6.0 Scientific Rationale for the Management of Anthropogenic Nutrient Sources

Highlights

- In Canada, excessive nutrient loading was first recognized as a problem in the Great Lakes in the late 1960s.
- Federally, the *Canadian Environmental Protection Act* is the only regulation that addresses phosphorus and then only in laundry detergents. It prohibits the manufacture, use, and sale of laundry detergents that contain P in concentrations exceeding 2.2 % by weight.
- Water Quality Guidelines in Canada are developed to provide basic scientific information about water quality parameters and to protect Canadian species and water uses. Most provinces have developed their own water quality guidelines for various nutrients (i.e., nitrate, ammonia, phosphorus), but in the absence of provincial guidelines, Canadian Water Quality Guidelines are usually applied.
- Varying degrees of nutrient legislation, regulations, objectives, guidelines, best management practices (BMPs) and other measures exist in all provinces and territories.
- Many of the approaches used to minimize nutrient loading and associated environmental impacts in Canada are also employed in other jurisdictions. However, compared to Canada, countries with a longer history of settlement and agriculture have tended to adopt tighter restrictions to minimize nutrient loading to the environment.
- New technologies for reducing nutrient impacts to the environment continue to be developed. Environmental policy should continue to emphasize integrating the best and most advanced science into practical solutions.

Nutrients are managed or are of concern in many countries around the world. As long ago as the 16th century, controls were implemented in parts of Europe to restrict the disposal of household waste, largely in an attempt to limit plagues and other health concerns caused by bacteria or the pests attracted to refuse. By the 1800s, disease outbreaks caused by bacterial contamination of water used for drinking or in food preparation were prompting engineering solutions, such as wastewater diversion, to solve water pollution problems. At present, access to clean water in relatively abundant quantities is taken for granted by most people in developed countries. However, many people do not realize that their actions put a burden on water quantity and quality – from water used in the production of produce, meat and dairy products for human consumption, to water used in industrial processes for cooling and cleaning, to tap water used for cooking, cleaning and personal hygiene. To protect the natural environment, to safeguard human health and to preserve water quantity and quality for beneficial uses such as drinking, industrial water supply, and recreational pursuits, nutrient management measures have been adopted in Canada and elsewhere.

This chapter identifies the various nutrient management programs operating in Canada, at both the federal and the provincial/territorial levels, and discusses the rationale behind these programs. The extent to which scientific concerns and issues have played a role in developing nutrient control measures in Canada is also examined. Nutrient control measures for other countries are also discussed, with a particular emphasis on measures not routinely employed in Canada. Finally, new or emerging technologies are described that may aid in reducing nutrient loading to the environment or

minimizing impacts.

6.1. Current Regulations, Guidelines, and Best Management Practices in Canada

In Canada, the first problem of accelerated eutrophication due to excessive P inputs was identified in the late 1960s for the Great Lakes. Although P and other nutrients occur naturally in the Great Lakes, excessive amounts of anthropogenically derived P led to severe disruptions in the ecosystem (see Lake Erie text box, Chapter 4.2). Concern by the governments of both Canada and the USA that the huge Great Lakes system could be so affected by anthropogenic nutrient loads led to the signing of the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA), an agreement aimed at reducing P loading to the Great Lakes.

Since that time, other environmental problems caused or associated with anthropogenic nutrient additions have been identified (Table 6.1). Governments (federal and provincial/territorial) as well as citizens' groups, industrial associations, agricultural producers and other concerned parties have responded with programs ranging from community-based volunteer programs to legally enforceable legislation (Tables 6.1 and 6.2).

This section focuses on initiatives undertaken in Canada in response to environmental concerns caused by nutrient addition from human activity. Existing control measures, including legislation (Acts and Regulations), guidelines, objectives, and voluntary initiatives that govern nutrients, fertilizers, and eutrophication are reviewed. The rationale behind these controls is identified, including an overview of any water or land use impairment, impact or perceived impact resulting from nutrients and fertilizers. Finally, additional programs aimed at assessment and remediation of the impact of nutrients and fertilizers are evaluated. The information contained in this section is based largely on interviews with individuals working in a variety of environmental and agricultural ministries across Canada. The anecdotal comments supplied by the interviewees provide an historical context and general overview of nutrient issues in various Canadian jurisdictions.

Federal Initiatives

Canada-United States Great Lakes Water Quality Agreement

Public concern over excess algae and plant growth in the lower Great Lakes, particularly Lake Erie, provoked investigation into probable causes. Scientific studies concluded that an excess of P from detergents and other cleaning products, municipal and industrial effluents, and agricultural runoff resulted in increased plant life which, in turn, led to increased organic material for decomposition and lower oxygen concentrations.

Various proactive measures, beginning with the 1972 signing of the *Canada-U.S. Great Lakes Water Quality Agreement*, have attempted to work towards a solution to the P problem. The Agreement includes municipal and industrial commitments to remove P from effluents and to eliminate P from detergents (Table 6.1). Canada's commitment to survey and monitor the Great Lakes under the *Canada-U.S. Great Lakes Water Quality Agreement* involves analyzing water samples for nutrients, organic contaminants, and physical parameters. These samples are collected as part of the Great Lakes Surveillance Program. The Surveillance Program, begun in 1967, focuses on one lake each

Table 6.1. Identified concerns and issues regarding nutrient control measures at the federal and provincial/ territorial level and the subsequent responses of each jurisdiction (Information up to June 2000.).

Jurisdiction	Identified Concern/ Issue	Response
Federal	• Eutrophication of the Great Lakes	• *Canada Water Act* (1973) - help reduce P loading into Canadian lakes • *Phosphorus Concentration Control Regulations* (1989) - limits P in cleaning products
	• Canada & U.S. concern about P in effluent and eutrophication of Great Lakes	• *Canada-U.S. Great Lakes Water Quality Agreement* (1972) - commitments to remove P from detergents and effluents • Surveillance and monitoring of the Great Lakes to evaluate trends and identify emerging issues
	• Environmental problems caused by toxic substances, hazardous wastes, and pollution of air and water	• *CEPA* (1999) - focus on assessment and regulation of toxic substances and hazardous waste emphasizing pollution prevention, ecosystem approach, biodiversity, the precautionary principle and user-producer responsibility
	• Requests for regulation and control of agricultural fertilizers	• *Fertilizers Act* (1885) - regulates the safety, efficacy and labelling of fertilizers imported into or sold in Canada
National	• Inconsistent and incomplete water quality standards	• *Canadian Water Quality Guidelines* (1999) and *Drinking Water Guidelines* – development of general, consistent, and scientifically sound management tools to ensure societal stresses do not lead to the degradation of Canadian waters (including drinking water supply; freshwater and marine life; agricultural uses; recreation and aesthetics; and industrial uses)
Alberta	• Complaints from residents regarding excessive algae, degraded water quality, and impaired water use	• Studies on the Bow River, in combination with other studies examining P and N controls, led the City of Calgary to voluntarily implement P controls at Calgary's WWTPs in 1982-83 • Developed partnerships with interested parties/ residents and stakeholders (e.g., Pine Lake Restoration Program)
	• Disposal of sewage sludge	• Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (1997) - developed to allow monitoring and controlled application to agricultural lands
	• Intensive livestock operations and their impact on the environment	• Codes of Practice for the Economic and Safe Handling of Animal Manures are voluntary guidelines for producers to manage agricultural nutrients in manures
	• Recognition that agriculture can have a deleterious effect on aquatic systems	• Industry-led Beneficial Management Practices manual development
	• P enrichment of surface waters in Alberta	• Development of P soil limits for application of manure on agricultural lands
British Columbia	• Eutrophication in various water bodies in the province (i.e., Okanagan Basin)	• *Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia (1975)* - permissible limits for discharged nutrients • *Waste Management Act* (1996) - nutrient discharge limits based on site-specific studies
	• Environmental impacts of agricultural wastes	• Agricultural Waste Control Regulation (1992) and Code of Agricultural Practice for Waste Management - practices for using, storing, and managing agricultural wastes • Management of Livestock and Poultry Manures in the Lower Fraser Valley (1994-1997) - joint provincial/ federal study • Tackling Non-Point Source Water Pollution - document compiled by MELP examining the association between agriculture and other activities and non-point source water pollution and providing best management practices.

Table 6.1. Identified concerns and issues regarding nutrient control measures (continued).

Jurisdiction	Identified Concern/ Issue	Response
Manitoba	• Prevention of unacceptable water quality impairment • Excessive growth of algae and macrophytes and overall eutrophication of surface waters	• *Manitoba Surface Water Quality Objectives* (1988) - conducted site-specific studies and developed water objectives • *Manitoba Clean Water Guide* (1997) - public education initiative and material • *Livestock Manure and Mortalities Management Regulation* (1998) - developed to control nutrient contamination • Much of the Department of Environment's resources are directed at dealing with this issue on a continuous basis
New Brunswick	• Water resource impacts from land use activities	• Promotion of Best Management Practices (BMPs) and development of recommended agricultural practices by the Department of Environment • Watershed groups have initiated a number of activities and projects to increase awareness about nutrient issues
Newfoundland	• Eutrophication of water resources related to agricultural seepage and surface runoff	• Promotion of good agricultural practices through provision of educational materials (technical information on nutrients and fertilizers) • *Farm Practice Guidelines for Livestock & Poultry* - currently under development
Northwest Territories	• Preserve the state of the North's waters and avert the problems experienced in southern Canada	• *Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories* (1992) - limits for P • *Receiving Water Quality Objectives* - recommend nutrient levels to avoid nuisance growth
Nova Scotia	• Nutrient related impacts on a site-specific, local scale • Environmental impacts related to agricultural practices	• NSDOE supports local programs and community-based partnership initiatives at specific sites in the province • Development of guidelines for land-use activities (having non-point sources of nutrients) such as forestry and agricultural operations • Development of educational materials related to residential development • Municipal wastewater approvals for larger operations require receiving water studies which can include TP modelling and associated limits • Introduced a Green Farm Initiative, involving BMPs to remediate and prevent environmental impacts to water resources
Ontario	• Maintain a certain level of quality in Ontario's surface waters • Undesirable changes in the aquatic system from excessive algal growth (partly due to recreational development of lakes) and watersheds of high P concentrations due to agricultural inputs and low flow • Eutrophication of the Great Lakes in the 1960s and obligations under the Canada-U.S. *Great Lakes Water Quality Agreement* (through the Canada Ontario Agreement of 1971)	• *Water Management Policies, Guidelines, Provincial Water Quality Objectives(PWQOs) of the Ministry of Environment and Energy* (1994) - direct management of waters • Interim PWQOs for P - to be used as a guideline (in conjunction with other site-specific programs) to protect against aesthetic deterioration; eliminate excessive plant growth in rivers and streams; avoid nuisance concentrations of algae; and protect the diversity of trophic status • Led to Certificates of Approval to limit loadings of P from individual dischargers into receiving waters
Prince Edward Island	• Eutrophication and excessive plant production	• Roundtable on Resources & Sustainable Land Use (1997) - reported on the impact of land uses on water resources • Developing legislation on water buffer zones • Voluntary programs initiated to clean up water quality problems

Table 6.1. Identified concerns and issues regarding nutrient control measures (concluded).

Jurisdiction	Identified Concern/ Issue	Response
Québec	• Environmental problems caused by toxic substances released in water • Maintain a certain level of quality in Québec's surface waters • Eutrophication of water resources related to intense agricultural activities (i.e., P and seasonally NH_3).	• Programme d'assainissement des eaux du Québec (1970s) - water clean up program for urban, industrial, and agricultural sectors • *Québec Surface Water Quality Guidelines* / *Critères de qualité de l'eau de surface au Québec* (1998) - direct management of waters • Regulations to reduce pollution from agricultural activities / *Règlementations sur la réduction de la pollution d'origine agricole* (1997) - information provided on nutrients and fertilizers to promote agricultural practices • Developing legislation on water buffer zones. • Directives for manure storage
Saskatchewan	• Excessive aquatic weed and algae growth in the Qu'Appelle River System • Impact of nutrient releases on Saskatchewan watersheds	• Prairie Provinces Water Board Objectives (1969) - implemented to address nutrients, fertilizers, and eutrophication • Review of nutrient loadings to the Qu'Appelle River and Fishing Lakes in the mid 1970's recommended further nutrient control measures • Development of ecological monitoring parameters by the Ecosystem Management Special Projects Unit
Yukon	• Nutrients are generally not an issue	• Domestic sewage from most communities is treated, retained in lagoons, and then discharged to lands or wetlands

year (except Lake Michigan, as it lies entirely within the United States), with Upper and Lower Lake surveillance cruises alternated on a biannual basis. The Program's objectives are to ensure compliance with water quality objectives, evaluate trends and identify emerging issues.

Data from the Ontario Water Resources Commission Sampling Program have also been useful in measuring the response of the nearshore Great Lakes to the International Phosphorus Control Program (Nicholls et al. 1980) and are essential to fulfilment of terms outlined by the *Canada-U.S. Great Lakes Water Quality Agreement*. This ongoing program, now managed by the Ontario Ministry of Environment, is part of an integrated plan involving several collaborators with the ultimate objective of generating data to assess the dynamics of the Great Lakes and interrelations among nutrients, organic contaminants, and biota.

Fertilizers Act

Improper application of fertilizers can result in nutrients leaching away from crop roots and into surface and ground waters. The *Fertilizers Act* is product-based legislation regulating fertilizers and supplements imported into or sold in Canada (Table 6.1). This legislation deals only with the actual product and its associated proprieties (composition, including formulants, contaminants, and sources of active ingredients; efficacy; safety in use; and representation in the marketplace, specifically through labelling).

The potential for fertilizers to cause eutrophication is addressed, in a general way, by the *Fertilizers Act* through labelling requirements. Recommended rates of application are developed at the provincial level by agricultural ministries, and use of a product is not recommended if eutrophication could result. Misuse of fertilizer products, resulting in damage to the environment, is also typically the responsibility of provincial ministries of the environment.

Fisheries Act

The 1985 *Fisheries Act* provides broad information for the protection of all fish habitat (Table 6.1). When the *Fisheries Act* was introduced, it was designed to address the basic concerns for coal ash and ballast (oil); there is nothing specific in it with respect to nutrients. However, Section 36 of the *Fisheries Act* prohibits the release of any substance that could have a deleterious impact on fish and their habitat and this allows for the inclusion of nutrients as deleterious substances. Regulations of the *Fisheries Act* generally regulate point sources, and are thus unlikely to address non-point nutrient sources such as agricultural runoff.

As Fisheries and Oceans Canada promotes aquaculture, they may be faced with concerns such as eutrophication and the impact of biocides and toxicological products designed to prevent disease. Although there is a general sense that water quality is a provincial concern, there is an understanding that in the future, there may be a need for some regulation of aquaculture activities under the *Fisheries Act*. Addressing the impact of nutrients would be an important aspect for consideration in future aquaculture regulations.

Canadian Environmental Protection Act

The 1988 *Canadian Environmental Protection Act* (CEPA) was created with the intention of responding to environmental pollution caused by toxic substances and hazardous wastes (Table 6.1). It incorporated provisions in the *Canada Water Act* authorizing regulation of P content in detergents and water conditioners. The renewed *CEPA* passed in 1999 emphasizes pollution prevention and the consideration of a holistic ecosystem approach when addressing environmental contamination. Under *CEPA*, the Governor in Council may, on the recommendation of the Minister, make regulations "for the purpose of preventing or reducing the growth of aquatic vegetation that is caused by the release of nutrients in waters and that can interfere with the functioning of an ecosystem or degrade or alter, or form part of a process of degrading or altering, an ecosystem to an extent that is detrimental to its use by humans, animals or plants" (*CEPA* 1999 Part 7, Division 1, 118(1)).

To date, federal nutrient regulations made under *CEPA* have focused solely on controlling P in laundry detergents. The 1989 *Phosphorus Concentration Regulations* prohibit the manufacture, use, and sale of laundry detergents containing P in concentrations exceeding the maximum permissible limit of 2.2 % by weight.

National Initiatives

Guidelines for Canadian Drinking Water Quality

The *Guidelines for Canadian Drinking Water Quality* identify substances found in drinking water and known, or suspected, to be harmful. For each substance, the Guidelines establish the maximum acceptable concentration (MAC) that can be permitted in water used for drinking. MAC values are typically 10 to 5 000 times lower than those levels at which any adverse effects on health have been observed during prolonged and repeated testing. The Guidelines also define a number of desirable aesthetic attributes of drinking water -- qualities that give it a pleasing appearance, taste and odour. Canadian drinking water guidelines have been developed for a variety of microbiological, chemical, physical and radiological parameters. These guidelines, which apply to drinking water from all private and municipal water sources, are developed by the Federal-Provincial Subcommittee on Drinking

Water and are published by Health Canada. The Subcommittee is composed of members from all provincial and territorial governments, as well as a member from Health Canada and Environment Canada. Health Canada acts as scientific advisor to this committee.

The Guidelines are recognized throughout Canada as the standard of drinking water quality. They provide a convenient, reliable, yardstick against which drinking water quality can be measured. Provision of drinking water is, however, a provincial responsibility; the guidelines are not applied federally except in those areas that fall under federal jurisdiction. Virtually all provincial and territorial governments have established their own measures of drinking water quality based on the Guidelines.

Guidelines for Canadian Recreational Water Quality

The *Guidelines for Canadian Recreational Water Quality* deal with health hazards associated with recreational water use, as well as aesthetic and nuisance conditions. Recreational waters refer to those natural waters used not only for primary contact activities such as swimming, windsurfing, and water-skiing, but also for secondary contact activities such as boating and fishing. Recreational use is defined as any activity involving intentional immersion (e.g., swimming) or incidental immersion (e.g., water-skiing) of the body, including the head in natural water. Natural water is in turn defined as any marine, estuarine or fresh body of water, as well as any artificially constructed flow-through impoundment using untreated natural water. The health hazards associated with direct contact with water include infections transmitted by pathogenic organisms as well as injuries and illness due to physical and chemical properties of the water.

The Guidelines are developed by an *ad hoc* Working Group formed at the request of the Federal-Provincial Committee on Environmental and Occupational Health (CEOH). The guidelines are periodically revised or adjusted as new or more significant data become available and are not to be regarded as legally enforceable standards except where promulgated by the appropriate provincial or federal agency.

Guidelines for Canadian Water Quality

The Canadian Council of Ministers of the Environment (CCME) was requested to develop nationally applicable guidelines by various organizations and jurisdictions in Canada. The original approach in the development of national guidelines was to attempt to adopt and modify existing guidelines from other sources. However, in many cases, existing guidelines proved to be inappropriate or unavailable. From this original attempt at guideline development, the need for nationally consistent, scientifically defensible standards for freshwater and marine life, and human drinking water was identified. As a result of the CCME's initiatives, the *Canadian Water Quality Guidelines* (CWQGs) were developed (CCME 1999; Table 6.1). References to the *Guidelines for Canadian Drinking Water Quality* and the *Guidelines for Recreational Water Quality* are reprinted in CCME's CWQGs with permission from Health Canada as both of these documents are published under the authority of the Minister of Health.

The rationale for these Guidelines was to provide basic scientific information on the effects of water quality variables on Canadian waters. The guidelines were developed to ensure that anthropogenic stressors, particularly toxic chemicals, do not lead to degradation of raw water for drinking water or industrial supply; water inhabited by freshwater or marine life; water used for agricultural purposes; or water used for recreation and appreciated for its aesthetics. The Guidelines may be either a numeric

value or a narrative statement. When several water uses are to be protected at a certain location, the Water Quality Guideline to be applied for a specific substance is that which provides protection for all users (i.e., highest and best use). This requirement means that the most restrictive guideline value is selected, and by default, it protects all users. For the majority of substances, aquatic life guideline values are usually the most restrictive (CCME 1999).

The CWQGs address concerns regarding increased plant growth caused by excessive nutrients. Eutrophication is addressed specifically in the Recreational Water Quality (Health Canada) and Aesthetics Section, where guidelines for avoidance of nuisance aquatic weeds growth are contained. Many of the provinces/territories have adopted the nationally derived CWQGs. However, some jurisdictions have developed their own N and/or P guidelines.

In 1999, the CWQGs were updated based on new scientific information. The new *Environmental Quality Guidelines* (EQGs) were expanded to cover, in addition to water quality, guidelines for air, soil, sediment quality, and tissue residues (CCME 1999). The EQGs include over 550 numerical or narrative guidelines for over 220 substances of concern. In addition, these guidelines offer the most current science on the fate and effects of these substances in the Canadian environment.

Provincial and Territorial Jurisdictions

Alberta

In Alberta, most rivers arise in the mountains and are inherently oligotrophic. However, the quality of these rivers may be impaired as a result of municipal or industrial discharges or agricultural runoff. Alberta's lakes, on the other hand, often have high background nutrient levels and although nuisance algal blooms may be in part a natural phenomenon, development activity has increased nutrient concentrations in some lakes with associated deleterious effects. Concerns about water quality led to the development of provincial water quality guidelines, the most recent version being *Surface Water Quality Guidelines for Use in Alberta* (1999) (Table 6.3).

To address residents' complaints about water quality and impaired water use, the government is building partnerships with interested parties and stakeholders (Table 6.1). For example, residents, farmers, and business people of Pine Lake, AB raised funds to begin clean up to protect the lake. In partnership with Alberta Environment, they commissioned monitoring studies, implemented a device to pump nutrient-laden water from the bottom of the lake, and initiated several beneficial management practices (BMPs) on farming operations.

Nutrient impacts on surface waters have also led to the adoption of nutrient controls for MWTPs in large cities (Table 6.1). An example, the Oldman Water Quality Initiative, has led to improved water quality in the Oldman River basin following the 1999 implementation of tertiary treatment with P removal at the City of Lethbridge municipal wastewater treatment plant. Improved sewage treatment results in great production of sewage sludge. To ensure appropriate use of sewage sludge as a soil amendment, *Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands* (2000) were developed. Some smaller communities discharge wastewater to lagoons for long term storage that can subsequently be used for irrigation.

The 1993 *Environmental Protection and Enhancement Act* (*EPEA*) is a broad piece of legislation that regulates substances released into waters in the province of Alberta (Table 6.2). Using regulations, facility design, and water quality stipulations, the *EPEA* has the authority to regulate municipalities for nutrients (municipal and industrial N and P compounds) discharged into the environment. Although livestock operations and their associated nutrients have seldom been regulated under *EPEA*, charges can be laid under various clauses. For example, the clauses dealing with substance release and deposition of manure on ice can be used. The *Code of Practice for the Safe and Economic Handling of Animal Manures* (AAFRD 2000) gives direction for establishing and operating livestock facilities, including recommendations on the application of manure to farmland. Alberta is also considering guidelines for management of intensive livestock operations.

British Columbia

In the 1970s, in response to signs of eutrophication in numerous water bodies, British Columbia developed nutrient objectives (Table 6.1). The objectives, outlined in the *Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia* (1975), are used to set permanent limits for discharged nutrients. Separate *Pollution Control Objectives in British Columbia* were also prepared for the *Chemical and Petroleum Industries* (1974); the *Food-Processing, Agriculturally Orientated and other Miscellaneous Industries* (1975); the *Forest Products Industry* (1977); and the *Mining, Smelting, and Related Industries* (1979). To provide further protection, federal and provincial grants were provided in the 1980s to upgrade many sewage treatment facilities to tertiary treatment processes with biological nutrient removal.

British Columbia is currently in the process of developing municipal sewage regulations to update and replace the existing 1975 *Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia*. Within these proposed regulations, the discharger will examine the nutrient levels in the receiving environment and propose a level of treatment based on this assessment. There are exceptions for freshwater systems of special concern, such as the Okanagan Basin. The best example of a site-specific case study in British Columbia was a major study carried out jointly by provincial and federal governments in the Okanagan Basin. This study found P loading to the basin to be the cause of eutrophication problems. Nutrient discharge limits to these waters have since been set for discharge permits issued under the *Waste Management Act* (1996).

The British Columbia Ministry of Agriculture and Food produces *Environmental Guidelines for Producers* that provide farmers with technical information on nutrients and fertilizer application to promote good practices (BCAF 1999). Also in 1992, the *Agricultural Waste Control Regulation* with its associated *Code of Agricultural Practice for Waste Management* was issued. The purpose of the *Code* was to describe practices for using, storing, and managing agricultural wastes in an environmentally sound manner. Since then, compliance has been attempted by a two-pronged process involving: (1) agricultural peer groups who handle low risk complaints; and (2) Ministry of Environment, Lands, and Parks (MELP) staff who deal with high risk problems. Industry and government have developed other strategies and guidelines to ensure compliance, including commodity producers.

Table 6.2. Legislation, regulations, objectives, guidelines, and associated control measures relevant to nitrogen (N), phosphorus (P) and other nutrient-related issues, as of June 2000. The table also provides details on the history and rationale surrounding these control measures.

Jurisdiction	Relevant Legislation, Regulations, Objectives, Guidelines, and other Control Measures
Federal	• *Fertilizers Act* (1885) • *Canada-United States Great Lakes Water Quality Agreement* (1972) • *Canada Water Act* (1973) - developed to help reduce P loads into Canadian lakes; now part of the *Canadian Environmental Protection Act* • *Fisheries Act* (1985) • *Phosphorus Concentration Control Regulations* (1989) - limit for P in cleaning products • *Yukon Waters Act* (1993) - addresses contaminants (i.e., waste discharges) and their effects when added to waters (habitat alteration, adverse effects to humans, fauna and flora) • *Canadian Environmental Protection Act* (1999; originally 1988) – nutrients addressed directly in the regulation for P in cleaning products and indirectly in the *Ambient Air Quality Objectives* (1989) that provide three ranges of ambient air quality objectives for NO_2
National	• *Canadian Water Quality Guidelines* (1987) - nationally applicable, scientifically based management tools • *Canadian Drinking Water Quality Guidelines* (1996) - guidelines for N compounds for the safety of consumers • *Canadian Environmental Quality Guidelines (1999)* – updated *Canadian Water Quality Guidelines* (e.g., nitrate, nitrate, ammonia)
Alberta	• *Guidelines for Limiting Contaminant Emission to the Atmosphere from Fertilizer Plants and Related Industries* (1976) - regulation under the *Clean Air Act* (1975) that suggests guidelines for ammonia and ammonium phosphate emitted into the air from fertilizer plants • Wastewater Effluent Guidelines for Alberta Petroleum Refineries (1985) - wastewaters are monitored for maximum deposits of substances (i.e., chemical oxygen demand and ammonia) to a water course from refineries • *Environmental Protection and Enhancement Act* (1993) - broad legislation that regulates substances released into water • *Alberta Ambient Air Quality Guidelines (1993)* – regulation under the *Environmental Protection and Enhancement Act* to assess air quality and to assist in setting source emission standards in approvals (e.g., NO_2) • *Standards & Guidelines for Municipal Waterworks, Wastewater & Storm Drainage Systems* (1997) - under Best Practicable Technology Standards there is standard for total P for municipalities of a certain size • Surface Water Quality Guidelines for Use in Alberta (1999) - updated Alberta Surface Water Quality Objectives (1977) and Alberta Ambient Surface Water Quality Interim Guidelines (1994) • Wastewater Management Review for Fertilizer Manufacturing Sector (1999) – update for Fertilizer Plant Wastewater Effluent Guidelines (1976). Compares Alberta wastewater management practices with management practices in other jurisdictions to determine technology based wastewater discharge limits (e.g., ammonia) • Water Act (1999) – provides legislative authority for implementing new polices accepted by government to guide water management • Framework for Water Management Planning (2000 draft) – requires the Government to establish a strategy for protecting the aquatic environment • Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands (2000) - regulate the application of sludge to monitored lands • Guideline for Municipal Wastewater Irrigation (2000) - ensure that municipal wastewater is used for irrigation only when environmentally acceptable and agriculturally beneficial (e.g., nutrient, salt, sodium contents are examined)

Table 6.2. Legislation, regulations, objectives, guidelines, and associated control measures (continued).

Jurisdiction	Relevant Legislation, Regulations, Objectives, Guidelines, and other Control Measures
British Columbia	• *Pollution Control Act* (1967) - based on the combined results of a public inquiry and ecological, health, technological, and economic considerations; it aims to preserve land, water, and air environments at the highest possible levels • *Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia* (1975) - N in effluent may be limited if it controls eutrophication or is abnormally high (based on site-specific studies) • *British Columbia's Water Quality Criteria for Nutrients & Algae* (1985) - protect water resources from degradation and use impairment by associating algae in areas of eutrophication with concentrations of P in order to set limits • *British Columbia's Water Quality Criteria for N (Nitrate, Nitrite, and Ammonia)* (1986) - criteria to control N compounds to protect specific water uses • *Agricultural Waste Control Regulation and Code of Agricultural Practice for Waste Management* (1992) - describes practices for good agricultural practices (i.e., use, storage, and handling of manure) • *Sanitary Regulation* (1992) – prohibits activities which make water unfit for human or domestic purposes • *Production & Use of Compost Regulations* (1993) - Regulation under the *Waste Management Act* that prescribes specific limits for N and P in composting waste • *Waste Management Act* (1996) - discharge limits for nutrients • *Water Act* (1996) • *Fish Protection Act* (1997) - protect and enhance fish habitat, acknowledges nutrient issues, but has no specific control measures for nutrients • Sewage Disposal Regulation (1997) – Regulation designed to ensure consideration of assimilative capacity of the receiving environment through prior treatment of waste • *Tackling Non-Point Source Water Pollution* (1997) - document by MELP examining the association between agriculture and other activities and non-point source water pollution • *Forest Practices Code of British Columbia* (1998) – prescribes land use practices on Crown Forest and Range land for the protection of water quality in community watersheds • *Health Act* (1998) – Allows for the termination and removal of health hazards or potential health hazards
Manitoba	• *Environment Act* (1987-1988) • *Pesticides and Fertilizers Control Act* (1987) - regulates the sale and use of fertilizers in the province • *Guidelines for Various Air Pollutants* (1988) – regulation under the *Environment Act* that provides two levels of ambient air quality and objectives for various air pollutants (e.g., NO_2) • Private Sewage Discharge Systems and Privies Regulation (1988) - no person shall discharge sewage or sewage effluent into or onto the surface or the ground except in compliance with this Regulation • *Anhydrous Ammonia Handling & Transportation Regulation* (1989) • *Manitoba Clean Water Guide* (1997) - educational guide created by Manitoba Environment for use by cottage associations, conservation districts, educational institutions, etc., to increase public awareness and participation regarding water quality issues • *The Livestock Manure and Mortalities Management Regulation* (1989) - one intention of this Regulation is to minimize the potential for excessive nutrient contamination of surface waters • *Manitoba Water Quality Standards, Objectives, and Guidelines* (2000) - limits for P to minimize algae and macrophyte growth and for several N compounds to ensure passage, maintenance, and propagation of fish species; protection of livestock and poultry; and safety of waters for swimming, boating, and aesthetic purposes • *Development of a Nutrient Management Strategy for Surface Waters in Southern Manitoba* (2000 draft) – outlines the main issues that need to be considered and addressed in the development and implementation of a nutrient management strategy
New Brunswick	• *Clean Environment Act* (1973) and *Clean Water Act* (1989) - both serve to control releases into water and to deal with sites where a release has occurred; and to protect qualities of water, animal/ plant life, and enjoyment/ use • Water Quality Regulation (1982) - contains numerical values for numerous parameters that should be met in the province's waters • *Watercourse Alteration Regulation* (1990) - indirectly addresses nutrients and their impacts when introduced into aquatic systems

Table 6.2. Legislation, regulations, objectives, guidelines, and associated control measures (continued).

Jurisdiction	Relevant Legislation, Regulations, Objectives, Guidelines, and other Control Measures
New Brunswick	• *Guidelines for Livestock Manure and Waste Management in New Brunswick* (1996) - assess the adequacy of design and operation of all livestock and poultry operations with respect to good agriculture practice and pollution control • *Air Quality Regulation* (1997)– regulation under the Clean Air Act (1997) that limits the release of some air contaminants (e.g., NO_2) so that the ground level concentrations do not exceed the maximum permissible ground level concentrations
Newfoundland	• *Waste Material Disposal Act* (1990) • *Environment Act* (1995) • *Environmental Control Water & Sewage Regulations* (1996) - regulations under the *Environment Act* that give specific values of N and P to control environmental releases • *Air Pollution Control Regulations* (1996) – regulations under the Environment Act that provide air quality standards and emission standards for certain nutrient-related pollutants (e.g., NH_3, NO_2, N_2O) • *Environmental Guidelines for Agricultural Development* (of certain sized livestock & poultry operations); *Guidelines & Conditions for the Approval of Swine, Poultry & Other Livestock Enterprise*; *Information Guide for Livestock Facilities*; *Manure & Waste Management in Newfoundland*; *Urban & Rural Planning Act*; and the *Municipalities Act* all broadly address nutrients • *Farm Practices Guidelines for Livestock and Poultry* - currently under development to deal specifically with nutrients and eutrophication • Environmental Farm Plan Initiative and Safety Net Programs assist livestock and poultry producers in developing manure storage and handling practices
Northwest Territories	• *Environmental Protection Act (1988)* • *Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories* (1992) - qualitative objectives for nutrients (i.e., avoid nuisance conditions) in order to meet the objectives of the NWT Water Board (conservation, development, and utilization of water resources) and to protect human health • *Guidelines for Industrial Waste Discharge into the NWT* (1998) - objectives for BOD, P, and ammonia • *Guideline for Agricultural Waste Management* (1999) – purpose is to establish clear and consistent waste management standards for the intensive livestock and agricultural industry in the NWT
Nova Scotia	• Water Act (1989) • *Environment Act* (1995) • *Air Quality Regulations (1995)* – regulations under the Environment Act providing criteria for ambient air quality for some pollutants (e.g., NO_2), expressed as maximum permissible ground level concentrations • *Water and Wastewater Facility Regulations* (1995) • *Activities Designation Regulations* (1995) • *On-site Sewage Disposal Systems Regulation* (1997) • *Guidelines for Forestry Practices* - on crown lands • *Guidelines for Manure Management* - recommendations regarding manure storage and spreading • Watershed management plans are currently being developed for waters designated under the Canadian Heritage River Program (two rivers in NS) and those in municipal water supply areas. The plans address nutrients and eutrophication • NSDOE issues approvals for sewage treatment plants by setting biological oxygen demand (BOD), total suspended solids (TSS) levels and occasionally ammonia levels, based on assimilative capacity of the receiving environment to receive nutrients (*e.g.,* total P) • Provincial approval for land based aquaculture operations in freshwater environments have set controls, based on the expected efficiency of solids management system, for TSS and total P loading NS is investigating options to better address aquacultural effluents and better protect receiving environments (New Brunswick approach is being investigated) and NS has adopted policy which prohibits commercial finfish aquaculture in lakes. These controls are partly a response to concerns regarding impacts to fish habitats, aesthetics and recreational, and drinking water uses

Table 6.2. Legislation, regulations, objectives, guidelines, and associated control measures (continued).

Jurisdiction	Relevant Legislation, Regulations, Objectives, Guidelines, and other Control Measures
Nova Scotia	• Metro Areas Lakes Program - community-based program which monitors nutrients and chlorophyll *a* in urban areas • Volunteer Lake Monitoring Program - helps to protect lakes against the impacts of residential development • Green Farm Initiatives - uses BMPs to remediate and prevent environmental impacts to waters

Ontario	• *Environmental Protection Act* (1990) - identifies nutrient issues in the following legislation:
	• *Agricultural Code of Practice for Ontario* (1973) - addresses issues such as areas for manure utilization, handling, and spreading in winter and spring;
	• *Guidelines for the Control of industrial Phosphorus Discharge in Liquid Effluents* (1976);*Discharge of Sewage from Pleasure Boats Regulation* (1990) - regulates the discharge of organic and inorganic wastes;
	• *Guidelines for Sewage Sludge Utilization on Agricultural Lands* (1977 – revised 1986)
	• *Guidelines for the Treatment and Disposal of Liquid Industrial Wastes in Ontario* (1978)
	• *General- Air Pollution Regulation* (1990 – revised 1998) – controls air contaminants (NH_3, NO_2)
	• *Ambient Air Quality Regulation (1990* – revised 1994) – identifies a desirable ambient air quality criteria for some contaminants (e.g., NO_2); and
	• *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (1992) - protects against harmful levels of contaminants including nutrients (total organic carbon, total Kjeldahl nitrogen, total phosphorus) in sediments
	• *Ontario Water Resources Act* (1990) - broadly addresses nutrients in the following documents:
	  • *Water Management Policies, Guidelines, Provincial Water Quality Objectives* (1994) - manages surface and ground water quality in the province through numerical Provincial Water Quality Objectives (PWQOs). Currently, there is a proposed Interim PWQO for P
	  • Waterworks and Sewage Works Regulations (1993)
	• Municipal Water and Sewage Transfer Act (1997)
	• Nutrient Management Plans - BMPs deal with the over application of nutrients and contain P index for Ontario for both soil and open surface water runoff
	• Provincial Water Quality Monitoring Network collects water quality data, including P measurements, and based on the properties and quality of the receiving waters. Certificates of Approval are issued to individual dischargers to limit P loadings

Prince Edward Island	• *Environmental Protection Act* (1988) - contains information regarding the adverse effects of nutrients • *Air Quality Regulations* (1992) – regulations under the *Environmental Protection Act* that sets out maximum ambient air contaminant levels (e.g., NO_2) based on ground level concentrations standards • Water Quality Certificate Regulation (1995) - issued when water parameters do not exceed the maximum acceptable concentrations or aesthetic objectives, as specified in the current *Guidelines for Canadian Drinking Water Quality* • 1997 Roundtable on Resources and Sustainable Land Use has led to the current development of legislation on buffer zones that will address nutrients and eutrophication indirectly
Québec	• *Programme d'assainissement des eaux du Québec (1970s)* - water clean up program for municipal, industrial, and agricultural wastes • Environment Quality Act (1977) - addresses contaminants (nutrients indirectly) • Bottled Water Regulations (1981) - limit the concentrations of nitrate + nitrites • Drinking Water Regulations (1984) - limit the concentrations of nitrate + nitrite • *Québec Surface Water Quality Guidelines / Critères de qualité de l'eau de surface au Québec* (1998) - values for maximum concentrations of total P and several N compounds • *Reduction of Pollution from Agricultural Sources Regulation* / *Règlementation sur la réduction de la pollution d'origine agricole* (1997) – agricultural management regulation under the *Environmental Quality Act* addressing the over application of nutrients, livestock waste storage, and spreading of fertilizing substances • Directives for manure management - for the protection of ground water and streams • Legislation on buffer zones - indirectly protects surface waters against direct nutrient releases

Table 6.2. Legislation, regulations, objectives, guidelines, and associated control measures (concluded).

Jurisdiction	Relevant Legislation, Regulations, Objectives, Guidelines, and other Control Measures
Saskatchewan	• Prairie Provinces Water Board Water Quality Objectives (1969) • *Environmental Management and Protection Act* (1983) • *Guidelines for the Use of Sewage Sludge on Agricultural Lands* (1987) - maximum values for both total N and P in sludge to ensure sewage sludge is applied to agricultural lands in a beneficial and environmentally acceptable manner • *Water Pollution Control and Waterworks Regulations* (1989) • *Clean Air Regulations* (1990) – regulations under the *Clean Air Act (1986)* setting ambient air quality standards for certain pollutants (e.g., NO_2)
Yukon Territory	• Environment Act (1991) - nutrients as contaminants are addressed • Contaminated Sites Regulation (1996) - aquatic regulations under the *Environment Act* for aquatic life, livestock watering, drinking water for nitrate and nitrate + nitrite • Sewage discharged to land or wetlands has undergone secondary treatment or better (with the exception of two communities)

One example of action taken on the environmental effects of agricultural waste management was the joint provincial/ federal study, *Management of Livestock and Poultry Manures in the Lower Fraser Valley* (Brisbin 1995). The association between agriculture and other activities and water pollution was also examined by the MELP with findings in the document *Tackling Non-Point Source Water Pollution* (Brisbin 1995). Future actions to mitigate the problem of over-production of manure in the Lower Fraser Valley are being developed through consultations with stakeholders and include the following

- MELP, the Ministry of Agriculture and Food, and three agricultural organizations have developed a Memorandum of Understanding to formalize peer advisory services to assist with resolving environmental issues and to promote sustainable agriculture. A mediation process to resolve operational issues of the services was recently initiated.
- Producer Conservation Organizations were established with assistance from federal Green Plan funding. These developed on-farm stewardship programs.
- The Sustainable Poultry Farmers Group initiated a manure transportation program to assist in achieving compliance with the *Code of Agricultural Practice for Waste Management*. This approach has resulted in approximately 40% of the excess manure in the South Matsqui area being relocated to other areas.
- Government and the hog industry are developing a transition plan for hog operations to achieve compliance. Industry in conjunction with government is examining the feasibility of treatment facilities and expanded storage facilities. There will be some funding available for storage facilities through Investment Agriculture.
- A recently formed Ten-Point Action Plan on Agriculture and the Environment was agreed to by the agriculture industry and the provincial government. A Working Committee is currently reviewing all agricultural-environmental issues requiring consultation and action.

The new 1997 provincial *Fish Protection Act* (Section 12) requires municipal bylaws to be implemented, where directed, regarding the protection and enhancement of riparian areas that may be subject to residential, commercial, or industrial development. Agriculture is exempted from this Section of the *Act* on the condition that other policy tools be developed to protect and enhance riparian areas within agricultural use areas.

Manitoba

To prevent unacceptable levels of water quality impairment, the Manitoba government developed the *Manitoba Water Quality Standards, Objectives, and Guidelines* (2000), which contain specific

Table 6.3. Water quality guidelines in Canada for nutrients (N and P) and aquatic plant biomass. AQL= Aquatic Life; ALL= All Water Uses; REC = Recreation and Aesthetics; LW= Livestock Watering

VARIABLES	VALUE µg/L	USE	RATIONALE	JURISDICTION	REFERENCE
Total P	5 - 15	AQL	Lakes only, with salmonids as predominant fish species [1].	BC	Pommen 1989
	10 (maximum)	REC	Lakes only [1].	BC	Pommen 1989
	10	ALL	For a high level of protection against aesthetic deterioration in lakes naturally below this value; ice-free period.	ON	OME 1984; OMEE 1994
	20 (average)	ALL	To avoid nuisance concentrations of algae in lakes; ice-free period.	ON	OME 1984; OMEE 1994
	< 30	ALL	To eliminate excessive plant growth in rivers and streams.	ON	OME 1984; OMEE 1994
	50% of "predevelopment" value (interim)	ALL	To provide guidance for protecting water quality and clarity.	ON	OME 1998
	20 - 30	ALL	Based on Ontario values (OMOE 1984) to eliminate the nuisance of algae and aquatic plants	QC	MEFQ 1990
	50% of natural ("background") level	ALL	Lakes with P levels between 10 and 20 µg/L; ice-free period. For sensitive habitats (e.g., lakes with trout), criteria will be validated with models predicting hypolimnetic oxygen.	QC	MEFQ 1998a
	50	ALL	Water quality suitable for most uses.	AB	Alberta Environment 1999
Elemental P	0.1	AQL	Based on U.S. values (USEPA 1976); for salted waters.	QC	MEFQ 1990
Total N	10 000	REC	For the prevention of nuisance growths of aquatic plants.	BC	Pommen 1989
	1 000	ALL	For total inorganic and organic N, based on the toxicity of ammonia and nitrate and on the role of N as a nutrient.	AB	Alberta Environment 1999
	1 000	ALL	Multipurpose water quality objective. For total organic and inorganic N based on toxicity tests.	SK	SERM 1983
	Narrative	ALL	For total organic and inorganic N to prevent nuisance growth of aquatic rooted, attached and floating plants, fungi, etc. which would render the water unsuitable for beneficial uses.	MB	Williamson 1983
Nitrate + nitrite (as N)	100 000	LW	To protect livestock when both nitrate and nitrite are present.	BC	Nordin and Pommen 1986
	100 000	LW	To afford protection to most livestock species as well as to the consumers or products derived from these livestock.	SK	SERM 1995
	100 000	LW	To protect livestock when both nitrate and nitrite are present.	MB	Williamson 2000
	100 000	LW	To protect livestock when both nitrate and nitrite are present.	ON	OME 1984
	100 000	LW	Based on USA (NAS/NAE 1973); Ontario (OME 1984) and Manitoba (Williamson 1983).	Canada	CCREM 1987

VARIABLES	VALUE µg/L	USE	RATIONALE	JURISDICTION	REFERENCE
Nitrate (as N)	200 000 (maximum) 40 000 (average) [2]	AQL	To protect freshwater aquatic life, based on literature reports.	BC	Nordin and Pommen 1986
	200 000	AQL	To protect freshwater aquatic life, based on British Columbia values.	QC	MEFQ 1990
	100 000	REC	For waters for which high concentrations of nitrate are not likely to cause any direct problems in terms of body contact or visual deterioration. To protect recreational users who may ingest water, it is recommended that the drinking water criteria be applied.	BC	Nordin and Pommen 1986
	100 000	REC	Based on British Columbia values. To protect users from the risk of ingesting the water, it is recommended to apply the criteria of drinking water to all water that is used for recreation.	QC	MEFQ 1990
	Narrative	ALL	A numerical guideline is not given for nitrate, but concentrations that stimulate prolific weed growth should be avoided	Canada	CCREM 1987
Nitrite (as N)	60 (maximum) 20 (average)	AQL	For the protection of aquatic life, on the basis of literature reports.	BC	Nordin and Pommen 1986
	60	AQL	Based on British Columbia values. A value of < 20 µg/L is reported as a chronic toxicity value.	QC	MEFQ 1990
	60	AQL	Based on toxicity test with fishes; will protect most species.	Canada	CCREM 1987
	10 000	LW	To protect livestock from toxic concentrations of nitrite alone.	MB	Williamson 2000
	10 000	LW	Based on livestock toxicity and Manitoba criteria.	Canada	CCREM 1987
	1 000 (maximum)	REC	To protect all water users against possible ingestion.	BC	Nordin and Pommen 1986
	1 000	REC	Based on British Columbia criteria	QC	MEFQ 1990
Total ammonia (NH_3 + NH_4^+ as N)	680 – 2 770	AQL	To protect freshwater aquatic life; varies with pH (6.5 – 9.0) and temperature (0 – 20°C).	BC	Nordin and Pommen 1986
	600 – 2 060	AQL	To protect freshwater aquatic life; varies with pH and temperature.	SK	SERM 1995
	21 – 231 000	AQL	To protect freshwater aquatic life; varies with pH (6.0 - 9.5) and temperature (0 - 30°C).	Canada	CCME 2000
	2 500 (maximum) 1 000 (30 day mean)	AQL	To protect marine aquatic life	BC	Nordin and Pommen 1986
	102 – 2 770	AQL	To protect marine aquatic life; varies with pH (6.5 - 9.0) and temperature (0 - 20°C); based on British Columbia criteria.	QC	MEFQ 1990
Ammonia (un-ionized – NH_3)	18 – 50	AQL	Varies with pH (6.5 - 9.0) and temperature (0 - 30°C).	MB	Williamson 2000
	19	AQL	Freshwater aquatic life. Based on least observed effects concentration (pathological lesion and tissue degradation in the kidney) in rainbow trout.	Canada	CCME 2000
	20	AQL	Based on the lowest concentrations reported for aquatic toxicity, bioaccumulation and mutagenicity.	ON	OMEE 1994

VARIABLES	VALUE µg/L	USE	RATIONALE	JURISDICTION	REFERENCE
Nutrients	narrative	ALL	N and other nutrient concentrations should not be altered from natural levels by discharges of effluents such that nuisance growths of algae or aquatic weeds result; to provide a minimum degree of protection of all beneficial uses [3].	SK	SERM 1983; SERM 1995
Aquatic plants	narrative	REC	Biota, which could be a nuisance to bathers if present in large numbers, should be absent from areas intended for development of bathing beaches. Biota includes floating or rooted aquatic plants, phytoplankton and periphyton.	Canada	Health and Welfare Canada 1983; CCREM 1987
Attached benthic algae	30 to 50 mg/m^2 chlorophyll *a* (interim)	AQL	The identification of objectionable biomass levels for aesthetic concerns is clearly a subjective matter. However, benthic algae in this range seems to be the "break point: between what is acceptable versus objectionable in salmonid streams.	Canada	Environment Canada 1995
	50 mg/m^2		To protect uses related to recreation and aesthetic in streams	BC	Nordin 1985
	100 mg/m^2		To protect against undesirable changes in aquatic life in streams	BC	Nordin 1985

[1] Refers to the spring overturn concentration (lake epilimnetic residence time greater than 6 months), or the mean epilimnetic growing season concentration (epilimnetic residence time less than 6 months)

[2] The average value is calculated from at least 5 weekly samples taken in a period of 30 days.

[3] These general objectives are applicable to all portions of a receiving waterbody except that portion designated by the Department as an effluent mixing zone. They are not applicable to intermittent streams except during flow periods such as spring runoff. These objectives should be achieved however, in portions of intermittent streams where ponded stream water is utilized for beneficial purposes.

Other Jurisdictions:

PEI: use CCME guidelines.

NF: use CCME guidelines.

NWT: use CCME guidelines.

NB: use CCME guidelines for the most part. Exceptions are the water quality objectives developed by Canada--US--state--provincial committees for the international portions of the Saint John River and the St. Croix River. Because CCME has not yet developed a guideline, NB uses the Ontario guideline of 30 µg/L total P for flowing waters. For lakes, NB usually refers to the P values which Dillon and Rigler (1975) used to define four trophic levels and to predict lake development capacity based on their trophic status.

requirements for nutrients (Table 6.3). These objectives are analogous to the *Canadian Water Quality Guidelines*, but have been adapted for site-specific use. The *Manitoba Water Quality Standards, Objectives, and Guidelines* assist in developing industrial and municipal waste discharge restrictions, assessing surface water quality, and determining the suitability of waters for certain uses. The information provided by the *Manitoba Water Quality Standards, Objectives, and Guidelines* also plays a role in predicting treatment costs at specific locations and in development of strategies to control land use practices.

The province has produced a number of educational materials about water quality issues aimed at increasing public awareness and participation. The 1997 *Manitoba Clean Water Guide*, issued by Manitoba Environment, and several pamphlets on the water quality of specific water bodies are examples of such materials used by cottage associations, conservation districts, and educational institutions.

Studies on specific parameters (i.e., P study of Clearwater Lake) as well as overall water quality assessments (i.e., water quality assessment of Whitemud River Watershed) have been completed by Manitoba Environment. Data from government studies are used in conjunction with information from such volunteer programs as the Manitoba Environment Volunteer Water Sampling Program to guide future management decisions in the province.

Manitoba provides information on practices and systems related to the storage, handling and disposal of livestock wastes (including manure) through its *Farm Practices Guidelines for Dairy (or Poultry, Beef or Hog) Producers in Manitoba* (Manitoba Agriculture 1994). The Manitoba Ministry of Agriculture produces the *Soil Fertility Guide* providing farmers with technical information on nutrients and fertilizer application in order to promote good practices (Manitoba Agriculture 1999).

Manitoba also has guidelines for managing application of sludge or biosolids to land in Manitoba. The concern over nutrients (organic nitrogen, ammonia, nitrate) is addressed in these general guidelines that vary from one location to another (e.g., soil type, sensitivity of groundwater, etc.), and are reflected in legally-binding licenses issued under the *Manitoba Environment Act*. Treatment of sludge prior to application would normally include anaerobic digestion or equivalent treatments. The level of treatment, including anaerobic digestion, will be specified in each license.

A nutrient management strategy is currently being developed for Manitoba, which will include the development of nutrient objectives for rivers and streams on a combination of regional-scale characteristics and considerations and the nutrient carrying capacity of Lake Winnipeg.

New Brunswick

New Brunswick relies, for the most part, on guidelines in the CCME *Canadian Water Quality Guidelines* (1999). However, the Province's 1989 *Clean Water Act* and the 1990 *Watercourse Alteration Regulation* both have authority to address indirectly nutrients introduced to aquatic systems and their subsequent impacts. The Province is currently developing and implementing a *Water Classification Regulation* that will include water quality standards for dissolved oxygen, bacteria, and benthic community structure for flowing waters. During the initial development of the *Clean Water Act*, this action had been considered as a method to address water resources on a watershed basis and to provide a role for the public in setting water quality goals.

For stream protection, New Brunswick currently uses Ontario's guidelines to set limits for nutrients in streams receiving effluent. In addition, New Brunswick promotes best management practices (BMPs) for land use activities. Site-specific BMPs have been developed such as the use of buffer strips to reduce nutrient loading to streams. For example, while the Department of Environment has the authority to specify which practices are permitted within a measured zone around drinking water sources, outside of this zone, they encourage agricultural practices that will maximize protection of watersheds. Watershed groups have also initiated a number of activities and projects in an attempt to increase awareness about nutrient issues. A riparian zone restoration campaign by the Trout Creek Model Watershed Group and septic system upgrades in the Buctouche River Sustainable Development Project are two examples.

New Brunswick also publishes *Manure Management Guidelines for New Brunswick* (NBARD 1997), which give direction for establishing and operating livestock facilities, including the application of manure to farmland.

Newfoundland

In Newfoundland, the protection of water quality, habitat, and the environment from nutrients and other agents are addressed in the 1990 *Waste Material Disposals Act*; the 1995 *Environment Act*; and the 1996 *Environmental Control Water and Sewage Regulation*. In addition, the province is developing *Farm Practice Guidelines for Livestock and Poultry*. These will deal specifically with nutrients, fertilizers, and eutrophication. Also, the Agricultural Extension Services, Specialists on Crops, Soil & Agricultural Engineering Services provides farmers with technical information on nutrients and fertilizer application in order to promote good practices. This initiative aims to prevent eutrophication of water resources associated with agricultural seepage and surface runoff.

Northwest Territories

Although much of the North is not subjected to anthropogenic nutrient loading, municipal wastewater discharges associated with a growing and more urban population have the potential to affect human health and environmental quality. The policy of the Northwest Territories Water Board is to apply best practical means in treating municipal waste before it is discharged into waters. The intent of this policy is to preserve the state of the North's waters and to "avert the problems allowed to build up in southern Canada where often strict controls were not imposed in the early days of municipal growth" (Water Board of NWT 1992).

In terms of nutrients, the *1992 Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories* and the 1998 *Guidelines for Industrial Waste Discharge in the Northwest Territories* recommend limits for P, though they apply only under certain conditions and are rarely a licensing condition. The type of sewage treatment facilities most practical in northern communities was an important consideration in developing these guidelines. *Receiving Water Quality Objectives* address nutrient concerns and recommend that levels outside the initial mixing zone be maintained in such a way as to avoid nuisance conditions.

Nova Scotia

In Nova Scotia the management and protection of water resources are addressed through legislation such as the 1995 *Environment Act*, the 1995 *Activities Designation Regulations*, the 1995 *Water and Wastewater Facility Regulations*, and the 1997 *On-Site Sewage Disposal Regulations*. These do not address nutrients directly but provide the authority to develop site-specific requirements. Site-specific development controls are established to reduce water quality impacts from various activities that can include nutrients sources. Predictive modelling and assessments of assimilative capacity have been used in establishing limits.

Operational guidelines have been developed for various land-use activities (e.g., forestry and agriculture) which promote the use of BMPS and reduction of impacts from non-point sources. Sewage management guidelines developed in 1992 require receiving water studies for larger treatment facilities, which can involve total P modelling and limits. Educational materials have also been developed to inform the public of potential nutrient related impacts from residential development and to promote volunteer preventative actions and stewardship of the water resource.

Watershed management plans are promoted for public drinking water supplies and in watersheds designated under the Canadian Heritage Rivers program. Various contaminants including nutrients would be addressed in both situations.

Recent policy development has prohibited commercial aquaculture operations within freshwater lakes and ponds. Land-based aquaculture operations are subject to controls limiting loading of nutrients.

The Nova Scotia Department of Environment (NSDOE) supports several site-specific water quality monitoring programs aimed at addressing local concerns regarding nutrients, including the Metro Areas Lakes Program, which monitors nutrients and phytoplankton biomass in protected areas; local community groups, which monitor nutrients and other parameters in certain water bodies; and a municipal based Volunteer Lake Monitoring Program, which helps protect lakes against the impact and extent of residential development.

For the agricultural community, there are recommended guidelines for operations (e.g., Brenton and Mellish 1996; Robinson and Gordon 1996) as well as the recently developed Green Farm Initiative. The purpose of this initiative is to use BMPs to remediate as well as to prevent environmental impacts to water resources. In an industrial context, the NSDOE has introduced a Pollution Prevention Program governing substance release.

Ontario

Direction for the management of Ontario's surface and ground waters is provided in the 1994 *Water Management Policies, Guidelines; Provincial Water Quality Objectives of the Ministry of Environment and Energy* (OMEE 1994). The document provides a basis for determining “limits of the uses of the resources” that will serve to protect the province’s water resources. Methods of achieving these defined limits are to be decided locally based on existing conditions and incorporating other pollution management strategies.

Provincial Water Quality Objectives (PWQOs) consist of ambient water quality criteria set so as to maintain the quality of surface waters of Ontario (Table 6.3). The criteria are for surface waters; however, they may also apply to ground water where it is discharged to surface waters. Although the criteria apply to nearly all waters in the province, interim PWQOs were developed to address specific water quality concerns. For instance, recreational development of lakes often results in phytoplankton blooms and other undesirable aesthetic and biological effects. Low flow and agricultural inputs can also cause high P concentrations in watersheds. Interim PWQOs are set using total P as a general guideline for use in conjunction with site-specific studies. These interim objectives are designed to protect against aesthetic deterioration; eliminate excessive plant growth in rivers and streams; avoid nuisance concentrations of algae in lakes; and protect the diversity of trophic status while still enabling development to occur. Thus, Ontario currently has a P interim PWQO for lakes on the Precambrian Shield that allows spring overturn values to rise to 50% above predevelopment levels. The *Rationale for a Revised Phosphorus Criterion For Precambrian Shield Lakes in Ontario* (January 1998; OME 1998) cites "preventing undesirable changes in the aquatic ecosystem due to increased algal growth" as the rationale for developing new P objectives.

In terms of assessment, the Provincial Water Quality Monitoring Network measures P concentrations in receiving waters. The data are used at the regional level for receiving water assessments and in the issuing of Certificates of Approval. These Certificates are legal instruments that may limit concentrations or loadings of P. Concern over eutrophication of the Great Lakes in the 1960s, as well as obligations under the *Canada-U.S. Great Lakes Water Quality Agreement* (through the 1971 *Canada-Ontario Agreement*), led to the implementation of these measures.

Ontario has a considerable number of voluntary initiatives in place. Within the Ministry of Environment, one of the most significant initiatives is total P management. The initiative is currently being formalized and, when adopted, will control the total amount of P discharged. For example, if a discharger wishes to increase its P loading then they will usually require a deviation when the PWQO is exceeded. A deviation is acquired by providing offsets within the watershed by reducing loadings from non-point sources, such as agriculture. Some municipalities are asking for offsets of 2:1 and greater.

There are also various agricultural initiatives within the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and organizations such as the Ontario Farm Environment Coalition, AGCARE, and Ontario Soil and Crop Improvement. Ontario provides information on practices and systems related to the storage, handling and disposal of livestock wastes (including manure) in its *Ontario's Nutrient Management Strategy* (Ontario Farm Environment Coalition 1998). Ontario produces *Field Crop Recommendations* that provides farmers with technical information on nutrients and fertilizer application in order to promote good practices (e.g., OMAFRA 1994). The Ontario Farm Environment Coalition (1998) is developing an agricultural nutrient management policy and is encouraging OMAFRA to integrate this policy and associated processes into Bill 146, the proposed *Farming and Food Production Protection Act*.

Prince Edward Island

Studies conducted in PEI have identified problems of eutrophication largely caused by land management activities, notably excessive plant production in the upper portions of several estuaries. A 1997 Roundtable on Resources and Sustainable Land Use examined the impact of various PEI land uses on water resources and recommended a number of changes to the current land uses. In

response to these recommendations, PEI is currently developing legislation on buffer zones to protect all water bodies situated in areas of livestock or crop production, particularly potato production.

Documented evidence of water quality problems in PEI (rising nitrate levels in surface waters) and the recent development of the proposed buffer zone legislation have served to educate the public and prompted voluntary initiatives. The agricultural community is working to improve land management through such initiatives. Special studies are often conducted to assess the impact of nutrients. In addition, PEI has developed *Guidelines for Manure Management for Prince Edward Island* that recommend manure management practices as well as provide direction for the establishment and operation of new livestock confinement facilities, expansion of existing livestock facilities, or changes in land use in rural areas (PEI Agriculture 2000).

Québec

Nutrient guidelines have been developed in the Province of Québec for the protection of aquatic life and the protection of water quality for recreational and aesthetic uses (Québec's Surface Water Quality Criteria [*Critères de qualité de l'eau de surface au Québec* (1998)]. These criteria are also used for development of receiving water objectives based on usual decontamination technologies. Modified from Ontario's objectives, Québec's provincial water quality criteria for total P are designed to protect against aesthetic deterioration; eliminate excessive plant growth in rivers and streams; avoid nuisance concentrations of algae in lakes; and protect the diversity of trophic status while still enabling development (Table 6.3).

Recently, Québec modified its criteria for total P in lakes. The new guideline allows values in lakes, during the ice-free period, to rise to 50% above natural background levels (MEFQ 1998a). As is the case for Ontario's provincial criteria, the prevention of undesirable changes in the aquatic ecosystem due to increased algal growth is the rationale behind the development of this new P objective. For protection of sensitive species habitats (i.e., lake trout), criteria must be validated with the lake ecosystem capacity method, which is based on hypolimnetic oxygen concentrations. There are also surface water quality criteria in Québec for total ammonia and nitrite, which have been adopted from criteria used in British Columbia, Ontario, and the United States (Table 6.3).

Environmental problems caused by toxic substance release from urban, industrial or agricultural sectors to water were addressed in the late 1970s by the water clean-up program, Programme d'assainissement des eaux du Québec. This Program generally regulated point sources, and was thus unlikely to address nutrient sources such as agricultural runoff. Because certain streams were impacted by nutrients (particularly P and, in certain seasons, ammonia) as a result of intense agricultural activities, regulations were developed in 1997 for the reduction of pollution from agricultural activities (*Règlementation sur la réduction de la pollution d'origine agricole*; MEFQ 1998b). This regulation provides farmers with technical plans on nutrients and fertilizer application to promote good practices. It is also designed to prevent eutrophication of water resources due to agricultural seepage and surface runoff. There are also directives for manure storage for the protection of ground water and streams, and legislation on water buffer zones that indirectly protects surface waters against nutrient releases. The legislation is unique in that, unlike other provincial manure management plans, it includes guidelines for manure application based upon soil and crop requirements for P, rather than N.

Saskatchewan

Concerns about excessive growth of aquatic weeds and algae in the Qu'Appelle river system prompted one of the first assessments of eutrophication in Saskatchewan. In 1970, the Governments of Canada, Saskatchewan and Manitoba signed an agreement to create a comprehensive framework to develop and manage the water and related land resources of the basin. To follow through on recommendations put forward under this agreement, the Governments of Canada and Saskatchewan signed the 10-year Qu'Appelle Agreement in 1975 to protect and improve the Qu'Appelle Valley's environment, resources and cultural heritage, and to promote economic growth in the area through tourism and recreation. As part of this agreement, Regina upgraded its sewage treatment facilities in 1976 to tertiary treatment, Moose Jaw diverted its sewage to agriculture through spray irrigation, and livestock operations in the basin were assessed and, if need be, relocated or upgraded.

Saskatchewan's 1995 *Surface Water Quality Objectives* aid in determining nutrient limits for point source discharges. Other controls, such as the *Water Pollution Control and Waterworks Regulations* (1989), do not address nutrients directly but provide the authority to develop site-specific requirements. Eutrophication of water bodies in the region also prompted the Riparian Habitat Initiative. Saskatchewan also has a manual outlining appropriate methods for handling, utilizing, and disposing of manure (SAF 1997).

Currently, the Ecosystem Management Special Projects Unit in the provincial Department of Environment and Resource Management is in the initial stages of determining ecological monitoring parameters that will address various water quality issues in the province. At this point, nutrients are one of the proposed indicators, though no criteria have been developed to date. The intent is to consider ecosystem impacts and therefore to look at the effects of nutrients not only on primary production but also on other elements of the aquatic food web.

Yukon Territory

Yukon aquatic and terrestrial systems are typically low in anthropogenic nutrients due to a small population and abundant water resources. Sewage from most communities in the Yukon receives at least secondary treatment, is retained in storage lagoons and then discharged to land or wetlands. Primary treated domestic sewage from the communities of Dawson and Carmacks is discharged directly into the Yukon River but effects cannot be detected largely because of the river's high discharge and cold temperatures. A large freshwater aquaculture facility has caused eutrophication of a stream, indicating that additional nutrient controls are required to maintain other water uses.

6.2. Selected Regulations, Guidelines, and Best Management Practices in Other Countries

Nutrients are managed or are of concern to many countries around the world. In the USA, 45% of all surveyed lakes, reservoirs and ponds and 30% of all surveyed river reaches are impaired by nutrients (USEPA 1998b). In England, 78 of 102 lentic sites were found to be eutrophic or hypereutrophic based on total P criteria (Carvalho and Moss 1995) and 2 540 km of 62 rivers and canals have been designated as eutrophic (UK Environment Agency 1998). A preliminary review of eutrophication in

Europe suggested the problem was pervasive, being most severe in Belgium, Denmark, Germany, Italy and The Netherlands, and moderate in Greece, Ireland, Luxembourg and Spain (Chiaundani and Premazzi 1988). The continuing concern about widespread deterioration in environmental quality due to nutrients has resulted in considerable effort directed at managing nutrients in the environment.

This section highlights some of the actions being undertaken by other countries with respect to regulations, guidelines, objectives, and best management practices to curb nutrient losses and their environmental impacts. There are basically two complementary approaches to tackling water pollution:

- ambient quality objectives that define the minimum quality requirements of ambient water, air or soil to prevent deleterious effects to aquatic life, human health, livestock, etc.
- source control that focuses on minimizing quantities of pollutants discharged from a particular source into the environment.

This section identifies some of the approaches used elsewhere to establish ambient quality objectives or to minimize nutrient losses from point and non-point sources.

Setting Ambient Quality Objectives for Nutrients

Several countries (such as the USA, Australia and New Zealand) are currently developing approaches for setting scientifically-defensible numeric nutrient and algal criteria applicable to their ecozones. A directly prescriptive approach to nutrient criteria development is not appropriate due to inherent regional differences in water quality.

In the USA, the Environment Protection Agency announced in June 1998 that it is going to require all states to develop and adopt numeric nutrient and algal criteria for all waters (USEPA 1998a). Frameworks for establishing science-based nutrient and algal criteria for rivers/streams, lakes, wetlands, and estuaries have been drafted and are currently being revised. These draft documents recommend an approach for setting criteria. For example, in the case of the rivers/streams document, criteria development would be based upon analysis of nutrient and algal data from reference and impact sites to determine conservative statistical thresholds at minimal or low impact sites and to establish nutrient-algal relationships.

Australia and New Zealand are also currently revising the Australian and New Zealand Environment and Conservation Council (ANZECC) *Water Quality Guidelines for Fresh and Marine Waters*, a document published in 1992. The main objective of the new guidelines document is to provide an authoritative guide for setting water quality objectives that will sustain current, or likely future, environmental values for natural and semi-natural water resources in Australia and New Zealand. Similar to the US EPA draft documents, the draft ANZECC document provides an approach for setting nutrient guidelines recognizing the need to tailor guidelines to specific ecosystem types (e.g., lowland rivers, upland rivers, reservoirs/lakes, wetlands, estuaries, coastal/marine waters), for specific localities or regions, and to relate nutrient concentrations to the risk of adverse effects.

In some countries (e.g., within the European Union), development of nutrient guidelines is set within the context of watershed management plans. A watershed management plan sets out a common vision for a watershed by identifying use-related objectives for water quality, along with actions to achieve the objectives. Historically, efforts at improving water quality were typically directed at managing a particular source or sector. This approach often elicited success because, prior to intensive agricultural, industrial and urban development and advances in waste treatment technology, pollution

could often be tracked back to a single source. However, now, with the gains made in our knowledge of environmental science and technology, it is rare that a single source determines the nutrient status of a waterbody. The additive effects of many individual sources of nutrient loading (no one of which may be a major polluter) must now be addressed and this can only be done through watershed management plans.

A watershed management plan involves:

- assessing the impact of human activities on surface waters and ground waters in each river basin, taking into consideration pollution from point sources, pollution from diffuse sources, water abstraction and other human activities that affect water status;
- setting ecological objectives for water quality and quantity based on an assessment of water needs, and impacts of human activities on water bodies;
- exploring management options for mitigating pollution;
- establishing and implementing a program of measures to achieve the ecological objectives which involves interested parties such as relevant government departments, local communities, and water utilities;
- establishing, measuring and monitoring systems for evaluating progress towards ecological objectives; and
- reviewing effectiveness of the action program at regular intervals.

Development of watershed management plans may range from a somewhat informal arrangement between interested parties (e.g., landowners, environmental groups, and local government) to formal regulations or directives. An example of the latter is the European Commission's proposed *Water Framework Directive* which, if and when adopted, will require management by river basin. The proposed Directive will require that a river basin management plan be established for all rivers to prevent deterioration of ecological quality and pollution of surface waters; prevent deterioration of ground water quality; restore polluted surface and ground waters; and ensure a balance between abstraction and recharge of ground water (EC 1999b). The restoration measures will comprise those required by existing Directives (such as those relating to urban waste water and agricultural nitrates), supplemented by whatever additional measures are needed to control pollution sources, point or diffuse, to achieve the stated objective.

Reducing Nutrient Loading from Point Sources

Historically, point sources (industrial and municipal wastewater) were the major sources of nutrient loading to aquatic ecosystems. However, because point sources are easily identified and regulated, nutrient contributions from point sources have declined over the past four decades in most industrialized countries. Despite these successes, population growth and the demand for industrial products have resulted in point source inputs still being a significant source of nutrients to many ecosystems. Solutions to further reduce nutrient loading from point sources are available and some are described below.

Compulsory treatment of all municipal wastewater: In the European Union and the USA, treatment of all municipal sewage is or soon will be mandatory. For example, in the USA, the *Clean Water Act* includes a deadline for cities to achieve secondary treatment of sewage. This deadline was originally

mid-1977. The US congress later extended that deadline to mid-1988. According to the US EPA, 87% of all communities complied with the 1988 deadline; 80% of those that missed the deadline were small cities (defined as those with less than 10 000 population). Cities that missed the 1988 deadline are now under judicial or administrative orders to comply as soon as possible.

In the case of the European Union, the European Commission's *Urban Waste Water Directive* requires all agglomerations above 2000 population equivalents (where 1 population equivalent equates to a five-day biochemical oxygen demand of 60 g of oxygen per day) to have sewer systems and secondary (i.e., biological wastewater) treatment. For certain marine waters, primary (i.e., mechanical treatment) might be sufficient provided it can be proved that water quality is not adversely affected. The deadlines for reaching the objectives depend on the size of the agglomeration and the character of the receiving water and range from 1998 (for communities > 10 000 that discharge to sensitive areas) to 2005 (for communities < 10 000). By 1998, any discharge of sewage sludge to water bodies is prohibited. The Directive also states that by December 2000, industrial wastewater from most food and beverage industries shall before discharge respect the established conditions for 4000 population equivalent or more (EC 1999a).

Advanced P removal from wastewater: Advanced P removal is a well-established technology for treating wastewater. Directives are in place in some jurisdictions requiring MWTPs discharging to sensitive water to upgrade to advanced P removal. For example, the European Commission's *Urban Waste Water Directive* requires agglomerations discharging wastewater to so-called sensitive areas (i.e., water bodies that are eutrophic or in danger of becoming so) to have wastewater treatment that is more advanced than secondary treatment (EC 1999a).

Upgrades to sewers: Repair and replacement of sewage systems have reduced pollutant loading from many cities, both in Canada and worldwide. Repair or replacement of sewers ensures minimal infiltration during wet weather and reduces leakage. Conversions of combined sewer systems to separate systems or shunting of the most toxic first flush of stormwater into storage facilities/ponds for subsequent treatment at a MWTP prevent untreated sewage from entering surface waters.

Reducing Nutrient Losses from Non-Point Sources

Large-scale agricultural production without some nutrient losses to ground and surface waters and to the atmosphere is virtually impossible. However, the impact of agriculture on water quality has become a point of concern in many nations. For example, the US EPA ranks agricultural activities as the most significant cause of impaired water quality in streams and lakes (USEPA 1994a,b); this trend is not surprising, given that agriculture is one of the most extensive users of the nation's land base (USEPA 1998b). The focus of much of this concern has been animal husbandry, where the geographic intensification of animal production in some regions has raised serious questions about the ability of the agricultural land base to assimilate animal manure nutrients without environmentally significant losses in erosion, runoff, leaching, or volatilization. Science-based solutions that can reduce agricultural nutrient losses further are available today and are described below. Improvements in environmental quality can be expected as nutrient losses are reduced.

Comprehensive Nutrient Management Plans for Individual Farms: Most provinces in Canada have in place or are developing nutrient management strategies (or "nutrient bookkeeping") for managing the production, storage and utilization of agricultural nutrients on farms. These are a valuable means to

improve a farmer's ability to manage nutrients more effectively, with the ultimate aim to reduce over-fertilization. Other jurisdictions (such as several US states) also require nutrient management plans, in particular submission of manure management plans by managers of large livestock operations (usually > 300 to 1 000 livestock units [or 300 000 to 1 000 000 lbs. of livestock], depending upon the state) to the regional authority.

Regional Nutrient Management Plans for Agriculture: In areas of intensive livestock production where the available agricultural land base is not sufficient for economic and environmentally-safe application of manure, animal and crop producers can work collaboratively to transport and apply animal manure on farmland that is nutrient deficient. This can be accomplished by means of a cohesive network of farm operators that brokers the exchange of surplus manure from animal producers to crop farms so as to reduce the amount applied to concentrated areas and redistribute it over a broader agricultural base. Such a centralized network was adopted in The Netherlands where a manure board was created to ensure application of manure to impoverished soils. Here, the government is pursuing a target of equilibrium manuring such that in about 10 years time, the amount of phosphate and nitrogen applied in the form of animal manure and chemical fertilizer must be broadly equal to the amount of phosphate and nitrogen utilized by the crops.

To limit over-application of manure, it may be necessary in some cases to reorganize livestock into smaller operations so that land application is more economically feasible. For example, in The Netherlands, the government is targeting large-scale farm operations so farmers will guarantee they have contracted enough land to receive their livestock manure safely. If they cannot achieve this guarantee, they must scale back their operation. In other words, The Netherlands is trying to create a land-based livestock sector.

Other considerations for effective farm nutrient management include assessments as to the siting of intensive livestock operations or crops (e.g., corn) and the proportion of land set aside compared to land intensively cropped. For example, the distribution of arable land in Europe has changed, especially since 1993, when the Common Agricultural Policy (CAP) reform went into effect. Although the primary goal of the policy was to take arable land out of cultivation to avoid build-up of a grain, it also served to reduce the land base to which agricultural chemicals were applied.

Guidelines for Manure Application to Soils: Land application of manure and commercial fertilizers should be based on a balance between the requirements of the crops and the supply to the crops from the soil and from fertilization. These guidelines are typically based on the N application rates because N is usually the nutrient that limits crop growth. However, manure is rich in P relative to N compared to plant growth requirements. This attribute means that application of manure to achieve a desirable level of N will result in an over-abundance of P in the soil. Although most soils have a high binding capacity for P, eventually excess P will reach surface waters where it may cause eutrophication. Certain countries where manure management from intensive livestock operations has long been an issue have adopted P guidelines for manure application (e.g., The Netherlands and Belgium).

Managing Nutrient Losses from Aquaculture Operations: Countries such as New Zealand, Japan, USA and Norway have a long history of aquaculture. Regulations and/or codes of practice have been established to minimize environmental impacts, including those associated with nutrient loss. These

include:

- Siting criteria to lessen impacts from nutrient losses from cages and from waste discharges and to determine if a waterbody can support an aquaculture operation.
- Open water cage technology so that cages can be placed away from restricted waters and shorelines.
- Criteria for collection and treatment of wastewater, particularly for cage operations in freshwater.
- Good management practices with respect to general site operations, waste disposal and garbage removal, and fish feeding practices.

6.3. New Technologies for Reducing Nutrient Loading

Modern engineering and environmental sciences are advancing at a remarkable pace, allowing for innovations that will increase the efficiency of nutrient use in a variety of sectors. Improvements in environmental quality can certainly be expected as nutrient losses are reduced through use of new, as well as well-established, technologies. Examples of some of the new or emerging technologies are:

Recovery and recycling of phosphate from wastewater: The chemistry of phosphate recovery and recycling appears relatively straightforward. Although industrial application of this process in municipal waste treatment facilities is still at an early stage, a number of research or demonstration installations are already running. The technology appears to hold considerable promise for recovering P, as phosphates, from MWTPs that can then be recycled back into the detergent phosphate industry and into other high-grade industrial uses. In addition, recycling of phosphates from wastewaters will reduce sewage sludge volumes and ash production where sludges are incinerated, and reduce chemicals used in sewage treatment works.

Increased nutrient retention by livestock: Livestock incorporate only 20 to 40% of the P and N originally present in the feed. Phytic acid is the main form of P in plants. Phytase (for breaking down phytic acid) is lacking in hogs and chickens (cows have phytase). Research is continuing on approaches for increasing nutrient retention by livestock and technologies are now emerging for adding phytase and/or other supplements to livestock diets (although this has to be tempered with health side-effects on animals) or to match animal diet to requirements. Plant genetic approaches are also looking at decreasing phytic acid content of plants.

Improved Feed Formulations for Aquaculture: Only 20 to 30% of the N and P added to aquaculture operations are incorporated into fish biomass and removed at harvest; the other 70 to 80% of added nutrients are lost to the environment as metabolic waste, faeces and uneaten food fragments. Improvements in feed quality have already reduced the feed coefficient (wet weight of feed used to wet weight of fish produced). New formulations should continue to focus on development of more nutritionally balanced and digestible feed to reduce waste discharges from feeding.

Treatment of Animal Wastes: With livestock and poultry industries becoming larger and more intensive, significant amounts of manure are generated that must be collected, stored, and utilized efficiently. Broad spectra of integrated manure management systems are available to collect, transfer, store, treat and efficiently utilize a great variety of sources and nutrient qualities of animal manures. Although treatment of animal waste is not a new technology, it has not been widely used as livestock and poultry producers have been given little incentive to implement such environmental practices and technologies.

In areas of intensive livestock production, treatment of animal waste could be evaluated as an option for reducing the risk of manure contamination of surface and ground waters.

Nutrient Management Best Management Practices (BMPs): Agriculture's contribution to non-point source pollution varies widely as a complex function of land use, cropping system, soil type, climate, topography, hydrology, and agricultural nutrient management practices. Despite this complexity, research-based nutrient management practices that are effective at reducing non-point source pollution are available throughout many countries, including Canada. New BMPs directed at specific crops or livestock or specific geographic conditions are continually developed. Wider implementation of new, as well as currently recommended, nutrient management BMPs by agriculture is essential if significant improvements in environmental quality are to be gained.

Although BMPs are most often discussed with respect to agricultural practices, the need for BMPs also applies to other sectors involved in land management, for example land clearing for oil, gas and mining operations, timber harvest, and urban development. Although less attention has been directed at developing nutrient management practices for sectors other than agriculture, there is a growing research base on BMPs that are effective at reducing non-point source pollution for other land-based sectors. Further research and implementation of nutrient management BMPs by land management operations are essential if significant improvements in environmental quality are to be gained.

6.4. Conclusions

In Canada, the problems of excessive nutrient loading were first recognized in aquatic ecosystems, notably Lakes Erie and Ontario, because of the highly visible problems associated with eutrophication: blue-green algal scums; unpleasant odours and tastes; and unsightly beaches. Scientific assessments of the problem identified nutrients, particularly P, as the pollution culprit. Federal and provincial/territorial governments responded with a wide range of measures including legislation, regulations, objectives, guidelines, and best management practices (Table 6.1). Over the years, these have been refined as new information became available. In many jurisdictions, there has been a shift from “end of pipe” responses to a more preventative or proactive approach. This shift is a result of a growing tendency towards a broad ecosystem approach to environmental protection.

Many of the approaches used to minimize nutrient loading and associated environmental impacts in Canada are also employed in other jurisdictions. Permit limits, for example, are a well established and widely used tool for regulating wastewater discharges from industrial and municipal sewage treatment plants. However, compared to Canada, countries with a longer history of settlement and intensive agriculture have tended to adopt tighter restrictions to minimize nutrient loading to the environment. Several countries (e.g., USA, Australia, New Zealand, and countries in the EU) are also developing frameworks for setting scientifically-defensible regional nutrient criteria.

In addition to the well-established approaches for reducing nutrient impacts to the environment, new technologies continue to be developed. They range from methodologies for source control of nutrients to operational practices to reduce impacts of nutrients on the environment. Environmental policy should continue to emphasize integrating the best and most advanced science into practical solutions.