Briefing Material on Water Quality

prepared for the

Lac Ste. Anne and Lake Isle
Water Quality Management Society

November 3, 1996

1. Lac Ste. Anne and Lake Isle Water Quality 1996: Interim Report
2. Fact Sheet on Lake Water Quality
3. Map of the watersheds of Lake Isle and Lac Ste. Anne

Lac Ste. Anne and Lake Isle Water Quality 1996

INTERIM REPORT

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Lac Ste. Anne and Lake Isle
Water Quality 1996

Lac Ste. Anne and Lake Isle are shallow, nutrient-rich lakes with green water during the summer and abundant shoreline vegetation. In recent years, lake users have become concerned that water quality in these lakes is deteriorating. They suggest that the frequency and duration of algal blooms are increasing. A report of toxic blue-green algae in Lac Ste. Anne in 1995 gave added cause for concern. These stakeholders worry that reversing this apparent trend will become more difficult as time goes on.

During the spring of 1996, landowners, municipal officials and other interested people in the area got together to draw up a framework toward development of a water quality management plan. They created the Lac Ste. Anne and Lake Isle Water Quality Management Society to coordinate activities leading to improvement or preservation of water quality in these lakes. In June, a public meeting was held to present the framework for the management plan and a schedule of activities toward accomplishing the two main objectives:

- A diagnostic study for both lakes to determine their present water quality, and to identify major nutrient sources and measure the amounts contributed by each (a nutrient budget).

- An evaluation of the feasibility of reducing nutrient loadings from the sources identified in the diagnostic study, including costs, practicality, effectiveness and environmental acceptability of various approaches.

Water Management Division of Alberta Environmental Protection agreed to conduct a sampling program on Lac Ste. Anne and Lake Isle to begin gathering some of the information needed for the water quality management plan. This interim report summarizes some of the data gathered during 1996.

1996 Sampling Program

The water quality monitoring programs on Lake Isle and Lac Ste. Anne focussed primarily on their fertility, which is a measure of the potential for aquatic plant growth. An increase in the capacity of a lake to produce plants could lead to nuisance algal blooms, decreased levels of dissolved oxygen in winter (and the threat of fish kills), higher turbidity, and a general decline in recreational water quality. Two main indicators of fertility in lakes are 1) the concentration of the nutrient phosphorus, and 2) the concentration of chlorophyll *a*, which is a measure of the quantity of algae in the water at the time a sample was collected. Other characteristics monitored were transparency or clarity of the water, general chemistry, temperature and dissolved oxygen.

During 1996, samples from both lakes were collected every two weeks beginning in mid-May and continuing through October. The east or main basin of Lac Ste. Anne was sampled separately from the shallower west end. Lake Isle and the two basins on Lac Ste. Anne were sampled by collecting water from several locations in deeper areas and combining it into one large container. The "whole-lake composite" sample obtained this way gives more representative data than if the water were collected from one or two spots only. On each sampling trip, a long weighted hose was lowered to the depth that light penetrated, as measured by a light meter. The water was poured into a jug, and the process was repeated in another area. Ten or more locations in each basin were sampled in this way.

Several major tributary streams entering Lake Isle and Lac Ste. Anne were sampled in the spring and summer as well. These included the Sturgeon River immediately upstream of Lake Isle (Sturgeon River at Magnolia); the Sturgeon River between Lake Isle and Lac Ste. Anne (Sturgeon River at Darwell); Mission Creek, which flows into Lac Ste. Anne at the pilgrimage site; and a small creek in the summer village of Val Quentin ("Val Quentin Creek"). The purpose of sampling these streams was to determine levels of phosphorus, nitrogen and other substances in streams draining the watersheds of the two lakes. Not all tributary streams draining to these lakes could be sampled in 1996, but data from these four provide a general picture of nutrient inputs from the watershed. These data can be used to begin construction of nutrient budgets, and can be compared with 1996 data from other Alberta streams that were sampled during an intensive study of agricultural impacts on water quality.

Preliminary Results

The data for the lakes and streams will be tabulated and interpreted over the winter of 1996-97. The following is a brief overview of some of the data that are available so far:

- Figure 1: Lac Ste. Anne East Basin, Lac Ste. Anne West Basin and Lake Isle fall into the hypereutrophic category of trophic status, based on the average amount of algae in the water (measured as chlorophyll *a* concentration). The data shown in the graph are from previous sampling programs on these lakes as well as for 1996. In 1996, levels of chlorophyll *a* were higher in Lac Ste. Anne West than in Lake Isle.

- Figure 2: Water quality in Lac Ste. Anne East and West and Lake Isle varied over the summer of 1996. The concentration of total phosphorus increased dramatically in July in Lac Ste. Anne West, perhaps as phosphorus moved from the bottom sediments into the lake water. To a lesser extent, phosphorus levels in Lac Ste. Anne East and Lake Isle also increased. At the same time, algal populations took advantage of the increased nutrient supply, resulting in higher chlorophyll *a* levels. The amount of algae was highest in Lac Ste. Anne West, and lowest in Lac Ste. Anne East. Water in the two basins would have been visibly different, particularly in mid-August.

- Figure 3: These graphs show results for phosphorus concentrations in samples collected from the four tributary streams sampled in 1996. The top graph is total phosphorus, which includes phosphorus in soil particles or bits of organic matter as well as dissolved in the water. The bottom graph shows levels of phosphorus dissolved in the water only. Usually, levels of nutrients in streams are highest during snowmelt runoff in spring, but occasional intense summer rainstorms may also produce high concentrations as phosphorus is scoured from the watershed and carried into streams.

The highest phosphorus concentrations (total and dissolved) were recorded in tiny Val Quentin Creek, and most of the phosphorus was dissolved rather than in the particulate form. Although levels of phosphorus in this creek are very high, the total amount of water that the creek contributes to Lac Ste. Anne is small. This creek may have local impacts however.

The tributary with the lowest phosphorus concentrations was Sturgeon River at Darwell. Phosphorus concentrations were low because the river is essentially Lake Isle water; the lake dilutes and settles out phosphorus entering from its watershed. Thus, the main inflow to Lac Ste. Anne has relatively good water quality. Mission Creek had higher concentrations of phosphorus, as did the Sturgeon River upstream of Lake Isle. The proportion of dissolved phosphorus in Mission Creek was slightly greater than in the Sturgeon River at Magnolia.

- *Figure 4*. These graphs compare concentrations of total phosphorus measured in a number of Alberta streams that were sampled in 1996 to determine the impact of agricultural activities on water quality. The categories are based on soil characteristics and agricultural use in the watershed area for each stream. The watersheds surrounding Lac Ste. Anne and Lake Isle are considered to have moderate agricultural intensity, and three of the streams sampled in 1996 are included on that graph. The Sturgeon River at Darwell was not included because it represents mostly lake water rather than a stream affected by watershed activities.

  The Sturgeon River at Magnolia and Mission Creek fall into the range of the other streams in this category, although some of the other streams occasionally had very high concentrations of phosphorus. Val Quentin Creek would fit better into the high agricultural intensity category. The reason for this is presently unknown.

Conclusions

Although Lake Isle and Lac Ste. Anne are nutrient-rich lakes, there is no evidence so far that water quality has changed appreciably in recent years. The data will be evaluated further to assess the very high concentrations of phosphorus and chlorophyll *a* in the west basin of Lac Ste. Anne, however.

The tributary stream sampling conducted in 1996 provides initial data for construction of a nutrient budget. Additional sampling will be needed to develop average stream concentrations and runoff coefficients for phosphorus that can be applied to portions of the watershed not drained by streams or by streams without access for sampling. As well, the tributary streams may require sampling along their lengths to determine specific nutrient sources.

Other nutrient sources, such as leaking septic systems, were not investigated this year. Because sewage inputs to lakes are very difficult to measure, most nutrient budgets assume that all sewage generated by cottages and camps along the lakeshore enters the lake. This provides a "worst-case" evaluation for the budget. However, for Lac Ste. Anne and Lake Isle, further refinement of this potential source may be needed.

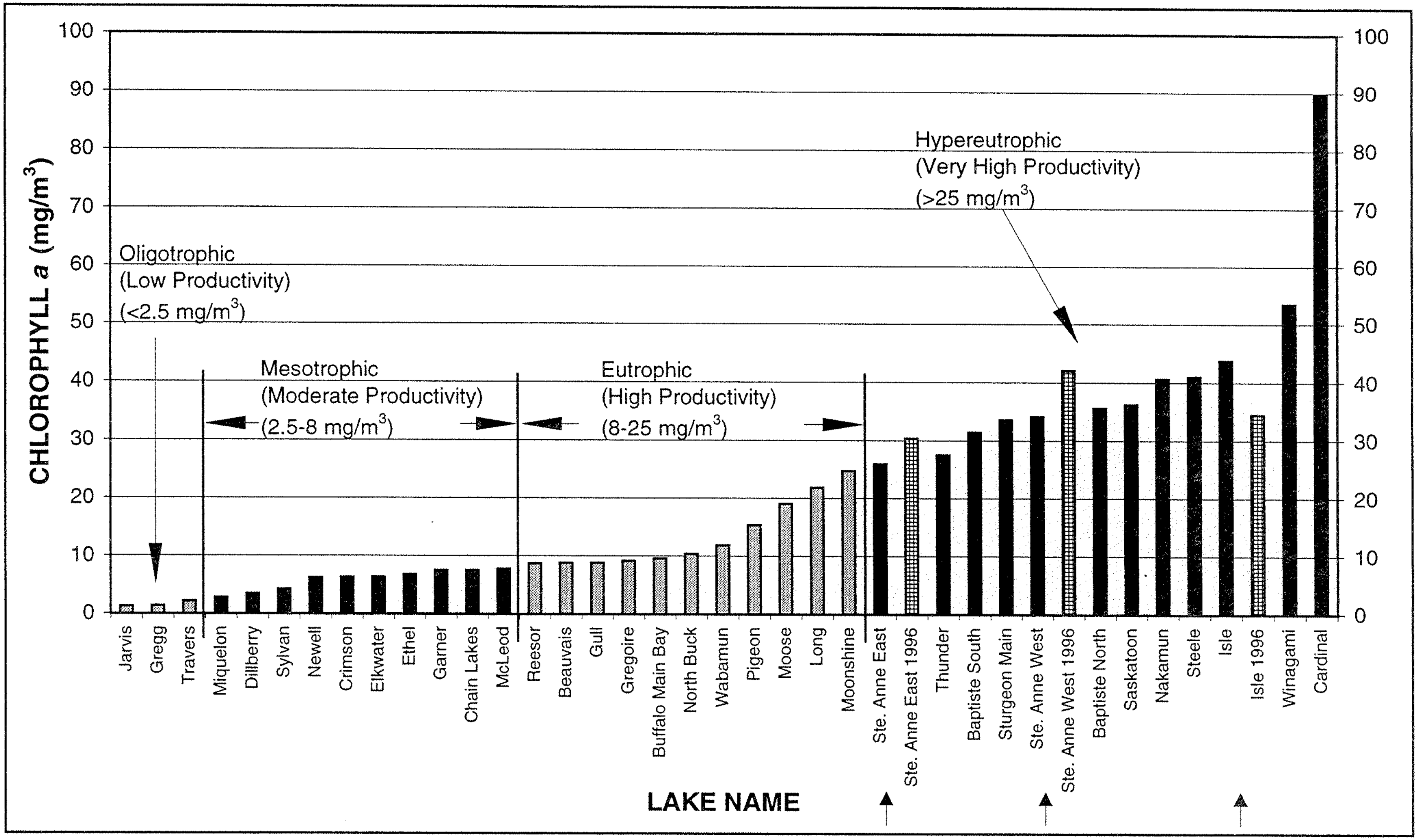

Figure 1. Approximate trophic categories for Alberta lakes based on average summer chlorophyll *a* concentrations, 1983-1995.

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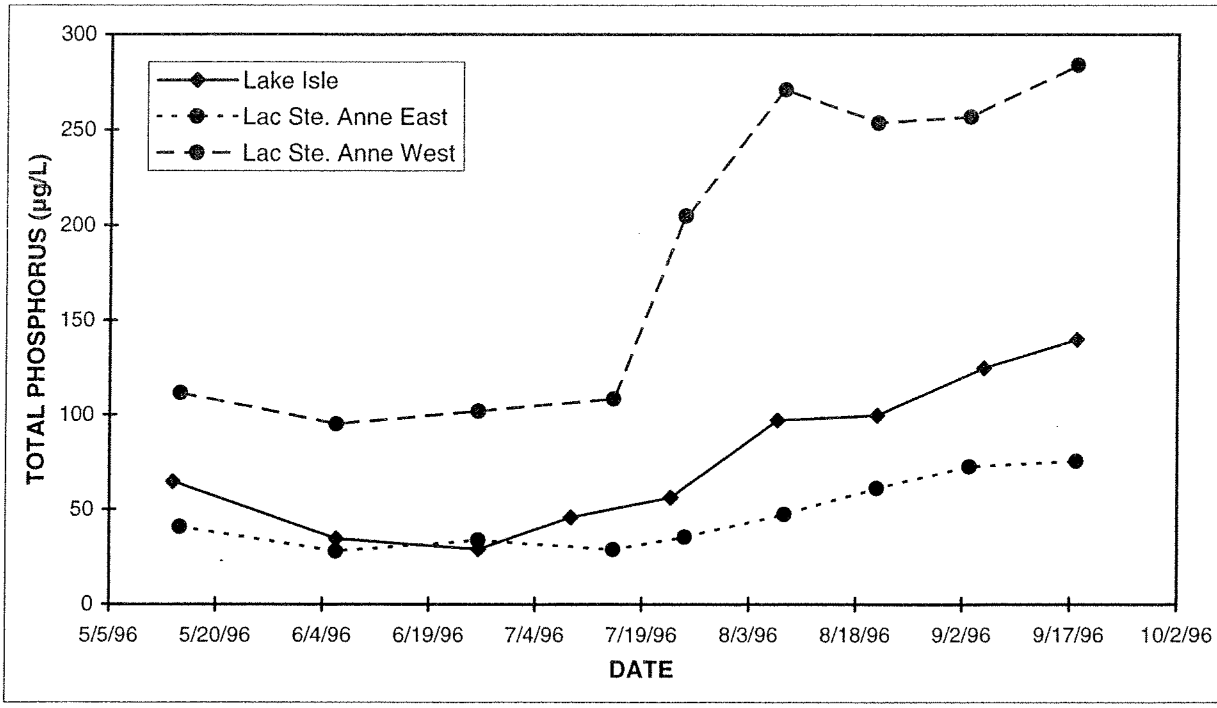

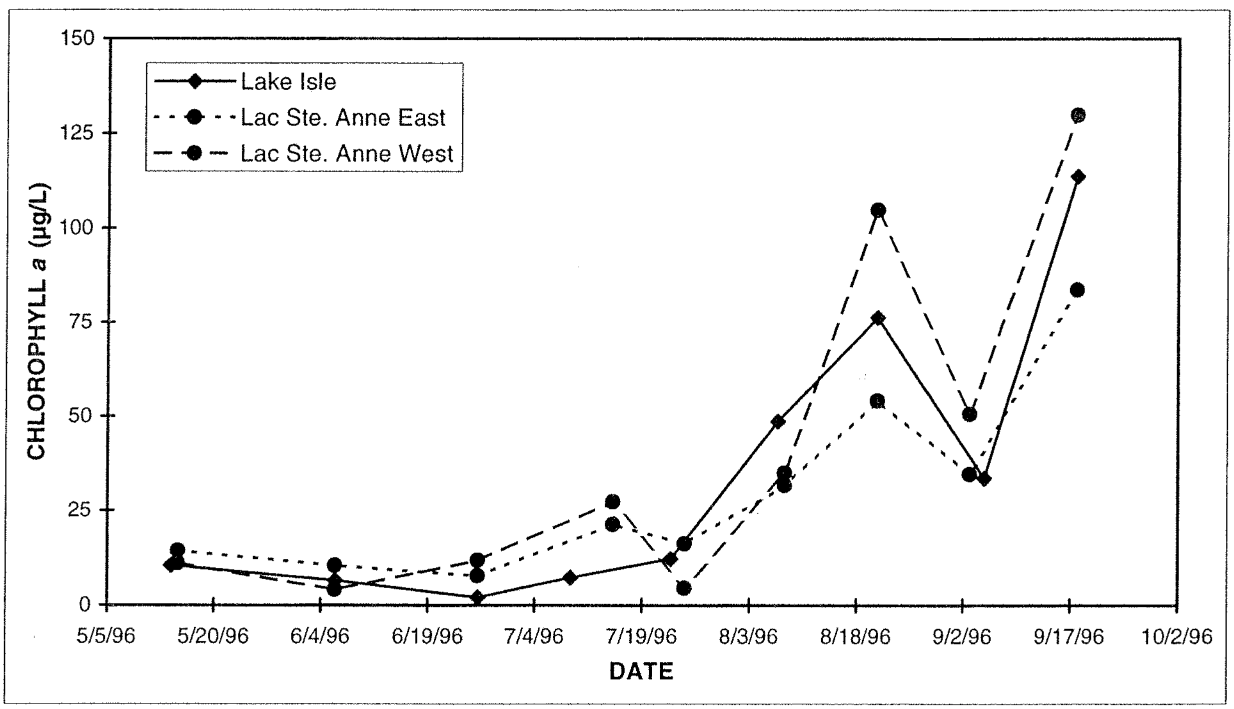

Figure 2. Comparison of total phosphorus and chlorophyll *a* concentrations in Lake Isle and Lac Ste. Anne (East & West), 1996.

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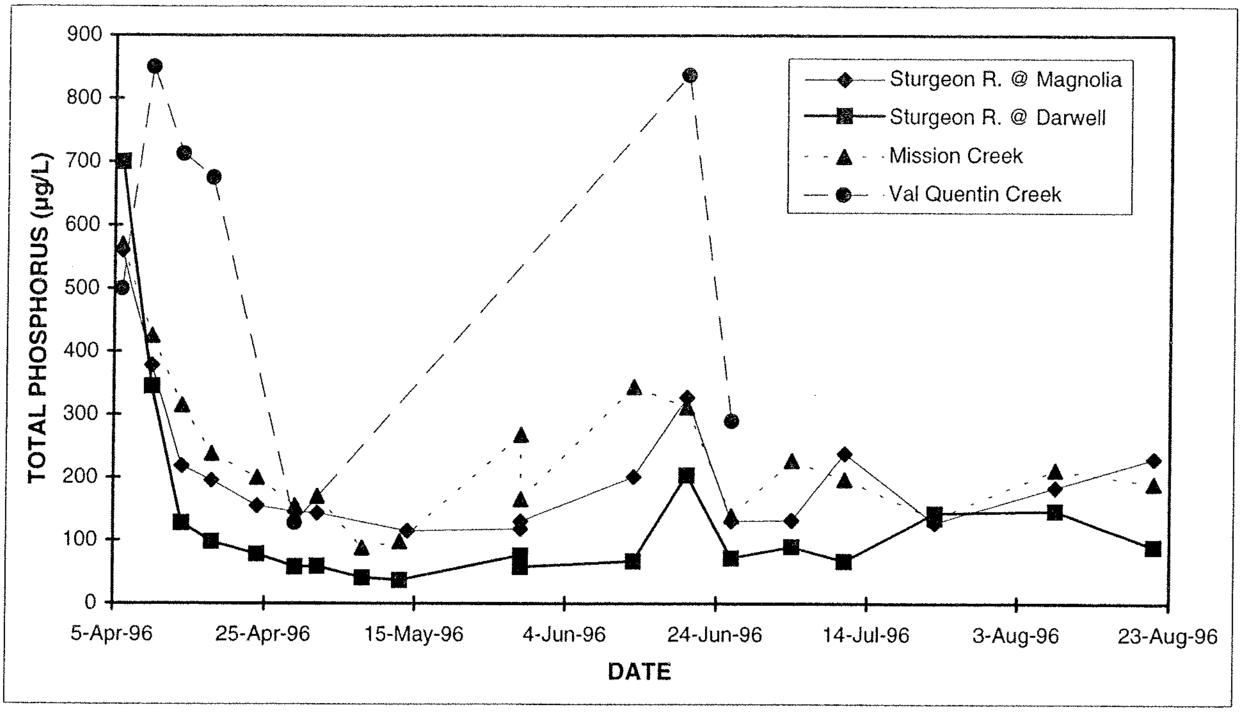

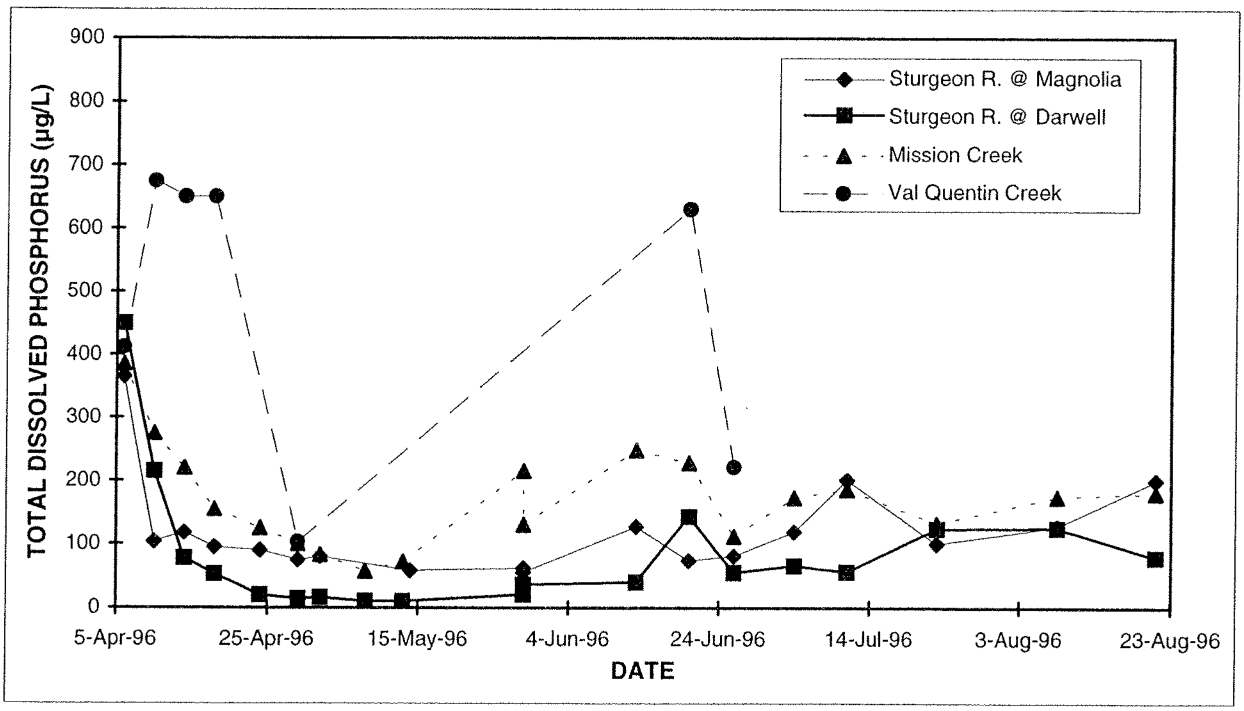

Figure 3. Total phosphorus and total dissolved phosphorus concentrations in tributaries to Lake Isle and Lac Ste. Anne, 1996.

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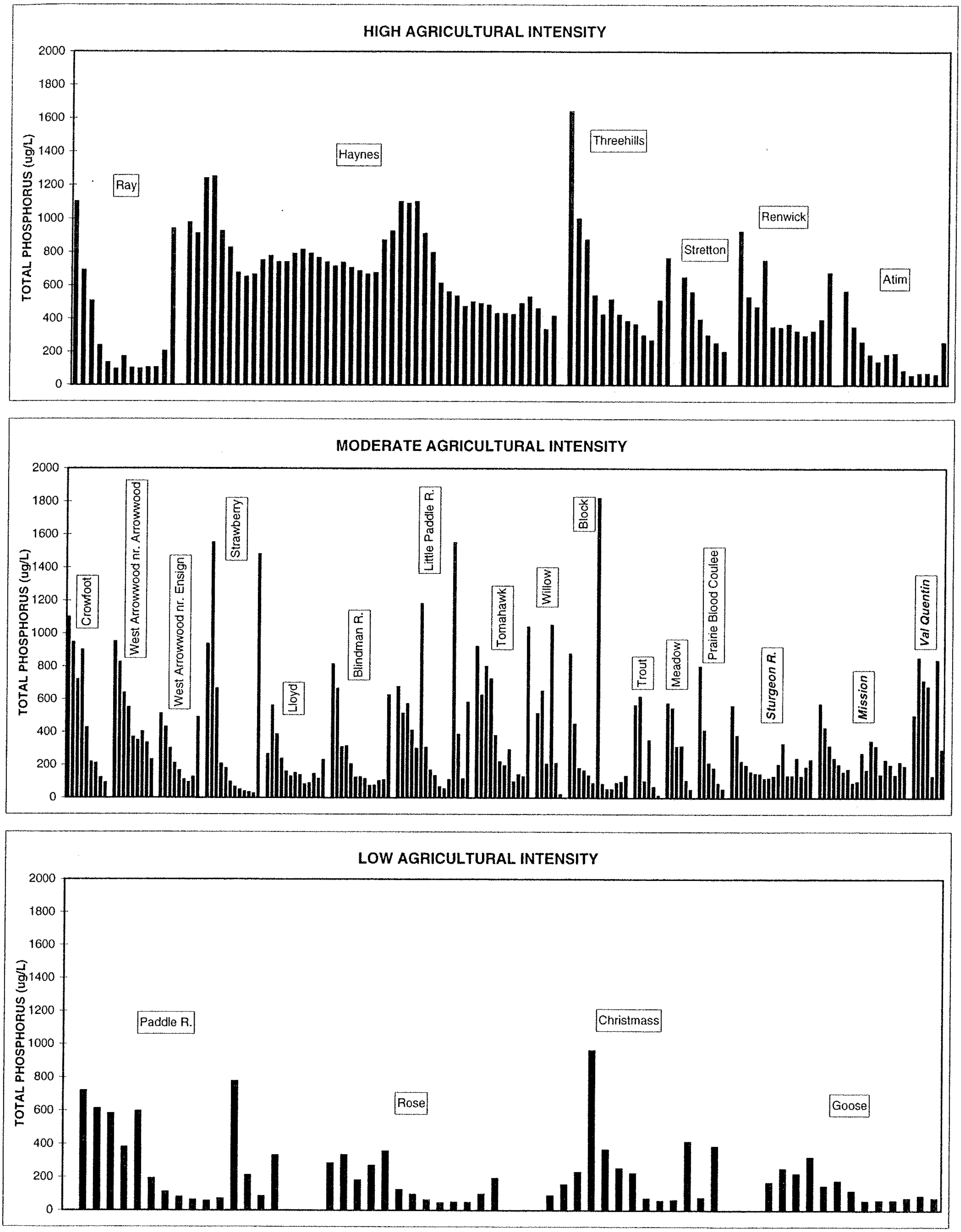

Figure 4. Total phosphorus concentrations in Alberta streams, March to August, 1996.

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Lake Water Quality

The Alberta landscape is diverse -- it varies from mountain to prairie, from boreal forest to dry grassland. Differences in climate and geology across the province result in a wide range of water and soil conditions, plant and animal species, and a large variety of lake types. Some Alberta lakes are shallow and *saline*, others are deep, cold and clear, while others are stained brown with organic material from peatlands. Lakes also vary in their level of fertility, or nutrient content. Some have high nutrient levels, and are choked with weeds and algae, others have very low fertility, and are clear and clean. The ideal lake for fishing and other recreational activities is probably somewhere in between.

Lakes are important to the people of Alberta. A few lakes are used as municipal water supplies, and a few are reservoirs built to store water for various purposes, but the most important use is recreation, including sport fishing. A pleasant recreational experience at a lake depends on its water quality. Lakes that are green and weedy detract from the recreational experience. People often think that lakes are like this because people have polluted them, and most lake users believe that water quality in lakes is deteriorating. The only way to know for sure is to carry out appropriate water quality studies, always remembering the first rule of lake management: *each lake is unique.*

The major water quality issue in Alberta lakes is *eutrophication,* the excessive growth of aquatic plants caused by high nutrient levels. *Acidification,* ecological changes caused by the deposition of acidic pollutants from the atmosphere, is not a concern in most lakes in Alberta, because they can buffer or neutralize these pollutants.

THE CONDITION OF ALBERTA LAKES

The nature of a lake depends on where it is located and how it was originally formed. Many mountain lakes were formed in preglacial valleys, and therefore are often deep. They are located in areas that receive large amounts of snow and rain, and inflowing water flushes them out. These lakes also tend to be situated in geological formations that weather very slowly. As a result, the transport of dissolved and suspended materials from the watershed is minimal, and the water in these lakes is soft, with low mineral content. Many are unproductive in terms of growing aquatic plants, and usually fish and other animals as well. A lake of this sort -- clear, with little evidence of algae or shoreline vegetation -- is termed *oligotrophic*, which means "poorly nourished." Many of the larger reservoirs in southern Alberta also fall into this category, because their water comes from the mountains. There are relatively few oligotrophic lakes in Alberta.

A lake on the prairie or in the parkland is typically shallow, green and relatively warm. It is situated in fertile soils that were formed from sedimentary geological materials. Soils and other materials from the watershed move into the lake during runoff, resulting in a lake that has a high mineral and nutrient content compared with lakes in the mountains. Evaporation is high relative to rainfall amounts, so flushing through the system can be very slow. For example, popular recreational lakes like Pigeon and Wabamun have *water residence times* (the time it would take to fill a dry lake basin completely under natural conditions) that exceed 100 years. In southeastern Alberta, natural lakes are rare, because climatic conditions do not allow depressions in the landscape to maintain water. Lakes that have a large supply of nutrients, and consequently are green with algae, are termed *eutrophic*, or "well nourished." Most of the lakes that are familiar to people living in central Alberta fall into this category.

Lakes that are more productive than oligotrophic lakes, but less productive than eutrophic lakes are called *mesotrophic*. They tend to be highly valued for recreation, because they usually have clear water and good fishing. Sometimes they have abundant rooted aquatic vegetation, but this is an asset for fish production. Many of the mesotrophic lakes in the province are found in the foothills and in the "Lakeland," northeast of Edmonton.

IMPACTS ON LAKE WATER QUALITY

The most visible and annoying water quality problem to lake users in central Alberta is the proliferation of aquatic vegetation in summer. Aquatic plants come in two major varieties. One is the rooted plants that grow in the water that people call "weeds," but are technically known as *macrophytes*, which means "large plants." The other is *algae*, single-celled plants suspended in the water or growing on rocks or other plants. When the population of algae in a lake is high, it has a green, scummy appearance. Alberta's shallow, eutrophic lakes rank among the world's most fertile and contain comparatively high levels of the nutrient *phosphorus*. This element is a key factor governing plant growth. When phosphorus levels are high, the lake will likely be green and weedy.

Alberta Environmental Protection has conducted several intensive studies to quantify nutrient sources to recreational lakes. These sources include the atmosphere (rain, dust, snow), surface runoff from forested and agricultural land, sewage from cottages and resorts, groundwater and the sediments on the bottom of the lake. Any disturbance of the natural vegetation in a lake's watershed has the potential to increase its nutrient supply, and thereby increase aquatic plant productivity. This could include clearing of trees to build cottages and roads, forestry operations, and agricultural development. It has been shown in several Alberta studies that streams draining agricultural land have much higher concentrations of phosphorus and nitrogen than streams draining forested or naturally vegetated land. When forested land in a lake watershed is cleared for agriculture, the movement of nutrients from that land to the lake may increase by several times. Livestock operations along watercourses that feed the lake, or near the lakeshore itself, can be major contributors of nutrients.

Leaking septic systems at the shore of the lake can contribute large amounts of nutrients, but if septic systems are properly designed, placed in good soils and maintained properly, there should be very little contribution to the lake. It is generally thought that sewage is not a major contributor to water quality problems in lakes in Alberta, but sewage could be a site-specific concern on particular lakes.

Because of the nature of the lake bottom in many of our productive lakes, the sediments can contribute sizable quantities of phosphorus during summer. So much phosphorus can be "recycled" from the bottom sediments that this process governs water quality in most or all of the shallow, productive lakes in central Alberta. It is believed that sediment recycling of phosphorus is largely natural, but it is not known how land-use changes in the watershed have influenced this process. Some studies suggest that if the nutrient supply entering the lake increases, the amount of phosphorus in the bottom sediments also increases, leading to the recycling of greater amounts from the sediments.

Although it is reasonable to assume that an increase in a lake's nutrient supply could lead to poorer water quality, we do not have scientific evidence that any lake has deteriorated. Lake studies were not conducted 50 or 100 years ago, before their watersheds were cleared for development, so there are no baseline data for comparison. Bottom sediment cores representing thousands of years of lake history have been collected from several Alberta lakes, but they do not indicate changes that have occurred since European settlement of the province. They do, however, suggest that these lakes have always been rich in nutrients and algae.

MANAGING AND PROTECTING LAKE WATER QUALITY

Lake scientists in Alberta Environmental Protection conduct survey programs to provide basic information on individual lakes. The data are used to resolve water quality management problems arising from shoreline or watershed development, agriculture, mining, forestry, water diversions or impoundments. Management solutions are often based on the use of models or budgets: the total amount of a substance entering the lake is calculated, and then lake characteristics such as flushing rate and lake volume are used to predict the concentrations of the substance in the lake water. Another model might be used to relate the predicted concentration to some key biological attribute. Finally, the predicted biological effect is compared with what might be expected by lake users.

A nutrient budget is usually the foundation for developing a management plan for a lake. A detailed budget allows stakeholders to focus on phosphorus sources that would be easiest to control for the greatest benefit. It also helps lake users understand what they can realistically expect from efforts to reduce nutrient loading from the lake's watershed.

For example, a phosphorus budget might be constructed by measuring or estimating the quantity of phosphorus that enters a lake in a year from precipitation, runoff, sewage, groundwater and the bottom sediments. Once the present situation in the lake is understood, a new phosphorus concentration can be predicted to determine the impact of a proposed development. Alternatively, one might want to subtract the quantity contributed by sewage or other sources to see the effect of a reduction in nutrient input. After the concentration is predicted, the amount of algae can also be predicted to determine how "green" the lake would be after the proposed change. The results can be evaluated to determine whether a development or mitigative options should proceed.

Leaking septic systems are often blamed for perceived water quality problems in lakes. Although there is legislation in place to control sewage dumping or known leakages from private systems, the detection of underground leakages from septic fields is virtually impossible without intensive (and expensive) surveys. For this reason phosphorus budgets are often constructed by assuming the worst case, that all sewage generated by shoreline cottages enters the lake. Other phosphorus sources are also difficult to assess and control. There are no provincial regulations to control excess nutrient concentrations in runoff from agricultural land, golf courses or cottage property, so mitigation of these sources requires concerted effort by stakeholders, including local and provincial governments.

Cottage owners and other lake users are beginning to realize that they themselves are the best managers of their lake. An example of a project that combines stakeholder interest and motivation with technical expertise from Alberta Environmental Protection is the lake restoration project at Pine Lake near Red Deer. The highly motivated Pine Lake Restoration Society has planned several projects to “clean up” the lake and its watershed, including reduction of agricultural runoff from seven farms, reduction of nutrient loading from sewage disposal systems and removal of nutrient-laden water from the bottom of the lake. The society is involved in several fundraising activities to carry out the proposed four-year plan.

Figure 1 shows possible steps toward cleaning up a lake, similar to the steps initiated by the Pine Lake group. The first step would probably be a meeting among all interested people around the lake, including cottage owners, farmers, people from counties and summer villages, anglers, resort owners and anyone else who wants to protect or enhance the lake. Then, the specific problems would be identified and clarified. This could lead to a water quality study (usually conducted by provincial government lake scientists, but with help from local residents), which would provide baseline data and a documentation of nutrient sources. From this, possible solutions to problem areas can be outlined, and an action plan developed. Part of this action plan would necessarily include ways to obtain funding for various clean-up programs. The final steps would be implementing the clean up measures, as well as developing a long-term water quality protection plan for the lake. Throughout this process, lake water quality sampling would continue, to get as much information as possible on how the lake functions. Monitoring would continue after implementation of the clean-up strategies as well.

The bar graphs on Figure 2 show the amounts of phosphorus that enter this hypothetical lake before the program begins (determined from the water quality diagnostic study), and after watershed nutrient reduction. Note that the actual reduction in the nutrient supply is relatively small. This is probably realistic for most of central Alberta’s recreational lakes, because the natural nutrient supply would likely be fairly high. These lakes were probably never pristine and clear, so at most they can only be “improved” to their original level of productivity-- perhaps mesotrophic or mildly eutrophic. But lake users would see a difference in the quality of their lake if even this reduction could be achieved.

The time required for a lake to respond to nutrient reduction strategies in its watershed is unknown, but would likely be years, because the bottom sediments of the lake will continue to supply large quantities of phosphorus for some time. The Pine Lake Restoration Society is hoping to see a difference in Pine Lake by the year 2000, if many of the restoration projects are implemented in the next year or two. For any water quality improvement project -- or even to preserve the lake’s present condition -- there is really no alternative but to tackle the difficult job of reducing the lake’s nutrient supply.

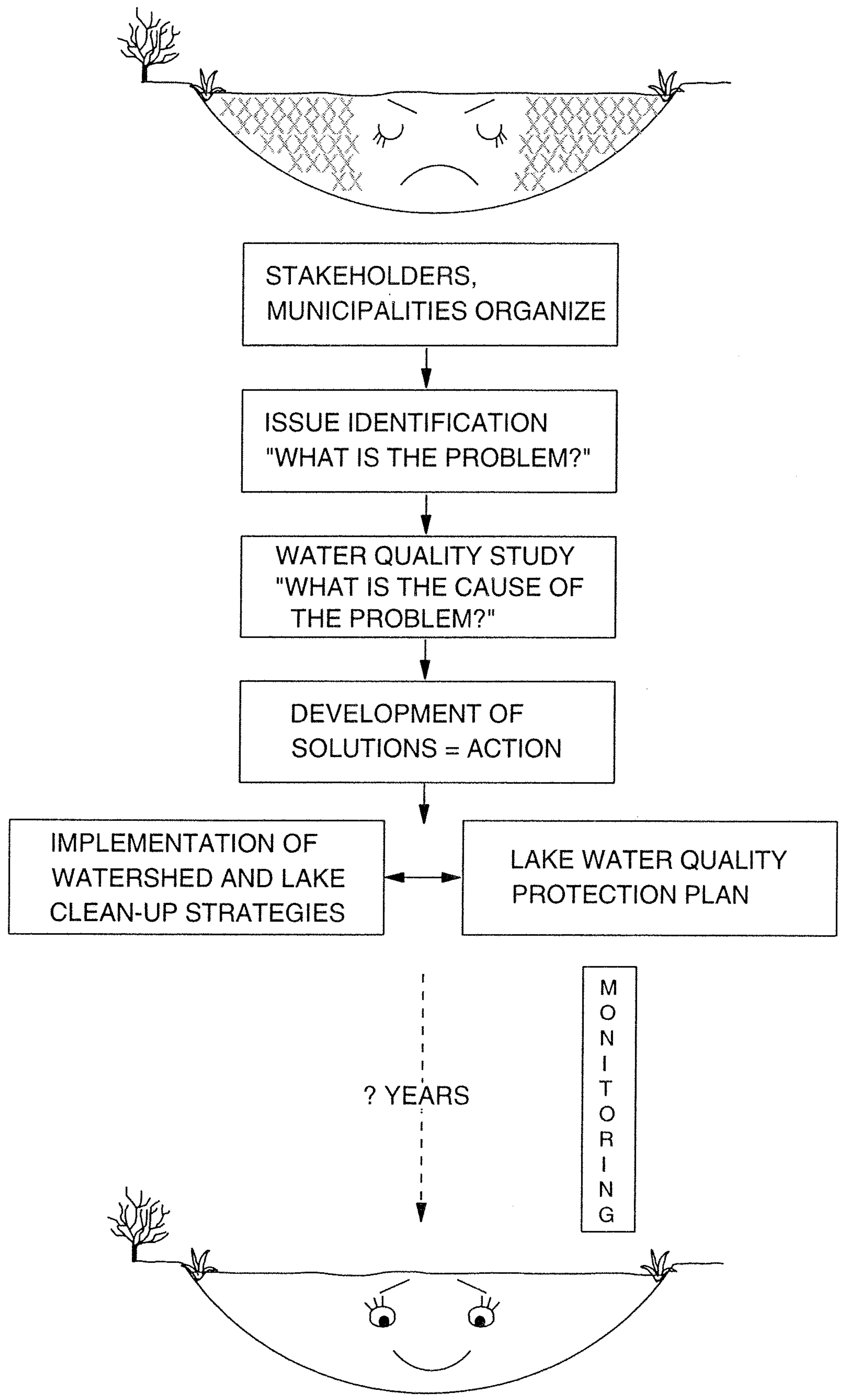


FIGURE 1. CLEAN-UP OF A HYPOTHETICAL LAKE.

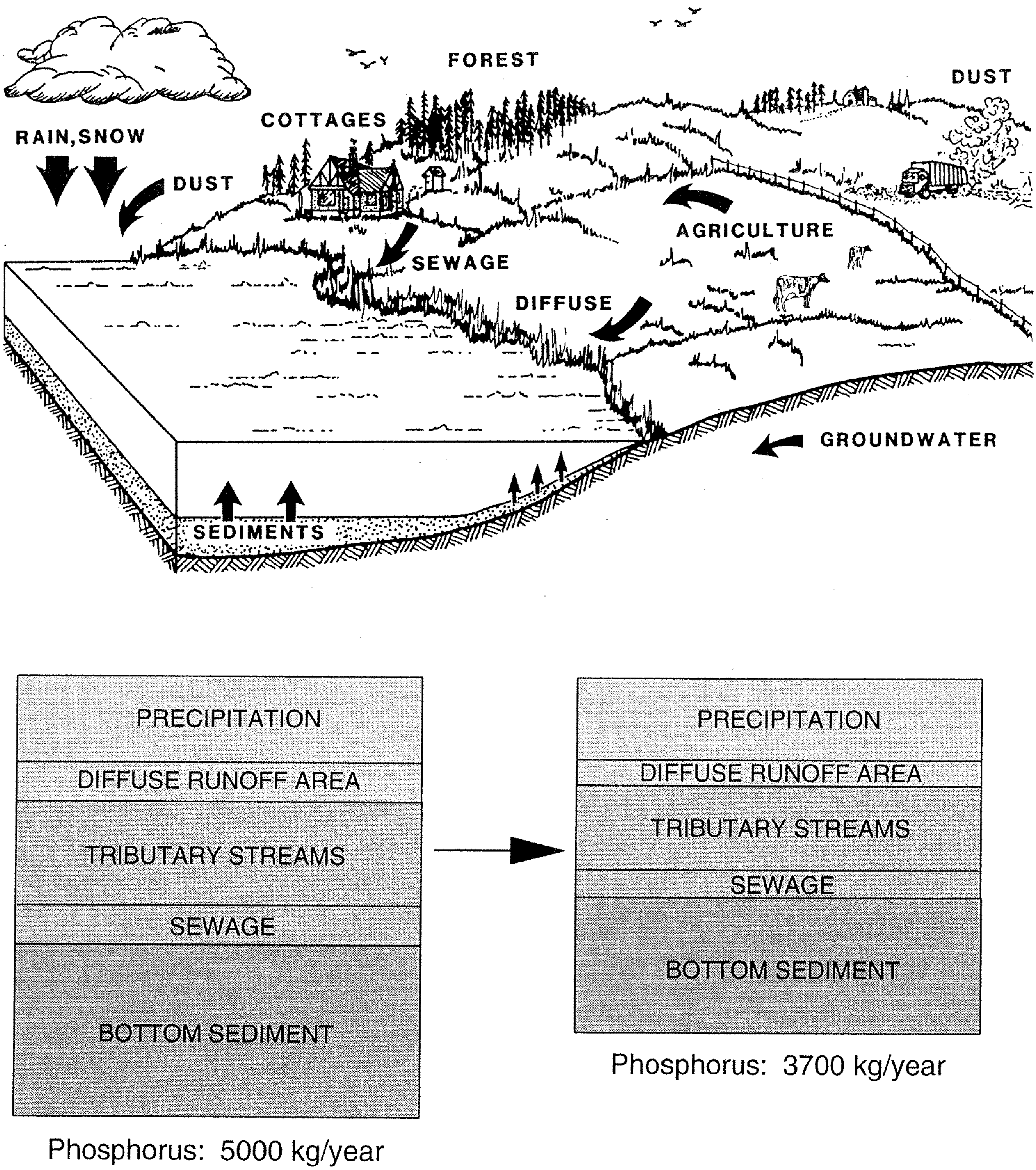
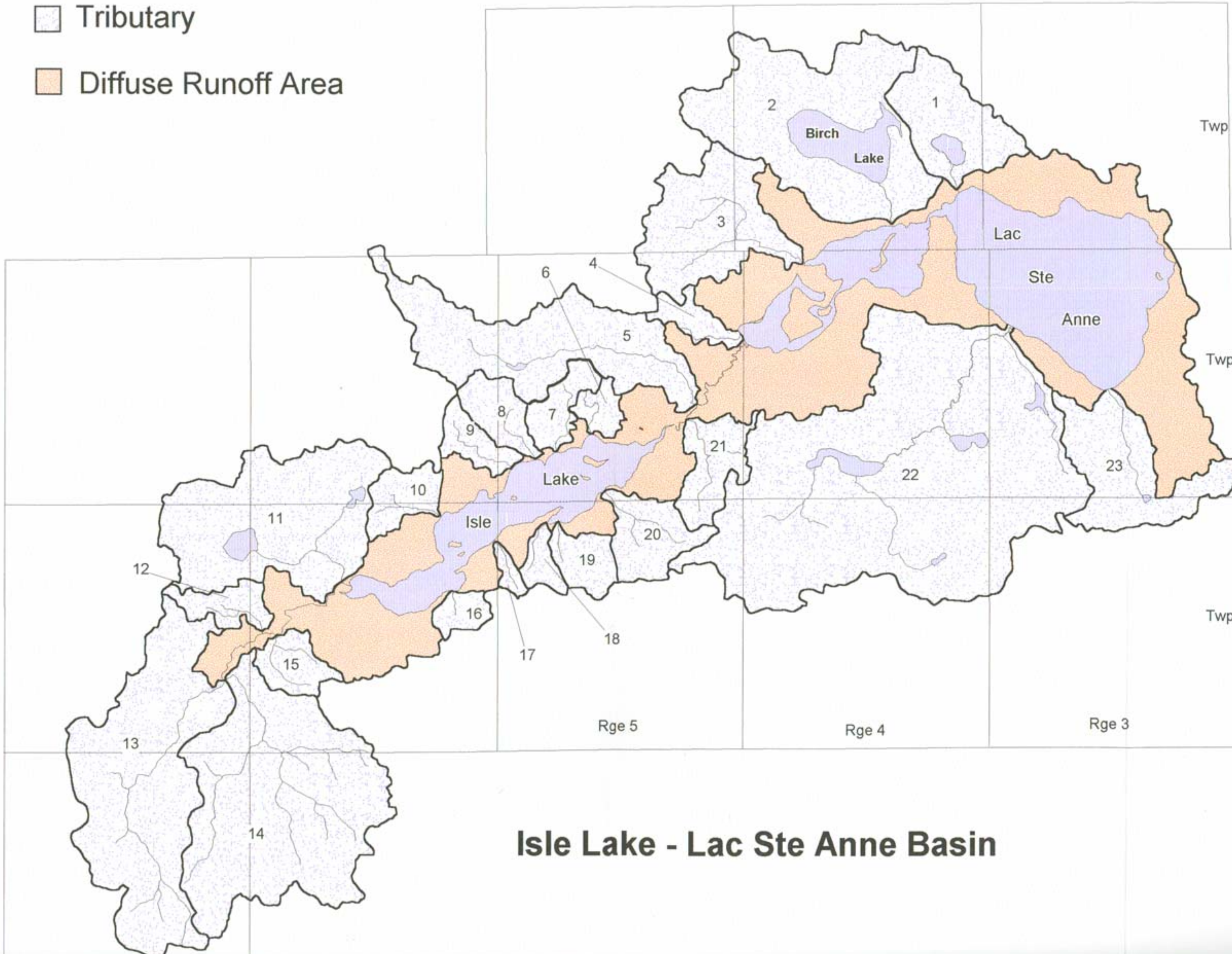


FIGURE 2. EXAMPLE: REDUCTION OF PHOSPHORUS LOADS FROM TYPICAL SOURCES.



Drainage Areas in square kilometers

1	15.66
2	46.35
3	22.54
4	3.91
5	33.26
6	3.11
7	5.32
8	6.07
9	4.57
10	5.86
11	38.85
12	5.06
13	50.16
14	56.55
15	5.54
16	3.01
17	1.42
18	2.78
19	5.31
20	9.34
21	8.72
22	115.40
23	20.05

Isle Lake - Lac Ste Anne Basin