Lake Iroquois

Diagnostic-Feasibility Study

Executive Summary

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and Environmental Engineering
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INTRODUCTION

The Lake Iroquois Diagnostic-Feasibility was undertaken by the Vermont Department of Water Resources and Environmental Engineering under a grant agreement with the U.S. Environmental Protection Agency, as authorized under the Federal Clean Lakes Program. Matching funds were provided by the State of Vermont. The purpose of the study was to diagnose the cause of water quality problems in Lake Iroquois and to use the results of the diagnostic work to direct feasibility studies for lake restoration. The ultimate purpose was to develop specific recommendations for measures to restore appropriate water quality conditions to the lake.

Lake Iroquois has had a long-standing problem of excessive algae and aquatic plant growth that has, at times, interfered with the recreational use of the lake. Lake Iroquois was selected to undergo a diagnostic-feasibility study primarily as a result of its ranking in the Vermont Lake Classification Survey (Vermont Department of Water Resources and Environmental Engineering, 1980). The lake was one of 14 Vermont lakes which possessed a combination of high spring phosphorus concentrations, a large percentage of the watershed under cultural influence, and a high level of public use. These characteristics made Lake Iroquois a high priority for restoration efforts aimed at reducing the eutrophication problems.

RESULTS AND CONCLUSIONS

Diagnostic Studies

Lake Iroquois is a highly valued recreational resource attracting and supporting such diverse uses as fishing, swimming, boating, and residency in lakeshore homes. These uses all depend on the maintenance of good water quality conditions in the lake. However, water quality problems related to lake eutrophication, such as excessive algae and aquatic plant growth, periodically interfere with these uses.

The diagnostic studies on Lake Iroquois were designed to determine the cause of the water quality problems by evaluating the various sources of phosphorus to the lake and the dynamics of phosphorus within the lake. The phosphorus budget studies showed that the hydrology and phosphorus loading to the lake was dominated by surface inflows. The streams entering Lake Iroquois contributed more than 80% of the total external phosphorus load to the lake during 1982 and 1983.

There were major differences in the phosphorus loading rates observed among the various sub-basins of the lake's watershed. The loading rate differences were related primarily to differences in land use among the sub-basins. The predominantly wooded sub-basins on the east shore of the lake and sub-basin W-10 (see Figure 1) had the lowest areal phosphorus export rates (0.8 - 0.13 kg/ha/yr), as would be expected from relatively undisturbed areas. The sub-basins along the lake's west shore having predominantly residential land use, including sub-basins W-2, W-3, W-4, W-5, W-6, W-8 and W-9 (see Figure 1), had considerably higher areal phosphorus loading rates (0.24 - 0.72 kg/ha/yr). The elevated phosphorus loading rates from these sub-basins were caused by erosion sources associated with residential development, such as ditching, modified or unstable drainageways, and exposed soil on construction sites. High phosphorus loading rates (0.21 - 0.49 kg/ha/yr) were also observed from sub-basin W-0 (see Figure 1). This sub-basin contained two dairy farms on which some nutrient runoff was still occurring, even after the construction of manure storage facilities and other runoff control measures on these farms in recent years. The effect of the farm runoff on the lake was probably reduced by phosphorus attenuation within the wetland downstream of the farms. Dramatically high phosphorus loading rates (2.43 kg/ha/yr) were observed from sub-basin W-1 (see Figure 1) during 1983 as a result of erosion from poorly conducted excavation work the previous fall by one landowner. Bulldozing of grassland and other regrading and ditching activities caused massive erosion of sediment and phosphorus into the lake and produced the highest areal phosphorus loading rate from any sub-basin observed during the study.

The phosphorus contribution to Lake Iroquois from groundwater and septic systems was relatively minor. Groundwater contributed less than 3% of the total phosphorus budget of the lake, and phosphorus derived from shoreline septic systems was only about 1% of the total external phosphorus load. Studies on individual septic system sites showed that these systems did influence the quality of groundwater entering the lake, particularly with respect to nitrogen. However, their impact on phosphorus loading was small because of the very high phosphorus attenuation rates (greater than 95%) observed in the shoreline soils. Thus, it was concluded that septic systems were not a major influence on eutrophication in Lake Iroquois.

There remain, however, some good reasons for proper maintenance and improvement of existing shoreline septic systems. First, there are obvious public health concerns associated with failing systems and the possible introduction of disease-causing organisms that could infect swimmers and other lake users. A second reason for good septic system maintenance is that some of the aquatic plant growth in Lake Iroquois may be related to localized nutrient sources along the shoreline. A failing septic system could contribute excessive amounts of nutrients to the groundwater passing through the near-shore lake bed, and thereby nourish aquatic plant growth. Thus, while the shoreline septic systems at Lake Iroquois appear to have no significant impact on the lake-wide growth of algae, they may contribute to localized problems of aquatic plant growth in some areas.

The internal dynamics of phosphorus within Lake Iroquois were found to have a major influence on water quality in the lake. A variety of internal sources contributed phosphorus to the surface waters of Lake Iroquois at various times of the year. These sources included release from anoxic hypolimnetic sediments, decay of macrophytes, and turbulent resuspension. Anoxic sediment release was particularly important during the summer. The lake is prone to this form of internal loading because of its small hypolimnetic volume and rapid hypolimnetic oxygen depletion rates during the early summer. Phosphorus released from anoxic bottom sediments during the summer was intermittently transported upwards by vertical mixing events into the epilimnion, where algal growth was stimulated. The phosphorus released during the summer did not appear to remain in the water column through the winter to promote algal growth the following spring, however. Short-term phosphorus budgets indicated that, while there was a substantial net release of phosphorus during the summer, this was followed by a period of net sedimentation during the fall turnover and winter. The phosphorus sedimentation resulted from the re-oxygenation of the hypolimnetic waters during the fall turnover and a very effective iron precipitation mechanism in Lake Iroquois. As a result of the efficient sedimentation of phosphorus during and after the fall turnover, Lake Iroquois had annual phosphorus retention characteristics similar to those of lakes without substantial internal loading.

Paleolimnological studies provided a long-term historical perspective on water quality changes in Lake Iroquois. The lake has experienced cultural impacts on water quality since the time of first European settlement around 1800. Land clearing and widespread farming in the watershed during the 1800's corresponded with evidence preserved in the lake sediments of increased erosion and sedimentation in the lake. The major water quality changes have occurred in more recent decades, however. Sediment indicators of hypolimnetic oxygen depletion showed increases since about 1930. Hypolimnetic oxygen depletion in Lake Iroquois may have been promoted by the rise in water level caused by the construction of the dam at the lake's outlet, but it is not clear why the evidence of oxygen depletion appeared 30 years after the dam construction. Sediment indicators of trophic state also showed a marked change to a more eutrophic condition since about 1920.

The general conclusion from the paleolimnological studies is that water quality in Lake Iroquois has been degraded substantially from its original condition by cultural activities in the watershed. The degradation has been mostly gradual, and the accelerated eutrophication of recent decades has probably been caused by sediment and nutrient inputs from the residential development that has occurred during this century, and from farming operations that have become more intensive and mechanized (although fewer in number).

The studies of aquatic plants in Lake Iroquois showed the extent of their coverage and their species composition. The major area of macrophyte concentration in Lake Iroquois was in the lake's shallow northern end where the plants at times reached nuisance densities and impaired lake uses. There was some evidence that the plants have been increasing in density and areal coverage in recent years. Mechanical harvesting efforts began on Lake Iroquois during 1984, and this method represents the best way to control nuisance plant growth in the lake. Careful and limited mechanical harvesting in Lake Iroquois would provide a number of benefits, including improved recreational uses and aesthetics, and a reduction in internal phosphorus loading by plant senescence and decay. Care should be taken in the harvesting program to preserve the positive values of aquatic plants, including fish habitat, shoreline and sediment stabilization, and other biological values.

The results of the diagnostic studies on Lake Iroquois were used to determine the direction of subsequent feasibility studies for lake restoration. The paleolimnological work indicated that water quality in the lake has been degraded by cultural activities in the watershed and therefore restoration efforts are believed to be appropriate for the lake. Erosion of sediment and nutrient runoff from residential land and farm areas within the watershed were found to be the chief causes of accelerated eutrophication in Lake Iroquois. These were the sources towards which the feasibility studies were primarily directed. Feasibility studies for watershed controls focused on two approaches: structural controls and regulatory controls. It was also found that internal phosphorus loading from anoxic lake sediments played a role in stimulating algal growth during the summer. Consequently, feasibility studies were also initiated to control the internal loading.

Feasibility studies

Structural Watershed Controls

A feasibility study for erosion control in the Lake Iroquois watershed was conducted by Barbaro and Ceto (1984) of the Winooski Conservation District and the U.S. Soil Conservation Service. The Barbaro and Ceto (1984) study involved a site by site field survey of areas of erosion and nutrient runoff. Specific recommendations were made for structural control measures at each site that was a significant problem. Streambank erosion was found to be the major problem in the Lake Iroquois watershed, although erosion from roads and house sites also contributed significant quantities of sediment and phosphorus to the lake. Specific recommendations for each erosion site can be found in the Barbaro and Ceto (1984) report and associated field sheets and maps. The study found that implementation of all recommended erosion control measures would reduce the annual phosphorus loading to the lake by 74 kg at a cost of $9,200.

Barbaro and Ceto also recommended certain nutrient runoff control measures for two farms in the watershed. The implementation of these measures, which include improvements in existing manure handling facilities and diversion of runoff to grass filter strips, would reduce nutrient runoff from these farms by 60-80% (55-75 kg/yr), at a cost of $9,700.

If all the recommended structural watershed controls were implemented, the annual phosphorus loading to the lake would be reduced by about 140 kg from the existing total load of 239-359 kg/yr measured during 1982-1983. This 35-60% reduction could be achieved at relatively minor cost ($18,900), and should have substantial water quality benefits. A lake modeling analysis indicated that a 40% loading reduction would lower average lake phosphorus concentrations by 32%, from around 31 ug/l to 21 ug/l. Algal abundance, as indicated by chlorophyll-a levels, would decline by about the same percentage. Average Secchi disc transparency would increase from around 3.4 meters to 4.4 meters. The areal hypolimnetic oxygen depletion rate would be slowed by about 33%, delaying the onset of anoxia about 20 days, thereby reducing the extent of internal phosphorus recycling during the summer.

Regulatory Watershed Controls

Many of the problems identified during the diagnostic studies and in the Barbara and Ceto (1984) report could have been avoided if proper erosion control practices had been followed. Regulation of land use activities in the watershed that cause erosion could be an effective way to improve and protect water quality in Lake Iroquois. Regulatory mechanisms available to control erosion in the watershed include the enactment of local zoning ordinances, as well as voluntary self-regulation by Towns and private landowners. Vermont's Land Use and Development Law (Act 250) also provides a mechanism to require proper erosion control practices for new large developments. Regulatory controls would be particularly important in protecting the lake from future degradation resulting from new development and road-building. Considering that most of the eastern portion of the Lake Iroquois watershed is currently undeveloped, it is clear that the potential for further water quality degradation of the lake is great if this area were to be developed without proper erosion controls.

The Barbaro and Ceto (1984) report identified three major erosion sources at Lake Iroquois: streambanks, roads, and house sites. Of these three, streambank erosion was the most critical. Specific measures to protect streambanks and reduce erosion are described in the Vermont Streambank Conservation Manual (Vermont Agency of Environmental Conservation, 1982) and in Barbaro and Ceto (1984). These reports provide guidance in implementing procedures such as the following:

fencing	rip-rapping
revegetating	limiting cutting
clearing channels	protecting vegetation
	constructing sediment traps

The requirement (when applicable) that a streambank erosion control plan consistent with the recommendations of these reports be approved as a condition for a local zoning or building permit, or for Act 250 approval, would be the best way to protect the lake from future degradation from this source.

Erosion from dirt roadbeds and ditches was a second major source of sediment and phosphorus to Lake Iroquois. Specific measures to reduce erosion from existing roads are described in the Vermont Backroad Maintenance Handbook (Zulick, 1979a) and in the Barbaro and Ceto (1984) report. These reports provide guidance for the following maintenance procedures:

road surface care	ditch maintenance
road pitch control	culvert protection
vegetation establishment	inspection

Many of the maintenance and erosion problems on dirt roads can be avoided by proper design and construction techniques. The Vermont Backroad Erosion Control Handbook (Zulick, 1979b) provides guidance in the following areas:

erosion control during construction
vegetation establishment
permanent structural erosion controls

Improved maintenance of existing roads by local governments and private road associations would be the best way to minimize their adverse effect on lake water quality. New road construction in the watershed should be permitted only with strict adherence to the erosion control practices described in the references cited above.

A third source of erosion in the Lake Iroquois watershed was house sites, particularly during construction. Because there is considerable potential for future house construction in the watershed, it would be important to insure that proper erosion control practices are followed for any new construction. Specific measures to reduce erosion from house construction are described in the Vermont Handbook for Soil Erosion and Sediment Control on Construction Sites (Vermont Geological Survey, 1982) and in the Barbaro and Ceto (1984) report. These measures include the following:

site planning	sodding
water diversion	silt fencing
buffer strips	sediment basins
seeding and mulching	surface roughening
hay bale dikes	stabilizing entrance
snow fencing	

Strict conditions attached to building or land use permits for any new construction in the watershed insuring that all appropriate erosion control practices are followed would be the best way to protect the lake from degradation from this source.

In-Lake Phosphorus Controls

The diagnostic studies showed that phosphorus released from anoxic hypolimnetic sediments was occasionally transported vertically into the epilimnion where it stimulated algal growth. Because it was possible that this internal phosphorus release might still occur to some extent even after all necessary watershed controls were applied, feasibility studies were initiated for ways to control this process as well. Booker Associates (1984) conducted a study of three alternative techniques for reducing internal phosphorus loading: hypolimnetic aeration by compressed air lift, hypolimnetic aeration by pumped sidestream aeration, and phosphorus inactivation using alum. Based on the Booker Associates (1984) report, it appeared that the two leading feasible alternatives were aeration using an Atlas COPCO air lift system ($60,000 initial cost plus $5,000/yr operating cost) and alum treatment ($90,000 initial cost with no further operation cost).

Both alternatives would probably be effective, but their cost would be quite high. Furthermore, in-lake treatments such as these would be appropriate only if all possible means to reduce phosphorus loading from the watershed were implemented first. If the recommended structural watershed controls were implemented, and if strong regulatory programs for lake protection were in place, it might be unnecessary to undertake the in-lake efforts. Therefore, the best course of action would be to implement the watershed controls, evaluate the water quality gains, and then pursue the in-lake controls only if all the watershed problems are corrected and the internal phosphorus recycling continues to cause undesirable levels of algae during the summer.

In summary, the opportunity exists to improve water quality in Lake Iroquois and protect the lake from future degradation by controlling erosion and nutrient runoff from residential development and farmland in the watershed through a combination of structural measures and regulatory efforts. The cost of these measures is relatively minor. The key to their success will be the willingness and dedication of local residents and Town officials in pursuing the recommendations that follow.

RECOMMENDATIONS

1. The structural watershed controls recommended in the Barbaro and Ceto (1984) report should be implemented in order to reduce erosion from residential areas and nutrient runoff from farmland. Technical assistance in designing these structures should be requested from the U.S. Soil Conservation Service. Funding should be sought from the Federal Clean Lakes Program, the Vermont Aquatic Nuisance Control Program, or other sources.

2. The regulatory watershed controls recommended in this report should be implemented in order to protect water quality in Lake Iroquois from the effects of future development. The possibilities for regulatory controls should be explored through discussions with town officials, the District Act 250 Commission staff, and the local residents and lake associations. Technical assistance in establishing regulations and in monitoring compliance should be sought from the Chittenden County Regional Planning Commission, the Vermont Association of Conservation Districts, and the U.S. Soil Conservation Service.

3. Any in-lake treatment such as alum treatment or hypolimnetic aeration to control internal phosphorus loading should be postponed until all possible structural and regulatory watershed controls are in place. In-lake treatments should then be considered only if undesirable levels of algae continue to exist as a result of vertical transport of hypolimnetic phosphorus during the summer.

4. Mechanical harvesting of aquatic plants in Lake Iroquois should continue, with care taken to balance the need for selective removal of nuisance aquatic plants with the need to preserve the beneficial values of these plants.

5. The wetland at the north end of the lake (in sub-basin W-0) should be preserved to help protect Lake Iroquois from the effects of nutrient runoff from the farmland upstream.

REFERENCES

Barbaro, H.L. and N. Ceto. 1984. Lake Iroquois watershed erosion study. Prep. for Vt. Dept. Wat. Res. Env. Eng.

Booker Associates. 1984. Lake Iroquois feasibility study of hypolimnetic aeration and alum treatment. Prep. for Vt. Dept. Wat. Res. Env. Eng.

Vermont Agency of Environmental Conservation. 1982. Vermont streambank conservation manual.

Vermont Department of Water Resources and Environmental Engineering. 1980. Vermont lake classification survey. Water Quality Surveillance Series. Report No. 8. Montpelier, VT.

Vermont Geological Survey. 1982. Vermont handbook for soil erosion and sediment control on construction sites. Spec. Publ. No. 3.

Zulick, C.A. 1979a. The Vermont backroad maintenance handbook. Prep. for Vt. Ag. Env. Cons.

Zulick, C.A. 1979b. The Vermont backroad erosion control handbook. Prep. for Vt. Ag. Env. Cons.