Development of Lake Water Quality Management Programs*

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Water quality management programs for lakes and impoundments that are experiencing deteriorated water quality related to eutrophication (excessive fertilization) should first focus on phosphorus input control. However, even with the control of phosphorus to the maximum extent readily achievable, most such waterbodies will still experience deteriorated water quality with the result that there will be need for an additional water quality management program. Presented below is an outline of the water quality management program that is recommended for all lake associations and municipalities that have the responsibility for lake water quality management. This program is applicable to lakes and impoundments. Additional information is available from the authors upon request.

Shoreline Cleanup

At twice weekly intervals from about May 1 through October 15 the shoreline (land and water) should be cleaned of all debris, weeds, and algal scum. The removal of algal scum may require vacuuming of the water. This clean-up can be done by volunteers who use the waterbody and/or by individuals hired for that purpose.

Monitoring of Planktonic and Attached Algae and Water Weed Growth

At weekly intervals from about May 1 through September 15 measure the Secchi depth transparency from a boat at mid-lake. If the lake has arms or is long and thin, then make measurements in each part of the lake.

Preferably at weekly, but at no less than biweekly intervals, measure the thickness of the weed and algal beds in the lake to develop contour maps of these growths as a function of location in the waterbody and water depth. Plot the results after each measurement and note trends. When the growth appears to be increasing to the point of significantly interfering with water use, then selectively harvest the weeds and/or treat for algal control. This should be done before the growth becomes sufficient to acutely affect water use. If readily possible, determine the dominant type of algae and weeds in the lake at times of weed bed extent measurements.

Phosphorus Control

Treat all significant domestic and industrial wastewater phosphorus sources for at least 90% phosphorus control. This may only need to be done seasonally for short hydraulic residence time lakes.

If the residents of the area are using septic tank wastewater disposal systems, if at all possible sewer residential areas that could serve as a significant source of phosphorus for the lake.

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If a sewerage system is not possible, then require that the septic tank wastewater systems not have surface discharges-seepage. If the septic tank wastewater systems are installed in aquifer systems that allow phosphorus transport via groundwater to the lake, then require that all residents install limestone or alumina beds to prevent phosphorus transport to the lake.

If one or more tributaries are the principal sources of phosphorus for the lake then treat the inflowing water with alum to bind the phosphorus as it enters the lake. Use preimpoundments to remove alum bound phosphorus.

If springs that enter the lake below the lake surface are an important source of phosphorus then install limestone or alumina beds in the groundwater aquifer to remove phosphorus before the groundwater enters the lake via the spring.

Restrict the use of phosphorus-based products, such as phosphate-based detergents to wash automobiles, and restrict the use of fertilizers on lawns, in the lake's watershed that could contribute significant amounts of phosphorus to the lake.

Restrict the feeding of animals and birds (ducks and geese).

Require the management of leaves, lawn clippings and other vegetative matter to prevent the transport of associated phosphorus to the lake.

Focus the control of non-point source phosphorus on algal available phosphorus. Sediment traps are of limited value in eutrophication control.

There is considerable misinformation on the role of lake sediment phosphorus on maintaining the fertility of a lake once the external phosphorus sources have been significantly reduced. A lake will rapidly adjust to a new trophic state based on a lake phosphorus residence time model. Dredging to remove lake sediments is not likely to be effective in controlling the fertility of the lake. It could, however, improve navigation ability and control rooted macrophyte growth.

Lake Evaluation Program

The typical limnological lake study program provides little useful information for developing lake water quality management programs.

It is generally found that previously collected data on a lake and its tributaries is unreliable as aresult of the use of inappropriate analytical procedures, sampling techniques and approaches and QA/QC.

Determine the morphology, hydrology and phosphorus sources for the lake with sufficient reliability to formulate a technically valid, cost-effective water quality management plan. This program will not likely require a routine water sampling program of the type typically used in limnologically based lake studies. It will also not require measurements on sediments and for that matter most of the limnological measurements that are typically made by in-lake management investigations. It

will require a carefully developed engineering study which is designed to answer site-specific questions about water and phosphorus sources for the lake.

A good estimate of water input sources and amounts and outputs is essential to developing a technically valid, cost-effective water quality management plan for a lake.

Septic Tank Wastewater Disposal Systems

There is considerable misinformation on the role of septic tank wastewater disposal systems on lake water quality. There may be no relationship between a "properly working" septic tank system and lake contamination by wastewaters from the septic tank.

Failed septic systems (surface discharge-seepage) in a lake's watershed will contribute phosphorus to the lake via surface runoff.

Properly working septic tank systems may contribute phosphorus to a lake via groundwater transport in some aquifer systems.

To determine if a septic tank system could be contributing phosphorus to the lake, the direction and rate of groundwater transport and type of aquifer material must be defined. Calcareous (hard water) and clay-containing aquifer systems normally do not transport phosphorus via groundwaters.

Quartz sand and gravel aquifer systems may transport phosphorus via groundwater to the lake if the direction of the groundwater flow is to the lake.

Those septic tank systems that have been demonstrated to be contributing significant amounts of phosphorus to the lake can be altered to prevent phosphorus transport with lime and/or alumina systems.

Phosphorus from old septic tank systems may be contributed to a lake via groundwaters many years after sewers are installed due to phosphorus stored in the soils. These aquifer-lake systems will recover more slowly than expected based on the phosphorus residence times.

Lake Fisheries

Fish quality, quantity and wholesomeness are of concern. Stunted fish populations frequently occur in excessively fertile lakes.

Carp affect water clarity, and weed and phytoplankton growth. Carp control may be desirable.

Fish stocking with game fish may be desirable.

Monitor fish every year for excessive concentrations of chlorinated hydrocarbons and mercury and other heavy metal content of edible tissue.

Monitor water at annual intervals using US EPA standard fish embryo/larvae and *Ceriodaphia* testing to evaluate the presence of contaminants that are toxic to fish.

Swimming Areas
Swimmers in any type of water tend to have more diseases than non-swimmers.

Fecal coliform concentrations are not reliable indicators of sanitary quality for contact recreation. *E. Coli* and *Enterococci* should be used as sanitary quality indicators.

Swimming areas should be isolated from the rest of the lake with floating curtains. Managers may want to treat waters in this area with alum and chlorine.

Lake Sediments
Considerable misinformation exists on the role of contaminants in lake sediments in influencing lake water quality.

Phosphorus released from lake sediments under anoxic conditions generally is not important to summer water quality problems.

Aerobic phosphorus release-mineralization of algae is important.

"Internal cycling" of phosphorus is accounted for in the monitoring evaluation program prescribed and in a phosphorus residence time model.

Lake sediments are not infinite sources of phosphorus. Lakes recover rapidly when external phosphorus sources are controlled in accord with the phosphorus residence time model.

Copper and other chemicals in lake sediments are generally not available to affect water quality.

Monitoring Program
If funds are available for a water quality monitoring program, the following measurements, as a minimum, should be made.

For each tributary measure at weekly intervals for at least one year:

Temperature	pH
Specific conductance at 20°C	Ammonia
Total phosphate	Soluble orthophosphate
Nitrate plus nitrite	Suspended Solids

Measure discharge of each tributary that contributes at least 10% of the water weekly and during periods of high flow. Also take special water samples during high flow and analyze for above parameters.

At mid-lake in mid-March, mid-April, mid-May and every two weeks from mid-May to the end of September, and in mid-October and mid-November, take a water sample a half meter below the surface, from mid-depth and from one meter above the bottom. These samples should be analyzed for:

Specific conductance at 20°C
Planktonic algal chlorophyll
Soluble orthophosphate
Total phosphate
Ammonia
Nitrate plus nitrite

At one meter intervals at mid-lake (deepest part), measure temperature and dissolved oxygen from the surface to the sediments. Also measure Secchi depth at mid-lake at weekly intervals using a 20 cm diameter, black and white quadrant disk.

The near-surface sample should be examined for dominant type of algae. Plankton nets should not be used for sampling algae.

Measure soluble orthophosphate with a procedure that will reliably determine 5 µg/L P. Measure planktonic algal chlorophyll with a procedure to reliably determine total chlorophyll as low as 2 µg/L.

All analytical procedures should be carefully selected from "Standard Methods" (APHA et al. latest edition) and evaluated for their applicability to the lake. Not all "Standard Methods" analytical procedures are reliable for eutrophication management programs. Proper QA/QC must be used for sample collection and analysis.

The most important part of the monitoring program is the evaluation-interpretation of the data for developing a technically valid, cost-effective water quality management program for a lake.

Background information on each of the issues outlined above is available in papers and reports on www.gfredlee.com, in the Excessive Fertilization/Eutrophication section. Additional information on these issues is available from gfredlee@aol.com.