NORTHERN RIVER BASINS ECOLOGICAL AND HUMAN HEALTH STUDIES: SUMMARY, RELEVANCE, AND RECOMMENDATIONS

NRB Human Health Monitoring Program Management Committee

For more information contact:

Health Surveillance
Alberta Health
P.O. Box 1360
10025 Jasper Avenue
Edmonton, Alberta Health
T5J 2P4

Phone: 780-427-4518
Fax: 780-427-1470

ISBN (0-7785-0202-3)

TABLE OF CONTENTS

SECTION **PAGE**

1. INTRODUCTION 1

2. SUMMARY OF ECOLOGICAL FINDINGS FROM THE NORTHERN RIVER BASINS STUDY 2
   - 2.1 Contaminants in Water, Sediments and Fish 3
   - 2.2 Effects of Contaminants on Aquatic Life 5
   - 2.3 Drinking Water Quality in the Basins 7
   - 2.4 Cumulative Effects 8

3 METHODS USED TO EVALUATE ASSOCIATIONS BETWEEN ENVIRONMENTAL AGENTS AND HUMAN HEALTH 10
   - 3.1 Risk Assessment 10
   - 3.2 Epidemiological Studies 13

4. SUMMARY OF THE NORTHERN RIVER BASINS HUMAN HEALTH MONITORING PROGRAM 16
   - 4.1 Purpose and Objectives 16
   - 4.2 Scope of the Human Health Monitoring Program 17
   - 4.3 The Design of the NRBS Human Health Monitoring Program 18
   - 4.4 Discussion of Contaminants of Potential Concern in the Basins 18
   - 4.5 Summary of the Findings of the Northern River Basins Human Health Monitoring Program 27
     - 4.5.1 General Results 27
     - 4.5.2 Diseases Found to be More Common in the Basins 27
   - 4.6 Limitations of the Health Study 32

5. RECOMMENDATIONS FOR FURTHER STUDIES IN THE NORTHERN RIVER BASINS 34
   - 5.1 Develop a Framework for Integration of Ecological and Human Health Studies 34
   - 5.2 Take Advantage of Current and Planned Ecological Monitoring 35
   - 5.3 Implement NRBS Recommendations Relevant to Human Health 37
   - 5.4 Coordinate with Other Current and Planned Health Studies in the Basins 37
   - 5.5 Prioritize Further Health Studies 39

5. REFERENCES 41

1. INTRODUCTION

The Northern River Basins Human Health Monitoring Program (the Health Program) was established in November 1994 to examine possible relationships between various environmental risk factors (including lifestyle factors as well as biological and chemical contaminants) and the health of northern residents. The Health Program was created in response to public concerns that the large scale Northern River Basins Study (NRBS) mainly examined ecological health, and did not include an explicit examination of human health. The Health Program was carried out by Alberta Health under the direction of a Management Committee representing eight government and public stakeholder groups.

This document, “Northern River Basins Ecological and Human Health Studies: Summary, Relevance, and Recommendations” (Summary Document) was requested by the Management Committee of the Health Program. The purposes of this document are: (1) link the ecological information collected by the original NRBS program with the information provided by the Health Program; (2) summarize issues and findings of the Health Program; and, (3) provide recommendations for further study. The Management Committee felt that a document was needed that provided perspective and context for the Health Program. This document is organized into the following main sections:

1. Summary of ecological findings from the NRBS;

2. Summary of the Health Program; and

3. Recommendations for further studies in the Northern River Basins.

2. SUMMARY OF ECOLOGICAL FINDINGS FROM THE NORTHERN RIVER BASINS STUDY

The NRBS ecological studies focused on several broad research questions related to:

- Traditional knowledge;
- The effects of flow regulation (dams on rivers);
- Fish distribution, movement and habitat;
- The effects of addition of nutrients resulting from human activities to the river system;
- Factors controlling dissolved oxygen concentrations in surface waters;
- Chemical contaminant concentrations in the environment;
- Effects of contaminants on aquatic life;
- The quality of drinking water in the Basins;
- Ecosystem health in general; and
- Cumulative or total effects from all stress (impacts) on the river systems.

Human health was not included in the research questions, although many of the ecological studies contributed data that were relevant to health. This section provides a brief review of the major findings of the NRBS that are relevant to human health concerns. This review focuses on contaminant concentrations in **water, sediments and fish**, the effects of contaminants on aquatic biota, and the quality of drinking water in the Basins. Cumulative effects are also reviewed.

2.1 Contaminants in Water, Sediments and Fish

This summary and discussion will focus on the contaminants of most potential concern to ecological health of the Basin's ecosystem. A large number of contaminants were examined in the NRBS, including chlorinated organic compounds, metals, pesticides, and radionuclides (such as uranium). These contaminants were measured in water, fish, and sediments at several locations in the Basins, especially above and below discharges from pulp mills or oil sands operations.

The mere *presence* of contaminants in water, sediments or fish does not necessarily mean that toxic effects will occur. Exposure to these compounds determines toxicity; that is, a particular dose must be reached before toxic effects will occur. Exposure to a contaminant is determined by several factors, including: the contaminant's concentration in water and in food sources; the length of time an organism spends in a particular section of the Basins; and, the ability of an organism to eliminate or break down the contaminant once it is ingested or absorbed into the body. For example, if a fish does not feed in an area just downstream of a pulp mill, and uses the area just for passing through, actual exposure to contaminants in pulp mill effluents will be negligible.

Dioxin and furan concentrations in fish have declined sufficiently that it has been recommended that existing fish consumption advisories for the upper Athabasca and the Wapiti/Smoky system be re-evaluated (NRBS 1996). Chlorinated phenolic compounds and resin acids are well below human health consumption guidelines (Gabos et al. 1996). Chlorinated organic compounds such as dioxins and furans, chlorinated phenols and chlorinated resin acids are byproducts of various human activities such as pulp and paper manufacturing, wood treatment, pesticide use and solvent use. These chemicals are commonly found at low levels in the environment largely due to their persistence or stability (many of these chemicals do not break down easily). Concentrations of these chemicals in water, sediments and fish have declined since the late 1980s; however, they can still occur in detectable levels in sediments and fish in the Basins (Wrona et al. 1997). In general, higher concentrations occur in areas immediately below pulp mill effluent discharges. The observed decline in the concentration of these contaminants in sediments and fish since the late 1980's is probably due to improvements in the bleaching process technology and effluent treatment by the pulp mills in the Basins (Wrona et al 1997). However, dilution with uncontaminated sediments and/or resuspension and redistribution within the aquatic system has also contributed to decreases in concentrations.

A preliminary assessment of the PCB and organochlorine pesticide concentrations in fish muscle and liver using Health Canada's tolerable daily intake (TDI) values and United States Environmental Protection Agency (USEPA) acceptable levels showed that concentrations did not represent a likely human health hazard (Pastershank and Muir 1996). Higher concentrations of polychlorinated biphenyls (PCBs- another byproduct of human industrial or manufacturing activities) and organochlorine pesticides such as DDT were found in burbot liver, and to a lesser extent mountain whitefish and northern pike muscle immediately downstream of municipal or industrial sources (including pulp mills) compared to other sides (Pastershank and Muir 1996). The reason for this is unclear. There were no differences in average PCB or DDT levels in fish collected from the Wapiti/Smoky river system from 1992 and 1994. Toxaphene (another pesticide) levels in burbot liver were lower than expected (Pastershank and Muir 1996). Many of the "contaminants" measured in the Basins have natural resources. Fish and other organisms in the Basins are exposed to certain contaminant concentrations because of natural factors such as the presence of oil sands formations or the presence of mercury in soils in the drainage basin. Thus, the presence of some types of contaminants does not necessarily mean the sources are industrial, municipal or agricultural discharges.

Measured mercury concentrations in sediments and fish tissues have remained relatively constant throughout the Basins since the 1980s, despite increased industrial activity (Wrona et al. 1997). There is no evidence to suggest that mercury levels in burbot change according to location in the Basins. Levels of mercury in samples of walleye collected in the lower Athabasca Basin in some cases exceeded Health Canada guidelines; recommendations have been made regarding continuation of fish consumption advisories in this region (Wrona et al. 1997).

Studies of contaminants in waterfowl, muskrats and mink in the Basins found either no or barely detectable levels (Wrona et al. 1996). Thus there is no evidence that consumption of waterfowl or muskrat by humans would lead to unacceptable exposure levels.

Gobas and coworkers (1996) recommended that the possible connections between mercury, dioxins, furans and toxaphene and human health should be examined in their review of contaminants of potential concern in the Basins. Other contaminants such as PCBs, chlorinated phenolics and radionuclides were at very low levels and within the human health guidelines recommended by government agencies.

The NRBS expressed a concern that the public perception that fish and other wildlife are contaminated with chemicals and unfit for consumption has resulted in major changes in the diet of the First Nation peoples in the Basins. These adjustments to diet would have health implications; for example, a change to processed foods with high fat, salt and sugar content may pose increased risks of heart disease. The NRBS recommended that this issue be investigated. Addressing the issue of diet change due to perceptions of contamination is very important, especially in light of the NRBS data showing that most contaminants (including dioxins and furans) (Golder 1997) are below Health Canada consumption guidelines. It appears that the main contaminant of concern is mercury in walleye from downstream areas of the Athabasca River. The source of that mercury is presently unclear, but it is likely natural rather than industrial.

2.2 Effects of Contaminants on Aquatic Life

Animals and plants living in the rivers of the Basins receive the maximum exposure to contaminants released to those rivers. Therefore, these organisms can be used as indicators of potential effects from contaminants. These effects are relevant to ecosystem health and may be useful as early warning indicators for humans living in the Basins. The ways that contaminants may cause toxic effects in aquatic organisms may be very different from that in humans, and the concentrations required to produce effects may be very different. However, monitoring of the health of aquatic life can provide part of the weight-of-evidence needed for an assessment of potential risks to human health. Most of the NRBS studies concentrated on fish.

Scientists use a variety of sensitive tests to determine whether effects due to contaminant exposures are occurring in aquatic life. These tests measure changes in the physiology of the organism. These physiological changes do not necessarily mean that the organism is experiencing harmful effects. Examples of physiological responses include changes in enzyme or hormone levels. A Basin-wide survey of physiological responses in fish indicated limited evidence of responses to pulp mill effluents, some responses in oil sands areas, and some responses that appeared to be unrelated to pulp mill or other obvious contaminant sources (Carey and Cordeiro 1997). Although preliminary studies were initially suggestive of physiological responses in fish downstream of a pulp mill, by the end of the study most of these responses were not evident (Carey and Cordeiro 1997). This apparent improvement was presumably due to process modifications that occurred at the mills during the study (Carey and Cordeiro 1997). Mild changes in liver enzymes occurred in organisms near oil sands industrial plants but also in natural oil sands areas where no development has taken place. Proteins produced in response to metal exposure were elevated at some downstream sites (especially in the Slave River Delta), but there was no relationship with pulp mills and there were no associated health effects in the fish with elevated protein levels.

Despite the general absence of physiological effects on fish in the Basins, there were three locations of concern identified in the NRBS: The Wapiti/Smoky River system; the Hinton-to-below-Whitecourt area of the Athabasca River and the oil sands area in the lower Athabasca. The first two locations are downstream of pulp mills.

The Wapiti/Smoky and Hinton-to-Whitecourt locations produced evidence of depressed sex hormone levels in fish, a higher ratio of immature to mature fish and a higher incidence of visible abnormalities than other areas in the Basins (Wrona et al. 1997). However, there were no differences in egg size or total egg number corresponding with low hormone levels in females. The high proportion of immature adult size fish may have been due to fish using different parts of the river basins at different stages in their lives (for example, immature fish may collect in certain habitats that correspond with locations downstream of pulp mills) (Carey and Cordiera 1997). The high incidence of visible abnormalities may be related to physiological and behavioural responses to spawning, differences between species (for example, longnose suckers appeared to have occasional very high frequencies of abnormalities that are unrelated to contaminants), or pulp mill effects (Mill et al. 1997). However, Mill and coworkers (1997) state that there is only a slight indication of adverse responses in fish near pulp mills. They also point out that other studies have not found consistent, significant differences in fish abnormalities near pulp mills compared with fish from elsewhere (Swanson et al. 1993, Shelast et al. 1994).

Fish in the oil sands area demonstrated physiological responses (for example, increases in liver detoxification enzymes, some increases in protein response to metals, and some reduction of liver vitamin content). These responses were not related to any particular discharge sources; rather, they appeared to reflect exposures to petroleum hydrocarbon and metal levels associated with natural oil sand deposits (Carey and Cordiera 1997). These researchers stressed that further work is required in the oil sands area.

There is also a need for more research into the possible connections between contaminants, physiological responses such as liver enzymes, and population-level responses (for example, number of eggs per female, growth and survival of fish). No population-level responses were found in fish in the Basins. The physiological responses may serve as early warnings of future ecological effects or they may represent natural variations that have no effects on fish populations (Wrona et al. 1997). It is difficult to tell which is the case at this point.

2.3 Drinking Water Quality in the Basins

Comparisons of water quality data from the NRBS and the Canadian Drinking Water Quality Guidelines indicates that chemical contaminants in drinking water are not likely to be a public health issue (Wrona et al. 1996). Concentrations of contaminants in general fall below these health-based guidelines. The only exception to this concerns the formation of trihalomethanes, which are by-products of treating water containing natural organic substances with chlorine (Wrona et al. 1996). The substances may cause the water to have undesirable taste or odour, but are not known to have health effects except at high doses. The NRBS confirmed the presence of taste and odour-causing trihalomethane compounds downstream of point sources such as pulp mills. While such tainting poses an aesthetic problem, this is not currently a human health concern (Wrona et al. 1996).

The NRBS determined that contamination of drinking water by bacteria, viruses and other microscopic disease-causing organisms represents a potentially greater threat to human health than chemical contamination (Wrona et al. 1996). Most of the Basins residents are served by excellent quality water. However, some small communities of less than 500 and/or communities that rely on non-conventional water supplies such as untreated or inadequately treated wells or streams have a moderate to high risk of encountering microbial contamination of water.

Microbial. The level of risk is highly dependent on the effectiveness of small water treatment plants and on individuals' methods of treating raw water (Wrona et al. 1996).

2.4 Cumulative Effects

Cumulative effects caused by contaminants in an ecosystem can be defined as the overall response of the ecosystem to exposures of all contaminants. The NRBS considered the contaminant results relevant to cumulative effects on human health. These results are for potential human exposure to water and fish. The NRBS summed up results relevant to cumulative human exposure to contaminants as follows(Wrona et al. 1996):

- Dioxins and furans occur in the water, sediments and fish of the Basins at low levels relative to other areas in Canada and have recently declined;

- Levels of PCB and organochlorine pesticides in the Basins do not represent a human health hazard;

- Natural sources and processes contribute to some of the perceived environmental problems (for example, mercury levels in fish, taste and odour of drinking water, hydrocarbon contamination in the oil sands region, and turbidity);

- The primary potential human health concerns are trihalomethanes and microbial contaminants in treated drinking water and dioxins, furans and mercury in edible fish; and, ;

- Dietary information (for example, fish consumption) should be used in reviewing health implications of environmental contamination

The NRBS reports recommended a focus on trihalomethanes and coliform contamination in drinking water [Armstrong et al. 1997]; mercury, dioxins, furans and toxaphene in fish [Gobas et al. 1996]; PCBs in fish [Wrona et al. 1997]; and naturally-occurring hydrocarbons in water and fish [Wrona et al. 1997]).

The NRBS recommended public involvement in monitoring ecosystem health and in decision-making affecting the sustainable use of Basin resources (Wrona et al. 1996). This stakeholder involvement is important in terms of identifying the problems of greatest concern as well as in efficient allocation of resources and funds.

3 METHODS USED TO EVALUATE ASSOCIATIONS BETWEEN ENVIRONMENTAL AGENTS AND HUMAN HEALTH

The following sections present some basic principles that apply to two common methods used to evaluate connections between the environment and human health. These two methods are risk assessment and epidemiology. It is important to understand the underlying principles of these methods because this understanding helps put the results of the NRB Human Health Monitoring Program into perspective. The Health Program used aspects of both risk assessment and epidemiology.

3.1 Risk Assessment

Principles

Human illness that can be shown to directly result from environmental exposures to contaminants is very rare. Therefore, the study of the effects of contaminants on human health is often based upon a risk assessment methodology. Risk assessment uses a systematic, step-by-step process that results in an estimate of risk of some adverse effect. Risk, as used in this context, is an expression that combines a probability or likelihood of an event with the consequences of that event. For example the risk of a small child choking on a small object (such as a toy, button, etc.) and dying from lack of oxygen may be a combination of the following probabilities, involving the child:

- Finding the object;
- Picking up the object;
- Inserting the object into her mouth;
- Swallowing the object;

as well as the probabilities that:

- The object sticks in her airway;
- The child is unable to cough the object out;

- No one finds the child in order to intervene;

and so on. The consequence of all these events occurring may be that the child dies. It should be apparent that the probability of the chain of events listed above all occurring in the correct sequence makes it rather unlikely that any one particular child will die from choking on a small object. It should also be apparent that specific measures can be taken to reduce the probability (and hence the risk) of a particular child choking to death. For example, childproofing a house so that small objects are quickly removed from reach would reduce the risk.

These considerations also apply to a person potentially exposed to contaminants in the environment. The risk of nervous system related birth defects (for example, delayed walking) to a child resulting from the mother's exposure to mercury in fish may involve the following events and associated probabilities:

- Mercury is released into the air;
- The mercury is deposited in a stream;
- The mercury sticks to sediments in the stream;
- Bacteria in the sediment convert the mercury to methylmercury (a form that is particularly toxic to the nervous system);
- Worm-like animals that live in the sediment absorb the methylmercury;
- A fish eats enough of the worms to accumulate a lot of methylmercury;
- A person catches and keeps the fish to eat;
- A woman who is at a particular stage of pregnancy eats some of the fish;
- Some of the methylmercury is absorbed into the woman's bloodstream;
- The methylmercury is transferred through the blood to the unborn child;
- The child is undergoing a crucial stage in nervous system development;
- The methylmercury is of sufficient concentration to interfere with the child's nervous system development; and
- The child is born.

As in the example of the choking child, it is apparent that the risk of adverse effects from mercury exposure involves a long chain of events, many of which are highly uncertain. Most environmental risk situations involve such chains of events and associated uncertainties. It is useful to compare such chains of events with, say, smoking cigarettes, which is a very direct exposure to known cancer-causing agents, or drinking large quantities of alcohol, which can kill a person in many different ways.

Human health risk assessment seeks to answer the following questions:

- What is the probability of health effects?

- How sure are we about that probability?

The first question is often addressed by comparing known or estimated environmental exposures to contaminants with levels that are known to cause adverse effects. Risk assessments use a wide variety of information sources, including epidemiology studies, occupational health studies, laboratory animal toxicology studies, and many others (Faustman & Omenn 1996). All of these sources of information have some degree of associated uncertainty; for example, we may be unsure of the exact amount of exposure. Therefore, risk analysis is usually synonymous with uncertainty analysis (Morgan & Henrion 1990). Uncertainty analysis is used to estimate the degree of confidence we have in an estimate of risk.

The stakeholders in the particular issue determine the acceptability of estimated risks. Often, an acceptable risk level is represented by standards or guidelines for exposure, such as fish consumption guidelines, that are derived by health agencies. Management or elimination of risk can be accomplished at many different steps in the chain of events described above; for example, fish advisories can prevent exposure to unacceptable levels of mercury in fish.

3.2 Epidemiological Studies

Principles

Epidemiology studies, which are statistical evaluations of the association between exposures and disease, often provide useful information for assessing health risks. It is very important to understand the limitations of epidemiological studies with respect to establishing a cause-effect relationship between environmental contaminants and human disease. Therefore, we provide a review of some basic principles of epidemiology in the following paragraphs.

Sir Austin Bradford Hill derived a set of postulates, based upon the earlier postulates of Jakob Henle and Robert Koch, for interpreting epidemiological studies (Hill 1965). These criteria are by no means rigid, but at least provide a starting point for evaluation of epidemiological studies. According to Hill's postulates, the associations between environmental levels of contaminants and disease should satisfy the following criteria in order to imply cause and effect (Streiner et al. 1989):

1. Strength: There should be a strong trend in the data showing a possible association between a contaminant and a particular disease;
2. Consistency: The association between the suspected cause and the disease should be seen across numerous studies;
3. Specificity: The cause should lead to only one outcome and that outcome should result from that single cause (Note: This criterion is rarely met with respect to diseases that may be linked to environmental contaminants because many of these diseases are known to have many causes that work together. An example is asthma);
4. Temporality: For contaminant A to cause health outcome B, exposure to contaminant A must precede the onset of disease B;
5. A dose-response relationship: If more exposure to the contaminant leads to more of the disease, the case for causality is strengthened;
6. Biological plausibility: If our understanding of the mechanism of action of the contaminant in the human body supports the association between the contaminant and the disease, then the case for causality is greater;

7. Coherence: The possible causal relationship should not conflict with what is generally known about the disease or disorder (If the triggering of a specific physiological response is required to trigger the onset of a disease, then the contaminant must be chemically capable of triggering the physiological response);
8. Experimental evidence: Experimental evidence can include laboratory experiments on animals, randomized trials where people are randomly divided into exposed and unexposed groups, or interventions in which some preventative action is taken and then a decrease in disease is noted; and
9. Analogous associations: If the contaminant is known to cause a certain disease by acting in a particular manner in the body, then it may also cause a similar disease by acting in a similar manner (Note: This is the weakest form of evidence regarding causality).

Even if a theoretical cause-effect relationship passes all of the above criteria, it does not necessarily prove causation beyond any shadow of a doubt. However, the more criteria that are met (especially the ones near the top of the list), the more likely it is that the causal hypothesis is correct (Streiner et al. 1989).

Design of an epidemiological study is critical in fulfilling the above criteria. Epidemiology studies generally fall into the following broad categories:

- Clinical trials;
- Cohort studies;
- Case-control studies; and
- Ecological studies (not to be confused with ecological studies of nonhuman species).

Clinical trials are essentially human population experiments, as in pharmaceutical trials of new drugs where people are divided into groups receiving the drug and groups that do not. The other study designs are observational in nature; that is, they rely upon estimates of exposure and disease gathered through observations.

In a cohort study, a group of people (a cohort) is assembled, none of who has experienced the disease of interest (e.g. coronary heart disease). On entry to the study, people in the cohort are classified according to those characteristics that might be related to the disease (e.g. smoking, cholesterol level, and blood pressure). These people are then observed over time to see which of them experience the disease (Fletcher et al. 1988).

Case-control studies compare the exposure to the suspected cause of disease among those who have that disease to a matched population without that disease. Researchers look back in time to determine the frequency of exposure in the two groups. These data can be used to estimate the relative risk of disease related to exposure (for example, the association between use of hormone replacement therapy and the risk of uterine cancer) (Fletcher et al. 1988).

In ecological epidemiologic studies (not to be confused with ecological studies of nonhuman species), data on specific diseases are gathered and compared to general data on risk factors (such as economic and dietary factors). There are no specific data on exposure of individuals to those risk factors; rather, people are classified by the general level of exposure in their environment (for example socio-economic class or relative consumption of red meat). Ecological studies cannot tell us how many exposed people actually have the disease of interest. That is, it is quite possible that the disease occurred in unexposed people and that the variables measured are not related (Streiner et al. 1989). There is no mechanism for controlling factors that may confound the relationship between exposure and disease, such as smoking, poor diet and alcohol use. Therefore, ecological studies are not useful for determining causality (NRC 1991).

4. SUMMARY OF THE NORTHERN RIVER BASINS HUMAN HEALTH MONITORING PROGRAM

4.1 Purpose and Objectives

The overall purpose of the Northern River Basins Human Health Monitoring Program (Health Program) was to investigate, understand and characterize the links between environmental factors and human health in the geographic area of Northern Alberta defined as the Peace-Athabasca-Slave River Basins (Ministerial Order #98/94).

The original objectives of the Health Program were to:

1. Produce accurate data and information on the exposure of individuals and communities to substances released into the environment and on other related factors;

2. Produce accurate data and information on the incidence and prevalence of disease in the population, other health effects and biological markers of exposure;

3. Analyze and investigate possible associations between measures of health status and measures of exposure;

4. Develop and propose strategies for reducing or eliminating human exposure to potentially harmful substances and for mitigating adverse health effects;

5. Ensure that the public is invited and encouraged to participate in and provide input to the program;

6. Ensure that the work of the program is carried out in an open and accountable manner and in cooperation with the communities in the area;

7. Ensure open and effective communications and information sharing; and

8. Provide periodic progress reports and a final report to the Minister of Health.

The original objectives proved to be too extensive given the budget allocated to the Health Program. The first four objectives were modified as follows:

1. Estimate the rate of diseases in the Basins;
2. Determine the most common diseases in the Basins;
3. Examine the relationship between diseases and environmental determinants;
4. Explore contributing factors to disease;

4.2 Scope of the Human Health Monitoring Program

The Health Program was a Phase One screening-level monitoring program. This is in contrast to a research project, which has a distinct focus and a definite end. Instead, the Health Program was meant to serve as a first step in identifying human health concerns in the Basins. The results of this first step provide the basis for recommendations for further monitoring, as well as for specific research projects.

The Health Program took a regional approach. It examined differences in the rate of disease among regions within the Basins area and between the Basins and other areas of Alberta. It did not focus on specific locations within the Basins.

The Health Program focused on reproductive health, birth defects, respiratory ailments, circulatory diseases, diseases of the stomach and bowel, physiological disorders such as diabetes and disorders of the nervous system. It did not include cancer because the Alberta Cancer Board has been conducting a monitoring program focussing on cancer during the time of this study. The results of the Cancer Board study were used for the Basins.

The Health Program used existing administrative sources of health and environmental data. Health data sources included records of hospital admissions, physician utilization, disease registries, and other statistical databases. Environmental data sources included NRBS databases, as well as data provided by Alberta Environmental Protection.

4.3 The Design of the NRBS Human Health Monitoring Program

The NRBS Human Health Monitoring Program is an ecological epidemiological study; that is, statistical correlations between exposures and diseases were examined on a geographical basis. This approach implies that some diseases occur in certain geographic regions more frequently than others do and that some exposures occur concurrently with these diseases. However, a one-to-one relationship between a particular exposure and disease in a defined population is not established; therefore, no causality can be inferred. As discussed earlier, ecological studies are sometimes useful for the purpose of hypothesis generation, but are not useful by themselves for the purpose of guiding public health policy.

The Health Program is not a full risk assessment; therefore, the likelihood of disease in any specific population from a particular exposure was not determined. Exposure assessment is critical in risk assessment. Since people are constantly exposed to mixtures of natural and anthropogenic chemicals, assessment of both presence and concentrations of particular chemicals of concern is necessary before analysis of health rates is useful. If an exposure does not exist in a population, then associated disease does not exist (NRC 1991). The Health Program was not designed to examine risks from specific agents; rather, it examined geographic correlations between disease rates and possible exposures.

4.4 Discussion of Contaminants of Potential Concern in the Basins

Although the Health Program is not a complete risk assessment, it is still useful to proceed through one of the initial steps in a risk assessment - evaluation of contaminants of potential concern. The following section describes the contaminants of potential concern arising out of the original NRBS, as well as our general understanding of environmental contaminants in the Basins. Table 1 briefly describes each contaminant in terms of its sources and any known connections between exposure and human health.

This discussion will be limited to those contaminants of potential concern (COPCs) that are of interest to the public and to health authorities, and which may have a possible role in the health outcomes identified as important by the Health Program. A large number of COPCs were evaluated in the overall NRBS (NRBS 1996). The reasoning for choosing these particular constituents for study is not presented in NRBS documents. Other COPCs are included in the following discussion because of their widespread nature and/or their possible connection with human health in the Basins.

Some of the COPCs, such as dioxins and furans, likely originate from human activities; others, such as arsenic and mercury, can have both natural and anthropogenic sources. As can be seen in Table 1, all of these substances have been identified as potential human toxicants by animal studies or by studies of humans exposed at high doses either occupationally or accidentally. However, these substances do not necessarily cause toxic effects at levels typically found in the environment. Some air pollutants have been identified as causing toxic effects in humans at exposure levels that occur in urban areas, but not necessarily at levels found in rural areas. The exception may be sensitive individuals such as asthmatics or elderly persons.

Potential toxic effects associated with the COPCs found in the Northern River Basins are dose-dependent. Typical environmental levels of these COPCs generally do not result in toxic effects (Table 1). High levels of these chemicals can cause disease, but it is unlikely that exposures occur at these levels in the Northern River Basins.

In general, pollution regulations and advisories issued by regulatory agencies are designed to prevent excessive exposure to toxic agents. Some of these guidelines, applied to the agents listed in Table 1, are listed in Table 2. More complete documentation of these guidelines is found in Health Canada (1996, 1997), Golder Associates Ltd. (1998), Canadian Council of Ministers of the Environment (CCME 1991) and Alberta Environmental Protection (AEP 1994) documents. These guidelines are in general not “written in stone”, and are subject to change as information becomes available. Exposures above these levels are NOT necessarily associated with adverse effects. Most of the guidelines are very conservative; that is, they tend to err on the side of safety.

When regulatory levels do not exist, evaluation of health risks must often be done on a case-by-case basis. The absence of a regulation or guideline does not mean that an agent is not toxic, but it may mean that the health agencies have judged that the agent is not a priority compared to other agents, or that there is insufficient information to derive a guideline. It is possible to derive criteria for these chemicals using a risk-based procedure similar to that used by regulatory agencies. This process results in conservative estimates of acceptable levels. Regardless, the recommended level should serve as a guide for further scientific investigation if environmental levels exceed that level.

Table 1: Examples of environmental contaminants of potential human health concern found in the Northern River Basins

(Note: All information is compiled from the U.S. Agency for Toxic Substances Disease Registry (ATSDR) Toxicological Profiles, which are individually listed in the References)

Contaminant	**Possible Past Sources of Environmental Contamination**	**Possible Present Sources of Appreciable Environmental Contamination**	**Possible Exposure Media**	**Indirect Evidence of Human Health Effects as a Result of Exposures at *High* Levels (laboratory or animal studies)**	**Direct Evidence of Human Health Effects as a Result of Exposures at *High* Environmental Levels (clinical or epidemiological studies)**	**Direct Evidence of Human Health Effects as a Result of Chronic Exposures at *Typical* Environmental Levels (clinical or epidemiological studies)**
Arsenic	Natural	Natural	Water, food, soil	Yes	Yes	No
Dioxins	Pulp mills, nonspecific long-range air transport	Nonspecific long-range air transport	Air, water, food, soil	Yes	Yes	No
Chlorinated furans	Pulp mills, nonspecific long-range air transport	Nonspecific long-range air transport	Air, water, food, soil	Yes	No	No
Polycyclic aromatic hydrocarbons (PAHs)	Oil Sands, combustion of fossil fuels, nonspecific long-range air transport, oil & gas facilities	Oil Sands, Combustion of fossil fuels, nonspecific long-range air transport, oil & gas facilities	Air, water, food, soil	Yes	Yes	No
Polychlorinated biphenyls (PCBs)	Nonspecific industrial sources, nonspecific long-range air transport	Nonspecific long-range air transport	Air, water, food, soil	Yes	Yes	No

Contaminant	Possible Past Sources of Environmental Contamination	Possible Present Sources of Appreciable Environmental Contamination	Possible Exposure Media	Indirect Evidence of Human Health Effects as a Result of Exposures at ***High*** Levels (laboratory or animal studies)	Direct Evidence of Human Health Effects as a Result of Exposures at ***High*** Environmental Levels (clinical or epidemiological studies)	Direct Evidence of Human Health Effects as a Result of Chronic Exposures at ***Typical*** Environmental Levels (clinical or epidemiological studies)
Mercury	Natural, nonspecific industrial sources, nonspecific long-range air transport	Natural, nonspecific long-range air transport	Air, water, food, soil	Yes	Yes	No
Chlorinated phenolics	Wood treatment, pesticides, nonspecific industrial sources	Wood treatment, residual pesticide contamination, nonspecific industrial sources	Air, water, food, soil, contact with treated wood	Yes	Yes	No
Toxaphene	Historical pesticide application	Residual pesticide contamination	Food, soil	Yes	Yes	No
Carbon monoxide (CO)	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Air	Yes	Yes	No
Nitrogen oxides (NO_x)	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Air	Yes	Yes	No
Ozone	Nonspecific industrial sources, nonspecific long-range air transport, automotive	Nonspecific industrial sources, nonspecific long-range air transport, automotive	Air	Yes	Yes	No

Contaminant	Possible Past Sources of Environmental Contamination	Possible Present Sources of Appreciable Environmental Contamination	Possible Exposure Media	Indirect Evidence of Human Health Effects as a Result of Exposures at *High* Levels (laboratory or animal studies)	Direct Evidence of Human Health Effects as a Result of Exposures at *High* Environmental Levels (clinical or epidemiological studies)	Direct Evidence of Human Health Effects as a Result of Chronic Exposures at *Typical* Environmental Levels (clinical or epidemiological studies)
Sulphur dioxide (SO_2)	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Air	Yes	Yes	No
Acid sulphates	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Nonspecific industrial sources, nonspecific long-range air transport, automotive, other combustion of fossil fuels	Air	Yes	Yes	No
Particulate matter (PM_{10})	Nonspecific industrial sources, nonspecific long-range air transport, automotive	Nonspecific industrial sources, nonspecific long-range air transport, automotive	Air	Yes	Yes	No

Table 2: Examples of Canadian regulatory criteria for contaminants of potential human health concern found in the Northern River Basins.

(Notes: See source 1: Health Canada [1996], 2: Health Canada [1997], 3: Golder Associates Ltd. [1998], 4: CCME [1991], 5:CCME [1997], and 6:AEP [1994] documents for more complete listing of regulations and guidelines. Some guidelines are interim, and subject to further study.

"- -" Means that a guideline is either not available or is not applicable to the particular contaminant)

Contaminant	**Drinking Water: Maximum Acceptable Concentration (parts per million)**	**Air: Alberta Environmental Protection Guidelines (parts per million)**	**Food: Guidelines/Tolerance Limits (parts per million)**	**Soil: Remediation Criteria (parts per million)**	**Notes**
Arsenic	0.025[1]	--	0.1[2] (Juice, cider, wine, other beverages) 1.0[2] (Edible bone meal) 3.5[2] (Fish)	12[5] (Agricultural) 12[5] (Residential) 12[5] (Commercial) 10[6] (AEP Tier I)	General note: "Residential" includes parklands, "Commercial" includes industrial properties.
Dioxins	--	--	0.00002[2]	0.00001[4] (Agricultural) 0.001[4] (Residential) 0.001[6] (AEP Tier I)	Food guideline based on 2,3,7,8-TCDD, which is considered the most toxic dioxin. Soil criteria are based on 2,3,7,8-TCDD. Criteria for other compounds are derived by dividing the TCDD criteria by factors depending on the relative toxicity of those particular compounds compared to TCDD.
Chlorinated furans	--	--	--	0.00001[4] (Agricultural) 0.001[4] (Residential) 0.01[6] (AEP Tier I)	Soil criteria are based on 2,3,7,8-TCDD. Furan criteria are derived by dividing the TCDD criteria by factors depending on the relative toxicity of those particular compounds compared to TCDD.
Polycyclic aromatic hydrocarbons (PAHs)	0.00001[1]	--	--	0.1[4] (Agricultural) 0.7[5] (Residential) 0.7[5] (Commercial) 0.1[6] (AEP Tier I)	Water criterion based on benzo(a)pyrene, which is considered the most toxic PAH. Health Canada identifies other PAHs as not requiring guidelines in drinking water. Soil criteria reflect the most toxic PAHs. Less toxic PAHs including napthalene, phenanthrene and pyrene have less stringent criteria.

Contaminant	Drinking Water: Maximum Acceptable Concentration (milligrams per liter)	Air: Alberta Environmental Protection Guidelines (parts per million)	Food: Guidelines/Tolerance Limits (parts per million)	Soil: Remediation Criteria (parts per million)	Notes
Polychlorinated biphenyls (PCBs)	--	--	0.2[2] (Meat/dairy products) 0.1[2] (Eggs) 0.5[2] (Poultry) 2.0[2] (Fish)	0.5[4] (Agricultural) 5.0[4] (Residential) 50[4] (Commercial) 0.5[5] (AEP Tier I)	--
Mercury	0.001[1]	--	0.5[2] (occasional consumption) 0.2[2] (subsistence consumption)	6.6[5] (Agricultural) 6.6[5] (Residential) 24[5] (Commercial) 0.2[6] (AEP Tier I)	Food tolerance for subsistence fish consumption per personal communication with J. Salminen of Health Canada.
Chlorinated phenolics	0.06[1] (pentachlorophenol) 0.1[1] (tetrachlorophenol) 0.005[1] (trichlorophenol)	--	--	7.6[5] (Agricultural) 7.6[5] (Residential) 7.6[5] (Commercial) 0.05[6] (AEP Tier I)	Soil criteria based on pentachlorophenol.
Toxaphene	--	--	--	--	Identified by Health Canada as not requiring a guideline for drinking water.
Carbon monoxide (CO)	--	5.0[3] (8-hour) 13[3] (1-hour)	--	--	
Nitrogen oxides (NO_x)	--	0.03[3] (Annual) 0.11[3] (24-hour) 0.21[3] (1-hour)	--	--	Air criteria based on NO_2.

Contaminant	Drinking Water: Maximum Acceptable Concentration (milligrams per liter)	Air: Alberta Environmental Protection Guidelines (parts per million)	Food: Guidelines/Tolerance Limits (parts per million)	Soil: Remediation Criteria (parts per million)	Notes
Ozone	--	0.025[3] (24-hour) 0.082[3] (1-hour)	--	--	
Sulphur dioxide (SO_2)	--	0.01[3] (Annual) 0.06[3] (24-hour) 0.17[3] (1-hour)	--	--	
Acid sulphates	--	--	--	--	Relevant guidelines do not currently exist.
Particulate matter (PM_{10})	--	120 micrograms per cubic meter[3] (Annual)	--	--	Federal guideline.

4.5 Summary of the Findings of the Northern River Basins Human Health Monitoring Program

4.5.1 General Results

In general, the population of the Basins area is younger, the family size is larger, and residents have their children at a younger age than do people in other areas of Alberta. Overall, the people living in the Basins have less education, but comparable income levels to other parts of the province. However, the income levels calculated for the entire Basins mask the sub-regional variations. The Northern Lights Health Region has a very high level of income. This skews the distribution and makes the average for the entire Basins area much higher.

Aboriginal people account for a much higher proportion of the population in the Northwestern and Keeweetinok Lakes Health Regions compared to the other regions in the Basins. In addition, these two health regions have the highest fertility rates, particularly among young mothers, as well as the most crowded living conditions. These two health regions also have more socioeconomic disadvantages than other regions in the province. The population in these two areas has lower education, lower income and more unemployment. These factors suggest that there are likely to be more poverty-related health problems in the two regions, including diseases from dietary deficiencies, smoking and alcohol consumption. Examples of such diseases are respiratory diseases and peptic ulcers. We can also expect to find more frequent health problems associated with childbirth complications due to the young age of the mother; e.g. low birth rate and birth defects.

4.5.2 Diseases Found to be More Common in the Basins

Six diagnoses were found to be more common in the Basins area compared to other areas of Alberta. These were endometriosis, heart and urinary tract birth defects, bronchitis, pneumonia, peptic ulcers, and epilepsy. The connection between these diseases and environmental contaminants is highly uncertain.

Endometriosis

The Health Program found that reporting of endometriosis was increased in the Northwestern, Mistahia and Peace Health Regions relative to the remainder of the Basins and the rest of Alberta. Reproductive disease outcomes are usually complex in terms of mechanism, and the causes are often unknown. Such is the case with endometriosis. The exposures chosen by the Health Program for further analysis included:

- Agricultural activities;
- Drinking water source;
- Dioxins and furans;
- Socio-economic factors; and
- Aboriginal differences.

The study found that the only factor that was correlated with endometriosis was low socio-economic status. It is difficult to determine whether these factors are causal, and what specific exposures lead to the possible increased risk. Potential causes of reproductive system disease are complex, and have strong lifestyle (including diet) and genetic components. Further exposure and epidemiology studies would be necessary to clarify risk factors. These studies would have to be designed to control for many confounding factors.

Congenital Anomalies

Congenital defects of the heart were more reported more often in the Mistahia Health Region and urinary tract defects were more common on the Peace Health Region relative to other regions in Alberta.

The ability of the Health Study to detect true excesses of these outcomes was limited. Rates of urinary tract defects were very low; therefore, apparent differences may be artifacts. Further analysis of heart defect data from the Mistahia Health Region confirmed that there were consistent differences between that region and the rest of the province.

Additional analyses were not conducted to examine specific possible causes of the higher rates of birth defects in the two regions. As with endometriosis, potential causes of developmental defects are complex, and have strong lifestyle (including diet) and genetic components. Further exposure and well-controlled epidemiology studies would be necessary to clarify possible risk factors.

Respiratory Diseases

The Health Program found that reporting of pneumonia and bronchitis was higher in the Keeweetinok, Peace and Northern Lights Health Regions compared to the remainder of the Basins and the rest of Alberta. In contrast, the rate of asthma and upper respiratory tract infections in the Basins was similar to or lower than in the rest of the province.

Further analyses were conducted to search for associations between socioeconomic and environmental factors and respiratory disease in the Basins. The factors examined were:

- Community socioeconomic status index
- Proportion of aboriginal people
- Population density
- Population size
- Rural or urban status
- Latitude and longitude; and
- Level of sulphur dioxide and nitrous oxides.

Community socioeconomic status was found to have the strongest association with bronchitis and pneumonia. Latitude was also associated with these two diseases; i.e. the farther north, the higher rates of these diseases. The proportion of the population who is aboriginal was also a significant predictive factor for bronchitis.

There was no positive correlation between predicted sulphur dioxide and nitrous oxide concentrations and increased pneumonia or bronchitis in the Basins. In other words, higher concentrations did not correspond with higher disease rates. Analysis for the entire province of Alberta showed a consistent, but small relationship between predicted sulphur dioxide concentrations and asthma, pneumonia and infections of the upper respiratory tract. The largest difference in the rate of asthma was less than 2 people per 100,000; therefore, other factors tended to overwhelm the effects of air pollutants.

It is not surprising that regional disease rate data did not reveal a clear connection with air pollutants. Since air pollution is a complex, ever-changing mixture, it is difficult to discern which specific components are related to disease outcomes, even in controlled studies such as cohort studies. Human and animal toxicology experiments have shed some light on this. High levels of sulphur dioxide (SO_2) have been found to cause constriction of airways in sensitive humans and animals, but the long-term effects from exposures to ambient levels are unclear. Exposures to high levels of nitrogen oxides (NO_x) have been shown to result in increased susceptibility to infection in both humans and animals, but again the long-term consequences are unclear.

The key uncertainty in these possible exposure-disease relationships is exposure level. The simple contaminant level model that was used in this study was not able to examine concentrations on a fine geographical scale. Therefore, a considerable degree of uncertainty exists regarding individual exposures. Furthermore, there was no way in this type of analysis to control for other respiratory risk factors such as smoking, wood smoke exposure, and indoor air quality.

The relative amount of exposure to industrially related outdoor air pollutants is likely small compared with smoking, exposure to smoke from fireplaces and barbeques and other sources of indoor air pollution. It has been notoriously difficult to study air pollution effects even in large populations exposed to urban levels (for example, see Lyon et al. 1995). As the Report mentions, levels of air pollutants in the Basins are below Alberta Environmental Protection guidelines 90% of the time, regardless of the location.

Peptic Ulcers

Peptic ulcers are more commonly reported in the Keeweetinok, Peace, Northern Lights and a small portion of the Mistahia Health Region (in Municipal District 19) than in other areas of the Basins and most health regions in the rest of the province.

There are many causes of peptic ulcer disease, including genetic factors, smoking, aspirin use, alcohol use, and consumption of caffeine. Peptic ulcers are among those conditions that are related to socioeconomic factors such as dietary deficiencies and unemployment. There are no obvious connections between peptic ulcers and the environmental contaminants of concern in the Basins.

Epilepsy

Epilepsy was reported more frequently in the Northern Lights Health Region relative to the rest of the Basins and most regions in the rest of Alberta. The highest rate of hospitalization for epilepsy is in Edmonton. Epilepsy was more commonly diagnosed for people who are aboriginal, including both First Nations and Metis.

The most common type of epilepsy is believed to be caused by microscopic brain lesions that occur during birth or some other trauma. Metabolic disturbances or exposure to certain contaminants may also cause them.

The only contaminant of concern in the Basins with links to neurological disease is mercury. However, there is no scientific evidence linking epilepsy with mercury exposure.

Outbreaks of Waterborne Diseases

An outbreak of shigellosis, a microbial disease that causes diarrhea, was reported in the Basins area in 1993. Risk factors for shigellosis include living in rural areas or in smaller communities where water treatment may be inadequate to remove the bacteria that cause the disease. Intervention is relatively straightforward; routine monitoring of wells and maintenance of water treatment systems will reduce the risk of outbreaks to a minimal level.

4.6 Limitations of the Health Study

Higher rates of many of the diseases identified by the Health Study may or may not truly exist in the Basins. Many sources of bias exist that can cause the results of a statistical analysis to be misleading. For example, patients in some geographic areas may have a better chance of having their disease detected than in others due to availability of health care. This would result in falsely elevated risks in those areas.

One main problem with ecological studies in general is a potential bias called the "ecological fallacy". The basis for the fallacy is that there is no guarantee that those people who develop the disease in question were the same ones who were exposed to the contaminant. Additionally, there is no mechanism for adjusting the analysis to control for confounding risk factors such as tobacco, alcohol, and diet. Ecological studies are most useful in coming up with hypotheses, which must then be tested with more rigorous research (Fletcher et al. 1988).

Due to the design of the Health Study, it was difficult to establish associations between specific possible environmental exposures in the Basins and specific diseases. Some of the diseases that appeared to occur at higher rates in certain portions of the Basins were subjected to further analysis by the Health Program to determine if any associations with environmental exposures could be hypothesized. Dioxins, furans, mercury, drinking water contaminated with coliform bacteria (bacteria associated with the human gut) and treated drinking water containing trihalomethanes were discussed in general terms. However, detailed data from the NRBS could not be analyzed (except in the case of pass/fail test data for coliform counts in drinking water) because of lack of data access and/or incompatibility of databases. The Health Program also examined the possible association between sulphur dioxide and nitrogen oxide concentrations in air and respiratory disease through the use of air quality modelling. The Health Program did not specifically discuss toxaphene, PCBs, or naturally occurring hydrocarbons.

Hypothesized links between environmental contaminants and adverse health outcomes must be discussed in the following context: *Toxicity is dose- and susceptibility-related*. Most substances, both natural and man-made, are toxic in large enough doses. The important issue is whether contaminant exposures in the Basins occur at sufficient doses to cause effects in the exposed population.

There is scientific debate as to whether all toxic substances have a threshold of effect, i.e. some dose below which no toxic effects will occur. However, it is unlikely that extremely low doses of *any* substance, even proven cancer-causing agents such as ionizing radiation, result in excess disease risk (Pitot & Dragan 1996). Furthermore, there are interactions between different people's physiology, as determined by their genetics and lifestyle (including diet, smoking, alcohol use, etc.), and possible toxic effects of environmental contaminants. Regardless, genetic and lifestyle risk factors may far outweigh the contribution to total risk from contaminants.

5. RECOMMENDATIONS FOR FURTHER STUDIES IN THE NORTHERN RIVER BASINS

5.1 Use a Quality-of-Life Framework That Ensures Integration of Ecological and Human Health Studies

At present, there is no overall framework for integration of the ecological work and the human health studies that have been performed in the Northern River Basins. This has created problems, including:

- Ecological data that are not relevant for use in analysis of health data (e.g. sample locations do not match locations of health issues);
- Health data that are gathered without the necessary supporting information on possible exposures to environmental contaminants (e.g. via patient histories);
- Misunderstanding and lack of communication with stakeholders;
- Incomplete study designs for new studies; and,
- An increased risk of redundant or irrelevant studies because of lack of integration across the health and environmental disciplines.

Most people are concerned about ecological and human health impacts because these impacts affect their quality of life. Therefore, an overall quantitative framework and analysis that addresses the quality of life in the Basins may be a useful tool for integration. The information gathered thus far in the ecological and human health studies could be utilized in assessing impacts to the quality of life. Such a framework would also allow consideration of the tradeoffs that are involved between economic and environmental factors. There is a well-characterized literature on quality-of-life studies that should be consulted before such a framework is planned. A review is found in Gill and Feinstein (1994). Participation of experts in the field is critical for proper design and implementation.

5.2 Take Advantage of Current and Planned Ecological Monitoring and Environmental Programs

There are several important environmental monitoring activities and research programs that are either currently underway or planned for the near future. These activities will provide additional evidence for the health of the river ecosystems and the health status of the Basins human population, as well as information that can be used to plan and prioritize any future human health studies.

Environmental Effects Monitoring

All pulp mills in Canada are required to conduct Environmental Effects Monitoring (EEM) every three years; this includes all of the mills located in the Northern River Basins. The first EEM "cycle" was completed in 1996 and provided data that supplemented and complimented data from the NRBS. For example, both EEM studies and the NRBS observed declining levels of dioxins and furans in the Basins. Furthermore, neither the EEM studies nor the NRBS found population-level changes in the fish; rather, there were some physiological changes that could either be in response to exposure to effluents and/or a reflection of natural variability. The second EEM cycle is now underway. All of the pulp mills on the Athabasca are cooperating in a Basin-wide EEM study that includes water and sediment quality, bottom-dwelling invertebrate studies and fish studies. Pulp mills on the Peace system are conducting similar studies, but on an individual basis. The new EEM data will provide valuable, updated information on the health of the river ecosystem and will record any further changes in contaminant levels and ecosystem health since the first EEM cycle and the NRBS.

Oil Sands Assessments and Monitoring

There has been considerable activity in the oil sands area since the completion of the NRBS, with several new oil sands operations announced. Four projects have submitted EIAs: Syncrude Aurora Mine Project; Shell Musket River Mine Project; Suncor Project Millenium; and, Suncrude Mildred Lake Upgrader Expansion. The Mobil Kearl Oil Sands Project EIA is still in preparation. These EIAs provide information on predicted impacts of each new operation. The EIAs address both ecosystem and human health, and can be used to help prioritize future monitoring and research. Furthermore, the oil sands operators are cooperating in a Regional Aquatic Monitoring Program (RAMP) that is examining water quality, invertebrates and fish populations, as well as fish habitat. The RAMP, together with special studies commissioned by individual operators (such as laboratory studies of the effects of exposure to oil sands reclamation waters on fish) will provide ongoing data on the health of the ecosystem in the oil sands area.

Northern Rivers Ecosystem Initiative

A follow-up program to the NRBS called the Northern Rivers Ecosystem Initiative (NREI) is in the planning stages. The NREI will focus on issues raised during the NRBS such as continuing to track the concentrations of specific contaminants, and examining physiological and population-level responses in fish populations. The NREI will be coordinated with the EEM second cycle studies and some aspects of the NREI program will involve participation of both government and industry.

Sustainable Development Strategy for the Athabasca Oil Sands

This is a recently-announced program of Alberta Environmental Protection. The goals and objectives of the program are still under development.

Wood Buffalo Environmental Association: Terrestrial Environmental Effects

Canadian Oilsands Network for Research and Development (CONRAD)

This is an industry-led initiative that coordinates research related to oil sands developments, including environmental research. Academic institutions, government agencies, industry and consulting firms are part of the network.

All of the above programs offer opportunities for providing input to human health studies. These programs can also be used to help prioritize future work in human health; for example, good overall ecosystem health is a sign that concerns for human health may be less urgent than if components of the ecosystem show definite contaminant-related effects.

5.3 Continue the Implementation of NRBS Recommendations Relevant to Human Health

Some of the key considerations recommended for further study in the river ecosystems that are relevant to human health are (Wrona et al. 1997):

1. Quantification of natural versus man-made sources of contaminants (NREI is addressing this);

2. Non-point source pollution associated with different land uses (for example, residential vs. agricultural land use), landfills and atmospheric deposition of contaminants that originate from distant locations;

3. Effectiveness of drinking water treatment in small communities (Alberta Health, Health Canada and Alberta Environmental Protection have projects related to this recommendation);

4. Public consultation, involvement and education;

5. Information management and multi-agency coordinated monitoring.

5.4 Co-ordinate with Other Current and Planned Health Studies in the Basins

There are several studies sponsored by Alberta Health that are already underway. These studies have arisen from the results of this study and/or are relevant to the issues identified in this study. They include:

- Mistahia Health Region congenital heart defects study

- Congenital Anomalies Committee: committed to a detailed analysis of congenital anomalies in Alberta

- Dioxins, furans and PCB's in food and environmental media: a study through the University of Alberta EcoResearch Chair to set up a laboratory to deal with analysis of dioxins, furans and PCB's in food and environmental media. Metals are also part of this initiative.

- Reproductive Outcomes: University of Alberta is developing bioassays to detect estrogen-like compounds

- Toxicology Centre, Heritage Research Centre, Calgary: projects on personal exposure monitoring, biological markers of exposure and organic compounds

- Trihalomethanes and cancer incidence: A Cancer Board project using an enhanced cancer surveillance system for bladder and colon cancer incidence versus trihalomethane concentrations in water supplies

- Drinking water quality: provincial laboratories for microbial and inorganic chemistry at the University of Alberta are establishing capability to detect organic compounds such as trihalomethanes

- Athabasca Oil Sands Community Exposure and Health Effects Assessment Program: a personal exposure research project in the Fort McMurray area that is examining individual personal exposure to a variety of air-borne chemicals from a range of sources

- Swan Hills Special Waste Treatment Centre Human Health Impact Assessment: a report was issued in October, 1997 and continued monitoring is occurring in conjunction with AEP and Health Canada

- High level particulate study: fort McMurray area: this study is focussing on teepee burner issues

- Clean Air Strategic Alliance: Alberta Health is participating in CASA initiatives around the province. The issues of the flaring of solution gas and possible connections with human health are relevant to the Basins and are being addressed by CASA.

- Fish contaminants and consumption advisories: Alberta Health is participating in the development and review of a new process for review of fish contaminant data and the establishment and lifting of fish consumption advisories in the Basins.

5.5 Prioritize Further Health Studies

Prioritization of future health studies should consider:

- A systematic prioritization of the COPCs present in the Northern River Basins. This prioritization should be based on monitored levels of these contaminants and on potential for human toxicity, and should include evaluation of uncertainties. The prioritization should be balanced by other health concerns in the area, such as nutrition, tobacco and alcohol use, as well as accidental death and injury. Applicable comparative risk assessment and risk ranking methodologies can be found in a report from the Resources for the Future (RFF 1996).
- Well-designed exposure assessments. As previously discussed, if an exposure does not exist in a population, then associated disease does not exist. Disease rates are not useful by themselves. Community and individual level exposure assessments could be conducted on the COPCs identified earlier. An example of this type of exposure assessment has been conducted in the form of the Alberta Oil Sands Community Exposure and Health Effects Assessment Program (AOSCEHEAP 1997). This type of exposure assessment program could be conducted on a broader scale to include the rest of the Northern River Basins.

- Alternative study designs. Environmental epidemiology studies are difficult to conduct properly and interpretation is problematic. Even a large-scale cohort study would likely have insufficient power to detect associations in the Northern River Basins, due to the small population size. Alternatives to "traditional" epidemiological designs, based on health services methodologies, may be useful in establishing populations at risk of disease. For example, methodologies have been developed for examining community-based interventions. These studies may be prospective (following people through time) or cross-sectional (at one point in time) in design (Diehr et al. 1995). For example, prospective studies have been performed on rates of teenage substance abuse between rural American Indian communities with and without substance abuse prevention programs (Cheadle et al. 1995). It may be possible to design such studies for health outcomes of interest in the Northern River Basins. Rates of disease in communities that are, say, downwind of potential air pollution sources could be compared with similar communities without such sources or with communities where sources have been removed. Of course, potentially confounding factors such as smoking, alcohol use, and diet should be statistically addressed in the analyses to the extent possible.

5. REFERENCES

AEP (Alberta Environmental Protection). 1994. Alberta Tier I Criteria for Contaminated Soil Assessment and Remediation (Draft). Soil Protection Branch, Lethbridge, Alberta.

AOSCEHEAP (Alberta Oil Sands Community Exposure and Health Effects Assessment Program), 1995, *Executive Summary*, Fort McMurray, Alberta.

Armstrong, T.F., D.S. Prince, S.J. Stanley, and D.W. Smith. 1997. Assessment of drinking water quality in the Northern River Basin Study Area. Northern River Basins Study Synthesis Report No. 9. NRBS, c/o Alberta Environmental Protection, Edmonton, AB

ATSDR (Agency for Toxic Substances and Disease Registry), 1989, *Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1990, *Toxicological Profile for Benzo(a)Pyrene*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1993, *Toxicological Profile for Arsenic*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1994a, *Toxicological Profile for Chlolorinated Dibenzofurans*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1994b, *Toxicological Profile for Pentachlorophenol*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1995, *Toxicological Profile for Polycyclic Aromatic Hydrocarbons*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1996, *Toxicological Profile for Toxaphene*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1997a, *Toxicological Profile for Polychlorinated Biphenyls*, Final, U.S. Dept. Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry), 1997b, *Toxicological Profile for Mercury*, Draft, U.S. Dept. Health and Human Services, Public Health Service.

Carey, J.H. and O.T.R. Cordeiro. 1997. Effects of contaminants on aquatic organisms in the Peace, Athabasca and Slave River Basins. Northern River Basins Study Synthesis Report No. 2. NRBS, c/o Alberta Environmental Protection, Edmonton, AB

CCME (Canadian Council of Ministers of the Environment). 1991. Interim Canadian Environmental Quality Criteria for Contaminated Sites. Report CCME EPC-CS34, September, Winnipeg, Manitoba.

CCME (Canadian Council of Ministers of the Environment). 1997. Recommended Canadian Soil Quality Guidelines. Report ***.

Cheadle, A, Pearson, D, Wagner, E, et al., 1995, "A Community-Based Approach to Preventing Alcohol Use Among Adolescents on an American Indian Reservation", *Public Health Rep*. **110**:439-437.

Costa, DL, Amdur, MO, 1996, "Air Pollution", in *Cassarett and Doull's Toxicology: The Basic Science of Poisons*, eds. Klassen, CD, Amdur, MO, Doull, J, McGraw-Hill, NY.

Diehr, P, Martin, DC, Koepsell, TC, et al., 1995, "Optimal Survey Design for Community Intervention Evaluations: Cohort or Cross-Sectional?", *J. Clin. Epidemiol*. **48**:1461-1472.

Faustman, EM, Omenn, GS, 1996, "Risk Assessment", in *Cassarett and Doull's Toxicology: The Basic Science of Poisons*, eds. Klassen, CD, Amdur, MO, Doull, J, McGraw-Hill, NY.

Fisher, LD, van Belle, G, 1993, *Biostatistics: A Methodology for the Health Sciences*, John Wiley & Sons Inc., NY.

Fletcher, R.H., S.W. Fletcher and E.H. Wagner. 1988. Clinical Epidemiology: The Essentials. Williams and Wilkins, Baltimore.

Gabos, S., W. Kindzierski, M. Prior, F.L.Wang and D. Prince. 1996. A review of population health status in Northern Alberta. Northern River Basins Study Synthesis Report No. 6. NRBS, c/o Alberta Environmental Protection, Edmonton, AB

Gill, T.M., Feinstein, A.R. 1994. “A Critical Appraisal of the Quality of Quality-of-Life Measurements”, *JAMA* **272**:619-625.

Golder Associates Ltd. 1997. Science Assessment Document: Assessment of dioxin and furan contamination and the fish consumption advisory in the Wapiti/Smoky river system. Submitted to Alberta Health by Weyerhaeuser Canada Ltd. Draft Report. Weyerhaeuser Canada Ltd., Grande Prairie, Alberta.

Golder Associates Ltd. 1998. Technical Reference for the Meteorology, Emissions, and Ambient Air Quality in the Athabasca Oil Sands Region. Prepared by Golder Associates Ltd. and Conor Pacific Environmental Technologies Inc.

Health Canada. 1996. Guidelines for Canadian Drinking Water Quality. Sixth Edition, Ottawa, Ontario.

Health Canada. 1997. Canadian Guidelines/Tolerances for Various Chemical Contaminants in Foods. Facsimile transmission from John Salminen, Chemical Health Hazard Division, to Golder Associates Ltd., dated November 6, 1997. Notes that “tolerances appear in Table I, division 15, Food and Drug Regulations except for mercury guideline”.

Hill, AB. 1965. "The Environment and Disease: Association or Causation?" *Proc. Royal Soc. Medicine* **58:**295-300.

Lyon, J.L., Mori, M, Gao, R, 1995, "Is There a Causal Association Between Excess Mortality and Exposure to PM-10 Air Pollution? Additional Analyses by Location, Year, Season, and Cause of Death," *Inhal. Toxicol*. **7:**603-614.

Mill, T.A., P. Sparrow-Clark and R.S. Brown. 1997. Fish distribution, movement and gross external pathology information for the Peace, Athabasca and Slave River Basins. Northern River Basins Study Project Report No. 147. NRBS, c/o Alberta Environmental Protection, Edmonton, AB

Minsterial Order***

Morgan, MG, Henrion, M, 1990, *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*, Cambridge University Press, NY.

NRBS (Northern River Basins Study), 1996, *Final Report*, Edmonton, Alberta.

NRC (National Research Council), 1991, *Environmental Epidemiology, Vol 1: Public Health and Hazardous Wastes*, Committee on Environmental Epidemiology, Board on Environmental Studies and Toxicology, Commission on Life Sciences, National Academy Press, Washington DC.

Pastershank, G. M. and D. C. G. Muir. 1995. Contaminants in Environmental Samples: PCDDs and PCDFs Downstream of Bleached Kraft Mills, Peace and Athabasca Rivers, 1992. Northern River Basins Study Project Report No. 44. 80 pp.

Pitot, HC, Dragan, YP, 1996, “Chemical Carcinogenesis”, in *Cassarett and Doull’s Toxicology: The Basic Science of Poisons*, eds. Klassen, CD, Amdur, MO, Doull, J, McGraw-Hill, NY.

RFF (Resources for the Future), 1996, *Comparing Environmental Risks: Tools for Setting Government Priorities*, ed. JC Davies, Washington DC.

Shelast, B.M., Luoma, M.E., Swanson, S.M., Martin, J.A., and K. T. Brayford. 1994. A Baseline Aquatic Monitoring Study on the Athabasca River Between the Town of Athabasca and Grand Rapids, 1991 - 1993. Volume 1. Prepared for Alberta-Pacific Forest Industries Inc. Boyle, Alberta.

Streiner, D., G.R. Norman, H.M. Blum. 1989. Epidemiology PDQ. B.C. Decker Inc. Toronto.

Swanson, S.M., R. Schryer, B. Shelast, K. Holley, I. Berbekar, P. Kloepper-Sams, J.W. Owens, L. Steeves, B. Birkholz and T. Marchant. 1993. Wapiti-Smoky Ecosystem Study. Weyerhaeuser Canada Ltd., Grande Prairie, AB.

Wrona, F.J., W.D. Gummer, K.J. Cash and K. Crutchfield. 1997. Cumulative impacts within the Northern River Basins. Northern River Basins Study Synthesis Report No. 11. NRBS, c/o Alberta Environmental Protection, Edmonton, AB.