Prairie Farm Rehabilitation Administration

A Prairie-wide Perspective of

Nonpoint Agricultural Effects on Water Quality

A Review of Documented Evidence and Expert Opinion

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Canada

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Specific organizations were generally not contacted for an 'official' review. It was felt that replies from individuals would better allow for a candid reflection of the diversity of water quality opinion that is known to exist within agencies. Over 135 individuals or groups were invited to participate. About half of those agreeing to do so were interviewed in person.

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Abstract

The potential contamination of surface and groundwaters from nonpoint agricultural activities is of concern on the prairies. But the extent and nature of the problem are by no means certain, and the public receive conflicting messages about the role of agriculture in water quality issues. Accordingly, we conducted a review of documented evidence and expert opinion to determine what is really known about the impact of agriculture on water quality, within the context of current schools of thought.

There is a clear public perception that water quality is worsening, and the concept of relative risk is central to the interpretation of water quality issues. However, risk assessment is at best an imprecise science and opinions vary widely between those advocating zero tolerance and those in favour of a water quality guidelines approach to evaluation. The prairies may be a low risk zone of pesticide contamination for a variety of reasons, but this view is not universal. When considering water quality data: a sensitivity for the complex chemical and biophysical interactions governing pesticide and nutrient movement, the ambiguity within current sampling and analysis protocol, and the limitations underlying the Canadian Water Quality Guidelines, must all be taken into account.

Within the context of the Canadian Water Quality Guidelines, we find no clear evidence on the prairies of the *wide-spread* contamination of surface and groundwaters from agricultural activities. This does not mean there are no problems nor the potential for them to occur. But current problems are generally neither wide-spread nor excessive in degree. Sediment loading on major rivers is, at most, a seasonal problem. Relatively few pesticides are detected in prairie surface and groundwaters, and these rarely exceed current guidelines. Nitrate contamination of groundwater is a more common probability, being a higher risk under intensively fertilized and irrigated lands. Phosphorus contributions to surface waters are evident, although the net effect of agricultural loadings is uncertain. Water quality risks associated with range livestock, irrigation salinity, and heavy metals are generally limited, with some local exceptions.

There is a need to clarify the merit of the information upon which public opinion is based, and to find a middle ground between the differences in opinion posed by the Zero Tolerance and Water Quality Guideline points of view. This may be as simple as agreeing to focus resources towards a better understanding of why detections are occurring, rather than on what they ultimately mean. Research priorities include the need to better understand the fate of agrichemicals, to address the reduction of application losses, and take an overall watershed approach to water quality management. Public policy should acknowledge current safe levels and practices, while encouraging increased public involvement in evaluations and decision making. There is a need for the prairie-wide coordination of water quality activities. This is required on a multi-agency basis to assure a unified approach towards effectively achieving common water quality priorities within the limited resources available.

About the Authors

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Brook Harker has 20 years of experience in soil/water and sustainable agriculture issues. Academic training includes an M.Sc. in Soil Chemistry from the University of Alberta, and a B.Sc. in Agronomy from Brigham Young University in Provo, Utah. He has lived and worked overseas. His specialization includes soil/water quality issues related to agricultural inputs and environmental sustainability; the remote detection, mapping and monitoring of saline lands; extensive experience in land drainage and reclamation; and agricultural extension practices.

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Lawrence Townley-Smith is an Agricultural Ecologist. After completing his M.Sc. in Plant Ecology, he conducted land use, environmental inventory and environmental planning studies for a variety of clients. While completing his Ph.D. in Agronomy he joined the Research Branch of Agriculture and Agri-Food Canada where he conducted crop and weed ecology research for 12 years. He has many interests in resource management including water quality in agricultural areas.

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Karen Bolton has a B.Sc. in Biology from the University of Saskatchewan and a Masters in Geography from the University of Regina. Her graduate studies focused on environmental planning and resource management. Karen worked as a consultant for Saskatchewan Agriculture and Food, and Saskatchewan Environment and Resource Management. Her current activities as an Agricultural Resource Specialist involve sustainability issues surrounding livestock, manure management and water quality across the prairies.

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Bill Bristol has a diploma in Renewable Resources Technology from Kelsey Institute and a B.Sc. in Biology from the University of Waterloo. He worked for Ducks Unlimited in Saskatchewan for 12 years, assessing wetland habitat for their project development. His interests at PFRA include grazing management systems for Community Pastures, and he is presently conducting a demonstration of grazing management practises in riparian areas that are beneficial to wildlife.

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Executive Summary

Nonpoint-Source Water Quality

Concerns over water quality issues on the prairies are increasing. These include the possible impact of nonpoint-source agricultural activities on water purity. Because of the wide-spread nature of agricultural activities, there is clearly the hazard that surface and groundwaters may become contaminated. Probable contributions from field-scale (nonpoint) agricultural operations relate to sediment loading, concentrations of pesticides and nutrients, and other factors. However, the extent and severity of the potential problem are by no means certain.

Process and Objectives

We examined documented evidence and expert opinion, to determine what truly is, and is not known, about the impact of nonpoint agricultural activities on prairie water quality. This involved the review of over 180 scientific articles; and interviews and consultation with many experts in a wide range of discipline including representation from various provincial, federal and university departments of agriculture, water and environmental protection. The information obtained will be used to provide field staff and others with a balanced perspective of the relationship between agriculture and water quality issues.

Public Perception

There is a public perception that water quality is deteriorating. Yet the public receives conflicting messages as to the role of agriculture in the process. Some experts say that agriculture is a "major contributor." Others say there is "very little evidence" of such a condition. Perceptions are often based on the analysis of very preliminary data. Since agrichemicals are used to grow food, perceptions of water quality are often closely linked to those of food safety. Yet recent testing confirms that Canadian food commodities are well within safety guidelines for pesticide residues.

Relative Risk

The concept of relative risk is central to our understanding of the water quality issue. Risk assessment is at best an imprecise science. Even among experts, there is great disagreement as to the meaning of water quality findings. As well, the public often takes little consolation in probabilities and finds the significance of parts per billion difficult to grasp. Public opinion on water quality is generally divided into 2 or 3 greatly differing points of view. The Zero Tolerance group fears that even a trace of unnatural substance in the environment is unhealthy and unacceptable. Proponents of Water Quality Guidelines accept the premise that there are contaminant levels below which people and the ecosystem are at reasonable risk. A third group considers current water quality guidelines to be excessively conservative.

Because of the wide-spread nature of agricultural activities, there is clearly the hazard that surface and ground-waters may become contaminated. However, the extent and severity of the potential problem are by no means certain.

Even among experts, there is great disagreement as to the meaning of water quality findings. The public often takes little consolation in probabilities and finds the significance of parts per billion difficult to grasp.

Prairie Setting

To understand the relative hazard of exceeding water quality guidelines, it helps to place the prairie setting within a North American and Canadian context. On a weight per unit area basis (kg/ha), average Canadian use of pesticides is 40% of the total applied in the United States. And the prairies average only 1/4 of the rate applied in Ontario. Some consider the prairies to be a relatively low risk zone for contamination from pesticides because our drier weather and lower intensity of agricultural inputs likely result in lower total leaching and runoff. Others contend that our dry, cold climate may lead to high-impact consequences as a result of slower pesticide degradation and seasonally concentrated leachate and runoff.

Some consider the prairies to be a relatively low risk zone for contamination from pesticides. Others contend that our dry, cold climate may lead to high-impact consequences.

Key Interpretation Concepts

Once water quality information has been obtained, an understanding of a few key concepts is central to effective data interpretation. These include a knowledge of how the chemical characteristics of a particular pesticide or nutrient interact with surrounding biophysical conditions. Sampling and analysis protocol can also play a key role in data interpretation. Results are often based heavily on estimates, can vary widely with the technique used, and must be interpreted within the context in which they were obtained. As well, we need to recognize that the Canadian Water Quality Guidelines are only that — guidelines. They contain inherent limitations and data gaps, and themselves stipulate only that *continually* exceeding them "may, in some instances, be capable of introducing deleterious effects on health." But the Guidelines represent a middle ground between the extremes of Zero Tolerance and the lack of any standard. As such, they can serve as a useful measure against which to assess relative water quality.

Results are often based heavily on estimates, can vary widely with the technique used, and must be interpreted within the context in which they were obtained.

Specific Prairie Findings

We have placed specific prairie findings within a North American and, less frequently, a European context for comparative purposes. Results are derived largely from a review of available summary documents and expert Prairie opinion. Where conclusions have been drawn, these assume that water quality guidelines are a legitimate basis of evaluation.

Sediment

Sediment in surface waters can be a problem in terms of both turbidity and silt loading. It can also be a transport medium to carry attached pesticides and nutrients from agricultural lands. Yet sediment loading in major prairie rivers is lower than predicted and is generally not considered to be a problem. This may be because erosion models have greatly over-predicted net erosion losses, or because sediment is trapped in prairie potholes, small rivers and streams before reaching major rivers. More work on the prairie pothole topography and small basin studies is required.

Pesticides

Pesticides are found to some extent in surface and groundwaters across the prairies. However, relatively few pesticides are consistently detected, and the great majority of these are well below Canadian Water Quality Guidelines. This applies to rivers, groundwater, dugouts and soils. Intensively used agricultural lands are the area of greatest risk. There is some evidence of pesticide leaching below irrigated prairie lands, but even beneath the most intensively farmed lands of Ontario, evidence of pesticide leaching is limited. A universal concern is to gain a better understanding of why detections occur in some locations and not in others.

Nitrate

Agricultural activities can elevate nitrate levels above water quality guidelines. However, the relative proportion of groundwater samples exceeding guidelines can vary widely (typically 0-25%), and it is often difficult to determine natural baseline concentrations of nitrate. Highly fertilized lands (from chemical or manure), sandy textured soils, and the timing and intensity of irrigation or precipitation events appear to increase the hazard. There is a need to better document baseline nitrate levels, including the use of in-field groundwater investigations to directly track changes under agricultural lands.

Phosphorus

Phosphorus loadings in lakes and streams can result from agricultural activities. But estimates of export coefficients vary widely and the net effect of agricultural practices can be difficult to document. The quality of mainstream waters on the prairies is generally within acceptable phosphorus limits and occasional eutrophication is a summer phenomenon downstream of sewage treatment plants. Phosphorus balances and loadings in small lakes and streams are variable and require further study. There is a critical need to refine phosphorus models and to calibrate them to local conditions. Until this is done, the view exists that a "healthy scepticism" of such models may be warranted.

Other Risks

Other risks of nonpoint agricultural pollution include the effects of range livestock on surface waters. These are generally no greater than those of wildlife, except at concentrated feeding and watering sites where sediment, nutrient and coliform bacteria loadings can be a problem. Fecal coliform counts may be elevated in groundwaters under intensively managed (heavily manured) lands. Negative impacts from irrigation waters on downstream salinity are generally not a problem on the prairies, where both surface supply and receiving waters are low in salt to begin with. Contamination of surface and groundwaters from trace elements and heavy metals is rare, with some local exceptions.

Priorities

Water quality priorities on the prairies fall into two main categories: research and monitoring, and policy direction. There is wide spread recognition of the need to better understand how agrichemicals move in the environment, to establish universal field sampling and analysis protocols, and for research towards reducing application losses. Importance is placed on a holistic watershed approach to water quality research and development. Current safe water quality levels and land management practices need to be clarified in the public mind. A prairie-wide focus towards addressing water quality issues is required, to assure the effective pursuit of common priorities and the efficient use of limited resources. The formation of a multi-agency working group will do much towards assuring that agency programs and activities are effectively structured and integrated at the early planning stage.

Current safe water quality levels and land management practices need to be clarified in the public mind. A prairie-wide focus towards addressing water quality issues is required.

Conclusions

It is clear that contamination by agrichemicals occurs to some degree. Yet results to date are uncertain and findings are still largely a collection of isolated studies. The challenge is to document *why* agrichemicals are found in certain locations and not in others. Even among professional researchers, and despite apparent standards, there seems to be no clear demarcation as to when a problem is significant. Consequently, the interpretation of results may depend heavily upon the background of the investigator or the bias of those applying the findings. The scientific and lay communities are justifiably confused by what findings mean. Nevertheless, within the context of the Canadian Water Quality Guidelines, there is no significant body of evidence to indicate the *wide-spread* contamination of surface and groundwaters from agricultural activities on the prairies. This does not mean there are no existing or potential problems. But current problems are generally neither wide-spread nor excessive in degree.

Within the context of the Canadian Water Quality Guidelines, there is no significant body of evidence to indicate the wide-spread contamination of surface and groundwaters from agricultural activities on the prairies.

Recommendations

There is a clear need to rationalize the opposing viewpoints of relative risk held by Zero Tolerance groups and Water Quality Guidelines proponents.

There is a need to clarify the conflicting messages received by the public, through identifying and verifying the information sources on which opinion is based. There is a clear need to rationalize the opposing viewpoints of relative risk held by Zero Tolerance groups and Water Quality Guidelines proponents. That may be as simple as agreeing to focus our attention on a better understanding of why detections are occurring, rather than on what they ultimately mean. We need open public discussion on the role and reality of agriculture in water quality issues. This includes clearer explanations of water quality terms and concepts, as well as greater public involvement in evaluations and decision making. A prairie-wide, multi-agency coordination of water quality activities is required to assure a unified approach towards achieving common objectives with the limited resources available.

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1.0 Nonpoint-Source Water Quality

The impact of agricultural practices on water quality is an issue on the Canadian prairies. Of particular concern is the possibility of wide spread, *nonpoint-source* contributions from agricultural lands. Nonpoint-source contributions are those that occur from agricultural practices on the land base in general, as compared with point-source contributions such as from a chemical spill or feedlot.

On the prairies, the issue around agricultural nonpoint-source water quality has been accented by problems with water quality in other parts of North America.

1.1 PFRA Interest

For over 60 years the Prairie Farm Rehabilitation Administration (PFRA) has been concerned with, and involved in, assuring that Prairie people have an adequate supply of water. As a regional arm of Agriculture and Agri-Food Canada (AAFC), we are increasingly interested in the quality of water available for both rural and urban users:

- ***Sustainable agriculture.*** On the prairies, PFRA plays a central role in supporting sustainable agricultural development while promoting efficient agricultural production

- ***Unique interface.*** PFRA represents a unique prairie-wide interface between agricultural production and water quality concerns

From this perspective, we felt it appropriate to conduct an in-depth review of current prairie understandings about the impact of nonpoint-source agricultural practices on water quality.

1.2 A Potential Problem

Runoff and leachate and airborne deposition from agricultural lands may be contributing unacceptable levels of sediment and agrichemicals to surface and groundwater supplies. This could adversely affect water use and safety for human life and the entire ecosystem.

Uncertain Extent and Severity

On the prairies, the issue around agricultural nonpoint-source water quality has been accented by problems with water quality in other parts of North America. These findings are being extrapolated to the prairies and have raised concerns. Yet the extent and severity of the problem are not clear:

- ***Localized hot spots.*** It is certain that localized agricultural "hot spots" occur

- ***Uncertain extent.*** It is not certain that these findings are representative of the effects of agriculture in general

Possible Sources
Possible nonpoint-source agricultural contributions can be grouped into 4 main categories:

- ***Sediment loading.*** Soil particles transported by wind and water erosion from agricultural lands into surface waters
- ***Pesticide residue.*** Pesticides may enter surface waters from the air, in runoff, or leach into groundwaters
- ***Nutrient Loading.*** Primarily nitrate and phosphorus derived from commercial fertilizers and the breakdown of plant material and manure
- ***Other effects.*** Includes direct access of range livestock to water bodies, fecal coliform bacteria and other pathogens, irrigation salinity, and heavy metals

A key objective of this report is to present a balanced look at what we actually know about the impact of agriculture on water quality.

1.3 Process and Objectives

The purpose of this review is to present a balanced perspective of water quality and related nonpoint-source agricultural issues on the prairies, and elsewhere. The focus is primarily on human health, as that is the standard most commonly referred to by researchers. Where other guidelines (e.g., aquatic, irrigation) are indicated, these are noted.

Balanced Agricultural Perspective
A key objective of this report is to present a balanced look at what we actually know about the impact of agriculture on water quality. In doing so, the authors acknowledge having approached the task from within an agricultural perspective. This does not mean to imply that all of agriculture is united in its perception of the effect of agriculture on water quality. Indeed, we have found as much variation within agriculture as without.

The Review Process
Our report is based upon findings from over 180 scientific references and a review of expert opinion:

- ***Extensive review.*** Various drafts of the paper were circulated to over 130 potential reviewers, including representation from provincial, federal and university departments of agriculture, water and environmental protection
- ***Personal interviews.*** Many of the reviewers were contacted personally and given an opportunity to express their thoughts in face-to-face interviews

By this process we later received over 60 appraisals, most in written form. We tried to incorporate or at least reflect an understanding of these comments in subsequent drafts before circulating the document for further review.

How Was The Report Received?
Reception to this report and the process used has been overwhelmingly positive. A few have seen no need for the document. Some say they would approach the topic differently. Two or three still feel that its contents "do not reflect a consensus of expert opinion" on water quality. We are not aware of such a consensus. Our intent has been to progress towards such an objective.

Policy and Program Direction
The report identifies many of the steps now being taken, and concludes by identifying those policies, programs and practices that might yet be applied to better address nonpoint-source water quality concerns:

- ***Inform field staff.*** An over-riding objective has been the collection of information useful to field staff
- ***Forum for discussion.*** It is hoped this report will provide a forum for comment and discussion amongst a wide range of professional, technical and lay opinion

2.0 Public Perception

There is an increasing public perception of wide-spread water quality problems. A recent video emphasizes the importance of water quality [Dickerman 1995], by using the cyclic nature of water to highlight the theme that "There is only one body of water," and we, being 75% water, should be vitally interested in its purity.

"There is only one body of water," and we, being 75% water, should be vitally interested in its purity. [Dickerman 1995]

A Serious Environmental Danger

In Canada, an Angus Reid opinion poll showed that many Canadians see water pollution as "the most serious environmental danger facing the world today" [Colgan 1992]. A Roper study in the United States found that 77% of Americans consider water quality to be the number one environmental problem.

A Green Plan study of urban residents across Saskatchewan and Manitoba reported that most people are concerned about the use of farm chemicals, yet do not consider agriculture to be among the most serious threats to the environment [The Advisory Group 1994]. In an Alberta survey, water supply and quality were specifically targeted [Birch 1992] and public expression reflected a desire for:

- ***Integration***. A more integrated approach to water management
- ***Information.*** Increased attention to water quality monitoring and public education
- ***Involvement.*** Greater public involvement in setting water quality standards

2.1 Conflicting Messages

The public receives conflicting messages about water quality. In contrast to the belief that agriculture is a significant contributor to water quality problems [USEPA 1994], Lindwall [1992] has said that documented research on the prairies provides "little evidence that agriculture is having a significant effect on the quality of surface and groundwater supplies."

Preliminary Data

Within the United States, agriculture is said to be the remaining major unregulated source of environmental contamination [Offutt 1990]. But such a position must be cautiously interpreted, because of the context of the data collection network used to arrive at this conclusion. According to Robert Wayland [1990] of the United States Environmental Protection Agency (USEPA):

We simply don't know whether prairie lakes are naturally eutrophic or are becoming so due to agricultural loadings. [Mitchell and Trew 1992]

> ***The assessment and monitoring programs the EPA administers with the States, "have not been designed to identify water quality status and trends"***

Rather, EPA monitoring systems were only established to help identify and understand problems. As such, findings are complicated by the fact that the overall data set is at best preliminary and findings are incomplete.

Given this preliminary data, Colgan [1992] expressed concern that negative "generalizations" are being used in school curricula. He is alarmed that:

> ***These might mislead the next generation into believing there is a serious environmental problem - when the extent and severity of the problem has not been adequately documented***

In its report to congress on the National Water Quality Inventory, the USEPA [1994] maintained that agricultural runoff was the most extensive source of pollution for surface waters within the United States. Agricultural sediment and nutrient loading were said to be two of the chief contributors to degraded water quality in about 40% of lakes and rivers.

Yet within the United States Department of Agriculture (USDA), the USDA Working Group on Water Quality observes that EPA estimates are based on non-representative sampling of less than 1/3 of the Nation's waters [Swader et al. 1994]:

> ***The Working Group's "worst case" estimate is that agriculture may be a factor in about 7% of US waters which may not support State-designated uses***

In Western Canada, many people perceive water quality in prairie lakes to be deteriorating, and believe that agriculture is largely to blame. Yet, according to Mitchell and Trew [1992] we simply don't know whether prairie lakes are naturally eutrophic or are becoming so due to agricultural loadings.

MacAlpine and Nguyen [1993] recently conducted a literature review of nonpoint-source pollution and water quality in Alberta. According to them, limited evidence to date suggests "there is no serious agricultural pollution problem . . . " in that province.

They point out that because Alberta's agricultural industry is primarily extensive (not intensive), researchers may not find the extent and severity of water quality degradation found in other places. Still, MacAlpine and Nguyen caution that:

- ***Perception.*** The public's perception of agriculture's role in a clean and healthy environment is very important and could still be at stake

- ***Farmers want to know.*** Because farmers live on the land and drink the water there, they will want to be among the first to know if there is a water quality problem

Chemical Residue in Food

Since agrichemicals are used to grow food, residue perceptions related to food safety are often closely linked to those of water quality. Yet findings from a 1993 survey of domestic agri-food products by Health Canada [AAFC 1993] indicate:

- ***99.3%*** of the country's food supply meets all government standards for pesticide (herbicide, insecticide, fungicide) residue

- ***84.5%*** of some 303,000 samples of domestic food products had no detectable residue

- ***0.7%*** of samples had residues above tolerance levels

In commenting on food safety, Dr. C.E. Koop, the former US Surgeon General says, "The US has the safest and most abundant food supply in the world. . . and [pesticide residues on food] are not dangerous to the people of this country" [Lindwall 1992].

A 1991 survey of food commodities in California found that of 8,278 samples from 167 commodities, more than 80% had no detectable pesticide residue. Less than 1% were over allowable limits or had residue from unauthorized uses [Lindwall 1992]. This finding was in spite of the fact that as many as 50 different pesticides may have been annually applied to some agricultural counties in California [Litwin et al. 1983].

2.2 Proactive Agriculture

Prairie agriculture needs to more actively address its role in reducing the potential to degrade water quality. Hicks [1992] warns that attention to environmental impact from agriculture will increase and that agriculture must be assertive in identifying and quantifying problems, and taking action where needed. He says, "Denying that agriculture is having any impact will not be accepted. Agriculture must be proactive to avoid future regulation."

Positive Government Stance

The need for an integrated approach to multiple resource management (including water quality) is increasingly reflected in government objectives.

In her introduction to the recent Toxic Management Policy for the Government of Canada [Environment Canada 1995], The Honourable Sheila Copps introduced a policy that calls for:

> ***"The virtual elimination from the environment of toxic substances that result from human activity and that are persistent and bioaccumulative"***

The preface to the National Environment Strategy For Agriculture and Agri-Food [1995] for Canada speaks of the need to achieve environmental sustainability, while seeking to balance social, economic and environmental objectives. The report to federal and provincial ministers stresses:

> ***This balance is required because the sector, "must be economically viable if it is to conserve the environment and support the social systems upon which it is based"***

On the Canadian prairies, the Mission Statement of PFRA (within AAFC) speaks of the need to build a healthy environment to achieve the high quality of life upon which agriculture ultimately depends [PFRA 1994].

"Denying that agriculture is having any impact will not be accepted. Agriculture must be proactive to avoid future regulation." [Hicks 1992]

From the Government of Alberta, the goal for agriculture includes a philosophy of contributing to "improved surface and groundwater quality through the use of environmentally sustainable production and processing practises" [Colgan 1992].

An Ecosystems Approach

Within the USDA, the Natural Resource Conservation Service (NRCS - formerly the SCS) is aligning its technology "to fit soils and nutrient management into an ecosystems approach to resource con servation," that includes water quality [Shaw 1994].

The NRCS provides an example of a holistic, comprehensive approach that takes into account:

- ***Balance.*** The need for a balance between economics and ecology

- ***Policy.*** Awareness of a shift in policy towards resource protection and sustainability

- ***Timing.*** Assuring that environmental aims are applied incrementally, to give agriculture time to adjust

Landowner Accountability

Landowners must demonstrate that responsibility for land use and accountability for water quality go hand in hand with property rights [Wayland 1993]. American society is spending $40 billion annually to protect and restore the quality of rivers, lakes and streams. Critics acknowledge that the most sensible, cost-effective approach to water quality degradation may well be a reliance on the farm community to devise and implement pollution control. Yet they warn that regulation is imminent and action is needed now [Offutt 1990].

Future Needs

The agricultural community has made significant advances toward reducing reliance on farm chemicals and decreasing potential impact on water-courses and groundwater systems. Nevertheless:

- ***Early warning.*** Some express the view that the trace concentrations being detected today might well be an "early warning" of significant problems to come [Williamson et al. 1995]

- ***Increased information.*** They caution that intelligent, well-informed consumers are demanding increasingly more information on which to make reasoned water quality decisions

- ***Best interest.*** It is in the best interest of all to provide the required information as soon as possible

Landowners must demonstrate that responsibility for land use and accountability for water quality go hand in hand with property rights. [Wayland 1993]

2.3 Summary

Problems with water quality on the prairies are perceived to be increasing. Many people see water pollution as a serious environmental danger. They want a more integrated approach to water management, better information, and more input into water quality decisions.

Conflicting Messages

The public is receiving conflicting messages about how severe and widespread water quality problems are on the prairies. Negative opinions are often based on an analysis of limited information. Perceptions of water quality are closely linked to those of food safety. Recent testing confirms that Canadian food commodities are well within safety standards for pesticide residues.

Proactive Agriculture

Agriculture needs to expand its proactive stance towards clarifying the role it plays in water quality issues. Governments of all levels have incorporated water quality objectives into their planning strategies with a view to secure a more holistic, comprehensive approach to resource conservation. The most sensible, cost-effective approach will likely be to allow the agricultural community to devise and implement pollution controls as needed. However, regulation is imminent and action is needed now.

Required Action

The very act of using water for most purposes changes its quality. Conflicting messages on water quality must be clarified. Agriculture must continue to expand its proactive role, because answers are needed now. It is in agriculture's best interest to work closely with others to clarify the status of water quality concerns as soon as possible.

2.4 References

AAFC. 1993. Annual Report on Chemical and Biological Testing of Agri-Food Commodities. Agriculture and Agri-Food Canada.

Birch, Alfred. 1992. Alberta public attitudes to water quality. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 94-97.

Colgan, Brian. 1992. Future direction and key issues in surface and groundwater quality. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 85-87.

Dickerman, A. 1995. The living water of life. Proc. Water In The 21st Century: Conservation, Demand, and Supply. Amer. Water Resources Assoc. Salt Lake City, UT. p.3.

Environment Canada. 1995. Toxic Substances Management Policy. Minister of Supply and Services Canada. Ottawa. Catalogue No. En 40-499/1-1995.

Hicks, Ron. 1992. Alberta's environmental legislation and agricultural impacts on surface and groundwater quality. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 92-93.

Lindwall, C. Wayne. 1992. Future direction and key issues in surface and groundwater quality: Research perspective. Proc. Agricultural Impacts on Surface And Ground-water Quality. Lethbridge, AB. p. 88-91.

Litwin et al. 1983. Groundwater Contamination by Pesticides: A California Assessment. State Water Resources Control Board, Sacramento, CA. Publ. No. 83. 45 pp.

MacAlpine, Neil, and Quang-Tuan Nguyen. 1993. Agricultural Nonpoint Source Pollution of Water: A literature survey form an Alberta Perspective. C & D Branch, AAFRD. Edmonton, AB. 95 pp.

Mitchell, P. and D. Trew. 1992. Agricultural runoff and lake water quality. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 73-79.

National Environment Strategy for Agriculture and Agri-Food. 1995. *For*, the Federal and Provincial Ministers of Agriculture. AAFC, Ottawa, ON. 43 pp.

Offutt, Susan. 1990. Agriculture's role in protecting water quality. J. Soil and Water Cons. 45 (1) 94-96.

PFRA. 1994. PFRA Business Strategy. Agriculture and Agri-Food Canada, Regina, SK. 20 pp.

Shaw, Robert R. 1994. You need to start with the soil: The Soil Conservation Service Experience. Supplement,J. Soil and Water Cons., Vol 49(2): 7-8.

Swader, F.N., L.D. Adams and J.W.Meek. 1994. USDA's water quality program - Environmentally sound agriculture. Proc. 2nd Environmentally Sound Agriculture Orlando, FL. p. 86-92.

The Advisory Group. 1994. Agriculture and the Environment; Urban Awareness Program - Manitoba And Saskatchewan. For, AAFC, Manitoba Agriculture and Saskatchewan Agriculture and Food. 194 pp.

USEPA. 1994. National Water Quality Inventory 1992 Report To Congress (Fact Sheet). United States Environmental Protection Agency. EPA841-F-94-002.

Wayland, Robert. 1990. What progress in improving water quality? J. Soil and Water Cons. 48 (4): 261-266.

Williamson, D., A. Beck and S. Gurney. 1995. Personal communication. Letter dated December 18, 1995. Manitoba Environment, Winnipeg, MB.

3.0 Understanding Relative Risk

The concept of relative risk is the subject of considerable discussion and debate. There is a need to clarify in the public mind, the relevance of encountering small amounts of pesticide (herbicide, insecticide, fungicide) or other agrichemical.

3.1 Risk Assessment

Risk assessment is at best an imprecise science. Adam M. Finkel, director of health standards at the U.S. Occupational Health and Safety Administration (OHSA), advocates risk assessment but acknowledges that it is a young field severely constrained by, "a dearth of qualified practitioners" [Finkel 1996].

Need for Balance

Finkel [1996] says we must be careful not to ask of risk assessment more precision, in terms of quantity and quality, than it can deliver. He says there is a need for balance and that we need to be cautious of:

- ***Non-average conditions.*** The danger of basing risk assessment only on average people and conditions — if in the process we fail to protect significant segments of non-average population
- ***Balancing health & economics.*** All estimates of risk involve some uncertainty and should be geared to "strike some balance between the health and economic costs of underestimating the risk and the costs of over estimating it"

Clear Answers Being Sought

Billions of dollars have been spent on biomedical research. Given this situation, Hrudey and Krewski [1995] emphasize that the public has reason to expect the scientific community to provide a clear answer as to whether there is a safe level of exposure to a carcinogen.

Yet, traditional approaches involving probabilities, statistics and risk analysis are not sufficient in the public mind. Scherer [1990] maintains that:

> ***"Risk assessment is a complex discipline not fully understood by experts, much less by the public"***

He says that public reaction to risk assessment is based on a different set of criteria. Scherer points out that technical and scientific problems are ultimately social problems, and these require both social and technical solutions.

"Risk assessment is a complex discipline not fully understood by experts, much less by the public." [Scherer 1990]

Outrage Dimension

The risk assessment criteria used by the public are more likely to focus on what Sandman calls an "Outrage Dimension" [Sandman 1987, in Scherer 1990]. This *outrage* perception is based on the integration of up to 20 factors that include:

"The scientific community's ability to detect chemicals is much more advanced that the understanding of the toxicology associated with such discoveries." [CAST 1992]

- ***Fairness of risk.*** Accounting for an individual's proximity to a hazard, like a nuclear reactor
- ***Degree of control.*** e.g., access to a private well as opposed to relying on public water supply
- ***Familiarity***. Exposure to common automobile accidents vs. exotic risks such as pesticide contamination

An example of perception of relative risk as it relates to *degree of control* might be seen in the results of a rural/urban survey of east-central Saskatchewan [Hass 1994]:

- ***Low priority risk.*** Most farmers in the survey ranked pesticide contamination and water quality as low priorities when it came to environmental concerns
- ***High priority risk.*** Urban community leaders saw water quality as the number one agriculture/environment issue
- ***Degree of control.*** Most farmers likely had their own water supply and felt they had some control over it. Urbanites would need to rely on a public source

Dose and Concentration

Risk assessment must consider both dose and concentration. This is because risk involves time/dose relationships; wherein the concentration of the substance involved must be related to the time period of exposure to determine the dose or total amount encountered [Belyk 1996].

When expressing concentration, it is important to put the term into a context that a lay person can understand. Concentrations are often expressed as parts per billion (ppb):

- ***Concentration.*** Uniformly mixing the molecules from a teaspoon of sugar into two Olympic swimming pools will result in a concentration of 1 part sugar to 1 billion parts of water by weight [Lindwall 1992]
- ***Impact.*** The relative impact of encountering a 1 ppb residue has been compared to the effect of experiencing 1 second in a 33 year life span (containing 1 billion seconds) [Lindwall 1992]. You are certain to encounter the one second, but what will its impact be on your life?

Such comparisons do not fully account for time/dose relationships. Waite [1995] contends that the "1 Second In 33 Years" example is overly simplistic. He says that a second is much too large a unit to use as an illustration of the hazard of encountering parts per billion. Although we may only be exposed to tiny amounts of a substance in our drinking water, this might occur on a consistent, daily basis, not just once in a lifetime.

Others caution that while any one substance may not be considered harmful in trace amounts, no one knows the effect of long term exposure to a "cocktail" of multiple trace elements [Lebedin 1995, Zakrevsky 1995].

3.2 Zero Tolerance

The concept of Zero Tolerance in water quality holds that even trace amounts of an unnatural substance are deemed to be unacceptable.

Uncertainty

There will always be uncertainty in declaring even trace amounts of a substance to be safe. The Council For Agricultural Science and Technology [CAST 1992] says that:

> ***"The scientific community's ability to detect chemicals is much more advanced that the understanding of the toxicology associated with such discoveries"***

Some feel that the safest course of action is to pursue one of zero tolerance. A survey of toxicologists indicates that 20% of them think there is no safe level of a carcinogen [Kraus et al. 1992, in Hrudey and Krewski 1995].

Scherer [1990] is of the opinion that public demand for zero risk is unreasonable. He acknowledges, however, the need for experts and policy makers to provide a better understanding of why such an objective may be deemed both unreasonable and unattainable.
Part of the problem of addressing zero tolerance, says Lindwall [1992], is the fact that "the zero in zero tolerance keeps getting smaller." Detections that used to be in parts per million (ppm) are now possible for some compounds in parts per quadrillion (1 and 15 zeros) with the sophisticated instrumentation that is available.

Hrudey and Krewski [1995] question the validity of a zero tolerance point of view. To test this position, they calculated the hazard of exposure to the smallest conceivable dose of a carcinogen:

- ***Conservative estimating.*** Conservative USEPA assumptions were used to calculate the risk from "lifetime exposure to one molecule a day of the most potent known carcinogen (TCDD)"
- ***No cancer produced.*** The authors concluded that exposing the entire world population to such a dose would not yield a single case of cancer
- ***Safe levels.*** Hrudey and Krewski conclude that "within a realistic concept of safety, there is a safe level of exposure" to even the most toxic of carcinogens

Probabilities

Risk analysis comes down to a matter of probabilities. Probabilities are usually:

- ***Based on historical data***
- ***Assume average conditions***
- ***Project that past trends will continue***

Some suggest that we need to keep the limited risk of harm from trace chemicals in perspective with the rest of life's hazards. This has been compared to the worry of sitting on a tack, while positioned beneath a 16 ton weight suspended by a fraying cord [Rogers 1995]. Zero Tolerance does not accept this view.

In a recent article in Discover Magazine, Kluger [1996] examines the everyday hazard that a person will die from falling out of bed (1:2 million) or from other risks.

Kluger's statistics are taken from "The Book of Risks" by Larry Landon, a professor of philosophy from the University of Hawaii. Landon estimates the annual likelihood of an average American dying (or being otherwise affected) from a range of mishaps:

1:77	**heart attack** (adult over 35)
1:3,500	**car accident** (age 14-25)
1:11,000	**murder victim**
1:40,000	**urban traffic**, as a *passerby*
1:170,000	*infected*, **flesh-eating bacteria**
1:750,000	*struck*, by **lightning**

How do these hazards compare with the probability of dying or being seriously affected by a small amount of chemical in drinking water? It's hard to say, and therein lies the problem with probabilities.

Hrudey and Krewski conclude that "within a realistic concept of safety, there is a safe level of exposure" to even the most toxic of carcinogens. {1995}

As Hively [1996] points out, "subjectivity always exists or scientists would never disagree."

Subjective Analysis

When it comes to extrapolating the probable effects of water-borne traces of agrichemicals on human life, we really have very little historical data. As well, toxicology findings from average laboratory rats may be far removed from average people, for although rats like us are mammals, "they are far away from us genetically" [Caldwell 1996].

Despite the best of testing in water quality, there's a lot of room for bias when interpreting final results. For as Hively [1996] points out, "***subjectivity always exists or scientists would never disagree.***"

3.3 Summary

The concept of relative risk is the subject of considerable discussion and debate. There is a need to clarify in the public mind, the relevance of encountering small amounts of pesticide or other agrichemical.

Risk Assessment

Risk assessment is at best an imprecise science having "a dearth of qualified practitioners." Traditional approaches involving probabilities, statistics, and risk analysis are not sufficient in the public mind. Risk assessment must consider both dose and concentration, because risk involves time/dose relationships.

Zero Tolerance

The concept of Zero Tolerance in water quality holds that even trace amounts of an unnatural substance are unacceptable. Yet demand for zero risk may be both unreasonable and unattainable. Risk analysis comes down to a matter of probabilities. And there's a lot of room for interpreting final results, for "subjectivity always exists or scientists would never disagree."

Required Action

Risk assessment must be put into a context that both the scientist and layperson can comprehend. We need to "strike some balance between the health and economic costs of underestimating the risk and the costs of overestimating it."

3.4 References

Belyk, Murray. 1996. Personal communication. Letter, dated June 14, 1996. AgrEvo Canada Inc., Regina, SK.

Caldwell, Mark. 1996. Beyond the lab rat. Discover Magazine. May 1996. p. 70-75.

CAST. 1992. Water Quality: Agriculture's Role. Task Force Report No. 120. 103 pp.

Finkel, Adam M. 1996. Who's exaggerating? Discover Magazine, May 1996. p. 48-54.

Hass, Glen. 1994. Toward A Greener Generation Of Rural Families, Final Report. Organizational Management Services, *for* The Advisory Committee, District 18 & 19 ADD Boards. CSAGPA. 120 pp.

Hively, Will. 1996. The mathematics of making up your mind. Discover Magazine. May 1996. p. 90-97.

Hrudey, Steve E. and Daniel Krewski. 1995. Environ. Sci. Technol. Vol. 29, No. 8, p. 370A-375A.

Kluger, J. 1996. Risky business. Discover Magazine, May 1996. p. 44-47, 82-83.

Kraus, N., T. Malmfors and P. Slovic. 1992. Risk Anal. 12(2), 215-232.

Lebedin, John. 1995. Personal communication. Earth Sciences Div., PFRA. Regina, SK.

Lindwall, C. Wayne. 1992. Future direction and key issues in surface and groundwater quality: Research perspective. Proc. Agricultural Impacts on Surface And Groundwater Quality. Lethbridge, AB. p. 88-91.

Rogers, B. 1995. Oral presentation - Risk Assessment. International Assoc. of Hydrogeologists Congress 26. Edmonton, AB.

Sandman, P.M. 1987. Communicating risk: Some basics. Health and Environ. Digest 1(11): 3-4.

Scherer, Clifford W. 1990. Communicating water quality risk. J. Soil Water Cons. 45 (2): 198-200.

Waite, Don. 1995. Personal communication. Environment Canada. Regina, SK.

Zakrevsky, J.-G. 1995. Personal communication. Environment Canada. Regina, SK.

4.0 Prairie Setting

The hazard that nonpoint agrichemical use will contribute to surface and groundwater contamination on the prairies is significant. This is because of the extent of agricultural contributions and the potential difficulty of controlling them [Reynolds et al. 1995].

4.1 Pesticide Use and Trends

Pesticide use is one example of the risk that nonpoint agrichemical use might contaminate surface and groundwaters on the prairies. Compared with many other developed nations, Canadians use far less pesticide. This is a function of the crops grown and the pests encountered, rather than grower or government policy. Nevertheless, the net result could be a reduced risk of surface and groundwater contamination.

Annual Pesticide Use

Average annual pesticide use (herbicides, insecticides, fungicides) in Canada is less than 50% of the average 2 kg/ha of active ingredient applied in the United States, and less than 20% of the 5.2 kg/ha applied on average in France. The United States, Germany, the United Kingdom, and France each apply 5 - 25 times the combination of insecticides and fungicides per ha as used in Canada [PFRA 1995].

Still, prairie people apply more than 20 million kg of pesticides annually (mostly herbicides) — with about 45% of that in Saskatchewan alone [Manitoba Agriculture 1991]:

- ***Prairie portion.*** Prairie use constitutes about 76% of the total pesticides annually sold in Canada [Crop Protect. Inst. 1995]
- ***Per ha use.*** Annual herbicide use per ha on the Prairies is relatively small, 0.6 kg/ha in Alberta vs. 2.5 kg/ha in Ontario [Paterson 1992]

Urban and Non-farm Chemicals

A portion of applied pesticides are for urban use. Figures for the United States (1982) indicate that of the total pesticides applied nationally [Brown et al. 1989, in Burland and Byrtus 1992]:

- **7.3%** was by urban home owners
- **19.4%** urban government and industry
- **26.7%** of US total was for urban use

But cities occupy a small portion of the prairie landscape and urban use may be a much lower percentage of the total than in more densely populated areas:

> ***In Alberta, limited data on domestic (homeowner applied) pesticide sales for 1993 indicates that only about 1% of sales are for domestic purposes. Use by urban government and industry may also be lower than in the US***
> [Byrtus 1996]

Compared with many other developed nations, Canadians use far less pesticide. The net result could be a reduced risk of surface and groundwater contamination.

While a dry prairie climate greatly reduces the risk of leaching, the limited volume that does occur may have relatively high concentrations of nutrients and pesticides. [McConkey 1996]

However, the use of agrichemicals by cities may result in urban islands of concentrated application on the prairies. Recent studies along the Red River in Manitoba show increased concentrations of two herbicides downstream of the city of Winnipeg [Currie and Williamson 1995]. Other non-farm sources of pesticide residue include forestry applications, mosquito control, black fly control, right-of-way vegetation management and aquatic vegetation control.

Changing practices

Although pesticide use is still increasing across North America, the use of more natural and environmentally friendly forms is slowly growing [Lindwall 1992]:

- ***Non-chemical*** pesticide sales in the United States were $1 billion annually and growing at 30% per year
- ***Chemical pesticide*** growth was only about 1% per year
- ***Relative volume*** of chemical pesticide use is still very large in comparison to non-chemical use

4.2 "Low Risk" Prairie Zone?

The soils, climate and cropping intensity of the prairies represent a different setting than where much of today's water quality data (from outside of the prairies) is being derived.

Groundwater

In relation to groundwater quality, some researchers say that within a national context, most of the prairie ecozone is at low risk of contamination [Reynolds et al. 1995, McNaughton and Crowe 1995]. This is primarily due to:

- ***Low cropping intensity.*** Generally less than elsewhere in Canada
- ***Dry weather.*** Less rainfall and a greater area of arid climate
- ***Fewer chemical inputs.*** A result of growing lower value crops
- ***Soil characteristics.*** Heavy textures pose a relatively low leaching hazard

There are, however, prairie exceptions, particularly on irrigated lands and those areas near intensive livestock operations (ILOs) that receive large amounts of animal manure.

High Risk Zone?

Not everyone agrees with the concept of a reduced leaching hazard on the prairies. McConkey [1996] points out that while a dry prairie climate greatly reduces the risk of leaching, the limited volume that does occur may have relatively high concentrations of nutrients and pesticides:

- ***Summerfallow.*** Fallow can result in increased leaching of nitrate [Campbell et al. 1984]
- ***Sudden flux.*** Given the net moisture deficit of much of the prairies, sudden storms or rapid snow melt may cause a flux of concentrated contaminants into groundwaters and surface streams [MacDonald 1996]
- ***Low total load.*** Nevertheless, total annual loading to the system may still be far less than in more humid zones [Reynolds et al. 1995]

Spring Runoff

The hazard of contaminating surface water on the prairies might be considered as "low risk" for reasons similar to those given for groundwater. However, this may not be so. The dry, cold prairie climate may make for worse surface water conditions than a warmer, wetter climate [McConkey 1996].

One reason is that dry, cold weather severely retards pesticide degradation. Hence fall applied herbicides may degrade very little prior to spring runoff:

- ***Spring runoff.*** Spring runoff can be up to 90% of total annual runoff [Nicholaichuk 1967, in Reynolds et al. 1995]

- ***Fall applied herbicide.*** A significant portion of fall-applied herbicide may move off the field in spring runoff [Nicholaichuk and Grover 1989]

- ***First units.*** Since the dryness of the climate results in less total runoff, the "first units" of runoff are often the only runoff that occurs and can have high concentrations of contaminants [McConkey 1996]

- ***Evaporation losses.*** Dry weather can also result in high evaporative losses, causing residues to concentrate in the surface waters of storage reservoirs [McConkey 1996]

A significant portion of fall-applied herbicide may move off the field in spring runoff. [Nicholaichuk and Grover 1989]

4.3 Summary

There is concern that nonpoint agrichemical use on the prairies may pose a hazard to surface and ground-water quality. This is because of the large spatial extent of agricultural contributions and the potential difficulty of controlling them.

Prairie Pesticide Use

Canadians use less pesticides than many other developed countries. The prairies apply less pesticides per ha than the rest of Canada, but almost 76% of the total applied nationally. Part of this is used for urban and non-agricultural purposes. The switch to more environmentally friendly pesticides is slowly increasing.

Low Risk Zone?

The risk that nonpoint agrichemicals might pollute surface and groundwaters on the prairies may be lower for several cropping, climatic and soil reasons. Exceptions are lands under intensive agriculture. But dry prairie conditions could result in seasonally concentrated runoff and leachate.

Required Action

The portion of agrichemicals applied in urban areas and their relative impact on water quality requires further study. We need to quantify the conditions that govern when and whether the prairies are a high risk vs. a low risk zone of contamination.

4.4 References

Brown, W.M., W. Cranshaw and C. Rasmussen-Dykes. 1989. Urban integrated pest management education and implementation: Implications for the future. *In*, Integrated Pest Management for Turfgrass and Ornamentals. USEPA, Wash., D.C., p. 57.

Burland, R. and G. Byrtus. 1992. Pesticide regulation and monitoring activities. Proceedings, Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 20-24.

Byrtus, Gary. 1996. Personal communication. Letter dated May 23, 1996. Alberta Environmental Protection, Edmonton, AB.

Campbell, C.A., R. De Jong, and R.P. Zentner. 1984. Effect of cropping, summerfallow and fertilizer nitrogen on nitrate-nitrogen lost by leaching on a Brown Chernozemic loam. Canadian J. Soil Sci. 64: 61-67.

Crop Protection Institute. 1995. 1994-1995 Annual Report. Crop Protection Inst. Etobicoke, Ontario. 22 pp.

Currie, R.S. and D.A. Williamson. 1995. An assessment of pesticide residues in surface waters of Manitoba, Canada. Water Quality Management Section, Manitoba Environment. Report #95-08.

Lindwall, C. Wayne. 1992. Future direction and key issues in surface and groundwater quality: Research perspective. Proc. Agricultural Impacts on Surface And Groundwater Quality. Lethbridge, AB. p. 88-91.

MacDonald, K. Bruce. 1996. Personal communication. Letter dated June 4, 1996. AAFC, Ontario Land Resource Unit, Greenhouse and Processing Crops Research Centre. Guelph, ON.

Manitoba Agriculture. 1991. Herbicides Used For Agricultural Weed Control In Western Canada: 1987-1989. Statistics Section, Economics Branch. Winnipeg, MB.

McConkey, B. 1996. Personal communication. Email dated March/96 and June/96. Research Branch, AAFC, Swift Current, SK.

McNaughton, D.C., and A.S. Crowe. 1995. Investigation of pesticides in groundwater at three irrigated sites near Outlook, Saskatchewan. Water Qual. Res. J. Canada. Vol. 30, No. 3, 399-427.

Nicholaichuk, W. 1967. Comparative watershed studies in southern Saskatchewan. Trans. ASAE 1:502-504.

Nicholaichuk, W. and R. Grover. 1989. Loss of fall-applied 2,4-D in spring runoff from a small agricultural watershed. J. Environ. Qual. 12:412-414.

Paterson, B.A. 1992. Preliminary assessment of water quality monitoring. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 65-72.

PFRA. 1995. Environmental Report Card (Draft) - An inter-country comparison of the environmental impact of red meat, grain and oilseed production systems. AAFC. 28 pp.

Reynolds, W.D., C.A. Campbell, C. Chang, C.M. Cho, J.H. Ewanek, R.G. Kachanoski, J.A. MacLeod, P.H. Milburn, R.R. Simard, G.R.B. Webster and B.J. Zebarth. 1995. Agrochemical entry into groundwater. *In* D.F. Acton and L.J. Gregorich (eds.). The Health of Our Soils, CLBRR, Research Branch, AAFC. p. 97-109.

5.0 Key Interpretation Concepts

Some key concepts are essential to understanding the probable effect of agrichemicals on soil and water systems. These have a bearing on our ability to interpret water quality results. They include the implications of chemical and biophysical interactions, sampling and analysis protocol, and the Canadian Water Quality Guidelines.

The possibility of a pesticide entering the soil or water and its probable effect, depends upon a range of pesticide and pesticide-use characteristics. [Yarish 1992]

5.1 Chemical & Biophysical Interactions

The interaction of agrichemicals as nonpoint-source contaminants with the soil, surface water and groundwater, will depend upon the physical and chemical characteristics of the contaminant and those of the medium they enter.

Pesticide Characteristics

The possibility of a pesticide (herbicide, insecticide, fungicide) entering the soil or water and its probable effect, depends upon a range of pesticide and pesticide-use characteristics [Yarish 1992] that include:

- ***Solubility**.* The potential to wash off crops and leach into the soil and water
- ***Adsorption**.* Tendency to attach to soil and other particles
- ***Persistence**.* Degradation time in terms of half-life
- ***Use pattern**.* Area treated, frequency of use, and timing of subsequent precipitation or irrigation
- ***Application rate**.* Amount of chemical applied per unit area
- ***Application method**.* e.g., spot spraying vs. irrigation application
- ***Toxicity.*** Relative toxic qualities

The Microenvironment

Farming practices can influence the transportation and transformation of pesticides and nutrients by the way they affect the soil microenvironment:

> ***Choice of tillage practice, cropping system, residue management, fertilizer practice and related decisions can result in "unique combinations of aeration, water availability, temperature distribution and availability of substrates"*** [Power 1994]

Environmental conditions that regulate chemical and biological reactions in the soil and water can greatly effect pesticide residence time (half-life):

It is possible that failure to collect representative field samples could be more of a limiting factor to accurate monitoring results than an ever-refined detection limit. [Taylor 1987, in Maynard et al. 1995]

- ***Soil conditions.*** The half-life of a pesticide can vary by a factor of three or more, depending on soil moisture, temperature, and other conditions [Yarish 1992]

- ***Groundwater features.*** Aquifer characteristics and nitrate levels (in conjunction with microbial balances) can greatly affect pesticide residence time [Priddle et al. 1988]

5.2 Sampling and Analysis Protocol

Given the small concentrations often being detected, sampling and analysis protocol can play a major role in whether a residue is found — and at what levels.

Estimates and Assumptions

Of necessity, many estimates and assumptions are made about relationships when conducting monitoring programs. Phosphorus (P) loading estimates are an example of this:

- ***Calculations.*** Phosphorus loadings are often based on calculations from isolated water samples and stream flow estimates

- ***Internal vs. external.*** Lake bottom sediments can release the equivalent of 1/2 to several times the annual supply of P from externally loaded sources [Mitchell 1985]

- ***Time frames.*** There is evidence of a relationship between changes to external loadings and internal cycling. But the relative time frames for doing so are uncertain [Mitchell and Trew 1992]

Because of the difficulties in directly sampling and monitoring P loadings, computer modelling techniques are often used. But this process is contingent upon many built-in assumptions. Until modelling methods have been locally verified to show they give results similar to those obtained from direct monitoring, a "healthy scepticism" of model predictions may well be justified [Daniel et al. 1994].

Field and Lab Technique

Detections can be greatly influenced by the field procedure used. A river study in Alberta was geared to select the best methods for sampling various aquatic media and to assess these media for use in routine pesticide monitoring projects [Anderson et al. 1992]. The study illustrated how detections varied with:

- ***Material sampled.*** River silt vs. fish livers

- ***Timing.*** Season and frequency of sampling

- ***Location.*** Point of sampling

- ***Technique.*** Method of collecting samples

Samples collected during high sediment runoff events, for example, may not be useful in providing accurate projections of loadings during average or low river flows. In Nebraska, pesticide findings varied considerably from one side of a braided river to the other, due to limited lateral mixing [Snow and Spalding 1988].

In the case of well water, significant fluctuations in herbicide content indicate that frequent sampling must occur to effectively monitor change [McKenna et al. 1988]. Chang and Entz [1996] have identified the need to sample shallow groundwater weekly during the growing season, otherwise peak nitrate levels will be missed. Given today's increasingly precise analytical capabilities:

> ***It is possible that failure to collect representative field samples could be more of a limiting factor to accurate monitoring results than an ever-refined detection limit*** [Taylor 1987, in Maynard et al. 1995]

Results can be greatly affected by the type of chemical tracer used and the method of chemical analysis. For example, leaching studies that use chloride as a tracer may be effective in identifying pathways, but can represent a worst case scenario because chloride does not transform or degrade in the soil as do nitrates and many pesticides. As well, results of pesticide analysis may be affected in several ways:

- ***Absorbed by plastics.*** Some pesticides may be absorbed by the PVC casing of sampling wells, or by the plastic bottles used to store samples [Hill 1995]

- ***Adsorbed to glassware.*** The researcher who rinses glassware may find the 2,4-D adsorbed there, which another researcher misses [Hill et al. 1994]

- ***Suspended sediments.*** Water samples de-canted from accompanying sediment may yield very different results than those with sediment in suspension [Hill et al. 1994]

- ***Metabolites missed.*** Parent compounds can degrade quickly into more stable metabolites which, if unknown to the researcher, may be missed

Context and Interpretation

The consistent, reliable evaluation of water quality data depends upon a realistic understanding of the overall context in which results are derived. In recent analytical procedures, there has been a marked increase towards multi-component determinations, at low concentrations and in complex sample matrices [Maynard et al. 1995]. Under these and other circumstances, it is critical to maintain a proper balance between the concepts of:

- ***Accuracy***. Agreement between measured and real values

- ***Bias***. Incorporating systematic error

- ***Precision***. Consistent agreement among independent measurements

More effective methods are needed to help explain the implications of water quality findings, including the context within which they are derived. What, for example, does it mean in terms of spatial variability and extent of degradation, when pesticide residue is encountered in 5 out of 20 wells in a monitoring network? And if residue is only detected near the surface of the groundwater, do these combined findings justify the inference that contamination may be occurring throughout the entire depth and lateral extent of the aquifer?

The consistent, reliable evaluation of water quality data depends upon a realistic understanding of the overall context in which results are derived. [Maynard et al. 1995]

5.3 Water Quality Guidelines

The *Canadian Water Quality Guidelines* (1987 and updates) are an attempt to define acceptable water quality for drinking, recreation, irrigation, and other uses [CCREM 1987]. Not everyone agrees with the guidelines. Some see them as overly stringent, others as far too liberal. It is important to note that water quality guidelines are just that — guidelines. As such, they are not legally enforceable standards unless so declared by the appropriate provincial or federal agency [Federal Provincial Working Group 1978].

Limitations

The Canadian Water Quality Guidelines represent a summary of existing research findings from Canada and elsewhere, considered applicable to Canadian conditions. Yet many of the limits defined within the Guidelines were not self-evident when the guidelines were established, and depended upon a subjective analysis of the data available:

The Introduction to the Guidelines points this out [CCREM 1987], indicating that:

The Canadian Water Quality Guidelines represent a middle ground between the extremes of Zero Tolerance and a lack of any standard. As such, they serve as a useful benchmark against which to assess relative water quality.

One of the obstacles in compiling the Canadian Water Quality Guidelines was "the difficulty of defining acceptable water quality for specific uses"

Gaps in the existing Guidelines indicate where data evaluations are urgently required for a number of *currently used* pesticides. These evaluations might provide information on aquatic life, wildlife and agricultural crops. According to the Guidelines, "for some parameters there were neither appropriate guidelines nor scientific data to modify existing guidelines for Canadian conditions." Even today, the analytical technology is often not available at the desired level of sensitivity for many of the older pesticides that are routinely used [Williamson et al. 1995].

Assessment Factors

The development of pesticide guidelines is based on a comprehensive 3-stage process [Caux 1992]:

- ***Information review.*** Gather and interpret scientific and technical information related to physical and chemical characteristics, mode of action, degradation, etc.
- ***Evaluation.*** Assess the quantity and quality of data available at the time of review; must meet minimum toxicological requirements for fish, invertebrates and plants
- ***Recommendation.*** Geared to protect the most sensitive species within a specific water use category

According to Byrtus [1996], over 500 active ingredients for pesticides are listed for sale in Canada. Approximately 100 of these are used on the prairies. Yet less than 50 pesticides have established guidelines nationally. Several high-use products in Alberta (individual sales greater than 10,000 kg of active ingredient/yr) have no Guideline [Cotton and Byrtus 1995].

One reason why more Guidelines have not been developed is because of the high cost of preparing them — about $40,000 each if contracted out. Another has been the difficulty of access to proprietary information and the lack of *published* research on environmental and toxicological aspects.

Applying Guidelines

Drinking water quality guidelines already incorporate safety factors of *at least* 10-100 times greater than specific test results would indicate. This aspect calls into question the relevance of exceeding a guideline by only a few parts per billion. In this regard, the Guidelines for Canadian *Drinking* Water Quality [Federal-Provincial Subcom-mittee 1987] clarify there is no hard and fast line between good and poor water quality, stating that:

<u>Continually</u> exceeding guidelines "may, in some instances, be capable of inducing deleterious effects on health. . ."

This effect will depend on the length of exposure to a substance and its relative toxicity.

Local application of The Canadian Water Quality Guidelines requires their modification to account for site-specific conditions. They should not be regarded as blanket values for national or local water quality [CCREM]. Appendix IV of the 1987 report goes on to say that:

The appropriate application of the Guidelines "requires an understanding of the chemical, physical and biological characteristics of the water body [affected] and an understanding of the behaviour of a substance once it is introduced into the aquatic environment"

Despite their inherent limitations and the difficulty of applying them:

The Canadian Water Quality Guidelines represent a middle ground between the extremes of Zero Tolerance and a lack of any standard. As such, they serve as a useful benchmark against which to assess relative water quality.

5.4 Summary

Some key concepts are fundamental to our understanding of the potential for agrichemicals and other nonpoint-source contaminants to affect surface and groundwater quality.

Chemical and Biophysical Interactions

The characteristics of individual agrichemicals and the effect of specific farming practices on the soil environment can significantly influence the bio-physical interactions that occur and their impact on water quality.

Sampling and Analysis Protocol

Water quality findings are often contingent upon a number of underlying assumptions. The sampling and analysis techniques used in the field and laboratory can greatly affect the results achieved.

Water Quality Guidelines

The Canadian Water Quality Guidelines are a generalized interpretation of water quality research. They are not hard and fast rules and *continually* exceeding them "may, in some instances, be capable of introducing deleterious effects on health." They are not accepted by everyone but serve as a useful benchmark against which to assess relative water quality.

Required Action

A better understanding of the chemical and biophysical interactions that regulate the availability and mobility of agrichemicals is needed. Further work is needed to clarify appropriate sampling and analysis protocol to allow for the effective, on-going comparison of multiple data sets. Both the scientific and lay public require a clearer understanding of the rationale behind the Canadian Water Quality Guidelines and other interpretations of relative water quality.

5.5 References

Anderson, Anne-Marie, Robert W. Crosley, F.P. Dieken, Dale S. Lucyk and Shaole Wu. 1992. Multi-media pesticide monitoring in the Battle River Basin. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 12-19.

Byrtus, Gary. 1996. Personal communication. Letter dated May 23, 1996. Alberta Environmental Protection, Edmonton, AB.

CCREM. 1987. Canadian Water Quality Guidelines. Canadian Council of Resource and Environment Ministers. Environment Canada, Ottawa.

Caux, P. Yves. 1992. Water quality guidelines for pesticides. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 4-11.

Chang, C. and T. Entz. 1996. Nitrate leaching losses under repeated cattle feedlot manure applications in southern Alberta. J. Environ. Qual. 25:145-153.

Cotton, M.M., and G. Byrtus. 1995. Pesticide Sales Trends In Alberta. Phase 2, Selection of Soil Landscape Units and Study Design Considerations . . . , Appendix A2. CAESA Water Quality Monitoring Committee. 66 pp.

Daniel, T.C., A.N. Sharpley, D.R. Edwards, R. Wedepohl and J.l. Lemunyon. 1994. Minimizing surface water eutrophication from agriculture by phosphorus management. J. Soil and Water Cons., Vol 49, No. 3, 30-38.

Federal-Provincial Subcommittee on Drinking Water. 1987. Minister of National Health and Welfare. No. H48-10/1987E. 20pp.

Federal-Provincial Working Group on Drinking Water. 1978. Guidelines for Canadian Drinking Water Quality. Minister of National Health and Welfare. H48-10/1978. 76 pp.

Hill, Bernie. 1995. Herbicides do leach in shallow Alberta groundwater. Proc. Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 172-176.

Hill, B.D, J.J. Miller, J. Rodvang and C. Chang. 1994. Sampling Protocol For Determining Herbicides in Ground-water in Southern Alberta. Farming For The Future, Project No. 92-0158. 57 pp.

Maynard, A.W., J.R. Downie and B.D. Mawdsley. 1995. Chemical analysis of environmental samples: Ensuring valid data. Proc. International Assoc. of Hydrogeologists 26. Edmonton, AB.

McKenna, D.P., S.F.J. Chou, R.A. Griffin, J. Valkenburg, L.L. Spencer and J.L. Gilkeson. 1988. Assessment of the occurrence of agricultural chemicals in groundwater in a part of Mason County, Illinois. Proc. Agricultural Impacts on Groundwater. National Water Well Assoc., Dublin, Ohio. p. 389-406.

Mitchell, P. 1985. Preservation of Water Quality in Lake Wabamun. Water Quality Control Branch, Alberta Environment, Edmonton, AB.

Mitchell, P. and D. Trew. 1992. Agricultural runoff and lake water quality. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 73-79.

Power, J.F. 1994. Understanding the nutrient cycling process. J. Soil Water Cons., Vol 49, No. 3, 16-23.

Priddle, M.W., R.E. Jackson and A.S. Crowe. 1988. Aldicarb and nitrogen residues in a sandstone aquifer. Proc. Agricultural Impacts on Ground-water. National Water Well Assoc., Dublin, OH. p. 191-210.

Snow, D.D. and R.F. Spalding. 1988. Soluble pesticide levels in the Platte River Basin of Nebraska. Proc. Agricultural Impacts on Groundwater. National Water Well Association, Dublin, OH. p. 211-233.

Taylor, J.K. 1987. Quality Assurance of Chemical Measurements. CRC Press Inc., Boca Raton, FL.

Williamson, D., A. Beck and S. Gurney. 1995. Personal communication. Letter dated December 18, 1995. Manitoba Environment, Winnipeg, MB.

Yarish, Walter. 1992. Pesticide characteristics and potential impact on water quality. Proceedings, Agricultural Impacts on Surface Water Quality. Lethbridge. AB. p. 1-3.

6.0 Prairie Water Quality

The effect of nonpoint agricultural practices on prairie water quality has been assessed in terms of both a recent general overview of prairie conditions, and a more detailed analysis of specific prairie findings.

6.1 A Recent Prairie Overview

A recent Green Plan symposium in Red Deer, Alberta (CAESA 1995) provides a timely update of nonpoint-source quality issues and projects across Western Canada. Although presentations focused mainly on Green Plan activities, findings may represent conditions generally.

Minimal Evidence of Contamination

During the oral and poster presentations, a number of examples were given of possible water quality contamination caused by agricultural practices. These included nitrate and pesticide detections [Bennett et al. 1995, Chang and Travis 1995, Hill et al. 1995, Rodvang et al. 1995]. Yet, most findings were based on site-specific results or limited sampling. No evidence was presented of widespread, long-term agricultural pollution in excess of Canadian Water Quality Guidelines. From these presentations, it is unclear as to how extensive, severe or transient agricultural water quality problems are.

Limited Testing Is Underway

A wide variety of projects on the prairies are currently underway to measure the impact of agriculture on water quality [Abrahamson 1995, Paterson 1995, Vermette 1995]. Many of these have been established to help develop a data base against which to judge future water quality changes. Yet, due to costs and logistics, few of these are either long term in nature or will be able to cover extensive areas of repeated, detailed sampling.

Emphasis On "Hot Spot" Evaluations

Efforts are underway to focus on existing and potential "hot spots" as early indicators of developing problems. Locations such as irrigation districts and lands adjacent to intensive livestock operations (ILOs) are likely to experience difficulties first. This is because of the intensity of the agriculture practised on them and/or the nature of the soils and landscapes they represent. In support of the need to look at "hot spots", Hill et al. [1995] contend that people "need to get over the shock of low levels of herbicides being detected . . ." He says that instead of worrying about trace amounts, our attention ought to be focused on identifying those worst case scenarios where herbicide concentrations may occasionally approach limits in Water Quality Guidelines.

Instead of worrying about trace amounts, our attention ought to be focused on identifying those worst case scenarios where herbicide concentrations may occasionally approach limits in Water Quality Guidelines. [Hill et al. 1995]

6.2 Specific Prairie Findings

The specific prairie findings reported hereafter are based largely on a review of available summary documents and expert opinion. The sources cited reflect a wide range of profession and discipline. Where conclusions are drawn, these are based on the assumption that Water Quality Guidelines are a legitimate basis of evaluation. Results focus on the general effects on water quality of sediment, pesticides, nitrate, phosphate and other potential risks.

Where conclusions are drawn, these are based on the assumption that Water Quality Guidelines are a legitimate basis of evaluation.

6.3 References

Abrahamson, B. 1995. Saskatchewan CSAGPA Program. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 8-17.

Bennett, D.R., B.M. Olson and S.J. Rodvang. 1995. Impacts of manure applications on shallow groundwater in irrigated and dryland areas of Alberta. Proceedings, Agricultural Impacts on Water Quality. CAESA. Red Deer, AB. p. 153-167.

Chang, C. and G.R. Travis. 1995. Repeated heavy manuring affects crops and soil, water and atmospheric quality. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 194.

Hill, Bernie, C. Chang, J.J. Miller, J. Rodvang and N. Harker. 1995. Herbicides do leach in shallow Alberta groundwater. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 172-176.

Paterson, B.A. 1995. Alberta CAESA program. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 3-7.

Rodvang, S.J., R. Schmidt-Bellach and L.I. Wassenaar. 1995. Nitrates in ground-water below irrigated fields in southern Alberta. Abstract. Proc. Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 187.

Vermette, A. 1995. Manitoba CMAAS program. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 18-23.

7.0 Sediment

Sediment can itself be a water quality problem. It can also be a transport mechanism for *naturally* occurring elements and the fertilizer and pesticide residues that might move into surface waters. Sediment can come from a variety of wind or water-eroded sources. In the United States, estimates indicate that agriculture is the primary source of nonpoint-source pollution, with sediment loading being "the most pervasive nonpoint pollutant" [Gomez 1995]. Canadian studies warn that wind and water erosion are a serious threat to sustainable agriculture [PFRA 1983].

In the mainstream rivers of the Saskatchewan River Basin, the "proportion of sediment from farmland erosion seems to be relatively insignificant." [Environment Canada 1990]

7.1 Natural Prairie Loadings

As expected, sediment loads in Western Canada tend to increase near the downstream end of *large* streams such as the Red Deer, and North and South Saskatchewan rivers. Yet, an in-depth review of sediment loading studies on behalf of Environment Canada found that these levels are apparently *not* primarily from agricultural land and generally reflect [Environment Canada 1990]:

- ***In-route erosion*** of channel banks and the gullying of valley slopes, wherein the "proportion of sediment from farmland erosion seems to be relatively insignificant"
- ***Sedimentation levels*** that are quite low most of the time
- ***Turbidity levels*** below those generally causing problems for fish, recreation, and municipal or industrial needs

Disparity In Rates/Locations

There is an apparent disparity between higher projected on-farm soil erosion rates and lower in-stream sediment yields [Environment Canada 1990]:

- ***Over estimation.*** In Saskatchewan, using cesium to trace erosion losses in hummocky soils, de Jong et al. [1983] concluded that net field erosion losses may be lower than projected [de Jong et al. 1983]
- ***Upstream accumulation.*** Perhaps eroded sediments are accumulating in watersheds upstream of sampling stations [Environment Canada 1990]

The spatial and temporal differences between apparent sediment delivery points and yield monitoring points make it difficult to assess the impact of soil erosion on water quality [Gomez 1995].

It is also possible that, where agricultural sediments occur to any extent, these may be coming from a very small portion of total farmlands:

Soil erosion from farmlands may pose a water quality problem; more so because of the nature of the surface soils being eroded than due to their volume. [Environment Canada 1990]

Work in the United States suggests that 53% of agricultural sediments come from 11% of total non-irrigated cropland [Gomez 1995]

Surface Soil Contribution

Soil erosion from farmlands may pose a water quality problem; more so because of the nature of the surface soils being eroded than due to their volume [Environment Canada 1990]:

- ***Nutrients and residue.*** Erosion of farmland tends to selectively remove surface soils which are often *naturally* fertile and easily contaminated from a variety of sources
- ***Relative contamination.*** Fine grained sediments and organics from these soils can disproportionately affect surface waters compared to higher silt loads from in-stream and gully erosion
- ***Small watersheds.*** Despite the low silting rates anticipated in small watersheds, a higher percentage of sediment there may come from surface soils

7.2 Small Basin Studies

In the small watercourses of the Saskatchewan River Basin, there is little information to indicate that sedimentation is a serious problem. However, this could be because the historic data set for sediment loading is insufficient [Environment Canada 1990].

Recently, a small watershed study in Manitoba looked at sediment loadings in Cooks Creek, within a relatively flat, intensive agriculture area immediately east of Winnipeg [Hughes et al. 1994]:

Sediment levels did not appear to be sufficient to impair water quality for most uses, including aquatic life

Researchers point out, though, that aquatic organisms will still suffer to some degree from the impacts of siltation that is at least partially induced by agricultural practices [Williamson et al. 1996].

Manitoba Environment conducted studies within the Turtle river watershed, which empties into Dauphin Lake in west central Manitoba [Williamson et al. 1992]:

- ***Uncertain source.*** It was unclear how much of the sediment loading was due to agricultural land use versus that coming from natural erosion within Riding Mountain National Park
- ***In-stream deposits.*** Much of the in-stream sediment was deposited before reaching downstream locations — though subsequent high flows may re-suspend such deposits

Ontario Comparison

Sediment loadings from the small drainage basins of Ontario are much lower than those of the United States [Wall et al. 1982, in Environment Canada 1990]. Compared to the more intensive agri cultural areas of southern Ontario, prairie loadings are lower still. Even so, Ontario findings related to sediment loadings indicate [Coote 1980, in Environment Canada 1990]:

- ***Minimal heavy metals.*** Contributions of heavy metals, often associated with fertilizers, were negligible
- ***Fish.*** Although pesticides periodically showed up in stream water, no deleterious effects on fish were found
- ***Phosphorus loading.*** Agricultural land was deemed to account for 60% of the diffuse phosphorus load, most bound to sediment

7.3 Prairie Pothole Topography

One landscape aspect that differentiates much of the Prairies from other regions, and may temper the effect of agriculture on sediment loading, is its pothole topography. For much of the landscape:

- ***Drainage is internal***, with sediment moving relatively short distances to surface sloughs or other areas [Anderson and Knapik 1984, in Environment Canada 1990; MacDonald 1996]
- ***As little as 5%*** of prairie agricultural lands may drain into water courses [Acton 1996]
- ***Slough drainage*** and pothole consolidation can significantly increase the amount of water draining from lands [PFRA 1984]

We need to study the impact of the prairie pothole topography on:

- ***Sediment transport*** from upper field slopes to water courses [Acton 1996]
- ***Water quality*** within potholes and its impact on aquatic life and dependent species such as nesting ducks [Sheehan et al. 1987]

Acton [1996] questions whether we understand the net effect of potholes on prairie water quality, noting that:

> ***Prairie potholes may be acting much like stormwater retention ponds in cities, filtering out silt and other materials before they have a chance to reach rivers and streams***

7.4 Increased Runoff

The volume and rate of runoff to streams can increase as native lands are cleared and cultivated for agricultural purposes [Maidmont 1993]:

- ***Extensive surface drainage***, such as within irrigation districts or many agricultural lands of Manitoba, further enhances runoff
- ***Native lands*** usually have lower, slower runoff due to a higher capacity for infiltration and internal wetland storage

Increased runoff from agricultural lands can increase the magnitude of peaks in stream hydrographs. Similarly increased drainage from urban areas can also affect river dynamics [Le clerc and Schaake 1973].

Increased flows can provide more instream, spawning habitat for fish [Environment Canada 1990]. But the duration of peak flows from agricultural lands will be much shorter than those from native areas. Hence, the benefits of higher flows may be short-lived.

Secondary Siltation

Despite the fact that runoff may be low in silt, higher stream flows will cause increased channel scouring. This can result in a secondary increase in sediment loading and greater downstream deposition of silt [Fisheries and Oceans 1992].

Such effects can have a localized, negative impact on aquatic life like fish:

- ***Spawning beds.*** Adverse effects to the walleye spawning beds of Lake Dauphin in Manitoba [Gaboury 1985]
- ***Fish health.*** Impacts such as blocked migration, disorientation, gill abrasion, loss of habitat [Fisheries and Oceans 1992]
- ***Aquatic environment.*** Damage to the aquatic environment in general

Some people consider sediment to be the number one habitat issue for fish [McGarry 1997].

Prairie potholes may be acting much like storm-water retention ponds in cities, filtering out silt and other materials before they have a chance to reach rivers and streams.

Channelization

River straightening and the construction of specific drains might be viewed more as point-source than nonpoint sources of silting. Still:

- ***Drainage requirement.*** A perceived need for downstream channel straightening may be due to increased flows from wide-spread, upstream drainage activity

- ***Net effect.*** On an alluvial fan within Wilson Creek, Manitoba, head-cutting due to drainage construction caused extensive re-suspension and downstream deposition of alluvial silts [Wilson Creek . . .1983]

7.5 Cattle Effect

Because cattle are so visible, there may be a tendency to over-estimate the impact of their activities on sediment loading. Compared to natural sources, the relative contribution of grazing cattle to sediment loading could be minimal. [Sauchyn and Lemmen 1996]

Concentrated grazing and watering sites for cattle can have a negative effect on riparian and in-stream habitat [Adams and Fitch 1995] and sediment and nutrient loading [Sweeten 1984 in Buchanan 1992]. However, this effect does not automatically apply to range cattle in general:

- ***No difference.*** The effects of range cattle on a watershed are often indistinguishable from the effects of wildlife [Dixon 1983a in Buchanan 1992]

- ***Short distances.*** Effects from unconfined livestock are often discernable for only short distances downstream [Dixon 1983b in Buchanan 1992]

The sight of cattle trampling local stream banks or fouling the water in mid-stream is a highly visual effect. Nevertheless, the relative contribution that cattle make to total silt loading is often not well documented and requires more study [Jensen 1997].

Because cattle are so visible, there may be a tendency to over-estimate the impact of their activities on sediment loading. Compared to natural sources, the relative contribution of grazing cattle to sediment loading could be minimal. A study on Battle Creek in the Cypress Hills area of Saskatchewan and Alberta found [Sauchyn and Lemmen 1996]:

- ***Geologic sources.*** Runoff from Police Point landslide resulted in "large volumes" (up to 438 ppm) of sediment in creek flow

- ***Minimal cattle effect***. Above the slide (where range cattle were at large) sediment levels were only 2 ppm

Proportional loadings likely occur from lesser cutbanks and slumps along other waterways.

7.6 Summary

Sediment can itself be a water quality problem or a transport mechanism for naturally occurring elements and the fertilizer and pesticide residues that might move into surface waters. Yet in major rivers of the Canadian prairies, the proportion of sediment loading from farmland erosion seems to be "relatively insignificant."

Loading Estimates

There is a disparity between projected on-farm soil erosion rates and in-stream sediment yields on the prairies. This may be because projected soil erosion rates are too high, or perhaps agricultural sediment is being trapped in fields or stored in streams before reaching sampling locations.

Pothole Topography and Runoff

The pothole topography of much of the prairies may temper whether eroded sediment reaches streams and rivers. The clearing and drainage of agricultural lands can increase surface runoff, thereby indirectly accelerating in-stream erosion and related silting problems.

Cattle

Concentrated grazing and watering sites can have a negative impact on riparian habitat and local sediment loading. In the watershed at large, however, the effect of range cattle are often indistinguishable from those of wildlife. The relative contribution of range cattle to silt loading may be minimal and remains largely undocumented.

Required Action

An increasing portion of investigative resources ought to be directed towards small-scale watershed evaluation. Further work is needed to clarify whether projected agricultural loadings are taking place. We need to better understand the place of pothole topography in filtering surface waters. The effect of increased agricultural runoff on in-stream erosion and secondary siltation can have a significant, negative impact on aquatic life and must not be ignored. Despite their high visibility, the relative contribution of range cattle to silt loading is uncertain and requires clarification.

7.7 References

Acton, Don. 1996. Personal communication. CSALE, University of Saskatchewan, Saskatoon, SK.

Adams, Barry and Lorne Fitch. 1995. Caring For The Green Zone - Riparian Areas and Grazing Management. CAESA, and Dept. of Fisheries and Oceans, and Environment Canada. Pub. No. I-581. 37 pp.

Anderson, M. and L. Knapik. 1984. Agricultural Land Degradation in Western Canada: A Physical and Economic Overview. For, Regional Development Branch, Agriculture Canada.

Buchanan, Bob. 1992. Agricultural impacts on water quality for domestic purpose. Proceedings, Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 50-58.

Coote, D.R. 1980. Agriculture and Water Quality in the Canadian Great Lakes Basin. Canada Agriculture. 25(1), p. 3-6.

de Jong, E., C.B.M. Begg and R.G. Kachonowski. 1983. Estimates of soil erosion and deposition from some Saskatchewan soils. Canadian Journal of Soil Science 63: 607-617.

Dixon, J.E. 1983a. Controlling water pollution from cattle grazing and pasture feeding operations. *In* Profit Potential of Environmental Protection Practices of Cattlemen. National Cattlemen's Assoc., Englewood, CO. p. 107.

Dixon, J.E. 1983b. Comparison of runoff water quality from cattle feeding on winter pastures. Trans. ASAE, 26(4):1146-1149.

Environment Canada. 1990. Off-Farm Sediment Impacts in the Saskatchewan River Basin. M.A. Carson & Associates, Victoria B.C., *for* Inland Waters Directorate, Saskatchewan District. 87 pp.

Fisheries And Oceans. 1992. Troubled Waters: Threats To Fish Habitat In The Prairie Provinces. Department of Fisheries and Oceans, Central and Arctic Region. Winnipeg, MB. 15 pp.

Gaboury, M.N. 1985. A Fisheries Survey of Valley River, Manitoba, With Particular Reference To Walleye . . . Reproductive Success. Manitoba Dept. Natural Resources, Fisheries Br. MS Report No. 85-02. 149 pp.

Gomez, Basil. 1995. Assessing the impact of the 1985 farm bill on sediment-related nonpoint source pollution. J. Soil Water Cons. 50(4) 374-377.

Hughes, C.E., D.A. Williamson and B.M. Lussier. 1994. Water Quality Assessment of Cooks Creek, Manitoba. Cooks Creek Conserv. District No. 5, and Manitoba Environment Rpt. No. 94-09. 46 pp.

Jensen, Ron. 1997. Personal Communication. Regional Fisheries Biologist, Saskatchewan Environment and Resource Mgt. (SERM). Swift Current, SK.

Le clerc, Guy and John Jr. Schaake. 1973. Methodology for Assessing the Potential Impact of Urban Development on Urban Runoff . . . Massachusetts Institute of Technology. Cambridge, MS.

MacDonald, K. Bruce. 1996. Personal communication. Letter dated June 4, 1996. Ontario Land Resource Unit, Crops Research Centre. Guelph, ON.

Maidmont, David R. (ed). 1993. Handbook of Hydrology. McGraw Hill Inc. p. 13.38-13.41.

McGarry, Pat. 1997. Personal communication. E-mail, Jan. 1997. Biologist, PFRA Regional. Winnipeg, MB.

PFRA. 1983. Land Degradation and Soil Conservation Issues on the Canadian Prairies. Soil and Water Conservation Branch, PFRA. Regina, SK.

PFRA. 1984. Evaluation of the Effects of Drainage Developments in the Rural Municipalities of Churchbridge and Langenburg. Hydrology Rpt. No. 101, Engineering Service, PFRA. Regina, SK.

Sauchyn, D.J. and D.S. Lemmen. 1996. Impacts of landsliding in the western Cypress Hills, Saskatchewan and Alberta. Geological Survey of Canada. Current Research, Vol. 1996-b: 7-14.

Sheehan, P.J., A. Baril, P. Mineau, D.K. Smith, A. Harfenist, and W.K. Marshall. 1987. The Impact of Pesticides on the Ecology of Prairie Nesting Ducks. Canadian Wildlife Service, Environment Canada. Technical Report Series No. 19.

Sweeten, J.M. 1984. Cattle feedlot waste management practices for water and air pollution control. USEPA. Texas Agricultural Extension Service.

Wall, G.J., Dickinson, W.T. and L.J.P. Van Vliet. 1982. Agriculture and Water Quality in the Canadian Great Lakes Basin. II. Fluvial Sediments. J. Envt. Qual. 11(3): 482-486.

Williamson, D.A., A. Beck and S. Gurney. 1996. Personal communication. Fax dated June 7, 1996. Manitoba Environment, Winnipeg, MB.

Williamson, D.A., M.P. Boychuk and M.T. Ledoux. 1992. Water Quality Assessment of the Turtle River and Two Tributaries, Manitoba, Canada. Turtle River Conserv. Dist. # 2, and Manitoba Environment Rpt. No. 92-05. 52 pp.

Wilson Creek Headwater Control Committee. 1983. Summary Report, Wilson Creek Experimental Watershed Study. Unpublished Report. Winnipeg, MB. 18 pp.

8.0 Pesticides

Water quality monitoring can include a variety of pesticide (herbicide, insecticide, fungicide) analyses. Results may be reported as generalized "pesticide" findings, or in more specific terms. Much of the research to date has been fairly short-term. The levels of detection, their frequency and geographic distribution are highly variable.

8.1 North American Context

A literature review of 1300 scientific abstracts in the United States [Fairchild 1987] indicates that:

- ***Regional detection*** of pesticides has occurred to "some degree" in 25% of individual States
- ***Localized detection*** of "some nature" has occurred in 50% of the States

However, the *nature* of individual investigations and the *degree* of these "detections" is inconsistent and of unclear meaning [Wayland 1993]. Interpretation depends very much on whether one takes a Zero Tolerance position that no level of detection is acceptable, or accepts a Water Quality Guidelines approach.

8.2 Prairie Rivers & Streams

The Saskatchewan River Basin drains much of the prairies. Pesticides in its major rivers have generally been at low levels [Environment Canada 1990]. Levels in fish are usually higher than in sediments, but are still regarded as safe.

Few Pesticides/Low Concentrations

A study summarizing findings on the large rivers of Alberta over the past 20 years [Anderson et al. 1995], reports that:

- ***Relatively few pesticides*** were detected
- ***Low concentrations*** were generally found
- ***Guidelines were exceeded*** for aquatic life and irrigation, in only a few cases

- ***Relatively few pesticides*** *were detected*
- ***Low concentrations*** *were generally found*
- ***Guidelines were exceeded*** *in only a few cases*

However, this low frequency of detection may only be a reflection of the pesticides sampled and the procedures used. According to Alberta Environment Protection [Anderson et al. 1995], such low detections may point to a need to upgrade pesticide monitoring techniques.

A multi-media sampling of the Battle River found 17 of 38 residues tested for. Most were well below sensitive-use guidelines [Anderson et al. 1992].

As small scale water bodies in the midst of agriculture, farm dugouts may represent a "worst case" scenario for potential pesticide contamination.

Currie and Williamson [1995] conducted an in-depth assessment of pesticide residues in the surface waters of Manitoba. They analyzed results from approximately 100 sites and 3,000 samples, collected over a period of 25 years:

- ***Similar prairie detections.*** Frequencies and concentrations were similar to those observed elsewhere on the prairies
- ***Most guidelines*** (drinking water, etc.) were exceeded less than 1% of the time, by only 3-4 of 65 pesticides tested
- ***Irrigation guidelines*** were exceeded more frequently by up to 3 pesticides — as much as 20% of the time for the highest (dicamba)
- ***Pesticide concentrations*** have generally remained the same or declined over time

Watershed Studies

A small watershed in Manitoba (Cooks Creek) was studied during a 3-yr period [Hughes et al. 1994]. There, 7 of 28 target pesticides were detected. None exceeded Manitoba Water Quality Objectives.

A watershed study of pesticide loadings is ongoing in the South Tobacco Creek drainage basin of Manitoba [Rawn et al. ca.1995a]. The first 2 years of data indicate that:

- ***Below guidelines.*** Herbicide concentrations are usually "well below guideline limits. . . for the protection of aquatic organisms"
- ***European standards.*** Concentrations are generally below current, more stringent European standards
- ***Atmospheric loadings.*** A significant portion of pesticide loadings is atmospheric, sometimes coming from the United States

Another 3-yr study in southern Manitoba [Rawn et al. ca.1995b], has sampled temporal trends for 23 pesticides within the Red River and 8 of its tributaries (including South Tobacco Creek). Preliminary analysis indicates that pesticide concentrations are generally well below water quality guidelines for Canadian and European standards [Muir and Rawn 1996].

8.3 Farm Dugouts

As small scale water bodies in the midst of agriculture, farm dugouts may represent a "worst case" scenario for potential pesticide contamination.

A report by Grover and Cessna [1996] reviews the work of a number of prairie studies on dugout water quality. The primary focus for most of these studies was simply to determine whether pesticides could be detected (within quantifiable limits). A secondary consideration was whether detections exceeded guidelines.

Short-term/Wide-spread Studies

The work Grover summarizes represents a range of fairly short-term, though in some cases wide spread activities. For example, a 2-yr project near Regina, Saskatchewan sampled one farm dugout seasonally for 5 herbicides and 5 insecticides [Waite et al. 1992]:

- ***Herbicide detections***. All 5 herbicides were at *quantifiable* levels (>0.05 ppb)
- ***No insecticides*** were found (>1.0 ppb)

In another 2-yr seasonal study, Grover et al. [1996] monitored 5-6 farm dugouts for 7 commonly used herbicides in each of 4 regions of Saskatchewan. Samples were collected in the spring before spraying, in summer after spraying and fall before freeze-up:

- ***2,4-D was frequently found*** in 75-89% of samples, being the most commonly used herbicide on the prairies over the past 50 years

- ***Other detections were much lower***. The frequency of detection for other herbicides was generally much lower, varying considerably with the herbicide

Off-season Sampling

Other studies summarized by Grover represent off-season findings to determine relative background levels shortly after and well after harvest. Single samples were taken in August from 161 dugouts in Manitoba [Jones et al. 1996]. Of 56 pesticides tested, 7 were detected.

During mid winter, MacDonald and McLeod [1992] took single samples from 30 surface water bodies in Saskatchewan. Of 30 pesticides scanned, 2 herbicides and 1 fungicide were detected at quantifiable levels (> 0.02 ppb) in some samples.

Overall Findings

Grover and Cessna [1996] concluded that even after long-term pesticide use on the prairies:

- ***Low median levels.*** The median residue level in farm dugouts continues to be at or near quantifiable detection limits

- ***Below guidelines.*** Levels are generally well below Canadian drinking water quality guidelines and "near or below the most stringent [European] guidelines. . ."

- ***Short-term maximums.*** Maximum residues are usually seasonal and short lived

8.4 Groundwater

Prairie Conditions

Pesticide detections in groundwater supplies on the prairies and elsewhere are generally of limited extent and well below water quality guidelines.

Sampling of shallow groundwater wells in Alberta found little evidence of pesticide contamination:

- ***Farmstead wells and dugouts.*** A one-time sampling in three areas of Alberta found no detectable levels in wells tested for 7 herbicides [Fitzgerald 1995]

- ***Farm wells.*** A 3-yr survey of 198 farm wells for up to 10 pesticides found residue in 4 instances [Shaw 1991, in Burland and Byrtus 1992]

- ***75 container disposal sites.*** Monitoring shows limited evidence of low level groundwater contamination [Burland and Byrtus 1992]

Eastern Canada

Because Ontario is more intensively farmed than the prairies, groundwater findings there may serve as an indicator of relative hazard in the West. Some 1300 domestic wells and 140 adjacent field wells were sampled across the province, during one winter and again during the next summer [Agriculture Canada 1993]:

- ***Common soil types.*** Most wells were in areas of intensive agriculture, representing common soil types and land uses

- ***Limited detections.*** From 8-12% of domestic wells and 4-6% of field wells had detectible levels of herbicide

- ***Rarely exceeded guidelines.*** 2 of 1300 domestic wells and 1 of 141 field wells exceeded drinking water guidelines.

In **Atlantic Canada**, Milburn et al. [1995] evaluated the impact of 4 pesticides on groundwater quality. Field scale tile drainage systems, farm wells and field-edge piezometers were variously monitored in

Pesticide detections in groundwater supplies on the prairies are generally of limited extent and well below water quality guidelines.

association with fields growing potatoes and corn:

Pesticides were often detected in drainage waters and have been found in wells. For the pesticides tested, mean annual concentrations were less than the current guidelines for drinking water. However, one herbicide had short-term and mean annual groundwater concentrations in the same order of magnitude as guidelines for fresh water aquatic life and irrigation.

U.S. Groundwater Examples

In the United States, pesticides are being detected in a minor portion of groundwater samples, generally at trace levels. Specific US examples help place Canadian findings within a North American context, given the wide range of soil, landscape and climatic conditions they represent:

Irrigated lands represent zones of intensive agriculture and water movement, where pesticides might have a higher probability of concentrating first.

- ***Montana***. A 1-year groundwater survey of 4 counties found very low levels of herbicides in one county [USEPA 1985, in Fairchild 1987]
- ***Iowa***. Of 355 wells sampled, at least one pesticide was found in 20% of wells [Detroy et al. 1988]
- ***Illinois***. A 3-year test for commonly used herbicides found residue in 1 well. Another study on sandy soil found trace levels of several herbicides [McKenna et al. 1988]
- ***Oregon***. Testing of public and private wells in areas deemed vulnerable to contamination found relatively few pesticides, generally at trace levels. 5 of 216 wells exceeded water quality guidelines [Pettit 1988]
- ***Virginia***. A one-time winter sampling of 359 private wells found pesticides in 14% of shallow and 7% of deep wells. About 3% of wells were above drinking guidelines [Bruggeman et al. 1995]

8.5 Irrigated Lands

Surface Waters

Irrigated lands represent zones of intensive agriculture and water movement, where pesticides might have a higher probability of concentrating first. Contamination of downstream waters on the prairies is occurring to a limited extent [Cessna 1996]. This may be influenced by the type of pesticide applied and the management practices used:

- ***Canal weed control.*** In southern Alberta, canals sprayed for weed control were monitored during 2 irrigation seasons. **After 24 hours, no chemical residue was detected** [Burland et al. 1984, in Burland and Byrtus 1992]
- ***Grasshopper control.*** Testing on an irrigation canal and several prairie streams and wetlands was conducted after intensive spraying for grasshoppers. **Detected residues were transitory and well below drinking standards** [Burland and Byrtus 1992]
- ***Spill drains.*** Irrigation return-flow drains were monitored on two separate occasions (10 years apart) to evaluate the effect of spraying for weed control on residue. **No pesticides were found** [Burland 1991, in Burland and Byrtus 1992]

In a 1-yr study, delivery and return flow waters were monitored on 3 sampling dates within 3 irrigation districts [Greenlee et al. 1993]. Very low levels for 6 of 26 pesticides tested were found. On 1 occasion, 1 herbicide (diclofop-methyl) exceeded irrigation guidelines.

Groundwaters

Herbicides have been found under irrigated soils, usually at low concentrations. In Alberta [Rodvang and Riddell 1992], seasonally applied herbicides were located in shallow groundwater under wheel move and pivot sprinkler irrigation. Levels were generally well below drinking water standards. A 1-yr study of irrigated, manured plots, found very few phenoxy herbicides in groundwater or soils [Miller et al. 1992].

Residues in surface and groundwaters may vary considerably with site condition (e.g., irrigation length-of-run) and the herbicide used. In a 1-year study using hexazinone on short, gravity-irrigated runs [Miller et al. 1995]:

- ***50% of surface runoff***. Hexazinone was detected in 50% of surface runoff samples
- ***<30% of groundwater***. Less than 1/3 of local groundwater samples contained residue
- ***Below guidelines.*** Concentrations were generally well below guidelines

In a different 1-year study using phenoxy herbicides on long, gravity-irrigated runs [Miller et al. 1995]:

- ***No residue in runoff***. No herbicides were found in surface runoff
- ***50% of groundwater.*** Residue occurred in at least 1/2 of local groundwater samples
- ***Below guidelines.*** Concentrations were generally well below guidelines

In southern Manitoba, the Assiniboine Delta Aquifer is pumped to irrigate about 6,000 ha of mostly potatoes. Single water samples were collected from irrigation systems representing 26 irrigation wells [Buth et al. 1992]. Waters were tested for 16 pesticides during late August/early September, 1991. One sample contained a single pesticide residue, deemed likely an artifact of chemigation practices earlier in the season.

In the sandy textured, central Platte region of **Nebraska**, atrazine was found in all 14 irrigation wells sampled beneath irrigated land. Water quality guidelines were not exceeded in any of the wells [Spalding et al. 1980]. In **Arkansas**, 56 irrigation wells were sampled for several pesticides at the beginning and peak of the irrigation season. One well gave a positive detection [Cavalier et al. 1988].

8.6 Tillage, Organic Matter

Tillage and crop rotation may have an effect on herbicide movement. A 1-yr study on 2 long-term (24-yr) dryland soil rotations in Alberta found [Miller et al. 1992]:

- ***Few soil detections.*** Tillage/rotation plots tested for 9 pesticides had less than 12% of total soil samples containing any residue
- ***Limited leaching.*** One or two herbicides were leached to the maximum sample depth of 80 cm
- ***Minimum till.*** None of the herbicides commonly used on the minimum tillage soils were detected, but residues occurred under conventional tillage [Lindwall 1996]

In a 3-yr fall irrigation study at the Saskatchewan Irrigation Development Centre (SIDC), only non-incorporated herbicides were leached into lysimeters and tile drains [Elliott et al. 1995].

Despite high soil organic matter content (9%), Hill and Harker [1996] observed that 5 of 6 herbicides will leach through a sandy loam in central Alberta:

- ***Heavy rainfall*** immediately following herbicide application can cause rapid leaching (within 7-15 days) to a shallow water table (1.5-2.5 m deep)
- ***Slower leaching.*** Without a heavy rainfall, leaching might take up to a year to occur
- ***Below guidelines.*** All herbicides were well below Canadian Drinking Water Guidelines

8.7 Summary

Pesticides are found to some extent in surface and groundwaters across the Canadian prairies. These waters contain relatively few pesticides, with most detections being well below water quality guidelines. Results are largely from isolated studies and are of unclear meaning.

Hazard areas

Intensive agricultural areas, including irrigated lands, have the potential to develop problems first. Some herbicides have been found in groundwater under agricultural lands on the prairies. However, even beneath the most intensively farmed lands of southern Ontario, there is limited evidence of pesticides in groundwater.

Governing factors

The extent and concentration of pesticides in surface and groundwaters might be affected by factors like soil texture, irrigation method, the type of pesticide used, tillage practice, and organic matter. Field condition at the time of application, prior to and during testing, might also be a factor.

Required Action

A continued focus on intensive agricultural lands is required to isolate the factors governing pesticide movement. We need to clarify the relevance of current pesticide detections on the prairies. How significant are the trace detections of chemical residues, their approach or exceedence of Water Quality Guidelines? When detections occur, how representative are they of long term levels and trends?

8.8 References

Agriculture Canada. 1993. Ontario Farm Groundwater Quality Survey. ISBN 0-662-20879-X. 162 pp.

Anderson, A.M., G. Byrtus, M. Cotton, D. Maurice and M. Tautchin. 1995. Evaluation of pesticide monitoring for surface waters in Alberta. Proc. Agricultural Impacts On Water Quality. Red Deer, AB. p. 62-79.

Anderson, Anne-Marie, Robert W. Crosley, F.P. Dieken, Dale S. Lucyk and Shaole Wu. 1992. Multi-media pesticide monitoring in the Battle River Basin. Proceedings, Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 12-19.

Bruggeman, A.C., S. Mostaghimi, G.I. Holtzman, V.O. Shanholtz, S. Shukla and B.B. Ross. 1995. Monitoring pesticide and nitrate in Virginia's groundwater - Pilot study. Trans ASAE, 38(3): 797-807.

Burland, G.R. 1991. Irrigation Canal and Return Flow Monitoring. Unpublished report. Alberta Environment, Pesticide Management Branch. 2 pp.

Burland, R. and G. Byrtus. 1992. Pesticide regulation and monitoring activities. Proc. Agricultural Impacts on Surface and Groundwater Qual. CAESA. Lethbridge, AB. p. 20-24.

Burland, G.R., M.D. O'Shea, D. Stix and R. Verger. 1984. Investigation Into The Behaviour of Magnicide H in Alberta Irrigation Canals. Alberta Environment, Pesticide Chemicals Branch. 66 pp.

Buth, J.L., H. Rohde and R. Butler. 1992. Groundwater Quality Assessment of the Assiniboine Delta Aquifer. Canada-Manitoba ESI, for Keystone Vegetable Producers Assoc., AAFC, and Manitoba Agriculture. Manitoba Agriculture. Carman, MB. 12 pp.

Cavalier, T.C., T.L. Lavy and J.K. Mattice. 1988. Monitoring groundwater in Arkansas for pesticides. Proc. Agricultural Impacts on Ground-water. National Water Well Assoc., Dublin, OH. p. 325-344.

Cessna, Alan. 1996. Personal communication. Research Br., Agriculture and Agri-Food Canada. Saskatoon, SK.

Currie, R.S.and D.A. Williamson. 1995. An assessment of pesticide residues in surface waters of Manitoba, Canada. Water Quality Management Section, Manitoba Environment. Rpt. #95-08.

Detroy, M.G., P.K.B. Hunt and M.A. Holub. 1988. Groundwater quality monitoring program in Iowa: Nitrate and pesticides in shallow aquifers. Proc. Agricultural Impacts on Groundwater. National Water Well Assoc., Dublin, OH. p. 255-278.

Elliott, J.A., A.J. Cessna and W. Nicholaichuk. 1995. Preferential flow and leaching of herbicides under irrigation in Saskatchewan, Canada. Proc. International Assoc. of Hydrogeologists 26. Edmonton, AB.

Environment Canada. 1990. Off-Farm Sediment Impacts in the Saskatchewan River Basin. M.A. Carson & Associates, Victoria B.C., for Inland Waters Directorate, Saskatchewan District. 87 p.

Fairchild, D.M. 1987. A national assessment of ground water contamination from pesticides and fertilizers. *In* D.M. Fairchild (ed.), Groundwater Quality and Agricultural Practices. Lewis Publishers, Chelsea, MG. p. 153-174.

Fitzgerald, D. 1995. Alberta farmstead water quality survey. Proc. Agricultural Impacts On Water Quality. CAESA. Red Deer, AB. p. 138-140.

Greenlee, G.M., T.M. Peters, and P.D. Lund. 1993. Surface Water Quality Monitoring of Irrigation Return Flow . . . - 1992. LERB, Irrig. and Resource Mgt. Div., AAFRD. Lethbridge, AB.

Grover, R. and A.J. Cessna. 1996. A Prairie-Wide Perspective of Pesticides and Farm Water Quality - I. Farm Dugouts. GCI/AAFC, Technical Report No. 96-1. Regina, SK. 39 pp., appendices.

Grover, R., D.T. Waite, A.J. Cessna, W. Nicholaichuk, D.G. Irvine, L.A. Kerr and K. Best. 1996. Magnitude and persistence of herbicide residues in farm dugouts/ponds in the Canadian prairies. Environ. Toxicol. Chem. 15: (in press).

Hill, B.D. and K.N. Harker. 1996. Herbicide leaching into shallow groundwater in Central Alberta. Proc. Western Pesticide Residue Analyst's Meeting. Saskatoon, SK.

Hughes, C.E., D.A. Williamson and B.M. Lussier. 1994. Water Quality Assessment of Cooks Creek, Manitoba. Cooks Creek Conservation District No. 5, and Manitoba Environment. Rpt. No. 94-09. 46 pp.

Jones, G., S.E. Gurney and D. Rocan. 1996. Toxic Algae/Rural Water Quality Study. Interim Report. Manitoba Environment, Winnipeg, MB (in press).

Lindwall, C. Wayne. 1996. Personal communication. Memo dated June 22, 1996. AAFC, Lethbridge Research Station, AB.

MacDonald, R.A. and B.R. McLeod. 1992. Saskatchewan Environment and Public Safety: Drinking Water Safety Project. M.R.-2 MacDonald Assoc. Regina, SK. 34 pp.

McKenna, D.P., S.F.J. Chou, R.A. Griffin, J. Valkenburg, L.L. Spencer and J.L. Gilkeson. 1988. Assessment of the occurrence of agricultural chemicals in groundwater in a part of Mason County, Illinois. Proc. Agricultural Impacts on Groundwater. National Water Well Association. Dublin, Ohio. p. 389-406.

Milburn, P., D.A. Leger, H. O'Neill, J.E. Richards, J.A. MacLeod, K. MacQuarrie. 1995. Pesticide leaching associated with conventional potato and corn production in Atlantic Canada. Water Quality Res. J. Canada, Vol. 30, No. 3: 383-397.

Miller, J.J., G.J. Beke, C. Chang, N. Foroud, B.D. Hill and C.W. Lindwall. 1992. Impact of agricultural management practices on water quality in southern Alberta. Proc. Agri. Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 42-47.

Miller, J.J., N. Foroud, B.D. Hill and C.W. Lindwall. 1995. Herbicides in surface runoff and groundwater under surface irrigation in southern Alberta. Can. J. of Soil Sci. 75: 145-148.

Muir, Derek and Dorothea Rawn. 1996. Personal communication. Freshwater Institute, Dept. of Fisheries and Oceans. Winnipeg, MB.

Pettit, G. 1988. Assessment of Oregon's groundwater for agricultural chemicals. Proc. Agricultural Impacts on Groundwater. National Water Well Association. Dublin, OH. p. 279-295.

Rawn, Dorothea, Thor Halldorson and Derek Muir. c.1995a. Pesticides In Lake Winnipeg Drainage Basin, South Tobacco Creek - 1994. Fresh Water Inst., Dept. of Fisheries and Oceans. Winnipeg, MB.

Rawn, Dorothea, Thor Halldorson and Derek Muir. c. 1995b. Pesticides in Lake Winnipeg Drainage Basin. 1. Red River - Summary of 1993/94. Fresh Water Inst., Dept. of Fisheries and Oceans. Winnipeg, MB.

Rodvang, J. and K.M. Riddell. 1992. Monitoring of phenoxy-neutral herbicides in subsurface drain effluent in southern Alberta. Proc. 29th Annual Alberta Soil Sci. Workshop. U. of Alberta, Edmonton, AB.

Shaw, G.G. 1991. Pesticide Residues in Water. Agriculture Canada Pesticides Directorate. Unpublished report.

Spalding, R.F., G.A. Junk and J.J. Richard. 1980. Pesticides in ground water beneath irrigated farmland in Nebraska. Pesticide Monitoring Journal, Vol. 14, No.2: 70-73.

USEPA. 1985. State Groundwater Program Summaries, Vol II. Washington, D.C.

Waite, D.T., R. Grover, N.D. Westcott, H. Sommerstad and L.A. Kerr. 1992. Pesticides in groundwater, surface water and spring runoff in a small Saskatchewan watershed. Environ, Toxicol. Chem. 11:741-748.

Wayland, Robert. 1993. What progress in improving water quality? J. Soil Water Cons. 48(4): 261-266.

9.0 Nitrate

The term "*nitrate*" as used here, refers to the concentration of nitrogen (N) present as nitrate (NO_3), ie., nitrate-nitrogen (NO_3-N). According to the Canadian Water Quality Guidelines for drinking water [CCREM 1987 and updates], a concentration of 10 ppm nitrate or greater may be particularly hazardous to the health of infants. A similar standard applies in the US.

It can be hard to differentiate between natural background levels of nitrate and possible agricultural contributions. [Silver and Fielden 1980, in Canter 1987]

9.1 North American Context

Agricultural activities can contribute significantly to nitrate concentration in groundwaters. In the United States, nitrate levels periodically exceed water quality guidelines [Fairchild 1987]:

- ***Regional findings.*** About 1/3 of US States are said to experience groundwater contamination to "some degree" regionally
- ***Local findings.*** Local, scattered groundwater problems of "some nature" are thought to occur in another 1/3 of States

However, the volume of data required to class a location as a "problem area" is loosely defined. As well, it can be hard to differentiate between natural background levels of nitrate and possible agricultural contributions [Silver and Fielden 1980, in Canter 1987]. Hence, the meaning of many nitrate detections is ambiguous.

9.2 European Findings, Multiple Sources

Comparison with other countries helps to place prairie findings in a world setting, and points to multiple sources for nitrogen inputs.

A 2-yr study along the Ondava River basin of **Slovakia** showed that as fertilizer application increased, nitrate and phosphate levels in surface and ground water also increased [Mendel and Pekarova 1995].

In **Finland**, streams from virtually undisturbed forest catchments have increased in nitrate during the last 20-25 years [Lepisto 1995]:

- ***Atmospheric deposition.*** This is because of increased atmospheric deposition from inorganic N as NO_x due to combustion, and NH_3 from agricultural processes

- ***Nitrogen saturation.*** There is evidence of nitrogen saturation occurring in watersheds — an inability of the biomass to use up all the N that is increasingly available

In the **United Kingdom**, cultivation on acid soils in high-rainfall areas increases the N in upland streams substantially. Yet increases are often transient, and according to Reynolds and Edwards [1995]:

> ***"There are relatively few published long-term data sets to indicate trends in dissolved nitrogen concentration for upland catchments"***

Clearly, not all nitrate increases to surface and groundwaters can be attributed to local activities or to agriculture alone.

Clearly, not all nitrate increases to surface and groundwaters can be attributed to local activities or to agriculture alone:

- ***Seasonal effects*** can have a large influence on the variability of nitrate concentrations in streams [Reynolds and Edwards 1995]

- ***Atmospheric inputs*** have increased greatly since pre-industrial times and can be a major source of N in upland catchments [Reynolds and Edwards 1995]

9.3 Prairie Surface Waters

The net effect of agriculture on the nitrate concentration in surface waters is uncertain:

- ***No difference.*** In Cooks Creek watershed near Winnipeg, Manitoba, no significant difference in N was found between upstream and downstream reaches [Hughes et al. 1994]

- ***Uncertain source.*** In west-central Manitoba, it was unclear how much of the in-stream nitrate increase after rainfall was due to land-use versus natural causes [Williamson et al. 1992]

- ***Irrigation effect.*** In Alberta, weekly samples of delivery and spill waters from 2 irrigation districts found N levels consistently below guidelines for human and stock use [Greenlee and Lund 1995]

9.4 Prairie Groundwater

Natural Levels

The natural background level of nitrate may be so high that it is difficult to track small agricultural additions. In southern Alberta, high groundwater nitrate from natural sources (100-500 ppm) has been commonly detected in oxidized (shallower) till and some shallow bedrock [Rodvang et al. 1995]. Such levels are generally attributed to geologic, not agricultural sources [Hendry et al. 1984].

Similarly, in Nebraska, large geologic quantities of nitrate exist within portions of the state [Boyce et al. 1976, in Canter 1987].

Prairie Literature Review

A literature review of nitrate in groundwater on the prairies [Henry and Meneley 1993; Henry 1995], reports that:

- ***Current concentrations*** are not generally excessive

- ***As early as the 1940s*** levels greater than 10 ppm were found in up to 20% of wells tested across the prairies

- ***Frequencies today*** are generally no higher than earlier levels

Manitoba

There is evidence of nitrate in Manitoba wells as early as 1947 [Henry 1995], yet wide-spread, nonpoint-source contamination is not a significant problem today. Still, nitrate levels up to 20 ppm have been found there in shallow, non-farmstead wells located in irrigated areas overlaying the Assiniboine Delta Aquifer [Render 1995].

Saskatchewan

In 1948, a Saskatchewan survey of 2,000 wells found that 18% contained nitrate greater than 10 ppm [Henry 1995]. Recent data suggests that the ratio of wells containing high nitrate in Saskatchewan today is no greater.

Alberta

Within Alberta, results vary considerably [Henry and Meneley 1993; Henry 1995]:

- ***5% in farmer samples.*** Of 1,425 water samples collected from farmers by Alberta Agriculture over a 10 yr period, 5% contained excessive nitrate

- ***4% in well samples.*** Of 12,342 well water samples on file at the Alberta Environmental Centre for a 6-yr period, 4% had greater than 10 ppm nitrate [Henry 1995]

- ***0-16% in well samples.*** Alberta Environment wells in selected areas of the province showed from 0-16% of wells exceeding guidelines

Variation in sampling frequency, seasonality and timing is critical to an understanding of the relative meaning of nitrate findings.

Other Groundwater Results

Other groundwater studies show similar, varied results across the prairies that may or may not be agriculturally related:

- ***Edmonton area.*** Half of wells tested were above 10 ppm nitrate, many greater than 100 ppm. Human and animal wastes were suspected [Stein 1976, in Paterson 1992]

- ***Tile drainage.*** In a 3-yr Alberta study of 20 tile drainage sites, mean nitrate level was 9 ppm. 25% of drains were above 10 ppm [Harker 1982; Paterson 1992]

- ***Irrigation wells.*** In a 1-time sampling of 26 irrigation wells near Carberry, Manitoba, nitrate ranged from less than 1 to 8 ppm [Buth et al. 1992]

In Saskatchewan, draft reports cover the 1-time sampling of a series of 117 shallow, domestic wells located across 4 areas of the province [Volgesang and Kent 1996]. Individual wells were located in actively farmed areas and selected according to an Aquifer Vulnerability Index — to represent wells with an **"extremely high potential for contamination:"**

- ***Nitrate levels.*** An average of 33% of wells exceeded guidelines

- ***Worst case*?** Sampling was in the summer of a wet year, when nitrate levels and leaching risk might be at a maximum

- ***Exceedence levels*** of nitrate in wells were often "not excessively high"

Variation in sampling frequency, seasonality and timing is critical to an understanding of the relative meaning of nitrate findings.

9.5 Groundwater Elsewhere

Eastern Canada

Ontario and Atlantic Canada may be worst case comparisons because of their intensive farming.

Of 1300 domestic and 140 field wells sampled during the winter and again during the following summer in **Ontario** [Agriculture Canada 1993]:

- ***Above guidelines.*** 15% of domestic and 25% of field wells had average nitrate levels above drinking water guidelines

- ***Nitrate layering.*** Up to 44% of field wells had maximum nitrate concentrations above guidelines at some depth within the well

Areas of sandy soils, shallow wells and intensive agriculture represent higher risk.

In **New Brunswick**, Milburn and Richards [1994] monitored subsurface drainage discharge from continuously cropped corn, year-round. Annual nitrogen inputs were about 90 kg/ha from manure and fertilizer sources. Over a 4-yr period:

- ***Flow-weighted*** nitrate level was 5 ppm
- ***Maximum mean*** summer nitrate level was 13.4 ppm
- ***Heavy rains*** occurring shortly after fertilizer application resulted in maximum levels

In another **New Brunswick** study [Richards et al. 1990], 47 private farm wells in 3 agricultural regions were sampled on a 15 year interval. Samples were collected once in a non-agricultural area for comparison, at the end of the trial:

- ***Farm wells.*** The mean nitrate level in agricultural wells was 9.5 ppm
- ***Non-ag site.*** Mean nitrate concentration at the non-ag site was 1.1 ppm
- ***Ag sources.*** Higher nitrate concentrations in agricultural areas apparently came from soil N or fertilizer N
- ***No increase.*** There was no significant change in the mean nitrate concentration in 2 of the regions, over 15 years. In one region, nitrate concentration decreased

U.S. Groundwater Comparisons

US comparisons reflect variability in nitrate findings. They also show that areas of sandy soils, shallow wells and intensive agriculture represent higher risk. Examples of relatively *high* incidence of nitrate contamination include:

- ***Illinois.*** Sandy soils had nitrate greater than 10 ppm in 50% of wells [McKenna et al. 1988]
- ***Oregon.*** A 1-time sampling of 380 public and private wells in "vulnerable agricultural areas" found nitrate above 10 ppm in 24% of wells [Pettit 1988]. The study concluded: ***"Nitrate contamination is widespread and constitutes a significant threat to future use of groundwater as a drinking source in a number of areas"***
- ***Virginia.*** A 1-time winter sampling of 359 private wells found nitrate above 10 ppm in 17% of shallow wells and 1% of deep wells [Bruggeman et al. 1995]

In contrast to these findings, relatively *low* incidences of nitrate contamination were encountered as follows:

- ***Ohio.*** Of 5,000 rural wells in 30 counties, less than 3% had nitrate levels above 10 ppm. Almost 80% had no contamination [Wallrabenstein and Baker 1988]
- ***Iowa.*** In a 1-yr study of 515 wells (less than 200 feet deep), 6% had nitrate above 10 ppm. Shallower wells had the greater the concentration [Detroy et al. 1988]
- ***Georgia.*** Of 3,419 sites, less than 4% of shallow wells and 1% of deep wells exceeded guidelines [Tyson et al. 1995]
- ***North Carolina.*** Both cultivated and forested land had low nitrate levels in coastal plain groundwater [Gilliam et al. 1974]

9.6 Soil Accumulation and Losses

There is some evidence of nitrogen build up in annually cropped soils — a possible precursor of future leaching hazard. This is particularly true of soils that are heavily fertilized for specialty crops or for manured fields.

Specialty Crops

A 3-yr survey was conducted of 256 fields in Manitoba [Ewanek 1995]. Excessive levels of nitrate were defined as those where nitrate was greater than 165 kg/ha in the root zone (top 120 cm of soil), or greater than 22 kg/ha per 30 cm of subsoil depth (below 120 cm). Findings indicate:

- ***Specialty crops.*** Soil nitrate was above acceptable levels in many cases
- ***Grass/alfalfa.*** High nitrate under grass, and either fertilized or manured alfalfa was rare

In Alberta, Heaney et al. [1988, in Paterson 1992] found negligible N increases on fertilized hayland.

Precipitation

Above-normal precipitation may substantially increase N leaching from the soil profile. In the semi-arid portion of Saskatchewan, Campbell et al. [1984] concluded that considerably more nitrate was being leached beyond the root zone than previously believed:

- ***Above normal (23%) summer rainfall*** was estimated to have leached at least 123 kg/ha of nitrate from a fallow soil
- ***Prairie breaking.*** From long-term precipitation data, 20% of the soil organic N present at the breaking of the prairies is estimated to have been lost via leaching
- ***Prevention.*** Applying fertilizer N at recommended rates can reduce leaching hazard, assuring sufficient vigorous crop growth to use soil N and prevent it from leaching

Where leaching waters are limited or soil texture restricts leaching, there is evidence that concentrated nitrate is less likely to be a problem. In Minnesota, a 3-yr study showed that the rate of N normally applied before tillage in the fall, resulted in little movement of N out of the tilled zone [Staricka et al. 1994].

In contrast, nitrate leaching may be significant within the Atlantic Coastal Plain of Maryland. There, nitrate recharge to groundwater increased by a factor of 3-6 times, about proportional to the documented increase in regional N fertilizer use [Bohlke and Denver 1995].

9.7 Irrigation

Manure

There is evidence that under irrigation, the amount of manure or chemical fertilizer applied and the irrigation management used, can significantly affect nitrate leaching on the prairies.

A Lethbridge study examined the effect of 11 years of manure application [Chang and Entz 1996]. Rates were up to 3 times the recommended application for irrigated land (up to 180 t/ha) and for dryland (up to 90 t/ha):

- ***Irrigated leaching.*** Nitrate was leached beyond the 150 cm soil depth, especially at high manure rates
- ***Groundwater concentration*** beneath irrigation was as high as 500 ppm nitrate
- ***Nitrate losses.*** Up to 320 kg/ha/yr leached from heavily manured and irrigated plots
- ***Dryland different.*** Similar losses weren't found under dryland conditions [Chang and Entz 1990, Chang et al. 1991, in Miller et al. 1992]

Riddell and Rodvang [1992] report nitrate greater than 10 ppm in near-surface groundwater, where annual manure application rates were 17-150 t/ha.

There is evidence that under irrigation, the amount of manure or chemical fertilizer applied and the irrigation management used, can significantly affect nitrate leaching on the prairies.

In all nitrate evaluations it must be clearly understood that timing of sampling in relation to precipitation or irrigation can significantly affect overall findings.

Chemical Fertilizer

The potential for chemical fertilizer to leach from the soil can also be linked to the amount of fertilizer applied, irrigation management, and precipitation patterns. Soil texture is also important.

Early work on irrigated sandy soils near Taber, Alberta showed little evidence of N losses to groundwater [Burnett 1981, Pike-Glover 1982, in Paterson 1992]. Yet Rodvang et al. [1995] found nitrate leaching from coarse, sandy soils under irrigation in the same area:

- ***Sandy soils.*** Nitrate levels up to 250 ppm were detected below a heavily fertilized potato/corn rotation

- ***Clay tills.*** Lower but significant levels have also been found in glacial tills below cereal crops receiving high rates of N fertilizer (200 kg/ha)

Evidence from the irrigated sandy soils of the Platte River Basin in **Nebraska** indicates:

- ***Groundwater increase.*** The average concentration of nitrate in groundwater increased 25% over a 10 year period [Olson 1974, in Canter 1987]

- ***High incidence.*** Nitrate in excess of 10 ppm occurred in 183 of 256 groundwater samples. Analysis suggested the primary source was fertilizer nitrogen [Gormly and Spalding 1979, in Canter 1987]

In **California**, tile effluent from a mature irrigated orange grove was 50-60 ppm nitrate, equivalent to 50% of applied N — although perhaps not from that source [Bingham et al. 1971, in Canter 1987].

In all nitrate evaluations it must be clearly understood that timing of sampling in relation to precipitation or irrigation can significantly affect overall findings.

9.8 Summary

There is evidence of the possible nitrate contamination of surface and groundwater on the prairies. Levels periodically exceed Water Quality Guidelines, but results vary widely.

Natural sources

It is frequently uncertain what portion of nitrate levels in surface and groundwaters derive from agricultural vs. natural causes. Long-term data on natural background levels is limited.

Fertilization and irrigation

Soils receiving high rates of manure and chemical fertilizer show evidence of nitrate buildup. Soil texture, cropping patterns, precipitation, and irrigation management appear to play a prominent role in leaching hazard.

Required Action

There is an urgent need to effectively document baseline nitrate levels, and to clarify the sources and predict the fate of nitrate contamination. Efforts should focus on intensive land use, shallow aquifers, and high precipitation or irrigation. Investigation within agricultural fields is needed, not just the collection of convenient data from nearby municipal and farm wells [Rodvang 1995].

9.9 References

Agriculture Canada. 1993. Ontario Farm Groundwater Quality Survey. ISBN 0-662-20879-X. 162 pp.

Bingham, F.T., S. Davis and E. Shade. 1971. Water relations, salt balance, and nitrate leaching losses of a 960-acre country watershed. Soil Sci. 112: 410-417.

Bohlke, J.K. and J.M. Denver. 1995. Combined use of groundwater dating . . . to resolve the history and fate of nitrate contamination in two agricultural watersheds. Water Resources Research, Vol. 31, No. 9: 2319-2339.

Boyce, J.S. et al. 1976. Geologic nitrogen in Pleistocene loess in Nebraska. J. Env. Qual., Vol. 5, No. 1: 93-96.

Bruggeman, A.C., S. Mostaghimi, G.I. Holtzman, V.O. Shanholtz, S. Shukla and B.B. Ross. 1995. Monitoring pesticide and nitrate in Virginia's groundwater - A pilot study. Trans ASAE, Vol 38(3): 797-807.

Burnett, R.W. 1981. An Evaluation of A Shallow Groundwater Flow Regime Near Taber, Alberta. M.Sc. Thesis, University of British Columbia. 275 pp.

Buth, J.L., H. Rohde and R. Butler. 1992. Groundwater Quality Assessment of the Assiniboine Delta Aquifer. Canada-Manitoba ESI, for Keystone Vegetable Producers Assoc., AAFC, and Manitoba Agriculture. Manitoba Agriculture. Carman, MB. 12 pp.

Campbell, C.A., R. De Jong and R.P. Zentner. 1984. Effect of cropping, summerfallow and fertilizer nitrogen on nitrate-nitrogen lost by leaching on a Brown Chernozemic loam. Can. J. Soil Sci. 64: 61-67.

CCREM. 1987. Canadian Water Quality Guidelines. Canadian Council of Resource and Environment Ministers. Environment Canada, Ottawa.

Canter, L.W. 1987. Nitrates and pesticides in ground water: An analysis of a computer-based literature search. *In* D.M. Fairchild (ed.). Groundwater Quality and Agricultural Practices. Lewis Publishers, Chelsea, Michegan. p. 153-174.

Chang, C. and T. Entz. 1990. Nitrate content in the groundwater under long-term feedlot manure application. Proc. Irrigation Research and Develop. Conf. '90. Water Resources Inst., U. of Lethbridge, AB. p. 339-356.

Chang, C. and T. Entz. 1996. Nitrate leaching losses under repeated cattle feedlot manure application in southern Alberta. J. Environ. Qual. 25: 145-153.

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.

Detroy, M.G., P.K.B. Hunt and M.A. Holub. 1988. Groundwater quality monitoring program in Iowa: Nitrate and pesticides in shallow aquifers. Proc. Agricultural Impacts on Groundwater. National Water Well Association, Dublin, Ohio. p. 255-278.

Ewanek, J. 1995. Survey of nitrate-nitrogen in the soil profile under different field management practices in Manitoba. Proc. Agricultural Impacts On Water Quality. CAESA. Red Deer, Alberta. p. 168-171.

Fairchild, D.M. 1987. A national assessment of ground water contamination from pesticides and fertilizers. *In* D.M. Fairchild (ed.). Groundwater Quality and Agricultural Practices. Lewis Publishers, Chelsea, MG. p. 153-174.

Gilliam, J.W., R.B. Daniels and J.F. Lutz. 1974. Nitrogen content of shallow ground water in the North Carolina Coastal Plain. J. Env. Qual. Vol 3, No. 2: 147-151.

Gormly, J.R. and R.F. Spalding. 1979. Sources and concentrations of nitrate-nitrogen in ground water of the Central Platte Region, NB. Ground Water Vol. 17, No. 3: 291-301.

Greenlee, G.M. and P.D. Lund. 1995. Impacts of irrigation return flow from two irrigation districts . . . on surface water quality. Proc. Agricultural Impacts on Water Quality. CAESA. Red Deer, AB. p. 80-93.

Harker, D.B. 1982. Projected impact of tile effluent on water quality within the South Saskatchewan River Basin of Alberta. Proc. 8th Symposium of the Water Studies Institute, Wastes and Prairie Water Quality. University of Saskatchewan, Saskatoon.

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. Proc. 25th Alberta Soil Science Workshop. U. of Alberta, Edmonton, AB.

Hendry, M.J., D. McCready and D. Gould. 1984. Distribution, source and evolution of nitrate in till of southern Alberta. J. of Hydrology Vol. 70: 177-198.

Henry, J.L. 1995. Nitrate in the groundwater of western Canada. Proc. International Association of Hydrogeologists 26. Edmonton, AB.

Henry, J.L. and W.A. Menley. 1993. Nitrates In Western Canadian Groundwater. Western Canadian. Fertilizer Association. 31 pp.

Hughes, C.E., D.A. Williamson and B.M. Lussier. 1994. Water Quality Assessment of Cooks Creek, Manitoba. Cooks Creek Conservation District No. 5, and Manitoba Environment. Report No. 94-09. 46 pp.

Lepisto, A. 1995. Increased leaching of nitrate at two forested catchments in Finland over a period of 25 years. J. of Hydrology, 171: 103-123.

McKenna, D.P., S.F.J. Chou, R.A. Griffin, J. Valkenburg, L.L. Spencer and J.L. Gilkeson. 1988. Assessment of the occurrence of agricultural chemicals in groundwater in a part of Mason County, Illinois. Proc. Agricultural Impacts on Groundwater. National Water Well Association. Dublin, OH. p. 389-406.

Mendel, O. and P. Pekarova. 1995. Impact of non-point source at the basin on surface and groundwater contamination. Proc. International Assoc. of Hydrogeologists 26. Edmonton, AB.

Milburn, P. and J.E. Richards. 1994. Nitrate concentration of subsurface drainage water from a corn field in southern New Brunswick. Canadian Agricultural Engineering, Vol. 36, No. 2:69-78.

Miller, J.J., G.J. Beke, C. Chang, N. Foroud, B.D. Hill and C.W. Lindwall. 1992. Impact of agricultural management practices on water quality in southern Alberta. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 42-47.

Olson, R.A. 1974. Influence of Fertilizer Practices on Water and the Quality of the Environment. US Dept of the Interior, Washington, DC. OWRT-B-022-NEB(3).

Paterson, B.A. 1992. Preliminary assessment of water quality monitoring. Proc. Agri Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 65-72.

Pettit, G. 1988. Assessment of Oregon's groundwater for agricultural chemicals. Proc. Agricultural Impacts on Groundwater. National Water Well Association. Dublin, OH. p. 279-295.

Pike-Glover, D. 1982. Hydrogeochemistry Variations Through Saturated Overburden Deposits Beneath An Irrigated Site In South-Central Alberta. M.Sc. Thesis, U. of Alberta. Edmonton, AB.

Render, Frank. 1995. Personal communication. Fax December 20, 1995. Manitoba Natural Resources.

Reynolds, B. and A. Edwards. 1995. Factors influencing dissolved nitrogen concentrations and loadings in upland streams of the UK. Agricultural Water Management 27: 181-202.

Richards, J.E., P.H. Milburn, A.A. MacLean and G.P. DeMerchant. 1990. Intensive potato production effects on nitrate-N concentrations of rural New Brunswick well water. Canadian Agricultural Engineering. p. 189-196.

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, AB.

Rodvang, J. 1995. Personal communication. Irrigation and Resource Development Branch, Alberta Agriculture. Lethbridge, AB.

Rodvang, J., R. Schmidt-Bellach, I.I. Wassenaar and J. Carefoot. 1995. Nitrates in soil and groundwater below irrigated fields in southern Alberta. Proc. International Assoc. of Hydrogeologists 26. Edmonton, AB.

Silver, B.A. and J.R. Fielden. 1980. Distribution and probable source of nitrate in ground water of Paradise Valley, Arizona. Ground Water Vol. 18, No. 3: 244-251.

Stein, R. 1976. Hydrogeology of the Edmonton Area (Northeast Segment). Alberta Research Council Report 76-1. Edmonton, AB.

Staricka, J.A., G.R. Benoit, A.E. Olness, J.A. Daniel and D.R. Huggins. 1994. Movement of fall-applied nitrogen during winter in western Minnesota. Proc. 2nd Environmentally Sound Agriculture. Orlando, FL. p. 106-112.

Tyson, A.W., P. Bush, R. Perkins and W.I. Segars. 1995. Nitrate contamination of domestic wells in Georgia. Proc. Water Conservation In The 21st Century: Conservation, Demand, and Supply. American Water Resources Assoc. Salt Lake City, UT. p. 509-515.

Volgesang, Greg F. and David B. Kent. 1996. Shallow Groundwater Quality Survey for ADD Districts # 1, 8, 15, & 39 (*Draft reports)*. Clifton and Associates, for SERM. Oct. 1-23, 1996. Regina, SK.

Wallrabenstein, L.K. and D.B. Baker. 1988. Nitrate contamination in Ohio private wells. Proceedings, Agricultural Impacts on Groundwater. National Water Well Assoc. Dublin, OH. p. 575-592.

Williamson, D.A., M.P. Boychuk and M.T. Ledoux. 1992. Water Quality Assessment of the Turtle River and Two Tributaries, Manitoba, Canada. Turtle River Conserv. Dist. # 2, and Manitoba Env. Rpt. No. 92-05. 52 pp.

10.0 Phosphorus in Surface Waters

Phosphorus (P) can enter surface waters as part of the sediment load attached to soil particles, or in a purely water soluble form. There is no Canadian Water Quality Guideline limit for P concentrations. The USEPA [1976] suggests a maximum desirable concentration of 0.10 ppm for flowing water. According to the Council for Agricultural Science and Technology [CAST 1992], under the right conditions very small amounts of P (0.01 ppm) can cause problems with algal growth. Much work remains to clarify the relative role of agricultural and other P sources in water quality.

Much work remains to clarify the relative role of agricultural and other P sources in water quality.

10.1 Large Prairie Rivers

The mainstem rivers and reservoirs of the Saskatchewan River Basin have P levels close to what Environment Canada [1990] refers to as "background" water quality:

- ***Sediment values.*** Most sediments are from stream-bed and gully erosion, having a P content comparable to surrounding soils and deeper sediments
- ***Occasional eutrophication*** is said to be largely a summer phenomenon, downstream of sewage treatment plants
- ***Seasonal runoff*** can result in short-term increases in P loading

In Alberta, a 1979-1982 study on the Bow, Oldman and South Saskatchewan rivers examined different forms of total P [Cross et al. 1986, in Environment Canada 1990]. Above the confluence of the Bow and Oldman rivers:

- ***Dissolved form.*** Most of the P (70-80%) was in dissolved form
- ***Sewage ratio.*** Virtually all of the P was from city sewage treatment plants

Since the 1979-1982 study, major sewage treatment facilities on these rivers have been upgraded, significantly reducing P loading from sewage sources.

Below the confluence of the Bow and Oldman rivers, the same study reported that particulate (sediment-borne) P accounted for 70-80% of the total load. However, most of the flow in the main rivers of the Saskatchewan Basin originates in the mountains and the great majority of the sediment load is from stream-bed erosion. Hence, neither the flow nor the sediment load (and its accompanying P) have come principally from agricultural lands [Environment Canada 1990].

10.2 Prairie Agricultural Contributions

Eutrophication is often the main issue in smaller lakes and streams. This may be due to the higher nutrient levels suspected from farmland runoff.

Eutrophication is often the main issue in smaller lakes and streams. This may be due to the higher nutrient levels suspected from farmland runoff.

According to Environment Canada [1990]:

> ***"Sediment-associated eutrophication in small water bodies appears to be directly related to farmland erosion"***

Streams and lakes that are tributary to the Saskatchewan river, and receive most of their water from prairie sources, are generally regarded as being more eutrophic. But potential agricultural contributions have not been closely documented.

In Western Canada, some people perceive water quality in prairie lakes to be deteriorating, and believe that agriculture is largely to blame. But in general:

> ***It is simply not known whether prairie lakes were already eutrophic or are becoming so due to agricultural loadings*** [Mitchell and Trew 1992]

As well, it cannot be assumed that P eroded from agricultural lands is necessarily fertilizer P. Indeed, this is unlikely to be so, as the amount of P applied in chemical fertilizers is minimal compared to the P indigenous to the soil (although not immediately available for plant use) [Environment Canada 1990].

Near cattle operations, stream concentrations of P are often the highest. As cattle numbers and associated manure volumes increase, P loading tends to increase [Mitchell and Hamilton 1982, in Mitchell 1992].

10.3 Smaller Lakes and Streams

A background report on the Assiniboine River Basin in Saskatchewan (1986) found that:

> ***"Concentrations of . . . P tend to be near or slightly above generally accepted water quality objectives"***[Hass 1994]

On Cooks Creek in Manitoba [Hughes et al. 1994], P was relatively abundant, with concentrations averaging 0.26 ppm; however:

- ***No significant differences*** were seen in P levels between upstream and downstream waters flowing through agricultural lands
- ***More work is needed*** to identify P sources and clarify whether a reduction in P loading is possible

In the Turtle River of Manitoba, P loadings sometimes increased in response to rainfall, yet it was unclear how much of the increase was due to land use as opposed to natural sources [Williamson et al. 1992].

10.4 Irrigation

In Alberta, Greenlee and Lund [1995] found P concentrations in the delivery and spill waters of 2 irrigation districts were generally below maximum EPA limits (0.10 ppm) for flowing water.

Oosterveld and Carefoot [1979, in Environment Canada 1990] looked at P loading in the spill drains of an irrigation district:

- ***Exceeded objectives.*** Average total P was up to 6 times the *Alberta Water Quality Objective* of 0.05 ppm

- ***Drain erosion.*** Most of the P was deemed to have come from drain erosion

In another study, Oosterveld and McMullin [1979] looked at field runoff from a 3,000 ha flood irrigated basin:

- ***Field runoff.*** Total P in field runoff averaged 0.18 ppm

- ***Drain P.*** P levels in drain waters (where particulate P was deemed to have settled out) were significantly lower

10.5 Estimating Loadings

Of necessity, when calculating P loadings, many estimates and assumptions are made about relationships:

- ***Calculations.*** Phosphorus loadings are often based on calculations from isolated water samples and stream flow estimates

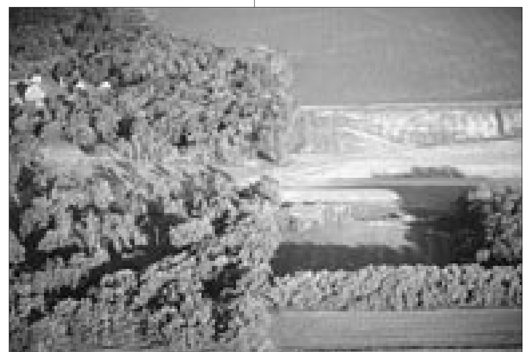
- ***Internal vs. external.*** Lake bottom sediments alone can release the equivalent of 1/2 to several times the annual supply of P from external sources [Mitchell 1985]

Variable Loadings
The export coefficients used to calculate the impact of agricultural P on surface water quality are of variable magnitude and meaning:

- ***Agricultural vs. forested areas.*** Export coefficients from agricultural lands can be 2-5 times that from forested areas

- ***Local variability.*** P exports from agricultural lands near Pine Lake, Alberta were up to 10 times *lower* than elsewhere in the province, perhaps due to limited rainfall and hummocky topography [Mitchell and Trew 1992]

- ***Low coefficients/ high loadings.*** Although overall export coefficients to Pine Lake were low, P loadings were fairly high from 4 relatively small agricultural sites



Rainfall Effect
Generally speaking, the flow-weighted P concentrations for streams draining forest land are consistent, while concentrations from agricultural lands might be highly variable [Mitchell and Hamilton 1982, in Mitchell and Trew 1992]. However:

- ***Extreme rainfall.*** P levels after an extreme rainfall event on the Turtle River basin of Manitoba (having significant agricultural lands), were similar to those for normal flow [Williamson et al. 1992]

- ***Sequential rainstorms*** can bring about a high degree of temporal variability in the runoff concentration of dissolved P [McIsaac et al. 1995]

This variability in P level with rainfall may have important consequences when trying to assess the impact of particular land management practices.

Lake bottom sediments alone can release the equivalent of 1/2 to several times the annual supply of P from external sources. [Mitchell 1985]

10.6 Net Effect

Clearing and cultivation apparently increase P loadings in runoff. But estimating the net effect of agricultural contributions on water quality can be difficult [Daniel et al. 1994].

For example, in Alberta, clearing only 21% of the Baptiste Lake watershed increased annual P load by as much as 88% [Trew et al. 1987]. And agriculture is

Until modelling methods have been locally verified to show they give results similar to those obtained from direct monitoring, a "healthy scepticism" of model predictions may well be justified. [Daniel et al. 1994]

by far the greatest contributor (55%) to P loadings on Moose Lake [Mitchell 1992]. Yet on Pine Lake, where the largest external loading (36%) is from agricultural and sewage sources:

- ***Internal cycling.*** The greatest portion of annual P loading (61%) is from the *internal* cycling of P historically deposited to lake sediments [Sosiak 1995]

- ***Limited availability.*** Loading estimates must take into account the possibility that only 50% of agricultural P may be biologically available [Mitchell and Trew 1992]

There is evidence of a relationship between changes to external loadings and internal cycling. But the relative time frames for seeing these changes are uncertain [Mitchell and Trew 1992]

Cause and Effect - Florida

According to Bob Buker [1994], an executive with US Sugar, experience with trying to manage P loadings in Florida illustrates the complicated nature of cause and effect relationships. Near the Florida Everglades, agricultural practices have been blamed for high P loadings despite:

- ***Fluctuating content.*** There are wide fluctuations in the P content of surface waters

- ***Unclear sources.*** It is difficult to clearly identify P sources

Still, a goal was set to reduce P loadings to surface waters by 25%. In response to modelling predictions, farmers reduced P applications by 36%, but became disillusioned when they saw *no net change* in P loadings to water bodies [Buker 1994]. This failure to see a short-term change is not surprising to those who understand the complexities governing long-term P balances [Aumen et al. 1995]:

- ***Time lag.*** It could take years before, and if, a reduction at the source leads to lower inputs to streams and lakes

- ***Watershed dependent.*** Results are very dependent upon the features of the particular watershed [Zakrevsky 1995]

Farmers near the Everglades are having difficulty accepting water quality standards that appear to be arbitrary and biased. The current P standard for surface water concentration is 50 ppb, and proposed standards call for a much lower discharge limit of 10 ppb. Opponents claim the new limit is cleaner than a brand-name mineral water (at 30 ppb) and far cleaner than urban runoff concentrations of P (620 ppb) from some Florida communities [Buker 1994].

10.7 Model Refinement

Because of the difficulties in directly sampling and monitoring P loadings, computer modelling techniques are often used. But this modelling process is contingent upon many built-in assumptions, and the observation had been made that:

> ***Until modelling methods have been locally verified to show they give results similar to those obtained from direct monitoring, a "healthy scepticism" of model predictions may well be justified*** [Daniel et al. 1994]

Prevention

Practices like minimum tillage bring about increases in plant organic matter. This reduces the risk that soils will erode, thereby reducing the potential for P to be lost as eroded sediment. But as their increased organic matter decays, minimum tilled sites often have increased water soluble P in runoff [Braden et al. 1991, in Connor et al. 1995]. Much work remains to clarify the relative role of agricultural P loadings on water quality and the management practices that are best suited to address potential problems.

10.8 Summary

Phosphorus loadings in lakes and streams can result from agricultural activities. But P loadings are often based on calculations and estimates and thereby subject to error.

Uncertain net effect

P loadings from agricultural and other lands can vary widely, depending on rainfall and other factors. Estimating the net effect of agricultural P on water quality is difficult. It is a complicated process and short-term effects can be hard to document.

Prairie waters

The mainstream rivers and reservoirs of the prairies have P concentrations close to background levels, and occasional eutrophication is largely a summer phenomenon downstream of sewage treatment plants. The level of P in small streams and lakes may be more closely related to agricultural practices, but relationships are unclear.

Required Action

There is a need to clarify the net effect of P loadings from agriculture vs. other sources, including the natural variability of P within ecosystems. Modelling predictions need to be calibrated to local field conditions before final decisions are based on the results.

10.9 References

Aumen, Nicholas G., Alan E. Steinman and Karl E. Havens. 1995. Impacts of nonpoint source runoff from agricultural operations on Lake Okeechobee, Florida. *In* K. Steele (ed.), Animal Waste And The Land-Water Interface. Lewis Publishers, Boca Raton, FL. p. 185-195.

CAST. 1992. Water Quality: Agriculture's Role. Council for Agricultural Science and Technology. Task Force Report No. 120. 103 pp.

Braden, J.B., R.S. Larson and E. Herrick. 1991. Impact targets vs. discharge standards in agricultural pollution management. Am. J. Agric. Econ., 73: 388-409.

Buker, R.H. 1994. Oral Presentation - Everglades Restoration. 2nd Environmentally Sound Agriculture. Orlando, FL.

Cross, P.M., H.R. Hamilton and S.E.D. Charlton. 1986. The Limnological Characteristics of the Bow, Oldman and South Saskatchewan Rivers (1979 - 1982). Environmental Protection Services, Alberta Environment. Edmonton, AB.

Connor, J.D., G.M. Perry and Richard M. Adams. 1995. Cost-effective abatement of multiple production externalities. Water Resources Research, Vol 31, No 7: 1789-1796.

Daniel, T.C., A.N. Sharpley, D.R. Edwards, R. Wedepohl and J.l. Lemunyon. 1994. Minimizing surface water eutrophication from agriculture by phosphorus management. J. Soil Water Cons., Vol 49, No. 3, 30-38.

Environment Canada. 1990. Off-Farm Sediment Impacts in the Saskatchewan River Basin. Prepared by M.A. Carson & Associates, Victoria B.C., for Inland Waters Directorate, Water Resources Branch, Saskatchewan District. 87 pp.

Hass, Glen. 1994. Toward A Greener Generation Of Rural Families, Final Report. Organizational Management Services. For The Advisory Committee, District 18 & 19 ADD Boards. CSAGPA. 120 pp.

Hughes, C.E., D.A. Williamson and B.M. Lussier. 1994. Water Quality Assessment of Cooks Creek, Manitoba. Cooks Creek Conservation District No. 5, and Manitoba Environment. Rpt. No. 94-09. 46 pp.

McIsaac, G.F., J.K. Mitchell and M.C. Hirschi. 1995. Dissolved phosphorus concentrations in runoff from simulated rainfall on corn and soybean tillage systems. J. Soil and Water Cons. 50(4) 383-387.

Mitchell, P. 1985. Preservation of Water Quality in Lake Wabamun. Water Quality Control Branch. Alberta Environment. Edmonton, AB.

Mitchell, P. 1992. Status Report on the Water Quality of Moose Lake. Environmental Quality Monitoring Branch, Alberta Environment, Edmonton.

Mitchell, P. and H.R. Hamilton. 1982. Assessment of Phosphorus Export From the Majeau Creek watershed Lac la Nonne. Water Quality Control Branch, Alberta Environment. Edmonton, AB.

Mitchell, P. and D. Trew. 1992. Agricultural runoff and lake water quality. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 73-79.

Oosterveld, M. and J.M. Carefoot. 1979. Water and salt transfers in an irrigation district. J. Irrig. and Drain. Div. 105: 197-204.

Oosterveld, M. and R.W. McMullin. 1979. Inflow-outflow of nutrients and sediment for a flood and a sprinkler-irrigated watershed in Alberta. Can. J. Soil Sci. 59: 177-182.

Sosiak, A.J. 1995. The Pine Lake restoration study. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, Alberta. p. 132-137.

Trew, D.O., D.J. Beliveau and E.I. Yonge. 1987. The Baptiste Lake Study Technical Report. Water Quality Control Branch, Pollution Control Division, Alberta Environment. Edmonton, AB.

USEPA. 1976. Quality Criteria For Water. United States Environmental Protection Agency. Washington, D.C.

Williamson, D.A., M.P. Boychuk and M.T. Ledoux. 1992. Water Quality Assessment of the Turtle River and Two Tributaries, Manitoba, Canada. Turtle River Conservation District # 2, and Manitoba Environment. Report No. 92-05. 52 pp.

Zakrevsky, J.-G. 1995. Personal communication. Environment Canada, Regina, SK.

11.0 Other Risks: Cattle, Salinity, Heavy Metals

Other risks to water quality include the effect of range livestock, increases in fecal coliform and other bacteria, the salt content in irrigation and drainage waters, and possible trace element and heavy metal problems.

11.1 Range Livestock

Except for concentrated feeding and watering sites, effects from unconfined *range* animals are generally short-term and can be hard to differentiate from those of wildlife.

General Effects

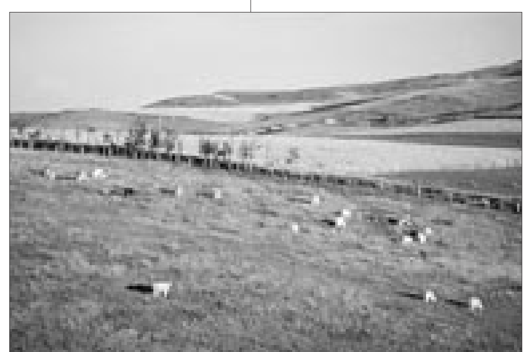
Range livestock production is said to be "an environmentally sound water quality management practise" [Sweeten 1984, in Buchanan 1992]:

- ***Often indistinguishable.*** The effects of range cattle on a watershed are often indistinguishable from the effects of wildlife [Dixon 1983a; in Buchanan 1992]
- ***Short distances.*** Where effects from unconfined livestock have been reported, these are often discernable for only short distances downstream [Dixon 1983b, Milne 1976; in Buchanan 1992]

Direct Watering

Allowing cattle to have direct access to streams and water bodies can result in an increased concentration of bacteria and sediment [Saxton et al. 1983, in Buchanan 1992]:

- ***Increased sediment & nutrients.*** In Texas, high impact feeding and watering sites increased sediment and nutrient loading [Sweeten 1984, in Buchanan 1992]
- ***Concentrated runoff.*** In Alberta, concentrations in runoff from winter feeding areas could be similar to that from feedlots [Buchanan 1992]
- ***Reduced cattle performance.*** When cattle are allowed direct access to farm dugouts, significant increases in sediment and bacteria levels can adversely affect cattle performance [Willms et al. 1995]



The effects of range cattle on a watershed are often indistinguishable from the effects of wildlife. [Dixon 1983a; in Buchanan 1992]

11.2 Fecal Coliform Bacteria

The presence of fecal coliform bacteria in surface and well waters can pose a significant health risk to humans. This may be due to the bacteria themselves or because they indicate that other, more harmful pathogens might be present:

> ***"It has been estimated that waterborne infections. . . affect 940,000 people and are responsible for 900 deaths every year in the US"*** [Bennett 1987, in CAST 1992]

Drains and Rivers

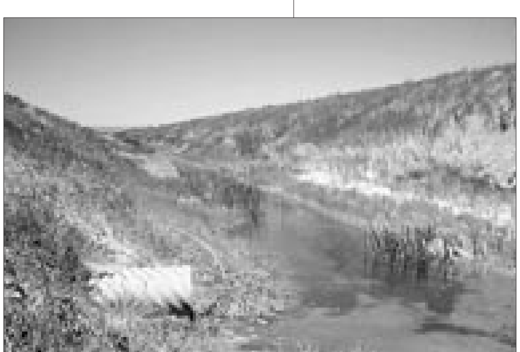
Although drains and rivers can show above-normal fecal counts, the reasons are often unclear.

Although drains and rivers can show above-normal fecal counts, the reasons are often unclear.

In Alberta, a 1-year study of surface water quality within two irrigation districts [Greenlee and Lund 1995] found:

- ***Bacterial counts*** were consistently above those in irrigation delivery water
- ***Public health standards*** were usually exceeded

In Manitoba, fecal counts in Cooks Creek were slightly above surface water quality guidelines in upstream reaches, but within guidelines downstream [Hughes et al. 1994]. It was unclear whether sources were point or non-point. These may have included:



- ***Direct watering*** access for cattle
- ***Discharge*** from animal holding facilities
- ***Runoff*** from manured fields
- ***Beaver presence*** in upstream reaches

On the Turtle River, coliform bacteria increased in response to rainfall but it was not clear how much of the increase was from natural sources as opposed to land-use causes [Williamson et al. 1992].

Wells and Dugouts

Fecal counts in well waters are variable. Rodvang [1995] found fecal coliform bacteria in a few very shallow wells, within an intensive livestock area.

- ***Alberta.*** In a one-time sampling of 192 farmstead dugouts and wells, 93% of wells but only 47% of dugouts met microbiological standards for drinking water [Fitzgerald 1995]
- ***Ontario.*** About 1/3 of 1300 domestic wells and 140 field wells exceeded coliform bacteria standards of 10 colonies per 100 ml. Up to 1/4 of all wells contained *fecal* coliforms at varying concentrations [Agriculture Canada 1993]

11.3 Irrigation Salinity

The salinity (EC) status of irrigation water can have a major impact on the potential salinization of irrigated lands and on associated downstream waters.

In western Canada, surface water for irrigation is generally of good quality (low in salt) and does not appear to adversely affect most soils, but may affect the groundwaters beneath them:

- ***Soils.*** In Alberta, long-term irrigation did not salinize 12 of 13 test sites deemed to represent typical soils within 4 irrigation districts [Chang and Oosterveld 1981]
- ***Groundwater.*** Water tables monitored beneath irrigated lands in Alberta for up to 20 years, showed a significant increase in groundwater EC at 3 of 9 sites [Beke et al. 1992, in Miller et al. 1992]

Downstream Water Quality

Water quality downstream of irrigation

projects is an issue in many places, but this is not generally the case in Western Canada:

- ***Return flow.*** In Alberta, salinity in 38 irrigation return-flow channels was similar to diversion-water quality [Bolseng 1991, in Paterson 1992]

- ***Tile drainage.*** The salinity of tile drainage effluent can be very high but typical drainage flows are low, and net effects are expected to be negligible at normal river flow [Harker 1983]

Subsurface (groundwater) return flow from irrigated lands has had minimal impact on river water quality in southern Alberta [Robertson 1988].

By comparison, surface water quality below irrigated lands is seen as a major problem on the upper Colorado River in Utah [Clark 1994]:

- ***Irrigation related.*** About 37% of river salinity is said to be irrigation-related

- ***Natural sources.*** Almost half (47%) of river salinity is from natural sources

- ***No clear solution.*** Because of this significant dual effect, many believe a reduction in irrigation will not solve the problem

11.4 Trace Elements/Heavy Metals

Certain trace elements, alone or in agrichemical combinations, can also affect water quality.

Rivers and Lakes

In the Saskatchewan River Basin, data for heavy metals are generally restricted to mainstem sites [Environment Canada 1990]. Many heavy metals on the prairies are preferentially bonded to in-stream sediments, but concentrations are generally comparable to natural levels.

Green and Beck [1995] report on 14 years (1978-1992) of monitoring the Assiniboine river of Manitoba to assess the potential for trace metals to bio-magnify in fish muscle:

- ***Normal concentrations.*** Residues of arsenic, cadmium, chromium, copper, nickel, zinc and selenium "appeared to be in the range of normal background concentrations" [Green and Beck 1995]

- ***Except mercury?*** Mercury may be the exception. There is no clear evidence that historically high levels are declining

- ***Natural levels.*** It is often difficult to discern between natural and man-made sources for trace elements like mercury

In Finland, selenium has been purposely added to artificial fertilizers since 1985, as an essential micronutrient for humans and animals [Wang et al. 1995]:

- ***Increasing.*** Selenium in Finnish lake waters has increased since the last century

- ***Origin uncertain.*** There is no firm evidence to show this has occurred because of fertilizer rather than natural additions

Small Streams

Limited information is available for small streams. In Manitoba, the content of 6 heavy metal in Cooks Creek does not appear to pose a hazard. There, chromium, nickel, copper, zinc, lead and cadmium were generally just at or below detection limits [Hughes et al. 1994].

Irrigation

In Alberta, Greenlee and Lund [1995] monitored delivery and spill waters

Many heavy metals on the prairies are preferentially bonded to in-stream sediments, but concentrations are generally comparable to natural levels.

weekly for 2 irrigation districts over a 5 month period. Trace elements monitored included arsenic, cadmium, copper, lead, selenium:

- ***Very low levels.*** Most elements were very low or below detection limits (0.001 ppm)
- ***Below guidelines.*** All detections were below guidelines for human, livestock and irrigation use

Two years earlier, Greenlee et al. [1993] had sampled 6 trace elements weekly at delivery and return flow sites within 3 irrigation districts:

- ***Exceeded guidelines.*** In this case, at some time during monitoring, levels of cadmium, lead and mercury exceeded human guide-lines at all 8 locations sampled

Tile drainage waters from irrigated lands have been found to contain traces of cadmium and selenium at or slightly above detection levels [Harker 1983, Paterson 1992].

11.5 Summary

Other water quality risks, such as those associated with range livestock, are generally limited and of more local concern.

Livestock and Bacteria

The effects of grazing cattle on a watershed are generally indistinguishable from those of wildlife. Exceptions are high impact feeding and watering sites which can increase sediment, nutrient loading, and bacterial counts. Direct access to dugouts can foul water for cattle consumption and thus reduce production. Potential groundwater contamination by coliform bacteria may be related to intensive manure management.

Salinity and Trace Elements

Most irrigation waters on the prairies are generally low in salt and do not adversely affect most soils or receiving streams. Trace elements and heavy metal content do not appear to pose a general problem on the prairies.

Required Action

We need a better understanding of the effects of concentrated livestock watering, feeding and over-wintering sites on water quality. The frequency of bacterial contamination and its implications need clarification.

11.6 References

Agriculture Canada. 1993. Ontario Farm Groundwater Quality Survey. ISBN 0-662-20879-X. 162 pp.

Beke, G.J., T. Entz and D.P. Graham. 1992. Long-term water quality of shallow ground water at irrigated sites. J. Irrig. Drain. Eng. (in press).

Bennett, J.V., S.D. Holmbert, M.F. Rogers and S.L. Solomon. 1987. Infectious and parasitic diseases. *In* R.W. Amler and H.B. Dull (eds.). Closing the Gap: The Burden of Unnecessary Illness. Oxford University Press, New York.

Bolseng, T.A. 1991. Water Quality in Selected Return Flow Channels. Land Evaluation and Reclamation Branch, Alberta Agriculture, Lethbridge, Alberta.

Buchanan, Bob. 1992. Agricultural impacts on water quality for domestic purpose. Proceedings, Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, Alberta. p. 50-58.

CAST. 1992. Water Quality: Agriculture's Role. Council for Agricultural Science and Technology. Task Force Report No. 120. 103 pp.

Chang, C. and M. Oosterveld. 1981. Effects of long-term irrigation on soil salinity at selected sites in southern Alberta. Can. J. Soil Sci. 61: 497-505.

Clark, Ronnie D. 1994. A comprehensive watershed planning approach to salinity control in the Colorado River basin (unpublished). Watershed Wise: A Workshop On Wetlands Protection. Grand Junction, CO.

Dixon, J.E. 1983a. Controlling water pollution from cattle grazing and pasture feeding operations. *In*, Profit Potential of Environmental Protection Practices of Cattlemen. National Cattlemen's Association, Englewood, Colorado. p. 107.

Dixon, J.E. 1983b. Comparison of runoff water quality from cattle feeding on winter pastures. Trans. ASAE, 26(4):1146-1149.

Environment Canada. 1990. Off-Farm Sediment Impacts in the Saskatchewan River Basin. Prepared by M.A. Carson & Associates, Victoria B.C., for Inland Waters Directorate, Water Resources Branch, Saskatchewan District. 87 p.

Fitzgerald, D. 1995. Alberta farmstead water quality survey. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, Alberta. p. 138-140.

Green, D.J. and A.E. Beck. 1995. Mercury And Other Metal Residues In Fish From The Assiniboine River, Manitoba, Canada. Manitoba Environment. Report No. 95-07. 160 pp.

Greenlee, G.M. and P.D. Lund. 1995. Impacts of irrigation return flow from two irrigation districts in southern Alberta on surface water quality. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, Alberta. p. 80-94.

Greenlee, G.M., T.M. Peters and P.D. Lund. 1993. Surface Water Quality Monitoring of Irrigation Return Flow Streams in Southern Alberta - 1992. LERB, Irrigation and Resource Mgt. Div., AAFRD. Lethbridge, AB.

Harker, D.B. 1983. Characteristics, trends and surface water quality implications of saline tile effluent. *In* R.H. French (ed.). Salinity in Water Courses and Reservoirs. Proc. International Symposium on State-of-the-Art Control of Salinity. Salt Lake City, Utah. Butterworth Publishers, Toronto. p. 325-334.

Hughes, C.E., D.A. Williamson and B.M. Lussier. 1994. Water Quality Assessment of Cooks Creek, Manitoba, Canada. Cooks Creek Conservation District No. 5, and Manitoba Environment. Report No. 94-09. 46 pp.

Miller, J.J., G.J. Beke, C. Chang, N. Foroud, B.D. Hill and C.W. Lindwall. 1992. Impact of agricultural management practices on water quality in southern Alberta. Proceedings, Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 42-47.

Milne, C.M. 1976. Effect of a livestock wintering operation on a western mountain stream. Trans. ASAE, 19(4): 749-752.

Paterson, B.A. 1992. Preliminary assessment of water quality monitoring. Proc, Agri Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 65-72.

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, AB.

Rodvang, J. 1995. Personal communication. Hydrogeologist, Irrigation and Resource Development Branch, Alberta Agriculture. Lethbridge, AB.

Saxton, K.E. et al. 1983. Effect of Animal Grazing on Water Quality of Non Point Runoff in the Pacific Northwest: Project Summary. EPA-600/SZ-82-071. USEPA, Ada, OK.

Sweeten, J.M. 1984. Cattle feedlot waste management practices for water and air pollution control. USEPA. Texas Agricultural Extension Service.

Wang, D., G. Alfthan, A. Aro, A. Makela, S. Knuttila and T. Hammar. 1995. The impact of selenium supplemented fertilization on selenium in lake ecosystems in Finland. Agriculture, Ecosystems and Environment 54: 137-148.

Williamson, D.A., M.P. Boychuk and M.T. Ledoux. 1992. Water Quality Assessment of the Turtle River and Two Tributaries, Manitoba, Canada. Turtle River Conservation District # 2, and Manitoba Environment. Report No. 92-05. 52 pp.

Willms, W.D., O. Kenzie, Z. Mir and D. Quinton. 1995. Effects of water supplied from old dugouts on the performance of cattle. Proceedings, 5th International Rangeland Congress, Vol. 1. Salt Lake City, UT.

12.0 Priorities

Policy makers, researchers and others have identified the steps they see as necessary to clarify the status of, and take action to prevent, water quality problems on the prairies. As a result, many of these actions are being addressed to some degree. But much work remains to be done. Priorities fall into two main categories: Research and Monitoring, and Policy Direction.

12.1 Research and Monitoring

Research and monitoring needs cover a wide range of general and specific topics. To be effective, these must be addressed from both agricultural and multi-disciplinary viewpoints.

Agricultural Perspective

From an agricultural researcher's perspective, water quality needs are seen to include [Lindwall 1992, 1996]:

- ***Transport mechanisms.*** The fate and pathways of agrichemicals
- ***Watershed evaluation.*** Study cause and effect relationships
- ***Establishing protocols.*** Standardizing field and lab procedures
- ***Model development.*** Models and decision support systems

Lindwall also says we need: an improved understanding of the impacts of agriculture on other ecosystems; to focus on reducing sediment as a potential source of surface water pollutants; and to clarify the status of chemical fallow as a possible source of groundwater contamination.

Multi-disciplinary Opinion

Elsewhere on the prairies, multi-disciplinary researchers from the National Hydrology Research Institute (NHRI) see things from a different perspective [Nicholaichuk and Hendry 1992]. Many of their research interests are similar to Lindwall's [1992], but they also perceive the need to study:

- ***Biofilm*** pesticide degradation
- ***Toxic organics*** and their broad spectrum characterization
- ***Geochemistry*** of glacial deposits and solutes
- ***Aquatic macrophyte*** growth in rivers
- ***Chronic and acute*** pesticide residue effects on wetland invertebrates

Additional priorities identified by other multi-disciplinary interests include [Bennett et al. 1992]:

- ***Phosphate*** loading and eutrophication
- ***Inorganic nitrates*** and their fate
- ***Manure management***

Research and monitoring needs cover a wide range of general and specific topics. To be effective, these must be addressed from both agricultural and multi-disciplinary viewpoints.

- *Application techniques* to minimize agri-chemical pollution

In Manitoba, an inter-agency workshop classed nonpoint-source water quality issues into four main areas of interest [Vermette 1995]:

- ***Intensive livestock operations*** (ILOs). Proper siting and manure management practices
- ***Riparian zones and waterways.*** Buffer zones, erosion control and direct access problems
- ***Agricultural inputs and cultivation.*** Impacts from the fate and mobility of nutrients and chemicals, and best management practices (BMPs)
- ***Health issues.*** Monitoring and data analysis for domestic and stock-watering quality

We need to find a middle ground between frontier economics and deep environmentalism. [Colgan 1992]

12.2 Policy Direction

Policy direction in water quality should take into account both agricultural and broad-based public concerns. To do so effectively will require a coordinated, multi-agency response to resource planning and information sharing.

There is increasing recognition that maintaining or even increasing soil quality will help to buffer and filter the potential adverse effects of agrichemicals. [Lindwall 1996]

Agricultural Perspective

As an agricultural administrator, Colgan [1992] states that future attention to water quality issues needs to stress:

- ***Safe food***. Emphasis that the existing food supply is safe now
- ***Sustainable practices.*** Protect current agricultural practices that are sustainable
- ***Middle ground***. Find a middle ground between frontier economics and deep environmentalism

Colgan [1992] also points out the need to:

- ***Clarify*** current water quality conditions
- ***Develop*** a reliable water quality data base
- ***Modify*** problem agricultural practices
- ***Provide*** increased public education
- ***Foster*** coordination amongst agencies

It is clear that water quality policy needs to focus on setting priorities on how and where to evaluate potential contamination [Lindwall 1992]. There is also value in establishing long-term monitoring sites under representative, regional agricultural practices [Paterson 1992].

Lindwall [1996] also emphasises the value of directing policy towards the growing body of evidence that sound soil and water conservation will reduce the risk of deteriorating water quality. He says there is increasing recognition that maintaining or even increasing soil quality will help to buffer and filter the potential adverse effects of agrichemicals.

A Coordinated Approach

In order to assure all that their concerns are being met, water quality issues must be identified and addressed from a multi-disciplinary standpoint. The World Wildlife Fund (WWF) of Canada [1995] laments the existence of persistent chemicals and warns against a continued use it says could:

> ***"Threaten our health . . . and risk the long-term survival of many wildlife species and humans"***

Accordingly, the WWF suggests a broad-based planning approach that involves:

- ***Detailed testing*** to screen chemicals and determine their effects

- *A phase out* of harmful chemicals
- ***Reduced use.*** Implement a national pesticide reduction plan

A survey of over 500 landowners and community leaders in the Canora area of Saskatchewan identified the need to develop both an area water management plan, and a long-term urban awareness program to provide information to non-farm residents [Hass 1994]. The study noted there was room for a more coordinated approach to planning and monitoring water resources among the water agencies involved.

Similarly, the water quality policy of the Government of Manitoba [ca.1990] emphasizes the need for a balanced approach among the responsibilities of government, local authorities, industry and individuals.

In Alberta, multi-disciplinary discussion groups have emphasized the need for a coordinated approach to resolving water quality issues [Bennett et al. 1992]:

- ***Central steering group.*** Establishing a water quality task force to bring various water quality interests together
- ***Long-term planning***. The creation of an integrated, long-term, strategic plan

Such planning and priority setting must involve representation from a broad spectrum of interests — including the agriculture industry, as well as government and academics [McNulty 1996, Strankman et al. 1996]. The initial role for such a group might simply be to provide a forum for discussion and the clearing of new ideas [Cross 1996].

Targeting Government Programs

In all of this, there is a need to assure that limited fiscal and technical resources are targeted where they are most needed and will do the most good. CAST [1992] has warned that:

> ***Efforts by multiple levels of government to protect water from agricultural contaminants "necessitates development of an effective coordination strategy to avoid conflicts and duplication of effort"***

CAST cautions that failure to do so will result in the squandering of limited resources and conflicting programs that may even increase the contamination of one water source, while seeking to reduce the problems of another.

Water quality specialists in the US perceive that this might best be achieved by mandating future cooperation and coordination among principal federal and state agencies. They also see the need to assure that BMPs are aimed at those areas contributing most to nonpoint source pollution [Gannon et al. 1996].

As an example, growing concern over sediment loading from agricultural lands has increasingly focused the attention of government programs on the off-site impacts of erosion. Yet:

- ***Inefficient targets.*** US policies designed to control soil loss from cropland aren't necessarily targeted to areas where improvements in water quality are likely to result from reduced soil erosion [Gomez 1995]
- ***Increased accountability.*** Multi-disciplinary input is a requirement of effective remedial action and funding should be directed to improve accountability and heighten awareness of achievements [Humenik 1995]

But Lindwall [1996] points out there is a real need to continue to assure that resources are specifically targeted to address research and policy requirements in water quality:

- ***Green Plan projects***. Much recent water quality work was initiated through *Green Plan* and other federal/

Efforts by multiple levels of government to protect water from agricultural contaminants "necessitates development of an effective co-ordination strategy to avoid conflicts and duplication of effort." [CAST 1992] provincial agreements. Yet Green Plan funding is slated to end, with no obvious replacement program

- ***Alternative funding*?** Lindwall asks how the water quality thrust begun under *Green Plan* can continue, without new resources or the reprofiling of existing funds

A survey of elected officials in the United States indicates that, in the final analysis, water-related decisions are not so much based on technical soundness as on who best presents their message to policy makers. [Berry et al. 1995]

Education Needs

Education and awareness were identified as key water quality tools during a Green Plan workshop in Manitoba [Vermette 1995].

> ***A survey of elected officials in the United States indicates that, in the final analysis, water-related decisions are not so much based on technical soundness as on who best presents their message to policy makers*** [Berry et al. 1995]

Educators identified the need for school resource materials that: present a balanced viewpoint on the role of agriculture in the environment; are teacher-friendly; and will help to stimulate informed debate on the topic. [Hass 1994]

Pesticides have long been viewed as a double edged sword, creating enormous benefits on the one hand, while creating potential problems on the other. Price [1992] says that education regarding the hazards of pesticide use should start with commercial applicators, then move to farmers and others, to address issues of:

- ***Zero tolerance*** and residue concerns
- ***Pesticide drift.*** The reality it will occur
- ***Damage to wildlife.*** Risk it will happen
- ***Disposal problems*** for chemicals
- ***Health of applicators***
- ***Hypersensitivity*** of some bystanders

Price points out that both urban and rural applicators require an appreciation of the need to read and follow label directions.

Ross Williams, a farmer near Regina, Saskatchewan [1996], says that:

> ***"Almost all of my neighbours have been sick at some time or another from applying pesticides or from others having done so"***

Mr. Williams is aware of the problems that pesticides might create for non-involved people, especially those with hypersensitivities. Yet Williams believes the evidence indicates that pesticide use is generally beneficial. He questions, though, whether there is sufficient water quality discussion in the school system — from both sides of the issue.

According to Rhonda Phillips, a high school teacher and environmental consultant in Saskatchewan [1996], there may only be a 1:3 chance that a high school student in the province will receive instruction in water quality. This is because water quality is only one of three options in grade 10 science, that also include studying the greenhouse effect or uranium. Students receive some instruction on water quality in elementary school.

A survey of over 1,000 urbanites across Manitoba and Saskatchewan found:

> ***"Little awareness of the positive action farmers are taking to improve agricultural practices"***
> [The Advisory Group 1994]

Those educators who were specifically polled during the study identified the need for school resource materials that: present a balanced viewpoint on the role of agriculture in the environment; are teacher-friendly; and will help to stimulate informed debate on the topic. The urban/rural study by Hass [1994] identified:

> ***A need for public education, starting in schools but including conscientious producers, special interest groups, politicians and community leaders***

Educational needs include an increased understanding of the concept of relative risk, the cost/benefit considerations associated with agrichemical use, and emphasis that all chemicals are not inherently bad [Lindwall 1996].

12.3 Summary

Water quality priorities must address both research and monitoring needs, and a requirement for policy direction.

Research & Monitoring

There is wide-spread recognition of the need to better understand how agrichemicals move in the environment. This will require the standardization of field sampling and lab analysis protocols, and the development of improved modelling techniques. Research is required towards reducing pesticide application losses — to see that inputs are applied in the appropriate formulations, amounts and locations. Importance is placed on a holistic approach to watershed management and its effects on the environment and human health.

Policy Direction

There is a need to clarify current safe levels, and to identify and promote sustainable land management practices. We must find a common ground of understanding between opposing points of view on water quality. A coordinated, integrated approach to research and policy direction is required. A balanced viewpoint on water quality concerns is needed — one that is client-friendly and leads to informed debate amongst producers, special interest groups, politicians and the public at large.

Required Action

A prairie-wide focus towards addressing water quality issues is required to assure the effective pursuit of common priorities and the targeting and efficient use of limited resources. The formation of a multi-agency working group to this end will do much towards assuring that government agencies, academics, industry and special interest programs are effectively integrated at the early planning stage. The impending cessation of Green Plan funding and the absence of a replacement program poses a serious constraint to continuing the water quality initiatives already underway.

12.4 References

Bennett, D.R., J.J. Miller and D.O. Trew. 1992. Water quality workshop discussions. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 98-103.

Berry, K.A., N.L. Markee, M.M.S. Stewart and Gary Giewat. 1995. Sources of knowledge: A survey of local elected policy makers . . . Abstract. Proc. Water In The 21st Century: Conservation, Demand, and Supply. American Water Resources Association. Salt Lake City, UT. p. 15.

Colgan, Brian. 1992. Future direction and key issues in surface and groundwater quality. Proc. Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 85-87.

Gannon, R.W., D.L. Osmond, F.J. Humenik, J.A. Gale and J. Spooner. 1996. Goal-oriented agricultural water quality legislation. Water Resources Bulletin, Vol. 32, No. 3:437-450.

Gomez, Basil. 1995. Assessing the impact of the 1985 farm bill on sediment-related nonpoint source pollution. J. Soil and Water Cons. 50(4) 374-377.

Government of Manitoba. ca.1990. Applying Manitoba's Water Policies. MG 3603A.

Hass, Glen. 1994. Toward A Greener Generation Of Rural Families. Final Report. Organizational Management Services; for The Advisory Committee, District 18 & 19 ADD Boards. CSAGPA. 120 pp.

Humenik, F., J. Spooner, J. Converse and R. Miner. 1995. Taking a position on non-point source control. Resource, ASAE, July 1995. P. 16-17.

Lindwall, C. Wayne. 1992. Future direction and key issues in surface and groundwater quality: Research perspective. Proc. Agricultural Impacts on Surface Water Quality. Lethbridge, Alberta. p 88-91.

Lindwall, C. Wayne. 1996. Personal communication. E-mail dated June 22, 1996. Research Branch, AAFC, Lethbridge, AB.

McNulty, Joe. 1996. Personal communication. Monsanto Canada Ltd. Winnipeg, MB.

Nicholaichuk, W. and M.J. Hendry. 1992. Agricultural impacts on surface and groundwater quality: NHRI update. Proc. Agric. Impacts on Surface and Groundwater Quality. Lethbridge, Alberta. p. 36-41.

Paterson, B.A. 1992. Preliminary assessment of water quality monitoring. Proceedings, Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, AB. p. 65-72.

Phillips, Rhonda. 1996. Personal communication. Telephone conversation, July 30, 1996. Rhonda Phillips Consulting. Lumsden, Saskatchewan.

Price, K. 1992. Pesticide certification program. Proceedings, Agricultural Impacts on Surface and Groundwater Quality. Lethbridge, Alberta. p. 25-35.

Strankman, Peggy, Gary Sergeant and Ron Glaser. 1996. Personal communication. Canadian Cattleman's Association. Calgary, Alberta.

The Advisory Group. 1994. Agriculture And The Environment, Urban Awareness Program - Manitoba And Saskatchewan. For Agriculture and Agri-Food Canada, PFRA, Manitoba Agriculture, and Sask. Agriculture and Food. 194 pp.

Vermette, A. 1995. Manitoba CMAAS program. Proceedings, Agricultural Impacts On Water Quality. CAESA. Red Deer, Alberta. p. 18-23.

Williams, Ross. 1996. Personal communication. Farmer, Regina, SK.

World Wildlife Fund Canada. 1995. Toxics are tampering with our hormones. Working For Wildlife, Fall 1995. p. 1.

13.0 Extended Summary

Following is a collection of the summary statements and recommended action steps, generally found separately at the end of each chapter of the report.

1.0 Nonpoint-Source Water Quality

The impact of agricultural practices on nonpoint-source water quality is an issue on the Canadian prairies. Nonpoint-source contributions are those that can occur from the application of agricultural practices to the land base in general. Runoff and leachate from agricultural lands may be contributing unacceptable levels of sediment and concentrations of pesticide and fertilizer chemicals to surface and groundwater supplies. This could adversely affect water use and safety for human life and the entire ecosystem.

Uncertain Extent and Severity

Findings elsewhere in North America and the world are being extrapolated to the Prairies and have raised concerns. Yet the extent and severity of the problem are by no means clear. It is certain that localized agricultural "hot spots" occur. It is uncertain how representative these isolated findings are of agriculture in general.

Balanced Perspective

The purpose of this review is to present a balanced perspective of agricultural nonpoint-source water quality issues. The information can be condensed for use at field office and public awareness levels. It is intended to serve as a platform towards identifying and achieving common research and policy priorities.

2.0 Public Perception

Problems with water quality on the prairies are perceived to be increasing. Many people see water pollution as a serious environmental danger. They want a more integrated approach to water management, better information, and more input into water quality decisions.

It is certain that localized agricultural "hot spots" occur. It is uncertain how representative these isolated findings are of agriculture in general.

Conflicting Messages

The public is receiving conflicting messages about how severe and widespread water quality problems are on the prairies. Negative opinions are often based on an analysis of limited information. Perceptions of water quality are closely linked to those of food safety. Recent testing confirms that Canadian food commodities are well within safety standards for pesticide residues.

Proactive Agriculture

Agriculture needs to expand its proactive stance towards clarifying the role it plays in water quality issues. Governments of all levels have incorporated water quality objectives into their planning strategies with a view to secure a more holistic, comprehensive approach to resource conservation. The most sensible, cost-effective approach will likely be to allow the agricultural community to devise and implement pollution controls as needed. However, regulation is imminent and action is needed now.

Required Action

The very act of using water for most purposes changes its quality. Conflicting messages on water quality must be clarified. Agriculture must continue to expand its proactive role, because answers are needed now. It is in agriculture's best interest to work closely with others to clarify the status of water quality concerns as soon as possible.

3.0 Understanding Risk

The concept of relative risk is the subject of considerable discussion and debate. There is a need to clarify in the public mind, the relevance of encountering small amounts of pesticide or other agrichemical.

There is a need to clarify in the public mind, the relevance of encountering small amounts of pesticide or other agrichemical.

Risk Assessment

Risk assessment is at best an imprecise science having "a dearth of qualified practitioners." Traditional approaches involving probabilities, statistics, and risk analysis are not sufficient in the public mind. Risk assessment must consider both dose and concentration, because risk involves time/dose relationships.

Zero Tolerance

The concept of Zero Tolerance in water quality holds that even trace amounts of an unnatural substance are unacceptable. Yet demand for zero risk may be both unreasonable and unattainable. Risk analysis comes down to a matter of probabilities. And there's a lot of room for interpreting final results, for "subjectivity always exists or scientists would never disagree."

Required action

Risk assessment must be put into a context that both the scientist and lay-person can comprehend. We need to "strike some balance between the health and economic costs of underestimating the risk and the costs of overestimating it."

4.0 Prairie Setting

There is concern that nonpoint agrichemical use on the prairies may pose a hazard to surface and groundwater quality. This is because of the large spatial extent of agricultural contributions and the potential difficulty of controlling them.

Prairie Pesticide Use

Canadians use less pesticides than many other developed countries. The prairies apply less pesticides per ha than the rest of Canada, but almost 76% of the total applied nationally. Part of this is used for urban and non-agricultural purposes. The switch to more environmentally friendly pesticides is slowly increasing.

Low Risk Zone?

The risk that nonpoint agrichemicals might pollute surface and groundwaters on the prairies may be lower for several cropping, climatic and soil reasons. Exceptions are lands under intensive agriculture. But dry prairie conditions could result in seasonally concentrated runoff and leachate.

Required Action

The portion of agrichemicals applied in urban areas and their relative impact on water quality requires further study. We need to quantify the conditions that govern when and whether the prairies are a high risk vs. a low risk zone of contamination.

5.0 Data Interpretation

Some key concepts are fundamental to our understanding of the potential for agrichemicals and other nonpoint-source contaminants to affect surface and groundwater quality.

Chemical and Biophysical Interactions

The characteristics of individual agrichemicals and the effect of specific farming practices on the soil environment can significantly influence the bio-physical interactions that occur and their impact on water quality.

Sampling and Analysis Protocol

Water quality findings are often contingent upon a number of underlying assumptions. The sampling and analysis techniques used in the field and laboratory can greatly affect the results achieved.

Water Quality Guidelines

The Canadian Water Quality Guidelines are a generalized interpretation of water quality research. They are not hard and fast rules and *continually* exceeding them "may, in some instances, be capable of introducing deleterious effects on health." They are not accepted by everyone but serve as a useful benchmark against which to assess relative water quality.

Required Action

A better understanding of the chemical and biophysical interactions that regulate the availability and mobility of agrichemicals is needed. Further work is needed to clarify appropriate sampling and analysis protocol to allow for the effective, on-going comparison of multiple data sets. Both the scientific and lay public require a clearer understanding of the rationale behind the Canadian Water Quality Guidelines and other interpretations of relative water quality.

6.0 Prairie Water Quality

The effect of nonpoint agricultural practices on prairie water quality has been assessed in terms of a recent general overview of prairie conditions, and a more detailed analysis of specific prairie findings.

Continually exceeding water quality guidelines "may, in some instances, be capable of introducing deleterious effects on health."

A Recent Prairie Overview

A recent Green Plan symposium (CAESA 1995) provides a timely update of nonpoint water quality issues and projects across Western Canada. No evidence was presented of wide-spread, long-term agricultural pollution. A wide variety of projects on the prairies are underway to measure the impact of agriculture on water quality. Emphasis is on existing and potential "hot spots" as early indicators of developing problems.

Specific Prairie Findings

The specific prairie findings reported herein are based largely on a review of available summary documents and expert opinion. Where conclusions related to specific contaminant levels have been drawn, these assume that water quality guidelines are a legitimate basis of evaluation.

7.0 Sediment

Sediment can itself be a water quality problem or a transport mechanism for naturally occurring elements and the fertilizer and pesticide residues that might move into surface waters. Yet in major rivers of the Canadian prairies, the proportion of sediment loading from farmland erosion seems to be "relatively insignificant."

Loading Estimates

There is a disparity between projected on-farm soil erosion rates and in-stream sediment yields on the prairies. This may be because projected soil erosion rates are too high, or perhaps agricultural sediment is being trapped in fields or stored in streams before reaching sampling locations.

The relative contribution of range cattle to silt loading may be minimal and remains largely undocumented.

Pothole Topography and Runoff

The pothole topography of much of the prairies may temper whether eroded sediment reaches streams and rivers. The clearing and drainage of agricultural lands can increase surface runoff, indirectly accelerating in-stream erosion and related silting problems.

Cattle effect

Concentrated grazing and watering sites can have a negative impact on riparian habitat and local sediment loading. In the watershed at large, however, the effect of range cattle are often indistinguishable from those of wildlife. The relative contribution of range cattle to silt loading may be minimal and remains largely undocumented.

Required Action

An increasing portion of investigative resources ought to be directed towards small-scale watershed evaluation. Further work is needed to clarify whether projected agricultural loadings are taking place. We need to better understand the place of pothole topography in filtering surface waters. The effect of increased agricultural runoff on in-stream erosion and secondary siltation can have a significant, negative impact on aquatic life and must not be ignored. Despite their high visibility, the relative role of range cattle in silt loading is uncertain and requires clarification.

Pesticides are found to some extent in surface and groundwaters across the Canadian prairies. Yet these findings are relatively few, with most detections being well below water quality guidelines.

8.0 Pesticides

Pesticides are found to some extent in surface and groundwaters across the Canadian prairies. Yet these waters contain relatively few pesticides, with most detections being well below water quality guidelines. Results are largely from isolated studies and are of unclear meaning.

Hazard Areas

Intensive agricultural areas, including irrigated lands, have the potential to develop problems first. Some herbicides have been found under irrigated lands on the prairies. However, even beneath the most intensively farmed lands of southern Ontario, there is limited evidence of pesticide detection in groundwater.

Governing Factors

The extent and concentration of pesticides in surface and groundwaters might be affected by factors such as soil texture, irrigation method, the type of pesticide used, tillage practice, and organic matter. Field condition at the time of application, prior to and during testing, might also be a factor.

Required Action

A continued focus on intensive agricultural lands is required to isolate the factors governing pesticide movement. We need to clarify the relevance of current pesticide detections on the Prairies. How significant are the trace detections of chemical residue, their approach or exceedence of Water Quality Guidelines? When detections occur, how representative are they of long-term levels and trends?

9.0 Nitrate

There is evidence of possible nitrate contamination of surface and groundwater on the Prairies. Levels periodically exceed Water Quality Guidelines, but results vary widely.

Natural Sources

It is frequently uncertain what portion of nitrate levels in surface and groundwaters derive from agricultural vs. natural sources. Long-term data on baseline nitrate levels is limited.

Fertilization & Irrigation

Soils receiving high rates of manure and chemical fertilizer show evidence of nitrate buildup. Soil texture, cropping patterns, precipitation or irrigation management appear to play a prominent role in leaching hazard.

Required Action

There is an urgent need to effectively document baseline nitrate levels and clarify the source and fate of nitrate contamination. Efforts should focus on intensive land use, shallow aquifers and periods of high precipitation or irrigation. Investigation within agricultural field boundaries is needed, not just the collection of convenient data from nearby municipal and farm wells.

10.0 Phosphorus

Phosphorus loadings to lakes and streams can result from agricultural activities. But P loadings are often based on calculations and estimates and thereby subject to error. Much work remains to clarify the relative role of agricultural P in water quality.

Uncertain Net Effect

P loadings from agricultural and other lands can vary widely, depending on rainfall and other factors. Estimating the net effect of agricultural P on water quality is difficult. It is a complicated process and short-term effects can be hard to document.

Estimating the net effect of agricultural P on water quality is difficult. It is a complicated process and short-term effects can be hard to document.

Prairie Waters

The mainstream waters of the prairies have P concentrations close to background levels and occasional eutrophication is largely a summer phenomenon downstream of sewage treatment plants. The level of P in small streams and lakes may be more closely related to agricultural practices, but relationships are unclear.

Required Action

There is a need to clarify the net effect of P loadings from agriculture vs. other sources, including the natural variability of P within ecosystems. Modelling predictions need to be calibrated to local field conditions before final decisions are based on the results.

11.0 Other Risks

Other water quality risks, such as those associated with unconfined range livestock, are generally limited and of more local concern.

Livestock and Bacteria

The effects of range cattle grazing on a watershed are generally indistinguishable from those of wildlife. Exceptions are high impact feeding and watering sites, which can increase sediment, nutrient loading, and bacterial counts. Direct access to dugouts can foul water for cattle consumption and reduce production. Potential groundwater contamination by coliform bacteria may be related to intensive manure management.

Salinity and Trace Elements

Most irrigation waters on the prairies are low in salt and do not adversely affect most soils or receiving streams. Trace elements and heavy metal content do not appear to pose a general problem on the Prairies.

Required Action

We require a better understanding of the effect of concentrated livestock watering, feeding and over-wintering sites on water quality. The frequency of bacterial contamination and its implications need clarification.

12.0 Priorities

Water quality priorities must address both research and monitoring needs, and the requirement for policy direction.

Research & Monitoring

There is wide-spread recognition of the need to better understand how agrichemicals move in the environment. This requires the standardization of field sampling and lab analysis protocols and the development of improved modelling techniques. Research is required towards reducing application

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losses — to see that inputs are applied in appropriate formulations, amounts and locations. Importance is placed on a holistic approach to watershed management and its effects on the environment and human health.

Policy Direction

There is a need to clarify current safe levels, and to identify and promote sustainable land management practices. We must find a common ground of understanding between opposing points of view on water quality. A coordinated, integrated approach to research and policy direction is required. A balanced viewpoint on water quality concerns is needed — one that is client-friendly and leads to informed debate amongst producers, special interest groups, politicians and the public at large.

Required Action

A prairie-wide focus towards addressing water quality issues is required to assure the effective pursuit of common priorities and the targeting and efficient use of limited resources. The formation of a multi-agency working group to this end will do much towards assuring that government agency, academic, industry and special interest programs are effectively integrated at the early planning stage. The impending cessation of Green Plan funding and the absence of a replacement program poses a serious constraint to continuing the water quality initiatives already underway.

14.0 Conclusions

1. Uncertain Findings
The wide-spread nature of agricultural practices on the Prairies makes it certain that contamination by agrichemicals will occur to some degree. Yet the extent and severity of the potential problem are uncertain.

2. Public Confusion
The public receives confusing messages as to the role of agriculture in water quality. There is a need to verify the merit of data sets upon which public opinion is based.

3. Relative Risk
The concept of relative risk is ill-defined and hard to understand. Even among professional researchers, despite apparent standards, there is no clear demarcation as to when a problem is significant.

4. "Low Risk" Prairie Setting
Because of its cold, dry climate, the Prairies may be a relatively "low risk" zone of contamination from agrichemicals, in comparison to other places. But these same Prairie conditions might cause their own, seasonal water quality problems.

5. Key Interpretation Concepts
Complex interactions between agrichemicals and the soil/water microclimate can greatly affect how agrichemicals impact on the environment. Individual perception of water quality guidelines, and the effect that sampling and analysis protocols have on results, can significantly influence the way we interpret water quality data.

6. Limited Contamination
Within the context of the Canadian Water Quality Guidelines, we find no clear evidence on the prairies of the *wide-spread* contamination of surface and groundwaters from agricultural activities. This does not mean there are no problems nor the potential for them to occur. But current problems are generally neither wide-spread nor excessive in degree.

- **Sediment.** Sediment loading on major rivers is, at most, a seasonal problem

- **Pesticides.** Relatively few pesticides are detected in prairie waters, and these rarely exceed current guidelines

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Within the context of the Canadian Water Quality Guidelines, we find no clear evidence on the prairies of the wide-spread contamination of surface and groundwaters from agricultural activities.

We need a prairie-wide, coordinated approach to research and policy direction, to assure the optimum use of limited fiscal and technical resources.

- **Nitrate.** Nitrate contamination of ground-water is more likely, being a higher risk under intensively fertilized and irrigated lands

- **Phosphorus.** Phosphorus contributions to surface waters are evident, but the net effect of agricultural loadings is uncertain

- **Other Risks.** Risks associated with range livestock, salinity, and heavy metals are generally limited and of local concern

7. Priorities

There is a commonly-held recognition of the need to better understand how agrichemicals move in the environment. Importance is placed on a holistic, watershed approach to research and development. We need a prairie-wide, coordinated approach to research and policy direction, to assure the optimum use of limited fiscal and technical resources.

15.0 Recommendations

The following recommendations might be applied by any agency concerned with water quality assessment and issues across the Prairies.

1. Facilitate Public Discussion
Facilitate open public discussion about the role and reality of agriculture in water quality. Examine the information sources upon which public opinion is based. Remind urbanites that they also use agrichemicals and may locally be a significant part of any perceived problem.

2. Confer on Relative Risk
Host or participate in a conference or educational activity to discuss the concept of relative risk and the merits of Zero Tolerance, Water Quality Guidelines, and other schools of thought. What are the economic and technical implications of these positions? Explore areas of common ground and interest. How can the lay public and scientific community be helped to better understand and assess the risk/benefit posed by agrichemicals?

3. Clarify Water Quality Concepts
Cooperate in the production of information defining and comparing important water quality terms and concepts. What is Zero Tolerance and how does it differ from a Guidelines approach to water quality? What are the criteria, strengths and limitations behind the Canadian Water Quality Guidelines? How is water quality sampled and analyzed and how can this affect final results?

4. Foster Watershed Planning
Encourage a small-basin thrust to water quality studies. Pursue a holistic approach to research, monitoring and development activities on representative watersheds. Involve the general public and local community groups in data evaluation and decision making.

5. Research and Monitoring Needs
Research and monitoring efforts might address specific topics within the following general categories:

- ***Baseline levels*** of sediment and nutrient loading over time
- ***Fate and mobility*** of agrichemicals and the factors that affect them
- ***Chemical use efficiencies.*** Improved strategies in the locations and amounts applied
- ***Sampling and analysis protocols***
- ***Significance of detections.*** Do ongoing detections indicate long-term trends or simple isolated findings?

We need to explore ways in which the lay public and scientific community can better understand and assess the risk/benefit posed by agrichemicals.

An urgent need involves targeting the direction of water quality policy, and securing alternative funding to replace the shortfall created with the end of Green Plan financing.

- ***Significance of variability.*** What level of variability in the spatial and temporal distribution of contaminant findings is deemed to constitute a problem?

- ***Net effect.*** How well can we predict and track the net effect of agriculture?

6. Promote Inter-Agency Coordination
Participate in a multi-disciplinary, inter-agency committee to coordinate water quality work across the Prairies. This would consist of joint discussion towards how best to use limited prairie fiscal and technical resources to achieve common goals and priorities. An urgent need involves targeting the direction of water quality policy, and securing alternative funding to replace the shortfall created with the end of Green Plan financing.