



# Assessment and Remediation of Contaminated Sediments (ARCS) Program



## ASSESSMENT OF SEDIMENTS IN THE SAGINAW RIVER AREA OF CONCERN



○ United States Areas of Concern

● ARCS Priority Areas of Concern

**ASSESSMENT AND REMEDIATION OF CONTAMINATED SEDIMENTS (ARCS)**

# **Assessment of Sediments in the Saginaw River Area of Concern**

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## 1. INTRODUCTION

### 1.1 Overview of the ARCS Program

The 1987 amendments to the Clean Water Act, in Section 188(c)(3), authorized the U.S. Environmental Protection Agency's (EPA) Great Lakes National Program Office (GLNPO) to coordinate and conduct a 5-year study and demonstration project relating to the control and removal of toxic pollutants in the Great Lakes, with emphasis on removal of toxic pollutants from bottom sediments. Five areas were specified in the Clean Water Act as requiring priority consideration in locating and conducting demonstration projects: Saginaw Bay, Michigan; Sheboygan Harbor, Wisconsin; Grand Calumet River, Indiana; Ashtabula River, Ohio; and Buffalo River, New York (see Figure 1.1). In response, GLNPO undertook the Assessment and Remediation of Contaminated Sediments (ARCS) Program. ARCS was an integrated program for the development and testing of assessment and remedial action alternatives for contaminated sediments. Information from the ARCS Program activities is used to guide the development of Remedial Action Plans (RAPs) for the 42 Great Lakes Areas of Concern (AOCs, as identified by the International Joint Commission), as well as Lakewide Management Plans.

Although GLNPO is responsible for administering the ARCS Program, it is a multi-organization endeavor. Other participants in the ARCS program include the U.S. Army Corps of Engineers (ACE), the U.S. Fish and Wildlife Service (FWS), the National Oceanic and Atmospheric Administration (NOAA), EPA headquarters offices, EPA Regions 2, 3, and 5, Great Lakes State Agencies, numerous universities, and public interest groups.

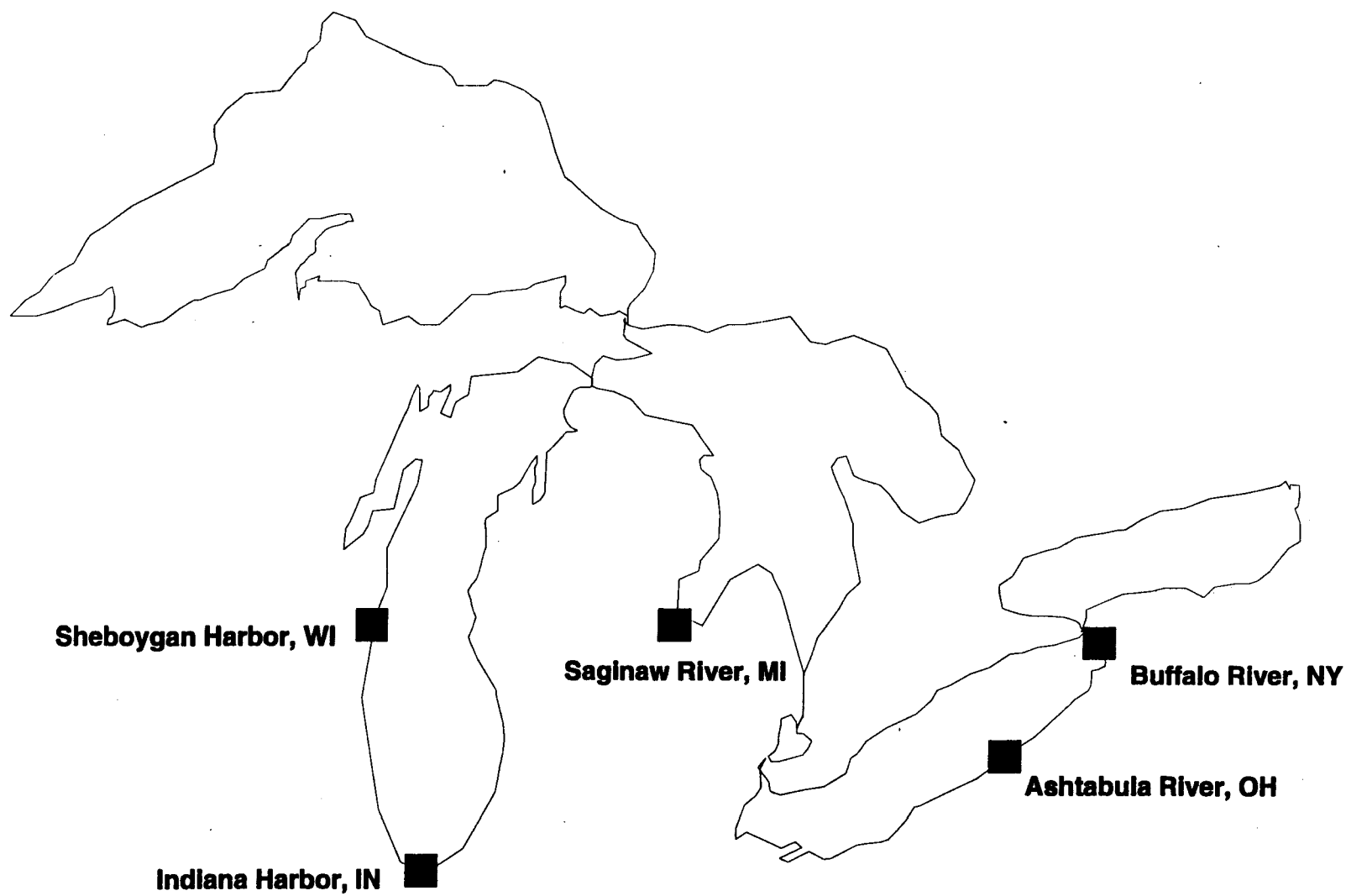
The Management Advisory Committee provides overall advice on ARCS Program activities. The Management Advisory Committee is made up of representatives from the organizations noted above. Three technical Work Groups identify and prioritize tasks to be accomplished in their areas of expertise. These are the Toxicity/Chemistry, Risk Assessment/Modeling, and the Engineering/Technology Work Groups. The Communication/Liaison Work Group oversees technology transfer, public information, and public participation activities. The Activities Integration Committee coordinates the technical aspects of the work groups' activities.

The overall objectives of the ARCS Program are:

- To assess the nature and extent of bottom sediment contamination at selected Great Lakes Areas of Concern;
- To evaluate and demonstrate remedial options, including removal, immobilization and advanced treatment technologies, as well as the "no action" alternatives; and
- To provide guidance on the assessment of contaminated sediment problems and the selection and implementation of necessary remedial actions in the Areas of Concern and other locations in the Great Lakes.



**Figure 1.1 ARCS Program Demonstration Areas**



The primary aim of the ARCS Program is to develop guidelines that can be used at sites throughout the Great Lakes. Another goal of the ARCS Program is to develop and demonstrate sediment remediation procedures that are scientifically sound, and technologically and economically practical. The intent is to provide the environmental manager with methods for making cost-effective, environmentally sound decisions. As a result, application of existing techniques is stressed over basic research into new ones.

It is important to stress that the ARCS Program is not a cleanup program, and will not solve the contaminated sediment problems at the five priority consideration areas. The Program will, however, provide valuable experience, methods, and guidance that could be used by other programs to actually solve the identified problems.

There are several important aspects of the management of contaminated sediments that will not be fully addressed by the ARCS Program. Regulatory requirements and socioeconomic factors in decision-making are two such aspects that will be critical in the choice of a remedial alternative (or whether to remediate at all). While not addressing such issues in depth, the ARCS Program will identify issues that need to be resolved before sediment cleanups can go forward.

## **1.2 Overview of the Saginaw River Area of Concern**

This report will focus on the Saginaw River Area of Concern (see Figure 1.2). The Saginaw River receives discharges from 87 industrial facilities and from 127 wastewater treatment plants, including the cities of Flint, Saginaw, Bay City, and Midland. Historic eutrophication and toxic materials have created degraded conditions in the Saginaw River and Bay areas, and fish consumption advisories have been issued based on elevated levels of polychlorinated biphenyls (PCBs) found in fish tissues. Other pollutants of concern found in fish tissue include hexachlorobenzene, furans and dioxins, diphenylethers, styrenes, and terphenyls.

Sediment contamination has been suspected for some time as a major factor contributing to the degraded conditions in the Saginaw River and Saginaw Bay. Contaminants in the sediments include toxic metals, PCBs, polybromated biphenyls, and DDT; the most highly polluted areas are located around Saginaw and Bay City. Sediment contamination has been found both in surficial and deep sediments. Sediment contamination is one of the reasons for the selection of the Saginaw River and bay area as one of the AOCs by the International Joint Commission.

## **1.3 Purpose and Organization of the Report**

The purpose of this report is to summarize and analyze the existing ARCS sediment data from the Saginaw River Area of Concern (AOC), in order to aid conclusions regarding the nature and extent of sediment contamination within the AOC. The report brings together data from four sampling surveys that have not been provided in a single source or in comparable formats.

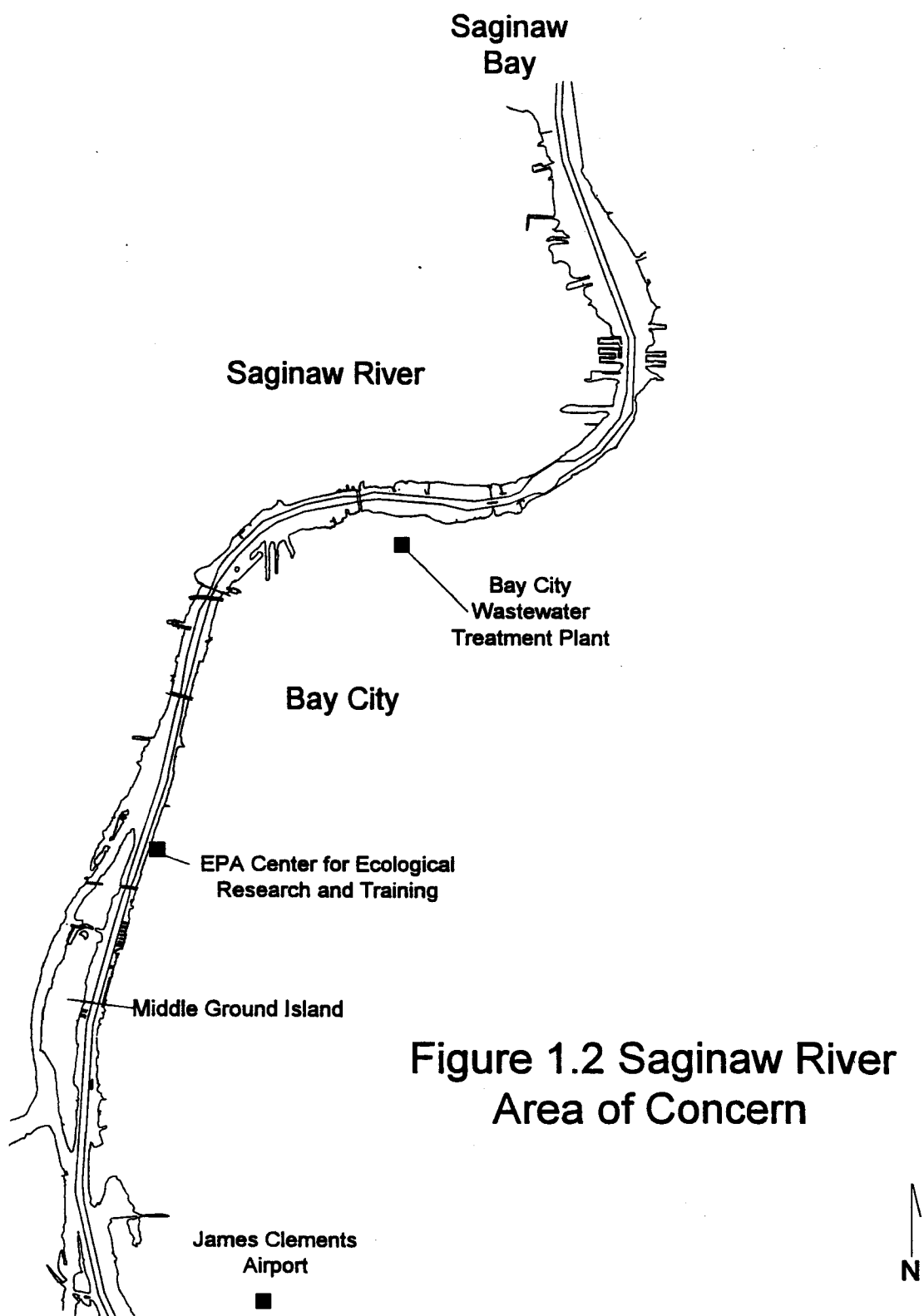


Figure 1.2 Saginaw River  
Area of Concern

The Saginaw River sediments were sampled and analyzed for ARCS in four surveys: Survey 1 (December 1989) covered seven of the twelve Masters Stations in the affected part of the river basin; Survey 2 (May 1990), performed by the Large Lakes Research Station (LLRS), included indicator assays of core samples along the whole river section; Survey 3 (June 1990) included core and grab samples taken at seven of the 12 Masters Stations; and the LLRS Survey 3 (June 1990) included indicator assays of core samples in an intensive area of the Saginaw River near the Bay City Wastewater Treatment Plant.

This report uses sediment quality guidelines and criteria to analyze the relative impact of sediment contamination and does not attempt to analyze or present actual biological impact data. The sediment guidelines may not be robust measures of the absolute impact of sediment contamination but they provide a good relative measure for the probability for impacts. The guidelines and criteria that are used in this report are discussed in detail in Chapter 3.

Chapter 2 of this report provides a complete description of the sampling and analytical methods used in the collection and analysis of sediment samples from the Saginaw River. The text of Chapter 2 draws heavily from documents produced by the ARCS Toxicity/Chemistry Workgroup.

Chapter 3 contains the summary and analysis of the data from the four sampling surveys. The data are analyzed both by chemical and by location. A complete description of the guidelines and criteria used for the analysis is presented in this chapter as well.

Chapter 4 presents the general conclusions which can be drawn from the results of the analysis.

## 2. SAMPLING AND ANALYTICAL METHODOLOGY

This chapter summarizes the methodologies used to sample and analyze the sediments in the Saginaw River area of concern (AOC). The methodology is discussed only to allow for an understanding of the nature of the samples used to generate the data presented in this report. The majority of the material in this chapter was taken from the report entitled *ARCS Toxicity/Chemistry Work Group Sediment Assessment Guidance Document* (Filkins, et.al. 1993). The methodologies have been edited from this reference for the purposes of presenting only the highlights of the sampling methodology. More detailed information can be found in the original report.

Assessment of sediment quality must begin by locating deposits of polluted sediments and by collecting representative samples of them. The overall quality of the assessment depends on this, since investigations based on non-representative samples should not be used to support any decision-making processes.

In general, contaminants tend to be associated more with silty sediments of high organic content than with clay or sand. Silts originate in part from suspended organic particles that absorb various contaminants from the water column. Once they settle and are buried over time by newer sediments, the original link with pollutant sources and water quality in general may be broken.

Waters and sediments of each harbor in the Great Lakes possess a unique mosaic of chemical and physical characteristics that reflects the sum of all its historic, anthropogenic alterations. These mosaics of chemical and physical characteristics are sufficiently complex that conducting even a general inventory is very difficult. Complete accounts of historic waste compositions, treatment and disposal practices are seldom available. Changing industrial locations can sometimes be mapped, but provide little information on waste disposal practices. Almost no prior surveys of contaminated sediments include the third dimension of depth, since collecting long cores has been difficult until recently. Consequently, studies of contaminated sediments usually involve a limited number of chemical and toxicological assays performed on surficial samples. These conventional assays are usually expensive, time-consuming and require relatively large volumes of material.

In most urban-industrial harbors, like those studied in the ARCS Program, contaminant distribution in sediments may be highly variable and "patchy". In shipping channels or wherever navigational dredging occurs regularly, deposits of polluted sediments are likely to be thin. However, where dredging was once practiced and then ceased years ago, thick layers of contaminated material may accumulate. Sediment quality in these depositional areas can reflect a complex history of pollution events occurring over a span of decades. Consequently, it is unrealistic to think that a few grab samples of surficial sediment will accurately represent sediment quality. Too often, however, this approach to sampling has formed the only basis for sediment quality assessment. Significant laboratory resources have been spent analyzing sediment samples that may not adequately characterize the system.

The ARCS Program addressed this dilemma by conducting two suites of assays: a set of quick, less expensive assays ("indicator assays") at a large number of reconnaissance stations, and conventional chemical and toxicological assays, performed at a limited number of "Master" stations throughout the study area. Multivariate equations relating the indicator values to the conventional assays were then generated and used to predict endpoints for the conventional assays at the many stations at which only

the indicator assays were conducted. The following sections provide details of the field, laboratory, and statistical procedures employed.

Biological, chemical, and physical assessments were conducted for all the surveys. Three sample matrices were analyzed; whole sediment (grain size, total and volatile solids, metals, solvent extractable residue, organohalogens, and total organic carbon), sediment elutriates (ammonia and Microtox), and sediment pore water (conductivity). The current document presents only the results of the whole sediment chemical and physical analyses. Additional information on the biological assessments or the results of porewater or elutriate analyses is contained in the *ARCS Toxicity/Chemistry Work Group Sediment Assessment Guidance Document* (Filkins, et.al. 1993) or the *Biological and Chemical Assessment of Contaminated Great Lakes Sediment* (USEPA, 1993a).

For Survey 1, the sediment physical characterization included total organic carbon (TOC) and percent solids. Sediment chemical characterization included the metals silver (Ag), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn); organometals (butyltins and methyl mercury); acid volatile sulfide (AVS); and PCBs, dioxins and Furans, organic pesticides, and polycyclic aromatic hydrocarbons (PAHs).

For LLRS 2 core samples, the sediment physical characterization included TOC, pH, conductivity, ammonia, bromine, chlorine, Microtox bioassay, extractable residue, and particle size. Sediment chemical characterization included the metals Cd, Cr, Cu, Fe, Ni, Pb, and Zn, and total PCBs.

For Survey 3 Master Station grab and core samples, the sediment physical characterization included TOC and percent solids. Sediment chemical characterization included the metals Ag, As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Se, and Zn; organometals (butyltins and methyl mercury); AVS; and PCBs, dioxins and Furans, organic pesticides, and PAHs.

For LLRS 3 intensive zone core samples, the sediment physical characterization included TOC, pH, conductivity, ammonia, bromine, chlorine, Microtox bioassay, extractable residue, and particle size. Sediment chemical characterization included the metals Cd, Cr, Cu, Fe, Ni, Pb, and Zn, and total PCBs.

## 2.1 Collecting and Processing Sediment Samples

### 2.1.1 Sampling Vessel

The sampling vessel, the Research Vessel *Mudpuppy*, capable of operating in shallow waters of less than three feet (1 m), was needed for the ARCS work. It had a climate controlled cabin for electronic equipment and was capable of lifting a ton (900 kg) of weight and 20 foot (6 m) sediment cores onto the deck. Electronic instruments used in the vessel operations included: a marine radio, a fathometer, a Global Positioning System (GPS), computers for data logging and ship's navigation, and a Loran-C receiver serving as a backup for the ship's positioning system.

### 2.1.2 Grab Samples

Grab samples of surficial sediments were collected by steel Ponar or Van Veen grab samplers at each master station and at a few reconnaissance stations where coring was not possible. Benthos samples

were collected prior to grab sampling for contaminants and bioassay analysis, to minimize disturbance of the organisms. Five replicate samples were collected at each of the master stations. For more details see USEPA (1993a).

### 2.1.3 *Core Samples*

Sediment cores were collected at each of the reconnaissance stations and at most of the master stations. The coring unit used in the Saginaw was a specially designed corer developed at the Large Lakes Research Station. The core length collected varied from 2 to 8 feet.

During the ARCS Program, each core was described and subsampled on board the sampling vessel. In subsequent, post-ARCS sediment surveys, cores were cut into 3 foot (1 meter) sections and transported to a shore-based facility where they were examined, described, and subsampled. This required a slightly larger field crew, but increased the number of cores that could be collected in a day and also facilitated in-field analyses of selected subsamples.

### 2.1.4 *Core Documentation*

Proper identification of individual cores and their subsamples was especially important in this project because of both the number of samples collected and the number of laboratories receiving splits of those samples. The visual characteristics of each sediment core total length, position of layers within the core, and color, texture, and composition of the material were recorded. Ancillary information collected in the field included percent fullness of the Ponar sampler and water chemistry information (dissolved oxygen, conductivity, temperature, and reduction potential) measured with a Hydrolab sonde positioned 3 feet (1 m) above the bottom.

## 2.2 Characterizing Sediment by Remote Sensing

In larger areas, remote sensing or profiling as a supplement to coring provides a means to interpolate sediment quality between infrequent sampling points. Remote sensing ensured that the locations of all principal sediment types were directly sampled for chemical analysis. Remote sensing also measured whether sediment chemical contamination was associated primarily or entirely with selected sediment deposits which have been geophysically mapped, or distributed in a fashion apparently independent of the mapped deposits. Seismic subbottom profiling and electrical resistivity are two geophysical profiling techniques used for remote sensing sediment characterization. Seismic subbottom profiling of sediments utilizes the reflection of sound waves from different subsurface sediment layers. These layers, exhibiting interfaces of different elasticity of density, are distinguished as distinct layers within the profile trace. Fine-grained sediments, such as clay, demonstrate high porosity, and are, if uncompacted, poor acoustical reflectors. Coarse-grained sediments, such as sand, exhibit lower porosity and tend to be good reflectors (Guigne' et al. 1991).

Electrical resistivity or conductivity profiling is the most common geophysical approach to pollution-related land studies. Despite a wide range of instrumentation and procedures, all of these techniques attempt to measure lateral and vertical variations in electrical resistivity or its reciprocal, electrical conductivity. With the exception of clay-rich material, the electrical resistivity of sediments is determined primarily by porosity, and pore fluid chemistry. For clay-rich sediments, the clay

mineralogy is also a significant factor. While it is generally not possible to separate the effects of porosity, pore fluid chemistry, or mineralogy on resistivity measurements, the method is regularly used in land studies for the detection and mapping of clay units or inorganically contaminated groundwater. Thus, electrical resistivity surveys provide a reasonable supplement to the acoustic measurements. Comparison of the electrical properties with actual cores would then provide a basis for associating the electrical properties with sediment types.

In theory, the interpretation of the seismic trace is accomplished by "ground truthing" using sediment cores collected at selected points along the ship's track followed during the seismic survey. The visual description of core stratigraphy is compared to the seismic profile record for that position. A comparison of the core profile to the seismic record allows interpretation of seismic reflectors (layers) as sediment types, such as gravel, sand, silt and clay. The characterization of sediment stratigraphy between cores is mapped using the interpreted seismic profiles, providing a complete picture of sediment distribution in the study area.

### 2.2.1 *Geophysical Survey Design*

In portions of the study areas which were less than 100 meters wide, three equally spaced lines parallel to the shoreline were surveyed. In wider portions of the study areas, three parallel lines were utilized with an additional series of diagonal lines forming a diamond pattern overlying the parallel lines. In all cases, the intervals between survey lines were approximately one third of the channel width or finer resolution. This survey geometry was efficient while it provided adequate coverage and an acceptable number of tie-points (line intersections). The tie-points serve to evaluate the how reproducible of seismic measurements taken at the "same point". The reproducibility of these measurements is a function of the reproducibility of the acoustical profiler and the ship's positioning system. In a quality assurance sense, the number of tie-points used depends on the requirements established in the Quality Assurance Project Plan. It ensured the geophysical profiling of all sediment areas with linear dimensions equal to one quarter of the channel width.

The accuracy of sediment strata thickness and depth measured from the seismic record was limited by the extent to which subsurface velocities were known. Marker beds seen within the "ground truthing" cores were compared to the seismic record for depth correction. When using cores for "ground truthing" seismic records consideration must be given to core compaction which may occur during sample collection. Compaction can be variable throughout the core with greater compaction occurring in the upper core containing less consolidated sediment. The sediment character, corrected depth and thickness of the strata were then mapped between core sites using seismic records.

### 2.3 Collecting, Storing and Handling Sediment Samples for Chemical Analyses and Bioassays

About 10 liters (L) of bulk sediment grab samples or 4 L of bulk core samples were collected from sample stations in all four surveys. All chemical analyses of sediment samples were provided by Battelle Laboratory in Sequim, Washington. The chemical samples were collected by personnel of the Large Lakes Research Station (LLRS) in Grosse Isle, Michigan.



The percentage solids in each sediment sample was estimated by freeze drying the sample and then comparing wet and dry weights. Freeze drying provided a fine, powdery sample that could be more uniformly homogenized. The TOC in samples was determined with a Leco Model WR-12 carbon determinator. Samples were pre-treated with concentrated hydrochloric acid to remove inorganic carbon. Then the samples were burned at 800 °C in an oxygen atmosphere connected to a boat inlet that transferred the evolved carbon dioxide (CO<sub>2</sub>) directly into an organic carbon analyzer. Particle size was determined with a Gilson Model WV-2 wet sieve, using U.S. Standard #18 (1 mm), 60 (250 µm), 230 (63 µm) and 400 (38 µm) sieves. Acid volatile sulfides (AVS) were determined according to the method of Cutter and Oattes (1987).

The sediment samples were analyzed for total metals concentrations using USEPA Method 200.4 (USEPA 1990). These techniques are not intended to measure the biologically significant portion of metals. The samples were completely dissolved by digestion with nitric, perchloric and hydrofluoric acids in Teflon<sup>®</sup> pressure vessels and then analyzed by use of cold vapor atomic absorption, or graphite furnace atomic absorption. For crustal elements that are difficult to dissolve with strong acids, a portion of the freeze-dried samples was ball-milled to about 120 mesh, pelletized, and analyzed with x-ray fluorescence (Nielson and Sanders 1983).

In methylmercury analyses, the homogenized samples were digested in 10 milliliter (mL) of a 25 percent solution of potassium hydroxide in methanol at 60 °C for 2 to 4 hours. Samples were allowed to cool for 24 hours and an additional 10 mL of methanol was added and mixed well by shaking. Before analysis undissolved solids were allowed to completely settle. The samples were analyzed with a cold vapor atomic fluorescence technique (Bloom 1989). The technique is based on the emission of 254 nm radiation by exiting mercury atoms in an inert gas stream. An ethylating agent, sodium tetraethylborate, was added to the sample digestate to form a volatile methylethylmercury derivative. The derivative was then purged onto graphite carbon traps for pre-concentration and removal of interferences. Then the samples were subjected to cryogenic chromatography and pyrolytic degradation to elemental mercury, which was quantified with a cold vapor atomic fluorescence detector.

During analyses for organotins, samples were extracted with 0.2 percent tropolone in methylene chloride, then filtered through glass wool. The filtrates were derivitized with 1 mL hexyl magnesium bromide, a Grignard's reagent, and cleaned-up with a Florisil column. Organotin concentrations were measured with a Hewlett Packard Model 5890 gas chromatograph equipped with a flame photometric detector.

Three groups of organic chemicals were measured for each sediment sample: PAHs, PCBs and chlorinated pesticides, and PCDDs and PCDFs. The analytical procedure for each chemical group included solvent extraction, extract purification with column chromatography, and chemical quantification with capillary column gas chromatography. In the analyses for pesticides and PCBs, aldrin, beta-BHC, gamma-chlordane, 4,4'-DDD, endrin, endrin aldehyde, endrin ketone, heptachlor epoxide, Aroclor 1242 and 1254 were detected in some samples, but either a less than 25 percent difference between the two gas chromatography columns for detected concentrations was observed, or the analyses were conducted at secondary sample dilution factors.

PAHs in sediment samples were extracted according to the USEPA Method 3550 (USEPA 1986). Before extraction, three isotopically labelled surrogate PAH compounds (D10-fluorene, D10-anthracene,

D10-pyrene) were added to the samples. Then the samples were extracted with methylene chloride in a Soxhlet extractor. Potential interferences by pigments, lipids and other macromolecules were removed by the use of the USEPA gel permeation chromatography (GPC) Method 3540 (USEPA 1986). Then the extracts were exchanged into hexane and analyzed with the USEPA Gas Chromatography/Mass Spectrometry (GC/MS) Method 8270 (USEPA 1986).

Aroclors quantified were 1016, 1221, 1232, 1242, 1248, 1254 and 1260. Aroclors were extracted from the sediment samples according to the USEPA Method 3550 (USEPA 1986). The GC surrogate compound dibutyl chlorodate (DBC) was added to the samples, and the samples were subsequently extracted with methylene chloride using sonication. Potential interferences by oily-type materials from highly contaminated sediments, lipids, and other macromolecules were eliminated by use of GPC or alumina column chromatography (USEPA 1986, Methods 3540 and 3610). Aroclors were quantified by USEPA Method 8080 (USEPA 1986) using a DB-5 fused silica capillary column (0.25 mm diameter x 30 m) and a Hewlett-Packard 5890 gas chromatography equipped with an electron capture detector (GC/ECD) and a computer for data acquisition. A dual column analysis was always performed simultaneously and the results from both columns were accepted if they showed no more than a 50 percent variation.

The USEPA isotope dilution Method 8290 (USEPA 1986) was used to extract and clean-up the sediment samples for analysis of PCDDs and PCDFs. Isotopically labelled PCDDs and PCDFs were added to the samples before extraction. The samples were extracted with benzene in a Soxhlet extractor for 18 hours. Then a three step column chromatography procedure with acidified silica gel, alumina, and AX-21 activated carbon on silica gel was used to enrich the samples and remove interferences. Isotopically labelled 2,3,7,8-TCDD was added to the samples before the enrichment to determine the efficiency of the method. Two internal standards were added to the samples after sample enrichment to determine percent recoveries. The PCDDs and PCDFs were quantified with capillary columns gas chromatography of groups of ion masses described in the USEPA Method 8290 (USEPA 1986).

Pore water samples were prepared by Battelle's Marine Sciences Laboratory in Sequim, Washington from about 40 L of sediment samples. Aliquots of the 40 L samples were extracted in acid-cleaned 500 mL Teflon jars by centrifugation in a modified clothing extractor at 2,000 RPM for 15 minutes. The pore water was decanted into clean 150 mL glass centrifuge tubes and then centrifuged again at 2000 RPM for one hour. The pore water was then pipetted without filtration into 500 mL acid-cleaned Teflon bottles, acidified to pH 2 with nitric acid (HNO<sub>3</sub>), and stored at room temperature for metal analyses.

Immediately after preparation, water quality characteristics of the dilution water and 100 percent elutriate samples were determined (APHA et al., 1975). Dissolved oxygen (mg/L) was measured with a YSI Model 54-A oxygen meter. Conductivity (umhos/cm, corrected to 25 °C) was measured with a YSI Model 33 S-C-T conductivity meter. The pH and alkalinity (mg/L as CaCO<sub>3</sub>) was determined by burette titration. Ammonia (mg/L) was measured with an Orion 940E ionalyzer and a 95-12 ammonia electrode. Turbidity (NTU) was measured with a Cole-Palmer Model 8391-35 turbidity meter. Unionized ammonia was determined by converting the total ammonia measured in the samples to unionized ammonia, and then correcting for pH and temperature (Thurston et al. 1974). After preparation of the dilution water and 100 percent elutriates, samples for chloride (mg/L) were placed in 250 mL I-CHEM bottles, labeled, and stored at 4 ± 3°C until analysis with an Orion 940E ionalyzer and

a 94-17B electrode. The pH, dissolved oxygen, and conductivity were measured at the beginning and end of each daphnid test in the 100 and 25 percent treatments, and in the dilution water control. About 500 mL of each 100 percent elutriate sample were placed in Teflon bottles, acidified to pH 2 with redistilled hydrochloric acid, and shipped via overnight courier to Battelle Marine Sciences Laboratory in Sequim, Washington for metals analyses.

Elutriate and pore water samples were analyzed for silver (Ag), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn). With the exception of Hg and Zn in elutriates, all pore water and elutriate samples were analyzed without sample preparation. The Zn in elutriates was quantified by flame atomic absorption. The Hg in elutriates were analyzed for metals by cold vapor atomic fluorescence with sub-nanogram per liter (ng/L) detection limits. Organics prevalent in many of the samples were broken down before Hg analysis by use of a bromine monochloride/UV oxidation procedure (Bloom and Crecelius 1983).

## 2.4 Quality Control and Quality Assurance

Accuracy and precision of the chemical analyses were determined by analysis of one blank, one matrix spike, one certified reference material, and one sample in duplicate or triplicate for each set of 20 samples. Acceptable recovery values ranged from 85 to 115 percent of the spike concentration for organics and organometals. Analytical values for reference materials were acceptable if they were within 20 percent of the certified ranges. The acceptable coefficient of variation for duplicate or triplicate sample analyses was  $\leq 20$  percent.

During chemical analyses, three to five standards containing concentrations that bracketed the expected range of concentrations in the samples were used for daily instrument calibrations. In analyses of samples for metals by atomic absorption spectrophotometry, these standards were analyzed as matrix spikes, and the slopes from linear regression analyses were used to estimate sample concentrations. The minimum acceptable  $r^2$  in the regression analyses was 0.97. The standards for each sample set were analyzed at the beginning and end of each analytical run. The analytical results were accepted if the values for standards were within 90 to 110 percent of their certified values. For some samples analyzed by atomic absorption, average response factors, rather than linear regression, were used for instrument calibration. The accuracy of this calibration method was checked by dividing each response factor by the average response value. The calibration values were accepted if they were within 5 percent of the average response value.

During chemical analyses, the method detection limit (MDL) was estimated according to procedures in the USEPA Federal Register (1984).

Three sample matrices were analyzed; whole sediment (grain size, total and volatile solids, metals, solvent extractable residue, organohalogens, and TOC), sediment elutriates (ammonia and Microtox), and sediment pore water (conductivity). The elutriate creation procedure was originally designed to mimic the rapid desorption of contaminants from sediments resulting from the open-water disposal of dredged materials (Plumb 1981). Elutriates are cheaply and easily prepared, but the mixing of the sediment and water may influence the availability of some contaminants by changing their oxidative states. Pore water sampling better reflects the interstitial concentration of contaminants resulting from the partitioning of chemicals from sediments, and appropriate sampling techniques probably have a lesser

impact on the chemistry of the contaminants than the elutriate procedure. Pore water squeezers and extractors are more expensive than the equipment required for elutriate preparation, however, and require a greater volume of sediment to produce a comparable volume of liquid test media.

Data storage, retrieval and manipulation were performed using Paradox, a PC-based relational database program. To facilitate use of the data, a user "shell" was created using the Paradox Applications Language (PAL). The user shell was designed to allow easy access to the data, calculate RPDs for QC checks, search for missing samples, format data for creation of icons and provide significant figure-formatted output. Analytical data were checked for entry accuracy by the analyst, and the quality of the data was verified by both the analyst and the project Quality Control coordinators by examination of the QC data associated with each assay (blanks, replicate RPDs, reference materials, etc.). Data were not used for statistical calculations (nor released to GLNPO) until all applicable QC criteria were met. Raw data from this study are archived by GLNPO in their Ocean Data Evaluation System (ODES) database.

### 3. RESULTS

#### 3.1 Introduction

This chapter presents a summary and analysis of the sediment chemical data collected from the Saginaw River AOC based on the four major sampling surveys performed by the ARCS Program. The purpose of the analysis is to provide a preliminary examination of the potential for chemical contaminants to cause adverse impacts to aquatic life or uses of the Saginaw River system. Since the data presented are chemical only and not biological, the analysis is limited in its ability to predict absolute biological effects.

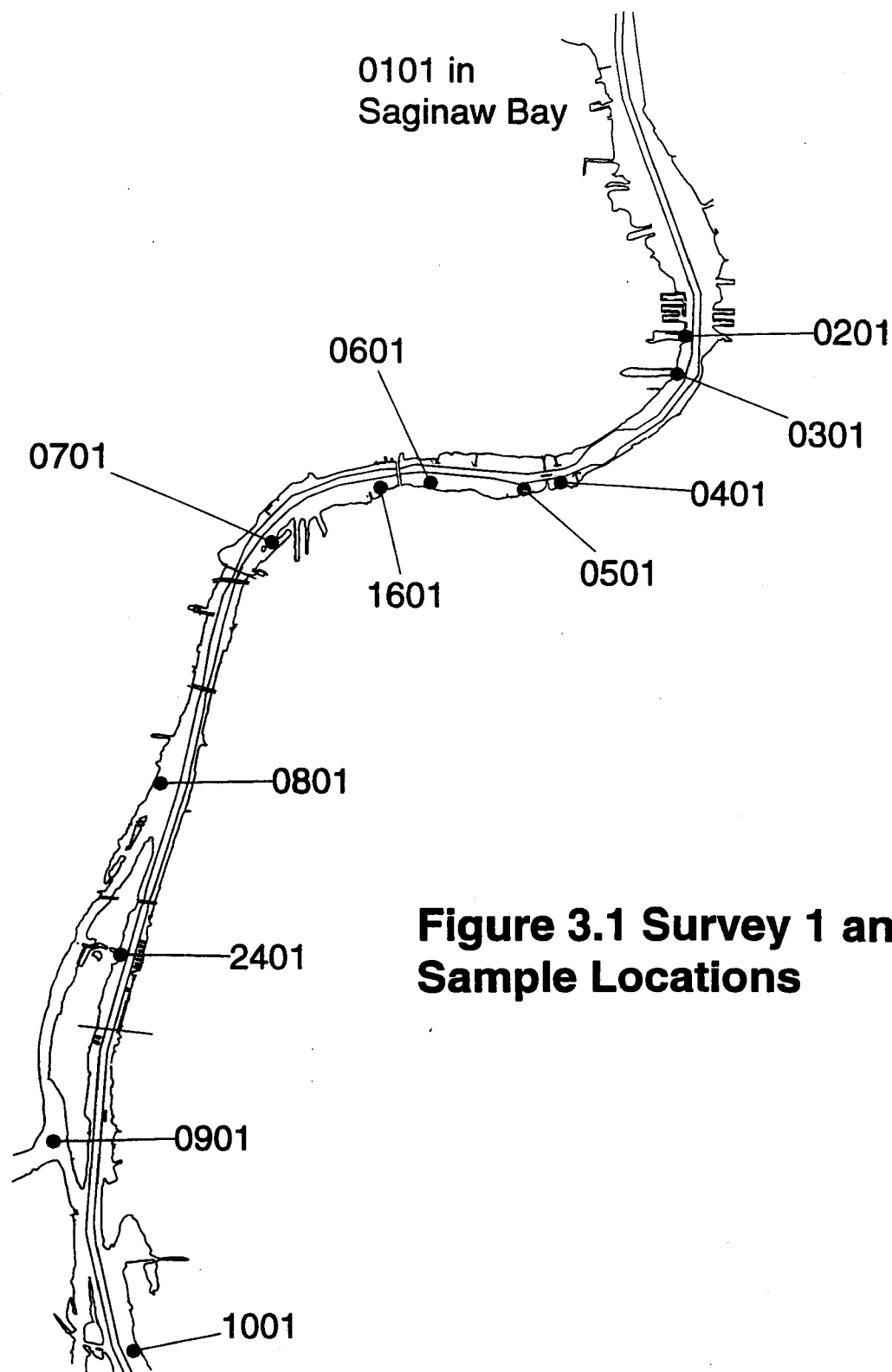
The data in this chapter are analyzed in two ways:

- On a chemical-by-chemical basis, providing an analysis of where unusually high and/or potentially harmful concentrations of individual chemicals are found within the Saginaw River AOC, and
- On a sample-by-sample basis, providing an analysis of which locations contain elevated levels for the greatest number of contaminants.

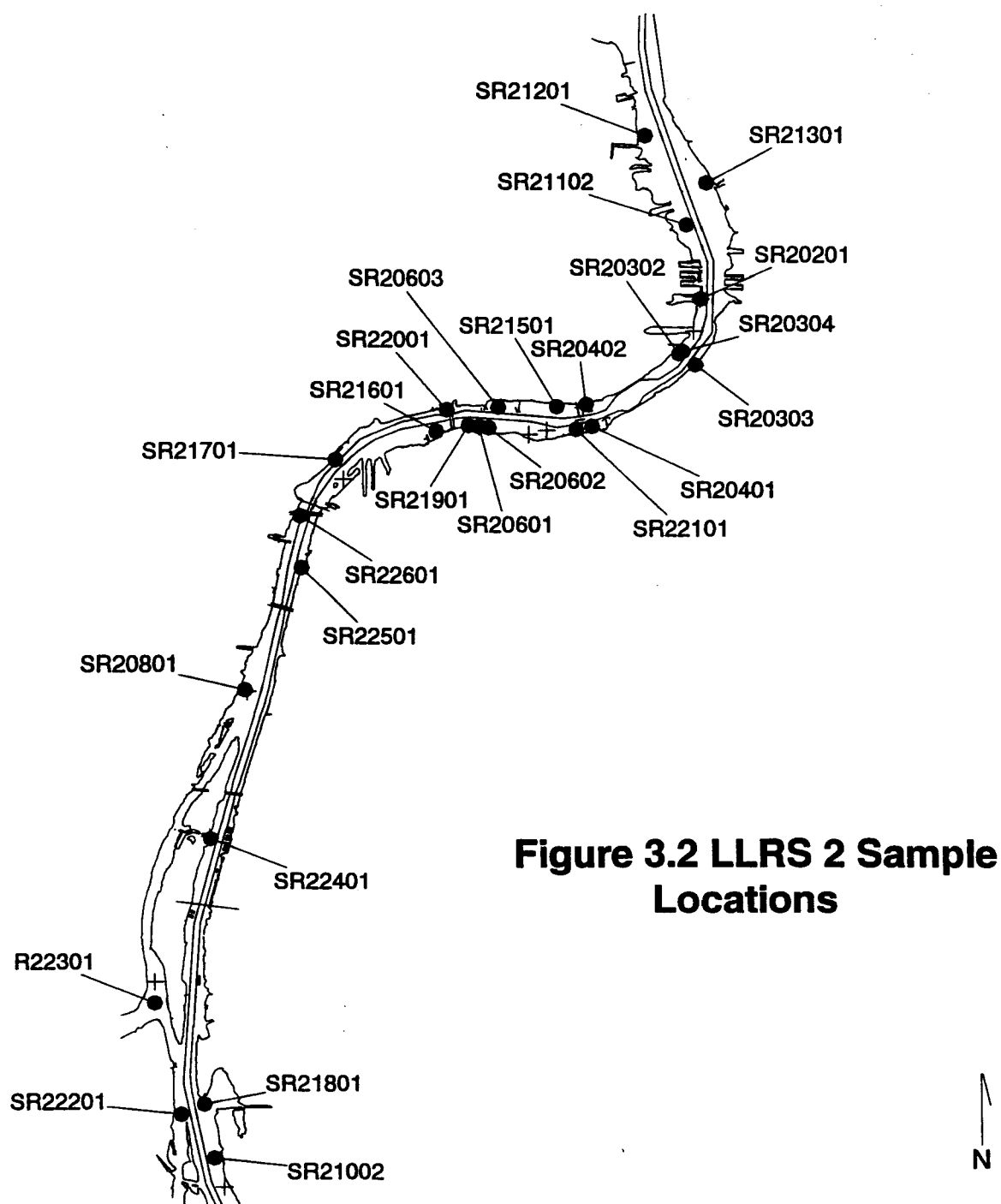
The first type of analysis aids in the determination of which *chemicals* are of greatest concern. The second analysis assists in determining which *areas* of the AOC suffer the greatest levels of sediment contamination. The analysis relies on the comparison of measured sediment concentrations to chemical-specific guidelines or criteria.

In order to estimate potential effects, benchmark criteria or guidelines were necessary against which the potential for a given concentration of sediment contamination to cause environmental harm could be assessed. USEPA has currently endorsed an equilibrium partitioning (EqP) based approach for assessing sediment contamination (USEPA, 1993b-f). Unfortunately, this method has only been fully developed for a limited number of heavy organic contaminants. A more comprehensive set of sediment quality guidelines has been developed by Long and Morgan (1990) for the NOAA Status and Trends program. The NOAA guidelines lack the toxicological precision of the EqP-based criteria, but their applicability to a wider set of parameters makes them useful for the current analysis. Both EqP and NOAA COSED guidelines are discussed more completely in Section 3.2.

The data presented in this section are based on the results of four primary sampling surveys. Surveys 1 and 3 (performed in December 1989 and June 1990, respectively) consist of grab samples taken from the 10 ARCS Saginaw River Master Stations. The locations and sample numbers of the Saginaw River sampling stations for both of these surveys are shown in Figure 3.1. The other two surveys referred to in this section, consist of a combination of 2 to 8 foot depth core samples and surface grab samples collected by the Large Lakes Research Station (LLRS) at the Master Stations, plus a number of additional sampling locations chosen to provide greater resolution on the areal extent and depth of sediment contamination in the AOC. These two surveys are hereafter referred to as LLRS 2 and LLRS 3. The LLRS 2 survey, performed in May 1990, collected samples from 26 locations along the entire length of the AOC. The locations of the LLRS 2 sample points are shown in Figure 3.2. The LLRS 3 survey, performed in June 1990, collected 25 samples within the short (< 2 mile) stretch near the Bay



**Figure 3.1 Survey 1 and 3  
Sample Locations**



City Wastewater Treatment Plant . The locations of the LLRS 3 sample points are shown in Figure 3.3. Methods for sample collection and analysis are more fully described in Chapter 2.

### 3.2 Availability of Sediment Quality Guidelines

The need for easily applicable yardsticks to make decisions regarding the impact of contaminated sediments is obvious. The primary EPA effort at preliminary sediment criteria development has focused upon Equilibrium Partitioning based approaches (USEPA, 1993b-f) that utilize the concentration of organic carbon in sediments along with a measure of the relative tendency of a contaminant to bind with organic carbon (the partitioning coefficient) to predict the interstitial water concentration of the contaminant within a particular sediment.

Other efforts have focused on the use of standardized bioassays, comparisons of concentration and effects data (e.g., AETs and PELs), and leachate and elutriate testing, among others. A complete overview of the available sediment assessment methods can be found in the *Sediment Classification Methods Compendium* (USEPA, 1992).

#### 3.2.1 Background on EPA EqP-Based Criteria

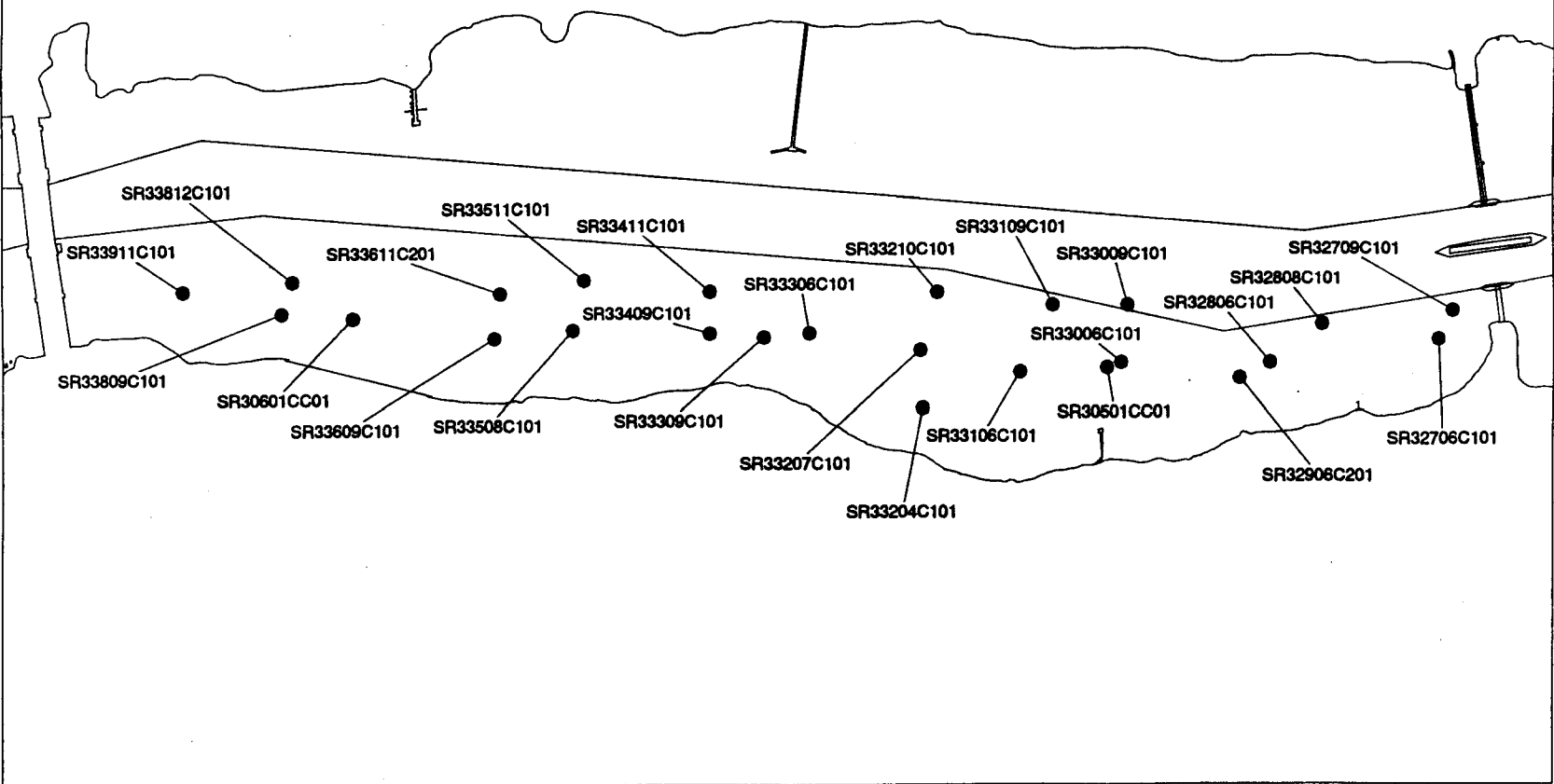
EPA has selected the equilibrium partitioning (EqP) method as its primary approach to developing numeric sediment quality criteria for contaminated sediments. The EqP approach is based on three primary observations about the toxicity of organic contaminants in sediment (USEPA, 1993b-f). These are:

- The toxicity of non-ionic organic contaminants in sediments is most closely related to the interstitial water concentrations of the contaminant rather than the bulk sediment concentration of the contaminant;
- Non-ionic organic contaminants bind primarily to the organic carbon within the sediment and partitioning models can relate the relative concentrations of contaminants bound to organic carbon and in pore water; and
- Benthic and water column organisms show similar sensitivities to chemicals so that currently established water quality criteria can be used to determine acceptable pore water chemical concentrations.

The EqP model uses the bulk concentration of contaminant and organic carbon in the sediment and a chemical-specific partitioning coefficient to predict the pore water concentration of the contaminant at equilibrium conditions. The term "equilibrium conditions" indicates that sediment conditions are not in a state of flux and that sufficient time has passed for sediment and pore water concentrations to stabilize. Examples of non-equilibrium conditions include situations where there is significant erosion or deposition of sediments or changes in contaminant concentrations.



Figure 3.3 LLRS 3 Sample Locations



There are several limitations to the EqP-based approach. The most obvious is that the method is currently only applicable to non-ionic organic contaminants. This eliminates the approach as a tool for determining the potential toxicity of lighter organic contaminants and toxic metals. Another drawback is that complete criteria are currently developed for only five contaminants. These contaminants are the polynuclear aromatic hydrocarbons (PAHs) phenanthrene (USEPA, 1993f), acenaphthene (USEPA, 1993b), and fluoranthene (USEPA, 1993e), and the pesticides dieldrin (USEPA, 1993c) and endrin (USEPA, 1993d).

For the five EqP-based criteria that are currently available, only phenanthrene and fluoranthene were analyzed for at the Saginaw River Master Station locations. A complete list of analytes for the four Saginaw River surveys and the applicable sediment quality criteria are presented in Table 3.1.

### 3.2.2 Background on NOAA Status and Trends Guidelines

Several sets of sediment quality guidelines have been developed through comparison of sets of sediment contaminant concentration data and associated biological impact data. The best known of these was published in Long and Morgan (1990). In the Long and Morgan approach, sediment concentrations of contaminants were compared to associated biological impacts data and evaluated to determine concentration ranges in which biological impacts were likely to occur, based on a preponderance of evidence approach.

The evaluation was performed by arranging all concentration data for a single contaminant in ascending order. Only data that had associated effects data were utilized and only where that associated data showed some measurable level of impact greater than zero. Therefore, all data utilized in the analysis are from sediments that have been associated with some adverse biological effect.

Long and Morgan used the tabulated data to determine two guideline numbers for each contaminant. These are:

- An Effects Range-Low (ER-L) which corresponds to the lower 10th percentile of the tabulated data; and
- An Effects Range-Median (ER-M) which corresponds to the 50th percentile of the tabulated data.

The ER-M and ER-L values are not official NOAA standards but are intended to be useful as guidance in the evaluation of bulk sediment chemistry data. They are utilized in this document with this intent. Exceedances of chemical concentrations of ER-L and ER-M levels should not be construed as an absolute indicator of biological impacts but only as a relative indicator for the potential for such.

Of the total number of sediment guidelines determined in the NOAA guidance, 25 are applicable to the analytical data collected for the Saginaw AOC. A complete listing of all analytes and the applicable NOAA guidelines is presented in Table 3.1.

TABLE 3.1 ANALYTES AND SEDIMENT QUALITY GUIDELINES

CHEMICAL	Parameters Analyzed			Sediment Quality Guidelines		
	Survey 1	Survey 3	Large Lakes	NOAA ER-M	NOAA ER-L	EPA EqP Criteria
<b>PAHS</b>						
Benz(a)anthracene	X	X		1,600 ng/g	230 ng/g	
Benzo(b)fluoranthene	X	X				
Benzo(a)pyrene	X	X		2,500 ng/g	400 ng/g	
Benzo(k)fluoranthene	X	X				
Acenaphthene		X		650 ng/g	150 ng/g	
1,2-Dichlorobenzene		X				
1,3-Dichlorobenzene		X				
1,4-Dichlorobenzene	X	X				
Naphthalene	X	X		2,100 ng/g	340 ng/g	
2-Methylnaphthalene	X	X		670 ppb	65 ng/g	
Dimethylphthalate	X	X				
Dibenzofuran	X	X				
Fluorene	X	X		640 ng/g	35 ng/g	
Phenanthrene	X	X		1,380 ng/g	225 ng/g	180 ug/gOC
Anthracene	X	X		960 ng/g	85 ng/g	
Fluoranthene	X	X		3,600 ng/g	600 ng/g	620 ug/gOC
Pyrene	X	X		2,200 ng/g	350 ng/g	
Butyl benzyl phthalate	X	X				
Bis(2-ethylhexyl) phthalate	X	X				
Chrysene	X	X		2,800 ng/g	400 ng/g	

TABLE 3.1 ANALYTES AND SEDIMENT QUALITY GUIDELINES

CHEMICAL	Parameters Analyzed			Sediment Quality Guidelines		
	Survey 1	Survey 3	Large Lakes	NOAA ER-M	NOAA ER-L	EPA EqP Criteria
Di-n-octyl phthalate	X	X				
Indeno(1,2,3)pyrene	X	X				
Benzo(g,h,i)perylene	X	X				
<b>PESTICIDES/MISCELLANEOUS ORGANICS</b>						
Cis-chlordane	X	X				
DDD	X	X		20 ng/g	2 ng/g	
DDE	X	X		15 ng/g	2 ng/g	
DDT	X	X		7 ng/g	1 ng/g	
Dieldrin	X	X		8 ng/g	0.02 ng/g	11 ug/gOC
Aldrin	X	X				
Endrin	X	X				
Endrin ketone	X	X				
Endrin aldehyde	X	X				
Endosulfan(alpha)	X	X				
Endosulfan(beta)	X	X				
Endosulfan sulfate	X	X				
Toxaphene	X	X				
Lindane	X	X				
Methoxychlor	X	X				
a-BHC	X	X				
b-BHC	X	X				

TABLE 3.1 ANALYTES AND SEDIMENT QUALITY GUIDELINES

CHEMICAL	Parameters Analyzed			Sediment Quality Guidelines		
	Survey 1	Survey 3	Large Lakes	NOAA ER-M	NOAA ER-L	EPA EqP Criteria
c-BHC	X	X				
Heptachlor	X	X				
Heptachlor Epoxide	X	X				
Trans-chlordane	X	X				
Dioxins and Furans	X	X				
PCBs	X	X	X	400 ng/g	50 ng/g	
<b>METALS</b>						
Cadmium	X	X	X	9 ug/g	5 ug/g	
Chromium	X	X	X	145 ug/g	80 ug/g	
Copper	X	X	X	390 ug/g	70 ug/g	
Iron	X	X	X			
Nickel	X	X	X	50 ug/g	30 ug/g	
Lead	X	X	X	110 ug/g	35 ug/g	
Zinc	X	X	X	270 ug/g	120 ug/g	
Silver	X	X		2.2 ug/g	1 ug/g	
Arsenic	X	X		85 ug/g	33 ug/g	
Mercury	X	X		1.3 ug/g	0.15 ug/g	
Manganese	X	X				
Methylmercury	X	X				
Tributyltin	X	X				
MBT	X	X				

TABLE 3.1 ANALYTES AND SEDIMENT QUALITY GUIDELINES

CHEMICAL	Parameters Analyzed			Sediment Quality Guidelines		
	Survey 1	Survey 3	Large Lakes	NOAA ER-M	NOAA ER-L	EPA EqP Criteria
Dibutyltin	X	X				
<b>NON-METALS</b>						
Total Organic Carbon	X	X	X			
Acid Volatile Sulfides	X	X				
Extractable Residue			X			
pH	X	X	X			
Conductivity	X	X	X			
Percent Solids	X	X	X			
Solids, Total	X	X				
Volatile Solids	X	X	X			
Microtox	X	X	X			
Ammonia	X	X	X			
Bromine			X			
Chlorine			X			
Grain Size	X	X	X			

### 3.3 Analysis of Chemical-Specific Data

This section reviews the analytical data on a chemical by chemical basis in order to determine sampling locations associated with exceedances of criteria or guidelines. For the application of EqP-based criteria, data were normalized using the sediment concentration of organic carbon. NOAA Guidelines have been applied on a bulk chemistry basis. The fact that a location contains chemical concentrations that exceed guideline levels is not an indicator of definite biological impacts but only of a heightened probability for such. On the other hand, levels below guidelines for a single chemical are obviously not

an indication that a sediment is "safe". The additive or synergistic effects of multiple contaminants are not addressed by single chemical criteria or guidelines.

### 3.3.1 *Explanation of Data Presentation*

The data in this section of the report are presented both in narrative and graphical forms. The narrative section provides:

- Summary statistics in the form of minimum, maximum, and median concentrations;
- The applicable sediment quality criteria or guidelines; and
- A narrative explanation of graphic data with conclusions on the areal distribution of high concentration data.

The summary statistics are chosen to indicate the range of concentrations present (through the minimum and maximum) and the central concentration (through the median) of a chemical. The use of the median rather than average concentrations eliminates the effect of outliers and the averaging of non-detect data. It should also be noted that the summary statistics presented for all surveys are independent of core depth (i.e., the minimum value may be from a surface sample and the maximum value from a subsurface core depth). However, any significant distinctions between core depths is noted in the text for each chemical.

Appendix A presents the raw data collected from Surveys 1 and 3 and LLRSs 2 and 3. In determining summary statistics, data from different surveys are not combined. The combining of the data sets was considered inappropriate given the differences in both sampling (grab samples versus core samples) and analytical methods between the surveys (refer to Chapter 2 for a complete description of sampling and analytical methods).

The graphical portion of the analysis consists primarily of a series of bar graphs indicating the relative level of contaminant concentration between various sampling locations within a given survey. The use of bar graphs was chosen over maps since the number of sampling points and the number of sampling depths in the various surveys make it difficult to present the data on maps in a way in which data from the multiple sampling depths could be directly compared. However, for reference, maps containing the data plotted for all surveys are provided in Appendix B.

The data in the bar graphs is separated by survey. Data in each of the graphs is arranged downstream to upstream. The actual reach of the river covered by the graphs varies by the area covered by the survey. Also, in order to simplify the cross references between the maps, graphs and text, the sampling locations have been renumbered with single digit location identifiers. Table 3.2 presents a cross-reference between the original sample numbers presented in Figures 3.1 through 3.3 and those used in the remaining figures in this chapter. Figure 3.4 depicts the location of the renumbered sample locations for Survey 1 and Survey 3. The renumbered sampling locations for LLRS 2 and LLRS 3 are found in Figures 3.5 and 3.6 respectively. The bar charts (Figures 3.7 through 3.27) are located at the end of the chapter (starting on page 61 of this report).

**TABLE 3.2 SAGINAW RIVER SURVEYS - CROSS REFERENCE TABLES****SURVEY 1**

CHART ID	SAMPLE ID
2	SR10201
3	SR10301
4	SR10401
6	SR10601
7	SR10701
9	SR10901
10	SR11001

**LLRS 2**

CHART ID	SAMPLE ID
1	SR21201C101
2	SR21301C101
3	SR21102C101
4	SR20201C101
5	SR20304C101
6	SR20302C101
7	SR20303C101
8	SR20401C101
9	SR20402C101
10	SR22101C101
11	SR21501C101
12	SR20603C101
13	SR20602C101
14	SR20601C101
15	SR21901C101
16	SR22001C101
17	SR21601C101
18	SR21701C101
19	SR22601C101
20	SR22501C101
21	SR20801C101
22	SR22401C101
23	SR22301C101
24	SR21801C101

**SURVEY 3**

CHART ID	SAMPLE ID
1	SR30101
2	SR30201
5	SR30501
6	SR30601
8	SR30801
16	SR31601
24	SR32401

**LLRS 3**

CHART ID	SAMPLE ID
1	SR30201CCX2
2	SR30201CCX3
3	SR32709C101
4	SR32706C101
5	SR32808C101
6	SR32806C101
7	SR32906C101
8	SR33009C101
9	SR33006C101
10	SR30501CC01
11	SR33109C101
12	SR33106C101
13	SR33210C101
14	SR33204C101
15	SR33207C101
16	SR33306C101
17	SR33309C101
18	SR33409C101
19	SR33411C101
20	SR33511C101
21	SR33508C101
22	SR33611C101
23	SR33609C101
24	SR30601CC01



**TABLE 3.2 SAGINAW RIVER SURVEYS - CROSS REFERENCE TABLES**

25	SR22201C101
26	SR21002C101

25	SR30601CCX2
26	SR30601CCX3
27	SR33812C101
28	SR33809C101
29	SR33911C101

The following features of the bar graphs should be noted:

- The numbers under each of the graphs correspond to the revised sample numbers for the surveys presented in Figures 3.4 through 3.6.
- The parallel dashed lines through the graphs indicate the level of the applicable criteria or guideline value for the contaminant, either NOAA or EPA EqP-based.

### 3.3.2 Analysis by Chemical Parameter

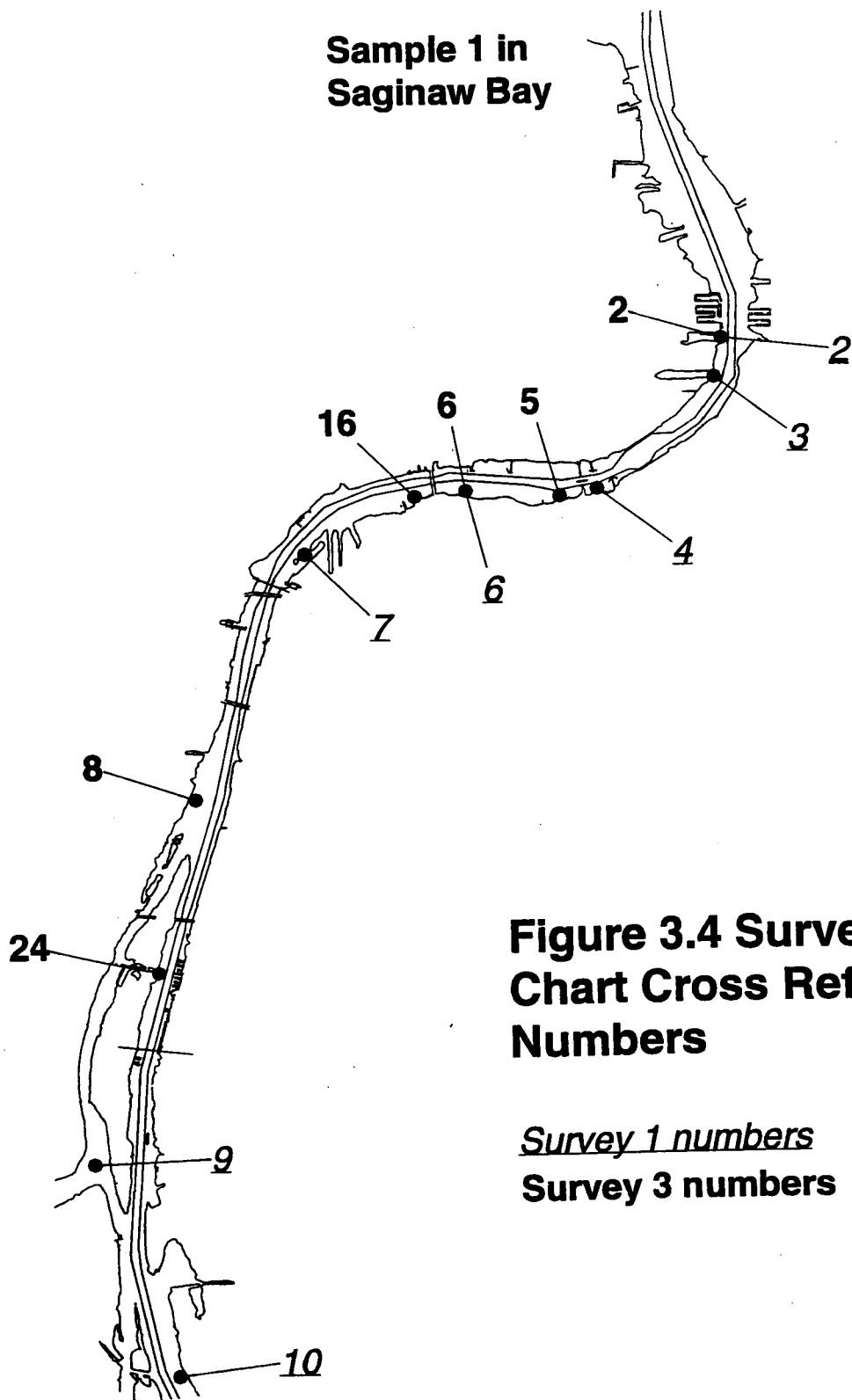
This section focuses on the chemicals for which either NOAA (ER-M and ER-L) or EPA (EqP-based criteria) are available. All other data are provided in Appendix A.

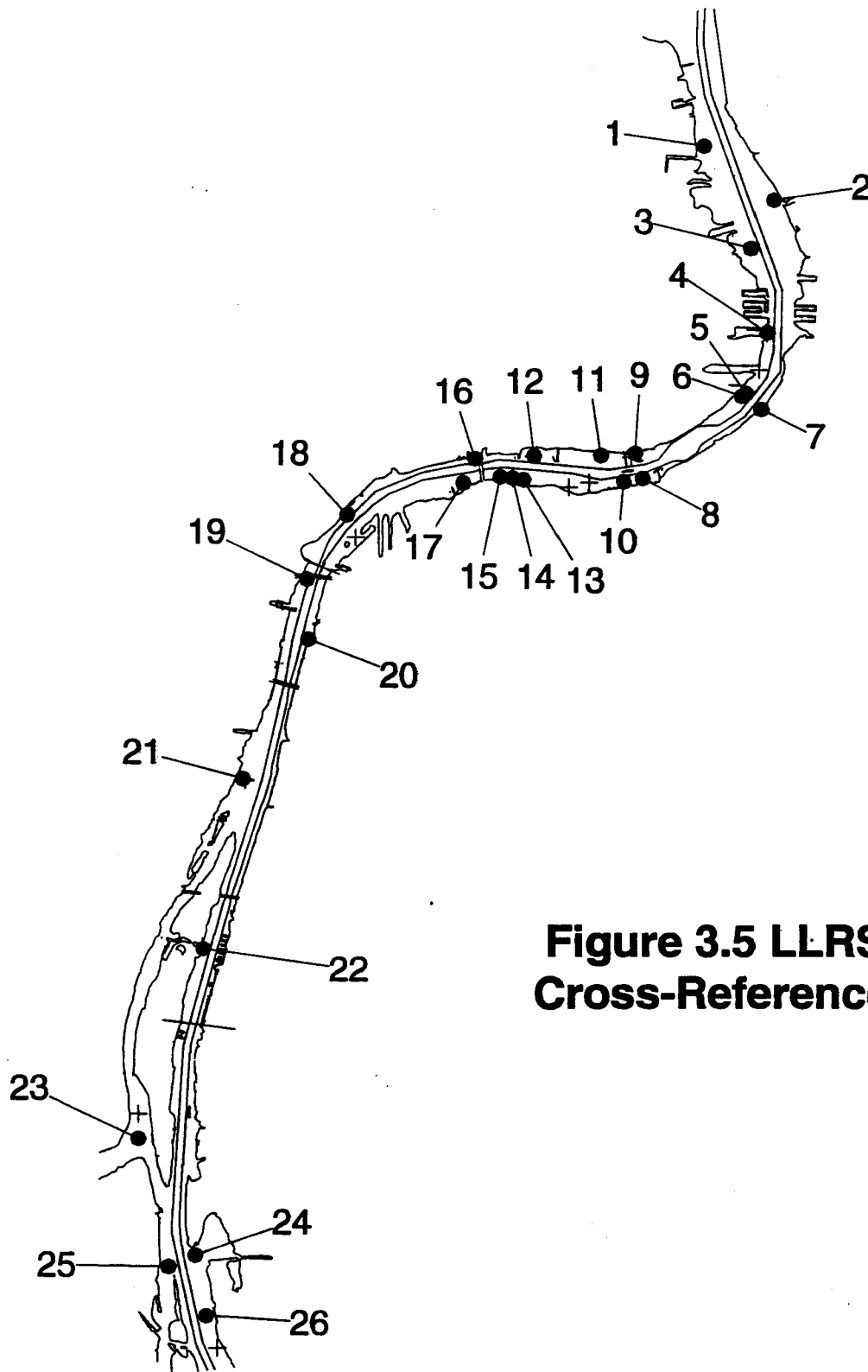
#### *Arsenic*

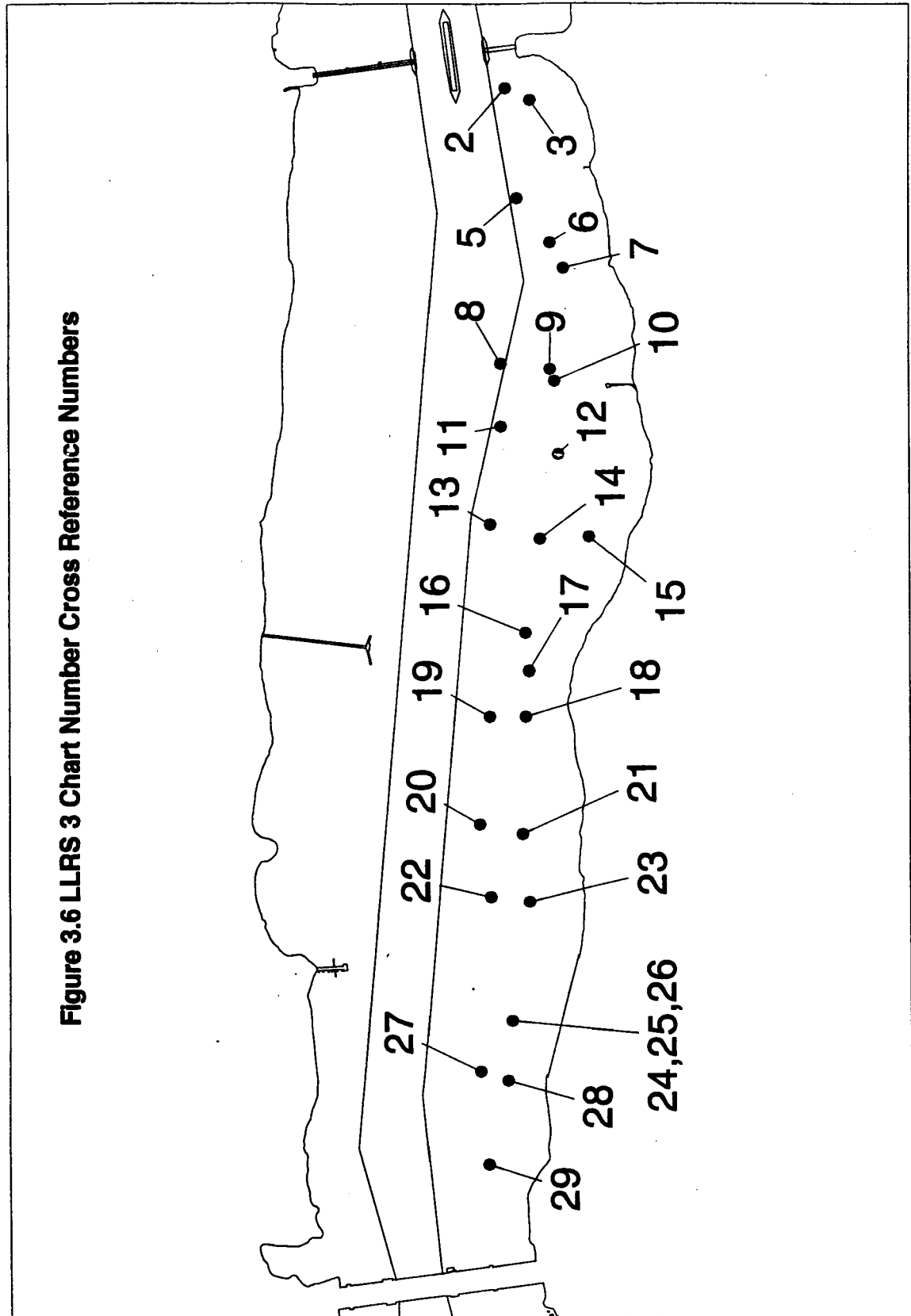
Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	3.6	10.9	16	N/A	33	85
LLRS 2	N/A	N/A	N/A			
3	6.4	24.1	217			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ug/g)

Survey 1 had no exceedances of the ER-L or the ER-M guidelines for arsenic (see Figure 3.7a). The maximum concentration of 16 ug/g, found just downstream of the Grand Trunk Railroad (sample 7), is well below the ER-L guideline.







In Survey 3 surface grab samples, there was only one exceedance of the arsenic ER-L and ER-M guidelines (see Figure 3.7b). This exceedance occurred about 1/4 mile downstream of the Bay City wastewater treatment plant (WWTP) in the intensive sampling zone (sample 16); the concentration found was 92.9 ug/g. No other surface grab samples exceeded the ER-L or ER-M in Survey 3. In the deeper core samples in Survey 3, however, all three sites for which cores were taken (sample sites 2, 5, and 6) had concentrations in excess of the ER-L; the core sample taken approximately 1 mile downstream from the intensive sample zone (sample 2) contained the highest arsenic concentration (217 ug/g) that also exceeded the ER-M.

### *Cadmium*

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	0.16	0.97	10	N/A	5	9
LLRS 2	<0.0026	0.9	7.1			
3	0.42	1.11	17.4			
LLRS 3	0	1.2	19			

N/A - Not Available  
(All units are in ug/g)

In Survey 1, the ER-L and ER-M were exceeded in the sample near the Bay City WWTP in the intensive sampling zone (sample 6), with a concentration of 10 ug/g. The ER-L and ER-M were not exceeded at any other sample location in Survey 1 (see Figure 3.8a).

As shown in Figure 3.8b, the ER-L and ER-M for cadmium were not exceeded at any location in Survey 3 surface grab samples. It should be noted that sample location 6 was sampled during Survey 1 and Survey 3. The Survey 3 concentration for sample location 6 was 0.5 ug/g, while the Survey 1 concentration was 10 ug/g. However, in the deeper core samples, exceedances of the ER-M and ER-L for cadmium did occur. In particular, the core samples taken downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core) and adjacent to the Bay City WWTP within the intensive sampling zone (sample site 6; 0-2 foot core) exceeded the ER-L for cadmium. In addition, the cadmium concentration in the 0.3-1 foot core sample from site 6 was the highest detected in Survey 3 (17.6 ug/g); this concentration exceeds the ER-M for cadmium.

In LLRS 2, the ER-L was exceeded at one sample location located just off-shore of the Bay City WWTP in the intensive sampling zone, with a concentration of 7.1 ug/g detected in the surface core (0-2 foot) sample. No other samples in LLRS 2 exceed the ER-M or ER-L for cadmium (see Figure 3.8c). In 12 of the 20 sites where deeper core samples were taken, the deeper core samples (2-4 foot) contained higher concentration than the surface core samples. However, there were no geographical trends related to these higher concentrations. None of the four surface grab samples (not shown on Figure 3.8c) contained concentrations in excess of the ER-L or ER-M guidelines.

In LLRS 3, the ER-L was exceeded at five locations with concentrations ranging from 5.0 ug/g to 19 ug/g (see Figure 3.8d). Four of the five ER-L exceedances were found in the surface (0-2 foot) core samples. The maximum concentration of 19 ug/g was found in a 0-2 foot core sample taken near the Bay City WWTP. This sample also exceeded the ER-M for cadmium. No other samples, including the seven surface grab samples, exceeded the ER-M or ER-L guidelines.

### ***Chromium***

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	40	70	319	N/A	80	145
LLRS 2	4.4	30	240			
3	24.7	59	687			
LLRS 3	4.5	35	590			

N/A - Not Available  
(All units are in ug/g)

As shown in Figure 3.9a, the ER-L of 80 ug/g was exceeded at three of the seven Survey 1 sample stations. Two of the ER-L exceedances were found approximately 1 mile upstream and downstream of the intensive sampling zone. The highest Survey 1 concentration, 319 ug/g, was detected near the Bay City WWTP within the intensive sampling zone. This high concentration also exceeds the ER-M guideline for chromium.

In Survey 3 surface grab samples, only one station, located at a master station between Veterans Memorial Bridge and Lafayette Street, exceeded the ER-L and the ER-M for chromium with a concentration of 95 ug/g (see Figure 3.9b). There were no other surface grab samples that exceeded either the ER-L or the ER-M. In all of the deeper core samples, however, exceedances of the ER-M and ER-L for chromium did occur. The highest concentration found (687 ug/g), that exceeded both the ER-L and ER-M, was from the core sample taken adjacent to the Bay City WWTP within the intensive sampling zone (sample site 6; 0.3-1 foot core). Other exceedances of the ER-M and ER-L also occurred downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core), within the downstream portion of the intensive sampling zone (sample site 5; 0-2 foot core), and in the 0-2 foot core sample from site 6.

As shown in Figure 3.9c, core samples at four LLRS 2 survey sample sites exceeded the ER-M for chromium. Core samples at six other samples sites in the LLRS 2 exceeded the ER-L. The maximum concentration of 240 ug/g was found in the 0-2 foot core sample taken near the Bay City WWTP. The other three ER-M exceedances occurred in 2-4 foot core samples located downstream of the intensive sampling zone (sample site 4), just downstream of the Veterans Memorial Bridge (sample site 20), and in between Veterans Memorial Bridge and Lafayette Street (sample site 21).

There were eleven sample sites in LLRS 3 where the ER-L for chromium was exceeded (see Figure 3.9d). At four of these locations, the ER-M was also exceeded. Two of the ER-M exceedances, including the highest detected concentration of 590 ug/g, were found in the 0-2 foot sample cores taken near the Bay City WWTP. The other high chromium concentrations occur in the southeast area of the intensive sampling zone (sample sites 1, 3, and 7).

### *Copper*

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	16	48	187	N/A	70	390
LLRS 2	2.1	27	230			
3	16.6	42.2	375			
LLRS 3	3.7	36	360			

N/A - Not Available

(All units are in ug/g)

Survey 1 had only one exceedance of the ER-L and no exceedances of the ER-M for copper (see Figure 3.10a). The exceedance of the ER-L occurred near the Bay City WWTP within the intensive sampling zone; the detected concentration was 187 ug/g, which is well below the ER-M guideline of 390 ug/g.

Survey 3 surface grab samples did not exceed the ER-L or the ER-M with the maximum concentration being 54.8 ug/g (see Figure 3.10b). Again, the deeper core samples in Survey 3 did contain concentrations of copper that exceeded the ER-M and ER-L. The highest concentration found (375 ug/g), that exceeded the ER-L, was from the core sample taken near the Bay City WWTP within the intensive sampling zone (sample site 6; 0.3-1 foot core). Other exceedances of the ER-L and ER-M also occurred downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core), within the downstream portion of the intensive sampling zone (sample site 5; 0-2 foot core), and in the 0-2 foot core sample from site 6.

As shown in Figure 3.10c, the ER-M was not exceeded at any location in LLRS 2, but the ER-L was exceeded at nine of the 26 stations sampled with concentrations ranging from 73 ug/g to 230 ug/g. Five of these exceedances were from 0-2 foot core samples, located in the downstream area of the river (sample sites 1 and 5), in the intensive sampling zone near the Bay City WWTP, and just upstream of the intensive sampling zone (sample site 17). The maximum concentration was found in the 2-4 foot core sample taken just upstream of the Veterans Memorial Bridge; the 4-6 foot cores at the same site and at Liberty Street (sample site 19) also exceeded the ER-L for copper. The 2-4 foot sample cores in the downstream area of the Saginaw River (sample sites 4 and 5) also exceeded the ER-L guideline for copper.

The ER-M was not exceeded at any location in LLRS 3 (see Figure 3.10d). The ER-L was exceeded at 7 of the 29 stations sampled with concentrations ranging from 72 ug/g to the maximum concentration of 360 ug/g, found in the 0-2 foot core sample just off of the Bay City WWTP in the intensive sampling zone. High copper concentrations were also detected in core samples taken in the southeast area of the intensive sampling zone (sample sites 3, 7, 9, and 10).

### Lead

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	19	55	86	N/A	35	110
LLRS 2	1.9	34	550			
3	16.9	39.8	168.2			
LLRS 3	0.3	32	220			

N/A - Not Available  
(All units are in ug/g)

In Survey 1, the ER-L for lead was exceeded at six of the seven locations, with a maximum concentration of 86 ug/g found at a station located near the Bay City WWTP (see Figure 3.11a). The ER-M was not exceeded at any of the locations.

As shown in Figure 3.11b, Survey 3 surface grab samples exceed the ER-L at three of the seven locations sampled. The maximum concentration of 68.7 ug/g occurs at a station located between Veterans Memorial Bridge and Lafayette Street; the second highest concentration occurs just upstream of Lafayette Street. The ER-M was not exceeded by surface grab samples at any of the locations. The Survey 3 core samples did exceed the ER-M at two sites; the core sample taken near the Bay City WWTP within the intensive sampling zone (sample site 6; 0.3-1 foot core) and the downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core).

The ER-L was exceeded at 17 of the 26 stations sampled, while the ER-M was exceeded at only two locations in LLRS 2 (see Figure 3.11c). Most of the exceedances were found in the 0-2 ft range with the maximum concentration of 550 ug/g found in the southeast end of the intensive sampling zone. Relatively high lead concentrations (in excess of the ER-L guideline) were also detected in 2-4 foot core samples in the portion of the Saginaw River located downstream of the intensive sampling zone. All core samples (0-2, 2-4, and 4-6 foot) at sample location 20 (downstream from the Veterans Memorial Bridge) also showed high concentrations of lead.

In LLRS 3, the ER-L was exceeded at 17 of the 29 stations sampled while the ER-M was exceeded at only two stations (see Figure 3.11d). The maximum concentrations of 220 and 180 ug/g were found in the 0-2 foot sample cores taken near the Bay City WWTP in the intensive sampling zone. High lead concentrations were also found in core samples located in the southeast area of the intensive



sampling zone (sample sites 3, 5, 6, 7, 9, and 10), and in the 0-2 foot core sample taken about 2 miles downstream of the intensive sampling zone (sample site 1). Finally, three of the seven surface grab samples taken in the Saginaw River (not shown on Figure 3.11d), also exceeded the ER-L for lead. These three surface grabs were taken from the area between Lafayette Street and Veterans Memorial Bridge, within the intensive sampling zone near the Bay City WWTP, and just downstream of the intensive sampling zone.

### **Mercury**

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	0.048	0.15	0.28	N/A	0.15	1.3
LLRS 2	N/A	N/A	N/A			
3	0.039	0.156	0.676			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available

(All units are in ug/g)

The ER-M of 1.3 ug/g for mercury was not exceeded in either Survey 1 or Survey 3. The ER-L was exceeded at three locations in Survey 1 with a maximum concentration of 0.283 ug/g found at the sample site located near the Bay City WWTP (see Figure 3.12a). As shown in Figure 3.12b, the ER-L was exceeded in surface grab samples at two locations in Survey 3, with the maximum concentration of 0.167 ug/g found outside of the ship canal just upstream of Lafayette Street. The mercury concentrations in the Survey 3 core samples were higher than the surface grab samples, but still below the ER-M. The highest concentration of mercury in the core samples occurred near the Bay City WWTP in the intensive sampling zone at the 0.3-1.0 foot core sample (0.676 ug/g). Other high concentrations that exceeded the ER-L also occurred downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core) and within the downstream portion of the intensive sampling zone (sample site 5; 0-2 foot core). Mercury was not analyzed as part of LLRS 2 or LLRS 3.

**Nickel**

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	15	37	157	N/A	30	50
LLRS 2	1.1	16	120			
3	8.3	29.3	316			
LLRS 3	3.7	23	290			

N/A - Not Available  
(All units are in ug/g)

In Survey 1, the ER-L for nickel was exceeded at five of the seven locations sampled (see Figure 3.13a). Only one sample location exceeded the ER-M with a concentration of 157 ug/g; the site was located near the Bay City WWTP in the intensive sampling zone.

In Survey 3, the ER-M was not exceeded by any surface grab sample, however, the surface samples exceeded at two of the seven locations sampled (see Figure 3.13b). The maximum concentration found in surface samples was 37.9 ug/g, that occurred between Liberty Street and the Veterans Memorial Bridge (sample site 8). Core samples at each of the three sites where core samples were taken, however, had nickel concentrations that exceed the ER-M. The highest concentration found was in the core sample taken near the Bay City WWTP in the intensive sampling zone at the 0.3-1.0 foot core sample (316 ug/g).

The ER-L was exceeded at seven of the 26 sample sites sampled under the LLRS 2, while the ER-M was exceeded at only three sample sites (see Figure 3.13c). The highest concentration (120 ug/g) was found in the 0-2 foot core sample taken near the Bay City WWTP. The two other ER-M exceedances occurred in 2-4 foot core samples; one located about 1 mile downstream of the intensive sampling zone (sample site 4), and the other located between the Veterans Memorial Bridge and Liberty Street (sample site 20).

As shown in Figure 3.13d, the ER-L was exceeded at 12 of the 29 stations sampled, while the ER-M was exceeded at only three stations under LLRS 3. The highest concentrations of 290 ug/g and 82 ug/g were found in the 0-2 foot core samples taken near the Bay City WWTP in the intensive sampling zone. The other exceedances of the ER-M occurred in the southeast section of the intensive sampling zone in both the 0-2 and 2-4 foot core samples. The majority of ER-L exceedances occur within the 0-2 foot core samples throughout the intensive sampling zone.

*Silver*

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	0.11	0.58	1.5	N/A	1	2.2
LLRS 2	N/A	N/A	N/A			
3	0.11	0.36	3.31			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ug/g)

The ER-M of 2.2 ug/g was not exceeded in Survey 1 (see Figure 3.14a). The ER-L was exceeded at only one location, near the Bay City WWTP in the intensive sampling zone, at a concentration of 1.5 ug/g.

In Survey 3 (see Figure 3.14b), neither the ER-L or ER-M were exceeded in the surface grab samples. However, the ER-M was exceeded at two of the three sites where core samples were taken. The highest concentration was found in the core sample taken near the Bay City WWTP in the intensive sampling zone at the 0.3-1.0 foot core sample (3.31 ug/g); the other ER-M exceedance occurred downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core). Silver was not analyzed in LLRS 2 or LLRS 3.

*Zinc*

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	99	352	389	N/A	120	270
LLRS 2	13	100	389			
3	46.1	197	714			
LLRS 3	26	130	720			

N/A - Not Available  
(All units are in ug/g)

In Survey 1, the ER-L and the ER-M for zinc were exceeded at six of the seven sample sites (see Figure 3.15a). The maximum concentration, 389 ug/g, was found at the sample site closest to the Saginaw Bay, about 1 mile downstream of the intensive sampling zone.

As shown in Figure 3.15b, the ER-M for zinc was exceeded in Survey 3 surface grab samples at three of the seven stations sampled, all of which are located upstream of the intensive sampling zone. The concentrations at these three sites ranged from 347 ug/g to a maximum of 541 ug/g (at sample site 24, located just upstream of Lafayette Street in the ship canal area). Two other sample locations had surface grab samples that exceeded the ER-L; in the southeast area of the intensive sampling zone (sample site 5), and about 1 mile downstream of the intensive sampling zone (sample site 2). For Survey 3 core samples, the ER-M was exceeded in two of the three core samples taken near the Bay City WWTP in the intensive sampling zone (in the 0.3 - 1.0 foot and 0 - 2 foot core samples). The 0.6 - 1.6 foot core sample zinc concentration at sample site 2 (224 ug/g) also exceeded the ER-L.

In LLRS 2, the ER-L for zinc was exceeded at 14 of the 26 stations sampled, while the ER-M was exceeded at five stations (see Figure 3.15c). Three of the four ER-M exceedances occur in the 0 - 2 foot core samples, a maximum concentration of 510 ug/g found south of Lafayette Street outside of the ship canal. Exceedances of the ER-L tend to occur throughout the Saginaw River in both the 0 - 2 and 2 - 4 foot core samples. The 4 - 6 foot core samples taken between the Veterans Memorial Bridge and the Grand Trunk railroad (sample sites 19 and 20) also showed high concentrations of zinc. The surface grab sample (not shown on Figure 3.15c) taken just downstream of the Grand Trunk railroad, also contained high concentrations of zinc (270 ug/g).

In LLRS 3, the ER-L was exceeded at 18 of the 29 stations sampled while the ER-M was exceeded at only two stations (see Figure 3.15d). The two ER-M exceedances occurred in 0 - 2 foot core samples, with the maximum concentration of 720 ug/g found near the Bay City WWTP. The majority of ER-L exceedances, found throughout the Saginaw Survey area, were attributable to the 0 - 2 foot core samples. Other high zinc concentrations were found in several of the surface grabs taken in LLRS 3 (not shown in Figure 3.15d), particularly at the site just downstream of the intensive sampling zone (site 0401 at 510 ug/g), near the Bay City WWTP outfall (site 0601 at 380 ug/g), and between Lafayette Street and the Veterans Memorial Bridge (site 0801 at 360 ug/g).

### *Acenaphthene*

Acenaphthene was sampled for only in Survey 3. All surface grab and core samples were reported as below detections levels. It should be noted however, that the reported detection levels at most sites was above the ER-L value for acenaphthene (160 ng/g).

***Anthracene***

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	< 8	38	70	N/A	85	960
LLRS 2	N/A	N/A	N/A			
3	< 60	< 250	800			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

The ER-L and ER-M were not exceeded for anthracene at any location in Survey 1 (see Figure 3.16a). All but one of the surface grab samples in Survey 3 were reported as below detection levels; the one detection was from the surface grab taken in Saginaw Bay (Survey 3) that exceeded the ER-L (see Figure 3.16b). It should be noted however, that the reported detection limits for all samples were above the ER-L, but well below the ER-M. In the Survey 3 core samples, anthracene was found above detection levels and above the ER-L in two sample cores, the highest of which (800 ug/g) occurred downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core). The other ER-L exceedance was found in the 0-2 foot core taken near the Bay City WWTP.

***Benz(a)anthracene***

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	15	160	300	N/A	230	1,600
LLRS 2	N/A	N/A	N/A			
3	< 160	340	2,000			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

In Survey 1, the ER-L for benz(a)anthracene was exceeded at one station near the Bay City WWTP (see Figure 3.17a). The concentration at this site was 300 ng/g. The ER-M was not exceeded at any location in Survey 1.

As shown in Figure 3.17b, benz(a)anthracene was detected at four of the seven surface grab samples taken in Survey 3. The highest surface grab sample value of 690 ng/g was found at a location south of Lafayette Street; all four samples exceeded the ER-L of 230 ng/g, but all stations were well below the ER-M of 1,600 ng/g. All Survey 3 core samples except one exceeded the ER-L for benz(a)anthracene. The highest concentration in Survey 3 (2,000 ng/g) was found downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core).

#### ***Benzo(a)pyrene***

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	<6	210	310	N/A	400	2,500
LLRS 2	N/A	N/A	N/A			
3	<160	<250	440			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

As shown in Figure 3.18a, all stations sampled in Survey 1 were below both the ER-L and ER-M for benzo(a)pyrene.

In Survey 3, the ER-M was not exceeded by any sample, but the ER-L was exceeded at one station south of Lafayette Street with a concentration of 440 ng/g (see Figure 3.18b). None of the core samples were reported above analytical detection levels.

#### ***Chrysene***

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	24	310	500	N/A	400	2,800
LLRS 2	N/A	N/A	N/A			
3	<160	320	2,200			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

There were no exceedances of the ER-M for chrysene in Survey 1 (see Figure 3.19a). The ER-L was exceeded at two locations with the maximum concentration of 500 ng/g found near the Bay City WWTP in the intensive sampling zone.

In Survey 3, two surface grab samples exceeded the ER-L (see Figure 3.19b). The highest concentration in the surface grab samples (600 ng/g) was found south of Lafayette Street (sample site 24). All three sample locations for which core samples were taken had concentration exceeding the ER-L; the highest concentration of chrysene (2,200 ng/g) was found in the core sample taken downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core).

### **Fluoranthene**

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	36	160	280	620 ug/gOC	600	3,600
LLRS 2	N/A	N/A	N/A			
3	< 160	490	1,400			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

As shown in Figure 3.20a, all the Survey 1 sample sites were well below the ER-L guideline of 600 ng/g, with the maximum concentration reported at 280 ng/g.

In Survey 3, two surface grab samples exceeded the ER-L, with the maximum concentration at 1,200 ng/g, found downstream of Lafayette Street (see Figure 3.20b). High fluoranthene concentrations were also found in the Survey 3 core samples, with ER-M exceedances found at two of the three sites. The highest concentration (1,400 ng/g) was detected in the core sample taken downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core). The 0 - 2 foot and 0.3 - 1.0 foot core samples taken near the Bay City WWTP also contained fluoranthene concentrations in excess of the ER-M (870 ng/g and 1,000 ng/g, respectively).

The EPA EqP-based criteria for fluoranthene is 620 ug/gOC. When fluoranthene data for the Saginaw River are normalized with respect to organic carbon, the distribution of criteria exceedances changes somewhat from bulk sediment concentrations. At no location in either Survey 1 or Survey 3 is the EqP-based criteria for fluoranthene exceeded (see Figures 3.20c and 3.20d). The maximum level is now found in the intensive sample zone near the Bay City WWTP (9.27 ug/gOC).

**Fluorene**

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	<7	25	69	N/A	35	640
LLRS 2	N/A	N/A	N/A			
3	<160	<250	300			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

Two stations sampled in Survey 1 exceeded the ER-L of 35 ng/g with concentrations of 38 ng/g and 69 ng/g (see Figure 3.21a). All stations were well below the ER-M guideline of 640 ng/g.

In Survey 3, all surface grab samples were below the detection limits, which were reported above the ER-L, but below the ER-M (see Figure 3.21b). All but one Survey 3 core sample were reported below detection limits. The one detection (300 ng/g) was in the core sample taken downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core).

**2-Methylnaphthalene**

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	<6	38	63	N/A	65	670
LLRS 2	N/A	N/A	N/A			
3	<60	<250	270			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

In Survey 1, there were no exceedances of the ER-L or the ER-M for 2-methylnaphthalene (see Figure 3.22a). the highest reported concentration (63 ng/g) was found near the Bay City WWTP in the intensive sampling zone.



In Survey 3, all sample concentrations were reported below detection limits, except for one surface grab sample taken in the Saginaw Bay (sample site 1). As shown in Figure 3.22b, the concentration at this site (270 ng/g) exceeds the ER-L, but is well below the ER-M for 2-methylnaphthalene. All of the Survey 3 core samples were reported below detection levels.

### *Naphthalene*

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	<6	40	55	N/A	340	2,100
LLRS 2	N/A	N/A	N/A			
3	<160	<250	270			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

In Survey 1, all concentrations found were well below the ER-L of 340 ug/g (see Figure 3.23a).

In Survey 3, all sample concentrations were reported below detection limits, except for one surface grab sample taken in the Saginaw Bay (sample site 1). As shown in Figure 3.23b, the concentration at this site (270 ng/g) does not exceed the ER-L or ER-M for naphthalene. All of the Survey 3 core samples were reported below detection levels.

### *Phenanthrene*

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	27	270	390	180 ug/gOC	225	1,380
LLRS 2	N/A	N/A	N/A			
3	<160	510	3,300			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g except as noted for the EPA EqP Criteria)

As shown in Figure 3.24a, the ER-L for phenanthrene is exceeded at 5 of the 7 stations sampled in Survey 1. The highest concentration of 390 ng/g was found in the sample located in the intensive sampling zone near the Bay City WWTP. There are no exceedances of the ER-M in Survey 1.

In Survey 3, six of the seven surface grab sample stations had samples that exceed the ER-L; phenanthrene was undetected at the Michigan Street sample location (see Figure 3.24b). One of the three core sample sites under Survey 3 contained a sample that exceeded the ER-M; the highest value (3,300 ng/g) was found in the core sample taken downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core). All four core samples taken near the Bay City WWTP in the intensive sample zone exceeded the ER-L, as well as the two core samples taken in the southeast area of the intensive sample zone.

When phenanthrene Survey 3 data for the Saginaw River are normalized with respect to organic carbon, the distribution of criteria exceedances changes from bulk sediment concentrations. No locations exceed the EqP-based criteria for phenanthrene. In Survey 1 (see Figure 3.24c), the maximum level is found near the Bay City WWTP in the intensive zone, at 18.75 ug/gOC that is well below the EqP-based criteria of 180 ug/g OC. In Survey 3, all values are well below the EqP-based criteria, with the maximum value being 69.57 ug/g OC, located again near the Bay City WWTP (see Figure 3.24d).

### Pyrene

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	44	550	670	N/A	350	2,200
LLRS 2	N/A	N/A	N/A			
3	< 160	880	6,600			
LLRS 3	N/A	N/A	N/A			

N/A - Not Available  
(All units are in ng/g)

As shown in Figure 3.25a, five of the seven stations sampled in Survey 1 were above the ER-L, with concentrations ranging from 460 ng/g to the maximum concentration of 670 ng/g. The reported concentrations of all the samples were well below the ER-M.

In Survey 3, the ER-L was exceeded at five of the seven surface grab samples taken, with concentrations ranging from 710 ng/g to 1,800 ng/g (see Figure 3.25b). The maximum concentration in the surface grab samples was found south of Lafayette Street. All three sample locations for which core samples were taken had concentrations exceeding the ER-L; the highest concentration of pyrene (6,600 ng/g) was found in the core sample taken downstream of the intensive sample zone (sample site 2; 0.6 - 1.6 foot core). The other ER-M exceedance (2,700 ng/g) was found in the 0.3-1.0 core sample taken near the Bay City WWTP.

**Total PCBs\***

Survey	Minimum	Median	Maximum	EPA EqP Criteria	NOAA ER-L	NOAA ER-M
1	< 260	< 460	60,000	N/A	50	400
LLRS 2	78.34	863.27	34,427.37			
3	< 29	335	87,100			
LLRS 3	16.18	500.68	10,991.24			

N/A - Not Available

(All units are in ng/g)

\* Total PCB concentrations under Surveys 1 and 3 were derived by summing the individual PCB Aroclor values for each site.

As shown in Figure 3.26a, the majority of samples taken for PCBs in Survey 1 were reported as below detection levels that were above the ER-L and ER-M. Several samples in Survey 1 did contain high detectable concentrations of PCBs, including those found near the Bay City WWTP in the intensive sample zone and in the area just downstream from the intensive sample area (sample site 4). High concentration of PCBs were also detected at sample site 10, that is the furthest upstream station in the survey.

In Survey 3, PCBs were detected in both the surface grab and core samples (see Figure 3.26b). The highest concentrations occur in the core samples taken near the Bay City WWTP, ranging in concentrations from 96 ng/g to 87,100 ng/g.

In LLRS 2, all samples contained detectable amounts of PCBs, several of which exceeded the ER-M for PCBs (see Figure 3.26c). The highest concentration occurs in the 0 - 2 foot core sample taken near the Bay City WWTP. The second highest concentration (14,523.35 ng/g) occurs in the 0 - 2 foot core sample taken on the southern shore of the river, just upstream of the intensive sample zone (sample site 17). Subsurface core samples (2 - 4 foot cores) also contained high PCB concentrations, particularly in the area about 1 mile downstream of the intensive survey zone (sample sites 4 and 5).

High concentrations of PCBs also were found in LLRS 3 samples (see Figure 3.26d). Many of the high concentrations are from the 0 - 2 foot core samples, with the highest concentration (10,991.24 ng/g) found in the southeast area of the intensive sample zone. Other high concentrations were found in samples from areas just upstream and downstream from the Bay City WWTP.

**Pesticides**

No pesticides were analyzed for under LLRS 2 or 3. However, under Surveys 1 and 3 several pesticides were monitored for, and the majority of sample values were found below detection limits. However, for the four pesticides for which ER-M and ER-L values are available (dieldrin, DDT, DDD,

and DDE), the few detectable values in Survey 1 were found to exceed both the ER-M or ER-L. In Survey 3, the few detectable values were found to exceed the ER-M or the ER-L. This was particularly true in the surface grab samples located in the furthest downstream areas as well as in Saginaw Bay.

When Survey 3 dieldrin data for the Saginaw River are normalized with respect to organic carbon, the distribution of criteria exceedances changes from bulk sediment concentrations. No locations exceed the EqP-based criteria for dieldrin. In Survey 1 (see Figure 3.27), the maximum level (about 5 ug/gOC) is found about 1 mile upstream of the intensive sample zone (sample site 7).

### 3.3.3 Ranking by Chemical Parameter

To provide a preliminary indication of which chemicals may be of concern in the Saginaw River AOC, a simple comparative analysis was performed based the relative exceedance of the ER-M value. In particular, the mean measured value of each parameter (assuming zero for any nondetect value) was compared to the ER-M value for the parameter. The resulting ratio (herein referred to as the "Mean Exceedance") was calculated for each chemical within each survey. Data between the four surveys are not combined, therefore each parameter may have four mean exceedance values (if the parameter was analyzed in all four surveys). The ER-M was chosen for comparative purposes since one was available for all chemicals discussed in Section 3.3.2, and was assumed to be a better indicator for concern (as particularly compared to the ER-L).

Once mean exceedance values were determined, the values were ranked. For the purposes of ranking, metals and organic parameters were ranked separately and separate ranks were determined for each survey. The results of the ranking for Surveys 1 and 3 are presented in Table 3.3. Table 3.4 presents the ranking for LLRSs 2 and 3.

**TABLE 3.3 MEAN EXCEEDANCE VALUES AND RELATIVE RANKS FOR CHEMICAL PARAMETERS IN SURVEYS 1 AND 3**

Chemical	Survey 1		Survey 3	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
<b>Metals</b>				
Arsenic	0.12	8	0.51	4
Cadmium	0.22	6	0.32	7
Chromium	0.7	3	0.88	2
Copper	0.15	7	0.18	8
Lead	0.48	4	0.51	5

**TABLE 3.3 MEAN EXCEEDANCE VALUES AND RELATIVE RANKS FOR CHEMICAL PARAMETERS IN SURVEYS 1 AND 3**

Chemical	Survey 1		Survey 3	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
Mercury	0.12	9	0.18	9
Nickel	0.97	2	0.97	1
Silver	0.27	5	0.35	6
Zinc	1.21	1	0.83	3
Organics				
Anthracene	0.042	9	0.078	7
Benz(a)anthracene	0.095	5	0.264	4
Benzo(a)pyrene	0.074	6	0.022	10
Chrysene	0.105	4	0.161	5
Fluoranthene	0.044	8	0.14	6
Fluorene	0.038	10	0.052	8
2-Methylnaphthalene	0.053	7	0.024	9
Naphthalene	0.018	11	0.008	11
Phenanthrene	0.176	3	0.519	3
Pyrene	0.2	2	0.61	2
Total PCBs	20.51	1	18.52	1

**TABLE 3.4 MEAN EXCEEDANCE VALUES AND RELATIVE RANKS FOR CHEMICAL PARAMETERS IN LLRS 2 AND 3**

Parameter	LLRS 2		LLRS 3	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
<b>Metals</b>				
Cadmium	0.16	5	0.25	5
Chromium	0.38	4	0.47	3
Copper	0.12	6	0.13	6
Lead	0.43	3	0.39	4
Nickel	0.46	2	0.59	1
Zinc	0.54	1	0.58	2
<b>Organics</b>				
Total PCBs	10.83	N/A	4.79	N/A

Of the nine toxic metals analyzed for in Surveys 1 and 3, zinc, nickel and chromium rank the highest of the metals in both surveys. The high concentrations for these parameters were particularly found in the subsurface samples in Survey 3.

As for the organic chemicals, the highest mean exceedances in both Surveys 1 and 3 were found for PCBs and the PAHs phenanthrene and pyrene. PCBs had the highest mean exceedance (on average a sample was found at about 20 times the ER-M value). It should be noted that the highest of the ER-M exceedances for PCBs were generally from the 0 - 2 foot core sediment samples.

In LLRS 2 and LLRS 3, zinc, nickel, chromium and lead had the highest mean exceedances of the metals. PCBs had the highest mean exceedance in both surveys; the average exceedance in LLRS 2 was almost 11 times the ER-M and in LLRS almost five times the ER-M.

#### 3.3.4 Analysis by Sample Location

The second portion of the analysis of Saginaw River sediment samples focuses on which sample locations are of concern. For purposes of this analysis, sample locations are examined in one of two ways; the number of chemicals that exceed the NOAA guidelines at a sample site, and the relative exceedance of the guidelines at the site.

One difficulty directly comparing sampling locations stems from differences in the total number of parameters sampled and the number of samples collected from different locations. While some locations are sampled at three sediment core depths, others are sampled at only two. Several parameters have been sampled at only a few sampling locations and usually only at one depth (typically surface samples). In light of these differences, an analysis by sample location was still performed to provide a preliminary indication of the areas of concern within the Saginaw River AOC.

As shown in Table 3.5, the surface grab samples taken near the Bay City WWTP had the greatest number of ER-M exceedances for both metals under Survey 1. Under Survey 3, the greatest number of exceedances tend to occur in three areas of the Saginaw River AOC, two of which are located in the intensive sampling area (see Table 3.6). The locations within the intensive survey area include sampling locations 5 (the southeast and downstream area within the intensive survey area) and sampling location 6 (near the Bay City WWTP). The third location within the Saginaw River AOC is for sampling location 2 (located about 1 mile downstream of the intensive sampling zone). It should also be noted that the greatest number of exceedances generally occurs in the deeper core samples.

As shown in Table 3.7, the greatest number of exceedances in LLRS 2 tend to occur in the same three areas of the Saginaw River AOC, two of which are located in the intensive sampling area. The locations within the intensive survey area include sampling locations 10 (the southeast and downstream area within the intensive survey area) and sampling location 14 (near the Bay City WWTP). The third location within the Saginaw River AOC is between the Grand Trunk Railroad and Veterans Memorial Bridge sampling location.

Finally, in LLRS 3, the greatest number of exceedances occur in the intensive sampling area, again in the southeast and downstream area within the intensive survey area and near the Bay City WWTP (see Table 3.8).

**TABLE 3.5 TOTAL NUMBER OF NOAA ER-M EXCEEDANCES BY SAMPLE LOCATION – SURVEY 1**

Sample Site	Metals	Organics
2	1	0
2 Duplicate (no PCBs)	1	0
3	1	0
4	1	1
4 Duplicate (PCBs only)	--	1

**TABLE 3.5 TOTAL NUMBER OF NOAA ER-M EXCEEDANCES BY SAMPLE LOCATION – SURVEY 1**

Sample Site	Metals	Organics
6	4	1
7	1	0
9	1	0
10	0	1

-- No Data

**TABLE 3.6 TOTAL NUMBER OF NOAA ER-M EXCEEDANCES BY SAMPLE LOCATION – SURVEY 3**

Sample Site	Metals			Organics		
	Surface	Depth 1*	Depth 2 *	Surface	Depth 1*	Depth 2 *
1 (Duplicate 1)	0	–	–	0	–	–
1 (Duplicate 2)	0	–	–	0	–	–
1 (Duplicate 3)	0	–	–	0	–	–
2	0	4	0	0	2	1
5	0	2	1	1	1	0
6	0	3	0	0	1	1
6b	–	5	0	–	1	1
8	1	–	–	0	–	–
16	0	–	–	1	–	–
24	1	–	–	0	–	–

-- No Data

\* Core depths vary per sample. Depth 1 for sample sites 5 and 6 is 0-2 foot; for sample 2 0.6-1.6 foot, and for sample 6b 0.3-1 foot. Depth 2 for samples 5 and 6 is 2-4 foot, for sample 2 1.6-3 foot, and for sample 6b 1-2.6 foot.



TABLE 3.7 TOTAL NUMBER OF NOAA ER-M EXCEEDANCES BY SAMPLE LOCATION – LLRS 2

Sample Site	Surface Grabs	0-2 Foot Cores	2-4 Foot Cores	4-6 Foot Cores
1	–	0	–	–
2	–	0	0	–
3	–	0	–	–
4	–	1	2	–
5	–	0	0	0
6	–	0	–	–
7	–	0	0	0
8	–	0	0	–
9	–	0	0	0
10	–	3	0	–
11	–	0	0	–
12	–	0	0	–
13	–	0	0	–
14	–	3	0	–
15	–	0	0	–
16	–	0	0	0
17	–	0	0	–
18	–	0	0	–
19	–	0	0	1
20	–	0	4	2
21	–	1	0	0
22	–	1	0	0
23	–	0	0	–
24	–	0	0	–
25	–	0	–	–
26	–	0	1	–
101	0	–	–	–

**TABLE 3.7 TOTAL NUMBER OF NOAA ER-M EXCEEDANCES BY SAMPLE LOCATION – LLRS 2**

Sample Site	Surface Grabs	0-2 Foot Cores	2-4 Foot Cores	4-6 Foot Cores
202	0	–	–	–
401	0	–	–	–
702	0	–	–	–

– No Data

**TABLE 3.8 TOTAL NUMBER OF NOAA ER-M EXCEEDANCES BY SAMPLE LOCATION – LLRS 3**

Sample Site	Surface Grabs	0-2 Foot Cores	2-4 Foot Cores	4-6 Foot Cores
1	–	–	0	–
2	–	–	–	0
3	–	0	0	–
4	–	0	–	–
5	–	0	0	–
6	–	0	–	–
7 (Duplicate)	–	3/3	3/3	–
8	–	0	–	–
9	–	0	0	–
10	0	0	0	–
11	–	0	–	–
12	–	0	0	–
13	–	0	–	–
14	–	0	–	–
15	–	0	0	0
16	–	0	0	–
17	–	0	0	–
18	–	0	0	–
19	–	0	0	–

TABLE 3.8 TOTAL NUMBER OF NOAA ER-M EXCEEDANCES BY SAMPLE LOCATION -- LLRS 3

Sample Site	Surface Grabs	0-2 Foot Cores	2-4 Foot Cores	4-6 Foot Cores
20	--	0	--	--
21	--	0	0	--
22	--	0	--	--
23	--	0	0	--
24	0	3	0	--
25	--	--	5	--
26	--	--	--	0
27	--	0	0	--
28	--	0	0	--
29	--	0	0	--
101	0	--	--	--
201	0	--	--	--
401	1	--	--	--
601	1	--	--	--
801	1	--	--	--

-- No Data

The second analysis performed provides a preliminary indication of which locations may be of concern in the Saginaw River AOC, using a simple comparative analysis based the relative exceedance of the ER-M value. In particular, the average of the mean exceedances of chemical concentrations (shown previously in Tables 3.3 and 3.4) was compared to the ER-M value. For purposes of this analysis, two different mean exceedances were calculated for each sample location for each survey; one for all metals and one for all organic chemicals (PAHs and PCBs). Data between the four surveys are not combined, therefore several locations may have four mean exceedance values (if a sample was analyzed at a location in all four surveys). The ER-M was chosen for comparative purposes since one was available for all chemicals discussed in Section 3.3.2, and was assumed to be a better indicator for concern (as particularly compared to the ER-L).

Table 3.9 presents the mean exceedance values determined for each Survey 1 sample location, and ranks them in relation to all other locations. As shown, sample location 6 (near the Bay City WWTP in the intensive sampling zone) possesses mean exceedances greater than one for both metals and organics. Sample location 7 (just downstream from the Grand Trunk Railroad) possesses a relatively high mean exceedance for metals, as does sample site 2 (located about 1 mile downstream of the intensive sampling zone) for organic chemicals (primarily PCBs).

Table 3.10a and Table 3.10b present the mean exceedance values determined for each Survey 3 sample location for metals and organic chemicals, respectively. The highest mean exceedances for both metals and organics occur in three areas of the Saginaw River AOC, two of which are located in the intensive sampling area. The locations within the intensive survey area include sampling locations 5 (the southeast and downstream area within the intensive survey area) and sampling location 6 (near the Bay City WWTP). The third location within the Saginaw River AOC is for sampling location 2 (located about 1 mile downstream of the intensive sampling zone). It should also be noted that the high mean exceedances occur in the deeper core samples.

As shown in Table 3.11, the highest mean exceedances for metals in LLRS 2 occur in the intensive sampling area. The locations within the intensive survey area include sampling locations 10 (the southeast and downstream area within the intensive survey area) and sampling location 14 (near the Bay City WWTP). In LLRS 3 (Table 3.12), the high mean exceedances for metals occur in the intensive sampling area, in the southeast and downstream area within the intensive survey area and near the Bay City WWTP. The highest mean exceedance was found in the 2-4 foot core samples near the Bay City WWTP.

As discussed previously in section 3.3.2, high PCB concentrations were detected in both LLRS 2 and LLRS 3. The highest concentrations occurred in the intensive survey zone (near the Bay City Wastewater Treatment Plant and the southeast area) and about 1 mile downstream of the intensive survey zone.

**TABLE 3.9 SURVEY 1 MEAN EXCEEDANCE VALUES AND RANKS FOR METALS AND ORGANICS**

Sample Site	Metals		Organics (PAHs and PCBs)	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
2	0.435	5	0.075	8
2 Duplicate (no PCBs)	0.451	3	0.112	5
3	0.439	4	0.102	6
4	0.398	6	0.468	4
4 Duplicate (PCBs only)	--	--	2	3
6	1.11	1	15.55	1
7	0.466	2	0.01	7
9	0.318	7	0.031	9
10	0.147	8	0.63	2

-- No Data

TABLE 3.10a SURVEY 3 MEAN EXCEEDANCE AND RANK BY SITE FOR METALS

Sample Site	Surface		Core Depth 1*		Core Depth 2*	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
1 (Duplicate 1)	0.214	12	—	—	—	—
1 (Duplicate 2)	0.1997	13	—	—	—	—
1 (Duplicate 3)	0.175	14	—	—	—	—
2	0.216	11	1.108	2	0.142	16
5	0.282	10	0.645	4	0.619	5
6	0.129	17	0.886	3	0.166	15
6b	—	—	2.29	1	0.378	9
8	0.462	8	—	—	—	—
16	0.534	6	—	—	—	—
24	0.49	7	—	—	—	—

— No Data

\* Core depths vary per sample. Depth 1 for sample sites 5 and 6 is 0-2 foot; for sample 2 0.6-1.6 foot, and for sample 6b 0.3-1 foot. Depth 2 for samples 5 and 6 is 2-4 foot, for sample 2 1.6-3 foot, and for sample 6b 1-2.6 foot.

TABLE 3.10b SURVEY 3 MEAN EXCEEDANCE AND RANK BY SITE FOR ORGANICS

Sample Site	Surface		Core Depth 1*		Core Depth 2*	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
1 (Duplicate 1)	0.23	10	--	--	--	--
1 (Duplicate 2)	0.076	15	--	--	--	--
1 (Duplicate 3)	0.022	16(tie)	--	--	--	--
2	0.151	12	0.829	5	0.104	14
5	0.249	8	1.066	3	0.267	7
6	0.022	16(tie)	20.07	1	1.054	4
6b	--	--	0.331	6	6.47	2
8	0.134	13	--	--	--	--
16	0.202	11	--	--	--	--
24	0.245	9	--	--	--	--

-- No Data

\* Core depths vary per sample. Depth 1 for sample sites 5 and 6 is 0-2 foot; for sample 2 0.6-1.6 foot, and for sample 6b 0.3-1 foot. Depth 2 for samples 5 and 6 is 2-4 foot, for sample 2 1.6-3 foot, and for sample 6b 1-2.6 foot.

TABLE 3.11 LLRS 2 MEAN SITE EXCEEDANCES AND RANKS FOR METALS

Sample Site	Surface Grabs		0-2 Foot Cores		2-4 Foot Cores		4-6 Foot Cores	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
1	—	—	0.48	15	—	—	—	—
2	—	—	0.23	36	0.15	47	—	—
3	—	—	0.18	42	—	—	—	—
4	—	—	0.44	17	0.83	7	—	—
5	—	—	0.63	11	0.56	14	0.27	33
6	—	—	0.38	20	—	—	—	—
7	—	—	0.25	35	0.34	25	0.37	21
8	—	—	0.06	62	0.04	63	—	—
9	—	—	0.1	59	0.16	45	0.09	61
10	—	—	1.24	1	0.27	32	—	—
11	—	—	0.34	24	0.13	50	—	—
12	—	—	0.28	31	0.18	41	—	—
13	—	—	0.17	43	0.29	29	—	—
14	—	—	1.14	3	0.11	57	—	—
15	—	—	0.28	30	0.11	58	—	—
16	—	—	0.16	44	0.03	65	0.03	66
17	—	—	0.61	13	0.09	60	—	—
18	—	—	0.19	40	0.37	22	—	—
19	—	—	0.12	53	0.12	56	0.75	8
20	—	—	0.31	28	0.95	5	0.83	6
21	—	—	0.66	9	0.47	16	0.12	55
22	—	—	0.61	12	0.42	18	0.26	34
23	—	—	0.2	39	0.15	46	—	—
24	—	—	0.22	37	0.04	64	—	—
25	—	—	0.12	54	—	—	—	—
26	—	—	0.12	52	0.21	38	—	—



TABLE 3.11 LLRS 2 MEAN SITE EXCEEDANCES AND RANKS FOR METALS

Sample Site	Surface Grabs		0-2 Foot Cores		2-4 Foot Cores		4-6 Foot Cores	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
101	0.14	48	—	—	—	—	—	—
202	0.32	27	—	—	—	—	—	—
401	0.33	26	—	—	—	—	—	—
702	0.4	19	—	—	—	—	—	—

— No Data

TABLE 3.12 LLRS 3 MEAN SITE EXCEEDANCES AND RANK FOR METALS

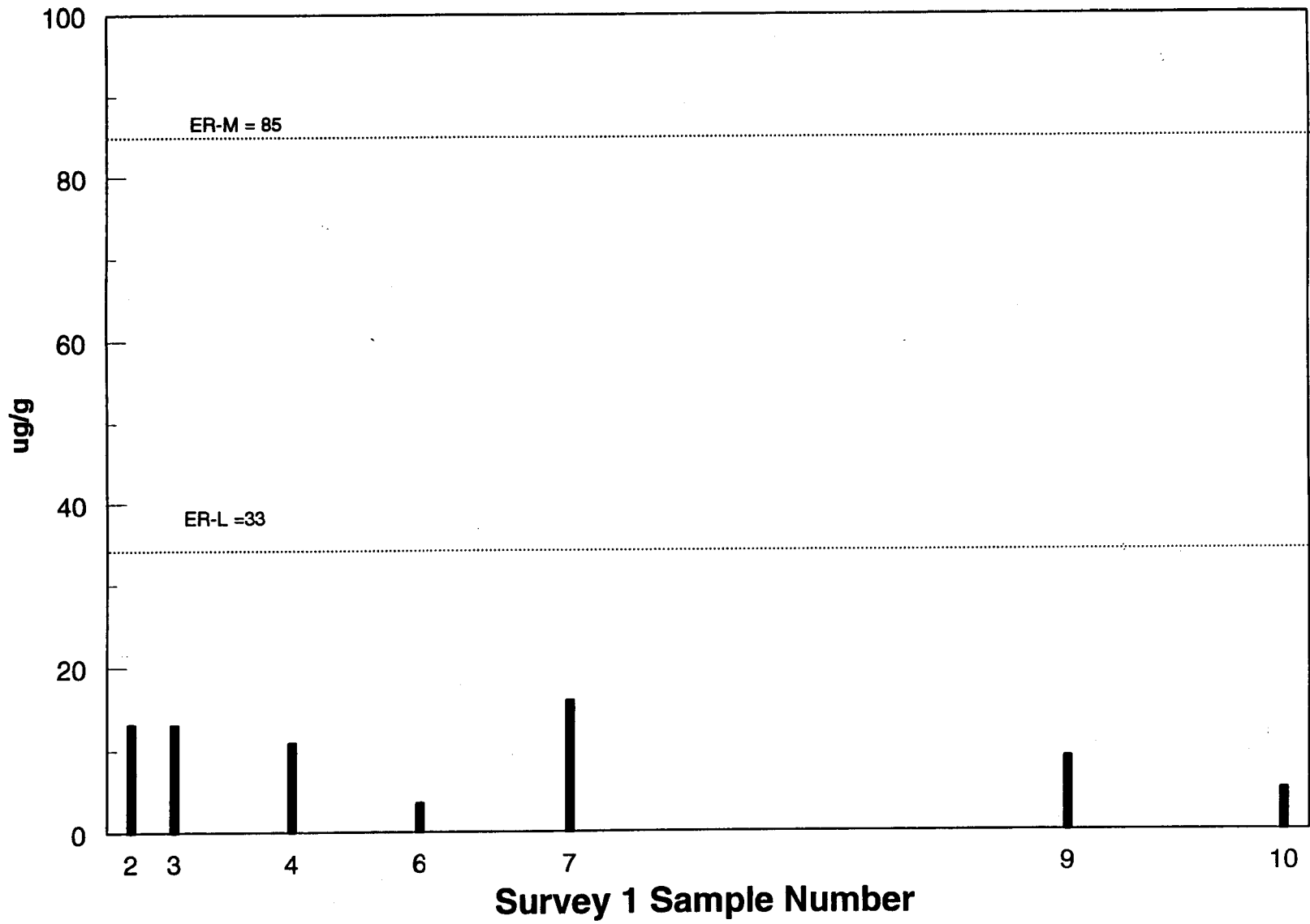
Sample Site	Surface Grabs		0-2 Foot Cores		2-4 Foot Cores		4-6 Foot Cores	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
1	—	—	—	—	0.88	7	—	—
2	—	—	—	—	—	—	0.10	48
3	—	—	0.53	16	0.33	25	—	—
4	—	—	0.06	54	—	—	—	—
5	—	—	0.37	22	0.22	35	—	—
6	—	—	0.33	26	—	—	—	—
7 (Duplicate)	—	—	0.96	3-4	0.93	5-6	—	—
8	—	—	0.32	30	—	—	—	—
9	—	—	0.56	11	0.29	32	—	—
10	0.33	27	0.65	8	0.56	13	—	—
11	—	—	0.05	57	—	—	—	—
12	—	—	0.18	46	0.08	51	—	—
13	—	—	0.06	55	—	—	—	—
14	—	—	0.15	42	—	—	—	—
15	—	—	0.26	34	0.07	53	0.08	50
16	—	—	0.13	45	0.59	9	—	—
17	—	—	0.16	40	0.32	29	—	—
18	—	—	0.37	23	0.26	33	—	—
19	—	—	0.33	28	0.055	56	—	—
20	—	—	0.14	44	—	—	—	—
21	—	—	0.36	24	0.57	10	—	—
22	—	—	0.19	37	—	—	—	—
23	—	—	0.44	19	0.37	21	—	—
24	0.10	49	1.00	2	0.12	47	—	—
25	—	—	—	—	2.87	1	—	—

TABLE 3.12 LLRS 3 MEAN SITE EXCEEDANCES AND RANK FOR METALS

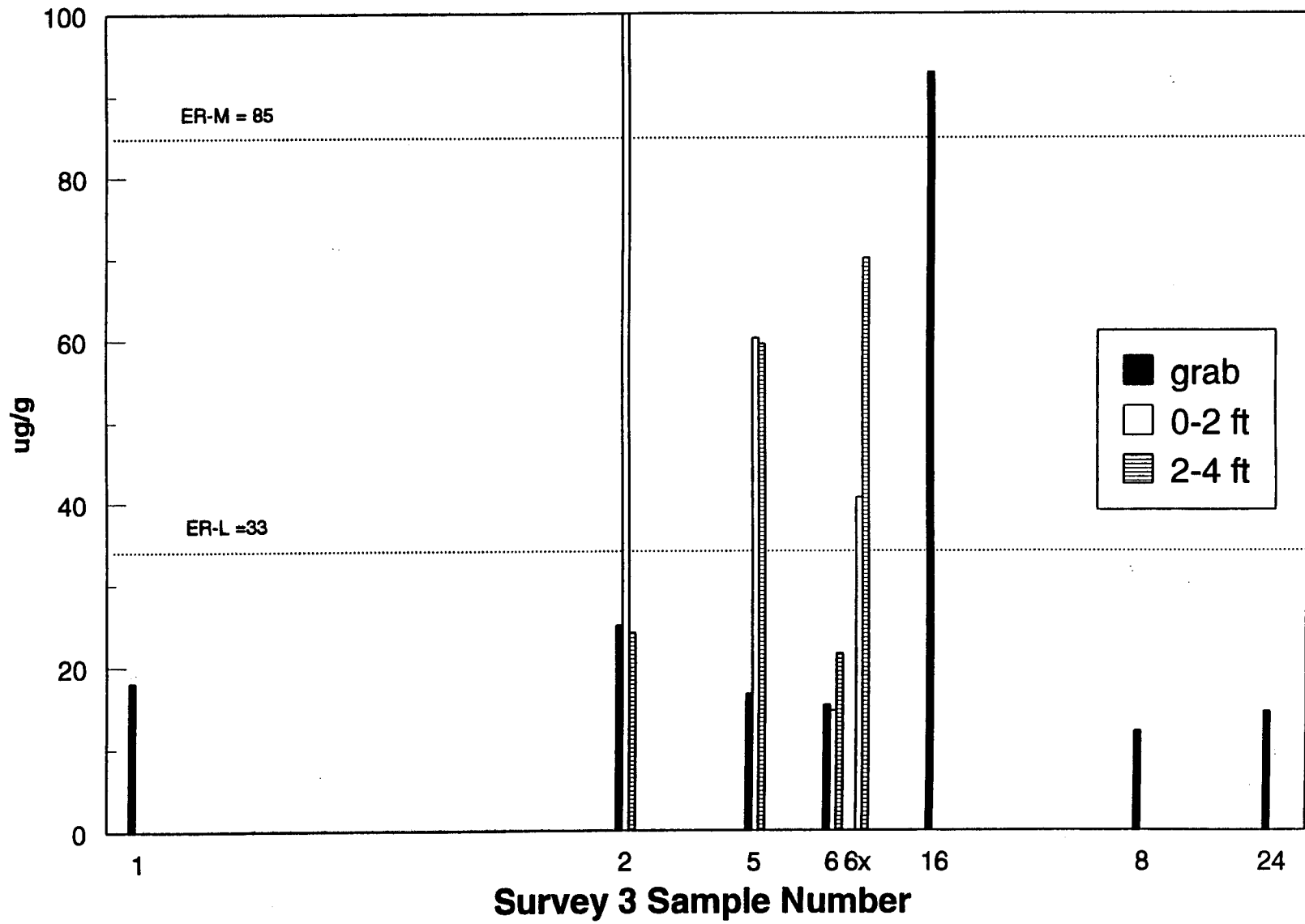
Sample Site	Surface Grabs		0-2 Foot Cores		2-4 Foot Cores		4-6 Foot Cores	
	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank	Mean Exceedance	Relative Rank
26	—	—	—	—	—	—	0.31	31
27	—	—	0.17	39	0.07	52	—	—
28	—	—	0.54	15	0.16	41	—	—
29	—	—	0.45	18	0.14	43	—	—
101	0.18	38	—	—	—	—	—	—
201	0.22	36	—	—	—	—	—	—
401	0.56	12	—	—	—	—	—	—
601	0.46	17	—	—	—	—	—	—
801	0.54	14	—	—	—	—	—	—

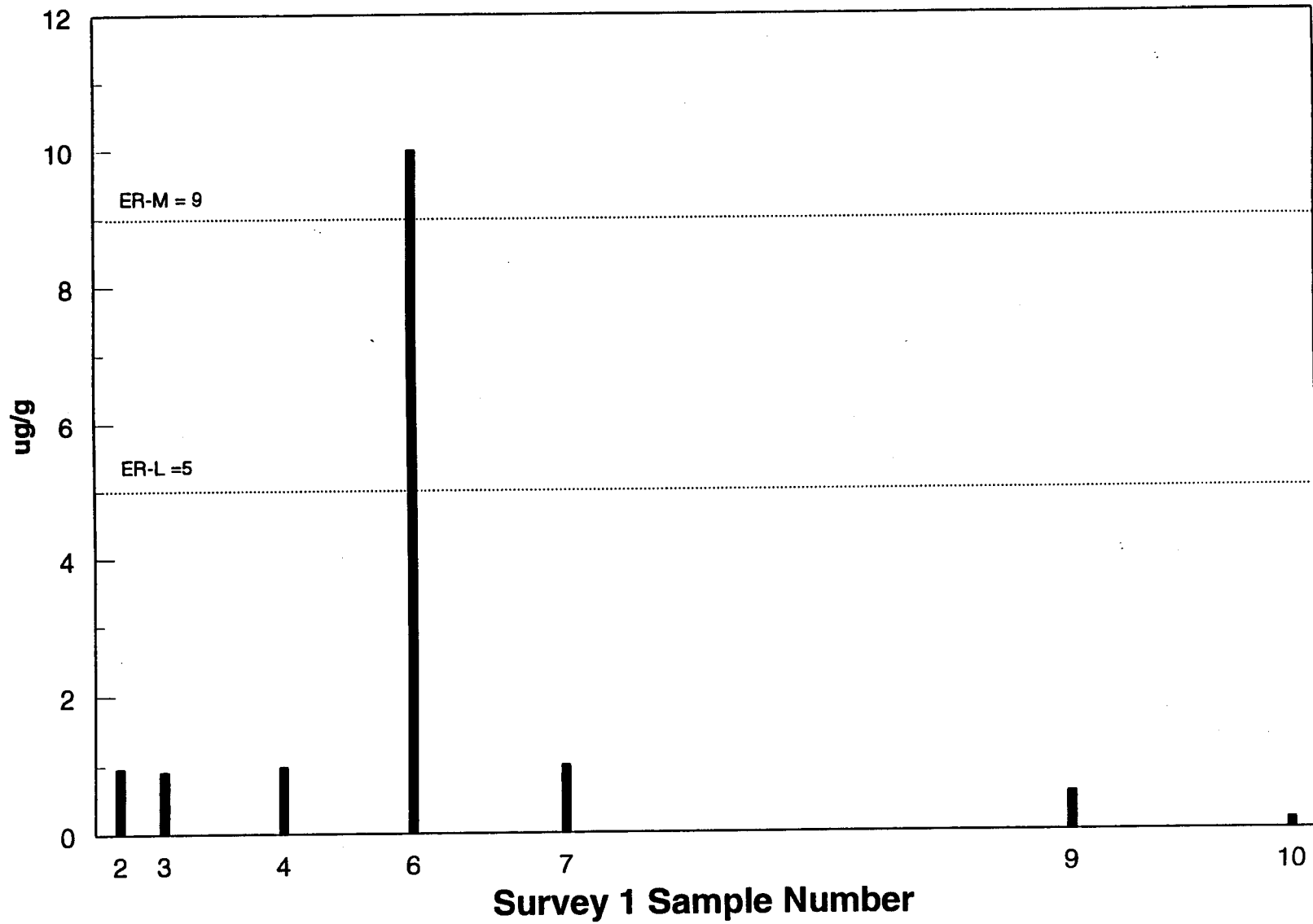
— No Data

**Figure 3.7a Survey 1 Arsenic Concentration vs. NOAA Guidelines**



**Figure 3.7b Survey 3 Arsenic Concentration vs. NOAA Guidelines**



**Figure 3.8a Survey 1 Cadmium Concentration vs. NOAA Guidelines**

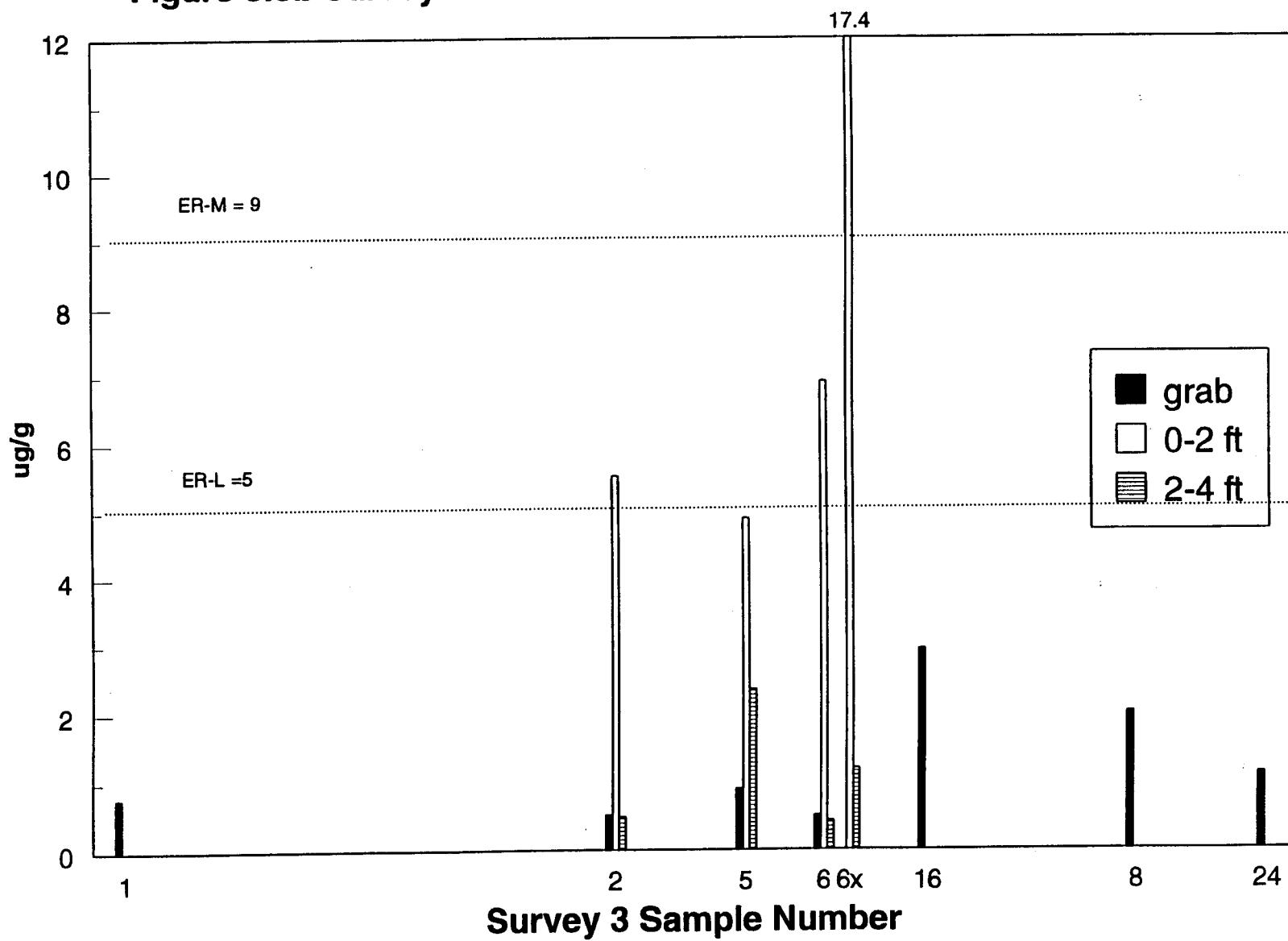
**Figure 3.8b Survey 3 Cadmium Concentration vs. NOAA Guidelines**

Figure 3.8c LLRS 2 Cadmium Concentration vs. NOAA Guidelines

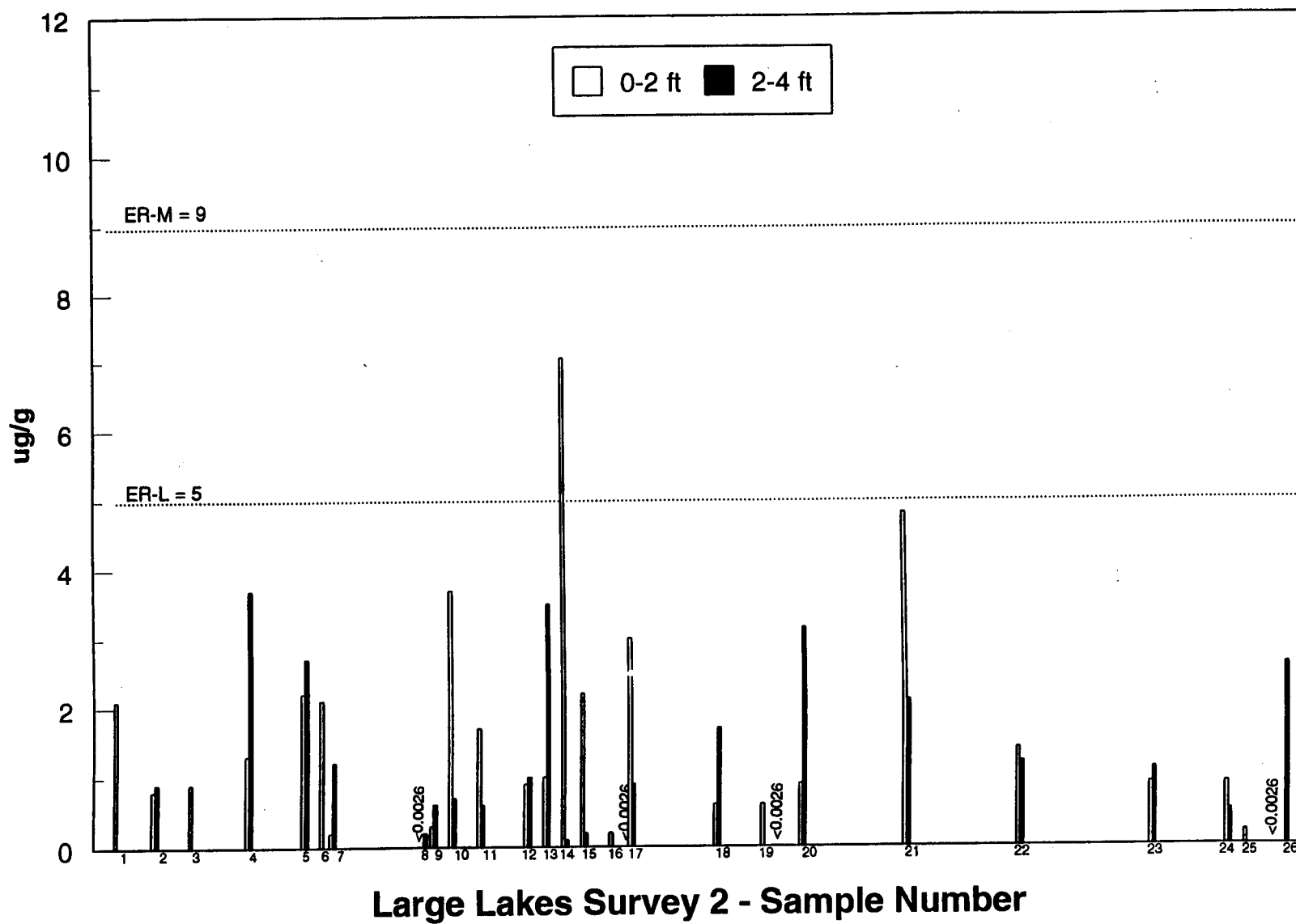
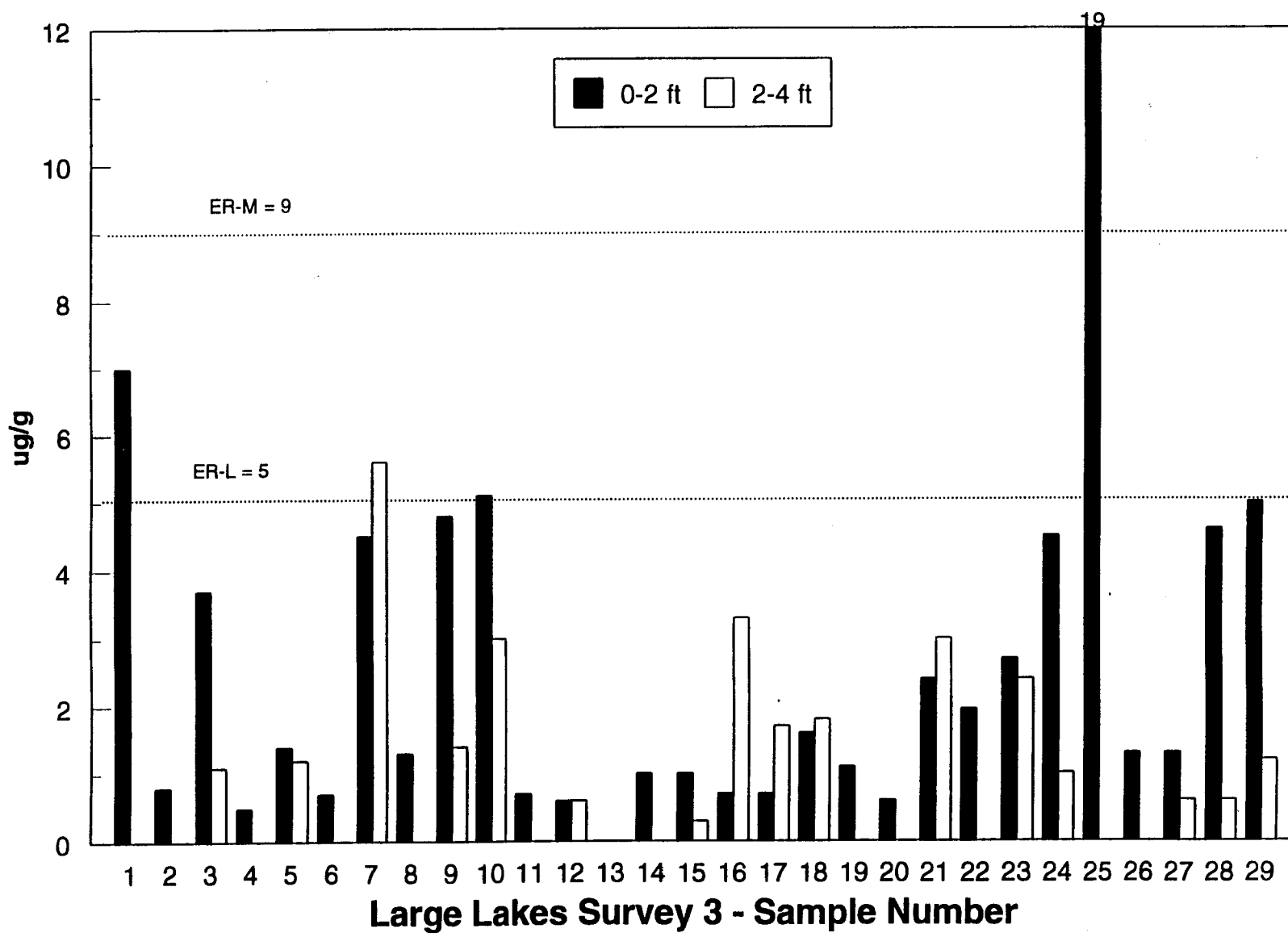




Figure 3.8d LLRS 3 Cadmium Concentration vs. NOAA Guidelines



**Figure 3.9a Survey 1 Chromium Concentration vs. NOAA Guidelines**

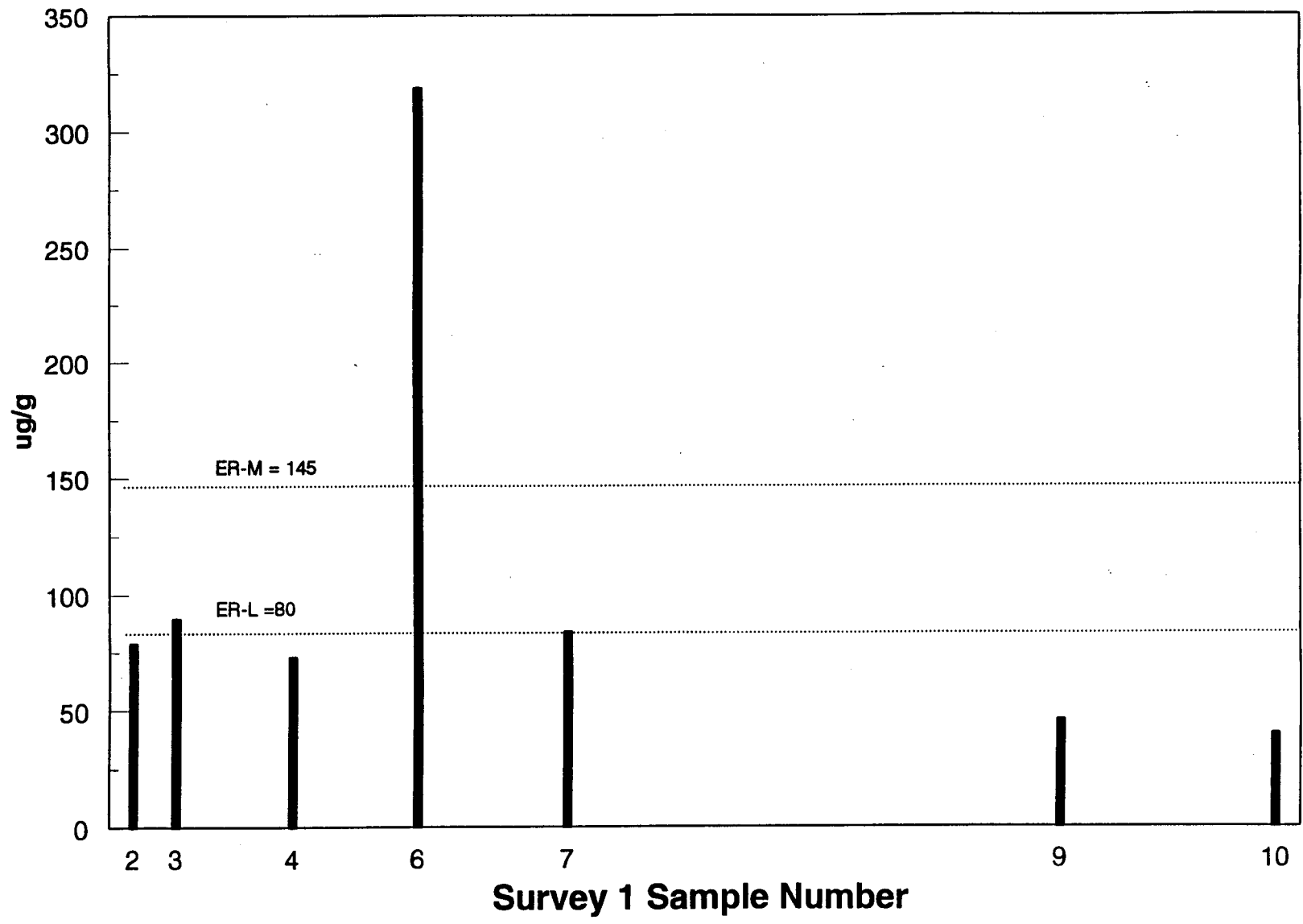
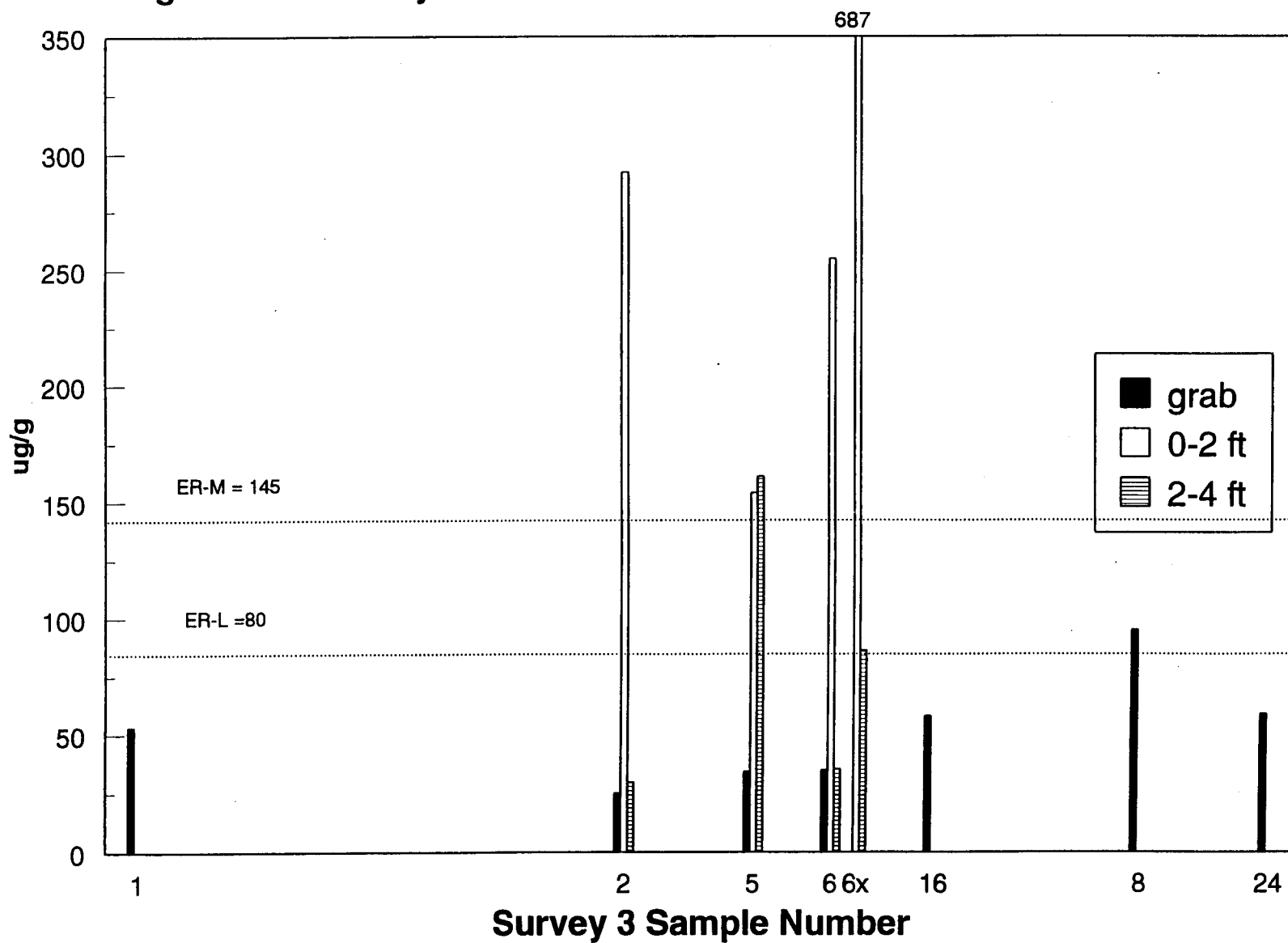


Figure 3.9b Survey 3 Chromium Concentration vs. NOAA Guidelines



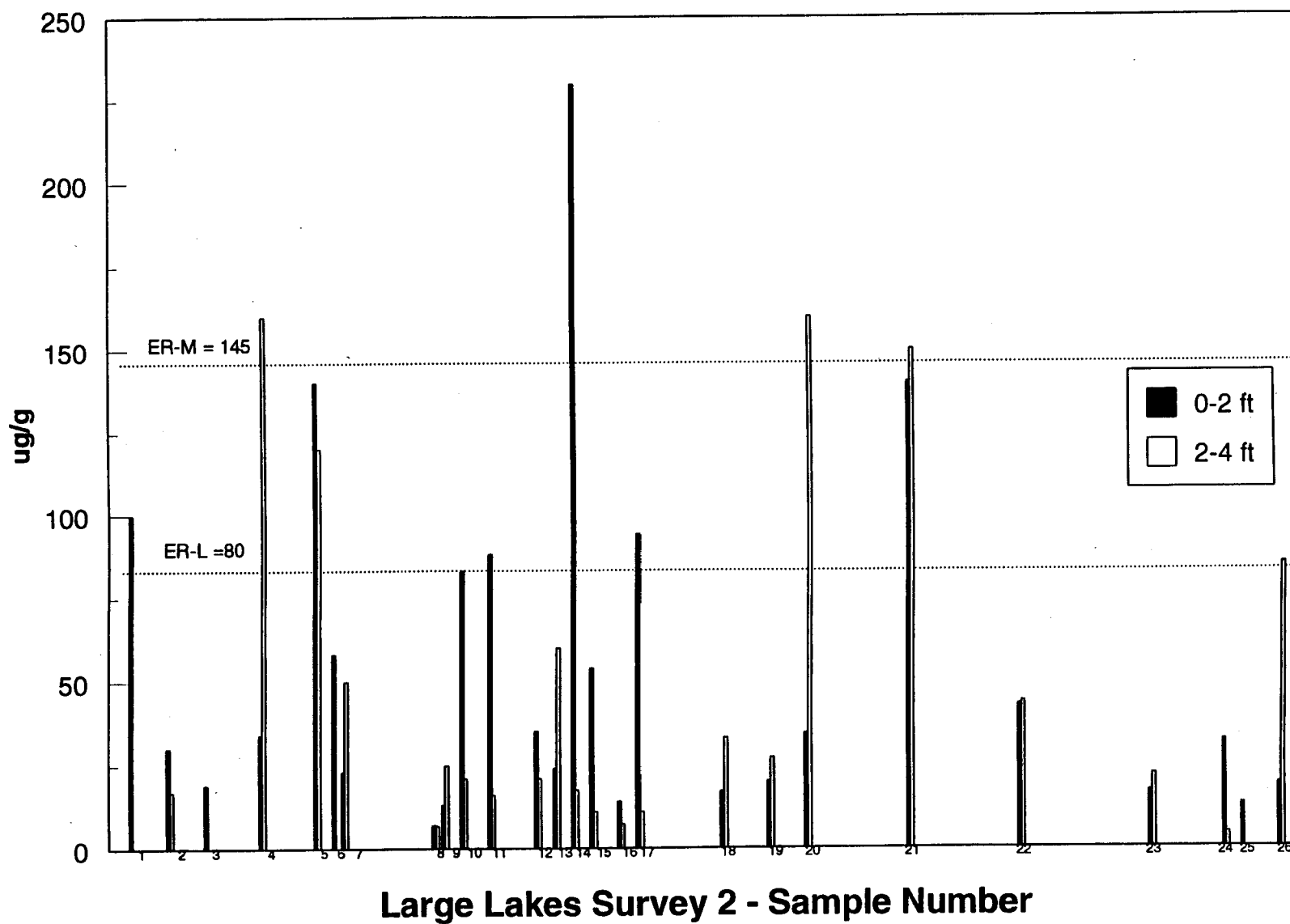
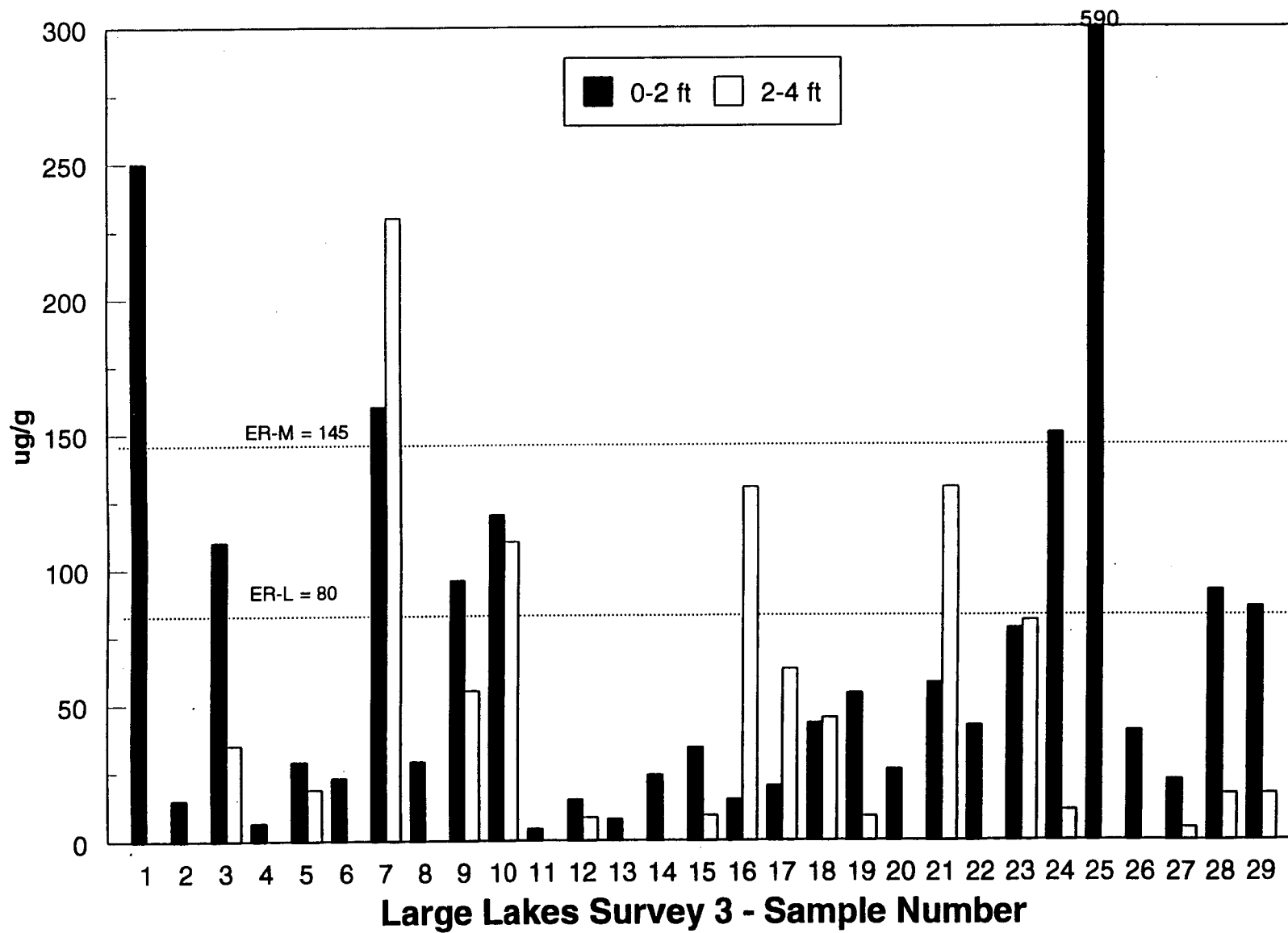
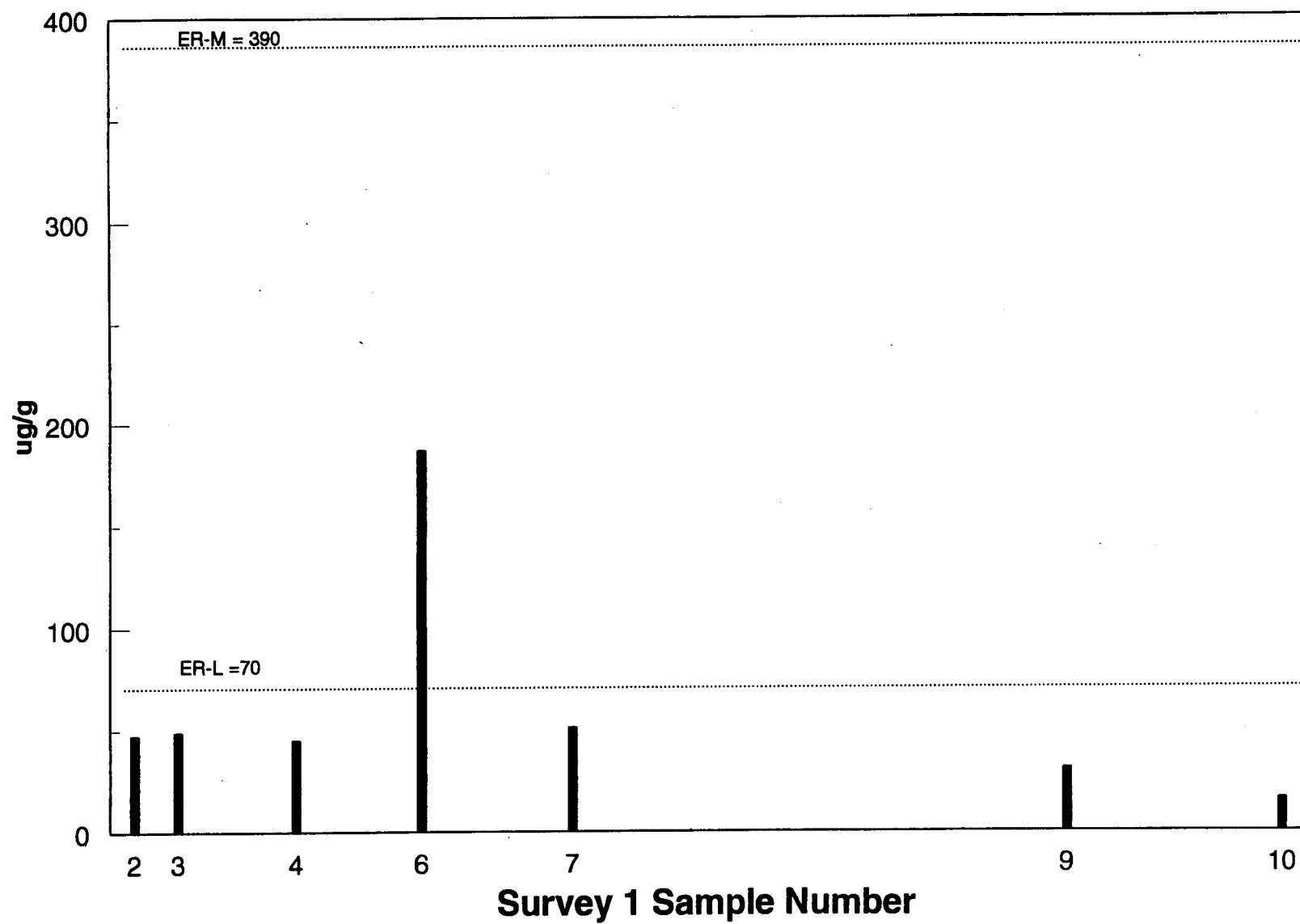
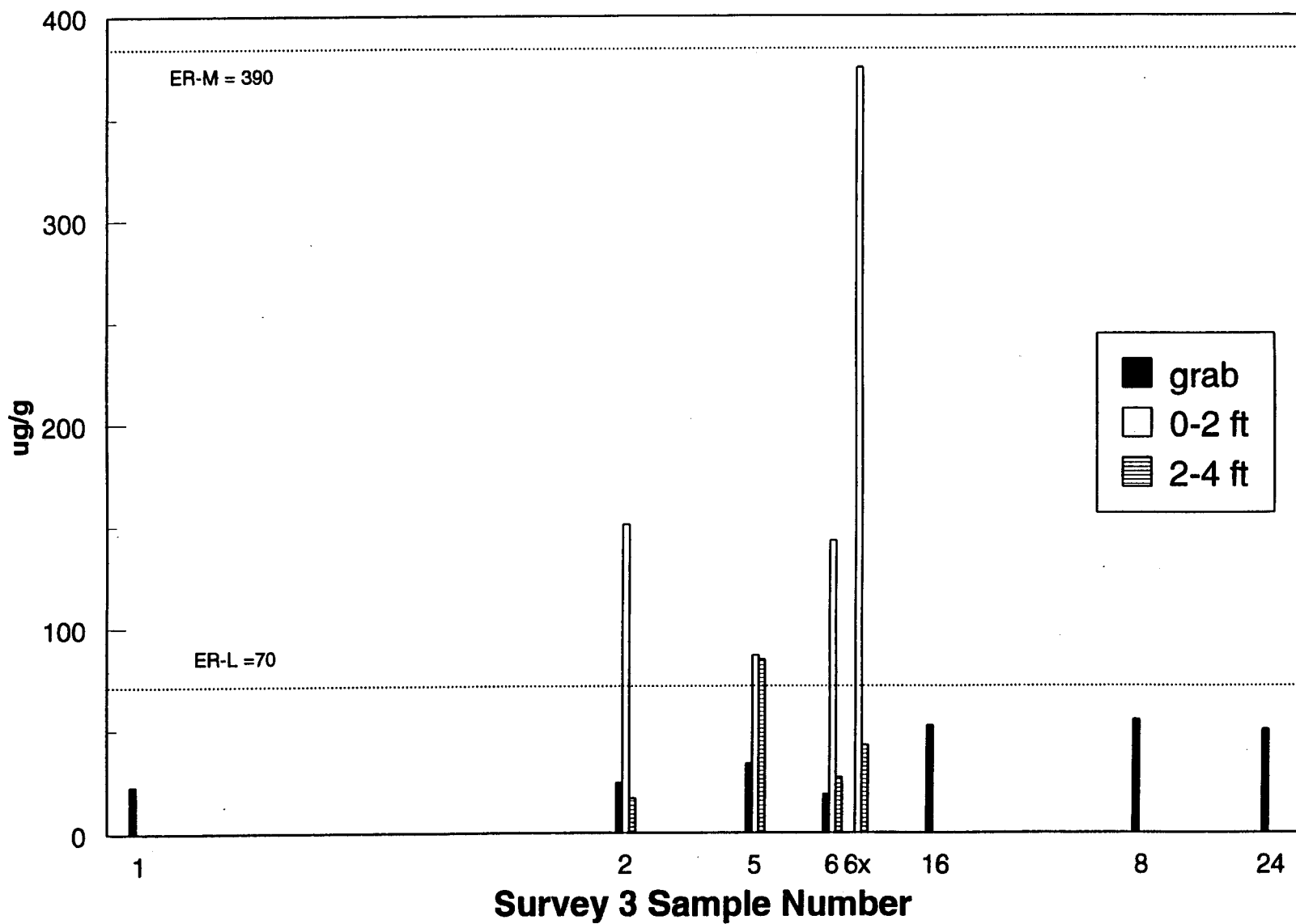
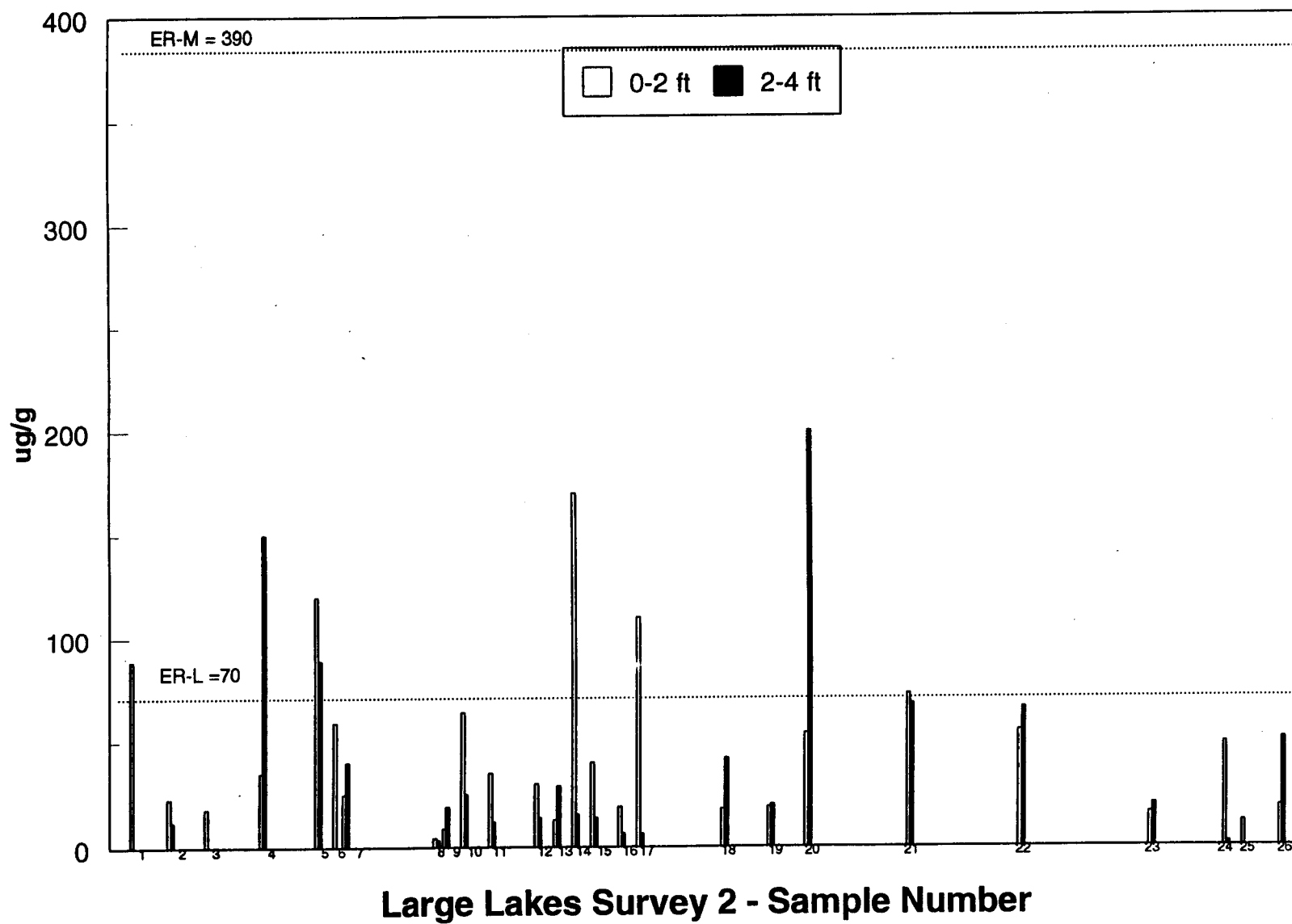
**Figure 3.9c LLRS 2 Chromium Concentration vs. NOAA Guidelines**

Figure 3.9d LLRS 3 Chromium Concentration vs. NOAA Guidelines

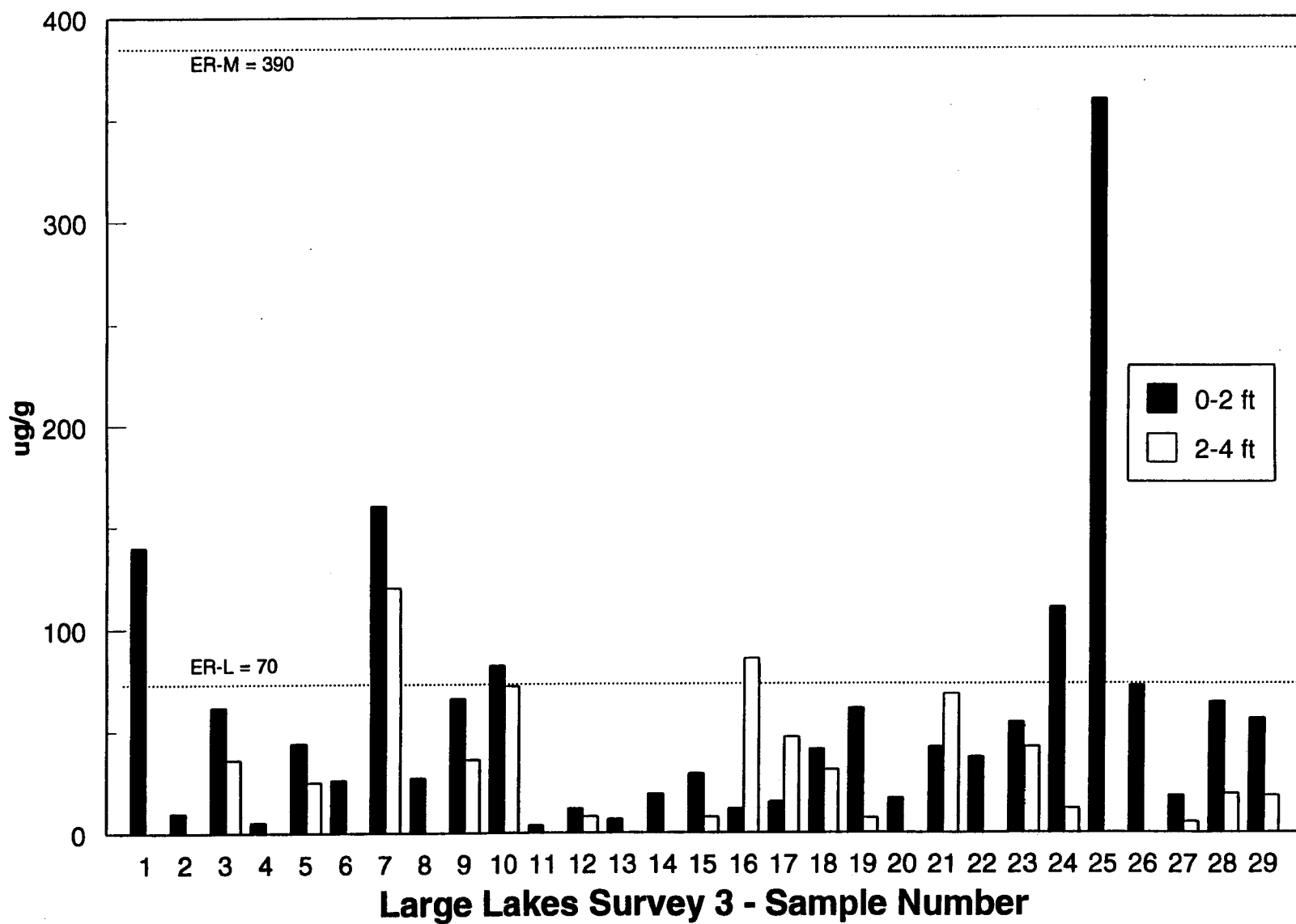


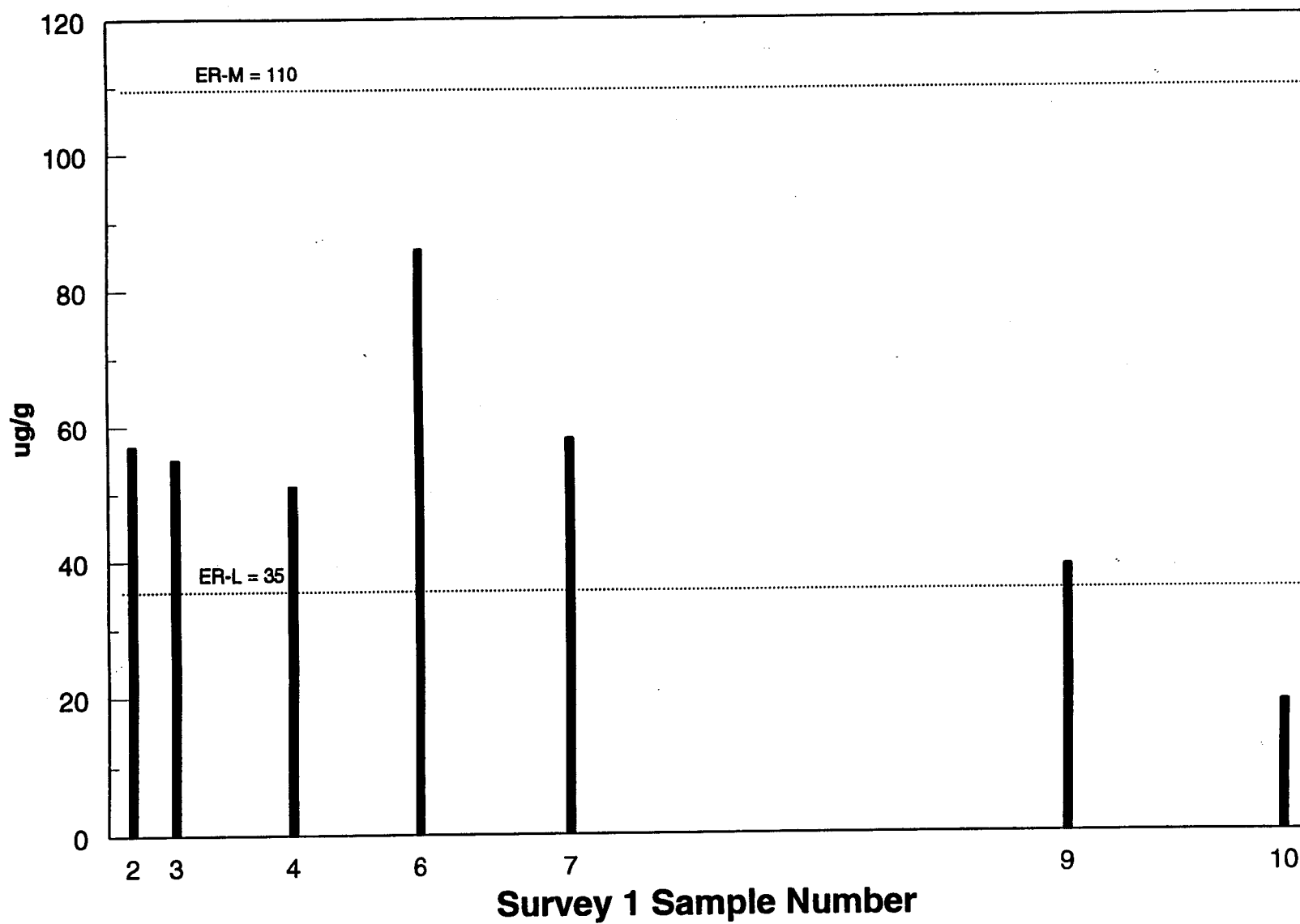
**Figure 3.10a Survey 1 Copper Concentration vs. NOAA Guidelines**

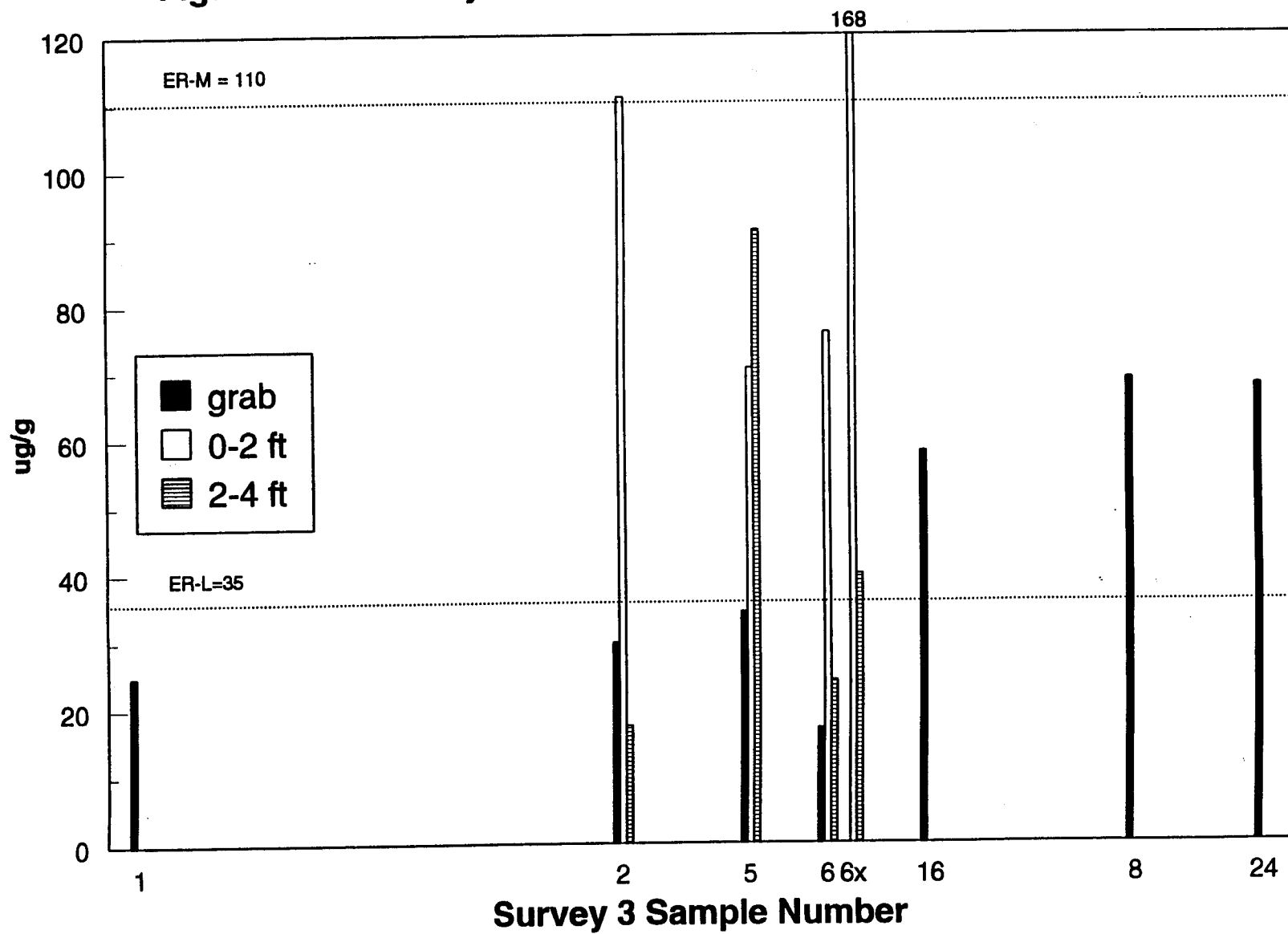
**Figure 3.10b Survey 3 Copper Concentration vs. NOAA Guidelines**

**Figure 3.10c LLRS 2 Copper Concentration vs. NOAA Guidelines**



**Figure 3.10d LLRS 3 Copper Concentration vs. NOAA Guidelines**

**Figure 3.11a Survey 1 Lead Concentration vs. NOAA Guidelines**

**Figure 3.11b Survey 3 Lead Concentration vs. NOAA Guidelines**

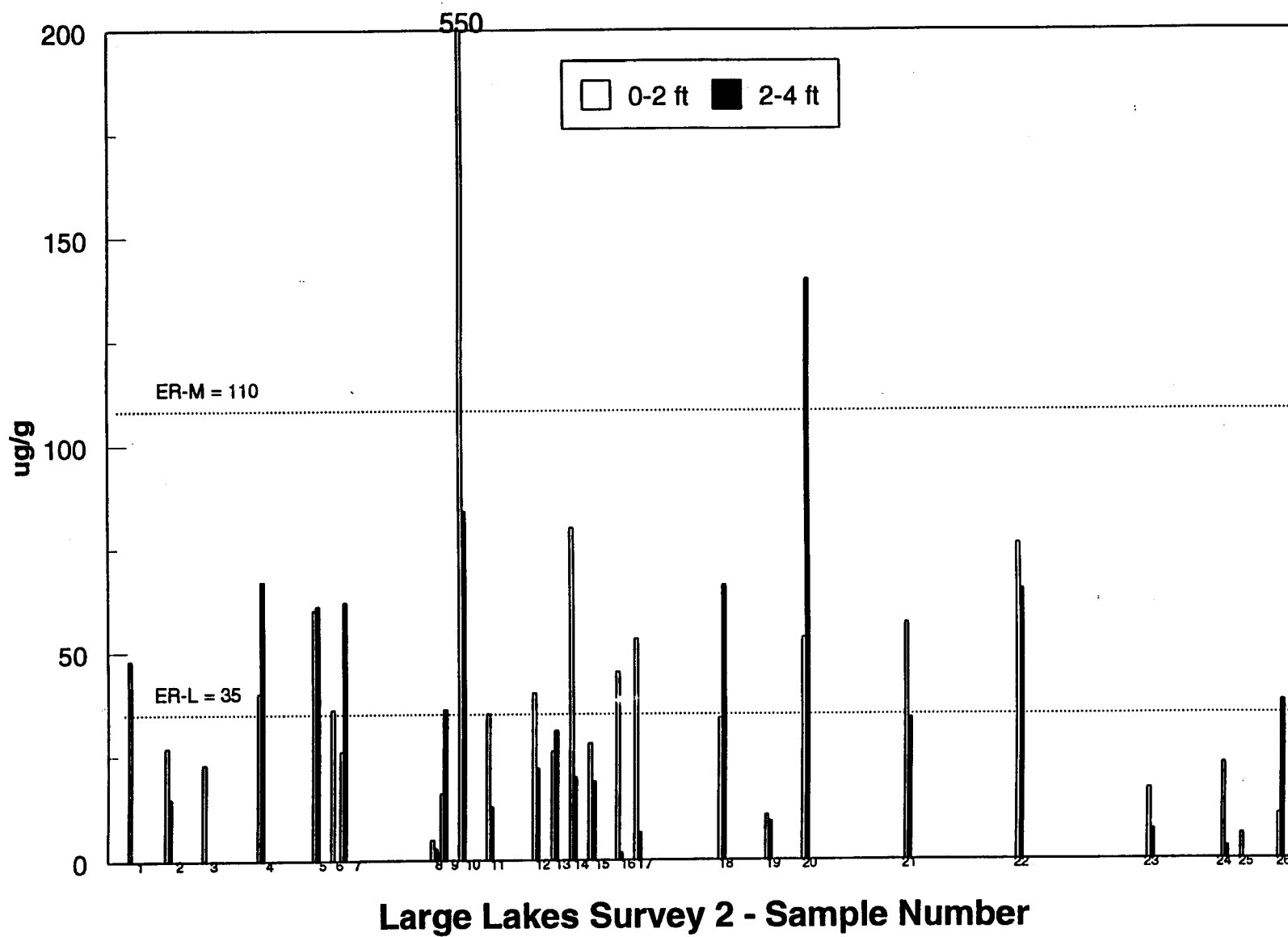
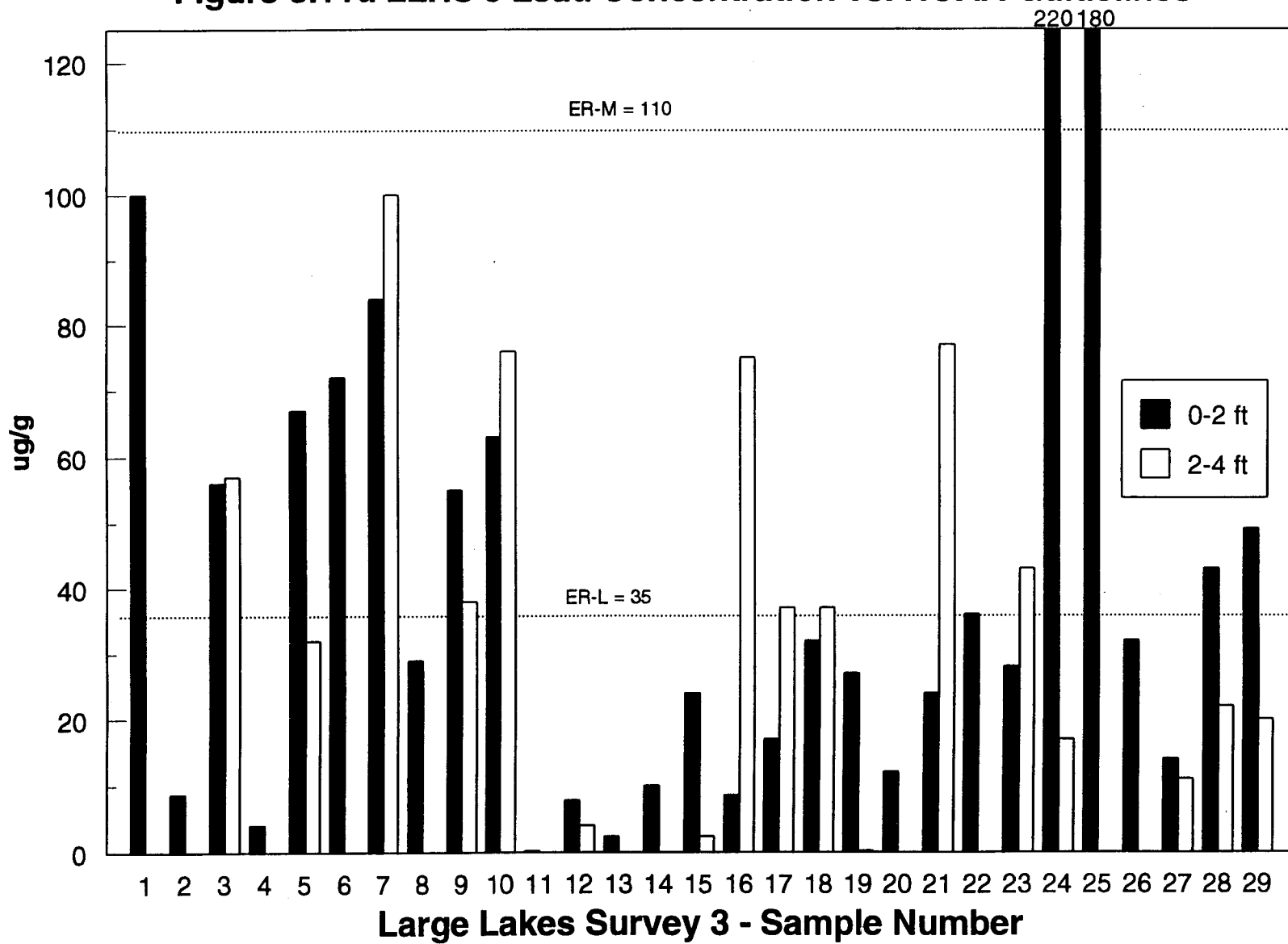
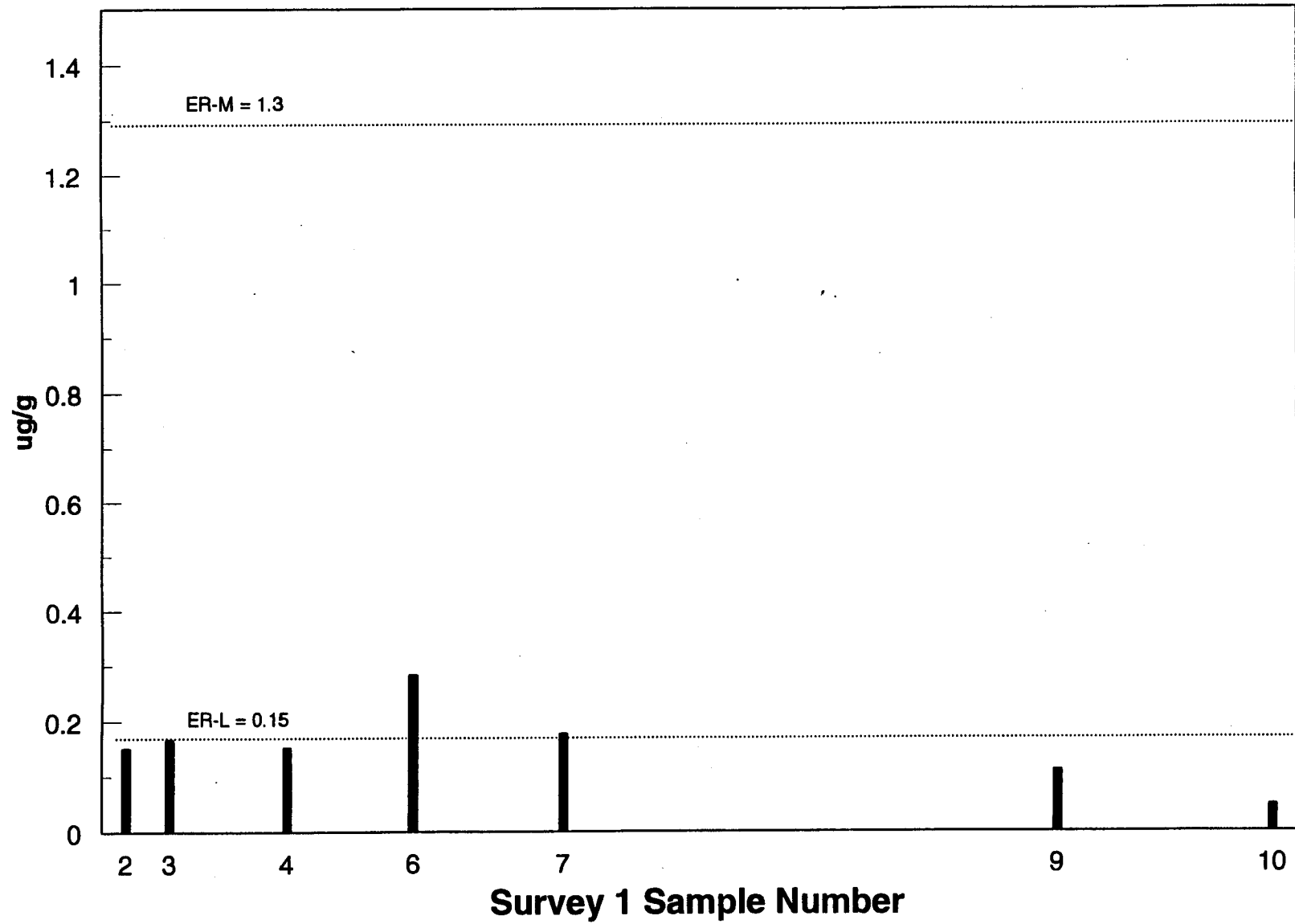
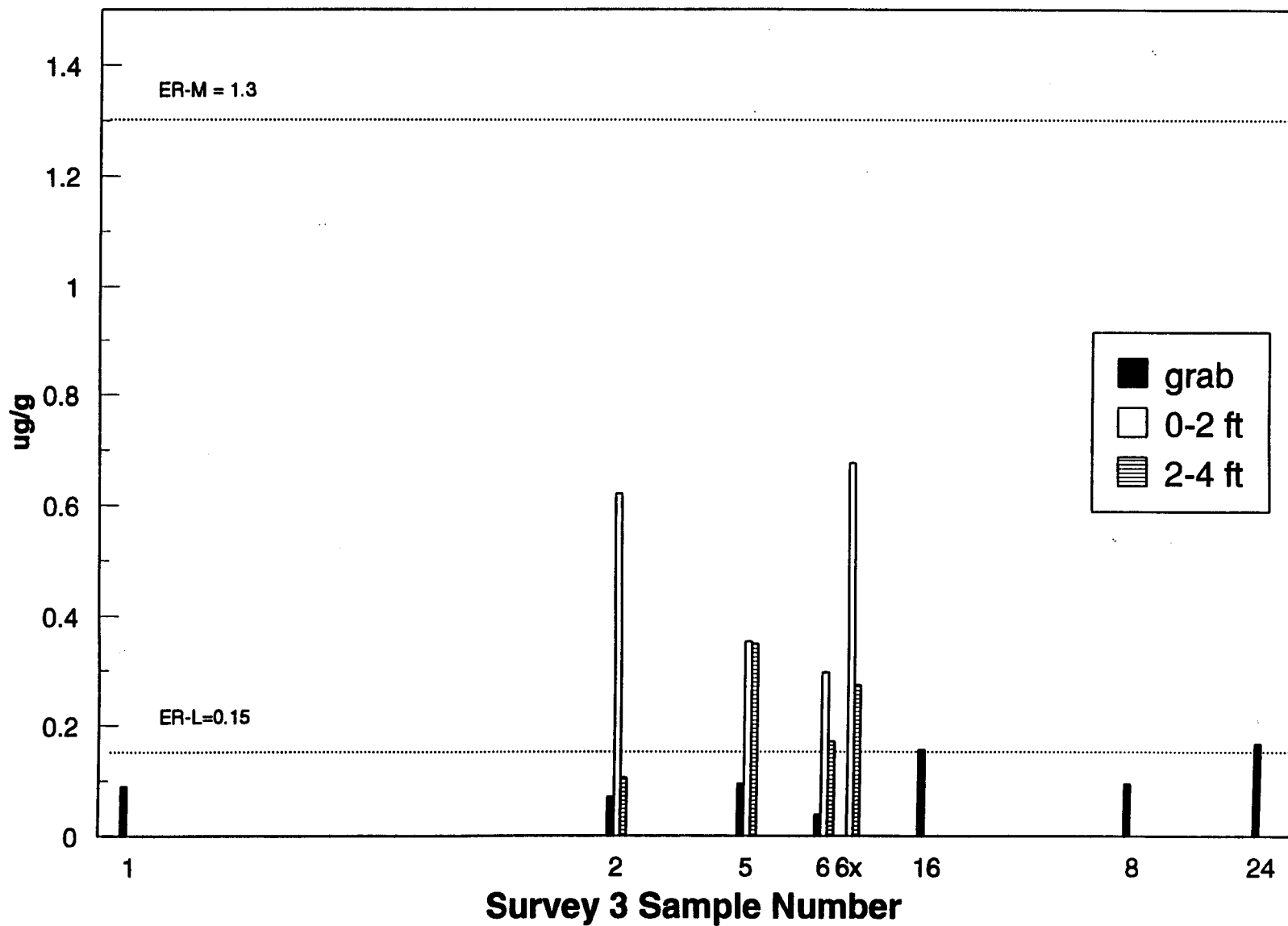
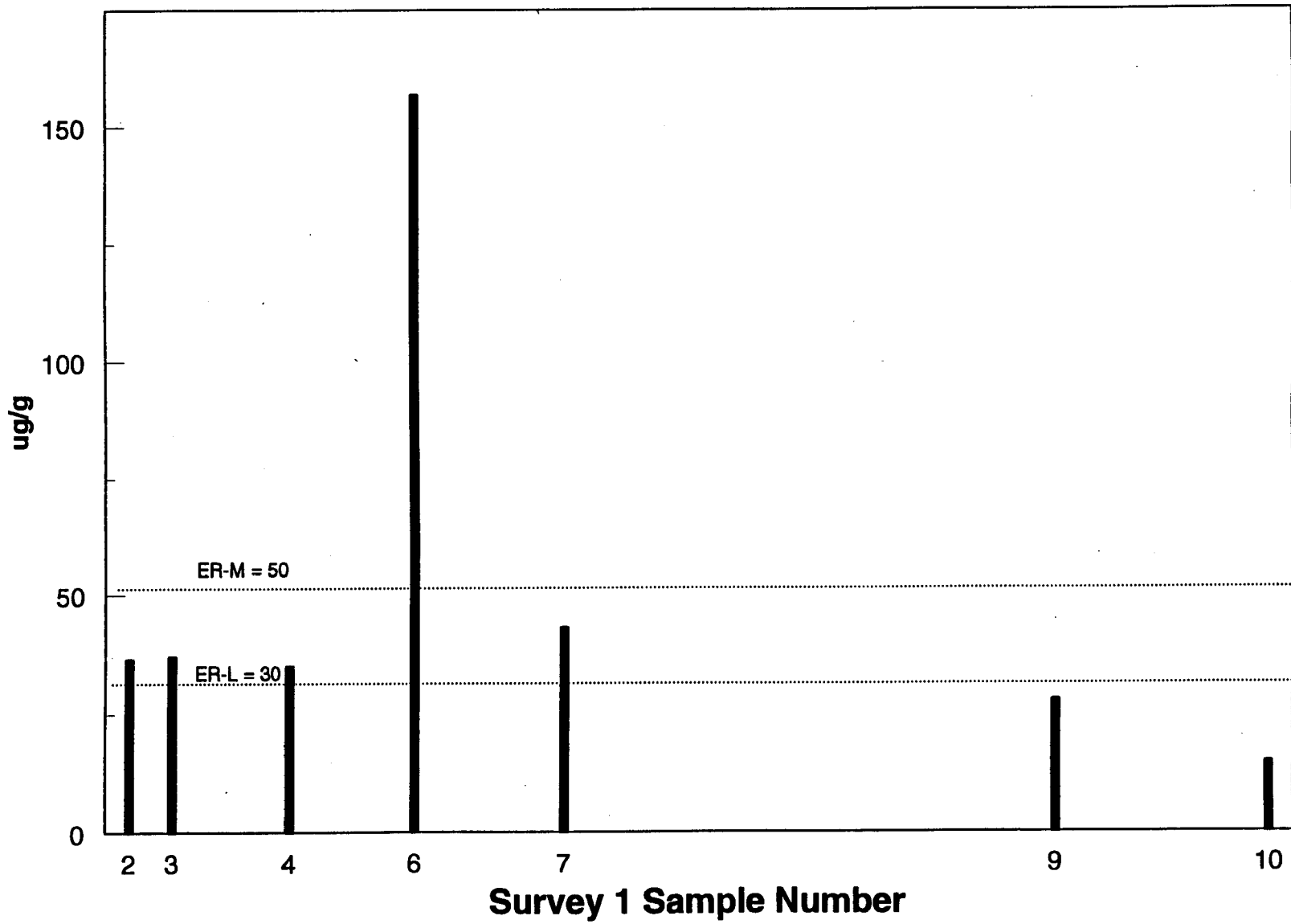
**Figure 3.11c LLRS 2 Lead Concentration vs. NOAA Guidelines**

Figure 3.11d LLRS 3 Lead Concentration vs. NOAA Guidelines

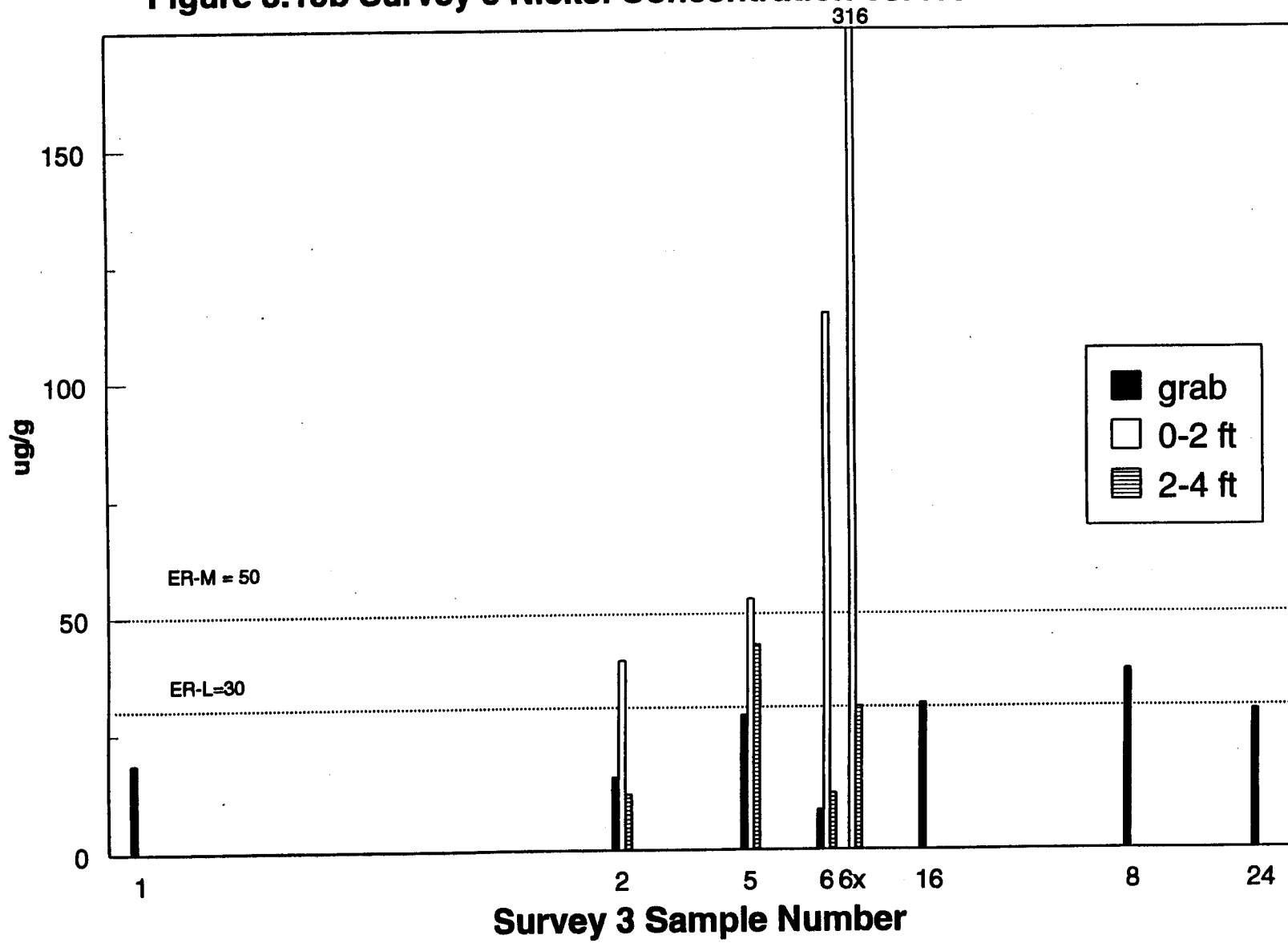


**Figure 3.12a Survey 1 Mercury Concentration vs. NOAA Guidelines**

**Figure 3.12b Survey 3 Mercury Concentration vs. NOAA Guidelines**

**Figure 3.13a Survey 1 Nickel Concentration vs. NOAA Guidelines**



**Figure 3.13b Survey 3 Nickel Concentration vs. NOAA Guidelines**

**Figure 3.13c LLRS 2 Nickel Concentration vs. NOAA Guidelines**

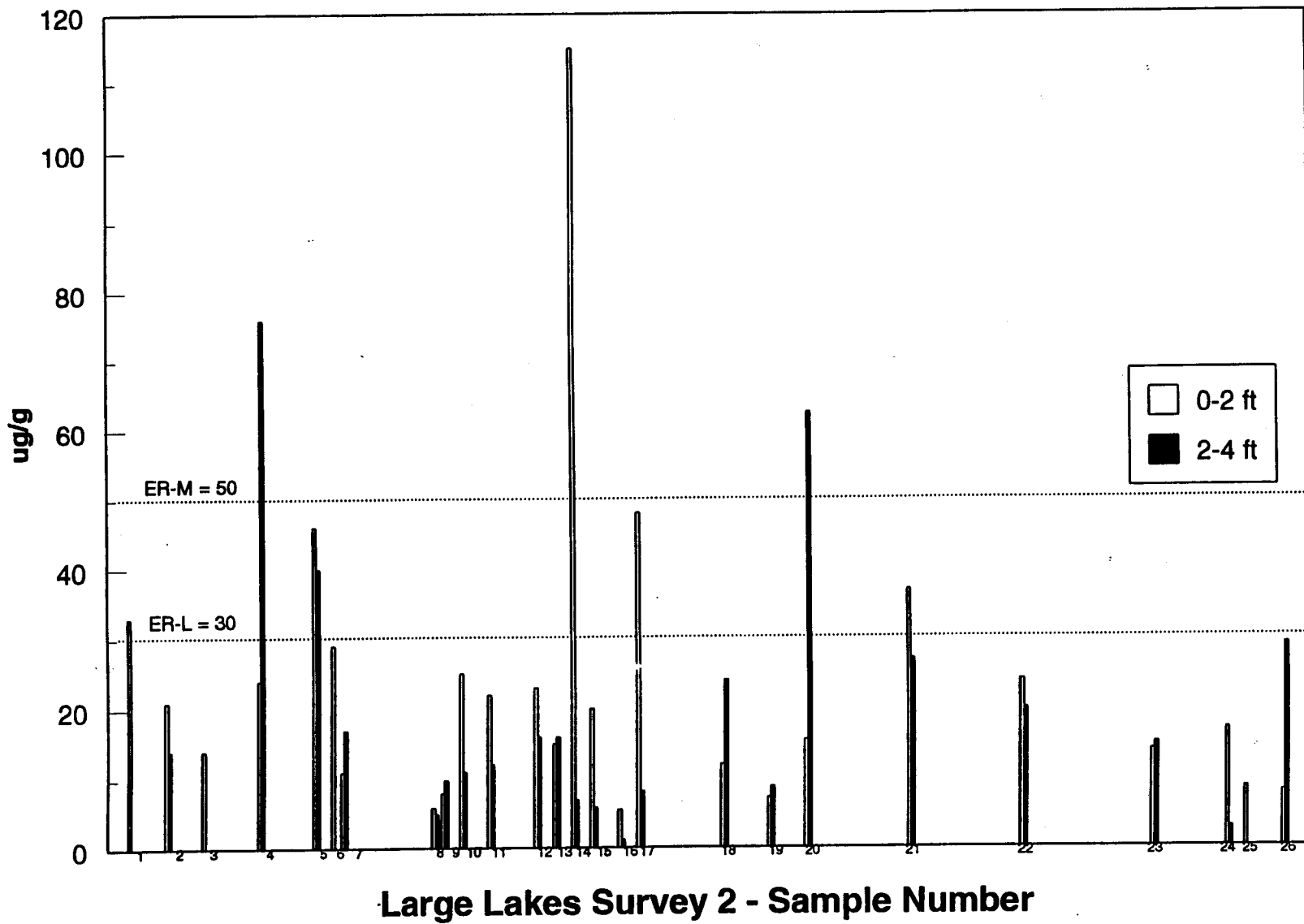
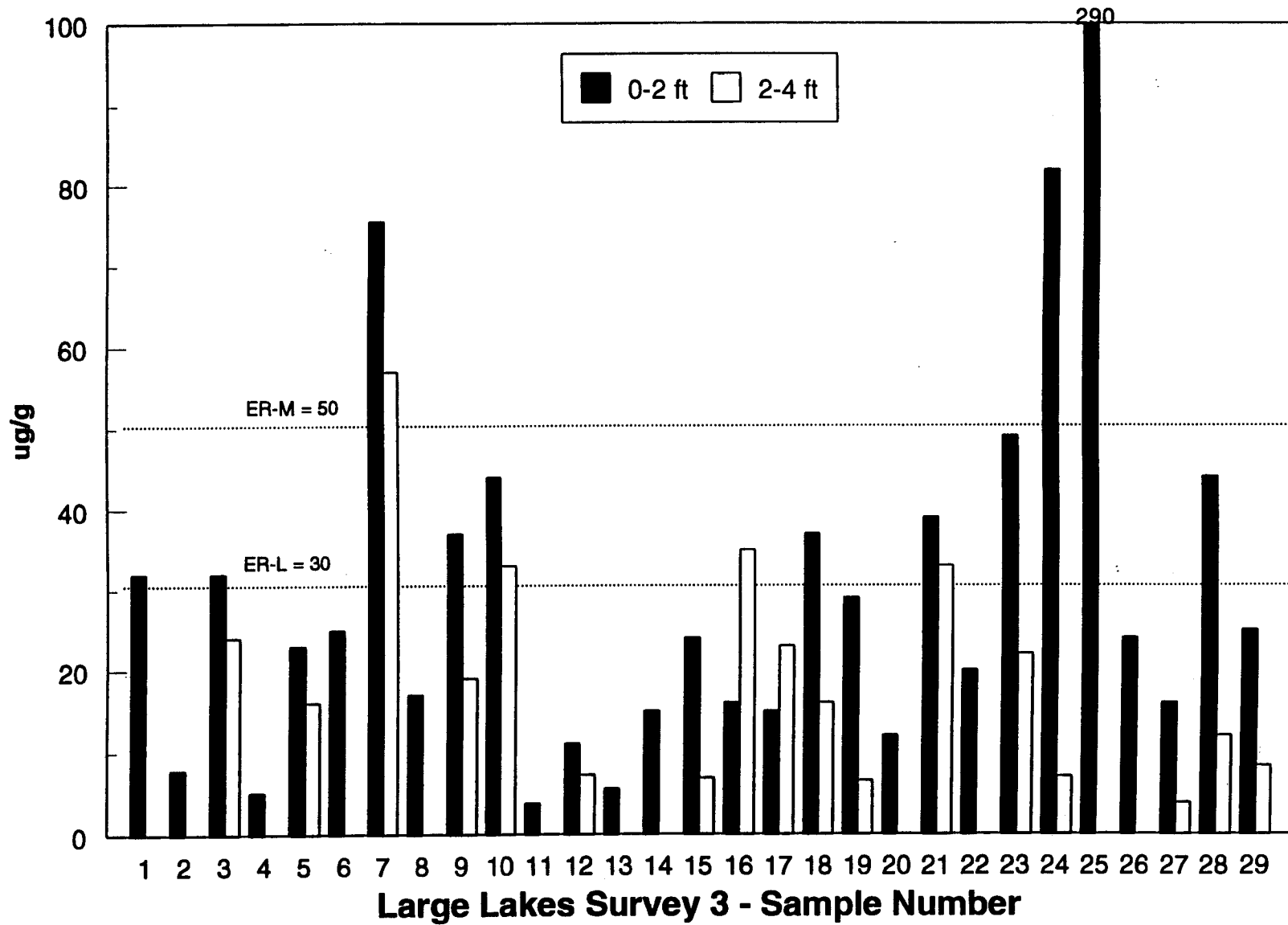
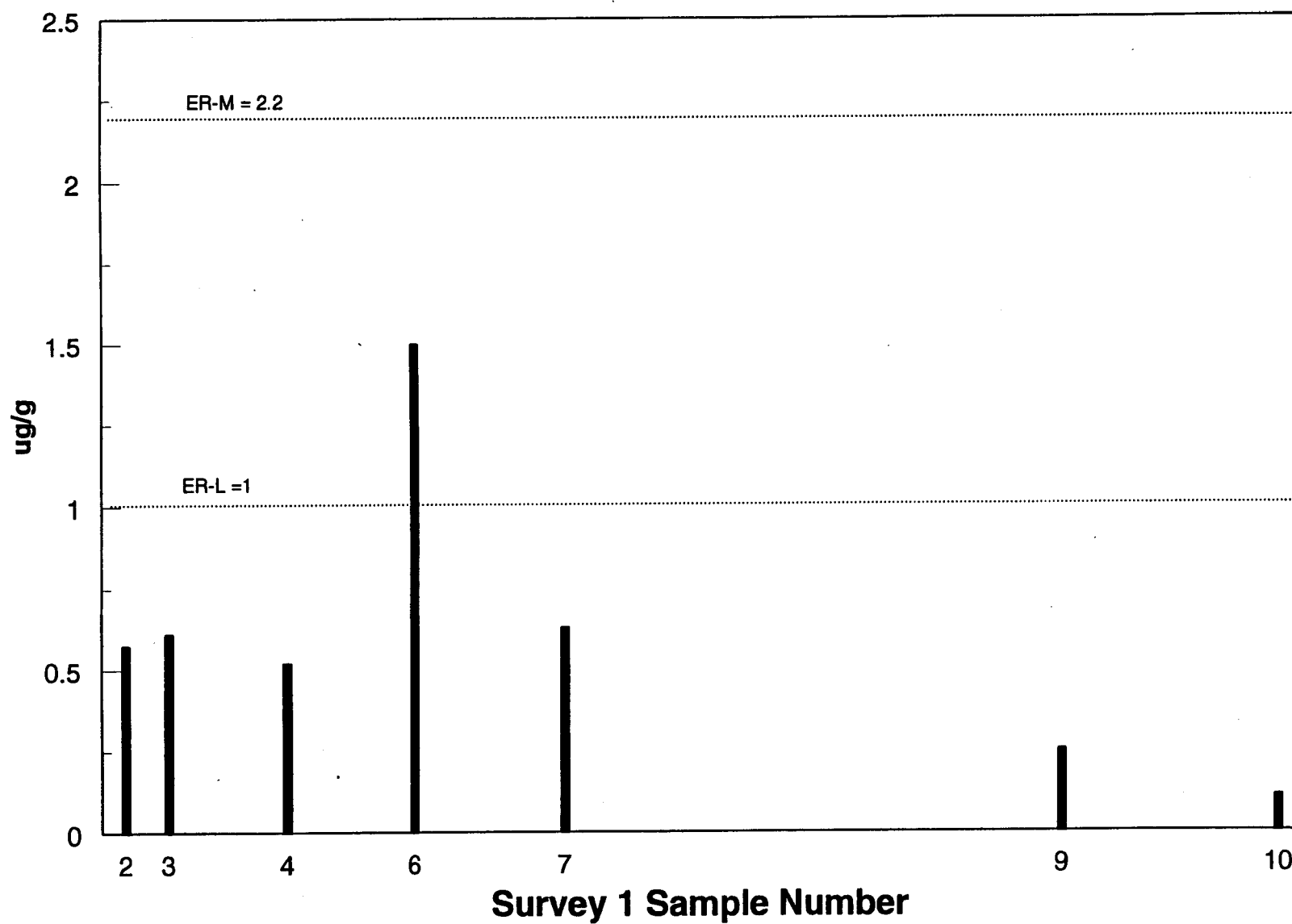
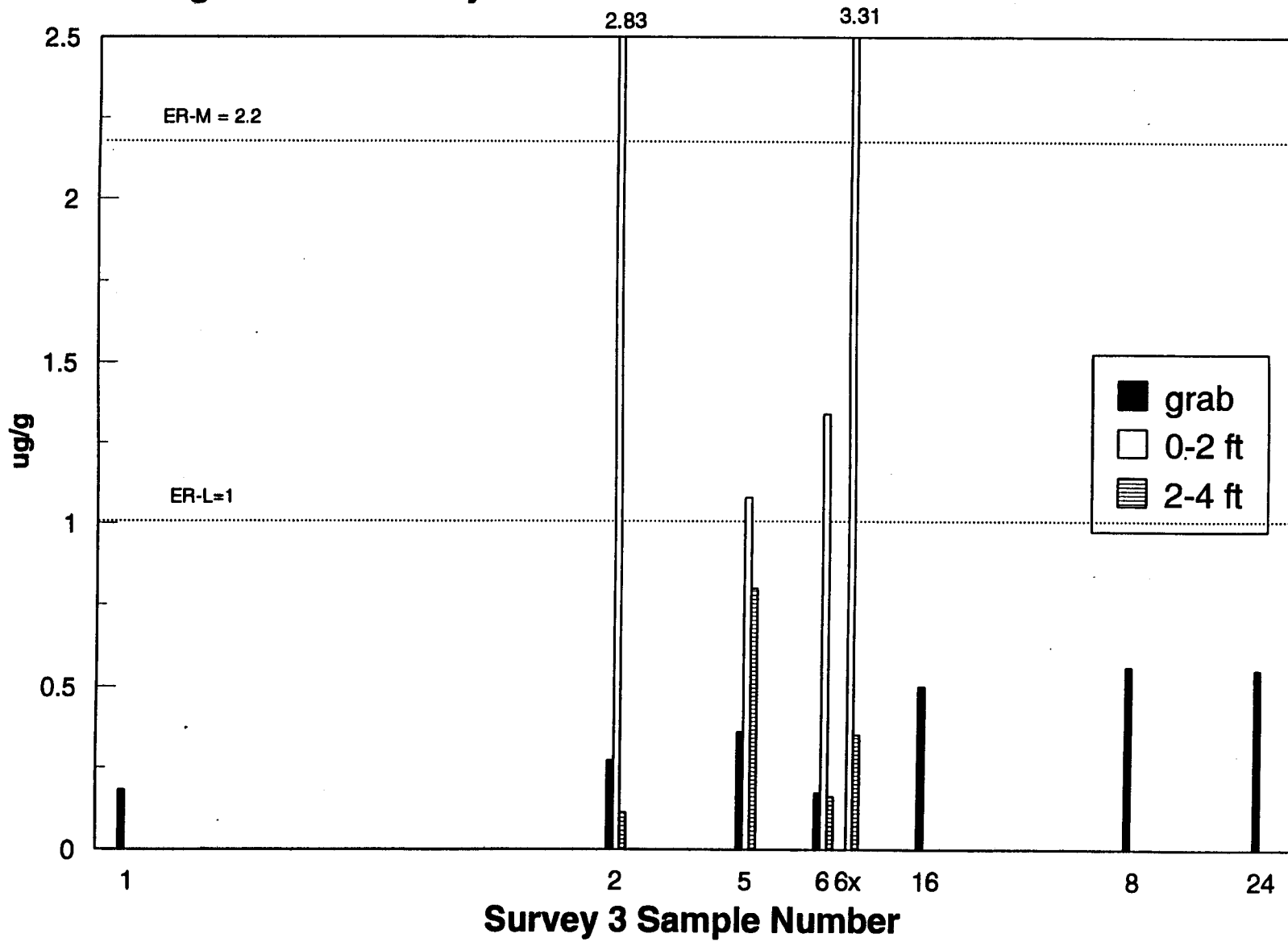


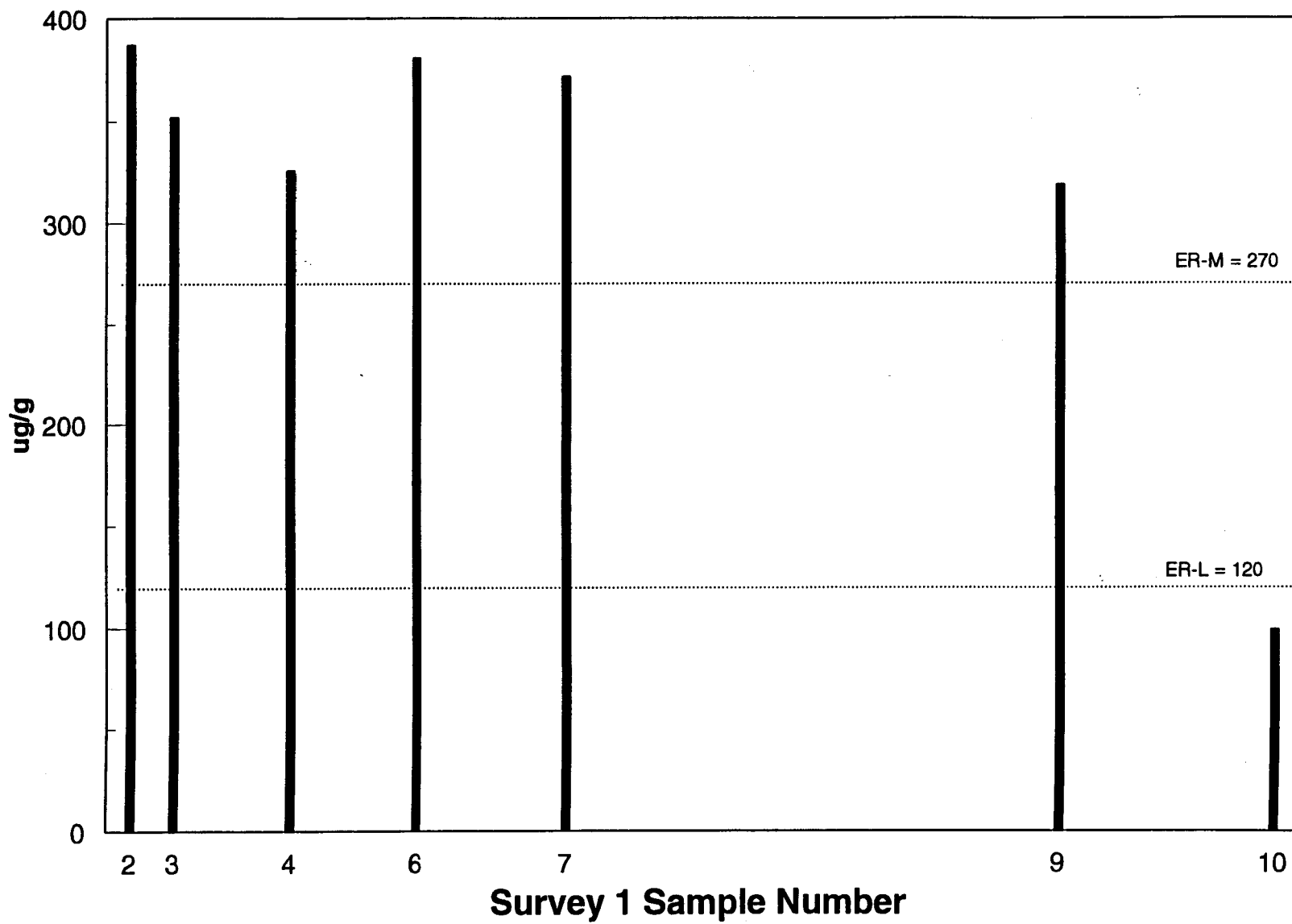
Figure 3.13d LLRS 3 Nickel Concentration vs. NOAA Guidelines



**Figure 3.14a Survey 1 Silver Concentration vs. NOAA Guidelines**

**Figure 3.14b Survey 3 Silver Concentration vs. NOAA Guidelines**



**Figure 3.15a Survey 1 Zinc Concentration vs. NOAA Guidelines**

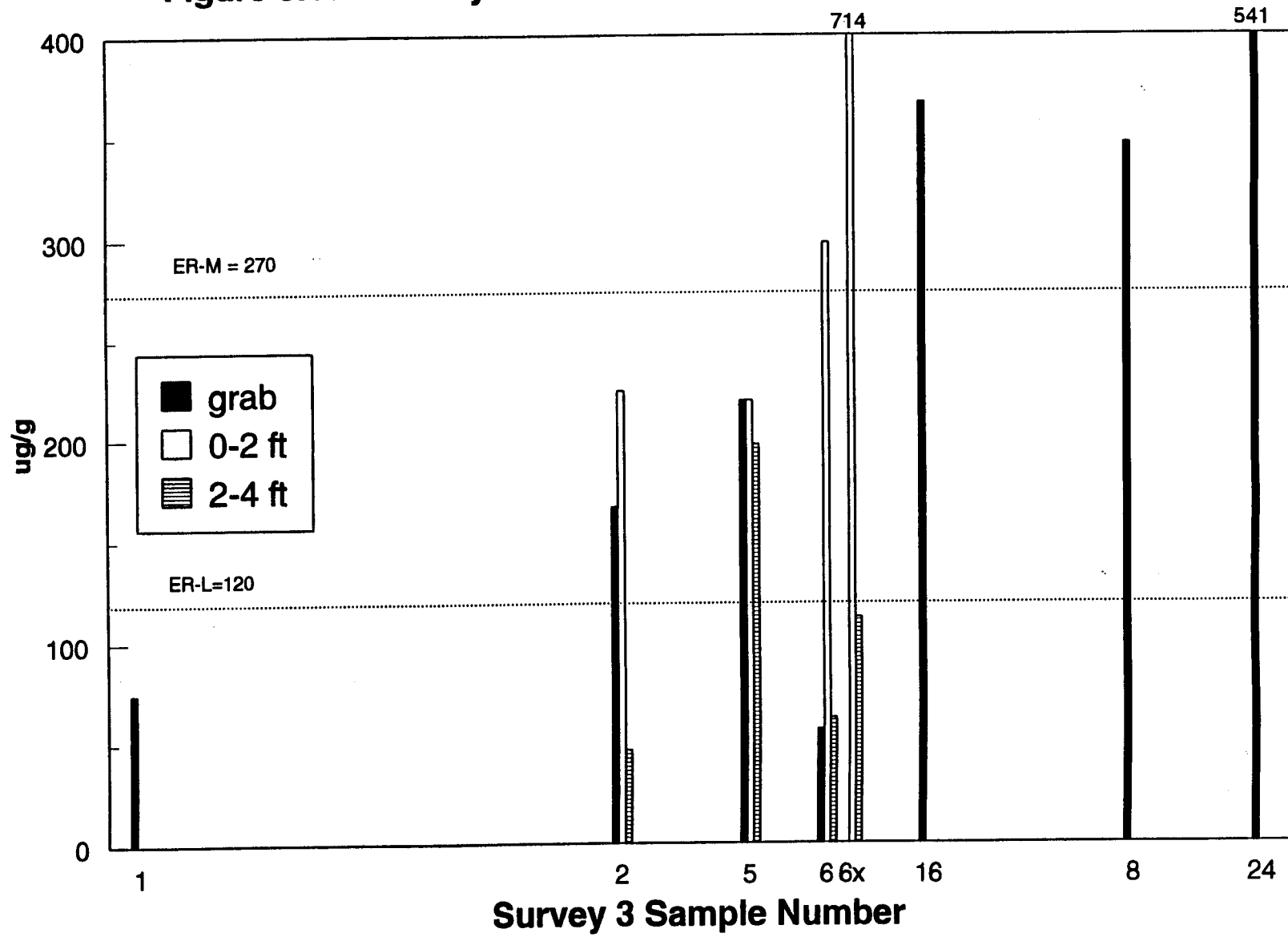
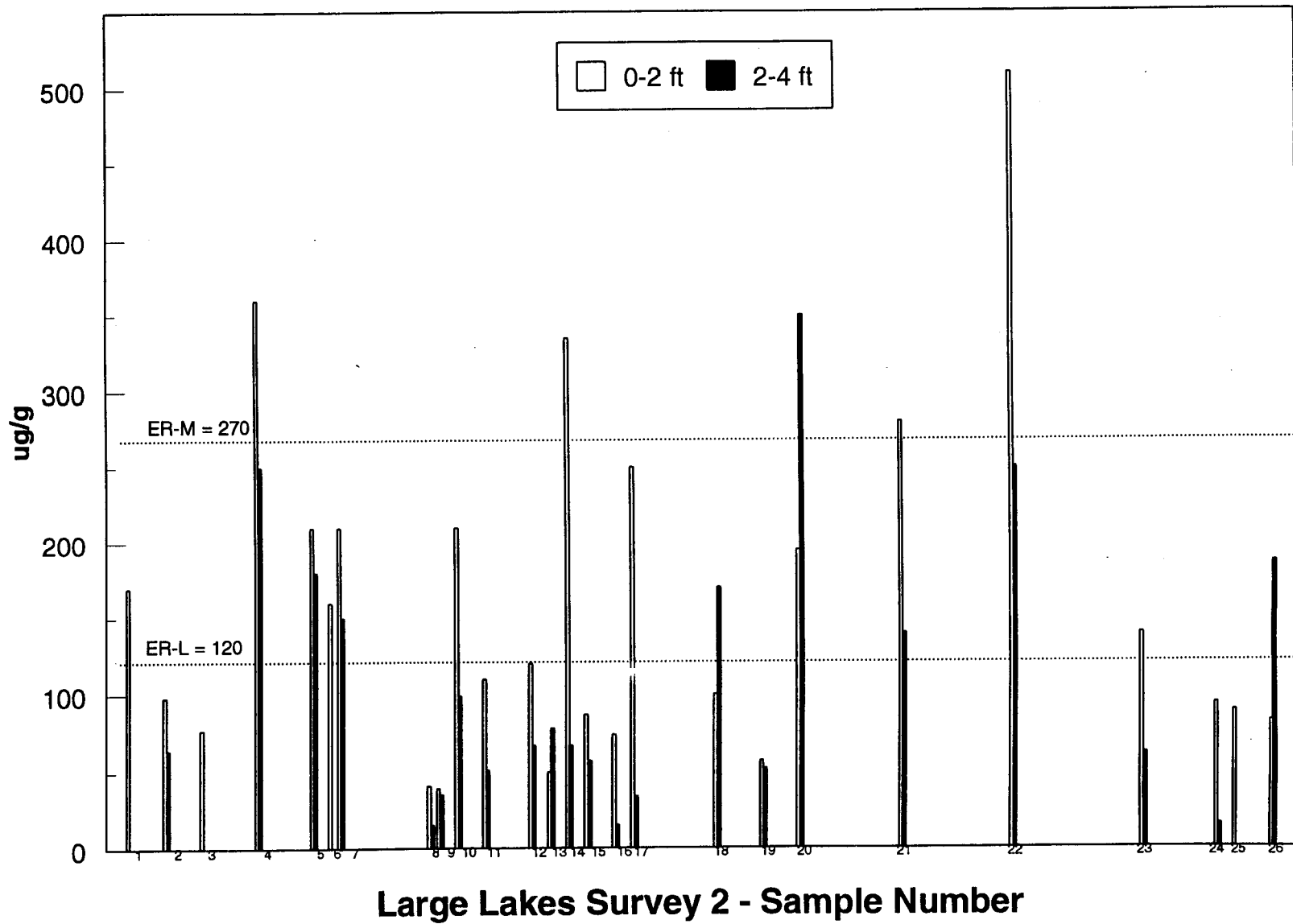
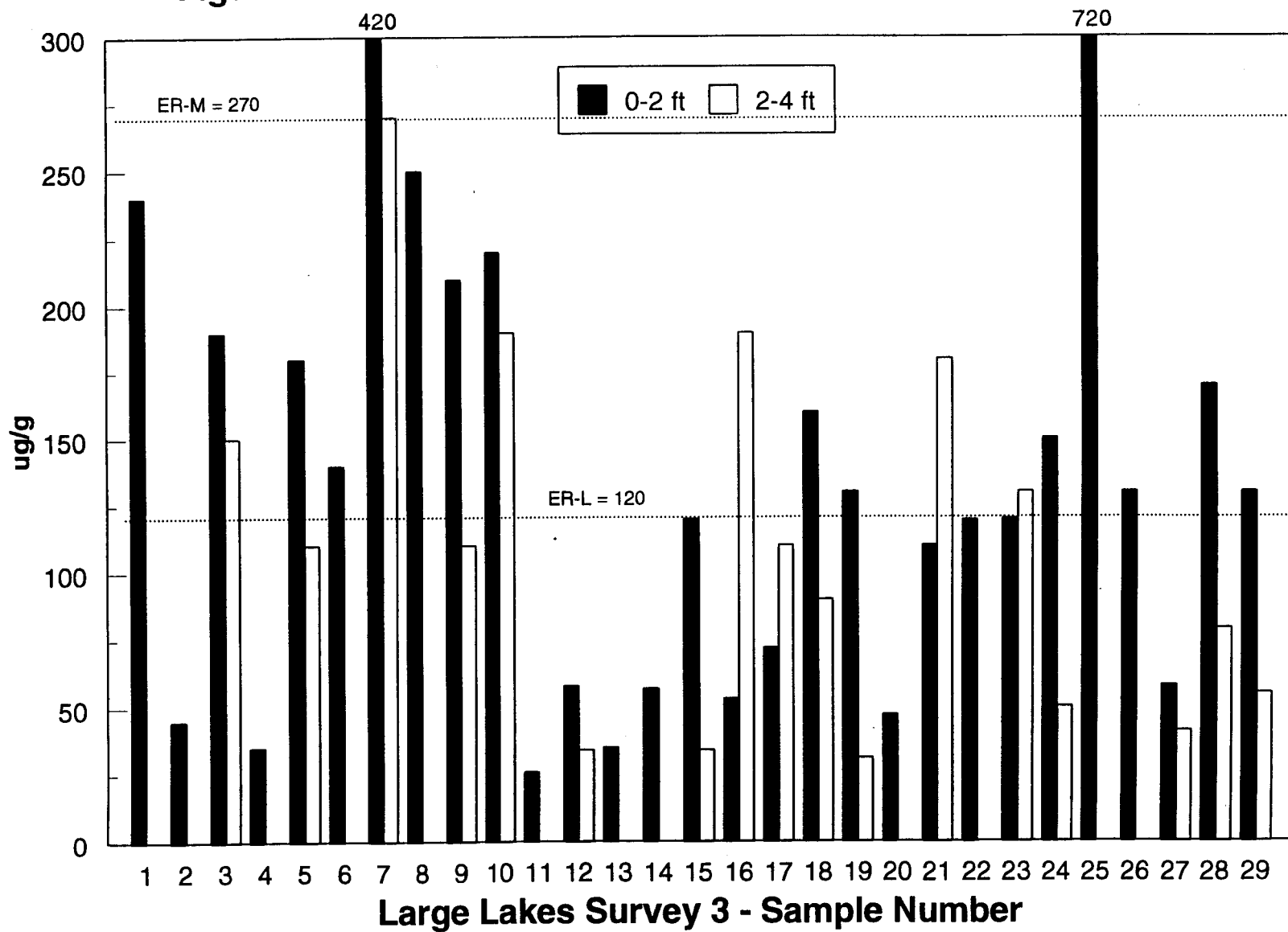
**Figure 3.15b Survey 3 Zinc Concentration vs. NOAA Guidelines**

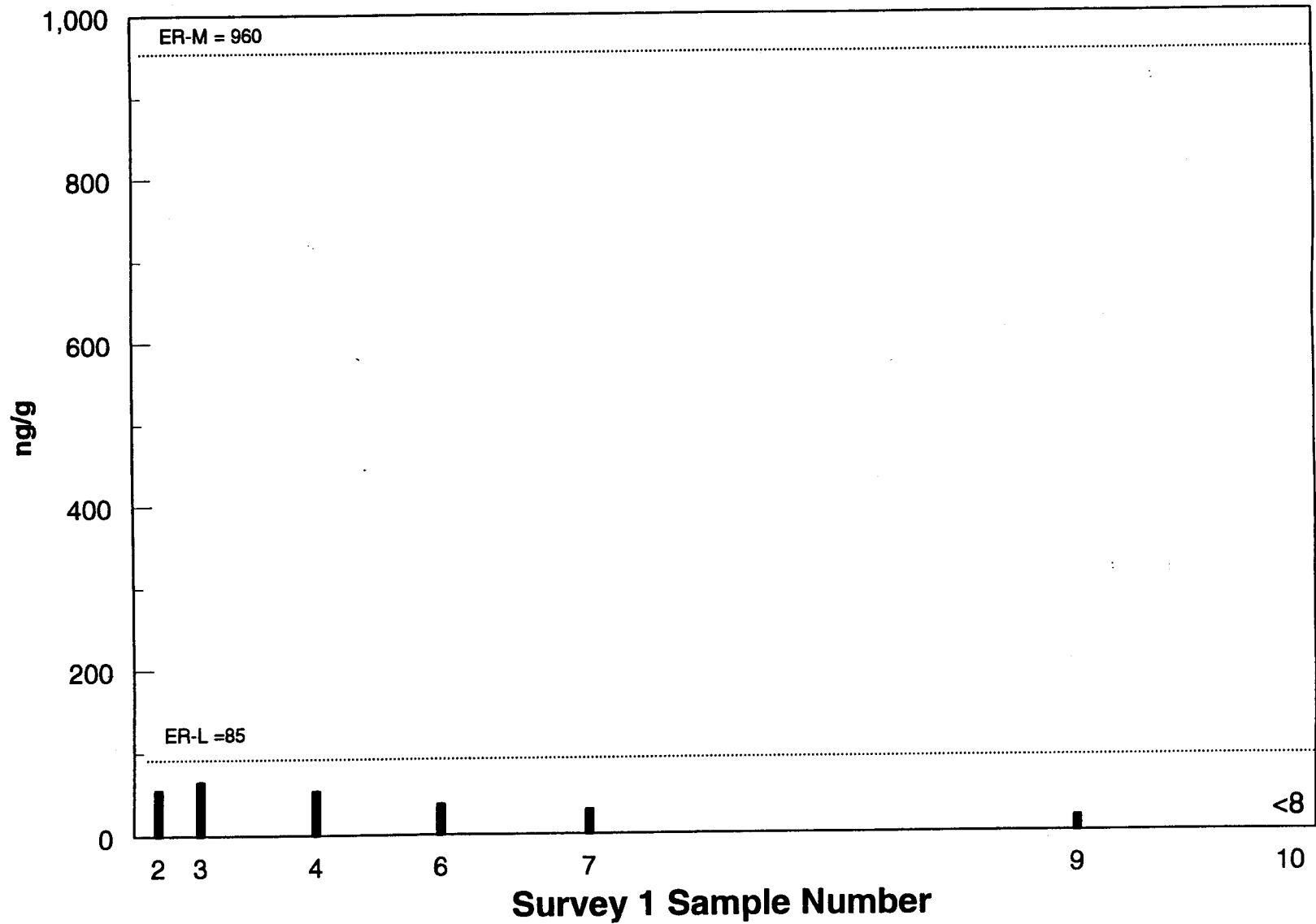
Figure 3.15c LLRS 2 Zinc Concentration vs. NOAA Guidelines

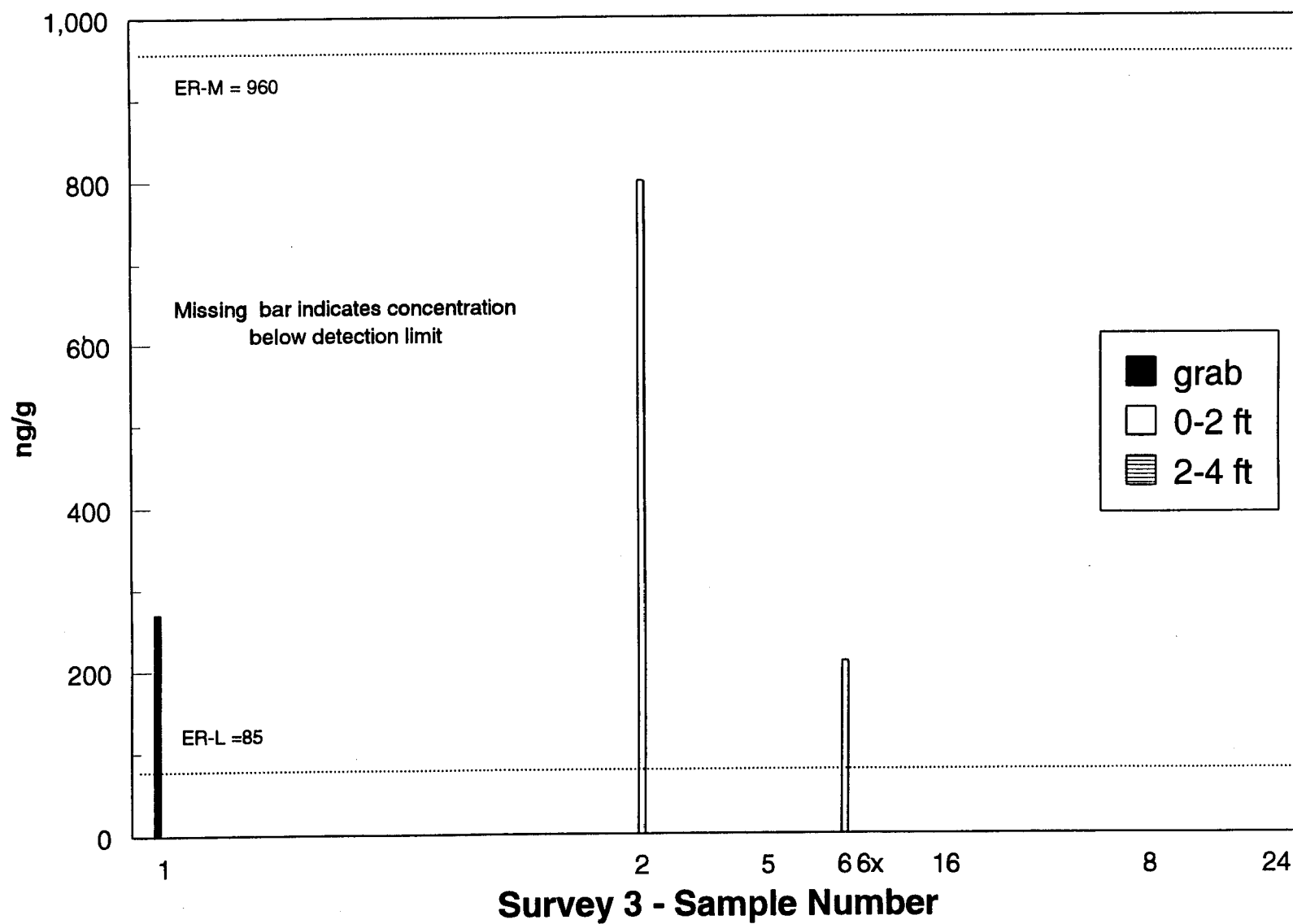


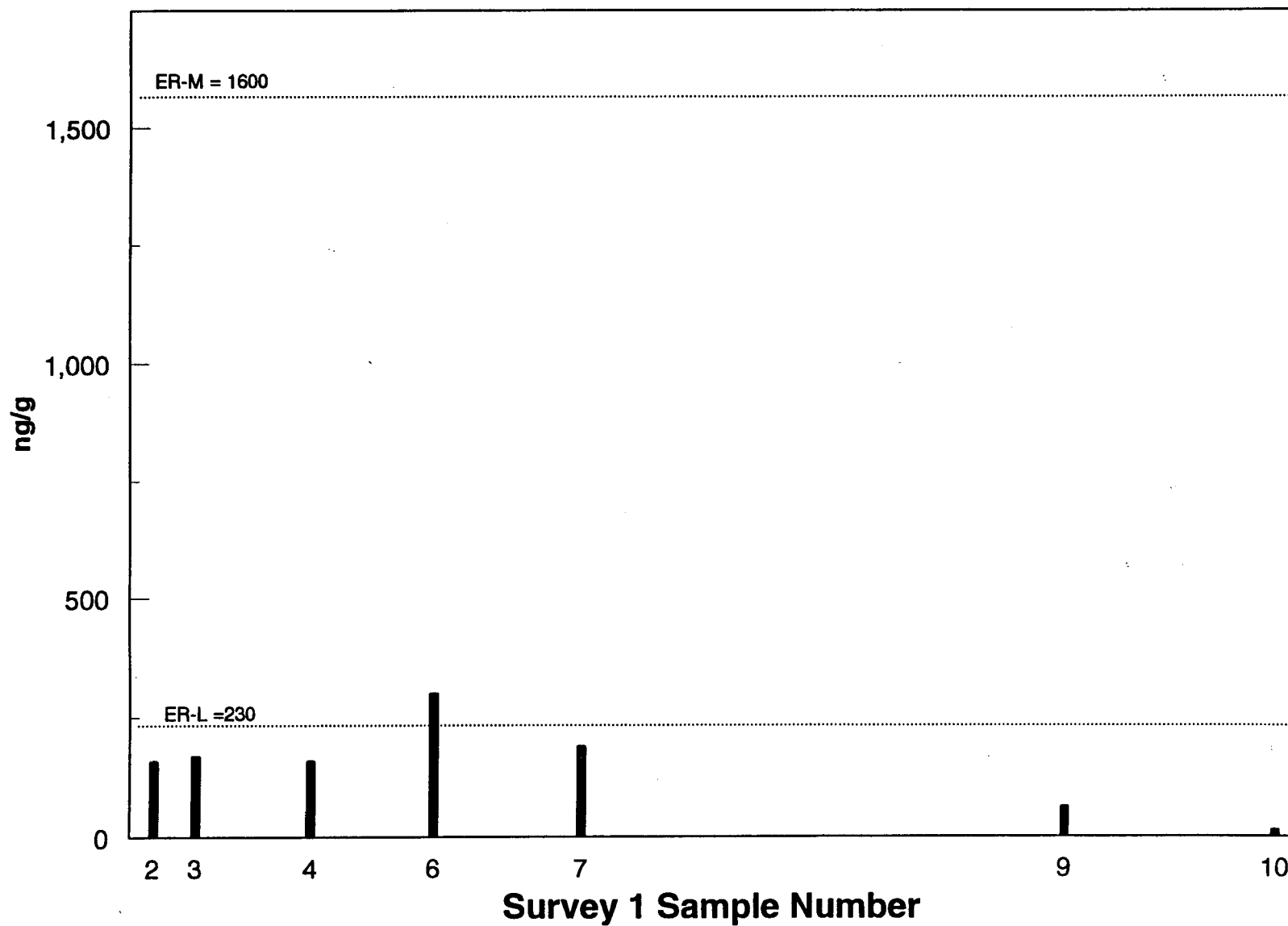


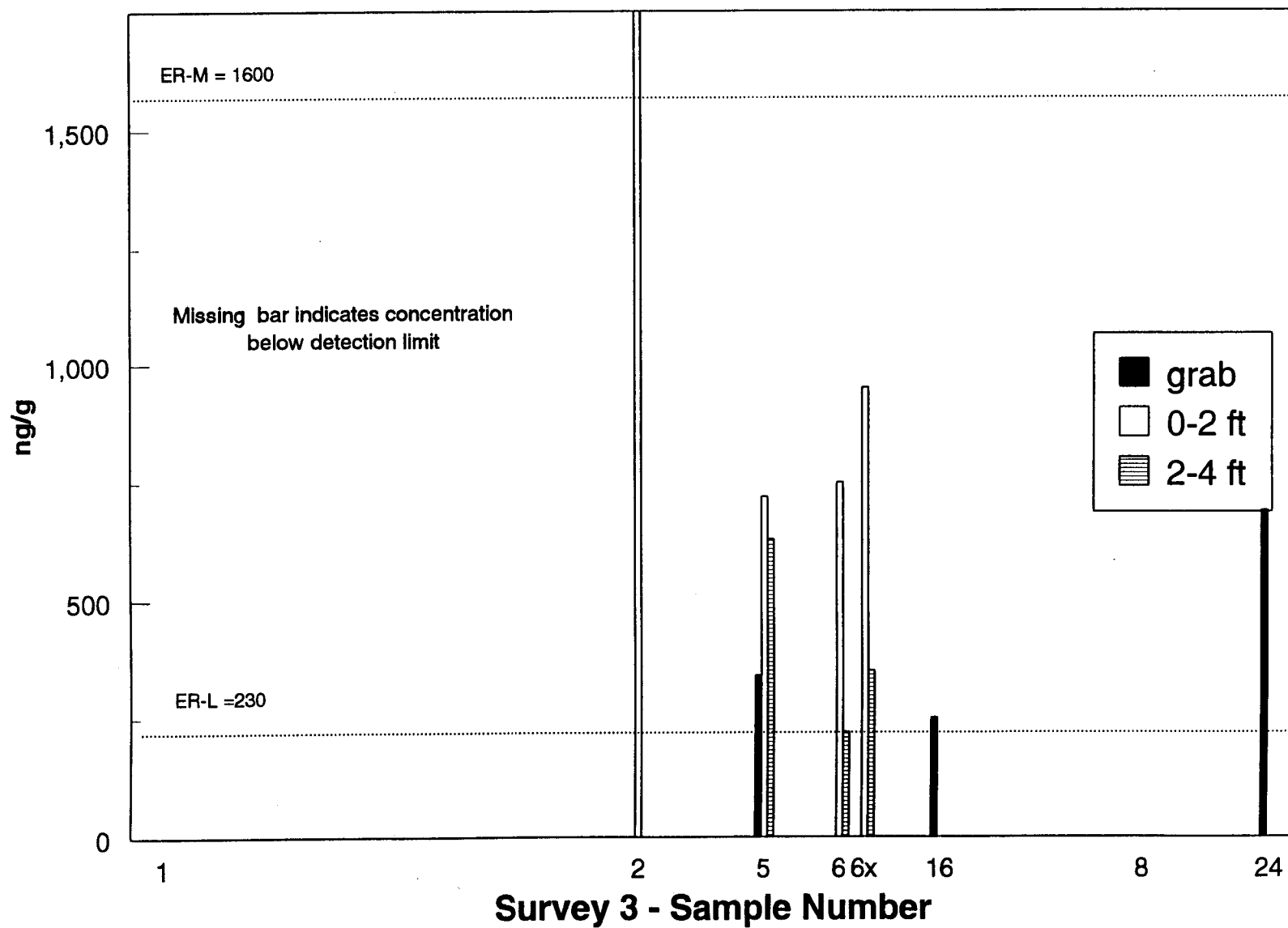
**Figure 3.15d LLRS 3 Zinc Concentration vs. NOAA Guidelines**

**Figure 3.16a Survey 1 Anthracene Concentration vs. NOAA Guidelines**

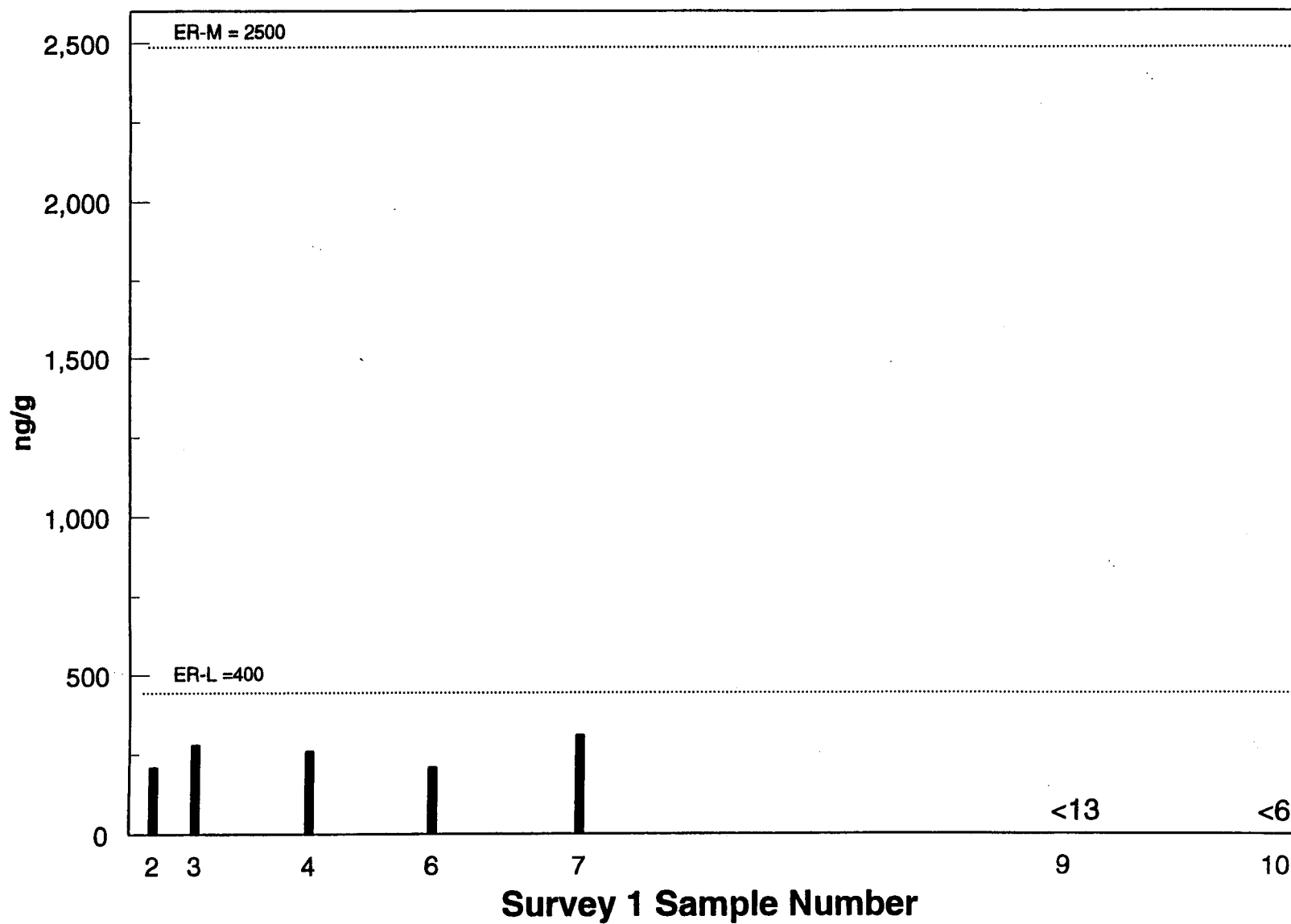


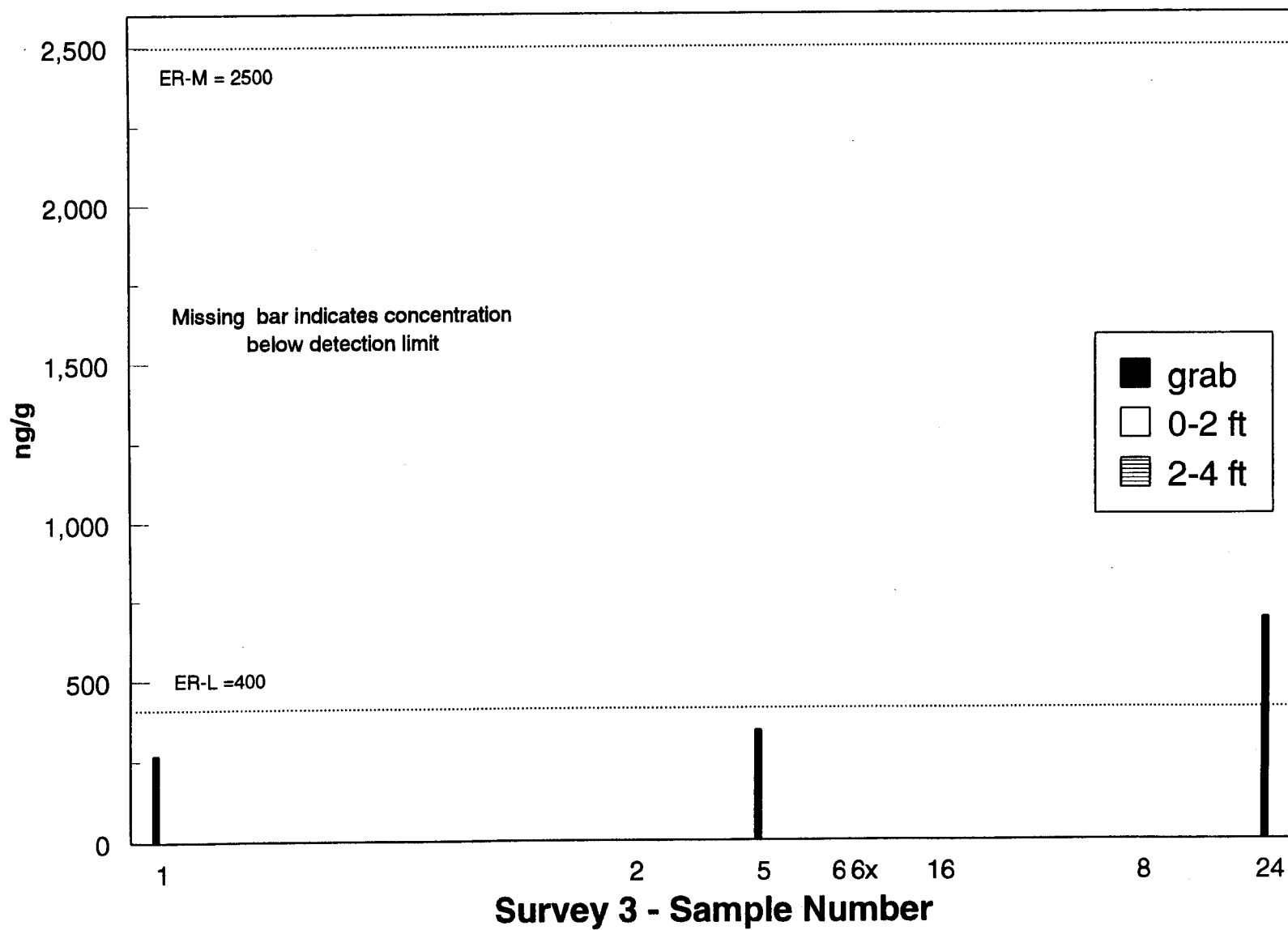
**Figure 3.16b Survey 3 Anthracene Concentration vs. NOAA Guidelines**

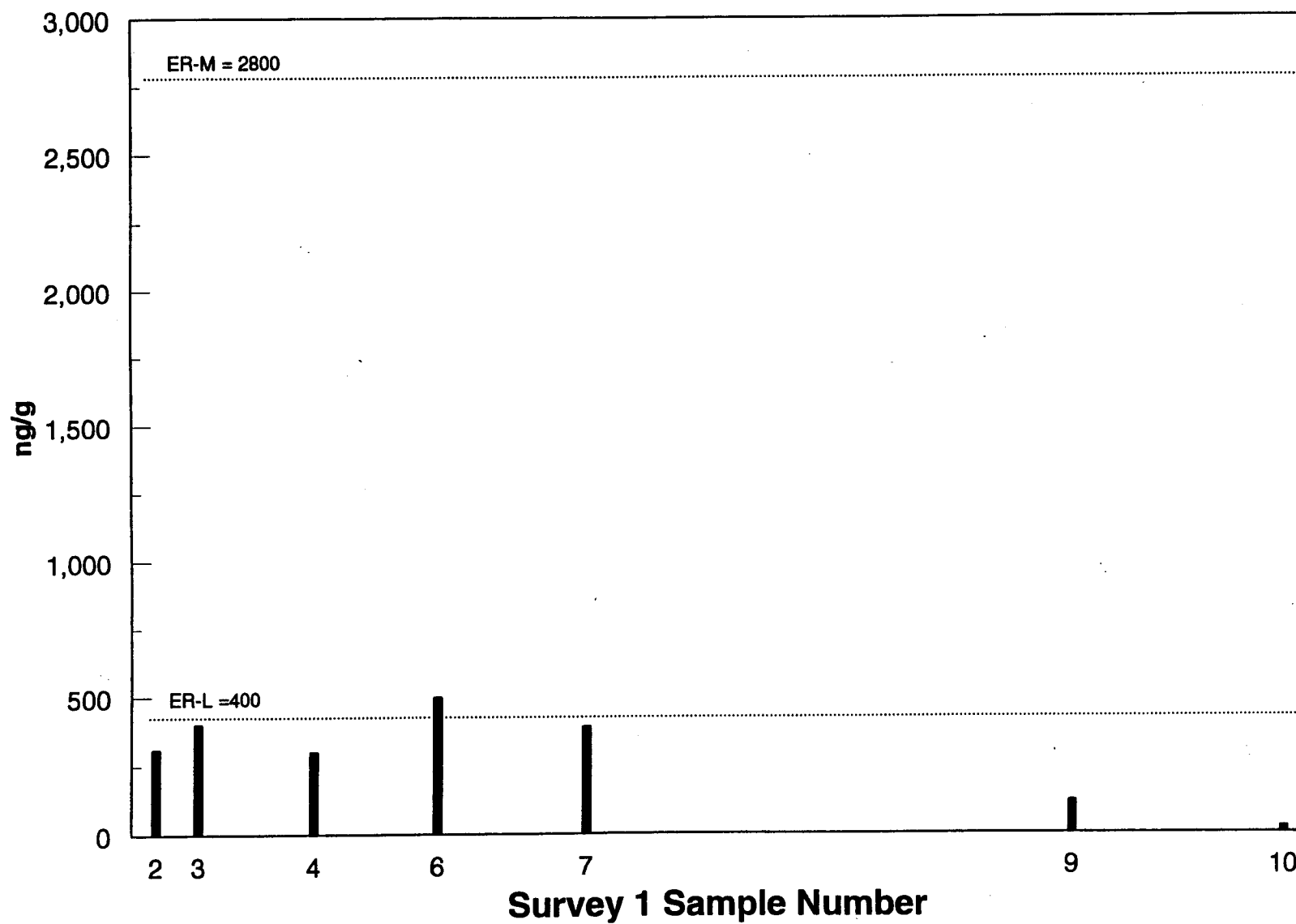
**Figure 3.17a Survey 1 Benz(a)anthracene Concentration vs. NOAA Guidelines**

**Figure 3.17b Survey 3 Benz(a)anthracene Concentration vs. NOAA Guidelines**

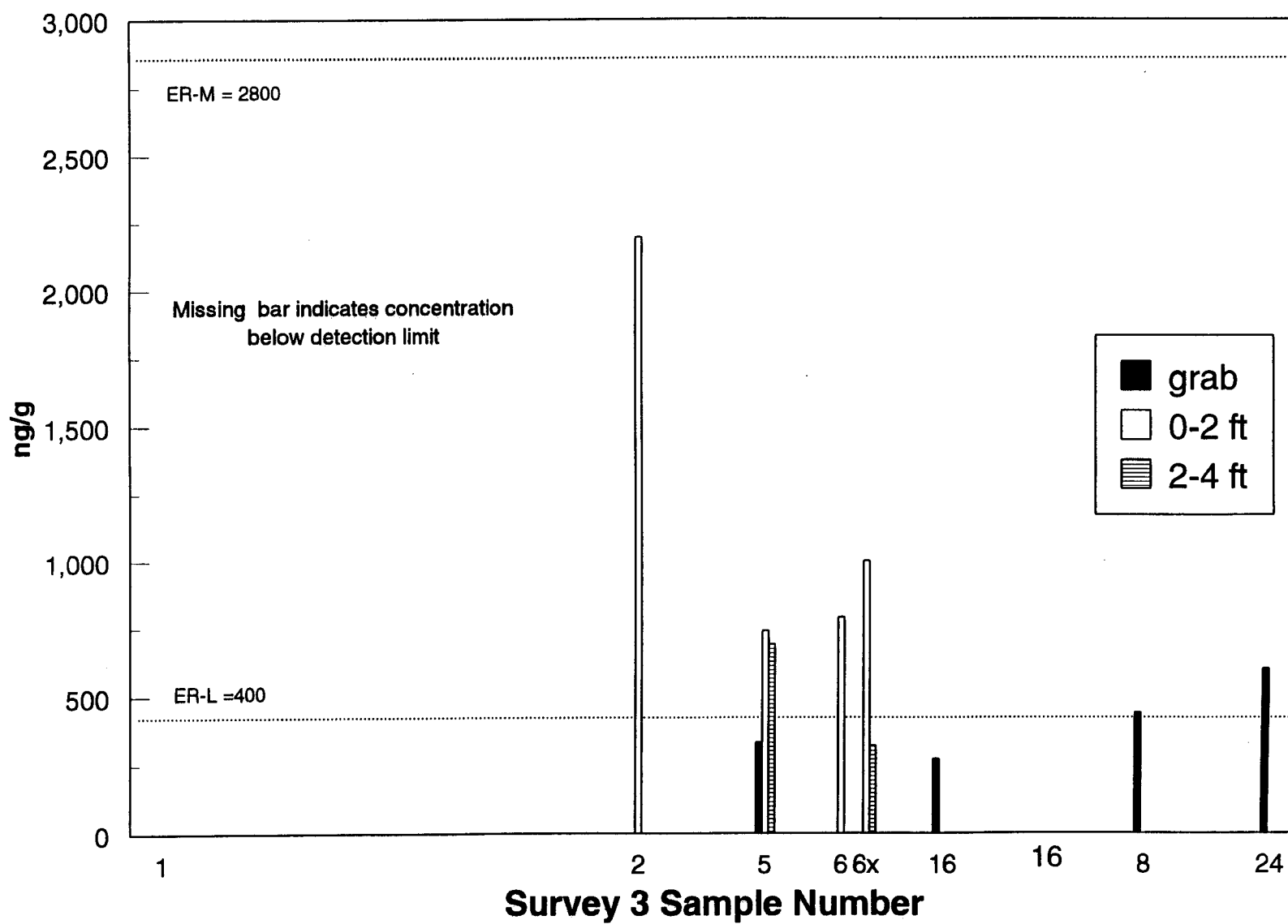
**Figure 3.18a Survey 1 Benzo(a)pyrene Concentration vs. NOAA Guidelines**

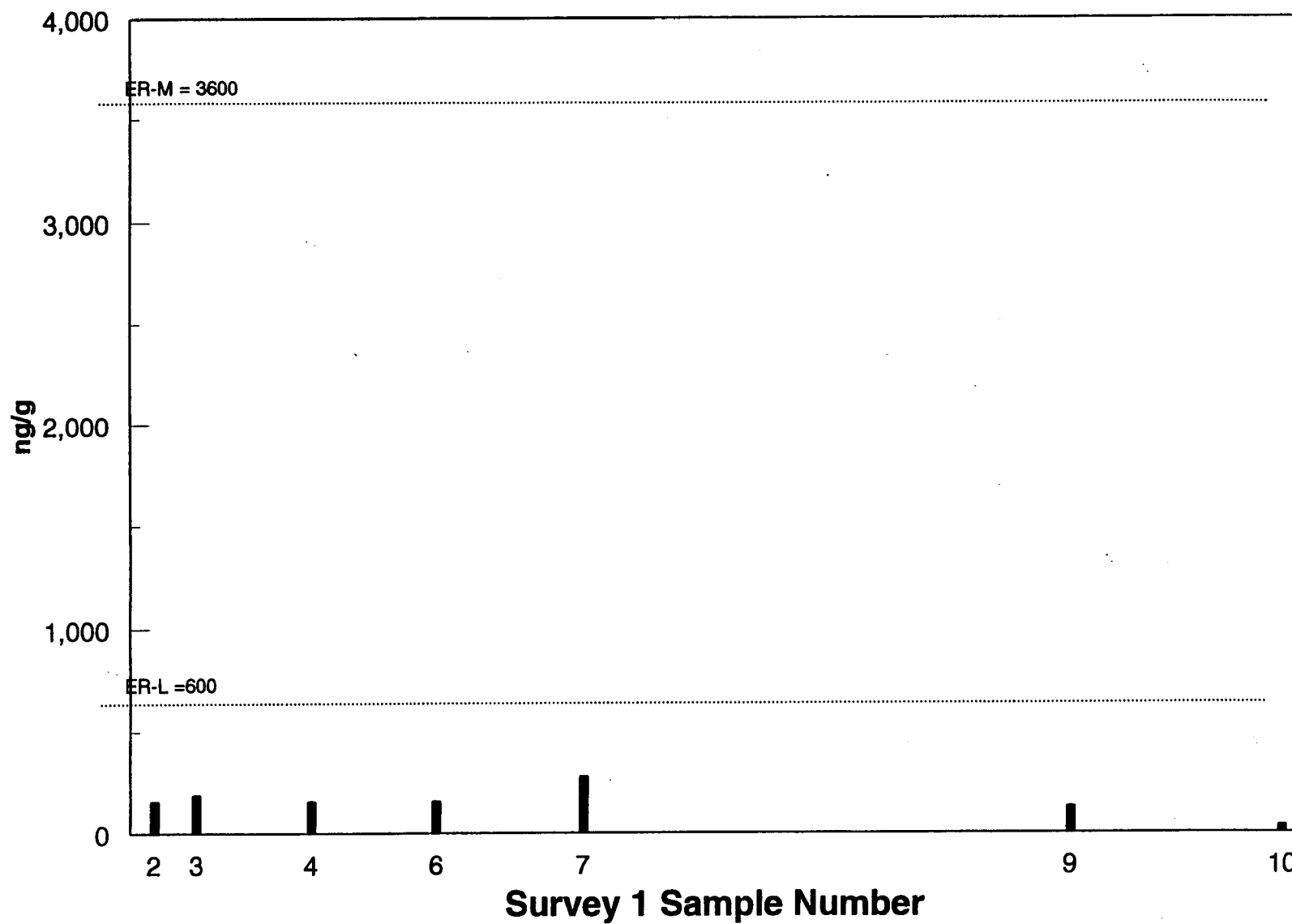


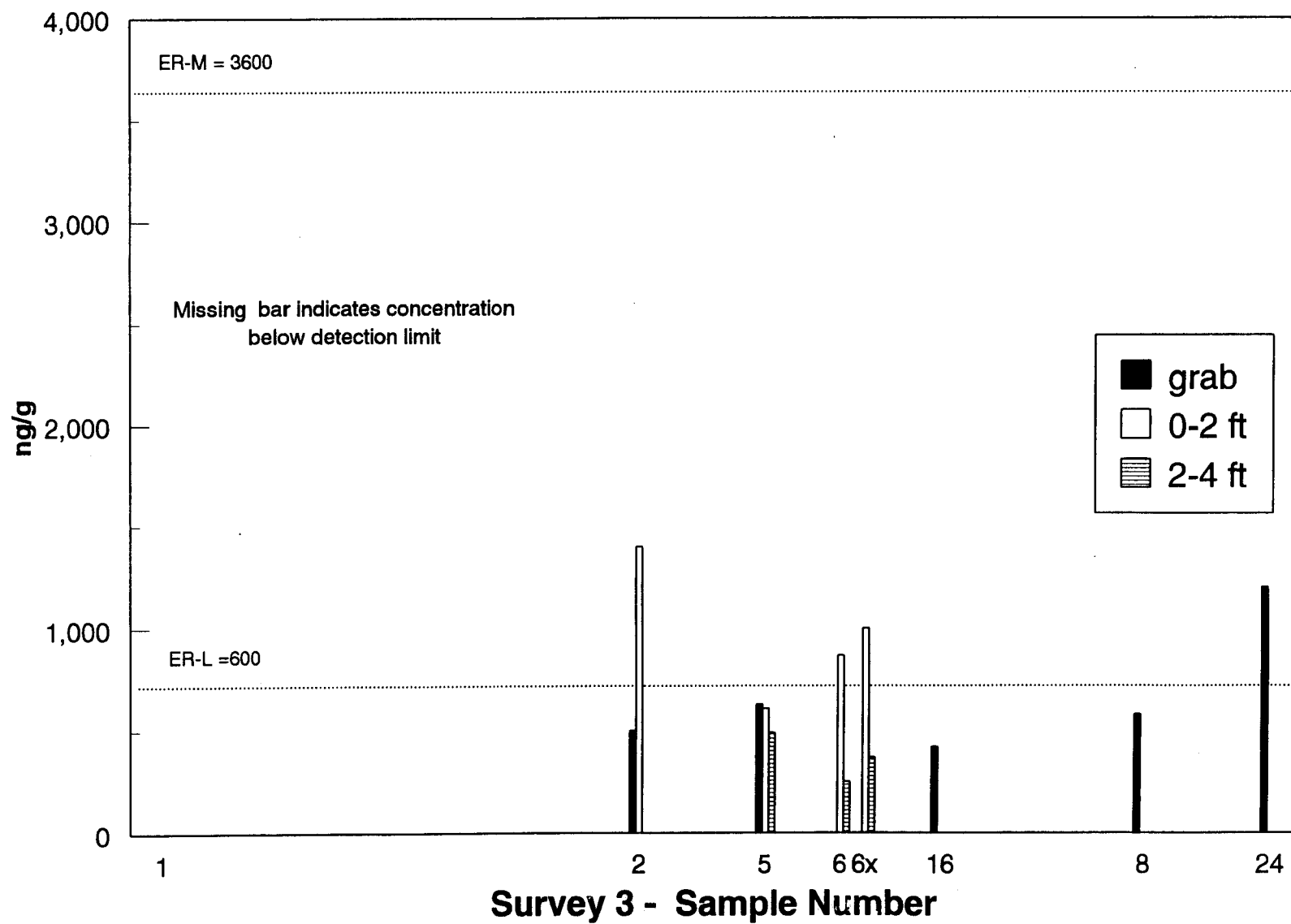
**Figure 3.18b Survey 3 Benzo(a)pyrene Concentration vs. NOAA Guidelines**

**Figure 3.19a Survey 1 Chrysene Concentration vs. NOAA Guidelines**

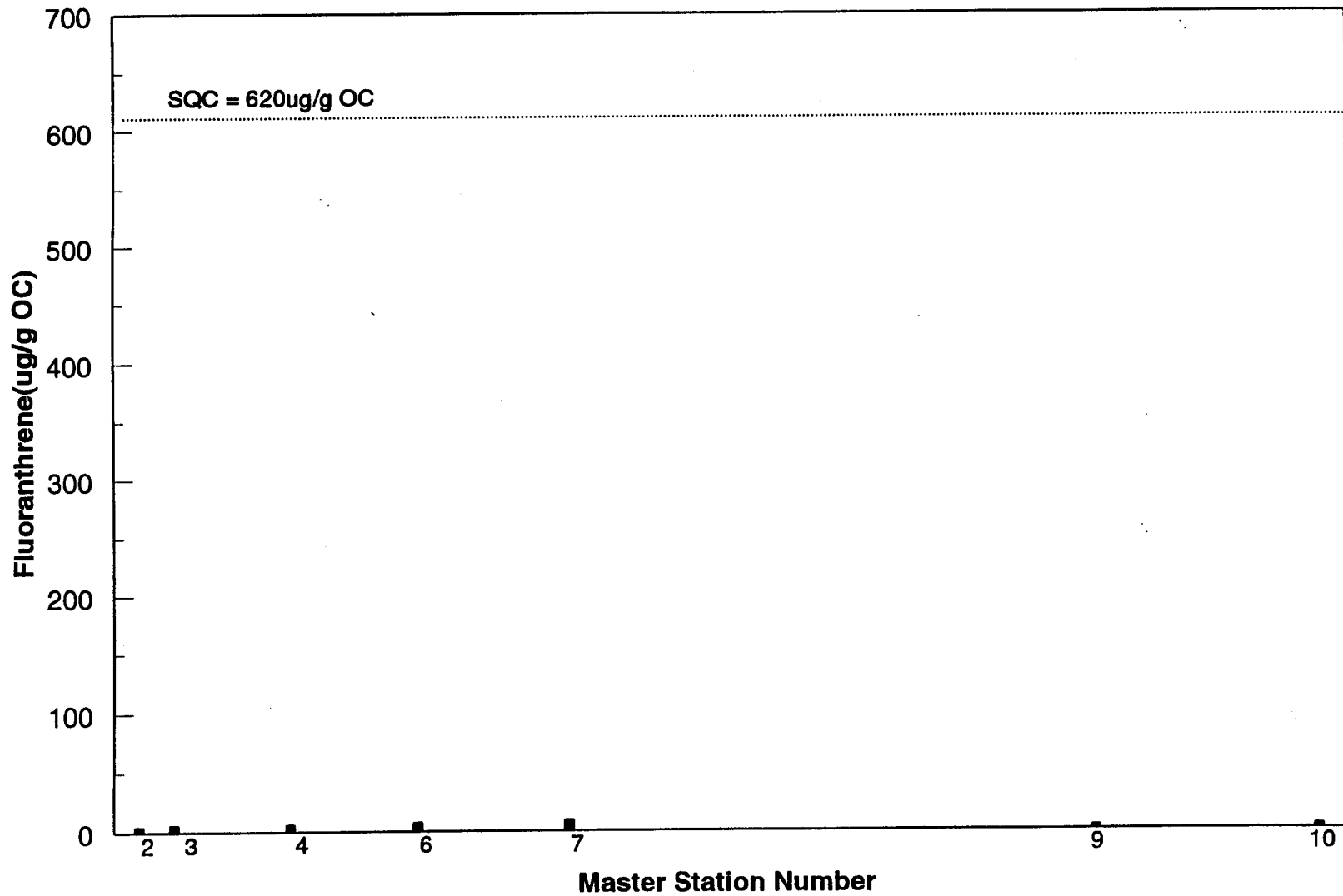


**Figure 3.19b Survey 3 Chrysene Concentration vs. NOAA Guidelines**

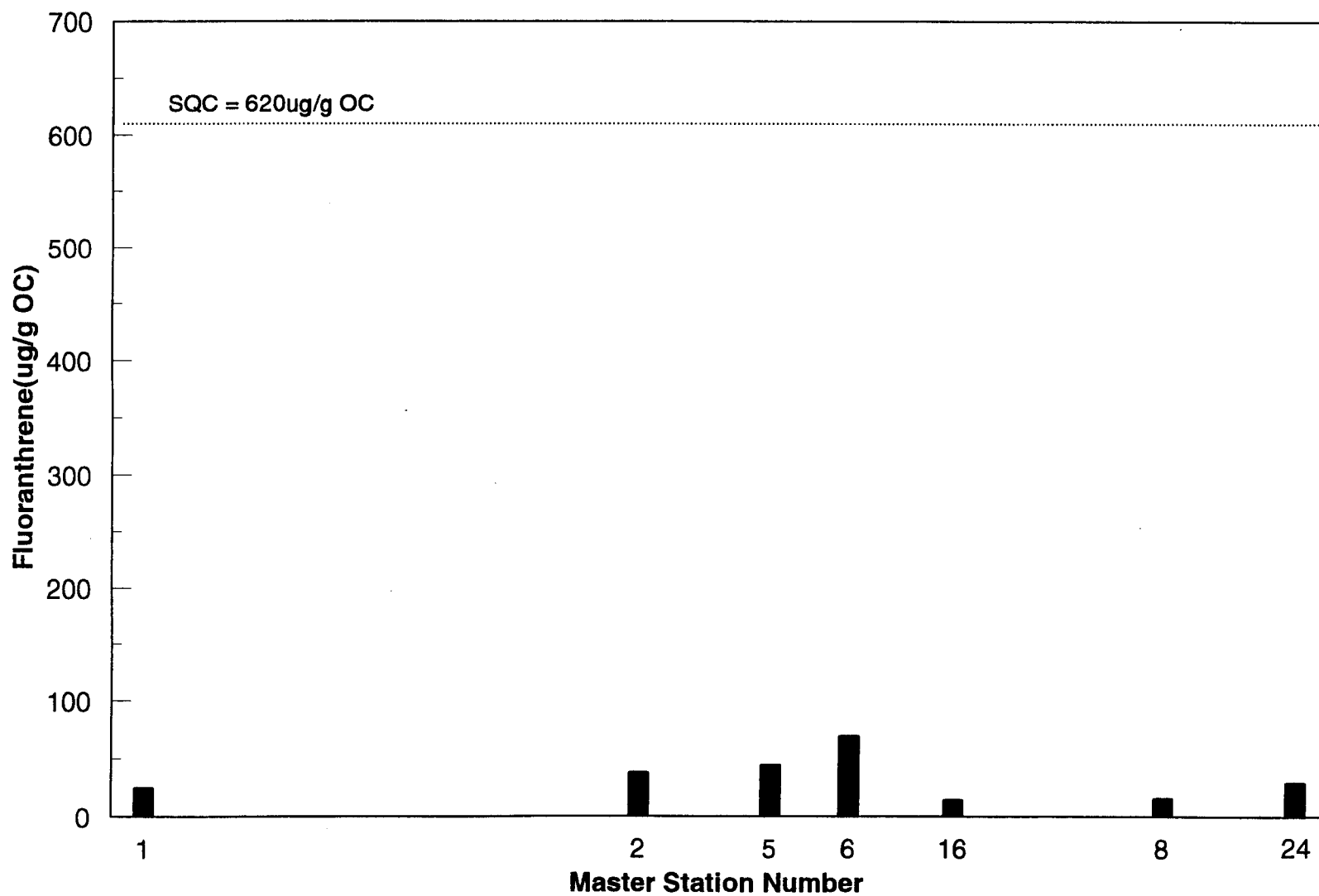
**Figure 3.20a Survey 1 Fluoranthene Concentration vs. NOAA Guidelines**

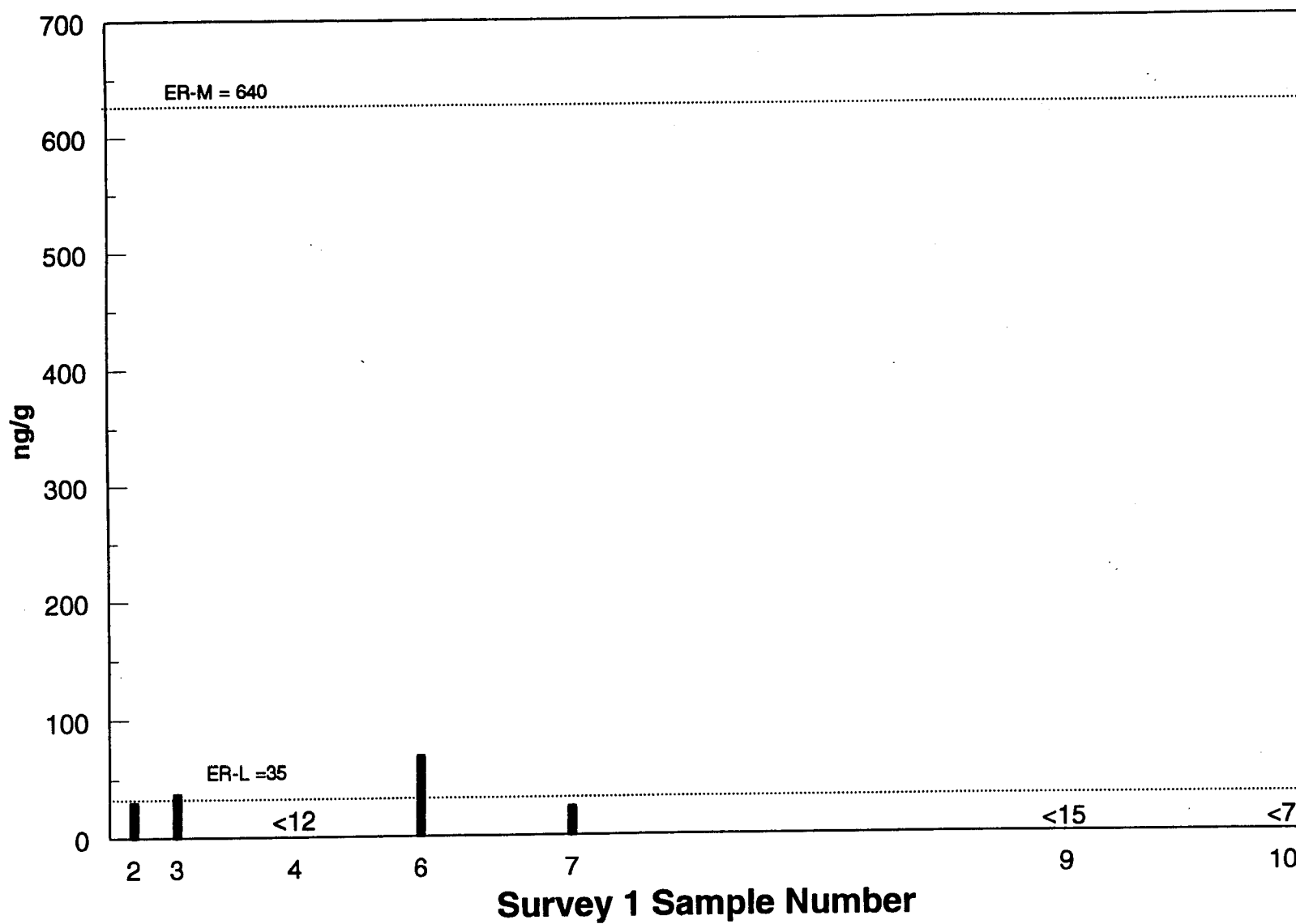
**Figure 3.20b Survey 3 Fluoranthene Concentration vs. NOAA Guidelines**

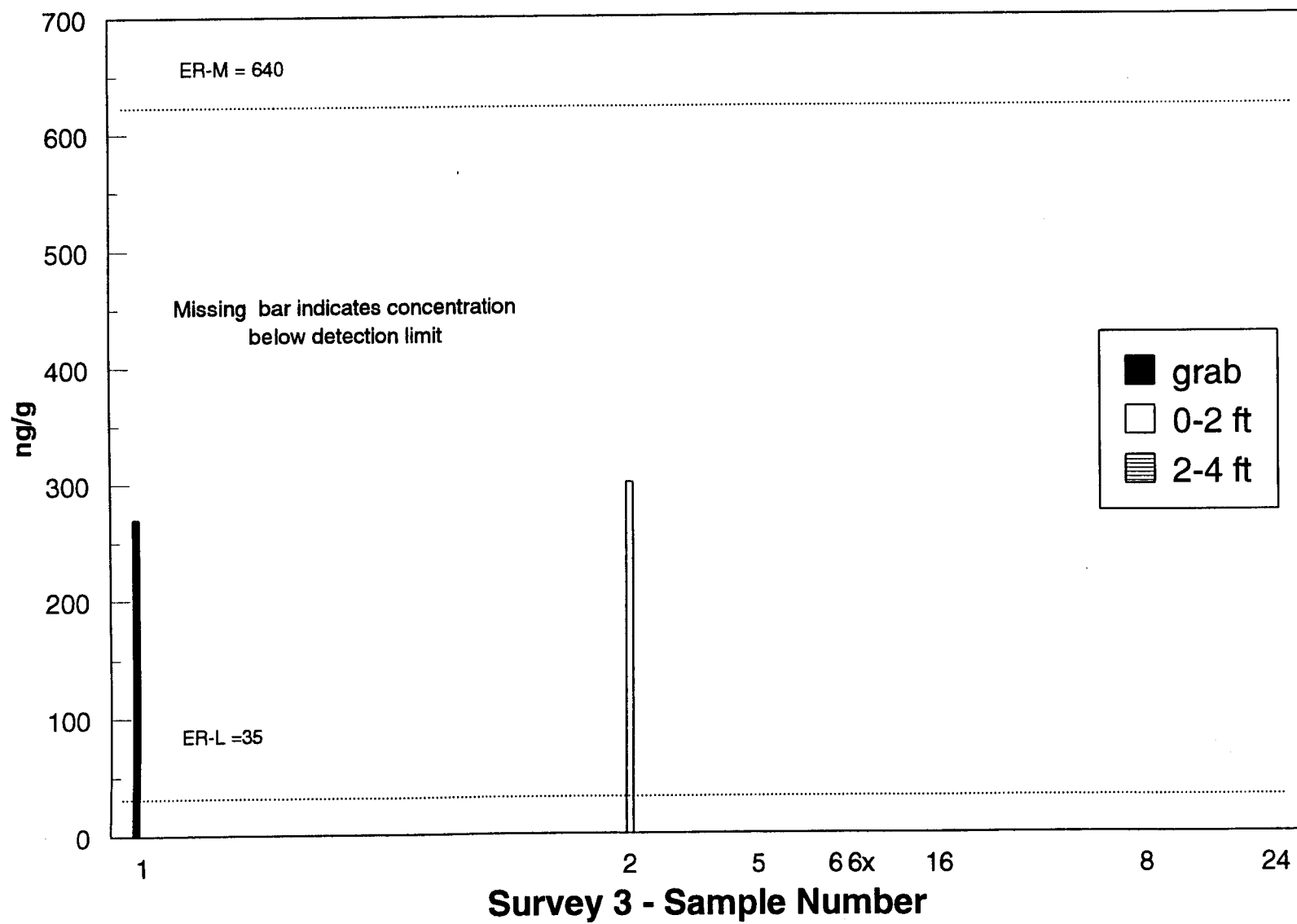
**Figure 3.20c Survey 1 Organic Carbon Normalized Fluoranthrene Concentration vs. EPA Sediment Quality Criteria**

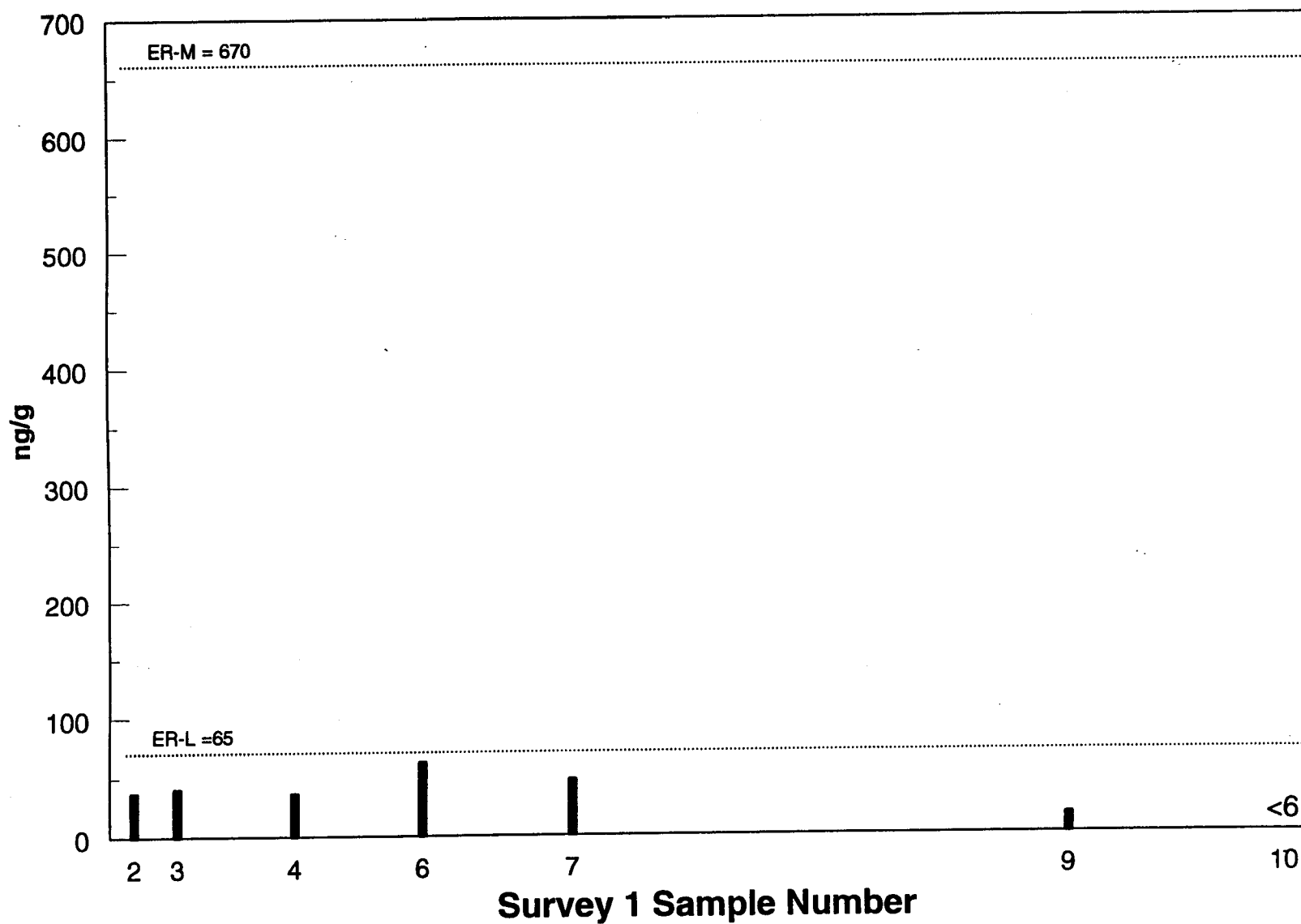


**Figure 3.20d Survey 3 Organic Carbon Normalized Fluoranthene  
vs. EPA Sediment Quality Criteria**



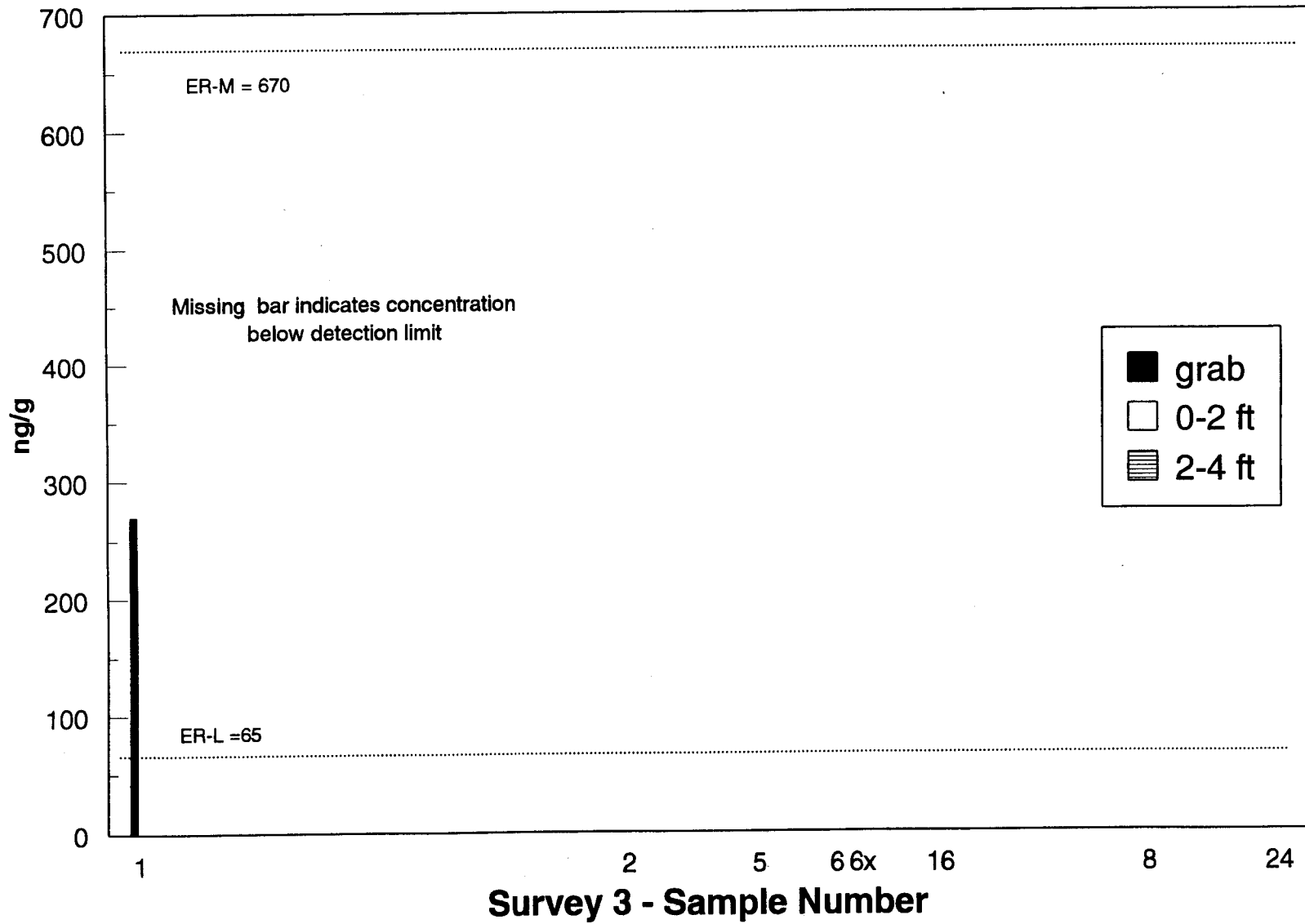
**Figure 3.21a Survey 1 Fluorene Concentration vs. NOAA Guidelines**

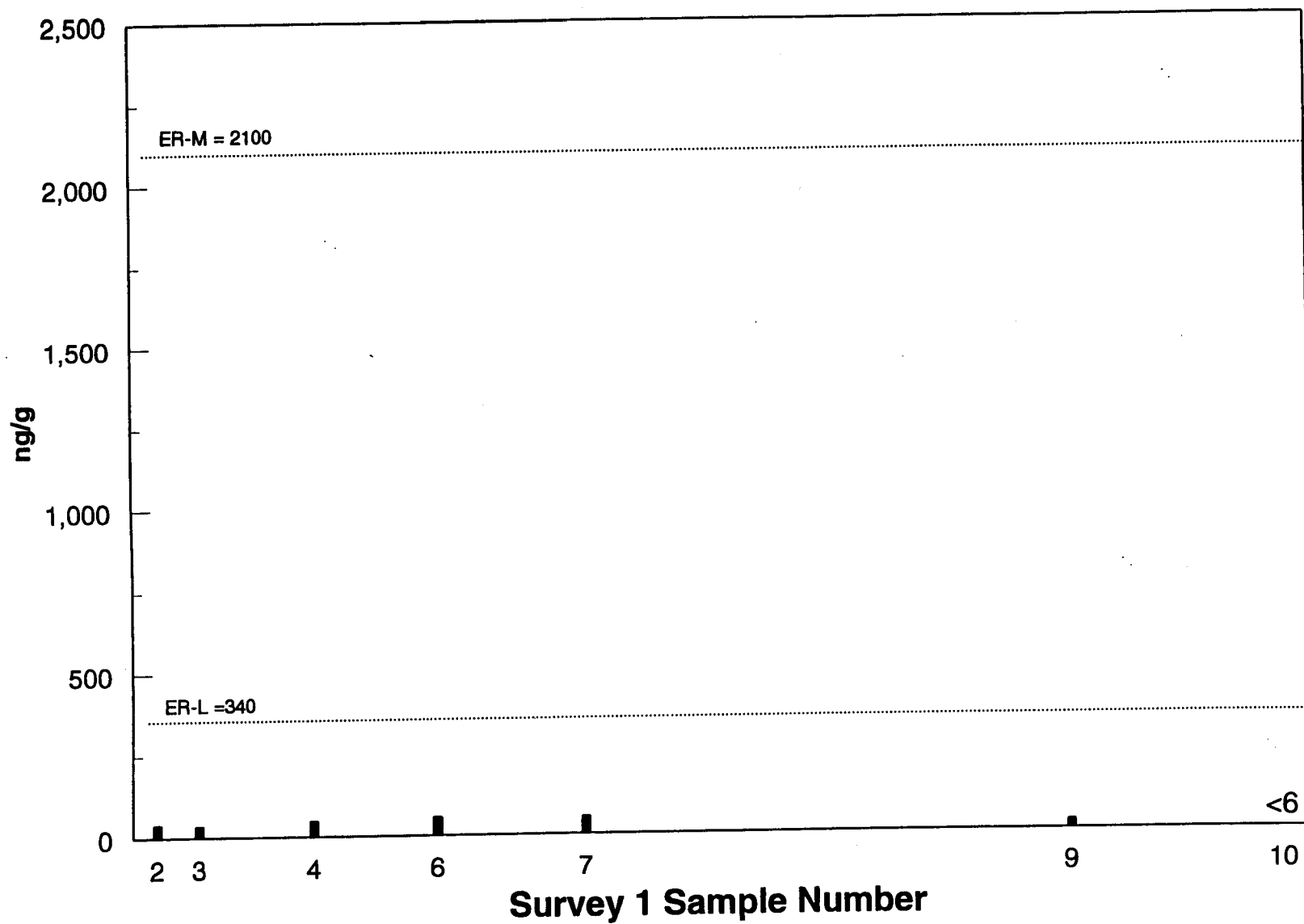
**Figure 3.21b Survey 3 Fluorene Concentration vs. NOAA Guidelines**

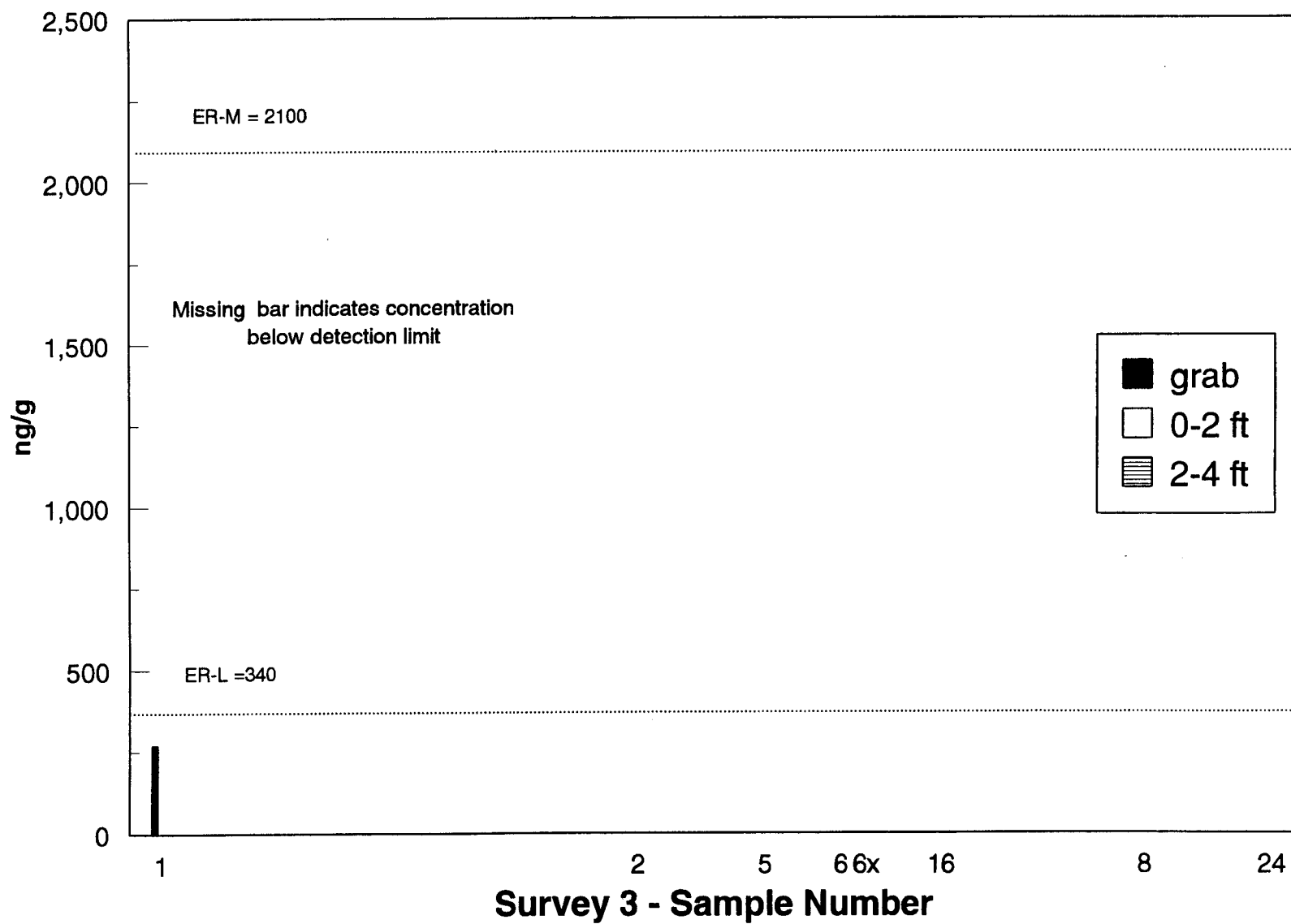
**Figure 3.22a Survey 1 2-Methylnaphthalene Concentration vs. NOAA Guidelines**

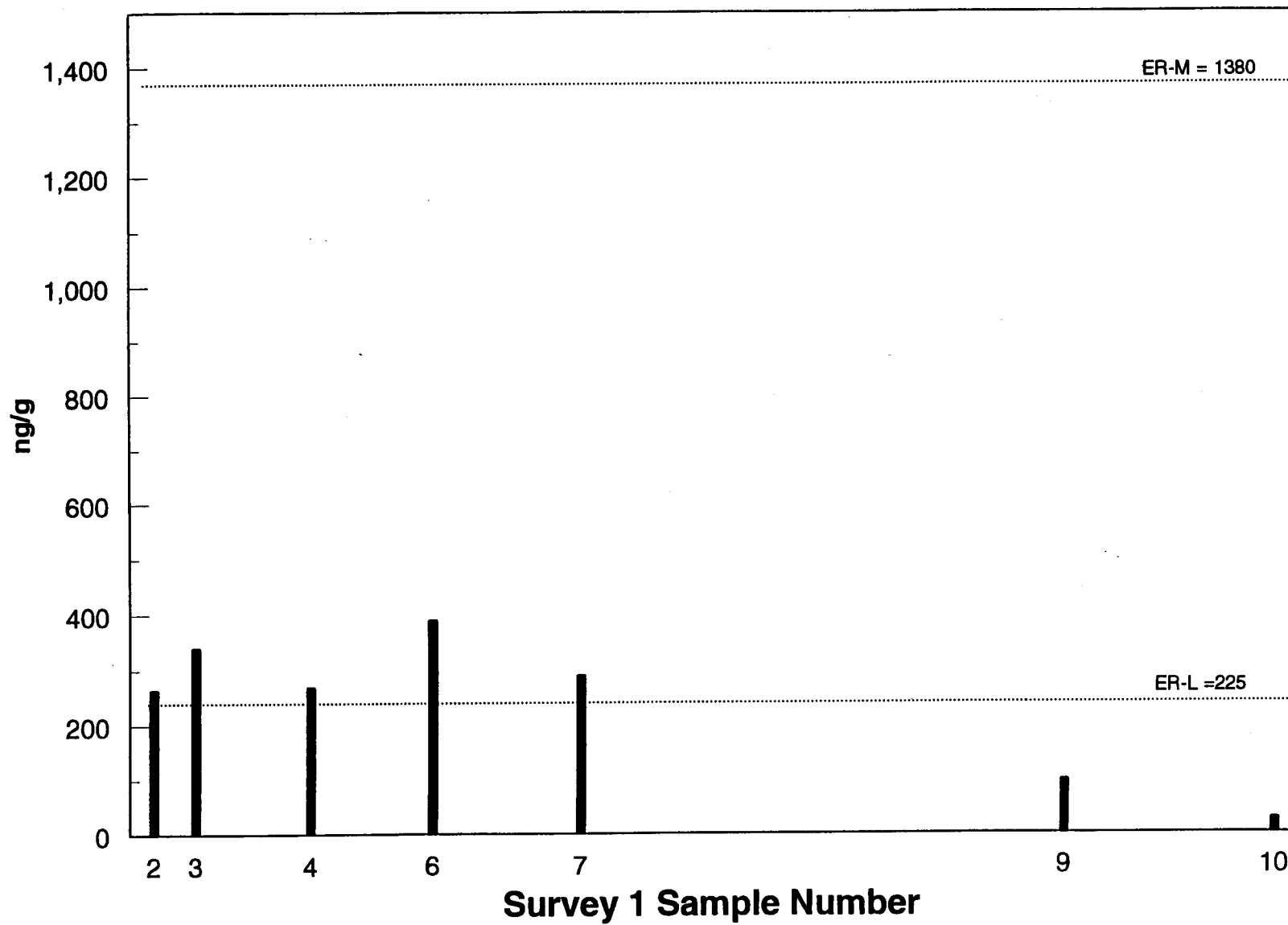


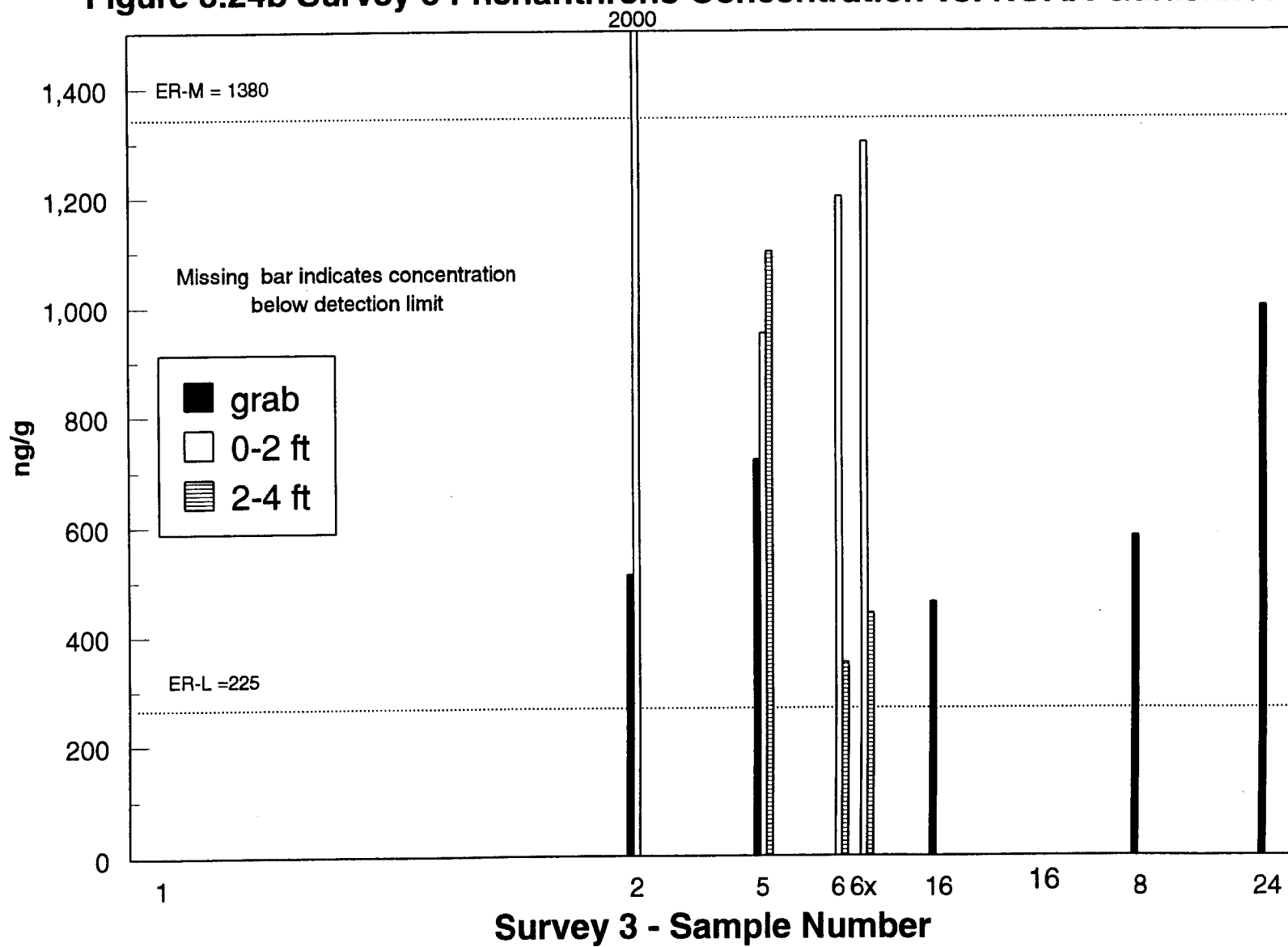
**Figure 3.22b Survey 3 2-Methylnaphthalene Concentration vs. NOAA Guidelines**



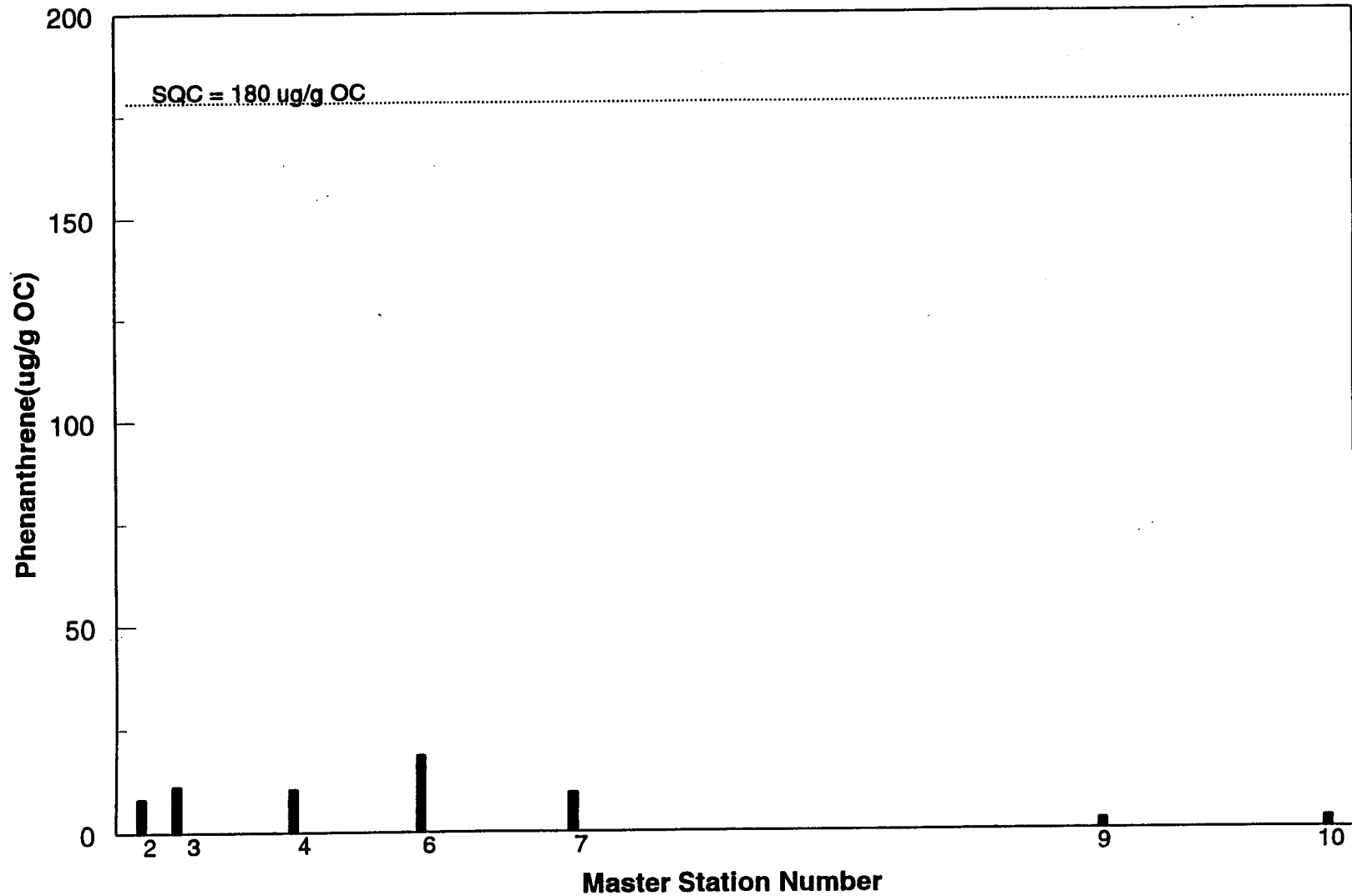
**Figure 3.23a Survey 1 Naphthalene Concentration vs. NOAA Guidelines**

**Figure 3.23b Survey 3 Naphthalene Concentration vs. NOAA Guidelines**

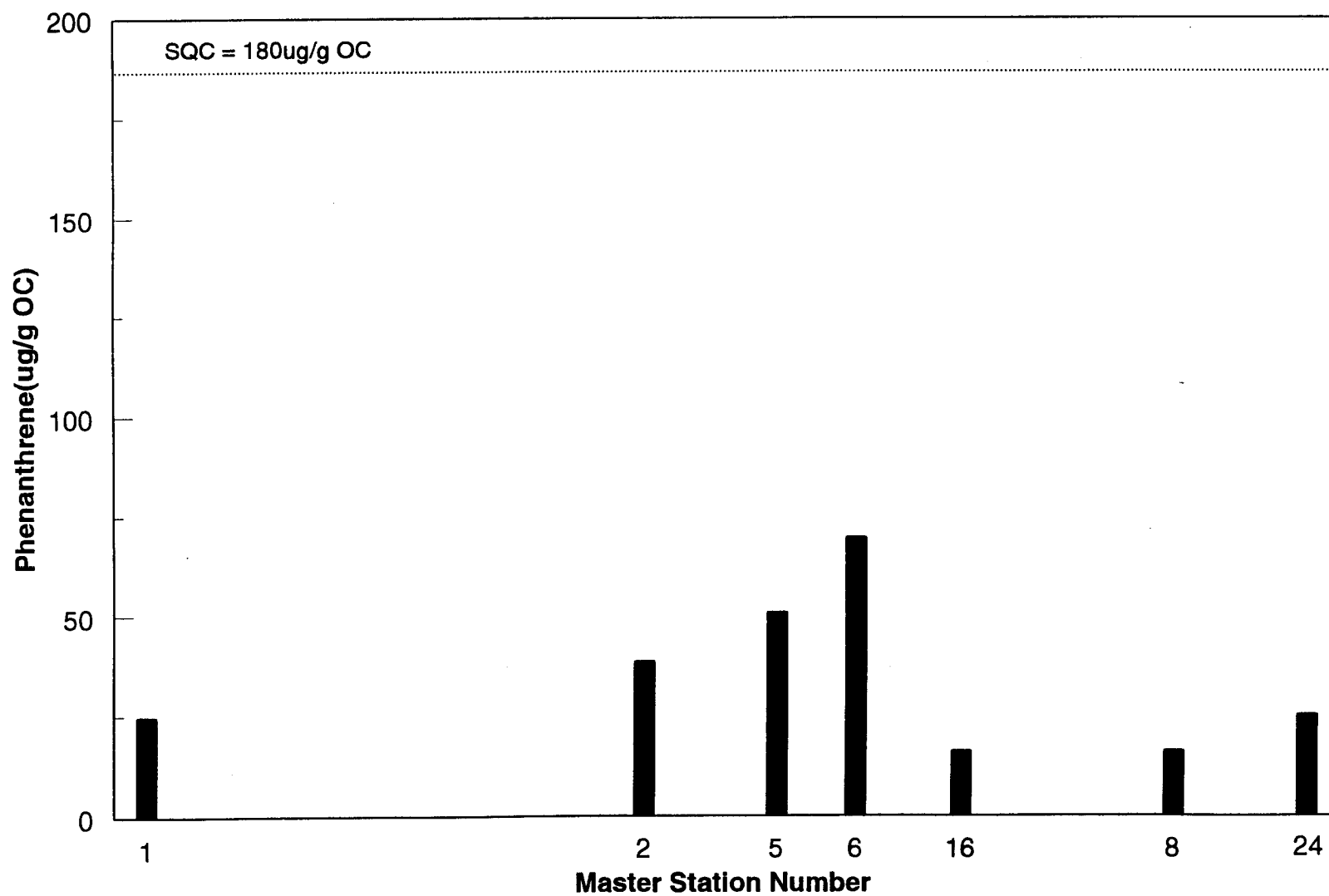
**Figure 3.24a Survey 1 Phenanthrene Concentration vs. NOAA Guidelines**

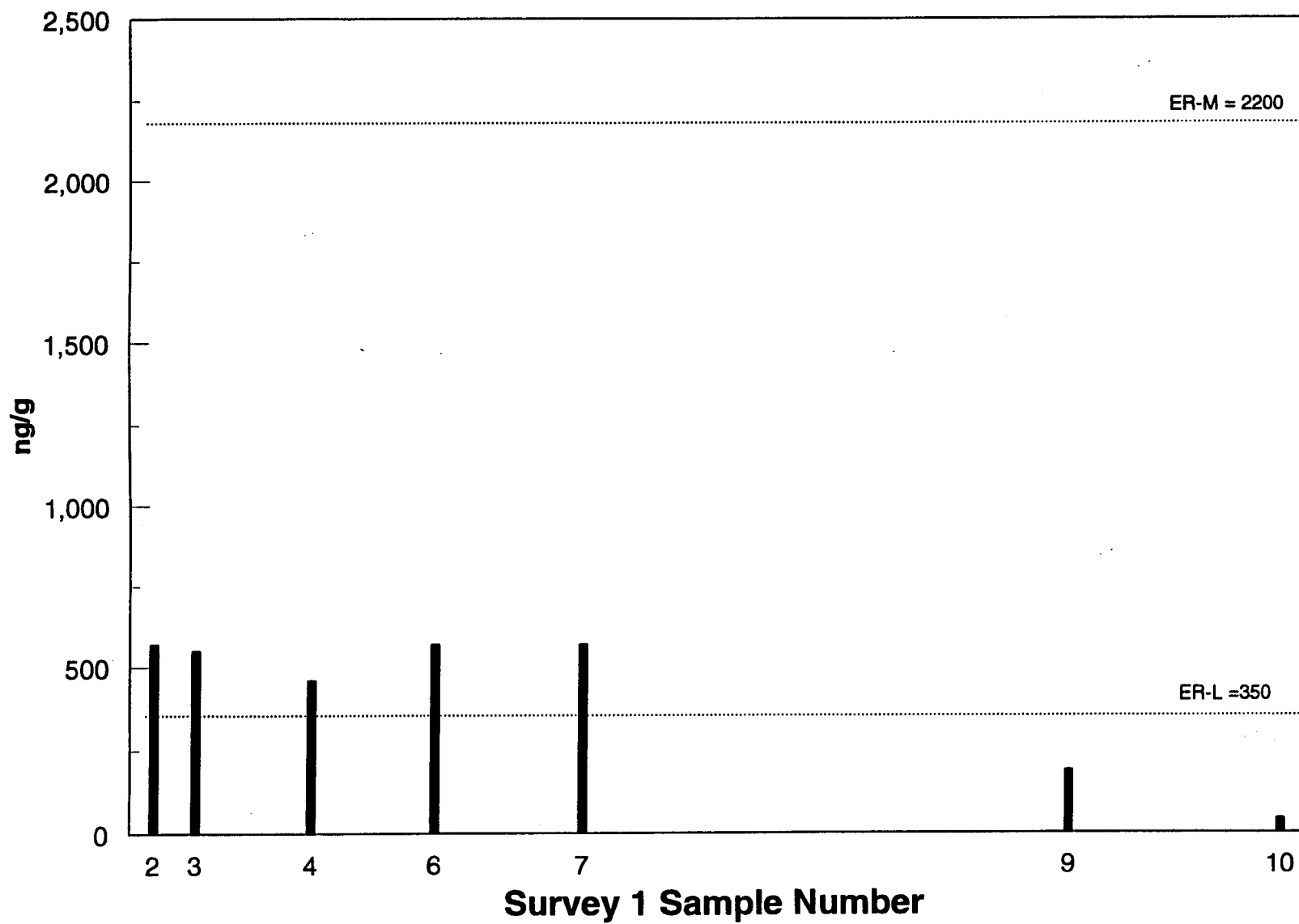
**Figure 3.24b Survey 3 Phenanthrene Concentration vs. NOAA Guidelines**

**Figure 3.24c Survey 1 Organic Carbon Normalized Phenanthrene Concentration vs. EPA Sediment Quality Criteria**

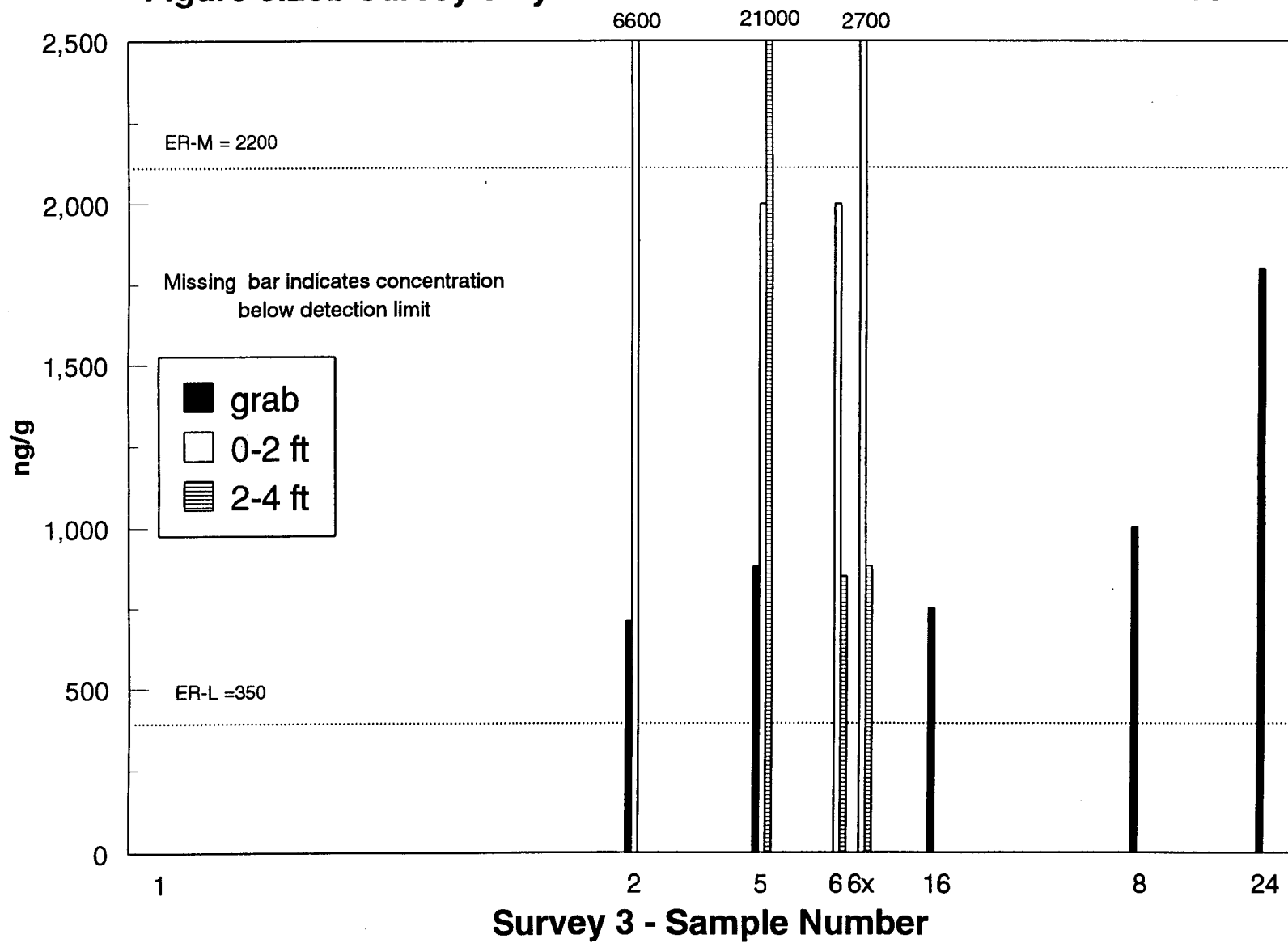


**Figure 3.24d Survey 3 Organic Carbon Normalized Phenanthrene  
vs. EPA Sediment Quality Criteria**

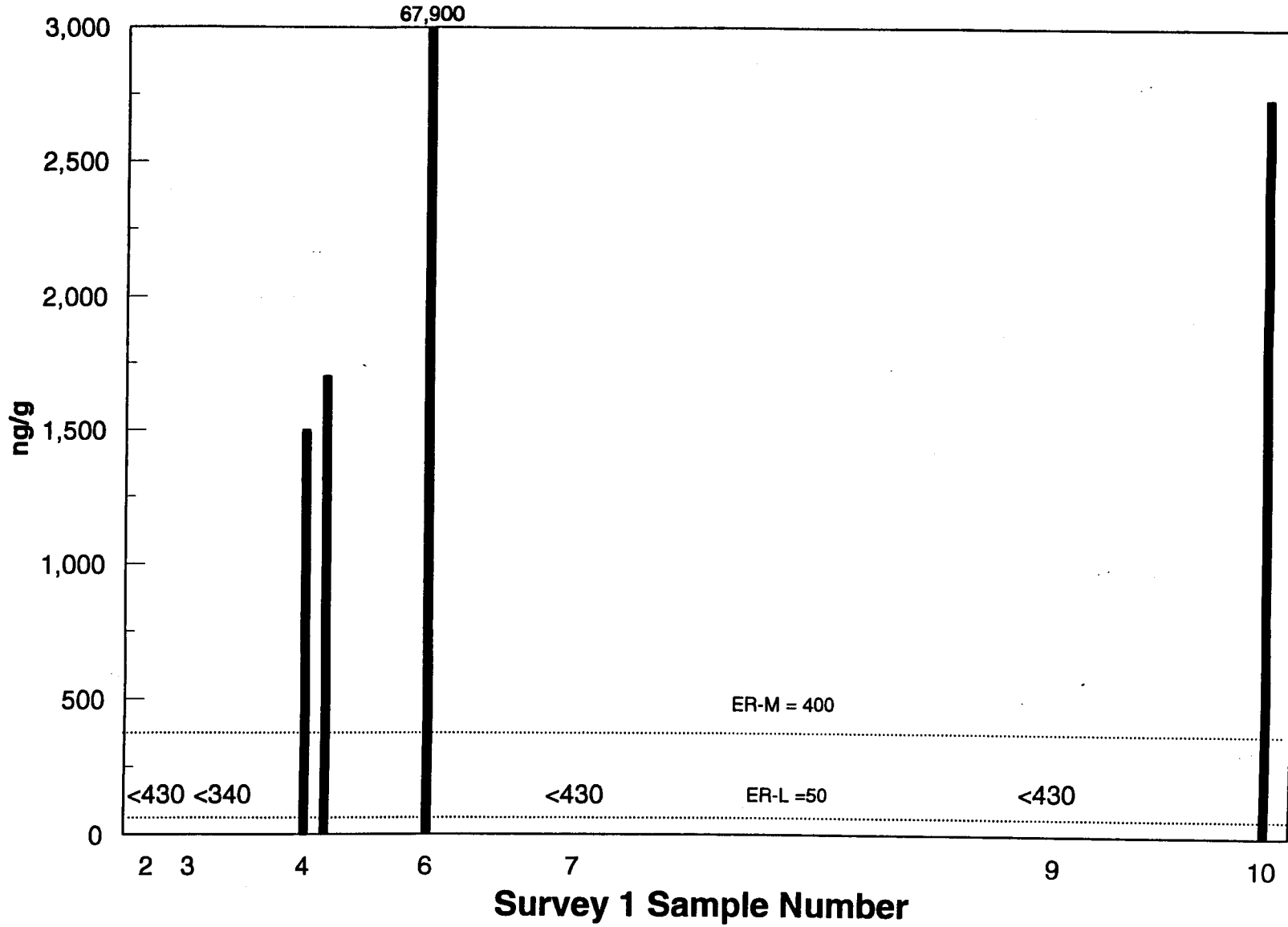


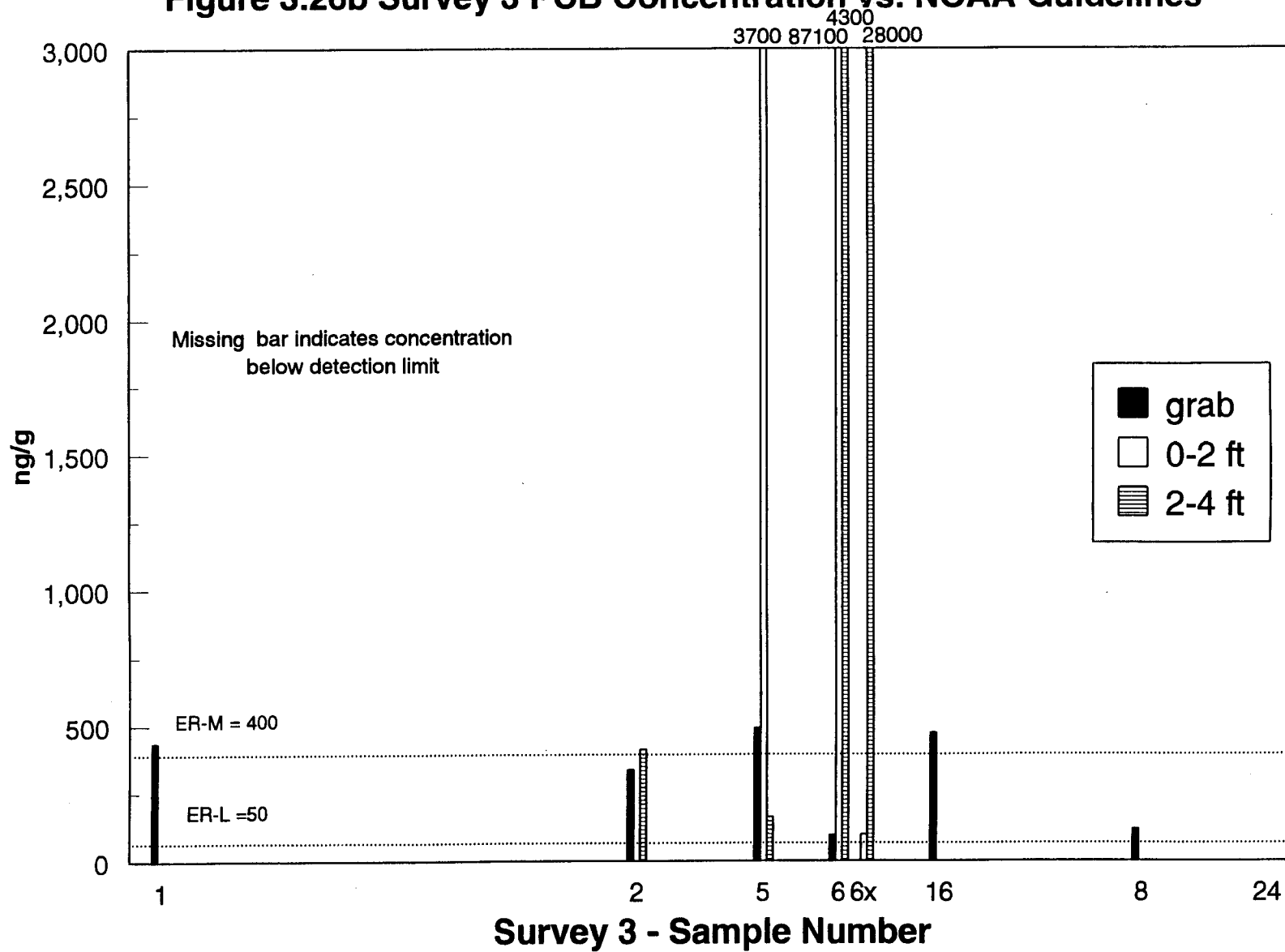
**Figure 3.25a Survey 1 Pyrene Concentration vs. NOAA Guidelines**

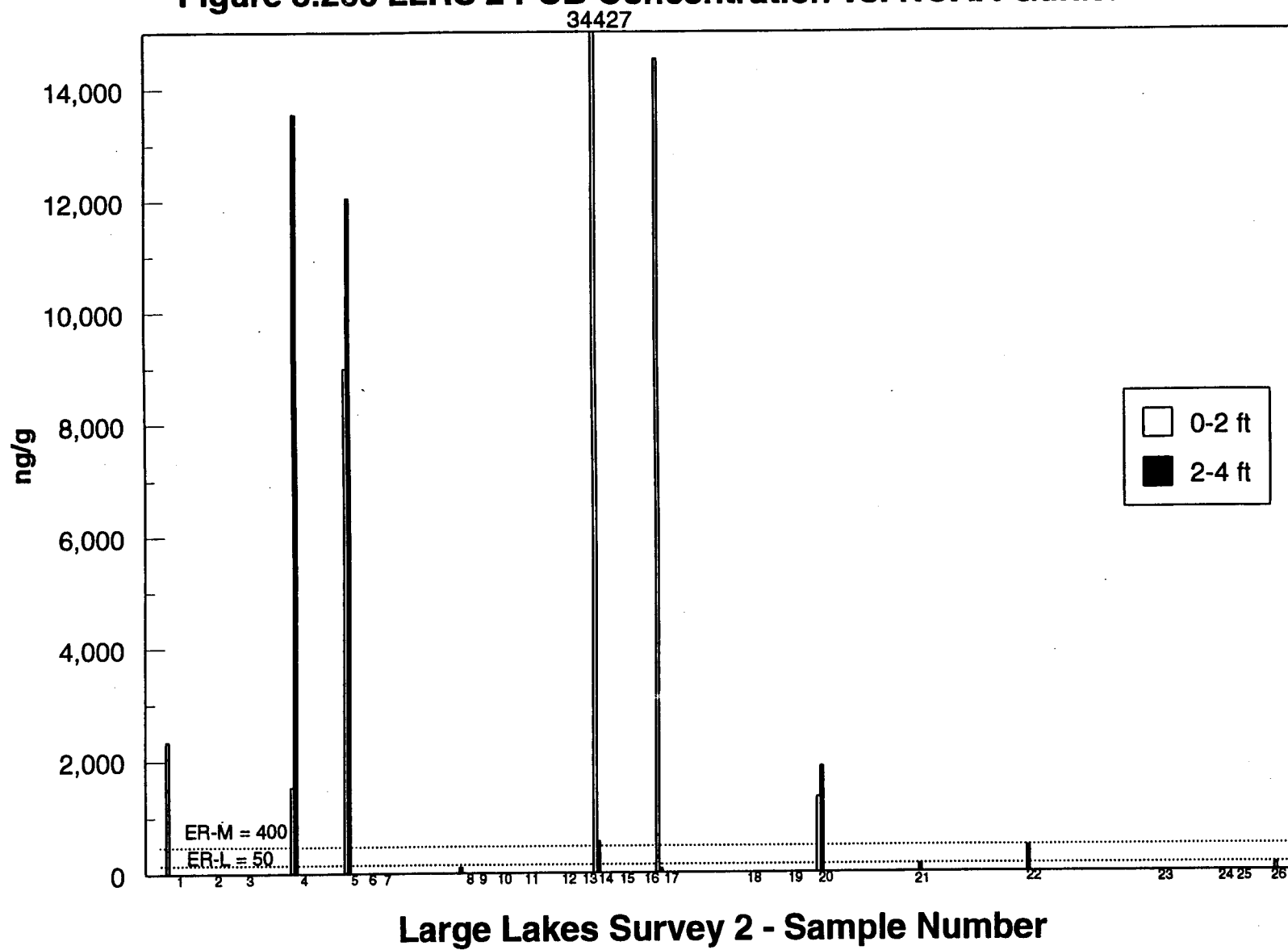


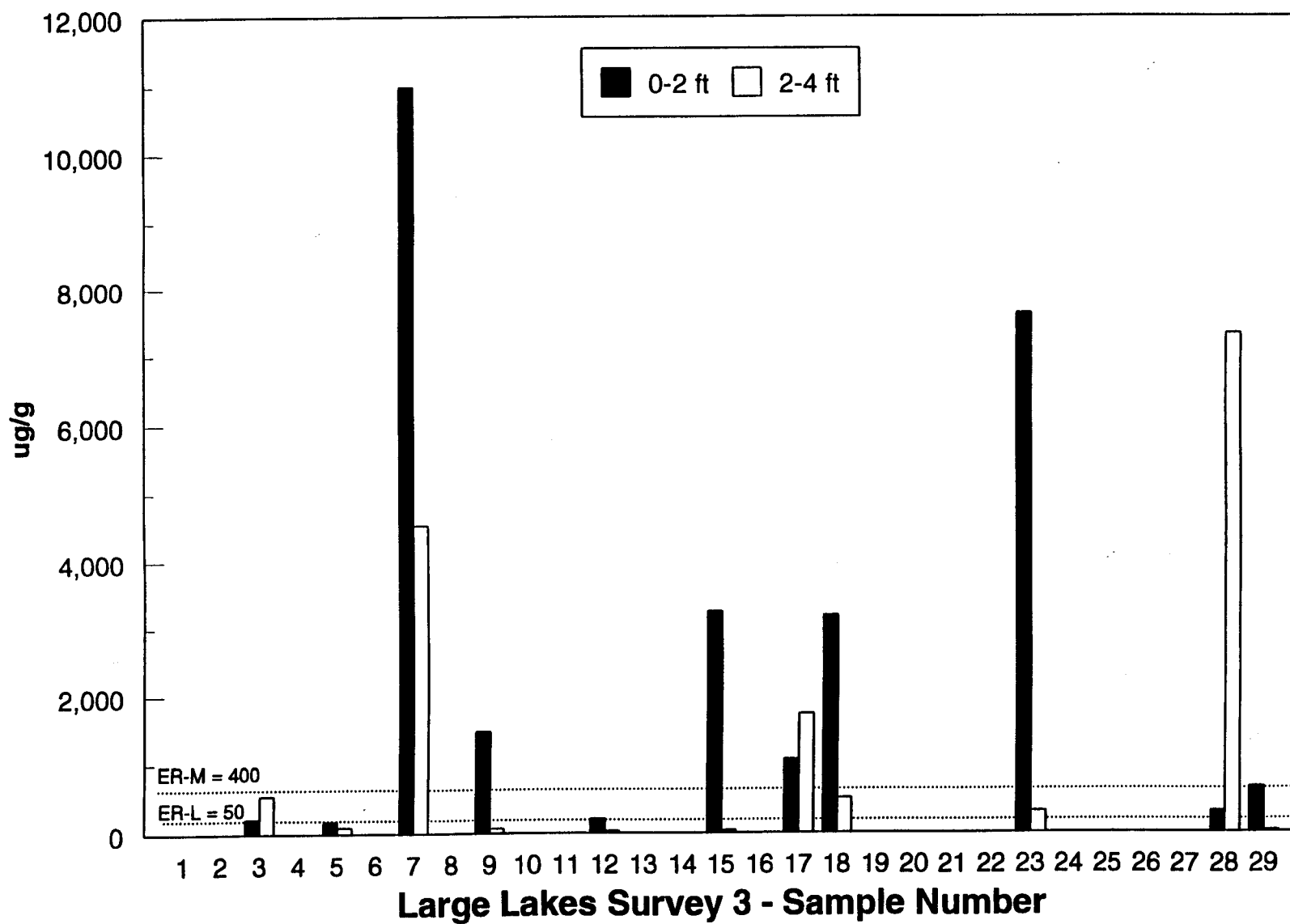
**Figure 3.25b Survey 3 Pyrene Concentration vs. NOAA Guidelines**

**Figure 3.26a Survey 1 PCB Concentration vs. NOAA Guidelines**

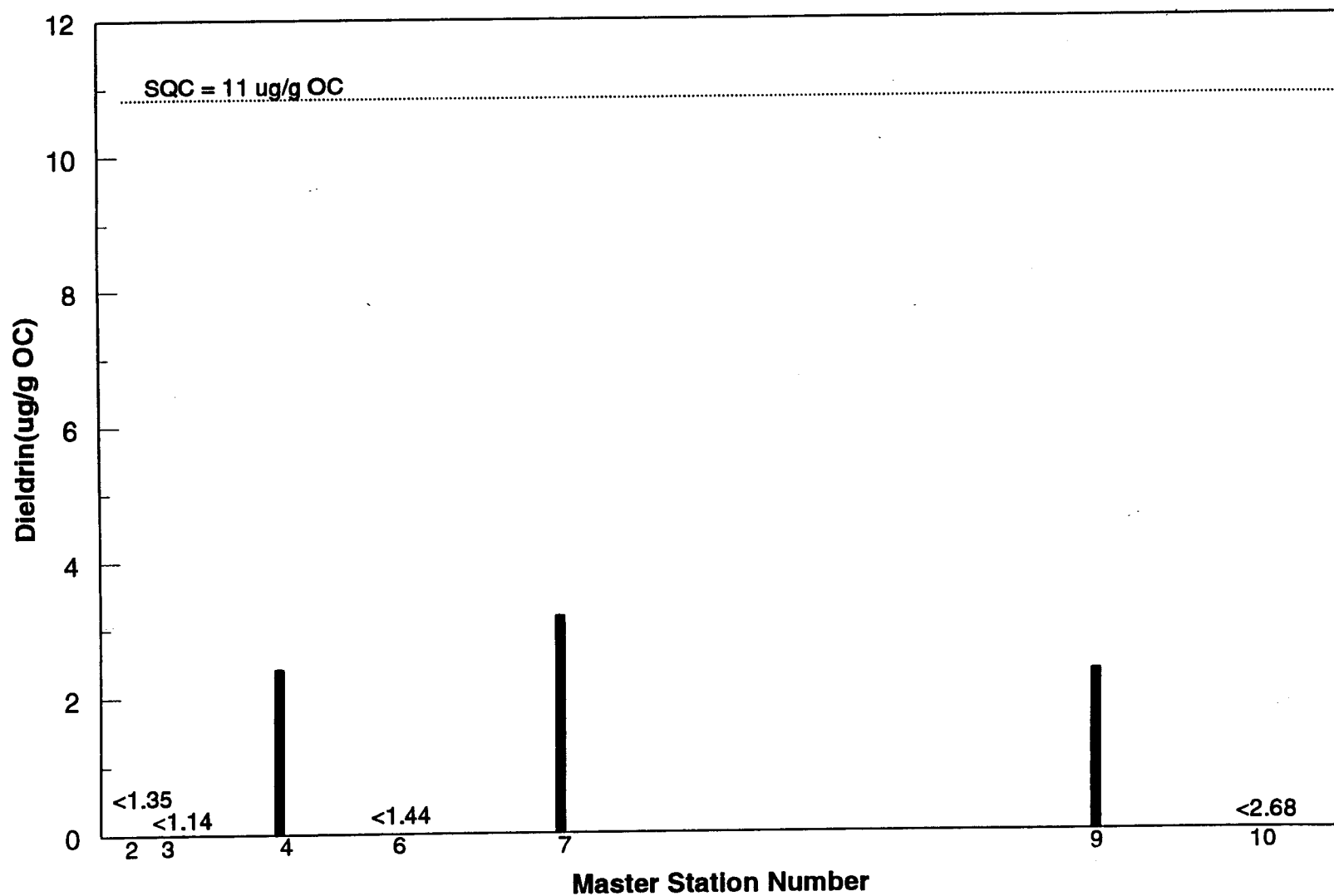


**Figure 3.26b Survey 3 PCB Concentration vs. NOAA Guidelines**

**Figure 3.26c LLRS 2 PCB Concentration vs. NOAA Guidelines**

**Figure 3.26d LLRS 3 PCB Concentration vs. NOAA Guidelines**

**Figure 3.27a Survey 1 Organic Carbon Normalized Dieldrin Concentration vs. EPA Sediment Quality Criteria**



## 4. CONCLUSIONS

This report summarizes the results from four sediment sampling surveys performed in the Saginaw River Area of Concern (AOC). This section presents several preliminary conclusions based on examination of the data resulting from the survey.

### 4.1 Metals

The only available guideline numbers for metals were taken from the NOAA Status and Trends guidelines document (Long and Morgan, 1990). Comparison of bulk sediment concentrations of arsenic, cadmium, copper, lead, mercury, nickel, silver and zinc indicate that zinc, nickel and chromium pose the highest potential risk for impacts to biota in the Saginaw River.

The areas where metal contamination of sediment occurred most significantly is in the intensive sampling zone, near the Bay City Wastewater Treatment Plant and in the southeast area of the zone. The location just upstream of the intensive sample area (near the Grand Trunk Railroad) also contained high metals concentrations. The metals contamination in these areas generally occurred in the shallow core samples (around the 0-2 foot depth).

### 4.2 Organic Chemicals

Based on the NOAA guideline numbers, total PCBs is the organic pollutant that poses the greatest risk in contaminated sediment in the Saginaw River AOC. On average, the total PCB concentration at a site ranged from five to 20 higher than the NOAA ER-M guideline. Other organics that on average came close to exceeding, the NOAA ER-M include the PAHs phenanthrene and pyrene (based on Survey 1 and 3 data only).

The high PCB concentrations generally occurred within the intensive sampling zone near the Bay City Wastewater Treatment Plant and in the southeast area. High concentrations were also detected in core samples taken about 1 mile downstream of the intensive sampling zone.

Examination of the Survey 1 and 3 sediment data under the EPA endorsed EqP-based criteria and the NOAA guidelines indicate two slightly differing sets of conclusions. The examination of carbon normalized data for fluoranthene and phenanthrene (the two PAHs for which EqP-based criteria are available and that were sampled in Surveys 1 and 3) indicate that neither chemical should be considered as a potential source for adverse biological effects in the Saginaw River. This differs in that there were samples that did exceed the NOAA ER-M values for each chemical. Most of the carbon normalized concentrations for phenanthrene and fluoranthene are less than one half of the criteria value considered to be protective of sensitive biota. For both of these contaminants the peak normalized concentration is found at the location near the Bay City Wastewater Treatment Plant.

## 5. REFERENCES

APHA (American Public Health Association), American Water Works Association and Water Pollution Control Federation. 1975. **Standard method for the examination of water and wastewater**, 14th ed. American Public Health Association, Washington, D.C.

Bloom, N. 1989. **Determination of picogram levels of methylmercury by aqueous phase ethylation, followed by cryogenic gas chromatography with cold vapor atomic fluorescence detection.** Canada Journal of Fish. Aquatic Sci. 46(7):1131-1140.

Bloom and Creclius. 1983. **Determination of mercury in seawater at sub-nanogram per liter levels.** Mar. Chem. 14:49-59.

Brandon, D.L., C.R. Lee, J.G. Skogerboe, J.W. Simmers, and H.E. Tatem. 1989. **Information Summary Area of Concern: Saginaw River, Michigan.** Miscellaneous Paper D-89-xx, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brannon, J.M., D. Gunnison, D.E. Averett, J.L. Martin, R.L. Chen, and R.F. Athow, Jr.. 1989. **Analyses of Impacts of Bottom Sediments From Grand Calumet River and Indiana Harbor Canal on Water Quality.** Miscellaneous Paper D-89-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Cutter, G.A. and T.J. Oattes, 1987. **Determination of dissolved sulfide and sedimentary sulfur speciation using gas chromatography and photoionization detection.** Anal. Chem. 59:717.

Guigne', J.Y., N. Rukavina, P.H. Hunt, and J.S. Ford. 1991. **An Acoustic Parametric Array for Measuring the Thickness and Stratigraphy of Contaminated Sediments.** J. Great Lakes Res., 17(1):120-131.

Filkins, J.C., V.E. Smith, J.E. Rathburn, and S.G. Rood. 1993. **ARCS Toxicity/Chemistry Work Group Sediment Assessment Guidance Document (Chapters 3-5).** U.S. Environmental Protection Agency, Environmental Research Laboratory - Duluth, Large Lakes and Rivers Research Branch, Grosse Island, MI.

International Joint Commission. 1987. **Report on Great Lakes Water Quality. Appendix A. Progress in Developing Remedial Action Plans for Areas of Concern in the Great Lakes Basin.** Report to the International Joint Commission Great Lakes Water Quality Board, Windsor, Ontario.

Lee, C.R., D.L. Brandon, J.W. Simmers, H.E. Tatem, and J.G. Skogerboe. 1989. **Information Summary Area of Concern: Buffalo River, New York.** Miscellaneous Paper EL-89-xx, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Long, E.R. and L.G. Morgan, 1990. **The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.** National Oceanic and Atmospheric Administration, Seattle, Washington.



- Nielson, K.K. and R.W. Sanders. 1983. Multielement analysis of unweighed biological and geological samples using backscatter and fundamental parameters. *Adv. X-ray Anal.* 26:385-390.
- Plumb, R. 1981. **Procedures for Handling and Chemical Analysis of Sediment and Water Samples.** U.S. Army Corps of Engineers, Vicksburg, MS. Technical Report EPA/CE-81-1.
- Thurston et al. 1974. **Aqueous ammonia equilibrium calculations.** Technical Report No. 74-1 (MSU-FBL TR 74-1). Fisheries Bioassay Laboratory, Montana State University, Bozeman, MT, 18 pp.
- U.S. Environmental Protection Agency (USEPA). 1993a. **Biological and Chemical Assessment of Contaminated Great Lakes Sediment.** EPA 905-R93-006. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.
- U.S. Environmental Protection Agency (USEPA). 1993b. **Sediment Quality Criteria for the Protection of Benthic Organisms: Acenaphthene.** U.S. Environmental Protection Agency, Health and Ecological Criteria Division, Washington, DC.
- U.S. Environmental Protection Agency (USEPA). 1993c. **Sediment Quality Criteria for the Protection of Benthic Organisms: Dieldrin.** U.S. Environmental Protection Agency, Health and Ecological Criteria Division, Washington, DC.
- U.S. Environmental Protection Agency (USEPA). 1993d. **Sediment Quality Criteria for the Protection of Benthic Organisms: Endrin.** U.S. Environmental Protection Agency, Health and Ecological Criteria Division, Washington, DC.
- U.S. Environmental Protection Agency (USEPA). 1993e. **Sediment Quality Criteria for the Protection of Benthic Organisms: Fluoranthene.** U.S. Environmental Protection Agency, Health and Ecological Criteria Division, Washington, DC.
- U.S. Environmental Protection Agency (USEPA). 1993f. **Sediment Quality Criteria for the Protection of Benthic Organisms: Phenanthrene.** U.S. Environmental Protection Agency, Health and Ecological Criteria Division, Washington, DC.
- U.S. Environmental Protection Agency (USEPA). 1992. **Sediment Classification Methods Compendium.** U.S. Environmental Protection Agency, Office of Water, Washington, DC.
- U.S. Environmental Protection Agency (USEPA). 1990. **Method 200.4. Sample preparation procedure for spectrochemical analyses of total elements in sediments. Version 1.0.** Environmental Monitoring Systems Laboratory, Office of Research and Development, USEPA, Cincinnati, OH.
- U.S. Environmental Protection Agency (USEPA). 1986. **Test methods for evaluating solid waste: physical/chemical methods.** 3rd Ed. SW-846, USEPA, Washington, D.C.

**APPENDIX A**

**SAGINAW RIVER**  
**ARCS SEDIMENT DATA TABLES**

# SAGINAW RIVER - DATA TABLES

Table	Parameter	Table	Parameter
Table A-1 Survey 1 - Inorganics	Ag	Table A-4 (continued)	Endrin Ketone
	As		Endrin Aldehyde
	Cd		Lindane
	Cr		Toxaphene
	Cu	Table A-5 Survey 1 - Dioxins and Furans	24 parameters
	Fe		
	Hg	Table A-6 Survey 3 - Inorganics	Ag
	Mn		As
	Ni		Cd
	Pb		Cr
	Zn		Cu
	Dibutyltin		Hg
	Methylbutyltin		Mn
	Tributyltin		Ni
	Methyl mercury		Pb
	AVS		Se
	Solids		Zn
	TOC		AVS
			Solids
			Methyl mercury
			TOC
			Dibutyltin
			Methylbutyltin
			Tributyltin
Table A-2 Survey 1 - PAHs	Anthracene	Table A-7 Survey 3 - PAHs	Acenaphthene
	Benz(a)anthracene		Anthracene
	Benzo(a)pyrene		Benz(a)anthracene
	Benzo(b)fluoranthene		Benzo(a)pyrene
	Benzo(g,h,i)perylene		Benzo(b)fluoranthene
	Benzo(k)fluoranthene		Benzo(g,h,i)perylene
	Butyl benzyl phthalate		Benzo(k)fluoranthene
	Chrysene		Bis(2-ethylhexyl)phthalate
	1,4-Dichlorobenzene		Butyl benzyl phthalate
	Bis(2-ethylhexyl)phthalate		Chrysene
	Dibenzofuran		1,2-Dichlorobenzene
	Dimethyl phthalate		1,3-Dichlorobenzene
	Fluoranthene		1,4-Dichlorobenzene
	Fluorene		Dibenzofuran
	Indeno(1,2,3-cd)pyrene		Dimethyl phthalate
	2-Methylnaphthalene		Fluoranthene
	Naphthalene		Fluorene
	Di-n-octyl phthalate		Indeno(1,2,3-cd)pyrene
	Phenanthrene		2-Methylnaphthalene
	Pyrene		Naphthalene
Table A-3 Survey 1 - PCBs	1016, 1221, 1232, 1242, 1248, 1254, 1260	Table A-8 Survey 3 - PCBs	Di-n-octyl phthalate
			Phenanthrene
Table A-4 Survey 1 - Pesticides	Aldrin		Pyrene
	Dieldrin	Table A-9 Survey 3 - Pesticides	1242, 1254, 1260
	Endrin		Aldrin
	Endosulfan(alpha)		Chlordane-alpha
	Endosulfan(beta)		Chlordane-gamma
	Endosulfan Sulfate		A-BHC
	Heptachlor Epoxide		B-BHC
	Heptachlor		C-BHC
	DDD		Lindane
	DDE		DDD
	DDT		DDE
	A-BHC		
	B-BHC		
	C-BHC		
	Chlordane-alpha		
	Chlordane-gamma		
	Methoxychlor		

# SAGINAW RIVER - DATA TABLES

Table	Parameter
Table A-9 (continued)	DDT
	Dieldrin
	Endrin
	Endrin Aldehyde
	Endrin Ketone
	Endosulfan (alpha)
	Endosulfan (beta)
	Endosulfan Sulfate
	Heptachlor Epoxide
	HEptachlor
	Methoxychlor
	Toxaphene
Table A-10 Survey 3 - Dioxins and Furans	25 parameters
Table A-11 Large Lakes Survey 2	Cd
	Cr
	Cu
	Fe
	Ni
	Pb
	Zn
	Dry Fraction
	Moist Fraction
	Volume Fraction
	Ammonia
	Bromine
	Chlorine
	Conductivity
	Extractable Residue
	Mircotox
	pH
	TOC
	Grain size - Five levels
Table A-12 Large Lakes Survey 3	Cd
	Cr
	Cu
	Fe
	Ni
	Pb
	Zn
	Dry Fraction
	Moist Fraction
	Volume Fraction
	Ammonia
	Bromine
	Chlorine
	Conductivity
	Extractable Residue
	Microtox
	pH
	TOC
	Grain Size - Five levels
Table A-13 Large Lakes - PCBs	Congener Total

**TABLE A-1 SAGINAW RIVER SURVEY 1 - INORGANICS**

<b>SAMPLE ID</b>	<b>AG (ug/g)</b>	<b>AS (ug/g)</b>	<b>CD (ug/g)</b>	<b>CR (ug/g)</b>	<b>CU (ug/g)</b>	<b>FE (%)</b>	<b>HG (ug/g)</b>	<b>MN (ug/g)</b>	<b>NI (ug/g)</b>	<b>PB (ug/g)</b>	<b>ZN (ug/g)</b>
SR10201G100	0.57	12.7	1	74	49	2.8	0.162	671	35	56	386
SR10201G200	0.58	13.6	0.93	84	46	2.8	0.141	672	38	58	389
SR10301G100	0.61	13.1	0.92	90	49	3.1	0.166	819	37	55	352
SR10401G100	0.52	10.9	0.99	73	45	2.6	0.152	661	35	51	326
SR10601G100	1.5	3.6	10	319	187	1.5	0.283	334	157	86	381
SR10701G100	0.63	16	1	84	51	3.2	0.177	817	43	58	372
SR10901G100	0.25	9.1	0.57	46	31	1.8	0.111	374	28	39	319
SR11001G100	0.11	5.1	0.16	40	16	1.2	0.048	305	15	19	99

<b>SAMPLE ID</b>	<b>DBT (ng/g)</b>	<b>MBT (ng/g)</b>	<b>TBT (ng/g)</b>	<b>METHYLH</b>	<b>AVS</b>	<b>SOLIDS (%)</b>	<b>TOC (%)</b>
SR10201G100	11	<1.1	20	<0.1	4.93	36	3.17
SR10201G200	14	<1.1	19	<0.1	4.36	37	3.21
SR10301G100	21	<1	15	<0.1	5.99	36	2.99
SR10401G100	7.4	<0.9	14	<0.1	5.6	44	2.57
SR10601G100	10	1.2	6.9	<0.1	15.46	56	2.08
SR10701G100	9	<1.1	12	<0.1	3.61	33	3.02
SR10901G100	5.8	<0.8	8.3	<0.1	5.82	42	3.85
SR11001G100	2.3	<0.6	2.2	<0.1	1.54	64	0.97

**TABLE A-2 SAGINAW RIVER SURVEY 1 - PAHS (ng/g dry wt)**

<b>SAMPLE ID</b>	<b>ANTRACE</b>	<b>BAA</b>	<b>BAP</b>	<b>BBF</b>	<b>BGHIPER</b>	<b>BKFLUOR</b>	<b>BBPH</b>	<b>CHRY</b>	<b>14DCB</b>	<b>BISPH</b>	<b>DBF</b>	<b>DMPH</b>
SR10201	42	140	180	150	190	200	<34	290	47	1700	18	80
SR10201	70	180	240	400	160	220	<51	330	33	2400	22	76
SR10301	66	170	280	220	310	280	1300	400	33	13000	<16	99
SR10401	54	160	260	130	270	300	270	300	47	1900	20	110
SR10601	38	300	210	310	290	400	<25	500	130	4200	38	68
SR10701	30	190	310	320	220	220	240	390	52	3800	<18	77
SR10901	19	64	<13	61	<27	61	<39	120	25	840	<15	21
SR11001	<8	15	<6	<7	<13	<9	<18	24	<4	170	<7	16

<b>SAMPLE ID</b>	<b>FLUORA</b>	<b>FLUORE</b>	<b>INDPYR</b>	<b>2MNAPH</b>	<b>NAPH</b>	<b>DNOPH</b>	<b>PHEN</b>	<b>PYRENE</b>
SR10201	130	27	120	35	34	<36	220	470
SR10201	190	34	110	41	46	54	310	670
SR10301	190	38	220	41	35	2200	340	550
SR10401	160	<12	210	37	48	76	270	460
SR10601	160	69	160	63	55	430	390	570
SR10701	280	25	200	48	53	<49	290	570
SR10901	130	<15	<22	17	27	<42	99	190
SR11001	36	<7	<10	<6	<6	<19	27	44

**TABLE A-3 SAGINAW RIVER SURVEY 1 - PCBS (ng/g dry wt)**

<b>SAMPLE ID</b>	<b>PCB1016</b>	<b>PCB1221</b>	<b>PCB1232</b>	<b>PCB1242</b>	<b>PCB1248</b>	<b>PCB1254</b>	<b>PCB1260</b>
SR10201	<430	<430	<430	<430	<430	<430	<430
SR10301	<340	<340	<340	<340	<340	<340	<340
SR10401	<400	<400	<400	1500	<400	<400	<400
SR10401	<390	<390	<390	<390	<390	<390	<390
SR10401	<390	<390	<390	1700	<390	<390	<390
SR10601	<300	<300	<300	60000	<300	7900	<300
SR10701	<430	<430	<430	<430	<430	<430	<430
SR10901	<430	<430	<430	<430	<430	<430	<430
SR11001	<260	<260	<260	440	<260	2300	<260

**TABLE A-4 SAGINAW RIVER SURVEY 1 - PESTICIDES (ng/g)**

<b>SAMPLE ID</b>	<b>ALDRIN</b>	<b>DIELDRN</b>	<b>ENDRIN</b>	<b>ENDOSULFAN (ALPHA)</b>	<b>ENDOSULFAN (BETA)</b>	<b>ENDOSULFAN SULFATE</b>	<b>HEPTACHLOR EPOXIDE</b>	<b>HEPTACHLOR</b>	<b>DDD</b>	<b>DDE</b>	<b>DDT</b>
SR10201	<43	<43	<43	<43	<43	<43	<43	<43	<43	<43	<43
SR10301	<34	<34	<34	<34	<34	<34	<34	<34	<34	<34	<34
SR10401	<40	62	<40	<40	<40	<40	<40	<40	<40	<40	<40
SR10401	<39	85	<39	<39	120	<39	<39	<39	<39	<39	<39
SR10401	<39	<39	<39	<39	<39	<39	<39	<39	<39	<39	<39
SR10601	360	<30	<30	<30	<30	<30	190	140	<30	140	<30
SR10701	<43	96	45	<43	130	<43	<43	<43	<43	<43	180
SR10901	<43	90	<43	<43	<43	<43	<43	<43	<43	<43	<43
SR11001	<26	<26	<26	<26	<26	<26	<26	<26	<26	<26	<26

<b>SAMPLE ID</b>	<b>A-BHC</b>	<b>B-BHC</b>	<b>C-BHC</b>	<b>CHLORDANE- ALPHA</b>	<b>CHLORDANE- GAMMA</b>	<b>METHOXY CHLOR</b>	<b>ENDRIN KETONE</b>	<b>ENDRIN ALDEHYDE</b>	<b>LINDANE</b>	<b>TOXAFEN</b>
SR10201	<43	<43	<43	<43	<43	<220	<43	<43	<43	<430
SR10301	<34	<34	<34	<34	<34	<170	<34	<34	<34	<340
SR10401	<40	<40	<40	<40	<40	<200	<40	<40	<40	<400
SR10401	<39	<39	<39	<39	<39	<196	<39	<39	<39	<390
SR10401	<39	<39	<39	<39	<39	<200	<39	<39	<39	<390
SR10601	390	<30	<30	<30	140	<150	<30	<30	<30	<300
SR10701	<43	<43	<43	<43	<43	<220	<43	<43	<43	<430
SR10901	<43	<43	<43	<43	<43	<220	<43	<43	<43	<430
SR11001	<26	<26	<26	<26	<26	<130	<26	<26	<26	<260



**TABLE A-5 SAGINAW RIVER SURVEY 1 - DIOXINS AND FURANS (pg/g dry wt)**

SAMPLE ID	1234-678-HPCDD	HPCDD_T	1234-678-HPCDF	1234-789-HPCDF	HPCDF_T	123-478-HXCDD	123-678-HXCDD	123-789-HXCDD	HXCDD_T	123-478-HXCDF	123-678-HXCDF	123-789-HXCDF
SR10201	700	1200	1100	46	2200	7.3	42	17	360	160	37	19
SR10201	1300	2300	1300	57	3000	5.6	69	30	460	180	45	22
SR10301	530	980	770	40	1600	10	32	9.5	270	190	35	17
SR10401	640	1200	1200	63	2300	6.9	39	16	340	880	200	88
SR10601	1100	1900	1900	69	4000	12	100	26	620	400	76	46
SR10701	630	1200	1100	85	1800	8.9	48	20	360	270	61	30
SR10901	300	550	540	26	980	3.3	21	11	200	110	28	13
SR11001	160	300	400	12	770	1.7	11	5.6	98	41	7.4	4.1

SAMPLE ID	234-678-HXCDF	HXCDF_T	OCDD_T	OCDF_T	12378-PECDD	PECDD_T	12378-PECDF	23478-PECDF	PECDF_T	2378-TCDD	TCDD_T	TCDF_T
SR10201	5.5	750	5700	1400	13	74	170	140	820	14	140	1300
SR10201	11	820	14000	2800	14	86	220	160	790	17	140	1300
SR10301	6	680	4100	1100	9.5	60	220	150	790	11	100	1100
SR10401	29	2100	4900	1300	15	73	1800	2500	8700	13	120	22000
SR10601	17	1500	9300	2700	22	120	630	540	2800	38	230	4900
SR10701	6.4	950	5000	1300	17	110	210	200	1000	12	160	1400
SR10901	<3.6	430	2200	610	7.3	50	130	120	650	9.3	94	950
SR11001	<2.3	210	1300	400	4.2	15	34	29	170	5.9	54	320

**TABLE A-6 SAGINAW RIVER SURVEY 3 - INORGANICS**

SAMPLE ID	AG (ug/g)	AS (ug/g)	CD (ug/g)	CR (ug/g)	CU (ug/g)	HG (ug/g)	MN (ug/g)	NI (ug/g)	PB (ug/g)	SE (ug/g)	ZN (ug/g)
Grab Samples											
SR30101G100	0.18	41.1	0.79	42	20.3	0.096	304	18.5	25.2	0.82	69.8
SR30101G200	.	.	.	.	.	.	.	.	.	.	.
SR30101G200	0.19	6.4	0.73	67	24	0.092	340	19.7	26.8	0.87	81.6
SR30101G300	.	.	.	.	.	.	.	.	.	.	.
SR30101G300	0.18	6.7	0.80	51	23	0.092	336	18.5	22.6	0.78	72.7
SR30201G100	0.27	25.0	0.51	24.7	24	0.071	293	15.3	29.8	<0.79	166.3
SR30501G100	0.36	16.6	0.89	34	33.1	0.094	379	28.5	34.2	<0.81	219.0
SR30601G100	0.17	15.2	0.50	34.8	18.3	0.039	99	8.3	16.9	<0.74	56.3
SR30801G100	0.56	12.0	2.00	95	54.8	0.094	397	37.9	68.7	1.22	347.0
SR31601G100	0.5	92.9	2.93	58	51.9	0.156	492	30.9	58.0	2.04	367.0
SR32401G100	0.55	14.4	1.11	59	49.8	0.167	549	29.3	67.7	1.06	541.0
Core Samples											
SR30201C1X2	2.83	217.0	5.52	292	150.7	0.621	578	40.2	110.9	3	224.0
SR30201C1X3	0.11	24.1	0.49	29.6	16.6	0.106	250	11.7	17.4	<0.8	46.1
SR30501C101	1.08	60.2	4.88	154	86.3	0.352	460	53.3	70.5	<0.85	219.0
SR30501C102	0.8	59.5	2.34	161	84.2	0.648	569	43.5	91.0	1.67	197.0
SR30601C101	1.34	14.5	6.90	255	142.8	0.296	292	114.4	75.8	<0.84	298.0
SR30601C102	0.16	21.5	0.42	35.3	26.6	0.171	155	11.9	24.0	<0.75	62.0
SR30601C1X2	3.31	40.6	17.40	687	375	0.676	604	316.0	168.2	<0.94	714.0
SR30601C1X3	0.35	70.1	1.18	86	42.2	0.273	194	30.2	39.8	<0.76	111.6
SR30602C102	.	.	.	.	.	.	.	.	.	.	.
SR30602C1X2	.	.	.	.	.	.	.	.	.	.	.

**TABLE A-6 SAGINAW RIVER SURVEY 3 - INORGANICS**

SAMPLE ID	AVS	SOLIDS (%)	METHYLH	TOC (%)	DBT (ng/g dry wt)	MBT (ng/g dry wt)	TBT (ng/g dry wt)
Grab Samples							
SR30101G100	4.55	55.08	<0.15	1.07	<0.4	<0.4	0.4
SR30101G200	4.95	56.83	<0.21	0.96	0.5	0.4	0.5
SR30101G200	.	.	.	.	.	.	.
SR30101G300	3.91	56.29	<0.12	1.12	3.3	<0.8	1.0
SR30101G300	.	.	.	.	.	.	.
SR30201G100	3.26	55.24	<0.17	1.33	3.0	1.4	6.2
SR30501G100	3.69	61.34	<0.14	1.42	2.7	0.8	3.9
SR30601G100	1.2	76.36	<0.14	0.23	0.7	0.4	0.8
SR30801G100	5.83	47.28	<0.15	3.63	3.7	0.7	6.6
SR31601G100	3.23	52.08	<0.17	2.89	6.1	1.8	10.0
SR32401G100	8.87	48.74	<0.16	4.02	5.6	0.9	9.2
Core Samples							
SR30201C1X2	5.04	53.05	<0.22	4.96	3.1	2.8	<0.6
SR30201C1X3	4.93	67.53	<0.21	1.48	<0.4	<0.2	<0.4
SR30501C101	7.44	59.04	<0.14	3.07	4.2	1.6	4.0
SR30501C102	10.01	53.8	<0.22	2.91	1.9	1.3	<0.9
SR30601C101	10.92	64.37	<0.23	1.89	6.3	3.0	3.9
SR30601C102	.	.	.	.	.	.	.
SR30601C1X2	36.82	49.21	<0.26	4.15	25.7	11.6	33.0
SR30601C1X3	8.39	76.31	<0.11	0.85	<0.3	0.8	0.7
SR30602C102	4.6	73.47	<0.24	0.6	6.6	3.1	7.0
SR30602C1X2	.	.	.	.	<0.4	<0.8	<0.4

**TABLE A-7 SAGINAW RIVER SURVEY 3 - PAHS (ng/g dry wt)**

<b>SAMPLE ID</b>	<b>ACENAP</b>	<b>ANTH</b>	<b>BAA</b>	<b>BAP</b>	<b>BBF</b>	<b>BGHIPER</b>	<b>BKFLUOR</b>	<b>BISPH</b>	<b>BBPH</b>	<b>CHRY</b>	<b>12DCB</b>	<b>13DCB</b>	<b>14DCB</b>	<b>DBF</b>	<b>DMPH</b>
<b>Grab Samples</b>															
SR32401	<290	<290	690	440	600	<290	<290	1000	<290	600	<290	<290	290	<290	<290
SR30601	<160	<160	<160	<160	<160	<160	<160	310	<160	<160	<160	<160	<160	<160	<160
SR30501	<200	<200	340	220	300	<200	<200	840	370	330	<200	<200	<200	<200	<200
SR30201	<250	<250	<250	<250	<250	<250	<250	1000	1300	<250	<250	<250	<250	<250	<250
SR31601	<230	<230	250	<230	<230	<230	<230	8300	2800	270	<230	<230	<230	<230	<230
SR30801	<250	<250	<340	<250	390	<250	<250	1000	340	440	<250	<250	<250	<250	<250
SR30101	270	270	270	270	270	270	270	1900	270	270	270	270	270	270	270
SR30101	<250	<250	<250	<250	<250	<250	<250	910	<250	<250	<250	<250	<250	<250	<250
SR30101	<260	<260	<260	<260	<260	<260	<260	2300	<260	<260	<260	<260	<260	<260	<260
<b>Core Samples</b>															
SR30201X2	<290	800	2000	<290	680	<290	620	4000	<290	2200	680	1100	1300	<290	<290
SR30201X3	<190	<190	<190	<190	<190	<190	<190	420	<190	<190	<190	<190	<190	<190	<190
SR3050101	<250	<250	720	<250	310	<250	280	1900	<250	740	<250	<250	450	<250	<250
SR3050102	<420	<310	630	<310	<310	<310	<310	21000	5200	690	<310	<310	<310	<310	<310
SR3060101	<170	210	750	<170	<170	<170	<170	22000	2000	790	<170	<170	<170	<170	<170
SR3060102	<170	<170	220	<170	<170	<170	<170	170000	<170	<170	<170	<170	<170	<170	<170
SR30601X2	<290	<290	950	<290	<290	<290	<290	31000	<290	1000	<290	<290	340	<290	<290
SR30601X3	<170	<170	350	<170	<170	<170	<170	740	<170	320	<170	<170	<170	<170	<170

**TABLE A-7 SAGINAW RIVER SURVEY 3 - PAHS (ng/g dry wt)**

<b>SAMPLE ID</b>	<b>FLURANT</b>	<b>FLURENE</b>	<b>INDPPYR</b>	<b>2MNAPH</b>	<b>NAPH</b>	<b>DINO</b>	<b>PHEN</b>	<b>PYRENE</b>
Grab Samples								
SR32401	1200	<290	<290	<290	<290	<290	1000	1800
SR30601	<160	<160	<160	<160	<160	<160	<160	<160
SR30501	630	<200	<200	<200	<200	<200	720	880
SR30201	500	<250	<250	<250	<250	<250	510	710
SR31601	420	<230	<230	<230	<230	2000	460	750
SR30801	580	<250	<250	<250	<250	<250	580	1000
SR30101	270	270	270	270	270	<270	270	270
SR30101	<250	<250	<250	<250	<250	<250	<250	<250
SR30101	<260	<260	<260	<260	<260	1000	<260	<260
Core Samples								
SR30201X2	1400	300	<290	<290	<290	<290	3300	6600
SR30201X3	<190	<190	<190	<190	<190	<190	<190	260
SR3050101	610	<250	<250	<250	<250	380	950	2000
SR3050102	490	<310	<310	<310	<310	6600	1100	2100
SR3060101	870	<170	<170	<170	<170	4500	1200	2000
SR3060102	250	<170	<170	<170	<170	<170	350	850
SR30601X2	1000	<290	<290	<290	<290	8800	1300	2700
SR30601X3	370	<170	<170	<170	<170	<170	440	880

**TABLE A-8 SAGINAW RIVER SURVEY 3 - PCBS (ng/g dry wt)**

<b>SAMPLE ID</b>	<b>PCB1242</b>	<b>PCB1254</b>	<b>PCB1260</b>
Grab Samples			
SR32401	<38	<38	<38
SR30601	95	<25	<25
SR30501	370	120	<29
SR30201	240	95	<32
SR31601	470	<87	<32
SR30801	21.4	94	<38
SR30101	210	<34	<34
SR30101	260	76	<34
SR30101	<72	95	<33
Core Samples			
SR30501	3700	<3200	<3200
SR30601	79000	8100	<3800
SR30201	<29	<29	<29
SR30601	4300	<2600	<2600
SR30501	62	100	<38
SR30201	410	<35	<36
SR30601	96	<25	<25
SR30601	28000	<2700	<2700

**TABLE A-9 SAGINAW RIVER SURVEY 3 - PESTICIDES (ng/g)**

<b>SAMPLE ID</b>	<b>ALDRIN</b>	<b>A-CHLOR</b>	<b>G-CHLOR</b>	<b>A-BHC</b>	<b>B-BHC</b>	<b>C-BHC</b>	<b>LINDANE</b>	<b>DDD</b>	<b>DDE</b>	<b>DDT</b>	<b>DIELDRN</b>	<b>ENDRIN</b>
<b>Grab Samples</b>												
SR30101	4.6	<3.4	5.7	<3.4	<3.4	<3.4	<3.4	<3.4	3.9	<3.4	<3.4	<3.4
SR30101	4.6	<3.4	<3.8	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	3.9	<3.4	<3.4
SR30101	3.8	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	7.6	<3.3	13.0	3.3	<3.3
SR30201	8	<3.3	5.9	<3.3	6.4	<3.3	<33.0	8.4	5.6	<3.3	<3.3	<3.3
SR30501	9.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
SR30601	<2.5	<2.5	<2.5	<2.5	3	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
SR30801	<3.8	<3.8	9	<3.8	<3.8	<3.8	17	<3.8	11.0	<3.8	<3.8	<3.8
SR31601	<3.2	<3.2	<3.2	<3.2	9	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2
SR32401	<3.9	<3.9	7	<3.9	<3.9	<3.9	<3.9	13.0	<3.9	<3.9	7.7	4.1
<b>Core Samples</b>												
SR302X2	<360	<360	<360	<360	<360	<360	<360	<360	<360	<360	<360	<360
SR302X3	<2.9	<2.9	5.3	<2.9	7	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9
SR30502	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	6.4	<3.9	<3.9	<3.9	4.5
SR30501	<320	<320	<320	<320	<320	<320	<320	<320	<320	<320	<320	<320
SR30602	<2.7	<2.5	<2.5	<2.5	4.1	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
SR30601	460	<270	<270	<270	<270	<270	<270	<270	<270	<270	<270	<270
SR306X2	1400	<380	<380	880	<380	<380	<380	<380	<380	<380	<380	<380
SR306X3	<260	<260	<260	<260	<260	<260	<260	<260	<260	<260	<260	<260

**TABLE A-9 SAGINAW RIVER SURVEY 3 - PESTICIDES (ng/g)**

<b>SAMPLE ID</b>	<b>ENDRNAD</b>	<b>ENDRNKT</b>	<b>ENDSFNA</b>	<b>ENDSFNB</b>	<b>ENDSFNS</b>	<b>HEPCLPX</b>	<b>HEPTCHL</b>	<b>METHXYC</b>	<b>TOXAFEN</b>
<b>Grab Samples</b>									
SR30101	<3.4	<3.4	<3.4	<3.4	<3.4	11	<3.4	<17	<34
SR30101	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<17	<34
SR30101	17	<3.3	<3.3	9.4	<3.3	<3.3	<3.3	<17	<33
SR30201	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<16	<33
SR30501	<2.8	<2.8	<2.8	7.7	<2.8	16	<2.8	<14	28
SR30601	<2.5	12	<2.5	<2.5	<2.5	<2.5	<2.5	<25	<2.5
SR30801	<3.8	<3.8	12	11	<3.8	17	<3.8	<19	<38
SR31601	<3.2	16	<3.2	5.2	<3.2	40	<3.2	32	<3.2
SR32401	<3.9	<3.9	6	<3.9	<3.9	15	<3.9	<19	39
<b>Core Samples</b>									
SR302X2	<360	<360	<360	<360	<360	<360	<360	<1800	<3600
SR302X3	<2.9	<2.9	<2.9	<2.9	<2.9	5.3	<2.9	<15	<29
SR30502	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<19	<39
SR30501	<320	<320	<320	<320	<320	<320	<320	<1600	<3200
SR30602	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<13	<25
SR30601	<270	<270	<270	<270	<270	<270	<270	<1350	<2700
SR306X2	<380	<380	<380	<380	<380	<500	<380	<520	<3800
SR306X3	<260	<260	<260	<260	<260	<260	<260	<1300	<2600



**TABLE A-10 SAGINAW RIVER SURVEY 3 - DIOXINS AND FURANS (ng/g dry wt)**

SAMPLE ID	1234-678- HPCDD	HPCDD_T	1234-678- HPCDF	1234- 789- HPCDF	HPCDF_T	123-478- HXCDD	123-678- HXCDD	123-789- HXCDD	HXCDD_T	123-478- HXCDF	123-678- HXCDF	123-789- HXCDF
Grab Samples												
SR32401	0.31	0.55	0.21	0.068	0.77	0.0041	ND	0.015	0.19	0.2	0.041	0.019
SR30601	0.04	0.074	0.049	0.0045	0.12	0.0011	0.0034	0.0026	0.033	0.095	0.024	0.0089
SR30501	0.7	1.1	0.52	0.044	1.7	0.0062	ND	0.015	0.28	0.23	0.043	0.015
SR30201	0.18	0.31	0.28	0.033	0.57	ND	0.0093	0.0039	0.087	0.35	0.06	0.016
SR31601	0.43	0.79	0.54	0.021	1.3	ND	0.018	0.013	0.16	0.12	0.025	0.007
SR30801	0.7	1.3	0.93	0.061	2.1	0.0095	0.06	0.027	0.46	0.29	0.082	0.022
SR30101	0.22	0.42	0.45	0.013	0.81	0.002	0.013	0.0061	0.065	0.073	0.028	0.0082
SR30101	0.21	0.39	0.44	0.012	0.78	0.0019	0.013	0.0067	0.15	0.069	0.026	0.0068
SR30101	0.21	0.39	0.44	0.011	0.77	0.0028	0.011	0.0065	0.12	0.052	0.024	.
Core Samples												
SR30501	2.5	4.4	9.4	0.45	18	0.03	0.26	0.098	1.5	1.2	0.28	0.073
SR30601	3.8	6.4	4.3	0.24	10	0.019	ND	0.066	1.2	1.2	0.22	0.088
SR30201	0.05	0.086	0.23	0.064	0.45	ND	ND	ND	0.022	1.2	0.21	0.046
SR30601	0.2	0.35	0.55	0.037	1.1	0.0017	0.018	0.0066	0.12	0.22	0.042	0.014
SR30501	0.034	0.034	0.98	0.079	1.7	ND	ND	ND	0.097	ND	0.13	0.036
SR30201	12	22	39	1.1	74	0.095	ND	0.21	3.3	ND	0.72	0.19
SR30601	0.0095	0.016	0.11	0.015	0.18	ND	ND	ND	0.0037	0.26	0.052	0.011
SR30601	1.4	2.5	2.4	0.11	5	ND	0.067	0.022	0.38	1.8	1.6	0.11

**TABLE A-10 SAGINAW RIVER SURVEY 3 - DIOXINS AND FURANS (ng/g dry wt)**

SAMPLE ID	234-678- HXCDF	HXCDF_T	OCDD_T	OCDF_T	12378- PECDD	PECDD_T	12378- PECDF	23478- PECDF	PECDF_T	2378- TCDD	TCDD_T	2378- TCDF	TCDF_T
Grab Samples													
SR32401	0.0058	0.61	2.6	0.85	ND	0.031	0.12	0.11	0.56	0.0083	0.064	0.29	1.1
SR30601	0.0038	0.2	0.34	0.089	0.0013	0.0038	0.24	0.25	0.85	0.0013	0.0057	1.6	3.1
SR30501	0.0076	0.49	5.1	1.6	0.015	0.024	0.26	0.19	0.94	0.011	0.05	0.71	1.6
SR30201	0.0046	0.66	1.8	0.53	ND	0.011	0.48	0.69	2.5	0.0052	0.038	1.7	3.4
SR31601	0.0021	0.34	4.1	0.94	ND	ND	0.11	0.072	0.28	0.0062	0.017	0.24	0.46
SR30801	0.011	1.2	6.4	1.8	0.02	0.15	0.25	0.16	0.94	0.032	0.23	0.58	1.7
SR30101	0.0019	0.37	2.2	0.73	0.0044	0.027	0.05	0.032	0.22	0.0042	0.026	0.11	0.33
SR30101	0.001	0.32	2.5	0.65	0.0035	0.02	0.046	0.03	0.21	0.004	0.025	0.11	0.29
SR30101		0.23	2.2	0.54	0.004	0.026	0.036	0.023	0.12	0.0045	0.018	0.099	0.23
Core Samples													
SR30501	0.021	5.9	25	12	ND	0.4	0.55	0.4	2.7	0.016	0.14	1.3	3.4
SR30601	0.021	4.6	34	10	ND	0.31	1.9	1.5	7.8	0.11	0.74	6.3	15
SR30201	0.023	1.9	0.55	0.29	ND	ND	1.5	0.67	3.8	ND	0.0012	1.5	3.3
SR30601	ND	0.51	1.9	0.79	ND	0.026	0.18	0.13	0.64	0.0036	0.0093	0.49	0.96
SR30501	ND	0.88	0.18	1.2	ND	ND	0.52	0.33	2	ND	0.014	1.1	3.8
SR30201	0.098	22	12	56	0.056	0.99	0.85	0.85	8.1	0.019	0.4	2.7	9.6
SR30601	0.0029	0.44	0.089	0.14	ND	ND	0.34	0.21	1.1	ND	0.0022	0.87	1.6
SR30601	0.035	5.6	14	4.3	0.028	0.12	2.8	2.1	11	0.042	0.32	8.6	20

**TABLE A-11 SAGINAW RIVER SURVEY 2 LARGE LAKES RECONNAISSANCE DATA FOR MASTER STATIONS**

<b>SAMPLE ID</b>	<b>CADMIUM</b> (ug/g dry wt)	<b>CHROMIUM</b> (ug/g dry wt)	<b>COPPER</b> (ug/g dry wt)	<b>IRON</b> (% dry wt)	<b>NICKEL</b> (ug/g dry wt)	<b>LEAD</b> (ug/g dry wt)	<b>ZINC</b> (ug/g dry wt)	<b>DRY_FR</b>	<b>MOIST_FR</b>	<b>VOL_FR</b>	<b>AMMONIA</b> mg/L
SR20201C101	1.3	34	35	1.3	24	40	360	0.52	0.48	0.08	15
SR20201C102	3.7	160	150	1.8	76	67	250	0.55	0.45	0.079	34
SR20202G100	1.2	24	25	1	16	35	250	0.56	0.44	0.044	2.2
SR20302C101	2.1	58	59	1.3	29	36	160	0.57	0.43	0.052	6.4
SR20303C101	0.2	23	25	1.1	11	26	210	0.65	0.35	0.037	14
SR20303C102	1.2	50	40	1.2	17	62	150	0.71	0.29	0.043	26
SR20303C103	1.7	42	46	1.9	20	68	170	0.64	0.36	0.059	27
SR20304C101	2.2	140	120	1.7	46	60	210	0.56	0.44	0.066	14
SR20304C102	2.7	120	89	1.8	40	61	180	0.56	0.44	0.073	17
SR20304C103	1.1	31	31	2	23	34	110	0.57	0.43	0.07	7.5
SR20401C101	<0.0026	7	4.4	0.3	5.8	5	41	0.77	0.23	0.011	2.2
SR20401C102	0.2	6.8	3.4	0.36	4.9	2.9	15	0.81	0.19	0.008	3.6
SR20402C101	0.3	13	8.8	0.51	7.9	16	39	0.7	0.3	0.042	9
SR20402C102	0.6	25	19	0.52	9.8	36	35	0.75	0.25	0.02	15
SR20402C103	1.1	9.8	2.9	0.52	7.6	9.4	25	0.74	0.26	0.024	7.8
SR20601C101	7	240	180	1.3	120	76	350	0.63	0.37	0.061	13
SR20601C102	0.2	17	15	0.6	7.1	16	52	0.71	0.29	0.024	13
SR20601C201	7.1	220	160	1.2	110	84	320	0.64	0.36	0.046	13
SR20601C202	<0.0026	18	16	0.9	6.7	24	82	0.72	0.28	0.024	15
SR20602C101	1	24	13	0.27	15	26	50	0.85	0.15	0.005	0.46
SR20602C102	3.5	60	29	0.93	16	31	78	0.71	0.29	0.007	11
SR20603C101	0.9	35	30	2.1	23	40	120	0.48	0.52	0.086	6.9
SR20603C102	1	21	14	1.3	16	22	67	0.68	0.32	0.034	0.51
SR20801C101	4.8	140	73	1.2	37	57	280	0.57	0.43	0.062	19
SR20801C102	2.1	150	68	1.7	27	34	140	0.57	0.43	0.057	12
SR20801C103	0.7	11	11	0.59	8.8	19	45	0.77	0.23	0.024	11
SR21002C101	<0.0026	19	19	1.4	8	11	82	0.65	0.35	0.043	5.4
SR21002C102	0.4	30	29	2.3	21	19	93	0.52	0.48	0.067	1.4
SR21002C201	<0.0026	19	19	1.4	8	11	82	0.66	0.34	0.048	3.3
SR21002C202	4.8	140	73	1.2	37	57	280	0.52	0.48	0.1	1.5
SR21101G100	0.7	12	9.4	0.32	14	8.5	78	0.75	0.25	0.008	0.91
SR21102C101	0.9	19	18	1.2	14	23	77	0.66	0.34	0.048	8.2
SR21201C101	2.1	100	89	1.8	33	48	170	0.6	0.4	0.083	7.2
SR21301C101	0.8	30	23	1.2	21	27	98	0.62	0.38	0.04	15
SR21301C102	0.9	17	12	1.2	14	15	64	0.56	0.44	0.083	18

**TABLE A-11 SAGINAW RIVER SURVEY 2 LARGE LAKES RECONNAISSANCE DATA FOR MASTER STATIONS**

<b>SAMPLE ID</b>	<b>CADMIUM (ug/g dry wt)</b>	<b>CHROMIUM (ug/g dry wt)</b>	<b>COPPER (ug/g dry wt)</b>	<b>IRON (% dry wt)</b>	<b>NICKEL (ug/g dry wt)</b>	<b>LEAD (ug/g dry wt)</b>	<b>ZINC (ug/g dry wt)</b>	<b>DRY_FR</b>	<b>MOIST_FR</b>	<b>VOL_FR</b>	<b>AMMONIA mg/L</b>
SR21401G100	0.9	38	40	2	24	34	200	0.45	0.55	0.074	8.1
SR21501C101	1.7	88	35	1.1	22	35	110	0.66	0.34	0.037	1.1
SR21501C102	0.6	16	12	1.2	12	13	51	0.66	0.34	0.041	6.8
SR21601C101	3	94	110	1.6	48	53	250	0.57	0.43	0.065	8.8
SR21601C102	0.9	11	6.3	0.8	8.2	6.8	34	0.58	0.42	0.044	7.7
SR21701C101	0.6	17	18	0.8	12	34	100	0.7	0.3	0.029	8.1
SR21701C102	1.7	33	42	2.2	24	66	170	0.53	0.47	0.072	33
SR21702G100	0.9	46	52	2.5	22	42	270	0.42	0.58	0.098	7.5
SR21801C101	0.9	32	49	0.93	17	23	94	0.71	0.29	0.031	5.1
SR21801C102	0.5	4.4	2.1	0.4	2.8	3.1	15	0.85	0.15	0.003	1.9
SR21901C101	2.2	54	40	0.9	20	28	87	0.69	0.31	0.041	2.7
SR21901C102	0.2	11	14	0.8	5.8	19	57	0.69	0.31	0.04	5.5
SR22001C101	0.2	14	19	1.3	5.5	45	74	0.64	0.36	0.057	5.9
SR22001C102	<0.0026	7.4	6.7	0.5	1.1	1.9	15	0.8	0.2	0.019	4.1
SR22001C103	<0.0026	7.2	5.5	0.4	1.1	2.1	13	0.83	0.17	0.017	2.2
SR22101C101	3.7	83	64	1.8	25	550	210	0.67	0.33	0.25	8
SR22101C102	0.7	21	25	1.4	11	84	99	0.58	0.42	0.066	8
SR22201C101	0.2	13	12	1.1	8.6	6.1	89	0.65	0.35	0.061	7
SR22301C101	0.9	17	16	0.9	14	17	140	0.67	0.33	0.041	7.7
SR22301C102	1.1	22	20	1.5	15	7.3	62	0.65	0.35	0.04	8.8
SR22401C101	1.4	43	55	1.9	24	76	510	0.49	0.51	0.1	18
SR22401C102	1.2	44	66	1.5	20	65	250	0.62	0.38	0.077	25
SR22401C103	0.8	40	41	1.2	18	38	110	0.64	0.36	0.093	13
SR22501C101	0.7	31	48	1.1	16	48	180	0.66	0.34	0.046	11
SR22501C102	3	150	230	2.6	67	120	350	0.64	0.36	0.25	16
SR22501C201	1.1	38	60	1.3	15	59	210	0.64	0.36	0.049	15
SR22501C202	3.3	170	170	2.5	58	160	350	0.54	0.46	0.12	39
SR22501C203	3.3	140	120	2.9	40	160	300	0.55	0.45	0.11	16
SR22601C101	0.6	20	19	1.1	7.2	11	57	0.7	0.3	0.036	18
SR22601C102	<0.0026	27	20	1.4	8.8	9.4	52	0.7	0.3	0.04	15
SR22601C103	3.2	200	110	2.1	38	98	230	0.6	0.4	0.099	28

**TABLE A-11 SAGINAW RIVER SURVEY 2 LARGE LAKES RECONNAISSANCE DATA FOR MASTER STATIONS**

SAMPLE ID	BROMINE (ug/g dry wt)	CHLORINE (ug/g dry wt)	CONDUCT (uSiemens)	EXTR_RES (ug/g dry wt)	MICRO. (EC-50)	PH	TOC (% dry wt)	GT38 (% dry wt)	GT63 (% dry wt)	GRAIN SIZE		
										GT250 (% dry wt)	GT1000 (% dry wt)	LT38 (% dry wt)
SR20201C101	0.08	2.4	1250	410	100	7.14	4.2	8	61	3.8	3	24
SR20201C102	0.35	21	2280	4100	100	7.15	4.3	9	14	0.89	0.14	69
SR20202G100	0.062	3.1	971	670	100	7.3	1.8	14	60	3.8	0.33	21
SR20302C101	0.056	2.6		420	100	6.95	2.1	10	36	7.6	2.6	46
SR20303C101	0.076	2.8	1350	430	100	7.34	1.1	4.5	33	33	1.7	26
SR20303C102	0.11	2.8	2460	1200	100	7.51	2.9	3.1	28	37	3.6	27
SR20303C103	0.044	1.5		990	45	7.6	2	2.3	30	16	0.68	49
SR20304C101	0.26	13	1570	2700	100	7.21	2.6	7.6	32	8.1	0.47	52
SR20304C102	0.3	9.9	2050	2200	100	7.19	0.3	7	29	6.1	0.59	59
SR20304C103	0.027	1	1850	170	100	6.96	3	5	16	3.4	0.47	74
SR20401C101	0.026	1.4	1040	170	100	7.36	0.83	1.2	62	28	0.42	5.7
SR20401C102	0.006	0.46	1470	<65	100	7.6	0.32	0.85	44	45	1.2	7.3
SR20402C101	0.041	1.1	1360	410	100	7.12	1	2.3	60	20	0.8	17
SR20402C102	0.065	0.94	1280	660	100	7.12	1.7	3.7	34	21	1.5	29
SR20402C103	0.009	0.49		120	100	6.33	1.4	6.2	68	5.4	0.23	17
SR20601C101	0.14	20	1690	3000	100	7.34	2.5	6.3	52	13	0.28	28
SR20601C102	0.05	1.7	1940	320	100	7.28	0.82	1.8	49	44	1.2	10
SR20601C201	0.063	1.8	1980	3900	100	7.21	2.1	6.5	53	14	0.4	27
SR20601C202	0.054	1.5	2420	310	100	7.17	0.77	2.4	29	33	0.28	26
SR20602C101	0.047	3.3	2400	380	100	6.99	<0.14	1.9	86	0.038	0.17	6.1
SR20602C102	0.13	3	1640	710	100	7.18	1.5	2.3	45	47	11	11
SR20603C101	0.036	1.9	2760	290	100	7.07	2.7	5.3	22	4.5	0.94	74
SR20603C102	0.008	0.75	3650	98	100	7.02	1.6	2.3	21	13	1.6	48
SR20801C101	0.23	7.2	1390	1100	100	7.22	2.9	11	47	6	0.15	37
SR20801C102	0.17	2.3	1770	1100	100	6.99	2.9	10	14	1.7	0.18	71
SR20801C103	0.049	0.79	3440	400	100	7.13	0.6	3.3	38	24	1.2	25
SR21002C101	0.029	1.6	1030	340	100	7.15	1.2	3.4	28	28	1.9	38
SR21002C102	0.015	0.88		<86	100	7.08	2.6	5.1	12	2.5	0.51	78
SR21002C201	0.015	1.3	922	340	100	7.22	1.5	3.1	28	29	1.2	38
SR21002C202	0.014	1.3		<140	100	7	2.1	4.3	11	6.6	0.56	78
SR21101G100	0.031	1	752	<88	100	7.11	0.4	1.6	64	28	0.2	4.6
SR21102C101	0.047	3.4	1510	710	100	7.19	2.4	4.8	56	1.8	1.6	33
SR21201C101	0.12	5	620	880	100	7.15	3.3	3.3	15	23	4.6	47
SR21301C101	0.026	0.77	1500	<100	100	7.09	2	12	47	4.5	1.7	37
SR21301C102	0.008	0.76	2370	<160	100	7.19	3	3.5	22	27	0.92	42

**TABLE A-11 SAGINAW RIVER SURVEY 2 LARGE LAKES RECONNAISSANCE DATA FOR MASTER STATIONS**

SAMPLE ID	BROMINE (ug/g dry wt)	CHLORINE (ug/g dry wt)	CONDUCT (uSiemens)	EXTR_RES (ug/g dry wt)	MICRO. (EC-50)	PH	TOC (% dry wt)	GT38 (% dry wt)	GT63 (% dry wt)	GRAIN SIZE			LT38 (% dry wt)
										GT250 (% dry wt)	GT1000 (% dry wt)		
SR21401G100	0.029	1.8	1600	290	100	7.26	3.5	8.5	17	7.6	2.1		57
SR21501C101	0.11	2.4	1530	600	100	7.08	1.2	5.4	35	26	3.5		30
SR21501C102	0.005	0.53	1790	<29	100	7.11	0.78	3.2	27	6.7	0.73		53
SR21601C101	0.25	14	1190	2200	100	7.11	2.8	9.2	37	9.9	1.1		42
SR21601C102	0.019	1.4		210	100	7.03	2.1	9.1	78	4	4.7		17
SR21701C101	0.12	2	1690	430	100	7.13	1.2	3.1	38	35	4.7		20
SR21701C102	0.1	1.8	2120	450	100	6.86	2.3	18	18	1.5	0.1		62
SR21702G100	0.044	2.3	1620	420	100	7.21	2.8	11	10	0.75	0.031		80
SR21801C101	0.22	4.1	1270	720	100	7.2	1.5	5.1	28	42	1.8		23
SR21801C102	0.006	0.33		<21	100	7.38	<0.13	0.1	13	77	6.7		1.1
SR21901C101	0.14	4.9	835	890	54	7.36	1.3	7.9	46	15	0.36		26
SR21901C102	0.047	1.3	1160	150	100	7.13	1.6	1.8	40	37	0.9		19
SR22001C101	0.025	0.96	2610	350	100	7.19	1.6	2.7	31	19	32		23
SR22001C102	0.006	0.88	4750	<93	100	7.07	0.44	1.9	36	30	3.2		9.5
SR22001C103	0.007	0.43	5150	<24	100	7.08	0.3	1.8	41	38	7		9.4
SR22101C101	0.095	1.6	2020	540	100	7.19	3.1	5.3	26	8.2	1.4		38
SR22101C102	0.045	1.6	4100	370	100	6.93	3	4.1	28	23	2.8		41
SR22201C101	0.013	1.2	1090	1500	100	6.9	1.4	8.3	36	19	2.4		33
SR22301C101	0.026	2.2	1140	210	100	7.22	2	5	55	17	0.16		22
SR22301C102	0.021	1.3	1450	210	100	7.04	1.2	2.1	13	31	0.11		53
SR22401C101	0.16	5.2	2790	900	100	7.09	4.1	15	31	2.1	0.28		44
SR22401C102	0.15	8.5	6750	1200	100	6.9	7.5	11	35	16	1.4		36
SR22401C103	0.11	3.1	12700	1000	100	6.94	2.4	8.2	45	17	3.9		28
SR22501C101	0.12	7.9	1680	860	100	7.15	1.6	9.4	58	11	0.67		21
SR22501C102	0.56	9.6	2130	2700	99	7.07	3.9	8.2	14	1.4	0.23		59
SR22501C201	0.082	5.3	1690	1100	100	7.26	1.5	10	53	6.2	0.26		29
SR22501C202	0.31	5.8	2640	1700	67	7.37	4.4	10	20	4.9	0.31		63
SR22501C203	0.82	6.4		5900	100	7.26	4.3	7	8.8	0.88	0.054		82
SR22601C101	0.022	1.2	1240	220	100	7.03	1.3	7.1	33	25	0.7		33
SR22601C102	0.034	1		320	100	6.69	1.1	8.6	30	8.3	0.6		48
SR22601C103	0.44	3.8		2700	100	7.11	3.8	13	32	1.6	0.14		53

**TABLE A-12 SAGINAW RIVER SURVEY 3 - LARGE LAKES RECONNAISSANCE FOR MASTER STATIONS**

<b>SAMPLE ID</b>	<b>CADMIUM (ug/g dry wt)</b>	<b>CHROMIUM (ug/g dry wt)</b>	<b>COPPER (ug/g dry wt)</b>	<b>IRON (% dry wt)</b>	<b>NICKEL (ug/g dry wt)</b>	<b>LEAD (ug/g dry wt)</b>	<b>ZINC (ug/g dry wt)</b>	<b>DRY_FR</b>	<b>MOIST_FR</b>	<b>VOL_FR</b>	<b>AMMONIA mg/L</b>
SR30101G100	1	26	19	1.1	15	16	78	0.53	0.47	0.035	0.72
SR30201CCX2	7	250	140	2.5	32	100	240	0.52	0.48	0.12	18
SR30201CCX3	0.8	15	10	0.8	7.9	8.7	45	0.67	0.33	0.055	14
SR30201G100	0.6	16	20	0.8	13	22	170	0.63	0.37	0.041	4.6
SR30501CC01	5.1	120	82	1.6	44	63	220	0.59	0.41	0.072	11
SR30501CC02	3	110	72	2.3	33	76	190	0.55	0.45	0.09	20
SR30501G100	1.1	26	30	0.9	24	32	220	0.67	0.33	0.042	5.2
SR30601CC01	4.5	150	110	1.1	82	220	150	0.7	0.3	0.036	12
SR30601CC02	1	11	12	0.6	7	17	50	0.78	0.22	0.021	17
SR30601CCX2	19	590	360	2.6	290	180	720	0.48	0.52	0.12	20
SR30601CCX3	1.3	40	72	0.8	24	32	130	0.8	0.2	0.049	14
SR30601G100	0.7	11	8.8	0.3	7.1	12	51	0.75	0.25	0.016	2.2
SR30801G100	2.4	54	47	0.1	31	58	360	0.52	0.48	0.088	5
SR31601G100	1	38	41	1.6	24	46	380	0.54	0.46	0.075	7.4
SR32401G100	0.9	35	45	2	22	62	510	0.49	0.51	0.11	11
SR32706C101	0.5	6.7	5.4	0.4	5.1	4.1	35	0.79	0.21	0.016	2.2
SR32709C101	3.7	110	62	1.4	32	56	190	0.68	0.32	0.053	14
SR32709C102	1.1	35	36	2.4	24	57	150	0.57	0.43	0.076	18
SR32806C101	0.7	23	26	0.7	25	72	140	0.68	0.32	0.053	13
SR32808C101	1.4	29	44	2.2	23	67	180	0.54	0.46	0.093	20
SR32808C102	1.2	19	25	1.8	16	32	110	0.63	0.37	0.069	19
SR32906C101	4.7	160	160	2.1	75	83	440	0.55	0.45	0.096	18
SR32906C102	5.6	230	120	2.5	57	100	270	0.57	0.43	0.092	23
SR32906C201	4.3	160	160	2.1	76	85	400	0.54	0.46	0.095	19
SR32906C202	5.6	230	120	2.5	57	100	270	0.49	0.51	0.085	18
SR33006C101	4.8	96	66	1.5	37	55	210	0.61	0.39	0.065	12
SR33006C102	1.4	55	36	1.6	19	38	110	0.61	0.39	0.15	17
SR33009C101	1.3	29	27	1.1	17	29	250	0.69	0.31	0.04	20
SR33106C101	0.6	15	12	1.1	11	7.8	58	0.67	0.33	0.053	4.4
SR33106C102	0.6	8.4	8.2	0.9	7.2	4.1	34	0.7	0.3	0.042	8
SR33109C101	0.7	4.5	3.7	0.5	3.7	0.3	26	0.81	0.19	0.016	4.5
SR33204C101	1	24	19	0.6	15	10	57	0.84	0.16	0.018	7.8

**TABLE A-12 SAGINAW RIVER SURVEY 3 - LARGE LAKES RECONNAISSANCE FOR MASTER STATIONS**

<b>SAMPLE ID</b>	<b>CADMIUM</b> (ug/g dry wt)	<b>CHROMIUM</b> (ug/g dry wt)	<b>COPPER</b> (ug/g dry wt)	<b>IRON</b> (% dry wt)	<b>NICKEL</b> (ug/g dry wt)	<b>LEAD</b> (ug/g dry wt)	<b>ZINC</b> (ug/g dry wt)	<b>DRY_FR</b>	<b>MOIST_FR</b>	<b>VOL_FR</b>	<b>AMMONIA</b> mg/L
SR33207C101	1	34	29	0.8	24	24	120	0.75	0.25	0.033	8.5
SR33207C102	0.3	9.2	7.8	8.1	6.8	2.4	34	0.74	0.26	0.028	7.3
SR33207C103	0.6	10	8.7	1	7.4	3.6	35	0.72	0.28	0.062	5.5
SR33210C101	<0.0026	7.9	6.7	6.9	5.5	2.4	35	0.78	0.22	0.012	6.5
SR33306C101	0.7	15	12	0.4	16	8.5	53	0.8	0.2	0.084	6.5
SR33306C102	3.3	130	85	2	35	75	190	0.6	0.4	0.053	17
SR33309C101	0.7	20	15	0.5	15	17	72	0.83	0.17	0.012	4.6
SR33309C102	1.7	63	47	1.2	23	37	110	0.74	0.26	0.027	14
SR33409C101	1.6	43	41	0.8	37	32	160	0.72	0.28	0.027	20
SR33409C102	1.8	45	31	1	16	37	90	0.7	0.3	0.041	17
SR33411C101	1.1	54	61	1.2	29	27	130	0.73	0.27	0.035	7.4
SR33411C102	0	8.9	7.4	0.8	6.5	0.3	31	0.76	0.24	0.02	13
SR33508C101	2.4	58	42	0.6	39	24	110	0.76	0.24	0.16	12
SR33508C102	3	130	68	1.6	33	77	180	0.65	0.35	0.048	17
SR33511C101	0.6	26	17	0.5	12	12	47	0.82	0.18	0.027	2.9
SR33609C101	2.7	78	54	0.6	49	28	120	0.8	0.2	0.013	9.4
SR33609C102	2.4	81	42	1.1	22	43	130	0.7	0.3	0.044	11
SR33611C101	2.9	63	53	1.7	24	50	150	0.59	0.41	0.061	9.2
SR33611C201	1	21	21	1.4	16	22	89	0.66	0.34	0.05	9.3
SR33809C101	4.6	92	64	1.2	44	43	170	0.67	0.33	0.036	13
SR33809C102	0.6	17	19	1.2	12	22	79	0.68	0.32	0.033	14
SR33812C101	1.3	22	18	0.5	16	14	58	0.8	0.2	0.014	2.2
SR33812C102	0.6	4.6	5.2	0.5	3.8	11	41	0.58	0.42	0.005	2.9
SR33911C101	5	86	56	1.3	25	49	130	0.63	0.37	0.046	14
SR33911C102	1.2	17	18	0.7	8.3	20	55	0.69	0.31	0.034	13



**TABLE A-12 SAGINAW RIVER SURVEY 3 - LARGE LAKES RECONNAISSANCE FOR MASTER STATIONS**

SAMPLE ID	BROMINE (ug/g dry wt)	CHLORINE (ug/g dry wt)	CONDUCT (uSiemens)	EXTR_RES (ug/g dry wt)	MICRO. (EC-50)	PH	TOC (% dry wt)	GT38 (% dry wt)	GT63 (% dry wt)	GRAIN SIZE		
										GT250 (% dry wt)	GT1000 (% dry wt)	LT38 (% dry wt)
SR30101G100	0.039	1.5	370	<150	100	7.47	1	13	57	0.89	0.025	29
SR30201CCX2	0.58	9.6		1600	51	7.14	4.8	9.3	22	1.8	0.34	68
SR30201CCX3	0.033	1	3420	540	100	7.11	2	10	72	2.2	0.89	21
SR30201G100	0.2	4.4	1020	390	100	6.94	1.9	6.1	78	2.7	0.65	13
SR30501CC01	0.14	4.2	1370	650	96	7.18	3.1	6.8	48	2.7	0.84	38
SR30501CC02	0.063	1.5	1980	560	100	6.94	2.9	6.7	22	2.5	0.78	68
SR30501G100	0.13	5.3	1070	240	100	7.1	1.7	9.9	61	9.3	0.27	18
SR30601CC01	0.18	5.3	1890	4300	100	7.24	2.1	4.4	50	24	0.98	21
SR30601CC02	0.033	1.5	2580	270	100	7.28	0.54	1.2	39	45	1.2	12
SR30601CCX2	0.13	22	3460	2400	100	7.15	4.9	8	22	5.7	0.52	63
SR30601CCX3	0.16	26	1880	930	100		3.4	3.9	49	31	1.6	12
SR30601G100	0.049	2.1	686	710	100	7.27	<0.2	1.5	58	40	0.34	2.3
SR30801G100	0.12	6.1	9470	590	100	7.31	4.6	14	52	2.7	0.41	30
SR31601G100	0.13	4.7	1030	330	83	7.25	3.1	13	41	5.5	0.57	38
SR32401G100	0.15	4.2	1590	1000	100	7.22	3.1	14	23	5.3	1.4	55
SR32706C101	0.011	0.93	2120	130	100	7.22	1	1.3	59	29	0.32	9.5
SR32709C101	0.075	2.1	5340	680	100	6.88	3.7	5.2	50	8.8	0.59	32
SR32709C102	0.064	1.8	14500	420	100	6.75	4.5	5.4	10	2.3	0.98	76
SR32806C101	0.082	4.5	2390	1300	100	7.05	1.2	2.6	54	24	4.2	15
SR32808C101	0.16	3	1690	970	100	7.04	3.7	6.2	35	3.8	2.7	56
SR32808C102	0.066	2.3		530	100	7.22	1.8	4.8	34	4.4	1.1	53
SR32906C101	0.71	29	1370	4000	70	7.18	3.6	14	23	1.4	0.21	59
SR32906C102	0.27	8.1	2010	3500	100	7.17	3.8	6.4	13	1.4	0.27	77
SR32906C201	0.17	13	1740	1600	80	7.2	3.9	15	26	1.5	0.28	54
SR32906C202	1.4	16	2120	4600	100	7.14	4.5	5.9	6.1	0.51	0.11	91
SR33006C101	0.35	9.3	1350	2000	100	6.99	2.2	10	45	1.8	0.17	40
SR33006C102	0.05	1.4	1340	270	84	7.11	4	5.5	39	8.1	2.7	50
SR33009C101	0.063	2.6	1400	410	45	7.23	1.5	3.2	46	23	1.2	26
SR33106C101	0.021	2.2	845	770	100	6.82	1.8	9.4	52	5.9	1.7	31
SR33106C102	0.022	2.1	1360	1100	100	7.3	1.7	7.8	62	1.9	0.28	26
SR33109C101	<0.017	1.2	830	250	100	7.18	0.63	1.4	80	6.9	0.62	7.6
SR33204C101	0.035	2.9	2820	460	100	7.33	0.49	4.1	46	32	1.7	11

**TABLE A-12 SAGINAW RIVER SURVEY 3 - LARGE LAKES RECONNAISSANCE FOR MASTER STATIONS**

SAMPLE ID	BROMINE (ug/g dry wt)	CHLORINE (ug/g dry wt)	CONDUCT (uSiemens)	EXTR_RES (ug/g dry wt)	MICRO. (EC-50)	PH	TOC (% dry wt)	GT38 (% dry wt)	GT63 (% dry wt)	GRAIN SIZE		
										GT250 (% dry wt)	GT1000 (% dry wt)	LT38 (% dry wt)
SR33207C101	0.11	7	881	1600	100	7.09	0.84	6.6	53	22	0.52	15
SR33207C102	0.01	1.4	871	220	100	6.9	3	8	65	1.6	0.72	28
SR33207C103	0.022	1.4	1220	210	100	7.32	1.2	7.3	69	1.5	2.4	25
SR33210C101	0.016	0.54	1880	<81	100	7.43	0.31	2.7	74	16	0.66	9.2
SR33306C101	0.041	2.9	1570	350	90	7.04	0.43	3.6	46	39	0.33	7.9
SR33306C102	0.073	2.1	1650	970	91	7.1	4.2	4.9	23	0.11	0.35	61
SR33309C101	0.037	1.5	961	270	100	7.27	0.44	2.4	40	47	0.055	5.5
SR33309C102	0.17	2.5	1690	1200	100	6.93	2.2	4.3	42	22	0.34	27
SR33409C101	0.066	6.3	1410	780	70	7.18	1.5	6.7	51	30	0.73	12
SR33409C102	0.05	1.6	1800	370	100	6.97	2.3	3.6	44	26	0.25	26
SR33411C101	0.081	11	1520	1200	100	6.98	2.8	5.8	37	21	1	31
SR33411C102	0.008	1.3		200	100	7.38	1	7.1	74	1.1	0.27	19
SR33508C101	0.081	7.4	1510	1100	77	6.99	1.7	4.4	39	45	0.55	12
SR33508C102	0.18	2.9	3450	1400	100	6.98	2.1	9.8	38	12	1.7	36
SR33511C101	0.019	1.4	1500	140	100	7.26	0.4	0.94	29	61	0.37	8.2
SR33609C101	0.09	7.3	2350	1400	100	7.05	0.44	3	38	39	0.28	12
SR33609C102	0.24	2.4	2920	1800	100	6.96	2.8	6.3	43	29	1	21
SR33611C101	0.08	2.3	1530	1200	100	6.99	4.5	8	26	14	0.19	52
SR33611C201	0.015	0.92	1460	220	100	7.09	1.5	2.4	31	29	2.2	40
SR33809C101	0.2	8	2350	1900	100	6.97	2.5	6.8	48	16	0.37	29
SR33809C102	0.07	1.3	2700	730	100	7.02	1.9	1.9	27	38	0.76	30
SR33812C101	0.037	2.8	1900	600	100	7.19	0.74	2.2	39	47	0.95	10
SR33812C102	0.012	0.58	1390	1600	100	7.26	0.42	0.52	27	100	2.4	6.3
SR33911C101	0.12	4.4	1350	1300	100	7.01	2.4	7.7	37	16	0.78	36
SR33911C102	0.12	8.8	3820	2600	100	7.06	2.6	2.1	52	39	1	14

**TABLE A-13 SAGINAW RIVER - SURVEYS 2 AND 3  
LARGE LAKES RECONNAISSANCE DATA FOR MASTER STATIONS**

<b>SAMPLE ID</b>	<b>PCBs(ng/g dry wt)</b>
SR20201C101	1527.54
SR20201C102	13546.44
SR20304C101	8997.32
SR20304C102	12062.38
SR20304C103	125.92
SR20401C101	103.16
SR20601C101	34427.37
SR20601C202	560.27
SR20801C101	867.44
SR20801C101	861.74
SR20801C101	864.8
SR20801C102	126.84
SR20801C103	120.16
SR20901C101	191.39
SR21002C101	120.45
SR21201C101	2334.74
SR21601C101	14523.35
SR21601C102	78.34
SR22401C102	452.71
SR22501C101	1331.05
SR22501C102	1873.49
SR22501C203	245.48
SR32709C101	215.42
SR32709C102	544.66
SR32808C101	175.6
SR32808C102	92.41
SR32906C101	10991.24
SR32906C102	4534.97
SR33006C101	1474.8
SR33006C102	62.54
SR33106C101	209.24
SR33106C102	27.07
SR33207C101	3242.59
SR33207C102	35.11
SR33207C103	32.84
SR33309C101	1060.87
SR33309C102	1725.38
SR33409C101	3183.65
SR33409C102	500.68
SR33609C101	7622.21
SR33609C102	307.54
SR33809C101	7307.77
SR33809C102	16.18
SR33911C101	654.56
SR33911C102	24.97

**APPENDIX B**

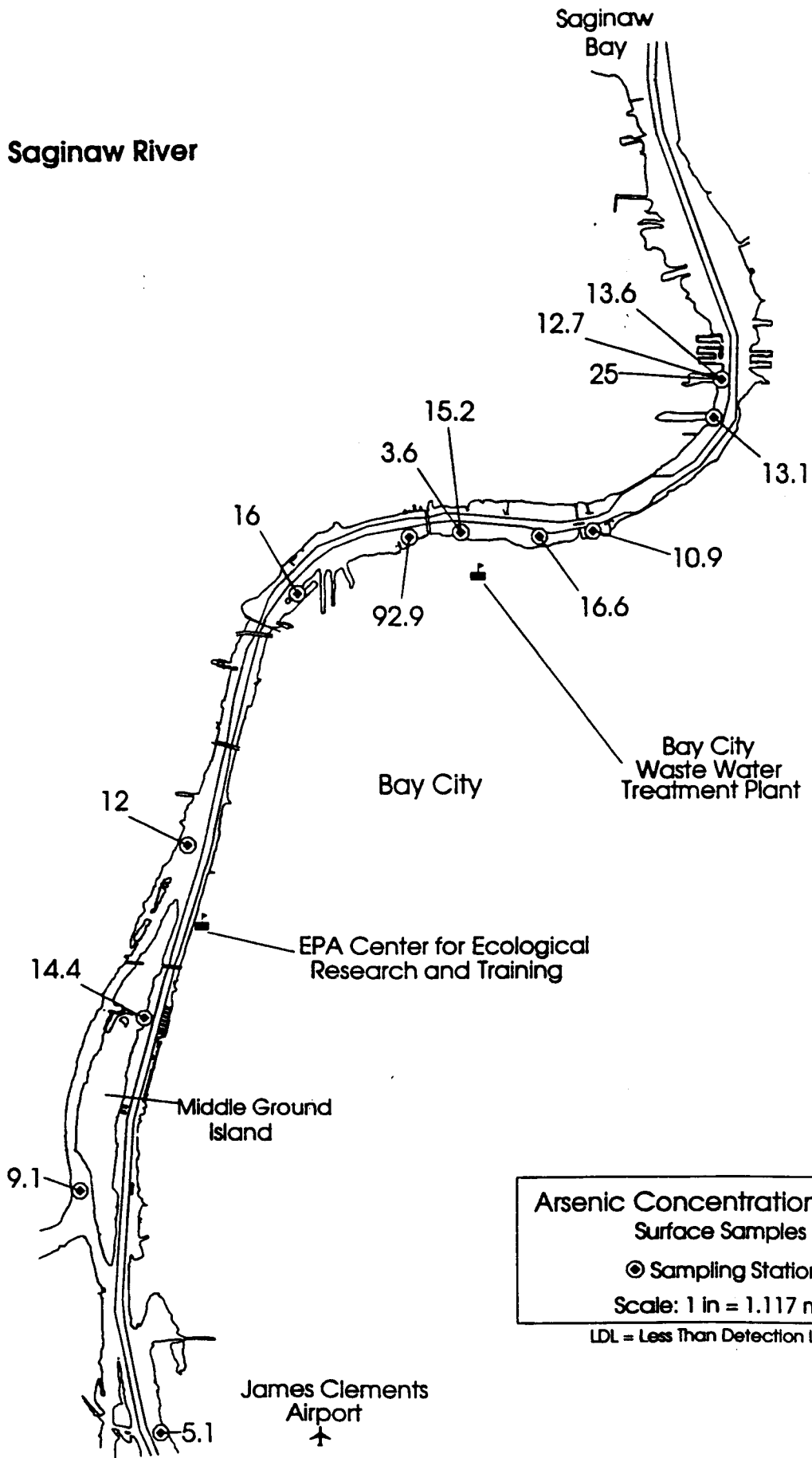
**SAGINAW RIVER**

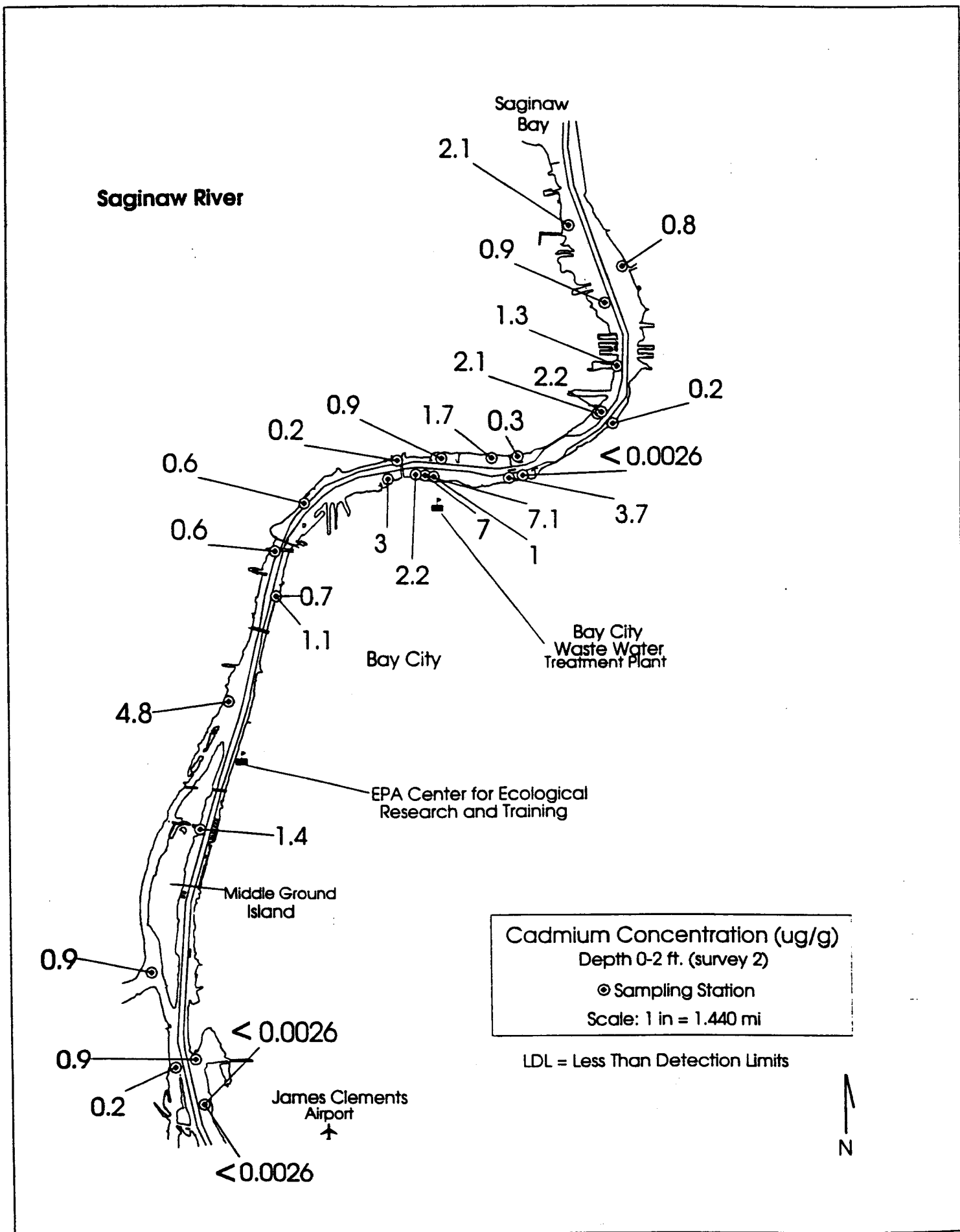
**ARCS RAW SEDIMENT DATA MAPS**

## SAGINAW RIVER - CONCENTRATION MAP TABLE OF CONTENTS

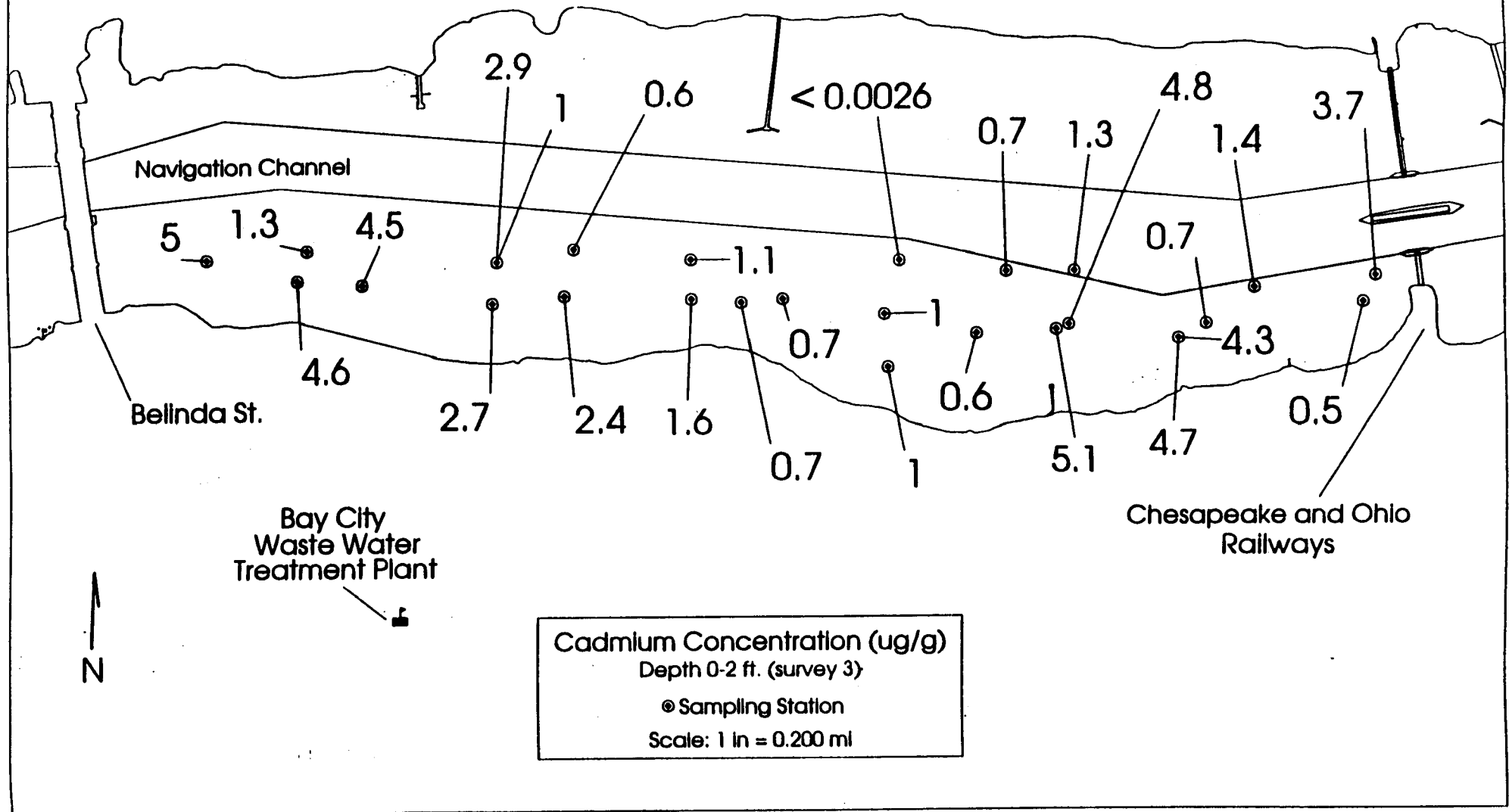
Table	Parameter	Survey (1&3)	Survey(1&3) and LLRS 2 (0-2ft)	LLRS 2 0-2ft	LLRS 3 0-2 ft	LLRS 2 2-4ft	LLRS 3 2-4ft	LLRS 2 4-6ft
Metals	Arsenic	B-3						
	Cadmium			B-4	B-5	B-6	B-7	B-8
	Chromium	B-9						
	Copper		B-10		B-11	B-12	B-13	B-14
	Lead		B-15		B-16	B-17	B-18	B-19
	Mercury	B-20						
	Nickel		B-21		B-22	B-23	B-24	B-25
	Zinc		B-26		B-27	B-28	B-29	B-30
PCBs	1242	B-30		B-32	B-33	B-34	B-35	B-36
PAHs**	Anthracene	B-37						
	Benz(a)anthracene	B-38						
	Benzo(a)pyrene	B-39						
	Fluoranthene	B-40						
	Naphthalene	B-41						
	Phenanthrene	B-42						
	Pyrene	B-43						
Dioxin	Total TCDD	B-44						
Furan	Total TCDF	B-45						
Additional Parameters	AVS	B-46						
	TOC	B-47						

# Saginaw River

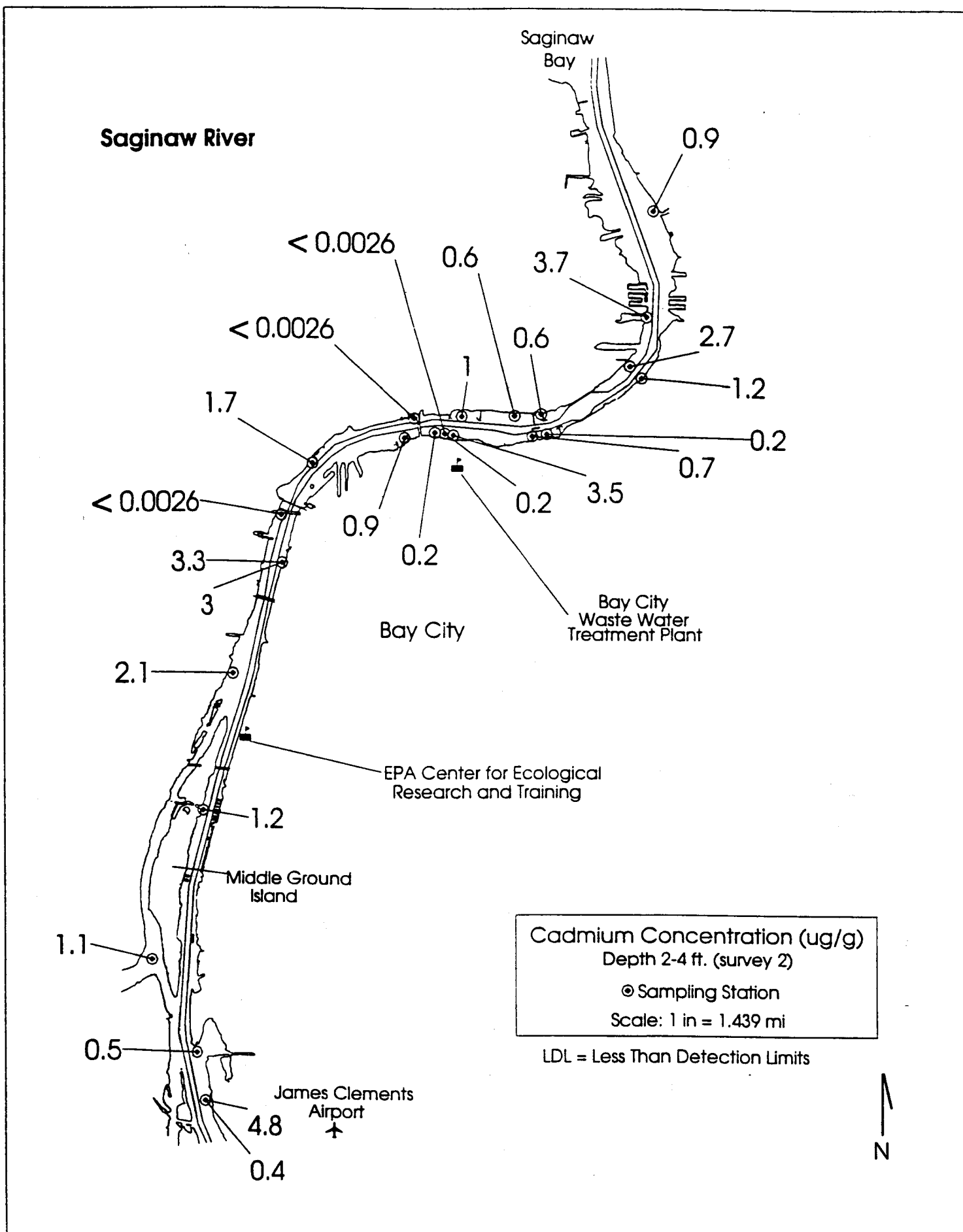




# Saginaw River Intensive Sampling Area

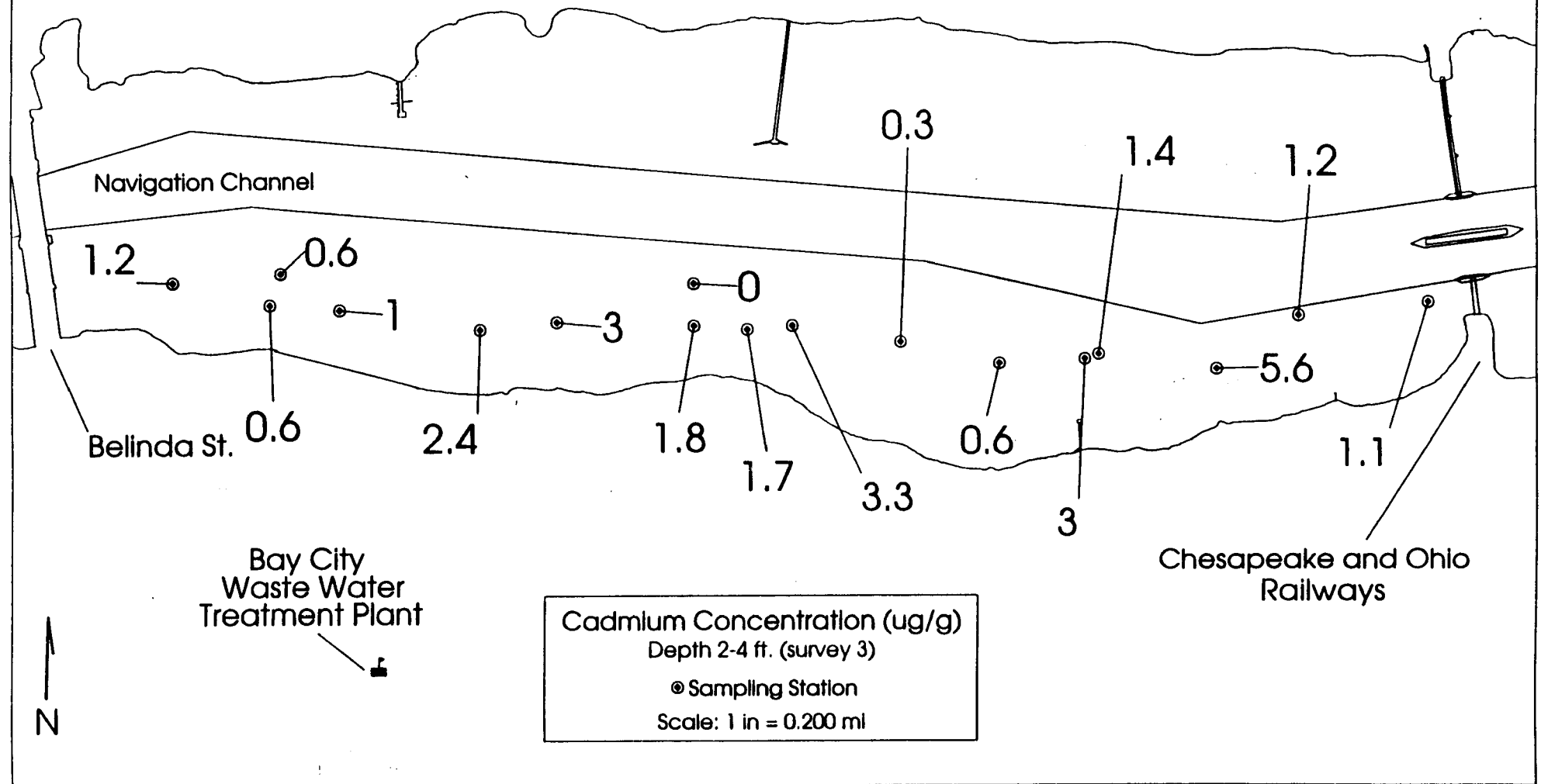


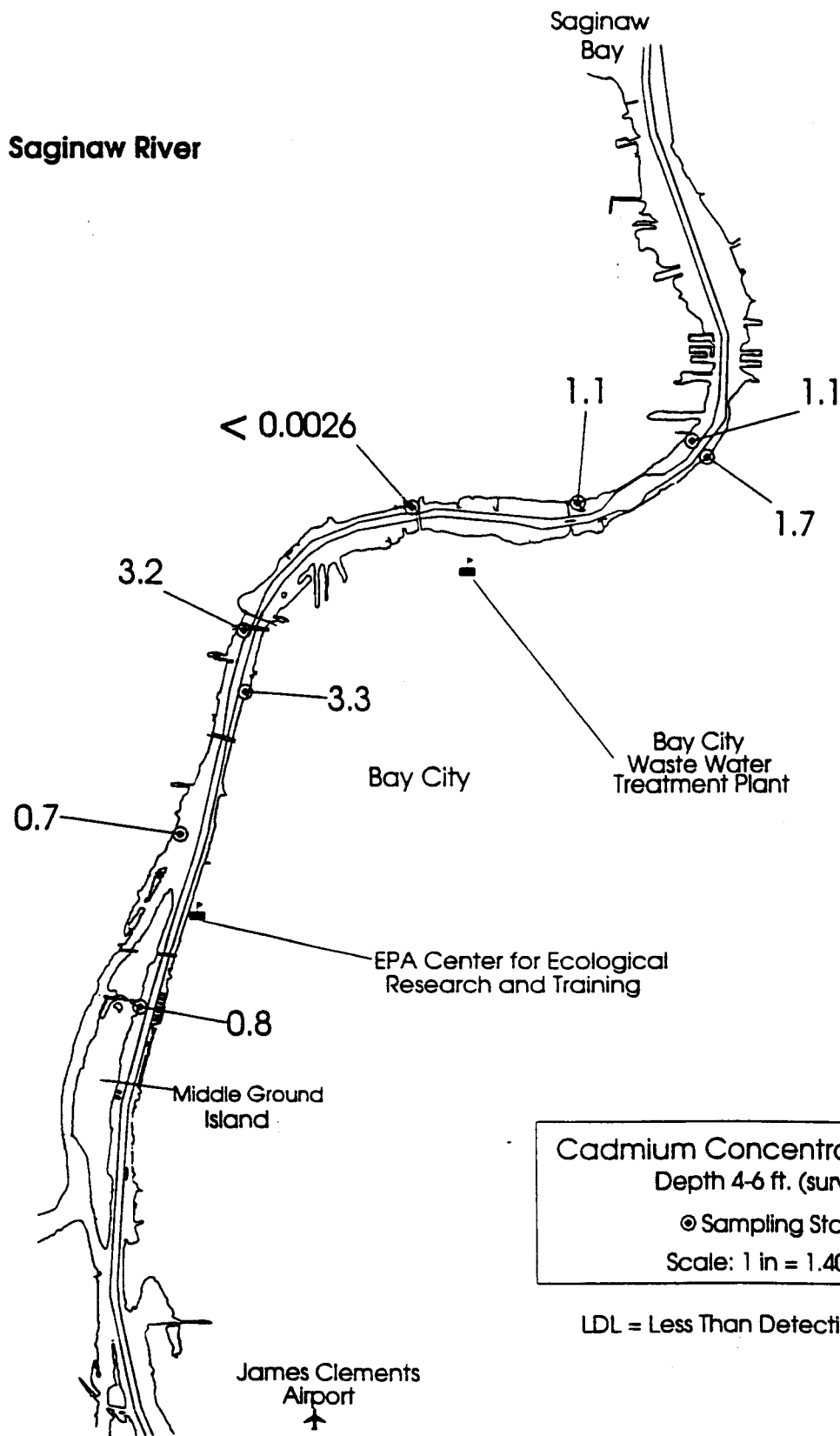


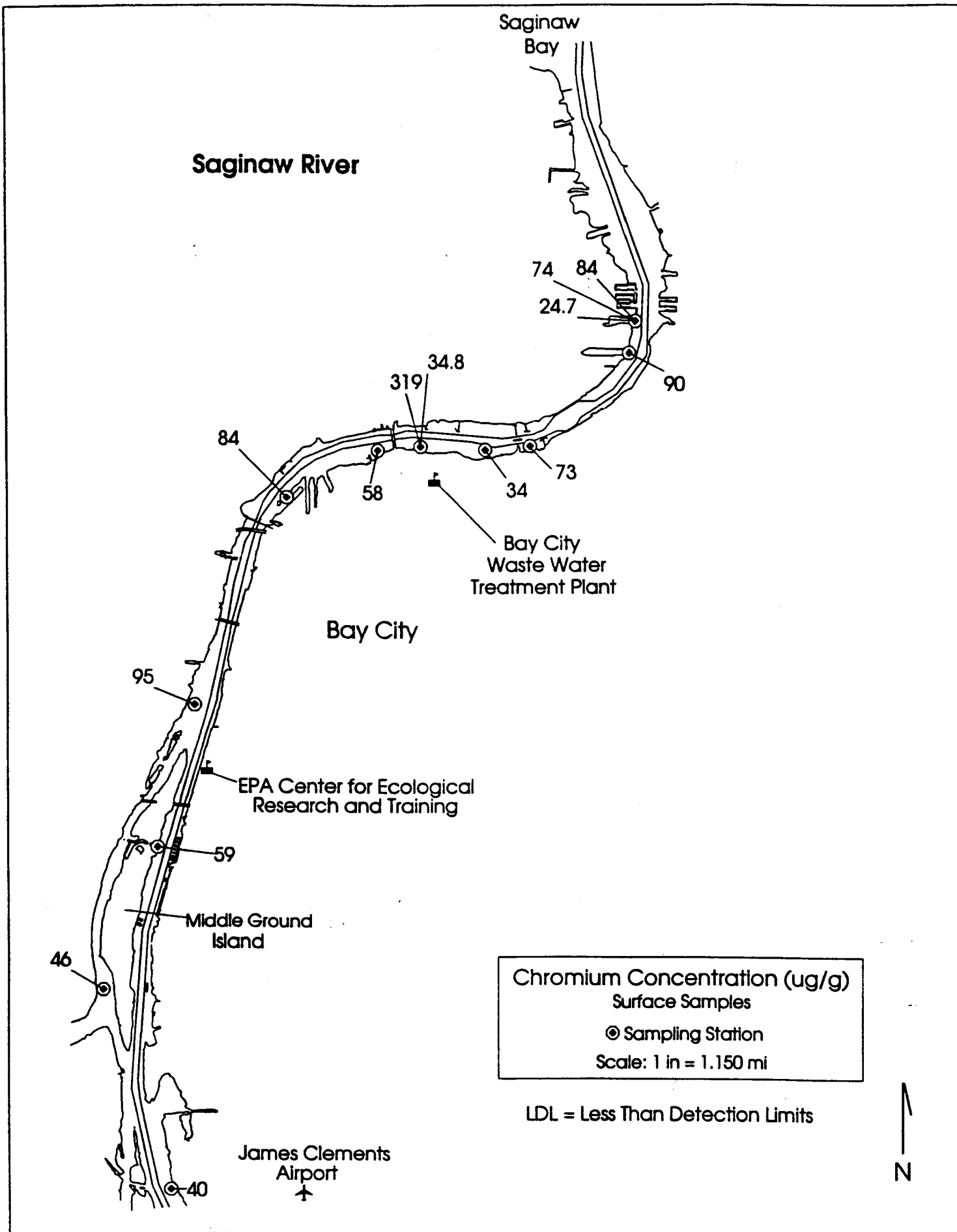


# Saginaw River

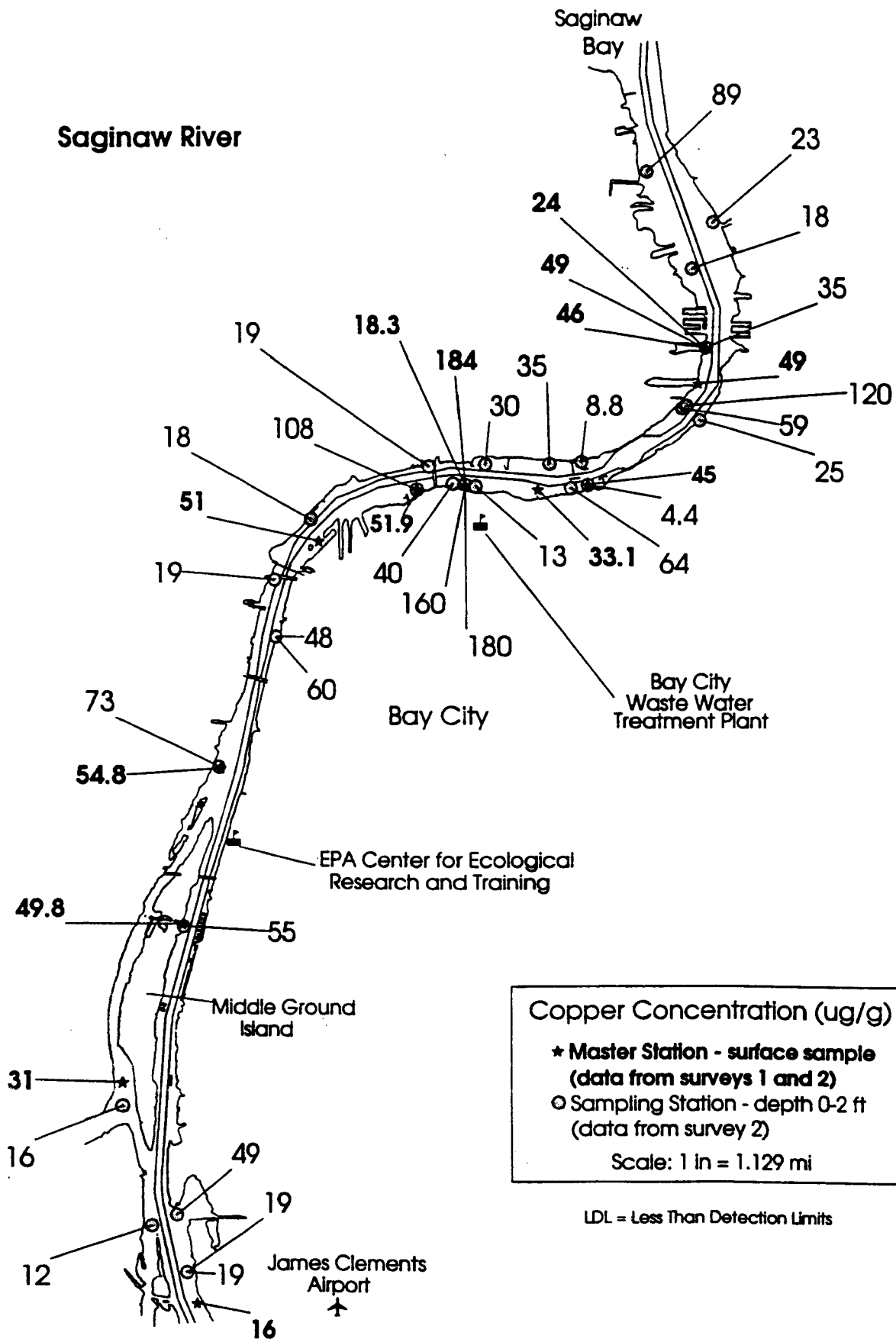
Intensive Sampling Area



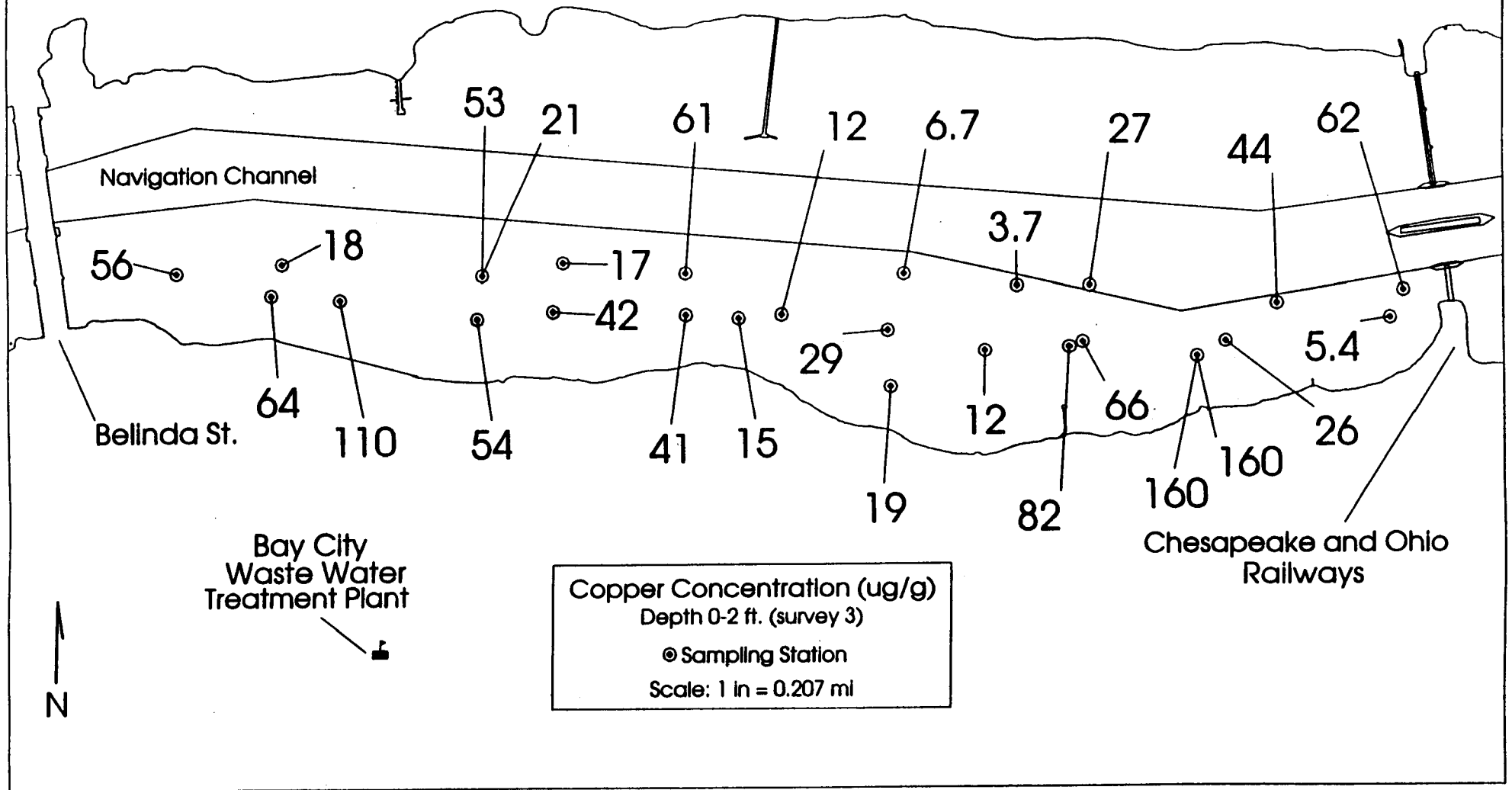


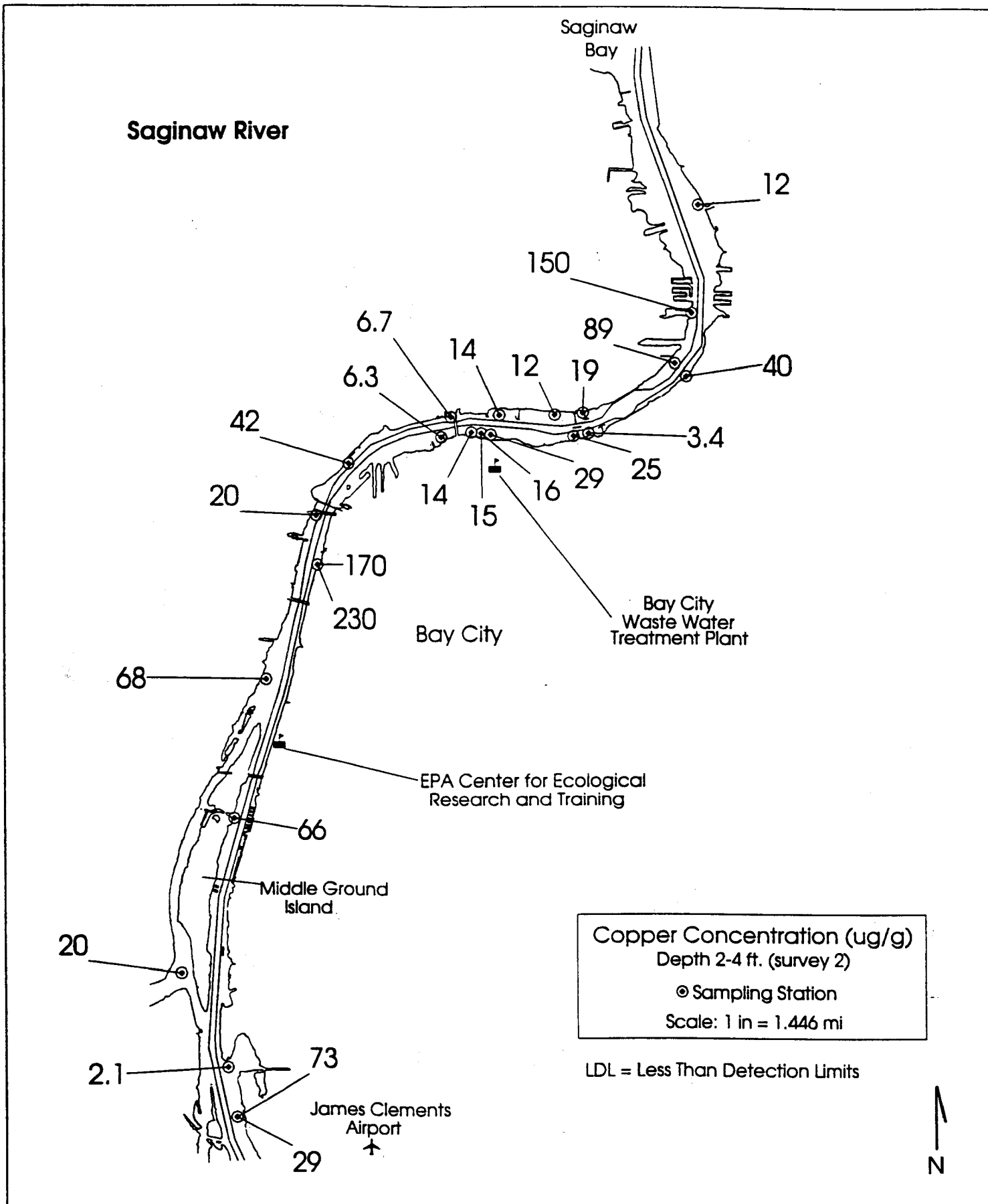


# Saginaw River



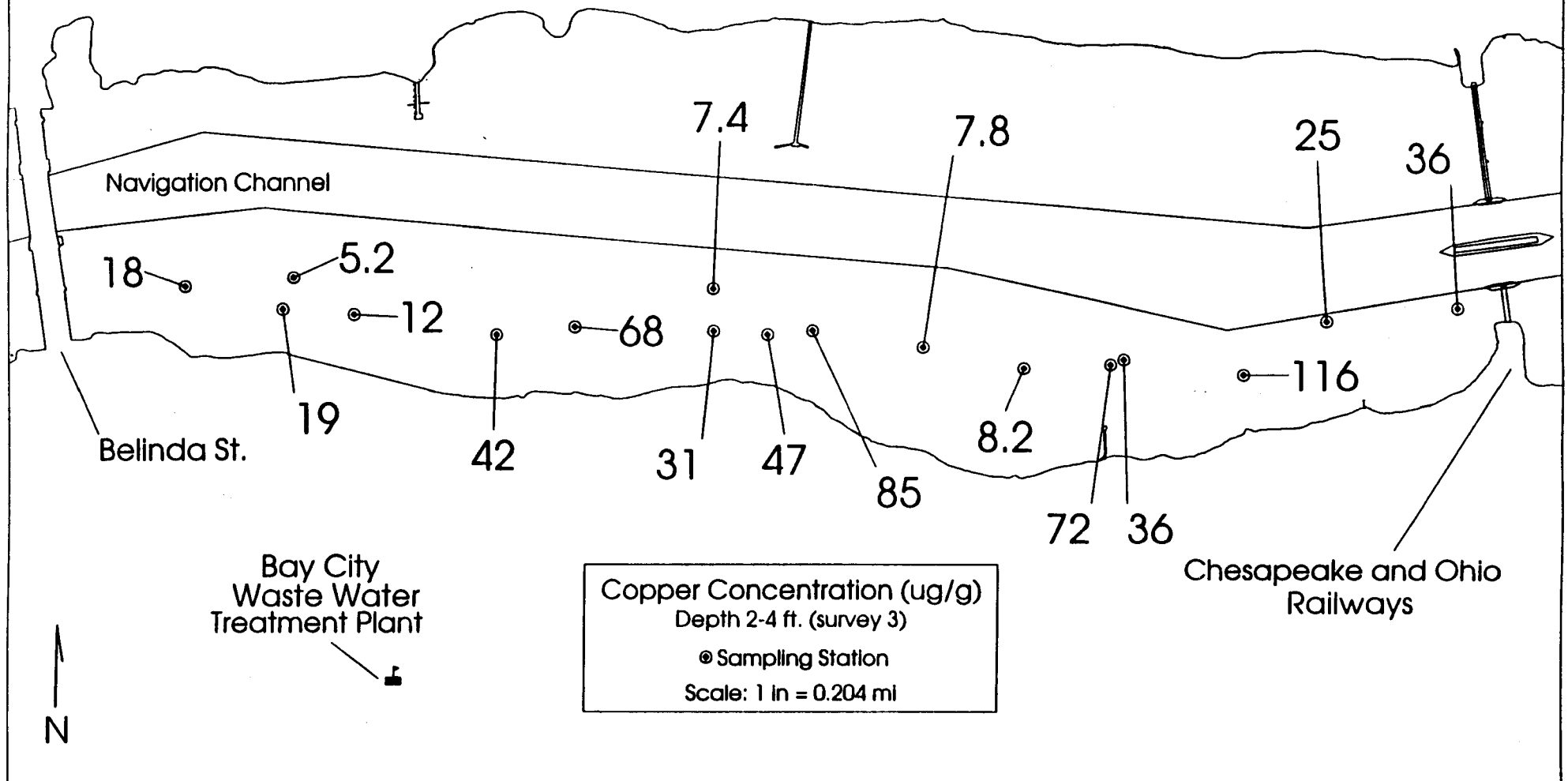
# Saginaw River Intensive Sampling Area



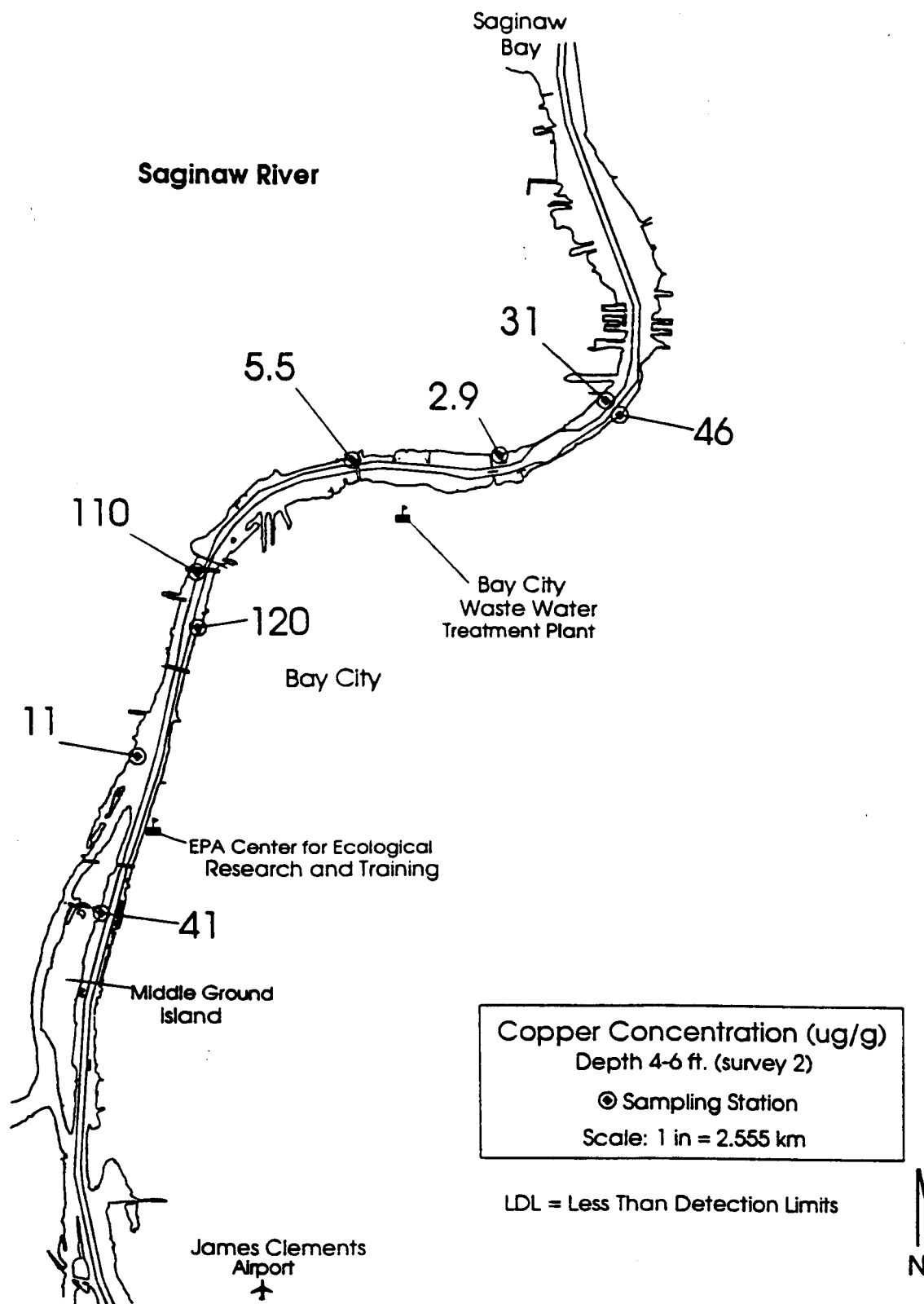


# Saginaw River

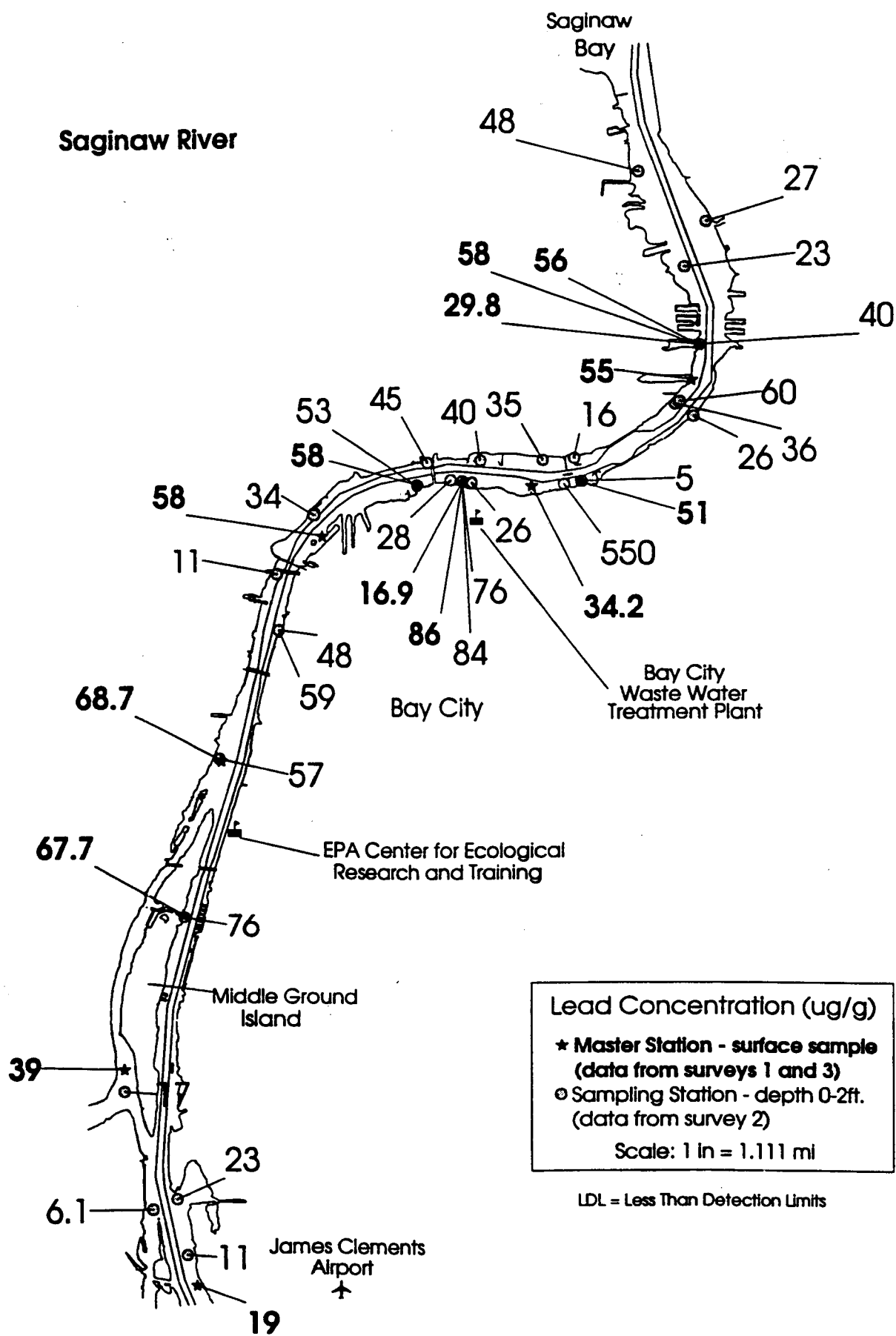
Intensive Sampling Area





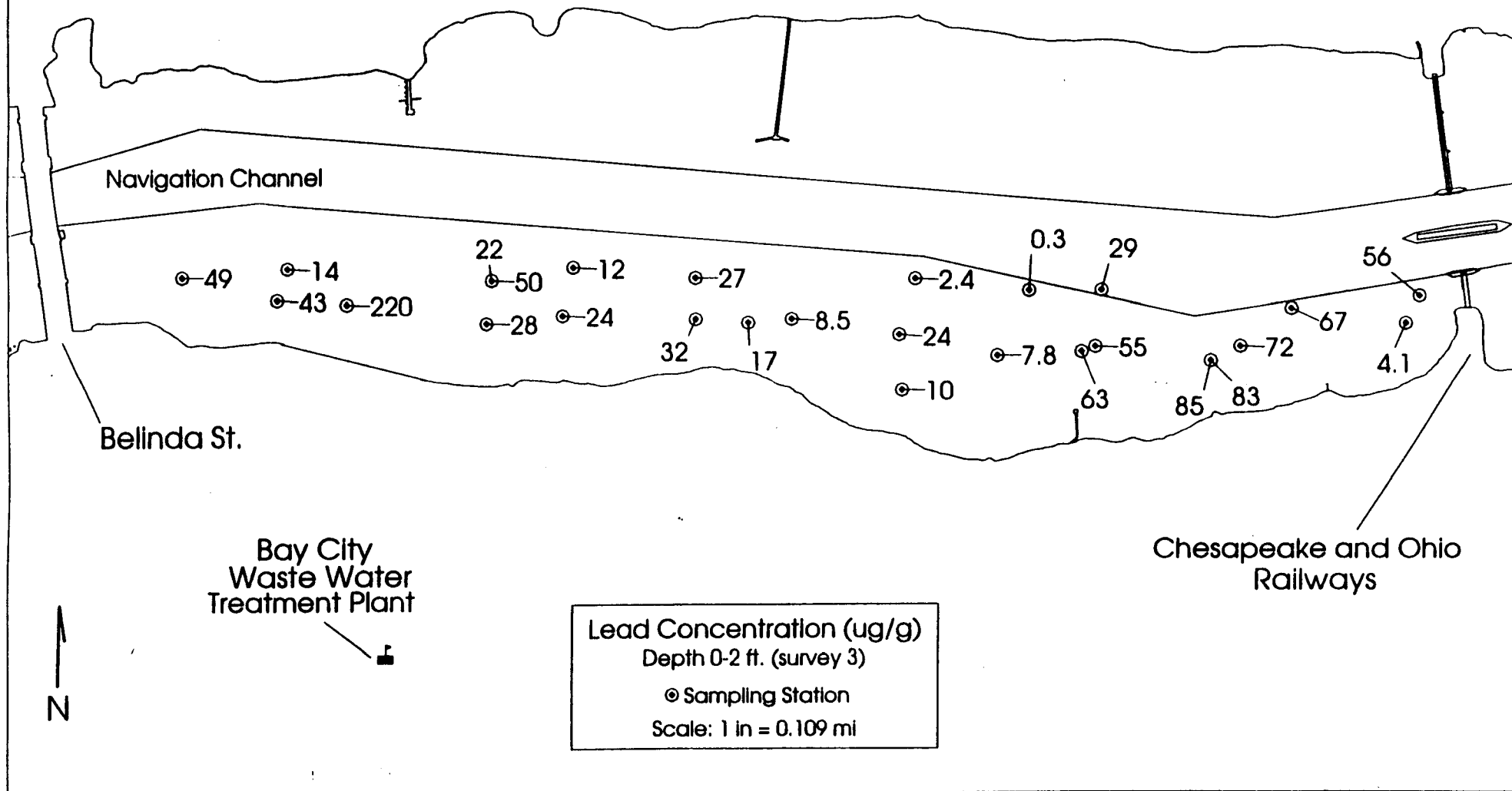


# Saginaw River



# Saginaw River

## Intensive Sampling Area



Saginaw River

Saginaw Bay

15

67

61

62

1.9

22

13

36

2.9

66

9.4

6.8

19

24

84

160

16

Bay City

Bay City  
Waste Water  
Treatment Plant

34

EPA Center for Ecological  
Research and Training

Middle Ground  
Island

65

7.3

3.1

57

19

James Clements  
Airport

Lead Concentration (ug/g)  
Depth 2-4 ft. (survey 2)

● Sampling Station

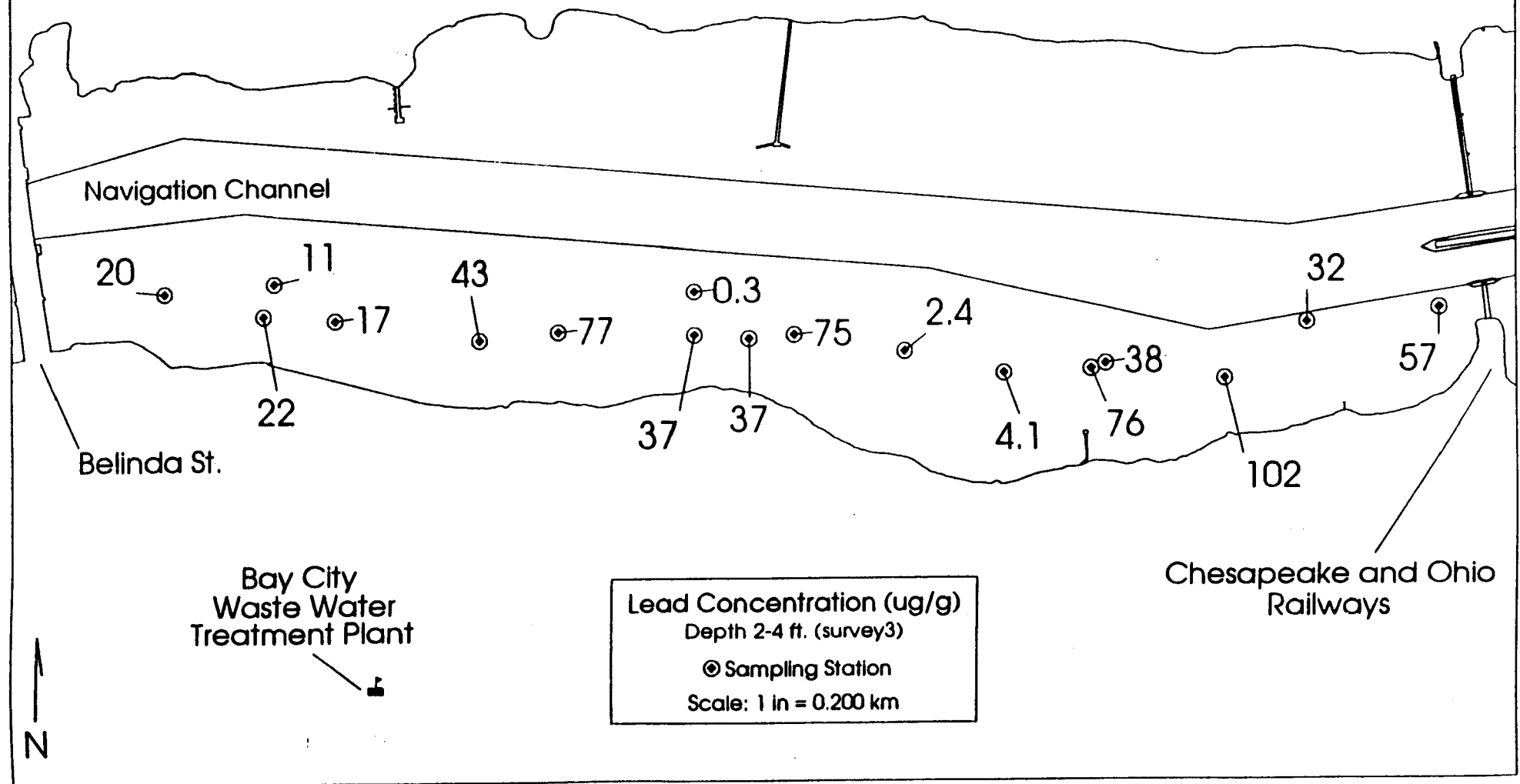
Scale: 1 in = 1.441 mi

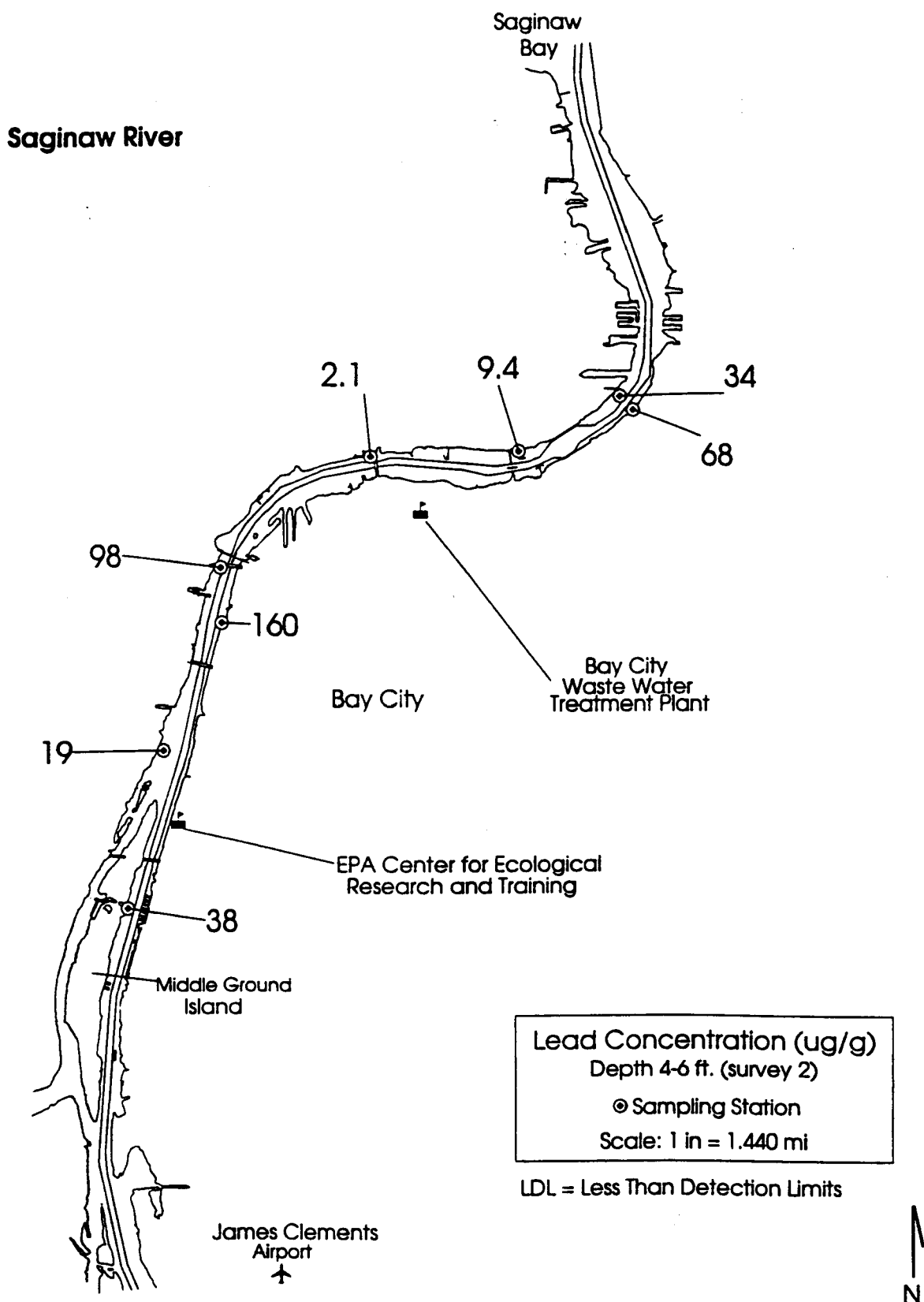
LDL = Less Than Detection Limits

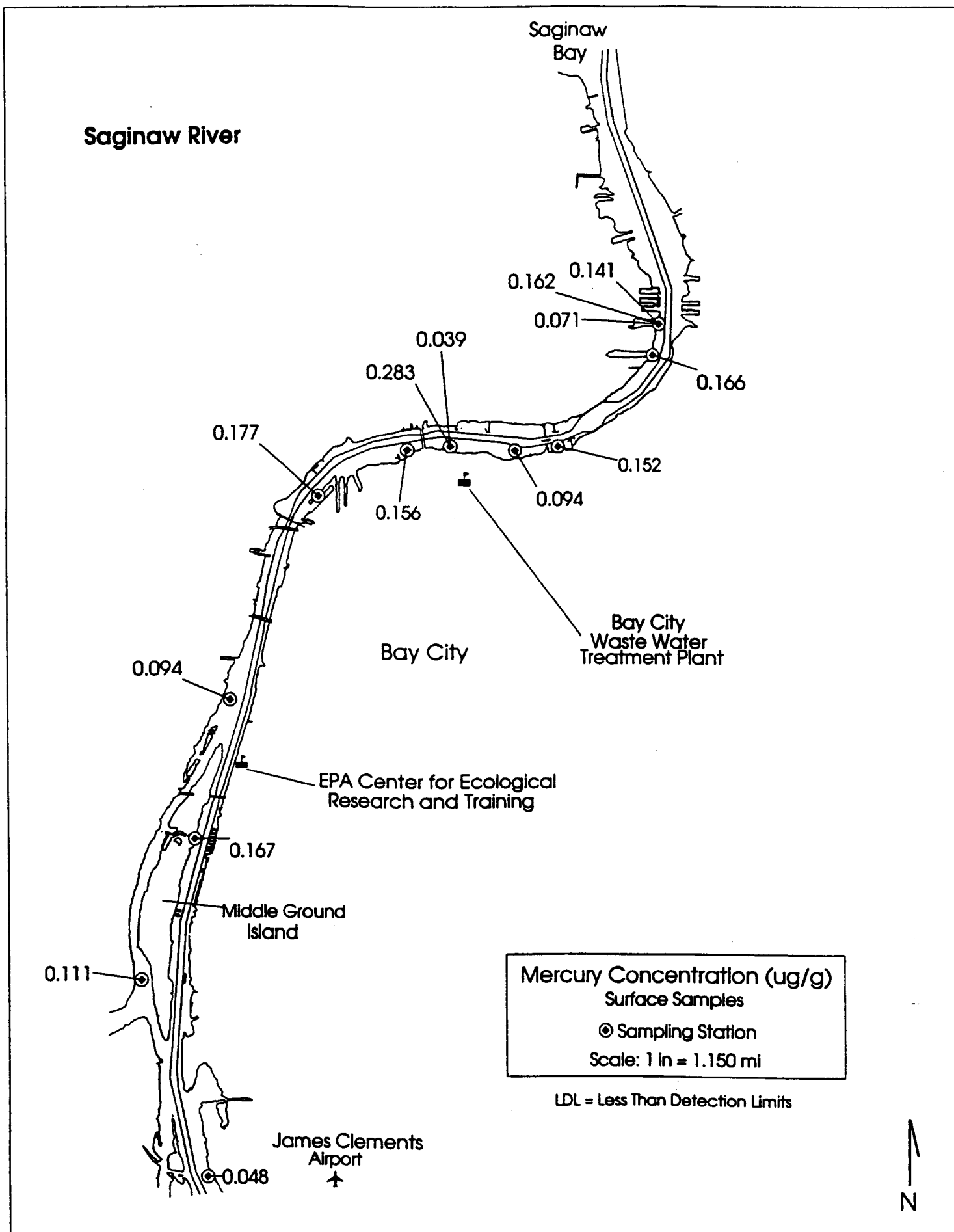
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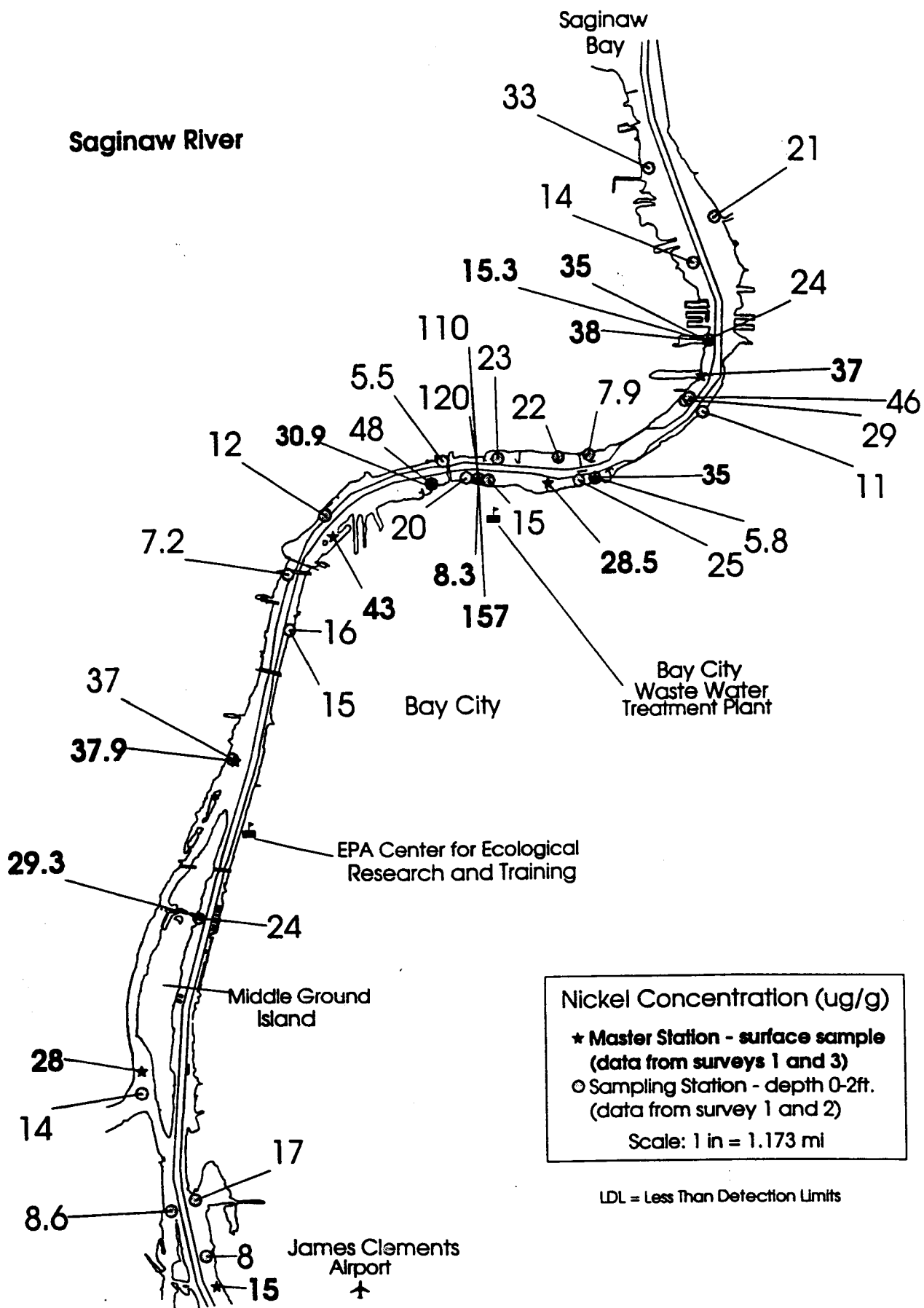
# Saginaw River

Intensive Sampling Area





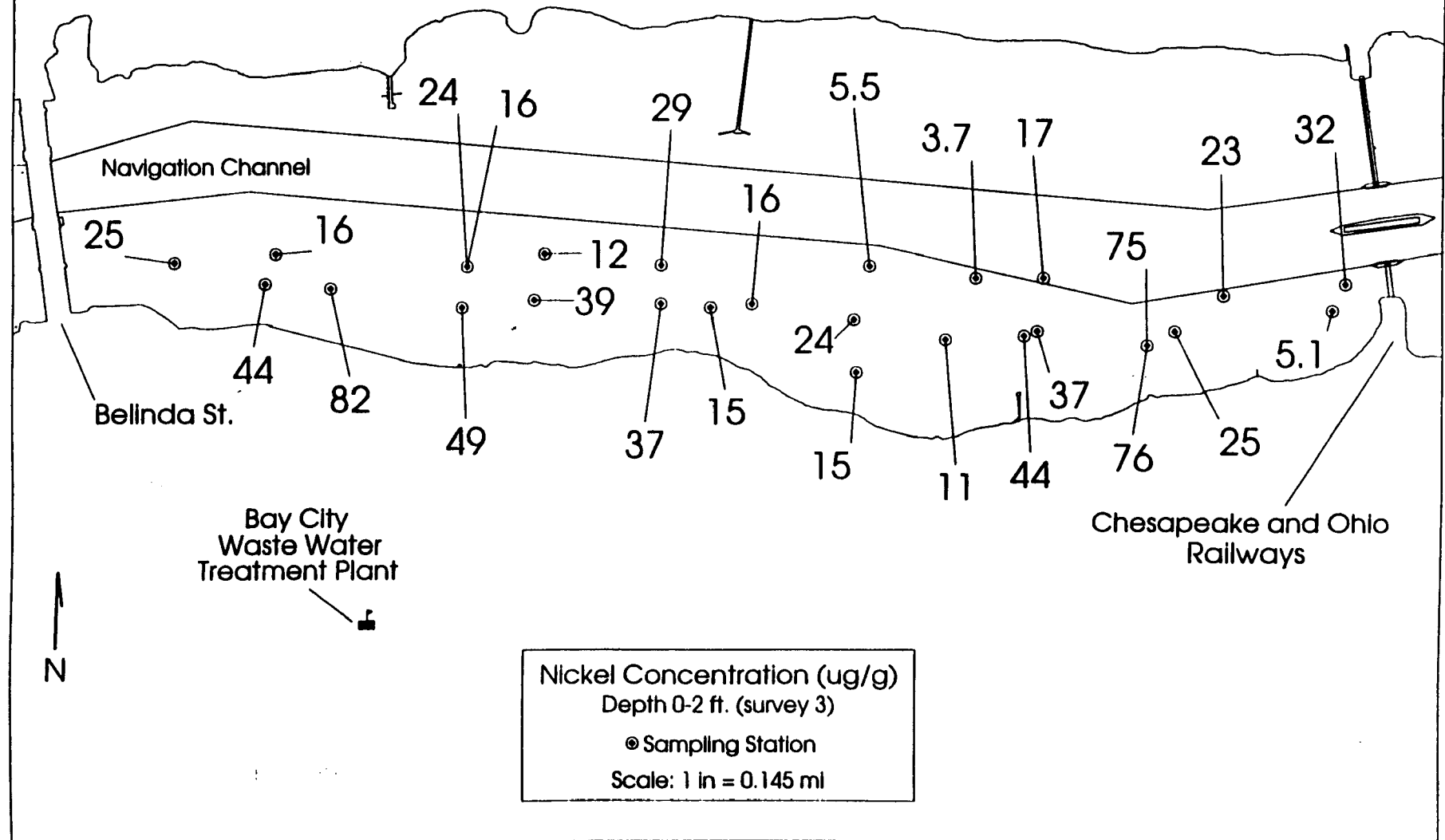




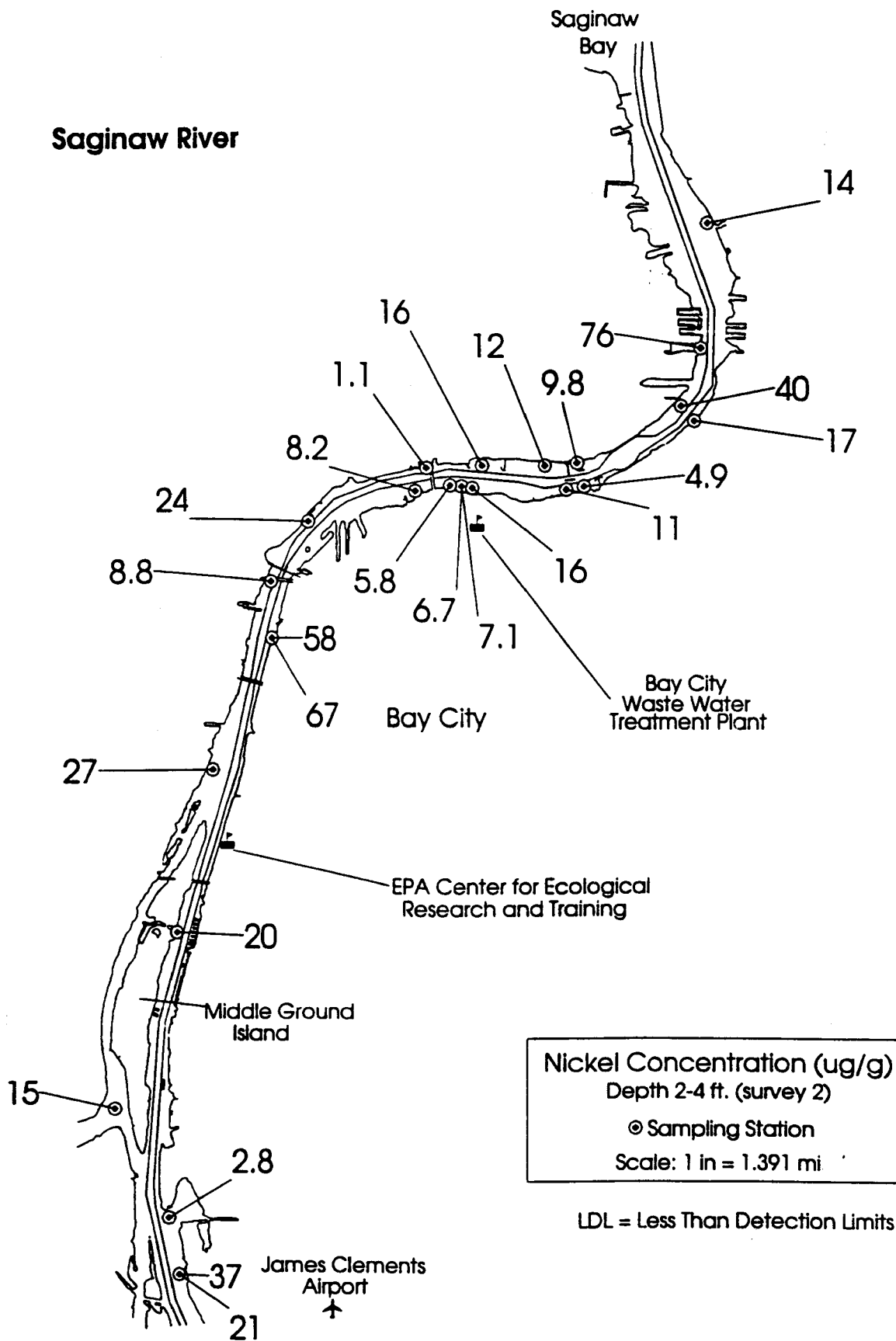


# Saginaw River

Intensive Sampling Area

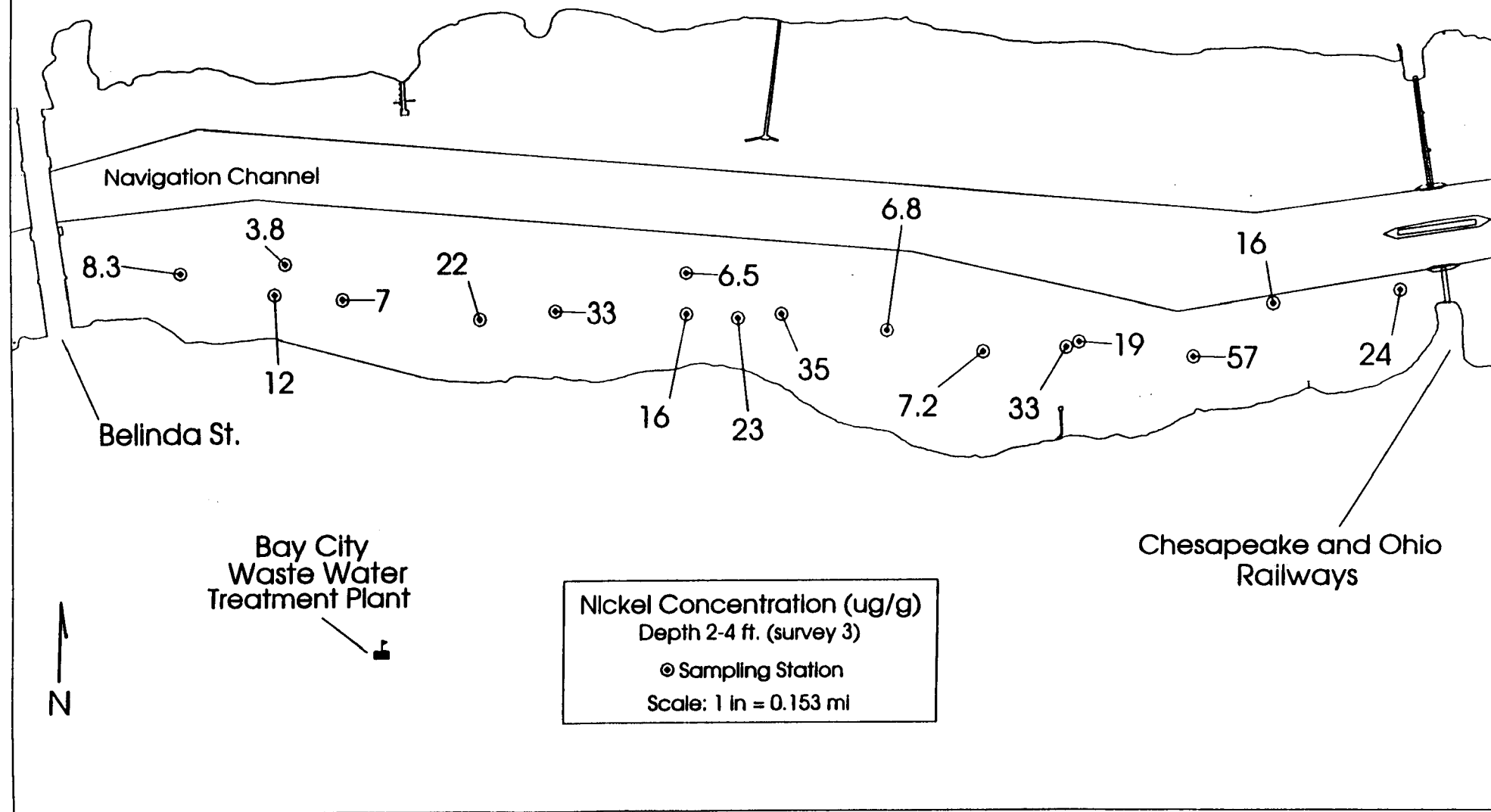


# Saginaw River

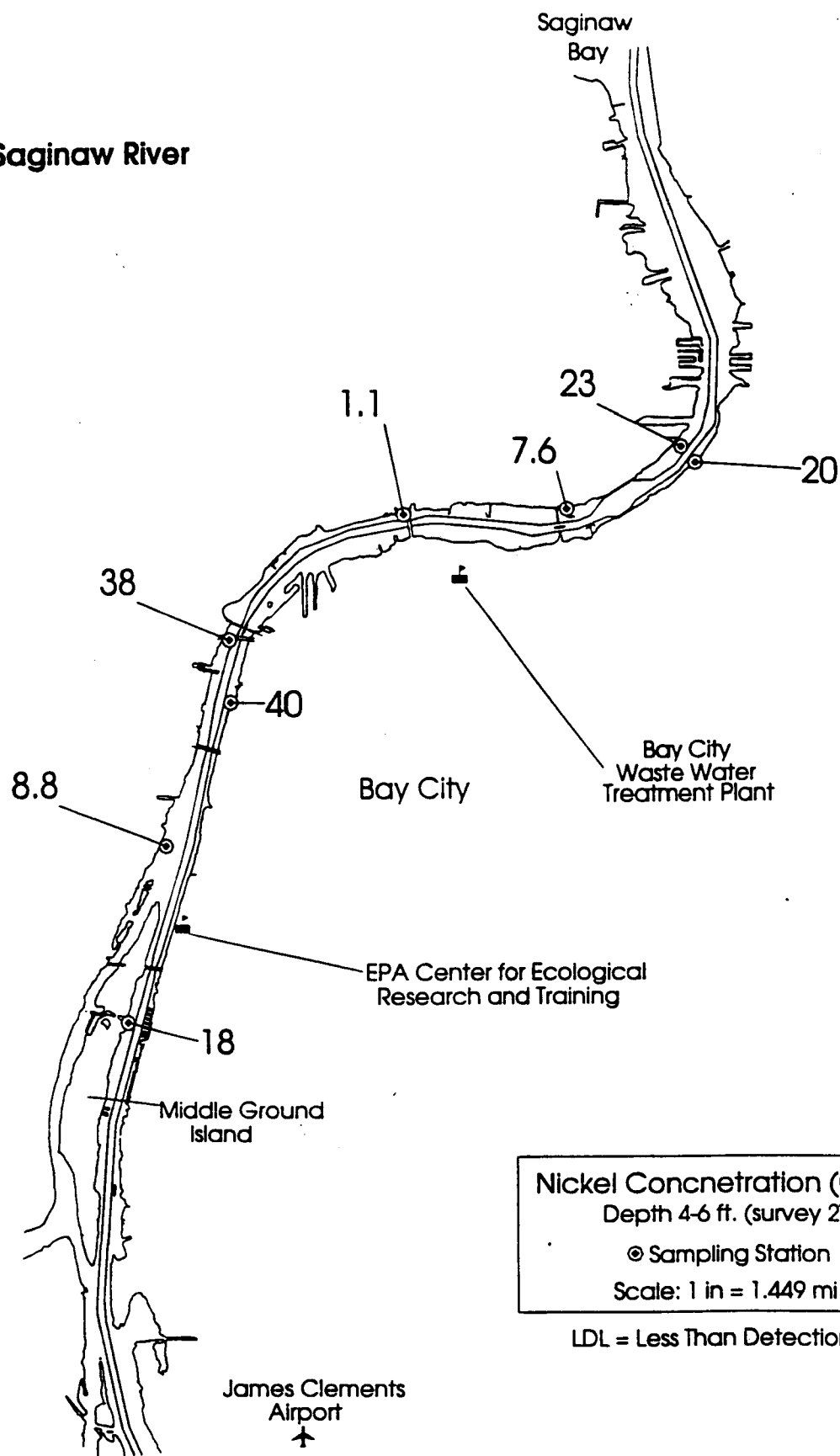


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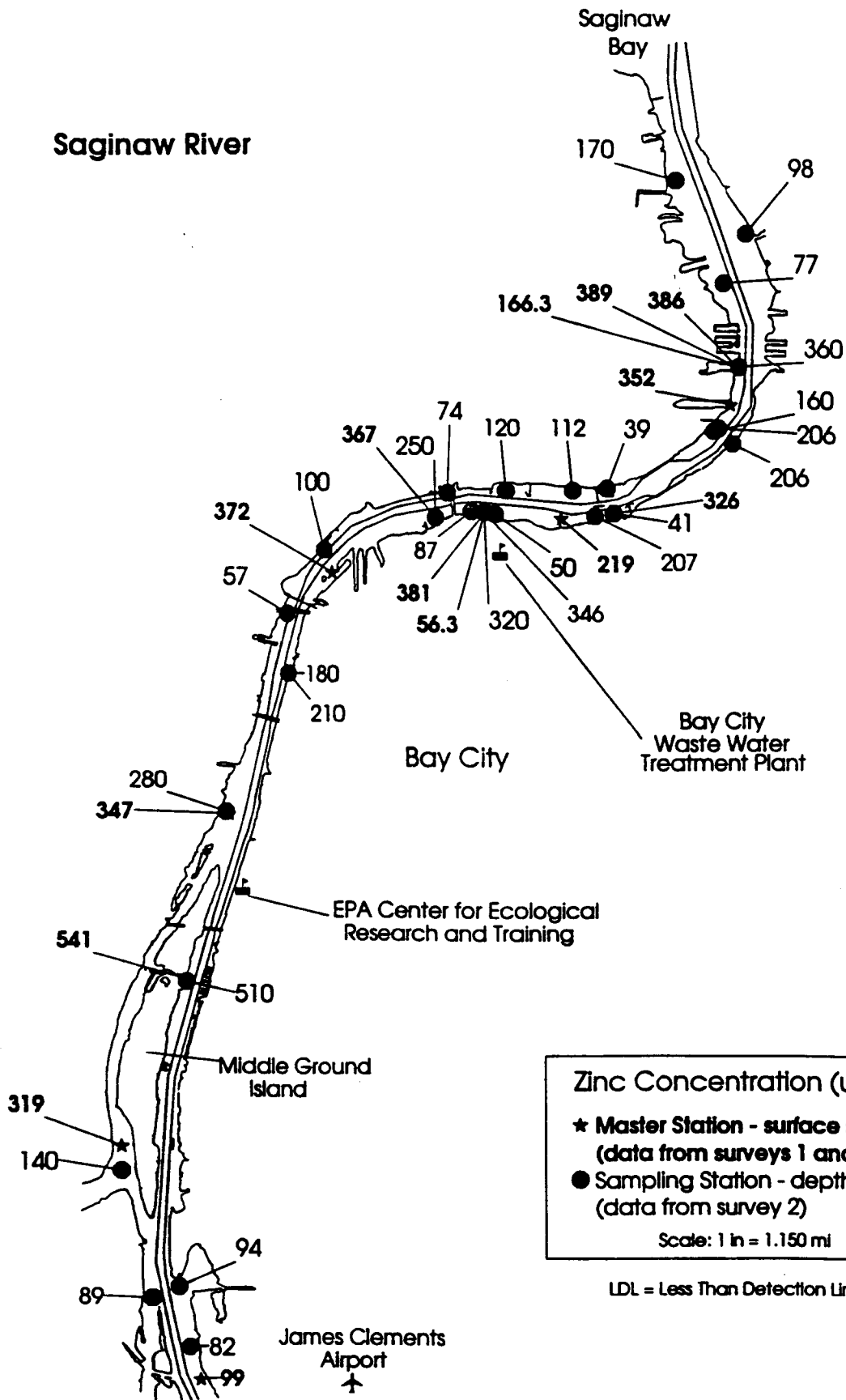
Intensive Sampling Area



Saginaw River

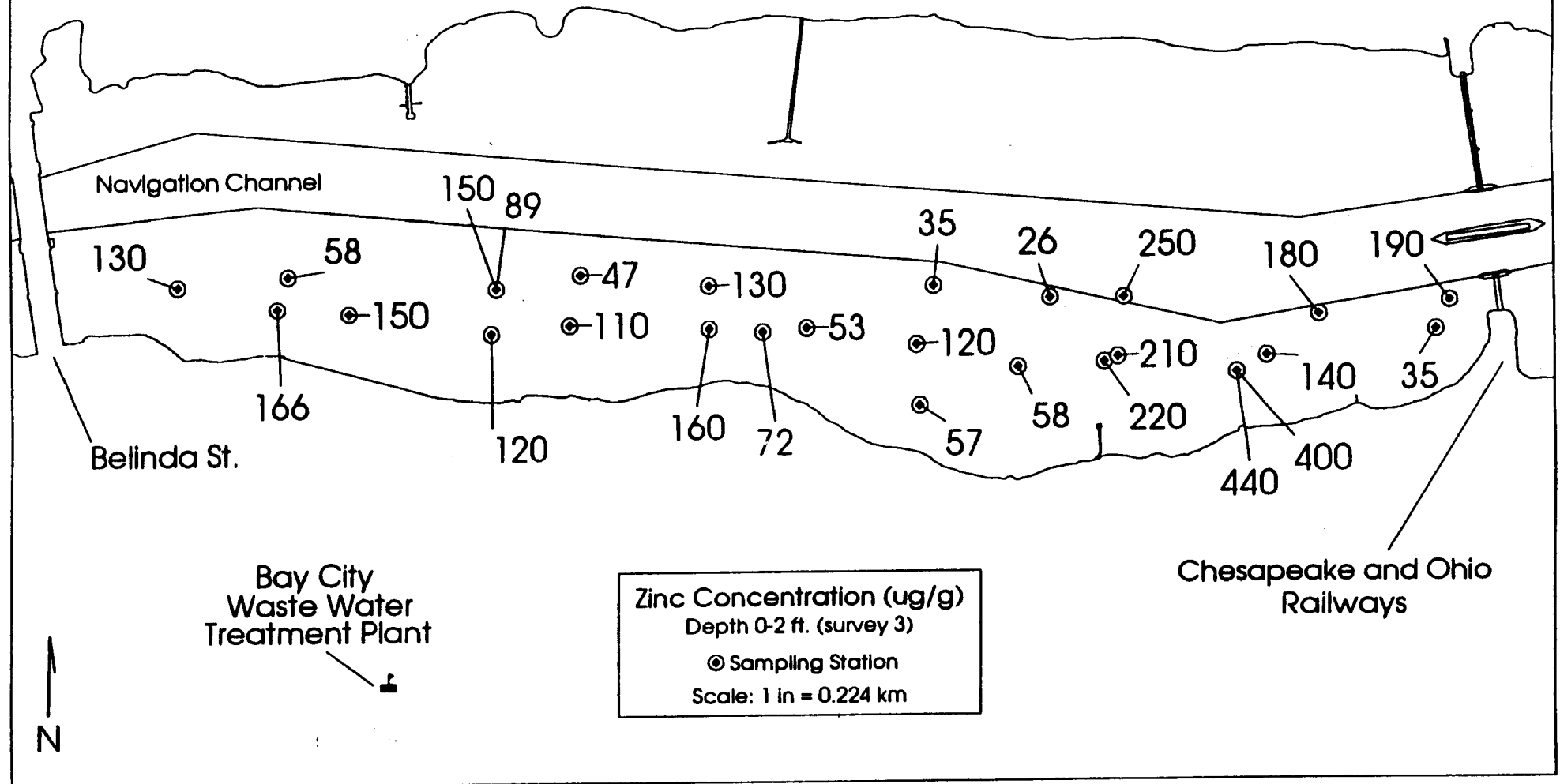


# Saginaw River

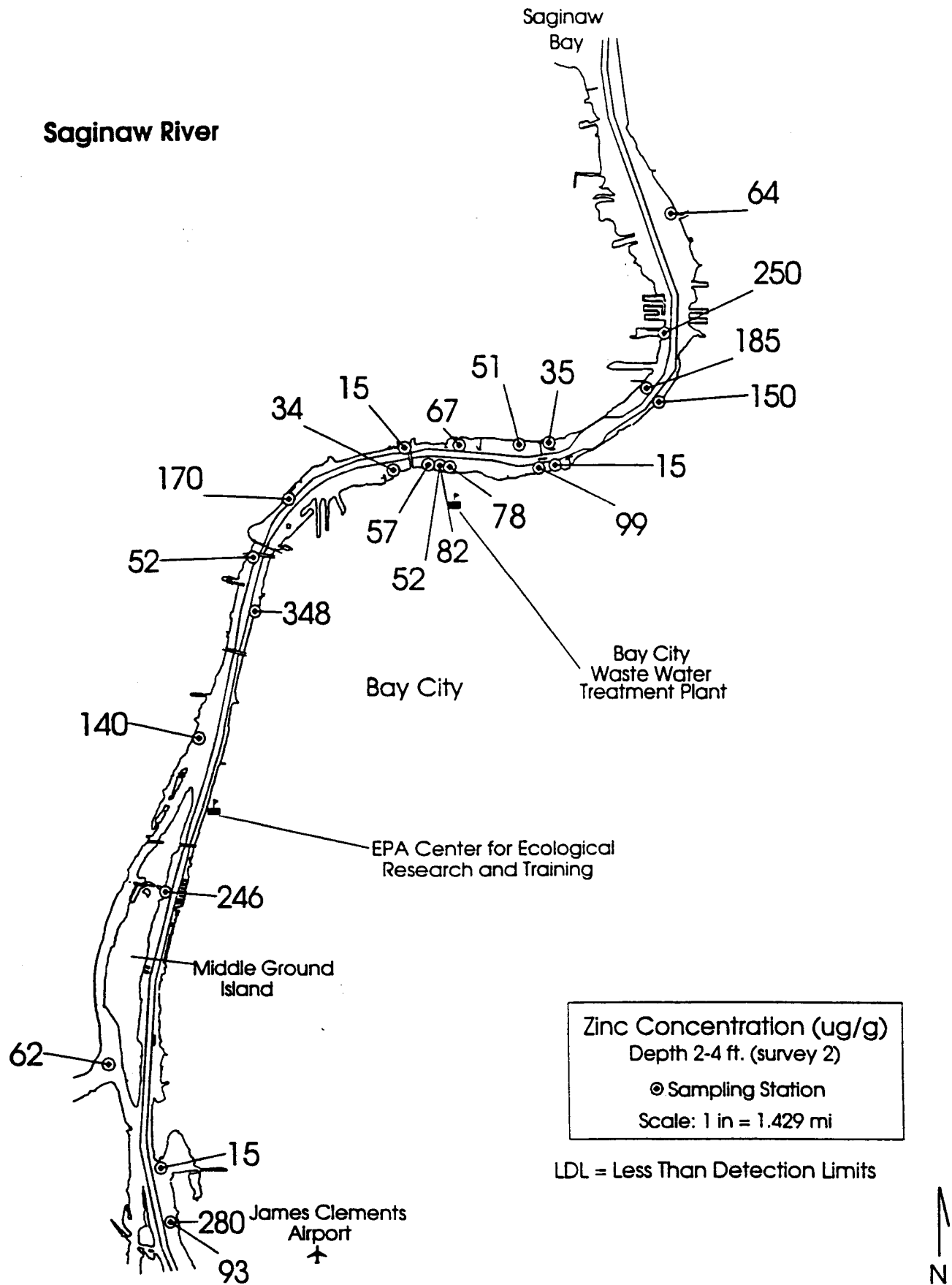


# Saginaw River

## Intensive Sampling Area

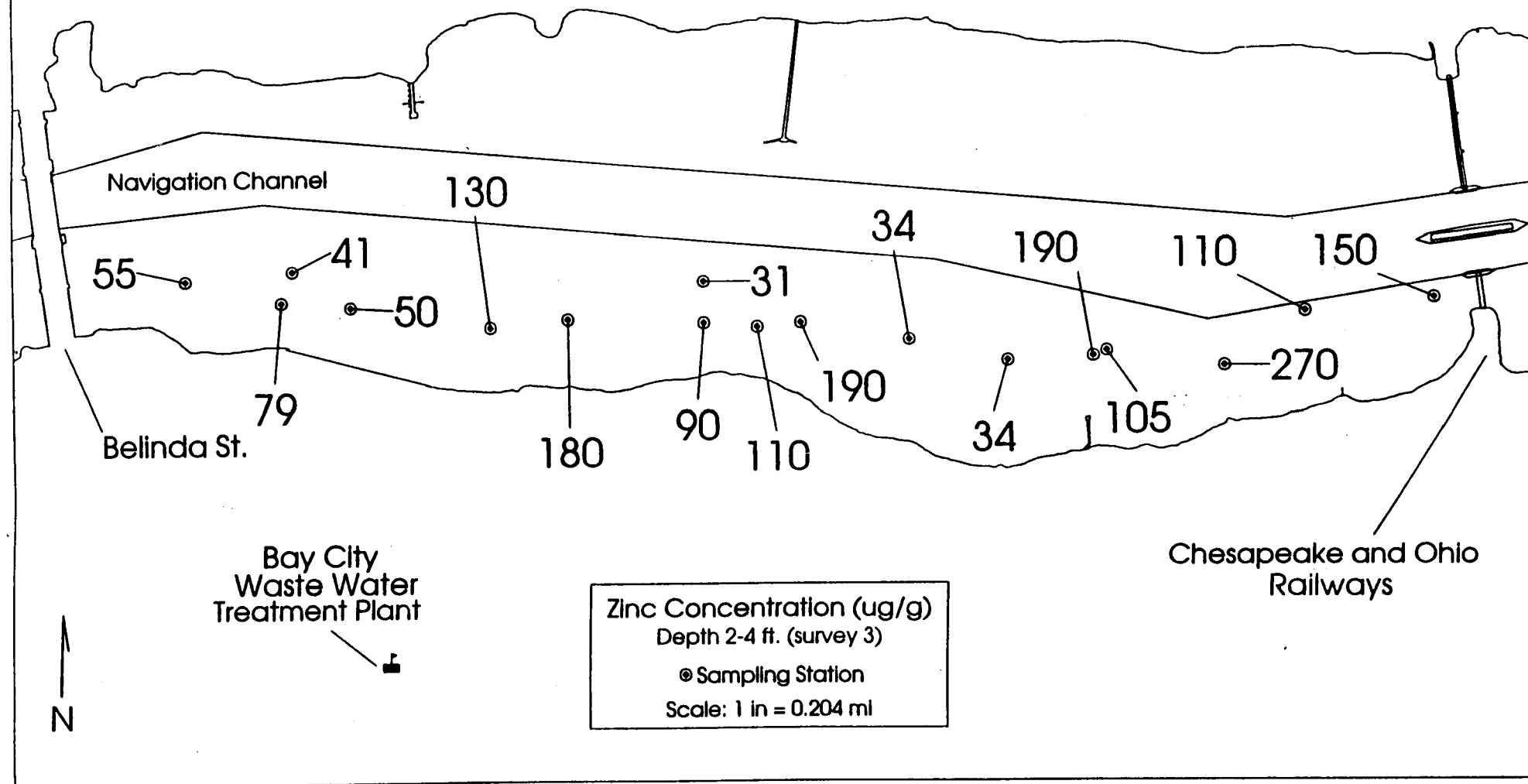


# Saginaw River

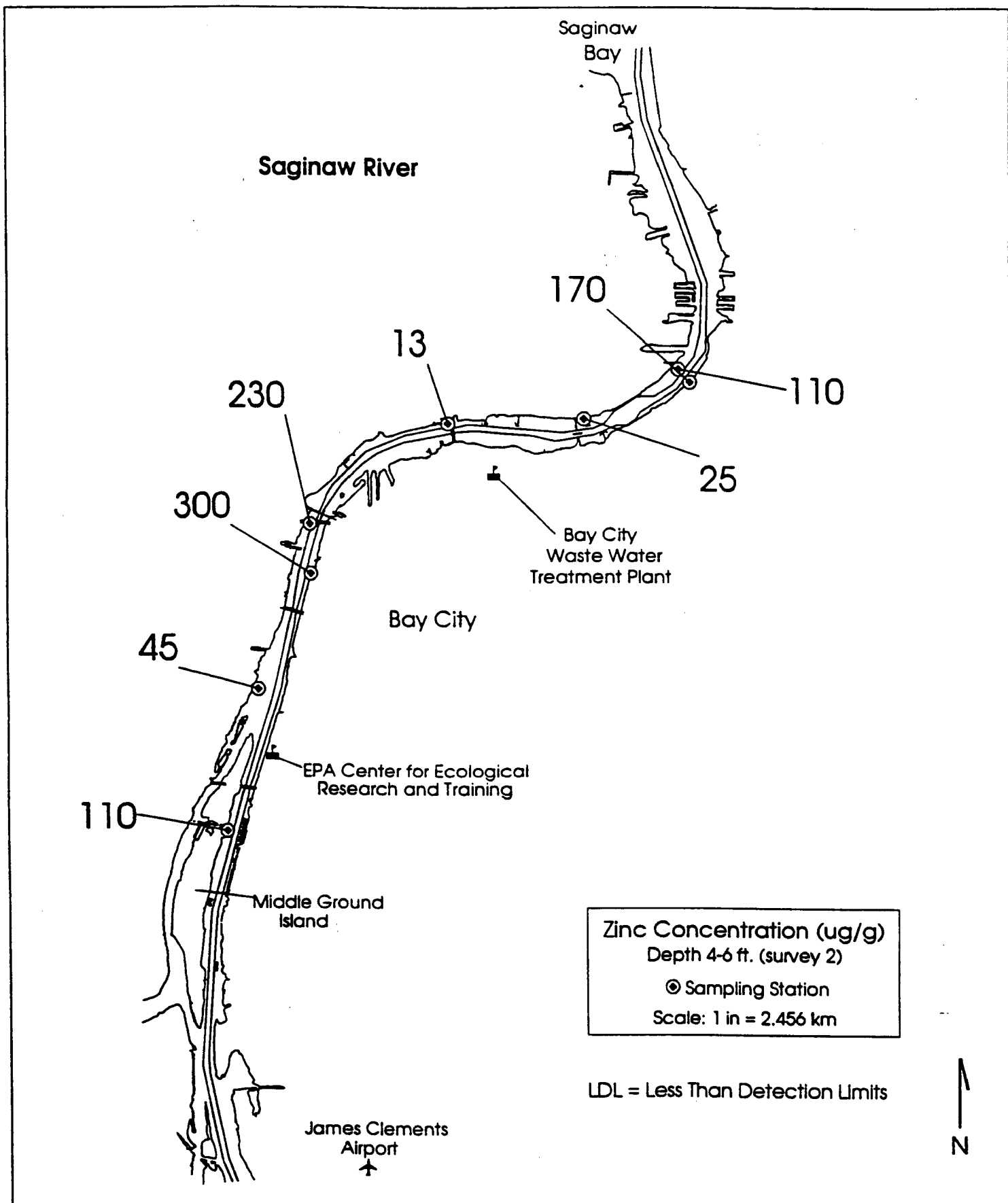


# Saginaw River

## Intensive Sampling Area

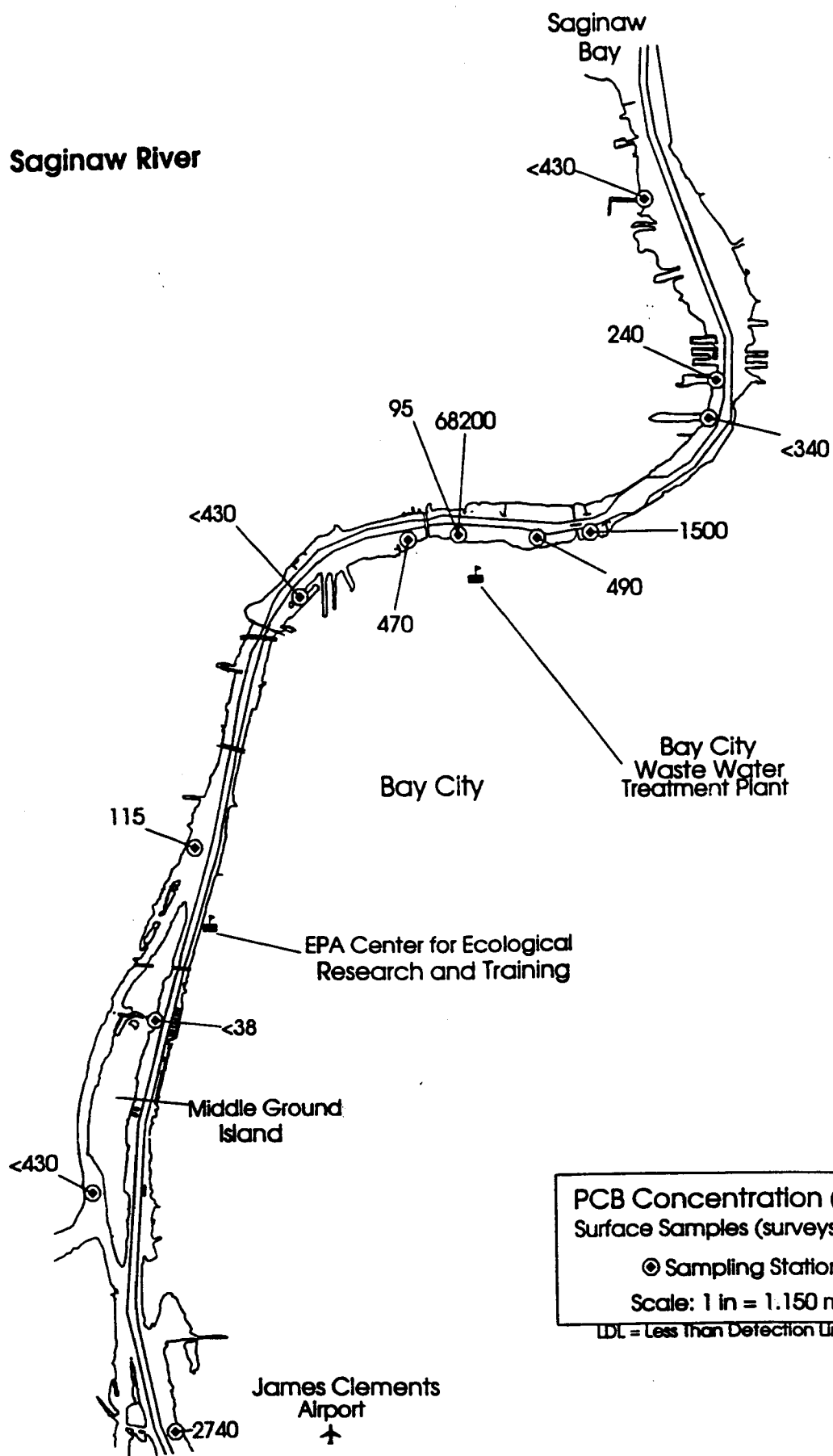


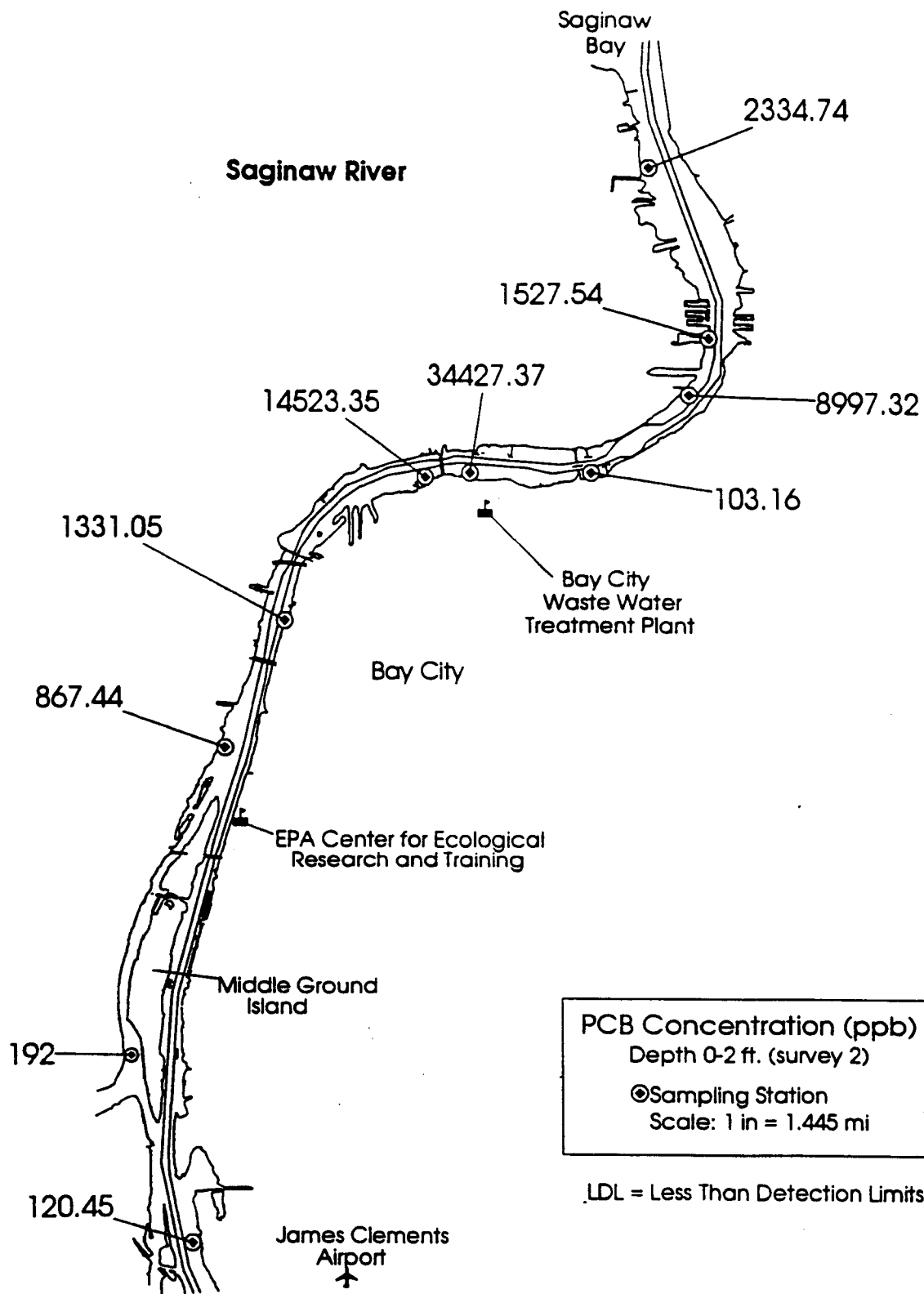




Saginaw River

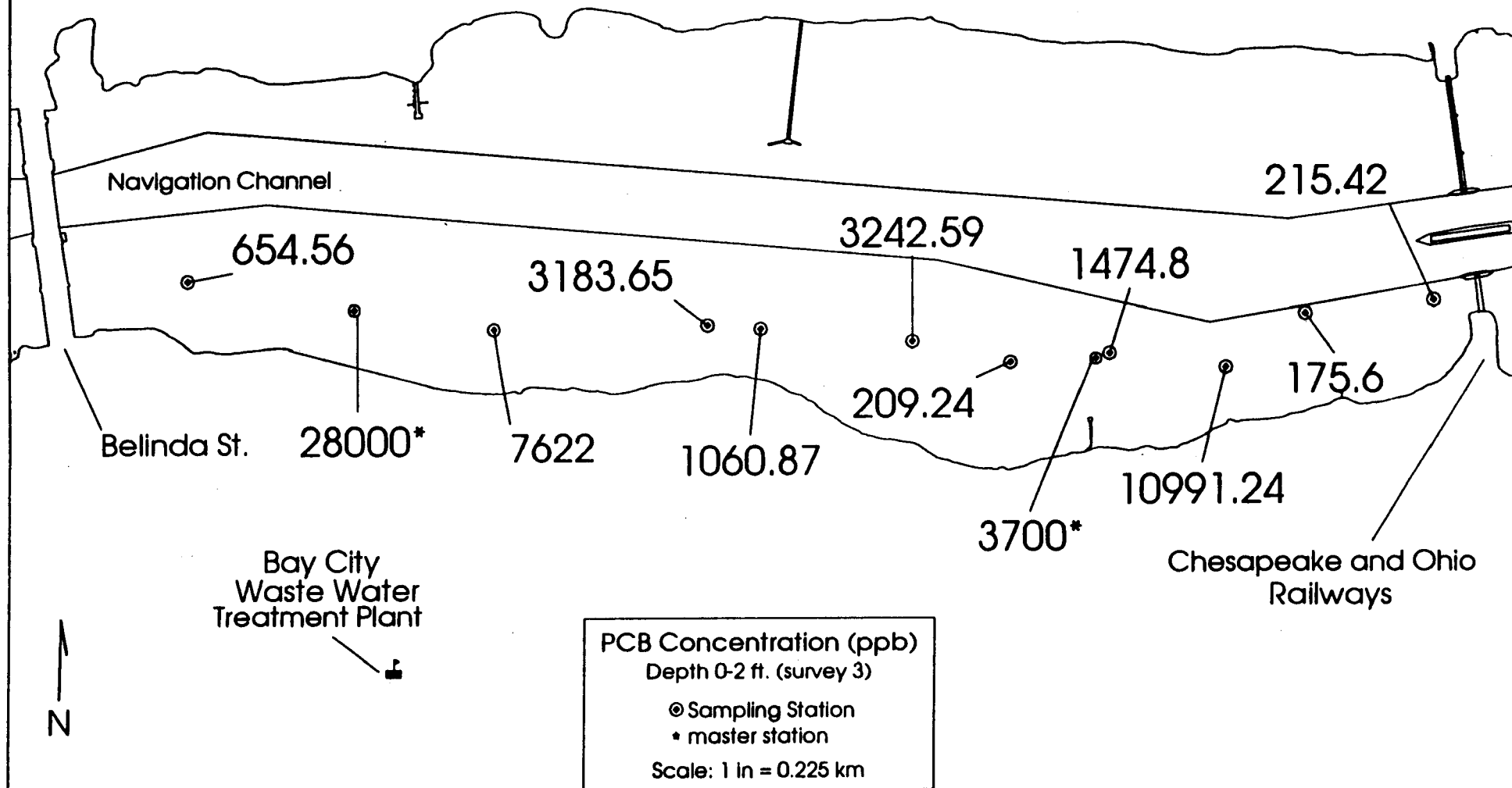
Saginaw Bay





# Saginaw River

## Intensive Sampling Area



Saginaw River

Saginaw Bay

13546.44

12062.38

560.27

78.34

1873.49

126.84

Bay City

Bay City  
Waste Water  
Treatment Plant

EPA Center for Ecological  
Research and Training

452.71

Middle Ground  
Island

PCB Concentration (ppb)

Depth 2-4 ft. (survey 2)

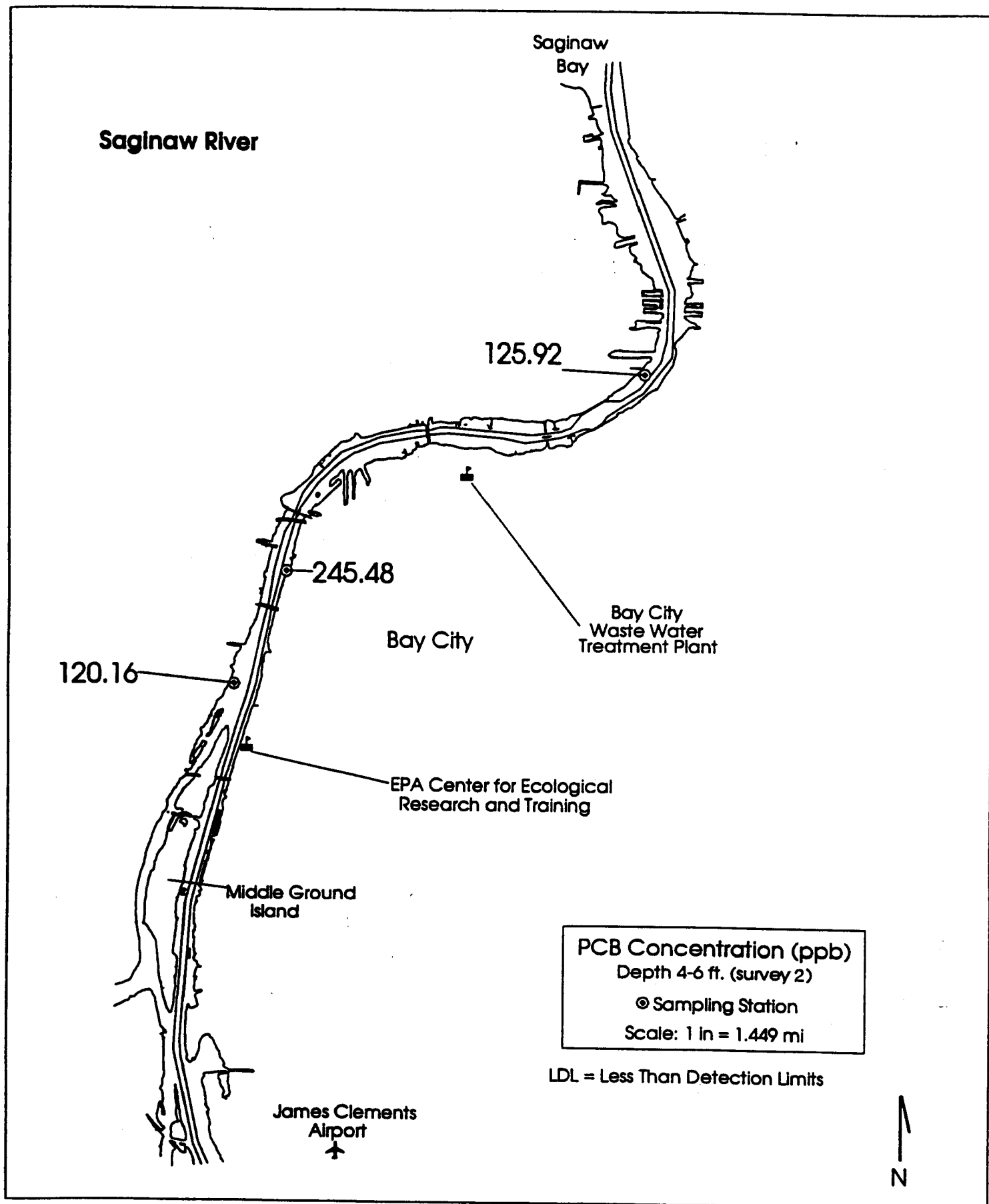
● Sampling Station

Scale: 1 in = 1.438 mi

LDL = Less Than Detection Limits

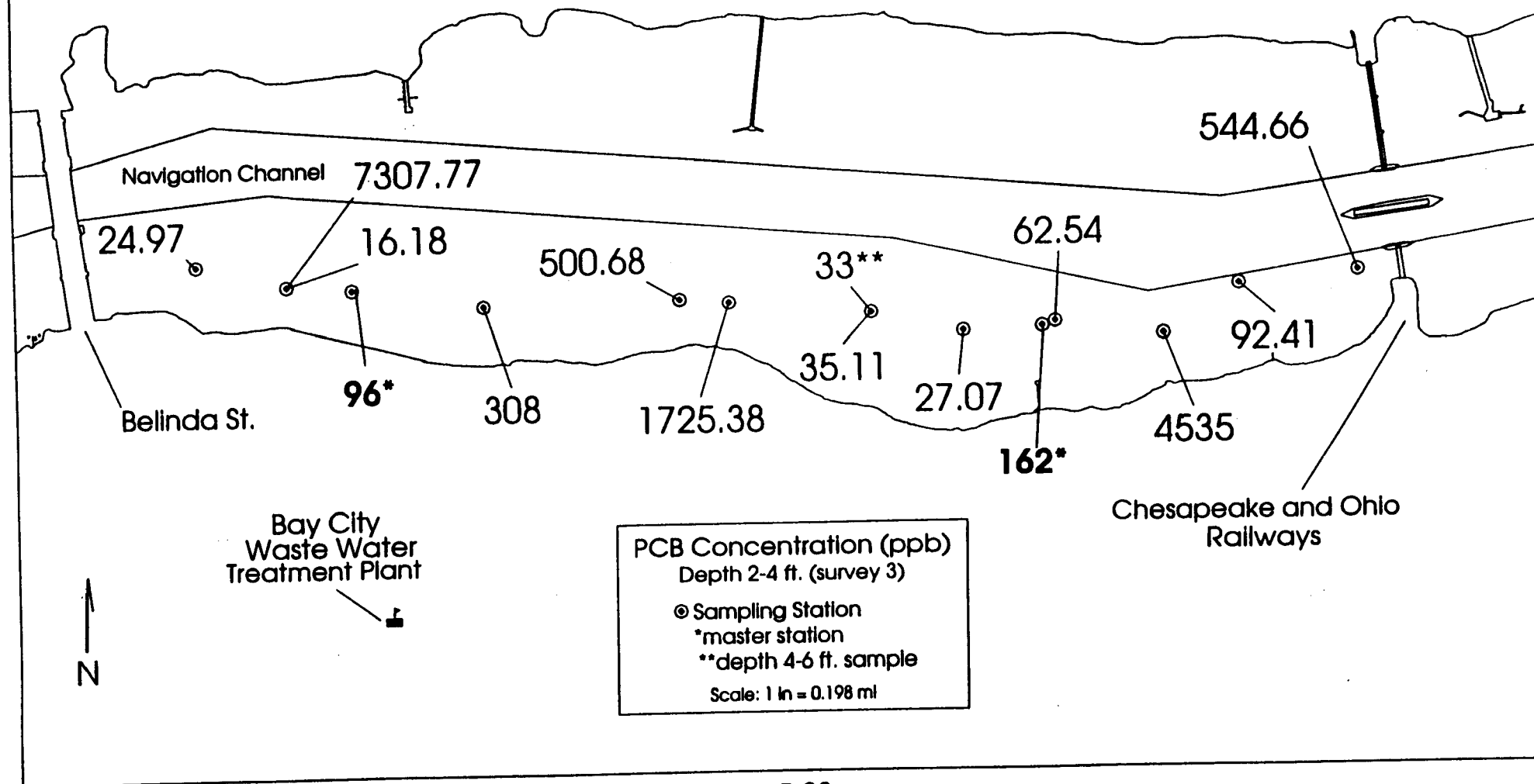
James Clements  
Airport

N



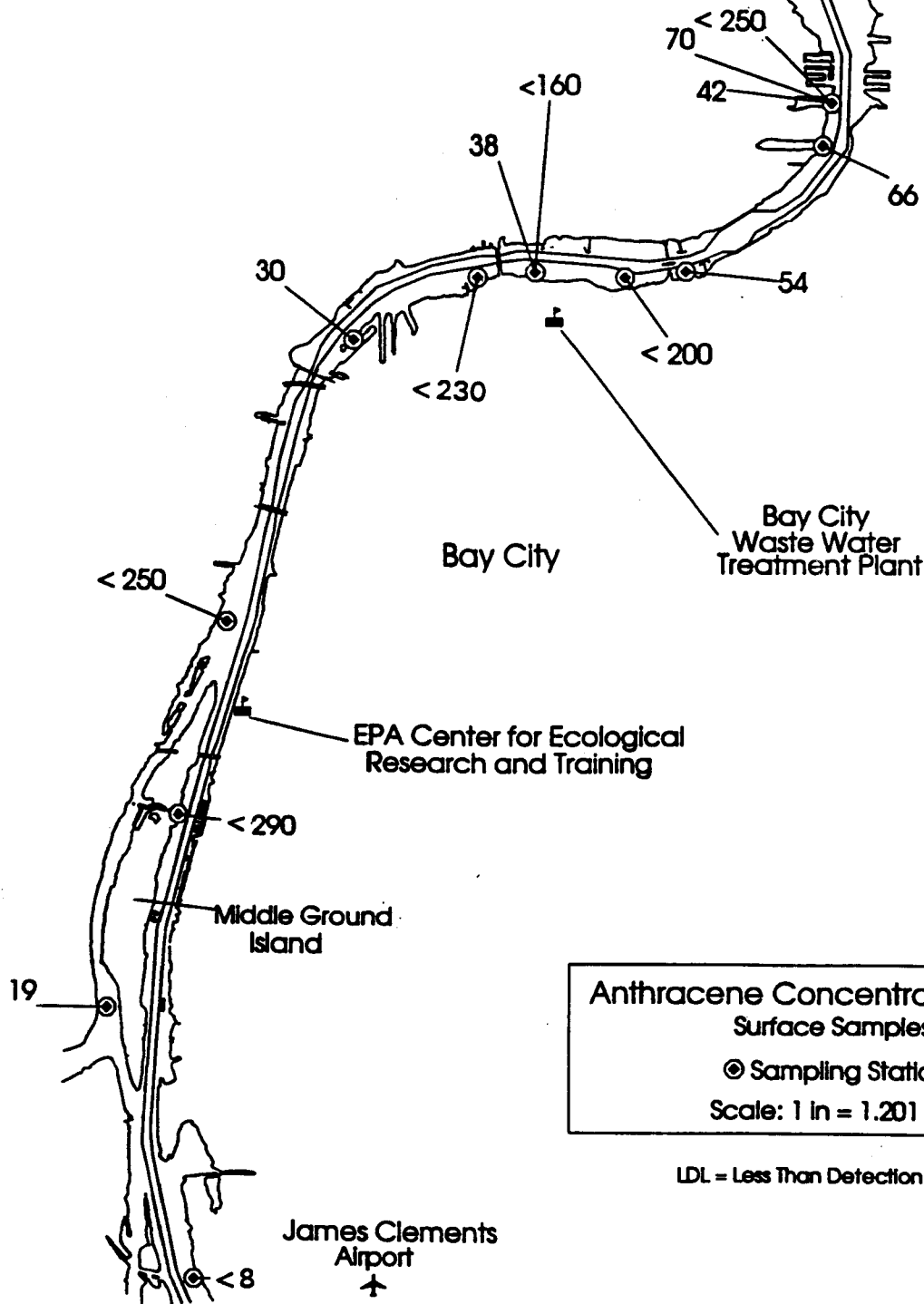
# Saginaw River

## Intensive Sampling Area



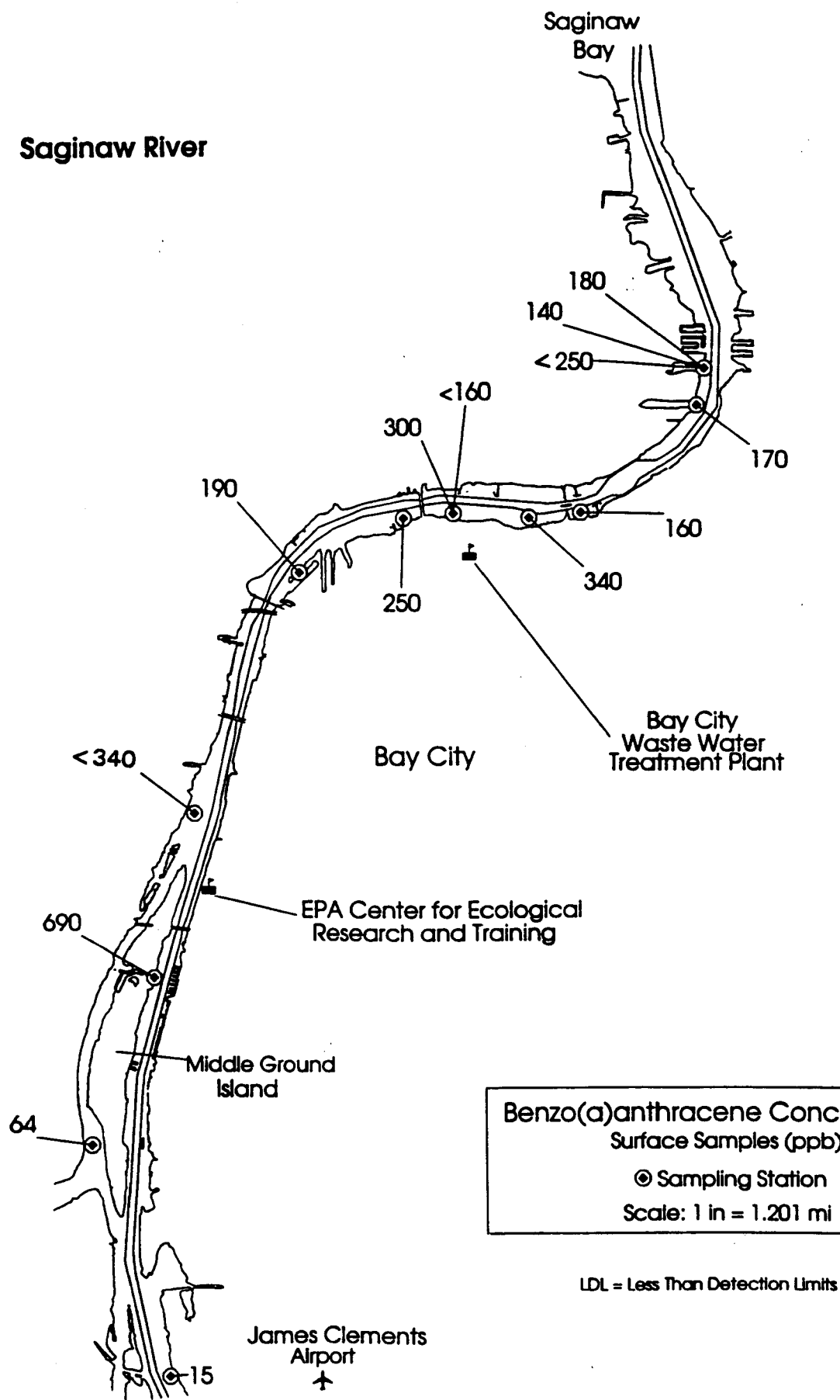
Saginaw River

Saginaw Bay

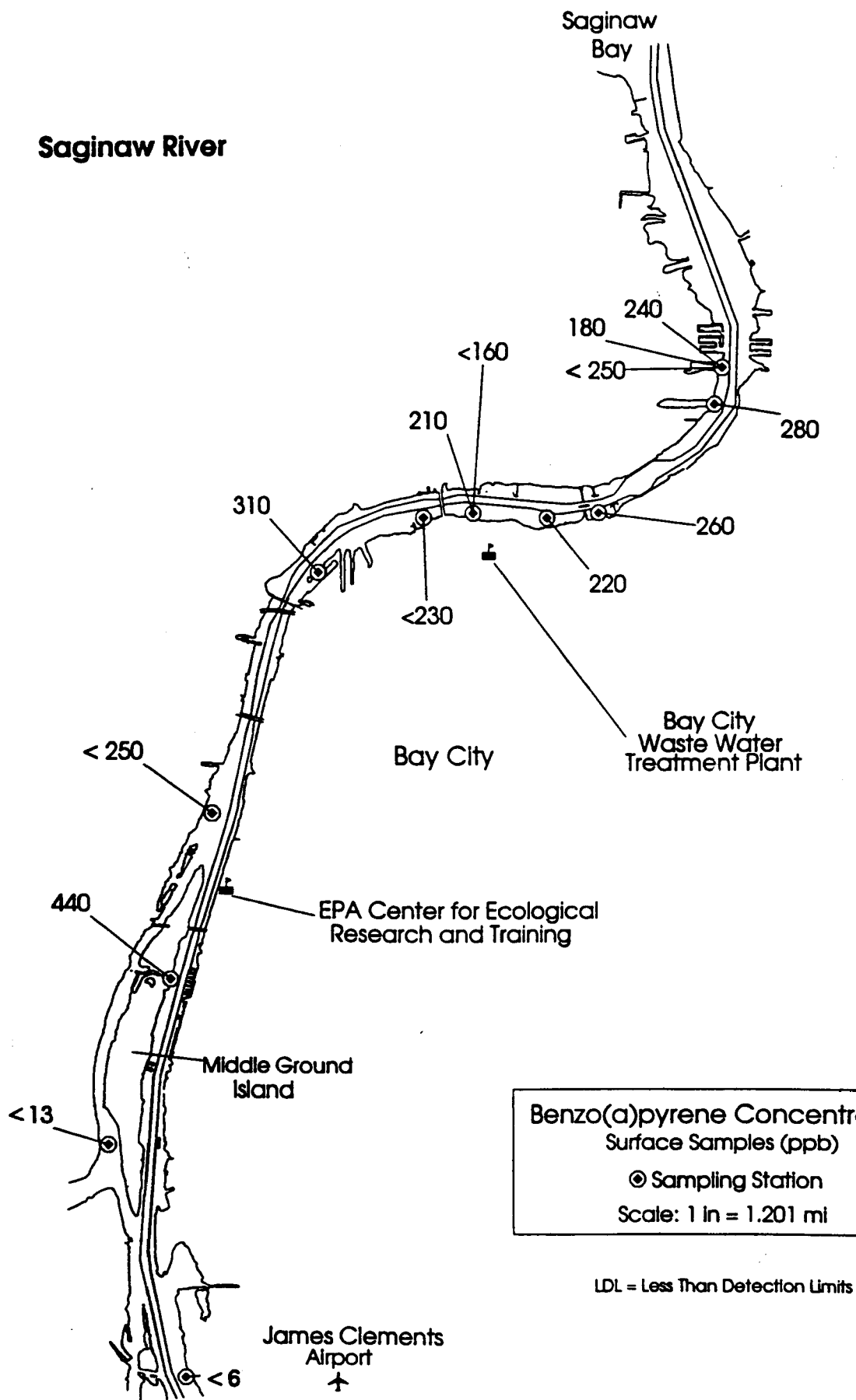




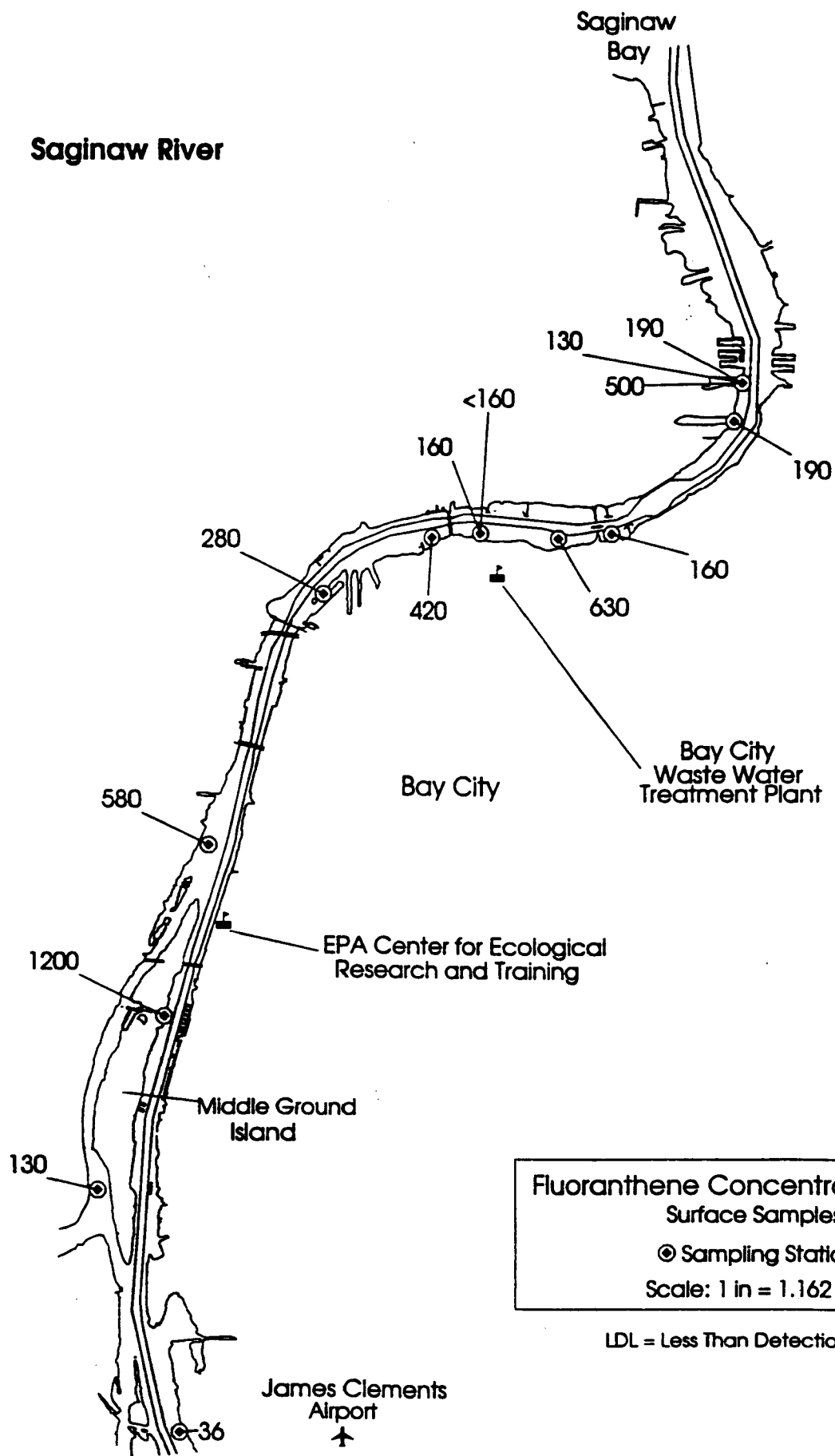
Saginaw River



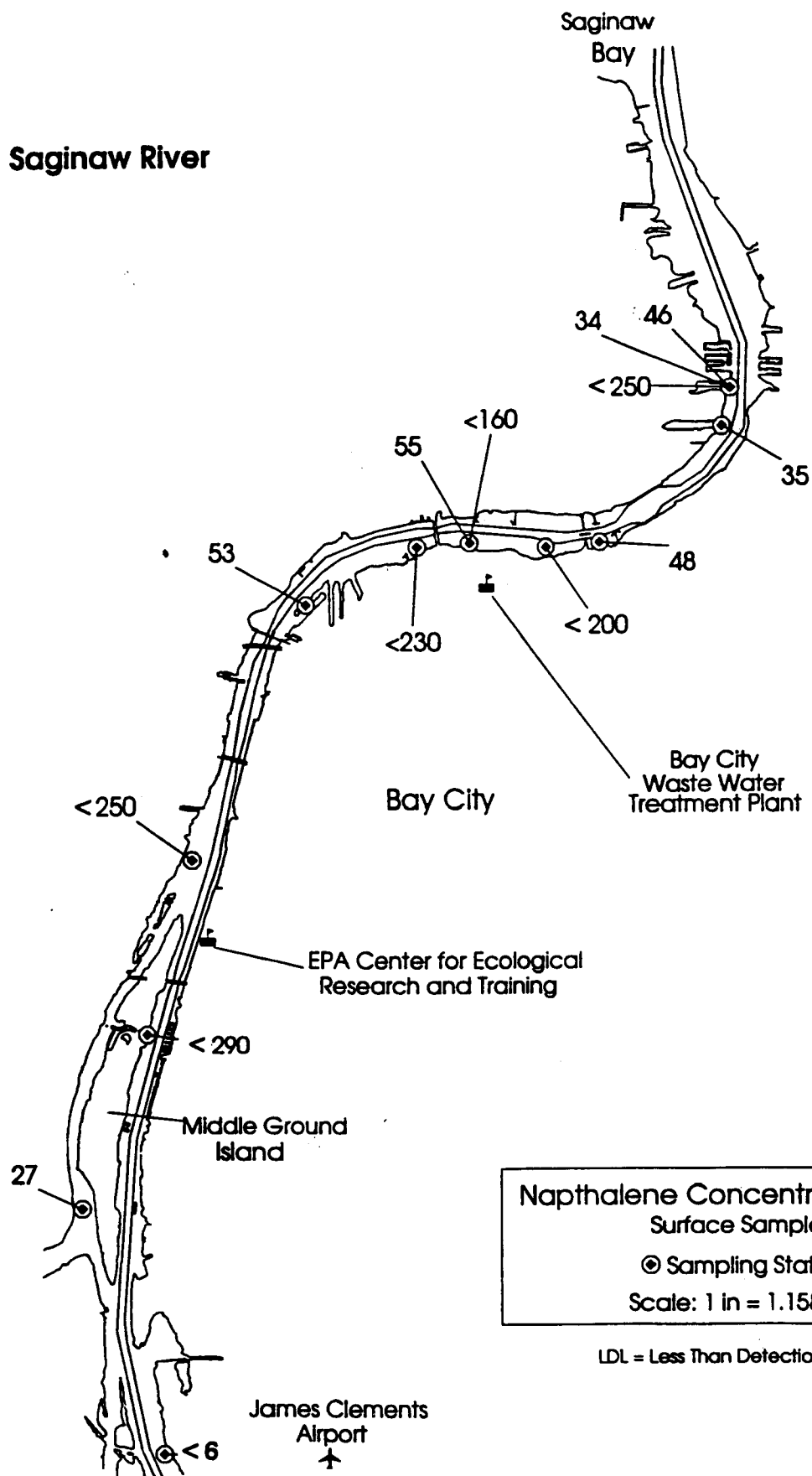
# Saginaw River



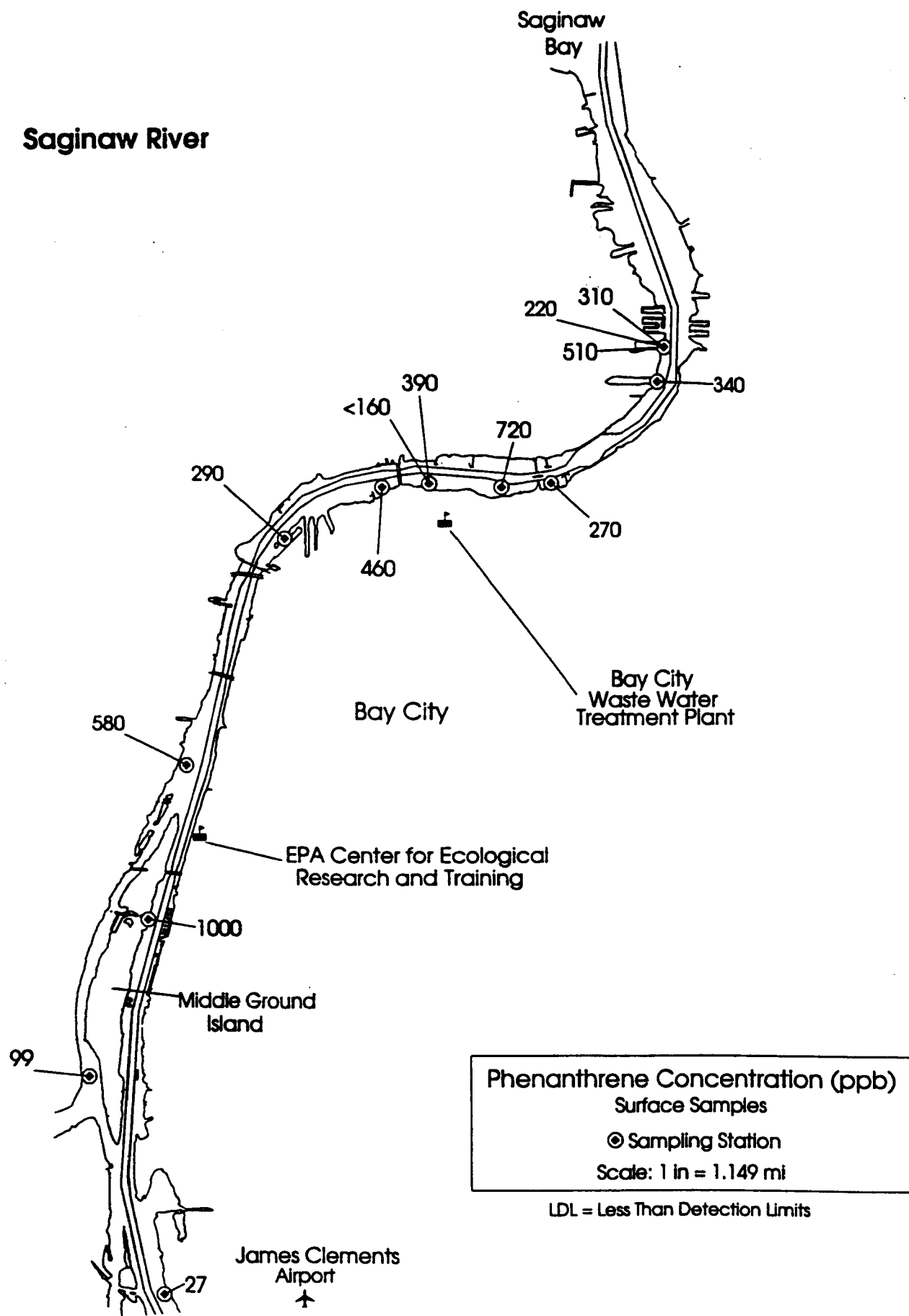
# Saginaw River

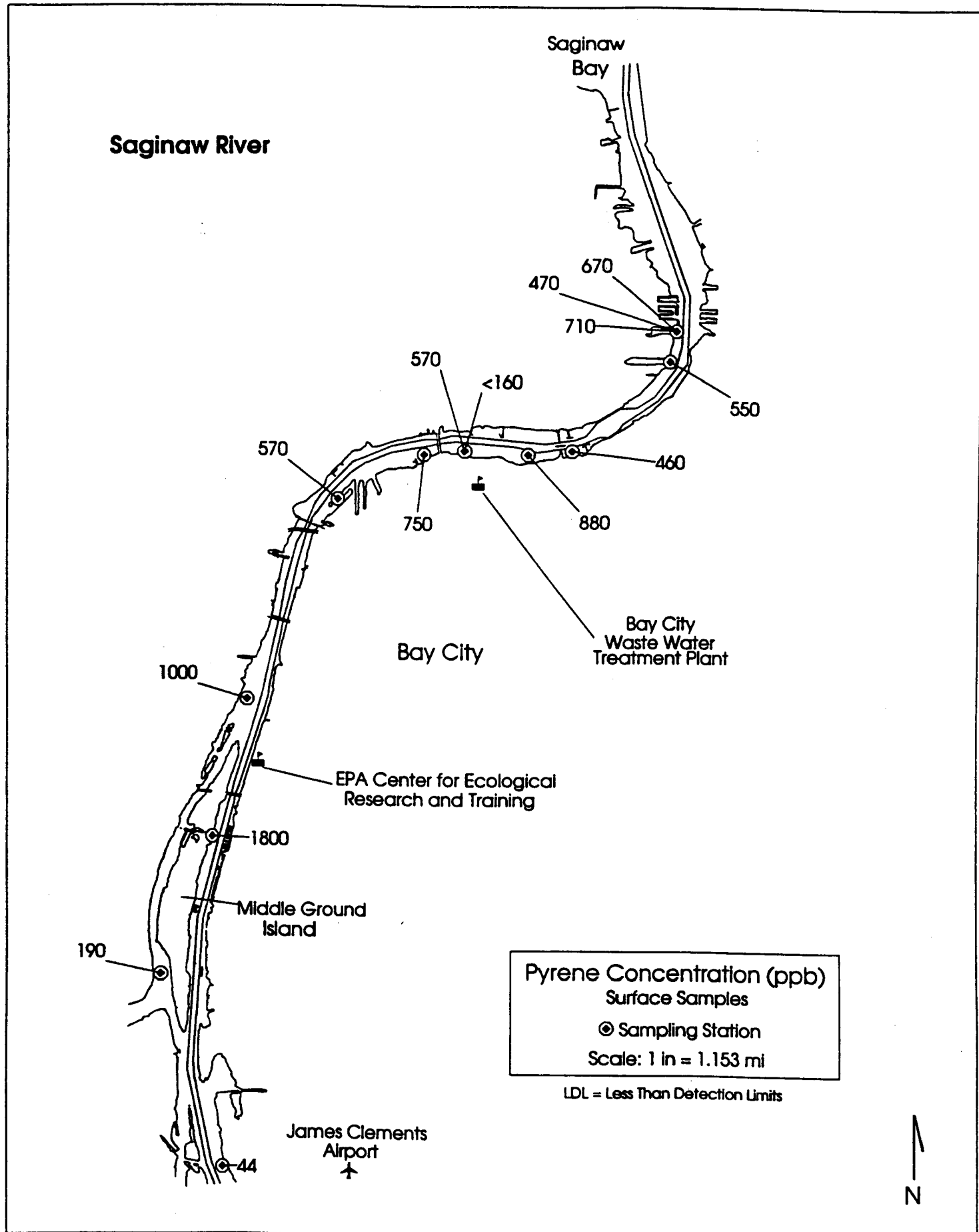


# Saginaw River



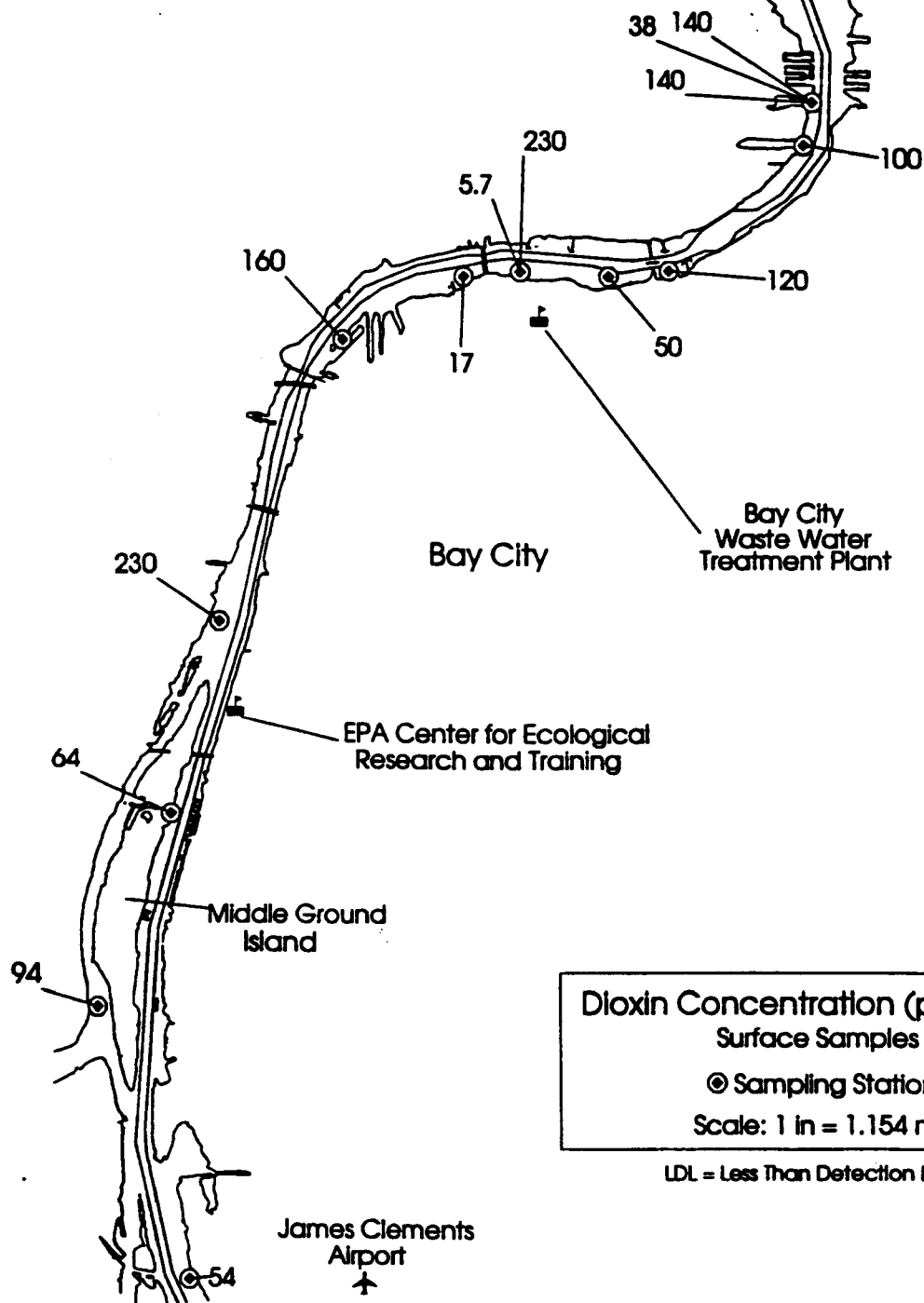
# Saginaw River





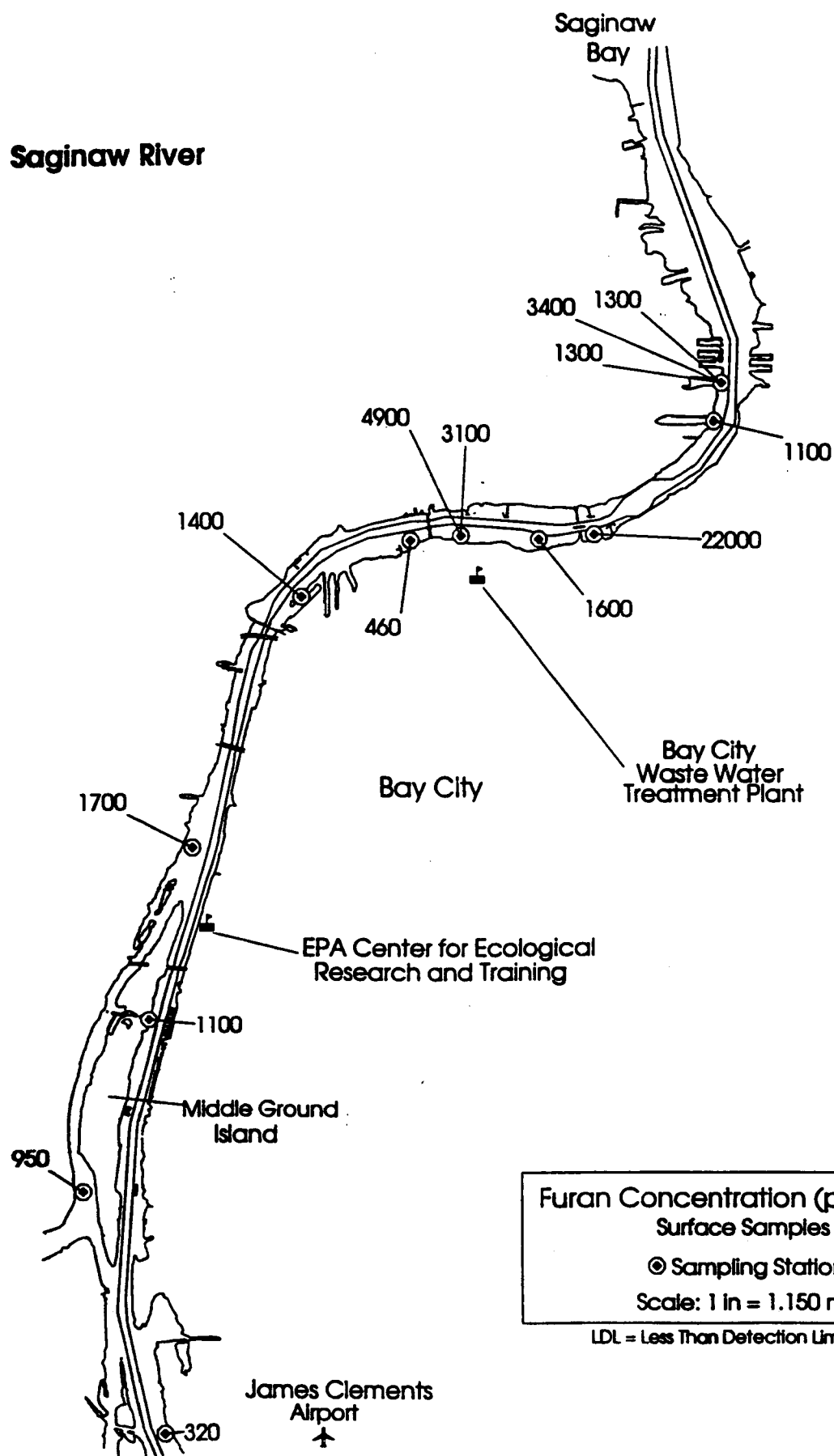
Saginaw River

Saginaw Bay



N

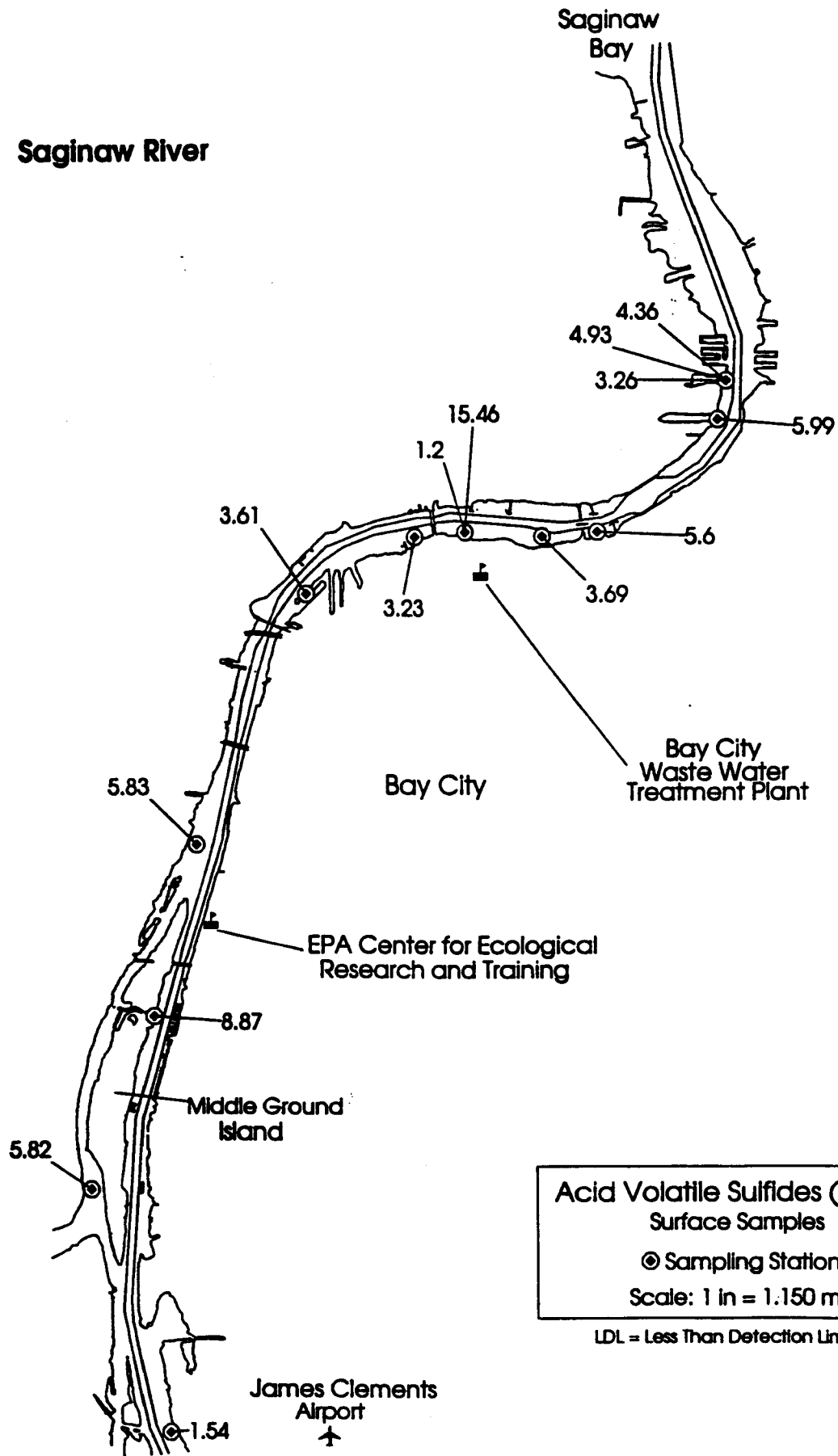
# Saginaw River





**Saginaw River**

**Saginaw Bay**



# Saginaw River

