PHASE I LAKE RESTORATION GUIDANCE AND PRIORITIZATION PLAN FOR HONEOYE LAKE

PREPARED FOR
THE HONEOYE VALLEY
ASSOCIATION
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(COVER PHOTO WILLIAM BANASZEWSKI – HONEOYE LAKE WATERSHED TASK FORCE 1999)

1. INTRODUCTION AND OVERVIEW OF PROJECT

Honeoye Lake is the second smallest of the eleven Finger Lakes. The lake's permanent pool totals 1,772 acres, and although it attains a maximum depth of approximately 30 feet, it averages only 15 feet in depth (Map1). The watershed that drains to the lake encompasses 23,500 acres. The greatest amount of watershed development occurs at the northern end of the lake, in the form of a mix of residential, commercial and institutional uses. It should be noted that the most intensely developed sections of Honeoye Village actually occur downstream of the lake's outfall. As such, they are not considered a contributing source of nutrients and other contaminants (Photograph 1). Along the western and eastern shorelines, most of the development is in the form of residential land uses. Most of the southern portion of the watershed is forested and sparsely developed, although portions have in the past been farmed and logged.

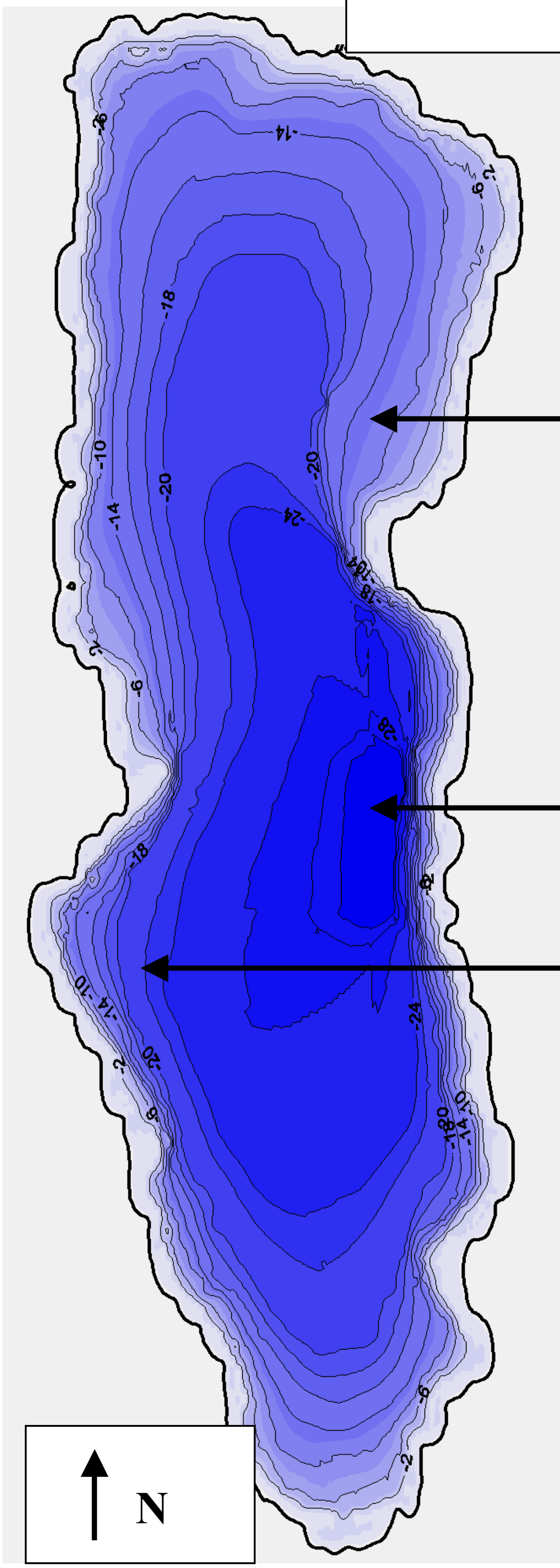
The main source of inflow to the lake is Honeoye Inlet, which enters the lake at the far south end. A number of other smaller streams and drainage sloughs enter the lake along the eastern and western shorelines, but none have a significant contributing watershed. The lake discharges to Honeoye Creek at the far north end. Outflow is regulated by a low weir. The lake's hydraulic retention time is relatively extended (0.8 to 1.0 years), although short in comparison to many of the other Finger Lakes.

Recognized in the region as a premier walleye and largemouth bass recreational fishery, the lake is also used for swimming and a variety of boating. Public access to the lake is gained through the Town Park boat launch, Sandy Bottom Beach, and the State boat launch. There is also a private boat launch associated with a marina that is located at approximately mid-lake, on East Lake Drive.

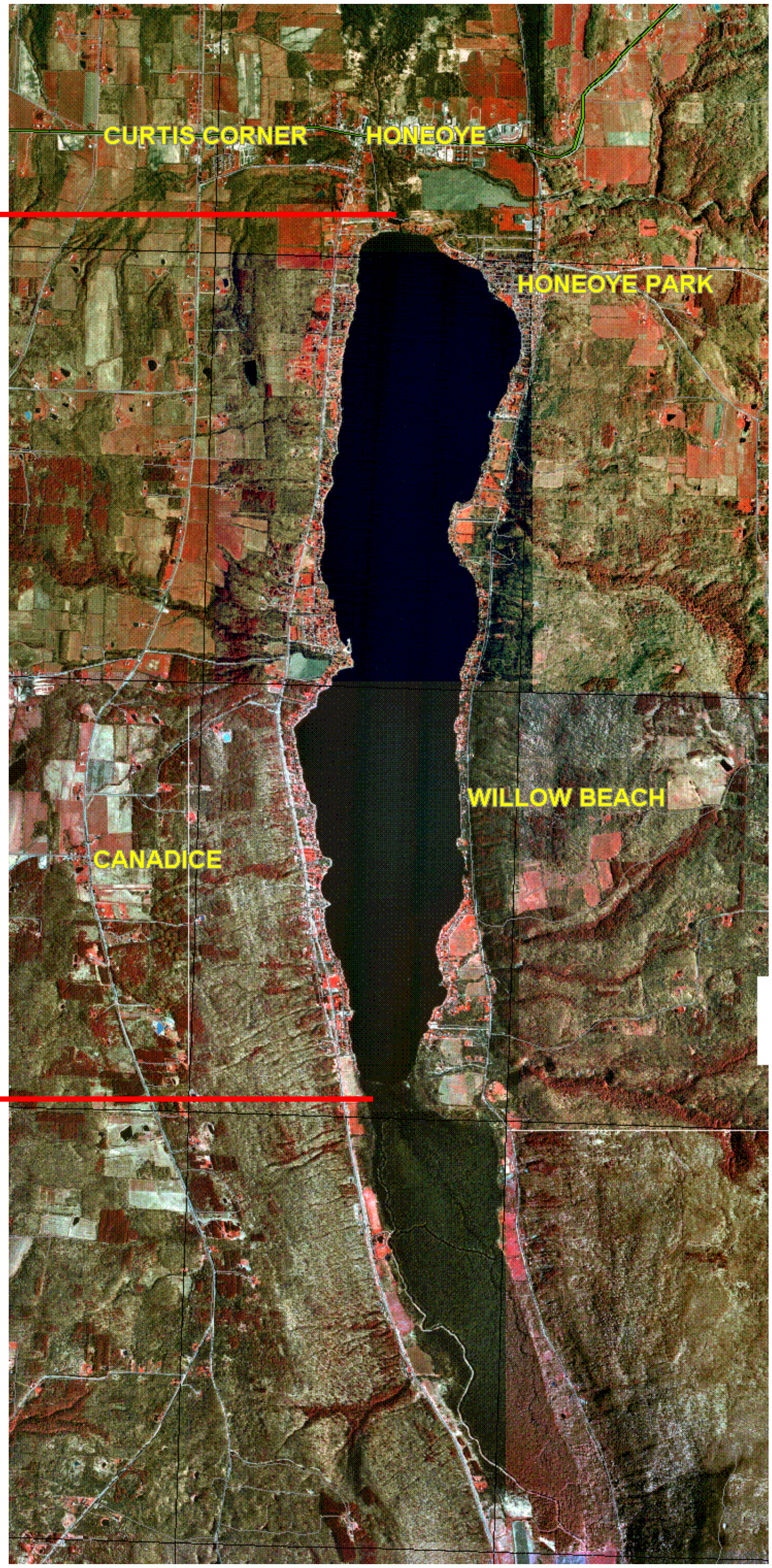
As per the data collected by various sources, including the New York Department of Environmental Conservation (NYSDEC), Honeoye Lake can be classified as eutrophic. For years, macrophytes, including invasive species such as *Myriophyllum* (milfoil), *Potomogeton crispus* (curly leaf pondweed), and *Vallisneria americana* (bass tape grass), have occurred in densities at times significant enough to impact recreational use. Although the weeds do not always "top out" throughout the shallow areas of the lake, weed growth is dense enough in water as deep as fifteen feet to impair recreation. Macrophyte growth has been controlled since the 1980's by means of weed harvesting.

During the later stages of the summer of 2002, the lake experienced a severe blue-green algae bloom. Spurred by the hot, dry climatic conditions, algal densities reached proportions never before observed on the lake. The bloom intensified in the northern end of the lake in wind driven concentrations of cell masses and filamentous algae mats. As a result of this bloom, and in recognition of the need to evaluate the feasibility of potential lake management and restoration options, a study was commissioned. The following report, reviews the cumulative water quality data compiled by various parties involved in the study and analysis of the lake. It also provides an analysis of the technical feasibility and effectiveness of various restoration alternatives including weed harvesting, destratification aeration and nutrient inactivation.

Map1 – Bathymetric Profile of Honeoye Lake (Underwater Technologies 1999)



Lake Outlet



Main Inlet

Photograph 1

False infrared aerial photograph of land use immediately surrounding Honeoye Lake. Note sparseness of development of the southern portion of the watershed and the limited amount of residential development along the eastern and western shorelines.

Source: - Finger Lakes Maps Underwater Technologies (1999)

2. REVIEW OF EXISTING DATA

Over the last 20 years, a variety of data has been collected on the physical, chemical and biological conditions of Honeoye Lake. Although the shared goal of most of these data collection and sampling efforts has been the increased understanding of the lake's ecological condition, the objectives of many of these efforts have been varied. A review of the majority of available water quality and lake ecology data was conducted by Princeton Hydro. The most significant and reliable sources of water quality data are those collected by the lake volunteers participating in the NYSDEC Citizen Statewide Lake Assessment Program (CSLAP) and those collected by and under the direction of Dr. Bruce Gilman of the Finger Lake Community College (FLCC). These data are used herein to highlight and assess the stated issues of concern and to identify management and restoration actions for the lake and its watershed. These data thus serve as the technical basis for Princeton Hydro's recommendations. Because of the diversity of the Honeoye Lake database, the analysis of the data in this report is divided into a series of subsections. Each subsection consists of a critical analysis of the data and includes a discussion of the data's relevancy, adequacy and conclusions.

2.1 In-lake Long-Term Water Quality Trends

In the past, Honeoye Lake has past participated in the NYSDEC Citizen Sponsored Lake Advisory Program (CSLAP). As a result, a relatively long-term database of key in-lake water quality data, collected following the same protocols and procedures, are available for assessment. These data were in turn compiled by the HVA and made available to Princeton Hydro. An analysis of the 1996 – 2000 CSLAP water quality database was conducted by Princeton Hydro. Focus was placed by Princeton Hydro on the phosphorus, Chlorophyll and transparency data (Figures 1, 2 and 3, and Table 1).

The CSLAP data show the existence of inter-seasonal and inter-annual variations in Total Phosphorus (TP) concentrations (Figure 1). In general, TP concentrations in Honeoye Lake tend to increase toward the end of the growing season[1]. Although the CSLPA data do not include water column profile measurements of dissolved oxygen, the data compiled by Gilman (1992) show that the bottom-most waters of the lake periodically become anoxic or devoid of dissolved oxygen. During these periods, internal recycling and loading processes may account for the observed increases in water column TP. The phenomena of sediment regeneration of TP under anoxic conditions will be discussed at length elsewhere in this report. Gilman (1993) however shows that in mid-summer, at depths in excess of 7 meters, TP concentrations are triple those measured at the surface of the lake. The role of internal phosphorus loading in the eutrophication of Honeoye Lake is not very well understood. Based on our experience with other similar lakes, the internal phosphorus load is likely the most important factor presently determining Honeoye Lake's trophic state.

[1] Defined herein as April through September

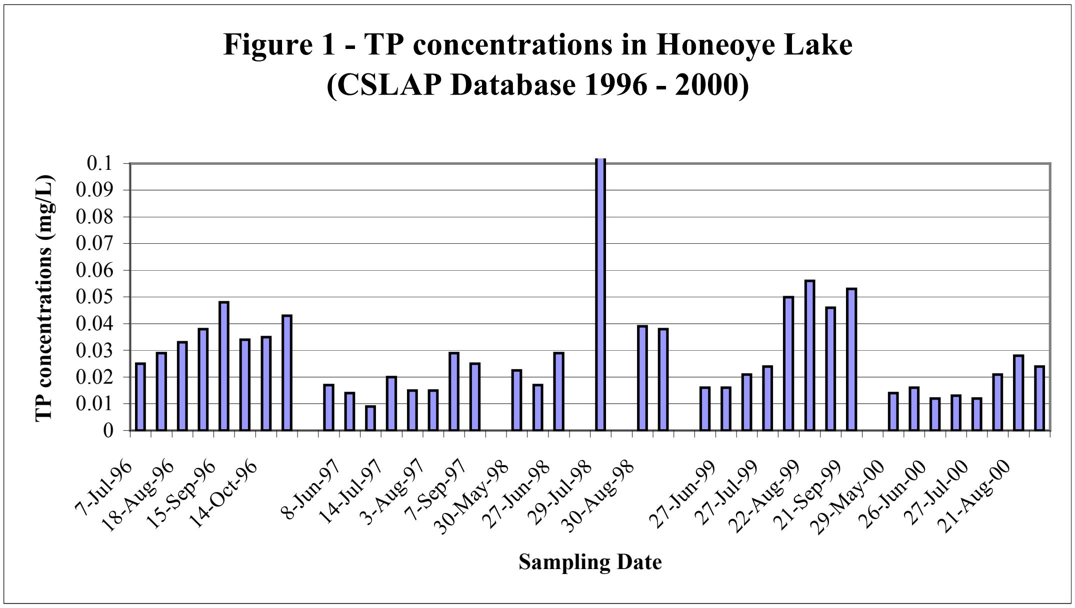


Figure 1 - TP concentrations in Honeoye Lake
(CSLAP Database 1996 - 2000)
TP concentrations (mg/L)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
7-Jul-96
18-Aug-96
15-Sep-96
14-Oct-96
8-Jun-97
14-Jul-97
3-Aug-97
7-Sep-97
30-May-98
27-Jun-98
29-Jul-98
30-Aug-98
27-Jun-99
27-Jul-99
22-Aug-99
21-Sep-99
29-May-00
26-Jun-00
27-Jul-00
21-Aug-00
Sampling Date

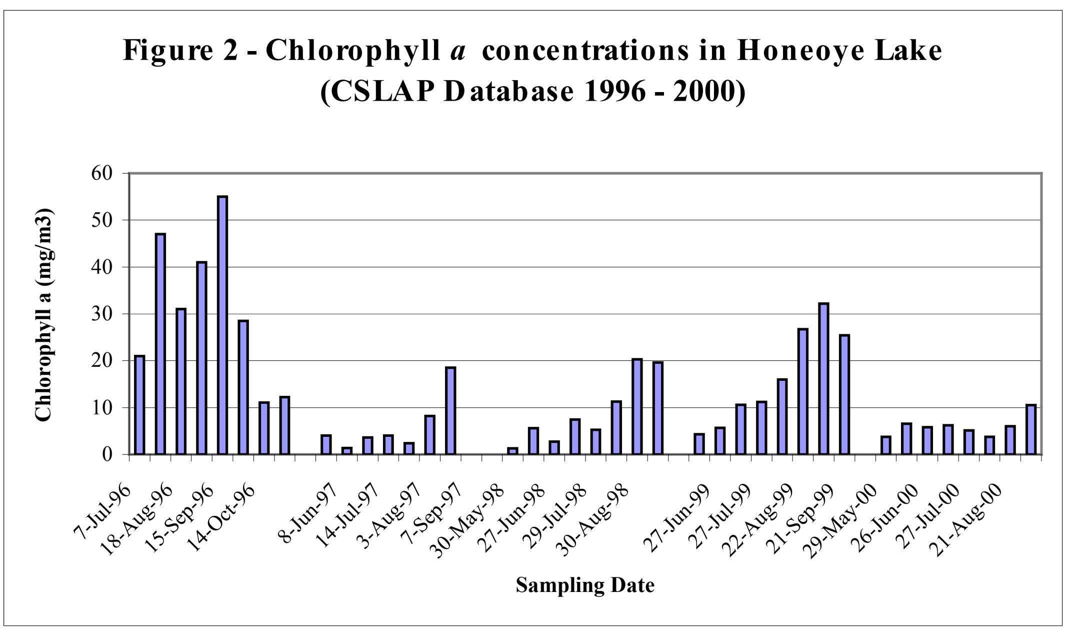


Figure 2 - Chlorophyll *a* concentrations in Honeoye Lake
(CSLAP Database 1996 - 2000)
Chlorophyll a (mg/m3)
0
10
20
30
40
50
60
7-Jul-96
18-Aug-96
15-Sep-96
14-Oct-96
8-Jun-97
14-Jul-97
3-Aug-97
7-Sep-97
30-May-98
27-Jun-98
29-Jul-98
30-Aug-98
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27-Jul-00
21-Aug-00
Sampling Date

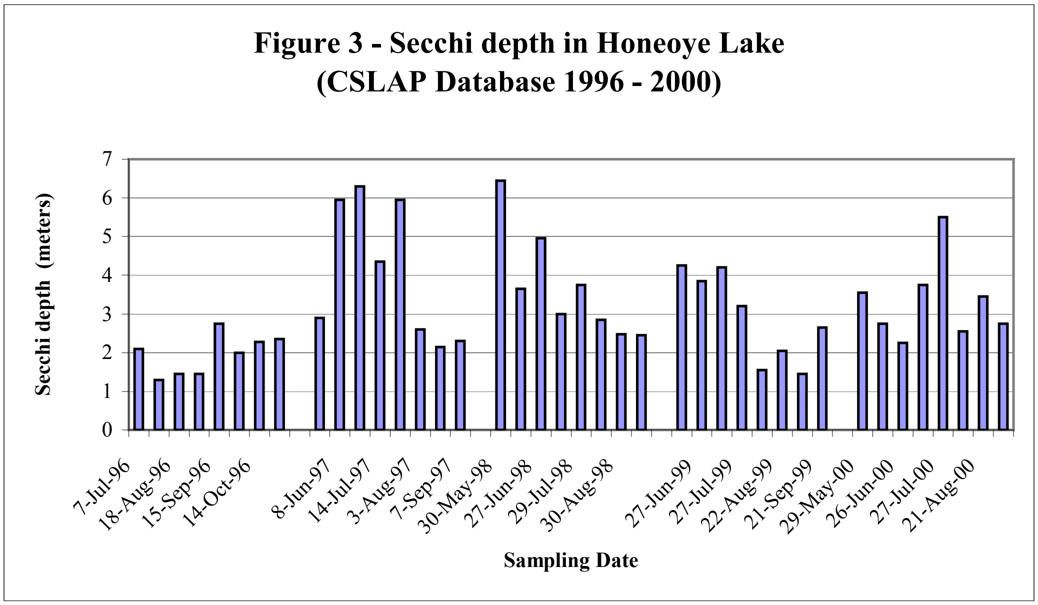


Table 1 - Secchi Disk Transparency (meters)

Year	Gilman	CSLAP	DEC - FLS	DEC- Fish
1985	2.7			
1986				
1987	3.4			
1988	4.1			
1989	2.9			
1990	3.5			
1991	2.7			
1992	2.3			
1993	3.7			
1994	4.1			
1995	2.7			2.4
1996	1.8	1.96	2.74	2.3
1997	4.8	4.06	4.44	3.8
1998	3.7	3.7	3.56	3.8
1999		2.9	4.3	3.66
2000		3.32		4.53
2001				3.81
2002				3.81
Mean	3.3	3.188	3.76	3.514

It was also noted upon review of the CSLAP data that TP concentrations were consistently lower in 2000 relative to the other sampling years (Figure 1). Regional droughts during the 2000 growing season and/or zebra mussel infestations may be responsible for this observed inter-annual difference in TP. Again, the role of such factors on the phosphorus dynamics of the lake will be discussed in later sections of the report.

Chlorophyll *a* is a photosynthetic pigment that occurs in algae. Measurement of Chlorophyll *a* is therefore an excellent means of measuring the amount of algae in the water. The CSLAP data show the existence of a relationship between elevated TP concentrations and elevated Chlorophyll *a* concentrations. In 2000, in-lake TP concentrations were lower than typically observed. Correspondingly, lower than average Chlorophyll *a* concentrations were also measured in 2000 (Figure 2). Specifically, in 1996 and 1999, growing season Chlorophyll *a* concentrations ranged from 21 to 55 mg/m^3 and from 4.3 to 32.2 mg/m^3, respectively. In contrast, Chlorophyll *a* concentrations ranged in the 2000 growing season from 3.8 to 10.5 mg/m^3 (Figure 2). This overall decline in Chlorophyll *a* and associated algal biomass in 2000 can be directly attributed to lower TP concentrations.

Water transparency is most commonly measured by means of a Secchi disk. Secchi disk readings are available in the CSLAP data. Review of these data show a relationship between Chlorophyll *a* and water clarity. Specifically, in 2000, the lower amounts of algae in the open waters of Honeoye Lake resulted in greater water clarity. For example, in 1996 Secchi depth values fluctuated between 1 and 3 meters, while in 2000 Secchi depth values ranged between 2 and 6 meters (Figure 3). It should be noted that Secchi depths greater than 5 meters were measured three times in 1997 and once in 1998.

As the CSLAP report indicates, overall 2000 water quality conditions in Honeoye Lake, from an open water perspective, were considered better than those observed between1996 and 1999. Princeton Hydro has concluded that these differences are a function of lower than normal concentrations of total phosphorus. With less available TP and other nutrients present in the water column, algal growth was reduced (as evidenced by the lower concentrations of Chlorophyll *a*). This in turn, led to greater water clarity.

2.2 Aquatic Plant (Macrophyte) Community

Although planktonic productivity has on occasion impacted the water quality and recreational use of the lake, most lake users attribute significant and chronic impacts on the recreational use of Honeoye Lake to excessive aquatic plant growth. While detailed, quantitative monitoring of the aquatic plants in Honeoye Lake was not conducted as part of the CSLAP program, it is certainly possible that growth rates, and perhaps densities, of rooted aquatic plants were higher in 2000 relative to previous years. One observation made in 2000 was that submerged aquatic plants were observed at the lake's surface, indicating that growth rates were high. Table 2 contains a list of the most commonly encountered species in the lake, as per the observations developed by NYSDEC.

Table 2 Commonly Occurring Aquatic Macrophytes (1994 - 1999)	
Species	**Common Name**
Myriophyllum spicatum	Eurasian water milfoil
Potamogeton crispus	curly-leafed pondweed
Vallisneria americana	bass tape grass
Potamogeton richardsonii	clasping leaf pondweed
Ceratophyllum demersum	Coontail
Najis flexilis	Naiad
Potamogeton gramineus	variable pondweed
Chara vulgaris	muskgrass
Potamogeton pectinatus	Sago pondweed
Elodea canadensis	elodea
Heteranthera dubia	water star grass

A very common response to increases in water clarity is an increase in the relative amount of submerged aquatic vegetation. This shift from an algal-dominant system to a submerged plant system was noted in one of the many studies on the aquatic plant community of Honeoye Lake (Gilman 1994). It should be emphasized that in general, it is easier to manage excessive rooted aquatic plant growth relative to nuisance planktonic algal blooms.

A number of highly detailed aquatic plant surveys have been periodically conducted at Honeoye Lake by Dr. Gilman through the FLCC. A long-term assessment of the aquatic plant community structure in Honeoye Lake revealed that in 1994 the dominant (abundant) plants included Eurasian watermilfoil (*Myriophyllum spicatum*), elodea (*Elodea*), coontail (*Ceratophyllum demersum*), flat stem pondweed (*Potamogeton zosteriformis*) and bass tape grass (*Vallisneria americana*). It should be noted that from 1984 to 1994 the abundance of all of the dominant species increased, except for the bass tape grass. Although the density of bass tape grass declined over this period, it was still considered abundant. Of particular note with respect to recreational use and macrophyte impacts was the increase in the density of the invasive, exotic species Eurasian watermilfoil.

In addition to an increase in the relative abundance of aquatic plant densities in Honeoye Lake, the amount of lake bottom area colonized by macrophytes also increased from 1984 to 1994. Specifically, the distribution of rooted aquatic plants in 1984 occurred over approximately 22% of the lake's bottom area. In contrast, the distribution of rooted aquatic plants in 1994 occurred over almost 50% of the lake bottom area. Again, this expansion of the aquatic plant community was attributed to an increase in water clarity. As will be described later in this report, a number of environmental factors contributed toward the observed improvements in water clarity from the later half of the 1990's to the present. Some of these factors include the sewering of the community(1978), a significant decline in alewife (*Alosa psuedoharengus*) (1996), a zooplanktivorous fish, and the establishment of zebra mussel in the lake (1998).

2.3 Phytoplankton and Zooplankton Communities

Unlike the aquatic plants, a minimal amount of detailed information on the community structure of phytoplankton and zooplankton of Honeoye Lake has been collected. The majority of data on the zooplankton and phytoplankton communities were collected between 1995 and 1998 by the New York State Division of Fish, Wildlife and Marine Resources.

Zooplankton are micro-animals that live largely in the open (pelagic) waters of a lake. Zooplankton feed on phytoplankton. Some of the large zooplankton can naturally control excessive algae growth through direct grazing. In addition, zooplankton are a source of food for forage and young gamefish. Over the four-year period during which the zooplankton community was closely observed, substantial changes or shifts within the zooplankton community were documented. For example, herbivorous (algae-eating) zooplankton, including species of the cladoceran *Daphnia* and the copepod *Diaptomus*, increased in density in 1997 and 1998.

While these large-bodied zooplankton graze heavily on phytoplankton, and thus can serve as a natural means of controlling excessive algal growth, they are also a favored source of food for a variety of forage and young gamefish. In particular, alewife and young yellow perch (*Perca flavescens*) are known to heavily graze on zooplankton. The available data suggest that prior to 1996, the abundance of large, herbivorous zooplankton was relatively low, due to the existence of a large number of zooplanktivorous, filter-feeding fish, especially alewife. However, a substantial shift in the fish community of Honeoye Lake occurred in the mid-1990's. There appears to be two factors responsible for this shift.

First, it was reported that a large portion of Honeoye Lake's alewife population died following thermal event in winter of 1996. Alewife are very susceptible to significant, rapid changes in water temperature. This is in fact used as a means of thinning or eliminating alewife. Second, an aggressive stocking program was implemented. Specifically, walleye (*Stizostedion vitreum*) were stocked in the lake. Walleye are recognized to be highly predacious on alewife. The combination of the1996 thermal event and walleye predation pressure contributed to the elimination of alewife in Honeoye Lake. With a decline in zooplankton grazing pressure, a community-based shift to larger, herbivorous zooplankton was facilitated. The average size of the largest zooplankton has increased by 30 to 33%. Such a shift in the zooplankton community is preferred from a water quality perspective, since herbivorous zooplankton aid in the natural control of phytoplankton.

While there were some limited data on the zooplankton of Honeoye Lake, no community specific data were available for the phytoplankton. As previously mentioned, the measured concentrations of chlorophyll *a* can be used to assess phytoplankton community densities. However, without the taxonomic identification and enumeration of the algae it is difficult to determine which algal group is dominating the phytoplankton community. Such data is needed in order to develop more site-specific recommendations for the management of Honeoye Lake's algal problems. Given the advent and intensity of phytoplankton related problems, it is highly recommended that phytoplankton community data be collected on a regular basis.

The identification and enumeration of phytoplankton data are important. In aquatic ecosystems, the phytoplankton are the base of food chain. There are a number of different types of phytoplankton, each having a unique ecological niche and effect on water quality. In general, phytoplankton can be divided into the following basic groups: green algae, diatoms, chrysophytes and blue-green algae. In most freshwater ecosystems, blue-green algae (Cyanobacteria) are considered the most problematic and greatest nuisance algal group. These algae, which are more bacteria-like than plant like, are well recognized for producing surface scums, dense algal blooms, and obnoxious odors. The specific measures for the control of blue-green algae are extremely dependent on the specific genus or species responsible for the nuisance conditions. For example, some blue-green algae, such as *Anabaena* and *Microcystis*, tend to bloom during the warm summer and early fall months, while others, such as *Coelosphaerium* and *Aphanizominon*, are more tolerant of lower water temperatures. Other blue-green algae, such as *Oscillatoria*, tend to bloom in deeper water depths, but are often transported to the surface in large numbers following a significant storm event. Given these habitat-specific preferences, it is critical that phytoplankton community be closely monitored and properly identified in order to select the most appropriate management measures.

2.4 Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) were first identified in Honeoye Lake in 1998. They likely colonized the lake sometime in the mid-1990's. The presence of the zebra mussel in Honeoye Lake has most likely contributed to some of the recently experienced increases in the lake's water clarity. Zebra mussels are filter feeders. Due to the high densities that these species attain in lakes, through their feeding they can remove large numbers of plankton (both zooplankton and phytoplankton) from the water column. The resulting reduction in primary producers (i.e. algae) can have a drastic negative impact on the lake's entire food web. This has been documented in the Great Lakes by various researchers.

Data collected by Gilman in 2002 revealed that zebra mussels occur largely at depths between < 1 to 4 m. The density of zebra mussels (per 0.5 square meters) was randomly distributed. That is, the highest or lowest densities were not consistently observed at the same depth throughout the lake. However, a distinct correlation was identified between water depth and the mean weight of the zebra mussels. Essentially, the mean weight of the zebra mussels decreased with depth; smaller (younger) zebra mussels were found in deeper water depths.

This relationship between zebra mussel mean weight and water depth was attributed to the type of substrate available for colonization by the mussels. The larger, older zebra mussels were found in the shallow water depths of the lake. These areas have a fair amount of rocky substrate. This rocky substrate tends to be relatively stable and provides the opportunity for zebra mussels to grow to maturity. In contrast, the smaller, younger zebra mussels were found in deeper water depths attached to the base of the stems of the rooted aquatic plants. Most aquatic plants are annuals, dieing back in the fall of each year. As such, aquatic plants do not provide a stable substrate for zebra mussels. Thus, any zebra mussels that utilize aquatic plants as a substrate appear to survive only one growing season. It is hypothesized that as the plants dieback and the stems weaken, the attached mussels fall into the soft muddy substrate and they themselves die, likely because of smothering. This hypothesis is supported by the age and size of the zebra mussels collected from the deeper edges of their distributional range in the lake. Along the deeper edge of the littoral zone, the sediments are characterized by soft silty sands. Closer to the shore, the lake is characterized by the more rocky, firm substrate easily colonized by zebra mussels.

The presence of zebra mussels and this association with aquatic macrophytes appears to also be playing a role in the lake's internal phosphorus dynamics. This will be discussed in greater detail in a following section of the report; however, it can be summarized as follows. The seasonal die off and subsequent decomposition of large numbers of zebra mussels, in combination with or independent of the seasonal die back of the lake's aquatic plants, seems to contribute to algal blooms by generating a phosphorus load. The bacterial decomposition of this organic material leads to the regeneration of organic forms of phosphorus. Such forms of phosphorus are readily utilized by blue-green algae thereby providing a competitive advantage to this algal group. The annual "pulsing" of organic phosphorus may be contributing to the recent increase in blue-green algae and facilitating an intensification in blooms. As mentioned above, this hypothesis will be discussed and examined more closely elsewhere in this report.

2.5 Watershed Related Phosphorus Loading

As previously mentioned, although the lake's watershed encompasses over 36 mi^2 (~30,000 acres), it is sparsely developed. As per the Honeoye Lake Watershed Task Force (1999), of the 1,500 homes occurring within the watershed, 970 (~65%) occur immediately around the lake. This immediate watershed is sewered, virtually eliminating septic related phosphorus loading to the lake. Nonetheless, the results of stream sampling show that at times high concentrations of phosphorus are measured in some of the tributaries especially under storm flow conditions (Table 3). These data show that inlet concentrations of TP can often exceed 0.1 mg/L. Given that a concentration of phosphorus greater than 0.03 mg/L is enough to stimulate algal growth, these concentrations appear alarming. The majority of the highest recorded in-stream concentrations coincide with elevated concentrations of Total Suspended Solids (TSS). This is not unusual as phosphorus has a high affinity in the terrestrial environment for soils, binding quite effectively to loamy type soils and soils with a high iron content. Once in the aquatic environment however, these bonds decay and some of the phosphorus is liberated into the water column. The rate of phosphorus release is determined by a number of biological, chemical and physical factors. However, it is accelerated, two to three-fold under anoxic as compared to oxic conditions. The remaining phosphorus present in the sediments is available for uptake by aquatic plants and benthic (mat) algae.

Table 4 - Honeoye Inlet - Data Collected in 2000, 2001 and 2002

Sample Station	Total Phosphorus (µg /L)	Tot Sus Solids (mg /L)
Inlet Grab –March 2000	113.4	46.5
Inlet Event – March 2000	65.8	38.6
Inlet - 1st flush –March 2000	135.2	69.5
Inlet Comp – April 2000	58.4	45.5
Inlet Grab – April 2000	78.2	53.6
Inlet Comp – April 2000	156.6	53.6
Inlet Event Comp – April 2000	364.8	258.0
Inlet Grab – May 2000	570.3	327.0
Lower Inlet grab – May 2000	289.5	447.0
Inlet Grab 0810 – May 2000	547.2	385.7
Honeoye-Inlet Comp – (April – Oct 2001)	98.7	66.6
Honeoye Inlet Comp - April 2001	46.8	42.5
Honeoye Inlet Grab – April 2001	42.5	40.3
Honeoye Inlet – Nov 2001	719.6	1549.5
Honeoye Inlet Grab – January 2002	16.0	12.8
Honeoye Inlet (first flush) – August 2001	695.9	153.0
Honeoye Inlet (first flush) – Feb 2002	6.8	1.5
Honeoye Inlet Grab – Feb 2002	35.9	31.0
Honeoye Inlet Baseline – March 2002	17.6	2.6
Honeoye Inlet Grab (Post Event) - March 2002	20.2	15.5
Honeoye Inlet Partial Comp - March 2002	122.6	80.5
Honeoye Inlet Grab - March 2002	258.0	125.0
Honeoye Inlet Event Comp – April 2002	406.5	528.8
Honeoye Inlet Event Grab – April 2002	136.1	160.0
Honeoye Inlet Baseline Grab – May 2002	14.3	13.4
Honeoye Inlet Baseline Grab – June 2002	20.2	8.0

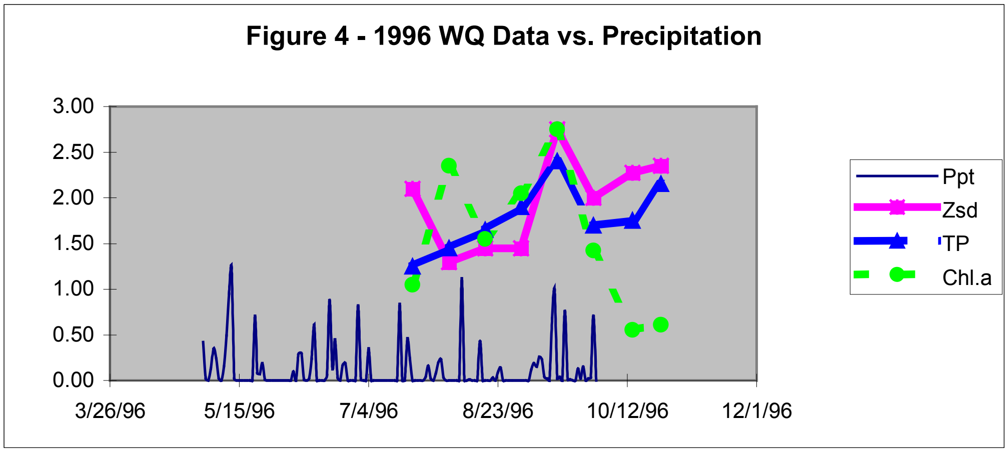


Figure 4 - 1996 WQ Data vs. Precipitation
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3/26/96
5/15/96
7/4/96
8/23/96
10/12/96
12/1/96
Ppt
Zsd
TP
Chl.a

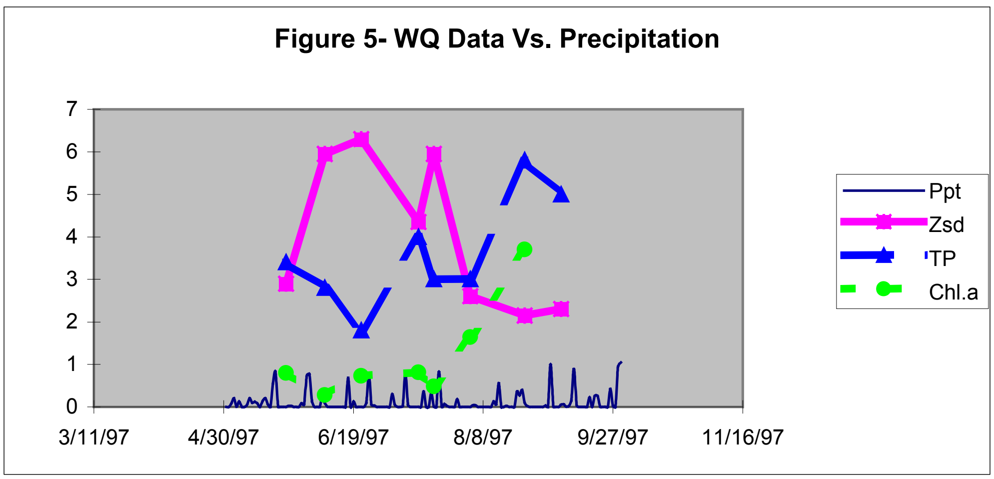


Figure 5- WQ Data Vs. Precipitation
7
6
5
4
3
2
1
0
3/11/97
4/30/97
6/19/97
8/8/97
9/27/97
11/16/97
Ppt
Zsd
TP
Chl.a

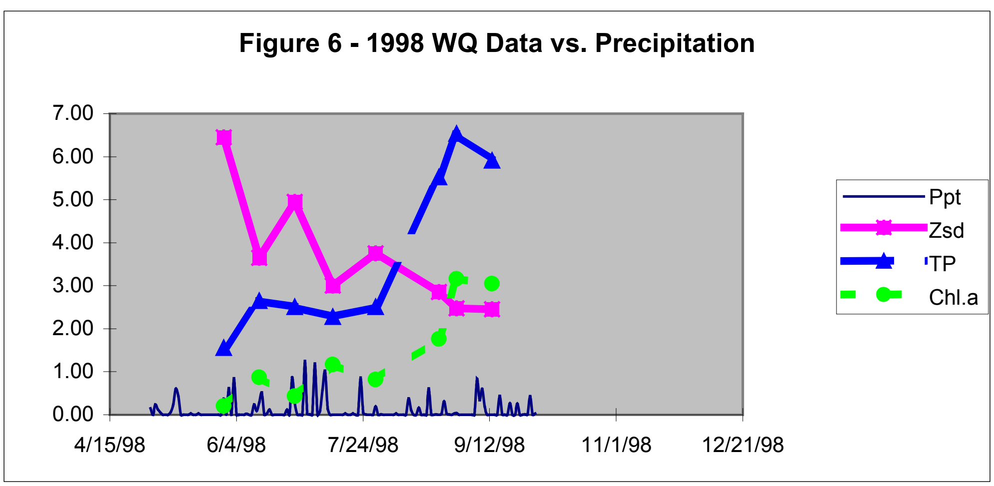


Figure 6 - 1998 WQ Data vs. Precipitation
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4/15/98
6/4/98
7/24/98
9/12/98
11/1/98
12/21/98
Ppt
Zsd
TP
Chl.a

Interestingly, the in-lake data (Figures 4, 5 and 6) show that in-lake TP and productivity levels are not significantly affected by precipitation. Although this suggests that external phosphorus loading events are not as important a forcing factor as are internal phosphorus loading events, it does not suggest that external phosphorus loading need not be controlled. It is highly possible that localized impacts, in the form of sediment deltas, filamentous algae blooms and dense stands of weeds are occurring because of the tributary phosphorus loads.

Although the data show no strong lake-wide relationship between tributary loading and in-lake productivity, intuitively any additional influx of phosphorus to the lake is detrimental. The large differences between TP/TSS concentrations under storm and baseline conditions (Table 3) show that erosion, sediment transport and other mechanisms by which soils are mobilized and carried into the lake are significant with respect to the introduction of phosphorus. Recommendations pertaining to additional monitoring of the lake's inlets and the long-term management of the lake's external TP and sediment loads are discussed in later sections of this report.

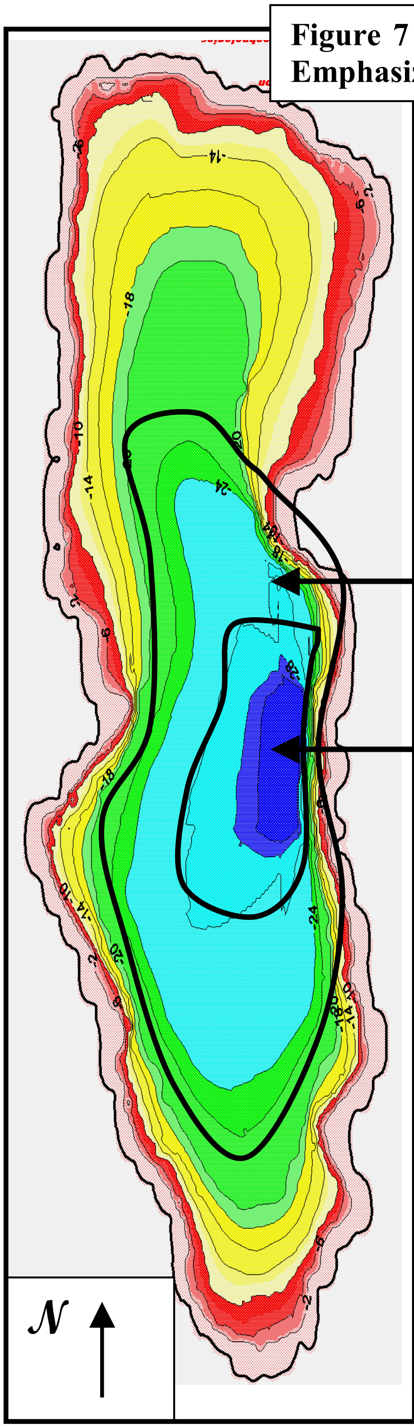
2.6 Thermal Stratification and Internal Phosphorus Loading

Honeoye Lake has been described by some as a monomictic lake. In the northeast, such waterbodies will tend to thermally stratify during the winter, especially under ice cover. In the early spring, following ice-out, the lake thermally destratifies and remains well mixed through the year until it freezes over in the subsequent winter. However, much of the *in-situ* data indicate that Honeoye Lake is actually better defined as a polymictic lake. That it, although it remains essentially weakly stratified throughout the growing season, it will, under the proper climatic conditions, experience short, but intense bouts of thermal stratification. This thermally stratified state however, is easily overcome by intense wind or rainfall events, largely because of the lake's shallow depth and long south-north seche (essentially, an internal flow pattern).

Specifically, as based on the existing water quality database, Honeoye Lake remains typically well mixed through the growing season. Surface and bottom water temperatures and dissolved oxygen concentrations are very similar. Under most conditions, it appears that Honeoye Lake is oxygenated from the surface to bottom through the course of the growing season. However, bottom-water dissolved oxygen concentrations occasionally decline below concentration of 5.0 mg/L, the concentration considered optimal for fish life.

As indicated, there have been instances when anoxic conditions (DO concentrations < 1 mg/L) were detected in the bottom waters of Honeoye Lake. Anoxic conditions have been periodically identified in Honeoye Lake over the last 20 years (Gilman 1986; NYS DEC Department of Fisheries 2003). For example, on 29 July 1994, Honeoye Lake exhibited a relatively strong degree of thermal stratification between 7 and 8 meters. In turn, DO concentrations at depths greater than 8 meters were less than 1 mg/L (Gilman 1994).

Figure 7 –Color Coded Rendering[1] of Honeoye Lake Bathymetry Emphasizing Portions of the Lake 7 Meters or Greater in Depth



Note that those portions of the lake at least 22 feet (6-7 meters) in depth have the potential to become anoxic during the summer month. Also, note that those sections of the lake less than 10 feet (3 meter) in depth are likely to support rooted macrophytes (weeds).

Sampling conducted this past summer also recorded anoxic or near-anoxic conditions at or near the bottom of the lake. Under these conditions of temporary anoxia, sediment redox conditions become altered leading to large amounts of phosphorus being released from the sediments. Gilman (2001) discusses the significance of this in detail. If these episodes of periodic anoxia result in waters greater than 7 meters becoming devoid of DO, the result is a relatively large percentage of the lake's bottom regenerating phosphorus at elevated rates (Figure 7).

As previously discussed, the morphometry of the lake (Map 1 and Figure 7) and the direction of the prevailing winds, strong thermal stratification is a rare condition for Honeoye Lake. However, under a particularly dry and hot summer, as was experienced in 2002, stratification can be strong enough to physically separate, as a result of thermal and density differences, the surface waters from the bottom waters. If these conditions persist over a long enough period of time, anoxia can be established over a large percentage of the lake's bottom sediments. Such conditions have been observed in Honeoye Lake during past monitoring programs. Figure 8, developed by the NYSDEC from data compiled in 2001, shows a significant increase in deep water (hypolimnetic) TP concentrations in the middle of the summer.

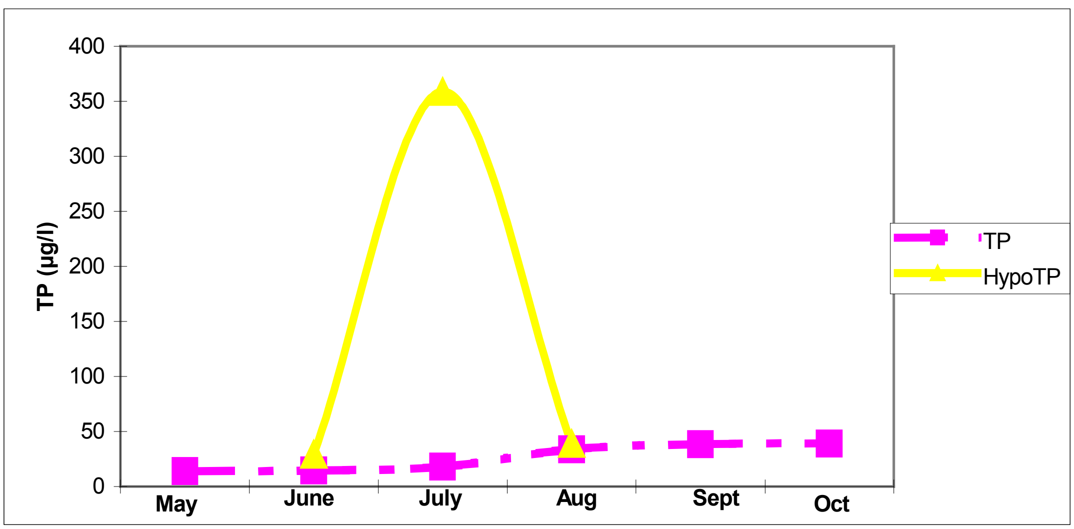


Figure 8 – Deep vs. Shallow Water TP Concentrations - 2001

In-situ data collected by NYDEC's Department of Fisheries during the 2002 growing season provide additional supporting evidence of internal phosphorus loading. On 18 July 2002 Honeoye Lake was strongly stratified between 5 and 6 meters, with bottom water DO concentration being less than 4 mg/L. By 20 August 2002 the lake was well mixed with bottom water DO concentrations less than 3 mg/L. In turn, on 3 September 2002 the lake remained well mixed and DO concentrations varied between 7.62 and 9.24 mg/L. Based on these observations, it is certainly possible for the bottom waters of Honeoye Lake to have become and remained anoxic between 18 July and 20 August

2002. Such anoxic conditions would facilitate the release of substantial amounts of phosphorus from the sediments into the overlying waters. Subsequent storm or wind events would transport this phosphorus-rich bottom water to the surface, where it can fuel the growth of the nuisance algal blooms, as experienced during the later half of the summer of 2002.

The actual amount of phosphorus released and recycled from the lake's sediments is dependent on the duration of anoxia and extent of affected bottom sediment area. As previously described, this internally generated phosphorus can be transported to the surface through several physical processes (entrainment, internal seches, strong, isolated storm events) and subsequently stimulate and sustain algal growth. This "pulse" of phosphorus, especially during the dry summer season when algal growth is severely nutrient limited, can easily result in dense nuisance blooms of blue-green algae. Research (Lubnow and Souza 1999) has demonstrated that the phosphorus generated by internal processes can drive summer Cyanobacteria blooms.

2.7 Honeoye Lake Fishery

As previously mentioned, Honeoye Lake is considered a premier walleye fishery. Recent evidence suggests that these fish may actually be spawning in Honeoye Inlet. Intensive sampling of the lake was conducted by the NYSDEC in 1997 and 1999 using both gill nets and electroshocking (NYSDEC 2001). The former was used to evaluate the lake's pelagic (open water) fishery, with particular emphasis placed on the collection of walleye and alewife. The electroshocking equipment was used in 1999 to primarily sample the lake's littoral (near shore) fishery, with emphasis placed on the collection of largemouth bass.

The fishery survey found no alewife in the lake. Surprisingly, the condition of the walleye fishery was considered poor, as based on the recorded weight of captured fish greater than 45 cm in total length. Stomach content analysis showed that the walleye were feeding mostly on sunfish. The lake's perch population showed signs of stress, concluded to be the result of grazing pressure from the walleye. Although sunfish (both bluegills and pumpkin seeds) are the major food items for the bass and walleye, the report concluded that the sunfish community was in excellent condition and that the lake provides a high quality sunfish recreational fishery. As with the sunfish, the lake's largemouth bass fishery was found to be excellent.

The NYSDEC concluded that because of the over crowded condition of the walleye population and the depressed status of the yellow perch population the size limit on walleye should be decreased from 45 cm to 38 cm (18 inches to 15 inches). Such a reduction would decrease the grazing pressure exerted by the walleye on the perch and help thin out some of the walleye numbers. The NYSDEC also rationalized that with the decimation of the alewife population, the need for the larger walleye size limit is no longer needed.

2.8 Summary of Available Data

The data compiled over the years by the NYSDEC, FLCC and others engaged in the monitoring of the lake show the lake to be a eutrophic, weed dominated system. The lake's phosphorus load is sufficiently adequate to support dense algal blooms. These blooms appear to intensify during dry summers, when the lake's flushing rate is reduced. However, the data also suggest that a wet spring (with a large influx of watershed contributed TP) in combination with a dry summer may be a climatic "trigger" for the shift from weed to algae dominance.

Honeoye Lake does not stratify as strongly as most of the other Finger Lakes, owing largely to its relatively shallow depth. However, the extent of stratification is great enough to result in periodic episodes of hypolimnetic anoxia. During these episodes, the lake regenerates a large amount of phosphorus from the bottom sediments. This additional phosphorus facilitates the development of blue-green (Cyanobacteria) blooms. In 2002, these blooms reached nuisance proportions and significantly impacted the lake's aesthetics and recreational use. The role of the internal TP load is not fully understood; however, it does appear to be an important forcing factor in determining the development of nuisance algae blooms.

3. Discussion and Recommendations

In the Findings and Executive Summary of the 2000 Interpretive Summary of the CSLAP data, NYSDEC states that the "water quality conditions in Honeoye Lake, in general, have not changed significantly since 1996". Although the report concludes that the lake is "slightly impaired", it also states that Honeoye Lake is among the lakes in the Genesse River basin where the use of the lake for bathing, boating and aesthetics is stressed and with a "water supply threatened as a result of excessive nutrients, nuisance algae and weeds and other pollutants". However, there have been a large number of ecosystem-based changes in Honeoye Lake over the last twenty years. Of particular note are the reduction in phosphorus loading following the sewering of the lake's immediate watershed, the invasion of zebra mussels and the elimination of alewife. These watershed and in-lake factors have altered the lake's ecology and have had an effect on its trophic state. Overall, the combined effect has been positive, resulting in an increase in the water clarity of Honeoye Lake. In turn though, this increase in water clarity has allowed the rooted aquatic plant community to expand into deeper sections of the lake.

The dominance of the lake by weeds, in itself is a desirable condition. However, it is compounded by the fact that macrophyte densities do attain nuisance proportions that impede recreational use. Evidence of this expansion of the rooted aquatic plant community is evidenced by comparing aquatic plant survey data from 1984 with that collected in 1994. Specifically, the distribution of rooted aquatic plants in 1984 covered approximately 22% of the lake bottom. In contrast, the distribution of rooted aquatic plants in 1994 covered almost 50% of the lake bottom. For almost two decades (Gilman

1995 and 1996), there have been lengthy discussions on how best to address macrophyte growth in the lake. The HVA has looked to maintain a balance between reducing the impact of weed growth on recreational usage while maintaining adequate fish habitat. New problems have arisen recently with the advent of dense Cyanobacteria blooms and the colonization of the lake by zebra mussels. Overall, the HVA recognizes that a well-defined plan is needed in order to manage the lake in a condition that satisfies swimmers, boaters, anglers and property owners, while not compromising the lake's ecological balance. To develop the data needed to make wise management and restoration decisions, monitoring of the lake has been occurring since the 1970's.

However, this database, although encompassing a relatively long time period, is lacking with respect to certain data, especially information pertaining to phytoplankton, deep-water TP concentrations, and the measurement of organic phosphorus. At present, these are the types of data most needed to evaluate the utility of certain management options including aeration, alum, and alternative macrophyte control strategies. There is also the need to better develop the lake's hydrologic budget and further understand the relationships, on a seasonal level, between in-flow, external nutrient and sediment loading, lake flushing and lake trophic state.

The lake's future management and restoration requires focus on the following:

1. Control of the lake's internal TP load,

2. Control of the lake's macrophytes,

3. Maintenance of the lake in a weed (macrophyte) dominated state and prevention of nuisance algal blooms,

4. Better management of the lake's fishery to improve the condition of the walleye and perch populations and maintain the excellent largemouth bass fishery by promoting additional predation on sunfish,

5. Management of the lake's external nutrient and sediment loads, and

6. Improved understanding of the dynamics of the lake's hydrologic properties and the interactions between water inflow, nutrient loading, lake flushing and internally driven algal blooms.

The following sections of this report discuss specific lake management options, but begin with a review of the data gaps that exist and the future monitoring and data gathering recommendations.

3.1 Future Monitoring Needs

In addition to the liberation of phosphorus from the sediments, under oxic and anoxic conditions, there are other internal sources of phosphorus. Such internal sources tend to be biological, associated with the seasonal death and decomposition of macrophytes, zebra mussels and even phytoplankton. Other internal phosphorus sources include the feeding activities and excretory waste products of benthic feeding fish (e.g., common carp and catfish) or filter feeding organisms (e.g., zebra mussel). However, the die-off of plants and animals is most significant because this can be a major source of organic phosphorus loading. Although all forms of phosphorus are important metabolic building blocks for algae and phytoplankton, organic phosphorus is particularly important with regard to the development of blue-green algae. Unlike other algae, blue-greens are metabolically capable of readily utilizing this form of phosphorus. When organic P is present in high concentrations, as commonly occurs after an herbicide induced die off of macrophytes, blue-green algae gain a large competitive edge over the other algal forms.

While internal sources of phosphorus do not introduce additional phosphorus into a waterbody, their capacity to make phosphorus more readily available, from a growing season perspective, indicates that their relative contribution to fueling algal growth will increase as external contributions decrease. For example, the role of internal sources of phosphorus in producing algal blooms may be particularly important during the height of the summer season and/or during low flow conditions (i.e. minimal amounts of external phosphorus loading). Given the potential importance of internal phosphorus, such forms of phosphorus need to be better quantified as part of the overall phosphorus budget of Honeoye Lake. This can be accomplished as follows:

1. Obtain an up to date estimate of the amount of lake bottom that is covered with rooted plants. Based on the most recent aquatic plant survey, almost 50% of the lake bottom was covered with aquatic vegetation.

2. Using the existing aquatic plant database for Honeoye Lake; obtain a reasonable, long-term estimate of the average amount of lake bottom covered with rooted aquatic plants through the growing season. The estimate of areal, seasonal coverage can be used with the aid of coefficients that represent rates of decomposition and other information (i.e. how much phosphorus is removed from the lake each year via mechanical weed harvesting), to quantify the internal load originating from macrophyte decomposition.

3. Collect additional data on the densities and distribution of zebra mussels throughout Honeoye Lake in 2003. Use existing zebra mussel density data, as well as phosphorus loading coefficients associated with zebra mussels, to quantify the internal phosphorus load originating from these organisms.

4. Collect water samples immediately above beds of zebra mussels for the analysis of inorganic (SRP) and organic phosphorus.

In order to obtain a complete view of the annual phosphorus budget entering Honeoye Lake, external sources of phosphorus need to be better quantified. Based on the provided information, the land use data has not been significantly updated since 1971. Although the watershed has not been intensively developed since that time, land use has changed. As such, the land use database needs to be updated to better represent existing conditions. Specifically, more recent land use data, available in a GIS format, should be accessed and utilized as the basis for quantifying the lake's external TP and sediment loads. Aerial photographs and land reconnaissance of the watershed should be used to verify the GIS land cover database.

The updated land use data can then be used in combination with specific phosphorus runoff loading coefficients to calculate the annual, watershed-based phosphorus loads. Other external sources of phosphorus, such as atmospheric, septic systems and point sources, should also be quantified in order obtain a more complete assessment of the lake's external phosphorus budget.

As cited above, an important component of the phosphorus budget that should be taken into account is on-site wastewater disposal systems (septic systems). While a sewer system does exist around the perimeter of the lake, septic systems adjacent to some of the lake's tributaries may still be contributing to its annual phosphorus budget.

Another source of phosphorus that should be quantified is the annual waterfowl contribution. This is particularly important for Canada geese, which defecate approximately 28 times a day and generate approximately 0.6 lbs/goose of phosphorus per year. While this may not seem like a large amount of phosphorus, one pound (1 lbs) of phosphorus can generate up to 1,100 lbs of wet algae. Furthermore, much of the phosphorus associated with waterfowl fecal is in an organic form. As mentioned above, this type of phosphorus is readily used by blue-green algae. Thus, the waterfowl source of phosphorus should be quantified. In order to develop a reasonably accurate phosphorus budget for Honeoye Lake, the following should be implemented:

1. Update the land use database for the Honeoye Lake watershed, preferably using a digital GIS format.

2. Use the GIS land cover data in combination with USEPA and/or NYSDEC pollutant loading coefficients to model the lake's watershed based nitrogen, phosphorus and sediment loads. The most appropriate land use loading coefficients should be selected for the land types within the Honeoye Lake watershed. These loading coefficients will be used to estimate the annual phosphorus loads originating from surface runoff associated with the various land types (i.e. agriculture, residential, forested). Quantification of the loads should be conducted on a sub-watershed specific level of detail. The actual model used to compute the loads can be any of the unit areal loading models, such as Uttrormark (Uttermark, et. al. 1974) or the techniques described in the Lake and Reservoir

Manual (NALMS 2002) or the USEPA's Clean Lakes Program Guidance Manual (USEPA 1990).

3. The GIS land cover data can also be used to model and compute the lake's hydrologic inputs. Specifically this will entail assigning runoff coefficients, or curve numbers, as based on land cover, imperviousness, soils and topography. Computation of the annual volume of runoff can be accomplished using the Modified Rational Method (USEPA 19980 and 1990).

4. To help validate the results of any of the hydrologic and pollutant load modeling described in 2 and 3 above, the HVA should monitor stream flow under baseline and storm flow conditions in the lake's 2 – 4 most significant tributaries. Princeton Hydro is working at present with HVA volunteers in development of standardized field procedures of the collection of these data. In general, this will entail the measurement of the geomorphometry of the stream channel or the dimensions of the culvert/conduit and the periodic measurement of flow using a flow meter. Once a stage-flow curve has been established for each monitored stream, a staff gage can be erected. Future measurements of flow can then be accomplished by recording the water height on the staff gage and converting the reading, using the stage-flow curve, into a flow or volume.

5. Quantify the phosphorus load contribution originating from septic systems still in operation within the Honeoye Lake watershed, especially any within 300 feet of the lake or a tributary. This can be accomplished by identifying and counting the number of houses still using septic systems and applying the loading coefficients developed for septic systems as per the USEPA (1990) and as discussed in Souza and Koppen (1983) and Brzozowski and Souza. (1984).

6. Quantify the waterfowl contribution to the lake's annual phosphorus load. This will entail counting the number of Canada geese present on the lake (average monthly counts), computing an annual average and multiplying the average number of observed geese the loading coefficients available in Uttormark et, al. (1974).

As mentioned in point 4 above, the results of the phosphorus budget should be compared to actual phosphorus loads entering Honeoye Lake. The modeled data should be validated through a sampling program that involves the collection of phosphorus data from each of the major streams and tributaries under both storm event and baseline flow conditions. From 1999 to 2002 a stream / inlet water quality monitoring program has been implemented for Honeoye Lake. Both storm event and baseline water quality samples have been collected for a variety of parameters, including TP, nitrate-N, TKN and total suspended solids. As previously discussed, the data show significant concentrations of phosphorus are measured in the lake's tributaries during storm events. The increases in TP concentrations are directly related to increased sediment loading. In addition, the concentrations of TP in the streams are particularly high in the spring, immediately in advance of the growing season. This spring influx in TP and sediments may set the stage for in-lake algal blooms.

The field data pertaining to stream flow are significantly lacking. This data is greatly needed and the HVA is currently in the process, with volunteers and assistance from the FLCC, to initiate the collection of stream flow data under both base flow and storm flow conditions. As mentioned above, Princeton hydro is providing guidance to the HVA with respect to the establishment of stream monitoring stations and the collection of stream flow and water quality samples.

Once a suitable stream database is developed, the measured pollutant concentrations can be multiplied by the flow data (estimated or measured) to quantify pollutant loads. In turn, the phosphorus loads can be used to update and validate Honeoye Lake's phosphorus budget.

3.2 Assessment of the Lake's Internal Phosphorus Load

The long-term water quality database indicates that in-lake phosphorus concentrations have declined somewhat since the 1970's. This has resulted in a slowing of the lake's eutrophication and an increase in water clarity, due to a reduction in the amount of algal biomass. In spite of this, a relatively severe algal bloom was experienced in the lake during the summer of 2002. The severe regional drought in 2002 more than likely contributed to this bloom, however, other potential forcing factors played a role in the development and sustenance of the bloom. The data suggest that internal phosphorus recycling from the lake's sediments and the release of phosphorus from decomposing plants and zebra mussels and the excretory products of zebra mussels played a major role in initiating and then sustaining the bloom. Although under climatologically normal conditions, the lake's internal phosphorus load probably accounts for a substantial proportion of the lake's summer phosphorus load, under very dry conditions, this internal load may be the primary driving factor, and a significant determinant, as to whether the lake is algae or weed dominated.

In order to identify the specific mechanism(s) responsible for the summer algal blooms, a set of recommendations have been developed for the existing monitoring program for Honeoye Lake. The lake should be monitored at least eight times during the growing season; May (1), June (1), July (2), August (2) and September (2). During each sampling event, a total of seven mid-lake sampling stations should be monitored for *in-situ* parameters such as temperature and dissolved oxygen from the surface to the bottom. Such detailed data will provide the water column specific information needed to quantify the lake's internal phosphorus load.

Discrete surface, mid-depth and bottom water samples should be collected at a mid-lake, sampling station that corresponds to the lake's deepest area, during each sampling event. These samples should be analyzed for total phosphorus (TP), soluble reactive phosphorus (SRP), total dissolved phosphorus (TDP), ammonia-N and nitrate-N. Organic phosphorus concentrations will be quantified from the results of the TP, SRP and TDP samples. Surface, mid-depth and bottom water samples should also be collected during the same sampling events for phytoplankton and zooplankton identification. Such data will be particularly useful in identifying potential bloom-forming genera of algae in Honeoye Lake, as well as the relative abundance of herbivorous (algae eating) genera of zooplankton. In turn, such data will be used to more closely manage the lake in terms of avoiding summer algal blooms.

An examination of the nitrogen (dissolved inorganic nitrogen) to phosphorus (total phosphorus) ratios (N:P ratios) should be conducted using the 2003 phosphorus and nitrogen data. It has been documented that even when phosphorus concentrations are relatively low, a low N:P ratio (that is, a proportionally larger amount of phosphorus relative to nitrogen) can favor the growth of nuisance blue-green algae. Such conditions may exist in Honeoye Lake.

Monitoring of the zebra mussels should be continued. This monitoring should include quantification, at the end of the growing season, of the numbers and population densities of zebra mussels in the shallow and deep-water zones of the lake. In addition to collecting data on the densities and mean weight of the zebra mussels, water samples should be collected immediately over the mussel beds and analyzed for total phosphorus, soluble reactive phosphorus, total dissolved phosphorus and ammonia-N. As mentioned above, the three phosphorus parameters will provide the information necessary to quantify organic phosphorus concentrations. These samples should be collected during three separate sampling events; once in late spring, once in mid-summer and once in late summer. The resulting data will be used to measure the potential loading of ammonia-N and various forms of phosphorus from the excretory products of zebra mussels.

Monitoring of the aquatic plant community should also continue. Detailed surveys, such as those conducted in 1984 and 1994 provide extremely useful data pertaining to the management, spread or decline of aquatic plants. At a minimum, it is recommended that in 2003 the relative distribution of the dominant / nuisance plant species and an estimate of the percent of lake bottom covered with rooted aquatic plants be quantitatively determined. Such data, coupled with mechanical weed harvesting records, will be used to quantify the internal phosphorus load originating from the aquatic plant community.

Finally, in order to both assess the potential short-term impacts of internal phosphorus sources, as well as develop a long-term management plan for both the lake and its watershed, a phosphorus budget analysis must be conducted. Essentially, all major sources of phosphorus should be quantified with the most current in-lake and watershed-based data. As discussed in 3.1 above, the developed phosphorus budget can be validated with water quality data collected during both storm event and baseline conditions. With all major sources of phosphorus quantified, efforts can be implemented to develop a cost effective, holistic Management Plan for Honeoye Lake.

3.3 In-lake Management / Restoration Techniques

In-lake management / restoration techniques are designed to improve the water quality and / or the aesthetic use of a waterbody by alleviating specific symptoms of eutrophication. Although these measures typically provide only short-term relief without controlling the source of the pollutants, they can substantially improve the aesthetics of a lake while the long-term, watershed-based management practices are being implemented. However, in the case of Honeoye Lake, some of these in-lake restoration measures are the key to the lake's long-term management.

3.3.1 Copper-based Algacide Products

One of the most obvious and frequently utilized means of controlling excessive algal growth is application of copper sulfate ($CuSO_4$) based algacides. The application of copper sulfate is an extremely effective means of killing a large portion of the resident algal community, however, this response is brief and only controls the symptom of the problem (excessive densities of algae) and not the cause (nutrient loads).

Several undesirable environmental impacts are known to be associated with copper-based algacide treatments. Negative impacts include fish and zooplankton toxicity, the depletion of dissolved oxygen, copper accumulation in the sediments, increased internal nutrient recycling and increased tolerance to copper by some nuisance species of blue-green algae. Zooplankton serve as a natural means of controlling excessive algal growth. In sufficient numbers, the zooplankton will limit, on their own, the development of algal blooms. However, zooplankton are known to be more sensitive to copper than algae. In fact, copper sulfate is approximately ten times more toxic to zooplankton then it is to phytoplankton. In addition, the generation time of zooplankton is substantially longer than algae. Therefore, these organisms require a longer amount of time to recover from copper treatments relative to algae. While the phytoplankton community can recover from a copper treatment within 1-2 weeks, recovery of the zooplankton community may take several weeks. Thus, the phytoplankton tends to rebound quicker than other aquatic organisms from copper treatments. If copper treatments cause a decline in zooplankton densities, a perturbation of the lake's food web will be experienced, resulting in the loss of the natural control of algal densities. Nominal use of copper based products will allow the zooplankton to proliferate and, in turn, graze on the algae.

There are other negative side effects of frequent copper treatments. After copper sulfate kills algae, and possibly other non-target organisms, in-lake rates of bacterial decomposition will substantially increase. Such elevated rates of bacterial decomposition will consume dissolved oxygen (DO). If bacterial respiration is too high, it is possible for in-lake DO concentrations to decline to levels that would negatively impact non-target organisms (i.e. fish). Such conditions can result in a fish kill, especially during the summer months.

The depletion of DO will mostly likely not be a problem in Honeoye Lake during the first half of the growing season due to its relatively shallow depth and extreme propensity for vertical mixing. However, the potential for the depletion of DO, especially during the later half of the summer, is certainly stronger if copper sulfate treatments are conducted. As the *in-situ* data revealed, DO concentrations in Honeoye Lake can at times become depleted (< 4 mg/l), especially when algal blooms are prevalent during the late summer and early fall seasons. Such declines may result in anoxia (DO concentrations < 1 mg/l), which in turn, increases the rate of TP release from the lake's sediments.

The expected potential problems of a copper sulfate treatment out weigh the expected benefits. Therefore, this in-lake management technique should be avoided. Treating intense Cyanobacteria blooms or expansive algal mats with copper sulfate will likely only further degrade water quality conditions and trigger even more intense Cyanobacteria blooms.

3.2.2 Biomanipulation

Within the scope of this study, biomanipulation is defined as "a series of manipulations of the biota of lakes and of their habitats to facilitate certain interactions and results which we as lake users consider beneficial - namely reduction of algal biomass and, in particular, of blue-greens" (Sharpiro 1990). In effect, biomanipulation is the re-structuring of the aquatic food web to favor the growth of beneficial algae and minimize the density of blue-green algae. An increase in piscivorous fish biomass could result in a decrease in planktivore (smaller forage fish) biomass. This in turn reduces grazing on the zooplankton, leading to increased zooplankton biomass and a decrease in phytoplankton biomass. These conditions ultimately produce an increase in water clarity and quality. Although there is some evidence to suggest that restructuring of the food chain would be beneficial, there is insufficient fishery and zooplankton data to recommend any fish stocking other than that done to simply improve the recreational fishery.

Biomanipulation can also be used to define the use of organisms to biologically control nuisance aquatic plant species. The vast majority of the research, and applications of this research, done to date has been with respect to the biological control of Eurasian milfoil with the milfoil weevil (*Euhrychiopsis lecontei*). More attention has recently been focused on the utility of the aquatic moth (*Acentrai ephemerella*) for the control of invasive aquatic plants. Some biological control has also involved the introduction of "weed eating" fish, such as the Asian grass carp (*Ctenopharangyedon idella*), to control aquatic macrophyte densities in general. Given the occurrence of *Myriophyllum* in the lake, the use of weevils or aquatic moths does appear feasible. However, before this can be done on a scale of any significance, it will be necessary to conduct a survey of the lake. The survey is needed for two main reasons. First, it is important to identify whether any of these milfoil control organisms are already present in the lake. If these organisms are currently present in the lake in low numbers, information is needed to determine why their densities are so low. Conversely, if the organisms are not present, information is needed to determine what factors inhibit their existence in the lake.

Second, before weevils or moths are stocked or transferred into Honeoye Lake, an assessment must be made as to whether suitable habitat exists for their successful introduction and subsequent establishment in the lake.

Although the introduction of grass carp is allowed in New York, Princeton Hydro does not recommend the stocking of this fish. First, their introduction, based on a price of approximately $10 to $15 / fish and a stocking density of 5 to 10 fish per acre, the cost is prohibitive. Second, and more importantly, there is insufficient fishery data for Honeoye Lake to evaluate whether the introduction of the grass carp would negatively impact the lake's fishery.

While biomanipulation, as defined above, is recommended for Honeoye Lake, there are some management activities / strategies that should be considered to ensure that fish habitat is maintained or enhanced. These management strategies include maintaining approximately 20% surface area coverage of aquatic plants. Based on numerous studies, weed coverage of approximately 20% favors the development of a large and healthy population of largemouth bass, while at the same time provides refuge for herbivorous zooplankton. Thus, aquatic plant control measures (discussed later in this section of the report) need to focus on the control, but not the complete eradication, of rooted aquatic plants in Honeoye Lake. Also, as mentioned above, avoid the use of copper-based algacides that may impact zooplankton and fish. While such chemicals do produce temporary control over nuisance algae, they can exert major perturbations on other non-target organisms within the food web.

3.2.3 Contact and Systemic Herbicides

The excessive density of rooted exotic aquatic plants, such as Eurasian water milfoil, is the primary factor impacting the recreational use of Honeoye Lake. The control of these plants is important to the overall success of the any long-term lake and watershed management plan. Currently, the control of aquatic macrophytes is a major priority of the HVA.

One of the most commonly used weed control techniques is the application of a contact herbicide. As the name implies, a contact herbicide impacts plants by coming in contact with the plant tissue. In doing so, the product penetrates the cell wall and causes the cells to lyse or disintegrate. To be effective, contact herbicides need to be introduced only after weed densities have started to peak. Because of their mode of action, these products typically need to be added at least twice over the course of the growing season to control first the early growing plants and then the plants that grow later in the summer. In some cases, depending on local climatic conditions and the nuisance species targeted for control, three or more treatments may be annually required through the course of one growing season. Each treatment, especially when conducted later in the growing season, increases the opportunity for phosphorus liberated from decomposing weeds to be channeled into algae biomass.

Contact aquatic herbicides function similarly to copper-based algacides; that is they provide immediate, short-term control of excessive densities of nuisance aquatic plants. Thus, contact herbicides have many of the advantages and disadvantages associated with copper-based algacides. The advantages include a fairly immediate (days to weeks) reduction in nuisance plant densities and relatively low associated costs. The disadvantages to the treatment of the lake in total with a contact herbicide include potential impacts to non-target, desirable macrophytes, a depletion of DO as a result of the bacterial decomposition of the dead organic matter, and the recycling of nutrients back into the water column that would otherwise be bound in plant biomass. In fact, algal blooms, especially Cyanobacteria that are biologically capable of effectively making use of the organic phosphorus liberated form the decomposing weeds, can occur immediately after the application of contact herbicides.

Given the balance between the benefits and impacts associated with contact herbicides, these chemicals are not recommended for the general control of Honeoye Lake's weed problems.

In contrast to contact herbicides, a systemic herbicide affects the targeted plant internally instead of externally. That is, uptake of the chemical disrupts biochemical functions thereby killing the plant. Sonar[R] and Avast[R] are two systemic aquatic herbicides. The active ingredient in these products is fluridone, which is assimilated through the roots and into the plant tissue early in the growing season, before significant plant biomass has developed. There it begins to disrupt the production of chlorophyll pigments, which are used in photosynthesis. This effectively "starves" the plant and it dies. This mechanism is in sharp contrast to contact herbicides that "burn" the plant tissue from the outside.

There are a number of advantages to using systemic, fluridone based herbicides relative to contact herbicides. First, contact herbicides typically require multiple applications, typically between two and four treatment, through the course of one growing season to obtain an acceptable level of control. In contrast, if properly timed and executed, one systemic herbicide treatment application can result in an entire year of control. Second, while contact herbicides need to be applied to lakes when plant biomass is peaking, fluridone is typically applied in the spring when seasonal growth rates are high, but before the plants have achieved maximum biomass. This treatment strategy effectively eliminates the depletion of DO and the possibility of fish kills; a potential secondary impact associated with large contact herbicide treatments. In addition, because the systemic herbicide treatment is conducted before the presence of a large amount of aquatic plant biomass, the liberation of phosphorus from dead and decomposing plants is far less that that experienced following a typical contact herbicide treatment. This decreases the likelihood of a treatment spurred algal bloom (Souza and Lubnow, 2000). Other advantages of fluridone use over contact herbicides are its extremely low toxicity on non-target organisms, its ability to control certain nuisance weed species while having nominal impact on desirable, non-target native species, and its ability to quickly bio-decompose.

There are some disadvantages associated with the use of a fluridone based systemic herbicide fluridone. The primary disadvantage is its relatively high cost. Although the volume of fluridone needed to impact nuisance species is low (on average 20 ppb), the typical unit cost of fluridone is over an order of magnitude greater than that of contact herbicides. Another disadvantage of fluridone use is that due to its mode of action, it is a slow acting herbicide, taking a minimum of 30 days to manifest some observable degree of plant control. As such, targeted control concentrations need to be sustained over the course of at least a month. This means outflow from the lake needs to be minimal during the period of treatment and the product may need to be introduced in a series of "splits". This increases the opportunity for improper introduction of the herbicide and sub-optimal control. Finally, in waterbodies such as Honeoye Lake where there are nearby well fields and water is diverted for lawn irrigation, special precautions and use-restrictions would need to be enacted. Specifically, the herbicide cannot be introduced within a safe distance of the well fields and residents will need to avoid watering lawns and gardens for 45 - 60 days from the time the chemical is first applied.

Weighing the benefits of implementing a fluridone treatment program against the costs and potential disadvantages of such a program, the implementation of this in-lake management technique is not recommended at this time for Honeoye Lake. Besides milfoil, as shown on Table 3, there are other plants in the lake including both native, desirable species of *Potamogeton* and bass tape grass (*Vallisneria*). The application of fluridone is not recommended for two main reasons:

1. Although many *Potamogetons* are not affected by the fluridone dosage rates used to control milfoil, they can be impacted. Until there is greater understanding of the location, density and occurrence of these species, the use of a systemic herbicide should not be conducted. It would be disastrous to reduce the densities of the beneficial plants and then have milfoil take over the newly available habitat.

2. Bass tape grass, another aquatic plant that impacts the recreational use of Honeoye Lake, is not affected by fluridone (or for that matter by any aquatic herbicide). As such, treatment of the lake with fluridone, specifically for the purpose of controlling this species, would yield no measurable benefit.

3.2.4 Mechanical Weed Harvesting

An alternative to the chemical control of nuisance aquatic plants such as Eurasian water milfoil, is the physical removal of the plant biomass via mechanical weed harvesting. A mechanical weed harvester can be thought of as an "aquatic lawn mower". A floating, barge-like machine, the harvester cuts and collects aquatic vegetation. The cut plant material is removed from the lake, transferred to dump trucks and transported off-site for disposal at a controlled location. For the past 10 + years, harvesting has been used as the primary means of controlling the lake's aquatic weed problem. To date, the program has been successful.

The advantages of mechanical weed harvesting include:

1. Avoidance of the potential negative side-effects associated with chemical control techniques,

2. The ability to achieve a high degree of plant removal within targeted control areas while maintaining desirable densities of aquatic plants in non-targeted areas,

3. The removal of the phosphorus load associated with the harvested plants, and

4. Through the implementation of creative harvesting techniques, the creation of "edge areas" that improve or enhance fish habitat, increase the predation success of piscivorous fish on forage fish, and improve recreational fishing.

As with any lake management technique, weed harvesting has some disadvantages or negative aspects as compared to alternative weed control techniques. These include:

1. The potential removal of macroinvertebrates and young fish along with the harvested vegetation,

2. Harvesting tends to proceed slowly (typically 1/2 – 2 acres per hour depending weed densities) often causing lake users to become impatient and dissatisfied with the results,

3. The inability to harvest weeds growing close to shore (in water < 18" in depth), between and around docks, and in areas where there are numerous submerged impediments such as rocks, fallen trees and sand bars,

4. Typically, the need (and associated cost) for the multiple harvesting of the same area over the course the growing season,

5. The need and cost for the disposal of the harvested plant biomass,
6. Operational and maintenance cost for the machinery, and

7. For plants that reproduce primarily through fragmentation (such as Eurasian water milfoil) the spread of plant fragments into non-infested areas caused by the improper harvesting or collection of targeted plants.

Based on information provided to Princeton Hydro, care is taken as part of the Honeoye Lake weed harvesting program to minimize the spread of fragments and to control the collection of fragments (or floaters) from harvested areas. This is also supported by the weed data compiled by Gilman (1985, 1986 and 1994) and information contained in the 2002 NYSDEC CSLAP summary report.

Although the program as it now exists is effective, some improvements could be made to increase overall effectiveness and expand the benefits of the program. This will entail the purchase and operation of additional machinery and the identification and use of additional drop off locations. For the past 15 + years, Princeton Hydro has managed Lake Hopatcong. The 2,500-acre lake is New Jersey's largest recreational waterbody. Weed densities are problematic and interfere with the lake's recreational use. There are over 10,000 boats, of differing sizes, uses and power configurations registered on Lake Hopatcong. In 1986, with monies made available through the USEPA and NJDEP, two 8-foot harvesters were purchased. When operating at their peak, these machines annually harvested approximately 2.5 million pounds of weeds. However, as harvesters became older, their performance and the effectiveness of the harvesting program declined. In 2001, the harvesting fleet was replaced with two new 8-foot harvester, two 6-foot harvester, and two high-speed transport barges. Although harvesting was conducted for one fewer month than in the past, over 5 million pounds of weeds were removed from the lake. The increase in productivity was linked largely to the use of the smaller machines in the tighter areas where docks and shoreline impediments existed and the use of the transport barges to ferry cut weeds to the drop off points.

It is recommended that the Honeoye Lake fleet be increased. At a minimum, we recommend that an additional 8-foot harvester be purchased, and possibly a transport barge be added. Based on information supplied to us, we also feel that greater productivity could be achieved if additional drop off points were established around the lake. Given the number of private properties directly on the lakeshore, this will require a considerable amount of effort on the part of the HVA to accomplish. However, by decreasing the haul time and increasing the harvesting time, improvements in productivity will be achieved.

3.2.5 Aeration

Aeration techniques are typically used to accomplish one of three objectives:

1. Introduce additional dissolved oxygen into the water column for the improvement of a lake's fishery,
2. Maintain a lake's water column in a well mixed, destratified state, and
3. Reduce hypolimnetic anoxia to control the release of phosphorus, minerals and metals from the sediments.

For Honeoye Lake, there has been discussion of the possible installation and operation of a destratification aeration to prevent thermal stratification and control internal recycling of phosphorus.

There are various aeration techniques, each suited for particular applications. For shallow lakes (< 30 feet), the most effective aeration technique is destratification. These types of aeration systems can range in price from $5,000 to well over $100,000 depending on the size and morphometry of the lake. For a lake the size and depth of Honeoye Lake, an installed destratification aeration system will likely be in the range of $100,000. This is based on our experience in the design and installation of destratification aerators in other lakes of relatively similar size to Honeoye Lake.

In the northern temperate lakes, that achieve depths in excess of 6 feet, thermal stratification is a normal process that occurs in the summer. It results from the heating of the water's surface by the increased intensity and duration of the summer sun. Waterbodies that stratify in the summer are subject to the formation of anoxic zones, typically close to the bottom of the pond or lake. These anoxic zones are devoid of oxygen. Not only will fish and other biota be unable to live in the anoxic zone of a lake, but also because of resulting changes in sediment redox properties, large amounts of phosphorus will be released from the sediments. As discussed elsewhere throughout this report, this internally recycled phosphorus can stimulate algae blooms. Typically, any lake greater than six feet in depth is subject to stratification and its associated problems. However, even shallower lakes, especially those having limited through-flow or wind mixing, can stratify. Although the degree of stratification is usually weaker than that observed in deeper lakes, it can be intense enough, and of sufficient duration, to trigger all of the above noted impacts.

Various destratification aeration techniques could be used to address the periodic anoxic conditions that develop in Honeoye Lake. Surface and subsurface destratification aerators are commonly used in shallow waterbodies such as Honeoye Lake to inhibit stratification, improve the vertical circulation of the water column, increase dissolved oxygen concentrations and control the formation of algal scum. These aerators typically use an airlift approach to stimulate water column mixing and to prevent the formation of the thermal gradients that cause a lake to stratify.

Review of the Honeoye Lake data show that the lake does in fact stratify; although the stratification is weak. More importantly, the data show a measurable mid-summer decline in DO with increasing water depth. Anoxic conditions are shown to be limited to waters in excess of approximately 22 feet. As such, aeration of the lake may be warranted, as it would help support fish life in the deeper reaches of the lake and help control the internal recycling of phosphorus. Although there are data to indicate that the lake experiences bouts of anoxia, the occurrence of these conditions seem too inconsistent to justify the need for the installation of a destratification aeration system. Thus, based on the available data and our experience with the design and installation of aeration systems, the installation of a destratification aerator is not recommended. The extent of stratification is not great enough to warrant the projected costs and there are better, more economically suitable means to control the lake's internal phosphorus loading.

3.2.6 Drawdown

Drawdown, the temporary lowering of a lake, is typically conducted for the purpose of weed control. Most lake drawdowns in the northeast are conducted in the winter. Lowering of the lake is achieved by diverting inflow or opening a valve, gate or other type of control device at the lake's dam or outfall. The lake is partially drained, allowing the littoral zone to become fully exposed to the elements. Once lowered, the lake is left in a drawn down state over at least a two-month period during the middle of the winter.

Drawdowns capitalize on exposure, freezing and desiccation to kill plant seeds or destroy roots and rhizomes. Exposure of the hydrosoils and remaining plant biomass in the littoral zone facilitates their freezing and physical disturbance. The impact of drawdown on the control of aquatic macrophyte growth is variable and largely dependent on the targeted species. For many of the most common nuisance aquatic species, this in-lake management technique is at best marginally successful. Milfoil (*Myriophyllum sp.*) and lilies (*Nuphar sp.* and *Nymphaea sp.)* tend to be affected. However, some weeds, for example curly leaf pondweed (*Potamogeton crispus*), may actually exploit such conditions. This plant reproduces, in part, by the spread of turions, specialized reproductive seedpods. The leathery nature of the pods increases their resilience to exposure, desiccation and freezing. Essentially, following a drawdown, curly leaf pondweed will colonize and/or expand their coverage into areas where other plants have been weakened or eliminated. Thus, it not uncommon to observe an increase in the density and occurrence of this plant following a winter drawdown.

In conclusion, drawdown is not a feasible management technique for Honeoye Lake. Besides having a deleterious impact on ice fishing and the winter use of the lake, the technique is not physically possible due to the design of the outfall and the bathymetry of the lake. It is not physically possible to alter the lake's pool elevation a significant enough amount to achieve a desirable degree of littoral area exposure. As such, not enough of the lake's perimeter shoreline would be exposed to achieve a measurable and effective impact on the weed beds. In addition, given the presence of curly leaf pondweed in the lake, there is the chance that a drawdown could promote the spread of that plant.

3.2.7 In-situ Treatment of Sediments with Alum

Measures need to be taken to better control the release of phosphorus during periods of anoxia from the lake's deep-water sediment deposits. As shown in the data compiled by both the NYSDEC and Gilman, mid-summer deep-water phosphorus spikes occur. The bottom water concentrations of TP following these episodes of sediment recycling are 3 to 5 times greater than those measured at the lake's surface. An alternative to aerating the water column, to prevent stratification, anoxia and phosphorus recycling, is the treatment of the sediments with alum. While aeration prevents the development of DO depleted conditions that favor the rapid release of phosphorus from the sediments, alum treatments help "fix" the phosphorus in place so that it is not excessively liberated and recycled into the water column. Alum treatment of the lake's sediments appears to be a particularly effective solution for the control of internal phosphorus recycling (Cooke, et. al. 1993).

Sediment "sealing" or "blanket" applications of alum involve the introduction of alum via a barge. The material is dispensed over the surface of the lake. The resulting alum floc coagulates and slowly settles to the lake bottom. The floc then becomes incorporated into the sediments. Phosphorus released from the sediments, either during aerobic or anaerobic conditions, is bound by the alum "blanket". This effectively reduces the liberation of phosphorus into the water column thereby decreasing the magnitude of the internal load. This form of alum treatment has been used for well over two decades in the management of lakes. As such, there are a considerable amount of scientific data and reports that validate the effectiveness of the alum blanketing of lake sediments. Princeton Hydro has implemented this type of alum treatment for at least six waterbodies. Based on the available data, it appears that an alum dose of approximately 150 gallons/acre will be required to properly treat Honeoye Lake. Approximately 40-60% of the lake's total bottom area should be treated. Alum should not be introduced in areas less than 8 feet deep, areas within 100 feet of the shoreline or in close proximity to the outlet of the lake. We anticipate, based on our previous work of this nature and the available data on alum blanketing, that the longevity of such an alum treatment should be on the order of 3 to 5 years.

However, before applying alum to the lake's sediments, a considerable amount of work will need to be conducted. First, the lake's flushing rate needs to be better quantified. This will aid in computing alum treatment dosages and evaluating the longevity of the treatment. Second, additional sediment cores will need to be collected for the analysis of a variety of chemical and physical parameters including grain size, organic content, percent solids, phosphorus concentration, and iron concentration. Third, a bench test will need to be conducted to evaluate appropriate and safe alum dosing rates. It is acknowledged that NYSDEC approvals will likely need to be obtained in advance of the alum treatment.

3.2.8 Fishery Management

Since recreational fishing is an important activity at Honeoye Lake, the management of its fishery needs to be addressed. Fishery surveys are typically conducted in Honeoye Lake once every three years. This year (2003) is the third year since the last fishery survey. The fishery survey conducted this coming year should focus on two primary objectives. First, data should be collected that properly identify the general health and population structure of the popular game fish and their associated forage fish. This information is needed in order to assess the current recreational value of the Honeoye Lake fishery community. Second, data should be collected to identify any fishery species that may be undesirable and/or invasive. Prior to 1996, alewife exerted a strongly negative impact on the water quality of Honeoye Lake. This was the result of the alewife's intense feeding on the herbivorous zooplankton community. However, a thermal event, coupled with predation pressure exerted by the lake's walleye population, decimated the alewife. This helped improve the lake's water clarity. A reintroduction of the alewife should not be allowed, regardless of the need to improve the lake's predatory fish food-base.

At this point in time, the fishery management action that appears most in need of implementation is a reduction in the legal catch limit for walleye. The latest fishery data indicate that the walleye fishery is stressed. The NYSDEC has concluded this is due to the overpopulation of this species. The NYSDEC has also concluded that the dense walleye population is having a negative impact on the lake's yellow perch population. A reduction in the legal size limit from 18" to 15" appears warranted.

The high numbers of sunfish need to be tracked. The increased density of the lake's weed beds may be inhibiting predation on bluegills and pumpkinseeds. Improvement in the harvesting program could positively aid the lake's largemouth bass fishery by thinning out the weed beds and increasing the opportunity for predators to graze down the pan fish community. This could be accomplished in the less developed sections of the lake's shoreline by creating fishing lanes (long, narrow rows) in the weed beds. These lanes increase the amount of edge habitat, which facilitates predation by bass, pickerel and pike. The lanes also are a benefit to recreational anglers, providing them easy access into the densely weeded portions of the lake without the fouling of their props.

3.3 WATERSHED MANAGEMENT – CONTROL OF EXTERNAL LOADING

In contrast to in-lake restoration techniques, watershed based techniques focus on the control of the cause of eutrophication rather than its symptoms. In essence, this translates to the management and reduction of sediment, nutrient and pollutant loading. The benefits of watershed management are usually neither as obvious nor as quickly observed, as the results of in-lake restoration techniques. The results of nutrient and sediment control efforts tend to take more time to be achieved and the resulting positive benefits observed. However, they are absolutely vital to the realization of effective, long-term improvements in the water quality and deceleration of the rate of eutrophication.

Watershed control measures are designed to reduce non-point source (NPS) pollution. NPS pollution is very diffuse, being generated over a relatively large area and originating from a wide variety of sources. For Honeoye Lake, the primary pollutants of concern are phosphorus and total suspended solids. Based on the information contained in the available reports, the primary sources of these pollutants are stormwater runoff from pervious and impervious surfaces. Contributions of these pollutants, as based on the measured in-stream TP and TSS concentrations, come from both residential and non-residential sections of the watershed. Over time, action must be taken to control these sources. Again, data generated through the implementation of a comprehensive modeling and sampling effort of the watershed are required in order to determine how best to direct and implement NPS control efforts. Some of the possible watershed management measures that should be considered by the HVA include:

1. The upgrade of the stormwater collection system draining runoff from the other more urbanized sections of the watershed. In effect, existing catch basins should be upgraded to basins that have a higher trap efficiency and have the ability to capture and retain sediments and particulate pollutants.

2. Implementation of septic management practices in those portions of the watershed that still rely on septic systems for the treatment of wastewater. This can be accomplished to some extent through septic management, which includes scheduled septic system inspections and septic tank pump outs, the use of low or non-phosphorus wash products, and proper care and management of the septic leach field.

3. Fertilizer and lawn care product management would also help reduce the phosphorus load to the lake. This is mostly accomplished through public education and outreach that emphasizes the role of lawn fertilizers in the eutrophication of lakes. Some lake communities have implemented non-phosphorus fertilizer ordinances to further control lawn related phosphorus loading.

Until more comprehensive and up to date watershed and tributary loading data are developed, storm sewer and catch basin upgrades should not be implemented. Without the updated pollutant load data it is not possible to properly prioritize, size or design structural NPS control measures, typically referred to as best management practices (BMPs). Conversely, public education and outreach efforts should be continued. The HVA has already done a considerable amount of work toward educating lake residents and raising their awareness concerning their role in the eutrophication of the lake. They have also been using educational materials to inform residents and lake users of the actions that they can take on their own to reduce pollutant loading and stem the lake's eutrophication.

3.4 EVALUATION OF MANAGEMENT AND RESTORATION ALTERNATIVES

The feasibility of each of the above potential in-lake and watershed measures was evaluated and judged on the basis of:

1. Pollutant reduction - How substantial a decrease in nutrient and/ or sediment loading could be expected from the implementation of this method?

2. Practicality - Can the method be practically implemented for Honeoye Lake and/or its watershed?

3. Effectiveness - Based on the scientific literature, how effective is this method in meeting desired management objectives?

4. Environmental Impacts - Are there any adverse environmental impacts associated with the implementation of the recommended measure?

5. Initial Costs - How much will it cost to design and initially implement the recommended measure as compared to expected improvements or returns?

6. Operations and Maintenance (O/M) Costs - How much will it cost to operate and/ or maintain the measure on a long-term, annual basis?

3.5 Recommendations

Based on these criteria the following is recommended for the long-term management of the lake and its watershed:

1. Immediately develop a long-term monitoring program. The program needs to be designed to fill specific data gaps and to provide the information needed to properly implement the recommended management measures. In particular, more accurate internal loading, phytoplankton, hydrologic, and watershed loading data are needed (Sections 3.1 and 3.2).

2. Develop a GIS based watershed model to identify pollutant loading by sub-watershed (Section 3.1). Along with this, the stormwater collection system should be mapped, and the location of all key catch basins and major outfalls located and mapped using GPS. The data generated through this effort will be used to direct specific watershed management efforts, specifically the upgrade of the existing stormwater collection system with catch basin retrofits that are effective in the trapping of sediments and particulate pollutants.

3. A detailed assessment of the lake's hydrologic budget is needed. These data are needed to better quantify watershed related nutrient and pollutant loading. Details of how these data should be collected are presented in Section 3.1 above.

4. Increase the control over the lake's milfoil and nuisance aquatic plants through an expanded weed harvesting effort. At a minimum, this will likely require the purchase of at least one additional harvester and perhaps the purchase of a high-speed transport barge. In the mean time, the HVA should identify and establish additional weed drop off points. This will increase the efficiency of the existing program by reducing the amount of time that the harvester needs to travel to off-load harvested plant material.

5. Investigate in more detail the feasibility of biological controls, specifically the

milfoil weevil and aquatic moths, for the control of Eurasian water milfoil (Section 3.3).

6. Conduct a surface application of alum for the purpose of blanketing the lake's deep-water sediments and reducing the rate and magnitude of internal phosphorus recycling. The target area should be all portions of the lake at least 8 feet deep, but especially those portions of the lake greater than 20 feet deep.

7. Avoid the use of copper based algacides.

8. Reduce the size limit on walleye to 15 inches. Monitor the densities of panfish and other zooplanktivorous forage fish.

3.6 Projected Cost Estimates for the Recommended Management Measures

The following costs reflect industry prices for the labor, materials and services associated with the recommendations presented above in Section 3.5. The costs also reflect Princeton Hydro's experience with the implementation of various lake restoration and management activities. It should be noted that with assistance from the volunteer organizations and the Finger Lakes Community College, it may be possible to decrease the overall costs of the monitoring elements of each restoration and management activity. For the purpose of clarity and consistency, the projected costs of each measure recommended above in Section 3.5 are presented in the same relative order.

3.6.1 Long Term Monitoring Program

A detailed in-lake and watershed monitoring program, involving the collection of *in-situ* and discrete water quality data, the biological monitoring of phytoplankton, zooplankton, fish, zebra mussels and fish will help address some of the significant data gaps identified in previous sections of this report. These data will also aid in the understanding of watershed/lake water quality relationships and internal nutrient recycling processes. Equally important, these data will serve as a benchmark against the improvement or the decline of the lake can be objectively assessed.

On an annual scale, assuming the monitoring is conducted on the scale discussed in Section 3.2 the annual cost of monitoring is projected to be in the range of $23,500 annually. This includes data processing, the interpretation of the data and the development of monthly and year-end reports. It is also inclusive of all labor, lab and equipment fees.

3.6.2 Stream Sampling

As discussed in Section 3.1, sampling of the lake's primary tributaries is critical of the overall relationship between the lake and its watershed is to be understood. These data will aid in the development and implementation of stormwater management initiatives and the corroboration of modeled watershed-loading data (discussed below and above in 3.5).

Sampling of the streams should be conducted under baseflow conditions during each of the in-lake sampling dates. In addition, sampling should be conducted during at least four storm events (Winter Thaw, Spring, Summer and Fall). The parameters to be measured should include all of the standard *in-situ* parameters, along with Fecal Coliform, TP, TN and TSS. Flows should be measured on each date as well.

A well-coordinated baseflow/storm stream sampling effort, involving the collection of samples at each of the main tributaries on 12 (8 baseline and 4 storm) dates will cost in the range of $8,300 to implement, assuming that the baseflow dates coincide with the in-lake sampling dates.

3.6.3 Modeling of Pollutant and Hydrologic Loads

Creation of a GIS database and its use to model the lake's watershed based pollutant load (TN, TP and TSS) and to quantify its hydrologic loads is part of the long-term understanding of the lake, its watershed and the factors that impact water quality and affect trophic state. These data are also important with respect to evaluating the longevity of an alum treatment. The Finger Lake Community College has created some of the basic GIS data layers required for these types of analyses. As such, the cost to create the actual underlying data should be minimal.

The actual modeling of the lake's pollutant and hydrologic loads can be conducted using a number of modeling techniques such as P8, SWMM and SLAMM. Using these models it is possible to compute projected in-stream concentrations for storms of various magnitude or frequency. However, these models are somewhat sophisticated and require a relatively detailed array of input data. The watershed modeling can also be conducted using UAL methodology (such as GWLF) together with a simplistic hydrologic computational approach. Although not as sophisticated as the SWM type analysis, this approach will achieve the goals of the HVLA. This approach is also the typical approach taken in moist lake diagnostic feasibility studies. As such, it is accepted by the NYSDEC and the USEPA.

It should be possible to conduct a relatively accurate assessment of the lake's hydrologic and pollutant loads using the aforementioned UAL approach. Assuming that all the required GIS data layers are available, the cost of this analysis should be in the range of $15,000 to complete.

3.6.4 Weed Harvesting Equipment Improvements

As discussed earlier, the overall efficiency of the weed harvesting operation could be improved through the purchase of another harvester, a high-speed transport barge and an additional shoreline conveyor. As based on prices obtained from Aquarius, a manufacturer of such equipment, the individual costs of the above noted equipment is as follows

Weed harvester - 8' all stainless steel construction		$120,000
High-speed transport barge – all stainless steel construction		$105,000
Trailers for above plus additional shoreline conveyor		$90.000
	TOTAL	$315,000

There will be additional labor costs to operate this equipment and additional costs associated with the operation and maintenance of the equipment.

3.6.5 Alum Treatment

Treatment of the lake with alum for the purpose of controlling the lake's internal nutrient load is estimated to cost in the range of $250,000. This includes all labor and materials. This cost is based on a projected alum dose rate of 150 gallons per acre, and treatment of perhaps 800 – 900 acres of lake bottom. This price includes permitting (authorization via the SEQR process), alum bench scale testing and monitoring before, during and after the application.

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