Michigan Department of Environmental Quality

Water Division

September 2004

Phosphorus Total Maximum Daily Load for Great Bear Lake Van Buren County

INTRODUCTION

Section 303(d) of the federal Clean Water Act and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations, Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are not meeting water quality standards (WQS). Within the TMDL framework, the loading of specific pollutants is reduced and allocated based on pollutant sources and instream water quality. The TMDL provides states with a process whereby point and/or nonpoint pollutant sources can be reduced appropriately so that WQS can ultimately be attained. This TMDL focuses on identifying appropriate reductions in nutrient loadings, specifically phosphorus, in the Great Bear Lake watershed that will enable WQS to be attained in Great Bear Lake.

PROBLEM STATEMENT

This TMDL focuses on reducing nutrient and sediment loading from 8,000 acres of watershed upstream of Great Bear Lake, which includes the Haven and Max Lake Drain and smaller agricultural tributary drains, all of which are warmwater designated water bodies in Van Buren County. The TMDL reach is 150 acres and is identified in the 2004 Section 303(d) list as follows:

Great Bear Lake Proper		WBID# 083102L
County: Van Buren	HUC: 4050002	Size: 150 Acres
Location: Great Bear Lake		
Problem: Nuisance algal growths, phosphorus		
TMDL Year(s): 2004		RF3RchID:4050002 7

Great Bear Lake is a 150-acre lake located in southwestern Michigan in Bloomingdale and Columbia Townships, Van Buren County. The lake consists of two distinct basins with a narrow channel connecting the smaller south basin to the larger north basin (Figure 1). The maximum depth of the south basin is 47 feet and the mean depth is approximately 23 feet. The north basin is deeper with a maximum depth of 55 feet and a mean depth of approximately 30 feet. The Great Bear Lake watershed encompasses approximately 8,000 acres of predominantly agricultural land and pasture in Van Buren County (Figure 2). The major tributary to the lake is the Haven and Max Lake Drain, which enters the north basin on the eastern shoreline. Baxter Drain is much smaller and enters the south basin of Great Bear Lake along the south shoreline. The lake outlet, Great Bear Lake Drain, is located on the west side of the lake. A concrete water control structure with removable wooden boards is present at the outlet allowing for minor adjustments of the lake level.

Snow (1978) measured spring and summer water chemistry and aquatic macrophytes in eight lakes in southwest Michigan including Great Bear Lake. He concluded that Great Bear Lake was moderate in productivity relative to the other lakes. Creal (1983) sampled Great Bear Lake in response to requests by the Great Bear Lake Association. The association was concerned that the lake was rapidly becoming enriched and unusable for recreation and fishing. Sampling in 1981 and 1982, documented that the lake was moderately productive based upon the levels of nutrients, chlorophyll a concentrations, and water clarity. The results were similar to those compiled in 1978, and did not indicate a continually worsening trend. Sampling again in 1985, by the Michigan Department of Natural Resources (MDNR, 1985), confirmed that Great Bear Lake was moderately productive and the water quality was not rapidly deteriorating or making the lake unusable for recreation and fishing.

Fusilier (2003) has evaluated the water quality of Great Bear Lake annually since 1993. He has also coordinated recent volunteer monitoring activities and analyzed water samples collected by Great Bear Lake Association members at sites throughout the watershed. The monitoring data were evaluated with an index, referred to as the Lake Water Quality Index, which uses nine parameters to develop a water quality rating between 0 and 100 that is expressed as an alphabetic grade between A (excellent) and E (poor) (Fusilier, 1982). The spring Lake Water Quality Indices from 1993 to 2002, averaged 80 (B) and ranged from 61 (D) in the south basin in 2000, to a high of 94 (A) in the north basin during 1994. The summer Lake Water Quality Indices averaged 82 (B) and ranged from 71 (C) in the north basin in 1995, to 91 (A) in the south basin during 1996. In summary, the Lake Water Quality Indices for Great Bear Lake were in the 70s (C) and 80s (B) most of the time and did not indicate any type of trend.

The total nitrogen to total phosphorus ratios demonstrate that phosphorus is the limiting nutrient in Great Bear Lake. Monitoring in 2002 (Walterhouse, 2003) and 2003 (Walterhouse, 2004- attached as supporting document- Appendix A), by Michigan Department of Environmental Quality (MDEQ) staff documented that spring and summer total phosphorus levels, chlorophyll a concentrations, and Carlson (1977) trophic status index ratings in Great Bear Lake have changed very little in the past twenty years. However, the volunteer monitoring of secchi depth by members of the Great Bear Lake Association since 1975, has shown a statistically significant decrease in water clarity (Walterhouse, 2004).

NUMERIC TARGETS

Rule 60 (2) of Michigan's WQS states "..., nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi or bacteria, which are or may become injurious to the designated uses of the water of the state." Frequent nuisance algal blooms have been reported at Great Bear Lake, particularly in the spring and early summer.

A spring overturn goal of 0.030 milligrams per liter (mg/l) of total phosphorus is recommended for Great Bear Lake. This in-lake concentration was chosen as a target based upon published information regarding 0.030 mg/l as the threshold between a high-eutrophic (highly nutrient enriched) lake and a low-eutrophic (moderately nutrient enriched) lake (Wetzel, 1988). The 0.030 mg/l total phosphorus goal has been established as a goal in several of Michigan's TMDLs (Belleville Lake, Brighton Lake, and Kent Lake) that were approved by the USEPA, and was historically established by the Water Resources Commission as a goal for several other Michigan lakes (Coldwater Lake and Muskegon Lake). These lakes are similar to Great Bear Lake and also located in the Southern Michigan Northern Indiana Till Plain ecoregion.

SOURCE ASSESSMENT

To provide an estimate of the relative contribution of phosphorus from the various land uses in the watershed, it was necessary to use a model to predict the annual loads of phosphorus from the land uses in the Great Bear Lake watershed. Land use throughout the Great Bear Lake watershed was quantified using the Web site model developed by Purdue University (http:www.ecn.purdue.edu/runoff/Index). Forested land in the watershed is relatively abundant, particularly for southern Michigan, accounting for 33% of the 8,000 acres. Agricultural use accounts for another 30%, and acreage devoted to pasture/grass accounts for 25%. Development is uncommon, accounting for slightly more than 1% of the acreage and the majority of the development is low density residential. The Purdue Web site includes a modeling scenario, developed with USEPA funds, that predicts phosphorus losses from the land uses in the Great Bear Lake watershed. The annual predicted load of phosphorus from agricultural land uses is estimated to account for 90 percent of the total annual nonpoint source (NPS) load from the watershed according to the model. The model does not account for loading related to precipitation that falls directly on Great Bear Lake or from failing or improperly operating septic systems along the shoreline of Great Bear Lake or along water bodies draining to the lake. Failing and inadequate septic systems along the shoreline of Great Bear Lake have been identified by MDEQ district staff and the local health department as problematic. Therefore, the percentage of the total annual phosphorus load attributable to agricultural land use in the watershed could be less than predicted by the model. MDEQ district staff that are familiar with the watershed suspect that significant phosphorus loading may be attributable to new construction in the watershed, as well as road crossings, storm water from the village of Bloomingdale, and stream bank erosion. Additional NPS will continue to be investigated as the TMDL is implemented.

There currently are no individual or general National Pollutant Discharge Elimination System (NPDES) permits in the Great Bear Lake watershed.

TMDL DEVELOPMENT

The TMDL represents the maximum loading that can be assimilated by a water body while still achieving WQS. The TMDL is focused on the reduction of phosphorus loading throughout the watershed to a level that meets WQS by reducing the spring in-lake phosphorus concentration, thereby reducing nuisance algal blooms and improving water clarity throughout the growing season. The critical condition for this TMDL is, therefore, the spring overturn phosphorus concentration. Reductions in spring overturn phosphorus concentrations are expected to result in attainment of WQS throughout the remainder of the year.

The current annual average phosphorus load to Great Bear Lake is 1,797 pounds/year from the following sources:

SOURCE	Annual Phosphorus Load (pounds/year)
Permitted Point Sources	0
Precipitation to Surface of the Lake	23
Shoreline Septic Systems	61
Watershed NPS Loading	1713
Total	**1797**

The total phosphorus load from precipitation falling directly to the surface of the 150 acre lake was estimated using a loading rate of 0.156 pounds/acre/year (USEPA, 1974).

Septic system loading to the lake was calculated by using the number of houses within 300 feet of the lake (121); a residency rate of 2.0 individuals per dwelling; and a value of 0.25 pounds/capita/year of phosphorus reaching the lake, after septic tank treatment and discharge to an adsorption field (USEPA, 1974). This is likely an overestimate since only about 15% of the houses are occupied year-round and occupancy rate of many of the homes is less than 2.0 individuals per dwelling (Loher, personal communication, 2004). However, the number of failing or inadequate septic systems surrounding Great Bear Lake is at least 10%, according to the Van Buren County Health Department, and the actual phosphorus contribution of septic systems could be much greater than what was assumed.

The average annual phosphorus load from the watershed was calculated by using the average annual flow from the watershed (13 cubic feet per second) and the average concentration of phosphorus in water samples collected from Haven and Max Lake Drain (0.067 mg/l) at the inlet to Great Bear Lake (Appendix B). The average annual flow was calculated by extrapolating the average annual flow of the Haven and Max Lake Drain inlet to encompass the remainder of the watershed. The average phosphorus concentration represents 43 samples collected from September 1996 through September 2003, with at least one sample from each of the months of the calendar year.

The acre weighted average total phosphorus concentration in Great Bear Lake during spring turnover in 2003 and 2004, was 0.038 mg/l (Walterhouse, 2004). Reckhow (1978) reviewed and evaluated empirical models that predict in-lake phosphorus concentrations. Given the appropriateness and constraints of the various empirical models, the Walker (1977) model was selected for Great Bear Lake. The Walker model predicts that the in-lake phosphorus concentration will be 0.042 mg/l using an annual phosphorus load of 1,789 pounds. Since the model over-predicts the in-lake phosphorus concentration by about 10%, it was used as a conservative assumption with a built-in margin of safety (MOS). In other words, any reductions in loading to the lake will actually yield a lower in-lake concentration than what is predicted by the model. The following equation represents the Walker model followed by site-specific variables used for Great Bear Lake:

$$P = Lt/z\ [1 / 1 + .824\ t^{0.454}]$$

Where:

- P = spring in-lake phosphorus concentration (mg/l)
- L = annual phosphorus loading (g/m^2/year) = 1.336
- t = hydraulic detention time (years) = 0.46 years
- z = mean lake depth (meters) = 8.84 meters

The model was rearranged so that it could be used to predict the annual phosphorus load at a given spring in-lake phosphorus concentration. The following equation represents the Walker model followed by site-specific variables used to predict the annual load at an in-lake concentration of 0.030 mg/l:

$$L = Pz/\ t\ [1 / 1 + .824\ t^{0.454}]$$

Where:

- P = spring in-lake phosphorus concentration (mg/l) = 0.030
- L = annual phosphorus loading (g/m^2/year)
- t = hydraulic detention time (years) = 0.46 years
- z = mean lake depth (meters) = 8.84 meters

The model predicts the goal of 0.030 mg/l can be obtained with a maximum annual phosphorus load of 0.9477 g/m^2/year. Converting this load to pounds per year involves multiplying the load by 607,050 (150 acres X 4,047 square meters per acre) and dividing by 453.6 grams per pound to obtain a load of 1,268 pounds per year.

ALLOCATIONS

A TMDL represents the maximum loading of a pollutant (phosphorus in this case) that can be discharged to a water body and still meet WQS. The TMDL consists of the sum of individual point source waste load allocations (WLAs) including individual and general NPDES permitted facilities, as well as load allocations (LAs) made up of the combined nonpoint and background sources. Uncertainty in the relationship between pollutant load and receiving water quality is accounted for by including an MOS in the TMDL, either explicitly incorporated in the allocation calculations, or implicitly integrated into other target areas for the TMDL. The equation representative of the TMDL calculation is:

$$TMDL = \sum^{WLAs} + \sum^{LAs} + MOS$$

WLA: 0.0 Pounds/Year

There are no individual or general permitted point source dischargers in the Great Bear Lake watershed. Therefore, the current phosphorus load is zero. It is proposed that a WLA of zero pounds of phosphorus per year be adhered to in the future.

LA: 1,268 Pounds/Year

The NPS and natural background levels of phosphorus are combined to produce the LA. The primary NPS of phosphorus in the Great Bear Lake watershed are runoff from various land uses, septic tanks in the vicinity of the lake, and precipitation that falls directly on the lake. The current estimated NPS loading is 1,797 pounds/year. The total LA is 1,268 pounds/year for NPS and background, which equates to a 29% reduction in phosphorus. Preliminary modeling indicates that a substantial portion of the annual phosphorus load delivered to Great Bear Lake is attributable to the agricultural land uses in the watershed. However, other NPS problems have been identified by district staff, particularly the septic tank issues, that need to be addressed.

MOS: 10% Less than Goal

The MOS is explicitly integrated into the TMDL because the Walker model over-predicts the current observed in-lake phosphorus concentration in the spring by slightly over 10%. Therefore, the predicted annual load reductions necessary to achieve the in-lake goal of 0.030 mg/l will actually yield a lower in-lake concentration.

SEASONALITY

Seasonality is addressed in this TMDL through the use of annual loads, which integrates the seasonal variability. Seasonal variability is inherent in NPS loading. Phosphorus loading is expected to vary seasonally. Nearly all NPS Best Management Practices (BMPs) to reduce phosphorus loading also yield annual reductions that will vary by season.

MONITORING PLAN

Following the implementation of NPS BMPs and other control measures in the watershed, the MDEQ will conduct annual monitoring to assess the progress toward meeting the TMDL goal. Sampling of Great Bear Lake will be conducted annually in April, July, and September to evaluate the spring overturn concentration. Assessments will continue until results from two consecutive years demonstrate attainment of the 0.030 mg/l spring overturn goal and designated uses have been restored.

REASONABLE ASSURANCE and IMPLEMENTATION

The following tasks have already been completed in the Great Bear Lake watershed to improve the water quality of Great Bear Lake:

Columbia Township has passed an ordinance that requires a septic system inspection upon the sale of property. The Van Buren County Health Department has inspected about eight homes on Great Bear Lake as a result of the ordinance, and found that half of the properties had either inadequate or failing septic systems. Bloomingdale Township is being encouraged by state and county officials to adopt a similar ordinance.

Members of the Great Bear Lake Homeowner's Association have participated in voluntary efforts to monitor the water quality of Great Bear Lake for thirty years.

The Michigan Lake and Stream Association received a Clean Michigan Initiative monitoring grant in 1999, to study the health of the Black River Watershed. The group collected water and macroinvertebrate samples at sites throughout the Black River watershed, including the Great Bear Lake watershed, to monitor water quality and identify problematic issues and areas. Subsequently, the Van Buren Conservation District received a federal Clean Water Act, Section 319 Watershed Planning Grant in the fall of 2002, to develop a watershed plan for the entire Black River watershed to address NPS pollution. This watershed plan will include the Great Bear Lake watershed. MDEQ district staff is working with the Black River Watershed Planning Group in the development of the watershed plan.

Three animal access sites within the Great Bear Lake watershed have recently been remedied. No additional sites are being investigated or are presently known.

An instream sediment trap was installed by the Van Buren County Drain Commissioner just upstream of Great Bear Lake in Haven and Max Lake Drain in 2004, at the request of the Great Bear Lake property owners. Maintenance of the sediment basin is expected to occur on an as-needed basis in the future.

A stream bank erosion and embeddedness study is currently being conducted on the Black River watershed by the Van Buren Conservation District. A Quality Assurance Project Plan has been developed by the Conservation District and approved by the MDEQ. Erosion and sedimentation has been determined to be one of the critical issues in the watershed, but data on the rate of bank erosion in the watershed is lacking. In addition to helping locate sites where erosion is most critical and providing estimates of sediment loading in the watershed, this study will provide a baseline against which to evaluate BMP effectiveness in the future. Bank pins have been installed on the Max Haven Drain at the Bloomingdale Park to measure the rate of erosion from this site. Pins may be installed at other sites along this drain at a later date.

A hydrology study is also being conducted by the MDEQ, Geological and Land Management Division, Hydrology Unit, for the entire Black River Watershed. This study will provide some baseline information on the Max Haven drain hydrology.

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Figure 1. Sampling locations on Great Bear Lake, Van Buren County, Michigan.

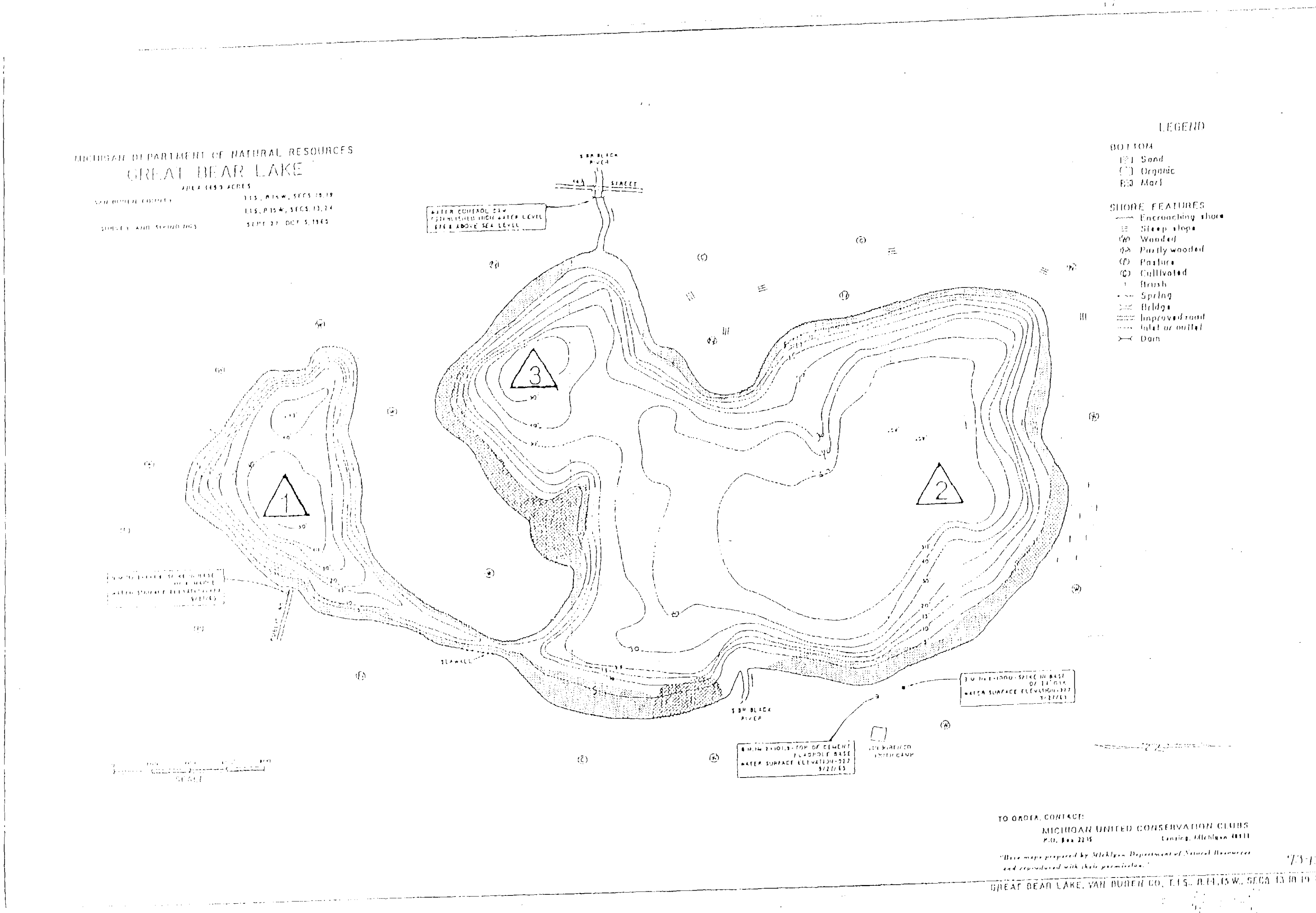
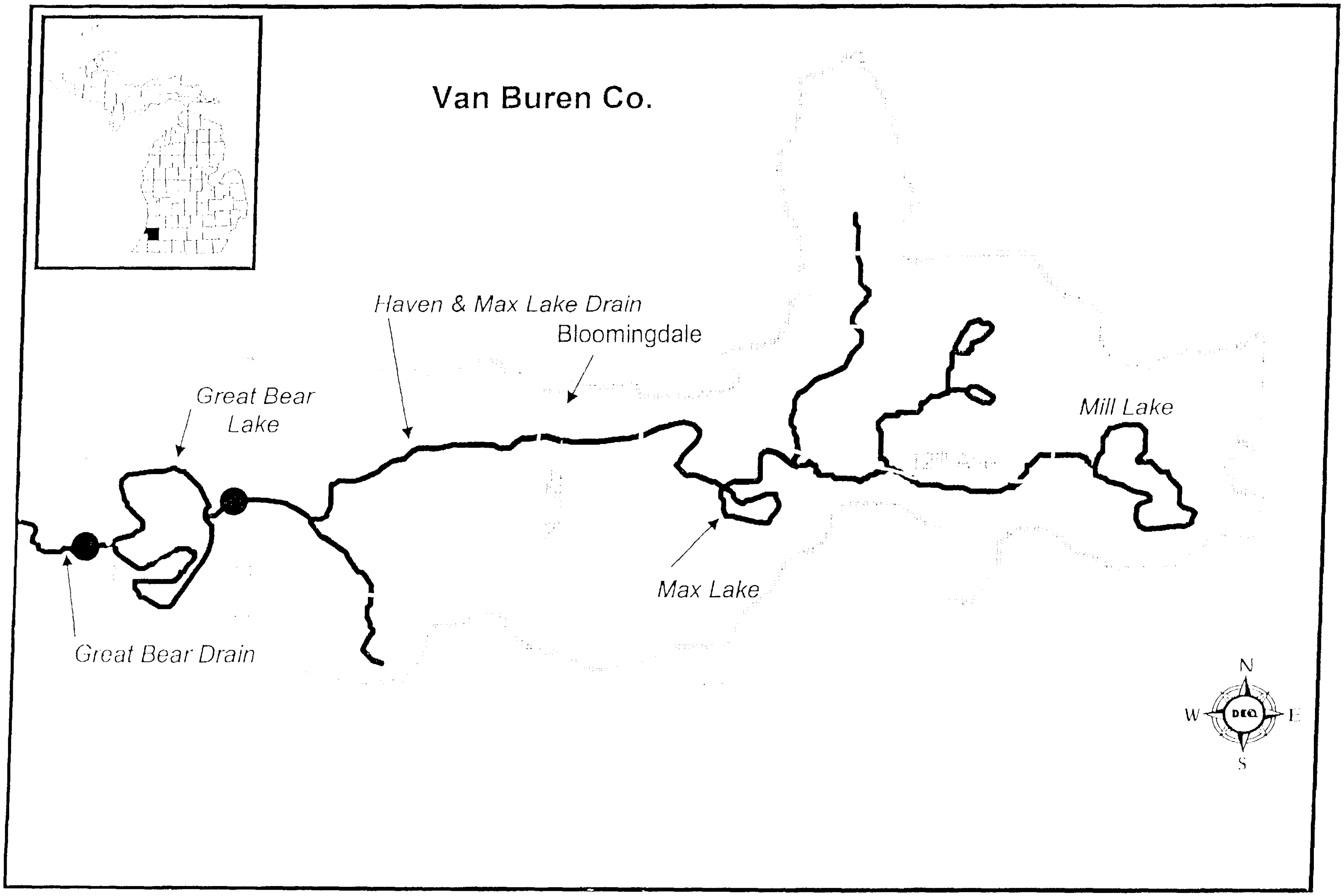


Figure 2. Great Bear Lake Watershed.



Appendix A

MI/DEQ/WD-04/010

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER DIVISION
APRIL 2004

STAFF REPORT

WATER QUALITY ASSESSMENT OF GREAT BEAR LAKE VAN BUREN COUNTY, MICHIGAN APRIL – SEPTEMBER, 2003

INTRODUCTION

Great Bear Lake is a 150-acre lake located in southwestern Michigan in Bloomingdale Township, Van Buren County. The lake consists of two distinct basins with a narrow channel connecting the smaller south basin to the larger north basin (Figure 1). The maximum depth of the south basin is 47 feet and the mean depth is approximately 23 feet. The north basin is deeper with a mean depth of about 30 feet and a maximum depth of 55 feet. The watershed of Great Bear Lake encompasses approximately 8,100 acres of predominantly agricultural land in Van Buren County (Figure 2). The major tributary to the lake is the Haven and Max Lake Drain, which enters the north basin on the eastern shoreline. Baxter Drain is much smaller and enters the south basin of Great Bear Lake along the south shoreline. The lake outlet, Great Bear Lake Drain, is located on the west side of the lake. A concrete water control structure with removable wooden boards is present at the outlet allowing for minor adjustments of the lake level.

The Village of Bloomingdale's Wastewater Treatment Plant (WWTP) is upstream of Great Bear Lake near the Haven and Max Lake Drain. The facility uses spray irrigation to dispose of their lagooned wastewater. Prior to 1980, effluent from the facility was discharged from the lagoons to Haven and Max Lake Drain on several occasions. However, there have been no permitted or accidental discharges from the facility for over twenty years. The Bloomingdale WWTP has recently begun to pursue a permit to expand and discharge effluent to Great Bear Lake Drain, downstream of Great Bear Lake. There are no other permitted point source discharges in the sparsely populated watershed. Great Bear Lake, Haven and Max Lake Drain, and Great Bear Lake Drain are listed for not attaining water quality standards in a report submitted to the United States Environmental Protection Agency (EPA), to fulfill the requirements set forth in Section 303(d) of the federal Clean Water Act (CWA), and Title 40 of the Code of Federal Regulations, Part 130, Water Quality Planning and Management (Creal and Wuycheck, 2002). The report identifies nutrient enrichment and nuisance algal growths as the problems causing the nonattainment.

Snow (1978) measured spring and summer water chemistry and aquatic macrophytes in eight lakes in southwest Michigan including Great Bear Lake. He concluded that Great Bear Lake was moderate in productivity relative to the other lakes. Creal (1983) sampled Great Bear Lake in response to requests by the Great Bear Lake Association. The association's concerns were that the lake was rapidly becoming enriched and unusable for recreation and fishing. Sampling in 1981 and 1982 documented that the lake was moderately productive based upon the levels of nutrients, chlorophyll a concentrations, and water clarity. The results were similar to those compiled in 1978, and did not indicate a continually worsening trend. Sampling again in 1985, by the Michigan Department of Natural Resources (MDNR) (MDNR, 1985) confirmed that Great Bear Lake was moderately productive, and that the water quality was not rapidly deteriorating or making the lake unusable for recreation and fishing.

Fusilier (2003) has evaluated the water quality of Great Bear Lake annually since 1993. He has also coordinated recent volunteer monitoring activities and analyzed water samples collected by Lake Association members at sites throughout the watershed. The monitoring data was evaluated with an index, referred to as the Lake Water Quality Index, which uses nine water quality parameters to develop a water quality rating between 0 and 100 (excellent) and an alphabetic grade. The spring Lake Water Quality Indices from 1993 to 2002 averaged 80 (B) and ranged from 61 (D) in the south basin in 2000, to a high of 94 (A) in the north basin during 1994. The summer Lake Water Quality Indices averaged 82 (B) and ranged from 71 (C) in the north basin in 1995, to 91 (A) in the south basin during 1996. In summary, the Lake Water Quality Indices for Great Bear Lake were in the 70's (C) and 80's (B) most of the time and did not indicate any type of trend.

The volunteer monitoring of secchi depth by members of the Great Bear Lake Association that has been conducted at Great Bear Lake since 1975, indicates a decrease in secchi depth (Fusilier, 2003).

METHODS

Water sampling was conducted once per month in April, July, and September at three stations in Great Bear Lake (Figure 1). Grab samples were collected at the surface, bottom, and mid-depth at each station. A depth integrated sample of the photic zone was also collected at each station for chlorophyll a analysis. Additional sampling at each station included a measurement of secchi transparency and a profile, at five-foot increments, of temperature, dissolved oxygen, conductivity, and pH from the surface to the lake bottom using a calibrated Yellow Springs Instrument 6 series environmental monitoring system.

Grab samples were also collected once per month, on the same day the lake sampling was conducted, at the inlet to Great Bear Lake (Haven and Max Lake Drain) and at the outlet of Great Bear Lake (Figure 2).

All of the samples from the lake and tributaries were collected, preserved (if necessary), stored at 4°C, and transported to the Michigan Department of Environmental Quality's (MDEQ's) Environmental Laboratory for chemical analysis using standard protocols (MDNR, 1994). The samples were analyzed for total and ortho-phosphorus, nitrate + nitrite, Kjeldahl nitrogen, nitrite, ammonia, suspended solids, and chlorophyll a.

SAMPLING RESULTS

Monthly water quality sampling results for Great Bear Lake and the tributary sites are presented by month in Tables 1 through 3. The growth of aquatic plants and algae in Michigan lakes is typically related to the amount of phosphorus available during the growing season. Occasionally the growth of aquatic plants is limited by the amount of nitrogen. When the ratio of total nitrogen (Nitrate+Nitrite + Kjeldahl nitrogen) to total phosphorus is greater than 15 to 1, it is commonly accepted that phosphorus is the limiting nutrient. In 2002, the total nitrogen to total phosphorus ratios in Great Bear Lake varied from a low of 28 to 1 in spring, to a high of 77 to 1 during September (Walterhouse, 2003). The ratios in 2003, varied from 19 to 1 in the north basin during April to 45 to 1 in south basin during July. Based upon these ratios and previous monitoring by the MDEQ, it is apparent that phosphorus is the limiting nutrient in Great Bear Lake.

The 2003 spring average monthly sampling results for total phosphorus are displayed in Figure 3, along with comparable historic data that was collected at the same locations during the spring months (Creal, 1983; MDNR, 1955; Snow, 1978; Walterhouse, 2003). The spring turnover concentration of total phosphorus measured in the north basin in 2003

(0.042 milligrams per liter (mg/l)) was slightly higher than the concentration measured in 2002, but was comparable to levels documented in 1982 and 1985 suggesting that water quality in the north basin has changed very little in twenty years. Sampling in the south basin during April 2003, revealed that the basin was beginning to thermally stratify, dissolved oxygen was depleted at depths greater than 30 feet, and nutrient concentrations near the bottom were elevated. The monitoring data indicates that the south basin did not mix or turnover in either the fall of 2002 or the spring of 2003, which probably explains the low total phosphorus concentration recorded in 2003. Fusilier (2003) reports an average spring surface sample total phosphorus concentration of 0.022 mg/l between 1993 and 2002 with no apparent trend. Michigan lakes with total phosphorus concentrations greater than 0.020 mg/l are typically classified as eutrophic (Bednarz, personal communication). Lakes with total phosphorus concentrations between 0.020 and 0.030 mg/l are referred to as low eutrophic lakes. Hypereutrophic lakes are those with phosphorus concentrations exceeding 0.050 mg/l.

In July and September, both basins of Great Bear Lake were thermally stratified and dissolved oxygen concentrations were depressed below the thermocline. Total phosphorus concentrations near the bottom were elevated because of the release of phosphorus from the anoxic sediments. Above the thermocline in the epilimnion total phosphorus concentrations during July were relatively low, in the mesotrophic range, with concentrations of 0.016 and 0.019 mg/l in the south and north basins, respectively. By September, the epilimnion phosphorus concentrations were still in the mesotrophic range with concentrations of less than 0.019 mg/l in both basins. Monitoring by Fusilier (2003) from 1993 to 2002, documented an average summer phosphorus concentration of 0.022 mg/l with some variability but no trend.

Chlorophyll a measurements provide an indication of the amount of algae present in the lake. In general, Michigan lakes with chlorophyll a concentrations greater than 22 micrograms per liter (ug/l) during the summer months are considered to be hypereutrophic. Typically, chlorophyll a concentrations are greater during the warm summer months and concentrations during or just after spring overturn are relatively low when water temperatures are low. Historic chlorophyll a concentrations measured by the MDEQ in the north and south basins of Great Bear Lake are presented in Figures 4 and 5. The monitoring during 2002 and 2003, demonstrated that chlorophyll a levels were greater in both basins during spring than later during the summer months. Surface water temperatures during both years were already relatively warm and the water column was beginning to stratify. A visible algae bloom was apparent throughout both basins in 2002, but not in 2003. The chlorophyll a monitoring that has been coordinated by Fusilier (2003) annually since 1993, generally shows a similar pattern of high chlorophyll a levels early in the year (April and May), which typically diminish during the remainder of the year to concentrations of less than 10 ug/l. These values warrant classifying the lake as eutrophic but not hypereutrophic.

Secchi depth readings provide a measurement of water clarity that is related to the chemical and physical properties of a lake. While water clarity is not a direct measurement of the chemical properties of lake water, it is an easy-to-understand indicator of a lake's water quality. Lakes in Michigan with secchi depth readings less than three feet are normally considered to be hypereutrophic and lakes with secchi depth readings less than 7.5 feet are considered to be eutrophic. The average secchi depth of 7.1 feet recorded during monitoring in April, July, and September of 2003, would classify Great Bear Lake as eutrophic. The average summer secchi depths recorded by volunteers at Great Bear Lake in the north and south basins have decreased between 1975 and 2002 (Figures 6 and 7). The linear decreases in secchi depth were examined and found to be statistically significant. The volunteer monitoring has shown that average summer water clarity is consistently less than 7.5 feet warranting a eutrophic classification.

Carlson's trophic status index is used by the MDEQ to classify Michigan's inland lakes. The classification system combines summer secchi disk transparency, surface phosphorus concentrations, and chlorophyll a concentrations to describe lakes as either oligotrophic (low nutrients), mesotrophic (moderate nutrients), eutrophic (high nutrients), or hypereutrophic (excessive nutrients). The monitoring conducted at Great Bear Lake in 2002 and 2003, yields trophic status index rankings of eutrophic in the north and south basins during both years. Only limited comparable data from 1978, 1982, and 1985 is available to evaluate changes in trophic status index. Historic data yields a trophic index of eutrophic suggesting that Great Bear Lake has not changed significantly in 25 years.

The total phosphorus concentrations in the water samples collected in July and September from Haven and Max Lake Drain, near the Great Bear Lake confluence, were 0.33 and 0.169 mg/l, respectively (Tables 2 and 3). These values exceed the mean concentration of 0.058 mg/l, recorded at least-impacted sites in the Southern Michigan/Northern Indiana Till Plain ecoregion (Lundgren, 1994). The July sample was collected late in the day after periodic heavy thunderstorms that produced runoff and also caused elevated levels of suspended solids. The samples collected from the outlet were chemically similar to the surface samples collected from the north basin of Great Bear Lake. Algae and aquatic vegetation were absent upstream and downstream of Great Bear Lake during this investigation.

Water samples collected upstream of Great Bear Lake and analyzed for total phosphorus between 1995 and 2000, showed that the highest concentrations were found in the upper reaches of the watershed in Munn Lake Drain (Fusilier, 2003). Average total phosphorus concentrations were less than 0.100 mg/l at all other sites throughout the watershed. The average total phosphorus concentration of the 30 samples collected between December 1998 and January 2002 from the Great Bear Lake inlet was 0.052 mg/l. It is normal for streams to have higher levels of total phosphorus than lakes, and concentrations of 0.100 mg/l or less are generally considered low enough not to stimulate algal blooms in flowing water. The sampling was initiated because residents of Great Bear Lake felt that the Bloomingdale WWTP was causing nutrient levels to increase and cause periodic algal blooms. The sampling included the collection of multiple water samples upstream and downstream of the Bloomingdale WWTP. The results of the sampling demonstrated that phosphorus and nitrogen concentrations do not increase downstream of the Bloomingdale WWTP (Fusilier, 2003). Similarly, MDEQ staff conducted an inspection of the Bloomingdale WWTP and collected water samples upstream and downstream of the facility on several occasions in 1998, finding that the WWTP lagoons were not contributing nutrient loads to Great Bear Lake (Holdwick, 1998).

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Fieldwork by: Diana Butler, Dan Rockafellow, Sarah Wolf, and Mike Walterhouse
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Figure 1. Sampling locations on Great Bear Lake, Van Buren County, Michigan.

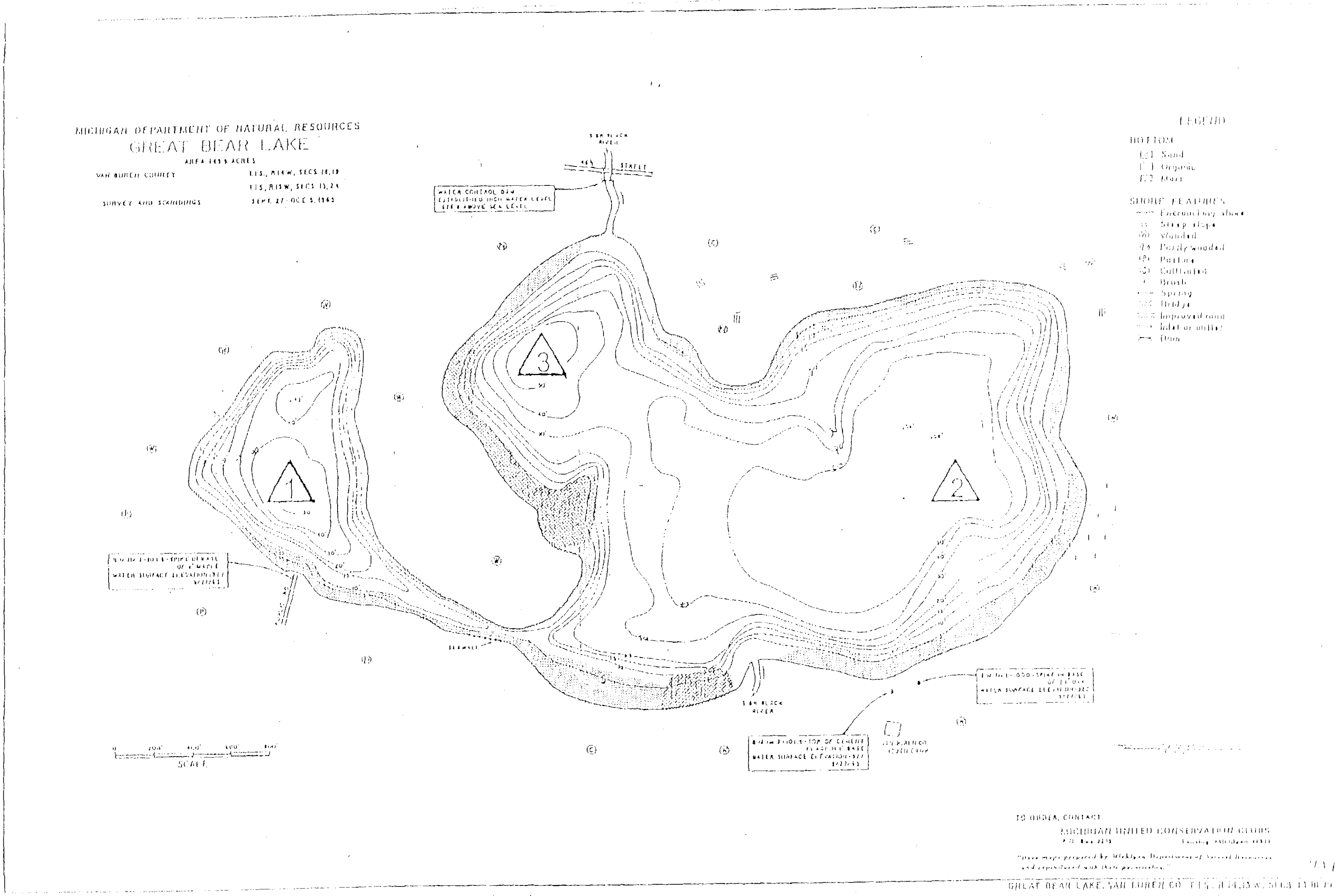

Figure 2. Great Bear Lake Watershed.

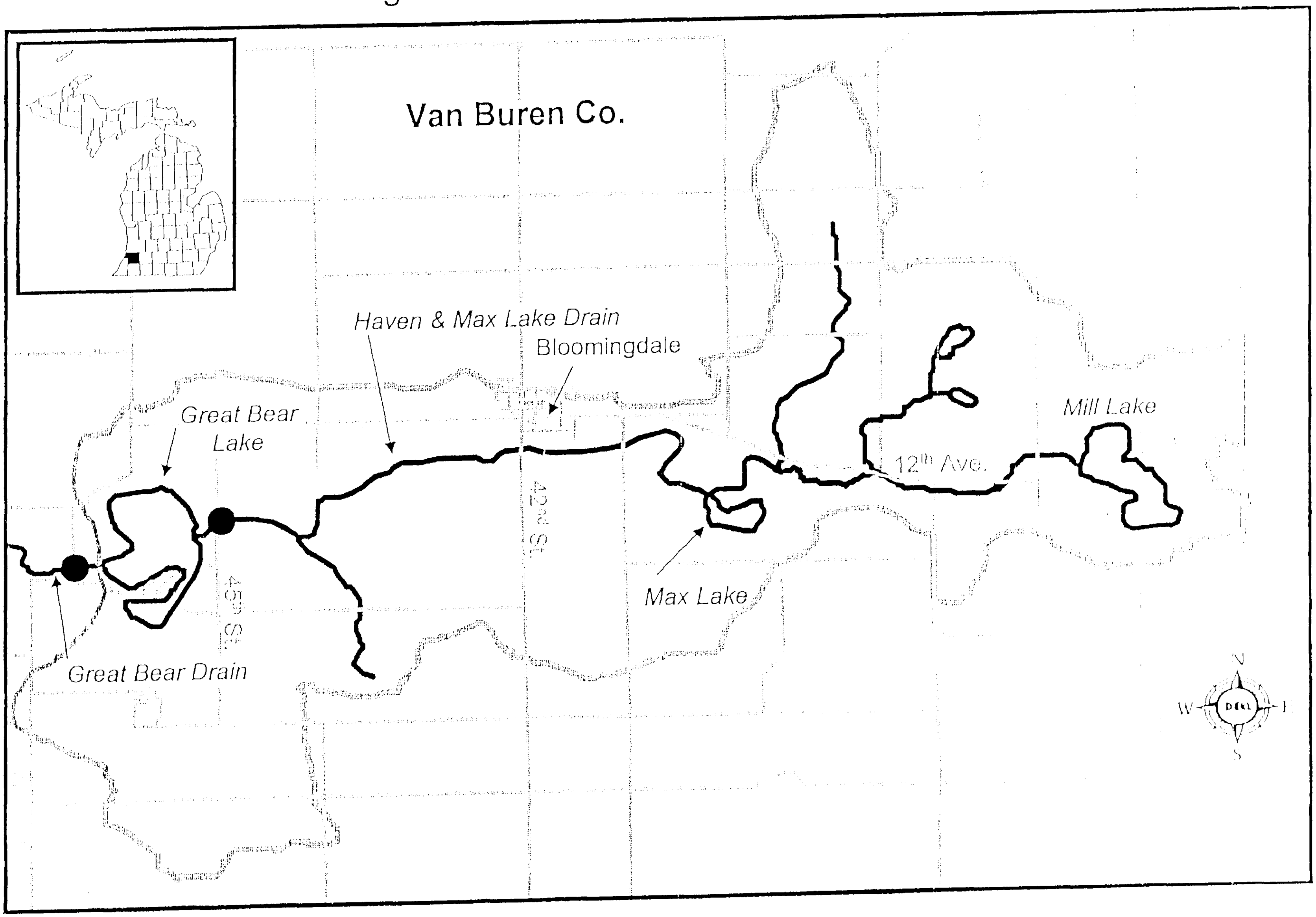

Figure 3. Spring Total Phosphorus Concentrations Great Bear Lake.

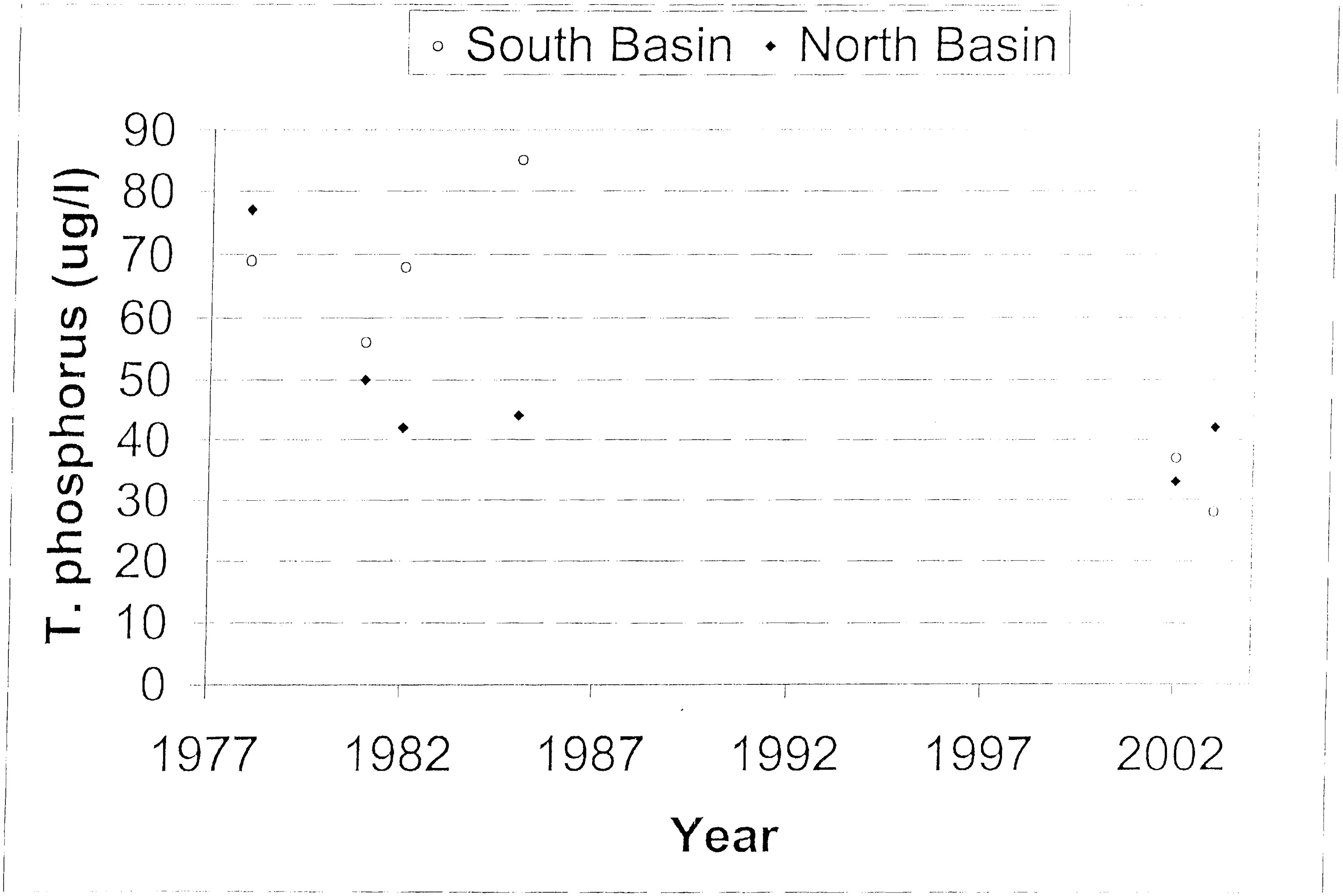

Figure 4. Historic chlorophyll a concentrations in the North basin of Great Bear Lake.

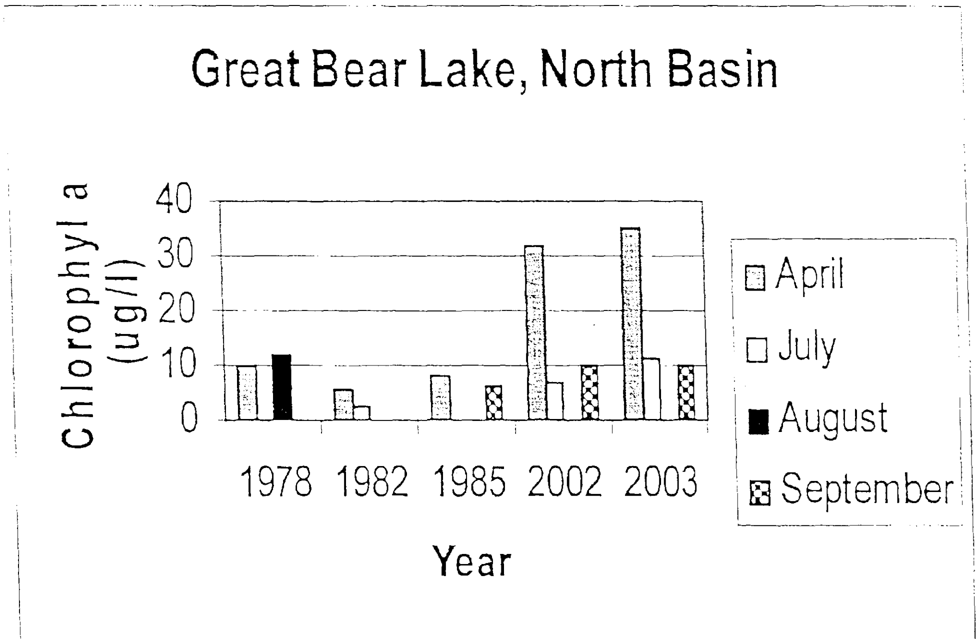

Figure 5. Historic chlorophyll a concentrations in the South Basin of Great Bear Lake.

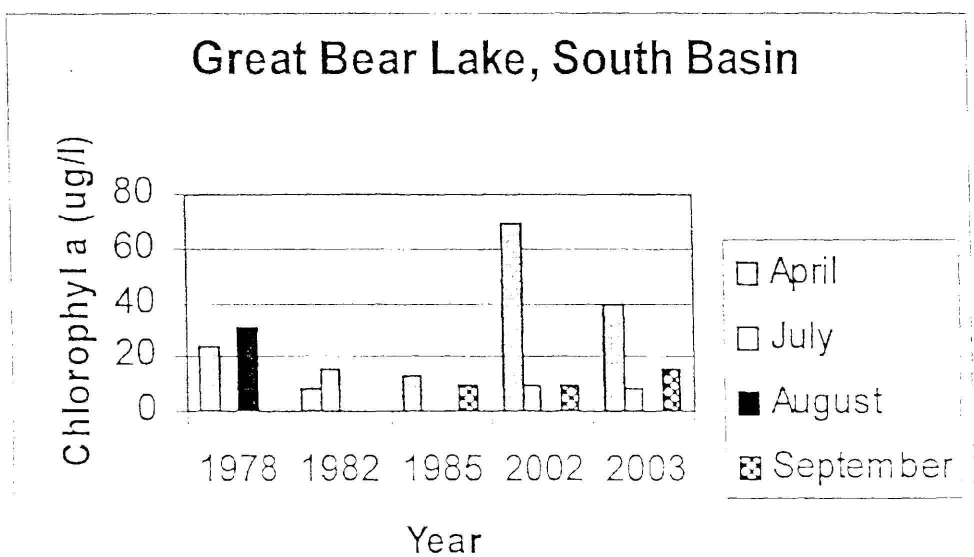

Figure 6. Volunteer monitoring annual summer average secchi depth measurements, North Basin Great Bear Lake.

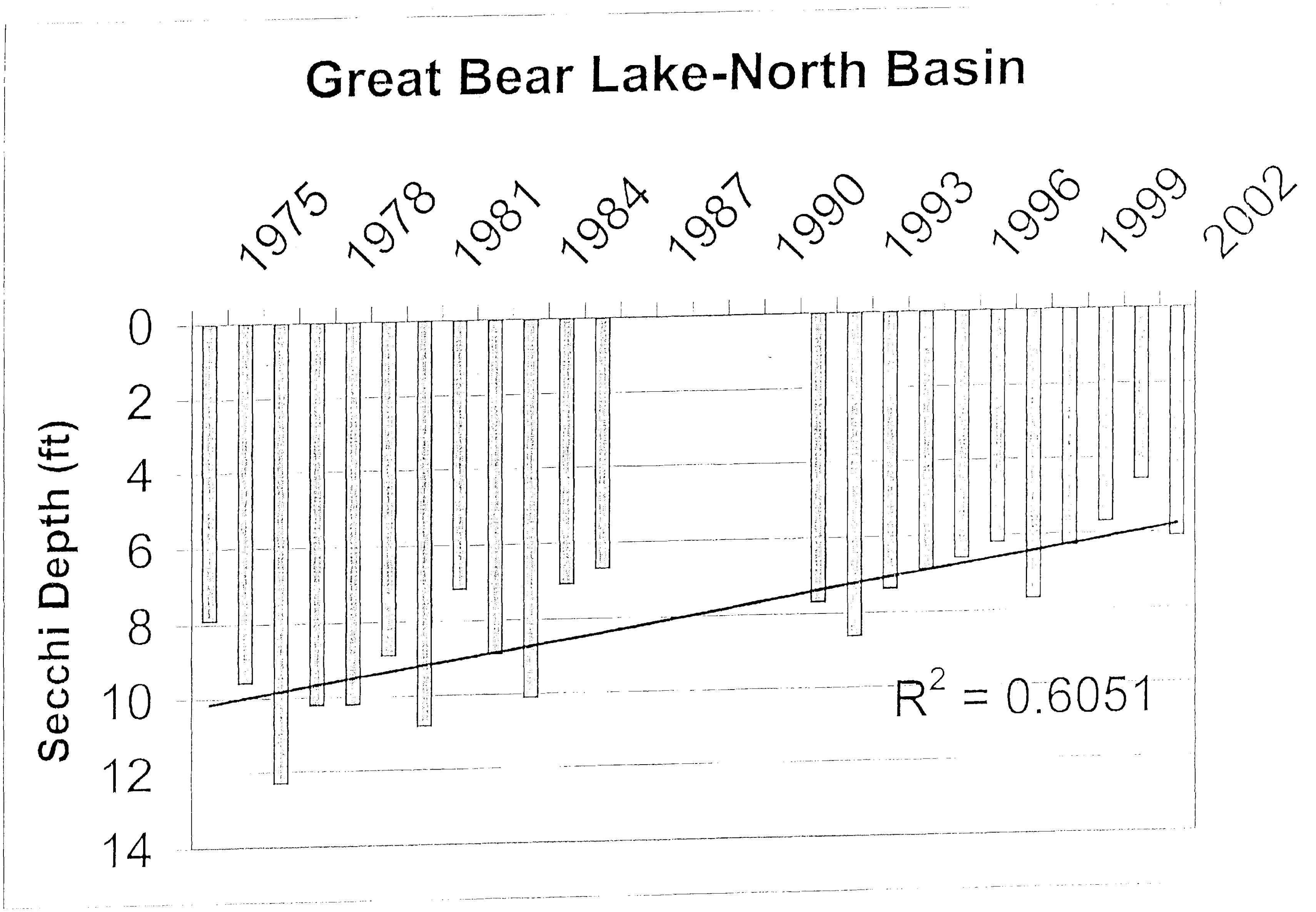

Figure 7. Volunteer monitoring annual summer average secchi depth measurements, South Basin Great Bear Lake.

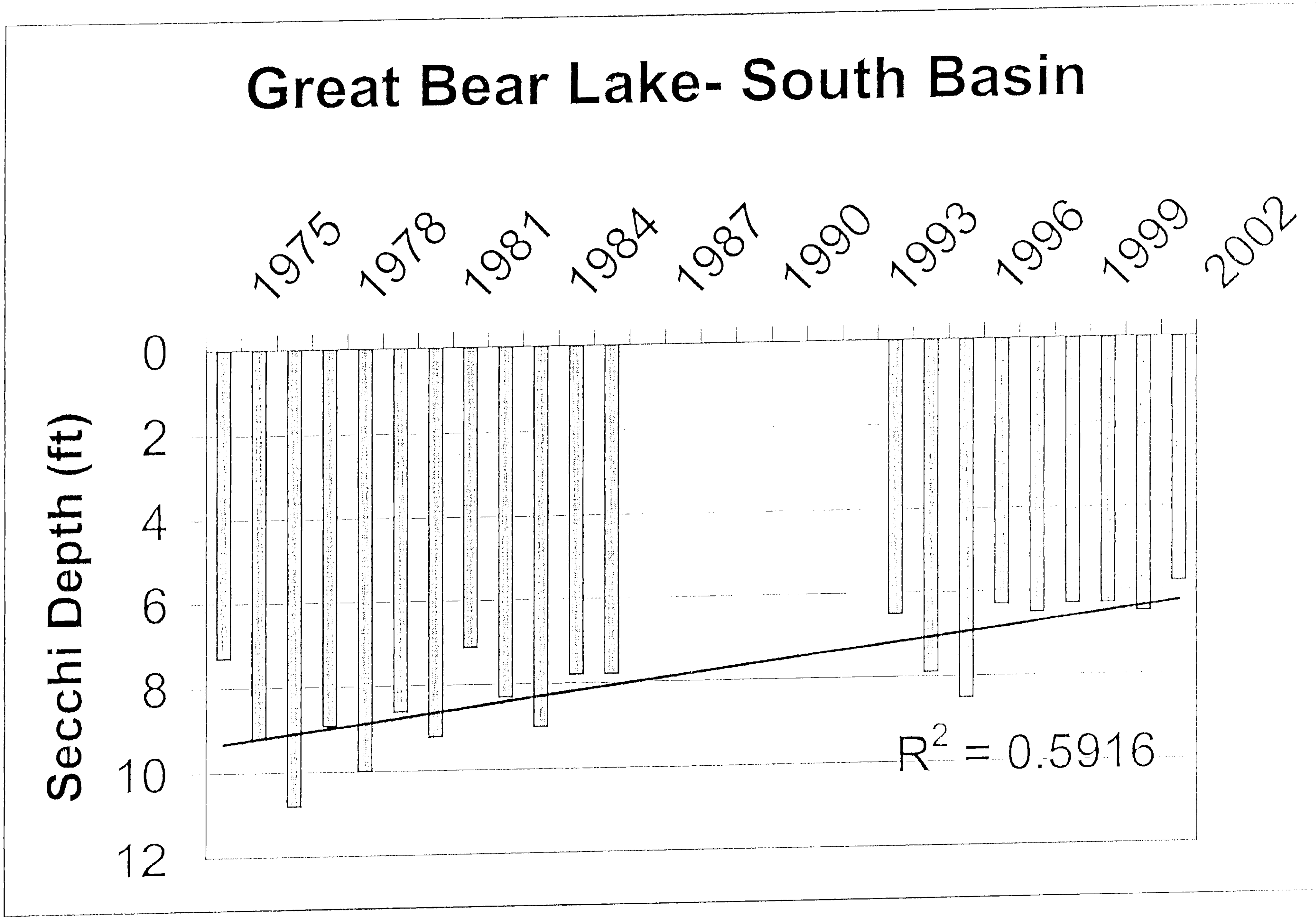

Table 1. Water Quality Sampling Results, Great Bear Lake and Tributaries, Van Buren County, April 15, 2003.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (mg/l)	TOTAL PHOS. (mg/l)	NITRITE (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	K. NITRO (mg/l)	ORTHO PHOS (mg/l)	TSS (mg/l)
Great Bear Lake-South Basin	Sur.	54.3	21.2	433	8.0	39	0.033	0.011	0.24	0.007T	0.65	0.005	4
Station #1 10:30 am	5	52.3	18.3	437	7.9								
Depth (ft): 47	10	43.4	15.8	434	7.4								
Secchi Depth (ft): 3.5	15	41.7	11.5	438	7.0								
Color: slightly brown	20	41.2	10.3	442	6.9								
	25	39.4	6.6	490	6.7		0.024	0.007	0.47	0.031	0.54	0.004	5
	30	38.7	2.3	513	6.5								
	35	38.7	1.1	522	6.5								
	40	38.8	1.0	527	6.5								
	45	39.0	1.0	537	6.4								
	47	39.1	0.9	572	6.0		0.31	0.007	0.007T	1.40	1.89	0.23	ND 4
Great Bear Lake-North Basin	Sur.	51.2	18.1	441	8.5	29	0.049	0.007	0.108	0.007T	0.79	0.010	1
Station #2 11:10 am	5	51.0	16.9	441	8.4								
Depth (ft): 52	10	50.9	16.5	442	8.3								
Secchi Depth (ft): 4.0	15	45.8	16.8	445	8.0								
Color: slightly brown	20	42.7	14.5	451	7.6								
	25	41.8	13.1	452	7.4		0.041	0.007	0.22	0.039	0.64	0.001	7
	30	41.6	12.3	453	7.3								
	35	41.5	12.0	453	7.4								
	40	41.3	11.9	453	7.4								
	45	41.3	11.6	454	7.4								
	50	41.2	10.4	476	7.1		0.036	0.007	0.25	0.078	0.63	0.006	ND 4
Great Bear Lake-North Basin	Sur.	48.5	17.0	442	8.3	41	0.040	0.008	0.13	0.008T	0.55	0.005	ND 4
Station #3 11:35 am	5	46.5	16.2	445	8.1								
Depth (ft): 51	10	44.9	15.9	447	7.9								
Secchi Depth (ft): 4.0	15	42.1	13.6	452	7.5								
Color: slightly brown	20	42.0	12.4	452	7.5								
	25	41.8	12.1	453	7.5		0.039	0.008	0.23	0.073	0.67	0.006	[illegible]
	30	41.6	11.8	453	7.4								
	35	41.7	11.6	452	7.5								
	40	41.7	11.5	453	7.5								
	45	41.5	11.3	454	7.4								
	50	41.5	10.9	454	7.4		0.046	0.011	0.23	0.120	0.71	0.006	7

Stream Sampling Results

Stream Name & Location	Visual Observations
Great Bear Lake, Outlet	Clear
Haven and Max Lake Drain @ 45th Street	Clear

ND = Non detectable

T = Reported value is less than the reporting limit.

Table 2. Water Quality Sampling Results, Great Bear Lake and Tributaries, Van Buren County, July 22, 2003.

STATION	DEPTH (ft)	TEMP. (F)	D. O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	TOTAL PHOS. (mg/l)	NITRITE (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)
Great Bear Lake-South Basin	Sur.	76.9	6.2	427	7.9	8.4	0.016	0.001	0.005	0.009	0.71	0.001	1
Station #1- 3:00 pm	5	76.9	6.1	425	7.9								
Depth (ft): 48	10	68.6	4.4	440	7.4								
Secchi Depth (ft): 9.5	15	51.4	5.6	445	7.2								
Color: slight greenish	20	44.3	5.8	449	7.1								
	25	40.8	5.3	483	7.0		0.052	0.011	0.060	0.28	1.08	0.005	1
	30	39.8	4.6	512	6.8								
	35	39.5	4.1	521	6.8								
	40	39.5	3.7	531	6.7								
	45	39.5	3.3	533	6.7		0.66	0.008H	ND-.05 D	3.1	4.2	0.43H	6
Great Bear Lake-North Basin	Sur.	76.5	5.9	449	8.0	13	0.025	0.005H	0.003T	0.005T	0.72	0.001W H	ND 4
Station #2- 4:00 pm	5	76.8	6.2	449	8.1								
Depth (ft): 52	10	76.0	5.9	457	8.0								
Secchi Depth (ft): 7.0	15	61.8	5.0	444	7.6								
Color: slight greenish	20	51.2	4.8	450	7.3								
	25	46.1	4.3	459	7.1		0.027	0.007H	0.020	0.007T	0.66	0.004H	ND 4
	30	44.6	4.1	460	7.1								
	35	43.5	3.7	459	7.0								
	40	42.8	3.6	462	7.0								
	45	42.2	3.2	471	6.9								
	50	42.0	3.0	497	6.8		0.25	0.004H	0.007T	0.72	1.20	0.189	6
Great Bear Lake-North Basin	Sur.	77.0	4.7	449	8.0	9.7	0.024	0.002H	ND-.05 W	0.007T	0.73	0.010	ND 4
Station #3- 4:30 pm	5	77.0	5.4	449	8.0								
Depth (ft): 51	10	77.0	5.6	449	8.1								
Secchi Depth (ft): 8.0	15	62.3	4.5	446	7.6								
Color: slight greenish	20	52.4	3.7	451	7.4								
	25	46.1	3.7	458	7.2		0.044	0.020H	0.330	0.059	0.57	0.017	ND 4
	30	44.7	3.3	461	7.1								
	35	44.0	3.0	461	7.0								
	40	43.6	2.8	462	7.0								
	45	43.4	2.5	468	6.9								
	50	43.3	2.4	482	6.6		0.35	0.005H	0.025	0.63	1.18	0.32	7

Stream Sampling Results

STREAM NAME & Location	Visual Observations	TOTAL PHOS. (mg/l)	NITRITE (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS. (mg/l)	TSS (mg/l)
Great Bear Lake, Outlet	Clear, 3-4 cfs	0.021		0.009T	0.026	0.70		
Haven and Max Lake Drain @ 45th Street	Clear, 2-3 cfs	0.33	0.008H	0.240	0.075	0.87	0.21	13

D = Analyte value quantified from a dilution(s); reporting limit (RL) raised.
H = Recommended laboratory holding time was exceeded.
ND = Non detectable
T = Reported value is less than the reporting limit.
W = Reported value is less then the method detection limit (MDL).

Table 3. Water Quality Sampling Results, Great Bear Lake and Tributaries, Van Buren County, September 23, 2003.

STATION	DEPTH (ft)	TEMP. (F)	D.O. (mg/l)	COND. (umho/cm)	pH	CHLORO A. (ug/l)	TOTAL PHOS. (mg/l)	NITRITE (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS (mg/l)	TSS (mg/l)
Great Bear Lake-South Basin	Sur.	68.1	8.5	435	7.6	16	0.017	0.002	0.009T	0.015	0.65	0.003	5
Station #1- 3:45 pm	5	68.0	8.5	435	7.7								
Depth (ft): 48	10	68.0	8.5	435	7.8								
Secchi Depth (ft): 11.0	13	67.1	6.5	442	7.6								
Color: clear	15	65.0	2.9	447	7.6								
	20	48.3	1.0	457	7.4								
	25	42.1	0.72	484	7.2		0.068	0.004	0.001W	0.172	1.07	0.002T	7
	30	40.6	0.46	510	7.2								
	35	39.9	0.30	527	7.1								
	40	39.8	0.27	540	7.0								
	45	39.9	0.26	552	6.9								
	50	39.8	0.23	624	6.6		0.52	0.004	ND-.05 D	2.6	3.5	0.45	11
Great Bear Lake-North Basin	Sur.	68.5	8.4	450	8.0	11	0.020	0.002	ND-.05 W	0.008 F	0.70	0.005	ND 4
Station #2- 4:20 pm	5	68.5	8.5	450	8.1								
Depth (ft): 52	10	68.5	8.4	451	8.1								
Secchi Depth (ft): 8.0	15	67.3	6.7	455	8.0								
Color: clear	17	58.8	4.0	458	7.6								
	20	62.4	1.9	455	7.6								
	25	49.4	0.55	458	7.5								
	30	46.0	0.44	462	7.4		0.075	0.003	0.001W	0.196	0.74	0.028	5
	35	43.9	0.43	464	7.3								
	40	43.4	0.35	475	7.3								
	45	42.9	0.32	485	7.2								
	50	42.6	0.29	506	7.1								
	52	42.3	0.28	607	6.8		0.43	0.002	ND-.05 D	1.2	1.83	0.38	7
Great Bear Lake-North Basin	Sur.	68.6	8.3	449	8.1	9.5	0.018	0.002	ND-.05 W	0.006T	0.64	0.003	7
Station #3- 4:50 pm	5	68.5	8.4	449	8.1								
Depth (ft): 50	10	68.2	8.0	451	8.1								
Secchi Depth (ft): 6.0	13	67.9	7.6	451	8.1								
Color: clear	15	66.9	6.8	455	8.0								
	17	62.8	1.8	460	7.6								
	20	56.4	0.23	456	7.5								
	25	48.2	0.46	460	7.4		0.072	0.002	ND-.05 W	0.189	0.79	0.024	ND 4
	30	45.6	0.40	465	7.3								
	35	44.5	0.36	468	7.3								
	40	74.0	0.33	475	7.2								
	45	43.8	0.30	482	7.2								
	48	43.7	0.28	489	7.1		0.33	0.003	0.003T	1.00	1.66	0.27	8

Stream Sampling Results

STREAM NAME & Location	Visual Observations	TOTAL PHOS. (mg/l)	NITRITE (mg/l)	NITRATE + NITRITE (mg/l)	AMMONIA (mg/l)	K. NITRO. (mg/l)	ORTHO PHOS (mg/l)	TSS (mg/l)
Great Bear Lake, Outlet	Clear, 2-4 cfs	0.018	0.001T	0.002W	0.011	0.61	0.003	5
Haven and Max Lake Drain @ 45th Street	Clear, about 2 cfs	0.169	0.027	0.37	0.067	0.81	0.0981	15

D = Analyte value quantified from a dilution(s); reporting limit (RL) raised.
F = Dilution required due to matrix interference; reporting limit (RL) raised.
ND = Non detectable
T = Reported value is less than the reporting limit.
W = Reported value is less then the method detection limit (MDL).

Appendix B. Total phosphorus concentrations in water samples collected from Haven and Max Lake Drain at 45th Street, Van Buren County, Michigan.

DATE	Total Phosphorus (mg/l)	Source (see references section)
9/8/1996	0.041	Fusilier, 2003
9/16/1996	0.055	Fusilier, 2003
11/29/1996	0.021	Fusilier, 2003
12/27/1996	0.026	Fusilier, 2003
1/28/1997	0.038	Fusilier, 2003
2/27/1997	0.031	Fusilier, 2003
3/28/1997	0.037	Fusilier, 2003
5/2/1997	0.028	Fusilier, 2003
6/3/1997	0.062	Fusilier, 2003
6/28/1997	0.07	Fusilier, 2003
7/29/1997	0.034	Fusilier, 2003
7/30/1997	0.118	K'zoo District Lab #97-08-115
8/28/1997	0.16	Cooper, 1999
8/31/1997	0.07	Fusilier, 2003
3/17/1998	0.06	K'zoo District Lab #98-03-087
12/19/1998	0.019	Fusilier, 2003
7/7/1999	0.154	MI Lake & Stream Assoc/ Cent. MI Univ. Lab
9/16/1999	0.068	MI Lake & Stream Assoc/ Cent. MI Univ. Lab
12/18/1999	0.044	Fusilier, 2003
1/31/2000	0.052	Fusilier, 2003
3/1/2000	0.197	Fusilier, 2003
3/21/2000	0.063	MI Lake & Stream Assoc/ Cent. MI Univ. Lab
4/19/2000	0.039	Fusilier, 2003
5/7/2000	0.063	Fusilier, 2003
5/10/2000	0.098	MI Lake & Stream Assoc/ Cent. MI Univ. Lab
6/10/2000	0.032	Fusilier, 2003
6/29/2000	0.14	MI Lake & Stream Assoc/ Cent. MI Univ. Lab
7/12/2000	0.039	Fusilier, 2003
8/6/2000	0.046	Fusilier, 2003
9/13/2000	0.044	Fusilier, 2003
10/13/2000	0.029	Fusilier, 2003
12/31/2000	0.076	Fusilier, 2003
2/16/2001	0.07	Fusilier, 2003
4/4/2001	0.024	Fusilier, 2003
6/5/2001	0.116	Fusilier, 2003
8/25/2001	0.034	Fusilier, 2003
11/30/2001	0.086	Fusilier, 2003
1/29/2002	0.03	Fusilier, 2003
4/16/2002	0.066	Walterhouse, 2003
7/25/2002	0.112	Walterhouse, 2003
9/25/2002	0.042	Walterhouse, 2003
7/22/2003	0.33	Walterhouse, 2004
9/23/2003	0.169	Walterhouse, 2004
Average	0.073	
Average	0.067*	

*excludes 7/22/03 outlier, collected during a rain event