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HEAVY METALS IN THE WATER AND SEDIMENT OF LAKES IN WESTERN MASSACHUSETTS III. LEAD

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William Hogan

Progress Report for Division of Water Pollution
Control, Massachusetts Water Resources Commission.
Contract Number 15-051454.



ENVIRONMENTAL ENGINEERING
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AMHERST, MASSACHUSETTS

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Massachusetts Water Resources Commission
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Environmental Engineering Program
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PREFACE

This progress report is the third in a series of detailed progress reports prepared for the division of Water Pollution Control, Massachusetts Water Resources Commission, Contract Number 15-51454, "Impact of Heavy Metals on the Aquatic Biota of Massachusetts Waters.

This particular report presents information on the levels of lead found in selected water bodies in Western Massachusetts. The research described herein was conducted by the authors from January to November, 1973. The authors are, respectively, assistant professor and graduate research assistant, Department of Civil Engineering, University of Massachusetts at Amherst.

This report will be brought to the attention of various agencies, organizations, companies, industries and individuals interested in the preservation of our natural resources.

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ABSTRACT

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Water samples and sediment samples were collected from each of seventeen lakes located in Berkshire, Franklin, Hampshire, and Worcester Counties, Massachusetts. The lakes were selected on the basis of suspected degrees of lead contamination ranging from natural, background levels of lead to high lead contamination (ranging from natural, background levels of lead to high lead contamination) from automotive exhaust, motor boat exhaust, and/or industrial discharge. The samples were analyzed for lead using a Perkin-Elmer 303 Atomic Absorption Spectrophotometer with an HGA-70 Graphite Furnace.

Mean lead concentrations in the waters of the seventeen lakes were found to be lower than the nationwide concentrations found in the literature. Mean lead concentrations in the sediments of the seventeen lakes were found to be similar with concentrations reported in the literature for four Massachusetts lakes.

Mean lead concentrations in the waters of lakes suspected of high lead contamination from heavy traffic, heavy motor boat use and/or industrial discharge were not significantly higher than the lakes selected for suspected natural, background levels of lead.

All the mean lead concentrations in the waters were well below even the lowest lead concentration reported in the literature as being acutely toxic to various fish. Thus, there appears to be no immediate danger to the fish species of these lakes from the lead contributed from man's activities.

INTRODUCTION

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Lead is a common heavy metal that has been known to man for many ages. The Roman civilization is associated with lead through their use of lead in their pipes and baths. It is associated with daily life today through its use in storage batteries, metal products, gasoline additives, and paints.

To date, the most widely publicized concern with lead has been lead poisoning, especially of children eating lead paints. Little attention, even in the environmental field, has been spent on the long-range, cumulative effect of lead contamination in water. Lead is introduced into water from outboard motor exhausts, industrial discharges, and particulate fallout from the atmosphere contaminated with natural dusts and automotive exhausts. Insufficient data is available to make sound, scientific judgments concerning environmental hazards of continued lead contamination.

This study was designed to collect data on the lead content of water samples and sediment samples from seventeen Massachusetts lakes in Worcester, Hampshire, Franklin, and Berkshire Counties.

The seventeen lakes were selected for lead analysis on the basis of suspected degrees of lead contamination ranging from natural, background levels to suspected high lead contamination from automotive exhaust, motor boat exhaust, and/or industrial discharge.

Five lakes were selected as being indicative of natural, background levels of lead due to limited land development near the water body, no use of motor boats, no known industrial pollution, and a distance of at least a mile from a state highway. These lakes were:

1. West Lake, Sandisfield
2. Upper Spectacle Pond, Sandisfield
3. Guilder Pond, Mt. Washington
4. North Pond, Florida
5. Prindle Lake, Charlton

Five lakes were selected for suspected high degrees of lead contamination due to heavy motor boat use, location within a thousand feet of a State or Federal highway, and/or industrial discharge. These lakes were:

6. Stockbridge Bowl, Stockbridge
7. Pontoosuc Lake, Lanesborough
8. Cheshire Reservoir, Cheshire
9. Indian Lake, Worcester
10. Silver Lake, Pittsfield

Seven other lakes were selected because of either light to moderate use of motor boats and/or location near a State or Federal highway. These lakes were:

11. Big Benton Pond, Otis
12. Pelham Lake, Rowe
13. Borrow Pit Pond, Whately
14. Cranberry Pond, Sunderland
15. Shaw Pond, Becket
16. Center Pond, Becket
17. Lake Metacomet, Belchertown

The objectives of this study were:

1. To establish mean lead concentrations in the water and sediment of each of the seventeen lakes.
2. To establish background levels of lead concentrations in the waters and sediments of lakes in western Massachusetts.
3. To recognize qualitative relationships between motor boat usage and/or proximity of highways to the lead concentration in the water and the sediment.
4. To compare the lead concentrations determined in this study with the lead concentrations established by other research as being acutely toxic to various fish species.
5. To provide basic data to assist in the selection of specific study lakes for future investigations concerning the long term effects of lead on the aquatic environment.

LITERATURE REVIEW

LITERATURE REVIEW

Lead is a natural constituent of water, soil, air, vegetation, and animal life. Significant sources of natural lead include dust from soils and particulates from volcanoes (15)* and leachate from mineral deposits (7). Sources of lead contamination related to man's activity include industrial and mining discharges, agricultural pesticides, ammunition, paint, solder printing, lead pipes and plumbing, manufacturing of lead salts, incineration of refuse, and combustion of coal and gasoline (7,4,14,3).

In 1963 the use of lead and its compounds in the United States was categorized as follows (3):

Storage batteries	43.1%
Metal products	26.2%
Chemicals**	20.1%
Pigments	7.5%
Miscellaneous	<u>3.1%</u>
	100.0%

**99% of the chemicals were tetraethyl lead and tetramethyl lead.

Most water-borne lead pollution emanates from motor boat exhaust, industrial and mining discharges, agricultural pesticides (prior to the 1950's), plumbing, weathering paint, and ammunition.

Atmospheric lead pollution is either particulate or gaseous. Particulate sources, such as coal and fuel oil combustion and lead smelting, account for less than 2% of all atmospheric lead pollution. Over 98% of atmospheric lead

*Numbers in parentheses refer to equivalent referenced article.

pollution is gaseous and results primarily from the combustion of gasoline additives (3). The two gasoline additives are tetraethyl lead, $Pb(C_2H_5)_4$, and tetramethyl lead, $Pb(CH_3)_4$. The two principle lead compounds emitted from gasoline combustion are $PbBrCl$ and $PbBrCl \cdot 2PbO$ (3). With time, however, these compounds react with the atmosphere and form primarily lead oxides, lead carbonates, and lead oxycarbonates.

There are two removal mechanisms that remove the lead from the atmosphere to the soil or water. The lead may simply settle out as the result of gravity or the lead may be washed out with precipitation. In either case, the atmospheric lead pollution is removed to either the soil or water system.

From atmospheric precipitation samples collected from 32 sampling stations located throughout the nation, the amount of lead in surface water supplies has been correlated with the amount of gasoline consumed in the sampling area (15).

The atmospheric lead concentration in urban areas may vary from five to fifty times greater than the concentration in non-urban areas. However, the lead concentration in most American cities has remained in a "steady-state" condition over the last 15 years despite increased lead emissions (3). It is reasoned that the lead is dispersing to remote areas and is being removed by natural mechanisms from the atmosphere to the land and water.

The lead concentration of an area depends upon the geology of the area and the proximity to sources of lead pollution.

In nature, lead exists primarily as galena, PbS , anglesite, $PbSO_4$, and cerussite, $PbCO_3$ (5). In areas of limestone and galena, lead concentrations in water have been known to reach the range of 400 to 800 $\mu g/l$, but this occurrence is quite rare (1).

In a 1970 survey for the U.S. Geological Survey, Durum et al (2) reported a nationwide range of 6 to 50 $\mu\text{g/l}$ Pb in rivers and lakes and ponds. Fourteen Massachusetts rivers and lakes were reported in the study. The average lead concentration in still waters was 5 $\mu\text{g/l}$ with a range of 4 to 9 $\mu\text{g/l}$. For the five Massachusetts rivers reported, the average lead concentration was 9 $\mu\text{g/l}$ with a range of 5 to 17 $\mu\text{g/l}$.

In a five year (1962-1967) summary of trace metals in rivers and lakes nationwide, Kopp and Kroner (1) reported lead concentrations ranging from traces up to 40 $\mu\text{g/l}$ with a mean of 10 $\mu\text{g/l}$. For the Northeast (New England, New York, and New Jersey) a 36% frequency of detection was reported. For the positive reports, the mean lead concentration was 17 $\mu\text{g/l}$ with a range of 4 to 48 $\mu\text{g/l}$. No still water bodies from Massachusetts were reported in this work.

deTreville (13) reported lead concentrations in water ranging from 0 to 55 $\mu\text{g/l}$ with a mean concentration of 5 $\mu\text{g/l}$. His 1961 study included 58 samples taken from 15 sampling stations nationwide.

As was the case with data on the lead content of Massachusetts waters, data is scarce in the literature on the lead content of Massachusetts sediments.

Isaac and Delaney (17) and Delaney (18) were the only sources for lead concentration in Massachusetts sediments.

Lake Quinsigamond in Worcester was the only lake reported by Isaac and Delaney (17). Lead concentrations were reported ranging from 130 to 400 mg/kg dry weight of sediment. Four rivers were also reported in their 1972 study. Lead concentrations for the four rivers ranged from 2 to 980 mg/kg dry weight with the four means ranging from 26 to 336 mg/kg dry weight.

Delaney (18) reported lead concentrations in sediments for Silver Lake, Pittsfield, Cranberry Pond, Sunderland, and Paradise Pond, Northampton. The values ranged typically from 48 to 150 mg/kg dry weight with two extremely high values, 9,350 and 16,300 mg/kg dry weight, for Silver Lake.

The most widely distributed source of organic lead compounds to lakes is outboard motors. The motor exhaust itself does not add any significant amount of organic lead. Rather, the large proportion of unburned fuel from two-cycle outboard motors is the source (33). Both tetraethyl lead and tetramethyl lead are classified as relatively unreactive organometallics (29) and would be quite stable in natural waters. They are also dense and immiscible in water, thus they would tend to settle to the sediments with time.

The chemistry of inorganic lead in natural waters revolves mainly around the solubility of lead compounds and the natural alkalinity of the surface waters. This is shown in Figure 1 (25). Figure 1 is a figure of the redox equilibrium for the $Pb-H_2O-CO_2$ system where $Pb_t = 10^{-4}M$ and $C_t = 10^{-2}M$. Although Figure 1 is for a particular set of conditions only, it does show that the chemistry of lead is very strongly influenced by the reaction of Pb^{+2} with $CO_3^{=}$. For the pH ranges found in most natural waters (6 to 9), it is obvious that the most predominant state of lead is as a solid. Additional solid phases such as phosphates and hydroxides may be formed in natural waters (25), although the lead carbonate system is the most predominant.

There are several removal mechanisms for the removal of lead from solution.

The most commonly cited mechanism is that of precipitation and sedimentation of lead particles. In a study done on Lake Hamilton, Arkansas, the concentration of Pb in particles larger and smaller than $0.45 \mu m$ was measured at various depths. It was determined that the concentration of larger particles increased with increasing depth (30). This was explained as the precipitation of lead as insoluble lead

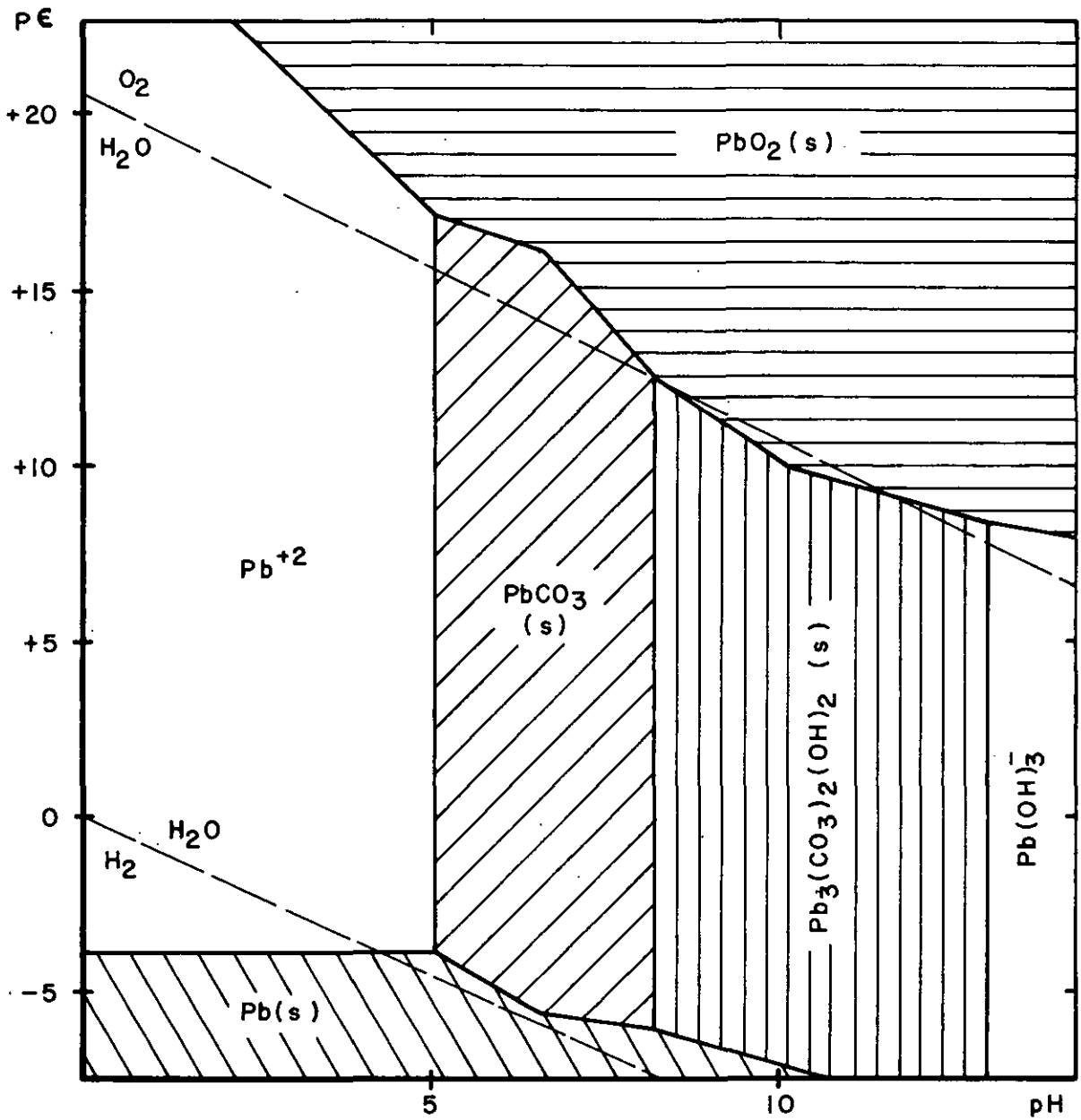


FIGURE 1

pE-pH Diagram (From Reference 25).
Redox equilibrium for the Pb-H₂O-CO₂ system.
 $Pb_f = 10^{-4} M$, $C_f = 10^{-2} M$

salts in natural still water.

Lazrus et al (30) determined that the average concentration of lead in precipitation was 34 $\mu\text{g/l}$, twice the average amount found in water supplies. The authors infer the existence of a removal process in which the lead is precipitated after reaching the earth's surface. The conclusion of a removal mechanism by Lazrus et al (30) is supported by recent Russian studies (30). Their studies reveal that lead is present in suspended matter, insoluble in natural surface waters and removed through sedimentation.

Two other removal mechanisms cited in the literature are adsorption of lead on silts and clays and coordination of lead with organic species. Ettinger (31) determined, from samples taken in heavily populated and industrial areas where the amount of waste pollution was high, that the water contained relatively small amounts of lead in solution. Ettinger reasoned that the lead is removed by precipitation and coordination of insoluble lead with silts and organic species, both of which act as excellent coordination sites for the lead. Analysis of waters for lead before and after decomposition of organic matter show that a considerable part of lead in natural waters is bound inorganic complexes (8,9).

Aquatic biota are also responsible for removal of lead from the water, although in small amounts. Cummings and Mathis (12) revealed that lead does not concentrate along successive trophic levels. Upon analysis, those organisms, such as clams and tubificid worms, that live in the sediments where the lead concentrations are the highest in the aquatic environment also exhibited the highest lead concentrations. However, the fish, primarily carnivorous in nature, exhibited the lowest lead concentrations.

The preceding discussion indicates clearly that the ultimate sink for lead is the sediments. This conclusion was somewhat verified in a study by Mulcahy (32). Three 20 liter plexiglass columns were filled with outboard motor subsurface

exhaust-recipient water and the filterable and nonfilterable lead concentrations were measured with time. Both filterable and nonfilterable lead concentrations decreased with time. Subsequent analysis of the sediments in the columns showed marked increases in lead concentration in the sediments.

In any discussion of water quality requirements for aquatic life, the concentrations of toxic substances is debated. Concentrations may be discussed as being either acutely toxic (lethal within 2 weeks) or as being chronically toxic (causing anemia or histological changes). However, these concentrations may be difficult to establish due to the sensitivity of different species and different developmental stages of a specific species. Also, the toxic concentrations depend upon other water quality characteristics including pH, dissolved oxygen content, temperature, and water hardness and upon other conditions such as ion antagonism or synergism, acclimatization, nature and condition of the species being considered (1,7).

Hard waters tend to decrease the effective concentration of lead as the lead is precipitated. Increasing the water hardness from 14 to 53 mg/l as CaCO_3 decreased the effective lead concentration from 8 to 1.6 mg/l (9).

The presence of calcium has an antagonistic effect to the toxicity of lead. Jones (26), in a 1 mg/l solution of lead nitrate containing stickleback, increased the calcium concentration from 0 to 5, 10, 20 and 50 mg/l. The corresponding survival times for the stickleback were 1, 3, 6, 7 and 10.5 days. Aronson (9) concluded from Jones' experiment that calcium somehow prevents the coagulation of mucus by the lead.

Pakkala et al (7) suggested several theories for the mechanism of acute lead toxicity as follows:

1. Lead is an enzyme poison. It has an affinity to amino, imino, and sulfhydryl groups which may comprise reactive sites on the enzyme.
2. Lead acts as a precipitant of essential metabolites or affects the permeability of cell membranes.
3. Coagulation film anoxia theory (credited to Carpenter (27)) in which the lead coagulates the normal mucus secreted by the gills, thus interfering with respiration, salt balance, and secretion of waste products.

Aronson supports Carpenter's theory of coagulation film anoxia (9).

Aronson notes that the mucus can be coagulated by other heavy metals other than lead. Stoker and Seager (3) support the enzyme inhibition theory.

Chronic lead toxicity causes gradual impairment in the functioning of the liver, kidney, and spleen and anemia and metabolic lesions in the intestine resulting in poor food utilization and reduced growth (10).

Acute toxic levels have been reported by many researchers. The Department of Fisheries reported that lead acetate killed fish in fresh water at 2.8 mg/l of Pb (14). No mention was made of the species or time period. Aronson reported that 3 mg/l of lead nitrate is fatal to killiefish in 12 hours (9). McKee and Wolf have summarized lead toxicity studies on fish (28). They report concentrations ranging from 0.1 mg/l Pb to as high as 75 mg/l Pb as being acutely toxic (lethal within 96 hours) to fish. The wide variation of toxic concentrations is due to the following:

1. variety of dilution waters (distilled to tap water)
2. different species of fish
3. varying calcium concentration
4. varying water hardness
5. varying temperature
6. varying dissolved oxygen content
7. various forms of lead used

It is exceedingly difficult to intelligently compare toxic concentrations as determined by various investigators due to the dissimilar testing as evidenced above. Thus, the concentration of 0.1 mg/l Pb may not represent the minimal concentration of lead that will prove toxic to sensitive fish under conditions most conducive to poisoning.

The effect of slug doses rather than constant concentrations upon brook trout were studied by Dorfman and Whitworth (10). They reasoned that metallic wastes are often introduced as slug doses and may fluctuate widely in volume and strength. They found a 25 mg/l Pb slug dose administered once per day reduced the growth of brook trout, but a 15 mg/l Pb slug dose had no apparent effect.

It should be noted here for purposes of comparison with the concentrations above, that the U.S. Public Health Services limit on lead content of drinking water is 0.05 mg/l.

EXPERIMENTAL METHODOLOGY

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Sampling Sites

Sampling sites were generally selected as inlets, outlets, greatest water depth areas, boat launching access points, shorelines adjacent to highways, and other sites to give dispersed coverage to the lake. A more detailed description of sampling sites for each lake is provided in the Appendix.

Sampling Procedure

Surface water samples were collected a few inches below the surface to avoid any floating matter. Depth water samples were collected in an Eckman dredge when it was determined by the sediment temperature that the lake was stratified. All water samples were immediately acidified with five milliliters of concentrated nitric acid and stored in acid-washed, one quart polyethylene bottles.

Sediment samples were collected in an Eckman dredge with the dredge penetrating to more than six inches into the sediment. Sediment samples were also stored in acid-washed, one quart polyethylene bottles.

Preparation of Water Samples

Initial analyses determined that lead concentrations in the water were too low to be adequately analyzed without concentration of the sample. Concentration was accomplished in the following manner:

1. In a 600 ml Erlenmeyer flask, 500 ml of the sample were acidified with 2 ml of concentrated nitric acid and evaporated on a hot plate to a volume of less than 10 milliliters.
2. The concentrate was transferred to a 10 ml volumetric flask and the volume adjusted to 10 ml by the addition of distilled, deionized water to yield a 50:1 concentration of the original water sample.
3. The 10 ml samples were then transferred to and stored in small acid-washed polyethylene bottles until analysis.

Preparation of Sediment Samples

The sediment samples, as well as the water samples, were analyzed for total lead. For that reason, the sediments required digestion to release any lead bound to organic matter and to solubilize any precipitated lead. Digestion was accomplished in the following manner:

1. Using a large, homogeneous sediment sample, a moisture loss versus drying time curve was established for 100 gram samples. Such a curve establishes the time required to dry a given sized sample to a constant weight. Constant weight was achieved in 48 hours.
2. 100 gams sediment samples were dried in evaporating dishes in a hot air oven at 70°C for 48 hours.
3. The dried residue was then pulverized with mortar and pestle and shaken on a No. 30 sieve. All components of the sample that failed to pass the sieve were discarded.
4. A 10.0 gram sample of the material which passed through the sieve was transferred to a 600 ml Erlenmeyer flask.
5. Five milliliters of concentrated nitric acid and approximately 100 milliliters of distilled, deionized water were mixed with the 10 gram sample and then digested with heat to dryness on a hot plate.
6. Step 5 was repeated to yield a total of two digestions.
7. After the second digestion, the residue was wetted with 3 milliliters of concentrated nitric acid and distilled, deionized water and then filtered through a No.42 Whatman filter. The filtered residue, the 600 ml Erlenmeyer flask, and the flask retaining the filtrate were rinsed twice. The filtrate and the rinse water were transferred into a 100 ml volumetric flask and the volume adjusted to 100 ml by the addition of distilled, deionized water.

8. The sediment sample was then transferred to an acid-washed glass bottle for storage until analysis.

This procedure requires that the micrograms per liter determined in the analysis of the 100 milliliter sample to be divided by 100 to obtain the milligrams per kilogram of dry weight sediment. The following calculations show the factor of 10^{-2} :

assume a typical reading of 100 $\mu\text{g}/\text{l}$

$$100 \mu\text{g}/\text{l} = 10 \mu\text{g}/100 \text{ ml} \text{ or } 10 \mu\text{g}/10 \text{ gram} = 1000 \mu\text{g}/\text{kg} = 1 \text{ mg}/\text{kg}$$

Glassware Preparation

All water added to the samples were distilled, deionized water. All glassware used was acid-washed and used only once before washing again. Acid washing consisted of a wash with detergent and tap water and the following rinses: chromic acid, tap water, 1:1 nitric acid, and distilled, deionized water.

Sample Analysis

Both water and sediment samples were analyzed by atomic absorption spectroscopy using a Perkin-Elmer 303 Atomic Absorption Spectrophotometer with an HGA-70 Graphite Furnace. The use of the graphite furnace permits detection of lead in the $\mu\text{g}/\text{l}$ range or ppb.

Each sample was analyzed by injecting a 20 μl aliquot into the graphite tube with an Eppendorf microliter pipet. With the proper program for lead selected on the graphite furnace, the instrument yields percent absorption on a strip chart recorder. The percent absorption values were then converted to absorbance and the lead concentration calculated from the calibration curves.

The concentrated water samples were pipeted directly into the graphite tube. The sediment samples required varying dilutions before pipetting to remain within the optimum analytical range of 0.1 to 0.5 absorbance units (23).

Operating parameters used for the lead analysis were:

wavelength setting: 2833 A⁰

slit setting: 4

scale expansion setting: 1

noise suppression setting: 1

light source: Pb hollow cathode lamp, 8 milliamperes

HGA-70 program setting 5:

drying time = 40 second

thermal destruction time = 90 seconds

atomization time = 20 seconds at 9 volts

Preparation of Calibration Curves

Calibration curves were prepared for each analysis of samples. Figures 2 and 3 are the calibration curves for the water and sediment samples, respectively.

Calibration curves were prepared as follows:

1. From a stock solution of 1000 mg Pb/l a standard solution of 1 µg Pb/ml was prepared.
2. From the 1 µg Pb/ml standard solution, 100 ml calibration solutions were prepared with concentrations of 0, 5, 10, 20, 40, 60, 100, 230, and 400 µg/l. The amount of acid in the calibration standards was adjusted to approximately 3 ml per liter to be consistent with the water and sediment samples.

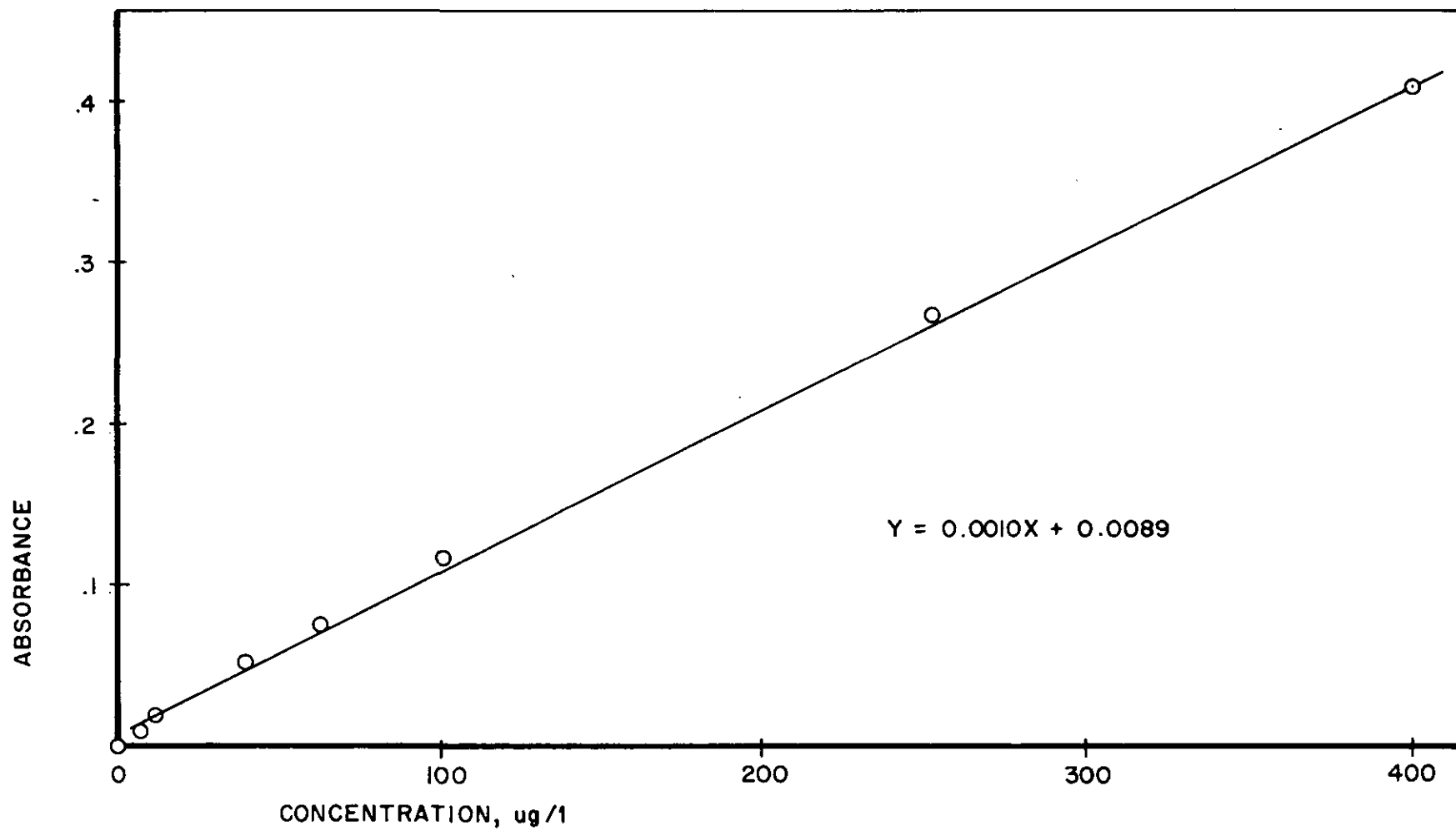


FIGURE 2
Calibration Curve for Determination of Lead in Water.

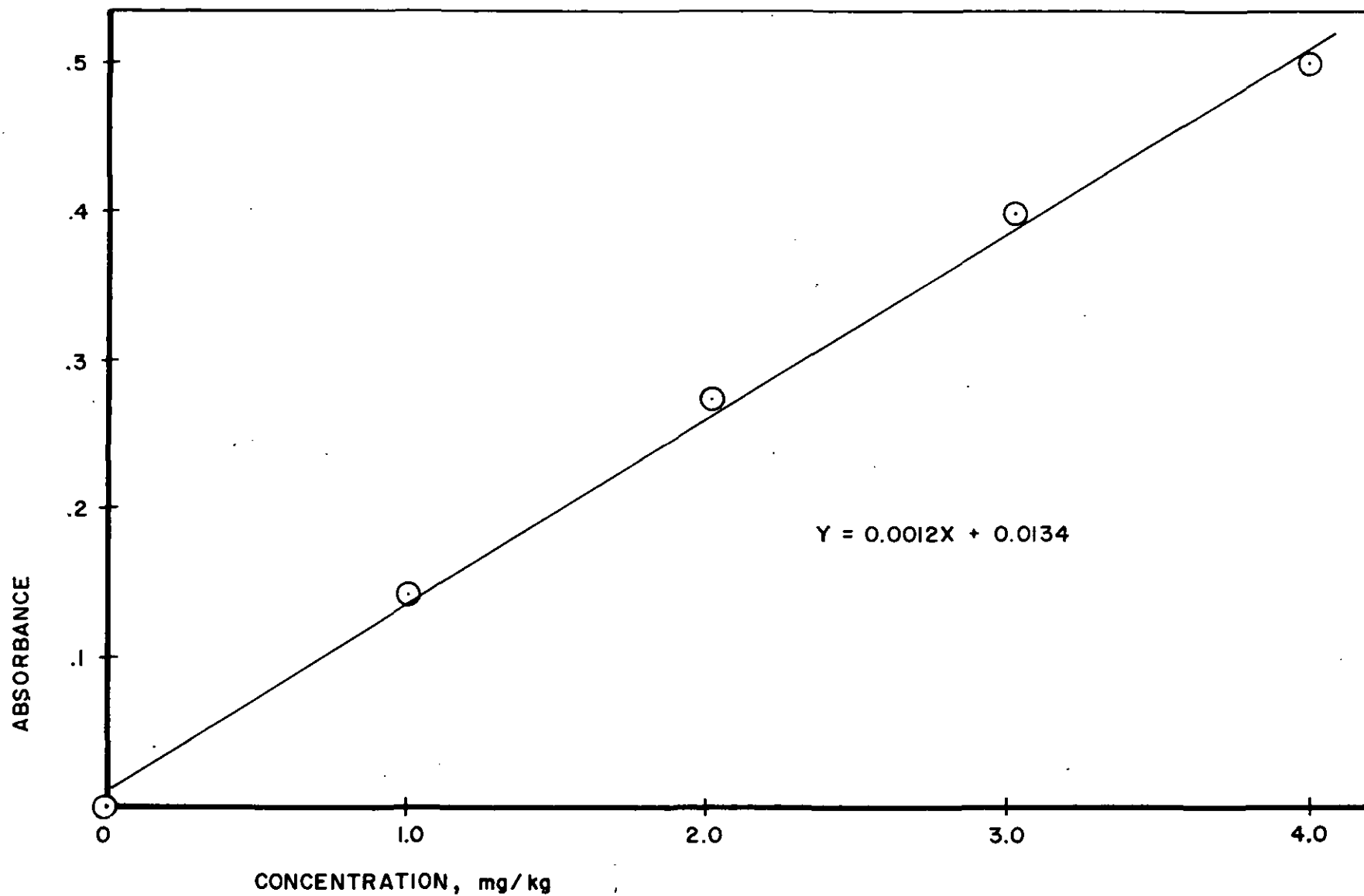


FIGURE 3
Calibration Curve For Determination of Lead in Sediment.

3. Starting with the blank and then working with increasing concentrations, each calibration solution was analyzed three times from which a reliable average was obtained. The percent absorption for the average was then recorded.

Preparation of Drying Curve

The following procedure was used on a large sediment sample collected from the UMASS campus pond:

1. 100 gram samples were weighed in tared evaporating dishes.
2. The samples were placed in a hot air oven with a drying temperature of 70°C.
3. Triplicate samples were removed at various times from the oven.
4. The triplicate samples were cooled for one hour in a desiccator.
5. After cooling, the samples were weighed and the percent weight reduction was plotted versus time (Figure 4).

A drying time of 48 hours was selected as representing the time to achieve constant weight.

Statistical Treatment of Data

To determine the required number of analyses for each sample to yield acceptable results, a statistical analysis of the accuracy of atomic absorption spectrophotometry for lead was done.

For a 95% confidence interval, the probability is 0.95 that the true value of the mean, \bar{X} , of n observations lies within the interval,

$$95\% \text{ C.I.} = \bar{X} \pm 1.96 \frac{\sigma}{\sqrt{n}}$$

$$\text{where } \bar{X} = \frac{\sum X}{n}$$

= standard deviation

$$= \left(\frac{\sum (X - \bar{X})^2}{n-1} \right)^{1/2}$$

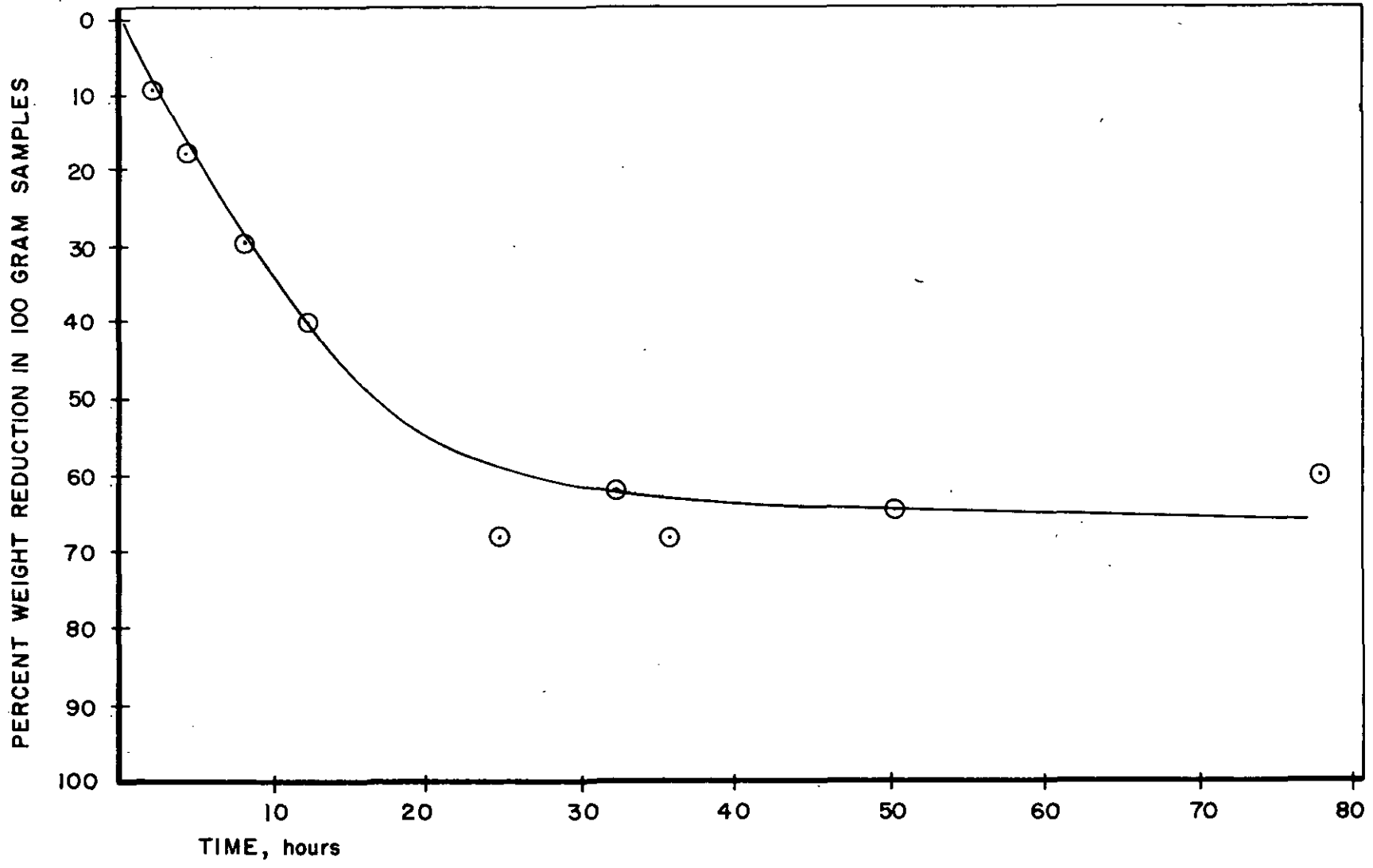


FIGURE 4
Drying Curve for Sediment Samples

A variation not greater than 20% of the true concentration was decided upon as acceptable. Mathematically this means:

$$X \pm .2X = X \pm 1.96 \frac{\sigma}{\sqrt{n}} \text{ or } .2X = 1.96 \frac{\sigma}{\sqrt{n}} \text{ and } \frac{\sigma}{X} = \frac{.2 \sqrt{n}}{1.96}$$

If $n = 1$, $\frac{\sigma}{X}$ must be less than 0.104 to meet the acceptable variation.

To determine the value of σ/\bar{X} for lead, a composite sample of water and of sediment was prepared (1 ml taken from each sample) and analyzed a minimum of 20 times as recommended by Homan (24).

The results were as follows:

$$\text{sediment composite: } \sigma/\bar{X} = 0.04$$

$$\text{water composite: } \sigma/\bar{X} = 0.09$$

Both values were below 0.104. Therefore only one analysis per sample was required for a 95% confidence interval that the true value of the concentration lies within the interval of $\bar{X} \pm .2\bar{X}$.

Other statistical analyses performed were the mean, \bar{X} , the standard deviation, and the correlation coefficient, r , where

$$r = \frac{(\sum (X-\bar{X})(Y-\bar{Y}))}{(\sum (X-\bar{X})^2 \sum (Y-\bar{Y})^2)^{1/2}}$$

The correlation coefficient is a measure of the linear relationship between any two sets of data. A correlation coefficient greater than 0.7 or less than -0.7 for a large number of observations indicates a high degree of relationship (22).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Lead Content of Waters

A summary of the lead concentrations in water as determined in this project is in Table 1. It appears from the values reported that the effects of man's activities are negligible concerning the concentration of lead in water. The lakes selected for suspected high concentrations of lead caused by industrial effluents, motor boat use, and location near heavily travelled roadways had lead concentrations ranging from 2.33 to 4.07 $\mu\text{g}/\text{l}$, yet the lakes selected for natural, background concentrations of lead had lead concentrations ranging from 0.78 to 3.12 $\mu\text{g}/\text{l}$. Thus, there appears to be no significant increase in the lead concentration in the water of lakes heavily influenced by man's activities over those lakes with limited influence by man's activities.

The mean lead concentrations in water for the seventeen lakes are below levels reported by several other investigators (1,2,13). The mean lead concentrations determined in this study ranged from a low of 0.6 $\mu\text{g}/\text{l}$ for Cranberry Pond to 4.07 $\mu\text{g}/\text{l}$ for Indian Lake. These values are slightly lower than the range of 4 to 9 $\mu\text{g}/\text{l}$ for still waters in Massachusetts reported by Durum et al (2) and much lower than the nationwide range of 6 to 50 $\mu\text{g}/\text{l}$. For the Northeast, Kopp and Kroner (1) reported a mean concentration of 17 $\mu\text{g}/\text{l}$. Contributing to the low values as determined in this study may be the following factors:

1. Only two lakes of the total seventeen were suspected to be contaminated by industrial effluents, these being Indian Lake and Silver Lake. These two lakes recorded the two highest lead concentrations in water.

TABLE 1. Mean Lead Concentrations in Water

Lakes Selected for Suspected Natural Background Concentrations of Lead	Water Concentration $\mu\text{g/l}$	Standard Deviation
West Lake [5]*	2.53	1.47
Upper Spectacle Pond [6]	2.42	1.50
Guilder Pond [5]	3.12	1.74
North Pond [6]	0.78	0.31
Prindle Pond [8]	1.66	0.85
Lakes Selected for Suspected High Concentrations of Lead		
Stockbridge Bowl [11]	3.13	1.07
Pontoosuc Lake [12]	2.33	1.02
Cheshire Reservoir [8]	2.69	1.41
Indian Lake [9]	4.07	2.17
Silver Lake [5]	4.06	----
Lakes Selected for Suspected Moderate Concentrations of Lead		
Big Benton Pond [7]	2.92	1.77
Pelham Lake [5]	2.86	2.60
Borrow Pit Pond [3]	2.94	0.56
Cranberry Pond [5]	0.60	0.25
Shaw Pond [8]	1.99	1.75
Center Pond [9]	3.01	2.12
Metacomet Lake [5]	0.79	0.25

*Numbers in brackets indicate number of samples collected from that lake.

2. Motor boat usage was not extensive. Only seven of the seventeen lakes reported moderate or heavy use of motor boats (19,20,21). It should be noted, however, that in this study the greater use of motor boats was on the larger lakes. Thus, the lead contributory effects of motor boat use will be diluted.
3. The general area of western Massachusetts is relatively sparse compared to the urban areas of the Northeast. According to Hall (15), the concentration of lead in water has been correlated with the amount of gasoline consumed by automotive use in the area.
4. Increasing hardness has been shown to decrease the lead concentration through precipitation of lead salts. The hardness in this region may be particularly higher than the hardness in the regions reporting higher lead concentrations.

Although the three sources of lead contamination discussed above are not the only possible sources, they are the only constant sources on a regional basis. Contributions from weathering paint or lead plumbing, for example, would be too localized to be used in comparing nationwide values of lead concentrations.

An examination of the lead concentrations in water for each lake showed no discernible pattern at inlets or outlets, boat launching ramps, areas bordering highways, or depth of unsaturated lakes with the remaining concentrations in the lake. This suggests either one of two things; since the lead contamination is not constant over an entire lake (greater near highways, points of discharge, and areas of motor boat use) either the lake is well mixed or the lead is removed as it enters the lake. Removal is presumably by means of precipitation and sedimentation.

Lead Content of Sediments

Table 2 is a summary of the lead concentrations in sediment as determined in this project. The concentrations ranged from 6.0 to 1546.4 mg/kg dry weight. It appears from the values reported that the effects of man's activities are decisive concerning the concentration of lead in the sediments.

The lakes selected for suspected high concentrations of lead definitely exhibited the highest lead concentrations in the sediments. Silver lake sediments were exceptionally high with a mean concentration of 1546.4 mg/kg dry weight. This lake is highly polluted by industry, is influenced by heavy city traffic, but has no motor boat use. Indian Lake in Worcester was second highest with a concentration of 314.1 mg/kg dry weight. Indian Lake is bordered by a major city street, has moderate to heavy motor boat use, and it is suspected that nearby industries contribute lead to the lake. The lakes with sequentially high lead concentrations were Pontoosuc Lake (113.5 mg/kg), Big Benton Pond (107.0 mg/kg), Stockbridge Bowl (83.5 mg/kg), North Pond (83.0 mg/kg), Cheshire Reservoir (82.4 mg/kg), and Center Pond (81.5 mg/kg). All of these lakes with the exception of North Pond are either used moderately or heavily by motor boats and/or located adjacent to a numbered state highway. North Pond does not allow the use of motor boats and is the most remote lake of the seventeen from roadways. A reasonable explanation is that the lead is contributed by the geology of the area.

Eight other lakes have lead concentrations in the sediments ranging from 29.2 to 68.8 mg/kg dry weight. These lakes are influenced by man to a lesser degree than the eight mentioned above. Borrow Pit Pond exhibited the lowest lead concentration in the sediment with a concentration of 6.0 mg/kg dry weight.

Table 2. Mean Lead Concentrations in Sediments

Lakes Selected for Suspected Natural Background Concentrations of Lead	Sediment Concentration mg/kg	Standard Deviation
West Lake [5]*	31.8	27.4
Upper Spectacle Pond [5]	29.2	11.9
Guilder Pond [5]	55.8	39.4
North Pond [4]	83.0	34.4
Prindle Pond [8]	64.7	41.6
Lakes Selected for Suspected High Concentrations of Lead		
Stockbridge Bowl [8]	83.5	15.1
Pontoosuc Lake [10]	113.5	69.0
Cheshire Reservoir [8]	82.4	27.1
Indian Lake [9]	314.1	174.7
Silver Lake [5]	1546.4	456.0
Lakes Selected for Suspected Moderate Concentrations of Lead		
Big Benton Pond [7]	107.0	72.5
PeIham Lake [5]	38.0	35.0
Borrow Pit Pond [2]	6.0	4.2
Cranberry Pond [5]	29.6	7.0
Shaw Pond [8]	49.4	16.1
Center Pond [9]	81.5	49.9
Metacomet Lake [5]	68.8	13.4

*Numbers in brackets indicate number of samples collected from that lake.

This pond was created in the construction of Interstate 91 during the mid 60's and has been subjected to lead contamination for only a few years, hence the low value.

It is extremely difficult to measure quantitatively the influence of man's activities on these lakes. Motor boat use has been termed either light, moderate, or heavy as judged by McCann and Daly (19,20,21). This is not an accurate evaluation of the effect of motor boat use on the lead concentration as it is arbitrarily so designated. An estimate of the quantity of gasoline consumed per acre of lake area would be more meaningful.

The contribution of lead from automotive exhaust is impossible to evaluate with the information at hand. The numbered highways in this study ranged from the lightly travelled Route 183 to the more heavily travelled Routes 7 and 8 and to the very heavily travelled Massachusetts Turnpike. Hence, the total amount of lead exhausted to the atmosphere is unpredictable.

Although it is extremely difficult to assess the influence of man's activities concerning lead contamination on these lakes due to the many variables and unknowns, it is the authors' opinion that the eight lakes which exhibited the highest lead concentrations in the sediment were indeed the most heavily influenced by automotive exhaust, motor boat exhaust, and industrial discharge.

The mean lead concentrations in sediments determined in this study were within the range of those of 213 to 265 mg/kg dry weight for Lake Quinsigamond as reported by Isaacs and Delaney (17) and the values of 48 to 150 mg/kg dry weight for several other lakes in western Massachusetts as reported by Delaney (18).

Correlations of Lead in Water and Lead in Sediment

Several correlations through the use of linear regression were attempted between the lead concentrations in water and the lead concentrations in sediment. No definite correlations were established.

For each of the seventeen lakes, a correlation was attempted between the lead concentration in the water and in the sediment of the lake. The lead concentrations in the water and in the sediment at the same sampling site were the ordered pairs used. The seventeen correlation coefficients ranged from -0.53 to 0.92.

Another correlation was attempted between the mean lead concentration in the water and the mean lead concentration in the sediment for all seventeen lakes. The mean lead concentrations in the water and in the sediments for each lake were the ordered pairs used. A correlation coefficient of 0.47 was obtained.

The low correlation coefficients are reasonable. From the discussion of the aqueous chemistry of lead, it is realized that the final depository for the lead is the sediment. The correlation coefficient would approach 1.0 only if the rate of lead contamination was constant for each lake and if the sediment samples represented the same period of time. A constant rate of lead contamination and a constant rate of sedimentation for every lake is obviously not to be expected.

A total of nine depth water samples were collected when it was determined by the temperature of the sediment that there was stratification at the sampling site. Depth samples were collected within five feet of the bottom. Seven of the nine samples showed definite increases in the lead concentration at the depth over the surface lead concentration. Two depth samples

were slightly less contaminated with lead than the surface sample. Since in a stratified lake there is a great resistance against mixing between surface waters and the lower layers, a correlation was attempted between the depth water concentration and the sediment concentration of lead. A correlation coefficient of 0.43 was obtained. Figure 5 is a scatter diagram for the nine points. Although no definite linear correlation was obtained, it appears that a trend exists for greater lead concentrations in the lower levels of a stratified lake than in the surface level due to either the release of lead from the sediments or to the presence of larger lead particles at increasing depths as suggested in the study on Lake Hamilton, Arkansas (30). Decomposition of organic matter will occur in the sediments, resulting in the release of CO_2 . The increased CO_2 concentration causes a shift in the carbonate equilibrium of the water and a decrease in pH. The lower pH may result in an increase in the solubility of the lead in the immediate overlying water.

Two distinctive types of sediments were collected. One type was generally muck, composed primarily of organic matter, clay, and silt. The other type of sediment was composed primarily of sand. Upon analysis, it was observed that the sand sediments contained much less lead than the organic-clay-silt sediments. This finding supports the findings of Goleva et al (8) that a considerable part of lead in natural waters is bound in organic complexes.

A notable exception to the preceding discussion was one sample collected from Big Benton Pond. A sediment sample collected within ten feet of a large dock used by fifteen or more motor boats had a lead concentration

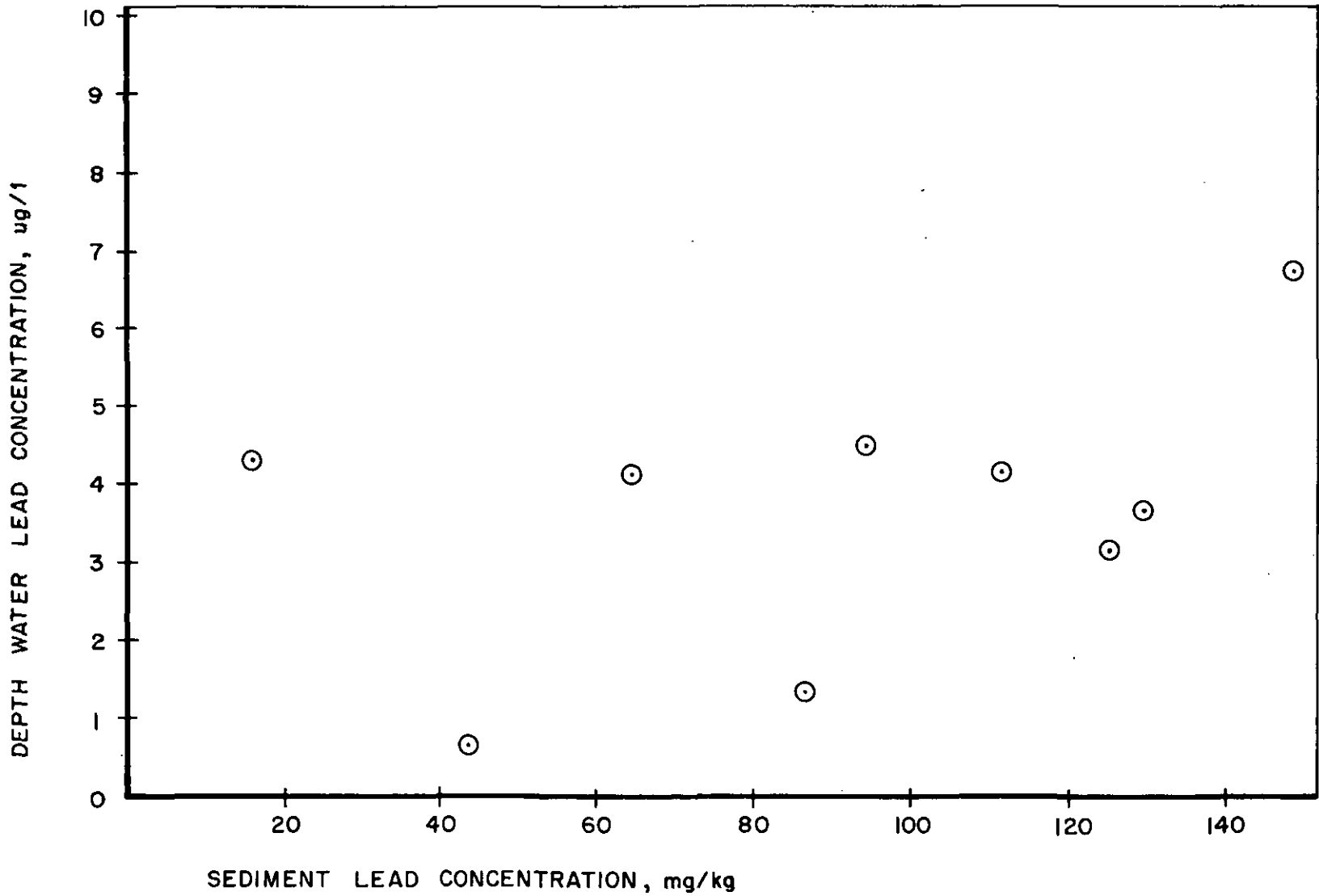


FIGURE 5

--Depth Water Lead Concentration VS. Sediment Lead Concentration.

twice the mean lead concentration for the entire lake even though the sediment was sand. The heavy and concentrated use of motor boats near the dock and spillage of gasoline introduces both inorganic and organic lead to the water which will settle to the sediment. A laboratory study similar to this situation at Big Benton Pond was examined by Mulcahy (32) and was discussed in the literature review. In essence, Mulcahy showed that the concentration of both filterable and non-filterable lead in water contributed by outboard motor exhaust decreased with time, in a quiescent column of water. An increase in lead concentration in the underlying sediments to these water columns with time, was also shown.

Toxicity of Lead to Aquatic Biota

In the literature review on lead toxicity, references concerning lead concentrations in water and its toxic effects on fish were the only subject type available. A thorough search revealed that references concerning lead concentrations in water and its toxic effects on other aquatic biota and references concerning lead concentrations in sediments and its toxic effects on aquatic biota apparently were not available.

The mean lead concentrations in water as determined in this study were a minimum of twenty-five times less than the lowest concentration (100 $\mu\text{g}/\text{l}$) reported as being acutely toxic to fish (28). It can be concluded that there is no danger to fish in these lakes from acute lead toxicity. However, no chronic toxicity levels were reported in the literature, nor were levels reported that might cause growth changes or interfere with species reproduction.

Natural "Background" Levels of Lead

An initial objective of this project was to determine natural, background levels of lead both in water and in sediment. Natural, background levels should be indicative of the natural levels of lead and not include lead contributed by man. Although it is impossible to obtain background levels without any lead

from man's activities because of atmospheric dispersion, it was hoped that some of the lakes were remote enough such that the influence of man's activities would be at a minimum.

Background levels of lead contamination can vary from lake to lake due to:

1. Different geological areas containing varying amounts of lead bearing minerals.
2. Varying degrees of water hardness effecting the lead concentration in the water.
3. The influence of man's activities varying.

As was discussed in the previous section of this report, 'Lead Content of Water', the lakes selected for suspected natural background concentrations of lead exhibited the same range of concentrations of lead as the lakes selected for suspected high concentrations of lead. This indicates that although the lead is introduced to the water, it does not remain in the water. It appears that natural, background levels of lead in water for western Massachusetts range from 1 to 3 $\mu\text{g/l}$.

The influence of man's activities on natural, background levels of lead in sediment was decisive as determined in this project. From the discussion in the previous section, 'Lead Content of Sediment', it appears that natural, background levels of lead in sediment for western Massachusetts range from 30 to 80 mg/kg dry weight.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The mean lead concentrations in water for the seventeen lakes ranged from 0.60 to 4.07 $\mu\text{g}/\text{l}$. These concentrations appear to be significantly lower than concentrations reported in three nationwide surveys, but are only slightly lower than lead concentrations determined for Massachusetts lakes and ponds in one of the nationwide surveys.
2. The mean lead concentrations in the sediments ranged from 6 to 1546 mg/kg dry weight with sixteen of the seventeen lakes in the range of 6 to 314 mg/kg dry weight. These latter concentrations are consistent with lead concentrations in four Massachusetts lakes reported by two investigators.
3. There appears to be no significant increase in the lead concentration in the water of lakes heavily influenced from man's activities over those lakes with limited influence from man's activities.
4. It appears that the effects of man's activities are decisive concerning the concentrations of lead in the sediments. The lakes selected for suspected high concentrations of lead due to the high influence of man's activities definitely exhibited the highest lead concentrations in the sediments.
5. Background concentrations of lead in water for western Massachusetts ranged from 1 to 3 $\mu\text{g}/\text{l}$. In the lakes surveyed in this study, background concentrations of lead in water are similar to lead concentrations in water heavily influenced by man's activities. This is due to the aqueous chemistry of lead; the lead is readily precipitated and removed to the sediments before any appreciable buildup occurs in the water.

6. Background concentrations of lead in sediments for western Massachusetts range from 30 to 80 mg/kg dry weight.
7. In stratified lakes a trend exists for greater lead concentrations in the lower levels of the lake than in the surface level.
8. The mean lead concentrations in the water found in the seventeen lakes pose no threat to fish in terms of acute toxicity. The mean lead concentrations were a minimum of twenty-five times less than the lowest concentration reported as being acutely toxic.

RECOMMENDATIONS

1. The accumulation of lead along successive trophic levels should be studied to determine if lead from the water and sediment is passed on to higher order species such as fish.
2. Utilizing the data available in this study, a study should be undertaken to determine whether the concentration of lead in selected biota living in water high in lead concentration is significantly greater than the same specie of biota living in water low in lead concentration.
3. Laboratory studies concerning the uptake rate and release rate of lead by various aquatic species should be conducted. Concentrations of lead of the magnitude found in this study should be utilized.
4. The establishment of chronic toxicity levels of lead for fish is vitally needed.
5. The contributory effect of lead from automotive exhaust over a period of time can be studied readily at Borrow Pit Pond. Borrow Pit Pond was created in the mid 60's when Interstate 91 was constructed. The mean lead concentration in the sediment was only 6 mg/kg dry weight, five times less than the second lowest concentration found in this study. Yearly sampling would expose the effect of the automotive exhaust on this pond.

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LITERATURE CITED

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APPENDIX

BIG BENTON POND, OTIS

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ((μg/l)</u>
w1	0	25' from west shore midway	4.44
w2	0	between large and small island	1.52
w3	0	75' west of island	2.50
	18	" "	6.72
w4	0	10' off docks	1.72
w5	0	25' from north shore	2.30
w6	0	middle of cove	2.08
w7	0	20' from access	2.08

			<u>Concentration (mg/kg)</u>
s1	5	25' from west shore midway	16
s2	25	between large and small island	147
s3	21	74' west of island	147
s4	3	10' off docks	200
s5	3	25' from north shore	72
s6	3	middle of cove	151
s7	2	20' from access	16

331 acres
Farmington River watershed
moderate boating
near Route 23
70% residential, 30% swamp

Mean water concentration 2.92 μ g/l s = 1.77
Mean sediment concentration 107 mg/kg s = 72:5

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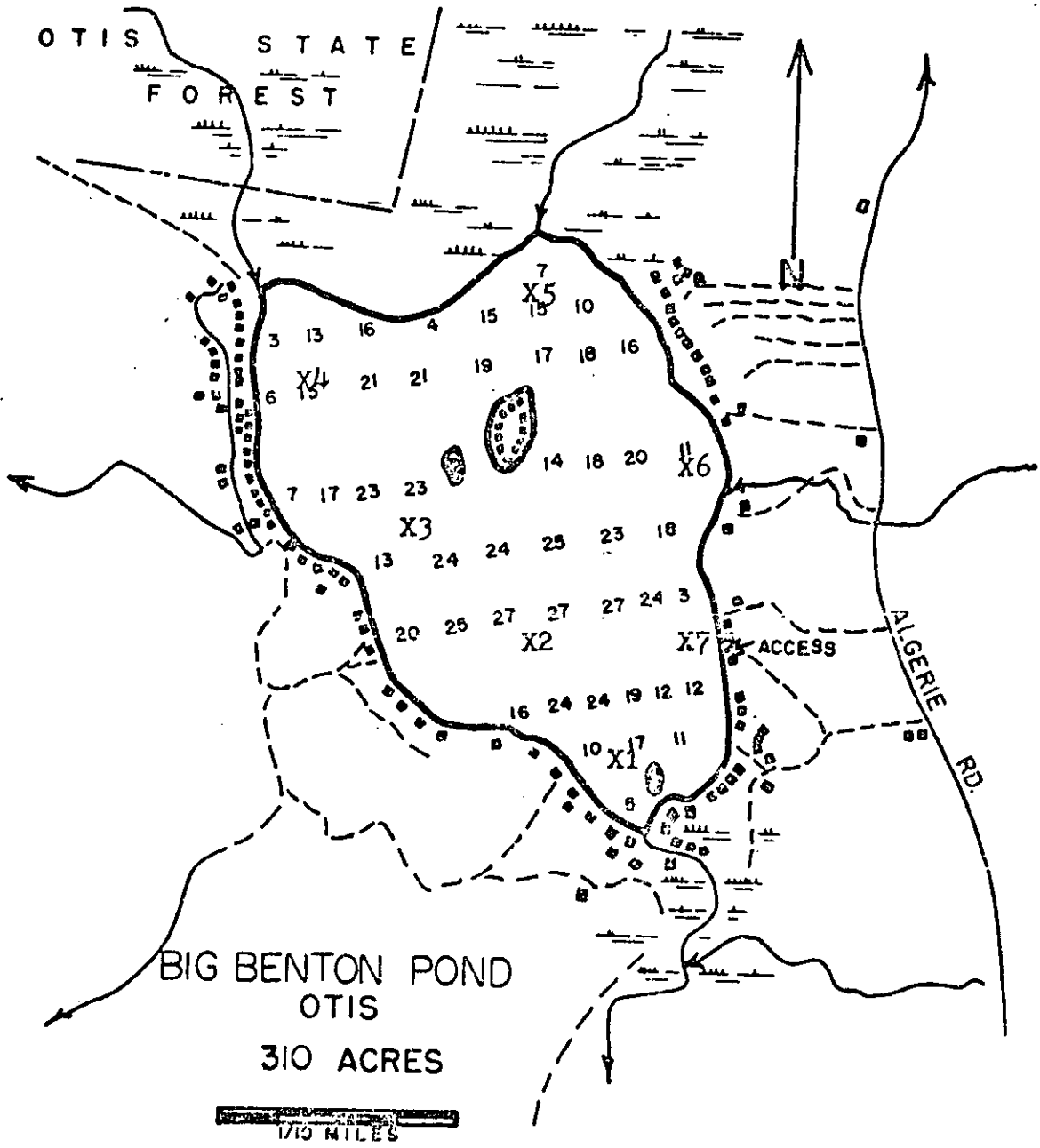
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BORROW PIT POND, WHATELY

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g/l}$)</u>
w1	0	50' from I-91	2.30
w2	0	150' from I-91	3.16
w3	0	300' from I-91	3.36
			<u>Concentration (mg/kg)</u>
s1	7	50' from I-91	lost sample
s2	7	150' from I-91	3
s3	7	300' from I-91	9

5 acres
 Mill River watershed
 no motor boating allowed
 within 50' of I-91
 70% fields, 30% highway

Mean water concentration 2.94 $\mu\text{g/l}$ s = 0.56
 Mean sediment concentration 6 mg/kg s = 4.2



CENTER POND, BECKET

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	middle of cove	0.76
w2	0	25' from outlet	1.84
w3	0	middle	1.84
w4	0	middle	1.44
w5	0	middle	4.72
w6	0	middle	6.90
w7	0	30' from shore	4.28
w8	0	25' from shore	5.50
w9	0	50' from shore	0.66

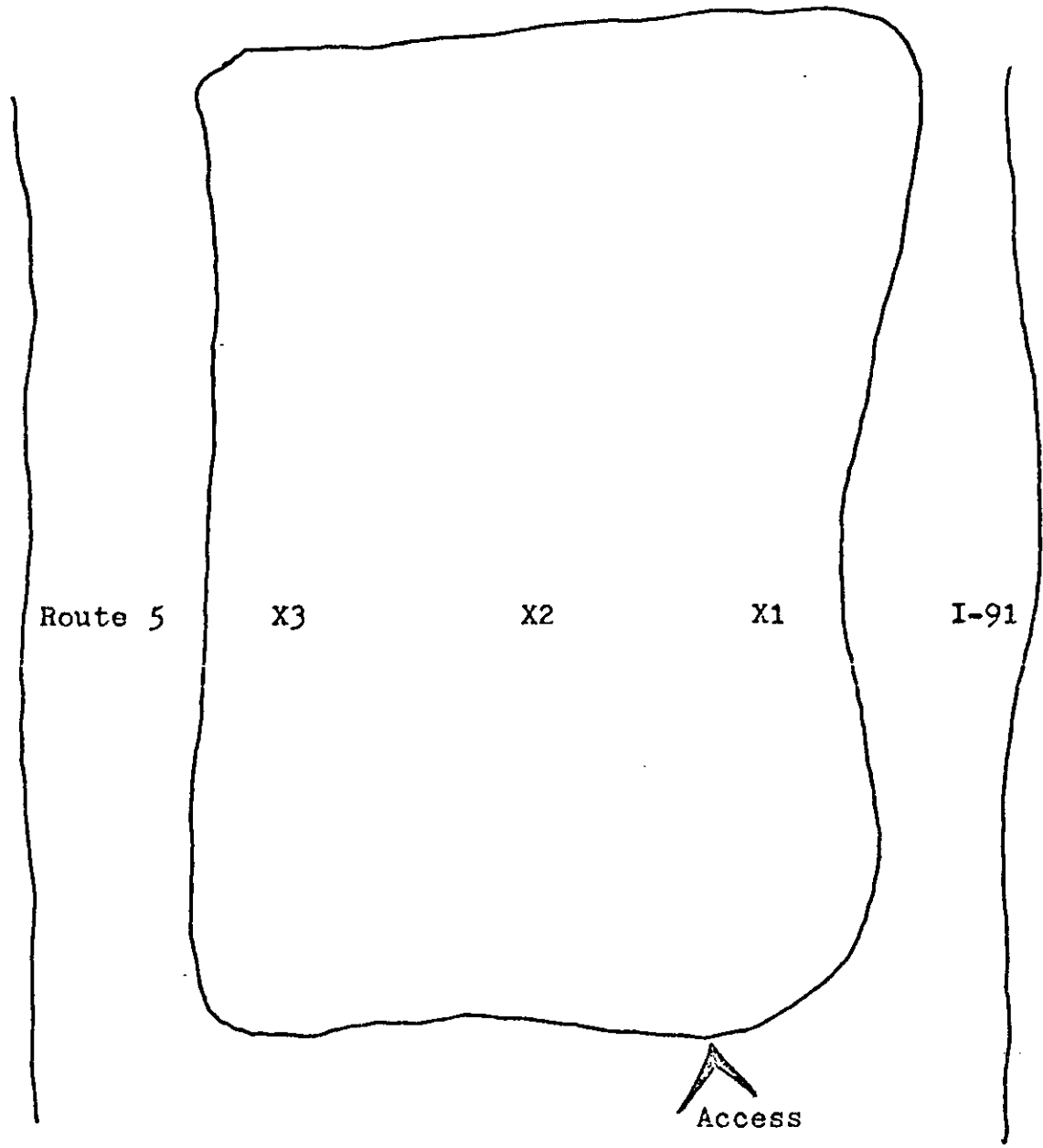
			<u>Concentration (mg/kg)</u>
s1	5	middle of cove	29
s2	5	25' from outlet	26
s3	14	middle	143
s4	11	middle	86
s5	13	middle	94
s6	13	middle	78
s7	10	30' from shore	147
s8	4	25' from shore	14
s9	8	50' from shore	118

125 acres
 Westfield River watershed
 moderate boating and water skiing
 near Route 8
 70% residential, 30% vacant

Mean water concentration 3.01 $\mu\text{g}/\text{l}$ s = 2.12

Mean sediment concentration 81.5 mg/kg s = 49.9

A4



BORROW PIT POND
WHATELY
10 ACRES

CRANBERRY POND, SUNDERLAND

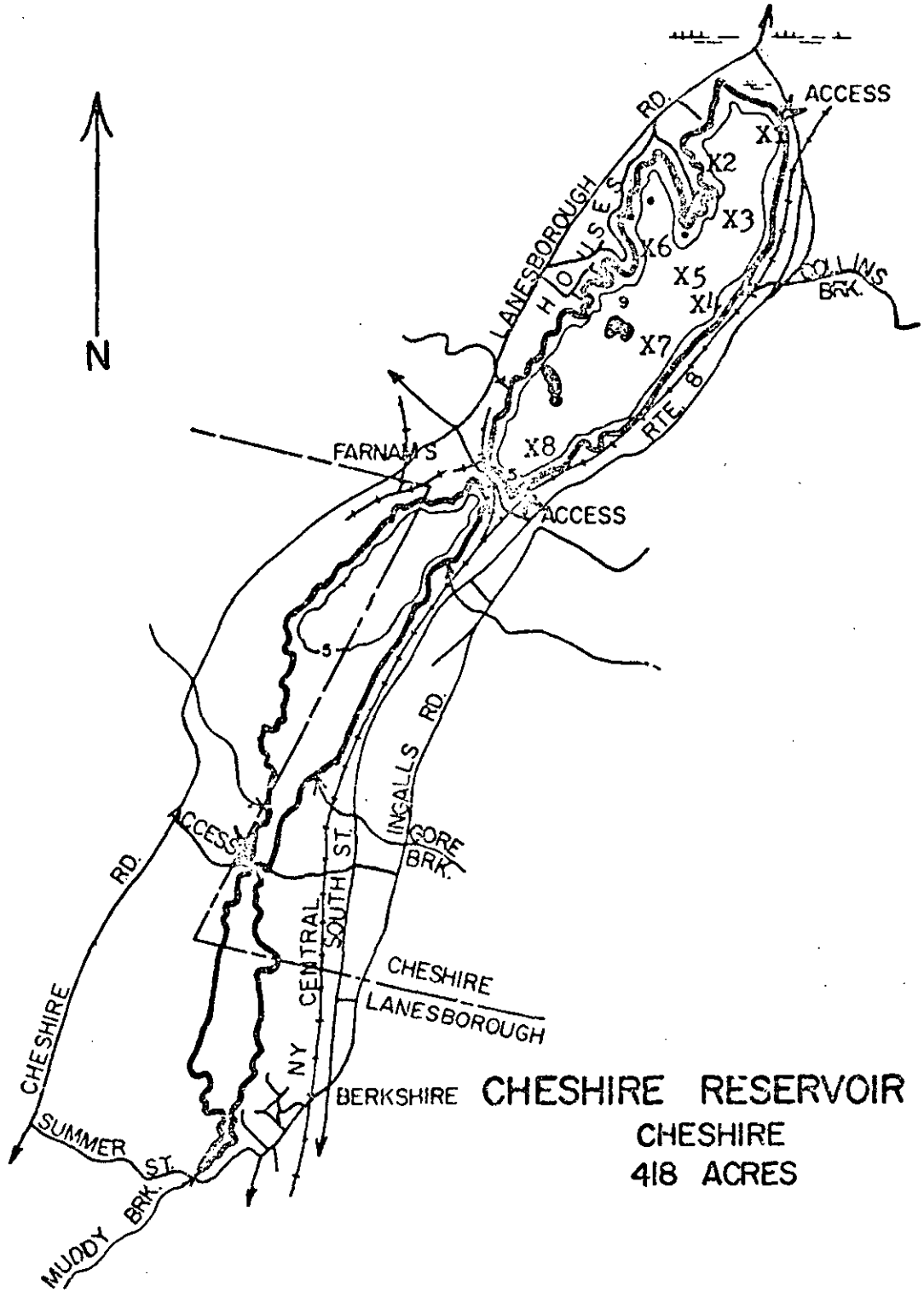
<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	10' from stump	0.76
w2	0	middle of deep area	0.54
w3	0	50' from west shore	0.48
w4	0	30' from east shore	0.96
w5	0	50' from west shore	0.30

			<u>Concentration (mg/kg)</u>
s1	4	10' from stump	35
s2	18	middle of deep area	26
s3	5	50' from west shore	22
s4	6	30' from east shore	26
s5	6	50' from west shore	39

24 acres
 Connecticut River watershed
 no motor boating allowed
 near Route 63
 90% wooded, 10% swamp

Mean water concentration 0.60 $\mu\text{g}/\text{l}$ s = 0.25

Mean sediment concentration 29.6 mg/kg s = 7.0



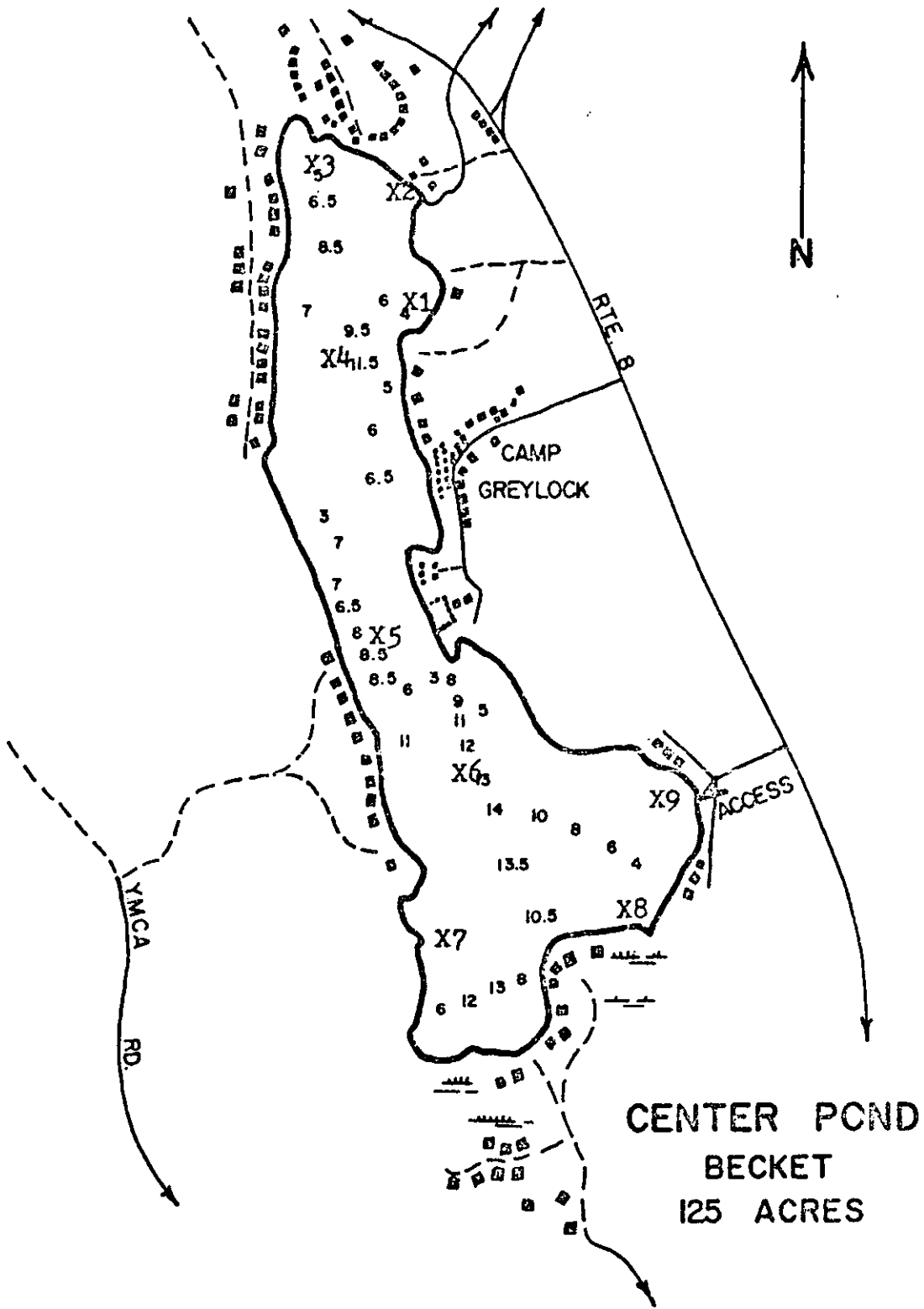
CHESHIRE RESERVOIR
CHESHIRE
418 ACRES

CHESHIRE RESERVOIR, CHESHIRE
(north section only)

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	20' from RR bridge	1.24
w2	0	100' from twin willows	4.0
w3	0	200' from boat houses	2.3
w4	0	20' from abandoned metal building	1.54
w5	0	500' from abandoned metal building	2.08
w6	0	100' from west shore	5.06
w7	0	200' from largest island	1.50
w8	0	10' from access ramp	3.82
			<u>Concentration (mg/kg)</u>
s1	8	20' from RR bridge	lost sample
s2	7	100' from twin willows	56
s3	10	200' from boat houses	47
s4	7	20' from abandoned metal building	98
s5	10	500' from abandoned metal building	65
s6	9	100' from west shore	92
s7	9	200' from largest island	123
s8	2	10' from access ramp	96

418 acres
Hoosic River watershed
heavy boating and water skiing
near Route 8
moderate industrial use
30% residential, 30% farm, park 10%, swamp 30%

Mean water concentration 2.69 $\mu\text{g}/\text{l}$ s = 1.41
Mean sediment concentration 82.4 mg/kg s = 27.1



INDIAN LAKE, WORCESTER

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	50' from island	8.18
w2	0	150' from bridge	3.60
w3	0	30' from shore in cove	7.10
w4	0	100' from shore and beach	3.46
w5	0	midway from cove to lighthouse	1.84
w6	0	300' from lighthouse	2.50
w7	0	30' from lighthouse	2.74
w8	0	20' from highway	4.50
w9	0	30' from access ramp	2.74
			<u>Concentration (mg/kg)</u>
s1	1	50' from island	405
s2	4	150' from bridge	670
s3	6	30' from shore in cove	225
s4	7	100' from shore and beach	26
s5	12	midway from cove to lighthouse	244
s6	13	300' from lighthouse	312
s7	8	30' from lighthouse	220
s8	5	20' from highway	358
s9	6	30' from access ramp	367

190 acres
 Blackstone River watershed
 light boating
 highway: Grove Street
 80% residential, 20% highway

Mean water concentration 4.07 $\mu\text{g}/\text{l}$ s = 2.17

Mean sediment concentration 314 mg/kg s = 174.7

A12



X4

X3

X2

X5

X1

Access

Road

GUILDER POND
MT. WASHINGTON
15 ACRES

GUILDER POND, MT. WASHINGTON

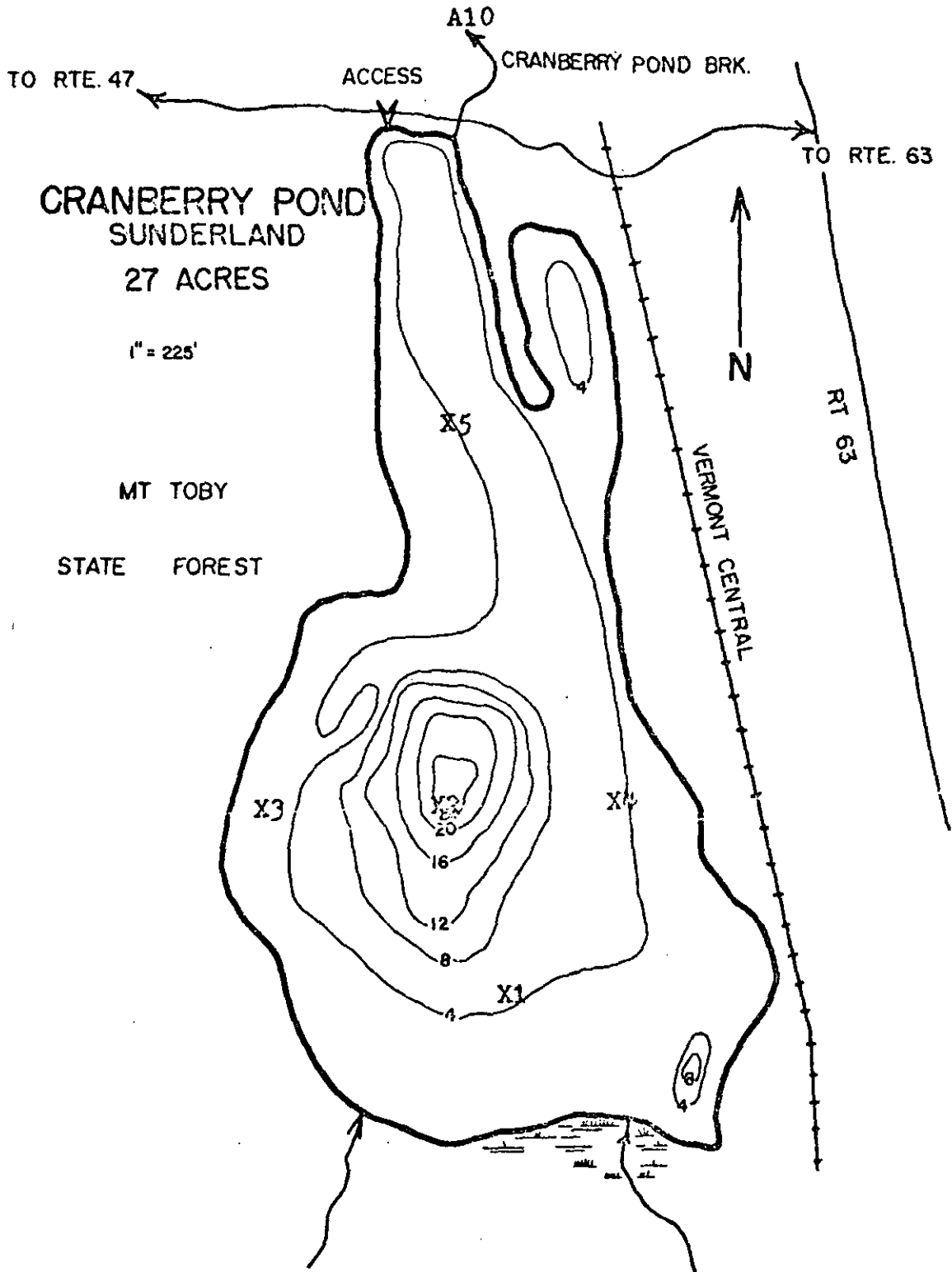
<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	5' from shore	1.80
w2	0	middle of cove	2.16
w3	0	middle	6.16
w4	0	25' from shore	2.62
w5	0	40' radius	2.86

			<u>Concentration (mg/kg)</u>
s1	4	5' from shore	54
s2	3	middle of cove	28
s3	4	middle	7
s4	3	25' from shore	93
s5	3	40' radius	97

15 acres
 Mt. Washington River watershed
 no boats allowed
 no highway
 90% wooded

Mean water concentration 3.12 $\mu\text{g}/\text{l}$ s = 1.74

Mean sediment concentration 55.8 mg/kg s = 39.4



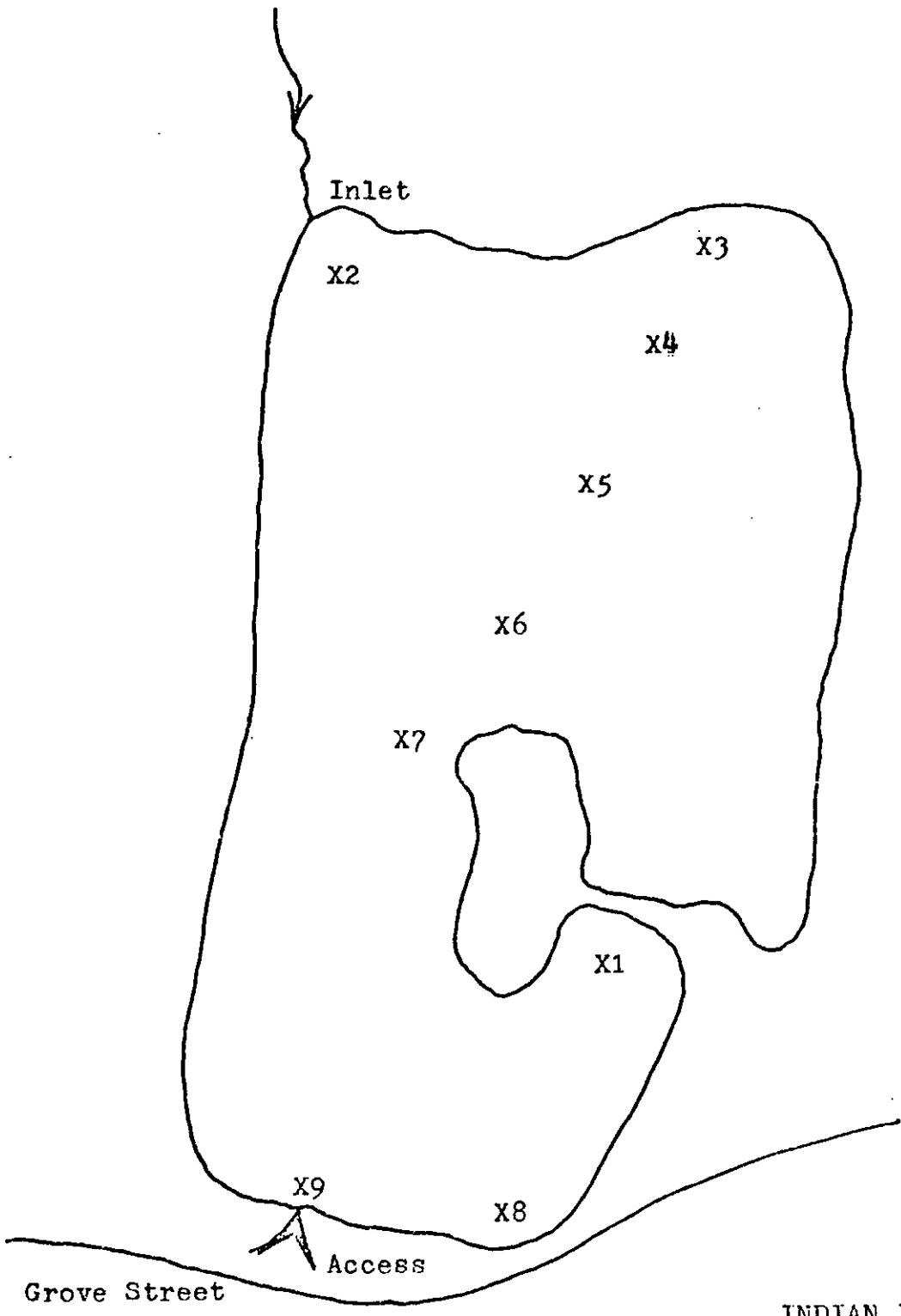
LAKE METACOMET, BELCHERTOWN

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration (µg/l)</u>
w1	0	100' from outlet	1.14
w2	0	100' from large willow tree	0.56
w3	0	150' from island	0.56
w4	0	150' from point	0.76
w5	0	50' from public access	0.96
			<u>Concentration (mg/kg)</u>
s1	10	100' from outlet	72
s2	5	100' from large willow tree	31
s3	14	150' from island	69
s4	13	150' from point	58
s5	3	50' from public access	114

74 acres
 Connecticut River watershed
 heavy boating
 no highway
 70% of shore residential

Mean water concentration 0.79 µg/l s = 0.25
 Mean sediment concentration 68.8 mg/kg s = 13.4

A14



Inlet

X2

X3

X4

X5

X6

X7

X1

X9

X8

Access

Grove Street

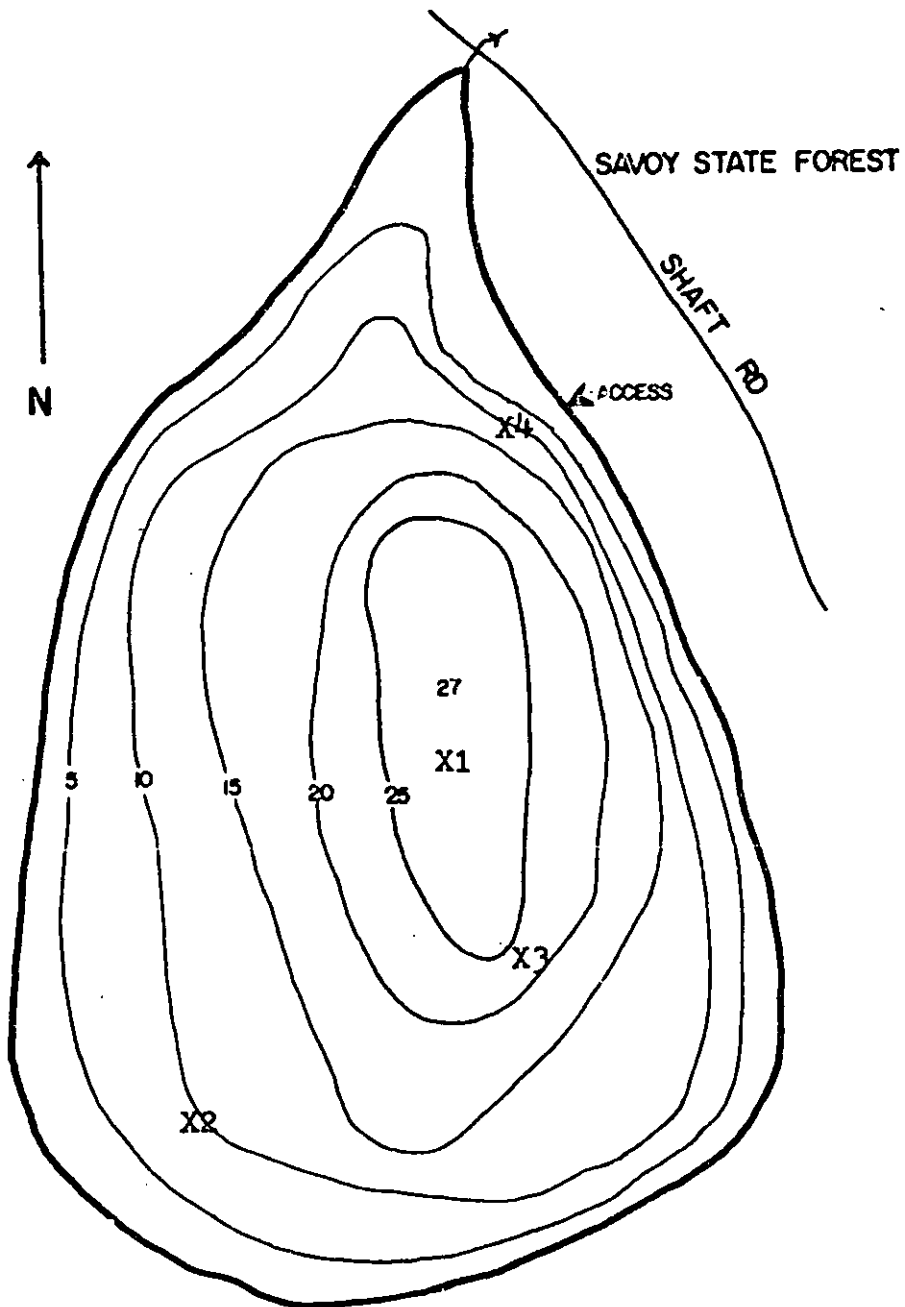
INDIAN LAKE
WORCESTER
190 ACRES

PELHAM LAKE, ROWE

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g/l}$)</u>
w1	0	50' from SE shore	1.92
w2	0	center of pond	1.54
w3	0	50' from south point	1.62
w4	0	50' from inlet	1.70
w5	0	125' from dam	7.52
			<u>Concentration (mg/kg)</u>
s1	7	50' from SE shore	552
s2	8	center of pond	20
s3	3	50' from south point	6
s4	5	50' from inlet	40
s5	12	125' from dam	86

71 acres
 Deerfield River watershed
 light boating
 no highway
 10% residential, 10% municipal, 80% wooded

Mean water concentration	2.86 g/l	s = 2.60
Mean sediment concentration	38.0 mg/kg	s = 35.0
*without 552 value		



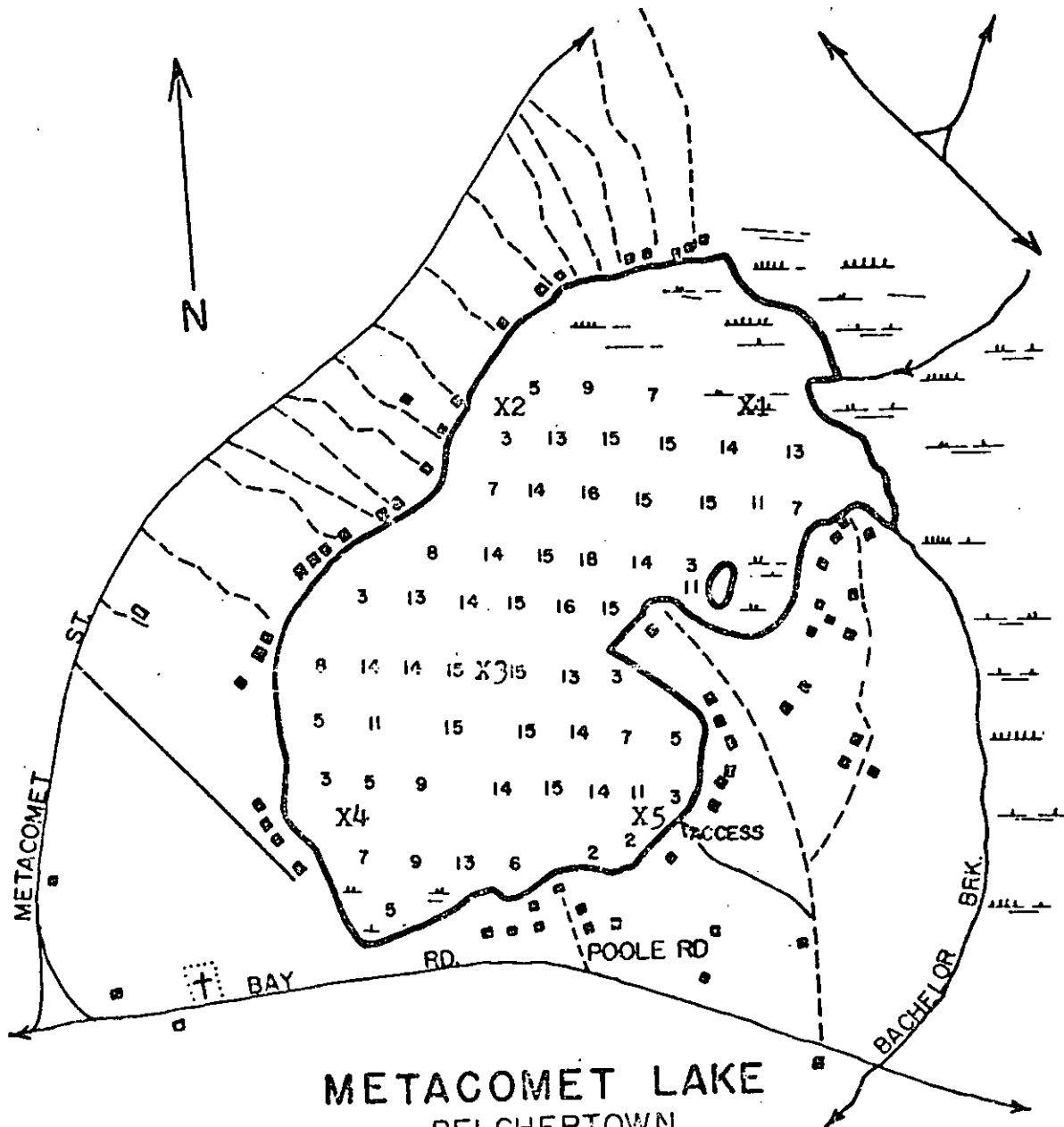
NORTH POND
FLORIDA
18 ACRES

NORTH POND, FLORIDA

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g/l}$)</u>
w1	0	100' from south point of swim area	0.86
	22		0.66
w2	0	75' from west shore	0.56
w3	0	150' from large boulder on east shore	0.76
	17		1.36
w4	0	50' from boat launch	0.48
			<u>Concentration (mg/kg)</u>
s1	27	100' from south point of swim area	41
s2	10	75' from west shore	78
s3	21	150' from large boulder on east shore	86
s4	8	50' from boat launch	126

18 acres
 Housatonic River watershed
 no motor boating allowed
 no highway
 90% park land, 10% wooded

Mean water concentration 0.7 $\mu\text{g/l}$ s = 0.31
 Mean sediment concentration 83.0 mg/kg s = 34.4



METACOMET LAKE
BELCHERTOWN
74 ACRES

1/32 MILES

PRINDLE LAKE, CHARLTON

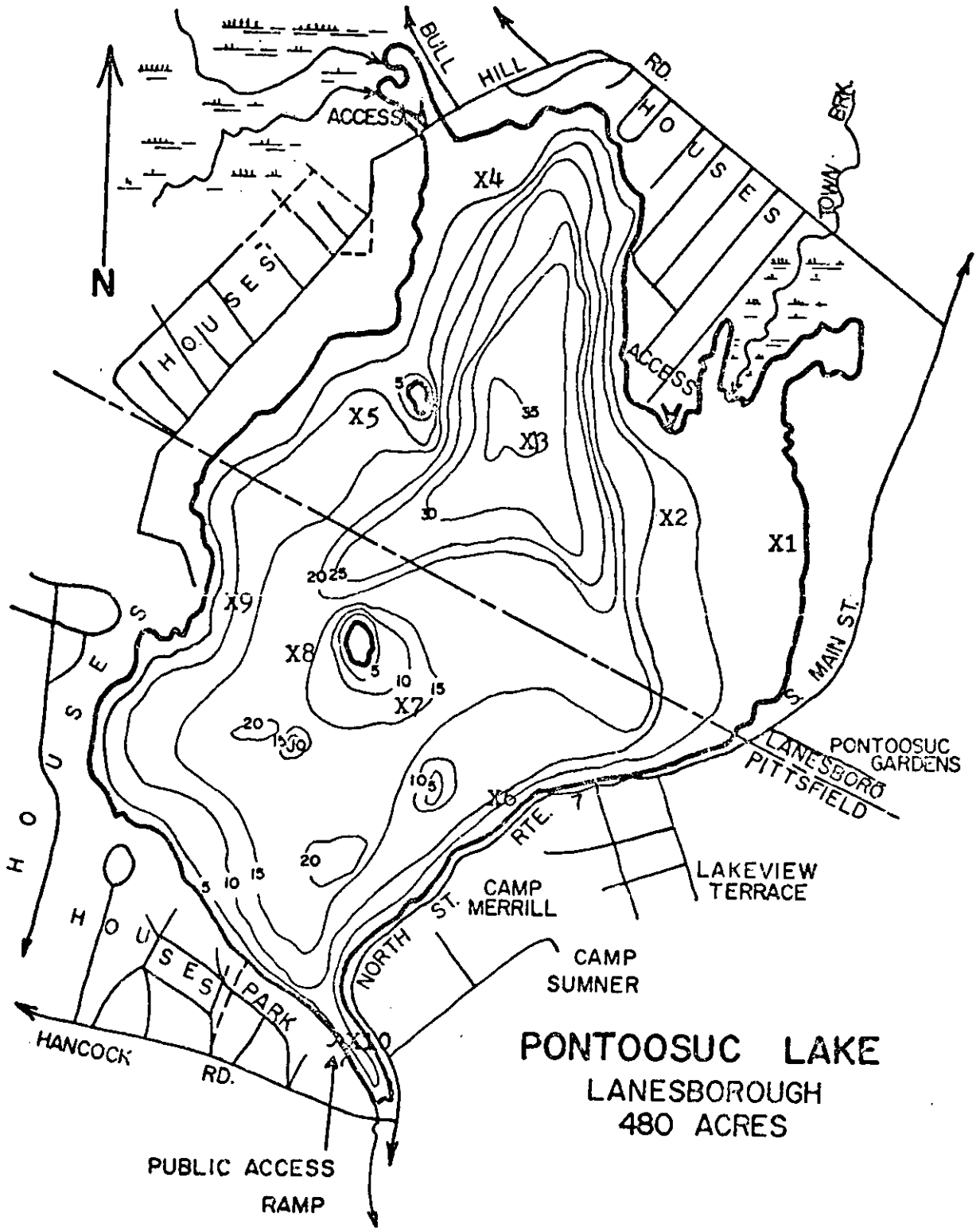
<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	Center of small cove	1.24
w2	0	50' off point	3.60
w3	0	center of large cove	0.96
w4	0	mouth of large cove	1.14
w5	0	150' off point	2.06
w6	0	40' from shore	1.32
w7	0	25' from shore	1.64
w8	0	3' from shore at access	1.32

			<u>Concentration (mg/kg)</u>
s1	6	Center of small cove	83
s2	5	50' off point	37
s3	5	center of large cove	45
s4	6	mouth of large cove	34
s5	5	150' off point	37
s6	4	40' from shore	64
s7	5	25' from shore	59
s8	1	3' from shore at access	159

71 acres
 Quinebaug River watershed
 no boating allowed
 no highway
 60% vacant, 20% residential

Mean water concentration 1.66 $\mu\text{g}/\text{l}$ s = 0.85

Mean sediment concentration 64.7 mg/kg s = 41.6



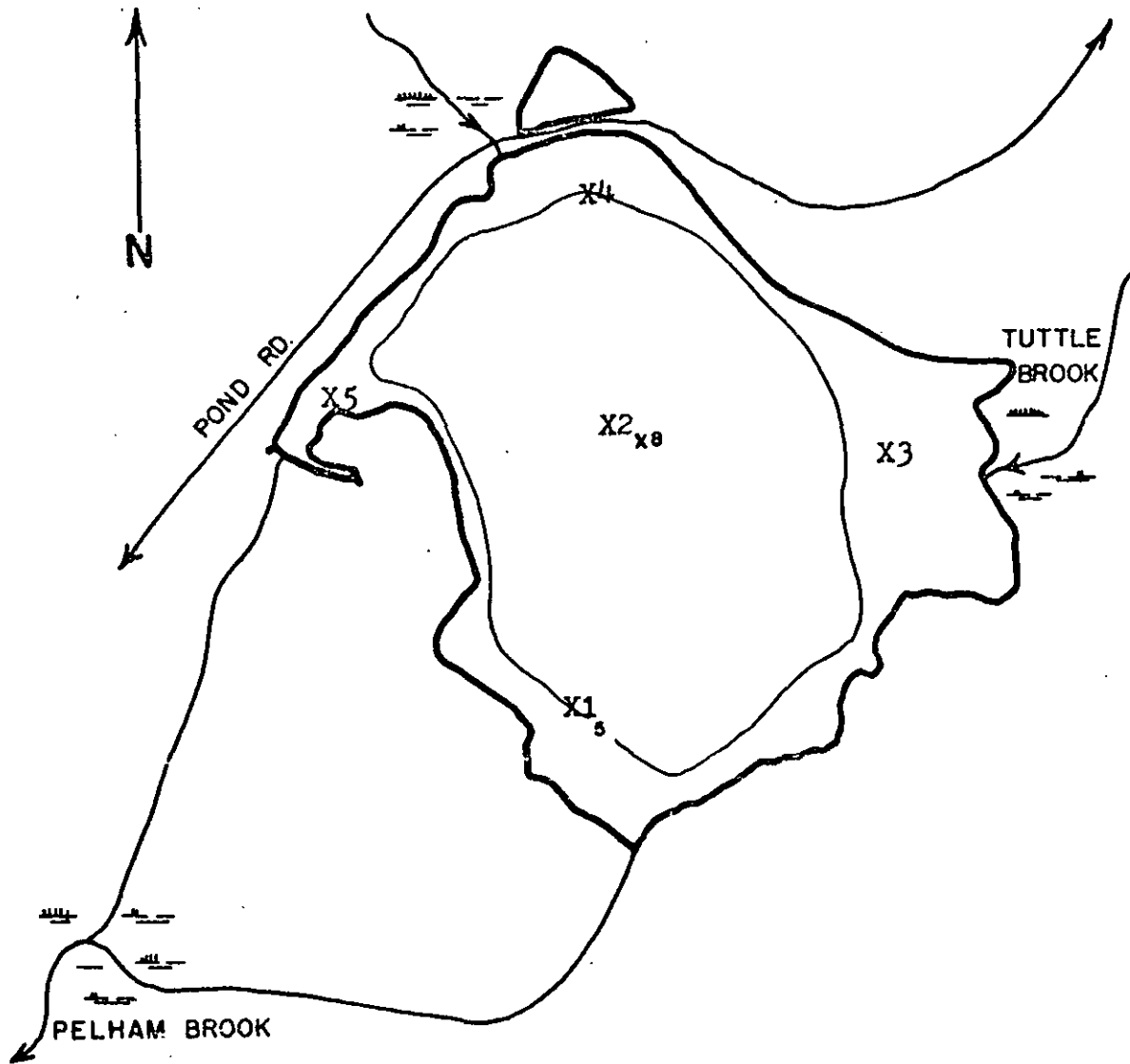
PONTOOSUC LAKE
LANESBOROUGH
480 ACRES

PONTOOSUC LAKE, LANESBORO

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g/l}$)</u>
w1	0	100' from prominent white house	2.98
w2	0	200' from point	0.66
w3	0	500' from large island	1.56
	20		
w4	0	200' from highway culverts	3.10
w5	0	150' from large island	2.62
w6	0	20' from white house	1.12
w7	0	15' from shoal marker	2.16
w8	0	100' from small island	1.84
w9	0	200' from barn on west shore	1.44
	15		
w10	0	10' from boat launch	3.88
			<u>Concentration (mg/kg)</u>
s1	6	100' from prominent white house	20
s2	8	200' from point	45
s3	32	500' from large island	124
s4	6	200' from highway culverts	67
s5	12	150' from large island	127
s6	8	20' from white house	259
s7	8	15' from shoal marker	70
s8	14	100' from small island	123
s9	16	200' from barn on west shore	127
s10	2	10' from boat launch	174

480 acres
 Housatonic River watershed
 heavy motor boating
 near Route 7
 90% residential, 10% municipal

Mean water concentration	2.33 $\mu\text{g/l}$	s = 1.02
Mean sediment concentration	113.5 mg/kg	s = 69.0



PELHAM LAKE

ROWE

71 ACRES



1/24 MILES

SHAW POND, BECKET

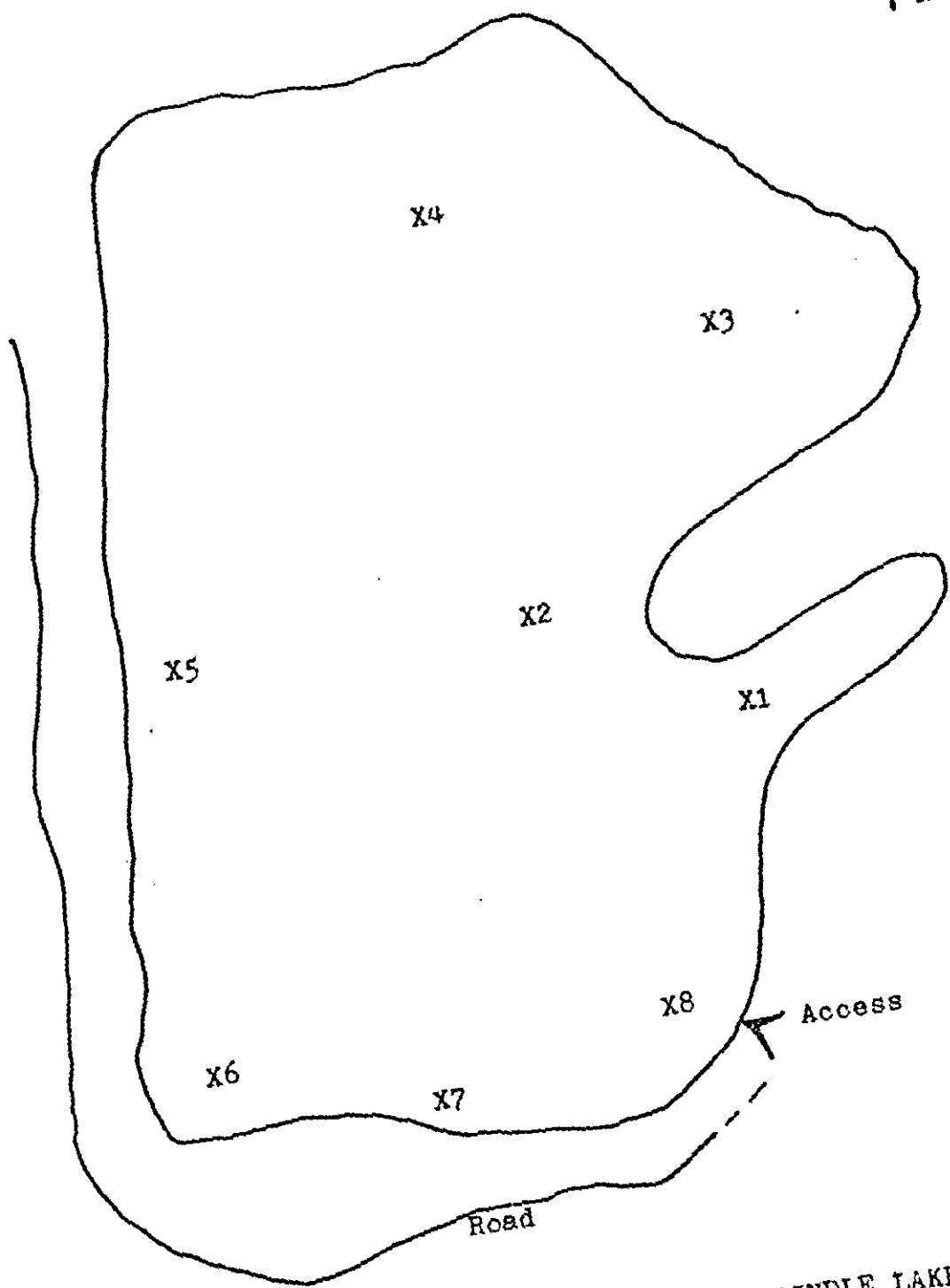
<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g/l}$)</u>
w1	0	10' from shore	1.34
w2	0	middle	1.14
w3	0	50' from shore	1.44
w4	0	middle	6.0
w5	0	100' from north shore	0.66
w6	0	100' from outlet	0.96
w7	0	30' from north shore	2.98
w8	0	50' from public access	1.44

			<u>Concentration (mg/kg)</u>
s1	3	10' from shore	41
s2	9	middle	61
s3	9	50' from shore	64
s4	14	middle	60
s5	15	100' from north	42
s6	4	100' from outlet	20
s7	13	30' from north shore	64
s8	8	50' from public access	54

100 acres
 Farmington River watershed
 light boating
 near Route 8 and Mass Pike
 30% residential, 70% vacant

Mean water concentration	1.99 $\mu\text{g/l}$	s = 1.75
Mean sediment concentration	49.4 mg/kg	s = 16.1

A24



PRINDLE LAKE
CHARLTON
71 ACRES

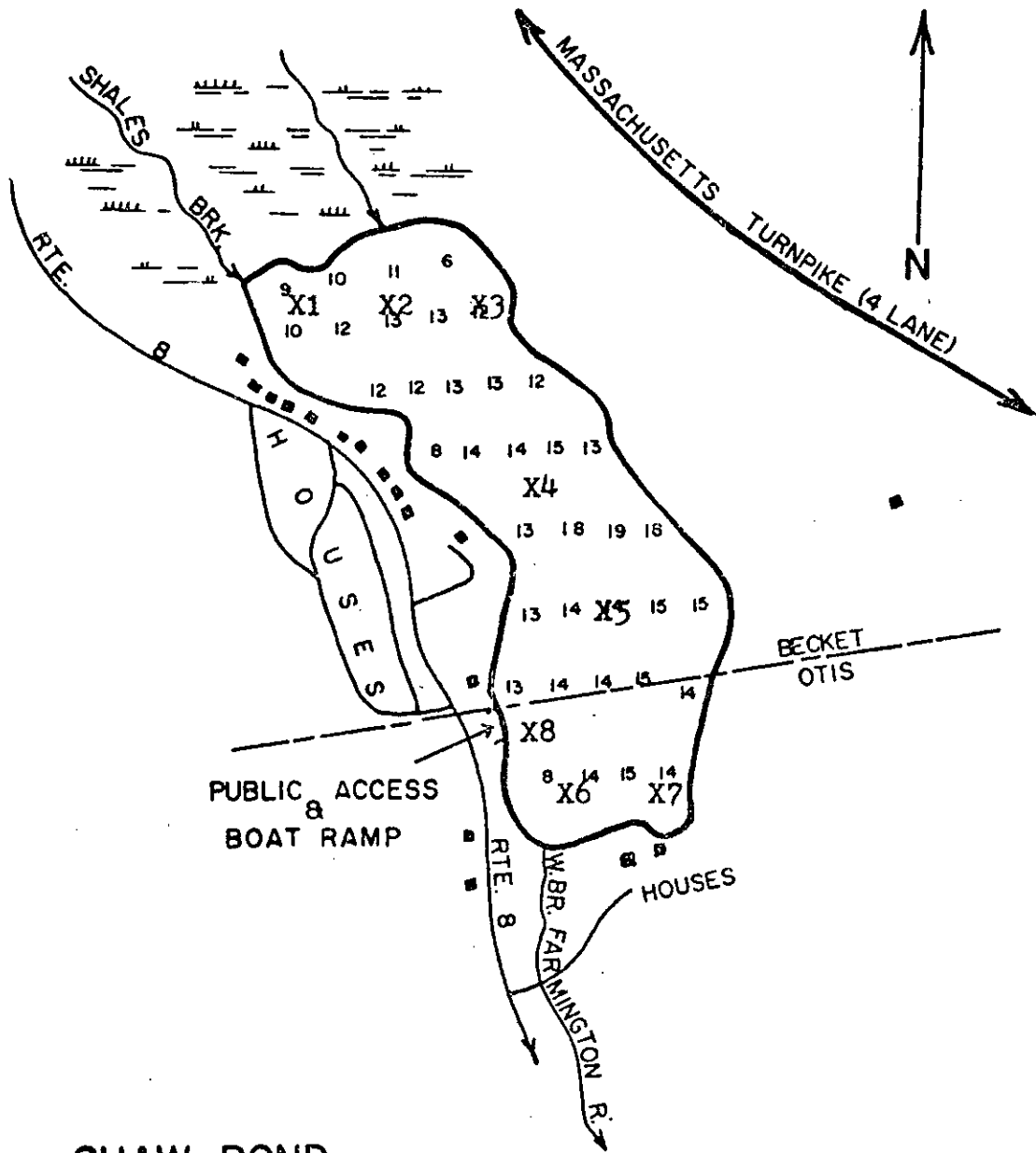
SILVER LAKE, PITTSFIELD

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g/l}$)</u>
w1	5	150' from smoke stack	48.0
w2	7	200' SW from building in lake	3.36
w3	7	75' from north shore	5.2
w4	7	100' from high tension tower	3.8
w5	7	100' from visible outfall	3.86
			<u>Concentration (mg/kg)</u>
s1	20	150' from smoke stack	1560
s2	17	200' SW from building in lake	1710
s3	23	75' from north shore	1812
s4	25	100' from high tension tower	1890
s5	15	100' from visible outfall	760

24 acres
 Housatonic River watershed
 kettlehole
 heavy industrial and cooling use
 no motor boating
 60% highway and industrial, 40% vacant

Mean water concentration 4.06 $\mu\text{g/l}$ s =
 *without 48.0 value

Mean sediment concentration 1546 mg/kg s = 456



SHAW POND
BECKET
100 ACRES



STOCKBRIDGE BOWL, STOCKBRIDGE

<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	20' from west shore	3.10
w2	0	75' east of island	1.48
	25	" "	4.30
w3	0	40' off east shore	1.74
w4	0	middle	4.44
	30	middle	4.16
w5	0	150' off east shore	2.88
w6	0	middle	2.08
	30	middle	4.16
w7	0	25' from shore	2.58
w8	0	10' off boat ramp	3.60

			<u>Concentration ($\mu\text{g}/\text{l}$)</u>
s1	4	20' from west shore	89
s2	28	75' east of island	93
s3	16	40' off east shore	68
s4	37	middle	112
s5	12	150' off east shore	84
s6	37	middle	64
s7	20	25' from shore	82
s8	3	10' off boat ramp	76

372 acres
 Housatnoic River watershed
 heavy boating
 near Route 183
 80% residential, 10% municipal

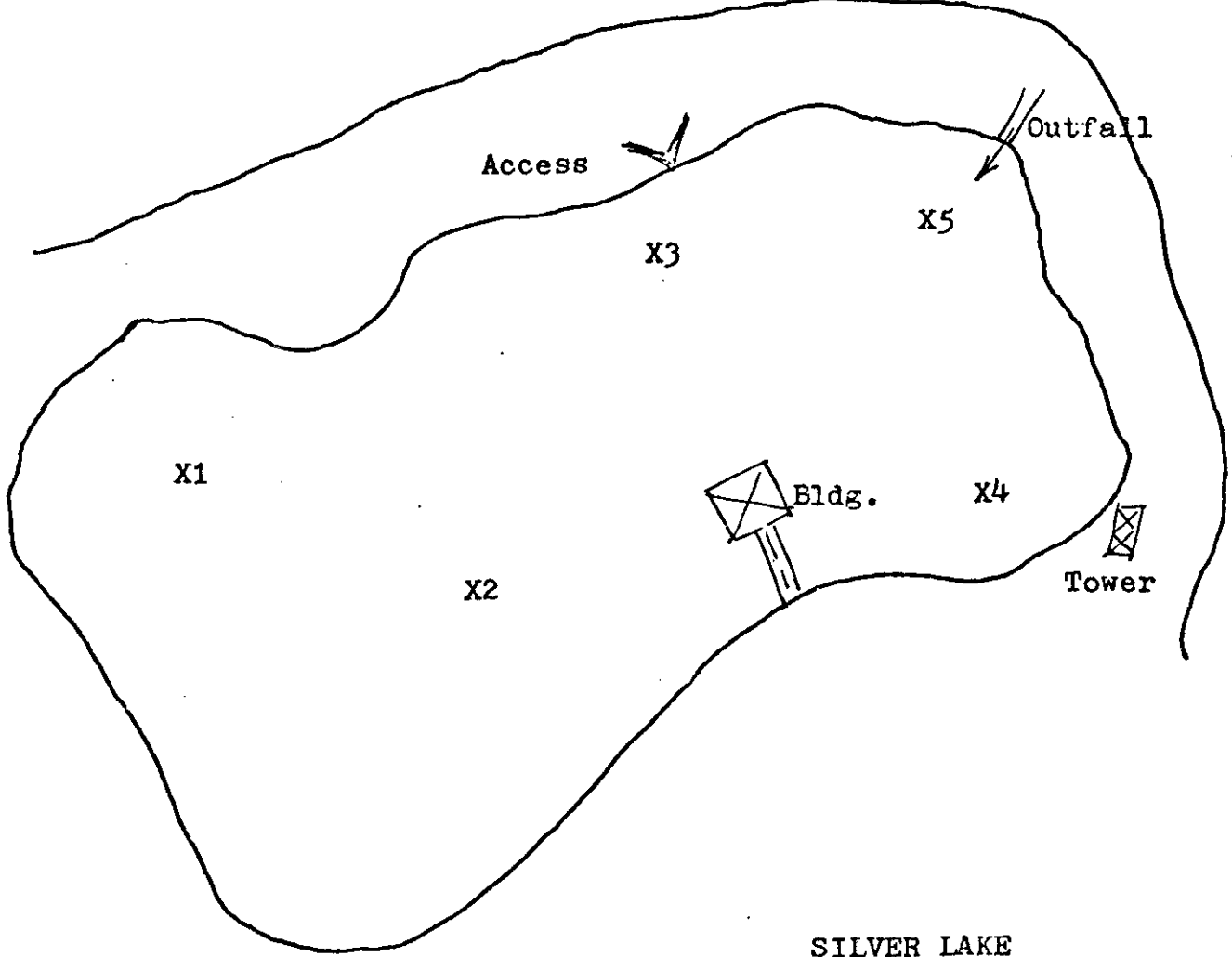
Mean water concentration 3.13 $\mu\text{g}/\text{l}$ s = 1.07

Mean sediment concentration 83.5 mg/kg s = 15.1

A28



Silver St.



SILVER LAKE
PITTSFIELD
24 ACRES

UPPER SPECTACLE POND, SANDISFIELD

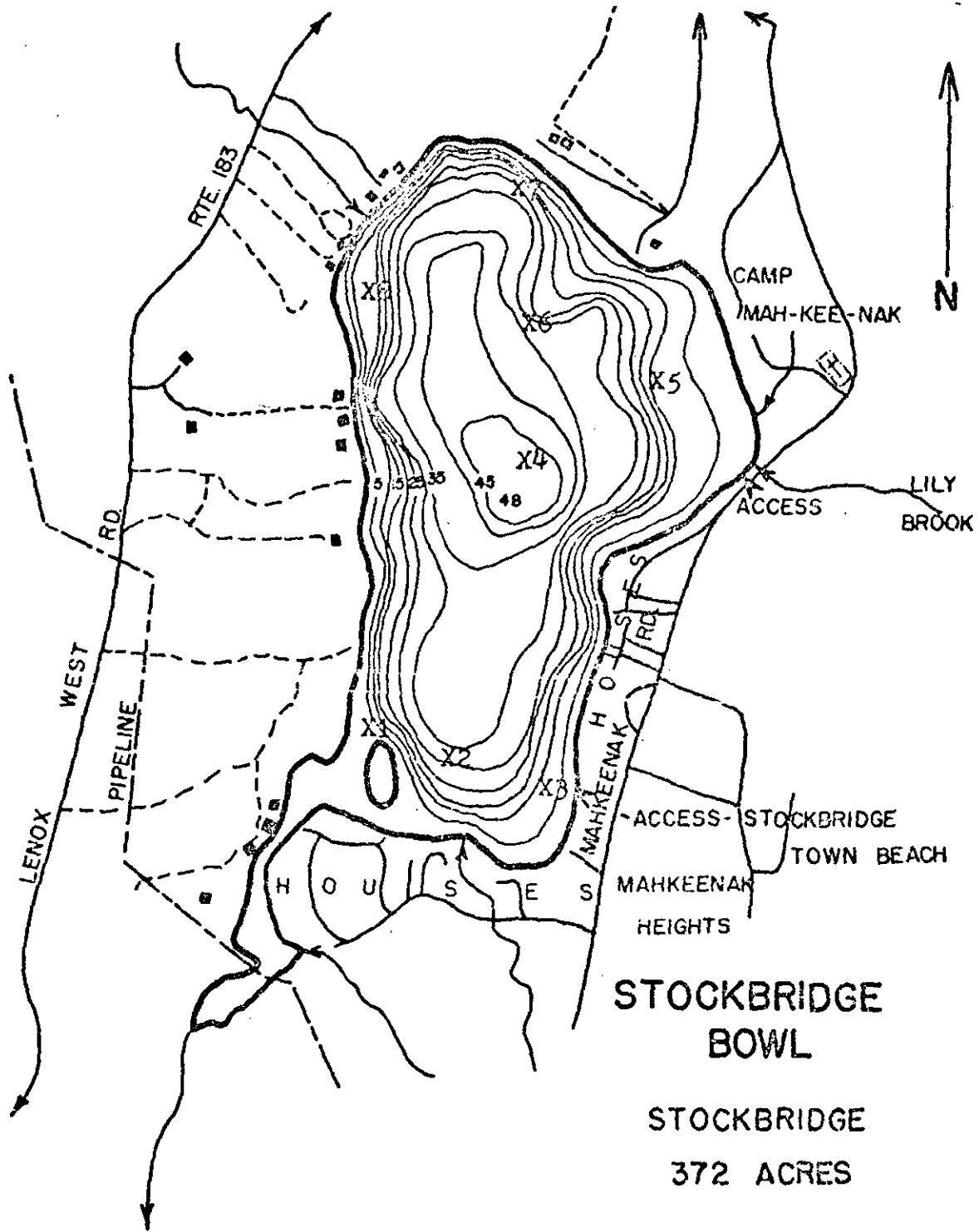
<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g/l}$)</u>
w1	0	midway between island and west shore	0.58
w2	0	middle of cove	1.14
w3	0	middle of lake	3.60
w4	0	50' from rock,	3.36
	14	middle of cove	4.28
w5	0	40' from outlet	1.64

			<u>Concentration (mg/kg)</u>
s1	6	midway between island and west shore	27
s2	3	middle of cove	44
s3	10	middle of lake	39
s4	16	50' from rock, middle of cove	17
s5	13	40' from outlet	19

72 acres
 Farmington River watershed
 no motor boating allowed
 no highway
 90% park land

Mean water concentration 2.43 g/l s = 1.50

Mean sediment concentration 29.2 mg/kg s = 11.9



WEST LAKE, SANDISFIELD

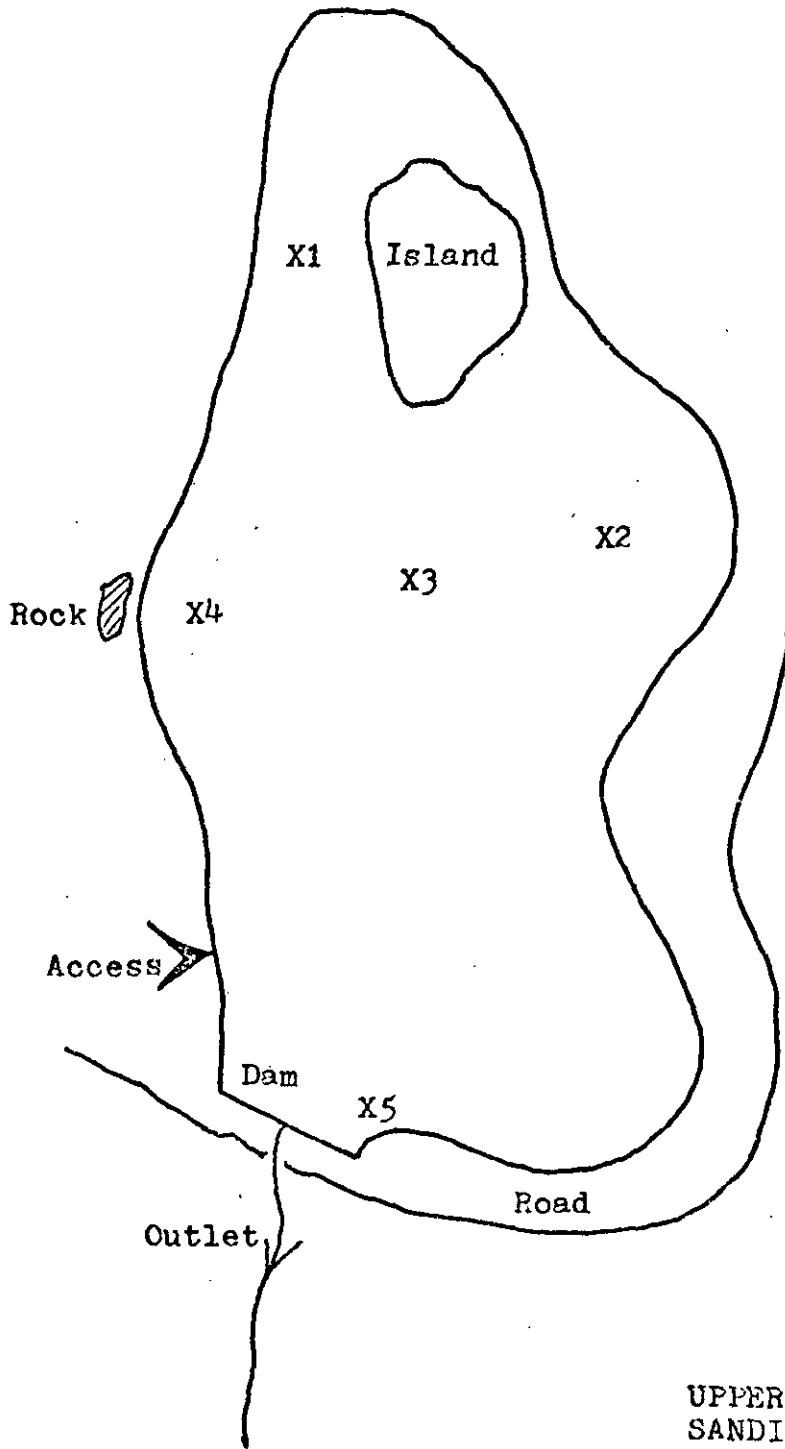
<u>Sample Number</u>	<u>Depth (Feet)</u>	<u>Distance from Landmark</u>	<u>Concentration ($\mu\text{g}/\text{l}$)</u>
w1	0	100' from inlet	2.08
w2	0	300' from fallen tree	1.72
w3	0	40' from dam	5.06
w4	0	30' from shore	1.32
w5	0	20' from access	2.48

			<u>Concentration (mg/kg)</u>
s1	7	100' from inlet	39
s2	15	300' from fallen tree	23
s3	14	40' from dam	20
s4	9	30' from shore	75
s5	2	20' from access	2

60 acres
 Farmington River watershed
 light boating
 no highway
 80% vacant, 20% swamp

Mean water concentration	2.53 $\mu\text{g}/\text{l}$	s = 1.47
Mean sediment concentration	31.8 mg/kg	s = 27.4

A32



UPPER SPECTACLE POND
SANDISFIELD
72 ACRES

