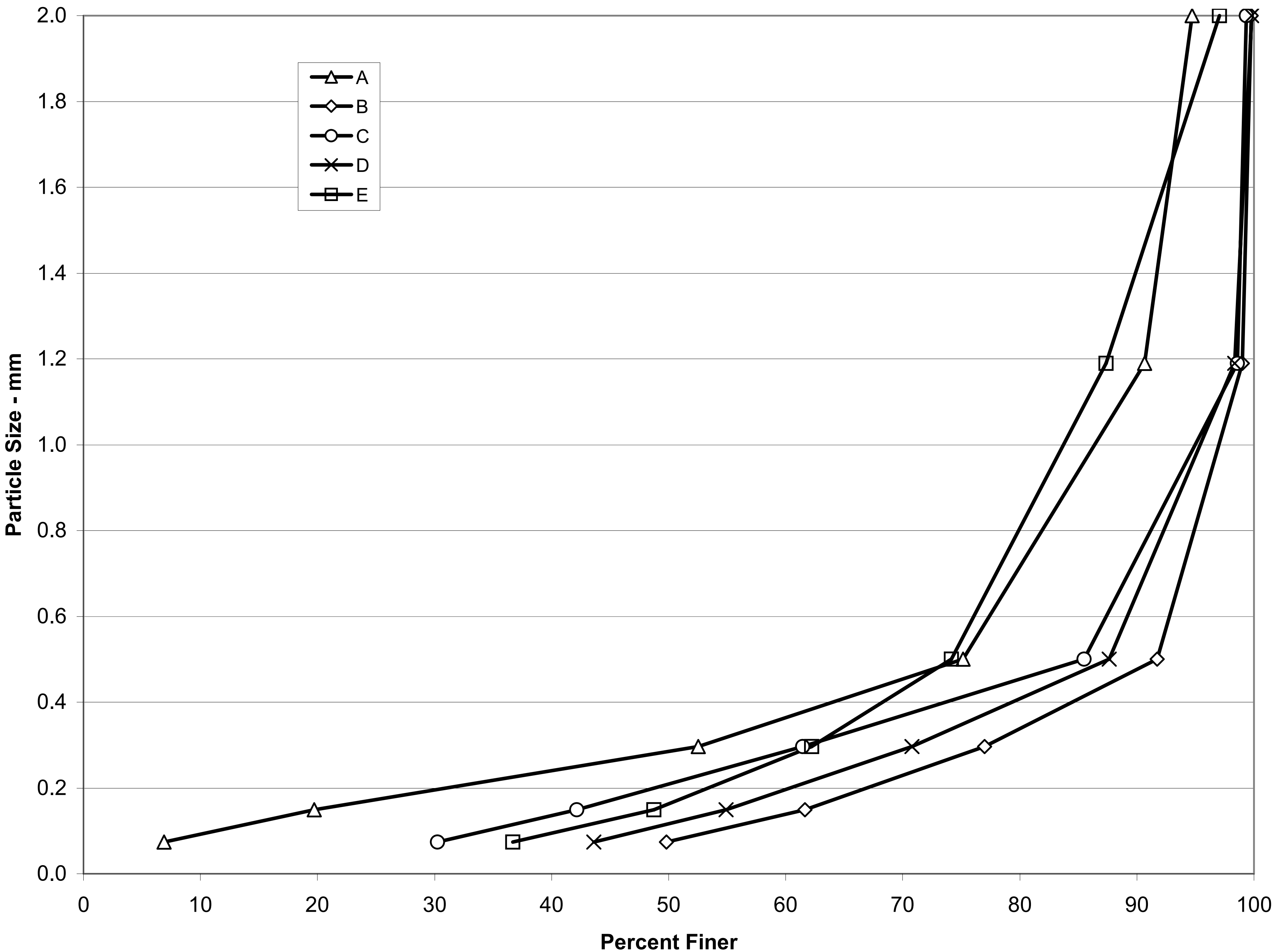


Figure A-9. Particle Size Distribution for Locke Lake Pond Sediments

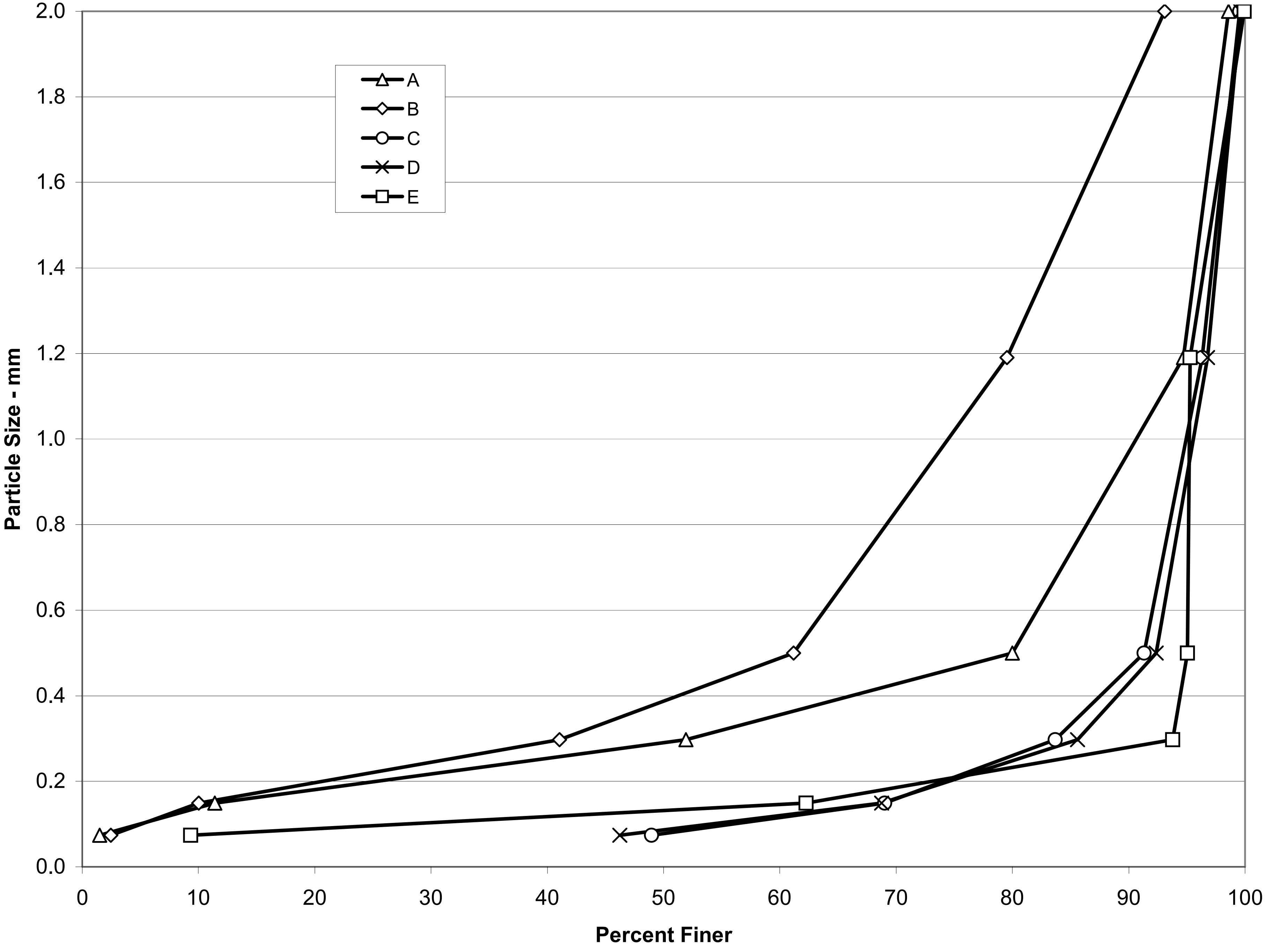


Figure A-10. Particle Size Distribution fopr Anoka Pond Sediments

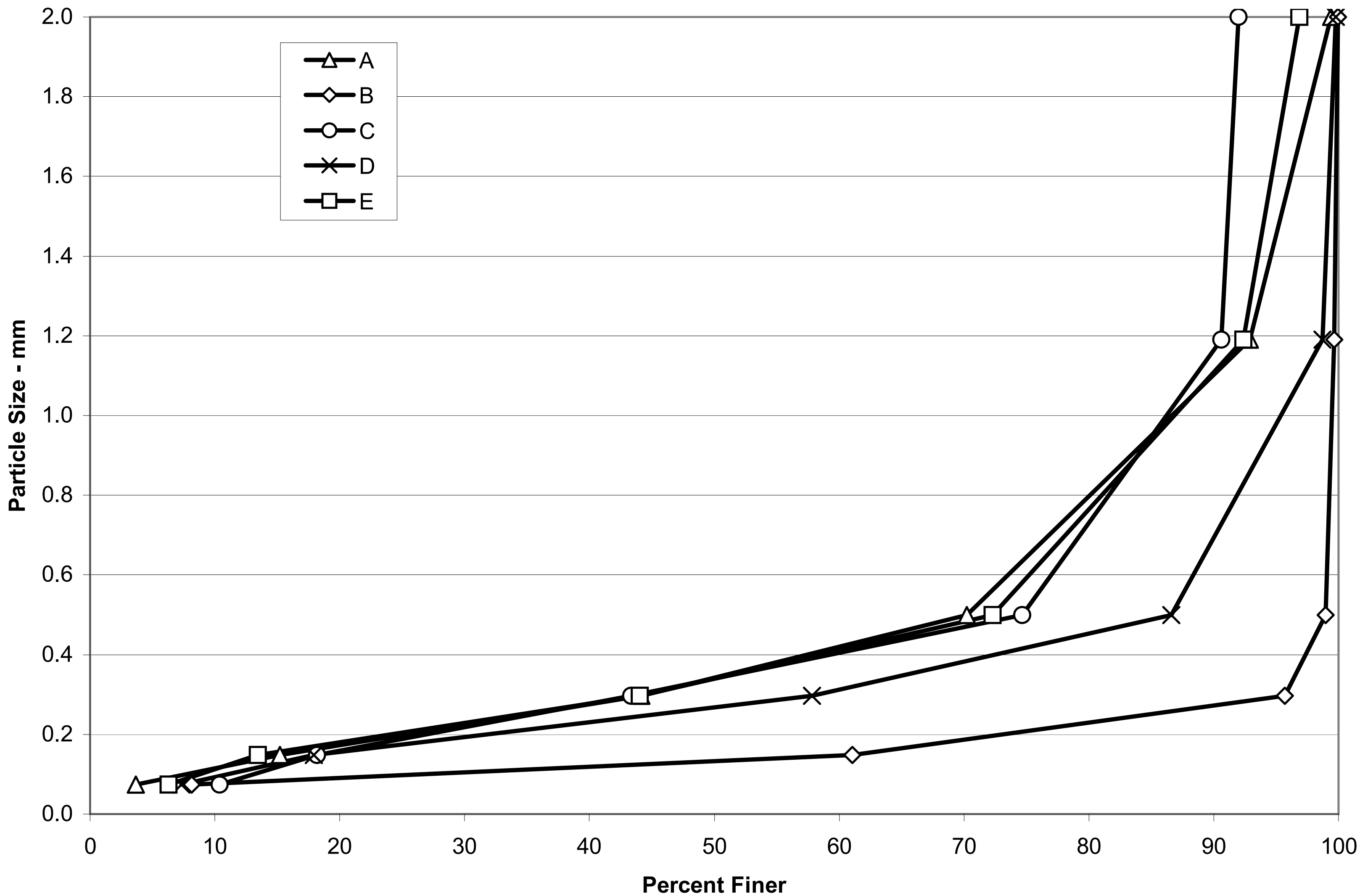


Figure A-11. Particle Size Distribution for Top Soils

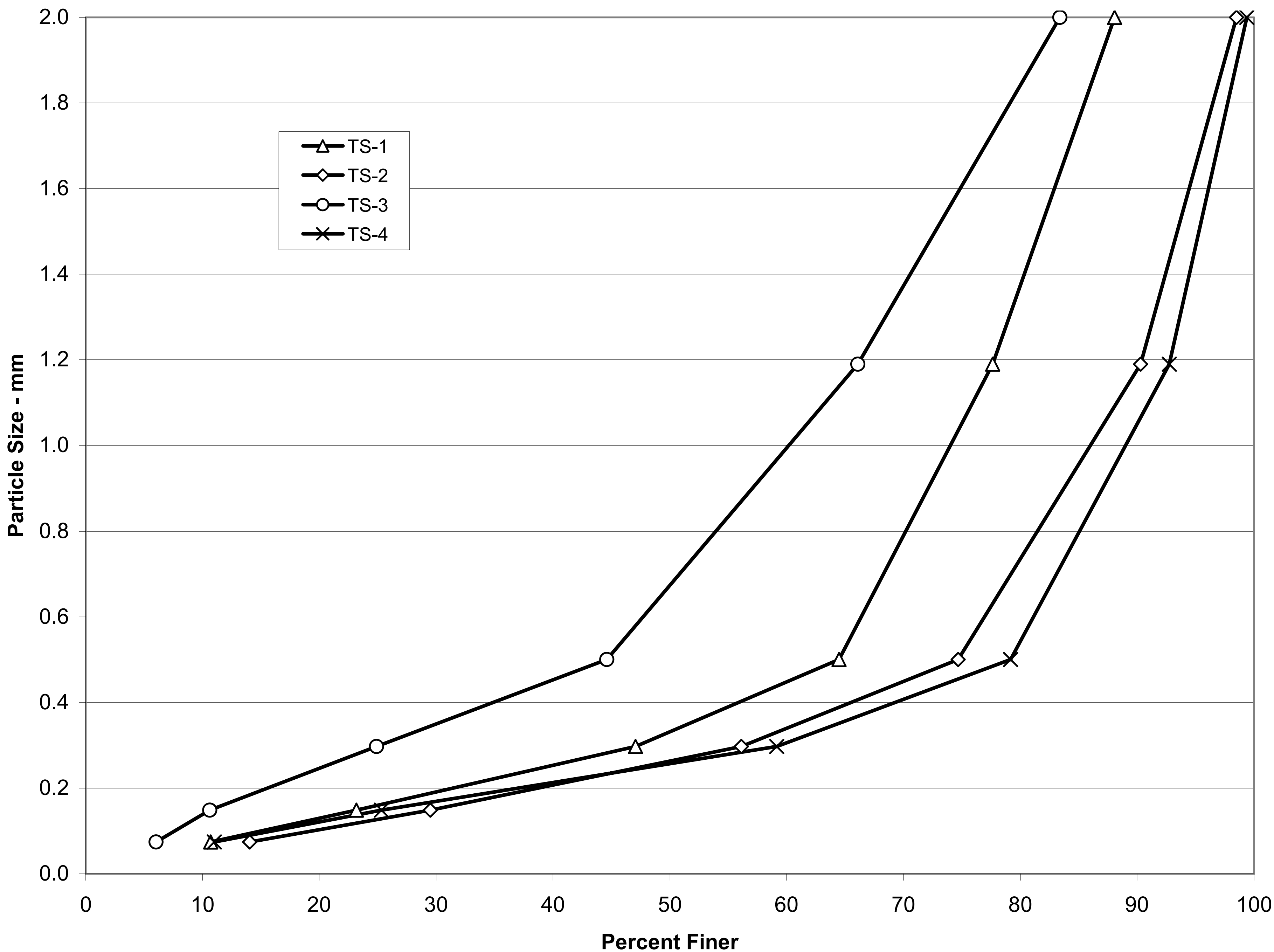
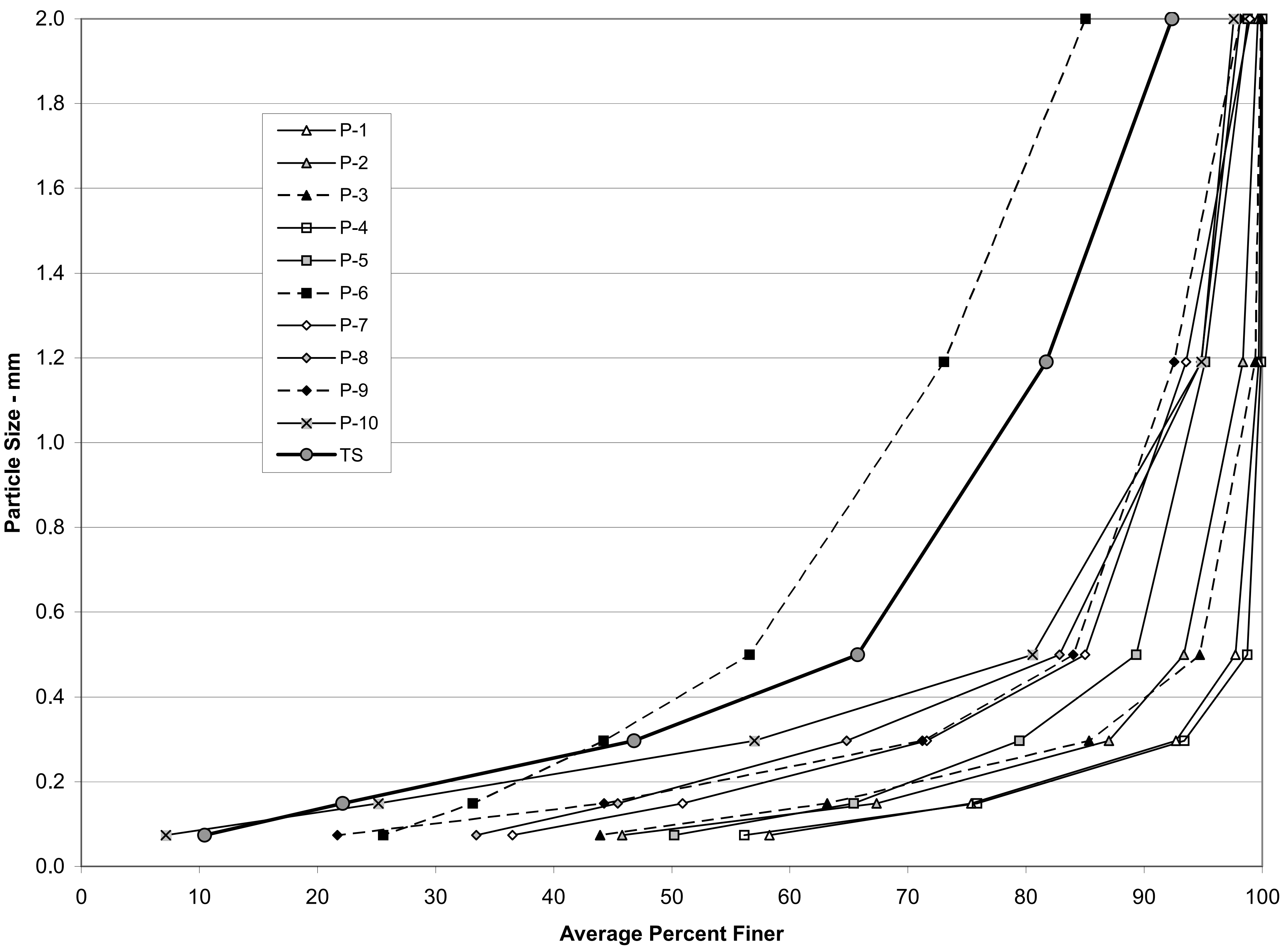


Figure A-12. Average Particle Size Distributions



APPENDIX C - NUTRIENT DATA

Core #	TKN	TP	NH3-N	NO3-N	NO2-N
1A1	1,450	245	31	<0.65	<0.65
1A2					
1B1	1,400	515	61	<0.65	<0.65
1B2	965	355	40	<0.65	<0.65
1C1	1,300	550	56	<0.65	<0.65
1C2	1,650	525	85	<0.65	<0.65
1D1	1,567	380	81	<0.65	<0.65
1D2	950	265	82	<0.65	<0.65
1 E1	3,333	557	123	0.66	<0.65
1 E2	2,900	543	102	<0.65	<0.65
2A1	9,000	480	140	1.12	<0.65
2A2	9,450	475	129	0.69	<0.65
2B1	6,900	460	116	1.07	<0.65
2B2	6,800	370	64	0.945	<0.65
2C1	10,250	573	178	1.36	<0.65
2C2	8,100	500	185	0.99	<0.65
2D1	4,200	280	80	0.87	<0.65
2D2	3,000	230	49	0.865	<0.65
2 E1	6,250	540	192	0.88	<0.65
2 E2	8,800	757	198	0.89	<0.65
3A1	6,933	570	171	0.995	<0.65
3A2	6,850	577	167	1.29	<0.65
3B1	4,300	610	307	0.785	<0.65
3B2	3,250	570	287	1.12	<0.65
3C1	5,400	545	162	1	<0.65
3C2	5,750	460	155	1.04	<0.65
3D1	5,933	420	180	1.695	<0.65
3D2	5,800	375	167	1.445	<0.65
3 E1	3,000	485	181	1.15	<0.65
3 E2	2,067	573	240	<0.65	<0.65
4A1	1,700	475	96	0.955	<0.65
4A2	1,850	440	111	0.76	<0.65
4B1	2,250	665	66	1.085	<0.65
4B2	3,000	800	76	1.225	<0.65
4C1	4,500	1260	75	3.425	<0.65
4C2	3,400	835	77	1.515	<0.65
4D1	2,567	653	51	1.29	<0.65
4D2	2,150	485	44	<0.65	<0.65
4 E1	855	165	30	0.795	<0.65
4 E2	1,150	235	34	1.515	<0.65
5A1	4,250	425	114	<0.65	<0.65
5A2	3,200	385	118	<0.65	<0.65
5B1	5,250	440	168	<0.65	<0.65
5B2	5,900	490	188	0.75	<0.65
5C1	1,200	450	104	<0.65	<0.65
5C2	805	450	117	<0.65	<0.65
5D1	10,100	623	279	0.735	<0.65

Core #	TKN	TP	NH3-N	NO3-N	NO2-N
5D2	8,400	645	366	<0.65	<0.65
5 E1	6,550	535	194	<0.65	<0.65
5 E2	6,100	505	190	0.73	<0.65
6A1	285	203	14	<0.65	<0.65
6A2	330	570	13	<0.65	<0.65
6B1	26	141	11	<0.65	<0.65
6B2	44	175	10	<0.65	<0.65
6C1	2,000	835	142	<0.65	<0.65
6C2	3,300	500	82	<0.65	<0.65
6D1	1,567	660	140	<0.65	<0.65
6D2	1,500	660	118	<0.65	<0.65
6 E1	1,100	375	37	<0.65	<0.65
6 E2	3,700	585	63	0.4925	<0.65
7A1	1,150	550	99	<0.65	<0.65
7A2	1,150	460	80	0.925	<0.65
7B1	1,150	645	94	<0.65	<0.65
7B2	735	500	79	<0.65	<0.65
7C1	1,350	720	112	<0.65	<0.65
7C2	1,400	790	123	<0.65	<0.65
7D1	795	555	57	0.8	<0.65
7D2	780	545	66	1.325	<0.65
7 E1	1,650	585	65	0.96	<0.65
7 E2	730	525	61	0.79	<0.65
8A1	810	235	20	<0.65	<0.65
8A2	1,973	530	26	<0.65	<0.65
8B1	4,150	975	348	<0.65	<0.65
8B2	4,400	1050	334	<0.65	<0.65
8C1	1,500	410	68	1.655	<0.65
8C2	800	205	13	<0.65	<0.65
8D1	4,300	1300	414	<0.65	<0.65
8D2	4,500	1300	399	0.5025	<0.65
8 E1	2,700	895	245	<0.65	<0.65
8 E2	2,400	860	249	<0.65	<0.65
9A1	170	200	12	<0.65	<0.65
9A2	123	190	5	<0.65	<0.65
9B1	193	167	10	<0.65	<0.65
9B2	210	207	11	<0.65	<0.65
9C1	5,700	1,100	290	<0.65	<0.65
9C2	3,000	705	148	1.73	<0.65
9D1	5,750	1,150	296	<0.65	<0.65
9D2	5,400	1,200	268	1.355	<0.65
9 E1	1,350	390	59	1.05	<0.65
9 E2	1,100	370	60	<0.65	<0.65
10A1	150	250	13	<0.65	<0.65
10A2	350	210	13	0.6625	<0.65
10B1	175	325	23	<0.65	<0.65
10B2	355	375	24	<0.65	<0.65
10C1	393	380	30	<0.65	<0.65

Core #	TKN	TP	NH3-N	NO3-N	NO2-N
10C2	340	400	27	<0.65	<0.65
10D1	275	395	26	<0.65	<0.65
10D2	300	365	30	<0.65	<0.65
10 E1	293	290	28	<0.65	<0.65
10 E2	220	290	31	<0.65	<0.65
TS - 1	1,800	500	26	15.76	<0.65
TS - 2	1,750	420	32	2.965	<0.65
TS - 3	1,400	520	25	18.3	<0.65
TS - 4	12,500	585	46	33.32	<0.65

APPENDIX D - PAH DATA

Compound	1A2	1B2	1C2	1D2	1E2	2A2	2B2	2C2	2D2	2E2
Napthalene	14	6	20	15	21	38	28	42	9	18
1-Methylnapthalene	14	5	16	13	16	34	< 0.55	< 0.55	< 0.55	< 0.55
2-Methylnapthalene	7	2	8	7	8	17	14	15	3	8
1,5-Dimethylnapthalene	15	5	18	15	14	58	27	51	4	15
1,2-Dimethylnapthalene	8	3	10	8	8	28	11	11	3	5
Acenapthylene	19	4	87	28	18	98	50	94	13	45
2,6-Dimethylnaphthalene	4	1	5	4	5	17	12	11	2	6
Acenaphthene	16	8	31	20	23	105	6	7	21	3
2,3,5-Trimethylnaphthalene	12	5	15	13	16	47	24	39	5	14
Fluorene	32	16	53	42	49	137	4	5	22	2
1-Methylfluorene	12	8	19	20	30	68	9	16	4	9
Dibenzothiophene	16	6	32	19	21	49	0	1	0	1
Phenanthrene	289	166	719	356	438	1097	59	125	27	53
Anthracene	48	12	101	38	35	106	9	8	2	4
2-Methylphenanthrene	31	15	73	34	39	81	16	31	7	24
4,5-Methylenephenanthrene	46	26	107	55	63	136	81	137	43	80
1-Methylphenanthrene	23	11	60	28	39	55	16	32	7	24
4,6-Dimethyldibenzothiophene	16	6	31	19	18	5	10	15	4	8
3,6-Dimethylphenanthrene	11	5	25	14	15	29	16	29	5	11
Fluoranthene	716	390	1592	572	843	2322	5	1916	462	771
Pyrene	794	383	1313	566	978	2459	1096	1817	400	743
2-Methylfluoranthene	33	17	67	26	38	107	47	85	22	38
Retene	16	8	22	3	1	6	10	19	4	7
1-Methylpyrene	62	9	35	27	34	85	0	48	0	20
Benzo(b)naptho[2,1-d]thiophene	55	36	131	51	78	211	93	151	32	60
Benzo(a)anthracene	240	125	540	150	213	873	679	1147	277	477
Chrysene	448	268	916	295	550	1451	605	1025	247	425
1-Methylbenz(a)anthracene	17	6	15	4	6	174	85	24	35	62
5-Methylbenz(a)anthracene	15	5	19	22	27	79	18	28	7	12
10-Methylbenz(a)anthracene	27	4	19	23	20	56	42	66	20	36
6,8-Dimethylbenz(a)anthracene	96	14	65	66	3	5	46	82	6	12
3,9-Dimethylbenz(a)anthracene	14	3	9	7	29	43	14	30	5	9
Benzo(b)fluoranthene	832	564	1703	634	1070	2375	1155	3424	660	1200
7,12-Dimethylbenz(a)anthracene	14	6	17	24	17	32	21	34	5	13
Benzo(k)fluoranthene	250	158	452	236	373	701	931	2759	29	964
Benzo(e)pyrene	505	219	625	261	384	756	378	805	156	282
Benzo(a)pyrene	376	200	637	243	413	989	475	1001	205	345
8,9,11-Trimethylbenz(a)anthracene	65	9	26	37	38	10	5	11	2	4
Perylene	88	41	136	69	104	187	95	185	19	30
Indeno(cd-)pyrene	384	207	674	41	130	166	431	1235	162	325
Dibenzo(a,h)anthracene	98	42	140	17	96	47	77	215	32	58
Benzo(g,h,i)perylene	592	210	747	218	567	884	439	1266	181	334
Coronene	114	58	201	71	131	218	80	240	31	58
Total PAH – 43	6485	3294	11533	4412	7020	16442	7216	18282	3179	6616
Total PAH – 13	3121	1635	6222	2377	3717	9804	3107	7433	1724	2969

Compound	3A2	3B2	3C2	3D2	3E2	4A2	4B2	4C2	4D2	4E2
Napthalene	82	48	118	75	51	158	44	67	12	6
1-Methylnapthalene	42	< 0.55	46	31	27	86	26	29	5	2
2-Methylnapthalene	23	15	32	25	18	86	23	22	4	3
1,5-Dimethylnapthalene	91	192	453	113	50	82	19	29	4	2
1,2-Dimethylnapthalene	12	22	49	27	19	81	21	22	4	2
Acenapthylene	327	348	872	420	450	1339	563	543	112	49
2,6-Dimethylnaphthalene	10	7	12	8	7	26	8	7	1	1
Acenaphthene	95	3	181	105	99	431	113	121	21	13
2,3,5-Trimethylnaphthalene	33	2220	55	41	14	50	15	15	5	2
Fluorene	115	202	201	132	92	498	87	117	30	16
1-Methylfluorene	36	1715	35	30	19	74	17	23	7	2
Dibenzothiophene	45	4287	98	48	35	196	42	56	15	7
Phenanthrene	814	24764	1539	938	746	5295	1346	1574	446	295
Anthracene	218	894	532	307	257	1238	341	442	111	48
2-Methylphenanthrene	96	8784	146	218	108	764	192	191	62	33
4,5-Methylenephenanthrene	15	18328	334	234	196	890	217	262	68	35
1-Methylphenanthrene	85	8802	146	218	112	766	189	19	11	32
4,6-Dimethyldibenzothiophene	59	52	50	28	25	22	10	12	3	1
3,6-Dimethylphenanthrene	68	36	60	36	35	83	33	38	11	4
Fluoranthene	2002	1944	4025	2227	1872	4466	2756	3295	1084	421
Pyrene	3569	2046	3570	2148	1913	4162	2511	2864	951	368
2-Methylfluoranthene	230	139	221	155	146	364	183	188	63	24
Retene	214	15	77	52	93	38	15	41	5	3
1-Methylpyrene	243	91	145	101	102	190	116	108	38	13
Benzo(b)naptho[2,1-d]thiophene	319	201	309	182	172	316	182	225	71	21
Benzo(a)anthracene	1640	1071	1700	1263	1201	2548	1565	2005	628	219
Chrysene	2610	1436	2311	1240	1294	2430	1525	1686	600	202
1-Methylbenz(a)anthracene	64	46	223	54	250	404	181	161	50	16
5-Methylbenz(a)anthracene	85	35	60	37	23	32	27	24	15	1
10-Methylbenz(a)anthracene	48	106	45	77	43	55	45	54	14	3
6,8-Dimethylbenz(a)anthracene	103	76	83	112	84	124	60	56	28	5
3,9-Dimethylbenz(a)anthracene	21	16	41	26	23	71	17	63	7	2
Benzo(b)fluoranthene	2831	2614	4725	3824	3269	8531	2266	3128	938	258
7,12-Dimethylbenz(a)anthracene	44	1	82	48	40	118	37	60	9	3
Benzo(k)fluoranthene	1494	2246	2115	3291	1201	3181	1381	2076	625	176
Benzo(e)pyrene	1158	806	1547	1205	975	2695	947	1355	409	105
Benzo(a)pyrene	1466	1194	2170	1753	1593	4561	1720	2418	699	207
8,9,11-Trimethylbenz(a)anthracene	43	8	16	12	10	33	6	11	3	0
Perylene	269	250	540	378	377	818	308	447	157	36
Indeno(cd-)pyrene	1260	2753	1343	1168	1312	3722	1145	1110	399	117
Dibenzo(a,h)anthracene	180	718	302	255	297	744	212	195	70	28
Benzo(g,h,i)perylene	986	2812	1419	1305	1349	3835	1188	1145	416	126
Coronene	160	768	418	293	278	871	269	316	106	36
Total PAH – 43	23309	92113	32446	24238	20278	56477	21967	26619	8316	2949
Total PAH – 13	13215	43452	17667	11079	9973	28635	12975	15518	4825	1906

Compound	5A1	5B1	5C1	5D1	5 E1	6A1	6B1	6C1	6D1	6 E1
Napthalene	< 3.9	< 3.9	< 3.9	< 3.9	9	38	< 3.9	17	14	< 3.9
1-Methylnapthalene	2	2	1	2	5	14	2	13	9	1
2-Methylnapthalene	1	1	1	1	3	16	2	9	6	0
1,5-Dimethylnapthalene	1	8	1	1	14	19	2	18	10	1
1,2-Dimethylnapthalene	0	0	0	0	1	3	1	3	2	0
Acenapthylene	1	2	2	3	5	131	6	50	35	2
2,6-Dimethylnaphthalene	0	0	0	0	1	4	1	6	3	0
Acenaphthene	2	4	3	5	12	389	24	305	162	16
2,3,5-Trimethylnaphthalene	1	1	1	1	5	8	3	13	8	1
Fluorene	5	9	3	3	25	550	35	330	207	23
1-Methylfluorene	1	2	1	1	6	29	5	31	19	2
Dibenzothiophene	1	2	2	2	3	275	23	170	104	11
Phenanthrene	17	33	28	26	57	7183	600	4290	2669	339
Anthracene	2	4	3	3	5	836	96	532	265	51
2-Methylphenanthrene	2	3	4	4	4	441	53	317	195	28
4,5-Methylenephenanthrene	3	6	6	6	6	740	78	533	322	43
1-Methylphenanthrene	1	3	2	2	7	195	25	167	86	12
4,6-Dimethyldibenzothiophene	1	2	1	1	1	14	9	41	20	1
3,6-Dimethylphenanthrene	1	6	1	1	3	44	13	74	36	3
Fluoranthene	28	57	60	57	69	7290	1342	4126	4010	509
Pyrene	23	46	48	46	57	5542	1039	6480	3055	388
2-Methylfluoranthene	2	3	2	2	4	234	46	322	149	18
Retene	72	182	18	16	117	25	14	445	73	8
1-Methylpyrene	1	2	1	1	2	103	30	196	93	8
Benzo(b)naptho[2,1-d]thiophene	2	5	6	6	3	405	111	555	267	25
Benzo(a)anthracene	9	17	18	18	14	2464	514	3217	1327	179
Chrysene	16	32	39	38	26	3381	757	4454	2088	220
1-Methylbenz(a)anthracene	1	1	1	1	1	101	21	80	38	8
5-Methylbenz(a)anthracene	0	1	1	1	1	45	15	57	29	3
10-Methylbenz(a)anthracene	1	7	2	2	6	83	17	113	48	6
6,8-Dimethylbenz(a)anthracene	2	3	4	5	4	70	34	56	49	4
3,9-Dimethylbenz(a)anthracene	0	0	1	1	1	14	5	11	9	1
Benzo(b)fluoranthene	18	23	41	43	36	4008	616	3569	2288	280
7,12-Dimethylbenz(a)anthracene	1	1	2	2	1	80	26	1	5	3
Benzo(k)fluoranthene	14	18	34	34	27	3009	465	2299	1779	238
Benzo(e)pyrene	10	13	22	23	20	1890	308	1454	1010	135
Benzo(a)pyrene	12	15	27	27	21	3731	522	2728	1758	237
8,9,11-Trimethylbenz(a)anthracene	2	2	3	3	1	3	18	22	23	< 0.22
Perylene	7	40	114	112	78	655	105	459	300	49
Indeno(cd-)pyrene	15	38	35	33	47	3148	480	3158	1875	175
Dibenzo(a,h)anthracene	2	4	4	5	3	667	106	449	213	30
Benzo(g,h,i)perylene	5	23	32	31	28	2572	412	2412	1442	143
Coronene	3	8	8	8	7	353	65	343	205	16
Total PAH – 43	288	631	584	577	746	50803	8046	43927	26307	3218
Total PAH – 13	121	228	241	236	307	32642	5095	27296	15999	2024

Compound	**7A1**	**7B1**	**7C1**	**7D1**	**7 E1**	**8A1**	**8B1**	**8C1**	**8D1**	**8 E1**
Napthalene	27	28	33	28	55	64	49	8	37	39
1-Methylnapthalene	19	23	14	17	44	24	28	5	27	38
2-Methylnapthalene	19	15	11	10	25	21	21	4	18	28
1,5-Dimethylnapthalene	19	13	10	11	42	42	34	2	25	40
1,2-Dimethylnapthalene	13	3	3	2	7	7	8	1	4	10
Acenapthylene	98	142	463	157	278	269	291	10	94	212
2,6-Dimethylnaphthalene	8	4	4	3	7	6	7	1	6	12
Acenaphthene	157	201	43	35	202	475	95	10	100	128
2,3,5-Trimethylnaphthalene	14	9	12	10	19	15	8	2	19	45
Fluorene	159	247	60	80	385	499	195	15	179	178
1-Methylfluorene	28	23	14	20	51	45	31	3	26	31
Dibenzothiophene	83	118	32	40	232	356	104	10	99	104
Phenanthrene	2141	3229	826	916	5638	10448	2505	266	2334	2408
Anthracene	333	476	278	134	611	1484	378	27	214	295
2-Methylphenanthrene	236	240	91	111	454	752	220	24	181	198
4,5-Methylenephenanthrene	298	438	187	195	717	1347	445	37	335	306
1-Methylphenanthrene	132	113	53	62	216	374	128	11	91	100
4,6-Dimethyldibenzothiophene	25	27	16	33	73	20	41	3	145	46
3,6-Dimethylphenanthrene	48	51	23	34	109	67	55	6	102	46
Fluoranthene	3690	6376	2441	2419	11330	16237	5997	692	5235	4415
Pyrene	2906	4911	1892	1883	8588	12377	4510	536	6916	3102
2-Methylfluoranthene	177	234	110	101	422	540	215	26	365	149
Retene	27	40	29	46	116	62	113	10	132	104
1-Methylpyrene	99	116	61	56	279	267	104	13	195	68
Benzo(b)naptho[2,1-d]thiophene	270	409	158	176	829	860	288	45	550	221
Benzo(a)anthracene	1448	2164	749	666	3342	6519	1423	203	2215	1024
Chrysene	2224	3397	1539	1481	5799	8035	2790	377	4191	1890
1-Methylbenz(a)anthracene	72	95	39	35	118	247	70	9	67	44
5-Methylbenz(a)anthracene	42	15	5	30	324	95	42	5	220	31
10-Methylbenz(a)anthracene	44	74	17	21	102	209	38	7	73	33
6,8-Dimethylbenz(a)anthracene	52	76	74	106	221	75	155	14	109	154
3,9-Dimethylbenz(a)anthracene	11	14	10	15	64	46	43	5	30	40
Benzo(b)fluoranthene	2026	3170	2978	2283	8499	8233	5739	552	4115	3803
7,12-Dimethylbenz(a)anthracene	38	45	43	49	3	161	74	8	71	71
Benzo(k)fluoranthene	1489	2557	2149	1664	4406	7320	4071	469	2739	2905
Benzo(e)pyrene	1037	1659	1684	1170	3213	3892	2998	271	1688	1879
Benzo(a)pyrene	1689	2494	1606	1308	4979	7513	3439	356	2389	2102
8,9,11-Trimethylbenz(a)anthracene	2	3	29	3	78	23	4	4	57	74
Perylene	262	438	337	211	768	1478	705	58	419	446
Indeno(cd-)pyrene	1565	2335	1442	1321	7711	5832	1753	324	1975	1593
Dibenzo(a,h)anthracene	287	393	48	217	1467	1092	248	52	368	229
Benzo(g,h,i)perylene	1344	2129	1465	1326	6012	4791	1743	281	1669	1540
Coronene	185	447	269	269	908	860	358	44	321	236
Total PAH – 43	24845	38993	21346	18755	78742	103077	41564	4805	40144	30416
Total PAH – 13	15397	24298	10066	9436	43127	65764	22140	2575	24452	16219

Compound	**9A1**	**9B1**	**9C1**	**9D1**	**9 E1**	**10A1**	**10B1**	**10C1**	**10D1**	**10 E1**
Napthalene	< 3.9	2	26	26	15	7	< 3.9	< 3.9	< 3.9	< 3.9
1-Methylnapthalene	1	1	15	15	7	2	1	2	1	2
2-Methylnapthalene	0	1	10	10	5	1	0	1	1	1
1,5-Dimethylnapthalene	1	1	13	13	11	2	1	1	1	1
1,2-Dimethylnapthalene	0	1	7	6	2	1	0	1	1	1
Acenapthylene	3	5	44	42	28	6	1	2	1	1
2,6-Dimethylnaphthalene	0	0	4	3	2	0	0	0	0	0
Acenaphthene	4	13	63	63	53	5	1	3	1	2
2,3,5-Trimethylnaphthalene	1	1	12	9	4	2	1	1	1	1
Fluorene	8	28	73	81	58	14	4	8	5	8
1-Methylfluorene	1	3	18	15	5	4	1	2	4	2
Dibenzothiophene	6	14	39	41	28	8	4	8	3	6
Phenanthrene	171	380	1034	1094	792	172	28	4	46	5
Anthracene	23	61	169	146	140	28	3	4	44	7
2-Methylphenanthrene	15	25	110	95	15	16	3	6	5	7
4,5-Methylenephenanthrene	22	40	157	10	7	27	2	7	7	5
1-Methylphenanthrene	7	14	74	76	37	11	2	8	3	8
4,6-Dimethyldibenzothiophene	1	1	14	15	3	7	1	2	1	2
3,6-Dimethylphenanthrene	2	3	25	28	14	4	1	3	2	3
Fluoranthene	333	521	2285	2378	1564	373	35	93	48	112
Pyrene	250	387	1815	1889	1218	312	46	105	75	127
2-Methylfluoranthene	12	18	108	99	56	12	1	3	2	3
Retene	5	2	106	105	145	11	2	4	3	1
1-Methylpyrene	6	9	87	85	27	10	1	2	1	2
Benzo(b)naptho[2,1-d]thiophene	20	27	178	196	20	27	2	1	4	8
Benzo(a)anthracene	125	186	914	1049	640	88	6	72	31	73
Chrysene	155	234	1409	1521	739	172	16	5	23	6
1-Methylbenz(a)anthracene	4	6	23	27	107	42	3	10	4	8
5-Methylbenz(a)anthracene	2	2	23	101	45	7	0	2	1	2
10-Methylbenz(a)anthracene	1	5	35	39	20	4	0	2	3	5
6,8-Dimethylbenz(a)anthracene	7	5	57	42	22	27	2	1	1	2
3,9-Dimethylbenz(a)anthracene	2	2	23	23	8	3	1	2	1	1
Benzo(b)fluoranthene	258	279	2287	2023	912	228	34	134	71	183
7,12-Dimethylbenz(a)anthracene	3	3	2	28	13	12	0	2	0	1
Benzo(k)fluoranthene	163	203	1166	1061	570	140	29	6	3	8
Benzo(e)pyrene	106	121	830	758	408	129	16	24	11	32
Benzo(a)pyrene	178	241	1294	1236	787	157	18	36	17	48
8,9,11-Trimethylbenz(a)anthracene	1	2	64	57	11	6	1	1	1	1
Perylene	30	42	292	280	157	34	5	9	5	12
Indeno(cd-)pyrene	173	200	1723	1357	509	90	13	37	19	49
Dibenzo(a,h)anthracene	29	33	331	290	105	16	2	2	0	1
Benzo(g,h,i)perylene	109	125	1087	968	384	92	14	39	20	45
Coronene	15	18	159	154	54	22	3	12	5	11
Total PAH – 43	2254	3265	18204	17554	9749	2332	302	666	473	805
Total PAH – 13	1298	2115	9567	9910	6155	1365	161	342	298	399

Compound	**TS-1**	**TS-2**	**TS-3**	**TS-4**
Napthalene	< 3.9	< 3.9	11	17
1-Methylnapthalene	2	1	9	10
2-Methylnapthalene	1	1	7	5
1,5-Dimethylnapthalene	1	1	4	6
1,2-Dimethylnapthalene	1	1	4	3
Acenapthylene	3	1	19	3
2,6-Dimethylnaphthalene	0	0	2	1
Acenaphthene	2	1	11	9
2,3,5-Trimethylnaphthalene	1	1	4	5
Fluorene	3	2	11	19
1-Methylfluorene	2	0	1	11
Dibenzothiophene	1	1	7	5
Phenanthrene	23	10	177	98
Anthracene	6	2	50	8
2-Methylphenanthrene	2	1	8	3
4,5-Methylenephenanthrene	8	5	11	22
1-Methylphenanthrene	2	1	10	3
4,6-Dimethyldibenzothiophene	0	0	2	2
3,6-Dimethylphenanthrene	1	1	7	4
Fluoranthene	35	18	342	54
Pyrene	35	19	310	134
2-Methylfluoranthene	2	1	18	1
Retene	3	2	7	20
1-Methylpyrene	1	1	13	0
Benzo(b)naptho[2,1-d]thiophene	2	1	26	< 0.062
Benzo(a)anthracene	10	4	203	6
Chrysene	19	11	221	8
1-Methylbenz(a)anthracene	3	2	44	0
5-Methylbenz(a)anthracene	0	< 0.10	5	0
10-Methylbenz(a)anthracene	0	0	6	< 0.094
6,8-Dimethylbenz(a)anthracene	1	1	11	< 0.15
3,9-Dimethylbenz(a)anthracene	0	0	4	< 0.095
Benzo(b)fluoranthene	15	8	421	13
7,12-Dimethylbenz(a)anthracene	1	< 0.12	11	0
Benzo(k)fluoranthene	12	6	219	7
Benzo(e)pyrene	8	5	197	4
Benzo(a)pyrene	2	2	230	4
8,9,11-Trimethylbenz(a)anthracene	0	0	3	< 0.22
Perylene	2	1	52	120
Indeno(cd-)pyrene	13	6	156	1
Dibenzo(a,h)anthracene	3	1	18	0
Benzo(g,h,i)perylene	13	6	177	2
Coronene	2	1	25	< 0.39
Total PAH – 43	240	126	3074	608
Total PAH – 13	145	75	1613	362

APPENDIX E - BIOASSAY DATA

10-DAY SEDIMENT TOXICITY-TEST
BIOLOGICAL INFORMATION (PONDS 3 & 8)
(September 20-30, 2005)

Test Organism : *Chironomus* *tentans*

Sample I.D.	Control silica sand	Reference Site	R&D Site #3	R&D Site #8
Number of Live Test Organisms (of 10) :				
Test Beaker 1	10	6	8	9
Test Beaker 2	9	10	9	10
Test Beaker 3	9	1	9	9
Test Beaker 4	10	0	8	10
Test Beaker 5	10	10	10	6
Test Beaker 6	8	10	8	9
Total Number of Live Organisms (of 60) :	56	37	52	53
% Survival (of 60)	93	62	87	88
Total Dry Weight per Treatment (mg)	77.62	74.01	71.76	97.48
Avg. Dry Weight per Test Org. (mg)	1.386	2.000	1.381	1.839

Test Organism : *Hyalella* *azteca*

Sample I.D.	Control silica sand	Reference Site	R&D Site #3	R&D Site #8
Number of Live Test Organisms (of 10) :				
Test Beaker 1	9	5	6	8
Test Beaker 2	9	6	8	8
Test Beaker 3	9	7	6	10
Test Beaker 4	10	6	7	9
Test Beaker 5	10	7	9	9
Test Beaker 6	10	7	9	10
Total Number of Live Organisms (of 60) :	57	38	45	54
% Survival (of 60)	95	63	75	90

NOTE : Both tests were acceptable because they met the following required performance criteria : Survival of *C. tentans* in the Control sediment was greater than 70% and average weight of *C. tentans* in the Control sediment was greater than 0.6 mg. at the end of the test. Survival of *H. azteca* in the Control sediment was greater than 80% at the end of the test.

10-DAY SEDIMENT TOXICITY-TEST
WATER CHEMISTRIES (PONDS 3 & 8)
(September 20-30, 2005)

Test Organism : *Chironomus tentans*

Sample I.D.		Control	Reference Site	R&D Site #3	R&D Site #8
Parameters					
Alkalinity					
(mg/l CaCO3)	Day 0	48	49	54	50
	Day 10	47	47	65	48
Mean		47	48	59	49
Hardness					
(mg/l CaCO3)	Day 0	82	84	84	80
	Day 10	82	84	96	80
Mean		82	84	90	80
Ammonia (mg/l)					
Total	Day 0	0.02	0.03	0.12	0.11
	Day 10	0.06	0.03	0.60	0.20
Mean		0.04	0.03	0.36	0.16

Test Organism : *Hyalella azteca*

Sample I.D.		Control	Reference Site	R&D Site #3	R&D Site #8
Parameters					
Alkalinity					
(mg/l CaCO3)	Day 0	49	48	58	50
	Day 10	46	49	53	47
Mean		47	48	55	49
Hardness					
(mg/l CaCO3)	Day 0	80	80	92	82
	Day 10	80	88	86	80
Mean		80	84	89	81
Ammonia (mg/l)					
Total	Day 0	0.02	<0.02	0.21	0.11
	Day 10	0.05	0.03	0.11	0.02
Mean		0.03	0.02	0.16	0.07

NOTE : Overlying water was charcoal filtered tap water. Control sediment was fine silica sand and Reference Site was St. Croix River (SC 25.8) sediment.

10-DAY SEDIMENT TOXICITY-TEST
EXPOSURE CONDITIONS (PONDS 3 & 8)
(September 20-30, 2005)

Test Organism : _Chironomus_ _tentans_

Sample I.D.		Control	Reference Site	R&D Site #3	R&D Site #8
Dissolved Oxygen (mg/l)					
Mean		6.50	5.95	3.67	4.95
Range	Min.	5.50	4.93	2.51	4.04
	Max.	7.59	6.86	6.70	6.70
Temperature (C)					
Mean		22.9	22.9	22.8	22.8
Range	Min.	22.4	22.4	22.2	22.2
	Max.	23.3	23.3	23.3	23.3
Ph					
Mean		7.15	7.06	6.93	6.78
Range	Min.	6.84	6.85	6.66	6.52
	Max.	7.50	7.51	7.39	7.19
Conductivity	Day 1	244	233	279	247
	Day 10	234	227	274	244
Mean		239	230	276	246

Test Organism : _Hyalella_ _azteca_

Sample I.D.		Control	Reference Site	R&D Site #3	R&D Site #8
Dissolved Oxygen (mg/l)					
Mean		6.92	6.63	6.24	6.2
Range	Min.	5.67	5.71	4.38	4.01
	Max.	7.90	7.76	7.55	7.38
Temperature (C)					
Mean		23.0	22.9	22.9	22.8
Range	Min.	22.6	22.5	22.5	22.3
	Max.	23.4	23.4	23.4	23.4
Ph					
Mean		7.02	6.99	6.98	6.96
Range	Min.	6.61	6.57	6.65	6.49
	Max.	7.55	7.46	7.23	7.31
Conductivity	Day 1	230	241	415	264
	Day 10	206	235	245	239
Mean		218	238	330	252

NOTE : Overlying water was charcoal filtered tap water. Control sediment was fine silica sand and Reference Site was SC 25.8 sediment.

APPENDIX F – SRM DATA FOR METALS

RESULTS OF ANALYSES OF STANDARD REFERENCE MATERIAL NIST 2704 FOR METALS – mg/kg

Pond	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**
Laboratory	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**
Replicate	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Copper	90	90	91	87	97	96	106	97	90	87
Nickel	36	37	36	36	38	37	38	36	39	36
Lead	162	166	168	160	148	155	161	149	151	142
Zinc	452	404	417	439	423	415	478	455	427	434
Cadmium	4	3.8	4	3.8	3.9	3.5	4.7	3.1	3.6	3.6
Chromium	79	82	79	79	85	79	84	78	85	76
Aluminum	11835	13965	13396	13384	14217	11407	13760	12170	13831	11133
Arsenic	19	19	19	19	19	20	21	20	17	16
Iron	30000	31234	31439	30150	32273	30376	31030	29820	31479	29347
Manganese	471	487	476	461	484	473	498	475	456	439
Vanadium	23	28	27	27	28	23	31	30	31	24
Titanium	126	134	134	142	119	98	196	182	134	76
Selenium	3.8	3.6	3.7	4.1	3.4	7.7	<2	<2	<2	<2
Molybdenum	3.3	3.4	3.3	3	3.6	3.2	2.3	1.5	2.8	2.8

RESULTS OF ANALYSES OF STANDARD REFERENCE MATERIAL NIST 8704 FOR METALS – mg/kg

Pond	**6**	**6**	**7**	**7**	**8**	**8**	**9**	**10**			
Laboratory	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**MCES**	**U of M**	**U of M**	**U of M**
Replicate	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**1**	**1**	**2**	**3**
Copper	86	80	84	86	84	83	84	81	84	90	83
Nickel	39	34	37	37	39	36	39	40	40	42	40
Lead	157	131	136	136	137	136	148	133	143	153	137
Zinc	384	356	394	391	372	384	374	368	367	389	368
Cadmium	3.3	3	3.3	3.1	3.2	3.1	3.2	3.1	2.9	3.1	3.0
Chromium	73	64	66	69	78	68	74	71	71	75	72
Aluminum	13279	12185	12036	12318	15224	12149	17756	17461	14020	14973	14727
Arsenic	13	12	13	12	13	13	13	13	18	18	17
Iron	33935	29736	31482	32669	32494	30637	34102	33865	31597	33143	32277
Manganese	501	438	470	484	485	473	514	505	463	484	475
Vanadium	30	29	26	28	31	25	28	29	48	46	44
Titanium	117	118	96	136	148	109	313	133	112	110	114
Selenium	<2	<2	<2	<2	<2	<2	<2	<2	1.6	1.4	1.5
Molybdenum	2.4	1.9	2.2	2.3	2.8	2.5	3.3	3.2	3.7	3.5	3.3

APPENDIX G – SRM DATA FOR PAH

RESULTS OF ANALYSIS OF STANDARD REFERENCE MATERIAL NIST 1944 FOR POLYCYCLIC AROMATIC HYDROCARBONS

PAH	Certified Conc. (ug/g dry)	Reference Conc (ug/g dry)	Uncertainty + or - (ug/g dry)	Cert/Ref Conc Corrected for Moinsture (ng/g)	1 SRM 1 (ng/g)	3 SRM 1 (ng/g)	6 SRM 1 (ng/g)	6 SRM 2 (ng/g)	7 SRM 1 (ng/g)	9 SRM 1 (ng/g)	9 SRM 2 (ng/g)	9 SRM 3 (ng/g)
Naphthalene	1.65		0.31	1629.4	1325.7	1302.0	1134.0	1199.6	1365.8	1462.2	1224.4	1333.2
1-Methyl-Naphthalene		0.52	0.03	513.5	578.5	359.9	495.6	500.3	649.5	575.6	494.3	530.1
2-Methyl-Naphthalene		0.95	0.05	938.1	350.6	333.2	320.2	353.4	442.3	434.6	358.3	386.9
Acenaphthene		0.57	0.03	562.9	496.3	549.2	486.1	623.4	726.0	674.0	550.5	569.5
Fluorene		0.85	0.03	839.4	629.8	758.9	590.6	461.9	600.1	656.8	672.1	634.3
DibenzoThiophene		0.62	0.01	612.3	688.4	874.0	767.0	629.9	620.3	665.8	612.2	663.5
Phenanthrene	5.27		0.22	5204.1	5333.9	5848.2	6460.5	5840.3	6630.2	6808.5	6299.9	6659.4
Anthracene	1.77		0.33	1747.9	1629.0	1983.4	2264.9	1551.4	1422.1	1702.1	1499.8	1647.4
2-Methyl-Phenanthrene		1.90	0.06	1876.3	1342.8	1741.3	1617.4	1453.7	1363.5	1708.8	1633.5	1655.3
1-Methyl-Phenanthrene		1.7	0.01	1678.8	1325.0	1718.2	1207.3	1183.0	1174.5	1292.3	1249.9	1681.7
Fluoranthene	8.92		0.32	8808.5	6634.8	8259.4	8673.0	8221.4	6584.5	8331.7	6889.9	7372.9
Pyrene	9.70		0.42	9578.8	6732.6	9269.1	9226.5	8570.9	9738.8	8906.1	7293.7	7927.8
1-MethylPyrene		1.29	0.03	1273.9	925.7	1340.6	999.3	911.8	1325.8	1201.4	916.2	1164.1
Benzo(a)anthracene	4.72		0.11	4661.0	3767.8	6157.9	4729.0	4433.6	6003.5	6042.6	5090.1	5162.9
Chrysene	4.86		0.10	4799.3	3274.3	6084.9	5754.5	5470.1	6661.5	6103.1	4792.7	4797.8
Benzo(b)fluoranthene	3.87		0.42	3821.6	5252.5	5623.5	4877.2	4852.3	5450.0	6236.4	6563.8	6363.5
Benzo(k)fluoranthene	2.30		0.20	2271.3	2320.4	2633.5	3012.4	3091.1	2998.2	3236.7	2335.4	2480.7

PAH	Certified Conc. (*ug*/g dry)	Reference Conc (*ug*/g dry)	Uncertainty + or - (*ug*/g dry)	Cert/Ref Conc Corrected for Moinsture (ng/g)	1 SRM 1 (ng/g)	3 SRM 1 (ng/g)	6 SRM 1 (ng/g)	6 SRM 2 (ng/g)	7 SRM 1 (ng/g)	9 SRM 1 (ng/g)	9 SRM 2 (ng/g)	9 SRM 3 (ng/g)
Benzo(e)Pyrene	3.28		0.11	3239.0	2473.2	2647.5	3091.0	3035.1	2974.8	3167.2	3040.0	3107.7
Benzo(a)pyrene	4.30		0.13	4246.3	3482.8	4186.1	4816.3	5008.7	5010.2	3876.3	3842.6	3780.6
Perylene	1.17		0.24	1155.4	838.2	844.1	908.2	885.1	878.5	923.1	1050.2	945.5
Indeno(cd-)pyrene	2.78		0.10	2745.3	2154.0	2489.0	3164.0	3137.7	2779.3	2712.3	2047.9	2948.1
Dibenzo(a,h)anthracene	0.424		0.069	418.7	552.9	659.9	730.8	763.2	662.6	558.4	456.6	615.9
Benzo(g,h,i)perylene	2.84		0.10	2804.5	2401.9	2757.7	2999.9	2857.8	2323.4	3062.8	2202.2	3168.4