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NATIONAL WORKSHOP PROCEEDINGS AGRICULTURAL IMPACTS ON WATER QUALITY: CANADIAN PERSPECTIVES

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The National Workshop on "Agricultural Impacts on Water Quality: Canadian Perspectives" was organized as a result of a recommendation submitted by the Canada Committee on Engineering Services in Agriculture and Food (CCESAF) to the Canadian Agricultural Services Coordinating Committee (CASCC) in November 1989. The concept of such a Workshop was also supported by the Centre for Land and Biological Resources Research (CLBRR) and the Canada Committee on Land Resources Services (CCLRS).

The Workshop objective was to provide a national forum for the exchange of scientific information on the impacts of agricultural practices on water quality in Canada, and to discuss future needs and trends (i.e., research, regulation, guidelines). Specific goals were to provide concise, national overviews of: 1) the results of Canadian agricultural and non-agricultural studies that quantify or assess the impacts of agricultural production practices on water quality; 2) the background objectives and type of information expected from on-going studies related to agriculture and water quality; 3) existing and proposed regulation/guidelines that affect agricultural practices; 4) information gaps/future research needs, as identified by workshop participants during scheduled discussion periods.

A unique cross-section of regulators, researchers, consultants, producers, and agri-business representatives attended the Workshop. Consistent with the multidisciplinary nature of water and water quality, Workshop speakers represented several disciplines, interests, and agencies both within and outside of traditional agriculture. These Proceedings contain recommendations to the Canadian Agricultural Research Council (CARC) and the text of presentations delivered at the Workshop. The presentations are divided into those addressing the results of research (Section 1) and those dealing with regulations/guidelines (Section 2). Recommendations to CARC were prepared by the Planning/Program Committee, and represent the dominant themes identified by participants in their discussion groups.

The Program/Planning Committee wishes to thank the speakers, participants, and discussion group leaders for their contributions to this Workshop. Appreciation is also extended to staff of the Centre for Land and Biological Resources Research who graciously hosted the event.

The financial contributions of CARC, the Atlantic Land Improvement Contractors Association, and Hoskins Scientific are gratefully acknowledged. The efforts of Mr. Paul Milburn, Dr. Wally Nicholaichuk, and Dr. Clarke Topp for editing, and the consistent support of Mrs. Sylvie LaForest for preparing camera-ready documents, are much appreciated.

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RECOMMENDATIONS TO THE CANADIAN AGRICULTURAL RESEARCH COUNCIL

Planning/Program Committee

1. From the workshop discussion groups, which involved a wide cross-section of participants including regulators, industrial representatives, extension personnel and researchers, it was consistently acknowledged that existing regulations governing agricultural practices are generally adequate in relation to water quality, whereas research into the water quality consequences of existing and alternative agricultural practices across Canada is lacking. **It was recommended, however, that greater effort be expended to ensure a heightened understanding of the current guidelines/regulations and their administration.** This is a recommendation which applies both to the farm population and the general public.

2. **It is recommended that funding for water quality research be programmed over longer terms (up to 10 years) in recognition of and in synchrony with the time frame that operates and controls the major water quality processes in watersheds. Short-term initiatives do not provide a long enough time frame for sound scientific investigations to be completed. Funding should be administered to achieve the following objectives:**

   - **to develop a holistic approach involving all aspects of agriculture and, where appropriate, non-agricultural sectors such as forestry, natural resources, environment, fish and wildlife;**
   - **to include socio-economic considerations;**
   - **to involve studies and modelling of the transport and transformation of chemicals in landscape and watershed settings and to provide risk assessments;**
   - **to provide for monitoring to determine the effect of remedial measures.**
   -

3. Concerning national or provincial water quality guidelines and regulations, **it is recommended that better linkages be established between policy makers and researchers so that researchers are keenly aware of policy issues, and that research results are quickly and widely distributed within the policy community.**

4. It was observed within the discussion groups that potential impacters on water quality, that is, land users and industries, often do not have ready access to direct and pertinent information from current research. **It is, therefore, recommended that education and extension be given a higher profile within the spectrum of research activity.**

WATER RESOURCES IN A GLOBAL ENVIRONMENT: THE POLICY ISSUES

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INTRODUCTION

Technology has provided the key to the transformation of agriculture in the industrial world throughout the 20th century. The mechanical era of 1920 to 1950 allowed the transition from horsepower to mechanical power and greatly increased productivity. The industrial and agricultural chemical revolution from 1950 till today has further boosted crop yields and increased the intensity of livestock production. These trends have been reinforced by government support programs designed to ensure maximum food output.

Stimulated by government policies, and the application of science and technology to agriculture, the integration of agriculture into the industrial economy has led to a radical restructuring of Western agriculture. In particular there has been a massive concentration of production on a decreasing number of farms. Throughout the industrial world fewer farmers feed more people than ever before. In this, Canada is no exception. Farm numbers have fallen by 60 per cent since 1941 and now total fewer than 300 000. Today seven per cent of Canadian farmers account for 50 per cent of total agricultural production. [1]

This massive increase in productivity has been achieved at high cost to the environment. There is in Canada and elsewhere, abundant evidence of environmental degradation, including soil erosion and compaction, a decline in species diversity, and serious problems of water pollution. In the United States agricultural activities are the largest source of surface water pollution? In northwest Europe agricultural effluents are killing many minor rivers and are a major factor in the contamination of some of Europe's largest and most important rivers, including the Rhine, Rhône, Seine, Thames, and Po[3].

Groundwater pollution is more insidious. Good data are rare, but in the United States a survey by the EPA found that 10 per cent of community wells and 4 per cent of private wells were contaminated — in a country where 40 per cent of all drinking water is from wells In Europe the data are even more incomplete, but it is assumed a similar situation exists; indeed, given the greater concentration of people and animals in a smaller area, the problem may well be worse. In Canada, no comprehensive groundwater data exist, and information about contamination of groundwater by agricultural practices is particularly scarce. It has been estimated that the health of as many as a million Canadians may be at risk from contaminated groundwater.[5]

POLICY ISSUES

From a review of agriculture and water quality issues in Canada and other developed countries, two points stand out:

(1) The impact of modern agricultural practices on water is similar throughout the industrial world. However, the incidence of problems — whether in terms of the degradation of aquatic life, contamination of groundwater, eutrophication, or increased detection of pesticide residues in water — varies widely from one country to another and within any one country. In all cases the solution lies in the management and control of the inputs used in agricultural production, not in the better disposal of waste products. There is a need to focus on causes rather than symptoms.

(2) Just as Canadians are urged to change the way we do business, so too we need to change the way we do science. What is needed is a more ecological approach to problem analysis. This approach requires not only a partnership between environmental and agricultural scientists but also stronger links between the physical and social scientists. Science can change the world but so too can society have a major impact on science. The need for a new approach to scientific research is being brought about by the changing social context of environmental issues.

THE THREAT TO THE ENVIRONMENT

Over the last 25 years, use of nitrogenous fertiliser in many developed countries has more than doubled. In the United States it has increased by 300 per cent, in Denmark by 225 per cent, and in the Netherlands by 150 per cent.[6] Canada has followed suit and since 1970 nitrogenous fertiliser use has increased by 300 per cent.[7]

However, whereas in Europe fertiliser use is now the highest in the world, with a high in the Netherlands of 250kg/ha,[8] Canada is at a level of 26.1kg/ha,[9] with New Zealand even lower at 21 kg/ha.[10] Not surprisingly on the most intensively cropped farms in the European Community (EC), use of nitrogen is far above the maximum set under EC guidelines. Levels of 7080 per cent above official allowable levels have been recorded. Levels even up to 150 per cent above allowable levels are known, posing a major threat to water quality."

Despite these known levels of fertiliser use in Europe there is a scarcity of data to substantiate the impact on water quality. This again highlights the need to reconsider existing water testing procedures and the need for better analytical techniques.

Pesticide use has also greatly increased in the developed countries. Since 1975, for example, Denmark has increased its usage by 70 per cent. Elsewhere, increases of 30-50 per cent are common. In Canada between 1971 and 1986, the value of annual pesticides applied on farmland increased five-fold. Frequency of use has multiplied — in Denmark up 115 per cent in the three years between 1981 and 1984[12]. On the other hand, the outlawing of the most persistent organochlorines such as DDT has led to a major recovery of aquatic animal life and a reduction in the concentration of contaminants in lakes and rivers. In Canada, for example, this has resulted in the partial restoration of the bald eagle population around the Great Lakes.

For the most part, however, the impact of efforts to reduce pesticide use are patchy. Official reports inevitably highlight key success stories. Increased regulatory control and the decreasing effectiveness of certain pesticides have reduced their usage in some areas. In the United States the development of an integrated pest management program for cotton has decreased the active ingredients used from 33 million kilograms in 1972 to 8 million kilograms in 1982. But similar programs in other cropping systems have been less successful and major problems of pesticide residues in water sources persist.[13]

Perhaps the most intractable problem remains the disposal of animal manure. This is particularly so in Europe where in the most intensive livestock areas disposal rates are three to four times acceptable levels. In some areas the quantities are such that the nitrogen level is 10 times above that which plants can absorb and the threat to water quality is widespread.[14]

ISSUES AND CHALLENGES

At the end of the day, the source of contaminants is less important than the level of contamination and the success of control efforts. The threat to water quality from modern, industrial agriculture is not tied to any one farm type or individual farm practice.

It is risky to generalize about the effects on water of the intensity of pesticide and fertiliser use and increased quantity and concentration of animal manure. All these inputs pose a threat to water quality. However, the severity of the impact depends on a wide range of factors including precipitation, soil temperature, and the geological and geographical character of different regions.

All this makes it difficult to quantify the impact of pollution, to draw useful comparisons, and to assess the effectiveness of controls. These difficulties are particularly acute with respect to groundwater.

The EC is promoting common environmental standards and encouraging standardised monitoring and measure techniques. In the United States there is interest in developing a more comprehensive national database for water quality issues.

For the most part, however, understanding of water quality problems related to agriculture in industrial countries remains based on individual examples and wide generalizations.

There is no evidence that Canada has the data to properly assess the extent or severity of water quality problems related to agricultural practices. Environment Canada's *State of the Environment Report* 1991[15] specifically identifies inadequate data as a problem facing the effective development of environmental policies.

Four years ago, the Science Council published *Water 2020,*[16] a policy report on the needs for water science into the 21st century. In July 1992, the Science Council will release *Sustainable Agriculture: The Research Challenge.*[17] This report will identify policy initiatives required to reconcile agriculture and the environment. In both reports water quality concerns related to agriculture are a focus of particular interest.

Drawing on these reports and the experience of other developed countries, it is possible to identify a set of simple policy needs that must be tackled if the problem of agriculture's impact on water quality is to be properly addressed:

- A focused effort on those areas most at risk.

The scale and diversity of the problem are such that rapid, cost-effective action is possible only with selective attention to high risk priority areas.

- A more effective use of sampling techniques to develop a national data base and allow the monitoring of changes over time.

It is unrealistic to expect uniform data collection across a country as vast and diverse as Canada. Indeed, such an approach is unnecessary and would be ineffective. However, it is unacceptable that management policies for agriculture/ water issues continue to rely on hunches or suppositions. There is a need for more and better measures of water quality and improved testing procedures; and a reassessment of monitoring techniques including the scale and timing of analysis. In particular, a better means is needed to assess progress or slippage in water.

- A major effort to prevent water pollution at the farm level.

The need to move from clean-up to prevention requires a huge program to adapt agricultural production systems to work with nature rather than against it.

CONCLUSIONS

Controlling farm inputs poses problems that can be addressed only with the closest cooperation between social and behavioral scientists, physical scientists, policy makers, and farmers themselves. It is the failure to better manage the farm input system that thwarts the development of a more sustainable agriculture and ensures the persistence of agricultural water quality concerns. Resolution of these problems calls for a different kind of science and a translation of the results of this science into changes in farm practice.

But bridging the gap between the different branches of science is not enough. The environment — in particular water quality — tops the list of public concerns throughout the industrial world, ensuring water quality a high priority on the political agenda. Farmers are equally concerned. Fifty per cent of Canadian farmers report that they have changed their production practices as a result of concern for the environment.[18] It is such social perceptions and pressures that are setting and will set the agenda for research — and that shape the questions posed and the way in which they must be addressed.

The questions concerning agriculture and water quality are chronic, complex, and global. The intensity of water quality problems in other parts of the world is forcing radical action. The Dutch and Danes in particular are setting national standards for agricultural water quality well above EC levels. It is inevitable that these standards eventually (and probably soon) will become the European norms. It is probably inevitable too that these same standards will soon become a factor in international trade negotiations, putting additional pressure for change on Canadian producers.

Better control of agriculture/water quality problems is ecologically and economically essential. Sound environmental policies must be based on science. But those policies must also take into account the interrelationships between science, technology, and society.

REFERENCES

STATISTICS CANADA, *Historical Statistics of Canada,* 2nd edition (Ottawa, 1983), table M12-22; Statistics Canada, *Socio-economic Characteristics of the Farm Population 1986* (Ottawa, 1989), table 1.1; Statistics Canada, *Canada Year Book* (Ottawa, 1990), p. 9-1; and R.D. Bollman and P. Ehrensaft, "The microdynamics and family farm economics of structural change in agriculture," in U.S. Bureau of the Census, *1990 Annual Research Conference Proceedings* (Washington, D.C.: U.S. Department of Commerce and Bureau of the Census, 1990), Table 2.

UNITED STATES OF AMERICA NATIONAL REPORT, United Nations Conference on Environment and Development (Washington, D.C.: Council on Environmental Quality, 1992), p. 156.

AGRICULTURE AND THE ENVIRONMENT: HOW WILL THE EC RESOLVE THE CONFLICT?, Agra Europe, Special Report No. 60 (London: Agra Europe (London) Ltd., 1991), p. 8.

Ibid., p. 14.

J.A. CHERRY, "Groundwater Occurrence and Contamination," *in Canadian Aquatic Resources,* M.C. Healey and R.R. Wallace, eds. (Ottawa: Ministry of Supply and Services, 1987), p. 415.

AGRICULTURAL AND ENVIRONMENTAL POLICIES: OPPORTUNITIES FOR INTEGRATION, Organisation for Economic Co-operation and Development (Paris, 1989), p. 34.

ROGER LARSON, Canadian Fertilizer Institute, personal communication, 15 January 1992.

AGRA EUROPE, op. cit., p. 9. ROGER LARSON, op. cit.

AGRA EUROPE, op. cit., p. 9. AGRA EUROPE, op. cit., p. 11.

ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, op. cit., p. 34.

COUNCIL ON ENVIRONMENTAL QUALITY, op. cit., p. 150.

AGRA EUROPE, op. cit., p. 15.

ENVIRONMENT CANADA, *State of the Environment Report 1991,* (Ottawa, 1992).
WATER 2020: SUSTAINABLE USE FOR WATER IN THE 21ST CENTURY, Science Council of Canada, Report 40 (Ottawa, 1988).

SUSTAINABLE AGRICULTURE: THE RESEARCH CHALLENGE, Science Council of Canada Report 43 (Ottawa, 1992).

ANGUS REID GROUP INC., "A Survey of Canadian Farmers," survey prepared for Agriculture Canada, 1990, p. 71.

THE IMPACT OF AGRICULTURAL ACTIVITIES ON WATER QUALITY IN ATLANTIC CANADA

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SUMMARY

Water quality can be adversely affected by agricultural activities in Atlantic Canada. Surface water quality has been reduced by water induced soil erosion, both from increased sediment load and from direct transport of agro-chemicals from the point of application to surface waters. Generally, soil erosion losses can be reduced by the adoption of improved soil management strategies, thus minimizing the attendant water quality problems. Ground waters are also vulnerable to contamination from agricultural practices. Soils used for intensive row-crop production are generally coarse-textured and there is percolation of water through the root zone during the year. Based on a survey of published literature, we concluded that non-point leaching of currently registered pesticides from soil is not a major problem in Atlantic Canada. One concern is, however, the wide-spread occurrence of atrazine in well waters in Kings County, Nova Scotia. Although concentrations are low, a downward revision of the MAC may affect our general conclusion. Nitrate is, by far, the most pervasive contaminant of ground waters in intensely cropped regions. Nitrate concentrations are related to the intensity of row-crop production. We concluded that the elevated NO_3 concentrations of well waters in the intensely cropped regions is a non point source contamination problem and is due to wide-spread leaching of NO_3 from intensely cropped soils. Preliminary results from on-going research show that NO_3 concentrations of waters leaving the root-zone may be decreased by a fall "catch crop"; other research is urgently required that specifically addresses the fate of leached chemicals and that develops better soil and fertilizer management strategies to minimize NO_3 leaching.

INTRODUCTION

Atlantic Canadians are concerned about the quality of their water resources. Many obtain their livelihood from activities associated with water. In addition, ground water is the principle source of potable water in Atlantic Canada for an estimated 1.2 million people. Indeed, the province of Prince Edward Island (PEI) is wholly dependent upon ground water for drinking water. Since 70% of the PEI water supply is from private wells with an average well depth of approximately 30 m, there is concern that these waters are especially vulnerable to contamination.

Although there are many concerns and perceived adverse effects of agriculture of water resources in Atlantic Canada, there is very little scientific literature available which includes data from Atlantic Canada. The purpose of this document is to summarize and to present the current state of knowledge in this field. In preparing this manuscript, we relied most heavily on published information, drawn primarily from peer-reviewed articles. In addition, we assumed that most agricultural effects on water quality are non-point.

Table 1. Total land area and agricultural land within each of the four provinces of Atlantic Canada (Statistics Canada 1987).

Province	Total Area	Total farm area	Total improved land
	- - - - - - - ha	- - - - - - - -	
NB	7,156,913	408,892	168,913
NS	5,284,093	416,506	389,752
PEI	566,171	272,432	186,316
NF	91,833,600	36,561	10,740
Canada	922,097,312		

DESCRIPTION OF AREA

Atlantic Canada is a complex and large region and comprises four provinces of varying agricultural production. Despite its size, only a small portion of the land mass is used for agriculture. Within Atlantic Canada, the proportion of land used for agricultural production varies considerably among the provinces (Table 1). For example 48 % of the total land area of PEI is defined as farm area by Statistics Canada and 33 % as total improved farm area, the highest in Canada. However, in Newfoundland, less than 1 % of the total land area is designated as total improved farm area, the lowest of any province.

Agricultural production is concentrated in two areas in New Brunswick (NB). Dairy production is centered in southern NB around Sussex, while potato production is concentrated in the upper St. John River Valley of north western NB. Approximately 50,000 ha are in a rotation which contains potatoes, with 20 to 22,000 ha cropped to potatoes in any one year. In PEI, approximately 90,000 ha is in rotation with potatoes and 31,000 ha are cropped to potatoes annually. The area cropped to potatoes in PEI has increased over the past ten years, and most of the increased hectarage of potatoes is due to a shortening of the rotation, rather than expansion onto new land. Approximately one-fifth of the total area in Canada planted to potatoes are located in Atlantic Canada (Statistics Canada 1987). In Nova Scotia, agricultural production is concentrated in Kings County where 38,000 ha of the 224,000 ha of the county is cropped. In 1986 there were approximately 17,000 ha of annual crops with about 2,400 ha of corn (NSAS 1989); in addition there are approximately 8,400 ha. of forage crops in Kings County.

Atlantic Canada has a humid climate. For example, in the NB potato producing area annual precipitation is approximately 1,000 mm while potential evapo-transpiration is 600 mm.

Thus there is a potential for 400 mm of precipitation to percolate through the root zone. The amount of water leaving the root zone and recharging the ground water varies, and is dependent upon, among over things, the intensity of the precipitation event, the soil's water infiltration capacity and the porosity of the underlying geologic materials. In many instances, a considerable portion of the precipitation may be lost from the soil as run-off, with a concomitant loss of soil sediment. The eroded soil may ultimately end up in surface waters resulting in a degradation of these resources.

SURFACE WATER

Contamination by Soil Erosion

Soil erosion is the major agricultural cause of surface water contamination in Atlantic Canada. Soil erosion by water is widespread in the potato producing regions of NB and PEI and was identified as the major soil degradation problem in the region (Coote *et al.* 1981). Soil erosion by water results not only in a degradation of the soil resource but also of surface waters. It results in the transport of silt-sized particles from the agricultural field to surface waters, with a concomitant increase in sediment content of surface waters. Adsorbed agro-chemicals may also be transported with the soil particles and potentially reduce surface water quality.

The topography of the potato-producing regions of NB and PEI ranges from undulating to moderately rolling, and potato production on slopes greater than 12 % is not uncommon. The soils used for potato production are generally coarse-textured, low in organic matter and have relatively low water aggregate stability. In NB, soils are shallow (< 1m) with frequent outcrops of bedrock. Potatoes are frequently harvested in late fall, when soils are wet and prone to compaction (Edwards 1988). Reduced water infiltration due to compaction in combination with the unfavorable water aggregate stability of the soils results in high erosion potential, especially during the summer prior to full crop canopy development and following harvest. In the absence of soil conservation practices, losses can reach 40 to 45 tonnes/ha (Himelman and Stewart 1979; T.L. Chow, Agriculture Canada Fredericton Research Station, personal communication).

Soil losses are aggravated by up-and-down slope cultivation of fields (Chow 1990). The extensive inter-row cultivation associated with potato production creates drainage channels, which can unintentionally expedite removal of water, especially during high-intensity summer rains. Chow *et al.* (1990) reported that both runoff and soil loss were higher from soils planted up-and-down the slope than from fallowed soils; soil loss and runoff were almost non-existent when potatoes were planted perpendicular to the slope.

Covering the soil during late fall, following crop harvest, can reduce soil erosion. In PEI, soil loss and sediment concentrations in runoff from frozen soil were reduced by applying straw to the soil surface or by sowing fall rye (Edwards and Burney 1989, 1991). In PEI, considerable "cool season erosion" can occur, with an average of 40 freeze-thaw cycles. Establishment of a fall cover crop is hampered by the lateness of the potato harvest which frequently occurs immediately prior to freezing (Edwards and Sadler 1992). Hence, Edwards and his co-workers have attempted to sow winter rye immediately after top-killing of potatoes but prior to harvest (Edwards and Sadler 1992), or during the potato harvest per se. (Edwards and Hergert 1990).

Although soil erosion is a serious problem in Atlantic Canadian potato production its severity can be minimized considerably. Soil erosion losses can be reduced by the adoption of different tillage techniques, the use of terraces to decrease slope length, use of fall cover crops and better crop rotation. Decreased soil erosion will lead to decreased contamination of surface waters.

Contamination by Pesticides Adsorbed to Transported Soil Particles

Pesticide presence in surface waters and bottom sediments associated with surface waters was attributed to transport on soil sediments eroded from agricultural fields (Stewart et al. 1977). Stewart *et al* (1977) sampled bottom sediments from two streams draining agricultural land in the Upper St. John River Valley of NB and analyzed these sediments for organochlorine and organophosphourus insecticide residues. One of the streams drained land that was intensively planted to potatoes while the other drained land that had a lower percentage of the area planted to potatoes. They found that DDT and its metabolites were present in most samples, with concentrations up to 2 ppm. Endrin was found in one-third of the samples (up to 0.45 ppm) while one-fifth of the samples contained dieldrin (up to 0.01 ppm). Highest residues were in the bottom sediments from the watershed with the highest percentage of its land planted to potatoes.

Similarly, O'Neill and Doull (1992) analyzed samples of surface water, bottom sediments and biota for atrazine, metribuzin, and simazine from 1984 to 1989. Only atrazine was detected (38 of 125 water samples) and its concentration ranged from 0.011 to 0.34 µg/L. The source of the atrazine was not pursued and may have resulted from a combination of both soil erosion and atmospheric deposition.

Contamination by Atmospheric Deposition

Agricultural contaminants can also enter surface water through atmospheric deposition. Although in intensely cropped areas the source of contamination is often difficult to isolate, presence of chemicals in remote non- agricultural regions can be taken as proof of atmospheric disposition.

Lockerbie and Clair (1988) reported that there was long range transport of long lived organic compounds from areas of operational use to isolated lakes on the border between Labrador and Quebec. They found the most soluble compounds most often in lake waters. Less soluble compounds, such as DDT and PCB's, were in sediments and fish. The nearest reported use of DDT was 420 km southwest of the study area.

Brun *et al.* (1991) analyzed wet precipitation for ogranochlorine, polychlorinated biphenyls (PCB), and polynuclear aromatic hydrocarbons (PAH) from 1980 to 1989. They used three precipitation monitoring sites, one in a non-agricultural area (Kejimkujik National Park), one 100 km downwind from the Annapolis Valley and one in PEI. The most commonly found pesticide was lindane, and its concentration decreased during the later stages of the study. The presence of lindane at all three collection sites was attributed to long range transport from out of the region. The presence of PCB and PAH was attributed to both long range and localized sources. Seasonal patterns were observed, with greatest concentrations occurring in spring and fall.

O'Neill *et al* (1992) analyzed for chlorothalonil in three atmospheric monitoring systems, one in the Kejimkujik National Park the other two in Jackson, Nova Scotia, 100 km downwind (east) from the Annapolis Valley. In the remote area (Kejimkujik National Park), 50% of the samples had detectable chlorothalonil concentrations while 83% of the samples from Jackson had detectable concentrations. Some seasonality was observed, such that O'Neill et al. speculated that a portion of the chlorothalonil they detected was derived from silviculture. The concentrations detected were low and ranged from 0.006 to 0.01 µg L^{-1}.

Effect of Tile Drainage Effluent

Atrazine was present in waters derived from a tile drainage system at a controlled land use experiment at Corn Hill, New Brunswick (Lakshminarayana *et al.* 1992). Maximum concentrations were 13.9 µg/L in the tile drain waters and 1.89 µg/L in the receiving stream. Phytoplankton and zooplankton samples were collected biweekly at various distances from the tile drain effluent entry point into the stream. Tile drain waters affected plankton populations in a 20-m section of the small stream immediately downstream of tile drainage outlet. It could not be demonstrated, however, that the reduced populations were solely due to the presence of atrazine in the drainage waters, since the stream had very low flow rates when atrazine was detected, and a significant portion of the stream flow was derived from the tile drain effluent. Regardless, no negative impacts on plankton populations were evident beyond 50 m downstream of the tile drainage outlet.

GROUND WATER
Contamination by Pesticides

Pesticides have been detected in wells located in some agricultural regions in Atlantic Canada. Perhaps the most widely publicized occurrence was the detection of low concentrations (1 to 6 µg/L) of aldicarb in wells in PEI (Gillis and Walker 1986; Matheson et al. 1987). Aldicarb is a systemic soil applied insecticide and was widely used in potato production in Atlantic Canada. The MAC (proposed guideline) for aldicarb is 9 µg/L (Health and Welfare Canada 1987).

Approximately 18% of wells around potato fields contained aldicarb (Matheson *et al.* 1987). Priddle *et al.* (1988, 1989) reported that aldicarb persistence in PEI soil was related to its application at planting. The low soil temperatures at planting and the acidic nature of PEI soil inhibited aldicarb breakdown. Aldicarb was also detected in samples of well waters from the potato producing region of NB (Ecobichon 1988).

In Nova Scotia, 98 randomly selected wells in King's County were sampled for analysis of pest control products (Government of Nova Scotia, 1990). Thirty-seven wells had low concentrations of pest control products; 96% of these wells had concentrations less than 1 µg/L. Atrazine was the most commonly detected pest control product (31 wells), followed by simazine (5 wells), metribuzin (4 wells) and alachlor (3 wells). Atrazine concentrations ranged from 0.02 to 2.19 µg/L and the median concentration was 0.12 µg/L, well below the current Maximum Acceptable Concentration (MAC) of 60 µg/L. It should be noted that the MAC of atrazine in the US is 3 µg/L and that in Canada it is being reviewed and will likely be revised downwards.

Dinoseb was detected in waters from 8 of 45 wells sampled from the potato producing region of NB (as cited by Milburn *et al.* 1991); concentrations ranged from the detection level to 12.4 µg/L. Dinoseb was also detected in well waters in PEI (Gillis and Walker 1986, as cited by McRae 1991).

Milburn *et al.* (1991) detected dinoseb in tile drain waters during both the year of application and in the following spring melt; average concentrations, however, were low and ranged from the detection level (0.02 µg/L) to 0.21 μg/L. Ninety-five percent of all samples collected during the study in which dinoseb was detected had concentrations less than 2 mg/L. Past use of dinoseb had no effect on concentrations detected in the tile drainage waters, suggesting that dinoseb is readily decomposed in Atlantic Canadian soils. There is currently no MAC for dinoseb in drinking waters (Kent *et al.* 1991) although the interim MAC when the study was conducted was 10 μg/L.

Milburn *et al.* (1991) reported that metribuzin was present (0.22 μg /L) in tile drain waters 10 months after application to a potato field in north western NB; the MAC for metribuzin is 80 µg/L (Health and Welfare Canada 1987). Ivany *et al.* (1983) calculated the half-life of metribuzin to be 33 days in Atlantic Canadian soils, based on field trials conducted for three years in PEI.

In the potato producing region of New Brunswick, O'Neill *et al.* (1992) did not detect chlorothalonil in well waters. Chlorothalonil is a fungicide that is widely used in potato and cereal production. The wells sampled by O'Neill *et al.* were known to be affected by agricultural practices due to their elevated NO_3 levels. Chlorothalonil was, however, detected (0.005 to 0.008 µg/L) in 4 of 66 samples of tile drain discharge collected 7 months after application in PEI. There is no MAC for chlorothalonil at the time of writing.

All pesticides discussed in this section have a high potential to leach (McRae 1991), with the exception of chlorothalonil; chlorothalonil's potential to leach was classified as low by McRae (1991). The presence of pesticides in well waters appears to agree with our understanding of their ability to leach in soil. It should be noted that two of the pesticides detected in well waters, dinoseb and aldicarb, are no longer recommended for potato production in Atlantic Canada. When detected in well waters, pesticides concentrations were generally considerably less than the MAC. Based on this, we suggest that pesticide contamination of rural drinking water from non-point sources is not a major problem in Atlantic Canada.

Contamination by Nitrates

Since in Atlantic Canada precipitation exceeds evapo-transpiration, dissolved solutes, such as NO_3, are prone to leach from the rooting zone into ground water. Consequently, attention has been focussed on nitrates in rural drinking water supplies. Monitoring studies have been conducted in Nova Scotia, PEI, and NB.

There are three completed studies on NO_3 in well waters in Nova Scotia. Two studies were conducted during the 1970's around Truro and in the north-eastern portion of Kings County. Five of the 183 wells sampled around Truro had NO_3 concentrations exceeding 10 mg N/L, and there was considerable temporal fluctuation in nitrate of these wells. In the second study, 359 wells were sampled and 20 wells were sampled repeatedly. Sixteen of the 20 wells had elevated NO_3-N levels, and in 12 of the cases the source was either a septic field or manure pile. Well construction appeared to play a role in NO_3 contamination. Moerman (1989) provided a good review of these studies.

The final study involved a survey of 234 wells in Kings County, the most agriculturally intense county in NS (Government of Nova Scotia 1990). Twelve percent of these wells had NO_3-N concentrations exceeding the 10 mg/L guideline. Over the entire province, 7% of wells monitored had NO_3 concentrations exceeding 10 mg /L, illustrating that wells in Kings County were more susceptible to NO_3 contamination. Nitrate contamination was higher in shallow than deep wells and tended to be higher in areas with coarse-textured than fine-textured soils. The source of NO_3 was not identified.

In PEI a three year study was recently completed; 54 wells were sampled on a monthly basis for three years (G. Somers, PEI Dept. of Environment, Personal Communication). The wells were evenly divided into three main areas of PEI and into 6 land use activities. Average ground water NO_3 concentrations were highest in wells located in areas of row-crop production (5.6 ppm), followed by wells near farms with on-site manure storage (5.3 ppm), then by subdivisions with on-site sewage disposal (4.3 ppm) and non-row crop production areas (4.0 ppm). Nitrate concentrations were 1.2 ppm in non-agricultural areas. It would appear that crop production has elevated NO_3-N concentrations, but so too did urban on-site sewage disposal.

Elevated NO_3-N concentrations in well waters occur in New Brunswick (Ecobichon *et al.* 1988, Richards *et al.* 1990); the magnitude being related to the intensity of agricultural production (Richards *et al.* 1990). In the St. Andre region of the upper St. John River Valley, 20 to 25 % of the land area is cropped to potatoes annually. This is approximately one-half the improved agricultural land in the region, suggesting that virtually all improved agricultural land is in a rotation with potatoes. The mean NO_3 concentration in well waters there was 9.5 ppm, only 0.5 mg less than the Canadian Water Quality Guideline for potable water. Thirty-nine percent of the wells sampled had NO_3-N concentrations exceeding the 10 ppm guideline and only 6 % had NO_3-N concentrations less than 5 ppm. Nitrate concentrations were considerably lower (5 to 5.7 ppm) in two other agricultural regions which had a lower proportion of their land cropped to potatoes (7 to 9 %), and lowest (1.1 ppm) in a fourth non-agricultural region. Over the 16-year course of the study, NO_3-N concentrations decreased in one of the regions of moderate agricultural intensity and remained the same in the other two agricultural regions.

Milburn *et al.* (1990) analyzed tile drainage effluent NO_3 to determine the effect of field-scale cropping practices on NO_3 losses from April to December. They found that, regardless of previous crop, the annual flow weighed NO_3-N concentration always exceeded 10 ppm when soils were cropped to, potatoes and remained so in the year following potatoes. Since a potato- cereal rotation is common in N.B., they speculated that NO_3-N concentrations of water leached from the root zone always exceed the 10 ppm guideline for a two-year potato rotation in NB.

Recent attention has been focussed on developing soil and crop management strategies to minimize NO_3 leaching from Atlantic Canadian soils. In PEI, different management techniques following potatoes were investigated for their influence on annual NO_3 leaching (MacLeod *et al.* 1991; Milburn and MacLeod 1991). Following harvest of the early potatoes (which had received 145 kg N/ha at planting) in mid-September, NO_3 concentrations in tile drain waters were about 23 to 26 mg N/L. Three treatments were imposed on the soil: untreated control, 4 t/ha of wheat straw, and sowing a winter wheat crop. Flow-weighted NO_3 concentrations were reduced below the 10 mg N/L guideline when winter wheat was sown; application of straw reduced NO_3 leaching, but not to the same extent as the winter wheat crop.

Although the source of NO_3 leaching from soils is generally perceived to be from fertilizers, some of the NO_3 can be from organic sources. Milburn and Richards (1991) reported that annual NO_3 losses were 80 kg N/ha of a fallowed soil following installation of tile drainage; they attributed the mineralization of soil organic nitrogen as the source of all NO_3 detected in the drainage waters. The time of plowing crop residues may also influence NO_3 leaching. Sanderson and MacLeod (1991) found that there was more leaching of N derived from the breakdown of lupins when they were plowed down early in the fall rather than later.

SUMMARY AND CONCLUSIONS

Many, and perhaps all, of the adverse effects of agriculture on water quality can be reduced by changes in soil and crop management practices. Nitrate concentrations in tile drain effluent were decreased below 10 ppm N when a fall catch crop was planted following the harvest of early potatoes. Addition of straw to the soil, to stimulate immobilization of the NO_3, also reduced NO_3 concentrations but not to the same extent as the catch crop. Time of fall plowing and other cultivation practices effects the quantity of soil organic N mineralized in PEI and may influence the amount of NO_3 leached from soils.

Based on the survey of the available literature, we conclude that water quality can be adversely affected by agriculture in Atlantic Canada. In particular, the following points were isolated.

1: Surface water quality has been detrimentally affected by agriculture

Soil erosion by water transports soil particles and adsorbed agro-chemicals from their point of origin to surface waters. Surface water quality can be degraded both by sedimentation and by chemical input. Research in Atlantic Canada has demonstrated that the presence of pesticides and their metabolites in surface water is due to transport during soil erosion. Many soils in Atlantic Canada are susceptible to soil erosion, due to the rolling topography, intensity of rain fall, and production of potatoes. Local research has clearly shown that soil erosion losses can be reduced considerably by adoption of improved soil and crop management strategies.

Surface water quality can also be degraded by pesticide deposition in precipitation. Pesticides have been detected in surface waters, biota and bottom sediments considerable distances from their point of application.

2: There is leaching from the root zone of some pest control products and soil nutrients

Dinoseb, metribuzin, atrazine and chlorothalonil were detected in tile drain effluent. High concentrations of NO_3 nitrogen (greater than 10 ppm N) occur in tile drain effluent from soils cropped to potatoes; concentrations remain high in the year following potatoes. Nitrate concentrations are considerably lower in tile drain effluent of soil not cropped to potatoes recently or from soils cropped to forages.

3: Trace amounts of pesticides have been found in rural well drinking water supplies but concentrations are considerably less than MAC. At this time pesticide contamination of rural drinking water supplies is not a wide-spread problem in Atlantic Canada.

In all three Maritime Provinces, pest control products have been detected in well waters. The concentrations of these compound are usually considerably less than their Maximum Allowable Concentration (MAC) for potable waters. When in use, atrazine appears to be the most prevalent pest control product occurring in well waters.

Since the removal of dinoseb and aldicarb from the market, it is concluded that pesticide contamination of well waters in the Maritime Provinces is not a serious issue at this time. However, constant monitoring of well waters in susceptible areas is required.

4: Nitrate concentrations of rural well waters are elevated in areas of intensive agriculture.

Elevated NO_3 concentrations in well waters are ubiquitous to regions of intense agricultural production in Maritime Canada. Nitrate concentrations are highest in regions of intense row-crop production and lowest in non-agricultural areas. Interestingly, NO_3 concentrations in subdivisions with septic fields are similar to those found in wells located in areas where field crops are grown. Although NO_3 concentrations are high, concentrations have either remained the same or decreased over 16 years in New Brunswick. Based on these results we suggest that a further reduction in NO_3 concentrations of rural drinking water supplies is possible with changes to cropping practices. For example, in on-going studies in PEI, NO_3 concentrations of tile drainage effluent from soils cropped to early potatoes were reduced by planting a fall "catch" crop. Other studies aimed at determining the optimum time of fall plowing to minimize fall mineralization of soil organic N and basing the level of fertilizer application on yield expectation and available soil N may also play a role in reducing NO_3 leaching. At the time of writing, however, we must conclude that NO_3 contamination of rural ground water supplies is the most contentious issue in the field of agricultural impacts on ground waters.

RECOMMENDATIONS

Reduction of the input of agro-chemicals into both surface and sub-surface waters requires changes to present management practices. In some cases, such as erosion, the answers are known and Best Management Practices can be implemented immediately. In other cases such as NO_3 leaching into well waters and reducing pesticide use, considerable research is required prior to changing recommendations. It should be recognized that productivity may suffer temporarily during the adoption of newly developed management strategies but that the development and adoption of these strategies is essential for the long-term viability of Atlantic Canadian agriculture and the natural environment.

1: The establishment of multi-year, multi-location field trials in which both the crop response to applied N and the environmental fate of soil and fertilizer N is measured.

We identified NO_3 contamination of ground water as the most contentious issue affecting the impacts of agriculture on water quality in Atlantic Canada. Although much is known about the behavior of soil and fertilizer N in Atlantic Canadian soil, considerable information must be collected before we can successfully model the soil N cycle here.

Fertilizer recommendations in Atlantic Canada are based on single year field trials in which crop response to applied N was measured. These trials were terminated when the crop was harvested and the fate of soil and fertilizer N was not considered during the non-crop portion of the year. It is our strong opinion that multi-year fertility trials are required. The effect of previous crop and previous N additions on net mineralization need to be elucidated more fully.

Presently, 135 to 165 kg N/ha is recommended for potato production in Atlantic Canada (Asiedu *et al.* 1987), but many producers apply considerably more N. Due to the elevated NO_3 concentrations in areas of intense potato production, it is evident that a more rationale basis for fertilizer recommendation is required. Ne can not solely rely upon remedial measures, such as a "catch crop", to reduce NO_3 in the leachate to an acceptable concentration. General 'utilizer recommendations which do not account 'or differences in the nitrogen supplying capacity of soils must be revised. Basic long-term research must commence on the nitrogen supplying capacities of our soils, the response of crops to applied N in relation to soil properties and past management, and on quantifying N losses from the system.

2: Continued monitoring of Pest Control Products in tile drain effluent, rural well water supplies, and continued research on Integrated Pest Management strategies.

Considerable information on the behavior of selected agro-chemicals under Atlantic Canadian conditions has been gathered recently by the analysis of tile-drainage discharge emanating from soils on which the product was used. These studies should continue and if possible be enhanced. We also recommend that there be continued or enhanced monitoring for selected pesticides in rural well waters in areas vulnerable to contamination.

Although we concluded that pesticide contamination of well waters was not an immediate problem in Atlantic Canada, we recognize that a more rationale use of pesticides for crop production is required. Traditionally in potato production, for example, pest control products (such as fungicides and insecticides) have been applied on a calendar basis. Future agricultural production systems will use less pesticides, as a result of the advent of new models to predict the occurrence of certain pests, the introduction of effective biological pest control products, and the introduction of plant resistance to diseases and insects through bio-technology. Clearly Integrated Pest Management strategies (IPM) will play an increasingly important role in intensive row crop production in Atlantic Canada and research in IPM will have a positive impact on both ground and surface water quality.

LITERATURE CITED

ASIEDU, S., S.E COLEMAN, T. HALIBURTON, and M.O HAMPSON, (eds) 1987. Atlantic Canada potato guide. Publication 1300/87. Published by authority of the Atlantic Provinces Agricultural Services Co-ordinating Committee. 47pp.

BRUN, G.L., G.D. HOWELL, and H.J. O'NEILL. 1991. Spatial and temporal patterns of organic contaminants in wet precipitation in Atlantic Canada. Environ. Sci. Technol. 25:1249-1261.

BURNEY, J.R. and L.M. EDWARDS. 1989. Cool season erosion. Paper No. 892153. Paper presented at the annual meeting of Can. Soc. Agr. Eng., Quebec, PQ, June 25-28, 1989.

CHOW, T.L., DIAGLE, J.-L., GHANEM, I. and CORMIER, H. 1990. Effects of potato cropping practices on water runoff and soil erosion. Can. J. Soil Sci. 70: 137-148.

COOTE, D.R., DUMANSKI, J., and RAMSEY, J.F. 1981. An assessment of the degradation of agricultural land in Canada. Land Resource Research Institute, Contrib. No. 118. Agriculture Canada, Ottawa, Ontario.

ECOBICHON, D.J., HICKS, R., ALLEN, M. and ALBER, R. 1988. Ground water contamination in rural New Brunswick. Unpublished Report. N.B. Dept. of Health, Fredericton, N.B.

EDWARDS, L.M. 1988. The effects of slope position and cropping sequence on soil physical properties in Prince Edward Island. Can. J. Soil Sci. 68: 763-774.

EDWARDS, L.M. 1991 The effect of alternate freezing and thawing on aggregate stability and aggregate size distribution of some Prince Edward Island soils. J. Soil Sci. 42: 193-204.

EDWARDS, L.M. and BURNEY, J.R. 1987. Soil erosion losses under freeze/thaw and winter ground cover using a laboratory rainfall simulator. Can. Agric. Eng. 29: 109-115.

EDWARDS, L.M. and J.R. BURNEY. 1989. The effect of antecedent freeze/thaw frequency on runoff and soil loss from frozen soil with and without subsoil compaction and groundcover. Can. J. Soil Sci. 69: 799-811.

EDWARDS, L.M. and J.R. BURNEY.1991. Sediment concentration of interrill runoff under various soil, ground cover, soil compaction and freezing regimes. J. Environ. Qual. 20: 403-407.

EDWARDS, L.M. and J.M. SADLER.1992. Relationships between cover performance and date of fall-seeding where winter rye was broadcast into a standing potato crop. Can. J. Plant Sci. 72: 269-274.

GILLIS, M. and D. WALKER. 1986. Pesticides and groundwater in the Atlantic Region. Water Planning and Management Branch, Environment Canada, Dartmouth, Nova Scotia.

GOVERNMENT OF NOVA SCOTIA. 1990. Nova Scotia Farm Well Water Quality Assurance Study. Phase I. Final Report. Nova Scotia Department of Environment, Nova Scotia Department of Agriculture and Marketing, Nova Scotia Department of Health and Fitness.

HEALTH AND WELFARE _CANADA. 1987. Guidelines for Canadian Drinking Water quality. Canadian Government Publishing Centre, Ottawa, ON. 20pp.

HIMELMAN, D., and STEWART, N.E. 1979. Soil erosion studies in Prince Edward Island. Paper, Soil Erosion Workshop, NSAC, Truro, N.S. April 17-19. 9pp.

IVANY, J.A., SADLER, J.M., KIMBALL, E.R. 1983. Rate of metribuzin breakdown and residue effects on rotation crops. Can. J. Plant. Sci. 63 481-487.

KENT, R.A., PAULI, B.D., and CAUX, P.-Y. 1991. Canadian water quality guidelines for dinoseb. Scientific Series No. 189. Inland Waters Directorate, Water Quality Branch, Environment Canada, Ottawa, ON.

LAKSHMINARAYANA, J.S.S., O'NEILL, H.J., JONNAVITHULA, S.D., LEGER, D.A., and MILBURN, P. 1992. Impact of atrazine-bearing agricultural tile drainage discharge on planktonic drift of a natural stream. Environ. Poll. 76: 201- 210.

LOCKERBIE, D.M., and CLAIR, T.A. 1988. Organic contaminants in isolated lakes of southern Labrador, Canada. Bull. Environ. Contam. Toxicol. 41: 625- 632.

MACLEOD, J.A., MILBURN, P., and SANDERSON, J.B. 1991. Effects of fall addition of straw or winter wheat on nitrate levels in drainage water following a potato crop. Abstract of paper presented at the Canadian Society of Soil Science Annual Meeting, Fredericton, NB. July 29-31 1991. Can. J. Soil Sci. 71:272.

MATHESON, R.A.F., R.M. FRANCIS, D.E. JARDINE, M.N. GILL, and W.P. ERNST. 1987. Assessment of PEI ground water for the pesticide aldicarb. EPS-5-AR- 87-4. Environment Canada, Environmental Protection Services, Atlantic Region, Dartmouth, NS, B2Y 2N6.

MCRAE, B. 1991. The characterization and identification of potentially leachable pesticides and areas vulnerable to groundwater contamination by pesticides in Canada. Publication 91-01. Issues, Planning and Priorities Division, Pesticides Directorate. Agriculture Canada, Ottawa, ON.

MILBURN, P., and J. MACLEOD.1991. Considerations for tile drainage-water quality studies in temperate regions. Applied Engineering in Agriculture 7:209-215.

MILBURN, P., H. O'NEILL, C. GARTLEY, T. POLLOCK, J.E. RICHARDS, and H. BAILEY. 1991. Leaching of dinoseb and metribuzin from potato fields in New Brunswick. Can. Agric. Eng. 33: 197-204.

MILBURN, P., J.E. RICHARDS, C. GARTLEY, T. POLLOCK, H. O'NEILL, and H. BAILEY. 1990. Nitrate leaching in systematic tile drainage waters from potato fields in New Brunswick, Canada. J. Environ. Qual. 19: 448-54.

MILBURN, P, and J.E. RICHARDS. 1991. Annual nitrate leaching losses associated with agricultural land use in New Brunswick. Paper No 91-109. Presented at the annual meeting of the Can. Soc. Agr. Eng., July 29-31, Fredericton, NB.

MOERMAN, D.1989.Agriculture and groundwater quality in Nova Scotia. Proceedings of the Second Soil Moisture Workshop, Agriculture and Water Quality, Charlottetown, PEI., Sponsored by the Atlantic Committee on Soil and Climate. pp 23-27.

NSAS 1989. Nova Scotia Agricultural Statistics 1989. Nova Scotia Department of Agriculture and Marketing. Halifax, Nova Scotia.

O'NEILL, H.J., and J.A. DOULL. 1992. Triazine herbicide occurrence in agricultural watersheds of maritime Canada; 1983 - 1989. Submitted to Can. Water Res. J. (August 1991)

O'NEILL, H.J., P. MILBURN, D.A. LEGER, J. MACLEOD, and J. RICHARDS. 1992. A screening survey for chlorothalonil residues in waters proximal to areas of intensive agriculture. Can. Water Res. 17: 7-19.

PRIDDLE, M.W., R.E JACKSON, A.S. CROWE, and J.P. MUTCH. 1988. Aldicarb and nitrogen residues in a sandstone aquifer. Proc. Agricultural Impacts on Ground Water Conf., Des Moines, Iowa, NWWA, Dublin, Ohio, pp. 191-210.

PRIDDLE, M.W., JACKSON, R.E., and MUTCH, J.P. 1989. Contamination of the sandstone aquifer of Prince Edward Island, Canada by aldicarb and nitrogen residues. Ground Water Monit. Rev. 134-140.

RICHARDS, J.E., MILBURN, P.H., MACLEAN, A.A., and DEMERCHANT, G.P. 1990. Intensive potato production effects on nitrate-N concentrations in rural New Brunswick well water. Can. Agric. Eng. 32: 189-196.

SANDERSON, J.B. and MACLEOD, J.A. 1991. Influence of time of incorporation of a legume on soil nitrate profile. Abstract of paper presented at the Canadian Society of Soil Science Annual Meeting, Fredericton, NB. July 29-31 1991. Can. J. Soil Sci. 71:279.

STATISTICS CANADA. 1987. Census of Canada 1986. Agriculture. Minister of Supply and Services, Ottawa, ON.

RÉPERCUSSIONS DE L'AGRICULTURE SUR LA QUALITÉ DES EAUX AU QUEBEC: BILAN SOMMAIRE ET ELEMENTS DE SOLUTION

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INTRODUCTION

L'agriculture, comme toute autre activité économique, a évolué vers un système hautement productif en termes de volume produit par hectare de sol cultivé. Cette augmentation de productivité volumétrique s'est faite sur la base d'une augmentation des intrants: engrais minéraux, pesticides, carburants, etc. Ce faisant, certains cycles naturels don't celui de l'azote et du phosphore ont été perturbés; conséquemment, les pertes de ces éléments dans l'environnement ont fortement augmentées.

La spécialisation des fermes dans la culture de céréales et de maïs et de l'élevage porcin intensif a créé une pression énorme sur l'environnement de certaines régions agricoles du sud du Québec.

Le drainage intensif des sols et l'amélioration des cours d'eau municipaux peuvent contribuer à perturber le régime hydrique de nos rivières et la qualité des eaux en raison d'un trop grand écart dans les débits.

Les sédiments provenant de l'érosion des sols, la contamination des eaux par l'azote, le phosphore, les pesticides et les bactéries en restreignent plusieurs des usages. En outre, plusieurs municipalités doivent s'approvisionner à même des rivières don't l'eau est déclarée de médiocre qualité. On a détecté dans certaines régions agricoles des puits contaminés par les nitrates et plusieurs pesticides, parfois à des concentrations supérieures aux normes dites acceptables pour la santé.

Il n'est pas trop tard pour réagir.Plusieurs solutions s'offrent à nous. La première partie de la solution, et sans doute la plus importante, est d'informer et d'éduquer nos producteurs agricoles sur les effets de la pollution diffuse et les dangers qui en découlent pour eux-mêmes, et que de simples changements dans leur pratique peuvent faire une grande différence.

Enfin, la deuxième partie de la solution est l'application des connaissances et des techniques connues à date, qui permettrait de régler une bonne partie des problèmes. La recherche en plein champ a des défis considérables relever pour mettre au point avec le producteur des techniques de production plus respectueuses de l'environnement.

L'ÉVOLUTION DE L'AGRICULTURE
Pour L'ensemble

Dans l'ensemble du Québec, l'agriculture a considérablement évolué depuis une quarantaine d'années, comme nous le montre le tableau 1. Le changement s'est manifesté par une forte diminution du nombre de fermes et une augmentation considérable de la monoculture céréalière et des élevages bovins et particulièrement, les élevages porcins, qui se sont concentrés dans certaines régions.

Spécialisation de la Monoculture Céréalière

L'agriculture est principalement concentrée dans les basses terres du Saint-Laurent composées de sols fertiles et jouissant de conditions climatiques favorables des cultures de maïs exigeantes en unités thermiques (figure 1).

Il s'est également effectué un changement vers la spécialisation des fermes. La culture céréalière et le maïs-grain se sont développés dans les régions agricoles1 de Nicolet (04), de Saint-Hyacinthe (06), du Sud-Ouest de Montréal (07) et de l'Assomption (10). Le développement de la culture du maïs-grain a été spectaculaire dans les régions de Saint-Hyade Montréal (07) et on remarque qu'il s'estcinthe (06) et du Sud-Ouest effectué au détriment des superficies cultivées en fourrages (Figure 2).

Spécialisation des Élevages

La diminution du nombre de fermes a été compensée par un accroissement de la surface cultivée, et aussi par une augmentation considérable du nombre d'unités animales. L'élevage porcin a complètement changé de face en 30 ans. D'une douzaine de porcs par ferme en 1951, le cheptel a augmenté plus de 720 porcs en moyenne par ferme en 1985 (Tableau 1).

A l'échelle réelle toutefois, les élevages de porcs sont concentrés sur des exploitations, don’t plusieurs souffrent d'un manque d'entreposage et de surface d'épandage pour les lisiers. Pour l'ensemble du Québec, la population de porcs a triplé, passant de 1,116,000 à 3,338,000 de 1966 à 1986. La seule région de Saint-Hyacinthe (06) possède près de 25 % de tout le cheptel porcin plus de 800,000 têtes.

IMPACT DES ACTIVITÉS AGRICOLES SUR LA QUALITÉ DES EAUX
Impact du Drainage Agricole

En raison de leur topographie plane et du faible gradient hydraulique vers les rivières et les cours d'eau, d'un excédent de précipitationannuel, less basses terres du Saint-Laurent ont nécessité l'amélioration du drainage naturel par le creusage de cours d'eau et l'installation de drainage souterrain pour atteindre leur plein potentiel de production. Pour atteindre une plus grande performance, les agriculteurs ont drainé entre 1963 et 1991, une surface de 586,000 ha par l'installation de 323,521 km de drains; dans la même période, dans le cadre

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[1] Régions administrative du M.A.P.A.Q.agricole

de son programme Sol-Plus, le MAPAQ a dépensé plus de 100 M$ pour redresser et recalibrer 13,180 cours d'eau municipaux en milieu agricole pour une longueur totale d'environ 20,000 km, qui dans certaines régions a artificialisé 80 % de tous les cours d'eau (Francoeur, 1991).

En outre de ces travaux, les agriculteurs ont profité de généreux programmes d'aide individuels pour le creusage de fossés et l'amélioration de l'égouttement superficiel de leur terre par le modelage en planches souvent très bombées. Dans les basses terres du Saint-Laurent, actuellement en culture, on retrouve généralement un fossé d'une profondeur d'environ 1 m à tous les 60 m.

Cette intensification du drainage de la parcelle agricole a pour effet d'augmenter considérablement le débit de pointe à la fonte des neiges et lors des orages. On observe généralement de forts débits des cours d'eau municipaux et rivières avec des concentrations excessives de matières en suspension au printemps et à l'automne. Durant la période sèche, une grande partie de ces cours d'eau a un débit d'étiage très faible, rendant la vie aquatique difficile. Au niveau des rivières principales, on observe de grandes variations entre les débits de pointe du printemps et les débits d'étiage, qui dans certains cas, créent des problèmes au niveau de l'approvisionnement des municipalités qui s'alimentent à même ces rivières. A titre d'exemple, au 21 juin 88, la valeur moyenne des besoins équivalait à 180 % du débit de la rivière Yamaska; les étiages de cette rivière sont les plus sévères depuis 25 ans (Pesant, 1990).

Impact des Élevages

Les concentrations d'élevage peuvent créer un impact sérieux sur la qualité des eaux de surface et souterraines par les apports d'azote et de phosphore lessivés aux rivières, à cause des épandages abusifs sur des superficies restreintes. Le MENVIQ a étudié en profondeur la qualité des eaux de trois bassins hydrographiques où sont concentrés des élevages porcins, soit ceux des rivières Chaudière, Assomption et Yamaska (tableau 2).

Les études du MENVIQ démontrent une forte corrélation (R^2=0,88) entre l'azote totale mesuré à l'embouchure des rivières et la densité animale dans le bassin; pour le phosphore et les matières en suspension, une corrélation de 0,77 a été également observée (dans Grimard, 1990).

Ces études (dans Gagné, 1991) démontrent que les trois bassins, don’t les élevages porcins constituent environ 50 % de la densité animale, souffrent d'un manque d'entreposage et de municipalités. Il en découle donc des épandages qui dépassent les doses agronomiques recommandées, et dans plusieurs cas, les épandages se font à l'automne lorsque les cultures sont absentes.

Les concentrations d'élevage peuvent avoir un effet considérable sur la qualité de l'eau de petits assins agricoles. Une étude de Asselin *et al.* (1992), sur un bassin de 436 ha où l'on retrouve une concentration d'élevage porcin avec des surplus de lisiers, montre clairement l'effet desépandages a fortes doses qui entraînent des concentrations d'azote $N\text{-}NO_3$ dépassant les 10 mg/L dans les eaux de surface. Pour les eaux de drainage souterrain, les concentrations dépassaient les 30 mg/L de $N\text{-}NO_3$ l'automne 91.

L'impact de L'érosion des Sols

L'érosion hydrique est probablement le plus grand facteur de dégradation des eaux de surface. Non seulement nos rivières et cours d'eau subissent une dégradation physique et biologique par l'ensablement du lit, mais aussi une détérioration des rives par l'emportement des talus par les crues.

En outre, le drainage rapide de nos terres agricoles, le travail excessif du sol en monoculture céréalière, combinés aux effets des gels et dégels printaniers, rendent la couche arable vulnérable. Elle est facilement emportée par une mince couche au printemps lors de la fonte. Il n'existe a peu près pas d'étude en plein champ qui a quantifié ce type d'érosion, qui selon Kirby et Mehuys (1987), peut représenter jusqu'à 90 % de l'érosion annuelle dans certaines conditions dans les sols argileux.

L'érosion printanière lors de la fonte et lorsque le couvert végétal des cultures est absent est assez considérable. En 1974, des études de l'INRS-Eau (dans Asselin, 1990) ont estimé un transport de matières en suspension de l'ordre de 2,000 T/j la sortie de la rivière Yamaska durant le mois de mai. Selon leurs données, une grande partie de l'érosion se produit durant avril, mai et juin.

Par ailleurs, l'étude de Frenette (1990), nous révèle les débits annuels de solides transportés par les principaux tributaires du Saint-Laurent qui sont considérables (tableau 3).

Pour la rivière Yamaska, ces données ont permis de calculer un facteur de dégradation spécifique du bassin de 0,45 T/ha-an (Frenette, 1990). Ce facteur de dégradation représente que les éléments fins transportés la rivière et un faible pourcentage de l'érosion se produisant sur le bassin.

Les bassins terres du Saint-Laurent ont en général des topographies planes avec des pentes inférieures à 1%, et il a été démontré par Madramootoo et Van Roon (1988), que ces terres avaient des taux d'érosion significatifs. Dans une évaluation du modèle GAMES dans un bassin d'environ 10,000 ha don’t les pentes variaient entre 0,05 % et 1,74 % Madramootoo *et al.* (1988) estiment les pertes de sol annuelles entre 3,3 et 4,1 t/ha.

L'impact de la Surfertilisation

A notre connaissance, il n'y a pas d'étude qui a fait le portrait des habitudes des producteurs en termes de leur fertilisation. Toutefois, plusieurs conseillers agricoles s'accordent à dire que dans la production de maïs, une proportion de 10 à 15 % des producteurs fertilisent à des taux de 160 kg-N/ha, alors qu'environ 40% fertiliseraient à des taux supérieurs à la norme recommandée de 180 kg-N/ha du C.P.V.Q., laquelle serait déjà élevée pour plusieurs sols (Brunelle, comm. pers.). Ce qui est pour la fertilisation azotée vaut aussi pour la fertilisation phosphorique et potassique, ce que l'inventaire des sols a remarqué sur 300,000 ha (Tabi *et al.*, 1990).

Il est aussi bien connu que la valeur des fumiers et lisiers n'a pas toujours été prise en compte à sa juste valeur, pour ne pas dire délibérément négligée. Ceci s'observe encore aujourd'hui malheureusement sur des fermes porcines ayant des surplus de fumiers, où on a observé des fertilisations organiques qui souvent comblaient les besoins de la culture, et auxquelles on ajoutait une fertilisation minérale (Bernier *et al.*, 1991).

Dans cette même étude, Bernier *et al.* (1991) mesurèrent des taux de lessivage qui atteignaient 45 mg/L de $N-NO_3$ et des charges polluantes annuelles de 104 kg-N/ha. Des données de cette étude, on observe que la moitié des producteurs de porcs qui cultivaient le maïs, appliquaient des fertilisations dépassant de 1,5 fois les besoins en azote et de 2 à 6 fois les besoins en phosphore et en potasse.

Même avec des doses de fertilisation azotée recommandée, il faut se demander si nous ne sommes pas déjà en excès. Des suivis dans la pomme de terre par Madramootoo (1991), révèlent des pertes de $N-NO_3$ de 20 à 40 mg/L. Un autre suivi dans la région de Nicolet montre une perte de $N-NO_3$ de 20 à 30 mg/L dans la pomme de terre et de 10 à 12 mg/l $N-NO_3$ dans le maïs et le soya à l'automne 91 (Asselin, 1992).

L'impact des Pesticides

En 1982, selon Reiss *et al.* (1984), les agriculteurs du Québec ont acheté 2 308 400 kg de matières actives, pour la plupart des herbicides (68 %); les ventes furent surtout faites dans la région hydrographique 03, regroupant tous les bassins hydrographiques du sud du Saint-Laurent en partant de la rivière Nicolet (figure 1). Pour le seul bassin de la rivière Yamaska, la quantité de matières actives totalisait 447 125 kg, soit en moyenne 2 kg/ha sur les 218,780 ha cultivés de ce bassin.

La plupart des rivières du sud du Québec comme la Nicolet, St-François, Yamaska, Richelieu, St-Jacques, St-Régis, L'Assomption, Châteauguay et St-Louis présentent toutes une certaine contamination de l'eau et des sédiments par les pesticides (figure 3). Des produits tels l'atrazine, le diazinon, le lindane et l'endosulfan ont été découverts dans plusieurs rivières des concentrations excédant parfois les seuils recommandés pour la vie aquatique (Giroux et Morin, 1990). Les cas de contamination se distinguant le plus, étaient ceux de la rivière

Yamaska et de la Tortue, lesquelles sont situées dans des zones à forte activité agricole (Giroux et Morin, 1990).

L'atrazine est un herbicide très utilisé dans le maïs. Son utilisation intensive, sa persistance et son application sur sol nu au printemps en font un produit A fort potentiel de contamination. Il semble d'après les études de Cossette *et al.* (1988), que dans les bassins de la rivière Yamaska et St-Régis, les densités théoriques d'utilisation (quantité vendue /superficie cultivée en maïs) dépassent la dose la plus élevée recommandée de 2 à 4 fois pour atteindre les 18 kg/ha dans le bassin de la St-Régis (dans Giroux et Morin, 1990).

Les suivis de qualité effectués par le MENVIQ en 1987 et 1988 ont révélé plusieurs cas de contamination des prises d'eau potable par les pesticides (Giroux et Morin, 1990). L'atrazine a été un des produits le plus couramment retrouvé dans l'approvisionnement de 15 municipalités sur les 18 faisant partie de l'échantillonnage pour les eaux de surface, quoique en concentrations bien inférieures à la norme de 60 µg/L établie par Santé et Bien-être social Canada. Entre autres, un échantillonnage effectué entre la fin avril et la fin août 1987 par la ville de Saint-Hyacinthe a révélé des concentrations maximales de 5,7 µg/L dans l'eau traitée au début juin, période correspondant aux pulvérisations (Ayotte *et al.*, 1990).

En ce qui concerne l'eau souterraine, on a trouvé plusieurs cas de contamination de puits privés par l'aldicarbe dans la MRC de Portneuf où l'on retrouve une culture intensive de pomme de terre. Ce produit fut mesuré dans huit puits, don't trois avec une concentration dépassant la valeur acceptable de 9 µg/L; une teneur maximale de 52 µg/L fut mesurée (Paradis *et al.*, 1991).

D'autre part, entre 1984 et 1991, 250 puits privés répartis dans une trentaine de localités du Québec dans diverses régions de culture intensive de pommes de terre (Portneuf, Lanaudière, Estrie, Montérégie), ont été échantillonnés pour les résidus d'aldicarbe. Au total, 55 puits ont montré la présence d'aldicarbe don't 17 ont présenté à un moment ou l'autre en 1984 et 1991, une contamination supérieure à la norme de 9 µg/L établie par Santé et Bien-être social Canada pour l'eau potable. La concentration la plus élevée, soit 61 µg/L, a été observée en 1991 dans un puits privé de la localité de Sainte-Sophie au nord de Montréal (Giroux, comm. pers.).

Le métribuzine et le carbofuran ont été également retrouvés dans l'eau du puits de la municipalité de Sainte-Catherine-de-la-Jacques-Cartier entre 1980 et 1983 en concentration élevée; ce puits a été abandonné depuis lors (Giroux et Morin, 1990).

LES ÉLÉMENTS DE SOLUTION

La Sensibilisation des Agriculteurs

A notre humble avis, c'est l'élément-clé de la solution à la protection de l'environnement. Une plus grande connaissance de l'impact de leurs pratiques sur l'environnement sera un élément beaucoup plus motivateur que n'importe quel règlement élaboré par les spécialistes.

Une étude du MENVIQ en 1985 (dans la Aloue, 1988) montra qu'en général, les agriculteurs percevaient que l'agriculture contribuait que peu la pollution de l'eau. Cette perception a probablement évoluée depuis 1985, mais il n'en demeure pas moins, que ces derniers doivent être sensibilisés aux effets que leurs pratiques peuvent avoir sur l'environnement, leur entreprise et éventuellement sur leur santé et celle de leur famille long terme.

Des programmes d'information et d'éducation sont notre avis des moteurs de changement beaucoup plus efficaces long terme que des réglementations qui fixent des standards ne pas dépasser, mais que personne ne peut appliquer ou en surveiller l'application de façon adéquate, faute de budget.

En outre la sensibilisation, les gouvernements devront instaurer des programmes d'aide à long terme sur le transfert technologique vers des pratiques agricoles plus performantes.

Gestion des Fumiers

Il a été démontré par les études du MENVIQ, l'influence des élevages sur la qualité des eaux des quelques bassins agricoles par l'apport d'azote et de phosphore (tableau 2).

A cause de capacité d'entreposage insuffisante, les producteurs sont obligés d'épandre tôt au printemps et tard l'automne, période où les cultures sont absentes. Il s'en suit donc un lessivage important que l'on évalue grosso modo à 50 % de la fraction azotée, laquelle se retrouve dans les cours d'eau ou la nappe.

Tout le monde convient que les déjections animales doivent être utilisées en saison de culture. Pour ce faire, le producteur doit disposer de capacité d'entreposage qui lui permettra une certaine flexibilité au niveau de ses épandages. Dans cet optique, les programmes d'aide devraient s'appliquer des constructions avec des capacités d'entreposage d'au moins 300 jours.

Il est reconnu que les régions productrices la fois de porcs et de maïs sont celles qui ont le plus grand impact sur la qualité des eaux (Primeau et Grimard, 1990). En conséquence, l'on doit développer davantage l'utilisation du lisier en postlevée du maïs. Les essais sur des fermes commerciales montrent des économies d'engrais minéraux jusqu'à 100 $/ha (Lavoie, 1991).

D'autres alternatives comme la réduction des teneurs en nitrates et en phosphore des lisiers par une modification de la régie alimentaire et le contrôle des volumes d'eau l'intérieur des porcheries devront être développées davantage. La recherche devra également s'intéresser développer des régies et des bâtiments pour des élevages sur litière.

Controle de L'érosion Hydrique

Les études du MENVIQ (dans Beaulieu, 1990) rapportent que l'érosion des sols est responsable des 3,3 millions de tonnes de matières en suspension que l'on retrouve annuellement dans le Saint-Laurent. Les dernières études de Frenette (1992) les évaluent plutôt 6,5 millions de tonnes annuellement, don't 5 millions proviennent uniquement des tributaires du sud du Québec, en majorité fortement agricoles.

On a observé que la monoculture du maïs avec travail conventionnel du sol est un facteur important, sinon majeur, du taux d'érosion et des fortes teneurs de matières en suspension mesurées dans nos rivières (Grimard, 1990).

Avec les particules en suspension sont entraînés les fertilisants, en particulier le phosphore et les pesticides. Les études de Pesant (1990) montrent assez bien l'importance de l'érosion du sol dans la culture du maïs avec un travail du sol conventionnel par rapport un semis avec travail minimum du sol. Celui-ci a remarqué que le travail minimum du sol a réduit de plus de trois fois les pertes de K et de plus de 12 fois les pertes de phosphore.

Plusieurs conviennent que le régime actuel de stabilisation des revenus dans le maïs n'incite pas les agriculteurs â changer leur pratique de travail du sol conventionnel vers des pratiques de travail réduit comme les billons permanents et les semis directs. Bien qu'il reste un développement technique â faire dans ces pratiques, les quelques rares études faites au Québec montrent assez clairement que ces pratiques sont avantageuses au point de vue économique tout en maintenant les rendements des cultures (Cantin, 1990).

Les essais en parcelles par Côté (1989) sur une culture de blé, et sur des fermes dans le maïs par Brunelle (1990), montrent que le remplacement de la charrue conventionnelle par le chisel et la charrue â disques n'entraîne pas de baisse de rendement dans les sols légers.

L'implantation de cultures de couverture â la suite de récoltes hâtives ne laissant pas de résidus serait de nature â réduire l'érosion hydrique et par conséquent la charge polluante due au phosphore. Un essai de culture de blé d'hiver sur retour de pomme de terre sur des parcelles de 3,5 ha a montré une réduction allant jusqu'à 50 fois des matières en suspension comparativement â la parcelle labourée en dépit que le débit de ruissellement fut 3 fois supérieur (Asselin, non publié). L'étude de Madramootoo (1991) sur l'effet d'un couvert végète' a montré une réduction des pertes d'azote de 24 % et de 70 % des sédiments par rapport à un champ de pommes de terre conventionnel.

En plus de retenir le sol et de réduire l'érosion hydrique, les cultures de couverture peuvent fixer des quantités appréciables de N, P et K dans la biomasse et les retourner au sol pour la culture de l'année suivante. Un réseau de fermes de démonstration dans la région de Nicolet a montré que les cultures de couverture ont fixé en moyenne 93 kg-N/ha en 1990 et 61 kg-N/ha en 1991; des valeurs jusqu'à 150 kg-N/ha furent mesurées (Brunelle, 1992).

Gestion des Fertilisations

Selon les études du MENVIQ (dans Beaulieu 1990), la contribution des activités agricoles à la pollution de dix tributaires du Saint-Laurent totalise plus de 48 000 tonnes d'azote et 16 000 tonnes de phosphore annuellement. Selon le même auteur, l'application d'une meilleure régie de fertilisation et des connaissances actuelles permettrait de réduire ces pertes à 20,000 tonnes pour l'azote et à 5,000 tonnes pour le phosphore (Beaulieu, 1990).

Il reste un besoin pour développer et préciser les bilans agronomiques et l'utilisation des teneurs en nitrates résiduels présents dans le sol au printemps pour diverses cultures. A date, la détermination du nitrate résiduel permet une fertilisation beaucoup plus rationnelle dans le maïs.

Suite au développement de la méthode de dosage du nitrate résiduel par le chercheur E. Beauchamp de Guelph, quelques régions agricoles ont appliqué cette méthode. Dans un essai sur une quinzaine de fermes dans la région de Nicolet, Poulin (1992) a observé que le dosage des nitrates résiduels a permis des augmentations de profit-net de 22 $/ha en moyenne par rapport à une fertilisation conventionnelle selon les normes du C.P.V.Q. Les économies de fertilisants azotés furent de 40 kg/ha en moyenne.

En ce qui concerne la fertilisation phosphorique et potassique, il semble que les recommandations actuelles sont basées sur des régressions peu précises. Donc la recherche a un champ à explorer dans la calibration des besoins en phosphore et potasse des principales cultures sur la base de regroupement de séries de sol de comportement homogène par rapport à ces fertilisants (Brunelle, comm. pers.). Les travaux de Giroux et Tran (1991) montrent que l'intégration de certaines propriétés du sol comme le pH et la saturation en K permettrait une interprétation plus juste de la disponibilité du potassium au sol et une recommandation plus précise. Dans le cas du phosphore, Tran et Giroux (1990) soulignent l'importance du pouvoir de fixation du P des sols et le placement de l'engrais phosphaté le plus près possible de la zone racinaire pour éviter le contact avec les composants fixateurs du sol.

Gestion des Eaux

Dans le passé, le réseau de cours d'eau agricoles a été conçu pour évacuer les eaux de drainage et éviter les submersions des terrains en culture, ce qui implique nécessairement des capacités hydrauliques élevées des canaux. Ceci est bien en saison de culture, mais lors des débits de crues au printemps et durant les orages torrentielles d'été, ces capacités de canaux peuvent créer des inondations dans les plaines de débordement entre autres.

De l'évacuation des eaux excédentaires, on devra passer au contrôle des eaux et à la gestion du débit des rivières. Il faudra étudier les possibilités de gérer les débits à l'intérieur des bassins agricoles par l'addition de mini structures ou de bassins permettant de retenir un certain volume d'eau, diminuant ainsi le débit de crue tout en permettant une déposition du sédiment grossier, et une réutilisation des eaux à des fins agricoles.

Protection des Eaux Souterraines

Du fait qu'elle soit invisible, l'eau souterraine est souvent oubliée. Mais on doit garder à l'esprit la vulnérabilité de cette ressource. Toute contamination peut entraîner des répercussions sérieuses à moyen et long terme.

De par la nature des dépôts, le Québec possède en général des nappes aquifères don’t les vulnérabilités à la contamination sont relativement élevées dans plusieurs régions telles que définies par les cartes de Mc Cormak (1985).

La contamination des nappes souterraines par les micropulluants et les pesticides a été détectée dans plusieurs régions comme en fait mention la synthèse des campagnes d'échantillonnage (Giroux et Morin, 1990).

Il existe aussi les contaminations bactériologiques et par les nitrates. Les premiers cas rapportés sont ceux survenus dans la région de Saint-Patrice de Beaurivage en 1984 où un puits de la municipalité a dû être fermé en raison d'une teneur de plus de 40 mg/L $N\text{-}NO_3$ (Levallois, 1987). Plus récemment dans la M.R.C. de Portneuf, on a relevé par les nitrates à plus de 10 mg/L $N\text{-}NO_3$ (Paradis *et al.*, 1991). D'autres études sont également en cours et montrent des contaminations de nappe et de puits par les nitrates (Gangbazo, comm. pers.). Les études en cours de Prasher (1991) tendent à montrer qu'un contrôle du drainage souterrain réduit les pertes de pesticides vers la nappe et les cours d'eau.

L'amenagement du Territoire

La loi de protection des terres agricoles décrète une zone exclusivement à usage agricole et en restreint ou élimine les autres usages tels que l'industrie, l'habitation. Cependant, aucune provision n'a été prévue à l'intérieur de cette loi prévoyant l'utilisation de terres en bordure des rivières à d'autres fins comme la récréation, le tourisme. De ce fait, il est très difficile de définir de nouvelles vocations, qui sans être préjudiciables à l'agriculture, pourraient être dans certains cas, un avantage économique et écologique à certaines régions.

Le sud du Québec possède de très belles rivières qui pourraient dans certains cas, offrir des parcs linéaires à la population avoisinante et aux adeptes du plein air. Nous croyons que certaines rivières pourraient faire l'objet d'évaluation et d'aménagement en ce sens, dans le but d'offrir de nouveaux usages de l'eau.

Par ailleurs, avec la diminution des superficies en culture, il faudra trouver de nouvelles utilisations de ces terres. Dans le contexte actuel de restructuration de l'industrie des pâtes et papiers, le reboisement des terres abandonnées, en commençant par les sols et les zones sensibles à l'érosion, serait de nature bénéfique à long terme pour ce secteur d'activité, par le fait que l'on rapprochera les sources d'approvisionnement des usines.

Pour l'environnement et la qualité du réseau hydrographique, l'accroissement des surfaces boisées et le reboisement des coulées et des abords des cours d'eau seraient de nature à temporiser les débits de pointe et d'assurer un débit d'étiage qui rencontrerait les besoins des utilisateurs et de la faune aquatique. Ces bandes boisées assureraient une plus grande stabilité des cours d'eau et rétabliraient l'établissement d'une faune qui était auparavant absente.

CONCLUSION

Nous avons essayé d'établir un bilan sommaire des répercussions de l'agriculture sur la qualité des eaux. Les diverses études d'évaluation par le ministère de l'Environnement du Québec, montrent sans l'ombre d'un doute, que nos eaux de surface en milieu agricole sont dégradées au point d'en restreindre plusieurs usages.

Quant à l'eau souterraine, les études montrent des contaminations par différents herbicides et insecticides un peu partout au Québec. D'où l'importance du phénomène, et l'intérêt à y apporter des solutions.

Les solutions à la conservation de la qualité des eaux sont de deux ordre: 1) informer et éduquer nos producteurs et, 2) appliquer les connaissances et les techniques connues à date.

BIBLIOGRAPHIE

ASSELIN, R. 1992. Suivi du lessivage des nitrates dans la région de Nicolet. Journées agricoles de la région 04. Février.

ASSELIN, R. 1990. Aménagement et gestion des sols et conservation de la qualité de l'eau. Journée agricole, MAPAQ, Nicolet.

ASSELIN, R. *et al.* 1992. Projet d'aménagement intégré du bassin de la rivière Duncan. Rapport d'étape. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Nicolet, Mars.

AYOTTE, P., M. LARUE. 1990. Micropolluants organiques: campagnes d'échantillonnage printemps-été 1987 et hiver 1988. Ministère de l'Environnement du Québec, Québec.

BEAULIEU, R. 1990. L'état de la qualité de l'eau en milieu agricole au Québec. Revue Agriculture, Vol. 47, No. 3, décembre, pp. 19-22.

BERNIER, Y., L. LAPERRIÈRE. 1991. Impact des périodes d'épandage du lisier de porc sur la qualité des eaux de drainage. Rapport no. 3B1-18480260-023. Entente Canada-Québec.

BRUNELLE, A. 1992. Suivi des cultures d'engrais verts dans la région 04 entre 1989 et 1992. Rapport d'un programme de démonstration. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Nicolet.

BRUNELLE, A. 1990. Comparaison de l'effet de trois méthodes de travail primaire du sol sur le comportement de culture de maïs. Rapport d'un programme de démonstration. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Nicolet.

CANTIN, J. 1990. Culture du maïs-grain/soya sur billons permanents. Journée agricole du 8 février. MAPAQ, Nicolet, pp. 52-59.

COTE, D. 1989. Le travail minimum de sol en relation avec la conservation des sols et la productivité. Agrosol, Vol. 2, No 1, pp. 56,57.

DE LA NOUE, J. et D. PROULX.1988. Ladépollution: luxe ou investissement. Agriculture, automne 1988.

FRANCOEUR, A.-G.1991.L'agriculture d'aujourd'hui héritage ou dette? Agriculture, Vol. 48, No. 2, Septembre, pp. 15-22.

FRENETTE, M.1992.Communication personnelle. Département Génie civil, Université Laval, Québec.

FRENETTE, M. 1990. Analyse macroscopique de l'érosion des bassins et du transfert sédimentaire dans les tributaires du Saint-Laurent. Dans: Colloque sur la conservation de l'eau en milieu agricole. C.P.V.Q., Février, pp. 248-268.

GAGNE, J.C. 1991. L'agriculture contribue la détérioration de l'eau. Terre de Chez-Nous, Vol. 9, No. 5.

GANGBAZO, G.1992.Communication personnelle. Ministère de l'Environnement, Québec.

GIROUX, M. 1992. Communication personnelle.

GIROUX, M. 1980. Rapport sur l'échantillonnage de l'aldicarbe au Québec pour l'année 1989. Document de travail. Direction de la gestion et du contrôle des pesticides, Ministère de l'Enviro nnement, Québec.

GIROUX M. et C. Morin. 1990. Contamination des eaux de surface et souterraines par les pesticides au Québec: synthèse des programmes d'échantillonnage réalisés depuis 1980. Direction du milieu agricole et du contrôle des pesticides, Ministère de l'Environnement.

GIROUX, M. et S. TRAN. 1991. Evaluation de la disponibilité du potassium du sol et des engrais en relation avec les propriétés des sols. Agrosol, Vol. 4, No 1, pp. 30-38.

GRIMARD, Y. 1990. Qualité de l'eau au Québec. Dans: Colloque sur la conservation de l'eau en milieu agricole. C.P.V.Q., pp. 24-37.

KIRBY, P. et G. Mehuys, 1987.Seasonal Variations of Soil Erosion by water in Southwestern Quebec. Can. Jour. of Soil Science, Vol. 67, pp. 55-63.

KIRBY, P. et G. MEHUYS. 1987. Seasonnal Variation of Soil Erodabilities in Southwestern Québec. Journal of Soil and Water Conservation, Vol. 42, pp. 211-215.

LAVOIE, M., 1991. Epandage du lisier de porc en postlevée dans le maïs. Journées agricoles du 7 février 1991. MAPAQ, Nicolet.

LEVALLOIS, P., M. LAVOIE et S. THEBERGE. 1987. Etude de l'impact du lisier de porc sur la qualité de l'eau dans le bassin de la rivière Beaurivage en regard de la santé humaine. Département de santé communautaire du Centre Hospitalier de l'Université Laval, Sainte-Foy.

MADRAMOOTOO, C. 1991. Erosion Control for Potato Production. Project #3B1-72720260-012. Entente Canada-Québec.

MADRAMOOTOO, C. et E. VAN ROON. 1988. Fertilizer concentrations and sediments loadings from an extensive agricultural watershed. Proc. Sixth World Water Resources Congr., Ottawa.

MADRAMOOTOO, C., L. LAPERRIÈRE et S. BARRINGTON. 1988. Modeling sediment loss from a Quebec Watershed. Proceedings of the International Symposium on Modeling Agriculture, Forestry and Rangeland hydrology, A.S.A.E.

MENVIQ. 1988. L'environnement au Quebec: un premier bilan. Ministère de l'Environnement, Sainte-Foy, 431 p.

PARADIS, D., P.J. BERNIER et P. LEVALLOIS. 1991. Qualité de l'eau souterraine dans la MRC de Portneuf. Ministère de l'Environnement. Quebec.

PESANT, A. 1990. Ruissellement et erosion des surfaces cultivées. Dans: Colloque sur la conservation de l'eau en milieu agricole, C.P.V.Q., Février, pp. 90-99.

PESANT, C. 1990. Les ressources hydriques au Quebec et leur abondance relative. Dans: Colloque sur la conservation de l'eau en milieu agricole. C.P.V.Q., Février, pp. 5-23.

POULIN, V. 1992. Fertiliser le mais en tenant compte des nitrates du sol. Journées agricoles 1992. Region 04 - MAPAQ, Nicolet.

PRASHER, S. 1991. Environmentals benefits of control drainage and subirrigation systems on drainage water quality in an organic soils. Rapport d'étape. Conseil des recherches en pêche et en agro-alimentaire du Quebec, Décembre.

PRASHER, S. 1990. Groundwater pollution from agricultural pesticides. Dans: Colloque sur la conservation de l'eau en milieu agricole. C.P.V.Q., Février, pp. 152-168.

REISS, R., J. PERRON, J. PARÉ et R. ST-JEAN. 1984. Le en agriculture au Quebec en 1982. Ministère des Approvision-nements et Services Canada.

SIMONEAU, M. et Y. GRIMARD. 1989. Qualité des eaux du bassin de la rivière L'Assomption. Ministère de l'Environnement du Quebec, EMA 88-31, 234 p.

TABI, M., L. TARDIF, D. CARRIER, G. LAFLAMME et M. ROMPRÉ. 1990. Inventaire des problèmes de degradation des sols agricoles du Quebec. Rapport synthèse. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Quebec.

TRAN, T.S. et M. GIROUX. 1990. Relation entre les propriétés du sol et la disponibilité du phosphore la plante. Agrosol. Vol. 3, No 1. pp. 7-12.

Tableau 1. Évolution de l'agriculture au Québec entre 1951 et 1985.

	1951	1985	POURCENTAGE DE VARIATION
Nombre de fermes prati-quant l'élevage	134,000	32,000	- 76
Superficie totale des terres améliorées (ha)	3,573,000	2,373,000	- 34
Nombre moyen de vaches laitières par ferme	8	41	+ 402
Nombre moyen de porcs par ferme	12	721	+ 5,668
Volume total de fumiers (Mm^3)	24	24	0
Nombre d'agriculteurs man-quant de superficie d'épandage	0	3,100	-
Quantité d'engrais chimi-ques utilisés (tonnes)	120,500	498,700	+ 314

Source: Grimard (1990).

Tableau 2. Apports massique et situation de l'agriculture et de l'élevage dans le bassin des rivières Chaudière, l'Assomption et Yamaska[1].

CARACTERISTIQUES	BASSIN A CHAUDIÈRE	 B L'ASSOMPTION	 C YAMASKA
APPORTS MASSIQUES (t/an)			
Azote	3 853	1 904	5 422
Phosphore	393	305	618
AGRICULTURE			
Superficie totale cultivable (ha)	137 583	64 578	218 779
ELEVAGE			
Cheptel (unité animale)	180 638	98 797	277 349
(%)	(100)	(100)	(100)
	47,4	28,0	34,0
Bovins (%)			
	44,4	48,0	53,0
Porcs (%)			
	7,0	21,0	11,0
Volailles (%)			
	1,8	3,0	2,0
Autres (%)			

[1] D'après Gangbazo et Buteau, 1985.

Source: Terre de Chez-Nous, Vol. 9, No. 5, 1991.

Tableau 3. Débit de solides dans les rivières du Québec.

RIVIERE	DEBIT DE SOLIDES (10^3 T)			CONCENTRATION (mg/L)	
	Maximum journaller	Moyen annuel	Maximum annuel	Moyenne	Maximale
Chaudière	64,2	342	591	79	3 291
Nicolet	116	333	643	134	1 080
St-François	155	565	733	56	2 140
Yamaska	40,7	233	376	65	5 054
Châteauguay	11,7	69,2	112,2	56	574
Assomption	27	206	316	66	977

Source: Frenette (1990).

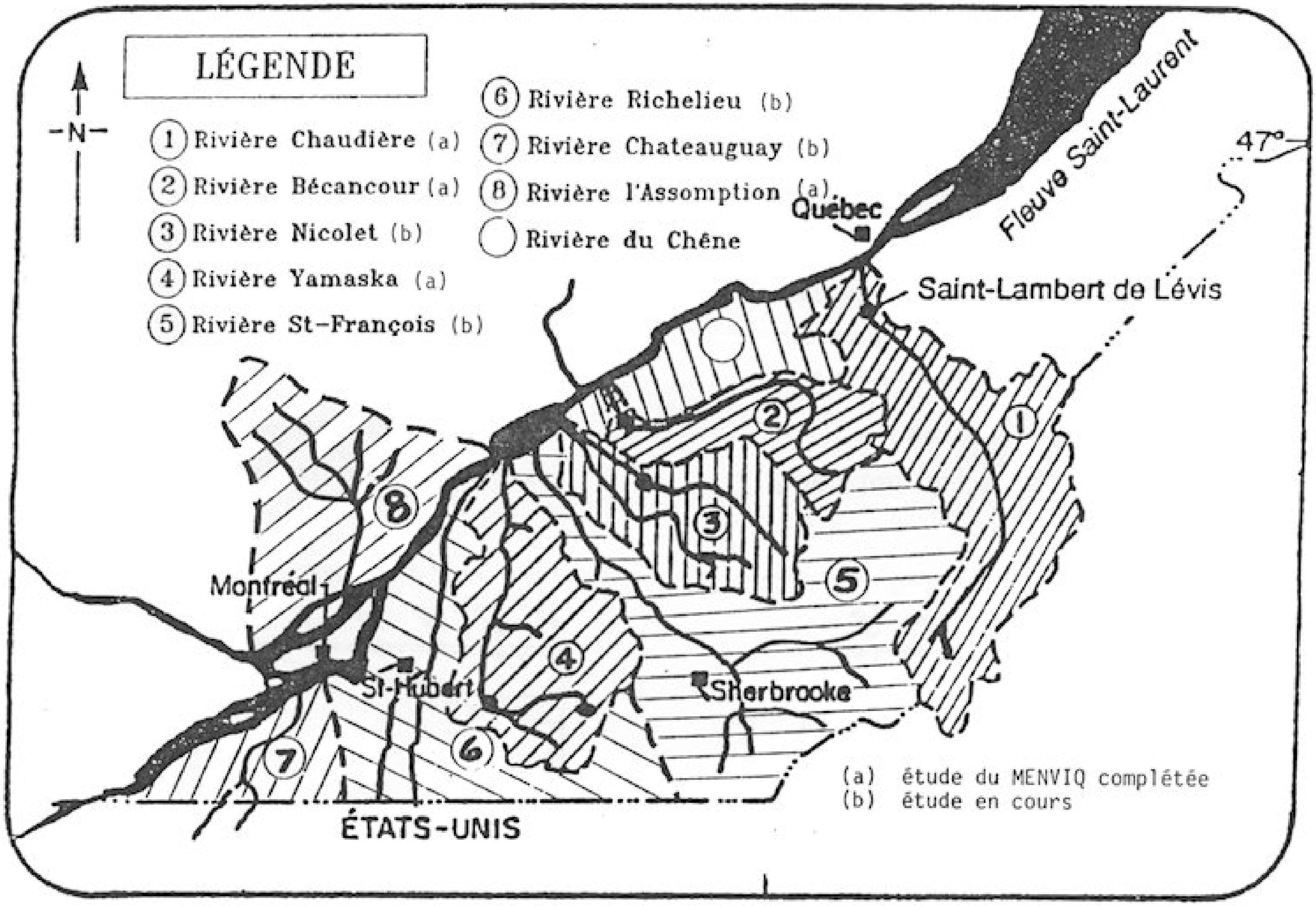

FIGURE 1: Localisation des bassins versants où est concentrée l'agriculture.

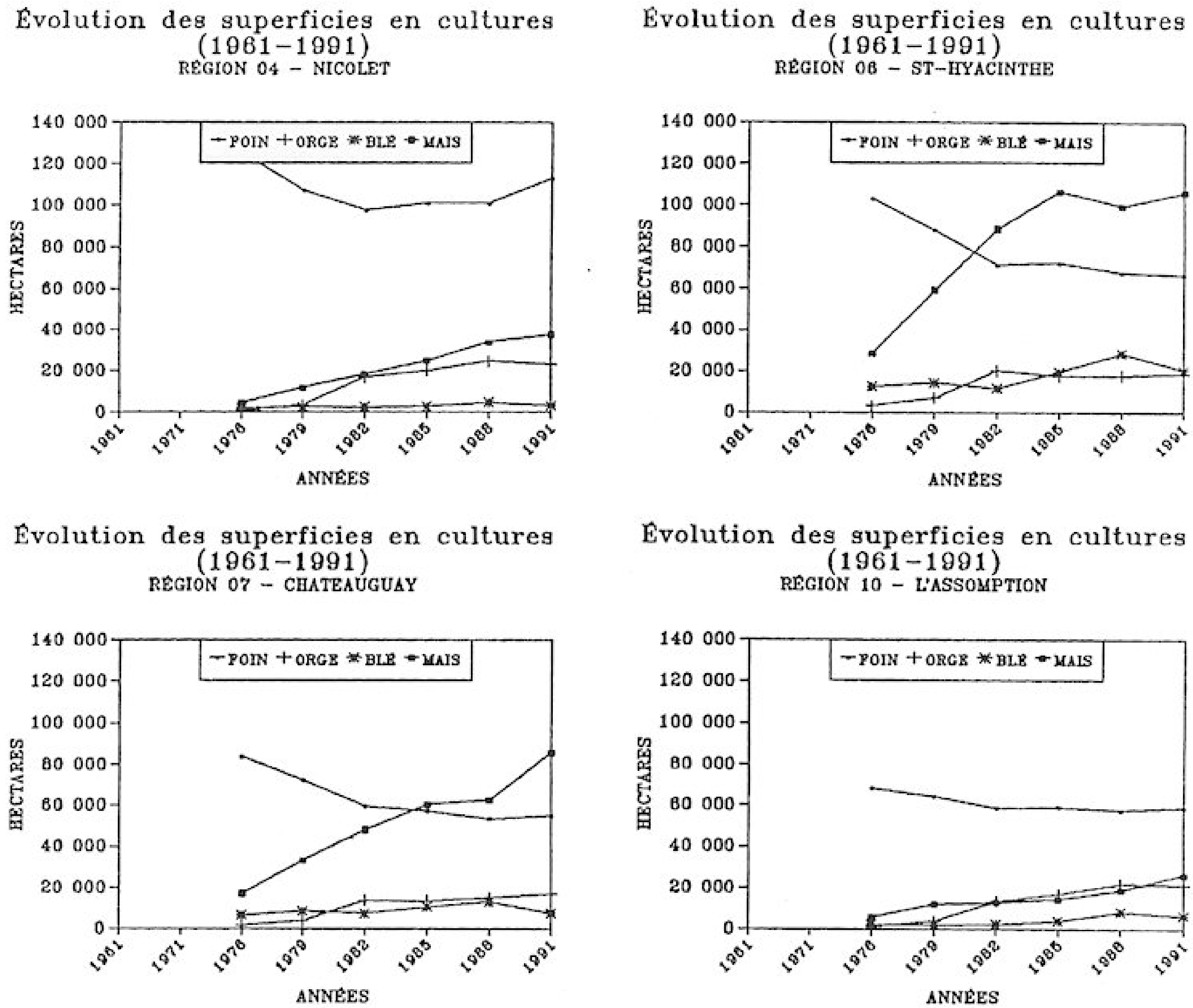

FIGURE 2: Evolution de la culture céréalière dans les régions du Sud du Québec.

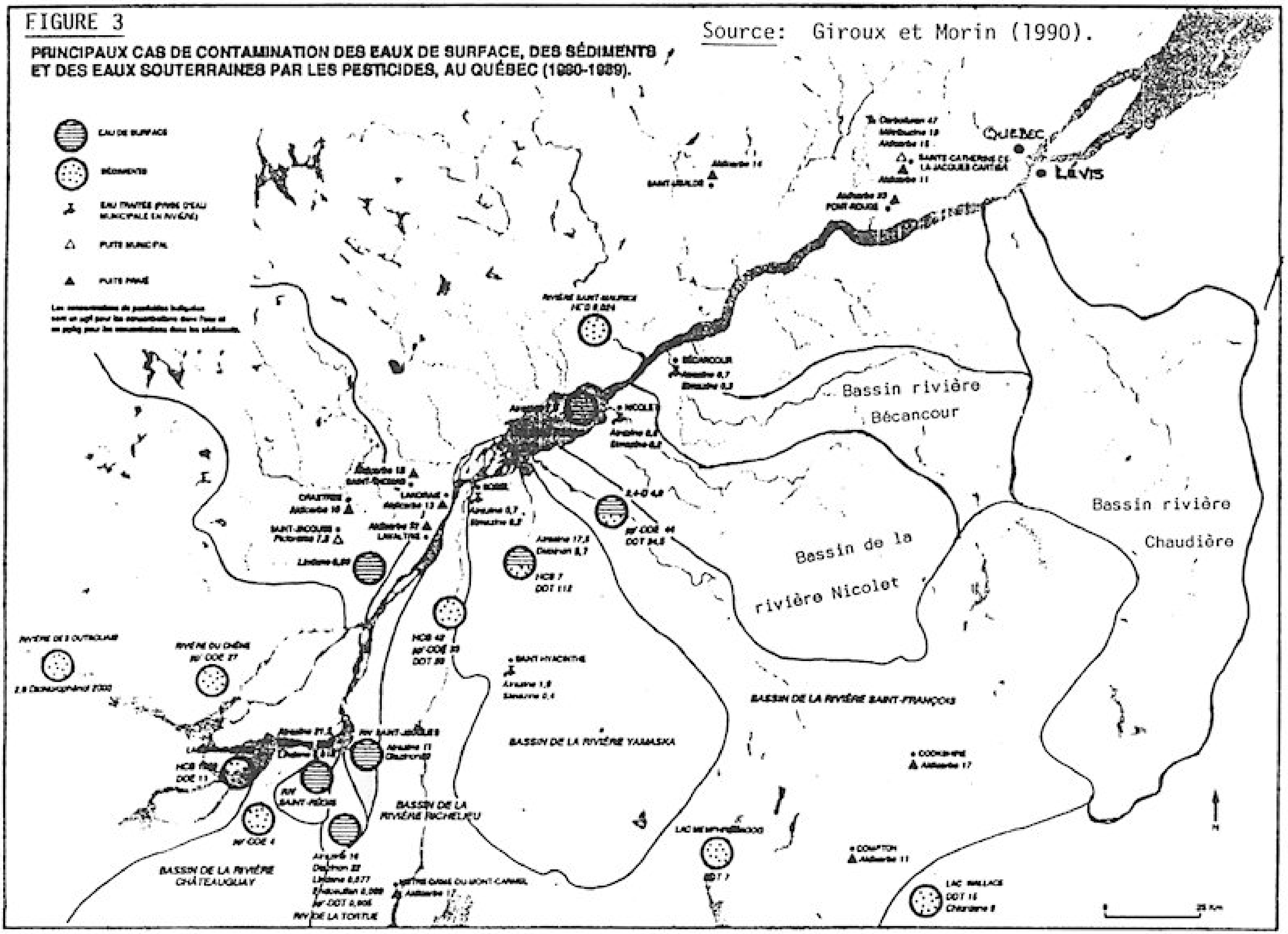

FIGURE 3
PRINCIPAUX CAS DE CONTAMINATION DES EAUX DE SURFACE, DES SÉDIMENTS ET DES EAUX SOUTERRAINES PAR LES PESTICIDES, AU QUÉBEC (1980-1989).

AGRICULTURAL IMPACTS ON WATER QUALITY: AN ONTARIO PERSPECTIVE

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INTRODUCTION

The potential impacts of agricultural production practices on water quality have been of concern in Ontario for almost 25 years. Prof. Len Webber was one of the first in Ontario to address the potential for nitrate contamination of groundwater from fertilizers and animal manure application (Webber and Elrick, 1968; Webber *et al.*, 1968). The concern was reflected in the Agricultural Code of Practice for Ontario, developed in 1976, which included guidelines on the safe rate of animal manure application based on the potential for nitrate contributions to groundwater.

Concern for deterioration of water quality in the Great Lakes, particularly Lake Erie, in the late 1960's resulted in a joint US-Canada research program under the auspices of the International Joint Commission. The program, called PLUARG (Pollution from Land Use Activities Reference Group,) included major studies to determine the contribution of contaminants, particularly sediment and phosphorus, that could be attributed to runoff from agricultural land. It was established that runoff from cropland was responsible for about 30% of the total P input to Lake Erie (PLUARG 1978). Runoff from cropland was found to be responsible for about 70% of the P input to Lake Erie from the Ontario portion of the watershed (Miller *et al.* 1982). The higher proportion attributable to agriculture in Ontario was a reflection of the reduction from other sources, particularly sewage treatment plants, that had been accomplished in Ontario, rather than a greater contribution from agriculture.

The concerns for phosphorus contamination of surface waters and nitrate contamination of groundwaters along with those for pesticides in water supplies and the deterioration of soil quality have resulted in several programs in Ontario during the 1980's and early 1990's. These are summarized below. Further details on studies that have been conducted, and on current projects are provided in subsequent sections dealing with specific contaminants.

PROGRAMS IN ONTARIO

Soil and Water Environmental Enhancement Program (SWEEP)

A $30 million, 5-yr joint Federal-Provincial program which arose from the US-Canada agreement signed in 1982 as a result of the PLUARG studies. The two Countries agreed to implement programs which would result in reduction of phosphorus input by Lake Erie of 3000 t y^{-1}. Canada's share of this reduction was 300 t y^{-1}. The subsequent Canada-Ontario agreement stipulated that a reduction of 200 t y^{-1} in the contribution from agriculture be achieved by 1992. Recognizing the close relation between soil erosion and the contribution of sediment and phosphorus to surface water, SWEEP, which was established in 1986, had two objectives. (1) to reduce phosphorus loadings to surface waters in the Lake Erie basin from agriculture and (2) to improve the productivity of southwestern Ontario agriculture by reducing soil erosion. Projects funded under SWEEP have included (1) the Tillage-2000 (T-2000), a joint Ontario Ministry of Agriculture and Food (OMAF) - University of Guelph program of on-farm conservation tillage demonstration/research plots to assess the yield and net returns as well as the environmental effects of different conservation tillage practices; (2) the Technology Evaluation and Development program funded by Agriculture Canada, which has supported a wide range of research projects by University and private sector researchers; (3) establishment of the Soil and Water Conservation Information Bureau at the University of Guelph to promote the dissemination of information to leading farmers and the general public; and (4) Establishment of a paired watershed program (PWS) to evaluate the effect of introduction of conservation practices on water quality at the watershed level.

Land Stewardship I and II (LSI and LSII)

The Province of Ontario established a $40 million 3-y Land Stewardship Program in 1987 to provide incentive to farmers to adopt/practices that would conserve soil and reduce the impacts of agriculture on the environment. Through a program managed by the Ontario Soil and Crop Improvement Association (OSCIA) payments were made to farmers who adopted conservation practices including conservation tillage, cover crops, rotation etc. Funding was also provided to assist farmers to improve manure management practices and erosion control structures. LSI also included funding for research and established the Chair in Land Stewardship at the University of Guelph. LSII has continued the payments to farmers and has supported joint work between researchers and farm organizations to evaluate conservation technology on commercial farms including the effectiveness in reducing the impact on water quality.

Food Systems 2002 (FS2002)

A $10 million 5-y provincial program was established in 1988 with the objective of reducing the pesticide use on cropland by 50% by 2002. This program has provided funding for research and development of application technology as well as efficacy of use of pesticides.

National Soil Conservation Program (NSCP)

A joint Federal-Provincial agreement was signed in 1991 to provide $11.1 million from both Canada and Ontario over a 3-y period. A major portion of the funding is being used as incentive payments to farmers to adopt conservation practices including retirement of marginal land from crop production. Funding ($1.1 million) has been provided to research soil management systems that protect fragile land, improve the environment and that are economically viable.

Great Lakes Water Quality Program (GLWQP)

An initiative which arose out of the Great Lakes Water Quality Agreement between Canada and the United States has the stated purpose "to restore and maintain the chemical, physical and biological integrity of the water of the Great Lakes Basin Ecosystem". Although much broader than the SWEEP program, $5 million over 5 years has been made available to Agriculture Canada for research.

Environmental Sustainability Initiative Funding (ESI)

Funding has been made available in Ontario under the ESI program for a number of projects. One is the development of a set of Best Management Practices handbooks for crop and livestock management. A second project is a survey of farm groundwater quality.

Evaluation of Programs

These programs in aggregate have provided rather large amounts of money in Ontario directed to reducing the impact of agricultural practices on water quality. The programs have greatly increased the awareness of everyone involved of the potential impacts of agriculture on the environment. In 1991 almost 20% of cropland in S. Ontario was in a conservation tillage system. This awareness and the growing demands from society for an improved environment have resulted in a recent initiative by a coalition of farm organizations in Ontario entitled Our Farm Environmental Agenda. The aim of this program is to have every farmer in Ontario develop an environmental farm plan in which key opportunities for environmental enhancement are identified and an implementation strategy defined.

Unfortunately, the effect of the programs from a research standpoint has been considerably less than it could have been. Some of the programs have lacked a clear focus and development of research priorities, there has been relatively little co-ordination amongst programs, and all of them have been of short duration. Many of the issues in agriculture and water quality require research that extends over several years. Most of the research projects conducted under these programs have been of 3-y duration or shorter, some less than one year. In submitting research proposals, scientists were forced to design their projects to fit the time frame rather than designing a project that would address the issue more adequately. As a result we have many empirical studies that are of insufficient length to allow conclusions and have insufficient depth to contribute significantly to our scientific knowledge.

STATUS OF KNOWLEDGE OF SPECIFIC CONTAMINANTS

Phosphorus in Surface Water

Reduction of phosphorus in surface waters has been a major emphasis in the SWEEP program because of the conclusion from PLUARG that excess phosphorus was the main cause of eutrophication of Lake Erie. The PLUARG program identified runoff from cropland as the dominant agricultural source of phosphorus. Two factors, clay content of surface soil, and proportion of land in row crops were identified as predictors of the phosphorus in runoff based on detailed studies of 11 watersheds in Ontario (Miller *et al.*, 1982).

Because phosphorus is strongly adsorbed on soil particles, it is transported primarily with eroded sediment. The amount of P entering surface water is, therefore, determined by the amount of soil being eroded and the delivery of the eroded sediment to water courses.

Research in Ontario (Miller *et al.* 1982) has shown that 70-80% of the P entering Lake Erie is in particulate form. Thus there is a close relation between sediment load and total P load in runoff. What is frequently overlooked in assessing the phosphorus contribution is that there is not a simple relation between sediment load and soil erosion. Dickinson and Rudra (1992) have determined that up to 80% of P loading is produced from 20% of the area in rolling upland watersheds in southwestern Ontario. Conversely Miller *et al.* (1982) found that P loading from relatively level, fine textured soils is occurring over most of the landscape with the very large P loss attributable to cumulative small contributions from many land units.

The difference in erosion and sediment delivery process has a major implication for development of preventative programs. Loss of productivity because of soil movement by erosion and tillage is most serious in the complex topography representative of much of the area in Southwestern Ontario. Erosion on the level, dominantly clay, plains of Kent, Essex and Lambton Counties is not sufficient to cause significant yield reductions, yet it is there that delivery of sediment, and hence phosphorus, is greatest. Although this was recognized in SWEEP, there has been insufficient effort to target funding for either research or implementation programs to the region where the phosphorus loads are greatest.

A major focus of SWEEP has been conservation tillage to reduce erosion. Conservation tillage, including no-till, has been shown to be as profitable as conventional tillage on medium and coarse-textured soils and in conjunction with increased crop rotation and/or cover crops, can maintain the quality of soils as well as reduce the phosphorus contribution to surface water. The Land Stewardship Program has provided assistance to farmers to change to these more environmentally friendly production practices.

The Pilot Watershed Study being conducted under SWEEP is designed to quantify the agronomic and environmental benefits from conservation practices. The program involves about 75 cooperating farms. Pairs of watersheds ranging in size from 400 to 500 ha were selected based on similarity of soil and management characteristics. A conservation plan was developed and implemented on farms in one watershed (test) while in the second (control), practices were continued as previously. Sediment and phosphorus in runoff are being determined at a plot and microbasin scale within the watersheds as well as at the outlet from the watersheds. Figure 1, which is a sample of data being obtained, indicate unit area discharge (m^3 ha^{-1}) and total P loads (g ha^{-1}) from one microbasin within the Kettle Creek control (KCB1) test (KTB2) watersheds for a runoff event during Oct., 1990. The main differences between these two microbasins are the use of chisel plow rather than conventional tillage and the introduction of buffer strips in the test watershed.

This project is going to provide a massive data set. Unfortunately the conclusions that can be drawn will be limited because of the time frame within which the project was forced to operate. There was insufficient time to characterize existing soil conditions in the watersheds to ensure their similarity or to collect adequate baseline outflow data from the paired watersheds, and insufficient years of monitoring to account for climatic variation or to allow the conservation practices to achieve the maximum effect. In addition, the range of practices between the test and control watersheds is not great in two of the sets. Again, scientists have been forced to design the project to fit an unrealistic time frame. Although they have done as well as could be expected, the benefits derived from the project will not be as great as expected by many.

Two additional phosphorus sources of concern in Ontario are milkhouse waste and manure application.

The widespread use of pipeline milking systems has made the dairy farmer's life much easier, but it has also greatly increased the amount of water and chemicals needed to clean milking equipment. A typical operation now produces 150 gallons of wash water each day. Since phosphate detergents are used, average milkhouse wash water has concentrations of phosphorus which are <u>1000 times</u> over the guidelines set by the Ontario Ministry of the Environment. The Upper Thames River Conservation Authority has determined that approximately <u>200 tonnes</u> of phosphorus enter Souther Ontario rivers annually from this source alone. This is equivalent to the reduction required from agriculture in the Canada/Ontario agreement. Although septic systems with seepage beds have been recommended for many years, many of them have failed because of the presence of milk solids. Farmers with a liquid manure or feedlot runoff storage system can simply add their milkhouse washwater to these storages. Where such systems are not used, solutions are not so simple. A number of alternatives are currently being investigated.

Runoff from fields to which manure has been applied but not incorporated has been recognized as a significant contributor of phosphorus for many years (Miller *et al.*, 1982). This poses particular problems for livestock farmers who wish to use no-till systems. Systems such as injection of liquid manure, while effective, are more costly and management-intensive. Recently in Ontario there has been considerable concern for transport of phosphorus and other contaminants through macropores to underground drainage systems in untilled soil. In recent studies by the Ausable-Bayfield Conservation Authority tile drains were monitored following application of liquid manure on 12 occasions on a total of seven sites over two years (Dean and Moran 1991). Although total P concentrations in tile effluent increased markedly within 2 to 4 hours of application of liquid manure, the total contribution of phosphorus was insignificant in relation to other sources. Macropore transport of bacteria and pesticides is, however, of greater concern and will be discussed further in later sections.

NITRATE IN GROUNDWATER

Nitrate (NO_3) contamination of water, particularly groundwater, is rapidly becoming a major concern in both Europe and North America. Agriculture is recognized as the major contributor of NO_3 although other sources such as septic disposal systems may be major contributors in some instances.

In Ontario, several studies have found NO_3-N concentrations in excess of 10 mg L^{-1} (the maximum acceptable level in drinking water) in groundwater in agricultural areas. Concentrations of NO_3-N in excess of 30 mg L^{-1} were found in groundwater at a depth of more than 12 m on a coarse-textured soil to which high rates of manure had been applied for several years (Miller *et al.* 1985). The groundwater group at the University of Waterloo have been involved in studies of the occurrences of nitrate in groundwater for about 12 years (Gillham, 1988). They have found NO_3 to be ubiquitous in unconfined aquifers in areas of intensive agricultural production, with concentrations ranging from below 10 mg NO_3-N L^{-1} to in excess of 50 mg L^{-1}.

Nitrate contamination of groundwater must be understood within the context of the environment and the agricultural production system. Wherever water moves through a soil with a significant nitrate concentration, nitrate is transported by the water. Soil nitrate concentrations are determined by the soil nitrogen cycle. If 1) conditions are aerobic, 2) plant uptake is not sufficient to use the net mineralized nitrogen, and 3) water is leaching through the soil, then nitrate will be leached. These conditions occur in most intensively-cropped agricultural systems in semi-humid to humid environments, or under irrigation.

In the Ontario environment, leaching occurs in the fall, after harvest to freeze-up, during extended mid-winter thaws and again with spring thaw. Little occurs during the growing season. Numerous studies in Ontario have measured the NO_3-N in soil or tile drainage water in association with varying rates of manure application. These were summarized recently (Miller 1991) so will not be repeated here. Several programs currently underway in Ontario are summarized in the following sections.

Survey of Farm Groundwater Quality

Although there are numerous incidences of elevated NO_3-N concentrations in ground and surface water in Ontario, there have not been systematic surveys or monitoring programs to provide an overall assessment of the status. A monitoring program is currently underway in which some 1200 farm wells have been sampled. This project was funded in 1991 by Agriculture Canada through the ESI program. Ontario Soil and Crop Improvement Association is the primary contractor. The Universities of Waterloo (Centre for Groundwater Research) and Guelph, together with OMAF and MOE are responsible for sample analysis and interpretation of data. The samples are analyzed for nitrate, 9 pesticides, faecal and total coliform bacteria. Petroleum derivatives were also tested for at 150 locations.

Farms were selected as follows:

1. Four per township if agricultural land covered at least 50% of area. Otherwise one per township.
2. Must be on one of major 2 soil types within township.

At 172 sites, multilevel piezometers have been installed so that groundwater contamination can be attributed to field practices, through detailed nitrogen budgets. Data from this project are currently being collated.

A Budgeting Approach to Nitrogen Management

One method for predicting regional losses of nitrate from agriculture to groundwater is to calculate the nitrogen balance for a whole farm, taking account of animals and crops. The resultant N-budget can be formulated so that a positive balance indicates the amount of N potentially available for leaching. This amount for typical farming systems could then be combined with hydrological information and climatic data using a Geographic Information System to predict maximum nitrate-N concentrations moving to groundwater from farming in the region.
The basic relationships for the nitrogen budget of a farm can be summarized as:

Nitrogen in inputs = nitrogen in output + change in nitrogen assets

Calculation of an N budget can be simplified by assuming that there is no net change in nitrogen assets. Thus for an arable farm it is assumed that soil organic matter content, and consequently soil N content, remain constant on a yearly basis for monoculture systems or over the course of a rotation when a sequence of crops are grown. Similarly for a livestock operation it is assumed that the number of animals and their demography remain constant. The N-budget for one cycle of the farming system, either one year or the length of a crop rotation can then indicate the long term potential of a given farming system to cause nitrate-N contamination of groundwater.

The Centre for Land and Water Stewardship at the Univ. of Guelph is currently preparing nitrogen budgets for some 400 farms in conjunction with the Farm Groundwater Quality Survey. This enables the predictions of nitrate concentrations in groundwater made from nitrogen balances to be compared with measured values.

The conclusion from the comparisons so far made suggests that the budgetary approach can predict contamination of groundwater for farming systems that are close to equilibrium. They can therefore be used to compare the potential of different farming systems to cause contamination of the environment.

Nitrogen Management to Reduce Nitrate Contamination

Studies are being conducted at several locations to evaluate management practices to reduce nitrate contamination of surface and groundwater. It is not possible to refer to all of these but the following will illustrate the scope of the studies, many of which relate to manure management.

A spring nitrate soil test was introduced in Ontario in 1991. This test will help to reduce the over application of N fertilizer, but it will not overcome problems associated with excess NO_3 from manure or other organic materials, including cover crops.

An Agriculture Canada project is monitoring the nitrate in drainage water from a mixed farm operation. The study involves three areas on the Central Experimental Farm in Ottawa. There are two major watersheds involved and a unit of 3 fields. Data was collected on water quality changes in the creek water form the start to the end of its course through the monitored areas.

Records of manure and fertilizer usage on the areas were kept and some information on the N content. The monitoring periods cover the period between 1975-79 and 1990 onwards.

A project funded by NSCP, is being conducted cooperatively by the Univ. of Guelph and Kemptville College of Agricultural Technology at the Winchester Research Station to determine the fate of N in applied cattle manure and from alfalfa residues. The possibility of substantial conservation of N from fall-applied manures or fall-plowed alfalfa hay by incorporation into a cover crop, or immobilized in straw residues, is being studied.

A project, funded by Ontario Ministry of the Environment, is underway at the Univ. of Guelph to determine the amount of nitrate and soluble organic carbon in water draining from the rooting zone, in relation to the source of nitrogen fertilizer (inorganic or cattle manure (solid or slurry) and the rate of application. The significance of crop uptake for reducing nitrate leaching is being studied, together with denitrification potential with depth in the soil.

Agriculture Canada scientists are conducting research into controlling the overland movement of manure nutrients and bacteria in the Kintore watershed (Oxford County), using rainfall simulation and natural collection troughs. Liquid hog and solid cow manure are being used in five tillage systems: no-till, mouldboard incorporated, mouldboard top spread, chisel incorporated and chisel top spread. No-till and mouldboard incorporated seem more effective in controlling nutrient and bacteria losses in surface runoff. Low fall and winter contamination levels increased with warm temperatures in spring. Top spread mouldboard plough plots produced higher levels of nutrients and bacteria, from fall until spring. Not enough data has been collected from plots to determine the effectiveness of chisel ploughing.

There are some differences between liquid and solid manure plots. Liquid manure on no-till and incorporated sites showed higher levels of contaminants in runoff. Top spread liquid or solid manure plots showed no notable differences. Research is continuing and should be finished in spring 1992.

An Agriculture Canada project under the Great Lakes Water Quality Agreement is studying soil, crop and water management practices to abate nitrate and pesticide losses. The main research facility is at Harrow Research Station, and consists of 0.1 ha plots hydrologically isolated to a depth of 1.8 m and having tile drains and surface flow monitoring. The soil is Brookston clay loam. Fall mouldboard ploughing or conservation tillage (tine and discs), with and without annual ryegrass cover crop are the agronomic treatments, and the watertable is controlled to 20 cm or 40 cm. Four flow events in the fall and winter of 1991-2 resulted in concentrations of nitrate ranging from 14.7 to 74.8 mg N L^{-1} . The concentration of nitrate in water leaving the plots where the watertable was controlled at 40 cm was greater than for the shallower watertable treatment. However this reflected the greater yield of corn obtained with this latter treatment in the previous drought season. The plough treatment also resulted in greater nitrate concentrations than did conservation tillage.

A joint program between the Univ. of Guelph and Agriculture Canada is being carried out at the Delhi Research Station. A field experiment on Fox sandy loam compares no-till and spring ploughing for corn with six levels of nitrogen fertilizer (0, 50, 100, 125, 150, 200 kg N ha^{-1}) with and without irrigation. Detail ed soil characterization, including hydrology and solute transport parameters has been completed. Nitrate leaching has been assessed using suction cups to draw soil water leaving the rooting zone. Maximum economic rate of N-fertilizer was 150 kg N ha^{-1}. Even at this rate the concentration of nitrate-N exceeded 10 µg L^{-1}. Differences between tillage treatments were small and not conclusive.

A project has also been completed by Univ. of Guelph scientists funded by SWEEP to study the use of cover crops for nutrient conservation. Annual ryegrass, oilseed radish and red clover were grown as cover crops following winter wheat or barley. Although ryegrass reduced the nitrogen available for leaching, it did not release the nitrogen to a succeeding corn crop. Oilseed radish also reduced the nitrogen available for leaching in the fall, but appeared to release it in the spring before the succeeding corn crop was able to recover it. Only 35% of the N in the oilseed radish in November was recovered in the succeeding corn crop compared to 70% for red clover. Red clover, although, it supplied much more N to the succeeding corn crop than the other two cover crops, did not reduce the amount of N available for leaching in the fall and winter.

PESTICIDES IN GROUND AND SURFACE WATER

Pesticides differ widely in their reactions with the soil and rate of biodegradation. Their persistence in the soil and their transport to ground or surface water thus varies markedly. Several surveys have been conducted in Ontario, principally by Dr. Richard Frank, recently retired from the Ontario Ministry of Agriculture and Food and by the Ontario Ministry of the Environment. Frank and Logan (1988) measured the concentration of four herbicides at the mouth of the Grand, Saugeen and Thames rivers periodically between 1981 and 1985. Atrazine was found in over 90% of samples from the Grand and Thames river and over 60% of the samples from the Saugeen.

With the exception of 2-4-D in the Thames (30%), other pesticides were detected in less than 10% of the samples. With the exception of Alachlor in the Grand and Thames river, all values were less than 10% of the interim maximum acceptable concentration (IMAC). It should be emphasized, however, that the IMAC for atrazine (60) is much higher than that used in the U.S.A. (3). The concentration in the Thames exceeded the value used in the U.S.A. while that in the Grand was only slightly below.

Frank *et al.* (1987) surveyed farm wells for a selected group of herbicides. Of 45 farms surveyed using alachlor, only one well was contaminated and that could be attributed to a spill. Two of the 3 wells in which metolachlor was found were contaminated by spills. Twenty-four of the 172 wells on farms using atrazine were contaminated, 14 by spills.

Clearly atrazine is the major pesticide contaminating water supplies. Atrazine use has decreased considerably in recent years but a significant quantity is still being used. Questions as to acceptable concentrations need to be addressed.

As with nitrate, numerous studies are underway to reduce the contamination of ground and surface water with pesticides. A 3-year project was started in 1990 at the Central Experimental Farm in Ottawa, to compare the effects of conventional till (CT) and no-till (NT) on soil, ground and tile water, and to measure contamination with N, P, atrazine (ATR) and metolachlor (DEA). The study includes comparison of crop yields, the effects of different tillage practices and the long-term effects of mixed farming on agricultural drainage water quality.

A project is underway at the Centre for Land and Biological Resources Research in Ottawa to study the physical chemical parameters controlling pesticide persistence and leaching in soils as part of the Great Lakes Water Quality project. Twenty one atrazine-soil experiments have been completed at three temperatures - using pesticides at normal field concentrations. A particle size analysis and atrazine-particle size fraction experiments have also been done.

Another project in pesticide behaviour in soils being conducted by Agriculture Canada Scientists in Ottawa, is investigating pesticide movement and the effects of temperature and moisture on dispersal of ATRAZINE and METOLACHLOR are being examined. The data will be used for predicting how agricultural pesticides reach groundwater and ultimately the Great Lakes. Laboratory tests and field plot trials are measuring the behaviour of the two pesticides.

Two projects, one at the Agriculture Canada London Research Centre and the second a cooperative project between Environmental Soil Services - Guelph and Agriculture Canada scientists in Ottawa are being funded under the National Soil Conservation Program. Both are investigating the effect macropore flow on transport of contaminants, including pesticides.

Bacterial Contamination of Surface Water

It has been recognized for many years that bacterial densities in runoff from livestock feedlots, manure storage and recently manured fields frequently exceed water quality standards (Baxter-Potter and Gilliband, 1988). However, it is frequently assumed that bacteria are not transported appreciable distances through soil.

Recent monitoring studies by the Ausable-Bayfield Conservation Authority have greatly increased concern in Ontario for direct transport of liquid manure to tile drains (Dean and Foran, 1991). Tile drains were monitored following application of liquid manure on 12 occasions on a total of seven sites over two years. Subsurface tiles became contaminated with fecal coliform (FC) shortly following manure application for 9 of the 12 events. Marked increases in both bacteria and nutrients occurred shortly after application of manure, peaked about five hours following application, then declined rapidly to close to background levels within 10 hours. The total amount of N and P discharged is very low and does not significantly impact on water quality.

The bacterial contribution is of greater concern. There are insufficient data available to establish the importance of this contribution relative to overland flow from manured fields or pastures, or runoff from manure storage facilities or feedlots. Contamination immediately following application occurred only when the tile drains were flowing at the time of application. Tile flow was absent for two of the spreading events and minimal contamination resulted when tile flow resumed. On the third event in which little contamination occurred, the field had been tilled just prior to manure application. It is assumed that the bacteria and other contaminants are gaining direct access to the tile drain through soil macropores. Tillage would shear the macropores at the soil surface, causing flow to pass through the soil matrix.

These studies were continued in 1991. Liquid pig manure was applied on a clay loam soil with tile drains at 15 m spacing. Comparisons included application by irrigation gun compared with soil injection; recently disturbed (8 cm) compared with soil undisturbed since fall ploughing. Escherichia coli (nalidixic acid resistant strain) was added to the manure before application to act as a biological tracer. Samples from the tile drains were taken frequently after manure application. In undisturbed land the bacterial count rate reached 10^6 s^{-1}, three hours after application began, compared with 10^4 s^{-1} on the cultivated land. Contamination of drainage water after injection was 200 times that after irrigation. Bacterial count rate peaked earlier after injection than after irrigation.

These results are clearly of concern to surface water quality at the point of discharge from the tile drain. To fully understand the significance of fecal bacteria from a farm site which enters an agricultural drain, the question of the distance it is transported downstream in the drain has to be addressed. Across the province, four Conservation Authorities, working in conjunction with the Ministry of the Environment, conducted a similar experiment in four different water courses which receive agricultural runoff. The purpose was to demonstrate the distance fecal associated bacteria travelled once they were introduced into the receiving stream (Palmateer, 1992).

The Ausable-Bayfield Conservation Authority introduced E. coli with nalidixic acid resistance into the Desjardine Drain. The results of the experimental runs conducted in the late fall (mid-November) demonstrated that fecal bacteria dispensed into the headwaters of the drain could travel the 18 km to Grand Bend Beach in a time period of one to five days, depending upon the stream flow (Palmateer, 1992).

SUMMARY

It is apparent that there has been a major emphasis in research in Ontario on the impacts of agriculture on water quality. Unfortunately most of the funding programs have been of short duration and have ended or will be ending shortly. It is clear that unless new funding becomes available, the amount of research over the next few years will be considerably reduced from that of the past 10 years.

It is imperative that a much better system for coordination of the research is developed if we are to make the most effective use of the remaining funds and of any new funds which become available.
We suggest that a strong recommendation should come from this workshop for major improvements in the funding of research related to agriculture and water quality. Funding programs that recognize the time frame required for the necessary research need to be implemented and the research projects need to be better coordinated.

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REFERENCES

BAXTER-POTTER, W.R. and M.W. GILLILAND. 1988. Bacterial pollution in runoff from agricultural lands. J. Environ. Qual. 17:27-34.

DEAN, D.M. and M. E. FORAN. 1991. The effect of farm liquid waste application on receiving water quality. Final Report RAC Projects 430 G and 512 G for Ontario Ministry of the Environment. Ausable-Bayfield Conservation Authority.

DICKINSON, W.T. and R. RUDRA.1992. Agricultural sources of stream sediments. pp 13- 34. In Agriculture and Water Quality Proceedings of an Interdisciplinary Symposium, M.H. Miller, J.E. Fitzgibbon, G.C. Fox, R.W. Gillham and H.R. Whiteley Eds. Centre for Soil and Water Conservation, Univ. of Guelph.

FRANK, R. and L.L. LOGAN. 1988. Pesticide and industrial chemical residues at the mouth of the Grand, Saugeen and Thames Rivers, Ontario, Canada, 1981-85. Arch. Environ. Contam. Toxicol. 17: 741-754.

FRANK, R., B.D. RIPLEY, H.E. BRAUN, B.S. CLEGG, R. JOHNSTON, and T.J. O'NEILL, 1987. Survey of farm wells for pesticides residues, southern Ontario, Canada. 1981-1982, 1984. Arch. Environ. Contam. Toxicol. 16:1-8.

GILLHAM, R.W. 1988. Nitrate contamination of groundwater in Southern Ontario: A hydrogeological perspective. In Agricultural Chemicals and Water Quality in Ontario. Proceedings of a workshop sponsored by the Ontario Water Management Research and Services Committee, Kitchener, ON. Nov. 17-18, 1988. J.A. Stone and L.L. Logan Eds.

MILLER, M.H., J.B. ROBINSON, D.R. COOTE, A.C. SPIRES and D.W. DRAPER. 1982. Agriculture and water quality in the Canadian Great Lakes basin. Ill Phosphorus J. Environ. Qual. 11:487-493.

MILLER, M.H., J.B. ROBINSON and R.G. GILLHAM. 1985. Self-sealing of earthen liquid manure storage ponds: A case study. J. Environ. Qual. 14:533-538.

MILLER, M.H. 1991. Environmental considerations in land application of animal manure-water pollution. In Proceedings of the National Workshop on Land Application of Animal Manure. Ottawa June 11-12, 1991. D.A. Leger, N.K. Patni, S.K. Ho. Eds. Canadian Agricultural Research Council.

PALMATEER, G. 1992. Transport of biological pollutants from agricultural sources through aquatic sediment systems in Ontario. pp 59-78 In Agriculture and Water Quality. Proceedings of an Interdisciplinary Symposium, M.H. Miller, J.E. Fitzgibbon, G.C. Fox, R.W. Gillham and H.R. Whiteley Eds. Centre for Soil and Water Conservation, University of Guelph.

PLUARG.1978. Environmental management strategy for the Great Lakes system. Final report of the International Reference Group on Great Lakes Pollution from Land Use Activities to the International Joint Commission, Windsor, ON.

WEBBER, L.R. and D.E. ELRICK. 1968. Water pollution by nitrates from the agricultural industry. In Proceedings of the Second Annual Symposium on Water Pollution Research. Jan. 26, 1967. McMaster Univ., Hamilton ON.

WEBBER, L.R., T.H. LANE and J.H. NODWELL. 1968. Guidelines to land requirements for disposal of liquid manure. Eighth Industrial Water and Waste Water Conference. Lubbock, TX.

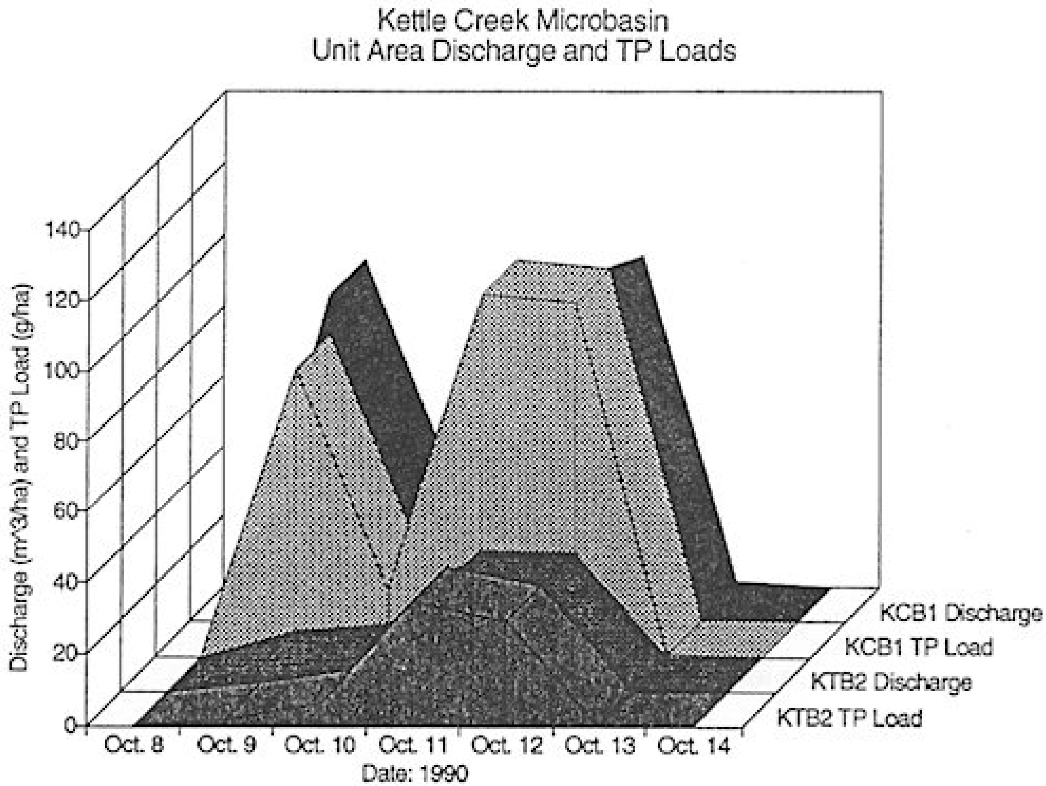

Figure 1: Unit area discharge (m^3 ha^{-1}) and total P load (g ha^{-1}) from control (KCBI) and a test (KTB2) microbasin in the Kettle Creek Pilot Watershed during a runoff event in Oct. 1990.

EFFECTS OF AGRICULTURE ON WATER QUALITY: PREVIOUS AND ONGOING STUDIES RELATED TO SEDIMENTS, NUTRIENTS, AND PESTICIDES - MANITOBA

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INTRODUCTION

(A) NUTRIENTS

(1) Groundwater

Several studies have been conducted and are ongoing to determine the effects of particular agricultural practices on contamination of groundwaters with nutrients. Virtually all of these studies focused on contamination of groundwaters with nitrate-nitrogen.

Accumulation of animal manures near farmsteads has resulted in contamination of groundwater with nitrate-nitrogen particularly in coarse-textured soils with shallow depths to groundwater (Hedlin 1971). Hedlin (1971) presented the results obtained when NO_3-N content of water was measured in wells located at various locations in a farmstead on a coarse textured soil. Concentrations of NO_3-N exceeding 100 ppm were recorded. The area of contamination, however, was restricted mainly to the farmstead area. Denitrification of NO_3-N occurred in the soil near the soil surface and in the groundwater and thus the NO_3-N was denitrified before it could move away from the feedlot or farmstead area (Partridge and Racz 1972; 1973). Both NO_2-N and significant quantities of N_2O gas dissolved in the groundwater was taken as evidence of denitrification occurring in the groundwater (Table 1).

Recent studies show that present practices for manure disposal may lead to contamination of groundwater with NO_3-N. A survey of farm fields showed high levels of NO_3-N in soils treated with manure (Table 2) (McGill). NO_3-N content of manured fields was very high; much of the NO_3-N in the manured fields was at depths below rooting depth of annual crops. The results obtained clearly show that rates of manure presently being applied by many farmers are excessive and could result in contamination of groundwater with NO_3-N.

Farm practices other than disposal of manure results in accumulation of NO_3-N in soils below rooting depth of most crops and thus pose a threat to quality of groundwater. Michalyna (1959) found up to 200 kg N/ha of NO_3-N between 120 and 180 cm in clay soils in the Red River Valley on land frequently followed. Fallowing of land in Manitoba, however, is not widely and frequently practiced today and thus is not of major concern. Less than 8% of the land area in Manitoba is fallowed in any particular year. Adding nitrogen fertilizers to stubble land at rates required to reach near maximum yield also does not pose a threat to quality of groundwater. Table 3 shows results from experiments in, which nitrogen was applied to barley at six locations on fallow land and six locations on stubble land (Racz, Unpublished Data). The data indicated that the crop uses nearly all the nitrogen when it is applied at rates needed to reach near maximum yields.

Near maximum yields were obtained with 70 to 100 and 30 to 70 kg N/ha on stubble and fallow land, respectively. Where very high rates of N were added, most of the excess was recovered in the surface 60 cm of soil at harvest. More detailed results (not shown) indicated most of the excess N in most soils remained in the surface 15 cm. Other studies, based on soil water holding capacities, rainfall, and evapotranspiration also show that the probability of leaching of NO_3-N from the 0 to 15 cm in depth of soil to depths below 90 cm during the growing season is very low even on coarse textured soils.

Downward movement of NO_3-N in soils has received considerable attention. Field Ridley (1975) applied 550 kg N/ha as $(NH_4)_2SO_4$), $CaNO_3$, and Urea to loam and clay soils in the Red River Valley and maintained the plot area free of plant growth. The study was conducted for a two-year period and while both upward and downward movement of NO_3-N occurred in response to changes in the environment, movement of NO_3-N below rooting depth was negligible. In contrast, a similar study by Chang and Cho (1974) on a coarse textured soil showed that while the nitrate was retained in the surface 30 cm during the first summer after application„ nearly all the added N was leached below 120 cm during the first fall and spring after application. Movement of NO_3-N in the soil profile was by advective flow.

Application of N fertilizer in excess of that required by the crop over a period of time has also resulted in accumulation of NO_3-N in soils below depths of 90 cm or more. Although leaching of a single application of N fertilizer is not likely over period of one year in most soil-climatic areas of Manitoba, applying N fertilizer in excess of that required eventually results in movement of the excess N below rooting depth of annual crops. The fate of the N leached to soil depths below 90 to 120 cm as a result of excess rates of manure and/or commercial N fertilizer is unknown.

Grift *et al* (1992) initiated studies in 1991 to study the effect of N fertilization on NO_3-N content of groundwater. Preliminary results for the two sites selected are shown in Table 4. NO_3-N, was detected in groundwaters at both sites; NO_3-N content at site 2 were very high prior to and after establishment of the site. Both sites were located on coarse textured soils and on fields which had not been manured or excessively fertilized. The study, referred to above, will be continued for a period of several years. The objective of the studies ongoing and planned are to determine the fate of NO_3-N in soil and to formulate a model on fate of NO_3-N in soil based on soil moisture, soil temperature, biological activity, oxygen transport in addition to NO_3-N transformation and denitrification.

The model, if developed, would be used to propose means by which groundwater pollution by nitrate from commercial fertilizers could be minimized. Other studies planned include modelling the production and fate of NO_3- N from animal manures as a function of the parameters listed for NO_3-N derived from commercial fertilizer.

Very little work has been conducted on impacts of nutrients other than N to groundwaters from various agricultural practices. Campbell and Racz (1975) reported that P had moved from surface soils to groundwater in an alkaline sandy soil beneath a feedlot with large accumulations of manure. Movement of P occurred both in organic and inorganic forms.

(2) Surface Waters

The effect of particular agricultural practices on nutrient inputs into surface waters is not well defined. Runoff from farmsteads and feedlots contribute N, P and other nutrients to steams and rivers. A study of sediments in the La Salle River showed increased levels of NH_4-N and P in sediments downstream from farmsteads, feedlots and rural communities located adjacent to the river. Sediments downstream from land drainage ditches, (ditches draining agricultural land) did not show an increase in nutrient concentration. Very little or no work has been conducted to determine the quantities of nutrients in waters directly from agricultural land versus rural and urban communities and other point sources such as feedlots and farmsteads located close to rivers and streams. The effects of P inputs into waters on algal growth and eutrification, however, has been extensively studied. Increases in rate of eutrification of waters is a direct result of increases in P concentration.

Hargrave (1992) recently completed a study to determine total N and P losses from soil due to water erosion. The experimental site, located on land with 9% slope to measure soil erosion, showed that annual losses of N and P were substantive on these highly erodible slopes (Tables 5 and 6). The quantities of N and P removed from the upper slopes and entering surface waters was not measured. It is likely that most of the sediments remained the depositional areas downslope and did not enter waters (rivers etc.).

More work has to be conducted to determine amount of sediments entering surface waters and the effect of these sediments on nutrient inputs to waters. Studies by Racz (1979) showed that mineralization of organic P in organic soils occurred under both aerobic and anaerobic conditions. Two organic soils were incubated at 10°C for periods up to 24 months. Mineralization of organic P was somewhat greater under anaerobic than aerobic conditions. The above finding suggests that soil sediments entering lakes etc. may contribute more P from the organic fraction than from the inorganic fraction.

B. SEDIMENTS

Pauls (1987) and Wahome (1989) studied rates of soil erosion by water as a function of soil type, weather, cropping and tillage practice. The study is being continued to obtain sufficient information to use the Universal Soil Loss Equation for prediction of soil loss under Manitoba conditions. Soil loss due to rainfall events as well as due to snowmelt is being investigated. This project is an ongoing study and will be continued for several more years. The study, however, does not include the effects of eroded sediments on sedimentation in waters and the direct and/or indirect effects on water quality, aquatic plants, waterfowl, water supply to communities, etc.

A land use/land cover mapping project of the Valley River watershed was undertaken and completed in 1983 to quantify land use changes on the Dauphin Lake Fishery resource (Pokrant and Goboury 1983). By 1980, there was 63% more land under cultivation than in 1948, 48% less woodland, 20% less pasture and 68% fewer wetlands. It was found that land clearing and drainage had a profound effect on the hydrologic regime of the Valley River with current spring peak discharge almost double that recorded between 1913 to 1918. Attenuation of flows after peak discharge has increased. The rapid flush was attributed to loss of woodland and wetland storage. It was suggested that the higher stream discharges and erosion of streambank increased sedimentation of bottom substrates covering suitable spawning areas and/or suffocating incubating fish eggs. It was also stated that the rapid attenuation of flows after spring discharge resulted in low flows in the stream during Walleye spawning and/or incubation periods causing de-watering of eggs and changes in water temperature. Survival of newly-hatched Walleye larvae would also be reduced due to reduced water flow.

Erosion and deposition from agricultural runoff has created a large delta at the mouth of Edwards Creek in Lake Dauphin and sedimentation within the lake. The siltation was considered a factor decreasing spanning areas and reduction in fish populations. The above study is being continued with the objective of assessing land use practices, pesticide use etc. on the pesticide, nutrient and sediment content of waters, and their effects on the Dauphin Lake fishery, waterfowl, wildlife and water supply to communities.

In addition to the above Studies, Manitoba Department of Water Resources conducts studies on the sediment load in rivers and the effect of these sediments on storage capacity of structures.

C. PESTICIDES

(1) Groundwater

Studies on the effects of agricultural practices on contamination of groundwaters with pesticides were initiated mainly during the last 10 to 15 years. Krawchuk and Webster (1987) studied the movement of pesticides and their residues to groundwater on a coarse textured soil which was irrigated and had a tile drain system. A total of 21 different pesticide formulations were used. An extensive sampling detected residues of chlorothalonil on eight occasions in 1982 hanging from 0.06 to 3.66 µg/L in the tile drain water.

Groundwater under the field was found to contain chlorothalonil at 10 to 272 µg/L in 1982 and from 0.4 to 9.0 µg/L in 1983. Carbofuran at concentrations of 11.5 to 158 µg/L in 1982 and <0.5 to 1.0 µg/L in 1983 were detected in groundwater.

Monitoring of groundwater in the Assinboine Delta aquifer for pesticides is presently being conducted by the Manitoba Department of Agriculture. To date, the presence of one herbicide (related to a spill into or adjacent to the well) was detected in one of the wells sampled. Studies are currently being conducted at the Department of Soil Science, University of Manitoba to determine the pesticide content of groundwaters in the Assiniboine Delta aquifer and to study pesticide-soil interactions related to fate and mobility of pesticides and their residues in soil. Pesticides were not detected in water samples taken from the aquifer and water quality met requirements set for domestic use. Work at present is focusing on characterization of some soils of the area, (i.e.) separation of the humic and fulvic acid fractions and particle size analysis. Soil-pesticide interactions with characterized fractions and whole soils have been studied with the herbicides atrazine, metribuzin and propanil to study the nature of adsorption and degradation in soil as it relates to movement.

(2) Surface Waters

Several studies to determine extent of contamination of surface waters with pesticides used in agriculture have been completed are ongoing or planned. Muir and Grift (1987) conducted a survey during March to October 1984 to determine levels of MCPA, diclofop-methyl, dicamba, bromoxynil, 2,4-D, triallate and trifluralin in the Ochre and Turtle Rivers which flow into Dauphin Lake. Triallate concentrations in the Turtle and Ochre Rivers, exceeded 25 ng/L and were unrelated to changes in river flow.

Bromoxynil and diclofop were found at concentrations of 113 and 476 ng/L, respectively, in the Turtle River after a major high water event, but were usually not detected at other sampling times. Dicamba and 2,4-D were detected at low levels <100 ng/L in both rivers at all sampling times. High levels of dicamba and 2,4-D (5476 and 2568 ng/L, respectively) were in the Turtle River at one sampling time. Total amount of herbicides discharged via the rivers represented less than 1% of the amounts of the seven herbicides used in the watershed. The study indicated that herbicide contamination of Manitoba streams draining agricultural areas is generally low except when major runoff occurs during the application period of the herbicide.

Kenny (1992) recently completed a study of the loss of the herbicides bromoxynil octanoate, dicloflop-methyl and atrazine from three soils in Manitoba. The study sites were located on land with 9% slope, the herbicides were applied at recommended rates, and runoff and sediments were collected for determination of concentration of herbicides. Percentage of herbicide lost via runoff was very low (Table 7). Concentrations of atrazine in runoff from the corn plots varied from about 250 to 900 g/L whereas the maximum concentration of de-ethyl atrazine in runoff varied from 8 to 50 g/L for the various sites. Maximum concentrations of dicylofop, Bromoxynil octanoate and Bromoxynil in runoff from the various sites were about 135 µg/L, 17 µg/L and 16 µg/L, respectively.

Pesticides can also enter surface waters via precipitation. Muir et al (1990) collected precipitation samples between May and October 1989 at the Experimental Lakes area (S.E. of Kenora, Ontario) to determine the inputs of anthropogenic organic chemicals. The specific objective was to calculate the flux of herbicides, widely used in Western Canada and the upper mid-west U.S. to this site from an agricultural region. The nearest agricultural region was about 200 km west of the study site. Seven herbicides, atrazine, trifluralin, dicamba, diclofop, bromoxynil, chlorthal-dimethyl (Dacthal) and triallate were routinely found in extracts of the water samples. Atrazine was the major herbicide in rainfall and varied from 42 to 197 ng/L in May to June to 2.9 to 6.3 ng/L in August to October. Bromoxynil, Dacthal and dicamba were also present at highest concentrations in June and lowest in the fall. Trifluralin and triallate were present at concentrations of 2 to 6 ng/L in fall, but not detected in samples in June. Annual fluxes, based on this 5-month survey, varied from 100 mg/ha for atrazine to 3 mg/ha for triallate. Trifluralin, triallate, bromoxynil, diclofop, and dicamba are widely used in various herbicide formulations used in Manitoba and North Dakota. Atrazine and Dacthal are not widely used in Manitoba or North Dakota and thus must have been transported from the corn growing areas in the U.S.A. (over 500 Km).

The above studies indicate losses of pesticides by runoff from agricultural land to be small (1.0%) of that applied. Despite these small losses there is a need to determine the effects of small amounts of pesticides or low concentrations of pesticides on the shifts in macro- and microphytes and other nontarget organisms. The study conducted by Muir *et al.* (1990) clearly shows that aerial transport and wash-out in precipitation is of concern. Perhaps more emphasis in research has to be placed on the aerial pathway of entry of pesticides into surface waters than via runoff. Studies are needed to examine volatilization of pesticides during and after application and fluxes into lakes and streams.

A study to investigate pesticide inputs into Lake Winnipeg is planned by the Freshwater Institute, Fisheries and Oceans. Inputs via runoff and precipitation will be measured. The effects of these inputs on fish as well as the source of the pesticides will be examined.

Studies have been conducted or are being conducted to determine the effect of pesticides in waters on non-target organisms. Muir *et al* (1991) studied the fate and toxicity of bromoxynil esters in a prairie wetland. The toxicity of a single application of bromoxynil octanoate and bromoxynil butyrate were studied in small experimental ponds in the Delta Marsh area of Manitoba. Ponds were treated at rates of 2.5, 50, 100 and 500 µg/L. Complete mortality of caged brook stickleback fry occurred within 24 h at the two highest treatments. Survival at the low and medium concentration treatments were 40 and 35%, respectively, after 50 hr whereas survival was 95% after 50 hrs in the control treatment. *Hyalella azteca* had higher survival rates than the stickleback fry. Survival of the amphipods in controls and low concentration treatments were similar (70% after 50 h). Survival was 40%, 15%, and 5%, one hour after application, at 35 to 64 µg/L, 86 to 110 µg/L, and at 290 to 650 µg/L, respectively. The studies showed that due to the possible impacts of these herbicides on aquatic macrophytes and algal communities studies of impacts of these pesticides on nontarget organisms be continued.

The effects of 1, 3, 6, 8 tetrachloro-dibenzo-p-dioxin, the principal tetrachloro-dioxin contaminant in 2,4-D, on aquatic systems was investigated, (Corbet and Webster (1988) and Muir *et al.* (1985)). Corbet and Webster (1988) found that 1,3, 6,8 tetrachlorodibenzo-p-dioxin bio-concentrated (10^4 to 10^5X) in floating and rooted aquatic vegetation. Muir *et al.* (1985) showed that transformation of 1, 3, 6, 8 TCDD to degradation products in soils and sediments was very slow. Other studies (Servos 1988) showed that the dioxin was bioavailable to benthic invertebrates and fish.

Studies ongoing at the Department of Botany, University of Brandon, have the objective of assessing the impact of commonly used agricultural herbicides on aquatic plants (algae and vascular plants). Changes in species, nutrient dynamics, O_2 levels in water as affected by herbicide levels are being studied. Preliminary results indicate that algal growth is reduced, photosynthesis is affected, nutrient in water increases and general productivity of the aquatic plant community decreases.

D. SUMMARY

The review of pertinent information shows that agricultural, in particular instances, has had or could have negative effects or quality of surface and groundwaters in Manitoba. The following are of particular concern:

(1) Contamination of groundwaters with NO_3-N from commercial N fertilizers and animal manures.

(2) Effect of sediments from agricultural land and other lands on fish populations, waterfowl, wildlife, water supply to communities, storage capacity of reservoirs, etc.

(3) Contamination of groundwaters with pesticides and the effect of loss of pesticides from agricultural land via runoff and precipitation(volatilization from agricultural land fallowed by wash-out in precipitation) on aquatic plants and other nontarget organisms.

REFERENCES

CAMPBELL, L.B. and G.J. RACZ. 1975. Can. J. Soil Sci. 55:457-466.

CHANG, C. and C.M. CHO. 1974. Proc. Man. Soil Sci. Soc. Publications Branch, Man. Dept. of Agric.

CORBET, R.L. and G.R.B. WEBSTER. 1988. Environ. Toxicol. Chem. 7: 167-180.

FIELD-RIDLEY, G. 1975. M.Sc. Thesis. Dept. of Soil Sci. Univ. of Man.

GRIFT, S., G. MORDEN, and C.M. CHO. 1992. Proc. Man. Soil Sci. Soc. Publications Branch, Man. Dept. of Agric.

HARGRAVE, A. 1972. M.Sc. Thesis. Dept. of Soil Sci. Univ. of Man.

HEDLIN, R.A. 1971. Can. J. Soil Sci. 51:75-84.

KENNY, D.F. 1992. M.Sc. Thesis. Dept. of Soil Sci. Univ. of Man.

KRAWCHUK, B.P. and G.R.B. WEBSTER. 1987. Water Poll. Res. J. Can. 22:129-146.

MCGILL, K.S. (Unpublished Data). Man. Dept. of Agric.

MICHALYNA, W. 1959. M.Sc. Thesis. Dept. of Soil Sci., Univ. of Man.

MUIR, D.C.G. and N.P. GRIFT. 1987. J. Environ. Sci. Health. B22(3):259-284.

MUIR, D.C.G., N.P. GRIFT, and W.M.J. STRACHAN. 1990. Abs. 18th Workshop on the Chemistry and Biochemistry of Herbicides, Regina.

MUIR, D.C.G., D.F. KENNY, and N.P. GRIFT. 1991. Environ. Toxicol. Chem. 10:395-406.

MUIR, D.C.G., A.L. YARECHEWSKI, R.L. CORBET, G.R.B. WEBSTER, and A.E. SMITH. 1985. J. Agric. and Food Chem. 33:518-523.

PARTRIDGE, J.R.D. and RACZ, G.J. 1972. Proc. Man. Soil Sci. Soc. Publications Branch. Man. Dept. of Agric.

PARTRIDGE, J.R.D. and G.J. RACZ. 1973. Proc. Man. Soil Sci. Soc. Publications Branch. Man. Dept. of Agric.

PAULS, W.J. 1987. M.Sc. Thesis, Dept. of Soil Sci. Univ. of Man.

POKRANT, H. and M. GABOURY. 1983. Report on "Remote sensing to assess land/use/land cover changes affecting the Dauphin Lake fishery. Man. Surveys and Mapping Branch.

RACZ, G.J. 1979. Can. J. Soil Sci. 59:337-339.

RACZ, G.J. Unpublished Data. Dept. of Soil Sci., Univ. of Man.

SERVOS, M.R. 1988 Ph.D. Thesis. Dept. of Soil Sci., Univ. of Man.

WAHOME, E.K. 1989. M.Sc. Thesis. Dept. of Soil Sci., Univ. of Man.

Table 1. Chemical Analysis of Groundwater Beneath a Feedlot on a Coarse Textured Soil (Partridge and Racz 1973).

Sampling Data	NO^-_3-N (ppm)	NO^-_2-N (ppm)	N_2O (mg/L)
May 15	37	6	0.1
May 29	31	14	0.5
June 13	23	19	1.1
June 26	33	19	0.7
July 9	27	20	0.4
July 24	25	23	0.1
Aug 7	40	15	0.2
Aug 21	42	17	0.3
Sept 4	36	14	0.1
Sept 18	53	11	0.2
Oct 2	57	8	0.3
Oct 15	62	8	0.2
Oct 29	60	7	0.2
Nov 12	51	7	0.1

Table 2. Effect of Different Cropping Practices on Soil NO_3-N Content (McGill, Unpublished Data)

Depth (m)	Soil NO_3-N Content (Kg/ha)		
	Annual Crops	Manure	Manure/fallow
0 - 0.3	37	109	155
0.3 - 0.6	50	88	104
0.6 - 0.9	32	75	139
0.9 - 1.2	18	75	84
1.2 - 1.5	13	48	53
1.5 - 1.8	13	39	36
1.8 - 2.1	10	34	32
2.1 - 2.4	10	32	22
2.4 - 2.7	8	32	18
2.7 - 3.0	7	31	13
Total	199	564	656

Table 3. Nitrate Nitrogen Content of Fallow and Non-fallow Land after Cropping to Barley (Kg/ha) (Racz, Unpublished Data)

	Fertilizer Treatment at Seeding (Kg N/ha)						
Depth (cm)	9	34	67	100	134	202	269
Fallow sites							
0 - 60	21	27	35	46	65	109	153
60 - 120	18	18	16	18	20	21	31
0 - 120	39	45	50	53	85	130	185
Stubble sites							
0 - 60	19	17	22	35	34	83	150
60 - 120	13	13	15	19	19	30	43
0 - 120	32	30	37	54	53	113	193

Note: Nitrate nitrogen at seeding in (a) fallow sites: 0 - 60 cm - 83 kg/ha; 0 - 120 cm 105 kg/ha; and (b) stubble sites: 0 - 60 cm - 24 kg/ha; 0 - 120 cm - 37 kg/ha.

Table 4. Nitrate-nitrogen content of groundwater in two coarse textured soils (Grift *et al.* 1992)

	Nitrate-Nitrogen Content (Mg N/Kg)*		
	Site 1		Site 2
Date	Unfertilized	Fertilized	
June	-		51
July	7.0	8.3	59
August	4.6	6.2	58

* Values are means for samples obtained in each month.

Table 5. Total Phosphorus losses due to Water Erosion (Hargrave 1992).

Site	[TP] Antecedent	[TP] Sediment	(1)	(2)	(3)
Gretna C	788	939 a*	72.0	0.42 a	0.085 a
Ryerson SCL	677	882 a	5.4	0.03 b	0.006 b
Carroll CL	757	794 b	7.2	0.02 b	0.005 b
Leary SL	514	469 c	10.9	0.09 b	0.022 b
LSD 0.05		62		0.23	0.046

1. Average annual total phosphorus losses (kg P ha^{-1} y^{-1})
2. Total phosphorus losses per mm of rainfall (kg P ha^{-1} mm^{-1})
3. Total phosphorus losses per erosive unit (kg P h MJ^{-1} mm^{-1})

* Means followed by the same letter within each column did not significantly differ ($p<0.05$).

Table 6. Total Nitrogen Losses due to Water Erosion (Hargrave 1992).

Site	[TN] Antecedent	[TN] Sediment	(1)	(2)	(3)
Gretna C	1630	2379 b*	162.0	0.96 a	0.201 a
Carroll CL	2374	2938 a	23.9	0.08 b	0.016 b
Ryerson SCL	2216	2865 a	15.4	0.09 b	0.018 b
Leary SL	408	458 c	7.2	0.05 b	0.012 b
LSD 0.05		179		0.48	0.088

1. Average annual total nitrogen losses (kg N ha^{-1} y^{-1})
2. Total nitrogen losses per mm of rainfall (kg N ha^{-1} mm^{-1})
3. Total nitrogen losses per erosive unit (kg N h MJ^{-1} mm^{-1})

* Means followed by the same letter within each column did not significantly differ ($p<0.05$).

Table 7. % Loss of Applied Herbicide (Kenny 1992)

Site	Bromoxynil Octanoate	Diclofop Methyl	Atrazine
Miami	0.05	0.06	0.51
Roseisle	0.18	0.08	0.59
Whitewater	0.06	0.83	0.23

AGRICULTURAL IMPACTS ON WATER QUALITY IN SASKATCHEWAN

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INTRODUCTION

Concerns over the deteriorating water quality from non-point sources have resulted in numerous studies of nutrient and pesticide loss via agricultural run-off (Asmussen *et al* 1977; Burwell *et al* 1975; Dunigan *et al* 1976; Sharpley and Syers 1983; Wauchope 1978; White *et al* 1976). Many of these studies have been conducted in United States where climatic conditions and agricultural practices often differ from those in Saskatchewan. Although it is recognized that the use of agrochemicals has increased, little information is available on water quality. This paper will attempt to summarize known studies in Saskatchewan.

NUTRIENTS:

Nitrogen and Phosphorous:

Nitrogen exists in a variety of forms which are continually changing due to chemical and biological transformations. Nitrate, the most oxidized form of nitrogen, is the principal form of nitrogen found in natural waters. A major source of nitrates is human and animal waste. Ammonia is the most reduced form of nitrogen; it results from decomposition of organic matter and is a constituent of treated sewage. Organic nitrogen results from nitrogenous debris and biological transformations. Total Kjeldhal nitrogen is a measure of ammonia and organic nitrogen and is an indication of nitrogen available for biological activity.

Phosphorous is the nutrient that commonly limits weed growth in fresh waters. It can occur in numerous organic and inorganic forms, and as dissolved and particulate species. Total phosphorous, total dissolved phosphorous and soluble reactive phosphorous species are the species for which data is usually available. Soluble reactive phosphorous is the fraction which is most actively taken up by plants. Particulate phosphorous consists of phosphorous in association with sediment, some of which may be available under oxygenated conditions. The amount of phosphorous in each form is constantly changing due to the process of decomposition and synthesis. Phosphorous from effluent generally contributes to the dissolved fraction. Phosphorous from agricultural sources is evident in the dissolved, as well as the particulate phosphorous fractions.

A South Saskatchewan River Basin Report (1991) suggests that in the concentrations of total Kjeldahl nitrogen, nitrite-nitrate do not appear to change over time except for normal seasonality. Chlorophyll-a and ammonia values tend to be higher in recent years, whereas ortho-phosphorous may be decreasing in concentration.

A South Saskatchewan River Basin study report (1991) indicates that phosphorus loading in Lake Diefenbaker is a function of upstream loading. Total phosphorous levels are attributed to a high quantity of suspended material. The concentrations show variation, reflecting the increase in particulate and flow in the spring and decline through summer and fall. Concentrations do not appear to change from year to year.

Nicholaichuk and Read (1978) measured the nutrient transport in surface runoff from snow on cropped and summerfallowed fields on a Brown Chernozemic soil (Wood Mountain loam) in S.W. Saskatchewan. Fertilizer was applied at a rate of 54 kg/ha to one summerfallow plot. The fertilizer was left on the frozen ground in the late fall to increase the possibility of loss via runoff. From the six year study, nutrient losses were much greater from summerfallow than stubble plots especially in the higher runoff years. The six year average loss of Nitrate-N was 0.1, 0.3 and 0.3 kg/ha/yr for stubble, sunnmerfallow and fall-fertilized summerfallow respectfully. Similarly, for Nitrate-N, the average loss was 0.4, 2.5 and 4.1 kg/ha/yr. For total phosphorus in snowmelt, the average loss was 0.4, 1.4 and 2.9 kg/ha/yr for stubble, unfertilized summerfallow and fall-fertilized sunnmerfallow respectively. The 6-year average loss of orthophosphorous in snowmelt runoff was 0.1, 0.2, and 1.2 kg/ha/yr for the stubble, summerfallow and fall-fertilized summerfallow plots, respectively.

A similar watershed study (Harrison and Waite 1989) was conducted in Southern Saskatchewan to assess potential fertilizer impacts. They found 1.4 to 1.5% of the TP was found in surface runoff compared to a 9.8% los of late fall applied fertilizer Nicholaichuk and Read, (1978).

A more recent study conducted under irrigation conditions (Nicholaichuk *et al* 1988) suggest that 0.22% and 0.10% of the applied phosphorous and nitrogen was lost to surface drainage water. Loss of either nutrient in the first irrigation was approximately twice that in the second irrigation.

The three Saskatchewan studies indicate that although losses in spring runoff are not agronomically significant, the concentrations can exceed the Canadian Water Quality Guidelines (1987).

PESTICIDES

Pesticide research and monitoring in Saskatchewan is summarized in the annual report of Environment Canada's Research Program (1988).

A survey of 43 community water well supplies scattered throughout rural Saskatchewan for herbicides indicated that for a majority of the samples analyzed their were no positive detections. In another survey by NHRI, low level traces of herbicides such as diclofop-methyl, 2,4-D, MCPA, triallate and dicamba could be found in some groundwater samples from beneath irrigated lands.

With respect to surface water within the South Saskatchewan River Basin, all the anthropogenic organic contaminants potentially present in the basin are listed in the SSRBS Technical Report D.4. Many of the identified compounds did not appear to pose a threat to aquatic life. The maximum values that were observed in the basin were below the Saskatchewan water quality objectives; atrazine, alpha-BHC, carbofuran, dicamba, 2,4-D, picloram and 2,4,5-TP. Other compounds had no detectable levels in the basin: chlorpyriphos, DDT and metabolites, diallate, methoxychlor and trifluralin. Although routine water quality monitoring data suggests that methoxychlor does not pose a threat to aquatic life, special studies have identified low levels in sediments, plants, invertebrates and fish.

In an irrigation study to determine the impact of corrugation irrigation return flows on receiving waters, the total loss to drain water was 0.13% (0.13 g/ha) of dicamba and 0.11% (0.44 g/ha) of MCPA (Nicholaichuk *et al.* 1988). The maximum concentrations observed were 4.3 and 10.7 µg/L of Dicamba and MCPA respectively. The highest concentration of herbicides was found in the first flush of surface drain water from irrigation as opposed to the second. Only trace levels were observed in the groundwater (Maathuis et al 1988).

In another recent study (Nicholaichuk *et al* 1992) to determine the movement of herbicides in the unsaturated zone under sprinkler irrigation conditions, the total herbicide concentration did not exceed water quality guidelines of 10 µg/L in any of the water samples. Dicamba and bromoxynil were not found in significant quantities in the lysimeters or drainage effluent. 2,4-D was detected in a large number of samples from all soil depths and the tile drain (<0.05 µg/L).

Diclofop was not detected in as many samples as 2,4-D but the concentrations measured were generally greater (0.2 µg/L). On the last sampling in each year, diclofop was still present in the lysimeters in significant concentrations (>0.05 µg/L). Diclofop tended to be greatest in the water samples from 150 cm depth.

SUMMARY

Within the South Saskatchewan River Basin, eutrophication was identified as a water quality issue (SSRB Report D.4). Enrichment of a water body is a concern due to the potential for promotion of excess growth of algae and aquatic weeds and for changes in the biological community. An increase in biological productivity may impair various uses of the water body. To this end, studies in Saskatchewan do indicate the rate of eutrophication may be increased by current agricultural practices. Saskatchewan based studies suggest that levels of nitrate and phosphorous in surface runoff from agricultural practices can exceed current water quality guidelines.

To assess the impacts of contaminants in surface waters, an assessment of the state of aquatic health is required. The true condition of any water body is the health of the biological organisms which inhabit it. A South Saskatchewan River Basin review of all potential compounds that may be a threat to aquatic life suggests that all compounds are well within the Saskatchewan Surface Water Quality Objectives.

Specific studies to examine agricultural impacts on surface and groundwater suggest that trace levels of pesticides do move in surface waters and into groundwaters. Although the levels are well within guidelines, the main concern is the cumulative effect of pesticides and the potential impact of degradation products from these chemicals.

REFERENCES:

ASMUSSEN, L.E., A.W. WHITE, E.W. HAUSER, and J.A. SHERIDAN, 1977. Movement of 2,4-D in a vegetated waterway. J. Environ. Qual. 6: 159- 162.

BURWELL, R.E., D.R. TIMMONS, and R.F. HOLT. 1975. Nutrient transport in surface runoff as influenced by soil cover and seasonal periods. *In* Proceedings of the Soil Science Society of America. 39th Annual Meeting, Knoxville, Tennessee. 39 (3): 525-528

CCREM 1987. Canadian Water Quality Guidelines. Canadian Council of Resource and Environment Minister. Prepared by the Task Force on water Quality.

DUNNIGAN, E.P., R.A. PHELAN, and C.L. MONDART, JR. 1976. Surface runoff losses of fertilizer elements. J. Environ. Qual. 5(3): 339-342.

ENVIRONMENT CANADA 1989. Pesticides Research and Monitoring. Annual Report 1987-988. En 40-11/13-1988E. Minister of Supply and Services Canada, Ottawa.

HARRISON J.T. and D.T. WAITE, 1989. A study of nutrients and trace elements in an agricultural watershed. Report CP(EP)WNR89/90-1. Environment Canada. Regina. Sask.

MAATHIUS, H., V. WASIUTA, W. NICHOLAICHUK and R. GROVER. 1988. Study of herbicides in shallow groundwater beneath three irrigated sites in Outlook Irrigation District, Saskatchewan. Saskatchewan research Council Publication R-844-13-E-88

NICHOLAICHUK, W. and D.W.L. READ. 1978. Nutrient runoff from fertilized and unfertilized fields in western Canada. J. Environ. Quality.

NICHOLAICHUK, W., R. GROVER, and J. Whiting. 1988. Herbicide, Nutrient and Water Balance from an Irrigated Field. Abstracts, 6th IWRA World Congress on Water Resources. Ottawa. National Hydrology Research Institute Contribution No. 8803.

NICHOLAICHUK, W., K.B. BEST, A.J. ELLIOT, A.J. CESSNA, L. KERR, and R. GROVER. 1992. Final Report: Herbicide and nutrient loss using low pressure (high volume) irrigation systems.

SHARPLEY, A.N., and J.K. SYERS. 1983. Transport of phosphorous in surface as influenced by liquid and solid fertilizer phosphate addition. Water, Air and Soil Pollution, 19:321-326.

WAUCHOPE, R.D. 1978. The pesticide content of surface waste draining from agricultural fields - A Review. J. of Environ. Qual. Vol. 7, no.4.

WHITE, A.W., L.E. ASMUSSEN, E.W. HAUSER, and J.W. TURNBULL, 1976. Loss of 2,4-D in runoff from plots receiving simulated rainfall and from a small agricultural watershed. J. Environ. Qual. 5: 487-490.

1991 Canada-Saskatchewan South Saskatchewan River Basin Study. Technical Assessment B: Water Quality. South Saskatchewan River Basin Study Office. Moose Jaw, Sask.

1987 South Saskatchewan River Basin Technical Report D.4: Contaminant Organic Compounds in Surface Waters of the South Saskatchewan River Basin. South Saskatchewan River Basin Study Office. Moose Jaw, Sask.

AGRICULTURAL IMPACTS ON WATER QUALITY IN ALBERTA

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INTRODUCTION

Alberta's agricultural land base is approximately 24M ha (Figure 1). According to 1988 Alberta Agriculture statistics, there are 57,777 farms in Alberta, occupying about 20 M ha. Of this, approximately 9.6 M ha was cropped in 1988. Alberta has the largest area under irrigation (560,000 ha), accounting for 62 percent of Canada's total irrigated land base. Most of this irrigation takes place within the 13 organized irrigation districts within the South Saskatchewan River Basin (Figure 2).

Most of the irrigation in Alberta utilizes surface water diverted from one of three river systems; the Bow, the Oldman and the St. Mary. The water originates in the foothills and the Rocky Mountains and is trapped and stored by during spring snowmelt by a series of dams and on and off-stream reservoirs. Approximately 10,000 km of canals, lateral and ditches deliver the water to the individuals farmers within the 13 irrigation districts. Farmers outside of these organized districts pump water directly from the rivers and reservoirs.

Agriculture is the major water user in Alberta, with estimates as high as 90 - 95 percent of the total water consumed each year. Irrigation, which represents the most intensive agriculture in the province, is responsible for most of this consumption. In the South Saskatchewan Basin, irrigation expansion limits are being imposed to ensure that over-allocation of the current water supplies does not occur.

Public awareness and concern about water quality has increased over the past decade in Alberta, due in large part to well publicized problems in the Great Lakes area of Canada and the United States and California's irrigation regions. Alberta and the other prairie provinces have not been considered as high risk for water quality problems because of relatively low precipitation and less intensive agricultural development than other parts of Canada. However, where extensive irrigation is practised, concerns are now being expressed about pesticide contamination (Leblond, 1990).

In the past 2-3 years, Agriculture Canada and Alberta Agriculture have significantly expanded research and monitoring activities related to organic and inorganic contaminants in surface and groundwater regimes. Much of this work has focussed on the irrigated areas because of the relatively large amounts of water and chemical inputs used and the presence of secondary agricultural processing related to irrigation agriculture. Alberta Environment is also carrying out increasing monitoring of surface and groundwater quality outside of the irrigation areas.

This paper will discuss the current understanding of agriculturally related water quality issues in Alberta and outline monitoring and research work being carried out. Four main contaminant areas will be discussed, including: Pesticides; Nitrates; Salts; and Trace Elements. Very little work has been carried out on biological issues and will therefore not be covered in any detail in this paper.

PESTICIDES

Total pesticide use in Alberta in 1986 was estimated at 5,700 tonnes of active ingredient (Davis *et al*, 1989). Herbicides were the predominant pesticide used (5,251 tonnes). Assuming the total pesticide application relative to annual cropped land (9.6 M ha), approximately 0.6 kg/ha is used. This is considerably less than application rates for Ontario and much of the United States. Data is not readily available which differentiates dryland and irrigated pesticide use in Alberta, although it is acknowledged that in general greater quantities of a broader range of pesticides would be used for irrigated crops.

In general, monitoring has been inadequate to provide a clear picture of potential pesticide contamination in either surface or groundwater. The limited monitoring which has been conducted showed no evidence of pesticide contamination problems. Environment Canada's monitoring and analyses at 29 locations for 16 rivers provides the best available information on changes in pesticide levels as rivers flow through agricultural areas.

Water quality analyses carried out in 1985 on the South Saskatchewan River at the Alberta/Saskatchewan border show very low levels of pesticides, usually below the detection limits (Environment Canada, 1985). These levels are very similar to those found in the Bow River at Cochrane (upstream of Calgary) and at Canmore (immediately downstream of Banff) and for the Oldman River north of Taber, which is located in an area of intensive irrigation. Similar results are found for other rivers located within the major agricultural areas of the province.

A monitoring program initiated in 1986 by Alberta Environment, in cooperation with the Food Production and Inspection Branch of Agriculture Canada, collected more than 300 water samples from sixty five surface and groundwater sources in southern

Alberta. The analyses found no evidence of pesticides above the detection limit of 1 µg/L (Shaw, 1991). No residues were found to exceed the Maximum Acceptable Concentration permitted in water by Health and Welfare Canada (1987). Trace levels of Bromoxynil were found in one sample in 1988 (0.9 µg/L) and one sample in 1989 (0.3 µg/L).

Two research studies, initiated in 1991 under the Federal Environmental Sustainability Initiative, did show site-specific occurrences of pesticide contamination in surface and shallow groundwater under irrigated conditions. The first study, carried out by Alberta Agriculture, monitored herbicide levels in shallow groundwater and subsurface drainage effluent under four sprinkler irrigated fields and surface runoff and subsurface drainage under a flood irrigated field. Herbicides were detected in the shallow groundwater and subsurface drainage effluent during irrigation events at three of the five sites (Rodvang and Riddell, 1992). Generally, the detected herbicides were well below drinking water standards, with the exception of diclofop-methyl, which was detected at concentrations of 130 µg/L in the shallow groundwater at one site and 137 µg/L in the drainage effluent at a second site. This was somewhat surprising since diclofop-methyl is considered an improbable leacher. In addition, herbicides were detected which had not been applied during the 1991 crop season.

A second study, initiated by Agriculture Canada, evaluated herbicide levels in surface runoff and groundwater under both conventional and surge irrigation during the 1991 at two sites (Miller *et al*, 1992). At one site, significant concentrations of hexazinone were found in both the surface runoff and shallow groundwater at levels of 35 µg/L and 38 µg/L respectively. At the second site, concentrations of dicamba (15 µg/L), 2,4-D (29 µg/L) and mecoprop (4.8 µg/L) were found in the shallow groundwater. Herbicides (dicamba, MCPA and diclofop-methyl) were also found in the surface runoff from flood irrigation by Nicholaichuk *et al.* (1989) in Saskatchewan.

The presence of herbicides in the shallow groundwater was somewhat surprising, particularly since their detection occurred very quickly after irrigation was initiated. This suggests that unsaturated flow through soil cleavage zones or through earthworm and root channels plays a significant part in the movement of the pesticides into the groundwater system.

The results of these two studies, while not conclusive, do suggest that herbicide movement into the shallow groundwater is occurring under normal irrigation practices. Additional work is required to fully characterize the movement processes and determine the potential impact on groundwater and surface water regimes. The data also suggests that pesticide movement into the shallow groundwater under dryland conditions may also occur, particularly in areas where rainfall is significant. There is some concern about the potential contamination of surface and groundwater as a result of widespread adoption of minimum or zero tillage practices on the prairies. The increased dependency and multiple application of herbicides for broad spectrum weed control with minimum tillage systems, particularly with chemical summerfallow, may increase the potential risk of surface or groundwater contamination. This could occur not only through pesticide movement through macropores but also as a consequence of wind-blown sediment or surface runoff (Grover, 1991). Some recent analyses of wind-blown soils in southern Alberta and Saskatchewan indicated the presence of residues form several herbicides (Cessna, personal communication). However, there were no detectable levels of glyphosphate, the most commonly used minimum tillage herbicide, from the analysis of soil and groundwater samples under long-term (10-25 years) zero tillage fields in southern Alberta.

NITRATES

Contamination of surface and groundwater by nitrates is a growing concern in Alberta. Leaching of nitrate through the soil profile into the shallow groundwater from agricultural fertilizer use and manure management for intensive livestock operations is the greatest concern. Stein (1976) conducted groundwater studies in the Edmonton area and found that nearly half of the wells contained nitrate-N concentrations in excess of 10 mg/L, with many in excess of 100 mg/L. Both human and animal waste were thought to be the major contributors. Hendry *et al.* (1984) found high nitrate-N levels in areas of southern Alberta and attributed them to geologic sources rather than recent agricultural ones. Dryland saline seeps may contain nitrate-N concentrations of 50- 100 mg/L (Brown *et al.*, 1982). These "geologic" contributions often make it difficult to analyze the agricultural impacts on nitrate contamination of groundwater and surface waters.

A monitoring study carried out in 1991 on 38 irrigation return flow channels showed average nitrate-N concentrations of 0.1 mg/L (Bolseng, 1991), well below the maximum drinking water standard of 10 mg/L (CCREM, 1987). This corresponds to an earlier study which monitored irrigation supply and surface drains associated with flood and sprinkler irrigation in the Vauxhall/Hays area of southern Alberta (Oosterveld and McMullin, 1979). They estimated that 1.5 percent of the applied fertilizer N and 1 percent of the fertilizer P was exported from each of the predominantly flood and sprinkler irrigated basins respectively.

Fertilizers

The total nitrogen fertilizer (actual N) sold in Alberta in 1985 was approximately 353,000 tonnes (Goettel, 1987), which is a significant increase from the 90,000 tonnes sold in 1968. In 1985, nitrogen (actual N) application rates on dryland ranged from about 20 kg/ha in the drier areas to 45-60 kg/ha in central Alberta. In general, crop N uptake equals or even exceeds N application rates for most soils (Goettel, 1987), which suggests that excess nitrate-N movement below the root zone and into the shallow groundwater should not be a problem. This is supported by research carried out by Heaney *et al.*, (1988) which showed negligible nitrate-N accumulations on hayland when recommended N application rates did not exceed 120 kg/ha. However, at N application rates above 150 kg/ha, significant accumulations of nitrate-N occurred, which could result in leaching to the groundwater if precipitation was sufficient.

A survey carried out in the irrigation districts of southern Alberta found that for barley, the average nitrogen (actual N) applied under irrigation was approximately 100 kg/ha, while for dryland the rate was about 50 kg/ha. For crops such as sugar beets, which are grown only on irrigated land, the average N application was approximately 165 kg/ha. Nitrate movement to the shallow groundwater is of particular concern with irrigation since leaching is a requirement to ensure that salt balances are maintained and irrigation remains sustainable. While crop uptake under irrigation is much higher than for dryland, the potential for nitrate leaching is significant, particularly on sandier soils.

A study carried out in the Taber area, where pivot irrigation on sandy soils was being carried out, found little evidence of fertilizer nitrate-N moving into the underlying groundwater (Burnett, 1981; Pike-Glover, 1982). However, monitoring of shallow subsurface drainage systems installed in irrigated sandy soils has found significant nitrate-N concentrations in the drainage effluent. It is estimated that approximately 25 percent of the subsurface drains installed throughout the irrigation districts contains nitrate-N concentrations in excess of 10 mg/L. However, the flows from these drainage systems are generally very low, with 95 percent having less than 1 L/S. The impact of these drainage systems on surface receiving streams is considered to be negligible.

Nitrate (and phosphorus) contamination of streams and lakes through surface runoff is becoming an increasing concern in central and northern Alberta. Similarly, this process of eutrophication in irrigation canals and dugouts leads to the rapid increase in aquatic vegetation which reduces water delivery efficiency and the subsequent need for chemical control.

A joint research project, involving a number of federal and provincial government agencies under the Committee on Biological Control of Aquatic Vegetation, is evaluating the use of triploid grass carp (*Ctenopharyngodon idella*) for weed control. Preliminary results from this research are very promising. If successful, chemical herbicides would no longer be required for weed control in the irrigation canals and farm dugouts throughout the province.

Livestock

Nitrogen contamination related to intensive livestock operations likely poses the most serious threat to surface and groundwater in Alberta. It is estimated that approximately 4800 cattle feedlots currently operate in Alberta, with 3300 of these located in or adjacent to the irrigated areas of southern Alberta. In addition, about 1.75 M hogs and 8.5 M chickens/turkeys are fed throughout the province.

Runoff from the actual feedlot or manure storage piles is of concern throughout the province, particularly in central Alberta where precipitation and snowmelt are relatively high. Goatcher *et al.* (1991) studied surface runoff from 4 feedlots in Alberta (3 in the south and 1 in east-central Alberta). The research evaluated microorganisms, nutrients, metals and other contaminants and found that while minor to moderate water quality problems exist at the feedlots, the adverse affects were generally short-lived. However, the report suggested that surface waters immediately downstream of the feedlots not be used for "body contact recreational activities".

Leaching of nitrate-N below the feedlot itself does not appear to be a major concern. Studies have shown that the hoof action of the animals, combined with the dietary salts, dispersed the surface soil, thereby significantly reducing soil permeability (Mielke and Ellis, 1976). However, any surface runoff to areas immediately adjacent to the feedlot might result in nitrate-N leaching into the shallow groundwater. In Alberta, there seems to be little information regarding leaching below or adjacent to feedlot operations.

Manure spreading appears to be the major concern related to nitrate migration to the shallow groundwater. It is recommended that up to 22-27 Mg/ha of solid cattle and hog manure can be spread on dryland soils and up to 56-67 Mg/ha on irrigated soils (Alberta Agriculture, 1982). However, Chang *et al.* (1991) found that long-term applications of feedlot manure at these recommended rates on irrigated soils may result in nitrogen leaching into the groundwater system. Riddell and Rodvang (1992) monitored nitrate levels in shallow groundwater under five irrigated site where farmers had applied manure over varying time-frames.

Annual application rates varied from 20 - 60 Mg/ha. Nitrate-N levels in the shallow groundwater was greater than 10 mg/L under the manured treatments at all five sites. Somewhat surprising was the fact that nitrate-N levels were also high under two of the control sites, where manure had not been applied, perhaps the result of high fertilizer applications by the farmers in the past.

Using the 1982 Alberta Environment/ Agriculture guidelines, 1 ha of irrigated land (2 ha of dryland) is required to handle the manure from 30 feeder cattle. A 5000 head feedlot will therefore require approximately 160 ha of irrigated land (320 ha dryland) for annual manure disposal. The actual acreage needs to be somewhat higher of course, since hay and pasture lands are not normally used for manure disposal.

Based on the research carried out by Chang *et al.* (1991), the recommendations in the 1982 guidelines may need to be revised downward and feedlot operators may have to look for additional lands on which to safely dispose manure. Feedlot separation distances in many parts of southern Alberta are already short, which may result in increased hauling distances, and hence increased costs, for feedlot operators.

Additional research and monitoring needs to be carried out to better relate groundwater nitrate levels under actual feedlot manure disposal rates to the long term research results found by Chang *et al* (1991). The monitoring program also needs to be expanded to evaluate the impacts of manure disposal on groundwater nitrate-N in dryland areas in southern and central Alberta.

SALTS

The semi-arid climate of southern Alberta results in relatively high concentrations of salt in the soil and much of the groundwater regime. These salt concentrations are not normally high enough in the soil root zone to affect crop production. However, most of the salts are very soluble and can cause problems in both dryland and irrigated areas when excess groundwater further concentrates them in discharge areas. It is currently estimated that about 800,000 ha of dryland and 80,000 ha of irrigated land is affected to some degree by excess salts in the root zone.

Control and reclamation of these problem soils has been an important priority for the Alberta and Canadian Governments, farmers and irrigation districts for the past twenty years. Within the irrigated areas, one of the most successful methods of salinity control and reclamation is through subsurface drainage. While the practice has been utilized in dryland areas, most of the drainage is currently located within the irrigation districts.

Concerns about potential water quality problems resulting from the drainage effluent prompted Alberta Agriculture to initiate a monitoring program in the 1970's and early 1980's. These studies found that, while the salt concentrations in the drainage effluent was high, the flows were very low and the relative impact on the receiving waters was negligible (Harker, 1983). In 1990, many of these drainage sites were again monitored to determine whether changes to the flow and salt concentrations had taken place. The results of this monitoring showed no change in flow or salt concentrations, which supports the earlier salt loading projections.

Average electrical conductivity (EC) values for 38 irrigation return flow channels monitored in 1991 was 0.4 dS/m, which is similar to the EC value of the river water prior to initial diversion into the irrigation canals (Bolseng, 1991). Salt loading in the irrigation return flow channels does not appear to be a concern. This is not surprising since most irrigation return flow water simply flows through the irrigation canals.

Alberta Agriculture has conducted a number of hydrogeologic studies to evaluate the impact of irrigation development on groundwater quality and subsequent impact on rivers. Studies were completed in the Milk (Robertson, 1988), the Oldman (Hendry *et al.*, 1982) and the Bow River (Hendry, 1981) basins. Results from these studies show that subsurface irrigation return flows have minimal impact on surface water quality, even in areas where intensive irrigation has been practiced for some 70-80 years.

Salt movement into streams and lakes through surface runoff is generally not considered a problem because of the relatively low precipitation in areas where surface salts collect. Monitoring during severe summer storm events have shown high salt levels in surface runoff, but the time frame is usually short and the overall impact negligible.

TRACE ELEMENTS

In general, natural trace element concentrations are relatively low in Alberta soils and contamination sources, including sewage sludge and fly ash applications, are not thought to be a problem if appropriate application rates are followed (Abboud, 1986). However, public concerns about trace elements in surface and groundwater has increased in Alberta, particularly in the irrigated areas. The Kesterson Reservoir controversy in the San Joaquin Valley of California accelerated the concern when it was found that surface drains flowing into the reservoir contained high concentrations of Selenium (Se), Arsenic (As), Molybdenum (Mo) and Boron (B) (Westcot, 1989; Tanji and Valoppi, 1989).

Alberta Agriculture has initiated monitoring studies to evaluate trace element concentrations in surface canals and subsurface drainage systems over the past 2-3 years. Se levels in subsurface drainage effluent was especially targeted. Results from the initial monitoring show that all trace elements analyzed were at concentrations at or slightly above minimum detection limits and well below accepted drinking water standards in both surface and subsurface drainage waters.

Chang et al (1991) studied Zinc (Zn) and Copper (Cu) levels in the soil profile beneath irrigated and non-irrigated manured land and found significant increases in Zn in the top 30 cm. The Cu content was not significantly changed. These results are supported by a similar study of manured fields by Alberta Agriculture in 1991 (Riddell and Rodvang, 1992).

Goatcher (1991) found trace element concentrations in the surface runoff from 4 feedlots were generally low and had no discernable impact on receiving surface waters.

Irrigation with sewage effluent is an effective method of waste disposal and will likely increase in Alberta. Concerns with this type of irrigation relates to concentrations of trace elements such as Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Mercury (Hg). Heavy irrigation applications on sandier soils may result in some leaching of any of these elements (Tanji and Valoppi, 1989). Strict guidelines and monitoring is required to ensure that shallow groundwater contamination does not occur.

FUTURE DIRECTION

The scattered monitoring and research which has been carried out in Alberta over the past decade indicates that serious water quality problems do not appear to be a serious concern. However, it is also recognized that information regarding the agricultural impacts on surface and groundwater in Alberta is totally inadequate and that a significant increase in monitoring and research is required. Both Alberta Agriculture, Alberta Environment and Agriculture Canada have all increased research and monitoring work in the past 2 years, particularly in the groundwater regime, where information is severely lacking.

Alberta Agriculture carried out a review of water quality issues related to irrigation in 1989 (Alberta Agriculture, 1990) to determine future research priorities. Pesticide contamination of groundwater was the top priority, not because it was considered the most serious problem, but it was the area we knew the least about. In addition, public concern about pesticide contamination has been heightened because of problems in parts of Europe and North America. Also, recent studies suggest that the sampling protocol for specific pesticides requires some review. Groundwater contamination by nitrates also ranked as a high priority, mainly because of concerns related to the disposal of manure from intensive livestock operations.

There will also be continued pressure to monitor the biological quality of surface and groundwater regimes and define the agricultural impacts.

There is no doubt that Alberta must become more proactive in evaluating surface and groundwater quality issues and developing appropriate recommendations before any serious problems develop. It is hoped that resources associated with the Federal Government's Greenplan may be made available for increased joint research and monitoring among various government departments in the next five years.

REFERENCES

ABBOUD, S.A. 1986. Are heavy metals a problem in Alberta? In 23rd Annual Alberta Soil Science Workshop Proceedings. University of Alberta, Edmonton, Alberta.

ALBERTA AGRICULTURE. 1990. Impact of irrigated agriculture on water quality. Land Evaluation and Reclamation Branch, Lethbridge, Alberta.

ALBERTA AGRICULTURE. 1988. Alberta 1987 irrigation survey. Statistics Branch, Edmonton, Alberta.

ALBERTA AGRICULTURE, ALBERTA ENVIRONMENT. 1982. Confinement livestock facilities waste management - code of practice. Print Media Branch, Alberta Agriculture, Edmonton, Alberta.

BOLSENG, T.A. 1991. Water quality in selected return-flow channels. Land Evaluation and Reclamation Branch, Alberta Agriculture, Lethbridge, Alberta.

BROWN, P.L., A.D. HALVERSON, F.H. SIDDOWAY, H.F. MAYLAND, and M.R. MILLER.1982.Saline-seep diagnosis, control and reclamation. USDA Conservation Research

Report No. 30. 22 pages.

BURNETT, R.W. 1981. An evaluation of a shallow groundwater flow regime near Taber, Alberta. M.Sc. Thesis, University of British Columbia. 275 pages.

CHANG, C., T.G. SOMMERFELDT, and T. ENTZ. 1991. Soil chemistry after eleven annual applications of cattle feedlot manure. J. Environ. Qual. 20: 475-480.

CCREM (CANADIAN COUNCIL OF RESOURCE AND ENVIRONMENT MINISTERS). 1987. Canadian Water Quality Guidelines. Prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers. Environment Canada, Ottawa, Ontario.

ENVIRONMENT CANADA, INLAND WATERS DIRECTORATE. 1985. Detailed surface water quality data, Alberta, Manitoba, Northwest Territories and Saskatchewan. Ottawa, Ontario.

GOATCHER, L.J., L.R. GOODWIN, A.K. SHARMA, M.R. BENNETT, B.S. WEST, F.P. DIEKEN, and A.A. QURESHI. 1991. Impact of cattle feedlot wastes on surface water quality in Alberta: microbiological and chemical surface water quality. Alberta Environmental Centre, Vegreville, Alberta. 181 pages.

GOETTEL, A.W. 1987. Crop nutrient removals and additions in Alberta. Pages 219-232 In 24th Annual Alberta Soil Science Workshop Proceedings. University of Alberta, Edmonton, Alberta.

GROVER, R. 1991. Nature, transport and fate of airborne residues. In Grover, R. And Cessna, A.J. (eds.) Environmental Chemistry of Herbicides. Volume II, CRC Press, Inc., Boca Raton, FL. pp. 89-117.

HARKER, D.B. 1983. Characteristics, trends and surface water quality implication of saline tile effluent. Pages 325-334 *In* R. H. French (ed). Salinity in watercourses and reservoirs. Proc. International Symposium on State-of-the-Art Control of Salinity. Salt Lake City, Utah.

HEANEY, D.J., E.D. SOLBERG, J.T. HARAPIAK, and M. NYBORG. 1988. Influences of fertilizer N management and region on nitrate leaching potential of several Alberta soils. In 25th Annual Alberta Soil Science Workshop Proceedings. University of Alberta, Edmonton, Alberta.

HENDRY, M.J. 1981. Subsurface return flows under irrigated lands in the Bow River Irrigation District. Alberta Agriculture, Lethbridge, Alberta.

HENDRY, M.J., D. GLOVER-PIKE, and R.G. BURNETT. 1982. Subsurface return flows under irrigated lands north of Taber, Alberta. Alberta Agriculture, Lethbridge, Alberta.

HENDRY, M.J., D. MCCREADY, and D. GOULD. 1984. Distribution, source and evolution of nitrate in glacial till of southern Alberta. Journal of Hydrology, Volume 70, pages 177-198.

LEBLOND, G. 1990. Growing Together - Federal-Provincial Agriculture Committee on Environmental Sustainability. Agriculture Canada, Ottawa, Ontario

MILLER, J.J., N. FOROUD, C. CHANG and B.D. HILL. 1992. Hexazinone and phenoxy herbicides in surface runoff and groundwater under conventional and surge irrigation. In 29th Annual Alberta Soil Science Workshop Proceedings (In Press). University of Alberta, Edmonton, Alberta.

MIELKE, L.N. and J.R. ELLIS. 1976. Nitrogen in soil cores and groundwater under abandoned cattle feedlots. J. Environ. Qual. Volume 5, pages 71-75.

PIKE-GLOVER, D. 1982. Hydrochemistry variations through saturated overburden deposits beneath an irrigated site in south-central Alberta. M.Sc. Thesis, University of Alberta, Edmonton, Alberta.

RIDDELL, K.M. and J. RODVANG. 1992. Soil and groundwater chemistry in irrigated land receiving manure applications in southern Alberta. Land Evaluation and Reclamation Branch, Alberta Agriculture, Lethbridge, Alberta.

RODVANG, J. and K.M. RIDDELL.1992. Monitoring of phenoxy-neutral herbicides in subsurface drain effluent in southern Alberta. In 29th Annual Alberta Soil Science Workshop Proceedings (In Press). University of Alberta, Edmonton, Alberta.

ROBERTSON, C. 1988. Potential impact of subsurface irrigation return flow on a portion of the Milk River and Milk River aquifer in southern Alberta. M.Sc. Thesis, University of Alberta, Edmonton, Alberta.

SHAW, G.G. 1991. Pesticides in the aquatic environment. Food Production and Inspection Branch, Agriculture Canada, Edmonton, Alberta.

STEIN, R. 1976. Hydrogeology of the Edmonton area (northeast segment). Alberta Research Council Report 76-1. Edmonton, Alberta.

TANJI, K. and L. VALOPPI. 1989. Groundwater contamination by trace elements. Pages 229-274 In H. Bouwer and R.S. Bowman (ed). Agriculture, Ecosystems and Environment. Elsevier Science Publishers B.V., Amsterdam.

WESTCOT, D., S. ROSENBAUM, and G. BRADFORD. 1989. Trace element buildup in drainage water evaporation basins, San Joaquin Valley. Pages 123-136 In J.B. Summers and S.S. Anderson (ed). Toxic substances in agricultural water supply and drainage. Proc. of the Second Pan-American Regional conference on Irrigation and Drainage. U.S. Committee on Irrigation and Drainage, Denver, Colorado.

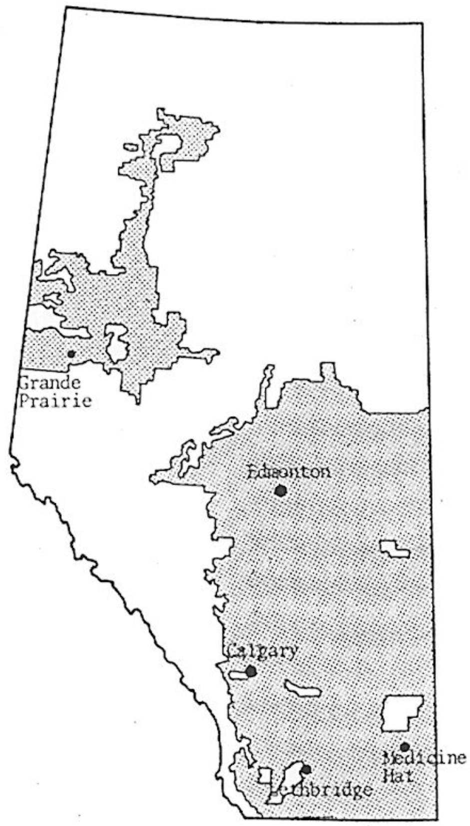

Figure 1: Agricultural Land Use

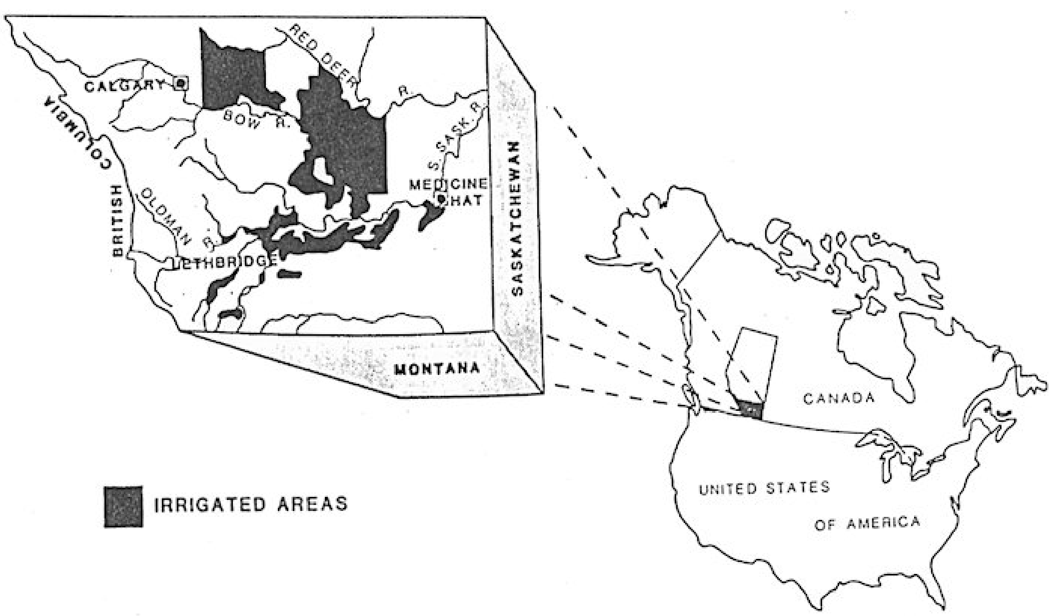

Figure 2: Irrigation in Alberta

WATER QUALITY ISSUES AND RESEARCH IN BRITISH COLUMBIA

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INTRODUCTION

The geography and climate of British Columbia is very diverse. As a result, the geographic distribution of agricultural production is complex. The province can, however, be divided into four distinct regions in terms of the climatic conditions and agricultural production: the Peace River, interior, Okanagan, and coastal regions. This report will first deal with water quality issues relating to the leaching of nutrients and pesticides on a region-by-region basis, and will then deal with water quality issues relating to surface run-off on a provincial basis.

PEACE RIVER

Approximately one-third of the agricultural land in British Columbia is located in the Peace River region (Table 1). This region is cold and dry (Table 2). The dominant agricultural production is cereal grains (Table 3). The region is similar to the prairie provinces, although the climate is somewhat wetter and a wider range of crops are grown. As a result, the water quality issues are similar to those in the prairie provinces and will not be dealt with in detail in this report.

INTERIOR

Approximately one-half of the agricultural land in British Columbia is located in the interior region (Table 1). The region is generally very dry (Table 2), however, total precipitation tends to increase with increasing elevation and some wetlands are present at higher elevations. Beef cattle production is the dominant agricultural industry and a large proportion of the land is used for grazing. Crop production is primarily for animal feed and a significant area of land is under irrigation.

In non-irrigated areas, the low annual precipitation precludes leaching of nutrients from being a major concern. A significant response to inorganic fertilizer nitrogen application can be observed from three to, in some cases, up to ten years following application (Mason and Miltimore 1972), indicating that losses of nutrients from the soil profile occur relatively slowly. In irrigated areas, there is a greater potential for nutrient losses, however, these losses are not considered to be a significant concern because application of water can be carefully controlled.

Pesticide usage is generally low in this region and pesticide leaching is not perceived to be a concern.

Water quality research in the region is focussed primarily on improving soil fertility management. The yield response to the application of major nutrients, how this response varies with climatic zone and crop species, the residual effects of the nutrient applications, and the economics of fertilizer application are being studied (e.g. van Ryswyk 1988).

OKANAGAN

This region is smaller in size than the previous two (Table 1), and consists primarily of mountain valleys. The climate is quite dry (Table 2), however, lakes and rivers within the region provide a ready source of irrigation water. Tree fruit production is the dominant crop in terms of gross farm return (Table 3).

Similar to the interior region, leaching of nutrients is not generally considered a concern because of the low rainfall and the high degree of control of water application provided through irrigation management. Many of the soils in the region are, however, very coarse textured and are susceptible to leaching. In many cases the nutrients are applied to tree fruits with the irrigation water.

Water quality is focussed primarily on improved irrigation management including improved application technology and improved recommendations for the quantity and timing of irrigation required. As a part of these studies, the influence of the time and quantity of water and nutrient applications on the efficiency of crop nutrient use, on the mobility of the applied nutrients, and on soil acidification resulting from the nutrient applications are being studied. Nitrogen is the major nutrient of concern in terms of leaching, although there is some evidence that phosphorus movement may be a concern in some of the very coarse soils (Neilsen, unpublished data).

Due to the coarse texture of the soils, leaching of pesticides is a concern and research on the potential for leaching of pesticides is ongoing. For example, soil column experiments have been used to determine the mobility and persistence of herbicides in orchards (Hogue *et al.* 1981).

COASTAL

This region is relatively small in terms of area of agricultural land, but produces over one-half of the gross value of agricultural production in British Columbia (Table 1). Agricultural production in the region is very intense: the mild temperatures and high annual precipitation provide few climatic limitations to crop production (Table 2). The dominant agricultural industries include dairy and poultry production although there is also a significant swine industry. Forage grass is the dominant crop produced and other major crops include silage corn and raspberries. There are also a wide variety of vegetable and other small fruit crops produced.

Leaching is a major concern in the region for three reasons. First, annual precipitation in the region is very high (in excess of 1500 mm annually) and occurs primarily outside of the growing season. Second, the winters are very mild and minimal soil freezing occurs. For example, mean monthly soil temperature at 1 cm depth at Agassiz is at or above 4°C for 11 months of the year (Ouellet *et al.* 1975).

As a result, leaching can occur year-round and significant chemical and biological activity can occur throughout most of the winter. Third, the land in the region is managed very intensively. For example, in excess of 11 million kg of manure nitrogen is excreted annually in the lower mainland and Vancouver Island (Table 4). This is the equivalent of approximately 140 kg manure nitrogen per ha of improved land. In addition, it was estimated from the 1981 census data that approximately 120 kg inorganic fertilizer N was also applied per ha of improved land.

Groundwater contamination is a concern in this region because of the factors listed above, and due to the presence of unconfined aquifers which have little or no stratigraphic protection against leaching. The Abbotsford Aquifer has been identified as a particular concern with respect to contamination by leaching of nitrates from the root zone.

The Abbotsford Aquifer is an unconfined sand and gravel aquifer approximately 100 km^2 in size in Canada and in excess of 100 km^2 in Washington state. The aquifer is an important source of domestic, municipal and industrial water supplies on both sides of the border. The B.C. Ministry of Environment has collected information which indicates that nitrate-N concentrations in the aquifer have been increasing since 1970. It is believed that agricultural production is a significant contributor to the elevated nitrate levels in the aquifer.

As a result of increased concerns over the environmental impacts associated with agricultural production, the Waste Management Act has been changed to include a Code of Agricultural Practice for Waste Management. This code will regulate the storage and use of agricultural wastes including animal manures, wood wastes, plant wastes. A series of guidelines, one for each commodity group, are currently being developed to provide guidance as to what management practices should be followed in order to comply with the code.

Water quality research in the region has focussed primarily on nitrogen management. The major objectives of the research have been to obtain a better understanding of nitrogen dynamics in the soil under local soil and climatic condition (e.g. Kowalenko 1987b; 1989), and to develop management practices which will utilize manure and fertilizer N more efficiently, thereby reducing the risk of nitrate leaching.

Research on improved efficiency of nitrogen use is currently underway in four broad directions. First, research is underway to obtain more accurate estimates of the nitrogen requirement of different crop species in the region (e.g. Kowalenko 1991); Zebarth *et al.* 1991). This research is hampered by the lack of an effective soil test for nitrogen. Second, work is underway to obtain a better understanding of the nitrogen dynamics associated with manure application, in order to better predict the quantity and timing of nitrogen availability in the soil (e.g. Maynard and Bomke 1980; Khan 1986; Paul and Zebarth 1992; Paul *et al.* 1992). This work includes research on dairy, swine and poultry manure on forage grass, silage corn, and raspberry crops. Third, research is underway to utilize improved cropping systems to improve the efficiency of nitrogen use. Included in this research is work on the use of inter-row cover crops in raspberries, use of shorter season silage corn crops in combination with overwintering forage crops, and relay cropping. Fourth, a major effort is being made to collect field data for calibration of the Nitrogen Management Model (Bulley and Cappalaere 1978). The model is designed to predict the influence of management decisions on the efficiency of nitrogen use, and the potential for nitrogen losses.

Proposed research at Agassiz includes reducing the nitrogen content of animal manure through improved feeding practices for poultry production and improved feed quality for dairy production, composting of swine and poultry manure for use on non-livestock operations, and improved technology for manure application on forage grass.

There is some concern over the potential for the leaching of pesticides in south coastal British Columbia, due in large part to the evidence of significant nitrate leaching occurring in the region. There is insufficient information available at this time, however, to evaluate to what extent pesticide leaching may be a concern in the region. A joint Environment Canada - Agriculture Canada study is currently underway to assess the degree of pesticide contamination of the Abbotsford Aquifer.

SURFACE RUN-OFF

The primary concern in B.C. with respect to runoff is its effect on fish. Fisheries are a major industry in the province and the Fraser River system drainage basin covers a large proportion of the province. Concerns for fisheries related to agricultural practices include the addition of sediments (i.e. turbidity), ammonium, pesticides and substances with a high biological oxygen demand to surface waters. Thus, a particular concern is surface run-off of animal manures into surface waters. Phosphorus additions to the Okanagan lake system is also a major concern (Epp 1990).

REFERENCES

BULLEY, N.R. and B. CAPPALAERE. 1978. A dynamic simulation model of nitrogen movement on livestock farms. Paper 7-211. Can. Soc. Agric. Engin. annual meeting, Regina, Sask.

EPP, P.F. 1990. Okanagan water quality control project. Pg. 292-298 in Soil Pollution in British Columbia, Proc. 13th B.C. Soil Science Workshop.

HOGUE, E.J., S.U. KHAN and A. GAUNCE. 1981. Leaching of four orchard herbicides in soil columns. Can. J. Soil Sci.

KHAN, M.R. 19867. Effects of rates and method of swine slurry application on crop nitrogen uptake and nitrogen distribution in the soil. Ph.D. thesis, UBC.

KOWALENKO, C.G. 1987a. An evaluation of nitrogen use in British Columbia. Agriculture Canada Research Branch Tech. Bull. 1987-3E.

KOWALENKO, C.G. 1987b. The dynamics of inorganic nitrogen in a Fraser Valley soil with and without spring or fall ammonium nitrate applications. Can. J. Soil Sci. 67:367-382.

Kowalenko, C.G. 1989. The fate of applied nitrogen in a Fraser Valley soil using 15 N in field microplots. Can. J. Soil Sci. 69:825-833.

KOWALENKO, C.G. 1991. Fall vs. spring soil sampling for calibrating nutrient applications on individual fields. J. Prod. Agric. 4:322-329.

KOWALENKO, C.G., S. FREYMAN, D.L. BATES and H.E. HOLBEK. 1989. An evaluation of the T-sum method for efficient timing of spring nitrogen applications on forage production in south coastal British Columbia. Can. J. Plant Sci. 69:1179-1192.

MASON, J.L. and J.E. MILTIMORE. 1972. Ten years' yield response of beardless wheatgrass from a single nitrogen application. J. Range Management 25:269-272.

MAYNARD, D.G. and A.A. BOMKE. 1980. The response of a grass-legume sward to poultry manure. Can. J. Soil Sci. 60:451-459.

OUELLET, C.E., R. SHARP and D. CHAPUT. 1975. Estimated monthly normals of soil temperature in Canada. Agrometeorology Research and Service, Can. Dept. Agric., Ottawa, Ont. Tech. Bull. 85.

PAUL, J.W. and B.J. ZEBARTH. 1992. Influence of time of manure application on leaching and denitrification - 1991 highlights. Agriculture Canada Agassiz Research Station Tech. Rept. No. 86.

PAUL, J.W., G. HUGHES-GAMES, and B.J. ZEBARTH (eds.). 1992. Proc. Manure Management Workshop, Abbotsford, B.C.

VAN RYSWYK, A.L. 1988. Wetland Management: Cariboo-Chilcotin. Pg 90-105 in Proc. Eleventh Meeting B.C. Soil Sci. Workshop.

ZEBARTH, B.J., S. FREYMAN and C.G. KOWALENKO. 1991. Influence of nitrogen fertilization on cabbage yield, head nitrogen content, and extractable soil inorganic nitrogen at harvest. Can. J. Plant Sci. 71:1275-1280.

Table 1. Distribution of farmland and irrigation in British Columbia based on 1981 census data (Kowalenko 1987).

	Peace River	Interior	Okanagan	Coastal	Total
Total land	19,506	45,675	2,146	21,934	89,130
Land in farms*	721	1,132	162	164	2,179
Improved farmland*	377	382	72	115	946
Irrigated land*	-	60	28	13	101
Average holding size (ha)	385	206	38	20	
Total crop value (millions $)	60	138	114	488	799

* Land area in thousands of ha.

Table 2. Climatic characteristics for four locations in British Columbia, one from each of four regions of agricultural production (Canadian Climate Normals 1951-1980, Atmospheric Environment Service).

	Dawson Creek (Peace River)	Kamloops (Interior)	Summerland (Okanagan)	Agassiz (Coastal)
	Mean Daily Air Temperature (°C)			
Year	0.9	8.7	8.9	10.1
January	-17.7	-5.4	-3.4	1.2
July	14.9	21.4	20.9	17.9
	Degree Days > 10°C			
	451	1311	1200	1014
	Total Precipitation (mm)			
Year	444	242	291	1693
May - Sept.	258	111	126	380
	Hours of Bright Sunlight			
Year	-	2048	2040	1513
May - Sept.	-	1298	1316	966

Table 3. Distribution of major crops in the different regions of British Columbia based on 1981 census data (Kowalenko 1987).

	Peace River	Interior	Okanagan	Coastal
		(Thousands of ha)		
Cereal grains	144,454	15,488	5,262	4,596
Corn	6	2,117	1,680	8,008
Alfalfa hay	28,272	69,009	16,893	1,752
Hay and other fodder	60,431	101,166	6,576	42,819
Vegetable	15	523	630	6,699
Tree fruits	-	791	10,437	289
Small fruits	2	78	1,239	4,260

Table 4. Annual manure nitrogen production in the lower mainland and Vancouver Island of British Columbia based on 1981 census data (Kowalenko 1987).

Species	N voided per year
	(kg voided per 300 days)
Cattle	5,724,900
Poultry	3,655,200
Pigs	1,525,800
Horses	285,600
Other	101,100
Total	11,292,600

SECTION II

REGULATIONS AND GUIDELINES

CANADIAN DRINKING WATER QUALITY GUIDELINES IN RELATION TO AGRICULTURE

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Health and Welfare Canada

INTRODUCTION

Under the Canadian Constitution the authority to regulate drinking water quality lies largely with the Provinces. The only exceptions are those areas in the Federal domain such as Indian Reserves and National Parks. Nevertheless we do have in place a system for setting national drinking water guidelines, and I am a member of the section within the Environmental Health Directorate of the Department of National Health and Welfare that does the health risk assessments for the Canadian Drinking Water Quality Guidelines' . The process for establishing a drinking water guideline is initiated when a contaminant is seen in drinking water with sufficient frequency to be of concern, or when the chemical is used in sufficient quantities that it is likely to be detected occasionally.

FIG. 1 - Risk Determination in Drinking Water

The health risk assessment is developed within the Criteria Section and a tentative maximum acceptable concentration (MAC) calculated. After external and management review the MAC is presented to the Federal-Provincial Subcommittee on Drinking Water.

FIG. 2 - New Guidelines, Steps for Approval

At this level there is consideration of the risk management issues which include what treatment technologies are available to remove or reduce the contaminant. Economics also play a role because the costs of complying can sometimes be considerable. Instances do arise where the MAC is raised to a higher value because there is no suitable treatment method, or the costs are unreasonable compared to the reduction in risk. Following approval by a majority vote the decision is forwarded to the Federal-Provincial Advisory Committee on Environmental and Occupational Health for their approval. At this level a unanimous vote is required to approve the MAC. The decision is then reported to the Conference of Deputy Ministers of Health. One year after publication of the MAC in the Guidelines it becomes effective if no objections are received and upheld. In a few provinces the health-based MACs have the force of law, but in most they are used as guidelines or objectives. The health risk assessment of a contaminant includes a thorough review of the literature available on its occurrence in the environment, and its chemistry, metabolism and toxicology.

FIG. 3 - Threshold vs Non-threshold Effects

If the literature shows clearly that it is an animal or human carcinogen then the risk is calculated on the assumption that there is no toxicity threshold and a linear extrapolation model is used. For a carcinogen the goal is to reduce the level to zero but practicality dictates that it cannot be lower than the lowest detectable level. In most cases the calculated risk at the MAC is usually 10^{-6} or lower for lifetime exposure. If the evidence suggests that the contaminant is not a carcinogen then a no observed adverse effect level (NOAEL) is calculated on the basis that there is a threshold.

FIG. 4 - Calculation of ADI from No-Observed Adverse-Effect-Level

An acceptable or tolerable daily intake (ADI or MI) is then calculated that incorporates uncertainty factors that vary with the data available and the type of toxicity observed. These factors usually lower the value by 100 to 1,000 times, and may be considered as a safety factor.

FIG. 5 - Calculation of MAC from ADI

The MAC is then calculated from the ADI using an average body weight and daily water intake, and an allocation to drinking water.

With regard to agriculture and drinking water I am going to concentrate on pesticides and nitrates since these are the major problems. In the registration of new pesticides consideration is now given to the potential to leach into groundwater. Many factors can affect this potential but the 4 major ones are volatility, solubility, adsorption onto soil and biodegradability.

FIG. 6 - Reasons for inclusion of Pesticides in GUIDELINES

Even though our current drinking water guidelines cover only a fairly small proportion of the total number of pesticides registered in Canada they do in fact cover about 80% of the total by weight actually used.

FIG. 7 - Agricultural Chemicals (pi chart)

The current situation is that there are remarkably few cases of pesticides exceeding the drinking water guidelines.

FIG. 8 - Margin of Safety between Guideline and Lowest NOAEL

Even when guidelines are exceeded it should be borne in mind that there are large safety margins built into the MACs. When problems do occur they are mostly in private wells in rural areas. Many of these problem cases are due to spills or excessive and improper use of the pesticide. Nitrate on the other hand seems to be growing problem, and there are areas of Canada where it is causing serious concern. This is particularly the case where major aquifers have become contaminated such as in the Fraser Valley, B.C. In this case the aquifer is being used to supply drinking water to large numbers of people using wells and there is no easy solution in regard to finding an alternate supply. It should be emphasized that farming is not the sole cause of this problem in many cases. Another important contributor is nitrate from septic systems. In terms of the toxic effects of nitrate it should be noted that most of it is due to its reduction to nitrite.

FIG. 9 - Derivation of Guidelines, Nitrate

Nitrite clearly causes methaemoglobin-aennia, although new born infants are much more prone to this effect than adults. In addition there are grounds for suspecting that nitrite can lead to the formation of carcinogenic nitrosamines in the gastrointestinal tract. This is a controversial area since although the chemical reaction can be readily performed *in vitro,* and some animal studies have been positive, there is no clear epidemiological evidence in humans with nitrate in drinking water.

REFERENCES

GUIDELINES FOR CANADIAN DRINKING WATER QUALITY. Fourth Edition, 1989. Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, K1A 0S9.

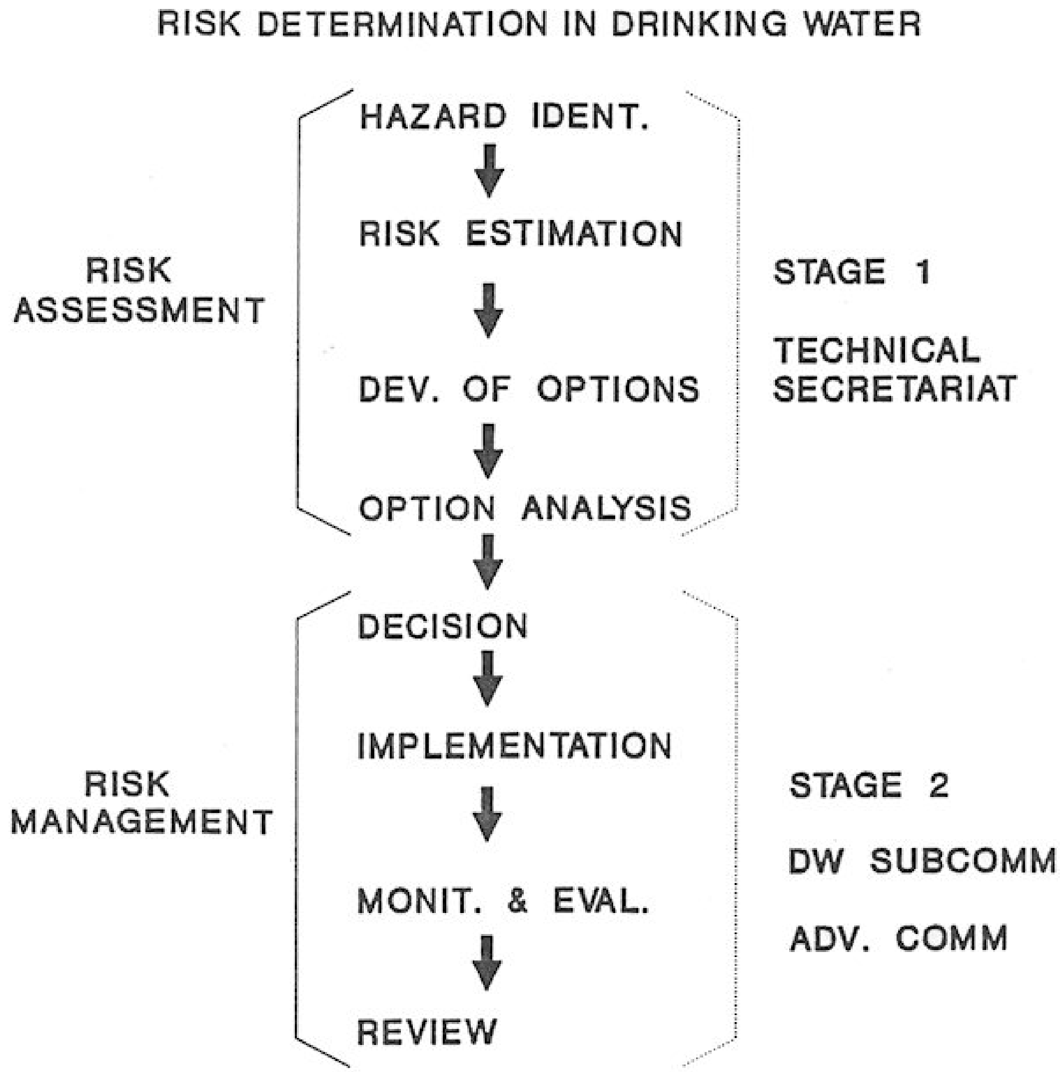

RISK DETERMINATION IN DRINKING WATER
HAZARD IDENT.
RISK ESTIMATION
DEV. OF OPTIONS
OPTION ANALYSIS
DECISION
IMPLEMENTATION
MONIT. & EVAL.
REVIEW
RISK ASSESSMENT
RISK MANAGEMENT
STAGE 1
TECHNICAL SECRETARIAT
STAGE 2
DW SUBCOMM
ADV. COMM

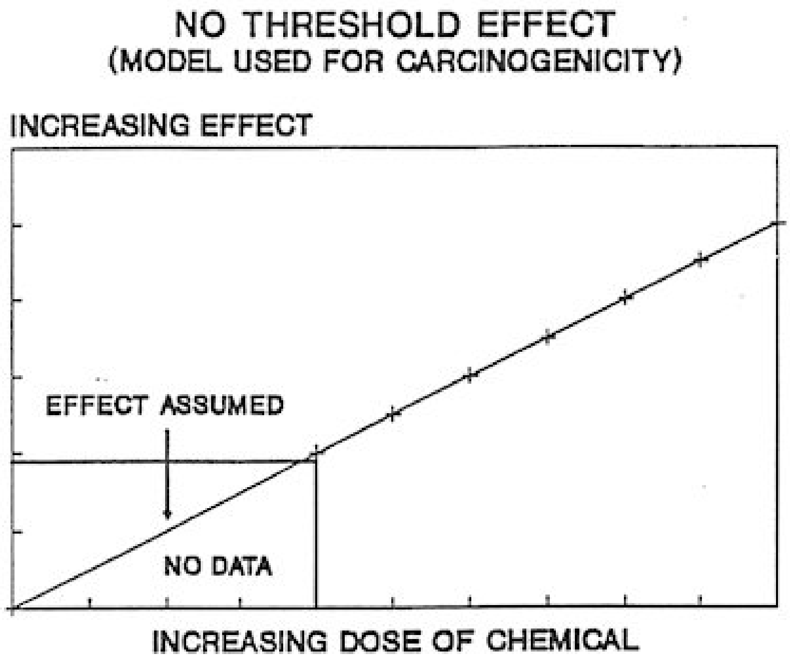
FIGURE 1

NEW GUIDELINES
STEPS FOR APPROVAL

- **Approval of RMAC by NHW**
- **Approval of MAC by Subcommittee (2/3 majority)**
- **Approval of MAC by Advisory Committee (full consensus)**
- **Submission of MAC Deputy Ministers (for information)**
- **Publication of the new guidelines book (Minister of NHW)**
- **One year comment period**

FIGURE 2

THRESHOLD VS NON-THRESHOLD EFFECTS



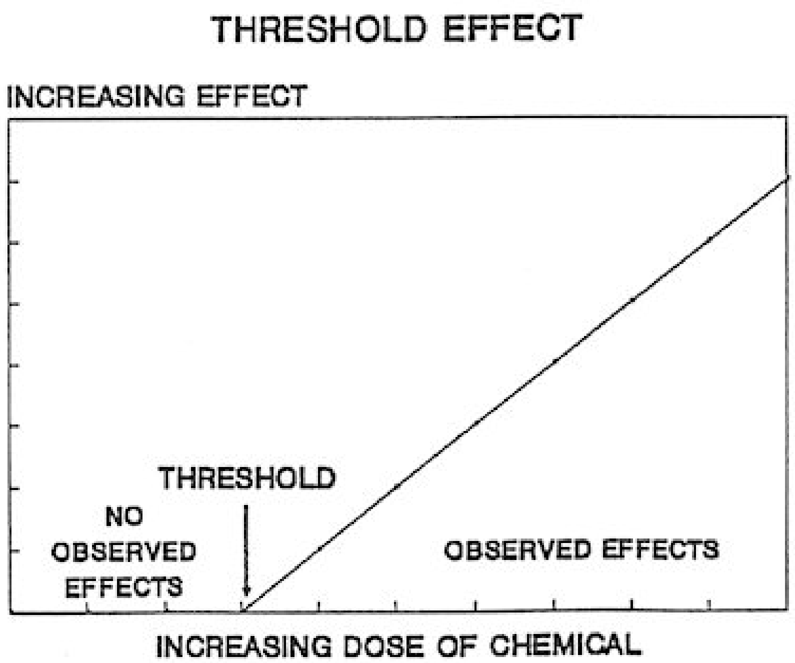


FIGURE 3

CALCULATION OF ADI FROM NO-OBSERVED-ADVERSE-EFFECT-LEVEL

$$\textbf{ADI}\ (\text{mg/kg bw}) = \frac{\textbf{NOAEL}\ (\text{mg/kg bw/d})}{\textbf{Uncertainty Factors}}$$

Where ADI: Acceptable Daily Intake
NOAEL: no-observed-adverse-effect level

And Uncertainty Factors are 1-10x for:

- variation between species: extrapolation to humans from animals
- variation among species: sensitive individuals
- less than lifetime studies
- use of LOAEL rather than NOAEL
- severity of effect
- equivocal or missing data

FIGURE 4

CALCULATION OF MAC FROM ACCEPTABLE DAILY INTAKE

$$\textbf{MAC}\ (\text{mg/L}) = \frac{\textbf{ADI}\ (\text{mg/kg bw}) \times \textbf{Average bw}\ (\text{kg})}{\textbf{Av. intake of drinking water/d}\ (\text{L})} \times \text{Apportionment}$$

Where:

Average body weight of an adult = 70 kg
Av. Intake of drinking water per day = 1.5 L

Apportionment = fraction of exposure coming from water

FIGURE 5

REASONS FOR INCLUSION OF PESTICIDES IN GUIDELINES

- risk of long-term health effects
- high toxicity
- frequent detection in water
- high use, especially if used in several areas
- physico-chemical properties indicating
- high leaching potential (low volatility,
- high solubility, low adsorption onto soil
- and low biodegradability)
- persistence in the environment,
- bioaccumulation

FIGURE 6

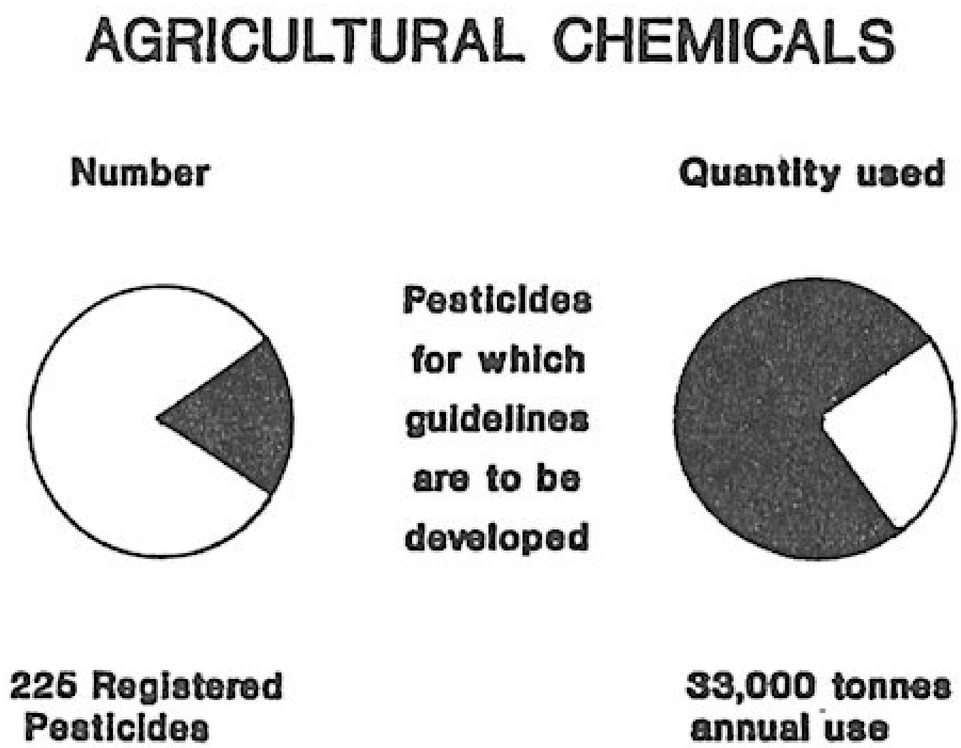

AGRICULTURAL CHEMICALS
Number
Quantity used
Pesticides for which guidelines are to be developed
225 Registered Pesticides
33,000 tonnes annual use

FIGURE 7

FIGURE 8. MARGIN OF SAFETY BETWEEN GUIDELINE AND LOWEST NOAEL

Pesticide	Guideline mg/L	mg/day	NOAEL mg/day	Margin of Safety
Carbaryl	0.09	0.135	700 (animal)	5200
			4.2 (human)	31
Dinoseb	0.01	0.015	70	4670
Glyphosate	0.28	0.42	210	500
Metolachlor	0.05	0.075	105	1400
Picloram	0.19	0.275	1400	5100
Phorate	0.002	0.003	3.5(rat)	1200
			0.7(dog)	230
Diquat	0.07	0.105	53	505

DERIVATION OF NITRATE GUIDELINE

- methœmoglobinœmia in infants: > 112.5 mg/L
- weak evidence of carcinogenicity (Group III)
- threshold approach and uncertainty factor
- based on sensitive sub-population (infants)
- protective also of adults

Stage 1 Recommendation = 11.25 mg/L

- removal technology (anion exchange)
  - feasible at 45 mg/L
  - difficult at 11.25 mg/L

Maximum Acceptable Concentration (MAC) adopted by the subcommittee = **45 mg/L** (as nitrate)

FIGURE 9

WATER QUALITY GUIDELINES FOR PESTICIDES

The presentation was adapted directly from the "Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life" written by the Eco-Health Branch of the Environmental Sciences and Evaluations Directorate.
(Presentation acetates follow the references)

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INTRODUCTION

Change is an important characteristic of aquatic ecosystems. Species composition, various rate processes, degree of complexity and many other community characteristics change over time. Changes in aquatic ecosystem structure and function may result from storms, floods, changes in rainfall patterns, sedimentation and a variety of other natural causes. Additionally, changes may result from societal stresses such as toxic chemical inputs and nutrient enrichment. An ecosystem may recover from both types of change - however, the recovery process will rarely produce a system identical to the original when a societal stress is involved (Cairns 1980). The first edition of the Canadian Water Quality Guidelines for aquatic life (CCREM 1987, Chapter 3) was developed as one of a series of management tools to ensure that societal stresses, particularly the introduction of toxic chemicals, do not lead to the degradation of Canadian fresh waters.

1.1 Background

Chapter 3 of this document (Freshwater Aquatic Life) includes water quality guidelines for approximately 65 water quality variables and continues to be updated and expanded with the addition of guidelines for industrial solvents, in-use pesticides, and other variables of concern to freshwater aquatic life (see preceding appendices). However, since the publication of the 1987 edition of the Canadian Water Quality Guidelines, several concerns have been raised regarding the protocol used to develop guidelines for the protection of freshwater aquatic life. The protocol contained in Chapter 3 was considered to be incomplete regarding the identification and selection of key studies and the mechanism of guideline derivation. Further, several jurisdictions have since reassessed their protocols for guideline development, while other jurisdictions have requested a similar protocol for the marine environment. In response to these issues, the Canadian Council of Ministers of the Environment Task Force on Water

Quality Guidelines undertook a review of the protocol used in Chapter 3 of the Canadian Water Quality Guidelines. The revised protocol for the derivation of water quality guidelines for the protection and maintenance of aquatic life is presented in this update. Additionally, a protocol for marine aquatic life guidelines is presented. **All guidelines previously approved by CCME, however, continue to apply unless a future review is deemed necessary.**

1.2 Guiding Principles for the Development of Water Quality Guidelines for Aquatic Life

The following are an update of the Chapter 3 guiding principles for the development of aquatic life guidelines as originally adopted by the CCME Task Force on Water Quality Guidelines (CCREM 1987). Provincial jurisdictions, however, may aim for greater or lesser levels of protection depending upon circumstances within each jurisdiction.

(1) In deriving Canadian water quality guidelines for aquatic life, all components of the aquatic ecosystem (e.g., algae, macrophytes, invertebrates, fish) are considered if the data are available. Where data are available but limited, interim guidelines are deemed preferable to no guidelines.

(2) The approach to the development of guidelines for aquatic life follows that of the International Joint Commission Water Quality Board (IJC 1975) and the Ontario Ministry of the Environment (OMOE 1979, 1990). This approach states that guidelines "are set at such values as to protect all forms of aquatic life and all aspects of the aquatic life cycles". The goal is to protect all life stages during an indefinite exposure to water. Whether this goal can be realized is a water management issue and does not affect the guideline derivation procedure.

(3) For most water quality variables a single maximum value, which is not to be exceeded, is recommended as a Canadian water quality guideline. This maximum value is based on a long-term no-effect concentration.

(4) Unless otherwise specified, a guideline value refers to the total concentration in an unfiltered sample. Total concentrations will apply unless it can be demonstrated that: (i) the relationship between variable fractions and their toxicity is firmly established, and (ii) analytical techniques have been developed which unequivocally identify the toxic fraction of a variable in a consistent manner using routine field-verified measurements.

1.3 The Guideline Derivation Procedure

The following is a brief overview of the guideline derivation procedure which is outlined in detail in Sections 2, 3 and 4 (see Figure 1).

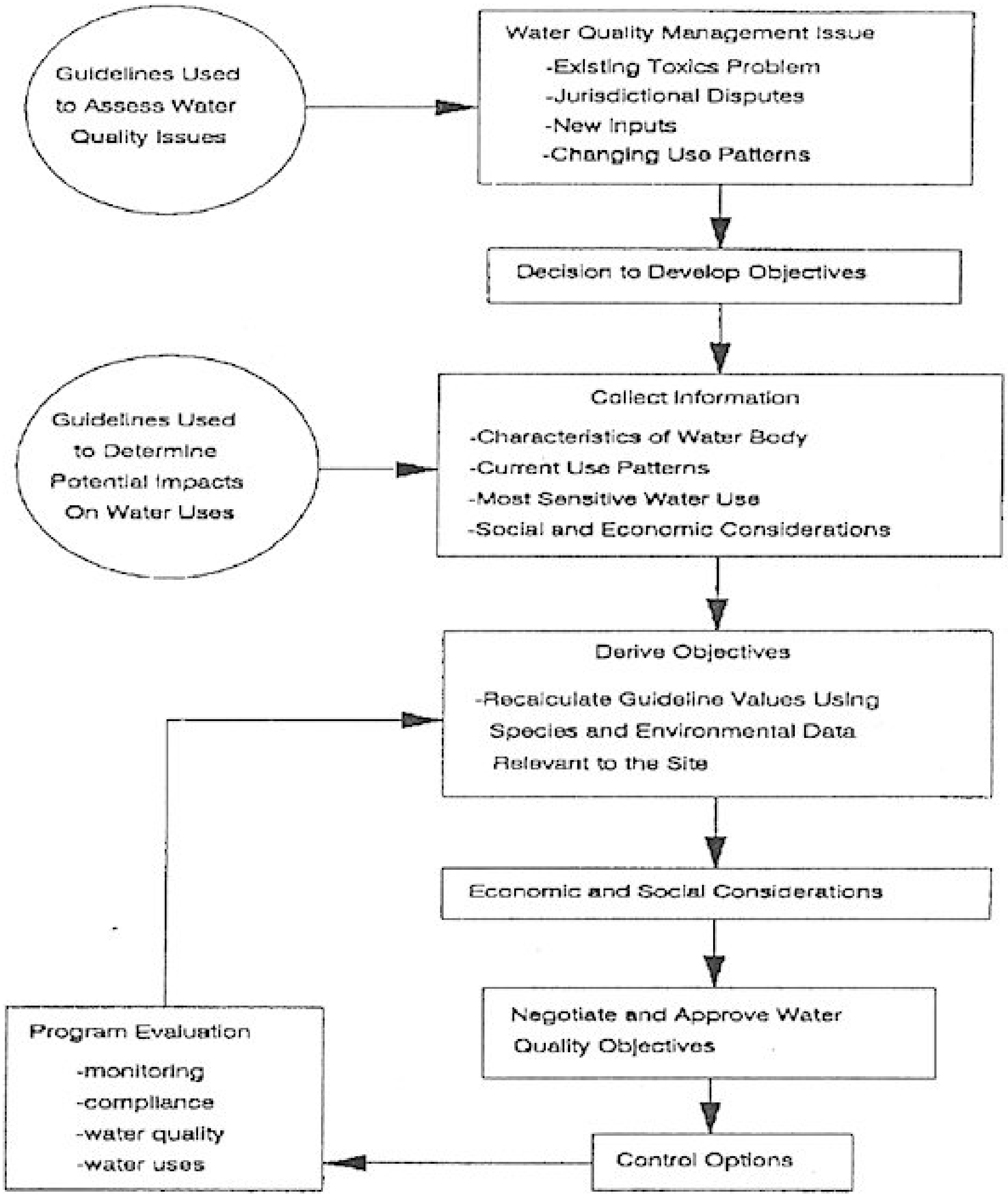

Figure 1: The procedure for deriving Canadian Water Quality Guidelines.

Selection of Variables

Variables of concern at the national level are given priority for guideline development. For example, the Canadian Environmental Protection Act includes a Priority Substances List (Canada Gazette 1989) for which water quality guidelines are required. Variables are also selected for guideline development after consultation with federal and provincial jurisdictions.

Literature Search

For each variable selected, a literature search is conducted to obtain information on the following: (i) physical and chemical properties, (ii) environmental concentrations, (iii) environmental fate and behaviour, (iv) bioaccumulation potential, (v) acute toxicity to aquatic biota, (vi) chronic toxicity to aquatic biota, (vii) genotoxicity, and (viii) information from other jurisdictions.

Data Set Requirements

In order to proceed with the guideline derivation process, certain minimum toxicological and environmental fate data set requirements must be met (see Section 2). In cases where there is insufficient information, an interim guideline can be derived providing that a less stringent minimum data set is available.

Evaluation of Toxicological Data

Each toxicological study found in the literature search is evaluated to ensure that acceptable laboratory practices were used in the design and execution of the experiment (see Section 3). Each study is then classified as primary, secondary or unacceptable.

Guideline Derivation

When available, the most sensitive lowest observable effects level (LOEL) from a chronic exposure study is multiplied by a safety factor of 0.1 to arrive at the final guideline concentration (see Section 4). Alternatively, the most sensitive 140 or Eq, from an acute exposure study is multiplied by an acute/chronic ratio or appropriate application factor to determine the final guideline concentration. The derivation procedure is the same for guidelines and interim guidelines.

1.4 The Use of Water Quality Guidelines and Objectives in Water Quality Management

Canadian water quality guidelines for aquatic life are developed to provide basic scientific information about the effects of water quality variables on water uses. This information is used to assess water quality issues and to establish water quality objectives for specific sites (Figure 2).

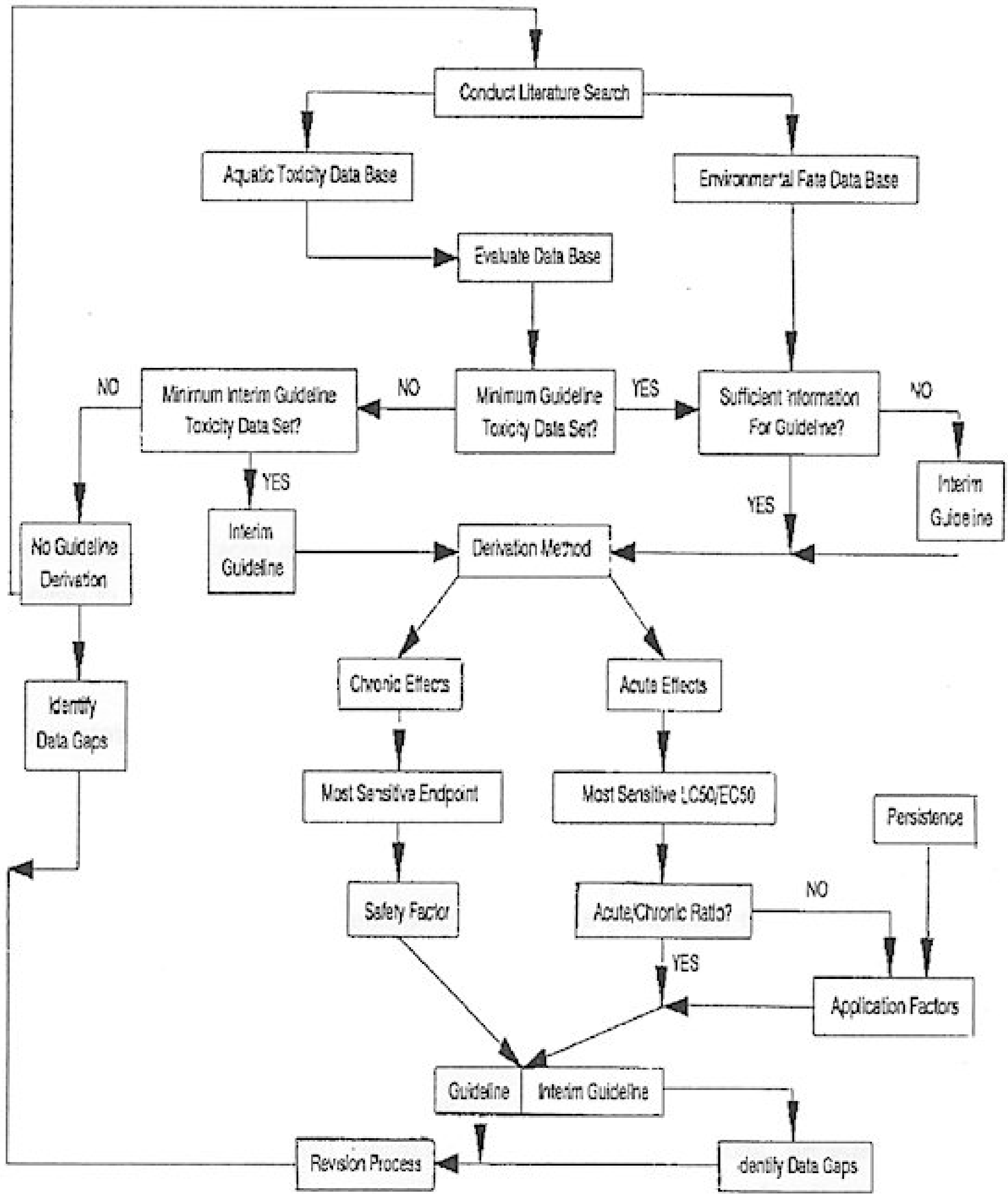

Figure 2: The role of water quality guidelines and objectives in water quality management.

The need to develop water quality objectives often arises when an industry announces a new project which could affect water quality in a basin. Objectives may also be required to address an existing problem or to provide preventative watershed protection. Those charged with developing objectives (which may include, for example, Environment Canada, Indian Affairs and Northern Development, provincial and territorial governments, and water management agencies such as the Prairie Provinces Water Board) must decide what uses are to be protected, obtain the necessary information, formulate the objectives, and present them for approval to the appropriate jurisdiction(s) (Figure 2).

Developing site-specific objectives to protect aquatic life is a complex process, especially when it concerns objectives for toxic substances. At a given site, there are many species each of which can respond differently to the often large number of toxic substances produced by human activities. To develop a site-specific objective requires an extensive knowledge of the chemical, physical and biological properties of the water body and, as well, the social and economic characteristics of the local area. Once this information has been acquired, objectives are derived using the same protocol as outlined in section 1.4 for guidelines, except that only species and environmental conditions relevant to the site are considered. Social and economic factors are then evaluated to determine if the objectives can realistically be attained. In general, when setting effluent regulations to meet objectives, social and economic factors are factored in by giving longer deadlines to smooth out the transition period. Periodic assessments then fine tune the objectives and pollution control program to ensure that the desired water quality is maintained.

As a minimum, water quality objectives should protect the existing and potential uses of a water body. Where water bodies are considered to be of exceptional value, or where they support valuable biological resources, it is the policy of the CCME that **degradation of the existing water quality should always be avoided.** Similarly, modifications of guidelines to site-specific objectives should not be made on the basis of aquatic ecosystem characteristics which have arisen as a direct result of previous human activities.

1.5 Guideline Derivation Protocols for Other Water Uses

The 1987 edition of the Canadian Water Quality Guidelines includes guidelines which will protect and maintain other water uses (raw water sources for drinking water, recreation and aesthetics, irrigation, livestock watering, and industrial water supplies) not discussed in this appendix. The protocols used to derive guidelines for these water uses are found in the appropriate chapters of the Guidelines document. The long-term goal is to prepare revised guideline protocols for each of the major water uses in Canada. Each revised protocol will be made available to interested parties after review and approval by the CCME Task Force on Water Quality Guidelines.

2. DATA REQUIREMENTS FOR GUIDELINE DERIVATION

2.1 Minimum Aquatic Toxicological Data Requirements for Freshwater Guidelines

The intended goal of freshwater aquatic guidelines is the protection and maintenance of all forms of aquatic life and all aquatic life stages. Therefore, it is essential that data from fish, invertebrates and plants be included in the guideline derivation process. For this purpose, the following minimum data set requirements have been set. In the derivation procedure (see Section 4), guidelines or interim guidelines may be derived from studies involving species not required in the minimum data set (e.g., amphibians, protozoa, bacteria), provided that the minimum data set requirements outlined below are met.

FISH

- at least three (3) studies on three (3) or more freshwater species resident in North America, including at least one (1) coldwater species (e.g., trout) and one (1) warm water species (e.g., fathead minnow),

- of the above studies, at least two (2) must be chronic (partial or full life cycle) studies.

INVERTEBRATES

- at least two (2) chronic (partial or full life cycle) studies on two (2) or more invertebrate species from different classes, one of which includes a planktonic species resident in North America (e.g., daphnid).

PLANTS

- at least one (1) study on a freshwater vascular plant or freshwater algal species resident in North America,

- for highly phytotoxic variables, the requirements increase to include four (4) acute and/or chronic studies on non-target freshwater plant or algal species.

It is important to emphasize that the guideline derivation process for freshwater aquatic life need not always follow a fixed approach. Consideration must also be given to the nature of the variable. For example, the requirement for two chronic studies for fish may be waived when acceptable acute/chronic ratios from fish species exist to convert the results of acute studies, or if the toxicity of the variable has been shown not to increase during chronic exposures. Other scientifically justified exemptions may also be considered on a case-by-case basis.

The reduced requirements for plant toxicity studies were deemed necessary because fewer studies on plants have been conducted (Swanson and Peterson 1988). The minimum data requirements for plants could be increased in the future if data availability improves.

In cases where the minimum data requirements for guideline derivation are not met, interim water quality guidelines may be developed provided the following minimum data requirements are met.

FISH

- at least two (2) acute and/or chronic studies on two (2) or more fish species, one of which includes a coldwater species (e.g., trout) resident in North America.

INVERTEBRATES

- at least two (2) acute and/or chronic studies on two (2) or more invertebrate species from different classes, one of which includes a planktonic species resident in North America (e.g., daphnid).

If a toxicity study indicates that a plant species is the most sensitive species in the data set, than this study shall be used in the interim guideline derivation process. However, in the absence of data on plants, interim guidelines can be derived provided that this data gap is noted. The information which is required to elevate an interim guideline to guideline status needs to be clearly identified in order to stimulate research which will generate the necessary data.

2.2 Minimum Aquatic Toxicological Data Requirements for Marine Guidelines

In the United States, 35% of the U.S. EPA criteria continuous concentrations (the U.S. equivalent of Canadian water quality guidelines) which were calculated separately for fresh- and marine waters, differ by a factor of greater than five (Hansen 1989). Given this information, Canadian water quality guidelines need to be developed separately for each environment. For most variables, however, there is less toxicological information available for marine species, particularly phytoplankton and macroalgae, than is available for the freshwater environment (Hansen 1989). Since the goal of marine aquatic guidelines is the protection and maintenance of all forms of aquatic life and aquatic life stages, it is essential that data from marine fish, invertebrates and plants be included in the guideline derivation process. As with the requirements for freshwater aquatic life guidelines, the following minimum data requirements have been set. In this appendix, marine species include those species found in estuarine, coastal and open ocean habitats, any of which may be used to derive a guideline or interim guideline.

FISH

- at least three (3, studies on three (3) or more temperate marine fish species, including at least two (2) chronic (partial or full life cycle) studies.

INVERTEBRATES

- at least two (2) chronic (partial or full life cycle) studies on two (2) or more temperate marine invertebrate species from different classes.

PLANTS

- at least one (1) study on a temperate marine vascular plant or marine algal species.

In cases where the minimum data requirements are not met, interim water quality guidelines can be derived providing the following data requirements are met.

FISH

- at least two (2) acute and/or chronic studies on two (2) or more marine fish species, one (1) of which is a temperate species.

INVERTEBRATES

- at least two (2) acute and/or chronic studies on two (2) or more marine species from different classes, one (1) of which is a temperate species.

If a toxicity study indicates that a plant species is the most sensitive species in the data set, then this study shall be used in the interim guideline derivation process. However, in the absence of data on plants, interim guidelines can be derived provided that this data gap is clearly identified. As with freshwater aquatic life guidelines, the information required to elevate an interim guideline to a guideline needs to be clearly identified in order to stimulate research which will generate the necessary data.

2.3 Environmental Fate and Behaviour Minimum Data Set Requirements

In addition to the minimum toxicological data requirements set out above, studies which have investigated the major environmental fate processes and persistence of the variable in water, soil and sediment, air and biota are required. Potential fate processes include volatilization, hydrolysis, oxidation, photolysis, aerobic and anaerobic biodegradation, long-range transport, soil and sediment sorption/desorption, and bioaccumulation. However, it is not required to have information on each potential fate process. Rather, the intent is to be able to identify the major environmental pathways and fate of a variable in the aquatic environment. Specifically, the following should be determined:

(i) the mobility of the variable and the compartments of the aquatic environment in which it is most likely to be distributed, (ii) the kinds of chemical and biological reactions that take place during transport and after deposition, (iii) the eventual chemical form(s), and (iv) the persistence of the variable in water, sediment and biota. Where possible, the persistence of a variable should be expressed in terms of its half-life. Where significant environmental fate information is lacking, interim guidelines are set. In these cases, the information required to elevate the interim guideline to a guideline needs to be clearly identified in order to stimulate the necessary research.

2.4 Additional Information

The following are not required elements of the minimum data set but, because each is useful in assessing the potential hazard of a variable, they should be included when available.

- Production and uses
- Physical and chemical properties
- Organoleptic effects (taste, odour, fish flesh tainting)
- Sources to the aquatic environment
- Methods of analysis and current detection limits
- Concentrations in the aquatic environment
- Mutagenicity, carcinogenicity and teratogenicity
- Sensitivity of birds and wildlife consuming aquatic organisms
- Guidelines, objectives and standards of other jurisdictions

3 EVALUATION OF TOXICOLOGICAL DATA

Since standard protocols for toxicity testing may become outdated or are not always available or followed, a great deal of variability exists in the quality of published toxicity data. To ensure a consistent scientific evaluation for each variable, the data included in the minimum data set should meet certain criteria.

These include information on: test conditions/design (e.g., flow-through, renewal, static), test concentrations, temperature, hardness, pH, adjuvants, experimental design (controls, number of replicates), and a description of the statistics used in evaluating the data. A variety of standardized test protocols have been developed for fish, invertebrates and plants and, when appropriate, these should be consulted during the evaluation process (for example, see EPS 1980; ASTM 1980; OECD 1981; Rand and Petrocelli 1985; U.S. EPA 1985a,b,c; Sergy 1987; Swanson and Peterson 1988). Information useful for interpreting toxicity data is also available (Buikema *et al.* 1982; Rand and Petrocelli 1985, Chapters 1-11), and should also be consulted when necessary. When consulting test protocols, it is important to be aware of the following limitations: (I) protocols consider only a few well studied species and biological processes, (ii) our knowledge of extrapolation from one species to another (i.e., comparative ecotoxicology) is very limited, (iii) there is limited knowledge of the effects of metabolites and other environmentally transformed products of the parent chemicals, (iv) protocols do not take into account cumulative effects of chemicals, or compensatory responses of organisms (such as acclimation, or reduced density-dependent mortality amongst juveniles), and (v) the predictability of laboratory exposures and effects to aquatic ecosystems has not been adequately tested (Sheehan *et al.* 1984; Arthur 1988; Petersen and Petersen 1988). Therefore, it is essential that the evaluation of toxicological data not follow a rigidly fixed format. Once evaluated, the data are classified as primary, secondary or unacceptable as described below.

PRIMARY DATA

- Toxicity tests must employ currently acceptable laboratory practices of exposure and environmental controls (see, for example, citations in text above). Other types of tests using more novel approaches will be evaluated on a case-by-case basis.

- As a minimum requirement, variable concentrations must be measured at the beginning and end of the exposure period. Calculated concentrations or measurements taken in stock solutions are unacceptable.

- Generally, static tests are unacceptable unless it can be shown that variable concentrations did not change during the test and that adequate environmental conditions for the test species were maintained.

- Preferred endpoints from a partial or full life cycle test include a determination of effects on embryonic development, hatching or germination success, survival of juvenile stages, growth, reproduction and survival of adults.

- Responses and survival of controls must be measured and should be appropriate for the life stage of the test species used.

- Measurements of abiotic variables such as temperature, pH, dissolved oxygen, and water hardness should be reported so that any factors which may affect toxicity can be included in the evaluation process.

SECONDARY DATA

- Toxicity tests may employ a wider array of methodologies (e.g., measuring toxicity while test species is exposed to additional stresses such as low temperatures, lack of food, or high salinity).

- Static tests are acceptable.

- Preferred test endpoints include those listed for primary data as well as pathological, behavioural, and physiological effects.

- Calculated variable concentrations are acceptable.

- All relevant environmental variables should be measured and reported. The survival of controls must be measured and reported.

All data included in the minimum data set must be primary in order for guideline derivation to proceed. For interim guideline derivation, primary or secondary data may be used. Toxicity data which do not meet the criteria of primary or secondary data are unacceptable and cannot be used in either derivation procedure.

4. GUIDELINE DERIVATION

Guidelines or interim guidelines are preferentially derived from the lowest observable effects level (LOEL) from a chronic study using a non-lethal endpoint for the most sensitive life stage of the most sensitive aquatic species investigated. However, when this type of data is unavailable, guidelines can be derived from acute studies by converting short-term median lethal or median effective concentrations (LC_{50}, EC_{50}) to long-term no-effect concentrations. Species not required in the minimum data set (e.g., amphibians) may be used in either derivation procedure provided that the life stage under investigation was completely aquatic. Each study chosen for the guideline derivation procedure must have demonstrated a clear dose/response relationship and, where applicable, the LOEL must be statistically significant.

4.1 Guideline Derivation from a Chronic Study

The most sensitive LOEL is multiplied by a safety factor of 0.1 to arrive at the guideline value. This safety factor has been chosen to account for differences in sensitivity to a chemical variable due to differences in species, laboratory versus field conditions, and test endpoints (Kimerle 1986; Mayer *et al.* 1986; Mayer and Ellersieck 1988).

4.2 Guideline Derivation from an Acute Study

When available, acute/chronic ratios (ACR) can be used to convert the median lethal results of a short-term study to an estimated long-term no-effect concentration (Kenaga 1982). An ACR is calculated by dividing a LC_{50} or EC_{50} by the no observed effects level (NOEL) from a chronic exposure test for the same species (i.e., LC_{50}/NOEL). It is important to note that an ACR should only be used from studies which were designed for this purpose in order to avoid complications arising from different test conditions or different test populations. Further, the use of an ACR needs to be carefully rationalized since the available evidence indicates that for a given chemical variable, ACRs may vary between species with different sensitivities and across major taxonomic groupings (Mount 1977; Stephen 1985). The guideline value is derived by dividing the most sensitive LC_{50} or EC_{50} by the most appropriate ACR.

In the event that acute/chronic ratios are not available, the alternate method of choice to derive a guideline value from an acute study is to multiply the LC_{50} or EC_{50} value by a universal application factor. At present, ACRs are not available for all variables and, to meet this situation, universal application factors have been widely used (U.S. EPA 1972). The application factor (AF) for non-persistent variables (ti in water < 8 weeks) is 0.05, and for persistent variables the AF is 0.01. These application factors are now endorsed by the majority of Canadian jurisdictions involved in developing water quality criteria, guidelines or objectives (e.g., International Joint Commission, Ontario, Manitoba, Saskatchewan, British Columbia). However, it must be emphasized that, although the above universal application factors have been empirically tested and supported (e.g., Kenaga 1982), several studies (Mount 1977; Buikema *et al.* 1982; Mayer *et al.* 1986) have suggested that these factors may be inappropriate for several variables (e.g., diazinon, zinc). Therefore, the use of universal application factors for deriving a guideline or interim guideline should be used only in the absence of chronic data and in the absence of ACRs for acute data.

5. PROCEDURE FOR THE PREPARATION, REVIEW AND PUBLICATION OF CANADIAN WATER QUALITY GUIDELINES

Both a Technical Report, containing all relevant information pertaining to the selected water quality variable, and a CCME Guideline Report, containing the recommended guideline value(s) and the rationale(s) for selecting the value(s), are prepared. The Technical Report and the CCME Guideline Report are circulated to scientific experts and to the CCME Task Force on Water Quality Guidelines for review.

Once reviewed, the appropriate revisions are incorporated, and both reports are returned to the CCME Task Force on Water Quality Guidelines for final approval.

Upon approval by the CCME Task Force, the reports are submitted to the CCME Water Advisory Committee and to the Canadian Council of Ministers of the Environment. The Technical Report is published in the Environment Canada Inland Waters Directorate Technical Series and is made available through mailing lists and library loans. The CCME Guideline Report is published by CCME as an appendix to the 1987 CCME Canadian Water Quality Guidelines and is made available to those requesting guideline updates and library loans.

6 REFERENCES

ARTHUR, J.W. 1988. Application of laboratory-derived criteria to an outdoor stream ecosystem. Intern. J. Environmental Studies 32: 97-110.

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS). 1980. Standard practice for conducting acute toxicity tests with fishes, macroinvertebrates and amphibians. In: Annual Book of ASTM Standards, E729-780. ASTM, Philadelphia.

BUIKEMA, A.H., B.R. NIEDERLEHNER and J. CAIRNS. 1982. Biological monitoring. Part IV. Toxicity testing. Water Res. 16: 239-262.

CAIRNS, J (ed.). 1980. The Recovery Process in Damaged Ecosystems. Ann Arbor Science Publ. Inc., Ann Arbor, Michigan.

CANADA GAZETTE. 1989. Priority Substances List. Extract Canada Gazette, Part I, February 11, 1989, Ministry of Supply and Services Canada.

CCREM (CANADIAN COUNCIL OF RESOURCE AND ENVIRONMENT MINISTERS). 1987. Canadian Water Quality Guidelines. A report prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers. Toronto, Ontario.

EPS (ENVIRONMENTAL PROTECTION SERVICE). 1980. Standard Procedure for Testing the Acute Lethality of Liquid Effluents. Environment Canada, EPS 1-WP-80-1.

HANSEN, D.J. 1989. Status of the development of water quality criteria and advisories. Water Quality Standards for the 21st Century, pp. 163-169. Proceedings of a National Conference, March 1-3, 1989, Dallas, Texas. Office of Water, U.S. Environmental Protection Agency, Washington, D.C.

IJC (INTERNATIONAL JOINT COMMISSION). 1975. Great Lakes Water Quality 1974. 3rd Annual Report. Appendix A. Water Quality Objectives Subcommittee, Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario.

KENAGA, E.E. 1982. Predictability of chronic toxicity from acute toxicity of chemicals in fish and aquatic invertebrates. Environ. Toxicol. Chem. 1: 347-358.

KIMERLE, R.A. 1986. Has the water quality criteria concept outlived its usefulness? Environ. Toxicol. Chem. 5: 113-115.

MAYER, F.L. and M.R. ELLERSIECK. 1988. Experiences with single-species tests for acute toxic effects on freshwater animals. Ambio 17: 367-375.

MAYER, F.L., K.S. MAYER and M.R. ELLERSIECK. 1986. Relation of survival to other endpoints in chronic toxicity tests with fish. Environ. Toxicol. Chem. 5: 737-748.

MOUNT, D.I. 1977. An assessment of application factors in aquatic toxicology. Recent Advances in Fish Toxicology. A Symposium Held in Corvallis, Oregon on January 13-14, 1977. Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, Oregon. EPA 600/3- 77-085.

OECD (ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT). 1981. OECD Guidelines for Testing of Chemicals. ISBN 92-64- 12221-4, Paris, France.

OMOE (ONTARIO MINISTRY OF THE ENVIRONMENT). 1979. Rationale for the Establishment of Ontario's Provincial Water Quality Objectives. Toronto, Ontario.

OMOE (ONTARIO MINISTRY OF THE ENVIRONMENT). 1990. Ontario's Water Quality Objective Development Process (in press, June, 1990). Aquatic Criteria Development Committee, Toronto, Ontario.

PETERSEN, R.C. and L.B.-M. PETERSEN. 1988. Compensatory mortality in aquatic populations: Its importance for interpretation of toxicant effects. Ambio 17: 381-386.

RAND, G.M. and S.M. PETROCELLI (editors). 1985. Fundamentals of Aquatic Toxicology, Methods and Applications. Hemisphere Publishing Corporation., Washington.

SERGY, G.A. 1987. Recommendations on Aquatic Biological Tests and Procedures for Environmental Protection, C&P, DOE. Technology Development and Technical Services Branch, EPS, Edmonton.

SHEEHAN, P.J., D.R. MILLER, G.C. BUTLER and P. BOURDEAU (editors). 1984. Effects of Pollutants at the Ecosystem Level. John Wiley and Sons Ltd., New York.

STEPHAN, C.E. 1985. Are the guidelines for deriving numerical national water quality criteria for the protection of aquatic life and its uses based on sound judgements? Aquatic Toxicology and Hazard Assessment: Seventh Symposium, pp. 515-526, ASTM STP 854. American Society for Testing and Materials, Philadelphia.

SWANSON, S. and H. PETERSON. 1988. Development of Guidelines for Testing Pesticide Toxicity to Non-Target Plants (draft document, October, 1988). Conservation and Protection Branch, Environment Canada, Ottawa, Ontario.
U.S. EPA. 1972. Water Quality Criteria. A Report of the Committee on Water Quality Criteria, National Academy of Sciences. U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. 1985a. Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms (3rd Edition). Office of Research and Development, U.S. Environmental ProtectionAgency, Cincinnati. EPA/600/4-85/013.

U.S. EPA. 1985b. Short-term Methods for Estimating the Chronic Toxicity of Effluents in Receiving Waters to Freshwater Organisms. Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati. EPA/600/4-85/014.

U.S. EPA. 1985c. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

AGRICULTURAL DEVELOPMENT AND ENVIRONMENTAL CONTROL LEGISLATION IN NEWFOUNDLAND

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ABSTRACT

This paper reviews the agricultural development in Newfoundland and its impact on the environment. There are 651 agricultural holdings in the province with a total farm area of 90,345 hectares. Among various existing agricultural activities, livestock operation is the most common with 4,090 dairy cows and 2,300 beef cattle. Wet manure associated with livestock operation is considered to be a major cause of environmental problems. Provincial legislation, regulations and guidelines are discussed and sections related to agricultural activities are summarized. No specific legislation exists to control environmental impacts of agricultural activities except MC9'78 which is an old document and needs to be updated.

There is a need to educate farmers about the environmental aspects of their agricultural activities and to develop and implement environmentally sustainable agricultural management practices. A recently signed federal-provincial agreement on environmentally sustainable agricultural program is a good effort in this direction.

1.0 INTRODUCTION

The Province of Newfoundland covers an area of 404,000 sq.km, of which 119,000 sq. km. comprise the Island of Newfoundland and the remaining 285,000 sq.km. form Labrador. Labrador adjoins the Province of Quebec and is separated from the Island by the Strait of Belle Isle. The province has innumerable lakes, ponds, streams, and rivers and it is estimated that between 10% and 20% of its area is occupied by these water bodies. These constitute the primary sources of water for hydro-electric power, fisheries, industries, mining, agriculture, recreation, domestic and municipal water supply. The municipal water supply systems in the province generally receive water either from natural lakes or ponds or directly from streams and rivers.

In contrast to other provinces of Canada, water treatment facilities in Newfoundland generally consist of chlorination plants only. Because of this, it is important to maintain the high quality of natural water through some regulatory measures. Such measures would be helpful in preserving the quality of our environment and, in many cases, cost effective.

Resource development activities, such as logging, agricultural operations, urban and suburban development, transportation activities, mining and mineral exploration, etc., have been documented as the major sources of water quality impairment. These resource development activities have been going on in this province for many years. The detrimental effects of these developments on the natural quality of receiving waters are of serious concern to the public as well as to the government. As a result, the government has focused its attention towards the development and implementation of environmental regulations and guidelines in resource development sectors of the province. The main objectives of such regulatory efforts are to ensure that environmental concerns are adequately addressed and development agencies comply with the requirement of environmental legislation in order to minimize the detrimental effects of the development and associated activities on water resources and the environment. This paper presents an overview of agricultural development in Newfoundland, major environmental impacts of agricultural activities and provincial regulations/ guidelines to minimize such impacts.

2.0 AGRI-FOOD DEVELOPMENTS IN NEWFOUNDLAND

Agricultural development in this province dates back to the 1800's but commercial production process began in the late 1960's and has continued to grow since then. Water, land base and climate are the three main governing factors for agricultural development in an area. Fortunately, water is in abundance in this province but land base and climate are not very encouraging from an agricultural point of view. Much of the province is covered with forest, lakes, ponds and bogs. The terrain is rough with mineral soil being mostly shallow and stony. In addition to a limited agricultural land base, the growing season is also very short (70 to 150 frost free days) because of the northern latitude of the province.

The total land area of Newfoundland is 404 x 105 hectares, but only 0.25% (101 x 103 hectares) of this is suitable for large scale farming. According to recent estimates, only 26,541 hectares of the suitable land have been developed for agriculture and only 10,000 hectares of this have been used for commercial purposes (Report of Task Force on Agrifoods, 1991). In addition, there are approximately 500,000 hectares of peat lands which may be available for agricultural development. At present, only a minute fraction of this, about 800 hectares, has been developed for agricultural purposes.

A profile of the agricultural sector including agricultural holding, total farm area, improved land area and unimproved land area is presented in Table 1. According to Table 1, the total number of agricultural holdings in the province is 651 occupying a total farm area of 90,345 hectares. The approximate location of major agricultural areas and the main commodity produced by these areas are shown in Figure 1.

From a production point of view, there are three basic types of agricultural activities in Newfoundland: (1) livestock, (2) fruits and vegetables, and (3) forage crops. Among these, livestock operation is the most common activity. According to a 1989 survey, there are 74 registered holders of milk quotas in the province with a total of 4,090 diary cows. In addition, there are 2,300 beef cattle on 160 farm units.

Table 1. Number of Agricultural Holdings, Area of Improved and Unimproved Land in Newfoundland and Labrador

Region	Agricultural Holding	Total Farm Area (Hectares)	Improved Land (Hectares)	Unimproved Land (Hectares)
Eastern	329	50,764	12,363	38,401
Central	157	10,052	4,154	5,898
Western & Labrador	165	29,529	10,024	19,505
Total	651	90,345	26,541	63,804

3.0 ENVIRONMENTAL IMPACTS OF AGRICULTURAL DEVELOPMENT

Every resource development project (logging, mineral exploration, etc.) and land use activity (rural and urban, recreational, agricultural, etc.) causes some degree of impairment to our natural environment. The magnitude and extent of impairment depend on the type of activity, period of activity, and mitigative measures adopted at the source to minimize the adverse impacts. Farming is one of the many nonpoint sources of environmental pollution.

The advancement in knowledge and technology has resulted in modern farming techniques, including the widespread use of chemical fertilizers and pesticides. This generates a variety of wastes, some of which eventually find their way to surface or ground water and may cause serious water pollution problems such as siltation of waterways and chemical pollution of surface and groundwater. These pollutants can have highly adverse effects on human and animal health.

Major agricultural activities, and associated pollutants and resulting environmental impacts are presented in Table 2 (U.S. EPA, 1984) and briefly discussed below.

1. Soil Erosion: Soil erosion, runoff and sediment transport are natural processes and occur on all crop lands as well as irrigated lands. This phenomenon is accelerated by land use practices, notably those which leave the soil bare. Soil erosion is one of the major concerns associated with agricultural development.

2. Chemical Fertilizers: Addition of fertilizer has become the basic component of modern agricultural practices in this province as well as elsewhere. Thousands of tons of various types of fertilizers are annually added to fields to increase the crop yield. This practice has increased the crop production but it has also caused serious environmental problems in terms of water quality degradation. Phosphorus and nitrogen are the main components of fertilizers used in agriculture. If these two nutrients are not worked into the soil, they tend to move off the fields with runoff and result in water quality impairment. No data is available on the exact quantity of fertilizers used in Newfoundland.

3. Livestock Manure: Manure is a valuable source of nutrients for crop production; however, it is also a potential source of disease-causing pathogenic organisms such as bacteria and viruses. Animal manure sometimes can cause serious water pollution problems if the manure is not properly managed and the available land base is not adequate. The environmental impacts associated with the use of manure include degradation of water quality, increasing BOD in streams, and other pathogenic contamination that can be readily transmitted to man.

According to the *Canada Waste Management Guide (1979)* and the *American Society of Agricultural Engineers (1981),* each beef and dairy cow (545 kg) produces 28.3 & 45.3 litres of liquidified manure per day respectively. Therefore, beef and dairy cows in Newfoundland produce 250,367 litres of liquidified manure on a daily basis. Land spreading of liquified manure for crop production is currently the most common use of manure by Newfoundland farmers.

4. Pesticides: The advent of the Green Revolution has resulted in the increased use of pesticides and herbicides per unit area. Pesticides are agents used to destroy unwanted organisms. Herbicides, insecticides, and fungicides are widely used in agricultural sectors to increase yield and enhance product quality. The most common pesticides, insecticides and fungicides used by the agricultural sector in Newfoundland and their primary uses are listed in Table 3 (Environment/Agriculture Canada, 1987). According to the table, approximately 5.0 metric tons of pesticides were used in the agricultural sector. Sixty percent (60%) of this was herbicides, twenty percent (20%) insecticides, and twenty percent (20%) fungicides. The fate of pesticides in the environment is a highly complex phenomena and depends on many factors such as properties of individual substances, environmental conditions, etc.

4.0 ENVIRONMENTAL CONTROL LEGISLATION

In Newfoundland, the Department of Environment and Lands is the main government agency responsible for environmental quality control. *The Department of Environment and Lands Act, 1989* is the principle legislative mechanism to protect and enhance the quality of the natural environment. The mandate of the Department, as derived from the Act, is a sweeping one and encompasses supervision, control and direction of all matters relating to the water, air and soil quality.

The Department is also responsible for developing and implementing regulations and guidelines to enforce the provisions of the Act. In line with its mandate, the main goal of the Department is to protect and enhance the quality of the natural environment. Therefore, it is the responsibility of the Department to ensure that water resources of the province are of a quality which is satisfactory for human consumption, aquatic life and recreation and other purposes.

There are two other provincial departments (Department of Health and Department of Municipal and Provincial Affairs) which are interested in water quality. Though these departments are not directly mandated to control and monitor environmental quality, they have specific interests which are related to water quality.

Table 2. Major Environmental Impacts of Agricultural Development

Nonpoint Source(s)	Pollutant	Water Quality and Associated Impacts
Cropland, pasture, streambanks, construction activities, roads, livestock operations, other land disturbing activities	Sediment	1. Decrease in transmission of light through water. - increase in primary productivity (aquatic plants and phytoplankton) upon which other species feed, causing decrease in food supply - obscures sources of food, habitat, hiding places, nesting sites; also interferes with mating activities that rely on sight and delays reproductive timing 2. Direct effects on respiration and digestion of aquatic species (e.g. gill abrasion). 3. Decrease in viability of aquatic life -- decrease in survival rates of fish eggs and therefore in size of fish population affects species composition. 4. Increase in temperature of surface layer of water, increases stratification and reduces oxygen mixing with lower layers, therefore decreasing oxygen supply for supporting aquatic life. 5. Decrease in value for recreational and commercial activities: - reduced aesthetic value - reduced sport and commercial fish populations - decreased boating and swimming activities - interference with navigation 6. Increases drinking water costs.

Agricultural activities	Salts	1. Favours salt-tolerant aquatic species and affects the types and populations of fish and aquatic wildlife. 2. Fluctuations in salinity may cause greater problems than absolute levels of salinity. 3. Destruction of habitat and food source plants for fish species. 4. Reduced suitability for recreation through higher levels (skin/eye irritation) and higher evaporation rates. 5. Affects quality of drinking water.
All lands where pesticides are used: (cropland, pastures, irrigation return flows)	Pesticides & herbicides	1. Hinders photosynthesis in aquatic plants. 2. Sub-lethal effects lower organism's resistance and increase susceptibility to other environmental stresses. 3. Can affect reproduction, respiration, growth and development in aquatic species as well as reduce food supply and destroy habitat for aquatic species. 4. By definition, these chemicals are poisons; if released to the aquatic environment before degradation, they can kill non-target fish and other aquatic species. 5. Some pesticides/herbicides can bioaccumulate in tissues and other species. 6. Some pesticides/herbicides are carcinogenic and mutagenic and/or teratogenic. 7. Reduces commercial/sport fishing and other recreational values. 8. Health hazard from human consumption of contaminated fish/ water.

Erosion from fertilized areas, animal production operations, cropland or pastures where manure is spread	Nutrients (phosphorus, nitrogen)	1. Promotion of premature aging of lakes and estuaries -- eutrophication. - algal blooms and decay of organic materials create turbid conditions that eliminate submerged aquatic vegetation and destroy habitat and food source for aquatic animals and waterfowl - blooms of toxic algae can affect health of swimmers and aesthetic qualities of waterbodies (odour and murkiness) - favours survival of less desirable fish species over commercially/ recreationally more desirable/sensitive species - interference with boating and fishing activities - reduced quality of water supplies - reduced dissolved oxygen levels can suffocate fish species - reduction of waterfront property values - NO_3 (Nitrates) can cause infant health problems
Animal operations, cropland or pastures where manure is spread	Bacteria	1. Introduction of pathogens -- disease bearing organisms -- to surface waters. 2. Reduced recreational usage. 3. Increase in treatment costs for drinking water. 4. Human health hazard.

Table 3. The Major Pesticides Active Ingredients Used in Newfoundland

Pesticide	Quantity Used in Metric Tonnes	Major Commercial Fields of Use
Herbicide	3	
2, 4-D		Weed control in field crops and non-cropland; soil sterilant; restricted use as an aquatic weed control agent
Glyphosate		Non-selective weed control in field crops, non-cropland and turf.
Insecticide	0.5 - 1.0	
Carbofuran		Control of specified root worms, maggots, beetles and leaf hoppers in vegetables; restricted products are used to control grasshoppers, alfalfa weevil and other insects in field crops.
Chlorpyrifos		Control of specified insects in field crops, vegetables, and fruits; seed treatment for corn, beans and peas; mosquito control.
Diazinon		Control of certain insects on fruits, vegetables, turf and non-cropland; insect control in livestock buildings; seed treatment.
Malathion		Control of specified insects on livestock and in certain field crops.
Fungicide	< 1.0	
Captan		Control of specified fungal diseases on potato seed pieces, flower, fruit, vegetables, turf, and tobacco

The total complement of environment related legislation currently administered by the Department comprises of the following:

1. *The Department of Environment and Lands (DOEL) Act, (1989)*
2. *The Waters Protection Act, Chapter 394, (1970)*
3. *The Waste Material (Disposal) Act, (1973)*
4. *The Pesticides Control Act, Chapter 52, (1983)*
5. *The Environmental Assessment Act, Chapter 3, (1980)*
6. *The Well Drilling Act, Chapter 14, (1981)*
7. *The Environmental Control (Water & Sewage) Regulations, (1980)*
8. *The Pesticides Control Regulations, (1984)*
9. *The Environmental Assessment Regulations, (1984)*
10. *The Well Drilling Regulations, (1982)*
11. *Air Pollution Control Regulations, (1981)*
12. *Storage and Handling of Gasoline and Associated Product Regulations, (1982)*
13. *The Prevention of Misfueling of Light Duty Vehicles Regulations, (1986)*
14. *Mobile PCB Destruction Facility Regulations, (1989)*

The above are existing legislation for environmental pollution control in the province. Two other proposed legislation (1) Draft *Water Resources Act* and (2) Draft *Protection of Public Water Supply Area Regulations* are under review by Government and may become law at any time. Table 4 presents a brief summary on provision, regulatory authority, year of promulgation and status of the above legislation. Major sections of the legislation dealing with water quality control are presented in Table 5.

In addition to the above legislation, the following guidelines are also in use. These were developed either as a part of the legislative requirement or at the direction of the Cabinet.

1. Environmental Guidelines/Stipulations for Agricultural Development (Non-Livestock or Poultry Production).

2. Environmental Guidelines/Stipulations for Agricultural Development (Livestock /Poultry operations less than five animal unit).

3. Development Plan Guidelines for Agricultural Development in Protected Water Supply Areas.

The first two guidelines were developed at the direction of Government and are commonly known as MC9'78. The last guideline was developed as a part of a legislative requirement to regulate Agriculture development in protected water supply areas. Table 6 presents the high-lights of these guidelines related to environmental quality control.

Table 4. Environmental Pollution Control Legislation in Newfoundland

Legislation	Year of Promulgation	Regulatory Authority	Status	Scope
A. Act				
1. The Department of Environment and Lands Act	1989	DOEL	Existing	The Act prohibits the pollution of any water body and provides for the protection of the public water supply areas and quality of environment in general. The Minister may issue a *Stop Order* if an operation is causing pollution of air, soil or any body of water.
2. The Waters Protection Act	1970	DOEL	Existing	The Act provides for the general supervision and care of all inland waters for the purpose of keeping them, whenever possible, fit for drinking and domestic purposes and free from any conditions which are or might be injurious to health.
3. The Waste Material (Disposal) Act	1973	DOEL	Existing	The Act relates to the proper disposal of waste material. The Department also participates in administering *The Transportation of Dangerous Goods Act.*
4. The Pesticides Control Act	1983	DOEL	Existing	The Act empowers the Minister to regulate the handling, storage, use and disposal of all pesticides.

Legislation	Year of Promulgation	Regulatory Authority	Status	Scope
5. The Environmental Assessment Act	1980	DOEL	Existing	The Act relates to protecting the environment and quality of life of the people through the institution of environmental assessment procedures prior to the commencement of any undertaking that may be potentially damaging to the environment.
B. Regulations				
1. The Environmental Control (Water and Sewage) Regulations	1980	DOEL	Existing	These regulations are designed to enforce the provisions of *The Department of Environment and Lands Act.* The regulations relate to the discharge of sewage and other materials into a body of water or a public sewer or sewer leading to a public sewer.
2. The Pesticides Control Regulations	1984	DOEL	Existing	The provisions of *The Pesticides Control Act* are enforced by these regulations. Once a pesticide has been registered under the *Federal Pest Control Products Act,* it comes into the domain of provincial authorities who are responsible for authorizing the use of pesticides within their jurisdiction.

Legislation	Year of Promulgation	Regulatory Authority	Status	Scope
3. The Environmental Assessment Regulations	1984	DOEL	Existing	The regulations enforce the provisions of the *Environmental Assessment Act.* Agricultural activities involving the clearing of land greater than 50 hectares in any area or involving the clearing of land in protected water supply areas are subject to registration under these regulations.
4. Storage and Handling of Gasoline and Associated Products Regulations	1982	DOEL	Existing	These regulations are designed to enforce the provisions of *The Department of Environment and Lands Act* and deal with the storage and use of gasoline and associated products.

Table 5. Salient Provisions of Environmental Legislation Related to Water Quality Control

Legislation	Title	Section	Scope
1. The Department of Environment and Lands Act	Water Conservation Studies	20(1)	The Minister may cause studies to be made on quantity, quality, character, location, use or possible use in the interest of conservation, development, control, improvement or proper utilization of water bodies.
	Pollution Prohibited	25	Subject to regulations, no municipal authority or person shall discharge or deposit material of any kind into a body of water or on a shore or bank of a body of water or in a place that may cause pollution or impair the quality of water for a beneficial use.
	Public Water Supplies	26(2)(a)	In a defined and prescribed area, no person shall place, deposit, discharge or allow to remain in the prescribed area material of a kind that might impair the quality of the water.
2. The Waters Protection Act	Protection of Public Drinking Supplies	6	The Minister's permission is essential before any person builds a house, establishes a farm or farm building, a cemetery or a sewage disposal of any kind upon the watershed of a body of water from which drinking or domestic water are drawn for public supply.
3. The Waste material (Disposal) Act.	Disposal of Waster Material	11(1)	A waste disposal site shall be used only for the dumping of waste material.

Legislation	Title	Section	Scope
4. The Environmental Control (Water and Sewage) Regulations		6	No person shall discharge into a body of water any effluent with pollutants concentration in excess of levels specified in schedule A of these regulations.

Table 6. Environmental Guidelines Related to Agriculture Development

Title	Objectives	Main Specific Guidelines
1. Environmental Guidelines/ Stipulations for Agricultural Development (Non-Livestock or Poultry Production)	The main objective is to pro vide environmental management to non-livestock, non-poultry production and development.	1. Manure may not be spread at least 30 metres from the nearest watercourse and at lease 90 metres from any well or public water supply and may not be spread on any watershed of any community water supply system. 2. Soil testing is recommended before any extensive quantity of manure is applied. 3. Any proposed use of pesticides should be in accordance with *The Pesticides Control Regulations, 1984.* 4. A 15 metre buffer zone of undis-turbed vegetation must be maintained between the operation site and adjacent water bodies. 5. Approval certificates must be obtained from all concern departments and agencies prior to the onset of the operation. 6. Waste material should be disposed in accordance with *The Waste Material (Disposal) Act, 1973.*

2. Environmental Guidelines/ Stipulations for Agricultural Development (Livestock/Poultry Operations)	To provide environmental management to small scale livestock/poultry production.	1. New livestock facilities shall not be permitted within 610 metres of an existing residence and vice-versa. 2. All manure storage systems must be impervious and should be covered to reduce odour problems. 3. A 30 metre minimum buffer zone of natural forage shall be maintained between agricultural land and any watercourse. 4. All livestock operations must have proper retention capacity for manure for six months to allow for over winter accumulation. 5. All effluent drainage to receiving water must be chlorinated and show coliform bacteria reading of zero. 6. The chemical quality of effluent discharges to receiving waters must meet *The Environmental Control (Water and Sewage) Regulations, 1980.* 7. All other conditions as outlined for non-livestock/poultry production will be applicable.
3. Development Plan Guidelines for Agricultural Development in Protected Water Supply Areas	To ensure that agricultural operations within a protected water supply area will not impair the quality of water.	1. Operations such as access road development, stream crossing, clearing of land, storage, disposal and application of manure and other agricultural related operations will be permitted provided the development plan is submitted and is environmentally acceptable. 2. Operations such as barns, vehicle parking and maintenance facilities, application of manure, fertilizers and pesticides will not be permitted within specified buffer zones. 3. Storage and/or disposal of waste will not be permitted at sites other then those approved. 4. Development plans must include detailed information on location, period of operation, site plan, buffer zones, site preparation, access roads, equipment, etc.

5.0 EXISTING ENVIRONMENTAL ISSUES AND FRAMEWORK FOR ACTIONS

Environmental impacts of agricultural operations were discussed in the previous section. These impacts have raised various issues including offensive odour problems, siltation of water bodies, chemical and pesticide pollution, pathogenic contamination of water supplies and risk to human health and aquatic life. The magnitude of these issues has been further compounded due to the close proximity of some agricultural projects in relation to the community water supply, urban/suburban area and environmentally sensitive land.

In the past, such projects generated serious concerns as among the public and there have been cases where community councils, individuals and, in some cases, even farmers have complained and threatened to sue the government for permitting agricultural operations close to the source of water supply and residential area. As a result, seriously polluted farms at Stanhope, Charleston, and Burgeo have had to be closed while others at Flatrock, Goulds, Bauline, Cormack, Bay Roberts area, Whitbourne and MacIvers have had restrictions placed on their activities.

Among various agricultural operations in this province, livestock operations (dairy farms, poultry operations, feed lots, building for grazing animals) are the most alarming and have raised serious environmental problems. These have been cited as potential sources of offensive odours, disease causing organism, water quality degradation, etc. There are approximately 380 commercial livestock farms in Newfoundland, containing over 25,000 cattle, pigs, sheep, and poultry and contribute significant amounts of nutrients and other contaminants to local surface and groundwater areas. Agricultural practices of concern are unrestricted access of livestock to streams and rivers; the concentration of animals in one area; improper storage and disposal of livestock manure; and the failure to mix in freshly spread manure.

The existence and magnitude of agriculture related environmental issues is an indication that either agricultural development in this province was carried out without environmental considerations or the development projects did not go through the existing legislative mechanism. In order to overcome the above issues, preserve natural resources, and enhance the quality of the environment, it is important that officials from the Departments of Agriculture and Environment work closely to develop a comprehensive management plan for sustainable agriculture. The plan should consist of the following main components:

Best Management Practices

The Department of Agriculture should take a lead role by identifying the best management agricultural practices. These practices will cutback on the amount of tillage; maintain cover crops or crop residues for soil cover; remove highly erodible and environmentally sensitive lands from production and maintain both high productivity and environmental quality.

Water and Land Use Policies

Officials of the Department's of Agriculture and Environment should work towards the development of a regional water and land use plan. The plan will identify the land use zones with a view to prevent unacceptable land uses; protect sensitive lands from agricultural development and enhance environmental protection. The plan will also include policies for buffer zone requirements and processes to resolve land use conflicts.

Monitoring and Enforcement

A program should be established to monitor changes in the quality of soil and water resources over a long period of time. Data collected through this program will facilitate analysis of changes in the quality of the environment and the development of environmental protection guidelines to minimize the environmental deterioration. There is a need for increased enforcement of existing regulations to restrict practices contributing to soil erosion, offensive odour and contamination of public water supplies.

Education and Awareness

Positive public education and media programs should be developed for sustainable agriculture. It will involve improved information transfer to the producers of agri-food products. The farming community should be made aware of environmental issues facing the agri-food sector and how to address these issues to ensure protection of resources and the environment.

Federal and provincial governments have recently signed a number of agreements under the Environmentally Sustainable Agriculture Program. This is a good initiative towards environmental protection. The scope of the program can be broadened to include all aspects of environmentally sustainable agriculture.

6.0 CONCLUSIONS

The most serious environmental problems associated with agricultural development are soil erosion, chemical and pathogenic contamination of water bodies. These give rise to other environmental problems such as an increase in sediment and nutrient loadings. Traditionally, wet manure has been considered the major source of odours and other problems, but there are several cases where cattle barns have given rise to serious environmental problems. The situation is further compounded by the poor economic conditions of most of Newfoundland's farmers.

Maintenance of a high quality of environment is important for every part of our society. Everyone, including the farming community, needs to work together to help protect and improve the quality of our environment. There is a need of environmental awareness among farmers. Farmers must be aware of the environmental risks of their operations and the need of adopting necessary measures for minimizing such risks. More research work is needed to develop and implement environmentally sustainable agricultural management practices. Source control through regulatory measures should also be given serious consideration rather than using treatment processes to purify the water.

Adoption of educational and regulatory measures will not only result in a better environment but may also prove to be economical for the farming community. For example, optimum doses of manure and fertilizer will reduce the risk of water contamination but will also be economical for farmers by reducing total cost of nutrient additives.

Recently, under the Environmentally Sustainable Agriculture Program, the Provincial Department of Forestry and Agriculture has initiated some projects to address the environmental issue of manure management on Newfoundland farms. Similar types of studies are required to address environmental issues associated with other agriculture related operations such as clearing of land, application of fertilizers and pesticides.

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REFERENCES

DEPARTMENT OF FORESTRY AND AGRICULTURE, GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Report of the Task Force on Agrifoods, 1991".*

ENVIRONMENT CANADA/AGRICULTURE CANADA *"Pesticides Registrant Survey Report, 1987".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Department of Environment and Land Act, 1989".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Waters Protection Act, Chapter 394 (1970) ".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"Department of Environment and Lands (DOEL) Act, (1989) ".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Waters Protection Act, Chapter 3&4, (1970)".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Waste Material (Disposal) Act, (1973)".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Pesticides Control Act, Chapter* 52 *(1983)".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Environmental Assessment Act, Chapter 3 (1980)".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR "The Well Drilling Act, Chapter 14 (1981) ".

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Environmental Control (Water & Sewage) Regulations, 1980".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Pesticides Control Regulations, 1984".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Environmental Assessment Regulations, 1984"*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Well Drilling Regulations, 1982".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"Air Pollution Control Regulations, 1981".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"Storage and Handling of Gasoline and Associated Product Regulations, 1982".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"The Prevention of Misfueling of Light Duty Vehicles Regulations, 1986".*

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR *"Mobile PCB Destruction Facility Regulations, 1989".*

U.S. ENVIRONMENTAL PROTECTION AGENCY, *Report to Congress: Nonpoint Source of Pollution in the U.S.*, Washington D.C.; U.S. EPA Water Planning Division (1984).

AGRICULTURAL IMPACTS ON WATER QUALITY - A P.E.I. PERSPECTIVE

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INTRODUCTION

Prince Edward Island's physical and economic well being depends heavily on the health of its land and water resources. Agriculture, fisheries and tourism all play pivotal roles in the provincial economy, and rely to a significant extent on the quality of these two fundamental resources. Not only do all these sectors stand to benefit from a clean productive environment independently, but the failure of one sector to manage its resources in an environmentally sensitive manner can lead to significant negative impacts on other sectors. This interdependence is well illustrated by the relationship between agricultural activities and water quality. This presentation summarizes the key issues relating to agricultural impacts on water quality on Prince Edward Island, and provides an overview of how the province is addressing these issues.

Before proceeding further, two points should be made. First, this is by its very nature a multidisciplinary issue. The perspective any person brings to such discussions will be biased toward their own areas of expertise or interest. The comments in this discussion will be rather heavily weighted towards the field of hydrogeology. It is hoped that any errors or omissions in other areas will not be too serious and that a general picture of the key elements of the issues will be conveyed. Secondly, the focus of this section of the workshop is on regulatory aspects of the issue and this presentation will not go deeply into technical details about the findings of programs or studies our department has undertaken. Nevertheless, the province is in the formative stages of new policy development in this area, and because effective regulations must be based on a solid scientific footing, some description of relevant research findings are presented.

BACKGROUND

Before beginning with the main topic of this discussion it is perhaps worthwhile to outline the physical and socio-economic setting of the province. Prince Edward Island is a small province with an area of just over 5700 km^2 and approximately 1600 km of coastline. It is characterized by gently rolling to undulating topography with a maximum elevation of 120 metres above sea level. River basins are generally small, and the main river systems are estuarine over a large portion of their length. The geology of the province is fairly homogenous and is comprised chiefly of a Permo-Carboniferous clastic redbed sequence, overlain by a thin mantle of glacial till. This redbed sequence is an excellent aquifer but is relatively vulnerable to contamination. Climate is generally cool and humid with annual precipitation in the range of 1100 mm. Groundwater recharge is in the order of 35% of annual precipitation, and groundwater discharge accounts for approximately 70% of annual streamflow.

Approximately 59% of the province's land mass is cleared, and the majority of this area is utilized by the agricultural sector in one manner or another. Prince Edward Island's population is a little under 130,000, of which slightly less than 40% live in urban centers. The relatively decentralized demographic character of the Island is in part a reflection of the principle industrial sectors of the economy, namely agriculture, fisheries and tourism.

These geographic characteristics have a couple of implications for the province in terms of resource utilization, management and protection. On the one hand these circumstances have the potential to lead to resource use conflicts while on the other hand they can result in a shared interest in resource management and protection.

Because of the province's limited land base, a number of different resource based interests must coexist in close proximity. Agricultural, fisheries, residential and tourism interests operate side by side, and any negative impacts attributable to one sector will have a readily apparent, and often costly impact, on other sectors. To illustrate the point one only needs to look at the dilemma of protecting drinking water supplies. A high proportion of the population rely on on-site water supply wells, which are more impractical to protect from potential contaminant sources than central water supplies, where adequate well field protection measures can be implemented. The decentralized nature of groundwater extraction, renders the designation of certain watersheds as "protected water supply areas", and the corresponding potential restrictions on land use, an untenable solution to the problem.

On the other hand, several resource users may share an interest in resource protection. At the same time that quality of the province's land resources is critical to the agricultural sector, the Island's largest industrial sector, the same activities which may enhance this resource provides benefits for other sectors. For example the reduction of soil erosion is not only important to the preservation of the productive capability of our land resources, it is also an important issue to those who depend on the fisheries for their livelihood.

In summary, the physical and demographic characteristics of P.E.I. are such that there is considerable potential for land use conflict, and a strong incentive for a comprehensive and integrated approach to resource management and development.

THE PRINCIPLE ISSUES

Surface water issues and groundwater issues have typically been treated separately, both in terms of research and in the administrative framework in which they have been addressed. While this discussion will adopt this same, arbitrary division, it is increasingly well recognized that surface water and groundwater quality are closely linked, particularly when they are considered within the context of their relation to land use. Nonetheless it is probably fair to say that most of us do tend to think in terms of these two components of the hydrologic regime separately, and the following issues will be arranged primarily along these lines.

In the background material earlier in this discussion, it was noted that the "redbed" sandstone aquifer is virtually the sole source of potable water in the province. This aquifer is highly productive, and groundwater quantity is not generally an issue. Groundwater withdrawals in the province are in the range of 2% of the available annual recharge, and withdrawals for primary agricultural production are limited. There are a few watersheds where groundwater withdrawals approach what we consider to be the maximum safe yield, however withdrawals of this magnitude generally are related to the food processing industry or municipal water supply, and have no bearing on this discussion. There are a couple of points of importance that are related however. First, the same factors that make the aquifer in P.E.I. fairly productive (ie. high permeability, high recharge rate and degree of fracturing) also render it relatively vulnerable to contamination. Secondly, groundwater discharge accounts for approximately 70% of annual stream flow, thus any impacts on the quality of groundwater must be assumed to also have an impact on surface water quality.

Natural groundwater quality on P.E.I. is generally very good, and the principle water quality issues related to agriculture include bacterial contamination, elevated nitrate concentrations and pesticides. Bacterial contamination in this context is generally a point source problem, most often relating to inadequate manure storage practices, sub-standard well construction, or both. For a considerable period now, and in many areas around the world, elevated nitrate concentrations in groundwater have been associated agricultural activities.

As in other jurisdictions the principle areas of concern in P.E.I. relate to the application of both chemical and organic fertilizers to row crops, and to manure storage practices. The impact of pesticide use is often high on the public agenda, however in P.E.I. the experience to date has shown that normal application of pesticides has had very limited impact on groundwater quality, and most problem situations have resulted from spills. These occurrences are perhaps more properly discussed in the context of the storage and handling of hazardous materials rather than in a discussion of agricultural impacts on water quality.

Surface water resources, both inland and estuarine waters are important in the role they play in supporting the fisheries, recreation and tourism sectors, all making substantial contributions to the Island economy. Key areas of concern are nutrient enrichment, bacterial contamination and siltation. Relatively little work has been conducted in recent years on the occurrence of pesticide residues in surface waters, and at this point this is not a high profile issue.

Water quality in freshwater streams is impacted by a number of land use activities that can have a negative impact on existing water uses. These include such agricultural activities as animal husbandry operations, land drainage projects, soil erosion and nutrient losses from chemical and animal fertilizers. While the sources of water quality degradation in estuaries are essentially the same as those for fresh water streams, the resulting consequences may be even more important because of the particular biochemical environment and the importance of these waters from an economic perspective.

Particularly important issues at this time include eutrophication caused by excessive biological productivity in estuaries and sanitary shellfish closures which are enforced where high faecal bacteria counts are present. Other estuarine management issues include siltation and infilling of estuaries and smothering of shellfish growing beds, potential bio-accumulation of low concentrations of pesticides and the potential for toxic algal blooms due to organic and nutrient enrichment in estuaries.

RESPONSE TO THE ISSUES - THE CURRENT REGULATORY REGIME

As with all government agencies, we rely on various legislative tools to protect the resources within our mandate, and hopefully to provide some guidance and consistency to the manner in which a particular resource is managed. For two reasons only a passing comment on specific legislation will be made here.

For one thing, there is very little legislation which is specifically aimed at agricultural activities, and secondly from a policy perspective the province is in a some what transitional stage, having just completed several comprehensive reviews of environmental issues including The Royal Commission on the Land and an internal review of the Island's "Conservation Strategy". While these initiatives have provided direction dealing with environmental issues, specific plans for implementation of these recommendations are still in their formative stages.

In P.E.I. the Environmental Protection Act, along with it associated regulations, is the principle legislative instrument relating to water quality issues. None of the regulations specifically address agricultural practices or operations and while the Act itself has a fairly broad definition of a contaminant, it generally does not distinguish between "contaminants" or the "discharge of contaminants" into the environment from any particular type of source. While provisions of the Act have been applied to water quality problems related to agricultural sources, these have generally been a result of point source discharges such as problems of groundwater contamination related to inadequate manure storage facilities, or surface water degradation resulting from access of livestock to watercourses, etc.

Some proposals for new agricultural undertakings or expansion of existing operations have been subjected to Environmental Impact Assessments under the Environmental Protection Act. Here too, these have usually involved some aspect of waste storage or disposal, and do not bear directly on issues related to distributed sources of contamination.

The Pesticides Control Act, administered by the P.E.I. Department of Agriculture, places restrictions on the sale and commercial application of pesticides in the province, although individual farmers do not require a license or permit to apply pesticides on their own lands.

This area is under review however, and it is possible that all agricultural applications of pesticides will require some form of training or licensing in the future. Beyond the Pesticide Control Act, the Department of Agriculture is active in improving erosion control and manure management practices, although at this point this is primarily in an advisory capacity.

RESPONSE TO THE ISSUES - RESEARCH EFFORTS AND FINDINGS

There has been a considerable amount of research activity in the area of water quality in the province over the past five to ten years, much of it involving either directly or indirectly agricultural impacts. The Department of Agriculture, and Agriculture Canada have been active in the fields of soil erosion control and nutrient management, and to some extent the occurrence of pesticides residues in groundwater.

The Department of the Environment and Environment Canada, through the Canada - P.E.I. Water Management Agreement have conducted a range of studies relating to water quality issues, several of which have some bearing on agricultural impacts on surface and groundwater resources. John Richards provided an excellent summary of research in the Atlantic Region and only a brief overview of selected work on P.E.I. is included here.

The P.E.I. Department of the Environment has just completed the third year of a survey investigating the distribution of nitrates in groundwaters under different land use settings. The program has involved the monthly sampling of a suite of 54 wells, distributed among six land use categories. These categories include agricultural, urban/suburban and pristine areas, with the agricultural classes including row cropped areas, sites with on-site manure storage and non-row cropped areas.

The results observed to date demonstrate a strong link between land use and NO_3-N concentrations in groundwater. Distinctions between individual land use classes is less clear, partly because of the small sample size, and partly due to the large number other variables such as well construction, position of the site in the watershed and variation in the management practices within each land use class. Nonetheless several clear trends do emerge from the data.

Samples collected from the "pristine" sites suggest that on average, background concentrations of NO_3-N are three times lower than the average value for the total sample population and four times lower than for samples collected from sites in the agricultural land use categories. A few summary statistics are presented in the Table 1 below, and provide some indication of the nitrate concentrations typically observed in domestic wells on P.E.I. It is important to note that there is a considerable overlap between the range of values for each category. The data also highlight the fact that agricultural activities are not the only source of elevated nitrate concentrations in Island groundwaters.

In general the data shows that the degree of nitrate "contamination" of Island groundwaters is not high relative to some areas, although NO_3 -N concentrations in slightly under 8 percent of the 1868 samples collected over the three year period have equalled or exceeded the 10 or mg/L NO_3-N drinking water limit, and nearly twelve percent of the samples collected from the three agricultural land use classes equalled or exceeded this level. In spite of the fact that a different sample design might reveal more distinct correlations between nitrate concentrations and individual land use classes, it is clear that land use has a substantial impact on groundwater quality, frequently to a level that merits concern.

Furthermore the elevated nitrate concentrations in groundwater can be expected to contribute to detrimental effect on surface water bodies, recognizing the fact that groundwater discharge comprises 70 % of annual stream flow and probably accounts for 100% of stream flow during a significant portion of the year.

One of the more surprising findings was the general lack of seasonal trends in the data, in spite of the substantial changes in NO_3-N concentrations observed in tile drain effluent in experiments conducted under similar geographic and climatic conditions. The explanation of this apparent discrepancy is presumed to lie in the fact that the samples from the domestic wells in this survey represent the averaged water quality over a significant aquifer thickness, with the result that much of the expected temporal and spatial variation is dampened.

This has positive implications in regard to sampling schedules, but more importantly, it illustrates the difficulties involved in interpreting groundwater quality data at a highly site specific scale.

Table 1. Nitrate Concentrations in P.E.I. Groundwaters by Land Use Class
Monthly sampling results, 54 sites

		Nitrate concentrations (mg/L NO_3-N)			
Land Use Categories:		mean	max	min	var
all sites		3.98	15.5	<0.2	9.11
row crop areas	5.57	15.0	2.1	13.74	
non-row crop areas		3.97	10.5	0.7	4.32
feed lot operations with on-site manure storage	5.30	13.0	<0.2	6.20	
non-cropped areas (pristine areas)		1.15	5.5	<0.2	1.07
subdivisions with on-site sewage disposal		4.25	15.5	<0.2	12.40
subdivisions with central sewage disposal		2.64	6.5	<0.2	2.21

At the other end of the spectrum, we know intuitively, that on a larger scale the aggregate effect of different land uses should be reflected in the water quality observed "downstream" of a given area of interest in a watershed, but we do not yet have the capability of modeling these phenomena. Both these shortcomings have implications for the manner in which we can measure progress in the development of new management practices aimed at reducing nutrient loading to groundwater and surface water.

Another somewhat surprising feature of the data is that the correlation between well construction and observed nitrate concentrations was relatively weak, at least in comparison to the link between land use and water quality. This however is perhaps not too important if you take the position that it is undesirable to allow degradation of the resource regardless of our ability to avoid such contaminated portions of the aquifer.

A number of investigations into the occurrence of pesticides in groundwater have been conducted on the Island. The results have indicated that while some pesticides reach the water table in detectable concentrations, almost without exception these concentrations are well below the levels for concern. Cases where recommended concentrations have been exceeded have usually been a result of a spill, not normal application of the pesticide.

It should be noted however that most of these surveys have been for the parent compound only, and there is little data on the occurrence of the metabolites of these compounds in groundwater. Also there are a number of pesticides for which drinking water guidelines do not yet exist, or where adequate analytic protocols are not yet well developed. An important by-product of these surveys has been an increased appreciation of the importance of maintaining high standards or quality control in all aspects of such surveys.

Based on the data available to date, the emerging picture seems to be that the normal application of pesticides does not appear to pose a serious threat to groundwater quality on Prince Edward Island, although it may be premature to rule out such adverse impacts.

With respect to surface water quality issues the Province has been involved in several studies and demonstration projects relating to the nutrient enrichment, bacterial contamination and soil erosion control. Lacking direct participation in any of these studies I can not comment in as much detail on this work, but I will try to provide an overview of our activities and level of understanding in these areas.

Nutrient enrichment in surface water bodies is an area of considerable interest to the Department, and the resulting over-productivity, has frequently contributed to eutrophication and the development of anoxic conditions, particularly in the province's estuaries. In the estuarine environment, nitrogen is generally the limiting nutrient, and potential sources and pathways include agricultural chemicals and manure in land wash, point discharges of waste from municipal and industrial waste water treatment plants and groundwater discharge. Studies of these estuarine systems is much more complex than many groundwater studies because of the range of contributing factors and the highly dynamic nature of these systems. Some of the variables which have to be considered are the hydrodynamics of the system, the interaction of two different fluid phases (marine and fresh waters), a complex biotic community, and the relative contribution of groundwater discharge and overland flow to the nutrient loading of the system. As with groundwater, there appears to be strong link between land use in a watershed and nitrate concentrations in surface water. So far it has proved difficult to quantify this relationship, partly because of the rapid temporal changes in surface water bodies, and because nitrate is not expected to be a conservative species in these systems (i.e. where as in groundwater we are dealing primarily with inputs to the system, in surface water systems biological uptake also has to be accounted for). Regardless of gaps in our information at this point, key sources of nutrient enrichment can be identified, and include agricultural activities.

Bacterial contamination of surface waters has been the subject of some investigation, and again while links between bacterial contamination and land use are suggested, these relationships are difficult to quantify. Land wash from agricultural lands is considered to be one of the primary sources of this contamination. One area of particular interest has been the relationship between precipitation duration and intensity and observed bacterial levels. One of the possible benefits of this research is the potential development of a predictive model which could allow less restrictive shellfish closures.

Only a limited amount of work has been done on the occurrence of pesticides in the province's surface water systems. It is difficult to say whether this level of activity reflects a lack of concern on this issue, or the conclusion from initial work that pesticides do not pose a serious threat to the aquatic environment. It should be recalled that potable water supplies rely almost exclusively on groundwater sources, and this may explain the lower profile of this issue compared with the study of pesticide in groundwater systems.

Soil erosion has long been identified as one of the major environmental issues on the Island, and along with highway construction, forestry and the building industry, the agricultural sector is viewed as a key player. The agricultural sector has a dual interest in this area, as concern for lost productivity of the land is as important as degradation of water resources. It is becoming more widely recognized that both on and off farms impacts of soil erosion must be addressed, and there have been research and demonstration projects which have focused on both aspects of the issue. Considerable progress has been made, and some technical solutions to the problem are out in the real world now.

Another initiative worth mentioning briefly relates more to basic research of water resources in general. Environment Canada and the Department of the Environment have recently completed a review of all their water related networks. This review has resulted in a change in the philosophy of collection of basic water related data from long term index stations, and provides a change in focus from the traditional "sectoral based" approach to monitoring to a more integrated approach where monitoring networks are designed not only to provide reasonable coverage independently, but will also complement each other. Under this new philosophy, data collection for climate, hydrometric, surface water and groundwater quality and groundwater observation stations will be concentrated in selected "index basins". The aim of this approach is to provide a better understanding of the entire hydrologic cycle in representative regions of the province. This more integrated approach to data collection will make it much easier to support multi-disciplinary studies with the necessary range of long term background information.

Finally, there has been an increasing emphasis on the study of the economic implications of various environmentally related issues. On Prince Edward Island there have been attempts to investigate economic aspects of several environmental issues. While some have had only an indirect bearing on the agricultural sector, on-farm and off-farm economic implications of soil erosion and the value of buffer strips or water course greenbelts has been investigated. It is perhaps to early to determine how easily economic techniques can be applied to environmental problems, but it is encouraging to see economic considerations are being recognized as an important component of efforts to address environmental issues.

In summary, the research conducted to date on P.E.I. indicates that the principle agricultural impacts on water quality are nutrient enrichment, soil erosion and bacterial contamination, and while not fully confirmed, the normal application of pesticides does not appear to pose a serious threat to the aquatic environment. Both surface waters and groundwaters are impacted by agricultural activities, and the general nature of the sources and pathways are known in at least a qualitative sense. Further research is needed before a quantitative understanding of many of these issues is reached.

FUTURE DIRECTIONS

The Department of the Environment has recently completed a review of the environmental issues facing the province in the near future, and identified a number of basic strategies for change. Not surprisingly, a number of the issues relate to agricultural impacts on the environment. Generally the key elements for change include research, education, demonstration projects and partnerships, and regulation.

A number of areas for future research have been identified, and in a broad sense can be separated into a need to develop standards and a need to develop a better understanding of the physical processes and links between various components of the environment.

For many areas of concern we do not yet have good quantitative standards for environmental quality. These are essential if we are to develop realistic goals for progress and to determine priorities and measure results. Part of this process will include the development of better baseline data which can support the assessment of impacts and provide a basis for measuring change. In addition widely accepted standards based on a solid scientific foundation are essential for effective regulation. While we can readily adopt existing standards in some instances, such as the Canadian Water Quality Guidelines, other parameters pose greater difficulty, such as standards for soil erosion, or for pesticides where the availability of an adequate body of research or reliable and analytic protocols limits our ability to set meaningful standards.

Basic research into the key processes controlling the distribution and transport of nutrients, bacteria and sediment within, and between different components of the environment are needed. Much of this work will be multi-disciplinary in nature, and will require communication and cooperation between researchers in a number of sectors. The development of better modeling capability may be an important component of this work and may contribute to a better quantitative understanding of the interactions between surface water, groundwater and land use, as well as aiding in the development of the predictive capability available to researchers, and in experimental design, and measurement of results. In the area of applied science, the development of economically and physically effective soil and nutrient management practices will be important.

Education will be an important element of change, and will involve a heightened awareness of the issues by the general public, and within the administrative and scientific communities. Demonstration projects and partnerships will be important in affecting technology transfer and provide a real world laboratory in which to test and refine evolving agricultural management practices.

Finally, regulations are a necessary component of ensuring the development of an environmentally sustainable agricultural sector. While enforcement of regulations is necessary in itself, regulations also provide a guide to currently acceptable practices. To be effective, regulations need to based on good science, but this does not imply that it is necessary to completely define all aspects of a problem before action is taken. Too often it is easy to ignore a problem based on the rationale that we have insufficient information. In many cases if we do not implement regulations before we have a complete understanding of the resource in question, irreparable damage will be done before we can act. Preferable we should act, based on the best information at hand, and refinement or revision of regulations can take place as better information becomes available.

This brief overview has only scratched the surface of the topic, but it is hoped that it provides some insight into the key issues on P.E.I., at least from the perspective of the P.E.I. Department of the Environment. The next decade should be an interesting one, as together we face the challenges ahead.

AGRICULTURAL IMPACTS ON WATER QUALITY - THE NOVA SCOTIA SCENE

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INTRODUCTION

In recent years, work involving Agricultural Impacts on Water Quality in Nova Scotia has focused on pesticides. Nutrients have been the subject of investigation several times in the last 30 years. Trescott reported their occurrence in his 1967 work which led to a thesis at the University of Waterloo by Thomas in 1974. Several internal reviews were carried out by Nova Scotia Department of the Environment in the late 1970s and early 1980s. Factors such as seasonal variation have been documented.

The recent history begins in 1987 when it was recognized that many agencies had an interest in the impact of pesticides on groundwater resources. In the fall of 1987, a meeting was held at Inland Waters Directorate in Dartmouth with most of the interested parties. At that meeting, it was decided that the roles of the various agencies should be determined to reduce the amount of overlap in the expensive field of pesticide groundwater research. This lead to the first principle in dealing with agricultural impacts research in Nova Scotia: Cooperation.

COOPERATION

Formal letters were exchanged between the federal and provincial governments indicating a willingness to work cooperatively. Nova Scotia Department of the Environment and Inland Waters Directorate were identified as the respective coordinating agencies for provincial and federal agencies involved in pesticide and groundwater research. Separate federal and provincial steering committees were established chaired by the respective coordinating agencies. To provide a link, the chairs represent the federal and provincial concerns on the other party's steering committee. The steering committee's membership may change to reflect the stakeholders in the current research. For example, on the original Nova Scotia project, the Kings County project, the Steering Committee consisted of Nova Scotia Departments of the Environment, Health, and Agriculture; and Inland Waters Directorate. A second project, likely a GIS mapping study slated for Cumberland County, will involve development of a municipal planning tool, therefore, the Nova Scotia Department of Municipal Affairs was invited to participate.

During the initial discussions among all parties, it was agreed that the provincial actions would focus toward an inventory type of research while the federal research would concentrate on a mechanism type research. As a result, the first respective provincial and federal projects were the Kings County Farm Well Project and the Sheffield Farm Aquifer Vulnerability Project.

The Kings County Project consisted of three portions. A random one-time sampling of 98 farm wells took place in the summer of 1989. Results were presented in an interim report released June, 1990. The second portion consists of a time study of 20 farm wells over a four-year period. The third consists of case studies identified in the first two portions. The final report on the Kings County project is expected by the fall of 1992.

The Sheffield Farm Aquifer Vulnerability Project consists of hydrogeologic instrumented fields to which known farming practices and chemical applications are applied. Water chemistry and water balance models were developed and monitored. Annual reports have been prepared by Inland Waters Directorate. As with the Kings County Project, the Sheffield Aquifer Vulnerability Study is winding down with a final report expected in 1993.

EDUCATION

The second principle in dealing with agricultural impacts is education. Nova Scotia Department of Agriculture has been the primary lead in this area. Their agricultural field representatives are available to discuss "Best Management Practices" with individual farmers.

Soil and water analyses are available through the Soil and Water Laboratory at the Nova Scotia Agricultural College in Truro, Nova Scotia. Interpretation of the soil and water results are provided by the Department of Agriculture and the Department of the Environment respectively.

The Department of Agriculture has programs for Land Evaluation and Planning; Farm Sprayer Calibration, and Financial Assistance for Manure and Pesticide Storage. The department has run short courses on Weed Control highlighting proper pesticide use and handling. Recently during National Soil Conservation week, the Department of Agriculture in conjunction with Agriculture Canada had an information insert highlighting programs and environmental research placed in the provincial newspaper.

The Nova Scotia Department of the Environment was involved with the Department of Agriculture in the development of an approved design to be utilized in the Pesticide Storage Program. The two departments along with the Federation of Agriculture and other interested agencies developed Guidelines for the Management and Use of Animal Manure in Nova Scotia. The Federation of Agriculture has started to provide training in pesticide handling. To date, this training has been received by about 350 farmers.

LEGISLATION

The third principle in dealing with agriculture impacts is legislation. In Nova Scotia, there are many pieces of federal and provincial legislation that touch the farm. The Nova Scotia Department of the Environment alone has 12 Acts and 29 sets of Regulations that may have some bearing on farm activities. This paper only deals with those pieces of legislation that have a direct link between agriculture and water.

The oldest piece of true provincial environmental legislation is the **Environmental Protection Act** passed in 1973. However, clause 50(2) exempts "accepted ordinary activities of individuals, households and **farms" ....** Farms, however, must abide by the **Water Act** which initially was an allocation of resource document introduced in 1919. In the 1970s, the Water Act was amended to be utilized for water quality protection. It currently deals with water allocation, watercourse alteration and water resource pollution. The **Well Drilling Act** and the **Health Act** (administered by the Nova Scotia Department of Health) also deal with the issue of water supply protection and provide separation distances from water supplies to sources of contamination such as manure piles and septic systems. The **Dangerous Goods and Hazardous Materials Handling Act** addresses farm issues, such as, fuel storage, cleaners and other solvents. The **Planning Act** administered by the Nova Scotia Department of Municipal Affairs provides for a variety of planning tools which may affect the building of farm structures and land use activities.

The act with the most current impact on farming activities is the **Pest Control Products Act** and its Regulations. Under the general regulations, the exemption from the Environmental Protection Act for individuals, households, and farms is addressed in Regulation 2. As a result, farm application must adhere to the Regulations for such items as buffer zones, filling, flushing, disposal, and notification. However, no permit is required for ground application. Permits are required for aerial application. Under the Pesticide Storage Regulations, storage of all commercial and restricted product must be reported to the local fire department; Signs of Notification on the Storage building must be posted and uncontrolled releases must be prevented.

THE FUTURE

Where are we going in the future?

First, from the Pest Control Products Act, It is proposed that a Regulation Amendment be enacted that will require the licensing of all agricultural applicators; that is, every farmer using pest control products. The tentative date for implementation of such action is March, 1995.

Secondly, on a much wider scale, there will be a great deal of change in the handling of Water Management Issues in the future. In 1989, a Task Force on Clean Water was struck to investigate all the issues of Water Management. The Task Force released a report containing 80 recommendations in July, 1991. Implementation of these recommendations is expected to take from five to ten years.

There are four cornerstone recommendations from this report:

1. Identification of a Lead Agency for water management issues. This identification will provide a mandate for coordination of water issues including agricultural impacts on water quality. It is likely this agency will be Nova Scotia Department of the Environment and the role will be coordination.

2. A New Water Resources Act. The current Water Act was introduced in 1919. Initially meant to address water allocation issues, the Act was amended in the 1970s to address environmental concerns, such as, water quality. The current Act has poor definitions and results in ineffective protection.

3. The Need for Standards. Nova Scotia currently uses the Canadian Council of Ministers of the Environment 1987 Canadian Water Quality Guidelines. These have not been formally adopted or made into provincial regulations. This will take place on a parameter-by-parameter basis after a provincial review. One area in which field staff have requested a Regulation is siltation. This is an issue addressed in several recommendations of the Task Force Report. While siltation is an agricultural concern, the Nova Scotia issue is driven more by development and forest roads.

4. The Need for Coordinated Land Use and Water Policy. Currently under the Planning Act, the Department of Municipal Affairs and the Environment are developing three land use policies. Those deal with Municipal Water Supply Areas (both surface and groundwater), Flood Risk Areas and Recreational Lakes (likely cottage development). Agriculture may be affected by some restrictions in these watersheds.

Further land use water policies have been identified for future development. These include wetlands (a major section of the Task Force Report), Urban/Suburban Lakes, Industrial Supplies, Rural/Agricultural, Wilderness Forestry, and Multi-use Watersheds.

A final thought on future developments -- Environmental Legislation in Nova Scotia could become consolidated such as is being done in Alberta. This would lead to a single Act with Regulations covering the individual issues from water, air, and land use. Change is definitely in the works. Cooperation/ Coordination, Education, and Regulation is the wave of the future.

REGULATIONS AFFECTING AGRICULTURE IN NEW BRUNSWICK

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ABSTRACT

There are several acts and regulations in New Brunswick which affect agricultural activities being carried out in the province. This paper will highlight these acts and regulations, both present and pending, that, are administered by the New Brunswick Department of the Environment.

HISTORICAL PERSPECTIVE OF WATER MANAGEMENT IN NEW BRUNSWICK

Legislated protection of water resources and the environment dates back to 1918 and the introduction of the Health Act. This legislation contained a series of requirements developed to combat the threat of communicable diseases and other public hazards. It also specified regulations and procedures governing the planning, construction, and operation of municipal water and sewage systems.

By the 1950's new components were being added to pollution control problems as a result of large scale economic development across the province. There was a major increase in the number and variety of pollutants being discharged into rivers, lakes and streams throughout the province.

By 1956 the Water Resources and Pollution Control Act was introduced, which shifted part of the responsibilities of environmental protection to the Minister of Lands and Mines. This act was repealed in 1961 when new legislation called the Water Act was passed. This act was specific to water resource management and water pollution control and became the basis for water management programs in the 1960's. Towards the end of the decade, focus shifted towards environmental problems which were only indirectly associated with water, such as open dumping and burning of garbage, and the negative impact of industrial air pollution.

In December of 1971, a new era of environmental protection legislation began in New Brunswick with the proclamation of the Clean Environment Act, which addressed all aspects of environmental protection. Subsequently, specific environmental programs were established, which included air quality and solid waste management programs. An environmental impact assessment procedure was also established and eventually became a full regulation in 1987.

In 1975 a separate and distinct Department responsible for environmental issues was established. By late 1976 all legislation under the Water Act was replaced by regulations under the Clean Environment Act. In April of 1979 the administration of the Pesticides Control Act was assigned to the Department of the Environment.

In 1985 the Departments of Municipal Affairs and Environment were integrated, and a land use function was added to the responsibility of the Departments. The Clean Water Act was passed in 1989, and several regulations under the Clean Environment Act were refiled under the Clean Water Act. The Department of Municipal Affairs and Environment was separated in 1989. The Department of the Environment is the administrating agency for three of the four acts, which are being outlined in this paper. These acts are the Clean Water Act, the Clean Environment Act, and the Pesticides Control Act. The Health Act is administered by the Department of Health and Community Services.

CLEAN WATER ACT

There are currently two regulations under the Clean Water Act that affect agricultural activities. These are the Watercourse Setback Designation (NB Reg. 90-136) and the Watercourse Alteration Regulation (NB Reg. 90-80).

Watercourse Setback Designation:

In order to protect municipal surface water supplies in New Brunswick, the Provincial Government has embarked on a long term program of WATERSHED PROTECTION through DESIGNATION. This is a proactive approach to maintaining both the water quality and quantity of municipal surface water supplies and is intended to be a cooperative effort between two levels of government, provincial and municipal.

Watershed Designation involves the designation of a watershed area - the area which drains into watercourses upstream of the municipal water supply intake - as a "protected area". In a protected area, land and water use activities are controlled above and beyond the normal health, environmental and subdivision controls which apply to the province as a whole.
Currently, there are 25 municipalities in New Brunswick which utilize 31 surface watersheds as their source of potable water. The watersheds cover an area of approximately eight percent of the total area of the province, yet serve over 34 percent of the population.

The first step towards implementing the watershed protection policy is the establishment of a watercourse setback. A truly technical definition of a watercourse setback would require detailed assessment of slopes, soils and vegetation. This would result in a setback whose width would vary considerably over the length of the watercourse. Because of the high cost associated with compilation and analysis of the data, as well as the problems associated with enforceability of a non-uniform setback, the Province of New Brunswick has identified a uniform setback of 75m on either side of the banks of protected watercourses. The width of the setback is based on the recommendations of 20 Watershed Protection Studies contracted by several different consulting firms. The consultants setback recommendations varied from 60m to 150m. The Department used an average of 75m, approximately 1% of the total area of the Province, to implement in New Brunswick.

The 75m Protected area was put into effect on November 8th, 1990, when the Watercourse Setback Designation (Regulation 90-136 of the Clean Water Act) was approved by the Lieutenant-Governor in Council. The Regulation designates water supply watersheds as protected areas in which land use would be controlled within 75m of all designated watercourses contained in the watersheds.

One land use activity affected by the Watercourse Setback Designation is agriculture. The Watercourse Setback Designation prohibits the establishment of any new agricultural land within the 75m protected area and requires that the following conditions be met for agricultural land in operation within the 75m setback area, at the time of the designation:

- no agricultural activity occur within 30m of a designated watercourse;
- ploughing or tilling is contoured against the slope;
- ploughing or tilling not occur on slopes greater than 5 horizontal to 1 vertical without diversion terraces;
- surface runoff from each field does not flow directly into the watercourse;
- fields utilized for livestock grazing shall have a suitable fence constructed along the periphery of the 30m in order to allow livestock no closer than 30m to the watercourse;
- the practice of green manuring occur in addition to inorganic fertilizing.

The above conditions are deemed necessary in order to reduce the risk of having nitrates, bacteria, soil, pesticides and petroleum products enter the watercourse. Individuals who, at the time of the designation, were unable to comply with these conditions, were given sixty days to notify the Minister to this effect and in so doing, would become eligible for an exemption pending the outcome of an on-site inspection. Exemptions are only granted for those activities the Department feels will not jeopardize water quality. Although agriculture is permitted within the protected area, the conditions required by the Watercourse Setback Designation have caused some impact on the Agricultural Community. Concerns as to the loss of yield from crops previously harvested within 30m (note however, an undisturbed distance of 15m was already required under the Watercourse Alteration Regulation), the cost of constructing fences and alternate watering sources for livestock, the loss of area in which to spread manure, as well as the loss of yield due to restraints on fertilizing, have been raised.

In response to these concerns the Canada-New Brunswick Environment Sustainability Initiative was established. Under this Initiative individual farmers could receive up to $125.00 per hectare for areas set aside from agricultural use for watercourse buffer zones, up to 55% of the cost of eligible activities which included farming, watering devices, sediment control basins, ditch and stream crossings for livestock and machinery, and up to 80% of project engineering costs. Under the same Initiative, funds were available to encourage on-farm adoption of environmentally sound manure management technology.

Buffer zones are an important first step in effectively managing and protecting a surface water supply, by limiting activities which are potential sources of contaminants and by preserving a naturally vegetated area which reduces channel velocities, filters sediments and stabilizes stream banks and floodplains.
At the present time the Watercourse Setback Designation is the only regulation established under the Watershed Protection Program which controls land use activity. Designation of the balance of the watersheds, including the watercourses themselves and those areas of land outside the 75m setback but inside the watershed boundary, are expected to begin late this fall.

As with the Watercourse Setback Designation, an order will be put forth to the Lieutenant-Governor in Council outlining which land use activities will be permitted, restricted, limited or controlled within the balance of a watershed. Although this designation touches a larger area of land and a proportionately greater number of land owners, the overall impact may be less as standards for land use activities are expected to be less stringent.

Land use activities targeted by this designation will primarily be those considered to be potential "point sources" of pollutants such as industrial and commercial uses. However, standards pertaining to certain aspects of "non point source" activities will also be included. In the case of agriculture, standards for both solid and liquid manure storage will be established as well as maximum rates of distribution.

The Province of New Brunswick is optimistic that the existence of Watershed Designation, specifying two zones of land and water use restrictions, will significantly reduce the risk of contamination of Municipal potable surface water supplies.

Watercourse Alteration Regulation:

Protecting the streams, rivers and lakes of the province from detrimental watercourse alterations is the purpose of the Watercourse Alteration Regulation. The regulation was originally developed and passed, (February, 1977), under the Clean Environment Act but was later refiled, (June 29, 1990), under the Clean Water Act as N.B. Reg. 90-80.

This regulation provides the N.B. Department of the Environment with the authority to regulate the alteration of any watercourse in the province. This is accomplished through a permitting process, where any individual wishing to undertake an activity which will disturb the ground within 30m of a watercourse requires a Watercourse Alteration Permit issued by the Department.

As water is an integral part of most farming activities, many agricultural lands are selected with respect to how readily this resource is available. Knowledge of the Watercourse Alteration Regulation and the proper procedure for obtaining permits is very important for farmers in New Brunswick as most have at least one watercourse, be it a stream, brook or pond, on their property. Agricultural activities which would require a Watercourse Alteration Permit would include such things as installation of an irrigation system which draws water from a surface source, construction of bridges or culverts required to allow the crossing of livestock and farm equipment. Even the harvesting of trees within 15m of a watercourse requires a permit.

There are however, several activities related to Agriculture that are exempt from requiring a permit. These include:

- the construction of a roadway, or agricultural drainage ditch if there is no danger of pollution as a result of the construction and the subsequent operation of the ditch and if the ditch does not break the bank of a watercourse.

- the repair of a structure if no modification is made to the size, shape, materials, and alignment of the structure.

- the maintenance of a roadway or agricultural drainage ditch if the ditch does not break the bank of a watercourse, no change is made to the alignment of the ditch, and there is no danger of pollution as a result of the maintenance.

An amendment to the Watercourse Alteration Regulation has been proposed. This amendment will exempt ploughing, tilling and grazing from requiring a Watercourse Alteration Permit provided these activities are carried out between 5 and 30 meters from the watercourse.

CLEAN ENVIRONMENT ACT

At the present time, one regulation under the Clean Environment Act affects agricultural practices. This regulation is the Petroleum Storage and Handling Regulation (NB Reg. 8797). There is however, a pending regulation referred to as the Proposed Agricultural Practices Regulation which will, when passed, establish certain environmental standards for agricultural operations.

Petroleum Product Storage and Handling Regulation:

The Petroleum Storage and Handling regulation (NB Reg. 87-97) was filed under the Clean Environment Act on July 30, 1987. Agriculture is again one of the land uses affected by this regulation. The Petroleum Storage and Handling Regulation requires that any agricultural operation which stores in excess of 2000 litres of petroleum products, obtain the following license:

> a farm license, for an operation that has agriculture, silviculture, animal husbandry or aquaculture as its primary purpose and that has a system for the primary purpose of providing fuel for vehicles and equipment used by that operation, other than a residence, on or before April 1, 1989.

In addition any such operation must be registered under the Petroleum Product Storage and Handling Regulation, and must carry third party liability insurance with a pollution exclusion clause for $100,000.

A removal schedule must be complied with which requires that all underground storage tanks without cathodic protection, be removed by June 30, 1992 if the manufacture date of the tank is between 1971-1975, and by June 30, 1993 if the manufacture date is after 1975.

The Petroleum Products and Handling Regulation prohibits any supplier from supplying products to any operation that is not registered under the Petroleum Products and Handling Regulation.

Proposed Agricultural Operations Practices Regulation:

The regulation proposes to use four mechanism to address environmental concerns arising from agricultural activity throughout New Brunswick. When passed, the regulation will give the Department of the Environment the authority to designate certain agricultural operations, regulate construction criteria and manure management, and impose requirements related to remedial action in the event of a spill.

Under this regulation, the Minister of the Department of the Environment may designate an agricultural operation which poses or is potentially a danger of causing air or water pollution as one which requires an Operating Approval to be applied for by the owner of the operation.

Once an application has been made, the minister may: issue an Operating Approval, refuse an Operating Approval stating reasons therefore, or issue a Ministerial Order to bring the operation(s) into compliance.

The Operating Approval, when issued, will specify terms and conditions with which the owner has to comply. The maximum period of time for which an Operating Approval can be issued is five years.

General construction criteria will consist of separation distances with which the person responsible for the construction or the major expansion of existing buildings for the housing of livestock and facilities for the handling and storage of manure, must comply. An owner who cannot comply with the separation distance requirements, due to unique geographic features, may apply to the Minister for a variance. On the other hand, unique geographic or topographic features may require that the Minister impose increased separation distances.

The management of manure will be addressed by regulating the types and capacities of manure storages, by limiting the rate of manure application, and by restricting manure application to certain periods of the year.

The regulation will require that owners take adequate action to minimize water pollution resulting from a discharge or spill of manure or contaminant. The owner will also be required to report any such spill or discharge to the Minister of the Environment. The report must outline the type and volume of manure or contaminant, the place where it was discharged, the waters affected and the remedial action taken by the owner. The Minister may order the person who has control of an agricultural operation to take such action as the Minister considers necessary to minimize water pollution.

PESTICIDES CONTROL ACT

Pesticides are regulated in New Brunswick under the authority of the Pesticides Control Act and General Regulation (NB Reg 83-57). The intent of the legislation is to ensure that pesticides are used and disposed of in an appropriate manner. Only pesticides that are registered under the federal Pest Control Products Act may be considered for use in New Brunswick.

Presently, all pesticide applications, including commercial and aerial applications, as well as applications to water and applications for research purposes are regulated. However, applications, for research purposes on parcels of land smaller than 5 hectares, are exempt from requiring a permit. The regulatory mechanisms are licensing, certification, and site specific or project specific permits.

Individuals who apply pesticides by ground on their own property must comply with federal requirements on the pesticide label but are presently exempt from the license, certification and permit requirements. Agricultural operations are subject to the general provisions of the Pesticide Control Act, however, permits, licenses and certifications are only required if aerial application is utilized, or if a professional ground applicator is engaged to carry out the application.

Currently, there is a proposed amendment to the Act which would require that all non-commercial applicators as well as all vendors be certified. Examples of non-commercial applicators are farmers, plant propagators, christmas tree growers, sod growers and other similar individuals.

The purpose of the proposed amendment is to increase the knowledge of those individuals wishing to apply pesticides on topics such as the safety of a given product and its proper use. This will increase the safety of the general public, the environment, and the applicators themselves. Applicators will be required to attend a course and pass an exam prior to being certified.

HEALTH ACT

The only regulation under the Health Act presently affecting agricultural activities is the General Regulation-Health Act (NB Reg 88-200). This regulation imposes conditions on transport and disposal of waste and carcasses, and imposes setbacks for construction and expansion of agricultural operations as per the following:

- No person shall transport slaughterhouse waste, offal, or animal waste over any public highway, except in a covered vehicle and in such a manner as to prevent or any other cause of nuisance.

- No pigsty, hog raising establishment, abattoir, poultry house or other livestock operation shall be built on marshy ground or on land subject to overflow, or within ninety meters of any inhabited house or occupied dwelling, other than that of the owner.

- No pigsty, hog raising establishment, abattoir, poultry house or other livestock operation shall be extended or enlarged unless it and the addition are located at least ninety meters from any inhabited house or occupied dwelling, other than that of the owner.

- The carcass of any animal not intended for human consumption shall be removed and disposed of within twenty-four hours by burial, incineration or any other method approved by a district medical health officer.

- No person shall incinerate waste or refuse in any way that may contaminate the surrounding area or create a nuisance.

CONCLUSION

The environmental legislation in New Brunswick was developed to address the complex environmental conflicts that have evolved throughout the province.

One of the objectives of the discussed legislation is to maintain acceptable water quality throughout the province, especially in the thirty one watersheds which provide drinking water. There are at the present time no crises situations within these watersheds, but pressure is being felt by concerned municipalities to protect this valuable resource. The Watercourse Setback Designation is an attempt to successfully address this concern.

The other legislation addresses water quality concerns throughout all of New Brunswick, resulting from both potential and existing conflicts, between water quality objectives and uncontrolled land-use activities.

This paper highlights the effect these regulations have on the agricultural activity carried out in the province of New Brunswick.

AGRICULTURE AND ENVIRONMENT: A REVIEW OF ONTARIO'S LEGISLATION AND GUIDELINES

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INTRODUCTION

This presentation will present some facts on Ontario's Agricultural pollution problems and put them into perspective with respect to the land base and use in the Province. The four main pieces of environmental legislation, these being the Environmental Protection Act, the Ontario Water Resources Act, the Pesticides Act and the Environmental Assessment Act will be discussed in detail to provide some insight into how each of these interacts with agricultural activities and their inherent pollution problems. The presentation will close with a brief discussion of some of the Ministry's main programs which are developed to interact co-operatively with the rural community and other Ontario Government Ministries to provide for pollution prevention and remediation rather than prosecution.

Ontario In Perspective

Before I talk about legislation, I would like to present you with some facts to try to put Ontario into perspective. The Province of Ontario has a total land area of 1.06 million square kilometres (11% of Canada's total). The land use in the province is roughly divided into 58% forest, 23% tundra, 7% agricultural and the remaining 12% in urban use. Approximately 17% of the province is covered by lakes (228,000) (181,153 square kilometres), this is somewhat astounding when one stops to consider that Canada is only 8% freshwater. If all the small lakes and ponds in excess of 0.01 square km. are counted then Ontario contains over 1 million lakes and ponds (MNR 1984).

To put the 7% agricultural land use into perspective, according to the 1986 census statistics there were 72,713 farms comprising a total land base of 13,953,009 acres, 8,544,820 of which were under crops. In addition to the crop land there were approximately 46.5 million cows, pigs, horses, chickens etc. (OMAF 1990).

Environmental Concerns

I will not dwell long on this aspect as we all are aware of the main environmental concerns regarding agriculture and the environment.

Pollution can enter streams and lakes from well defined point sources such as industrial and municipal outfalls or from diffuse sources such as field erosion. Some of our water quality concerns related to diffuse sources of pollution are; sediment and nutrient loadings, bacterial contamination, pesticide runoff, loss of stream habitat.

Sheet and rill erosion from cropland as well as bank erosion in some areas causes unacceptably high levels of suspended sediment. Sedimentation in streams can have direct effects such as inhibiting the development of a healthy bottom fauna. In addition, associated with the sediments are often high levels of metals and nutrients.

Waters highly enriched with nutrients are also a prevalent problem over much of Southern Ontario. This can result in dense growths of aquatic macrophytes and algae. During peak summer growth, respiration by plants can in some cases depress the dissolved oxygen concentration to the point where sensitive and important fish populations cannot be sustained.

Our routine water quality monitoring of approximately 700 locations throughout the province has shown that streams in many areas, and in fact most of southwestern Ontario, have phosphorus concentrations in excess of our Water Quality Objective of 0.03 mg/L (Whitehead pers. comm.). The significance of this is that this is also the area of most intensive agriculture in the Province. Similar trends are seen in suspended sediment, nitrogen and microbiological data.

The causes of these water quality problems are widespread and in many cases difficult to control. Erosion of soil from croplands contributes sediments, nutrients and pesticides as well as degrading the quality of the soil. Stream bank erosion adds sediments and nutrients to the streams. These are all sources of concern.

Soil erosion contributes to the decline in crop productivity through the loss of nutrients and organic matter. Eroded material accumulates in streams and rivers resulting in the destruction of aquatic habitat, sedimentation of reservoirs and harbours. Addition of related nutrients and pesticides contributes to eutrophication and drinking water problems.

Nitrates in drinking water can pose severe health problems for young children. Sources include commercial fertilizer, and manure. Manure is a major problem when applied at the wrong time of year, at wrong rates or when the potential for pollution is high.

Phosphorus is bound to soil particles and tends to move more with surface runoff. Agriculture is one of the principle sources. Manure, milkhouse washwater, septic systems, commercial fertilizer are all sources.

Bacterial problems arise from livestock manure gaining access to watercourses and livestock directly watering in streams. Milkhouse washwater and faulty septic systems also contribute significantly to the problem. Bacterial pollution of our streams has increased over the years to the point where over 10% of Ontario's 1200 recreational beaches are posted each year as being unfit for swimming. Cattle entering streams contribute to bank erosion and direct inputs of nutrients and bacteria. Runoff from feedlots and unprotected manure piles contributes nutrients and bacteria.

Water quantity is also an issue, particularly for irrigation purposes. In a multi user environment conflicts over water use are inevitable.

Noise and dust and odour complaints particularly in the urbanizing fringes are common problems. Proper timing and management techniques are essential and an important part of Ontario's attempts to effectively deal with these issues.

Pesticides are also an issue of concern both on and off the farm. Health concerns regarding proper handling and application as well as environmental concerns when pesticides leave the farm from runoff and spray drift are major issues of concern.

The Legislation

As the major industrial and municipal point sources of water pollution have come under control, the Ontario Ministry of the Environment has sharpened the focus on other impacting economic sectors such as agriculture. Water quality in rural areas worsens as the land becomes more intensely farmed. The water quality impact from non-point sources such as soil erosion, livestock access, and manure runoff, as well as the often more dramatic impact of point sources such as manure spills and milkhouse waste water have created problems both immediately downstream of the discharges and at some distance from the discharges, for example, at beaches or other recreational areas.

In recent years, the Ontario Ministry of the Environment has become more enforcement oriented. This, coupled with the continuing high number of agricultural occurrences has lead to a large number of farm prosecutions each year.

In the Ministry of the Environment's southwestern region, 20 to 30 major fish kills are documented each year. Of these, 80% to 90% are either directly or indirectly a result of agriculture. The majority of these are caused by the discharge of liquid manure with very few resulting from pesticide discharge. Approximately 20% of the region's total annual prosecutions, are against farmers (Blackie Pers. comm.).

Apart from the dramatic, localized impacts such as fish kills, the Ministry of the Environment also has concerns for downstream water use, for example, livestock watering, human consumption and recreational use. As rural water quality declines, the need to improve it rises.

In attempts to address environmental impact from agricultural sources, the following Ontario legislation and guidelines play a part in the regulatory process.

The Environmental Protection Act (EPA) through its general provisions covers all types of pollution, forbidding the discharge of any contaminant into the natural environment in amounts, concentration or levels exceeding those prescribed by regulation. A contaminant is defined as a solid, gas, liquid, odour, heat, sound, vibration, radiation or combination of any of these, resulting directly or indirectly from human activities, which may cause injury to humans, flora or fauna (EPA RSO 1980) .

In addition to regulated limits for its specific contaminants, the Environmental Protection Act prohibits any discharge that is likely to impair the natural environment for any use that can be made of it, injure or damage plant or animal life, cause harm or discomfort to any person, affect the health or safety of any person or render any property, plant or animal life unfit for human use.

The above noted prohibition of discharge that is likely to impair the natural environment for any use that can be made of it does not apply to animal waste disposed of in accordance with normal farming practice. The disposal of animal waste is not exempted from consideration of impact through the other adverse effects listed above.

The Ministry took a significant step in protecting the environment when Part 9 of the Environmental Protection Act came into force in 1985. Commonly known as the Spills Bill, it requires spills of pollutants discharged into the environment to be reported and cleaned up promptly by the owner or person in control of the material when it was spilled. It establishes a liability on those who own or control the spilled material to compensate those who incurred costs or suffer damages. The Environmental Protection Act also established the Environmental Compensation Corporation which receives applications for compensations from parties who have suffered loss or damage due to a spill.

To complement the Environmental Protection Act, the Ministry has established the Spills Action Centre (SAC). The centre receives notification of spills 24 per day, 365 days per year on a Province wide toll free number.

The Environmental Protection Act has a comprehensive system of penalties. The basic penalties are a maximum fine of $10,000.00 for first offence and $25,000.00 for subsequent offenses if the source is unincorporated. Should the source (including farms) be incorporated, the first offence would generate a minimum fine of $2,000.00 and a maximum fine of $200,000.00. Subsequent offenses would have a minimum fine of $4,000.00 and a maximum fine of $400,000.00. Under subsequent offenses there is the added possibility of a jail term along with the fine.

The Ontario Water Resources Act (OWRA) gives Environment Ontario extensive powers to regulate water supply, sewage disposal and the control of water pollution.

Under the Ontario Water Resources Act, any discharge into a body of water, on its shore or in any place that may impair the quality of the water, is an offence. It is also an offence to make any discharge that directly or indirectly causes injury to a person, animal or bird through the use or consumption of any plant, fish or other living matter in the water (OWRA RSO 1980).

Water quality criteria have been established as acceptable standards for various uses made of water. This document entitled "Water Management Goals, Policies, ..." (MOE 1984) or the BLUE BOOK as it is commonly known provides the basis for enforcement of the OWRA and is constantly under revision as scientific knowledge increases.

Under the Ontario Water Resources Act the structure of penalties is essentially similar to that of the Environmental Protection Act.

Both the Ontario Water Resources Act and the Environmental Protection Act also require polluters to notify the Ministry of the Environment following a discharge.

The Pesticides Act is legislation which restricts the storage, distribution, sale and use of pesticides. The Ministry examines and licenses professional exterminators and maintains a classification system to ensure that hazardous chemical pesticides are not handled or used by unqualified persons (Pesticides Act RSO 1980) .

The Environmental Assessment Act provides for the assessment of any proposed major undertaking - governmental, municipal or private - at the very earliest stages so that it may be altered or even cancelled if it is found to be environmentally unacceptable (Environmental Assessment Act RSO 1980) .

Guidelines, Policies, and Programs

Along with the above noted legislative tools, Ontario employs a wide range of guidelines, policies and program initiatives to attempt to resolve the multitude of conflicts and enforcement activities related to agricultural pollution experienced in the province.

The Agricultural Code of Practice (OMAF 1976), a document developed by the Ministry of Agriculture and Food in conjunction with the Ministries of the Environment and Housing offers an opportunity for the responsible siting of livestock buildings and manure facilities and the application of manures on farmland to avoid water quality problems, both groundwater and surface water. These guidelines deal with the siting (separation distances) of new or expanding livestock operations, the adequacy of manure storage, the adequacy of land base for manure application, and environmental control. They offer a basis to evaluate proposals and can act in lieu of a formalized approvals requirement.

Quasi-approvals tools such as Ontario's voluntary Certificate of Compliance Program have potential benefit but if not actively promoted, they will continue to be used minimally to formalize requirements. Many municipalities have adopted parts of the Agricultural Code of Practice which addresses siting but an evaluation of a Certificate of Compliance application goes far beyond siting to potential water pollution potentials.

The Certificate of Compliance states that the landowner has examined his operation and has undertaken all reasonable precautions to ensure that his operation will result in a minimized potential for environmental impact.

A set of procedures known as the "Protocols For Handling Farm Pollution Incidents" (OMAF/MOE 1988) have been developed through a joint effort of the Ontario Ministry of the Environment, and the Ontario Ministry of Agriculture and Food. The protocols are intended to be used by OMAF and MOE field staff when dealing with citizen requests, complaints or problems related to farm pollution problems and lay out respective responsibilities in matters of mutual concern ranging from odour, dust and noise complaints to water pollution incidents to dead stock disposal.

There are a total of 8 protocols: farm waste; improper disposal of dead animals; pesticide incidents; well water quality problems; Certificate of Compliance Program; minimum distance separation formula; odour, noise and dust; and media contacts. They lay out who is the lead agency and in general who does what, when, where, and how. They help support the growing degree of environmental leadership being shown by the Ministry of Agriculture and Food.

Pressures to protect the farmers from unfair harassment, persecution and civil actions have lead to the evolution of right to farm legislation in many jurisdictions. In Ontario this is known as the Farm Practices Protection Act (SO 1988).

It involves the use of a board to assess/define normal farm practice on a case by case basis in the hope that board decisions will help to facilitate resolution of land use conflicts or at least cut short the potential for civil action.

Conflicts over water supply, particularly those over irrigation usage is resolved through the Permit To Take Water Program. Under this program, any person who intends to withdraw water from either surface or groundwater sources in excess of 50,000 litres (10,000 gallons) per day is required to apply for and be in the possession of a valid permit to take water

(Eddie Pers. comm.).

Through the use of its Grower and Vendor Certification Program the Ministry is taking action to reduce and carefully control the use of chemical pesticides. This program contains a requirement for mandatory training for health and safety - both personal and environment. Compliance monitoring is an essential follow up. Our Ministry is working to move farmers, foresters, parks people and gardeners away from the use of chemicals and into alternative methods of controlling pests through education and encouragement, through research into alternatives to pesticides, and through tighter regulatory controls over their use.

The Ministry of Agriculture and Food's Food Systems 2002 program is aimed at reducing the use of pesticides by 50% by the year 2002 through a combination of education, research and Integrated Pest Management. Two major objectives of the program are to maintain efficient and sustainable crop production through the development of environmentally sound techniques, and to help increase grower awareness, while decreasing grower costs and the pesticide load in the environment. The program is a co-ordinated approach emphasizing three main areas: Research, Education, and Field Delivery of pest monitoring and management strategies.
Research into alternatives to chemical substances through the Ontario Pesticides Advisory Committee (OPAC) and working with the Ministry of Agriculture and Food toward a comprehensive provincial strategy dealing with outdated pesticides and empty pesticide containers, including initiatives which promote the reduction, use and recycling of pesticide containers is also a major program initiative with MOE.

The ministry actively participates in many multi-agency programs aimed at reducing the environmental impacts of agriculture. I will briefly outline a few of these programs below.

Groundwater investigations are an integral part of the ministry's program to understand and characterize the groundwater resources of the province. One study is assessing the potential for groundwater and surface well drinking water contamination by nitrates. In co-operation with the University of Waterloo an investigation on the extent of the problem and the pathways of this chemical in the environment is being carried out.

Many problems have occurred in the past, usually associated with high nitrogen fertilizer application and/or areas of manure application. Other groundwater investigations are being carried out in connection with the pesticide Aldicarb to determine potential contamination of groundwater and surface well drinking water supplies in some areas.

The SWEEP Program, a combined Federal-Provincial effort, was developed to prove the technology and management techniques required to provide for a 200 metric tonne per year reduction in the phosphorus load to Lake Erie. This program involves not only the Federal and Provincial governments, but also Universities and farmers at all levels of the research; from the small 10 metre square in field plots to entire watersheds.

MOE has co-operated both financially and technically with the Ministry of Agriculture and Food in their OSCEPAP and successor Land Stewardship I and II Programs. These programs have been highly successful in reducing erosion preventable by structural measures and in enabling livestock farmers to construct manure storages to reduce their impacts on the environment. Staff of MOE and OMAF have an ongoing dialogue in which we are continually looking for ways to develop similarly effective programs which consider both the environment and the needs and realities of farming.

The Rural Beaches Program is one of the most effective programs of the Ministry dealing with rural pollution. Through the involvement of several agencies and the keen interest and involvement by the farming community, involved Conservation Authorities were able to develop watershed specific action plans aimed at improving rural water quality and restoring the use of Ontario's rural beaches. These plans, known as CURB (Clean Up Rural Beaches) plans enabled MOE to develop a provincial program to provide the necessary incentives for rural residents to voluntarily implement measures that address their own specific water quality improvement plans. These plans are jointly developed between the landowner and our facilitators working at the Conservation Authority offices and reflect the most cost effective measures for attacking the problems specific to the property.

The program is designed to provide grant assistance to rural landowners undertaking projects such as; fencing livestock out of streams and provision of alternate watering supplies, new and effective milkhouse waste disposal systems, repair of faulty private sewage disposal systems, and improvements to manure management systems. The programs also provides for "grass roots" transfer of knowledge so that the capital works are accompanied by the best possible management techniques, thereby ensuring that the province's investment maximizes the improvements in water quality.

The CURB Program has received outstanding support from the rural residents in Ontario. I am happy to say that since the announcement of the program in late August we have approved over 200 individual projects and allocated close to 1 million dollars in grant assistance. This is in only the first 6 months of this 10 year program and I can only say that the future looks positive for both the agricultural community and the environment in terms of water quality.

These are a few of the current programs aimed at assisting agriculture in its attempts to form a harmony with the environment. I would like to finish this presentation by highlighting a few of the new initiatives which the Ontario Government is working on.

The Environmental Bill of Rights which is being proposed by the ministry is a new initiate for the Ontario Government. Although farmers have expressed concern about the potential impact of an Environmental Bill of Rights on their ability to continue farming as a profitable livelihood the Ministry will provide ample opportunity for their representatives to review an actual draft of the proposed legislation to ensure that their interests are served. This will be a bill which serves farmers and reinforces environmentally sensitive farming practices while also giving the agricultural community a greater voice in decisions which are made by government regarding the environment.

The concept of sustainable agriculture in a clean environment is a key concept contained within this piece of legislation. Farmers are working with government toward sustainable agriculture, combining best elements of conservation farming and integrated pest management, with a general regard for the environment and for the soil resource.

A Safe Drinking Water Act is also being planned to protect our groundwater resources. This is a strategy which is under development to protect our groundwater from toxic chemicals, sewage spills and other pollutants.

The Canada-Ontario Environmental Sustainability Accord Respecting the Agri-Food Sector (COESA) is an agreement between Agriculture Canada and the Ontario Ministry of Agriculture and Food which has been established to manage all environmental sustainability initiatives in Ontario's agri-food sector. The agreement was signed by the parties in October 1991. COESA membership includes both federal and provincial agencies; Agriculture Canada (Co-Chair), Environment Canada, and Department of Fisheries and Oceans, Ontario Ministry of Agriculture and Food (Co-Chair), Ontario Ministry of the Environment and the Ontario Ministry of Natural Resources. The Ministry of the Environment supports the conservation efforts of the agricultural agencies and works jointly with them to ensure that the environmental objectives are met.

The Ministry of the Environment recognizes that none of the above legislation, protocols, guidelines, etc. will work effectively without sound research into alternatives. The Ministry of the Environment funds environmental research projects related to agriculture through the Ministry's Research Management Program (also known as RAC). Examples of ongoing research topics include:

- milkhouse waste systems

- bacterial sediment absorption in agricultural drains

- integrated non-point source model

- manure spreading impacts on surface water quality

I want to finish this presentation by leaving you with the vision statement which staff from both the Ministry of the Environment and the Ministry of Agriculture and Food strive to achieve, that is to achieve "a Viable Agriculture in a Clean Environment".

I hope this paper has given you some insight into our initiatives in managing pollution from rural land use activities. I think that through continued co-operation between MOE, other government agencies, local interest groups, and interested private citizens, new approaches to better management of the problems will continue to emerge.

REFERENCES

BLACKIE, MURRAY. MOE Southwest Region, personal communication.

EDDIE, JIM. MOE Water Resources Branch, Personal Communication.

ENVIRONMENTAL ASSESSMENT ACT RSO 1980. Environmental Assessment Act, Revised Statutes of Ontario 1980.

EPA RSO 1980. Environmental Protection Act, Revised Statutes of Ontario 1980.

ESTRIN, D. and J. SWAIGEN. 1978. Environment on Trial. Canadian Environmental Law Research Foundation. Toronto.

FARM PRACTICES PROTECTION ACT SO 1988. Farm Practices Protection Act, Statutes of Ontario 1988.

MNR 1984. Water Quantity Resources Of Ontario. Ministry of Natural Resources.

MOE 1984. Water Management Goals, Policies, Objectives And Implementation Procedures of the Ministry of the Environment. MOE 1984.

OMAF 1976. Agricultural Code of Practice. Ontario Ministry of Agriculture and Food, Ontario Ministry of the Environment, Ontario Ministry of Housing. 1976.

OMAF/MOE 1988. Protocols for Handling Farm Pollution Incidents. Ontario Ministry of Agriculture and Food, Ontario Ministry of the Environment. 1988.

OMAF 1990. Agricultural Statistics For Ontario -1990. Ministry of Agriculture and Food.

OWRA RSO 1980. Ontario Water Resources Act, Revised Statutes of Ontario 1980.

PESTICIDE ACT RSO 1980. Pesticides Act, Revised Statutes of Ontario 1980.

WHITEHEAD, BRIAN. MOE Water Resources Branch. Personal communication.

Willson, K. E. 1989. Ministry of the Environment - Interests. Managing Ontario's Streams. Canadian Water Resources Association 1989.

AGRICULTURE AND WATER QUALITY - SASKATCHEWAN LEGISLATION

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There are four provincially administered statutes which contain provisions intended to protect or minimize the effects of agricultural activities on surface and groundwater quality. The Pest Control Products (Saskatchewan) Act (PCPA) addresses the use, distribution and handling of pesticides and the licensing of commercial applicators. The Environmental Management and Protection Act (EMPA) deals with the storage and disposal of hazardous substances including most pesticides and some chemical fertilizers. The Act also regulates the use of chemicals in surface waters for aquatic nuisance control. The Pollution by Livestock Control Act provides for the protection of water quality and proper waste management at intensive livestock operations. Lastly, the Fisheries Act provides for controls on land use activities which could impact on fish habitat.

PEST CONTROL PRODUCTS (SASKATCHEWAN) ACT

This Act is administered by Sask Agriculture and Food. The Act recognizes the federal Pest Control Products Act for matters concerning pesticide registration requirements. The Act also prohibits the application of pesticides to an open body of water. Section 9 prohibits the cleaning or locating of pesticide application equipment or containers in open bodies of water and requires backflow prevention devices on equipment used for mixing or applying pesticides.

All commercial pesticide applicators require a permit issued pursuant to the Act and renewed annually. Classes of permits and associated course requirements and qualifications are specified in the Pest Control Products Regulations. The Class 2 permit is designated for application of pesticides to non-agricultural lands or aquatic areas. The use of pesticides for controlling aquatic nuisance organisms is covered in the Class 2 course curriculum.

ENVIRONMENTAL MANAGEMENT AND PROTECTION ACT

This Act is administered by Saskatchewan Environment and Public Safety and includes regulations aimed at preventing or minimizing the contamination of water by chemicals and pesticides. The

Hazardous Substances and Waste Dangerous Goods Regulations (1992) prescribe requirements for the proper management of products such as fuel, most pesticides and chemical fertilizers like anhydrous ammonia. An approval is required for the construction, operation and decommissioning of any storage facility, including above ground and underground tanks. In addition, all storage facilities must be registered in order to receive a hazardous substance or waste dangerous good. For the agricultural sector these regulations focus primarily on the manufacturers, dealers and distributors of farm chemicals and other products. Private landowners and farms are generally exempt from the regulations except for the registration of underground storage tanks larger than 205 litres.

The Environmental Spill Control Regulations require mandatory reporting of spills of contaminants exceeding specified quantities. This includes all pesticides, generally in amounts greater than one kilogram. The spill reporting system in the province provides for a rapid response for on-site mitigation and clean-up to prevent or minimize contamination of water supplies.

The use of chemicals in surface waters to control aquatic nuisances is regulated under the Water Pollution Control and Waterworks Regulations. This includes nuisances such as algae, aquatic vegetation and biting fly larvae. Control programs undertaken in water wholly contained on private property (eg. farm dugouts) are exempt. An annual permit authorizing the control program is issued on a site-specific basis, with restrictions on the product(s) allowed and in most cases specifying the requirement for a licensed applicator. In the agricultural sector the common programs regulated are vegetation control in irrigation and drainage canals(wet and dry) and blackfly larvae control. As a matter of policy, the Department actively encourages the use of non-chemical control alternatives wherever feasible. An example is the use of mechanical harvesters in lakes and canals to control nuisance weed growth rather than herbicides.

Biologically-based products are generally preferred over chemicals such as the chlorinated organic pesticides. For example blackfly larviciding in the Saskatchewan River system is now carried out exclusively with the bacterial agent *Bacillus thuringiensis* (BTI). This annual program is intended to reduce the impacts of adult blackfly infestations on cattle production and prior to 1991 relied on the use of methoxychlor. BTI has proven to be just as effective and has the advantages of being more target-specific and non-persistent in the aquatic environment.

POLLUTION (BY LIVESTOCK) CONTROL ACT

This Act and companion regulations are administered by the Department of Agriculture and Food and focus on the prevention of surface and groundwater contamination from intensive livestock operations (ILO's) and associated waste disposal.

ILO' s larger than 300 animal units require a permit to construct and must be designed to prevent water pollution and with adequate provisions for manure disposal.

The Department has published a Guide of Recommended Practice which provides design criteria for runoff control, manure holding, land application of manure and dead animal disposal. There is considerable emphasis in the Guide on manure management to ensure field application is at a rate equal to crop use, thereby avoiding contamination of surface and groundwaters with excess nutrients.

FISHERIES ACT

The habitat protection provisions of the Fisheries Act are administered by the Department of Natural Resources. The Department encourages a cooperative approach with landowners and developers to promote land use practices which will reduce erosion, conserve streamside habitat and minimize loss of in-stream or lake habitat. Preventative measures for the agricultural sector include maintenance of shoreline vegetation, minimizing livestock access to water and controlling drainage works to reduce peak flows. Major developments generally require an approval and permit for shoreline or fish habitat alterations.

REFERENCES

ENVIRONMENTAL MANAGEMENT AND PROTECTION ACT. Sask. Statutes, Chapter E-10.2.

ENVIRONMENTAL SPILL CONTROL REGULATIONS. Sask. Regulation 53/83 ;Sask. Statutes, Chapter D-14 Reg 1.

HAZARDOUS SUBSTANCES AND WASTE DANGEROUS GOODS REGULATIONS. Sask. Regulation 25/92 ; Sask. Statutes Chapter E-10.2 Reg 3.

WATER POLLUTION CONTROL AND WATERWORKS REGULATIONS. Sask. Regulation 588/87; Sask. Statutes Chapter E-10.2 Reg 2.

FISHERIES ACT. R.S.C., c F-14.

PEST CONTROL PRODUCTS (SASKATCHEWAN) ACT. Sask. Statutes, Chapter P-8

PEST CONTROL PRODUCTS REGULATIONS. Sask. Regulation 1123/85 and 86/88

POLLUTION (BY LIVESTOCK)CONTROL ACT. Sask. Statutes, Chapter P-16.1

POLLUTION (BY LIVESTOCK) CONTROL REGULATIONS. Sask. Statutes, Chapter P-16.1 Reg 1.

INTENSIVE LIVESTOCK OPERATIONS GUIDE OF RECOMMENDED PRACTICE. Sask. Agriculture and Food, 1991.

AGRICULTURAL IMPACTS ON WATER QUALITY: ALBERTA REGULATORY INITIATIVES

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INTRODUCTION

Environmental values and concerns have changed dramatically since 1971 when the Alberta Department of the Environment was established. Pressures on the environment, and environmental problems, have become more complex with technological and societal changes in the past twenty years. People are now more concerned about environmental issues and want to play a more active role in environmental decision-making (Alberta Environment, 1991).

In this context, farmsteads and associated industries from the agricultural community, including designated livestock operations and food processing facilities, continue to be major stakeholders in current and proposed regulatory initiatives to sustain environmental protection in Alberta.

EXISTING POLLUTION CONTROL PROGRAM

General

Alberta's existing air and water quality management system, developed in the 1960s and 1970s, was to maintain local air quality and water quality by controlling local industrial emissions. Ambient objectives and "end of pipe, end of stack" standards were established in order to control pollution at acceptable levels. In the 1980s, new challenges arose through issues like acid deposition, global warming, smog and stratospheric ozone depletion (c.f. Alberta Energy/ Environment, 1992).

Alberta's current pollution control program has four main premises:

- emissions from each industrial source must be controlled using the best available demonstrated technology that is economically achievable;

- residual emissions must be dispersed through a stack or effluent outfall designed to keep ambient concentrations below the prevailing ambient air and water quality objectives;

- industrial operators must monitor emissions and the resulting air and water quality around their facilities and report the measurements;

- cumulative emissions from industrial sources are considered with respect to ambient objectives and regional air pollutant deposition and water pollutant dispersion.

Alberta regulations specify maximum permissible concentrations in ambient air for six different contaminants (gaseous emissions of sulphur dioxide, hydrogen sulphide, nitrogen dioxide, carbon monoxide, ozone and particulate). The best available demonstrated technology (BADT) for various industry categories is generally determined by joint government-industry task forces. The recommended industrial performance standards for air and water pollutants, and emission rates and implementation schedules are formalized as regulations, guidelines, policies and informational letters which are used to set individual licence limits. Based on the "polluter pay" principle, the cost of monitoring is borne by the industry. Alberta Environment restricts its activities to data quality assurance and spot checks. Licences issued by Alberta Environment to industrial operations contain a variety of conditions and specify equipment, operations, maximum emission rates, stack limits, source testing, ambient monitoring and data reporting. A tiered enforcement procedure is also in place to ensure compliance with licence conditions. The system achieves two goals:

- emissions from individual industries are minimized using BADT; and

- air and water quality in the vicinity of industrial operations meets prevailing objectives.

Food processing sector

With respect to the agricultural food processing sector such as meat, poultry and vegetable processing, etc., liquid effluents discharging to municipal sewage treatment plants are exempt from the licensing provisions of the *Clean Water Act.* Liquid effluent quality must comply with restrictions under municipal sewage by-laws. However, all effluents from municipal and industrial sources are individually licensed in order to regulate the aggregate impact of pollutant loadings to receiving streams. *Clean Air Act* licences are issued to address odour emissions in addition to regulated pollutants.

The application of treated industrial wastewater to land in the spray irrigation mode is an alternative which is competitive with other liquid effluent treatment methods. Site characteristics and technical considerations are reviewed by soil scientists in Alberta Environment and monitoring requirements for all sites are specified in licences issued under the *Clean Water Act.* The feasibility of irrigation projects depend on local weather and soil conditions, quantity and quality of wastewater, land availability, economics and potential health hazards. Control of groundwater quality impacts are governed by application rates, infiltration capacity and ion exchange properties of the soil, nutrient assimilation by soil fixation and crop uptake. These factors have favoured industrial projects in the South Saskatchewan River basin (Shewchuk, 1978).

Intensive livestock operations

The developers of new feedlots can benefit from the experience of Alberta's pioneers, and also obtain abundant technical information on planning, water supplies, weather, ecology, energy conservation and waste management. The productivity of a modern feedlot depends on adequate supplies of water, electricity, and fuel. In addition, consideration must be given to the effects of topography, sunlight, wind, snow accumulations, and manure disposal. These factors affect the efficiency of production, quality of life, and the aesthetic appearance of the operation.

In recent years, intensive livestock operations have increased both in number and size in the province of Alberta. This has been caused by a growing demand for meat and dairy products, and changes to the economics of livestock management and production. The development of confined livestock feeding has coincided with mounting public concern about the potential pollution of the environment caused by the concentration of manure and wastes in localized areas.

Management of the resulting livestock manure without contributing to air, soil and water pollution can be a major problem in the operation of modern feedlots. Conversely, it is also universally recognized that properly managed manure can be an important resource, especially if it is used to improve the physical conditions of soil, soil fertility and productivity (Alberta Environmental Centre, 1991).

During 1972, Alberta Environment initiated an Intensive Livestock Operations Committee to identify the status of waste management practices of Alberta livestock operations. The committee reviewed the environmental implications resulting from these activities. A "Confinement Livestock Facilities Waste Management Code of Practice" was published in 1973 with recommendations for uniform waste management requirements and acceptable practices for siting, construction and operation of confined livestock facilities. The Code was revised in 1982 to incorporate the minimum distance separation formula as a guideline in approving feed lots under a voluntary certification program jointly administered by Alberta Agriculture and Alberta Environment. The program assists farmers in interpreting and complying with the many regulations governing the establishment of livestock enterprises. With respect to waste management, the most important regulations involved are in the *Public Health Act* and the *Clean Air Act* and the *Clean Water Act.* The *Public Health, Provincial Board of Health Regulations Respecting the Keeping of Livestock and Poultry (Division 23)* regulations stipulates the minimum distances a livestock operation must be from towns, villages, and neighbouring residences. The reasoning behind these regulations is that intensive and confined livestock operations present potential health problems in the forms of water pollution, odour, and insect nuisance (Alberta Agriculture, 1981).

The *Clean Air Act* and the *Clean Water Act* stipulate controls designed to protect air, groundwater, and surface water from becoming polluted. Development permits are issued by the local county or municipal government for permission to build specific facilities on designated sites. Issued at County or M.D. offices, they are subject to local by-laws and may or may not be required in different areas. Some local authorities require a certificate of compliance pertaining to the siting and design of a facility before issuing building permits.

If all the requirements of the Code of Practice are met, a farmer may apply for a certificate of compliance. The certificate of compliance is a statement meaning the applicant is complying with all regulations, and at a level of technology or management for odour control and waste manure disposition within the guidelines of good practice as outlined in the Code of Practice. On this basis, the farmer has the approval of Alberta Agriculture and Alberta Environment for as long as he maintains adequate standards. Approximately 700 operations are currently certified.

It is estimated that there are approximately 6,700 operations in Alberta that could be defined as confined livestock operations. Based on 1989 inventory figures, an approximate distribution is as follows: 3400 hog producers; 2100 slaughter cattle producers; 1200 feeder cattle operators; 50 poultry operators (over 60,000 birds). Of these operations, there are 46 beef feedlots and 67 hog operations in excess of 5,000 head (Personal communication, Standards & Approvals Division, 1992).

REGULATORY INITIATIVES

<u>Alberta environmental protection and enhancement act</u>

The proposed *Alberta Environmental Protection and Enhancement Act (AEPEA),* first introduced in June 1991 in the Legislative Assembly of Alberta and re-introduced in May 1992, consolidates a solid base of existing environmental protection and enhancement legislation. It amalgamates Alberta's nine existing environmental acts which include the following: *Agricultural Chemicals Act; Beverage Container Act; Clean Air Act; Clean Water Act; Ground Water Development Act; Hazardous Chemicals Act; Land Surface Conservation and Reclamation Act; Litter Act;* and some sections of the current *Department of the Environment Act.* These are integrated into *AEPEA* to provide an overall framework for environmental protection and enhancement. *AEPEA* has been significantly influenced by public involvement at every stage of its development (Alberta Environment, 1992).

AEPEA has been organized in accordance with the following objectives:

- to provide a legislative framework that is based on preventive action first (consultation, communication and education, environmental impact assessments and approvals) moving progressively through remedial action (environmental protection orders) and finally to enforcement;

- to take an integrated approach to air, land and water, rather than independent management of each by including broader provisions that cover all areas of environmental protection such as purpose, guidelines, objectives and approvals;

- to streamline and simplify existing provisions, eliminating duplication and making them more consistent, for example, by providing a uniform appeal procedure, as opposed to five different procedures in the existing nine acts;

- to facilitate public access and service by providing a single-window approach to Alberta Environment, making for more streamlined administrative procedures.

The legislation's framework is divided into twelve parts:

Part 1: Consultation, Communication and Education

Part I encourages and assists participation of all Albertans in decisions affecting the environment. It maximizes participation by the public, government departments, other governments, industry and experts, recognizing the integrated nature of the environment.

Part 2: Environmental Assessment Process and Approvals

Part 2 describes the environmental impact assessment (EIA) and approval process for proposed activities. Overall, this part ensures that economic development in Alberta occurs in an environmentally responsible manner, with full public knowledge.

Part 3: Environmental Appeal Board

The Environmental Appeal Board serves as an independent review mechanism for decisions made under provisions of the Act, including approvals, Environmental Protection Orders, some Enforcement Orders and administrative penalties. This review process will support fairness in the decision making process.

Part 4: Release of Substances

Part 4 sets out the ways in which government will endeavour to prevent and control the release of substances into the environment. It ensures that unlawful, unauthorized or accidental releases of substances, as well as releases which exceed those amounts prescribed in an approval or the regulations, are remedied quickly in order to protect the environment. Part 4 also includes provisions which allow for the designation of contaminated sites, identification of persons responsible for a site based on a list of criteria, and remedial action to clean up the sites or restrict their use.

Part 5: Conservation and Reclamation

Part 5 of the proposed legislation is intended to ensure that proper conservation and reclamation practices are used on land affected by industrial activities such that land is maintained in an environmentally sound condition.

Part 6: Groundwater and Related Drilling

Part 6 is designed to protect and conserve groundwater by ensuring the competence of water well driller contractors and providing standards for their activities.

Part 7: Potable Water

Part 7 includes provisions to protect the quality of drinking water in waterworks systems as well as water distribution systems. It also enables the incorporation into regulations of water quality standards, such as the Canadian Drinking Water Quality Guidelines.

Part 8: Hazardous Substances and Pesticides

Part 8 of the proposed legislation outlines measures to control and regulate the use, handling and disposal of hazardous substances and pesticides, to ensure that such substances are used in an environmentally safe manner.

Part 9: Waste Minimization, Recycling and Waste Management

Part 9 of the proposed legislation is designed to ensure that waste minimization and recycling measures are considered, encouraged and implemented when possible. Incentives to assist in implementation are provided for. This Part also includes provisions to regulate disposal of waste, and regulate hazardous waste disposal facilities. Municipal waste facility management will continue to be a local authority responsibility under the *Public Health Act.*

Part 10: Enforcement

Part 10 sets out timely and effective application of a wide range of administrative and judicial measures to ensure compliance with the Act.

Part 11: Miscellaneous Provisions

Part 11 includes the general provisions for Environmental Protection Orders and for right of entry.

Part 12: Transitional, Consequential, Repeal and Commencement

This Part includes provisions to provide for the orderly transition from the existing legislation to the new legislation.

Revisions to the May 11, 1992 legislation were based on public comments and suggestions made on the legislation and during public review of the regulations which will accompany the Act and on the report and recommendations of the Contaminated Sites Liability Issues Task Force.

The revisions include:

- improvements in the wording and organization of the Act so that it is easier for Albertans to understand;

- new provisions to encourage Albertans to share in implementing certain responsibilities in the Act;

- new and expanded sections dealing with the designation and clean-up of contaminated sites;

- new sections on drilling for geotechnical and engineering testing to ensure that groundwater quality is protected from contamination;

- improvements to the enforcement provisions, including the powers of investigators and the protection against civil liability for individuals when administering the Act in good faith.

AEPEA regulatory review

On September 20, 1991, Alberta Environment made the draft regulations for the proposed *AEPEA* available to the public. As part of Phase I of the regulatory review process, Albertans were invited to review the drafts and provide comments and suggestions for redrafting. To assist Albertans in understanding the drafts, Alberta Environment held briefing sessions throughout the province. Some 800 Albertans attended information meetings during October and November 1991, in Edmonton, Calgary, Grande Prairie and Lethbridge. Additional information meetings were held with interest groups and associations at their request.

Approximately 300 public submissions were received and coded to assist in the review and identification of outstanding issues (Alberta Environment, 1992).

As part of Phase II of the regulatory review process, Alberta Environment held an issue discussion workshop, April 29 and 30, 1992 in Edmonton. The purpose of this workshop was to discuss, and where possible, reach consensus on outstanding issues identified from public submissions on the draft regulations (Alberta Environment, 1992).

An example of one of the issues pertaining to regulations for classes of activities focused on livestock operations: Should large-scale commercial livestock operations be required to obtain approval under *AEPEA?*

Numerous responses were received on this question. The majority strongly support requiring approvals for some types of intensive livestock operations. They cite potential contamination of waterbodies and drinking water supplies, noise and smell as reasons. Others have suggested that the term "commercial" should be the determining factor in which operations should require approval.

Farmers and farm groups are strongly opposed to the regulation of livestock operations on the basis that it would force them to undertake costly environmental studies and would be used by neighbours to limit expansion of their operations. Most of the submissions agreed that it would bevery difficult and somewhat misleading to arbitrarily regulate intensive livestock operations using a single criteria such as size.

In response to the agricultural community's concerns, Alberta Environment established a working group consisting of representatives of Alberta Agriculture, Alberta Health and Alberta Municipal Affairs. This group has recommended a process that would address environmental concerns for the majority of livestock operations. Only a handful of extraordinary livestock operations would be regulated under *AEPEA* (Alberta Environment, 1992).

Under the proposed process, the term "intensive livestock operations" in the schedule of activities would be revised to the term "designated livestock operations" which would be further defined in the regulations.

Environmental concerns for all other livestock operations would be addressed through:

1. Siting: Siting and management standards would be addressed for all new intensive livestock operations through development permits under the municipal planning system.

2. Conflict Resolution: A Provincial Farm Practices Board, to be established under the *Agricultural Operations Practices Act,* would resolve conflicts involving new and existing operations through changes to management practices.

Alberta Environment would retain the ability to apply enforcement procedures under *AEPEA* to deal with adverse environmental effects in cases where contamination was occurring and the Farm Practices Board had exhausted its options to correct the situation.

A follow-up workshop on issues related to procedural regulations is being planned. The regulations will be redrafted when the public consultation has been completed.

The results of the issue discussion workshop will be incorporated into the summary report on the regulatory review which will summarize the public's comments on the draft regulations and how the government responded. It is anticipated that the summary document will be released to the public when the regulations have been finalized later in 1992.

<u>Water management policy and legislation review</u>

Phase I of the Water Management Policy and Legislation Review process was officially launched on July 4, 1991 with the release of a discussion paper entitled "Water Management in Alberta - Challenges for the Future".

Five key challenge areas were identified:
- Involving the Public in Decision-Making
- Planning for the Future
- Protecting Our Surface & Groundwater Resource
- Using Our Water Resources Wisely
- Cooperating with Other Governments

To meet these challenges, the current water resource management policies, the *Water*

Resources Act and the regulations are being reviewed.

An integral component of the review process is consultation with the public, various levels of government, other departments and Alberta Environment staff. The Alberta Water Resources Commission, the Environment Council of Alberta and Alberta Environment are cooperating on the public consultation process. Key components of the first phase of public consultation included a series of open houses and workshops, a public survey and a special Water Policy Futures Workshop.

Background papers were prepared to provide more detailed information on topics ranging from the History of Water Management Legislation in Alberta, Aboriginal Water Issues, Water Resources Planning, Water Management Projects, Environmental Impact Assessment to Wetlands and the Role of the Alberta Water Resources Commission in Water Management.

Activities underway or planned for Phase II of the Water Management Policy and Legislation Review process include:

- the input received at public workshops and open houses, and all written submissions from Phase I will be coded and analyzed;

- a report summarizing all of the input received from the public will be prepared and distributed to the workshop and open house participants, those who made written submissions and interest groups. It will also be made available to the general public on request. The report will be completed by late spring of 1992;

- draft legislation and regulations and a policy guide will be prepared, with consideration of the public comments received. It will be released to the public in the summer of 1992;

- a further round of public workshops and meetings will be held to further consult with the public and receive their input (Alberta Environment, 1992).

REFERENCES

ALBERTA AGRICULTURE. 1981. Engineering Field Services Branch, Site location building location lesson one.

ALBERTA ENERGY/ENVIRONMENT. January, 1992. Clean air strategy for Alberta report to the ministers extracts.

ALBERTA ENVIRONMENT. 1992. Alberta environment and enhancement act, overview.

ALBERTA ENVIRONMENT. March 1992. Legislation and regulations staff bulletin.

ALBERTA ENVIRONMENT. April 1992. Legislation and regulations staff bulletin.

ALBERTA ENVIRONMENT. 1991. Summary of the proposed Alberta environmental protection and enhancement act.

ALBERTA ENVIRONMENT. April 29 and 30, 1992. The Alberta environmental protection and enhancement act, regulatory review.

ALBERTA ENVIRONMENTAL CENTRE. Nov. 1991. Impact of cattle feedlot wastes on surface water quality in Alberta, AEC V91-R2.

PERSONAL COMMUNICATION. 1992. Discussion paper, Confined livestock - waste management concerns, Standards & Approvals Division, EPSAD-01.

SHEWCHUK, P. Nov. 3, 1978. Alternative of wastewater disposal to direct stream discharge including land utilization, Alberta Environment.

IMPACT OF AGRICULTURAL PRACTICES ON WATER QUALITY: A BRITISH COLUMBIA PERSPECTIVE

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INTRODUCTION

Both water quantity and quality issues have come to the forefront, as demands for water grow in British Columbia. A need to sustain water resources for future use has been recognized by the regulating agencies, environmentalists, and people at large alike. While legislation/regulations have been put in place by various levels of governmental agencies to control discharges from point sources, non-point discharges from sources such as agriculture have been largely ignored. Guidelines to control and manage agricultural waste on farms have existed, but their implementation to improve surface and ground water quality on the farms has been left to the farmers. The adoption of best management practices by farmers on voluntary basis has not worked in all cases. As a result, various levels of government are being urged to take new initiatives to control agricultural impacts on surface and ground water quality.

This report discusses briefly the results of several studies from two different areas of British Columbia, illustrating impacts of agriculture on the surface and ground water quality. The recent initiatives taken by the Province to deal with water quality problems due to agriculture are also highlighted.

2. CASE STUDY 1: SAN JOSE RIVER WATER QUALITY SURVEY

2.1 Background

San Jose River originates at the outlet of Lac La Hache Lake,. After about 50 kilometer journey through the ranch lands, it enters Williams Lake. Borland Creek, Jones Creek, and Knife Creek are three major tributaries of the river. Other major tributaries, Valley Creek and Five Mile Creek, flow into Borland Creek (Figure 1).

The San Jose River and its tributaries are licensed for domestic water supply, stream improvement, water storage, and irrigation water supply (Table 1). Much of the land along the river is private; as a result, access to the river is restricted. Rainbow trout is the only recreationally important fish species in the watershed, but large-scale sucker, peamouth chub, northern squawfish, and red-side shiner are also found in the in the river and tributaries. In general, fisheries resources have declined in the area due, in part, to poor water quality. The Provincial Fisheries Branch in Williams Lake has determined that San Jose River and its tributaries have the potential to support a good rainbow trout fisheries.

Cattle ranching is the primary agricultural activity in the San Jose River watershed. Most ranches are cow/calf operations, with calves sold in the fall at 6 or 7 months of age. In a few cases calves are over-wintered and sold as yearlings Altogether there are about 6,500 ha of agricultural land in the watershed, including 120 ha along Five Mile Creek, 570 ha along Valley Creek, 540 ha along Borland Creek, 170 ha along Jones Creek, 550 ha along Knife Creek, and 4,500 ha along the main valley of San Jose River. The traditional ranching practices include watering and feeding of cattle adjacent to the creeks, and providing unrestricted access for cattle to a stream or a river channel.

2.2 Results

During an assessment of the lake water quality, Stitt *et al.,* (1979) and McKean *et al.,* (1987) found that Williams Lake was eutrophic and the San Jose River, the only major tributary to Williams Lake, was the primary external source of phosphorus (P) to the Lake. The annual total (dissolved + suspended) and the dissolved phosphorus loading to the lake from San Jose River, were estimated to range from 2,000 - 10,000 kg total P and 1 600 - 6,500 kg dissolved P between 1973 and 1984. Since cattle ranching is the major activity in the San Jose River watershed, it was recommended that agricultural practices, including the extent and location of cattle over-wintering areas, be identified and their effect on water quality be assessed (McKean *et al.,* 1987).

In 1990, Hart and Mayall were contracted to identify livestock over-wintering areas and evaluate their impact on water quality in the San Jose River watershed. The scheme used by Hart and Mayall (1990) to delineate low, moderate, and high potential impact areas is illustrated in Table 2. The impact of an over-wintering area on stream water quality is dependent on: (a) the total livestock density it supports, and (b) the areal potential to generate surface runoff during snow melt or rainstorm.

The 1990 survey of the San Jose River watershed by Hart and Mayall (1990) identified 62 cattle over-wintering sites. Of the 62 sites, 12 were identified with having high or moderate-to-high potential to transport phosphorus, generated at the site by livestock, to the adjacent water courses; 22 sites had moderate or low-to-moderate potential to impact surface water quality, and 28 sites were assigned a low potential impact rating. Hart and Mayall (1990) also found that surface runoff samples from 11 of the 12 agricultural (or over-wintering) sites, which were considered to have moderate-to-high or high potential impact (see above; water quality samples were not collected at the 12th site), contained high concentration of phosphorus, and that the effects of agricultural activities on stream water quality were very apparent from the upstream and downstream samples. The phosphorus concentrations as high as 16.2 mg/L total P in surface runoff from one of the sites and 4.6 mg/L total P (and 2.6 mg/L dissolved P) in Five Mile Creek downstream from a high potential impact agricultural site, were measured.

In 1991, the Ministry of Environment, Lands and Parks (MELP) undertook the task of setting water quality objectives in the San Jose River watershed (A report on this subject is in preparation). The underlying intent in this exercise is to set water quality objectives in the San Jose River and its tributaries, which, if met, will improve water quality in Williams Lake. Although San Jose River has been implicated in causing adverse water quality conditions in Williams Lake, the background water quality data for the tributaries in the watershed are practically non-existent (knowledge of the background water quality conditions is an important facet of the objective setting exercise). Therefore, additional data were collected to define clearly water quality conditions in the tributaries, including the mainstream San Jose River, both upstream (above all agricultural sites) and downstream at the mouth. The results of the 1991 water quality analyses are shown in Table 3.

The results (Table 3) show that the phosphorus loading from the background sites was minor; 59 kg total P in Valley Creek, 13 kg total P in Five Mile Ck., and 300 kg total P in the San Jose River at the outlet of Lac La Hache Lake. The agricultural areas surrounding the mainstream were the major source of phosphorus loading to the San Jose River. The next large contributor of phosphorus loading to the river is the Borland Creek watershed (26% of the total phosphorus loading). Within the Borland Ck. watershed Five Mile Ck. and Valley Ck. accounted for most of the phosphorus loading, Five Mile Ck. being the larger of two.

3. CASE STUDY 2: WATER QUALITY IN BOUNDARY BAY

3.1 Background

High nitrate-nitrogen levels (greater than the recommended level of 10 mg/L NO_3-N in drinking water by Health and Welfare Canada) have been determined in the ground water samples collected from Langley-Abbotsford in the Fraser Valley (Kwong, 1986) and Osoyoos in the Okanagan (Hodge, 1985) areas of British Columbia. The agricultural activities (e.g., use of fertilizers, manure) in the area were considered to be the primary source of high nitrate-nitrogen levels in the ground water. Nevertheless, an evidence based on hard data is practically non-existent in British Columbia, with regard to nitrogen losses from agricultural lands. In 1985, an opportunity arose to monitor nitrogen losses from experimental plots which were managed according to the agricultural practices of the area.

3.2 Results

The experimental plots were located at a site in the Lower Fraser Valley in the southwestern region of British Columbia. The site, a flat lowland which was drained using plastic drains at about one meter depth, was cultivated for potatoes, strawberries, silage corn, and hay. The average amount of nitrogen applied to the crops was about 150 kg N/ha in the 1985 and about 130 kg N/ha in the 1986 growing seasons. Nitrogen concentrations in ground water at the water table level and the rate of water flow through the plastic drains were measured periodically, to estimate nitrogen losses from the cropped area (Nagpal *et al.,* 1990).

The analyses of the results indicated that the nitrate-nitrogen concentration in ground water exceeded the Health and Welfare Canada drinking water guideline of 10 mg NO_3-N/L on several occasions. Also, a significant quantity of nitrate-nitrogen (as much as 71.5 kg NO_3-N/ha/y) was lost from the agricultural plots to ground water. Most of the nutrient loss occurred during the wet winter months. Finally, the annual loss of nitrate-nitrogen from the agricultural plots collectively, represented 17 to 48% of that applied as fertilizer nitrogen to the variety of crops grown on them.

4. BRITISH COLUMBIA. Legislative Initiatives

According to the existing Waste Management Act, any operation involved in the discharge of waste to the soil, water, or air in British Columbia requires a valid permit. However, conventional farming operations fall under Class C and are exempt from the provisions of the Waste Management Act. The types of waste material under Class C include: "all discharges of plant and animal waste emanating from "traditional farming operations" which are managed and applied in a "reasonable manner" as organic fertilizers to promote crop production, and all discharges or emissions into the air from "traditional" farming operations are exempt from the Pollution Control Regulations". In event of significant pollution, however, a Pollution Abatement Order can be served on a farmer. Unfortunately, the phrases "traditional farming operations" and "reasonable manner" are not clearly defined in the act. The B. C. Department of Agriculture had drafted environmental guidelines outlining how to handle waste in a reasonable manner from various agricultural operations, but these guidelines were not to be adopted into legislation, in whole or in part, by any level of government. These guidelines also did not address all environmental concerns from agricultural lands. As a result, they did not amount to much in terms of controlling agricultural impact on water quality.

The Waste Management Regulations were amended recently. The new regulations include "Code of Agricultural Practices for Waste Management" or the Code, which essentially defines the best waste management practices for the benefit of the farmers and the regulatory agencies (Agricultural Waste Control Regulation 1992). The purpose of the proposed amendment is to encourage farmers to manage agricultural wastes by following the Code, thereby minimizing an environmental impact from agriculture. A farmer, who carries out an agricultural operation in accordance with the Code is, for the purpose of carrying out that agricultural operation, exempt from section 3 of the Waste Management Act (i.e., those operations that follow the Code of Agricultural Practices for waste management will be exempt from normal permit procedures). Obviously, a person who contravenes the Code will be liable to a penalty under the Waste Management Act.

The B.C. Federation of Agriculture endorses the Code and the Regulations. A cooperative effort led by the B.C.. Federation of Agriculture, the Ministry of Agriculture, Fisheries and Food, and B. C.. Environment is underway to educate farmers and the staff about their responsibilities and obligation under the Code. The farming organizations under the B.C. Federation of Agriculture have established the Agricultural Environmental Protection Council (AEPC) which will: (a) ensure that farmers follow the Code, and (b) respond to pollution complaints brought against the farmers. B.C. Environment will deal directly with the operator who does not abide by the Code and violates the Waste Management Act.

REFERENCES

HART, J.S., and A.C. MAYALL. 1990. Phosphorus sources in the San Jose River basin: effects of winter livestock management practices. A report prepared for the Waste Management Branch, Ministry of Environment, Williams Lake, B.C. 71p.

HODGE, W.S. 1985. Groundwater quality monitoring and assessment program. Assessment of water quality and identification of water quality concerns and problem areas-Osoyoos. Groundwater Section, Water Management Branch, Ministry of Environment, Victoria, B.C. 32 p.

KWONG, J.C. 1986. Groundwater quality monitoring program. The occurrence of nitrate-nitrogen in groundwater in the Langley-Abbotsford area. Feb. 21, 1986 Memo to A.P. Kohut, Groundwater Section, Water Management Branch, Ministry of Environment, Victoria, B.C. 8 p.

NAGPAL, N.K., C.J.P. MCKEAN, and N.A. ZIRNHELT. 1992. San Jose River and its Tributaries: Water quality assessment and objectives. Water Quality Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. (in preparation).

NAGPAL, N.K., G.B. HOLMES, and S.T. CHIENG. 1990. Nitrogen leaching from a subsurface drained agricultural field in the Lower Fraser Valley. *In:* Soil Pollution in British Columbia. Proc. 13th B.C. Soil Science Workshop. February 15-16, 1990. p. 122-139.

MCKEAN, C.J.P., N.K. NAGPAL, and N.A. ZIRNHELT. 1987. Williams Lake water quality assessment and objectives: Technical Appendix. Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C. 75 p.

STITT, R.C., N.A. ZIRNHELT, and D.W. HOLMES. 1979. The trophic status of Williams Lake, B.C., with special reference to nutrient loading via the San Jose River. Waste Management Branch, Ministry of Environment, and Parks, Williams Lake, B.C.

AGRICULTURAL WASTE CONTROL REGULATION. 1992. Waste Management Act, Health Act. British Columbia Regulation 131 /92, 0.C.557/92.

Table 1. Summary of Water Licences in the San Jose River watershed (From Nagpal *et al.*, 1992)

Water Basin	Domestic Licences (#:m3/d)	Irrigation Licences (#:dam^3/y)	Storage Licences (#:dam /y)	Other Licences (#:dam/y)
Borland Creek	2: 31	8:2118	7:728	1:81
Five Mile Creek*	1: 9	6:1089	5:870	0
Jones Creek	3:29	5:1460	4:1233	0
Knife Creek**	2: 18	16: 4961	11: 3933	1: no record
San Jose River	5: 148	10: 2968	2:216	1:219
Valley Creek	2: 14	4: 850	3: 120	1: Volume?

* Includes North Five Mile Creek;

** Includes Coldspring Creek and Squawk Lake

Table 2. Potential Impact of Overwintering areas on Water Quality as a function of Surface Runoff Potential and Total Livestock Density

(From Hart and Mayall, 1990)

Total Livestock Density ▸ Surface Runoff Potential.	Potential Impact Rating: LOW	MODERATE	HIGH
LOW	low	low	low
MODERATE	low-moderate	moderate	moderate-high
HIGH	moderate	moderate-high	high

Table 3. 1991 Dissolved and suspended phosphorus concentrations in the San Jose River watershed

Water Quality Site	Dissolved Phosphorus		Suspended Phosphorus	
	Concentration (mg/L)*	Loading (kg)	Concentration (mg/L)*	Loading (kg)
Valley Ck.: Background (E215850)	0.035±0.018 (n=9)	35	0.012±0.008 (n=9)	24
Valley Ck. at the mouth: (0600319)	0.095±0.043 (n=36)	344	0.025±0.028 (n=36)	90
Five Mile Ck.: Background (E215830)	0.022+0.008 (n=16)	9	0.014+0.006 (n=16)	4
Five Mile Ck. at the mouth:(E213046)	0.252+0.074 (n=47)	745	0.026+0.029 (n=47)	103
Borland Ck.: Background (E215824)	0.022+0.007 (n=12)	-	0.021+0.026 (n=12)	-
Borland Ck. Below Valley Ck: (0600330)	0.058+0.018 (n=11)	-	0.030+0.025 (n = 11)	-
Borland Ck. at the mouth: (0600105) +	0.105+0.046 (n=18)	920	0.044+0.060 (n=18)	1080
Jones Ck. at Hwy 97 (E214700)	0.058+0.026 (n=30)	160	0.029+0.021 (n=30)	92
Knife Ck.: Background (E213042)	0.045±0.015 (n=15)	-	0.024±0.018 (n=15)	-
Knife Ck. at the mouth (0600124)	0.046+0.016 (n=29)	-	0.031+0.036 (n=29)	-
San Jose R. at Lac La Hache (0600021)	0.006+0.002 (n=7)	150	0.005+0.002 (n=7)	150
San Jose R. above Knife Ck. (0600312)	0.026+0.014 (n=20)	-	0.030+0.017 (n=20)	-
San Jose R. above Borland Ck. (0600317)	0.042+0.031 (n=33)	2090	0.055+0.036	3540
San Jose R. below Borland Ck. (0600316)#	0.054+0.033 (n=18)	3010	0.041+0.036 (n=18)	4620

* average standard deviation; n=number of samples

\# sum of Borland Ck. at the mouth and San Jose R. above Borland Ck.;

\+ total load from Borland Ck. (background), Valley Ck., and Five Mile Ck.

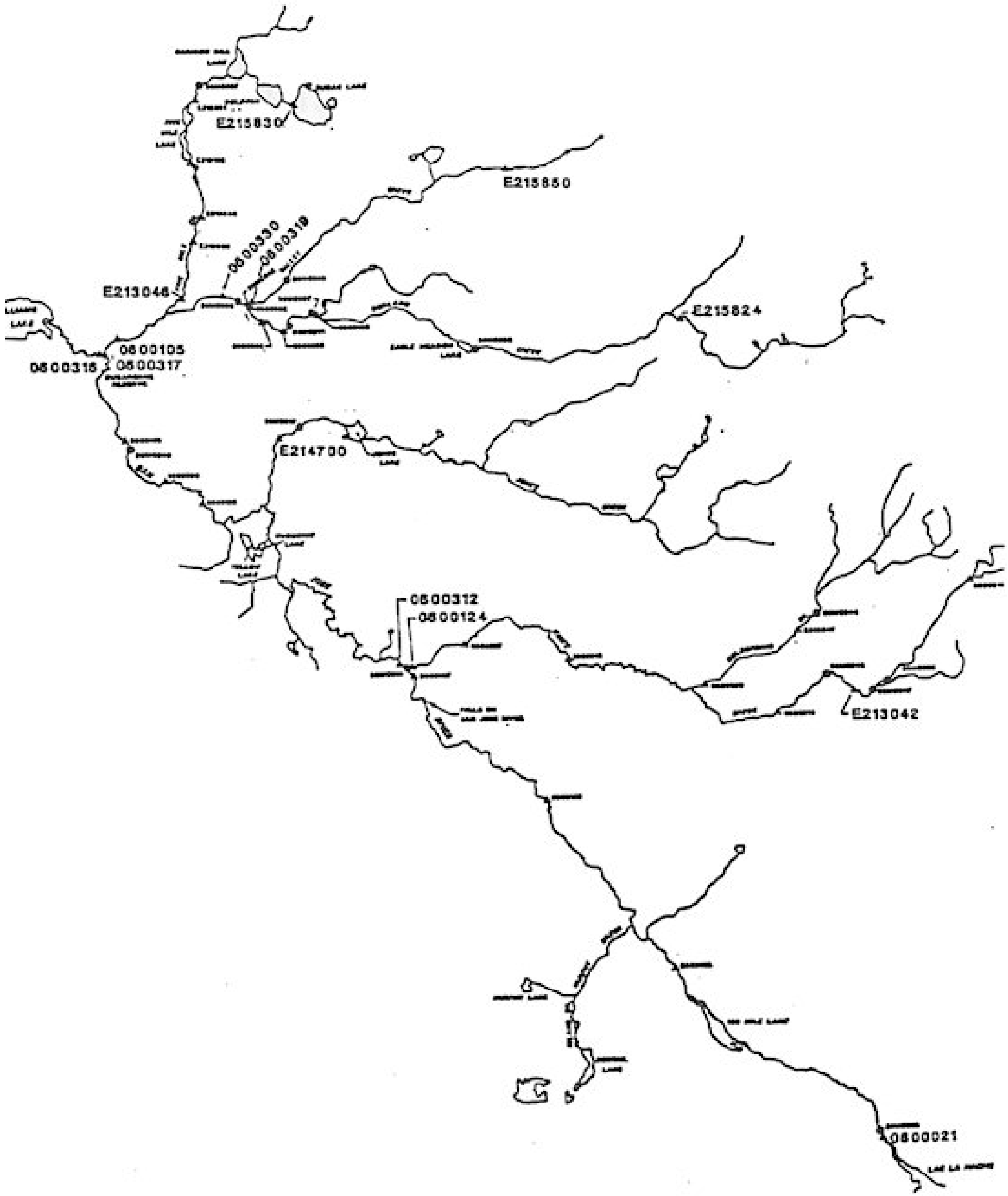

Figure 1: San Jose River watershed and its tributaries. Water quality sites addressed in Table 3 are highlighted.

AGRICULTURAL IMPACTS ON WATER QUALITY: INDUSTRY PERSPECTIVES.

A PRESENTATION BY THE CROP PROTECTION INSTITUTE TO THE NATIONAL WORKSHOP ON WATER QUALITY APRIL 24, 1992

P. Marshall
Monsanto Canada Inc.

INTRODUCTION

Each day, members of the agricultural community and members of the general public are confronted with information concerning the presence of pesticides in surface and groundwater. Much of the information provided in various types of media is replete with misinformation. Today, the Crop Protection Institute, the industry association representing the major pesticide manufacturers and formulators in Canada, would like to share with you the industry views concerning current problems and future research needs.

There are several routes by which pesticides may be introduced into both surface and groundwater.

Likely routes of pesticide movement into surface water include:

- runoff of soil/water from rainfall, irrigation
- tile drain runoff
- human error

Pesticides may also intrude into groundwater from these sources:

- human error
- leaching through the soil profile
- direct recharge (ie. sinkholes)

Depending on the time of the year, the principal route of movement into surface or groundwater may vary. The dynamics of surface and groundwater recharge, coupled with demands for water by plant growth and evapotranspiration, may modify the probability of a pesticide entering the surface or groundwater.

Several surveys have been conducted by various organizations to quantify this issue. The National Alachlor Well Water Survey conducted in the United States by Monsanto from 1987 to 1989 determined that only 0.11% of the 1,430 rural, domestic wells surveyed were found to have herbicides above the Maximum Contaminant Level (MCL) of 1-3 ppb. Approximately 12.8% of the wells surveyed were found to have detectable herbicide levels below the MCL. The remainder (87%), had no detectable levels. For several years, Rhône-Poulenc, in a cooperative effort with provincial authorities, has been monitoring drinking water in potato growing areas with a previous history of aldicarb use. To date, of 2,247 water samples analyzed, fewer than 2.5% of these samples have contained total aldicarb and associated metabolites above the federal drinking water guideline of 9 ppb.

It should be recognized that the detection of a pesticide in water does not necessarily imply a risk to public health. As advances are made in analytical methodology, it is apparent that the mere use of pesticides may result in their detection in ground or surface waters. Drinking water guidelines should continue to be established for individual pesticides using a portion of the Allowable Daily Intake (ADI) value for the determination, much as tolerances are established for food crops. Pesticides should not be grouped into broad categories, nor should a single arbitrary value be assigned as a water quality standard for all pesticides.

The proper use of pesticides according to label directions does not pose a significant hazard to surface and groundwater. The greatest threat to surface and groundwater from pesticides results from misuse, and farming practices that contribute to surface erosion.

In recent years, members of the Crop Protection Institute have increased their efforts to ensure that the proper use of pesticides in agriculture minimizes the movement of pesticides into surface or groundwater.

Among these initiatives is the continuing advance in pest management technology. One of the most significant of these changes is the introduction of new products requiring much lower rates of active ingredient for effective pest control. While use rates for new actives are orders of magnitude below those of 15-20 years past, toxicological risk has not increased correspondingly. Environmental loading is being reduced, which will ultimately reduce the potential for water contamination.

A greater environmental awareness among developed nations has led to more stringent regulation of pesticides. This has resulted in more rigorous screening of candidate molecules for development by industry. A strong emphasis is placed on development of products with low water solubility, strong soil adsorptivity, and low to moderate persistence. These inherent "environmentally friendly" characteristics of newer actives also serve to minimize detrimental effects.

A third area of innovation is the development of Integrated Pest Management strategies for pest control. The IPM approach incorporates selective application of pesticides in conjunction with population surveys, cultural control methods, biological control, and modification of farming practices. Pesticides are applied more judiciously, and again water effects are moderated.

As more information on pesticide behaviour in the environment becomes available, companies are revising label directions to reduce further the potential for surface and groundwater intrusion.

Recently, Ciba-Geigy revised the timing and rates of application on their atrazine labels to minimize surface runoff. Several years ago Rhône-Poulenc amended the Temik label to prevent application of aldicarb when certain environmental conditions known to reduce degradation rates were present. While there are a few occurrences of these products in surface or groundwater, these label amendments were targeted at further reducing these. Industry is taking the lead in stewarding their own products.

Currently, much can still be accomplished in further improving label directions by providing more information to growers to help minimize any potential for surface or groundwater contamination. This additional information might include the recommended use of anti-backflow devices during the mixing/loading cycle, or appropriate setbacks from wellheads. Product labels must accompany each package of product and therefore present an excellent opportunity to relay recommendations to the growers.

Technical bulletins and instructional videos such as those produced and distributed by the Crop Protection Institute, ICI Chipman, Monsanto and Ciba-Geigy, to name a few, are widely accepted forms of transferring information and technology to the growers. As well, the Crop Protection Institute supports the establishment of a National Minimum Training Standard for all applicators. Minimum national standards are being developed in a total of 10 applicator categories. It is anticipated that provinces will begin enacting mandatory certification for applicators based on these standards by the mid 1990s. By 1991, over 17,000 Ontario farmers had participated in an education and certification program, a number expected to grow to over 22,000 by the end of 1992.

The Crop Protection Institute has also been funding a container management program. Properly rinsed pesticide containers can be taken to designated collection sites for recycling. This reduces point source contamination as a result of improper disposal. However, this is only one solution to the disposal problem. New initiatives by industry in the area of water soluble and degradable packaging, returnable mini-bulk units and bulk delivery systems will reduce the need for collection sites. Closed delivery systems will eliminate the need for growers to handle concentrated product, reducing the potential for spills during the mixing/loading portion of the spraying operation.

Finally, application technology from within and outside of the industry will lead to more efficient use of pesticides. Among these are improved field sprayers able to place the product accurately where needed as opposed to blanket coverage of the entire field. Improved shutoff devices for granular applicators that eliminate spills at the end of the fields when the applicators are lifted are now available.

However, these are some of the more obvious remedies to application concerns. New innovative technologies in the areas of seed treatments may someday eliminate the need to spray or band pesticides.

Advances in seed coating technology, combined with improved pesticides, have already shown success in eliminating herbicide sprays in corn by placing the herbicide directly on the seed. Foliar fungicides in cereal production may be eliminated by seed treatment possessing season long activity. In addition to reducing the amount of pesticide required, application is made in a controlled environment at the seed plant, not in the farmer's field.

Biotechnology holds the promise of selectively delivering pest control molecules to the plant tissue. The toxin from *Bacillus thuringiensis* spp. has been incorporated into the genome of many crops, including corn and cotton, for targeted insect control. As these new cultivars become established and demonstrate their innate resistance to pests, field application of pesticides for these crops is expected to decline dramatically.

Preventive approaches to water contamination include adoption of improved farming practices which reduce surface runoff and soil compaction while improving soil structure and increasing organic matter. These consist of reduced tillage practices to improve soil structure and reduce compaction, crop rotation to increase organic matter content and improve soil tilth and improved tile drainage to manage excess soil moisture. Crop residue cover should be maximized to reduce sheet erosion. Selection of pesticides should take into account both the pest and the soil type.

As part of an overall educational effort, farmers are being encouraged to become more active stewards of their lands. While the great majority of farmers do not knowingly engage in agricultural practices that are detrimental to the environment, the concept of maintaining or improving the land for the next generation is gaining wider acceptance.

Recently a coalition of Ontario farm groups published Our Farm Environmental Agenda", committing Ontario farmers to recognize and respond to specific environmental concerns on individual farms. Environmental farm plans will be established for each farm, and strategies devised to surmount existing and/or potential negative environmental impacts. These strategies will require individual initiative, research, new technology, new regulations, community co-ordination, and financial assistance. The anticipated result is farms that are much more integrated with the surrounding environment.

Industry will continue to steward their products in the marketplace and publish results such as the National Alachlor Well Water Survey. Improved communication between Industry and various levels of public researchers will facilitate information/technology transfer to the ultimate benefit of the producer. In today's operating environment of critically underfunded initiatives, measures must be taken to reduce duplication of effort and to ensure resources are focused on the key issues. Pesticides in water must be kept in perspective with other water quality issues, such as sewage effluent and underground storage tanks.

The Crop Protection Institute maintains, that while the issue of pesticide contamination of our waters should not be ignored, there are more serious threats to water quality that require immediate action.

In conclusion, the Crop Protection Institute believes that the major area of focus for research and monitoring of pesticides should concern surface waters. Ground water occurrence of pesticides has been demonstrated to be, by and large, within the acceptable limits prescribed by federal health authorities. Point source contamination is the major contributor to groundwater contamination, and can best be avoided through increased awareness and vigilance by the farmer or pesticide applicator.

Modifications to farming practices that minimize the potential for surface runoff would contribute greatly to a reduction in the amount of pesticides reaching surface waters. These include reductions in tillage, use of trash covers, rotations which involve green manures, non-cultivation of vulnerable soil areas, proper placement and use of tile drains, and fall cover crops.

To protect and improve water quality, while maintaining production efficiencies of Canadian agriculture, is a challenge we all should commit to meet. The Crop Protection Institute proposes that the following recommendations be endorsed as a means of meeting this challenge:

- improved communication among all stakeholders
- better education for all applicators
- continued emphasis on "water friendly' characteristics of new active ingredients
- continued research into farming practices/technology that minimize soil erosion
- clear and harmonized provincial and federal guidelines.

Pesticides are only one of the many tools employed in modern agricultural systems. Used properly and responsibly, they will contribute to the production of a safe and abundant food supply, while posing negligible risk to the quality of Canadian ground and surface waters.

REFERENCES

DETAIL Groundwater and Agricultural Chemicals Manual. Monsanto Company, 1990.
GIFAP Position Paper on Pesticides in Water. Revised version, June 1990.

Groundwater and the Use of Pesticides in Ontario. ICI-Chipman Technical Information Bulletin No. 25. 1991.

HOLDEN, L.R. and J.A. GRAHAM. 1992. Results of the National Alachlor Water Survey. Environmental Science and Technology, 1992. (In Press)

Our Farm Environmental Agenda. Ontario Federation of Agriculture *et al.* 1992.

Water in Trust - A Grower's Guide. Crop Protection Institute. Willowdale, Ontario.

WATER QUALITY WORKSHOP
INDUSTRY PROPOSALS

- Improved education/training for applicators
- Better communication among stakeholders
- Continued research into farming practices technologies that reduce surface erosion
- Continued emphasis on environmental profile of new actives
- Clear and harmonized Federal and Provincial guidelines

WATER QUALITY WORKSHOP
INDUSTRY INITIATIVES

- Development of actives with lower rates, environmentally "friendly" profiles
- Supporting development of new farming techniques and technology
- Publishing of research in refereed journals
- Biotechnology research
- Grower/applicator education programs

WATER QUALITY WORKSHOP
PREVENTIVE MEASURES

Surface water solutions

- improved farming practices resulting in improved soil structure/reduced runoff
- 30% crop residue cover
- improved drainage
- reduced tillage

Groundwater solutions

- reduce human error through education
- properly constructed wellheads
- proper disposal of pesticide containers
- proper selection of product for soil/water table type

ATELIER SUR LES RÉPERCUSSIONS DU PRATIQUES AGRICOLES SUR LA QUALITÉ DE L'EAU :

UN APERÇU CANADIEN POINT DE VUE ET PRÉOCCUPATIONS DES PRODUCTEURS ET PRODUCTRICES AGRICOLES

Louis Ménard
L'union des producteurs agricoles

Mesdames, Messieurs,

Je souhaiterais, dans un premier temps, remercier le Comité de coordination des services agricoles canadiens ainsi que le Conseil canadien de la recherche agricole d'avoir sollicité la participation, à cet atelier, de l'organisation que je représente, l'Union des producteurs agricoles (UPA).

L'Union des producteurs agricoles est l'organisation officielle des 47 000 producteurs et productrices agricoles du Québec. L'UPA est structurée en regroupements régionaux (16 fédérations régionales) et spécialisés (17 fédérations spécialisées).

On m'a demandé d'exprimer le point de vue et les préoccupations des producteurs et productrices agricoles dans le cadre des objectifs poursuivis dans cet atelier qui porte sur les répercussions des pratiques agricoles sur la qualité de l'eau. Essentiellement, la tenue de cet atelier vise à promouvoir les échanges d'informations scientifiques et à discuter des besoins futurs et des tendances dans les domaines de la recherche et de la réglementation.

Avant de plonger dans le vif du sujet, je pense qu'il est bon de rappeler l'évolution de l'agriculture du Québec des dernières décennies dans le but de cerner la problématique actuelle.

L'agriculture québécoise a subi, au cours des dernières décennies, des changements importants. En effet, le nombre de fermes a diminué, au Québec, entre 1961 et 1986 de 67% pour se situer à 40 000 établissements. Au cours de cette même période, la superficie moyenne des fermes est passée de 73,1 ha à 88 ha, soit une hausse de 23 %.

Par ailleurs, la mécanisation des fermes, le recours aux engrais de synthèse, aux pesticides ainsi que l'amélioration génétique ont contribué à une grande spécialisation des fermes. Cette spécialisation a favorisé la concentration des élevages et des productions végétales dans plusieurs régions.

Dans les productions végétales, on a vu le: surfaces réservées aux grandes culture; augmenter, entre 1971 et 1986, de 41 %. Pa exemple, les surfaces consacrées au blé on augmenté de 285 %, celles de l'orge de 948% e celles du maïs-grain de 320%, pendant que le; pâturages ont diminué de 47 % et le foin cultivé de 11 %. A elle seule, la production de maïs grain occupe près de 320 000 hectares concentrée principalement dans trois régions agricoles, le Richelieu, le Sud-Ouest et le Norc de Montréal.

Dans son ensemble le cheptel québécois s'est maintenu en terme de volume de fumier et lisier produit de 1951 à ce jour. Cependant, or observe des changements dans le type des espèces animales ainsi que la répartition des élevages sur le territoire agricole.

Durant la période qui s'échelonne de 1971 à 1986, le nombre de bovins a diminué de 14 pour se maintenir aux alentours de 1,6 million de têtes. Les volailles perdaient 9 % de leur effectif pour se situer aux alentours de 20 millions. En contrepartie, le cheptel porcin passait de 1,3 à 4,7 millions de têtes, entre 1971 et 1990, soit une augmentation de 364 %. Environ 60 % de cette production se concentre maintenant dans les bassins des rivières l'Assomption, Yamaska et la Chaudière.

L'usage des engrais minéraux et des pesticides a augmenté entre 1971 et 1986. L'utilisation des engrais a grimpé de 171 %, passant de 302 402 à 519 519 tonnes. Les ventes de pesticides on augmenté de 6 millions (1971) à 30 millions er 1986. Ces hausses s'expliquent, notamment, par l'augmentation des superficies réservées aux grandes cultures.

Au cours des trente dernières années, des travaux de drainage et d'aménagement des cours d'eau en milieu agricole ont *été* réalisés afin d'accroître la productivité. Entre 1963 et 1991, 323 521 km de drains agricoles ont été installés sur 586 000 hectares et des travaux de creusage el d'aménagement des cours d'eau ont été réalisés sur 13 180 cours d'eau ou partie de cours d'eau sur une longueur totale de 20 000 km.

L'ensemble de ces interventions et investissements ont contribué certes à améliorer la productivité de l'agriculture. Les consommateurs ont tiré profit de cette efficacité accrue, les denrées ont été plus nombreuses, de meilleure qualité et leur coût relatif dans le budget familial a diminué, passant de 27% à 11 %, entre 1950 et 1990.

Une ombre figure cependant au tableau de ce bilan de l'agriculture. La détérioration des ressources agricoles et de l'environnement. Ce problème préoccupe de plus en plus la classe agricole et la population.

Plusieurs études viennent d'être rendues publiques au Québec sur la dégradation des sols et sur la qualité des cours d'eau.

Le rapport de l'inventaire des problèmes de dégradation des sols agricoles au Québec révèle que la plupart des sols où l'on exerce la monoculture, soit environ 430 000 hectares, subissent des problèmes de dégradation. On observe des problèmes de détérioration de la structure, d'acidification, de diminution de la matière organique, de compactage et de surfertilisation. Ces phénomènes de dégradation se répercutent principalement sur les sols don't le potentiel agricole est le plus élevé, soit les sols de la plaine du St-Laurent.

Le gouvernement du Québec procède depuis 1967 à la surveillance de la qualité des principales rivières du Québec. Une trentaine de rivières font l'objet d'un suivi où sont évalués des paramètres indicateurs de la qualité de l'eau. Une communication personnelle avec un des responsables de la surveillance de la qualité des cours d'eau au ministère de l'Environnement nous informe que, dans la plupart des rivières qui sillonnent le milieu agricole, on observe une tendance à la hausse des concentrations de nitrate dans l'eau. Par ailleurs, au cours des trois dernières années, le ministère de l'Environnement a publié des rapports sur la qualité des eaux pour quatre bassins versants. Dans ces bassins, l'agriculture occupe une activité importante. L'agriculture est identifiée comme l'une des activités responsables de la détérioration de la qualité de nos cours d'eau avec le secteur urbain et industriel. Dans l'un de ces rapports, il est mentionné:

> « De façon générale, la qualité de l'eau de la rivière Yamaska s'est dégradée au cours des treize années étudiées, sauf dans le secteur de la rivière Yamaska Nord et en aval des rejets traités. Cette détérioration du milieu aquatique est surtout causée par les apports considérables de substances nutritives... Il est évident que l'élevage et la pollution agricole diffuse demeurent les principaux problèmes. La réduction de ces sources de pollution est donc essentielle, voire impérative, si l'on désire maintenir ou récupérer les usages reliés à l'eau. »

Les sources de pollution agricole proviennent principalement de la pollution diffuse. Ce phénomène est complexe et conditionné par de nombreux facteurs climatiques, physiques et agronomiques en constante interaction.

LA PRÉOCCUPATION DES PRODUCTEURS ET PRODUCTRICES AGRICOLES AU SUJET DE LA DÉGRADATION DES SOLS ET DES COURS D'EAU

Depuis plusieurs années, les producteurs et productrices agricoles du Québec manifestent beaucoup d'intérêt face au problème de dégradation des sols et de l'eau.

Lors des derniers congrès annuels de l'UPA, les délégués des producteurs ont adopté plusieurs résolutions dans lesquelles ils revendiquent des moyens d'actions qui leur permettraient de modifier les pratiques agricoles responsables de la dégradation des ressources. Des demandes ont été formulées notamment pour le développement de programmes : de lutte intégrée pour le contrôle des ravageurs, de gestion intégrée des fumiers axée sur l'utilisation à des fins de fertilisation et d'amendement, de programmes de conservation des sols et de l'eau.

Par ailleurs, l'UPA a participé avec le ministère de l'Agriculture du Québec à l'élaboration d'une stratégie phytosanitaire don't l'objectif vise la réduction de 50 % de l'utilisation des pesticides au Québec d'ici l'an 2000.

L'année dernière, l'UPA a revendiqué la mise en place, à l'échelle provinciale et régionale, de comités multipartites qui regroupent des représentants des ministères de l'Agriculture et de l'Environnement et des producteurs. Ces comités ont le mandat d'élaborer et de proposer des mécanismes de gestion des surplus de fumier dans les régions à forte concentration de production animale.

Les producteurs et productrices agricoles pensent que la résolution des problèmes de dégradation des sols et de l'eau résident dans la mise en oeuvre de moyens d'action comme : la recherche et le développement, le transfert technologique, la formation des producteurs et conseillers agricoles ainsi que le développement de programmes agricoles sans conséquence pour l'environnement.

Il faut maintenir les efforts de sensibilisation auprès des producteurs et productrices agricoles mais leur proposer aussi des solutions aux problèmes et démontrer les bénéfices de ces nouvelles pratiques.

On constate que les ressources affectées à la recherche de solution et aux transferts des connaissances sont insuffisantes en fonction des besoins exprimés par le milieu. L'État n'exerce pas un leadership suffisant en matière de service d'encadrement à la ferme et programmes pour inciter les producteurs à modifier leurs pratiques agricoles.

Par ailleurs, les producteurs et productrices agricoles préconisent la réalisation de recherches multidisciplinaires en matière de conservation et protection des ressources et souhaitent qu'on les implique davantage dans le choix des orientations de recherches et dans la réalisation de ces dernières.

Certains groupes de pression proposent le recours à des mesures législatives plus sévères en matière de contrôle des pratiques agricoles. Par exemple, des mesures plus sévères sont revendiquées face à l'utilisation des pesticides, l'épandage des fumiers, le contrôle des odeurs. Dans bien des cas, l'application de mesures coercitives serait difficilement réalisable et s'avérerait extrêmement coûteuse.

Prenons, par exemple, le cas de la surfertilisation des sols causée, entre autres, par la mauvaise utilisation des fumiers et des engrais minéraux.

Pendant longtemps, les fumiers et les lisiers ont été considérés comme une nuisance plutôt qu'une ressource à valoriser. Conséquemment, il était difficile pour les producteurs et productrices de se procurer sur le marché des appareils d'épandage de fumier à calibrage précis pour les besoins des cultures ou d'obtenir des services-conseils sur la préparation de plans de fertilisation à base de fumure organique.

Heureusement, cette situation tend à changer depuis la mise en place, entre autres, du programme d'aide à l'amélioration de la gestion des fumiers au Québec. Ce programme comporte plusieurs volets don't l'aide à la construction de structures d'entreposage, la recherche, la promotion et la gestion des surplus de fumier. Lorsque les résultats de la recherche seront communiqués aux producteurs, et que l'ensemble des volets de ce programme seront mis en oeuvre, on devrait observer une amélioration de la qualité des cours d'eau.

Un autre exemple intéressant concerne les pesticides. Certains groupes de pression souhaiteraient un renforcement de la Loi sur les produits antiparasitaires pour limiter entre autres l'homologation de nouveaux pesticides. Une telle mesure serait-elle propice à assurer une meilleure protection de l'environnement? On peut en douter. En effet, dans certaines productions, une telle mesure pourrait se traduire par un emploi accru de pesticides dans les cas, notamment, où les produits disponibles n'offrent pas une flexibilité suffisante dans leur utilisation, notamment les périodes de retrait requises avant la récolte. Si le système d'homologation des pesticides avait pour effet de réduire la marge de manoeuvre des producteurs dans la gestion des risques face aux ennemis des cultures, une telle mesure irait à l'encontre du but recherché.

En outre, les producteurs s'opposent catégoriquement à l'imposition de mesures législatives qui pourraient compromettre la rentabilité ou la survie économique de leur exploitation. Par exemple, des mesures destinées à contrôler les odeurs dans les productions animales qui viseraient à interdire toute expansion du cheptel déjà existant sont contestées. Cependant, l'application de normes plus sévères dans le cas de nouveaux établissements de productions animales, de même que l'obligation de détenir un plan de fertilisation pour l'épandage de fumier pourraient être envisageables.

De plus, le recours à des normes arbitraires sont difficilement justifiables en agriculture et peuvent s'avérer sans fondement scientifique valable. Par exemple, l'application d'une bande riveraine en milieu agricole peut sembler, à première vue, une mesure intéressante pour le contrôle de l'érosion des sols et de la pollution diffuse. Cependant, en l'absence d'études, notamment sur les types de sols, la topographie, etc, une telle mesure est difficilement défendable et applicable sur une base arbitraire. Dans l'avenir, les autorités gouvernementales devront au préalable procéder à une évaluation scientifique des normes qu'elles souhaitent mettre en application et évaluer l'impact économique de leur application.

CONCLUSION

En conclusion, les producteurs et productrices agricoles sont sensibilisés aux problèmes de dégradation des ressources sol et eau.

Ces derniers préconisent des solutions de rechange aux pratiques agricoles qui sont la cause de problèmes environnementaux. Les producteurs croient que les efforts consentis dans la recherche, le transfert technologique et la vulgarisation des pratiques agricoles plus respectueuses de l'environnement, sont insuffisants.

Le recours unique à des mesures législatives plus sévères dans le but de modifier les pratiques agricoles existantes sont mal reçues. Les producteurs et productrices préconisent davantage la recherche, les activités de vulgarisation et d'encadrement à la ferme par des spécialistes bien formés ainsi que des programmes agricoles incitatifs.

La protection de l'environnement est une responsabilité sociale qui doit être assumée par les producteurs, mais aussi par l'ensemble de la société. Au cours des dernières décennies, le développement de l'agriculture a été réalisé avec l'intervention soutenue de l'État qui a investi dans la recherche, le transfert des connaissances ainsi que dans des programmes agricoles.

La protection de l'environnement devient maintenant prioritaire dans le développement de notre agriculture et l'État doit prendre la place et le leadership qui lui revient.

AGRICULTURAL IMPACTS ON WATER QUALITY: A FERTILIZER INDUSTRY PERSPECTIVE.

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EDITOR'S NOTE:

Mr. Tom Sawyer from the Fertilizer Institute of Ontario Inc. made an oral presentation at the workshop based on the ideas contained in "The Role of Fertilizers in Sustainable Agriculture and Food Production - A 1990 Position Paper from the Canadian Fertilizer Institute." The Executive Summary from this position paper is presented here. The complete paper is available from Canadian Fertilizer Institute, Suite 1540, 360 Albert Street, Ottawa, Ontario, Canada, K1R 7X7."

EXECUTIVE SUMMARY

The member firms and affiliated organizations of the Canadian Fertilizer Institute believe the proper use of mineral fertilizer is fully compatible with sustainable agricultural systems. Mineral fertilizer plays an important role in enhancing soil quality and, consequently, the capacity of land resources to produce adequate supplies of high quality, wholesome food for future generations.
Agriculture Canada defines sustainable agricultural systems as, "Those that are economically viable and meet society's needs for safe and nutritious food while conserving or enhancing Canada's natural resources and the quality of the environment for future generations." The Canadian Fertilizer Institute endorses that definition, recognizing that environmentally sustainable production embraces a broad spectrum of fertilization practices ranging from those that rely on inputs manufactured off-farm to those which utilize on-farm recycling of animal and plant manures.

The application of mineral fertilizer to cropland makes a substantial contribution to increased agricultural production. Recent estimates suggest that in some developing countries, 75 percent of production is attributable to mineral fertilizer. In Canada, an estimated 40 percent of crop production results from fertilizer use. Clearly, in a world where food consumption and production are normally delicately balanced, the crops produced as a result of fertilizer application are essential to adequate diet and affordable food.

Over the past fifty years, applications of mineral fertilizers have not kept pace with plant nutrient exports from cropland. Fertilizers can make a positive contribution to reversing the effects of past soil "mining" practices. Fertilizers increase both yield and dry matter production, thereby increasing nutrient uptake and organic matter returned. Additional crop residues rebuild soil structure, promote soil microbial activity and protect against soil erosion.

The "green revolution" of the 1960s and 70s vividly demonstrated the benefits of mineral fertilizer. More recently, however, there is heightened awareness of the costs which can be associated with improper fertilizer use. Agricultural production, like most economic activities, generates externalities - costs which are borne by stakeholders not directly associated with the particular farm or agricultural region.

Negative impacts on water quality is the most frequently cited externality associated with fertilizer use. When improperly applied, the nutrients in any fertilizer, whether mineral or derived from plant, animal or human wastes, can run off into surface water or leach into groundwater. Nutrient-loaded waters may be unsuitable for municipal water supplies unless special treatment procedures are adopted. For surface water, there may also be adverse impacts on aquatic vegetation and certain fish species as nutrients rise significantly above normal ranges.

The Canadian fertilizer industry recognizes that there are problems which must be intelligently and effectively addressed. In addition to the costs transferred to other natural resource users, fertilizer nutrients lost from agriculture represent a substantial economic loss to Canadian farmers. The fertilizer industry is dependent on the long-term strength and financial viability of the farm sector. Farmers, fertilizer companies and the general public all have a common interest in curbing the potential loss of nutrients from cropland. More effective fertilizer application results in improved farm profitability as well as reduced environmental risk.

Mineral fertilizers are a complement to livestock and green manures. Livestock manures are insufficient in volume and geographic availability to replace nutrients utilized by Canadian crop production. Human effluent and sewage sludge also have an important role to play but these sources of nutrients have limitations for crop production. Finally, green manures are an important element in crop rotations in many areas and are effective in raising soil nitrogen levels and improving soil structure. However, even green manure crops require proper application of other plant nutrients. It must be recognized that nutrient supplied by sources other than mineral fertilizers may also have adverse environmental impacts if improperly applied.

Members of the Canadian Fertilizer Institute, in endorsing the concept of sustainable agriculture, are committed to the following initiatives:

- Field-specific fertilizer recommendations based on soil testing. The Canadian fertilizer industry is currently participating in research to develop more precise soil testing methods. The value of field-specific recommendations cannot be overstated.

Fertilizer strategies must be fine-tuned to variations in Canada's soils, climates and crops.

- **Communication, education and extension.** The key to proper fertilizer use is an understanding of how fertilizer recommendations are arrived at and how to avoid economic and environmental costs. Fertilizer manufacturers and retailers support farmer education through training sessions and publications where research -based expertise is transferred.

- **Research, product and technological development.** The Canadian fertilizer industry is actively involved in research and development initiatives, often in close cooperation with universities and governments. Technological improvements leading to more uniform product size is one example that enhances the efficiency of fertilizer application. Precision fertilizer placement is another example of technological development that improves soil quality and crop production while reducing environmental risks.

In this decade, world population will increase at an average rate of 80 million each year. By the end of this century, world food production must increase by 25 percent just to maintain current dietary standards. It is well known these standards remain inadequate for major segments of the world's population.

Over the past thirty years the harvested wheat and coarse grains acreage has been stable. The primary reason why production has kept pace with demand has been steadily rising yields. Mineral fertilizers, combined with improved plant genetics and other intensive cultural practices, have played a major role in ensuring adequate supplies of safe, nutritious and affordable food.

In 1989, the Government of Canada set out its vision for the reform and future development of the Canadian agri-food industry. Its "four pillars" of agriculture are: more market responsiveness; greater self-reliance in the agri-food sector; the recognition of regional diversity; and increased environmental sustainability. The Canadian fertilizer industry believes that mineral fertilizers, wisely used both economically and environmentally, make a valuable contribution to each of the four pillars and the goals embraced therein.

In the future, mineral fertilizer use will ensure adequate supplies of food and economically viable farm operations. An intensified effort will be devoted to ensuring that fertilizer use is part of a sustainable agricultural system.

The key to such efforts will be cooperation and effective partnership among farmers, the fertilizer industry, universities and governments. Members of the Canadian Fertilizer Institute are strongly committed to playing a constructive role in this partnership.

APPENDIX A

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APPENDIX B

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PROGRAM

NATIONAL WORKSHOP "AGRICULTURAL IMPACTS ON WATER QUALITY: CANADIAN PERSPECTIVES"

Conference Room
Neatby Building
Central Experimental Farm
Ottawa, Ontario, Canada

April 23-24, 1992

COOPERATING AGENCIES

Canada Committee on Engineering Services in Agriculture and Food (CCESAF) Canada Committee on Land Resource Services (CCLRS)
Centre for Land and Biological Resources Research, Agriculture Canada (CLBRR)

PROGRAM/PLANNING COMMITTEE

Mr. P. Milburn,	Agriculture Canada Research Station, Fredericton, New Brunswick (CCESAF) Co-Chair
Dr. C. Topp,	Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario (CLBRR) Co-Chair
Dr. S.T. Chieng,	University of British Columbia, Vancouver, British Columbia (CCESAF)
Dr. D. Coote,	Land Resource Research Centre, Agriculture Canada, Ottawa, Ontario (CLBRR; CCLRS)
Dr. J. Millette,	Land Resource Research Centre, Agriculture Canada, Ottawa, Ontario (CLBRR)
Dr. W. Nicholaichuk	National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan (CCESAF)
Dr. J. Robertson,	University of Alberta, Edmonton, Alberta (CCLRS)
Mr. K. Stevenson,	Ridgetown College, Ontario Ministry of Agriculture and Food, Ridgetown, Ontario (CCLRS)

OBJECTIVE

To provide a national forum for the exchange of scientific information on the impacts of agricultural practices on water quality in Canada, and to discuss future needs and trends (i.e., research, regulation, guidelines).

GOALS

Provide a concise, national overview of:

1. The results of Canadian agricultural and non-agricultural studies that quantify or assess the impacts of agricultural production practices on water quality.

2. The background, objectives, and type of information expected from on-going studies related to agriculture and water quality.

3. Existing and proposed regulation/guidelines that affect agricultural practices.

4. Information gaps/future research needs, as identified by workshop participants during scheduled discussion periods.

SPONSORS

Canadian Agricultural Research Council
Atlantic Land Improvement Contractors Association Hoskins Scientific

NATIONAL WORKSHOP
AGRICULTURAL IMPACTS ON WATER QUALITY:
CANADIAN PERSPECTIVES
APRIL 23-24, 1992
NEATBY BUILDING
CENTRAL EXPERIMENTAL FARM
OTTAWA, ONTARIO

Day 1 (April 23)

8:00 - 8:45 Registration

8:45 - 9:00 AM Opening Remarks: P. Milburn, Agr. Can. Res. Sta., Fredericton

Chair: Dr. D. Coote, Research Branch, Agriculture Canada, Ottawa

I. Results from Agricultural Studies: Sediment/Nutrients/Pesticides
A speaker from each province/region will: a) summarize the results of research to date in that region, and; b) provide an overview of the background and objectives of studies currently underway.

National 9:00-9:20	Water Resources in a GlobalEnvironment: The Policy Issues	W. Smith, Science Council of Canada, Ottawa
Regional 9:20-9:40	Atlantic	J. Richards, Agr. Can. Res. Sta., Fredericton
9:40-10:00	Québec	C. Madramootoo and R. Asselin, Macdonald College, Ste. Anne de Bellevue, and MAPAQ, Nicolet
10:00-10:30	BREAK	
10:30-10:50	Ontario	M. Miller, Univ. of Guelph, Guelph
10:50-11:10	Manitoba	G. Racz, Univ. of Manitoba, Winnipeg

Day 1(Cont'd.)

11:10-11:30	Alberta	B. Paterson, Alberta Agr., Lethbridge
11:30-11:50	British Columbia	B. Zebarth, Agr. Can. Res. Sta., Agassiz
12:00-1:30PM	LUNCH	

Chair: **Dr. J. Millette,** Research Branch, Agriculture Canada, Ottawa

II. Regulations/Guidelines Concerning Sediment, Nutrients, Pesticides

Appropriate federal legislation will be reviewed, and present or pending provincial legislation affecting agricultural practices will be presented. The session will conclude with representatives from agricultural organizations addressing concerns related to regulation.

Federal

1:30-1:50	Canadian Water Quality Guidelines for Pesticides	P.Y. Caux, Env. Can., Hull
1:50-2:10	Canadian Drinking Water Quality Guidelines in Relation to Agriculture	B.H. Thomas, Health and Welfare Canada, Ottawa

Provincial (review existing or pending regulations/guidelines)

2:10-2:30	Newfoundland	K.U. Khan, Nfld. Dept. of Env. and Lands, St. John's
2:30-2:50	Prince Edward Island	G. Somers, PEI Dept. of Community and Cultural Affairs, Charlottetown
2:50-3:10	Nova Scotia	A. Cameron, NS Dept. of Env., Halifax
3:10-3:30	BREAK	
3:30-3:50	New Brunswick	P. Vanderlaan, NB Dept. of Munic. Affairs and Env.,Fredericton
3:50-4:10	Ontario	K. Willson, Ont. Min. of Env.,Toronto
4:10-4:30	Saskatchewan	R. Ruggles, SK Env. and Public Safety/ W. Nicholaichuk, NHRI, Env. Canada

Day 1(Cont'd.)

4:30-4:50	Alberta	P. Shewchuk, Alberta Env.,
4:50-5:10	British Columbia	R. Buchanan/ N. Nagpal, BC Min. of Env.,Victoria

Day 2 (April 24)

Chair: **Dr. W. Nicholaichuk,** NHRI, Environment Canada, Saskatoon

II. Regulations/Guidelines (Cont'd)

Public/industry concerns

8:30- 8:45 AM	Monsanto Canada Inc.	P. Marshall
8:45-9:00	Fertilizer Institute of Ontario	T. Sawyer
9:00-9:15	Union des Producteurs Agricole	Louis Ménard

Discussion Groups

III. 9:15-9:30	Instructions	
9:30-9:45	BREAK	
9:45-10:45	Discussion Groups (needs, concerns, data gaps, future direction) Leaders: • Dr .J. Millette (LRRC) • Dr. W. Nicholaichuk (NHRI) • Dr. D. Coote (LRRC) • Dr. S.T. Chieng (UBC) • Dr. C. Madramootoo (McGill) • Dr. J. Robertson (U of A)	
10:45-11:45	Presentation of Group Reports	
IV. 11:45-12:00	WRAP-UP	C. Topp, Res. Branch, Agr. Can., Ottawa