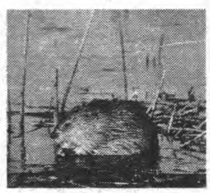
Canada Alberta Northwest Territories

Northern River Basins Study





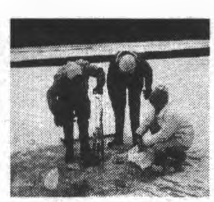




NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 39

REGULATORY REQUIREMENTS FOR NUTRIENT EFFLUENT DISCHARGES



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REGULATORY REQUIREMENTS FOR NUTRIENT EFFLUENT DISCHARGES

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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NORTHERN RIVER BASINS STUDY
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This publication may be cited as:

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F.J. Wrona | 8 June 94

(Dr. F.J. Wrona, Ph.D., Science Director) | (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [✓] No

P.A. Larkin | 8 June 94

(Dr. P. A. Larkin, Ph.D., Chair) | (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[✓] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington | June 9, 94

(Lucille Partington, Co-chair) | (Date)

(Date)

REGULATORY REQUIREMENTS FOR NUTRIENT EFFLUENT DISCHARGES

STUDY PERSPECTIVE

A particular concern related to municipal and industrial effluent discharges in the northern river basins is the effect of nutrients (nitrogen and phosphorus) on the aquatic environment. Nutrients enter a river from municipal and industrial effluents, agricultural and timber-harvesting runoff, natural runoff, groundwater sources and tributary inflow. Added nutrients can cause changes in the abundance and production of benthic biota and on the production, reproduction and survivorship of fish. Nutrients may also decrease dissolved oxygen concentrations as a result of enhanced plant growth, which is, in turn, decomposed by bacteria that consume oxygen. Understanding the influence of nutrients on the aquatic environment is therefore critical for regulating industrial and municipal effluent discharges to minimize eutrophication, protect aquatic habitats and preserve ecosystem health.

Related Study Questions

1 b) How can the ecosystem be protected from the effects of these compounds?

5) Are the substances added to the rivers by natural and man-made discharges likely to cause deterioration of the water quality?

7) What concentrations of dissolved oxygen are required seasonally to protect the various life stages of fish, and what factors control dissolved oxygen in the rivers?

13 b) What are the cumulative effects of man-made discharges on the water and aquatic environment?

Several projects have been implemented by the Northern River Basins Study to examine the relationship between nutrient discharges and impacts to the aquatic environment. These include; a synthesis of existing information and data related to nutrient effluent discharges and the effects of nutrients on the abundance and composition of benthic invertebrate and plant communities, field studies to determine which sections of the Peace and Athabasca river systems will be affected by additions of nutrients, and experiments in artificial streams to determine the effect of specific nutrient concentrations on the abundance and composition of benthic biota. All of these projects are related to assessing the consequences of controlling or not controlling nutrients. At the same time, consideration must still be given as to what is the amount of nutrients that any given activity (industrial, municipal, agricultural, etc.) will be allowed to discharge to receiving water bodies. This report outlines regulatory requirements for nutrient effluent discharges from a variety of jurisdictions in order to identify appropriate options for the regulation of nutrient effluent discharges in the northern river basins.

The Study's Science Advisory Committee reviewed the report and found section 2 overly simplified the interactions between nutrients and water and did not contribute to the overall project report. Readers are cautioned to seek out other detailed references to obtain a more thorough understanding of the issue. The section has been retained in this printing of the report to assist casual readers in understanding the general complexity of nutrients in the aquatic environment.

REPORT SUMMARY

This review includes both the instream water quality objectives for the nutrients, nitrogen and phosphorus, and the limits for phosphorus and nitrogen (as a nutrient) specified in effluent permits and regulations. The review concentrates on the Peace, Athabasca and Slave Rivers, but the scope also includes Alberta, Canada, and other jurisdictions. Regulatory information pertaining to pulp and paper mill effluents is emphasized.

Factors Affecting Nutrient Regulation

Nutrients are more difficult to regulate than other water quality variables because an increase in either phosphorus or nitrogen can have a beneficial impact, a negative impact, or no impact on a riverine ecosystem depending on the factor(s) limiting growth in the river and the water uses being impacted. Water uses may conflict in their nutrient requirements.

Nitrogen and phosphorus are present in the water from natural sources, nonpoint sources and point sources; therefore, the effectiveness of regulating the discharge from only one of these sources depends on the importance of point sources in the overall loading to the river. Other environmental factors (e.g. velocity, substrate, turbidity, light, temperature, and grazing) are important in river systems. The extent to which these factors control growth will also limit the environmental effect of regulating nutrients in discharges.

The success of water quality objectives that limit phosphorus or nitrogen depends on which nutrient (if any) is limiting, how much of the total nutrient is bioavailable, the concentration needed to saturate growth of the primary producers, and the loss of nutrients during transport down the river.

Water Quality Objectives[1]

The *Canadian Water Quality Guidelines* do not contain a guideline for nutrients; however, a draft guideline is now being reviewed internally. It is more likely to emphasize **nutrient effects** than **nutrient concentrations**. In an in-depth review of the nutrient objectives issue, the British Columbia Ministry of Environment identified important differences between rivers and lakes. For rivers, the Ministry recommends criteria based on a nutrient effect, specifically plant biomass (Table S.1).

Objectives for three other provinces and the *Guidelines for Canadian Recreational Water Quality* are also based on nutrient effects. Saskatchewan has narrative objectives to prevent nuisance growths of aquatic plants while Manitoba and Quebec have similar narrative objectives plus numeric guidelines for nutrient concentrations.

Alberta has numeric objectives for nutrient concentrations. Ontario has numeric guidelines which are not objectives (Table S.1). The provinces of New Brunswick, Prince Edward Island, Newfoundland and Nova Scotia, as well as the Northwest Territories and the Yukon Territory do not have provincial or territorial objectives. Site-specific, reach-specific and basin-specific objectives have been established by interprovincial and international committees at some locations (Table S.1).

The U.S.EPA has never recommended a criterion for phosphorus as a nutrient. In 1976, it presented a "rationale" that total phosphorus should not exceed 0.05 mg/L (as P) in any stream where it enters a lake, and 0.1 mg/L (as P) in streams that do not discharge to a lake. Variations

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1 Terms such as objectives, guidelines, criteria and standards are defined by each jurisdiction. These definitions may vary but, in general, objectives are set provincially or on a site-specific basis. Their development usually takes into account relevant guidelines or criteria as well as provincial or site-specific factors including existing water quality, aquatic biota and socio-economic factors. Criteria are numerical limits derived from an evaluation of scientific data. They may be established to protect designated water uses. The term guideline usually means interim guidance or advice to be considered until a firm objective can be set. The Canadian Water Quality Guidelines are, however, criteria established to protect designated water uses. All of these terms usually apply to concentrations or conditions in ambient waters that one should strive to achieve. Standards are recognized in enforceable environmental control laws. In the U.S., states have standards of ambient water quality. In Alberta, and other provinces, effluent limits set out in a Licence to Operate or Use are legally enforcable.

of these numbers have been widely used by other jurisdictions. It is unlikely that a numeric criterion for phosphorus will be developed by the U.S.EPA.

TABLE S.1
Summary of Numeric Water Quality Objectives and Guidelines for Nutrients[a] in Canadian Rivers[b]

	Objectives/Guidelines	Year	Numerical
Alberta	Alberta Surface Water Quality Objectives	1977	Total phosphorus = 0.15 mg/L (as phosphate). Total nitrogen = 1.0 mg/L (as N).
British Columbia	Water Quality Criteria for Nutrients and Algae	1985	1) to protect recreation and aesthetics in streams: 50 mg/m^2 chlorophyll *a* in algal biomass. 2) to protect against undesirable changes in aquatic life in streams: 100 mg/m^2 chlorophyll *a* in algal biomass.
Saskatchewan	South Saskatchewan River Basin Objectives	1991	Phosphorus = 0.06 mg/L.
Manitoba	Surface Water Quality Objectives	1988	For general guidance: total phosphorus ≤0.025 mg/L in a tributary to a waterbody, total phosphorus ≤0.05 mg/L in a stream.
Ontario	Water Management - Goals, Policies, Objectives and Implementation Procedures	1984	General guidelines which should be supplemented by site-specific studies: total phosphorus <0.03 mg/L in rivers and streams.
Quebec	Water Quality Objectives of Quebec	1992	Guideline: total phosphorus <0.03 mg/L in rivers.
Prairie Provinces Water Board	1990 PPWB Water Quality Objectives	1990	Total phosphorus ≤0.05 mg/L for the protection of recreation for eastward flowing rivers at the Saskatchewan-Manitoba boundary.
International Technical Subcommittee	Water Quality Objectives for the International Waters of the Saint John River Basin	1980	Rationale: phosphate (as P) ≤0.1 mg/L in flowing streams, phosphate (as P) ≤0.05 mg/L for streams entering an impoundment, phosphate (as P) ≤0.015 mg/L as an alert level to trigger a survey.
Souris River Bilateral Water Quality Monitoring Group	Water Quality Objectives for the Souris River Saskatchewan/North Dakota and North Dakota/Manitoba Boundaries	1991	Total phosphorus ≤0.10 mg/L (as P) dissolved nitrite plus nitrate (as N) ≤1.0 mg/L (as N)

a. If no nitrogen objectives/guidelines are presented, there are no objectives/guidelines pertaining to nitrogen as a nutrient. Many jurisdictions have objectives for ammonia as a toxicant and nitrite-nitrate as a human health hazard in drinking water. These are not included.

b. Many objectives/guidelines apply to both rivers and lakes. Where the two have been differentiated, the objective for rivers has been selected.

In a 1988 survey of U.S. states, three states had numeric values for phosphorus that were guidelines, nine states had numeric standards. The values, units and approaches varied. About 20 states do not specify standards for phosphorus nor provide guidelines. About 21 states have narrative statements to prevent impairment of the designated uses.

Many of the provinces and states have objectives or standards for ammonia, nitrites and nitrates which are related to toxicity and drinking water supplies. Very few states and provinces have numeric standards for total nitrogen as a nutrient.

Effluent Discharge Limits

The environmental effects monitoring (EEM) program initiated under the federal *Pulp and Paper Effluent Regulations* includes monitoring of nutrients in pulp and paper mill effluents. Currently some provinces such as Alberta, Ontario and Saskatchewan require nutrient monitoring as a licence requirement while other provinces such as British Columbia and Quebec do not.

The concentration of phosphorus or nitrogen (as a nutrient) in pulp mill effluents is not currently limited by licence or regulation anywhere in Canada. There are total phosphorus loading reduction targets for the Great Lakes. In Ontario, a technology-based loading limit for total phosphorus in each pulp and paper mill effluent will begin at the end of 1995. The long-term average effluent concentration of total phosphorus used in the calculation is 1.5 mg/L times a factor for variability of 1.32 which equals 2 mg/L of total phosphorus. Loading limits for regulated mills are expressed in terms of kilograms per day, based on loading limits of 0.280 kg/t for sulphate (kraft) and sulphite-mechanical mills and 0.163 kg/t for the other categories of mills listed. Consistent with Great Lakes protection, Michigan and Wisconsin require point source discharges to achieve 1 mg/L of total phosphorus as a monthly maximum, but both states allow alternate effluent limits for pulp mills. A permit limit of 2 mg/L total phosphorus is the most frequently used alternate.

The U.S.EPA has just released new technology-based effluent guidelines for the pulp and paper industry, but these do not limit nutrients. Some states have added nutrient limits to National

Pollutant Discharge Elimination System (NPDES) permits due to site-specific water quality concerns. Finland has a national technology-based phosphorus loading target of 60 g/t of pulp. New mills with biologically treated effluent have permit limits of 40-50 g P/t of pulp.

An effluent limit of 1 mg/L of total phosphorus is more common for sewage treatment plants which can achieve this level of nutrient removal with tertiary treatment. No municipality licensed within the NRBS area has either a monitoring requirement or a limit for total phosphorus. In Alberta, the policy with respect to phosphorus discharges from municipal systems is that, at the time of upgrading or expansion, all municipalities with projected design wastewater flows of greater than 20 000 m^3/d must reduce effluent phosphorus concentrations below 1.0 mg/L. (The need for ammonia and/or total nitrogen restrictions on municipal discharges in Alberta is assessed on a site-specific basis). This technology-based limit of 1.0 mg/L of total phosphorus is also used in other provinces such as Ontario, Saskatchewan, and Quebec, and in the Great Lakes Agreement. A limit of 0.5 mg/L has also been applied where eutrophication is a serious problem (e.g. Lakes Erie and Ontario). British Columbia has an objective of 1.5 mg/L when dilution in the receiving stream is less than 2000:1. All provinces consider the need for nutrient limits on a site-specific basis taking factors such as the water quality of the receiving stream into account.

ACKNOWLEDGEMENTS

This report was produced in consultation with the Nutrients Group of the NRBS. SENTAR would like to thank Dr. Patricia Chambers, Head of the Nutrients Group, and Greg Wagner of the NRBS for their assistance. The cooperation of individuals in the provincial environment departments across Canada, the Prairie Provinces Water Board, Environment Canada, the U.S. EPA, some northern states and the pulp and paper industry is greatly appreciated. Individuals who provided specific information used in the report are cited in Section 6, but there were many others who took the time to provide background information and contacts.

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SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 OBJECTIVE

This study reviews both the regulatory requirements pertaining to nutrients in effluent discharges, and the instream water quality guidelines or objectives for nutrients.

1.2 SCOPE

The Terms of Reference (Appendix A) of the project require that information on effluent regulations and instream objectives or guidelines pertaining to nutrients from Alberta, Canada and other jurisdictions be compiled and reviewed. In addition, the criteria that were used by each jurisdiction for setting nutrient quality objectives and regulatory requirements are included where available. Regulatory requirements imposed on nutrient loads from licensed discharges in the Peace, Athabasca and Slave River systems, and nutrient loading requirements imposed on pulp mills beyond the Northern River Basins Study area were targeted.

The scope is limited to the major nutrients, nitrogen and phosphorus in flowing waters. Supporting information such as the parameters measured by regulatory agencies for monitoring nutrient loads is also part of the scope.

1.3 REPORT

Preparation of a comprehensive synthesis report completes the requirements of this project. To assist readers who are not familiar with this topic, the report also contains a summary of the general effects of nutrients on river ecosystems (Chapter 2). Instream objectives or guidelines for nutrients are included in Chapter 3 and effluent standards in Chapter 4. For easy reference, the report contains summary tables that compare and contrast regulatory requirements in various jurisdictions (Chapter 5).

SECTION 2.0

REGULATION OF NUTRIENTS DISCHARGED TO RIVERS

2.0 REGULATION OF NUTRIENTS DISCHARGED TO RIVERS

2.1 THE NEED FOR NUTRIENT REGULATIONS

Eutrophication is the process by which rivers and streams become biologically more productive due to an increased supply of nutrients. Increased productivity due to moderate increases in nutrients can be beneficial. Increasing algal growth enlarges the base of the food chain and may enhance the growth of desirable species in nutrient poor waters. Based on responses of juvenile salmonids, addition of inorganic nutrients to increase periphyton (algal) production can maximize trophic enhancement in nutrient-deficient streams (Johnston et al. 1990, Perrin et al. 1987). Commercial and sport fish populations may increase. The size and, sometimes, the species richness of communities supported by this food source also increase. For example, monitoring of benthic macroinvertebrates on the Athabasca River near Hinton has demonstrated an increase in both the numbers of invertebrates and the species richness of the community (numbers of invertebrate taxa) (SENTAR Consultants Ltd. 1994).

2.1.1 Potential Negative Effects

If the amount of nutrients entering a stream continues to increase, the algal and macrophyte biomass may reach undesirable levels if the nutrients are bioavailable. Dense mats of periphyton (attached algae) and extensive stands of aquatic macrophytes (large plants) may reach nuisance levels reducing the usefulness of the stream or river. At this stage, eutrophication can have a negative effect on recreational use, agricultural uses such as irrigation and livestock watering, and aquatic life.

The recreation potential of the stream may be reduced as algae reduce the clarity of the stream, impede the movement of boats and swimmers, impart odours to the water, alter the taste of fish flesh, and reduce the aesthetic value of the stream.

An increase in nutrients, if they are in a form that is available for growth, eventually leads to a change in the aquatic community which may lead to a change in fish species and a reduction in the sport or commercial fishery. Excessive algal growth can cover over spawning areas in the stream bed, reduce water flow over these areas, and reduce the dissolved oxygen levels in interstitial waters of the gravels and cobbles in which some species of fish bury their eggs. Larvae and eggs of salmonids require very high levels of dissolved oxygen saturation (76%-95%) (Davis 1975).

Excessive algal growth can also reduce the invertebrate species, such as stoneflies or trichoptera, which are most suitable as fish food. The invertebrate community may shift to different species such as chironomids and oligochaetes which can reduce growth rates of some fish such as salmonids (Nordin 1985).

Increased algal and rooted plant biomass causes increased respiration and, therefore, increased oxygen demand. Although photosynthesis produces oxygen in the presence of light, oxygen is consumed as respiration continues during the hours of darkness. The result may be a diurnal fluctuation in dissolved oxygen levels, with minimum levels at night. Also, as vegetation dies and decays, the increased levels of bacterial respiration cause increased oxygen demand.

The agricultural use of the stream may be hampered when algae clog irrigation water intakes and both rooted plants and algae obstruct the flow of water in irrigation channels, though this is not an issue in the NRBS study area. Some species of algae have toxic strains which can cause livestock mortality when water supplies contain excessive algal growth. This is more likely to occur in lakes or ponds where toxic blue-green algae are more widely distributed and water-blooms of noxious species are known to occur.

2.1.2 When Are Nutrient Regulations Needed?

The reason for developing nutrient standards and objectives is to prevent the potential negative effects of excessive productivity on a river. Objectives or standards are only needed if the environmental effect is negative; that is, a recognized use of the river is impaired. Levels that are desirable for one use, such as commercial fish production, may be perceived as undesirable for another use, such as recreation. Thus, the type of basin-specific objectives needed will be related to the goals for water management in the basin.

In some cases, high concentrations of nutrients may not have a negative impact if natural processes prevent excessive growth. Factors, such as scouring, suitable substrate, turbidity, light, temperature and grazing, may limit biomass. Thus, the potential effect of increased nutrient concentrations may not be negative or it may not be realized because other factors limit growth. In these cases, it may not be necessary to regulate nutrients.

Before regulations or objectives are applied to a river basin, it must be established that nutrients are, in fact, limiting plant growth. The virtual absence of rooted aquatic macrophytes from most reaches of the major rivers in the NRBS area cannot be explained by nutrient levels alone. The limiting factor may also change seasonally, annually and longitudinally. For example, field measurements of sediment oxygen demand in the NRBS area showed that increased epilithic algal growth below point sources changed seasonally as a result of scouring (Casey 1990). Growth may be limited by the factors described in the following section.

2.1.3 Other Factors Controlling Plant[1] Growth

Normally, there are many potentially limiting factors in flowing waters; a change in any one can give rise to a change in growth rate. Short-term instability is a characteristic of river vegetation. Records of the occupation of particular sites often show frequent changes in species and biomass

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[1] Refers to both algae and rooted aquatic macrophytes.

which arise from constant interactions between physical, chemical and biological factors (Westlake 1973).

2.1.3.1 Water Velocity

Water velocity is likely to be one of the most important factors affecting the composition of species in river plant communities such as epilithic algae and rooted macrophytes. The effects may be direct by restricting establishment of the new plant, damaging the plant physically, or changing the rate of supply of the nutrient at the plant's surface. The effects may be indirect by altering the substrate (e.g. scouring) or by altering the populations of grazers.

Catastrophic flows or spates which remove large quantities of biomass annually, or on an irregular basis, can be a very important control on the proliferation of plant biomass. The high flows in the Athabasca River in the spring of 1991 have been cited by many authors as the probable cause of reductions in the benthic community (SENTAR Consultants Ltd. 1994).

Under low flows, increased velocity may enhance growth because increases in velocity result in increases in phosphorus uptake by periphyton (Lock 1979). Increases in current velocity to approximately 50 cm/s appear to assist the growth of periphytic organisms. In a study of six northwestern U.S. streams, Welch et al. (1987) showed that periphyton biomass was related to increased velocity, but not to increased nutrient concentrations.

With increases in velocity above approximately 50 cm/s, the negative effect of scouring becomes more important, overriding the increase in the rates of various biological processes (Horner and Welch 1981). In streams where velocities over 50 cm/s were measured, an increasingly greater proportion of the periphyton growth was eroded (Horner and Welch 1978). A sampling of data provided by pulp mills in the NRBS area for different rivers, seasons and years indicates that velocities often exceed 50 cm/s. For example, velocities for sites on the Athabasca River were 51-113 cm/s at Hinton in October 1992 (TAEM 1993), 67-111 cm/s at Hinton in April 1992 (TAEM 1992a), and 53-78 cm/s at Whitecourt in October 1991 (Beak Associates 1991).

Velocities were 33-110 cm/s for sites on the Wapiti River in January 1992 (TAEM 1992b), and 31-81 cm/s for sites on the Peace River in May 1992 (HBT Agra 1992).

2.1.3.2 Sediment

The distribution and standing crop of rooted aquatic plants is often related to the nature of the stream bottom. Substrates such as mud and sand generally are not sufficiently stable for periphyton colonization and growth; large amounts of algal biomass generally are found on cobbles, boulders or coarse gravel (Nordin 1985). The sediment type is correlated with flow; fine sediments found in depositional areas are good examples. Trask et al. (1981) concluded that the location of plant growths in a nutrient-rich river is heavily influenced by sediment type and flow regime.

Chambers et al. (1989) found that the biomass of a rooted macrophyte was primarily determined by sediment type and not significantly affected by open-water nutrient concentrations. Increased velocity results in river beds with larger sediment particles which are usually less nutrient-rich. The impact of regulations which decrease nutrient loading on rooted macrophytes will depend on the availability of nutrients in water and sediment, and the particle size of the river bed sediments.

2.1.3.3 Light

The importance of light relative to nutrients in limiting plant growth depends on the photosynthetically available radiation (PAR) and bioavailable nutrients. When phosphorus is not limiting, Bothwell (1988) found that the correlation of growth rate and light became significant in experimental troughs. In rivers with deeper water, greater turbidity or extensive shading from shoreline vegetation, light may exert a greater effect. The mainstem rivers in the NRBS study area are typically highly turbid during the summer while tributaries tend to be clear.

2.1.3.4 Water Temperature

When phosphorus and light are not limiting, temperature apparently exerts the dominant control over algal growth rates. In an experimental trough study (Bothwell 1988), temperature accounted for 90% of the observed annual variation.

2.1.3.5 Grazing

Grazing by some species of invertebrates can have a significant effect on the maximum algal biomass in flowing waters. Herbivores alter the stream algal communities in at least three ways: reduction of biomass through consumption and dislodgement (Power et al. 1985, Lamberti and Resh 1983), reduction in the cyclic fluctuations (rapid growth to maximum biomass followed by senescence), and changes in the species composition (Hart 1985, Sumner and McIntire 1982). The end result tends to be a relatively stable standing crop of algae; thick mats of periphyton do not occur (Lamberti et al. 1987). Changes in taxonomic structure of the periphyton appear to be related to the type of grazer (e.g. type of mouthparts, etc.) and the intensity of the harvest.

For example, aquatic insects can be important grazers. Some caddisfly (Trichoptera) species can immediately reduce algal biomass and pigment to extremely low levels and prevent any accumulation of algal material (Lamberti et al. 1987, McAuliffe 1984). In contrast, other insects such as mayflies (Ephemeroptera) with softer brushlike mouthparts do not have as great an effect on the periphyton.

2.2 SOURCES THAT SHOULD BE REGULATED

If regulations are based on water quality, reduction of nutrient inputs from point sources, nonpoint sources and background will be considered. In order to apply water quality-based limits, all sources of nutrients to the river should be considered. Significant inputs to the river may be due to pulp mill effluents, municipal effluents, agricultural run-off or other sources.

In technology-based regulations, minimum levels of technology such as secondary treatment, or concentrations of nutrients that can be readily achieved by that technology, are specified. Technology-based regulations often apply to municipal sewage treatment plant discharges or effluents categorized by industrial sector. Compliance with technology-based limits is not tied to instream effects. Therefore, compliance may, or may not, result in a reduction of plant growth in the river. Bothwell (1992) found that the concentrations of dissolved phosphorus in a Kamloops kraft mill effluent were typically below 0.5 mg P/L (ca. 1 mg P/L total phosphorus) and would have met a technology-based limit of 1 mg/L. However, even at in-river dilutions of 100-fold, the steady-state elevation of soluble phosphorus was high enough to stimulate algal production in rivers that were phosphorus-limited.

If point sources from other sectors and nonpoint sources supply sufficient nutrients to meet the growth requirements of the plants, compliance by only one sector may not result in a benefit to the river. If the natural background levels for the river exceed the water quality objectives as they do in some of the NRBS rivers, the nutrient levels will be lowered, but the objectives will not be achieved by regulating point source discharges.

Both phosphorus and nitrogen are naturally occurring substances that are derived from the weathering of minerals present in watershed soils (e.g. apatite), the atmosphere (e.g. gaseous nitrogen), and the decay of plant and animal remains. Both nutrients are exported from the watershed to the mainstem of the river by tributaries. Phosphorus is primarily transported in the fine suspended sediment load which may be enriched with adsorbed phosphorus, although dissolved phosphorus is also exported. Nitrate which is extremely soluble may enter the river as a subsurface flow. Nitrogen and phosphorus occur in the environment both naturally and as a result of human activities. Key anthropogenic (i.e. human origin) sources include non-point sources of nutrients such as agriculture and forestry, and point sources such as municipal sewage treatment plant effluents and industrial effluents (e.g. pulp and paper mill effluents). The sectors that might effectively be regulated may differ from one river to another.

Although nutrient loads from point sources can be more easily regulated, loading from other sources in the watershed can make a substantial contribution to the total load. The loads to the mainstem of the Athabasca River from tributaries, for example, are generally much larger than point sources (SENTAR Consultants Ltd. 1994).

2.3 REGULATING THE EFFECT

The lack of commonly accepted objectives for nitrogen and phosphorus is, at least in part, due to the lack of a universal dividing line between positive and negative impacts based on nutrient concentration alone. Instream objectives have often been set for the deleterious effects of eutrophication, rather than the nutrients directly. Objectives for dissolved oxygen and desirable levels of algae or aquatic macrophytes are two examples of indirect regulation of eutrophication. For example, the U.S.EPA (Ken Potts pers. comm.) is not intending to develop a phosphorus criterion. Instead, a task force will develop a strategy for reducing the negative environmental effects; this strategy may include revising the dissolved oxygen criteria. Because the cause of eutrophication is difficult to quantify, Canadian and American regulators have, instead, set objectives for the effect.

The public perception of a "problem" must also be considered in the appraisal. Although measurement of the cellular growth rate would be an immediate and direct measure of the stimulus from the nutrient, it is the accumulation of biomass that is associated with nuisance growth. If a cellular growth rate does not produce substantial biomass (due to high levels of removal by grazing or scouring, or poor penetration of the biomass by nutrients), the algae or macrophytes are not perceived as a problem. Thus, "desirable/undesirable" levels pertain to biomass. The perception of the problem is also related to the algal species. For example, diatoms are much less likely to be perceived as objectionable than the same mass of filamentous algae.

The most common indicator of biomass is chlorophyll *a*. Measurement methods for epilithic algae and macrophytes include dry weight and ash-free dry weight methods usually expressed as mass per unit area. The use of photographs, in addition to a measurement such as biomass or chlorophyll *a*, was recommended by Nordin (1985) for assessing the level of algae that is acceptable from an aesthetic point of view.

2.4 DETERMINING WHICH NUTRIENT IS LIMITING

Phosphorus may be the nutrient limiting the growth of epilithic algae or aquatic plants; however, nitrogen, either alone or with phosphorus, may also be limiting (Bothwell 1992). Even in phosphorus-rich waters where nitrogen becomes the limiting nutrient, removal of phosphorus may be the most feasible alternative both technically and biologically, provided that it can be lowered enough to become the limiting nutrient. Many sources of nutrients, such as pulp mill effluents, sewage outfalls and agricultural runoff, add both nitrogen and phosphorus. Thus, identification of the nutrient that is limiting, or that can be made to be limiting, is important.

There are a number of techniques that can be used to determine which nutrient is limiting. The critical concentration, usually established in laboratory experiments, is the minimum concentration of an element in a plant which will permit maximum plant yield and growth (Gerloff 1975). At concentrations below the critical level, growth rates will be reduced. This would indicate nutrient limitations. Gerloff (1975) found that the critical concentration for an element can vary greatly in different organisms, so much so that specific critical concentrations must be established for each aquatic species (based on the weight of N and P in water).

The N:P ratio provides an indication of the relative availability of these nutrients[2]. Earlier research on lakes found that nitrogen is limiting when the N:P ratio is less than 5:1 (Schindler 1977, Chiandani and Vighi 1974). Phosphorus is limiting when the N:P ratio is greater than 10:1 (Chiandani and Vighi 1974) or 12:1 (Dillon and Rigler 1974). It is reasonable to assume that ratios above 12:1 and below 5:1 indicate phosphorus and nitrogen limiting conditions, respectively. Intermediate ratios are less certain. The N:P ratio may be less useful in detecting nutrient limitation in streams than it has been in lakes (Bothwell 1985).

The N:P ratios have little meaning if both nutrients are in excess. When the supply of these two elements is above the amount required by the plant, growth will remain constant at the maximum growth rate and show no relationship to the N:P ratio (Wong et al. 1979). Conversely, when

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[2] Few authors have indicated which forms of nitrogen and phosphorus were used to calculate the N:P ratio.

both nutrients are below the critical level, the N:P ratio could fall in the intermediate range giving no clear indication that either is limiting when, in fact, both are limiting. Thus, the N:P ratio can only indicate which nutrient could be limiting, provided it is known that one nutrient is below the critical concentrations (Painter et al. 1976).

Other research methods are also available. Radiographic techniques can be used to measure the orthophosphate turnover time[3]. A rapid turnover time of <1 h indicates that phosphorus is limiting algal growth (Lean et al. 1983, Prepas 1983). Algae produce the enzyme alkaline phosphatase when concentrations of available phosphorus become limiting. The presence of high levels of this enzyme has been used to identify phosphorus limitation (Smith and Kalff 1981) although this method has to be used with care.

All of these methods have weaknesses as well as strengths. The results of a single method may be unreliable but, by combining the information gained from several methods, a more reliable determination of the limiting nutrient can be achieved.

2.5 CRITICAL CONCENTRATIONS OF NUTRIENTS IN RIVERS

2.5.1 Phosphorus

Laboratory research has shown that cellular growth rates saturate at extremely low levels of dissolved phosphorus; however, the phosphorus concentrations normally observed to produce maximum algal biomass accumulation in streams are much higher. Bothwell (1985) attributed this to the difference between concentrations required to saturate cellular growth rates and concentrations needed to produce maximum biomass of the entire algal mat.

Phosphorus addition experiments conclusively established that the cellular growth rates of periphytic diatoms in the Thompson River, B.C., were saturated at very low phosphate

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[3] Phosphate demand is assessed by the rate at which radioactive phosphate ($^{32}P\text{-}PO_4$) is removed by plankton, defined as orthophosphate turnover time.

concentrations of less than 0.001 mg/L (Bothwell 1988, 1987b). For example, Bothwell (1988) found that growth rate saturation occurred at a dissolved orthophosphate concentration of approximately 0.3-0.6 μg P/L.

Excessive growth of the algal mat did not occur until much higher concentrations. In B.C. streams, excessive growth of the mat occurred at concentrations of 0.0035-0.005 mg/L soluble reactive phosphorus (SRP) (Bothwell and Daley 1981, Derksen 1981). Similarly, concentrations of SRP of 0.002, 0.003 and 0.005 mg/L produced high biomass levels (345, 108 and 92 mg/m^2 of chlorophyll *a*, respectively) in western U.S. streams (Welch et al. 1987).

Excessive periphyton biomass accumulation usually reaches a maximum at SRP concentrations of 0.007-0.025 mg/L. In an *in situ* study of filamentous species, the concentration of SRP above which growth is saturated was estimated around 0.007 mg/L (Seeley 1986). In continuous-flow trough experiments at high and medium velocities (Horner et al. 1983), an apparent saturation of chlorophyll a accrual occurred at an average inflow SRP concentration of 0.015-0.025 mg/L.

Two B.C. studies are in close agreement with Horner et al. (1983). In experimental enrichment studies of a coastal stream in B.C., phosphate was added to attain ambient levels of 0.015 and 0.02 mg P/L, respectively (Perrin et al. 1987). The higher nutrient level more than doubled the periphyton chlorophyll *a* compared to the first treatment indicating that, even at a phosphate level of 0.015 mg P/L, biomass saturation had not been achieved. In experimental trough experiments (Bothwell 1987a), biomass continued to increase up to 0.025 mg/L phosphorus. A log-linear relationship between phosphate concentration (as P) and maximum sustainable biomass was apparent with saturation occurring just above 0.025 mg/L. In general, the concentration of phosphate required to saturate a sustainable standing crop of diatoms is about 0.02 to 0.03 mg P/L (Bothwell et al. 1989).

Standing crops of macrophytes and epilithic algae were significantly higher in the Bow River downstream of the Calgary sewage treatment plant (Culp et al. 1992). Due to phosphorus removal, average dissolved phosphorus concentrations have been substantially reduced in the Bow River below Calgary from 0.169 mg/L to 0.022 mg/L. No immediate and corresponding decrease in aquatic plant biomass occurred. Algal standing crops have not decreased in response to the lowered dissolved phosphorus concentrations which suggests that 0.022 mg/L is at or above the saturation (critical) concentration (Charlton and Bayne 1986).

Macrophyte growth was strongly affected by high discharges and scouring (Cross et al. 1984). Nutrient uptake by aquatic macrophytes may not be significantly affected by open water nutrient concentrations. Transplant experiments conducted in the South Saskatchewan River showed that the aquatic macrophyte *Potamogeton crispus*, obtained most of its nutrients through the roots (Chambers et al. 1989).

2.5.2 Nitrogen

Very little information is available on critical concentrations of nitrogen in rivers. Because aquatic plants are known to take up both ammonium and nitrate, a critical nitrogen concentration based on their sum, which is reported as total inorganic nitrogen, is preferred over nitrate-nitrogen alone.

In an enriched reach of the South Saskatchewan River, Hamilton (1985) found that tissue nitrogen levels in aquatic macrophytes correlated well with average summer ambient water concentrations of total inorganic nitrogen. This implied that plant tissue nitrogen levels were responding directly to ambient river water concentrations, whereas tissue phosphorus did not. Nuisance growth was occurring on the South Saskatchewan River at levels as low as 0.025 mg/L of total inorganic nitrogen (Hamilton 1985), but this was not necessarily the critical level.

In rivers that are nitrogen limited, nitrogen in fully treated kraft mill effluent can stimulate benthic algal production. Bothwell (1992) found that growth rates almost doubled even when the dissolved inorganic nitrogen (0.2 mg/L ammonia-N and 0.05 mg/L nitrate-N) in the effluent was completely diluted in the river (0.5% v/v).

2.6 FORMS OF NUTRIENTS PRESENT IN RUNNING WATER

2.6.1 Phosphorus

Phosphorus is present in water as orthophosphate or organophosphorus compounds, but a very large proportion of the phosphorus in flowing water is bound organically, or adsorbed to inorganic or particulate organic forms. Anions such as phosphate are strongly adsorbed at the surfaces of oxides, especially iron (III) oxides (Drever 1982, Strumm and Morgan 1981). The various fractions of phosphorus are dependent on the extraction scheme used[4].

Total phosphorus consists of total dissolved phosphorus and total particulate phosphorus. Total dissolved phosphorus is, in turn, made up of dissolved inorganic phosphorus (>90% bioavailable) and dissolved organic phosphorus (<50% bioavailable) (Logan 1982). Dissolved organophosphorus compounds can make up a significant fraction of the total dissolved phosphorus in stream water, but little is known about their chemical character, identity and bioavailability (Segars et al. 1986). Those forms of dissolved phosphorus in water that are measured by standard chemical techniques not using digestion are called soluble reactive phosphorus (SRP). Most of the SRP is presumed to be ortho-phosphate, a form of dissolved inorganic phosphorus.

Total particulate phosphorus is made up of three components: labile phosphorus, inorganic phosphorus and organic phosphorus. Labile phosphorus includes adsorbed, exchangeable, easily dissolved, and easily hydrolyzed forms which are potentially 100% bioavailable, but of unknown immediate bioavailability (Logan 1982). The labile phosphorus fraction of sediments constitutes a small fraction of the total particulate phosphorus. Particulate inorganic phosphorus is sometimes fractionated into apatite (essentially unavailable) and non-apatite (partially available) inorganic phosphorus (Williams et al. 1976a,b). Non-apatite inorganic phosphorus is associated mainly with iron and partly with aluminum sediment components (Armstrong 1979). Organic

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4 The following two paragraphs are a general summary which includes references to authors who use different extraction schemes. The reader should refer to the papers cited if a better understanding of these schemes is required.

phosphorus occurs in relatively stable humus compounds of generally unknown availability (Logan 1982).

2.6.2 Phosphorus Measurement

Total phosphorus is analyzed by digestion of an unfiltered sample. Measurement of total phosphorus has generally been used as a more reliable indicator of phosphorus concentrations because it avoids analysis problems with other forms of phosphorus and it includes all potential sources of phosphorus. Total phosphorus, however, also includes unavailable phosphorus such as apatite which makes it difficult to relate total phosphorus to environmental effects. In flowing waters, total phosphorus is a consistently poor correlate of available phosphorus in both nutrient-poor and nutrient-rich rivers (Bradford and Peters 1987). Peters (1978) estimated that bioavailable phosphorus is 18-57% of total phosphorus in rivers.

Total dissolved phosphorus is usually separated by filtration through a 0.45 μm pore diameter membrane filter. Soluble reactive phosphorus (SRP) includes inorganic orthophosphate and the colloidal fraction of the organic phosphorus. The molybdenum blue method used to determine SRP has problems especially at very low levels (i.e. <0.003 mg/L) of orthophosphate, another reason for the preference for total phosphorus in objectives.

2.6.3 Nitrogen

Nitrogen occurs as dissolved molecular nitrogen (N_2), a large number of particulate and dissolved organic compounds, ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). In natural waters, nitrite is an intermediate product which is usually rapidly oxidized. The dissolved organic nitrogen of fresh waters often constitutes a large percentage of the total dissolved nitrogen. The dissolved organic nitrogen is from five to ten times greater than the particulate organic nitrogen contained in the water column. The importance of dissolved forms over particulate forms sets nitrogen apart from phosphorus.

Algae take up ammonia the most rapidly, followed by nitrate (Murphy 1980). These forms are taken up by aquatic macrophytes as well. Urea, free amino acids and peptides are also available to algae although at a slower rate than ammonia (Reynolds 1984).

2.7 NUTRIENT TRANSPORT

Streams differ from lakes in that nutrient cycling is tied to downstream transport of the nutrient. This concept, which includes the interdependent processes of cycling and downstream transport, is known as spiralling (Newbold et al. 1983). Different types of flowing water would have different spiral lengths depending on flow, suspended solids, trophic status and other factors.

Nutrients entering the river from effluent discharges, runoff or groundwater are rapidly transferred to other compartments of the river ecosystem and transformed to other chemical species. This non-conservative characteristic of nutrients makes effluent regulations for nutrients more difficult to set. Studies of phosphorus translocation in streams by radioactive tracer techniques reveal that phosphorus is quickly removed from the water as it flows downstream (Gregory 1978). The rate at which phosphorus is removed from flowing water varies from river to river, within sections of a river, and with seasonal changes.

Phosphorus may be biologically assimilated, chemically precipitated and physically adsorbed from the flowing water mass. In biological assimilation, phosphorus is absorbed first by the algae, fungi and bacteria of the stream. Organic materials such as dead plant material on the stream bottom may also remove phosphorus from the water by adsorption. Soluble phosphorus may also combine chemically with metallic cations to form precipitates, but sorption of phosphorus by particulate material is generally a more important process in streams than precipitation. Physical adsorption of phosphorus onto inorganic sediments, especially clay minerals, accounts for further phosphorus removal (Gregory 1978, Nelson et al. 1969). It has been suggested that there may be an equilibrium between dissolved and total P in turbid waters (Mayar and Gloss 1980). Fine grained silty sediments were found to have a higher phosphorus sorption capacity than coarse sandy sediments (Klotz 1985).

Rigler (1979) and Meyer (1979) both suggest that sediments only act as a temporary "sink" for phosphorus and that flooding causes downstream transport of phosphorus. Phosphorus concentrations in stream water increase under high flow conditions by decreasing the phosphorus stored in the sediments (Harms et al. 1978). Total phosphorus increases because scouring causes the suspension of particulate phosphorus. Dissolved phosphorus also increases due to runoff events and the release of interstitial phosphorus from the bottom sediment (Harms et al. 1978; McDiffett et al. 1989).

Nitrogen cycling is mainly microbial. Ammonia is generated by heterotrophic bacteria as the primary end product of decomposition of organic matter. Two groups of nitrifying bacteria oxidize it to nitrite and then nitrate. The biologically important forms of nitrogen such as nitrate and ammonia are very water soluble and are, therefore, transported downstream.

SECTION 3.0

AMBIENT WATER QUALITY OBJECTIVES

3.0 AMBIENT WATER QUALITY OBJECTIVES

Effluent limits that are based on water quality impact are generally set so that instream water quality objectives will be met with some level of confidence. Water quality objectives can be established regionally (by river basin), or provincially. Water quality guidelines are provided by the federal government. Since water quality differs markedly within one province, the ideal situation is to have river basin objectives, but these are often unavailable. Generally, the provincial water quality objectives take precedence.

3.1 CANADA

3.1.1 Canadian Water Quality Guidelines

There is no guideline for phosphorus in the current *Canadian Water Quality Guidelines* (CCME 1993). A water quality guideline for nutrients in flowing waters has been under consideration for some time; contracts were let in the late 1980's to develop a scientific basis for a guideline. After a lapse of several years, a new draft has recently been prepared by the Eco-Health Branch of Environment Canada. It is under internal review. After revision, it will be sent out for external technical review and review by the CCME Task Force. Because the nutrient guideline is non-conventional, it is expected to receive a more extensive review than usual (Rob Kent, pers. comm.). The proposed guideline addresses excessive growth of filamentous algae and aquatic vascular plants. It is unlikely to contain a numerical limit for phosphorus concentration.

There are guidelines to protect aquatic life and livestock watering from ammonia, nitrite and nitrate nitrogen, but these are related to the toxicity of these forms, rather than their nutrient value.

3.1.2 Guidelines for Canadian Recreational Water Quality

The *Guidelines for Canadian Recreational Water Quality* (Health and Welfare Canada 1992) recommend that a bathing area should be as free as possible from nuisance organisms that could affect swimmers; however, the guidelines also point out that it is impossible to have natural areas free from nuisance organisms. Therefore, the guideline stated that no limits can be quantified for nuisance organisms, but "Recreational areas should not be developed if there is an excessive growth of aquatic plants where entanglement could occur...". Addressing aesthetics, the guidelines state "All water should be free from substances attributable to wastewater or other discharges in the amounts that would interfere with the existence of life forms for aesthetic value".

3.1.3 Guidelines for Canadian Drinking Water Quality

The *Guidelines for Canadian Drinking Water Quality* (Health and Welfare Canada 1993) refer to water that is available to the consumer after treatment. Therefore, the guidelines do not refer to instream water. Although the guidelines set acceptable concentrations of toxic forms of nitrogen in finished water, the guidelines do not address nitrogen as a nutrient nor phosphorus. Eutrophic waters may require more treatment to improve the aesthetic characteristics such as taste and odour.

3.2 ALBERTA

The *Alberta Surface Water Quality Objectives* (Alberta Environment 1977) specify a maximum concentration of 0.15 mg/L "phosphorus as PO_4 (total inorganic and organic)". This is the same as 0.05 mg/L total phosphorus (expressed as P)[1]. The objectives were established to protect the most sensitive use. The explanatory note for phosphorus states that it is a nutrient for plant growth and it interferes markedly with coagulation.

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1 based on the ratio of the molecular weights of P:PO_4 which is 31:95.

The *Alberta Surface Water Quality Objectives* include an objective for total nitrogen of 1.0 mg/L, but no objectives for specific forms of nitrogen such as ammonia. The explanatory notes for nitrogen indicate that: it is a nutrient for plant growth; ammonia nitrogen creates oxygen demand, indicates pollution and can be toxic to fish; and nitrate levels in excess of 40 mg/L as nitrate can be harmful to infants.

The water quality objectives for total nitrogen and total phosphorus have not been updated since they were established in 1977. Review of these objectives will be given a high priority when a Canadian water quality guideline for nutrients (currently under development by Environment Canada) is received by the Standards Research and Development Branch of Alberta Environment (Paul Shewchuk, pers. comm.). The existing water quality objectives remain in effect for the present.

The *Alberta Surface Water Quality Objectives* are province-wide in their scope but reach-specific guidelines are also set in Alberta for Instream Flow Needs Studies on a case-by-case basis.

3.3 NORTHWEST TERRITORIES

The government of the Northwest Territories (NWT) does not have surface water quality objectives that are specific to the Territories. The Water Resources Division of the Department of Indian and Northern Affairs, as manager of water resources in the NWT would use the *Canadian Water Quality Guidelines*.

3.4 YUKON TERRITORY

The government of the Yukon Territory does not have surface water quality objectives that are specific to the Territory. The Water Resources Division of the Department of Indian and Northern Affairs, as manager of water resources in the Yukon would use the *Canadian Water Quality Guidelines*.

3.5 BRITISH COLUMBIA

The British Columbia Ministry of Environment has adopted a process that is different than that used by other provinces. It has developed province-wide water quality criteria[2]. These are, in turn, used to develop site-specific water quality objectives[2]. The water quality objectives for specific lakes or rivers are based on the criteria, and also the water uses, waste discharges, flow patterns and water quality at the site. If a water body has several uses, the most sensitive use is considered.

The Ministry published a 104 page technical appendix providing the rationale for the water quality criteria for nutrients and algae (Nordin 1985). This was the first attempt by a Canadian government department to specify standards for nutrients or algae in such a detailed manner.

Because of the fundamental differences between streams and lakes, particularly in terms of water residence times, the Ministry (Nordin 1985) decided that bioavailable phosphorus must be defined differently for moving water (rivers and streams) than for lakes. In streams, algae can only make use of phosphorus that is dissolved and available for uptake. Other forms of phosphorus are available in lakes due to recycling of phosphorus. Thus total phosphorus is an appropriate measure in lakes, but not streams (Nordin 1985).

For streams, criteria could be set in terms of either nutrients or biomass. The Ministry chose biomass (measured as chlorophyll *a*) for several reasons. In streams, there are several necessary conditions which must be satisfied before phosphorus becomes a factor causing nuisance levels of growth. These conditions are suitable water velocity, substrate, light, temperature and grazing pressure. Only when all these conditions are within favourable ranges does phosphorus hold the potential of being the limiting factor. Then, very low concentrations of phosphorus (<0.003 mg/L) can cause heavy stream algal biomass accumulations (Nordin 1985). Since phosphorus concentration in the stream is such a poor indicator of algal biomass, and biomass

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[2] Criteria are numerical limits derived from an evaluation of scientific data. Objectives are based on criteria plus site-specific factors including existing water quality, aquatic biota and socio-economic factors.

is likely to be the focus of concern, the Ministry of Environment chose chlorophyll *a* for the criterion.

A value of **<50 mg/m²** chlorophyll *a* is recommended as the criterion to protect uses related to recreation and aesthetics in streams. A value of **<100 mg/m²** chlorophyll *a* is recommended to protect against undesirable changes in aquatic life. No criterion could be suggested for drinking water supply since any impairment of water use would only occur from sloughing of algae. No relationship between the amount of periphytic algae present and problems with algae drawn into water intakes appears to be documented.

For lakes, a well defined relationship exists between phosphorus, generally measured at the spring overturn, and the amount of algal biomass in a lake during the growing season. For lakes the Ministry of Environment recommended **<0.01 mg/L** total phosphorus to protect drinking water supplies and recreation. Problems with algae are unlikely to occur below this concentration, ensuring that the water withdrawn will be of high quality. A concentration of <0.01 mg/L basically ensures that lakes remain oligotrophic.

The criteria for aquatic life where salmonids are the predominant fish species is **>0.005 mg/L and <0.015 mg/L** total phosphorus. A range is given because lakes can have a range of characteristics which must be taken into account. A higher concentration of phosphorus is required to optimize fish production than is desirable for recreation or water supply.

The lake criteria apply to the concentration of phosphorus during the spring overturn (lake epilimnetic residence time >6 months) or mean epilimnetic growing season concentration (epilimnetic residence time <6 months).

The nutrient criteria values are conservative and, therefore, favour protection (Nordin 1985). They were developed specifically for British Columbia where salmonid fish production predominates in oligotrophic waters.

The 1985 criteria are currently used and site-specific nutrient objectives[3] have been established. The criteria of <50 or <100 mg/m^2 of chlorophyll *a* have been set as site-specific river objectives, depending on the most sensitive use (Roland Rocchini pers. comm.). Site-specific objectives have been set for lakes using the phosphorus criteria, although the objectives have not always been the same as the criteria. Phosphorus objectives have not been established for rivers.

3.6 SASKATCHEWAN

3.6.1 South Saskatchewan River Basin Objectives

As a result of the federal-provincial South Saskatchewan River Basin Study (SSRBS) (SaskWater and Environment Canada 1991), the South Saskatchewan River is one of the few Saskatchewan rivers to have specific water quality objectives. Water quality objectives were developed for the SSRBS area using existing water quality data and scientific information regarding the effect on specific uses. The basin-specific water quality objective for phosphorus is **0.06 mg/L**. The objective does not specify the form of phosphorus, but supporting information specifies total phosphorus.

3.6.2 Saskatchewan Surface Water Quality Objectives

The *Saskatchewan Surface Water Quality Objectives* (Saskatchewan Environment and Public Safety 1988) consist of general surface water quality objectives and objectives to protect specific uses. The general surface water quality objective for nutrients states "Nitrogen or phosphorus or other nutrient concentrations should not be altered from natural levels by discharges of effluents such that nuisance growths of algae or aquatic weeds result." Because aquatic nuisances, including algal blooms and excessive macrophyte growth, affect recreational and

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[3] British Columbia differs from other provinces in its water quality objectives. Criteria which are based primarily on an evaluation of scientific literature are prepared by the province. Each topic is addressed in a separate document. The criteria are used along with site-specific data to set site-specific objectives. British Columbia does not have province-wide objectives.

agricultural uses in many Saskatchewan lakes, Saskatchewan Environment and Public Safety (1986a) also published *A Guide to Aquatic Nuisances and Their Control.*

There is no numerical objective for phosphorus in the surface water quality objectives. There is no numerical objective for total nitrogen, but there are objectives for some forms of nitrogen based on their toxicity. The ammonia nitrogen objective for the protection of aquatic life and wildlife is in the form of a table since the toxicity varies with water temperature and pH. There is an objective for nitrate plus nitrite of 100 mg/L for the protection of livestock watering.

3.7 MANITOBA

After a thorough review, Manitoba Environment published the *Manitoba Surface Water Quality Objectives* (Williamson 1988) which replaced earlier objectives. It contains general requirements as well as numerical requirements for different classes of beneficial uses. The general requirement for nutrients state that "Nitrogen, phosphorus, carbon and contributing trace elements should be limited to the extent necessary to prevent the nuisance growth and reproduction of aquatic rooted, attached and floating plants, fungi or bacteria or to otherwise render the water unsuitable for other beneficial uses. For general guidance, unless it can be demonstrated that total phosphorus is not a limiting factor, considering the morphological, physical, chemical or other characteristics of the water body, total phosphorus should not exceed **0.025 mg/L** in any reservoir, pond, or in any tributary at the point where it enters such bodies of water. In addition, total phosphorus should not exceed **0.05 mg/L** in any stream except those identified in the immediately preceding statement. It should be noted that the maintenance of such concentrations may not guarantee that eutrophication problems will not develop".

Specific forms of nitrogen that can be harmful to human or animal health are addressed. An objective of 10.0 mg/L and 1.0 mg/L for nitrate (as N) and nitrite (as N) is included for Class 1 uses: domestic consumption, food processing and other household use. An objective for un-ionized ammonia in the form of a table of maximum acceptable concentrations according to pH and temperature is included for Class 2 use, aquatic life and wildlife. An objective of 10.0 mg/L nitrate-nitrite is specified to protect Class 4, Category D use, livestock.

Another review of water quality objectives has been started by the Water Standards and Studies Branch of Manitoba Environment (Dennis Brown pers. comm.). The 1988 objectives remain in effect and no changes in nutrient objectives are anticipated in the near future.

3.8 ONTARIO

The Ontario water quality objective for total phosphorus (Ontario Ministry of the Environment 1984) states "Current scientific evidence is insufficient to develop a firm objective at this time. Accordingly the following phosphorus concentrations should only be considered as general guidelines which should be supplemented by site-specific studies:

- To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed **20 μg/L [0.02 mg/L]**;

- A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of **10 μg/L [0.01 mg/L]** or less. This should apply to all lakes naturally below this value;

- Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below **30 μg/L [0.03 mg/L]**." (Ontario Ministry of the Environment 1984)

There is no objective for nitrogen related to plant growth. Ontario has a specific water quality objective for ammonia. The concentration of un-ionized ammonia should not exceed 0.02 mg/L for the protection of aquatic life.

3.9 QUEBEC

The Quebec water quality objectives (Ministère de l'Environnement du Québec 1992) have a narrative criterion for nutrients. The objective is the absence of excessive growth and reproduction of aquatic rooted, attached or floating plants, fungi and bacteria.

Quebec has objectives for ammonia nitrogen, nitrate nitrogen and nitrite nitrogen which are use-specific. The use categories are: raw water for drinking water supply, aquatic life (acute toxicity), aquatic life (chronic toxicity), recreation (contact recreation) and recreation (aesthetics). The objectives for nitrogen forms have been adopted from other jurisdictions, particularly the B.C. Ministry of Environment.

The objectives to protect aquatic life from acute and chronic toxicity to ammonia (as N) are in the form of tables (from Nordin and Pommen 1986) which take pH and temperature into account. The objective for raw water for drinking water supplies is 0.5 mg/L total ammonia (as N).

The concentration of nitrates and nitrites should not exceed 10 mg/L in raw water for drinking water supplies. Taken separately, the concentration of nitrates should not exceed 10 mg/L and the concentration of nitrites should not exceed 1.0 mg/L. The objectives for the protection of aquatic life are adopted from the B.C. Ministry of Environment (Nordin and Pommen 1986): The nitrate objectives are 200 and 40 mg/L (as N) for acute and chronic toxicity, and the nitrite objectives are 0.06 and 0.02 mg/L (as N) for acute and chronic toxicity, respectively. None of the numerical objectives for nitrogen forms given above refer to nitrogen as a nutrient.

The Quebec water quality objectives for total phosphorus are **0.03 mg/L** (as P) to eliminate excessive growth of aquatic plants in rivers, and **0.02 mg/L** (as P) to eliminate nuisances caused by algae in lakes. The Quebec objectives are similar to the objectives established by the Ontario Ministry of the Environment (1984). These objectives apply to aquatic life (chronic toxicity), contact recreation and aesthetics. The only numerical objective for raw water as a water supply is **0.1 mg/L** phosphate as phosphorus from the U.S.EPA (1976) criteria.

3.10 THE MARITIME PROVINCES

3.10.1 New Brunswick

New Brunswick does not have provincial water quality objectives. It relies on the *Canadian Water Quality Guidelines* (CCME 1993). Water quality objectives were developed for the international waters of the Saint John River Basin by the International Technical Subcommittee on Water Quality in the Saint John River (1980). (See also Section 3.12.1.)

3.10.2 Prince Edward Island

Prince Edward Island does not have provincial water quality objectives; the province uses the *Canadian Water Quality Guidelines* (CCME 1993). The province does not have regulations that specify maximum levels of nutrients; they have only a general statement to the effect that no person shall pollute the waters (Clair Murphy pers. comm.).

3.10.3 Newfoundland

Newfoundland does not have provincial water quality objectives; the province uses the *Canadian Water Quality Guidelines* (CCME 1993) (John Kingston pers. comm.).

3.10.4 Nova Scotia

Nova Scotia does not have province-wide water quality objectives. It relies on the *Canadian Water Quality Guidelines* (CCME 1993). Site-specific objectives have been developed to protect specific rivers. The Tusket River which receives effluent from a tin mine is one case where site-specific objectives are available for a limited range of parameters, but there are very few sites where objectives have been developed (Andrew Cameron pers. comm.).

3.11 INTERPROVINCIAL RIVERS

Interprovincial boards with a responsibility for water crossing provincial boundaries, have established concentrations for water quality parameters. Water quality objectives have been established for the Ottawa River and the eastward flowing prairie rivers (Blachford 1988).

The eastward flowing interprovincial rivers under the jurisdiction of the Prairie Provinces Water Board (PPWB) include the Beaver, North Saskatchewan, Red Deer, South Saskatchewan, Battle, Churchill, Saskatchewan, Carrot, Assiniboine and Qu'Appelle. In order to identify desirable levels of water quality on eastward flowing interprovincial rivers at provincial boundaries, the PPWB adopted water quality objectives that are reach-specific. The *1990 PPWB Water Quality Objectives* (PPWB 1991) were developed using provincial objectives, basin-specific objectives (where available), and CCME surface water quality guidelines. The PPWB objectives were jointly developed by Canada and the provinces of Alberta, Saskatchewan and Manitoba. They were agreed to by the Board in 1990 and subsequently incorporated into Schedule E of the *Master Agreement on Apportionment*. The objectives are closely tied to the ongoing Environment Canada monitoring program at the boundaries. The PPWB has developed the in-house capability to determine excursions and plot trends for all the parameters and rivers as needed (Gary Dunn pers. comm.). Reviewing excursions to the objectives is one part of the overall process to identify potential interprovincial water quality concerns. Other processes used by the Board are trend analysis and spill reporting.

The 1990 PPWB objective for nitrite and nitrate (as N) is 10.0 mg/L for the protection of drinking water. The objective for ammonia is based on the table for total ammonia nitrogen in the *Saskatchewan Surface Water Quality Objectives* (Saskatchewan Environment and Public Safety 1988) which takes pH and temperature into account. The sensitive use protected by the ammonia objective is fisheries. There are no other objectives for nitrogen.

There is a PPWB 1990 water quality objective for phosphorus for the rivers crossing the Saskatchewan-Manitoba boundary. The objective for the Saskatchewan, Carrot, Assiniboine, Churchill, Red Deer (Manitoba), and Qu'Appelle Rivers is **0.05 mg/L** total phosphorus for the protection of recreation. For all of these rivers except the Churchill River, phosphorus is flagged as a potential issue. The 1991 monitoring data (PPWB 1993) shows that the objective of 0.05 mg/L total phosphorus is easily met on the Churchill River. There have been three exceedances on the Saskatchewan River since 1974, seven on the Carrot River, and twelve on the Red Deer River (Manitoba). The objective is routinely exceeded in the Assiniboine and Qu'Appelle Rivers (PPWB 1993).

None of the PPWB 1990 reach-specific objectives for the river reaches crossing the Alberta-Saskatchewan boundary contain an objective for phosphorus.

3.12 INTERNATIONAL RIVERS

International working groups have developed water quality objectives for rivers which cross the Canada-U.S. boundary. These objectives are specific to each river, but they may be useful because they represent the collective opinions of provincial, state and federal (Canada/U.S.) technical/scientific representatives.

The Great Lakes Water Quality Agreement of 1987 had a provision for the control of eutrophication by specifying phosphorus loading rates to each of the Great Lakes in tonnes per year. There are no instream nutrient objectives set out by the IJC; water quality objectives/standards for the rivers flowing into the Great Lakes are the responsibility of the states and provinces and are addressed in other sections of this chapter.

3.12.1 Saint John River

Water quality objectives were developed for the international waters of the Saint John River Basin by the International Technical Subcommittee on Water Quality in the Saint John River (1980). No specific objective for phosphate was set. The general objective was that "phosphate levels should be low enough to prevent eutrophic conditions." A definitive phosphate objective was not set "because of the complexity of the interrelationships which exist with other nutrients and the available forms of phosphorus itself". The rationale quoted a phosphate (as P) level not to exceed

0.1 mg/L in flowing streams, **0.05 mg/L** in streams entering an impoundment, and **0.025 mg/L** in an impoundment, as being widely recommended. Phosphate levels higher than these will not necessarily result in undesirable blooms of algae.

The Saint John River objectives recommended that a survey to determine the trophic state of the water should be undertaken if the results for phosphate (as P) exceed **0.015 mg/L** on a seasonal basis. This level may be related to lakes and applying it to rivers may not be appropriate (Jerry Choate pers. comm.).

3.12.2 Red River

The International Red River Pollution Board, created in 1969 reports to the International Joint Commission in annual progress reports. The Board established water quality objectives for the specific point at which the Red River crosses the International Boundary to provide a useful method of determining the acceptability of the water quality of the Red River. The water quality objectives were adopted by the IJC in 1969; they include only five parameters. Only one of these, dissolved oxygen, has any relevance to nutrient enrichment. The objectives do not include nitrogen or phosphorus. At the IJC meeting in 1984, the concept of alert levels was introduced to complement the existing objectives. Alert levels for the most significant water chemistry variables were developed and approved in 1986. There are no alert levels for phosphorus or nutrient effects (International Red River Pollution Board 1992).

There are alert levels for ammonia nitrogen and nitrate nitrogen based on toxicity (International Red River Pollution Board 1992). The nitrate alert level of 10 mg/L (as N) is based on human consumption. It is the same as the Minnesota standard and the Manitoba objective for drinking water. The ammonia levels vary according to pH and temperature. They are based on standards from Minnesota and North Dakota for the protection of aquatic life.

The Objectives Working Group will meet prior to the 1993 Board meeting to review existing Red River objectives and alert levels and recommend any changes, deletions and additions to the Board. The Working Group and the agencies which are represented are currently exploring the development and use of ecosystem methodology for monitoring (Bill Gummer pers. comm.), including water column, sediment and biological indicators.

3.12.3 Souris River

The Souris River Bilateral Water Quality Monitoring Group developed objectives for the Souris River at two locations: the Saskatchewan/North Dakota boundary and the North Dakota/Manitoba boundary. The water quality objectives were derived from a consensus building process by: using the objectives/standards from the appropriate jurisdictions, examining the background water quality, and considering monitoring and analytical capabilities.

The *Souris River Basin International Water Quality Objectives* (Souris River Bilateral Water Quality Monitoring Group 1991) includes objectives specifically for eutrophication. They are **0.10 mg/L** total phosphorus in streams, and **1.0 mg/L** dissolved nitrite plus nitrate (as N). The objectives are the same at both locations. There is also an ammonia (un-ionized as NH_3) objective to protect aquatic life from toxicity which is calculated using temperature and pH. In 1991, monitoring showed that the phosphorus objective was exceeded in 100% and 90% of the samples at the Saskatchewan-North Dakota and North Dakota-Manitoba boundaries, respectively (Souris River Bilateral Water Quality Monitoring Group 1992).

3.12.4 Poplar River

Multipurpose water quality objectives for the East Poplar River at the International Boundary were recommended by the International Poplar River Water Quality Board to the IJC. The Poplar River objectives are unusual in that the concentrations are flow-weighted and there are three month and five year objectives. The Poplar River Bilateral Monitoring Committee (1993) compared the monitoring results to the objectives. There are no water quality objectives for phosphorus and none related specifically to nutrient enrichment. There is an un-ionized ammonia (as N) objective of 0.2 mg/L and a nitrate (as N) objective of 10.0 mg/L. Both are related to toxic effects.

3.13 UNITED STATES

The U.S.EPA criteria play a role similar to the *Canadian Water Quality Guidelines*. The criteria and other information are used by states to establish standards. State water quality standards differ from provincial objectives in that they are legally enforceable standards.

3.13.1 Federal Criteria

The *Quality Criteria for Water* (U.S.EPA 1976) did not provide an orthophosphate or total phosphorus criterion to control nuisance aquatic growths, although it did provide a rationale for such a criterion for consideration. Two basic needs must be met in establishing a phosphorus criterion for flowing waters; one is to control the development of plant nuisances within the flowing water; the other is to protect the downstream receiving water body. To prevent the development of biological nuisances and to control accelerated eutrophication, phosphates as phosphorus should not exceed **0.05 mg/L** in any stream at the point where it enters any lake or reservoir or **0.1 mg/L** in streams or other flowing waters that do not discharge directly into lakes or reservoirs. Another method to control the inflow of nutrients to a lake is to prescribe an annual loading to the receiving water.

The *Ambient Water Quality Criteria* documents produced mainly in the 1980's replaced the 1976 *Quality Criteria for Water*; however, a check of the National Technical Information Services (NTIS) and the U.S.EPA Publications and Information Center listings confirmed that there are no ambient water quality criteria for phosphorus or nitrogen (as a nutrient). A criteria document for ammonia nitrogen has been produced.

A Task Force has recently been assembled to develop a strategy related to eutrophication (Ken Potts pers. comm.). It will look at a number of related issues including nonpoint sources of nutrients. The strategy will likely include a number of approaches such as a revised criterion for dissolved oxygen that would allow better modelling of nutrient loading and reduced loads; better use of chlorophyll *a* or water transparency monitoring; and use of species changes (e.g. green algae to blue-greens). It is unlikely that a numerical criterion for phosphorus would be developed (Ken Potts pers. comm.).

3.13.2 State Standards

The U.S.EPA has a standards program that looks at state standards derived from federal criteria. A total of 26 *Water Quality Standard Criteria Summaries: A Compilation of State/Federal Criteria* were produced in 1988, including one for phosphorus (NTIS number PB89-141444) and one for nitrogen (including ammonia, nitrate and nitrite) (NTIS number PB89-141618).

Phosphorus

Many states had narrative statements to preserve natural conditions and/or prevent nuisance growths of plants or algae that would impair the designated uses. The U.S.EPA (1988a) listed 21 states which would fit in this category. These states were: Vermont, Texas, South Carolina, Rhode Island, Ohio, North Carolina, New York, New Mexico, New Hampshire, Michigan, Massachusetts, Louisiana, Kentucky, Kansas, Indiana, Idaho, Georgia, Florida, Delaware, Connecticut and Arkansas. The wording differs from state to state and also by the class of the stream. Numbers were used by three states, Utah, Arkansas and North Dakota, not as standards but as guidelines, interim limits, or indicators for further investigation. These guidelines are **0.05 mg/L** phosphate (as P) in Utah streams, and **0.1 mg/L** as total phosphorus in Arkansas streams (U.S.EPA 1988a). The North Dakota Department of Health (1991) set an interim guideline limit of 0.1 mg/L total phosphorus (as P).

The 1988 compilation of state/federal criteria for phosphorus (U.S.EPA 1988a) indicated that 20 states did not specify standards for phosphorus (as a nutrient) nor provide narrative nutrient guidelines. These states were: Alabama, Alaska, Colorado, Iowa, Maryland, Minnesota, Mississippi, Missouri, Montana, Nebraska, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Virginia, Washington, West Virginia, Wisconsin and Wyoming.

Only nine of the states had numerical standards for phosphorus. There was no consistency in either the numbers used or the units used. Some of these states have developed site-specific standards rather than state-wide standards. The numerical standards (U.S.EPA 1988a) are:

- 0.1 mg total phosphorus in New Jersey (streams) and New Mexico (cold water fishery only), unless the limit is shown to be unnecessary;

- 0.05 mg/L total phosphorus in all tributaries to Great Ponds in Maine;

- 0.3 mg/L total phosphate (as PO4) in Class A and B streams and 0.15 mg/L total phosphate in a stream entering any reservoir or lake in Nevada;

- 0.05 mg/L phosphorus (as P) for streams entering a reservoir or lake in Illinois;

- 0.05 and 0.03 mg/L geometric means of total phosphorus (as P) in streams during the wet season and dry season, respectively in Hawaii (single values not to exceed 0.15 mg P/L in the wet season and 0.08 mg P/L in the dry season more than 2% of the time);

- 0.2 mg/L total phosphorus for warm freshwater habitat, 0.1 mg/L total phosphorus for cold freshwater habitat, and 0.05 mg/L total phosphorus for recreation in California (Basin 3); and

- a range of annual means from 0.03 to 0.5 mg/L (the most common being 0.1 mg/L) total phosphate (as PO4) for site specific standards in Arizona.

<u>Nitrogen</u>

The U.S.EPA (1988b) compilation of water quality standards and criteria for nitrogen listed numeric nutrient standards for only four states. The total nitrogen standard for cold water fishery in New Mexico is 1.0 mg/L (as N). The standard in Arizona for total nitrogen for certain surface water segments is 0.3-1.0 mg/L as an annual mean (Arizona also has single sample maxima). Hawaii has a total nitrogen standard for streams of 0.25 and 0.18 mg/L as geometric means in the wet and dry seasons, respectively. Hawaii also has standards for single sample maxima from 0.06 to 0.80 mg/L total nitrogen depending on the percentile and the season. Nevada has standards which include total Kjeldahl nitrogen as well as total nitrate, total nitrite and ammonia nitrogen. These standards would, therefore regulate total nitrogen as a nutrient as well as the toxicity. The standards are not state-wide, but are set individually at various control points. The most common approach was a narrative statement referring to control of nutrients, often tied to further investigation. This approach was summarized on p. 3.16.

Many of the states have standards for ammonia, nitrites or nitrates which are related to toxicity and drinking water supplies. The 22 states that refer to nitrogen only in terms of toxicity include: California, Colorado, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Minnesota, Missouri, Nebraska, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Dakota, Utah, Virginia, West Virginia, Wisconsin, and Wyoming (U.S.EPA 1988b).

Some states have not specified any standard with respect to nitrogen or nutrients generally. These include: Alabama, Alaska, Connecticut, Georgia, Maine, Maryland, Mississippi, Montana, New Hampshire, Oregon, Tennessee, and Washington (U.S.EPA 1988b).

3.14 OTHERS

The regulatory guidelines for phosphorus in Europe and Japan (Table 3.14.1) are related to waste use. Finland is probably the farthest advanced of the Scandinavian countries in nutrient control from pulp mills (Tibor Kovacs pers. comm.), but industrial targets rather than instream water quality objectives are used. The European guidelines for nitrogen address ammonia and nitrite which are toxic substances rather than nitrogen as a nutrient. Japan has limits for total nitrogen (Table 3.14.2) which appear to include nutrient effects. Reacting to the major blue-green algal outbreak in Australia and New Zealand in 1990-91, Australia and New Zealand recommend an ambient water quality guideline of 0.1 mg/L total nitrogen and 0.01 mg/L total phosphorus.

TABLE 3.14.1
European, Australian, New Zealand and Japanese Water Quality Guidelines for Phosphorus

Value (mg/L)	Use	Rationale	Jurisdiction	Reference
0.20 (PO_4)	Aquatic Life	Limit value for salmonid waters, where salmonid waters shall mean waters which support or become capable of supporting fish belonging to species such as salmon (*Salmo salar*), trout (*Salmo trutta*), grayling (*Thymallus thymallus*) and whitefish (*Coregonus*); to reduce eutrophication.	Europe	ECEL 1988
0.4 (PO_4)	Aquatic Life	Limit value for cyprinid waters, where cyprinid waters shall mean waters which support or become capable of supporting fish belonging to the cyprinids (*Cyprinidae*), or other species such as pike (*Esox lucius*), perch (*Perca fluviatilis*) and eel (*Anguilla anguilla*); to reduce eutrophication.	Europe	ECEL 1988
0.005 (TP)	Aquatic Life	Annual average; conservation of scenic points and other natural resources; conservation of environment (refers to the limits at which no unpleasantness is caused to the people in their daily lives, including a walk along the shore).	Japan	J. Env. Agency (1987)
0.01 (TP)	Recreation and Aesthetics	Annual average; bathing	Japan	J. Env. Agency (1987)
0.01 (TP)	Aquatic Life	Annual average; for aquatic life such as salmon, sweet fish, small carp and silver carp.	Japan	J. Env. Agency (1987)
0.05 (TP)	Aquatic Life	Annual average; fishery class 2; smelt, carp and silver carp.	Japan	J. Env. Agency (1988)
0.10 (TP)	Aquatic Life	Annual average; fishery class 3; carp and silver carp; conservation of environment.	Japan	J. Env. Agency (1987)
0.01 (TP)	Aquatic Life		Australia and New Zealand	

TABLE 3.14.2
Nitrogen Guidelines for Japan, Australia and New Zealand

Value (mg/L)	Use	Rationale	Jurisdiction	Reference
0.10 (TN)	Aquatic Life	Annual average; conservation of scenic points and other natural resources; conservation of environment refers to the limits at which no unpleasantness is caused to the people in their daily lives, including a walk along the shore.	Japan	J. Env. Agency (1987)
0.20 (TN)	Recreation and Aesthetics	Annual average; bathing.	Japan	J. Env. Agency (1987)
0.20 (TN)	Aquatic Life	Annual average; for aquatic life such as salmon, sweet fish, smelt, carp and silver carp.	Japan	J. Env. Agency (1987)
0.60 (TN)	Aquatic Life	Annual average; fishery class 2; smelt, carp and silver carp.	Japan	J. Env. Agency (1987)
1.0 (TN)	Aquatic Life	Annual average; fishery class 3; carp and silver carp; conservation of environment.	Japan	J. Env. Agency (1987)
0.10 (TN)	Aquatic Life		Australia and New Zealand	

SECTION 4.0

SURVEY OF FINAL EFFLUENT PERMIT LIMITS

4.0 SURVEY OF FINAL EFFLUENT PERMIT LIMITS

Discharge limits can be technology-based or water quality-based. Both methods are commonly used; and will be examined in this survey of final effluent permit limits.

4.1 ENVIRONMENT CANADA

4.1.1 Pulp and Paper Effluent Regulations

The Department of Fisheries and Oceans is responsible for the *Pulp and Paper Effluent Regulations* under the federal *Fisheries Act*. The regulations apply to every mill in Canada except one mill at Port Alberni, British Columbia, as well as off-site treatment facilities treating a specified amount of mill waste. The regulations allow the operator of a mill to deposit "deleterious substances" in water if the quantity does not exceed the maximums specified in the regulations. The regulations also specify sampling, testing and reporting methods to be used in the monitoring.

The classes of substances that are covered in the regulations include: acutely lethal effluent, biochemical oxygen demand (BOD) and suspended solids. The regulations do not address nutrients. The monitoring includes: BOD, suspended solids, acute toxicity, pH, and electrical conductivity. Monitoring of nutrients is not required under the regulations directly, but the regulations do require environmental effects monitoring studies.

4.1.2 Environmental Effects Monitoring (EEM)

The environmental effects monitoring (EEM) program was developed to assess the adequacy of the effluent regulations under the federal *Fisheries Act* and to achieve national uniformity in monitoring of effects. The program requirements for environmental effects monitoring were stipulated by Environment Canada and Department of Fisheries and Oceans (1992a). Specific monitoring requirements for the pulp and paper sector are in *Annex 1; Aquatic Environmental Effects Monitoring Requirements at Pulp and Paper Mills and Off-Site Treatment Facilities*

Regulated under the Pulp and Paper Effluent Regulations of the Fisheries Act (Environment Canada and Department of Fisheries and Oceans 1992b). A *Technical Guidance Document* (Environment Canada and Department of Fisheries and Oceans 1993) for EEM has been published recently (April 1993).

The EEM requirements include monitoring for nutrients, specifically ammonia, nitrate plus nitrite, total Kjeldahl nitrogen and total phosphorus. The guidance document recommends analytical methods for effluents and receiving waters (Table 4.1.1).

4.2 ALBERTA

4.2.1 Pulp Mill Effluent Permits

All pulp mills have to monitor for nutrients as a requirement of their licence. The list of parameters to be measured in their effluent is included as Appendix B of their licence. The parameters listed in Appendix B are the same for all the Alberta pulp mills (Alberta Pacific, ANC, Daishowa-Marubeni, Millar Western, Weyerhaeuser, Slave Lake, and Weldwood). They include: ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total Kjeldahl nitrogen, dissolved phosphorus, and total phosphorus. Limits for total nitrogen and total phosphorus have not been established in current licences. In the most recent licence for Daishowa-Marubeni Industries, Peace River Pulp Division, a statement has been added to the effect that the Director may be setting nutrient limits in the future (Ian Mackenzie pers. comm.). This sentence is not legally necessary since all licences contain a clause in which the Director reserves the right to add or delete parameters in the Table of Effluent Limits. All pulp mills have been advised that effluent limits for nutrients are a distinct possibility. Most mills have been required to undertake nutrient minimization studies. Clause 11.05 of the Weyerhaeuser licence requires the submission of a plan that deals with nutrient control and schedules future limits on total phosphorus and total nitrogen.

TABLE 4.1.1
Summary of Analytical Methods for Nutrients in Effluents and Receiving Waters (Environment Canada and Department of Fisheries and Oceans 1993)

Parameter	Sample Preparation	Instrumental Method	Matrix Detection Limits		Precision[a]	Accuracy[b]	References
			Effluent (mg/L)	Water (mg/L)			
Total P	For manual determination, digestion by sulphuric acid/ potassium persulphate <u>OR</u> sulphuric acid/potassium sulphate/mercuric oxide if TKN being analyzed at same time.	Manual measurement of molybdate blue complex at 880 nm <u>OR</u> automated digestion, reagent addition, and colour measurement at 380 nm by segmented flow analyzer	0.002	0.002	±10%	95-105%	Environment Canada (1992) APHA (1989)
Ammonia	For manual determination, effluent samples and some waters will require distillation.	Manual measurement of indophenol blue at 630 nm <u>OR</u> automated distillation, reagent addition and colour measurement at 630 nm on segmented flow analyzer.	0.05	0.005	±10%	95-105%	Environment Canada (1992) APHA (1989)
Nitrate Plus Nitrite	None	Manual or automated reduction cadmium, addition of reagents to form azo dye, measurement of colour at 520 nm.	0.1	0.01	±20% at 0.5 mg/L	95-105%	Environment Canada (1992) APHA (1989)
Total Kjeldahl Nitrogen	For manual determination, digestion with sulphuric acid/ potassium sulphate/mercuric oxide solution required prior to distillation and instrumental determination of ammonia.	Manual measurement of indophenol blue at 630 nm <u>OR</u> automated digestion, distillation, reagent addition, and colour measurement at 630 nm by segmented flow analyzer.	0.02	0.02	±10%	95-105%	APHA (1989)

a. Acceptable performance for duplicates based on 1 standard deviation derived from historical data.
b. Acceptable performance for recovery of reference material or spikes, based on 1 standard deviation derived from historical data.

4.2.2 Municipal Sewage Treatment Plant Effluent Permits

The final effluent requirements for municipal sewage treatment plants in Alberta are based on a combination of technology-based limits and water quality-based limits. Technology-based limits tend to govern and are based on providing a secondary level of treatment. In the future, all larger municipalities (design wastewater flows greater than 20 000 m^3/d) will have to reduce effluent phosphorus concentrations below 1.0 mg/L and will have to have effluent disinfection. Water quality modelling and/or assessment of downstream water usage are conducted to determine if technology-based limits are sufficiently stringent to meet instream objectives. The instream objectives must be met using only one-third of the river as a mixing zone, leaving two-thirds as a zone of passage.

Ammonia is only limited if there is a need to do so. For example, the Calgary Bonnybrook Sewage Treatment Plant is currently being expanded and water quality modelling indicated a potential impact associated with ammonia discharges. Once it was determined that ammonia control was desirable, an ammonia limit based on the application of demonstrated ammonia control technology became the proposed requirement.

The discharge of treated sewage to rivers in the NRBS area is controlled by Alberta Environment through final effluent licences. The licences issued to municipalities with lagoon systems do not specify effluent limits for any parameters, as the design requirements for these systems ensure an effluent that exceeds secondary requirements. Municipalities are required to monitor the BOD levels in the lagoon effluent at the time of discharge. The towns with aerated lagoon systems and continuous discharge have a permit limit for BOD of 25 mg/L. A monitoring requirement for BOD and total suspended solids (TSS) is included in the permit. Towns in this category include: Slave Lake, Athabasca, Barrhead, Manning, Edson, Lac La Biche, Jasper and Fort McMurray. Towns with other treatment systems have permitted limits for TSS as well as BOD. Peace River Correctional Centre, Grande Cache, and Whitecourt have a limit of 25 mg/L for both BOD and TSS. Grande Prairie has a more stringent limit of 20 mg/L for both BOD and TSS. Dischargers chlorinating their effluent have a limit for maximum and minimum chlorine residual.

None of the permits issued to municipal dischargers in the NRBS area have monitoring requirements or limits for nutrients. Nutrients and heavy metals in the effluents from some of the municipalities are monitored for periodically by Alberta Environment. The reason that Alberta Environment does not require nutrient monitoring of most municipal effluents is that levels are always within a narrow and definable range and cannot be controlled. Nevertheless, this lack of nutrient monitoring data is in stark contrast to the extensive nutrient monitoring data requirements for the pulp mills. The loadings of nitrogen and phosphorus to the rivers from the larger municipalities such as Grande Prairie and Fort McMurray are in the same order-of-magnitude as the loadings from pulp mills. The concentration of nutrients in municipal effluents is often greater.

4.3 NORTHWEST TERRITORIES

The Northwest Territories (NWT) has no general regulations that pertain to nutrients in industrial effluents. The main developments in the NWT are mines, power dams, and one oil refinery at Norman Wells. Fort Smith discharges treated municipal sewage to the Slave River. Fort Smith is required to monitor nitrogen and phosphorus in the sewage treatment plant effluent but there are no permit limits.

4.4 YUKON TERRITORY

There are no pulp mills in the Yukon; the largest industrial sector has been mining. The municipalities of Whitehorse, Dawson and Carmacks discharge sewage to rivers. The permit for Dawson includes a maximum concentration of 5 mg/L of total phosphorus (as P); Dawson has minimal sewage treatment and discharges to the Yukon River. It has an interim licence and a new licence will be forthcoming. Whitehorse is also currently operating under a licence extension with a hearing for a new licence scheduled for November. The existing licence has phosphate, nitrate and ammonia limits, but the concentrations may change as a result of the licence hearings. Whitehorse also discharges to the Yukon River, but the flows at Whitehorse are much lower than the flows at Dawson. The new limits for the Whitehorse sewage are likely to be lower as well.

4.5 BRITISH COLUMBIA

4.5.1 Pollution Control Objectives

The *Pollution Control Objectives* are basically statements of policy. They are not standards but are used in preparing the effluent permits for industries. There are objectives for several industrial sectors including: the mining, smelting and related industries; the chemical and petroleum industries; the forest products industry; and the food processing, agriculturally orientated, and other miscellaneous industries. There are also *Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia* (B.C. Ministry of Environment 1975a).

The *Pollution Control Objectives for the Forest Products Industry of British Columbia* (B.C. Ministry of Environment 1977) does not contain nutrient objectives for effluent quality. The receiving water quality objective for nutrients is a negligible change in site-specific productivity-limiting parameters. Limiting parameters will normally be taken as phosphates and/or biologically assimilative nitrogen compounds (B.C. Ministry of Environment 1977).

The pollution control objectives in other industrial sectors include nutrients in some cases. The *Pollution Control Objectives for the Mining, Smelting and Related Industries of British Columbia* (B.C. Ministry of Environment 1979) are 2.0 to 10.0 mg/L total phosphate (as P)[1], 10.0 to 25.0 mg/L nitrite/nitrate (as N) and 1.0 to 10.0 mg//L ammonia (as N). The *Pollution Control Objectives for Food-processing, Agriculturally Orientated, and Other Miscellaneous Industries of British Columbia* (B.C. Ministry of Environment 1975b) sets separate objectives for the discharge of effluents from 15 different categories of industries. Two of these have objectives for nutrients. The objectives for effluents from fish hatcheries are 0.04 to 0.14 ammonia nitrogen, 0.12 nitrate nitrogen and 0.02 to 0.035 total phosphate phosphorus. All units are in lb of nutrient/100 lb fish/day. The objectives for the effluents from metal-finishing and industries discharging heavy metals are 1.0 to 2.0 mg/L dissolved ammonia (as N), 10.0 to 25.0 mg/L dissolved nitrate and nitrite (as N) and 2.0 to 5.0 mg/L total phosphate (as P). The *Pollution*

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[1] The actual wording in the objectives is "Phosphate (Total P biologically available in effluent)".

Control Objectives for the Chemical and Petroleum Industries of British Columbia (B.C. Department of Lands, Forests and Water Resources 1974) do not include nitrogen or phosphorus in the receiving water guidelines.

The effluent objective for municipal wastes discharged to receiving streams or rivers in British Columbia is 1.5 mg/L total phosphorus in the effluent when dilution in the receiving stream is <2000:1. Monitoring frequency for total phosphorus varies from monthly to daily depending on the quantity of effluent discharged. The total phosphorus requirement for effluents may be waived if it can be reasonably shown from a site-specific study that the receiving waters would not be subject to an undesirable degree of increased biological activity because of the input. The receiving water maintenance objective (B.C. Ministry of Environment 1975) is no detectable increase in site-specific productivity-limiting parameters. Limiting parameters will normally be taken as phosphates and/or nitrogen forms.

4.5.2 Pulp Mill Effluent Regulations

British Columbia regulates pulp mill effluent by the *Pulp Mill and Pulp and Paper Mill Liquid Effluent Control Regulation* (consolidated April 16, 1992) under the *Waste Management Act*. Effluent quality requirements apply to all of the pulp mills in the province, although two mills[2] have special quality requirements. The regulation is similar to the federal regulations. The regulation requires monitoring of total suspended solids, BOD, AOX, toxicity, temperature, dissolved oxygen, pH and flow. It does not require monitoring of nitrogen or phosphorus. The regulations do not restrict nitrogen or phosphorus in any form.

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[2] Special effluent quality requirements apply to the existing pulp and paper mill operations of MacMillan Bloedel Ltd. located at Port Alberni and the existing pulp mill operation of Western Pulp Inc. located at Port Alice.

4.5.3 Pulp Mill Effluent Permits

Effluent permits are issued and administered by the Regional Offices of the B.C. Ministry of Environment. Each pulp mill has its own permit which may be more stringent than the regulations. Permits are based on the pollution control objectives. There are no limits for phosphorus in any of the pulp mill permits. There are requirements in the permits for monitoring nitrogen but not phosphorus (Dave Morrison pers. comm.).

4.6 SASKATCHEWAN

4.6.1 Saskatchewan General Objectives for Effluent Discharges

The *General Objectives for Effluent Discharges* (Saskatchewan Environment and Public Safety 1988) are specified as universally applicable without any need for studies or surveys. They represent the minimum condition that should be achieved regardless of any other circumstances. They are applicable to all waters receiving effluents including the mixing zones adjacent to municipal outfalls. Discharges should be free from nutrients in concentrations that create nuisance growths of aquatic weeds or algae, or that result in an unacceptable degree of eutrophication of the waterbody.

The *Guidelines for Effluent Mixing Zones* (Saskatchewan Environment and Public Safety 1988) define a Limited Use Zone (LUZ) with respect to water use. The *General Objectives for Effluent Discharges* should be achieved at all sites within the LUZ. At the boundaries or outer edges of the LUZ, water quality objectives to protect beneficial water uses should be achieved. The LUZ in streams and rivers should be apportioned no more than 25% of the cross-sectional area or volume of flow, nor more than one-third of the river width at any transect in the receiving water during all flow regimes which equal or exceed the 7Q10 flow for the area.

4.6.2 Industrial Effluent Permits

Saskatchewan has about seven large industries that discharge to receiving waters. None have a limit for phosphorus in their permit (Daryl Nargang pers. comm.). Nitrogen, as a nutrient, is not limited, but an industry (e.g. Akzo Chemicals Ltd., Saskatoon) that discharges ammonia has limits for ammonia in their permit to prevent toxicity. Industrial permit limits are established on a site-specific basis and depend on the characteristics of the effluent and the potential effect on the receiving stream.

The only pulp mill in the province which discharges liquid effluent, the Weyerhaeuser mill at Prince Albert has a requirement to monitor phosphorus and nitrogen forms (Daryl Nargang pers. comm.). In setting permit limits for the pulp mill, Saskatchewan Environment reviews federal regulations and regulations from other provinces (particularly Ontario's regulations). Adoption of a regulation from another jurisdiction would be based on best professional judgement. The requirements for the discharge permit issued by Saskatchewan Environment will be at least as stringent as that required by the federal government. Nutrients will be monitored, but effluent permit limits for nutrients would be incorporated only if monitoring and environmental effects studies indicated that there was a need (Daryl Nargang pers. comm.). Thus, a permit limit for nutrients would be based on environmental effects.

4.6.3 Municipal Sewage Treatment Plant Effluent Permits

Some municipalities have phosphorus limits in their effluent permits. Eutrophication of the receiving stream has been a factor in each case. The limit is always 1 mg/L of total phosphorus. The limit in Saskatoon is currently technology based; Saskatoon uses a physical-chemical method that can achieve 1 mg/L. In this case, the initiative for a phosphorus limit came from the province and municipality based on a study of the river (Kerc 1986). Further studies of nutrient impact on the South Saskatchewan River are ongoing. Nutrient removal is not anticipated for cities discharging to the North Saskatchewan River.

Eutrophication has been identified as a problem in the Qu'Appelle River system. Municipalities discharging to the river system have phosphorus limits of 1 mg/L total phosphorus (as P). This applies to the City of Regina and much smaller municipalities such as Fort Qu'Appelle and Echo Valley Centre. The City of Moose Jaw opted for zero effluent discharge as an alternative to nutrient limits on the discharge of treated sewage and the sewage sludge is used for spray irrigation.

Saskatchewan has a technology based standard for the treatment of sewage at smaller communities (Saskatchewan Environment and Public Safety 1986b). All sewage from smaller communities discharged to receiving streams must be treated by a two cell lagoon or receive secondary treatment.

4.7 MANITOBA

4.7.1 Industrial Effluent Permits

All new industries are required to file an Environmental Impact Assessment. From this information a site-specific operating licence is issued. The parameters specified in the licence depend on the impact predicted by the assessment. Some licences include nutrients and others do not. Municipalities do not do their own monitoring but they must meet licence requirements. Whether or not nutrients are included in the licence is decided on a case-by-case basis.

There are currently two pulp mills in Manitoba. One mill (Repap Manitoba) does not have nutrient limits in the existing licence. The mill has made an application to expand and upgrade, but the expansion is not proceeding at this time. The licence for the expansion would contain effluent limits of 1 mg/L total phosphorus and 5 mg/L total nitrogen. The Abitibi-Price mill does not have a liquid effluent licence under Manitoba regulations. It is currently conducting an Environmental Impact Assessment and Manitoba Environment is in the process of issuing a licence (Doug Peterson pers. comm.). There are no overall regulations that limit nutrients.

4.7.2 Municipal Sewage Treatment Plant Effluent Permits

Permit limits for sewage treatment plants in Manitoba are site-specific, based on the type of development, the waterbody and the uses of the surface water. The limits are based on a combination of technology and site capability. There are no fixed values for total phosphorus, ammonia or chlorine (Doug Peterson pers. comm.).

4.8 ONTARIO

4.8. 1 Municipal Industrial Strategy for Abatement (MISA)

There are 26 pulp and paper mills located in Ontario discharging effluent into surface water courses in Ontario for which nutrient limits have been drafted. Three kraft mills have biological treatment systems at locations where the discharges were proven to have had pronounced effects on the receiving watercourse. In addition, one paperboard mill and two mills which de-ink wastepaper operate treatment systems.

Prior to the MISA initiative, Ontario pulp and paper mills monitored their effluents under the Ministry of Environment's Industrial Monitoring Information System (IMIS) requirements or under requirements imposed by Control Orders issued under the *Ontario Water Resources Act* or *The Environmental Protection Act*. The data reported under these programs included total phosphorus and nitrogen.

In 1986, the Ontario Ministry of the Environment initiated the Municipal/Industrial Strategy for Abatement (MISA) to identify and reduce the pollutants discharged from industrial and municipal sources into Ontario's lakes and rivers. Under the MISA program, each industrial sector was required to perform frequent testing of its effluents known as "sector characterization". A series of development documents for the effluent monitoring regulations were published including, for example, those for the metal casting sector, the inorganic chemical sector, the organic chemical sector, and the mineral industry sector.

The *Effluent Monitoring Regulation-Pulp and Paper Sector* took effect in July 1989 initiating a one year testing program primarily aimed at toxic contaminants (Ontario Environment 1993a). Effluent monitoring commenced on January 1, 1990. This first phase of the MISA program, which included effluent monitoring for over 300 major industrial discharges, has been completed (Ontario Ministry of the Environment 1992a).

The *Effluent Monitoring Regulation - Pulp and Paper Sector under The Environmental Protection Act* required, under Section 16, weekly monitoring of total phosphorus and nitrogen for mills which operated biological treatment systems with the addition of nutrients. Mills that did not add nutrients to the treatment systems were exempt from weekly monitoring. Monthly monitoring of total phosphorus and nitrogen was required at all mills. Nitrogen measurements included nitrite/nitrate, ammonia nitrogen and total Kjeldahl nitrogen. Once each quarter, a duplicate of the monthly sample was collected and analyzed; twice each year, blank samples and spiked samples, collected and prepared according to the Protocol for the Sampling and Analysis of Industrial/Municipal Wastewater (Ontario Ministry of the Environment 1991a), had to be processed.

The Ministry has begun the second phase, the regulation of industrial sector dischargers to reduce the amount of conventional and toxic contaminants being discharged. In September 1991, a report entitled *Municipal/Industrial Strategy for Abatement: Issues Resolution Process Final Report* was released (Ontario Ministry of the Environment 1991b). It resolved procedural issues and the criteria affecting limit regulations development. Although much of this strategy is directed at toxic substances, one of the strategy elements was the establishment of effluent limits for a list of sector-specific parameters which could include nutrients. The nine sectors that were targeted include: pulp and paper, petroleum refining, organic chemical manufacturing, iron and steel, mining, inorganic chemicals, metal casting, electric power generation, and industrial minerals. The strategy was also aimed at the 412 municipal sewage treatment plants and the industries discharging into municipal sewers.

4.8.2 Clean Water Regulation: Pulp and Paper Sector

The *Effluent Limits Regulation for the Pulp and Paper Sector* was promulgated by the Ontario Ministry of the Environment on November 25, 1993. The regulation establishes process effluent limits and monitoring requirements for each of the 26 mills in Ontario, based on their category, production level and the daily and monthly discharge standard. The four categories of mills are: sulphate (kraft) mills, mills using a sulphite-mechanical pulping process, corrugating mills and de-inking/board/fine papers/tissue mills. The regulation also incorporates a number of standard monitoring and reporting requirements which will begin 90 days after the regulation is filed. The new daily and monthly limits will take effect at the end of 1995.

Schedule 2 of the regulation limits the daily loading and monthly average loading of total phosphorus (Table 4.8.1) to the receiving water body for each mill (Ontario Ministry of the Environment 1993b). Total phosphorus is to be monitored weekly. There is no limit for nitrogen but there is a limit for toxicity which would protect aquatic biota from the toxic effects of ammonia. There is a monitoring requirement for cooling water but nutrients are not included in the list of parameters.

The rationale for the effluent limits regulation is contained in a draft development document which is available from the Ontario Ministry of the Environment (1993c). The effluent limits for phosphorus were developed from the intensive one year monitoring in phase one and the levels that could be achieved by the industry (Ontario Ministry of the Environment 1992b). The development of the limits began by averaging the concentrations of total phosphorus measured in the effluents from three mills; this average was 0.71 mg/L total phosphorus. Due to concerns expressed by both industry and government that these averages could not be achieved consistently by the industry, the value was increased slightly to 0.76 mg/L. Then, the maximum effluent concentration of 0.76 mg/L total phosphorus as a long term average was multiplied by a variability factor (1.32), by the flow based on the type of mill and by the reference production rate (specific to each mill) to yield the process effluent limits for each mill in kg/d. When the total phosphorus value of 0.76 mg/L is multiplied by the variability factor of 1.32, the result is

1.0 mg/L of total phosphorus in the effluent which is consistent with the Great Lakes Water Quality Agreement of 1987 limit for phosphorus in municipal effluents.

TABLE 4.8.1
Process Effluent Limits for Total Phosphorus Required Under MISA Regulations[a]

Pulp or Paper Mill	Category	Daily Loading Limit (kg/d)	Monthly Average Loading Limit (kg/d)
Abitibi-Price Inc., Fort William Division	Sulphite-Mechanical	120	72.8
Abitibi-Price Inc., Iroquois Falls Division	Sulphite-Mechanical	254	154
Abitibi-Price Inc., Provincial Papers Division	Sulphite-Mechanical	137	83.1
Beaver Wood Fibre Company Ltd.	D/B/F/T[b]	56.6	34.4
Boise Cascade Canada Ltd. (Fort Frances)	Sulphate (kraft)	322	196
Boise Cascade Canada Ltd. (Kenora)	Sulphite-Mechanical	296	180
Canadian Pacific Forest Products (Dryden)	Sulphate (kraft)	418	254
Canadian Pacific Forest Products (Thunder Bay)	Sulphate (kraft)	796	483
Domtar Inc., Containerboard Division (Red Rock)	Sulphate (kraft)	273	166
Domtar Inc., Containerboard Division (Trenton)	Corrugating	69.6	42.3
Domtar Inc., Fine Papers Division (Cornwall)	Sulphate (kraft)	237	144
Domtar Inc., Fine Papers Division (St. Catherines)	D/B/F/T[b]	31.9	19.4
E.B. Eddy Forest Products Ltd. (Espanola)	Sulphate (kraft)	340	207
E.B. Eddy Forest Products Ltd. (Ottawa)	D/B/F/T[b]	29.2	17.7
James River-Marathon Ltd.	Sulphate (kraft)	149	90.6
Kimberly-Clark Canada Inc. (Huntsville)	D/B/F/T[b]	19.2	11.7
Kimberly-Clark Canada Inc. (St. Catherines)	D/B/F/T[b]	23.0	14.0
Kimberly-Clark Canada Inc. (Terrace Bay)	Sulphate (kraft)	384	233
MacMillan-Bloedel Ltd.	Corrugating	49.1	29.8
Malette Kraft Pulp and Power Company	Sulphate (kraft)	116	70.6
Noranda Forest Products Inc., Recycled Papers	D/B/F/T[b]	46.3	28.1
QUNO Inc.	Sulphite-Mechanical	295	179
St. Mary's Paper Inc.	Sulphite-Mechanical	176	107
Sonoco Limited	D/B/F/T[b]	46.3	28.1
Spruce Falls Inc.	Sulphite-Mechanical	307	186
Strathcona Paper Company	D/B/F/T[b]	35.4	21.5

a. limits from schedule 2 in Ontario Ministry of the Environment (1993b)
b. D/B/F/T = De-inking/Board/Fine Papers/Tissue

The Ministry changed the maximum effluent concentration of total phosphorus from 0.76 mg/L as a long-term average used in the development document to 1.5 mg/L as a long term average before the regulations were promulgated. The original value could not have been achieved by the industry using practicable secondary treatment. It would have required some pulp mills to go to tertiary treatment for nutrient removal. The new effluent concentration limit will be about 2 mg/L when the long-term average of 1.5 mg/L is multiplied by the variability factor of 1.32. The Ontario Ministry of the Environment believes that all of the mills can meet a limit of 1.5 mg/L of total phosphorus in the effluent as a long term average (Alistair Stewart pers. comm.).

The unit of production loading limits for total phosphorus in the regulation promulgated on November 25, 1993, are 0.280 kg/t for the sulphate (kraft) and sulphite-mechanical categories, and 0.163 kg/t for the corrugating, de-inking, board, fine papers and tissue categories. The limits for total phosphorus loading are given for each mill in schedule 2 of the effluent monitoring and effluent limits regulation (Table 4.8.1).

Changes in mill production will be accommodated by comparing the new production rate to the reference production rate to obtain a factor which can be used as a multiplier to adjust the numbers in schedule 2. If the increase in production rate is greater than 10%, the mill will be required to file a report indicating that no impact will occur on the receiving water due to the increased production (Alistair Stewart pers. comm.).

4.8.3 Municipal Sewage Treatment Plant Effluent Permits

By ministerial policy, the minimum level of municipal sewage treatment is secondary treatment. Effluent requirements for nutrients will be established at the discretion of the water quality chief in each region on a whole-lake basis or a case-by-case basis. The phosphorus limit for sewage treatment plants of one million gallons per day capacity or greater discharging effluent to the Great Lakes is 1 mg/L total phosphorus as a monthly average. Smaller plants may have phosphorus limits if they discharge into small channels or Lake Erie. The final effluent limits for sewage treatment plants in Ontario are generally 1 mg/L total phosphorus (as P) for an annual average (Tony Ho pers. comm.). There is no minimum requirement for ammonia based on technology; the need for ammonia removal is based on instream levels as compared to the provincial water quality objectives. In establishing the effluent requirements, the characteristics of the receiving water body will be considered, as will federal and provincial effluent regulations and guidelines where applicable. For example, the total phosphorus loading to Lake Simcoe from all municipal sewage treatment plant effluents has been limited; all plants are limited to 0.3 mg/L total phosphorus. The effluent requirements so derived will be incorporated into Certificates of Approval (under Section 42, *Ontario Water Resources Act*) and will specify both waste loadings and concentrations.

The permit limits described above are typical but limits are not rigid. A water quality assessment may be done on the receiving stream and limits are based on the instream assessment. Thus, the limits depend on the information for each site including mixing zone data, size of mixing zone, dilution, etc. The instream assessment does not usually include biota. Provincial water quality objectives are used to determine these limits.

4.9 QUEBEC

In Quebec, there are more than 60 industries in the pulp and paper sector (Quebec 1992). The discharge of pulp and paper mill effluent is regulated under the *Environment Quality Act*. Industrial sectors such as pulp and paper, mining, etc., are regulated under this act. The pulp and paper mills regulations (Q-2, r.12) were first established in 1985. Regulations adopted in September 1992 (Q-2, r.12.1) provide further control of effluent quality. There have been a series of revisions in the regulations up to January 1993.

The regulations address a wide range of potentially toxic substances associated with pulp mills (organic and inorganic), toxicity, total suspended solids, BOD and COD. Nutrients are not identified in the regulations. There is no requirement to monitor or limit phosphorus. There is a requirement to sample surveillance wells and analyze for ammonia nitrogen and nitrite + nitrate nitrogen in June and October of each year.

In Quebec, the regulations for the discharge of municipal effluents are divided into two groups: the urban community of Montreal regulates discharges within its jurisdiction in concert with MENVIQ (Ministère de l'Environnement du Québec), and MENVIQ regulates municipal effluents in the remainder of the province. There are no general guidelines pertaining to nutrients in municipal effluents. Each effluent is considered on a case-by-case basis. Discharge objectives are based on the water uses that have been identified for protection (e.g. recreation, potable water, aquatic life). There are some cases in Quebec where a limit of 0.5 mg/L total phosphorus (as P) in effluents has been required. Phosphorus is limited if there is visible evidence of eutrophication or the effluent is discharged to a lake. The tributaries of Lac St. Pierre on the St Lawrence River have a phosphorus limit of 1 mg/L total phosphorus (as P). If ammonia nitrogen levels are toxic, MENVIQ will require treatment. The urban community of Montreal has a limit of 0.5 mg/L total phosphorus (as P) as a daily annual mean and 0.75 mg/L total phosphorus (as P) as mean maximum. Ammonia nitrogen is not regulated.

4.10 THE MARITIME PROVINCES

4.10.1 New Brunswick

New Brunswick has no general guidelines for industrial effluents. Effluents are regulated on a case-by-case basis. Pulp mills have been asked to cut back on the amount of phosphorus used, but there is no specific limit. Phosphorus limits have been set for fish hatcheries and food processing. The nonpoint source loading of phosphorus from highly erodible agricultural land was found to be very high. Over 90% of the phosphorus load to the Saint John River was found to come from nonpoint sources, making point sources insignificant in comparison, except in a local context (Jerry Choate pers. comm.)

Some municipal sewage treatment plants are required to monitor their effluent; BOD and SS are regulated. There are no permit limits for phosphorus except for a special case involving discharge to a lake (Jerry Choate pers. comm.).

4.10.2 Prince Edward Island

As part of its Environmental Assessment Process, Prince Edward Island requires new (within the last five years) industries to file an environmental management plan. Environmental monitoring is part of the plan. There are no general regulations that specifically limit nutrients in industrial effluents; industries are regulated on a case-by-case basis. Monitoring is not a regulatory requirement for municipalities. The province monitors effluent quality, but the parameters are the common ones such as BOD and TSS. The province has measured nutrients in municipal sewage treatment plant effluents, but monitoring for nutrients is not done routinely (Clair Murphy pers. comm.).

4.10.3 Newfoundland

There are three pulp and paper mills in Newfoundland, only one of which (Grande Falls) discharges to inland waters. The only pulp and paper mill with a secondary effluent treatment system is the Abitibi-Price Stephenville mill, which was converted to TMP-newsprint production in the late 1970's. That mill was considered to be a "new mill" under the 1972 Canadian Pulp and Paper Effluent Regulations. The other two mills were built more than 50 years earlier, before water and sewage regulations came into effect.

To date, Newfoundland has relied upon the federal government (Environment Canada) to regulate liquid effluents from pulp mills. Provincial standards established in the Environmental Control (Water and Sewage) Regulations (1980) for all effluent discharges have not been applied to the pulp mills. The Environmental Control Regulations contain concentration-based limits of 20 mg/L BOD_5, 30 mg/L TSS, 2 mg/L ammonia and 1 mg/L phosphate as P_2O_5. There are no specific regulations for nutrients in industrial wastewaters (Derrick Maddocks, pers. comm.).

4.10.4 Nova Scotia

Very few of the industrial effluents in Nova Scotia are discharged to freshwater, most are discharged to the ocean. There are no general regulations pertaining to industrial discharge of nutrients. Industries are regulated on a case-by-case basis, but the province is trying to standardize the requirements for each industry (Andrew Cameron pers. comm.). The *Environmental Protection Act* contains a permitting process and permits are site-specific. Phosphorus is not monitored. Elevated levels of ammonia and nitrate at a landfill site prompted monitoring of nitrogen forms. There is no guideline or standard for phosphorus in sewage treatment plant effluent in Nova Scotia. A limit for phosphorus could be included in the permit if it was needed for the protection of fisheries.

4.11 THE GREAT LAKES

The *Great Lakes Water Quality Agreement of 1978* addresses the control of phosphorus in the Great Lakes. Annex 3 provides phosphorus load reduction targets for basins in the Great Lakes in metric tonnes of phosphorus per year. This Annex also recommends municipal sewage treatment plant effluent concentrations of 1.0 mg/L total phosphorus maximum for plants in the basins of Lakes Superior, Michigan, and Huron, and of 0.5 mg/L total phosphorus maximum for plants in the basins of Lakes Ontario and Erie. This recommendation applies to all sewage treatment plants discharging more than one million gallons per day. The recommendation for industrial wastewaters was that phosphorus from industrial discharges should be regulated to the maximum practicable extent. Thus the numerical objectives of 1.0 and 0.5 mg/L apply to treated municipal sewage but not to industrial wastewater.

4.12 THE UNITED STATES

4.12.1 The NPDES Permitting Process

To achieve the water quality goals of the *Clean Water Act*, the U.S. Environmental Protection Agency's (U.S.EPA's) first objective is to ensure that technology-based controls on point sources are established and maintained as required by section 301(b) and 306 of the Act. Technology-based controls generally include best practical control technology currently available and secondary treatment. The goals of the *Clean Water Act* are achieved through the National Pollutant Discharge Elimination System (NPDES) permitting process. Both technology-based and water quality-based controls for point sources are implemented through the NPDES permitting process.

Water quality-based controls are determined by performing wasteload allocations using mathematical models to calculate water quality impacts in the receiving stream. Wasteload allocation calculations for non-toxic substances are primarily directed towards impacts of BOD on dissolved oxygen levels in the receiving stream; however, the U.S.EPA provides a Technical Guidance Manual addressing nutrient impacts. The methods for determining these wasteload allocations can be found in Book II Streams and Rivers-Chapter 2 Nutrient/Eutrophication Impact (EPA document # EPA 440/4-84-021).[3] Chapter 2 emphasizes the effect of photosynthetic activity stimulated by nutrient discharges on the dissolved oxygen regime of a stream or river. It is principally directed at calculating dissolved oxygen concentrations using simplified estimating techniques. Thus the rationale for NPDES permits using wasteload allocations (WLA's) is primarily related to reduced dissolved oxygen levels.

4.12.2 The Total Maximum Daily Load (TMDL)

The total pollutant load to a waterbody is derived from point, nonpoint and background sources. In recent years, nonpoint source contributions to water quality problems have become better understood and it is now clear that implementation of the *Clean Water Act* must encompass nonpoint source pollution problems and seek to address problems occurring over large geographic areas.

A Total Maximum Daily Load (TMDL) is based on the relationship between the pollution source and in-stream water quality conditions. Thus, permit limits based on TMDL's are water quality-based limits. Section 303(d) of the *Clean Water Act* establishes the TMDL process to provide more stringent water quality-based controls when technology-based controls are inadequate to achieve state water quality standards.

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[3] Manuals are available from the OWRS Monitoring Branch (phone 202-382-7056).

States are required by the Act to identify and report to the EPA their water-quality limited waters. That is, the waters that do not meet the water quality standards for the uses designated for those waters. States are required to establish a priority ranking for these waters, taking into account the pollution severity and the designated uses of the waters. States must then develop TMDLs which allow for seasonal variation and a margin of safety that accounts for any lack of knowledge concerning the relationship between effluent limitations and water quality.

Because nutrient loads may come from nonpoint sources as well as point sources, a guidance document (U.S.EPA 1991) was released to include load allocations ((LA's) as well as waste load allocations (WLA's). The TMDL is the sum of the individual waste load allocations for point sources and load allocations for non-point sources and natural background.

Where nonpoint source controls are involved, a phased approach is necessary. In order to allocate loads among both nonpoint and point sources, there must be reasonable assurances that nonpoint source reductions will, in fact, be achieved. States are expected to ensure that effective monitoring programs are in place for evaluating nonpoint source control measures.

4.12.3 National Effluent Guidelines for Pulp and Paper Mills

In the U.S., there are no federal requirements limiting nutrients in pulp and paper mill effluents (Jack Newman pers. comm.). The U.S. EPA prepared the *Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category* (U.S.EPA 1993), which was signed and published in the Federal Register, December 17, 1993. The guidelines are technology-based since all national standards are technology-based (state standards can be water-quality based). The national guidelines contain guidelines for TSS, BOD, COD, AOX and specific toxicants. The U.S.EPA has emphasized toxic pollutants; nutrients are not an issue except on a site- or lake-specific basis such as the Great Lakes (Jack Newman pers. comm.). The new guideline document does not address nutrients.

To develop the new guidelines, the industry was broken down into different operations: integrated mills, kraft pulp mills, sulphite mills, groundwood mills, etc. The rationale used in developing the guidelines was that a mill using primary and secondary treatment could be expected to achieve the guideline. In practice, mills can use any method as long as they achieve the guideline. Factors such as water use, treatment options and cost were taken into account in developing the guideline.

The U.S.EPA has a computerized permit compliance system which monitors compliance by major industries in the U.S. to effluent limits specified in their NPDES permits. This industrial database covers about 7200 industries designated as major according to a standard protocol. Some of the U.S. pulp and paper mills, although not necessarily all of the mills, are included in this system (Dela Ng pers. comm.). The U.S.EPA provided data on the pulp mill related industries in this database for inclusion in this report. There were 281 pulp mill and related industries in the database. Of these, only 18 industries had limits for total phosphorus and 34 industries had limits for nitrogen as ammonia or total Kjeldahl nitrogen. Four industries had both nitrogen and phosphorus limits. The only form of phosphorus included in the permits was total phosphorus. Although 18 industries had phosphorus limits, they were all found in seven states located near the Great Lakes or eastern U.S. The NPDES effluent limits for total phosphorus and nitrogen forms are presented in Tables 4.12.1 and 4.12.2, respectively.

An Alberta Environment review of permitted effluent limits at U.S. pulp and paper mills cited another kraft mill in Pennsylvania (Glatfelter) with an effluent limit of 2 mg/L (as P) as a monthly average (Ian Mackenzie pers. comm.). The nutrient limits do not have to be for phosphorus; nitrogen may also be limited in specific rivers. For example, Procter & Gamble are anticipating nitrogen limits for effluents discharged to nitrogen-limited waters at mills in North Carolina and Mississippi (Willy Owens pers. comm.). The need for nutrient limits in NPDES permits is usually determined on a site- or reach-specific basis by the individual states.

TABLE 4.12.1
Total Phosphorus Limits in U.S. Pulp Mill-Related Industries' Effluent Permits (U.S. EPA Data)

Industry	State	Phosphorus Loading		Phosphorus Concentration	
		Average (lbs/d)	Maximum (lbs/d)	Average (mg/L)	Maximum (mg/L)
Kimberley-Clark Corp-Lee Mills	Massachusetts	40			
Seaman Paper Company of Mass	Massachusetts				1.5
Champion Int-Quinnesec Mill	Michigan			1	
EB Eddy Paper Inc.	Michigan	67		1	
James River KVP Parchment	Michigan			1	
Manistique Paper Inc.	Michigan			1	
Menominee Paper Co.	Michigan	16.7		2	
Silver Leaf Paper Corporation	Michigan			1	
Simpson Plainwell Paper Co.	Michigan			1	
Stone Container	Michigan	100		2	
James River Corp. - Groveton	New Hampshire				2
Lyonsdale Division	New York	15.2			
Schoeller Technical Papers Inc.	New York			1	
Specialty Paperboard, Inc.	New York			1	
Ticonderoga Mill	New York	88	158	0.5	
Sonoco Products Company	Pennsylvania	12.5	25		
Mead Corp. Kingsport Mill	Tennessee	150	300		
Scott Paper Co. Oconto Falls	Wisconsin			1	

TABLE 4.12.2
Nitrogen Limits in U.S. Pulp Mill-Related Industries' Effluent Permits (U.S. EPA Data)

Industry	State	Parameter	Nitrogen Loading			Nitrogen Concentration	
			Units	Average	Maximum	Average (mg/L)	Maximum (mg/L)
Mead Corp., Stevenson Mill	Alabama	NH_3	lbs/d	188	376	5	10
National Gypsum Company	Alabama	NH_3				5	7.5
Louisiana-Pacific	California	NH_3	lbs/d	6 868	27 471	42	168
Dexter Corporation Non-Woven	Connecticut	NH_3					1.1
							0.8
							3.1
Federal Paper Board Co. Inc.	Connecticut	NH_3	kg/d	91	136		
				48	72		
				45	68		
Packaging Corp. of America	Iowa	NH_3	lbs/d		16		7
Jefferson Smurfit-Alton	Illinois	NH_3	lbs/d			1.5	3
Inland Container, Newport Mill	Indiana	NH_3	lbs/d	332	664		
				693	1 386		
Weston Paper & Mfg Company	Indiana	NH_3	lbs/d	100	200		
Scott Paper Co. Newman Plt	Kentucky	NH_3				20	30
						20	30
Patriot Paper Corp.	Massachusetts	NH_3				1	1.5
Westfield River Paper - Lee	Massachusetts	Kjeld, Tot	lbs/d	13	17.5		
				6.6	10.9		
				13	17.5		
				6.6	10.9		
Champion Int-Quinnesec Mill	Michigan	NH_3	lbs/d		280	1.5	
Alpha Cellulose Corporation	N. Carolina	NH_3	lbs/d	83	166		
Weyerhaeuser, New Bern	N. Carolina	NH_3	lbs/d	900	1 720		
				3 200	6 400		
Weyerhaeuser, Plymouth	N. Carolina	NH_3	lbs/d	1 600	2 400		
				1 600	2 400		
Monadnock Paper Mills, Inc.	New Hampshire	NH_3				7.86	
Finch, Pruyn & Company, Inc.	New York	Kjeld, Tot	lbs/d	5 000	10 000		
Ticonderoga Mill	New York	Kjeld, Tot	lbs/d	1 400	2 520		
Appleton Papers Inc.	Ohio	NH_3	kg/d	64	96	2.6	3.9
Fairfield Paper Co., Ltd.	Ohio	NH_3				2.2	3.3
Miami Paper Company	Ohio	NH_3	kg/d	22.7	34.8	1.5	2.3
Packaging Corp. of America	Ohio	NH_3	kg/d	12	18	1.5	2.25
Stone Container Corporation	Ohio	NH_3	kg/d	226	388	29.3	50.2
				219.7	376	29.3	50.2
The Mead Corporation	Ohio	NH_3	kg/d	98.12	927	0.9	8.5
W. Carrollton Parchment Co.	Ohio	NH_3	kg/d	7.61	11.41	3.2	4.8
Muskogee Lineboard Mill-Musk	Oklahoma	NH_3	lbs/d	25	50		
Appleton Paper-Springmill	Pennsylvania	NH_3				1.5	3
Sonoco Products Company	Pennsylvania	NH_3	lbs/d	50			
Bowater Inc./Carolina Div.	S. Carolina	NH_3	lbs/d	397			
International Paper Company	S. Carolina	NH_3					1
Mead Corp. Kingsport Mill	Tennessee	NH_3	lbs/d	150	300		
Champion International Corp.	Texas	NH_3	lbs/d	195	500		
The American Tobacco Co.	Virginia	NH_3	lbs/d	113	226		

4.12.4 State Effluent Standards for Pulp and Paper Mills

An effluent permit limit of 1 mg/L is the most common limit to be adopted for total phosphorus when a limit has been set by a state although alternate limits for total phosphorus of 2 mg/L are also common. The states around the Great Lakes and on the east coast have been the most active in setting phosphorus limits.

The State of Michigan has been a leader in setting nutrient limits. A state administrative rule was promulgated in 1986: "Consistent with Great Lakes protection, phosphorus which is or may readily become available as a plant nutrient shall be controlled from point source discharges to achieve 1 milligram per litre of total phosphorus as a maximum monthly average effluent concentration unless other limits, either higher or lower, are deemed necessary and appropriate by the commission." This rule allows the commission discretionary powers to determine what is necessary and appropriate. The rule applies to all industrial and municipal point sources, but the industrial sector that has most often been exempted from the 1 mg/L total phosphorus standard has been the pulp and paper sector. When a total phosphorus concentration higher than 1 mg/L is allowed, it is generally 2 mg/L (Bill McCracken pers. comm.). The most recent permit issued by Michigan (but not yet approved by the U.S.EPA) contained a loading limit rather than a concentration. The loading limit was based on a total phosphorus concentration of 2 mg/L at the design flow (Bill McCracken pers. comm.).

The State of Wisconsin has recently created an effluent standard for total phosphorus that is currently being incorporated into WPDES permits. An effluent limit equal to 1 mg/L total phosphorus as a monthly average will apply where more than 60 pounds of phosphorus is discharged per month from all outfalls of a facility. Compliance with the concentrations limit will be determined as a rolling 12 month average determined by the total phosphorus from all outfalls at the facility.

Alternate effluent limitations to the effluent standard may be requested in cases where: the 1 mg/L total phosphorus effluent standard is not practically achieved; a level equivalent[4] to 1 mg/L can be achieved; the effluent is not discharged into the basins of the Great Lakes or the Fox (Illinois) River; or phosphorus deficient wastewaters necessitate the addition of phosphorus to a biological treatment system to assure efficient operation and compliance with other effluent limitations. The alternative effluent limitation in the latter case may not exceed 2 mg/L as a monthly average. The permittee must also conduct a phosphorus minimization study; provide information that demonstrates that the 1 mg/L total phosphorus standard is not practically achievable; and provide the information necessary to establish an alternate effluent limitation. The need for alternate limits is not easily correlated with treatment technology such as methods of activated sludge treatment (Mike Hammers pers. comm.). Other alternatives such as a watershed study plan are available if the receiving watershed is not the Great Lakes or the Fox River. Because the Wisconsin effluent standards are new and contain a number of ideas that could be considered by other jurisdictions, they are included in Appendix A.

4.13 FINLAND

The concentration of phosphorus in Finnish inland waters is naturally low in comparison to other nutrients; thus, it is often the nutrient that limits growth. The percentage of total phosphorus discharged by the forest industry is only approximately 8% of the total phosphorus loading to Finnish waters (Priha 1993), but locally the relative load of a single mill may be far greater than that. Many of the lakes are shallow and flows are low. Because the lakes are susceptible to eutrophication, Finland has emphasized phosphorus loading over other effluent characteristics such as toxicity. Finland has been included in this survey because it is a leader in the control of nutrients; however, the receiving waters (e.g. clear shallow lakes and streams with low flows) are different from that found in the NRBS area.

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4 A level equivalent to 1 mg/L is described further in Section (2)(a)2 of the Wisconsin Effluent Standards (p. A.3 in Appendix B).

The Finnish Pulp and Paper Research Institute (Priha 1993) completed a two year study to examine the stability and bioavailability of different phosphorus fractions of pulp and paper mill effluents in order to assess the environmental benefits of reducing their phosphorus discharges. In activated sludge treated effluent from a bleached kraft mill, the proportion of dissolved phosphorus in relation to total phosphorus was on average 80%. During a 6-8 week incubation period, about 60-70% of the particulate phosphorus dissolved as soluble phosphorus. Altogether some 80% of the total phosphorus in activated sludge treated kraft mill effluent was available for algae, either immediately or after inherent degradation. The conclusion drawn from the study was that the potential bioavailability of all forms of phosphorus was high. The removal of total phosphorus (rather than specific phosphorus fractions) from the effluents would seem to be the most efficient means of controlling eutrophication.

In Finland, a national target level of 60 g of P per tonne of pulp for phosphorus was established a few years ago. Now most modern mills have surpassed the national target level. The level achieved in modern mills is closer to 40-50 g of P per tonne of pulp (Maarit Priha pers. comm.)

The effluent permit limits are specific to each mill and phosphorus limits are established, if necessary, when the permit is renewed every three to five years. Instream monitoring results are reviewed to determine if eutrophication is a problem. So far, the only nutrient that has been regulated in pulp mill effluents is phosphorus. Effluent monitoring includes nitrogen.

In Finland, pulp mill effluents are not regulated for ammonia and they are not subject to toxicity testing. Although activated sludge treatment systems may be limited in the amount of phosphorus discharged, nitrogen can be supplied in excess.

The main type of effluent treatment has been activated sludge although a few mills have aerated lagoons. Since the target limits were established, the mills have been able to reduce the concentrations of phosphorus in the effluent. Generally phosphorus is not added at pulp mills, but it is necessary at paper mills. Nitrogen is added to the treatment system (Maarit Priha pers. comm.).

SECTION 5.0

SUMMARY AND DISCUSSION

5.0 SUMMARY AND DISCUSSION

5.1 INSTREAM OBJECTIVES

Instream water quality objectives have followed a chronological pattern. In the 1970's, the complexity of the nutrient issue and the lack of definitive answers was recognized. Initially no objectives were set, but tentative values for phosphorus were put forward. The *Quality Criteria for Water* (U.S.EPA 1976) recommended that total phosphorus should not exceed 0.05 mg/L (as P) in a stream where it enters a lake and not exceed 0.10 mg/L in other streams. These values were used in the 1980 "rationale" for the Saint John River, an international river. In 1977, Alberta adopted a total phosphorus objective of 0.15 mg/L (as PO_4) which is the same as the lower value of 0.05 mg/L expressed as P.[1] Alberta is the only province to have a numeric objective for phosphorus (rather than a guidance statement).

When the U.S.EPA published ambient water quality criteria in the late 1980's, it did not publish a criterion for phosphorus. The Task Force recently formed to address this issue in the U.S. is expected to develop a strategy to deal with eutrophication rather than numeric guidelines for phosphorus and nitrogen.

Other jurisdictions continue to follow the tentative approach introduced by the U.S.EPA. Ontario and Manitoba do not have numerical objectives but recommend guidelines with reference to the fact that further site-specific study may be needed (Table 5.1.1). The Manitoba values are half of the U.S.EPA values. Ontario used only one value for total phosphorus in streams of 0.03 mg/L; the Ontario value has been adopted by Quebec. Three U.S. states also have guidelines for phosphorus (0.05 or 0.1 mg/L) rather than standards.

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[1] Based on molecular weight, PO_4:P is 3:1.

TABLE 5.1.1
Summary of Canadian and Provincial Water Quality Objectives for Nutrients in Rivers

Jurisdiction	Objectives/Guidelines	Year	Nutrient Objectives
Canada	Canadian Water Quality Guidelines (CWQG)	1987 updated to 1993	No current guidelines but guidelines for nutrients in flowing waters are under internal review. Numerical limits for P or N (as a nutrient) unlikely.
	Guidelines for Canadian Recreational Water Quality	1992	"A bathing area should be as free as possible from nuisance organisms... Recreational areas should not be developed if there is an excessive growth of aquatic plants..."
	Guidelines for Canadian Drinking Water Quality	1993	Guidelines apply to treated water and not instream water.
Alberta	Alberta Surface Water Quality Objectives	1977	Total phosphorus = 0.15 mg/L (as phosphate). Total nitrogen = 1.0 mg/L (as N).
Northwest Territories	No objectives		
Yukon Territory	No objectives		
British Columbia	Water Quality Criteria for Nutrients and Algae	1985	STREAMS: 1) to protect recreation and aesthetics in streams. 50 mg/m² chlorophyll *a* in algal biomass. 2) to protect against undesirable changes in aquatic life in streams = 100 mg/m² chlorophyll *a* in algal biomass. LAKES: 1) to protect drinking water supplies and recreation in lakes = <0.01 mg/L total phosphorus. 2) to protect aquatic life where salmonids are predominant = <0.015 mg/L total phosphorus.
Saskatchewan	South Saskatchewan River Basin Objectives	1991	Phosphorus = 0.06 mg/L.
	Saskatchewan Surface Water Quality Objectives	1988	"Nitrogen or phosphorus or other nutrient concentrations should not be altered from natural levels by discharges of effluents such that nuisance growths of algae or aquatic weeds result."
Manitoba	Surface Water Quality Objectives	1988	"Nitrogen, phosphorus, carbon and contributing trace elements should be limited to the extent necessary to prevent the nuisance growth and reproduction of aquatic rooted, attached and floating plants, fungi or bacteria or to otherwise render the water unsuitable for other beneficial uses." For general guidance: total phosphorus ≤0.025 mg/L in a tributary to a waterbody, total phosphorus ≤0.05 mg/L in a stream.
Ontario	Water Management - Goals, Policies, Objectives and Implementation Procedures	1984	General guidelines which should be supplemented by site-specific studies: total phosphorus <0.03 mg/L in rivers and streams.
Quebec	Water Quality Objectives of Quebec	1992	The absence of excessive growth and reproduction of aquatic rooted, attached or floating plants, fungi and bacteria. Guideline: total phosphorus <0.03 mg/L in rivers.
New Brunswick	No Objectives		
Prince Edward Island	No Objectives		
Newfoundland	No Objectives		
Nova Scotia	No Objectives		

The alternate approach is to set objectives to prevent the effects of nutrient enrichment, particularly, nuisance growth of algae and aquatic plants. This approach, in the form of narrative statements has been used by Saskatchewan, Manitoba, Quebec and the Federal-Provincial Working Group on Recreational Water Quality. Narrative statements that protect designated uses from nuisance growths also appear as standards for about 21 U.S. states.

The British Columbia Ministry of Environment is the first Canadian jurisdiction to do an in-depth review of the nutrient issue. It identified important differences between rivers and lakes, and proposed nutrient effects rather than nutrient concentrations for rivers. The Ministry recommends a criterion based on plant biomass of <50 mg/m^2 chlorophyll *a* to protect uses related to recreation and aesthetics in streams, and <100 mg/m^2 chlorophyll *a* to protect against undesirable changes in aquatic life. The Eco-Health Branch of Environment Canada has recently prepared a draft Canadian water quality guideline for nutrients which will also emphasize nutrient effects.

The provinces of New Brunswick, Prince Edward Island, Newfoundland and Nova Scotia, as well as the Northwest Territories and the Yukon Territory do not have provincial or territorial objectives. Since they rely on the *Canadian Water Quality Guidelines*, they currently do not have nutrient objectives. A review of state standards (U.S.EPA 1988a,b), found that about 20 U.S. states also did not have standards.

One might expect that numeric objectives first introduced as tentative guidelines would become firm objectives following further research, but this has not happened. Instead, there appears to be a trend away from numeric guidelines for phosphorus in flowing waters at the national and provincial level.

The concentration of phosphate that saturates the maximum sustainable biomass of algae in flowing water has been shown to be about 0.03 mg/L as P (Bothwell et al. 1989; see also chapter 2). The growth rates of individual diatoms saturate at much lower levels (<0.001 mg P/L) (Bothwell 1988). Thus, rivers which meet objectives and guidelines set above 0.03 mg P/L may contain phosphorus in excess of that needed to saturate growth, if the phosphorus is in an immediately available form. Whether these rivers show signs of eutrophication depends on the importance of other potentially limiting factors.

Numeric guidelines are more appropriate on much smaller scales such as: site-specific (e.g. the Souris River objectives), reach-specific (e.g. the PPWB objectives) or basin-specific (e.g. the South Saskatchewan River Basin objectives) (Table 5.1.2). This approach has also been used by U.S. states such as Arizona and Nevada (Table 5.1.3). The advantage of developing objectives on a smaller scale is that they can be based on further instream research on background concentrations, bioavailability, and other controlling factors. Where smaller scale objectives have been established, routine monitoring has shown that the objectives are often exceeded (e.g. PPWB objectives and Souris River objectives). This underscores the dilemma in applying growth-limiting objectives to rivers which have high background concentrations.

TABLE 5.1.2
Summary of Water Quality Objectives for Nutrients in Rivers at Inter-provincial and International Boundaries

Authority	Objective Document	Year	Objective/Alert Level
Prairie Provinces Water Board	1990 PPWB Water Quality Objectives	1990	≤0.05 mg/L for the protection of recreation for eastward flowing rivers at the Saskatchewan-Manitoba boundary. No objectives at the Alberta-Saskatchewan boundary.
International Technical Subcommittee	Water Quality Objectives for the International Waters of the Saint John River Basin	1980	"phosphate levels should be low enough to prevent eutrophic conditions". Rationale: phosphate (as P) ≤0.1 mg/L in flowing streams, phosphate (as P) ≤0.05 mg/L for streams entering an impoundment, phosphate (as P) ≤0.015 mg/L as an alert level to trigger a survey.
International Red River Pollution Board	Water Quality Objectives for the Red River at the International Boundary	1969	No objectives for nutrients.
	Water Quality Alert Levels	1986	No alert levels for nutrients.
Souris River Bilateral Water Quality Monitoring Group	Water Quality Objectives for the Souris River Saskatchewan/North Dakota and North Dakota/Manitoba Boundaries	1991	Total phosphorus ≤0.10 mg/L (as P) dissolved nitrite plus nitrate ≤1.0 mg/L (as N)
International Poplar River Water Quality Board	Poplar River Water Quality Objectives	1981	No objectives for nutrients.

TABLE 5.1.3
Summary of Water Quality Criteria and Standards[a] for Nutrients in Rivers in the United States

Jurisdiction	Criteria/Standard Document	Year	Criteria/Standard for Nutrients
U.S. Environmental Protection Agency	Water Quality Criteria for Water	1976	Guideline: total phosphate (as P) = 0.1 mg/L in streams. Total phosphate (as P) = 0.05 mg/L in a stream where it enters a lake or reservoir.
U.S. Environmental Protection Agency	Ambient Water Quality Criteria	1980	No criteria for phosphorus or nutrients.
Alabama, Alaska, Colorado, Iowa, Maryland, Minnesota, Mississippi, Missouri, Montana, Nebraska, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Virginia, Washington, West Virginia, Wisconsin, Wyoming	State Standards		No narrative or numeric standard for phosphorus nitrogen (as a nutrient) or nutrients.
Arkansas, Connecticut, Delaware, Florida, Georgia, Idaho, Indiana, Kansas, Kentucky, Lousiana, Massachusetts, Michigan, New Hampshire, New Mexico, New York, North Carolina, Ohio, Rhode Island, South Carolina, Texas, Vermont	State Standards		Narrative standards to preserve natural conditions and/or prevent nuisance growths of plants or algae that would impair designated uses.
Arizona	Site-Specific Standards		Total phosphate (as PO_4) annual means from 0.03 to 0.5 mg/L (most common = 0.1 mg/L) Total nitrogen 0.3 - 1.0 mg/L as an annual mean (single maximum also specified).
Arkansas	State Standards		0.10 mg/L total phosphorus as a guideline
California	State Standards		Total phosphorus = 0.2 mg/L for warm freshwater habitat, 0.1 mg/L for cold freshwater habitat, and 0.05 mg/L for recreation (Basin 3).
Hawaii	State Standards		0.05 and 0.03 mg/L geometric means for total phosphorus (as P) in streams during the wet and dry seasons, respectively (single maximum of 0.06 to 0.15 mg/L). 0.25 and 0.18 mg/L geometric means for total nitrogen (as N) in streams during the wet and dry seasons, respectively.
Illinois	State Standards		0.05 mg/L phosphorus (as P) for streams entering a reservoir or lake.
Indiana	State Standards		0.03 mg/L - Lake Michigan; 0.10 mg/L - East Branch of Grand Calumet River and Indiana Harbour Ship Canal.
Maine	State Standards		50 mg/L total phosphorus
Nevada	State Standards		0.3 mg/L total phosphate (as PO_4) in Class[b] A and B streams, and 0.15 mg/L total phosphate in a stream entering a lake or reservoir. Nevada has site-specific standards for all forms of nitrogen including total Kjeldahl nitrogen
New Jersey	State Standards		0.1 mg/L total phosphorus (stream)
New Mexico	State Standards		0.1 mg/L total phosphorus (cold water fishery); 1.0 mg/L total nitrogen (cold water fishery)
North Dakota	State Standards		0.1 mg/L phosphate (as Diss. P) as interim guideline.
Utah	State Standards		0.05 mg/L phosphate (as P) as a pollution indicator.

a. From U.S.EPA 1988a,b.
b. States commonly classify streams according to the uses to be protected; Class A is the highest level of protection.

Numeric guidelines are also more appropriate to the protection of lakes than rivers. In a recent President's Message to the North American Lake Management Society, Gene Welch (1993) made a case for lake quality standards. He pointed out that "...the relation between the concentration of limiting nutrient and the concentration of algae in lakes and most reservoirs is usually proportional, while in streams, algae and nutrients are not usually proportionally related." British Columbia chose a numeric criterion for phosphorus for lakes but not streams. Protection of the Great Lakes has also provided an impetus to phosphorus loading targets contained in the Great Lakes Water Quality Agreement of 1978. The leadership of Finland in limiting phosphorus in pulp and paper mill effluents came out of a concern for the shallow lakes that are vulnerable to eutrophication.

5.2 EFFLUENT DISCHARGE LIMITS

Nutrients are not included in the classes of substances covered in the *Pulp and Paper Effluent Regulations* under the federal *Fisheries Act*, but the regulations do require environmental effects monitoring (EEM). The monitoring of nutrients is an EEM requirement (Table 5.2.1); therefore nation-wide nutrient data will become available in the future.

Some provinces in Canada such as Alberta, Ontario and Saskatchewan require monitoring of nutrients in pulp and paper mill effluents as a licence requirement, while other provinces such as British Columbia and Quebec do not. No provincial or federal licence or regulation currently requires phosphorus limits on pulp and paper mill effluents discharged in Canada. Provinces differ in their level of interest in nutrient regulation and in their regulatory approaches.

British Columbia has pollution control objectives for different industrial sectors that are used in preparing effluent permits. These objectives which were introduced in the 1970's are unique to British Columbia. The objectives for the forest products industry do not contain nutrient objectives for effluent quality but they do contain a narrative objective for receiving stream quality. There are no limits for phosphorus in effluent permits for individual mills; monitoring is required only for nitrogen. The *Pulp and Paper Mill Liquid Effluent Control Regulations* under the *Waste Management Act* do not require monitoring nor contain limits for nitrogen or phosphorus.

TABLE 5.2.1
Summary of Pulp and Paper Effluent Licence Requirements for Nutrients in Canada

Authority	Monitoring	Licenced Limits
Dept. of Fisheries and Oceans (Environmental Effects Monitoring Program)	ammonia nitrate plus nitrite total Kjeldahl nitrogen total phosphorus	none
Alberta Environment (mill licences)	ammonia nitrogen nitrite nitrogen nitrate nitrogen total Kjeldahl nitrogen dissolved phosphorus total phosphorus	none
Northwest Territories	none	none
Yukon Territory	none	none
British Columbia Ministry of Environment, Lands and Parks (*Pollution Control Objectives for the Forest Products Industry of British Columbia*)	none	none
British Columbia Ministry of Environment, Lands and Parks (mill permits)	nitrogen	none
British Columbia Ministry of Environment, Lands and Parks (Pulp Mill and Pulp and Paper Mill Liquid Effluent Control Regulation)	none	none
Saskatchewan Environment and Resource Management (mill permits)	ortho-phosphate total phosphorus total phosphorus (filtered) total Kjeldahl nitrogen total Kjeldahl nitrogen (filtered) ammonia nitrogen	none[a]
Manitoba Environment and Workplace Safety and Health (mill permits)	permits pending or under development	permits pending or under development
Ontario Ministry of the Environment (Effluent Monitoring and Effluent Limits Regulation - Pulp and Paper Sector - regulation promulgated in 1993, effective 1995)	total phosphorus	daily loading limit and monthly average loading limit of total phosphorus for each mill
Ministère de l"Environnment du Québec (MINVIQ)	ammonia nitrogen nitrite-nitrate nitrogen	none
New Brunswick (mill permits)	case-by-case basis	none (but mills requested to reduce phosphorus additions)
Newfoundland	no effluent permit	no effluent permit

a. would only be added if need demonstrated by receiving water quality studies.

In contrast to British Columbia, Alberta requires all pulp mills to monitor for nutrients as a requirement of their licence (Table 5.2.1). No limits for nutrient concentrations in pulp and paper mill effluents have been set, but limits are under consideration. Saskatchewan has one pulp mill which is required to monitor for nitrogen and phosphorus (Table 5.2.1). The *General Objectives for Effluent Discharges* specify that discharges from Saskatchewan industries should be free from concentrations of nutrients that cause unacceptable effects. There are two pulp mills in Manitoba but limits for nutrients have not yet been set.

There are about 26 pulp and paper mills that discharge effluents in Ontario. These mills have completed one year of intensive monitoring, which includes nutrient monitoring, as part of the first phase of the MISA program. An effluent monitoring and effluent limits regulation was promulgated in 1993 which will limit the daily and monthly average loading of total phosphorus beginning at the end of 1995. Weekly monitoring of total phosphorus is included.

Quebec also has a large number of pulp and paper mills, but nutrients have not attracted attention. Regulations under the Environment Quality Act which have been adopted in 1992 and revised in 1993 address a wide range of chemicals but phosphorus concentrations in mill effluent are neither monitored nor regulated. Monitoring of nitrogen compounds is included.

There are no discharge limits for phosphorus in the Maritimes. New Brunswick has no permit limits for nutrients in pulp mill effluents, but mills have been asked to reduce the quantity of phosphorus added to effluent treatment systems. The only pulp mill on freshwater in Newfoundland is an old mill which was never permitted provincially.

Without question, the centre of interest concerning the industrial discharge of nutrients has been the Great Lakes. The *Great Lakes Water Quality Agreement of 1987* which recommends phosphorus load reduction targets for basins of the Great Lakes, also contains a recommendation that municipal sewage treatment plants discharging more than one million gallons per day should achieve a maximum effluent concentration of 1 mg/L total phosphorus to protect the quality of Lakes Superior, Michigan and Huron, and 0.5 mg/L to protect Lakes Ontario and Erie. These values do not apply to industrial effluents which should be regulated "to the maximum practicable extent". This statement leads to a technology-based approach which has been applied around the Great Lakes.

State and provincial regulators have extended the numerical limit to the industrial sector. The loading limits in the Ontario draft effluent limits regulation were initially based on a mean effluent concentration of 1.0 mg/L total phosphorus in the effluent. The states of Michigan and Wisconsin also set effluent standards for point source discharges at 1 mg/L total phosphorus as a monthly average concentration.

All three jurisdictions have also addressed the fact that this level cannot be achieved by all pulp and paper mills, especially those requiring the addition of phosphorus to biological treatment systems. Ontario has recently revised the numbers used in the draft regulations; the loading limits in the final regulations will be based on a long term average effluent concentration of about 2 mg/L total phosphorus. The Michigan standards include a phrase giving the commission the discretionary power to set other limits. The State of Wisconsin standards spell out alternate effluent limitations. The most common alternate in both states is 2 mg/L although there are other options.

Beyond the Great Lakes, nutrient regulation has received much less attention than other categories such as toxicity, biochemical oxygen demand and suspended solids. New effluent guidelines for the pulp and paper industry prepared by the U.S.EPA (1993) were released on December 17, 1993. These standards do not contain limits for nutrients.

Licence requirements are usually established on a site specific basis (e.g. New Brunswick, Saskatchewan, Manitoba, Alberta and British Columbia). These are water quality-based, in that they take the characteristics of the receiving stream into account. The need for a nutrient limit is related to eutrophication at the site, but the limits are also influenced by the technology available. In the U.S., pulp and paper mills are regulated by the NPDES permitting process. Wasteload allocations estimate the effect of nutrients on the dissolved oxygen concentrations in the receiving streams. The U.S.EPA industrial database for NPDES permits contained data for

281 pulp mills and related industries, but only 18 had limits for total phosphorus. They were located in seven states.

Ontario is the first province to adopt a technology-based approach establishing nutrient loading limits based on the type and production of the mill. Finland also has a technology-based guideline of 60 g per tonne of pulp to prevent eutrophication (although it does not have toxicity or ammonia guidelines).

Limits for phosphorus are more common in municipal sewage treatment plant effluent permits than industrial permits. Municipal permits seem to be the origin of the 1 mg/l total phosphorus limit since tertiary treatment plants can usually achieve phosphorus removal to less than 1 mg/L in municipal sewage. Thus, 1 mg TP/L is a technology-based limit derived from sewage treatment technology. This limit may be applied only if needed based on an assessment of the quality of the receiving water and the magnitude of the impact. Thus, the application of this limit may be water quality-based. Tertiary treatment is usually reserved for special cases such as eutrophication of the receiving waters or large volumes of sewage.

In Alberta, discharge of treated municipal sewage is controlled through final effluent permits. Sewage treatment plants with a design flow greater than 20,000 m^3/d have an effluent limit of 1 mg/L total phosphorus. None of the permits issued by Alberta Environment in the NRBS area have monitoring requirements or limits for nutrients although some have limits for BOD and TSS. This lack of a monitoring requirement for phosphorus and nitrogen is in contrast to the Alberta requirement for pulp and paper mills. Larger municipalities in the NRBS area have loadings similar to pulp and paper mills. Fort Smith which discharges to the Slave River in the Northwest Territories is required to monitor nitrogen and phosphorus.

The *Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia* specify an effluent objective of 1.5 mg/L total phosphorus when dilution in the receiving stream is $<$2000:1. In Saskatchewan, the municipal permit limit is 1 mg/L when there is a concern for the eutrophication of the receiving stream. This is a case-by-case decision and is not related to the size of the municipality or the dilution. Manitoba limits are based on a combination of technology and site-capability. The final effluent limits for sewage treatment plants in Ontario are generally 1 mg/L total phosphorus as an average, but requirements are established on a case-by-case basis. This basis is also used in Quebec. There are some cases in Quebec where a limit of 0.5 mg/L has been required.

SECTION 6.0

COMMUNICATIONS CITED

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SECTION 7.0

LITERATURE CITED

7.0 LITERATURE CITED

Alberta Environment. 1977. Alberta Surface Water Quality Objectives. Water Quality Branch, Standards and Approvals Division, Calgary.

APHA (American Public Health Association). 1989. Standard Methods for the Examination of Water and Wastewater. 17th ed. American Public Health Association, Washington, D.C.

Armstrong, D.E. 1979. Phosphorus Transport Across the Sediment-Water Interface. p.169-175. IN: Lake Restoration. Proceedings of a National Conference, U.S.EPA-440/5-79-001, Minneapolis, Mn.

Beak Associates. 1991. Benthic Invertebrate Monitoring Study on the Athabasca and McLeod Rivers Near Whitecourt, Alberta, 1990. Beak Associates Consulting Ltd., Calgary, Alberta.

Blachford, D.P. 1988. A Compendium of Water Quality Objectives Development Methodologies. Water Quality Branch, Western and Northern Region, Environment Canada, Regina.

Bothwell, M.L. 1985. Phosphorus Limitation of Lotic Periphyton Growth Rates: An Intersite Comparison Using Continuous-Flow Troughs (Thompson River System, British Columbia). Limnol. Oceanogr. 30(3):527-542.

Bothwell, M.L. 1987a. Growth Rate Response of Lotic Periphytic Diatoms to Experimental Phosphorus Enrichment. Limnological Research Division, National Hydrology Centre, Saskatoon, Saskatchewan.

Bothwell, M.L. 1987b. Phosphorus Control of Algal Production in the Thompson River, British Columbia. Executive Summary, Inland Waters/Lands Directorate-Weyerhaeuser Canada Ltd., Joint Research Project. NHRI Scientific Series Contribution No. 87002.

Bothwell, M.L. 1988. Growth Rate Responses of Lotic Periphytic Diatoms to Experimental Phosphorus Enrichment: The Influence of Temperature and Light. Can. J. Fish. Aquat. Sci. 45(2):261-270.

Bothwell, M.L. 1992. Eutrophication of Rivers by Nutrients in Treated Kraft Pulp Mill Effluent. Water Poll. Res. J. Canada. 27(3):447-472.

Bothwell, M.L. and R.J. Daley. 1981. Determination of Phosphorus Sufficiency and Growth Rates of Benthic Algae in the Thompson River, B.C., Using Experimental Flowing Troughs. Inland Waters Directorate, National Water Research Institute, Environment Canada. (Cited in Nordin 1985).

Bothwell, M.L., S. Jasper and R.J. Daley. 1989. Phosphorus Control of Algal Production and Biomass in the Thompson River, British Columbia. NHRI Paper No. 41, IWD Scientific Series No.165. Inland Waters Directorate, National Hydrology Research Institute, Saskatoon, Saskatchewan.

Bradford, M.E. and R.H. Peters. 1987. The Relationship Between Chemically Analyzed Phosphorus Fractions and Bioavailable Phosphorus. Limnol. Oceanogr. 32(5):1124-1137.

British Columbia Ministry of Environment. 1974. Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia. Reprinted 1990. Dept. of Lands, Forests and Water Resources, Water Resources Service, Victoria.

British Columbia Ministry of Environment. 1975a. Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia. Reprinted 1989. Water Management Branch, Victoria.

British Columbia Ministry of Environment. 1975b. Pollution Control Objectives for Food-Processing, Agriculturally Orientated, and Other Miscellaneous Industries of British Columbia. Water Management Branch, Victoria.

British Columbia Ministry of Environment. 1977. Pollution Control Objectives for the Forest Products Industry of British Columbia. Reprinted 1989. Pollution Control Board, Victoria.

British Columbia Ministry of Environment. 1979. Pollution Control Objectives for the Mining, Smelting and Related Industries of British Columbia. Reprinted 1989. Pollution Control Board, Victoria.

Canadian Council of Ministers of the Environment (CCME). 1993. Canadian Water Quality Guidelines. Task Force on Water Quality Guidelines. Eco-Health Branch, Ecosystem Sciences and Evaluation Directorate, Environment Canada, Ottawa (original Canadian Council of Resource and Environment Ministers (CCREM) 1987 document has been periodically updated to CCME April 1993).

Casey, R.J. 1990. Sediment Oxygen Demand During the Winter in the Athabasca River and the Wapiti-Smoky River System, 1990. Standards and Approvals Division and Environmental Assessment Division, Alberta Environment.

Chambers, P.A., E.E. Prepas, M.L. Bothwell and H.R. Hamilton. 1989. Roots Versus Shoots in Nutrient Uptake by Aquatic Macrophytes in Flowing Waters. Can. J. Fish. Aquat. Sci., 46(2):435-439.

Charlton, S.E.D. and D. Bayne. 1986. Phosphorus Removal: The Impact Upon Water Quality in the Bow River Downstream of Calgary, Alberta, Bow River Data Base 1980-1985. Water Quality Branch, Pollution Control Division, Environmental Protection Services, Alberta Environment, Edmonton.

Chiandani, G. and M. Vighi. 1974. The N:P Ratio and Tests with Selenastrum to Predict Eutrophication in Lakes. Water Res. 8:1063-1069.

Culp, J.M., H.R. Hamilton, A.J. Sosiak and R.W. Davies. 1992. Longitudinal Zonation of the Biota and Water Quality of the Bow River System in Alberta, Canada. p.31-49 IN: (C.D. Becker and D.A. Neitzel (eds.) Water Quality in North American River Systems. Battelle Memorial Institute.

Davis, J.C. 1975. Waterborne Dissolved Oxygen Requirements and Criteria with Particular Emphasis on the Canadian Environment. National Research Council of Canada, NRC Associate Committee on Scientific Criteria for Environmental Quality, Report No.13.

Derksen, G. 1981. The Effects of a Sewage Lagoon Effluent on the Water Quality of the Cowichan River During the 1980 Low Flow Period Plus an Evaluation of the Lagoon's Bacteriological Reduction Performance and Effluent Toxicity. Environmental Protection Service, Environment Canada, Regional Program Report No.82-5.

Dillon, P.J. and F.H. Rigler. 1974. The Phosphorus-Chlorophyll Relationship in Lakes. Limnol. Oceanogr. 19(5):767-772.

Drever, J.I. 1982. The Geochemistry of Natural Waters. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Environment Canada. 1992. Methods Manual for the National Water Quality Laboratory. Environment Canada, Inland Waters Directorate, Burlington, Ontario.

Environment Canada and Department of Fisheries and Oceans 1992a. Aquatic Environmental Effects Monitoring Requirements. Conservation and Protection, Ottawa. EPS 1/RM/18.

Environment Canada and Department of Fisheries and Oceans. 1992b. Aquatic Environmental Effects Monitoring Requirements. Annex 1: Aquatic Environmental Effects Monitoring Requirements at Pulp and Paper Mills and Off-Site Treatment Facilities Under the Pulp and Paper Effluent Regulations of the Fisheries Act, May 20, 1992. Conservation and Protection, Ottawa.

Environment Canada and Department of Fisheries and Oceans. 1993. Technical Guidance Document for Aquatic Environmental Effects Monitoring Related to Federal Fisheries Act Requirements Version 1.0. April 1993. Conservation and Protection, Ottawa.

European Community Environmental Legislation (ECEL). 1988. Volume 4: Water. C. Whitehead (ed.). Commission of the European Communities, Brussels.

Gerloff, G.C. 1975. Nutritional Ecology of Nuisance Aquatic Plants. National Environmental Research Centre. Office of Research and Development, United States Environmental Protection Agency, Covallis, Oregon. EPA-660/3-75-027.

Gregory, S.W. 1978. Phosphorus Dynamics on Organic and Inorganic Substrates in Streams. Verh. Internat. Verein. Limnol. 20:1340-1346.

Hamilton, H.R. 1985. Nutrient Removal Considerations at the City of Saskatoon Pollution Control Plant. Hydroqual Consultants Inc., Cochrane, Alberta. Prepared for Water and Pollution Control Department, City of Saskatoon.

Harms, L.L., P.H. Vidal and T.E. McDermott. 1978. Phosphorus Interactions with Stream-bed Sediments. J. Environ. Eng. Div. 104(EE2):271-288.

Hart, D.D. 1985. Grazing Insects Mediate Algal Interactions in a Stream Benthic Community. Oikos 44:40-46.

HBT AGRA. 1992. Environmental Monitoring Studies in the Vicinity of the Peace River Pulp division Mill at Peace River, Alberta, May 1992. HBT AGRA Limited (formerly Monenco Consultants Ltd.).

Health and Welfare Canada. 1992. Guidelines for Canadian Recreational Water Quality. Federal-Provincial Working Group on Recreational Water Quality of the Federal-Provincial Advisory committee on Environmental and Occupational Health. Supply and Services Canada, Ottawa.

Health and Welfare Canada. 1993. Guidelines for Canadian Drinking Water Quality. Fifth Edition. Supply and Services Canada, Ottawa.

Horner, R.R. and E.B. Welch. 1978. Effects of Velocity and Nutrient Alterations on Stream Primary Producers and Associated Organisms. Washington State Department of Transportation, Olympia. WA-RD-39 2, NTIS PB83-171868.

Horner, R.R. and E.B. Welch. 1981. Stream Periphyton Development in Relation to Current Velocity and Nutrients. Can. J. Fish. Aquat. Sci. 38:449-457.

Horner R.R., E.B. Welch and R.B. Veenstra. 1983. Development of Nuisance Periphytic Algae in Laboratory Streams in Relation to Enrichment and Velocity. p.121-134 IN: Wetzel, R.G. (ed.), Periphyton of Freshwater Ecosystems. Junk Publishers, The Hague.

International Red River Pollution Board. 1992. Red River. Thirty-Second Progress Report to the International Joint Commission.

International Technical Advisory Subcommittee on Water Quality in the Saint John River. 1980. Review and Update of Water Quality Objectives for the International Waters of the Saint John River Basin.

Japan Environment Agency. 1987. Quality of the Environment in Japan. Water Science Standards Section. Water Quality Bureau. Tokyo, Japan.

Johnston, N.T., C.J. Perrin, P.A. Slaney and B.R. Ward. 1990. Increased Juvenile Salmonid Growth by Whole-River Fertilization. Can. J. Fish. Aquat. Sci. 47:862-872.

Kerc, P. 1986. Nutrient Impact. IN The City of Saskatoon River Study, Baseline Data Report 1984-1985. The City of Saskatoon, Water and Pollution Control Department.

Klotz, R.L. 1985. Factors Controlling Phosphorus Limitation in Stream Sediments. Limnol. Oceanogr. 30(3):543-553.

Lamberti, G.A., L.R. Ashkenas and S.V. Gregory. 1987. Effects of Three Herbivores on Periphyton Communities in Laboratory Streams. J.N. Am. Benthol. Soc. 6(2):92-104.

Lamberti, G.A. and V.H. Resh. 1983. Stream Periphyton and Insect Herbivores: An Experimental Study of Grazing by a Caddisfly Population. Ecology 64:1124-1135.

Lean, D.R.S., A.P. Abbot, M.N. Charlton and S.S. Rao. 1983. Seasonal Phosphate Demand for Lake Erie Plankton. J. Great Lakes Res. 9:83-91.

Lock, M.A. 1979. The Effect of Flow Patterns on Uptake of Phosphorus by River Periphyton. Limnol. Oceanogr. 24(2):376-383.

Logan, T.J. 1982. Mechanisms for Release of Sediment-bound Phosphate to Water and the Effects of Agricultural Land Management on Fluvial Transport of Particulate and Dissolved Phosphate. Hydrobiologia. 9(2):519-530.

Mayar, L.M. and S.P. Gloss. 1980. Buffering of Silica and Phosphate in a Turbid River. Limnol. Oceanogr. 25(1):12-22.

McAuliffe, J.R. 1984. Resource Depression by a Stream herbivore: Effects on Distributions and Abundance of Other Grazers. Oikos 42:327-333.

McDiffett, W.F., A.W. Beidler, T.F. Dominick and K.D. McCrea. 1989. Nutrient Concentration-Stream Discharge Relationships During Storm Events in a First-Order Stream. Hydrobiologia 179:97-102.

Meyer. J.L. 1979. The Role of Sediments and Bryophytes in Phosphorus Dynamics in a Headwater Stream Ecosystem. Ecology 60:365-375.

Ministère de l'Environment du Québec. 1992. Critères de Qualité de l'Eau. Sainte-Foy, Quebec.

Murphy, T.P. 1980. Ammonia and Nitrate Uptake in the Lower Great Lakes. Can. J. Fish. Aquat. Sci. 37:1365-1372.

Nelson, K.J., N.R. Kevern, J.L. Wilhim and N.A. Griffith. 1969. Estimates of Periphyton Mass and Stream Bottom Area Using Phosphorus-32. Water Res. 3:367-373.

Newbold, J.D., J.W. Elwood, R.V. O'Neill and A.L. Sheldon. 1983. Phosphorus dynamics in a Woodland Stream Ecosystem: A Study of Nutrient Spiralling. Ecology 64(5):1249-1265.

Nordin, R.N. 1985. Water Quality Criteria for Nutrients and Algae. Technical Appendix. Resource Quality Section, Water Management Branch, British Columbia Ministry of Environment, Victoria.

Nordin, R.N. and L.W. Pommen. 1986. Water Quality Criteria for Nitrogen (Nitrate, Nitrite and Ammonia). Resource Quality Section Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria.

North Dakota State Department of Health. 1991. Standards of Water Quality for State of North Dakota. Rule 33-16-02. Bismarck, North Dakota.

Ontario Ministry of the Environment. 1984. Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. Toronto.

Ontario Ministry of the Environment. 1991a. Protocol for the Sampling and Analysis of Industrial/Municipal Wastewater. Water Resources Branch, Toronto.

Ontario Ministry of the Environment. 1991b. Municipal/Industrial Strategy for Abatement: Issues Resolution Process Final Report. Toronto.

Ontario Ministry of the Environment. 1992a. Clean Waters for Ontario - Municipal/Industrial Strategy for Abatement Overview. P1BS2100E. Public Information Centre, Ontario Environment, Toronto.

Ontario Ministry of the Environment 1992b. Best Available Technology for the Ontario Pulp and Paper Industry. Prepared by N. McCubbin Consultants Inc. for the Water Resources Branch, Toronto.

Ontario Ministry of the Environment. 1993a. Clean Water Regulation: Pulp and Paper Sector. P1BS2264E. Public Information Centre, Ontario Environment, Toronto.

Ontario Ministry of the Environment. 1993b. Effluent Monitoring and Effluent Limits - Pulp and Paper Sector. Water Resources Branch, Toronto.

Ontario Ministry of the Environment. 1993c. Draft Development Document for the Pulp and Paper Sector Effluent Limits Regulations. Water Resources Branch, Toronto.

Painter, D.S., S.K. Wong and R. Clark. 1976. Nutrient Growth Relationships for *P. pectinatus* and the Re-evaluation of Established Optimal Nutrient Levels for *C. gomerata* in Southern Ontario Streams. Grand River Study Team Technical Report No.7. Limnology and Toxicity Section, Water Resources Branch, Ontario Ministry of the Environment, Rexdale.

Perrin, C.J., M.L. Bothwell and P.A. Slaney. 1987. Experimental Enrichment of a Coastal Stream in British Columbia: Effects of Organic and Inorganic Additions on Autotrophic Periphyton Production. Can. J. Fish. Aquat. Sci. 44:1247-1256.

Peters, R.H. 1978. Concentrations and Kinetics of Phosphorus Fractions in Water from Streams Entering Lake Memphremagog. J. Fish. Res. Board Can. 35:315-328.

Poplar River Bilateral Monitoring Committee. 1993. 1991 Annual Report to the Governments of Canada, United States, Saskatchewan and Montana.

Power, M.E., W.J. Matthews and A.J. Stewart. 1985. Grazing Minnows, Piscivorus Bass, and Stream Algae: Dynamics of a Strong Interaction. Ecology 66:1448-1456.

Prairie Provinces Water Board (PPWB). 1991. Water Quality Procedures Manual. PPWB Report No.110. PPWB, Regina.

Prairie Provinces Water Board (PPWB). 1993. Interprovincial River Water Quality Data at PPWB Monitoring Stations April 1974 to December 31, 1991. PPWB Report No.120. PPWB, Regina.

Prepas, E.E. 1983. Orthophosphate Turnover Time in Shallow Productive Lakes. Can. J. Fish. Aquat. Sci. 40:1412-1418.

Priha, M. 1993. Bioavailability of Pulp and Paper Mill Effluent Phosphorus. 4th IAWQ Symposium on Forest Industry Wastewaters, June 8-11, 1993. Tamperc, Finland.

Québec. 1992. L'industrie Québécoise des Pâtes et Papiers. Situation et Perspectives d'Avenir. Ministère des Forêts, Québec.

Reynolds, C.S. 1984. The Ecology of Freshwater Phytoplankton. Cambridge University Press, Cambridge.

Rigler, F.H. 1956. A Tracer Study of the Phosphorus Cycle in Lake Water. Ecology 37:550-562.

Rigler, F.H. 1979. The Export of Phosphorus from Dartmoor Catchments: A Model to Explain Variations of Phosphorus Concentrations in Stream Water. J. Mar. Biol. Ass. U.K. 59:659-687.

Sask Water and Environment Canada. 1991. Canada-Saskatchewan South Saskatchewan River Basin Study. Final Report.

Saskatchewan Environment and Public Safety. 1986a. A Guide to Aquatic Nuisances and Their Control. Water Quality Branch, Regina.

Saskatchewan Environment and Public Safety. 1986b. A Guide to Sewage Works Design. WPC-77. Water Pollution Control Branch, Regina.

Saskatchewan Environment and Public Safety. 1988. Surface Water Quality Objectives. WQ110. Water Quality Branch, Regina.

Saskatchewan Water Corporation (Sask Water) and Environment Canada. 1991. Canada - Saskatchewan. South Saskatchewan River Basin Study. Final Report. Moose Jaw, Saskatchewan.

Schindler, D.W. 1977. Evolution of Phosphorus Limiting in Lakes. Science 195:260-262.

Seeley, M.R. 1986. Use of Artificial Channels to Study the Effects of Nutrients, Velocity and Turbidity on Periphyton. M.S. Thesis, University of Washington, Seattle.

Segars, J.E., R.A. Minear, J.W. Elwood and P.J. Mulholland. 1986. Chemical Characterization of Soluble Phosphorus Forms Along a Hydrologic Flowpath of a Forested Stream Ecosystem. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

SENTAR Consultants Ltd. 1994. Nutrient Loading on the Athabasca, Peace and Slave Rivers. Project 2511-B1. Synthesis Report. Prepared for Northern Rivers Basin Study, Edmonton.

Smith, R.E.H. and J. Kalff. 1981. The Effect of Phosphorus Limitation on Algal Growth Rates: Evidence from Alkaline Phosphatase. Can. J. Fish. Aquat. Sci. 38:1421-1427.

Souris River Bilateral Water Quality Monitoring Group. 1991. Souris River Basin International Water Quality Objectives for the Saskatchewan/North Dakota and North Dakota/Manitoba Boundary Crossings.

Souris River Bilateral Water Quality Monitoring Group. 1992. First Report to the Governments of Canada and the United States. 1990 and 1991.

Strumm, W. and J.J. Morgan. 1981. Aquatic Chemistry: An Introduction Emphasizing chemical Equilibria in Natural Waters. 2nd Edition. A Wiley-Interscience Publication. Toronto.

Sumner, W.T. and C.D. McIntire. 1982. Grazer-periphyton Interactions in Laboratory Streams. Archiv. Fur Hydrobiologia 93:135-157.

Terrestrial and Aquatic Environmental Managers (TAEM) Ltd. 1992a. Biological and Water Quality Survey of the Athabasca River, April 1992. TAEM Ltd., Saskatoon, Saskatchewan.

Terrestrial and Aquatic Environmental Managers (TAEM) Ltd. 1992b. Benthic Macroinvertebrate and Water Quality Survey of the Wapiti River, January 1992. TAEM Ltd., Saskatoon, Saskatchewan.

Terrestrial and Aquatic Environmental Managers (TAEM) Ltd. 1993. Biological and Water Quality Survey of the Athabasca River. October 1992. TAEM Ltd., Saskatoon, Saskatchewan.

Trask, K.I., J.C. O'Shaughnessy and F.C. Blanc. 1981. Rooted Aquatic Plant Effects on Nitrogen Budgets. J. Environ. Eng. Div. 107(EE3):481-492.

United States Environmental Protection Agency (U.S.EPA). 1976. Quality Criteria for Waters. Office of Water and Hazardous Materials, Washington, D.C.

United States Environmental Protection Agency (U.S.EPA). 1988a. Water Quality Standards Criteria Summaries: A Compilation of State/Federal Criteria. Phosphorus. EPA 440/5-89/012. NTIS Order No.PB89-141444. Standards Branch, Criteria and Standards Division, Office of Water Regulations and Standards, Washington, D.C.

United States Environmental Protection Agency (U.S.EPA). 1988b. Water Quality Standards Criteria Summaries. A Compilation of State/Federal Criteria. Nitrogen-Ammonia/Nitrate/Nitrite. EPA 440/5-88/029. NTIS Order No. PB89-141618. Standards Branch, Criteria and Standards Division, Office of Water Regulations and Standards, Washington, D.C.

United States Environmental Protection Agency. 1991. Guidance for Water Quality-based Decisions: The TMDL Process. EPA 440/4-91-001. Office of Water Regulations and Standards, Washington, D.C. 20460.

United States Environmental Protection Agency. 1993. Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper and Paperboard Category; National Emission Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper Production; Proposed Rule. Federal Register: 58(241):66078-66216 (Friday, December 17, 1993).

Welch, E.B., J.M. Jacoby, R.R. Horner and M.R. Seeley. 1987. Nuisance Biomass Levels of Periphytic Algae in Streams. Hydrobiologia 14:1-8.

Welch, G. 1993. The Case for Lake Quality Standards. Lakeline 13(3):4.

Westlake, D.F. 1973. Aquatic Macrophytes in Rivers. A Review. Polski Arch. Hydrobiol. 20(1):31-40.

Williams, J.D.H., J.K. Syers, R.F. Harris and D.E. Armstrong. 1976a. Characterization of Inorganic Phosphate in Noncalcareous Lake Sediments. Soil Sci. Soc. Am. Prog. 35:556-561.

Williams, J.D.H., J.M. Jaquet and R.L. Thomas. 1976b. Forms of Phosphorus in the Surficial Sediments of Lake Erie. J. Fish. Res. Bd. Can. 33:413-429.

Williams, J.D.H., T.P. Murphy and T. Mayer. 1976c. Rates of Accumulation of Phosphorus Forms in Lake Erie Sediments. J. Fish. Res. Bd. Can. 33:430-439.

Williamson, D.A. 1988. Manitoba Surface Water Quality Objectives. Water Standards and Studies Section, Department of Environment and Workplace Safety and Health, Winnipeg.

Wong, S.L., B. Clark and R.F. Kosciuw. 1979. Examination of the Effects of Nutrients on the Water Quality of Shallow Rivers. Hydrobiologia 6(3):231-239.

APPENDIX A

NORTHERN RIVER BASINS STUDY TERMS OF REFERENCE

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NORTHERN RIVER BASINS STUDY
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Project 2602-B1: Regulatory Requirements for Nutrient Effluent Discharges

I. Objective

The purpose of this project is to prepare a report that reviews effluent and instream nutrient guidelines/objectives, both in Canada and internationally.

II. Requirements

1) Compile and review information from Alberta, Canada and other jurisdictions on effluent and instream nutrient quality objectives/guidelines as well as the criteria (case/method, etc.) for selecting these objectives/guidelines. Regulatory requirements for nutrient loading from pulp mills should be examined where possible.

2) Based on the information assembled in 1, above, prepare a comprehensive synthesis report on criteria for the setting of nutrient quality objectives from various jurisdictions. The report should clearly state the criteria upon which the regulatory requirements are based and the parameters measured by regulatory agencies for monitoring nutrient loads. The report is also to include a brief summary of the general effects of nutrient loading on aquatic (river) ecosystems. The report should also clearly state the regulatory requirements imposed on nutrient loads from licensed discharges in the Peace, Athabasca and Slave river systems.

III. Reporting Requirements

1) Prepare a comprehensive synthesis report on the regulatory requirements of various jurisdictions for the setting of nutrient quality objectives. The report should contain tables that compare and contrast regulatory requirements in various jurisdictions.

2) Ten copies of the draft report are to be submitted to the Project Liaison Officer (Greg Wagner, Office of the Science Director, Northern River Basins Study; phone (403)427-1742, fax (403)422-3055) by March 22nd, 1993.

3) Three weeks after the receipt of review comments the Consultant is to submit ten cerlox bound copies and two-camera-ready originals of the final report to the Project Liaison Officer. An electronic copy of the report, in Word Perfect 5.1 format, is to be submitted to the Project Liaison Officer along with the final report. The final report is to contain a table of contents, list of figures (if appropriate), list of tables (if appropriate), acknowledgements, executive summary and an appendix containing the Terms of Reference for this contract.

APPENDIX B

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES
EFFLUENT STANDARDS AND LIMITATIONS

APPENDIX B
STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES
CHAPTER NR217
EFFLUENT STANDARDS AND LIMITATIONS

NR217.01 Purpose. The purpose of this chapter is to reduce the amount of pollutants discharged to surface waters by establishing effluent standards and limitations for pollutants in effluent discharged to surface waters of the state. Effluent standards and limitations are adopted pursuant to ch. 147, Stats.

NR 217.02 Applicability. This chapter is applicable to point sources which discharge wastewater to the surface waters of the state.

NR 217.03 Definitions. Definitions of terms and the meaning of abbreviations used in this chapter are as defined in chs. NR 102, 106, 205, 210 and 243. In addition: "effluent standard" means any requirement for a specific pollutant applicable to a category or class of point sources which are more stringent than the requirements under s. 147.04 (1) to (4), Stats.

NR 217.04 Effluent Standards and Limitations for Phosphorus.

(1) **GENERAL.** Effluent limitations for total phosphorus shall be imposed in WPDES permits for wastewaters discharged to surface waters as specified in this section.

(a) An effluent standard for total phosphorus shall apply as follows:

1. An effluent limitation equal to 1 mg/L total phosphorus as a monthly average shall apply to publicly owned treatment works and privately owned domestic sewage works subject to ch. NR 210 which discharge wastewater containing more than 150 pounds of total phosphorus per month, unless an alternative limitation is provided under sub. (2).

2. An effluent limitation equal to 1 mg/L total phosphorus as a monthly average shall apply in cases where the discharge of wastewater from all outfalls of a facility other than those subject to ch. NR 210 contains a cumulative total of more than 60 pounds of total phosphorus per month, unless an alternative limitation is provided under sub (2). Outfalls consisting of noncontact cooling water without phosphorus containing additives shall not be included in the calculation of the cumulative total of phosphorus discharged from the facility. Compliance with the concentration limit shall be determined as a rolling 12 month average as determined by the total phosphorus from all outfalls subject to the effluent limitation for the most recent 12 months divided by the total flow for all those outfalls for the same period.

3. Effluent limitations for phosphorus equal to 1 mg/L as a monthly average contained in permits on December 1, 1992, shall remain in effect.

4. Effluent limitations for phosphorus equal to 85% removal of influent concentrations of phosphorus contained in permits on December 1, 1992, shall be modified to 1 mg/L total phosphorus as a monthly average upon reissuance of the permit unless an alternative limitation is provided under sub. (2).

5. Runoff to surface waters from animal feeding operations shall be controlled using best management practices to achieve the purpose of this chapter pertaining to phosphorus.

6. The Department shall determine if a permittee is discharging more than the applicable threshold value specified in subd. 1. or 2. by examining available data on or requiring monitoring of the amount of phosphorus contained in the wastewater effluent. Such data shall be representative of the amount of phosphorus contained in the wastewater effluent during periods of discharge or operation.

Note: The threshold values of this section will be applied at the time of WPDES permit reissuance or permit modification which may occur due to changes in waste characteristics.

Note: See 102.06 in reference to water quality standards.

(2) ALTERNATIVE EFFLUENT LIMITATIONS TO THE EFFLUENT STANDARD FOR PHOSPHORUS.

(a) Permittees subject to sub (1)(a)1., 2. or 4 may request an alternative effluent limitation for total phosphorus if one or more of the following apply:

1. A permittee may request an alternative effluent limitation in cases where achieving the 1 mg/L total phosphorus effluent standard is not practically achievable.

a. A permittee requesting an alternative effluent limitation under this subdivision shall provide, as a part of the WPDES permit process, information which demonstrates that the 1 mg/L total phosphorus effluent standard is not practically achievable and information necessary for the Department to establish an alternative effluent limitation. The information provided shall include but not be limited to the following: the results of a comprehensive phosphorus minimization study to determine the sources of phosphorus to the wastewater, an evaluation of possible methods to reduce the sources of phosphorus to the wastewater, a description of actions implemented to reduce the sources of phosphorus to the wastewater. In addition, the permittee shall provide data on the phosphorus concentrations in the influent to and effluent from the wastewater treatment facilities which are achievable after phosphorus minimization steps have been implemented, alternative treatment technologies which may be employed to achieve the 1 mg/L effluent standard, and their associated removal efficiencies and costs and the requested alternative effluent limitation.

b. The Department shall review requests and the information provided by permittees and may establish alternative effluent limitations to the effluent standard imposed under sub. (1)(a)1., 2. or 4. where this standard, in the best professional judgement of the Department, is not practically achievable. For these cases, the Department shall establish an alternative effluent limitation considering the effluent quality achievable with the application of treatment technologies, process changes,and phosphorus minimization steps to reduce the amount of phosphorus to the maximum extent practically achievable taking into account energy, economic and environmental impacts.

2. A permittee may request an alternative effluent limitation in cases where the operation of specific biological phosphorus removal technologies will achieve a level of performance equivalent to a 1 mg/L effluent standard. Systems which employ biological phosphorus removal technology shall result in the removal of not less than 90 percent of the phosphorus which would be removed by achieving the 1 mg/L total phosphorus effluent standard based upon a mass determination.

a. A permittee requesting an alternative effluent limitation under this subdivision shall, as a part of the WPDES permit application process, provide information which demonstrates that achieving the requested alternative effluent limitation using biological phosphorus removal will achieve this requirement. The information shall include data on the total mass of phosphorus discharged using biological removal with and without chemical polishing and the total mass of phosphorus discharged using treatment technologies to achieve the 1 mg/L effluent standard and the information necessary for the Department to establish an alternative effluent limitation.

b. The Department shall review requests and the information provided by permittees and may establish alternative effluent limitations to the effluent standard imposed under sub. (1)(a)1., 2. or 4. where the alternative limitation, in the best professional judgement of the Department, will result in insignificant differences in the amount of phosphorus discharged by achieving the 1 mg/L total phosphorus effluent standard. For these cases, the Department shall establish an alternative effluent limitation considering the effluent quality achievable with the application of biological phosphorus removal technologies taking into account the total phosphorus removal performance on a mass basis. The alternative effluent limitation established by the Department under this subparagraph may not exceed 2 mg/L as a monthly average.

3. A permittee may request an alternative effluent limitation in cases where phosphorus-deficient wastewaters necessitate the addition of phosphorus to a biological treatment system to assure efficient operation and compliance with other effluent limitations.

   a. A permittee requesting an alternative effluent limitation under this subdivision shall, as part of the WPDES application process, provide information which demonstrates that achieving the 1 mg/L total phosphorus effluent standard is not practically achievable and the information necessary for the Department to establish an alternative effluent limitation. The information provided shall include but not be limited to the following: the results of a comprehensive phosphorus minimization study to minimize the amount of phosphorus discharged while allowing efficient operation of the wastewater treatment system, a description of actions implemented to reduce the amount of phosphorus discharged, the phosphorus effluent concentrations achievable after phosphorus minimization steps have been implemented, the removal efficiencies and costs associated with alternative treatment technologies which would be necessary to achieve the 1 mg/L effluent standard and the requested alternative limitation.

   b. The Department shall review requests and the information provided by the permittee and may establish alternative effluent limitations to the effluent standard imposed under sub.(1)(a)2. where this standard, in the best professional judgement of the Department, is not practically achievable. The Department shall establish an alternative effluent limitation considering the minimum phosphorus effluent quality achievable while allowing effluent operation of the wastewater treatment system. The alternative effluent limitation established by the Department under this subdivision may not exceed 2 mg/L as a monthly average.

(b) Permittees subject to sub.(1)(a)1. or 2. which do not discharge their effluent into the basins of the Great Lakes or the Fox (Illinois) River may request an alternative effluent limitation for total phosphorus according to the provision of this paragraph.

1. A permittee may request an alternative effluent limitation under this paragraph in cases where achieving the 1 mg/L effluent standard would not result in an environmentally significant improvement in water quality and material progress towards the attainment and maintenance of associated surface water quality standards for the receiving water as established in chs. NR 102 to 104.

2. A permittee requesting an alternative effluent limitation under this paragraph shall propose for the Department's approval a study plan to identify the receiving

waters affected or potentially affected by the discharge, describe how information will be obtained to justify an alternative effluent limitation under this paragraph, and provide the information necessary to establish interim and alternative effluent limitations under this paragraph. This study plan shall be submitted as a part of the WPDES permit application process. The results of the study shall include an evaluation of all point and non-point sources of phosphorus in the watersheds and the impacts of the phosphorus contributions on biological and chemical water quality conditions. Upon review of the study plan, the Department may require additional information as deemed necessary and may expand the study to include other watersheds or portions thereof that may be significantly impacted by the permittee's discharge of phosphorus.

3. The Department may establish an alternative effluent limitation where, in the best professional judgement of the Department and based upon the information provided by the permittee pursuant to the study plan and other relevant information, achieving the effluent standard under sub.(1)(a)1. or 2. would not result in an environmentally significant improvement in water quality and material progress towards the attainment of associated surface water quality standards for the receiving waterbody as established in chs. 102 to 104.

4. An interim effluent limitation and compliance schedule for completing the study shall be imposed in a permit until the request for an exemption from the 1 mg/L effluent standard is approved or denied. The interim effluent limitation shall be equal to the representative concentration of total phosphorus as a monthly average in the effluent based on the information provided by the permittee as a part of the WPDES permit application process.

5. Alternative effluent limitations established under this paragraph may not exceed the interim effluent limitation established under subd. 4.

(3) **ANALYTICAL METHODS AND LABORATORY PROCEDURES.** Methods used for analysis of influent and effluent samples shall be as described in ch. NR 219 unless alternative methods are specified in the WPDES discharge permit.

(4) **COMPLIANCE.** the Department shall determine and specify a reasonable compliance schedule in the permittee's WPDES permit if the facility is unable to meet the effluent standard or limitations determined according to this section at the time of permit issuance or reissuance. The date of compliance with this section may not extend beyond 3 years from the date of permit issuance or reissuance, unless the Department determines that circumstances beyond the permittee's control, such as an environmental impact statement, require additional time for compliance. In such circumstances, the date for compliance with this section may not extend beyond 5 years from the date of permit issuance or reissuance.

(5) **DEPARTMENT DETERMINATIONS.** Effluent standards and limitations established under subs.(1)(a) and (2) are not subject to the variance procedure under s.147.06, Stats.