PPWB Water Quality Monitoring Review
Phase 1: Qu'Appelle and North Saskatchewan Rivers

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TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background

The Prairie Provinces Water Board (PPWB) was formed in 1948 when the governments of Canada, Manitoba, Saskatchewan and Alberta signed the Prairie Provinces Water Board Agreement. In 1969 these same parties entered into the Master Agreement on Apportionment and in 1989, Schedule E of this Agreement defined the mandate of the PPWB Water Quality Program as being to "*foster and facilitate interprovincial water quality management among the parties that encourages the protection and restoration of the aquatic environment*". The primary objectives of the Water Quality Program (PPWB 1991) are to:

1. Promote a preventative and proactive approach to interprovincial water quality management.

2. Promote the protection and restoration of the aquatic environment.

3. Promote an ecosystem approach to the management of interprovincial waters.

4. Recognize the effect of quantity on the quality of water for the effective management of interprovincial waters.

5. Promote compatible water quality objectives for the effective management of interprovincial waters.

In order to satisfy these objectives the PPWB's Committee on Water Quality (COWQ) established a Water Quality Monitoring Program on major interprovincial streams. The objectives of the monitoring program (PPWB 1991) form a subset of the larger water quality program. These objectives are to:

1. Describe the quality of the aquatic ecosystems at the interprovincial boundary and identify the presence, absence and abundance of toxic substances, and other physical, chemical and biological attributes of transboundary waters.

2. Provide evidence of changes in trends in the concentration of chemical and physical substances, and in the biological integrity of the aquatic ecosystem.

3. Assess the achievement of water quality objectives, other water quality indicators and other water quality goals.

4. Maintain a scientifically credible data and information base on the quality of transboundary waters.

Data collection was initiated in 1974 and, with the recent addition of the Cold River, the number of transboundary river reaches currently monitored has expanded to twelve (Figure 1). The COWQ annually reports to the PPWB on general water quality and excursions to specific objectives at each of the monitored reaches and, less frequently (approximately every five years), examines long-term trends in water quality variables (Dunn 1995a, b).

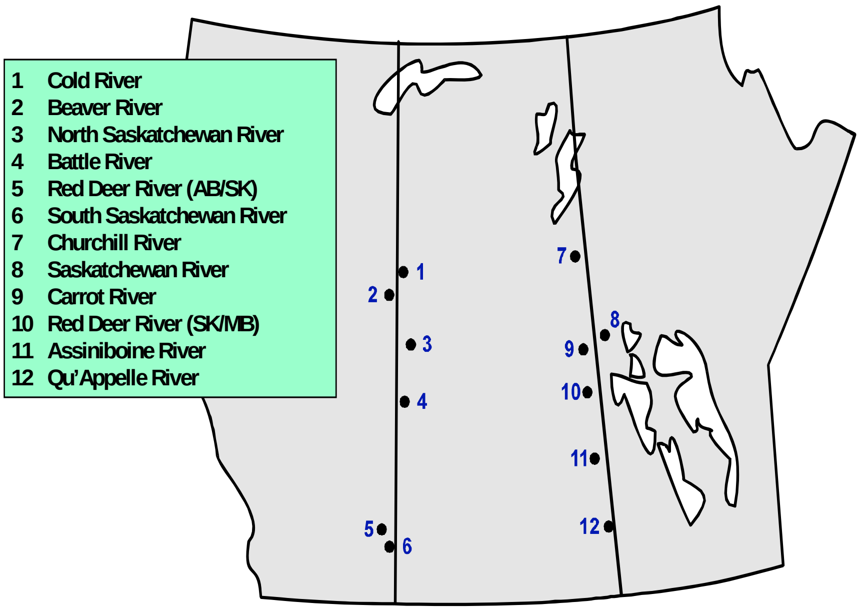

Figure 1. Location of PPWB Interprovincial Water Quality Monitoring Sites.

In light, of recent changes to the PPWB Water Quality Monitoring Program and because of changing funding pressures, the COWQ has chosen to undertake a comprehensive review of its current monitoring program. The purpose of this report is to provide background information and recommendations to facilitate the COWQ's discussions. It is also hoped that this report will help to ensure that the PPWB continues to meet its mandate in the most cost effective manner possible and that the data collected provide ecologically relevant information allowing for a characterization and assessment of environmental trends and current condition within each of the PPWB's twelve transboundary river reaches.

1.2 Objectives

This report will provide a starting point for discussions concerning a response to several important changes that have occurred since the establishment of the PPWB Water Quality Monitoring Program in the mid-1970s. First, recent and predicted changes in funding availability serve to emphasize the need to conduct environmental monitoring in the most cost effective manner possible and to ensure there is a high return of information for each dollar invested. Second, the field of environmental monitoring is a rapidly evolving one, and this review represents an opportunity to incorporate recent advances in the theory, practice and interpretation of aquatic monitoring into the PPWB program. Finally, and perhaps most importantly, the current PPWB database now spans a period of over two decades and provides an excellent foundation for the quantitative and statistically rigorous assessment of trends. This database further provides the context within which monitoring efforts can be reviewed and refocused so as to identify and concentrate on the most ecologically relevant components of the ecosystem. It can also be used to ensure that those components are monitored on the spatial and temporal scales most appropriate to satisfy the PPWB mandate.

The report will not attempt to summarize or re-analyze data presented in PPWB excursion or trend reports. Rather, it will provide a general ecological assessment of the current monitoring program and provide recommendations where appropriate. Specific examples will be used to better illustrate the arguments provided. To facilitate the review, the report will be divided into several sections: (1) A discussion of the ecosystem approach to environmental monitoring and the need for the development of ecosystem-specific monitoring programs. (2) A brief discussion and overview of issues relating to the current PPWB monitoring program. (3) An overview of issues relating to statistical techniques for trend analysis in the PPWB monitoring program. (4) Proposed changes to the current monitoring program for the Qu'Appelle River at the Saskatchewan/Manitoba Border. (5) Proposed changes to the current monitoring program for the North Saskatchewan River at the Alberta/Saskatchewan Border.

2.0 ECOSYSTEM APPROACH TO ENVIRONMENTAL MONITORING

2.1 The Ecosystem Approach

The most common approach to setting environmental regulations and designing environmental monitoring programs, particularly in North America, has been based largely on the assessment of physical and chemical attributes of anthropogenic inputs (e.g., effluent, or "end-of-pipe" analyses) and the distribution of those inputs within the receiving environments (e.g., ambient water quality monitoring). Consequently, most traditional designs of environmental monitoring and assessment have focused on developing and refining field and laboratory methods to assess and predict changes in the concentration and distribution of chemicals within the environment (e.g., quantifying and evaluating the types of stressors and their environmental fate and distribution) while paying less attention to the consequences for biological or ecological structure and function (Reynoldson and Metcalfe-Smith 1992; Loeb 1994).

An alternative approach to environmental assessment involves identifying physical and chemical stressors and their potential impacts on biological communities from a more holistic, ecosystem-based perspective. This approach represents a major shift away from the abiotic-based approach toward one that recognizes: 1) the complex and dynamic interactions (physical, chemical and biological) that occur at a variety of scales (spatial, temporal, and organizational) within an ecosystem; 2) the fact that human populations (and their activities) constitute an important component of that environment and that they cannot be viewed as being separate and apart from it; and 3) the need for human populations to make use of natural resources in a more sustainable fashion (Marmorek *et al.* 1992).

More recently, this approach has been embraced by policy makers and has come to be known as the “ecosystem approach” to environmental assessment. Although specific definitions of the “ecosystem approach” may vary, most contain four key traits: (1) an emphasis on the collection of reliable and integrated data, (2) a holistic perspective, (3) ethical management strategies and, (4) a recognition that humans are part of the ecosystem.

Although the objectives of the PPWB Water Quality Monitoring Program explicitly endorse an ecosystem approach (Objective No. 3 of the Water Quality Monitoring Program), the monitoring program has traditionally focused largely on the measure of chemical concentrations in the water column. However, as the extent and complexity of anthropogenic impact on the environment increases so does the need to develop effective management criteria that can be used to assess and maintain current levels of ecosystem structure and function. These criteria also provide the basis for the decision, where necessary and possible, take remedial action in systems deemed to have been unacceptably impacted. In most cases an exclusive focus on traditional measures of water quality alone will not be sufficient to develop such criteria. Expanding monitoring programs to include additional endpoints will be required.

The recent PPWB decision to sample contaminants in other media (e.g., fish tissue) represents a shift toward an ecosystem approach. Similarly, the development of appropriate biological indicators, evaluated in conjunction with more traditional water quality measurements, would contribute to the existing data base describing the general nature (i.e., structure and function) of the ecosystem being monitored. Such a shift would also provide early warning of changes to that system, and ultimately provide information as to the causes of those changes and the steps required to restore the ecosystem to some acceptable level of structure and/or function. The potential role of biological indicators will be discussed in greater detail below.

2.2 Ecosystem Boundaries and Ecosystem Health

Implicit in the concept of an "ecosystem approach" is the desire to maintain the ecosystem at some adequate level of function, or health. Unfortunately, both "ecosystem" and "health" have proven difficult to define precisely. An ecosystem is generally defined as a collection of interacting populations (e.g., microbes, plants, animals (including humans populations), *etc.*) and their abiotic environment and while there may be general agrement as to what constitutes an ecosystem, there is often considerable uncertainty as to what bounds it.

Ecosystems are not closed systems; energy, nutrients, and organisms move among ecosystems at a variety of spatial and temporal scales. Traditional ecology has defined ecosystem boundaries as regions of reduced ecological interaction or energy transfer (e.g., a river *versus* adjacent terrestrial habitat, meadows *versus* forest fringe), but has also recognized that even these boundaries are arbitrary, albeit necessary, conveniences. In other words, ecosystems are not self-contained. Superimposed on this definition of ecosystem boundary is the need to consider the context (spatial, organizational and temporal scales; political, economic and societal concerns) in which the system is being studied.

In the context of the PPWB, the ecosystem is monitored and assessed at those east-flowing river reaches that cross provincial boundaries. The underlying goal is to assure the quality of water entering the downstream jurisdiction. However, it is nevertheless recognized that activities upstream of those locations may have important consequences for both the monitored reach and downstream ecosystems (lakes, other rivers). The challenge for the PPWB Water Quality Monitoring Program is not only to measure and assess the state of the ecosystem within the monitoring reach, but to extrapolate from those measures to both upstream causes and downstream consequences of the observed patterns.

Of greater concern in the application of an ecosystem approach is the concept of ecosystem health. The concept of ecosystem health, and its obvious analogy with human health, has broad intuitive appeal and has come to be widely used by managers, certain researchers, and members of the general public (Rapport 1992 a,b). Consequently, there now exists a considerable body of literature exploring the philosophical, economic and scientific implications of the concept of ecosystem health (Costanza *et al.* 1992; Callicott 1995; Calow 1995) and members of the general public increasingly request measures of general condition or ecosystem health. Unfortunately, the concept of health is itself, difficult to define (Calow 1992, 1995), and the development of precise definitions of ecosystem health and ecosystem integrity is particularly problematic (Haskell *et al.* 1992; Suter 1993a; Ramonde 1995; Rapport 1995; Wicklum and Davies 1995).

Calow (1995) and Wrona and Cash (1996) have chosen to take the "pragmatic approach" to ecosystem health. This approach does not seek to develop a general definition of ecosystem health but rather, combines the best available scientific knowledge with societal expectations of the ecosystem to develop a pragmatic, operational view of the desired structure and function of the ecosystem being managed. This approach does not attempt to develop a precise and general definition of ecosystem health, and thus avoids the very real problems and pitfalls faced by those that do (Costanza *et al.* 1992; Suter 1993a). Rather, it makes full use of the best scientific information available but is also capable of making subjective assessments of ecosystem health based on this information. Importantly, the pragmatic approach is sufficiently flexible to allow for the ready incorporation of new information, changes in societal priorities and needs, improvements in monitoring techniques and/or refinements in theoretical understanding as they become available.

Because the pragmatic approach to ecosystem health relies on societal input and scientific information, the expectations of what any particular ecosystem should look like may change as individual uses (e.g., irrigation, drinking water, etc.), societal priorities, and the state of scientific knowledge change. As a consequence, the basis on which an ecosystem is judged to be either healthy or unhealthy may change from region to region and may change within a region over time. Implicit in this approach, is the recognition that the management of ecosystems and the development of specific indicators of ecosystem health must be considered on a case by case basis.

The pragmatic approach to ecosystem health is reflected in the PPWB approach to water quality monitoring. The choice of variables measured and objectives employed differ among sites and this variation is based on a recognition that the best measures of "ecosystem health" within any reach is dependent on the intrinsic nature of that system as well as the human demands placed on the system. The choice of sampling frequency is also dependent on the intrinsic nature of the system and the variables measured, however, to date the PPWB has relied largely on a standard, though arbitrary, monthly sampling scheme.

Given that each of the trans-boundary reaches currently being monitored by the PPWB is unique with respect to both its ecology and the suite of anthropogenic stresses acting upon it, it follows that the most appropriate monitoring techniques and parameters will vary from reach to reach. It is therefore necessary to consider each of the twelve river reaches separately so as to determine the environmental issues associated with each. The currently measured parameters should then be reviewed on a case by case basis to ensure their relevance for each particular reach. Those parameters deemed relevant within a given reach should be further reviewed to ensure they are measured on the most appropriate temporal and spatial scales.

In light of this variation in measures, objectives and sampling frequency, it is critically important that the collected data not only be analyzed at the level of the individual variable, but that the conclusions arising from these analyses are integrated to develop general statements concerning the overall health of the system. Such a process is not only necessary to the assessment of ecosystem health but can also be used to effectively address the primary concerns of both managers and the general public. The issues associated with summarizing and communicating statements describing the general health of these systems will be discussed in the next section.

3.0 THE CURRENT PPWB MONITORING PROGRAM

This section will provide a general discussion of several important issues concerning the PPWB Water Quality Monitoring Program. More specifically, a variety of ecological concerns will be addressed, most of which have been previously identified and discussed at length by the COWQ. The purpose in raising them again is to provide some common ground for discussion and to illustrate the reasoning leading to the recommendations provided in the sections dealing with monitoring the Qu'Appelle and North Saskatchewan rivers.

It is recognized that appropriate sampling techniques, analytical methodologies and quality assurance/quality control (QA/QC) protocols are essential to a successful monitoring program and can constitute a major financial and logistic constraint. However, a detailed discussion of such issues is beyond the scope of this report and will not be provided. It is assumed that appropriate sampling and QA/QC protocols are currently in place and are adhered to.

3.1 Sampling Location

The rivers and monitoring reaches that are part of the PPWB Water Quality Monitoring Program have been determined by PPWB Mandate and the positioning of Provincial Boundaries, rather than by the ecological character of the river reaches themselves (Figure1). As a consequence, ecological assessments made within a monitoring reach may be adequate in a proximal sense (i.e., they satisfy PPWB mandate and COWQ Objectives) but if they do not adequately represent conditions downstream of the reach it may be difficult to properly assess the ultimate (i.e., cumulative) impacts of upstream jurisdictions on transboundary waters.

Support for the view that it is difficult to extrapolate from water quality data collected at any particular monitoring reach to other river segments site can be found in Florence and Van Nguyen (1995). These authors examined required sample sizes and sampling frequencies at three monitoring stations on the North Saskatchewan River, between Edmonton and the Saskatchewan Border (the PPWB site). The authors generally found a low concordance of time series of water quality variables for different combinations of monitoring sites. These results suggest that water quality, and particularly trends in water quality might be better assessed using a network of sites (both upstream and downstream of provincial boundaries) rather than a single monitoring location.

Clearly, such a network is beyond the scope of the PPWB but coordination with provincial agencies in terms of both sample collection and data analyses should be possible. Such coordination would allow the PPWB to: (1) better explore temporal (e.g., Dunn 1995 a,b) as well as spatial trends in most of the transboundary rivers; (2) increase the overall efficiency of monitoring; (3) address the PPWB Water Quality Program Objective of promoting “compatible water quality objectives and; (4) address the COWQ

Water Quality Monitoring Program Objective of maintaining “a scientifically credible data and information base on the quality of transboundary waters”.

3.2 Establishment of Monitoring Objectives

The suite of core variables measured in the PPWB Monitoring Program has varied over the last several decades but is generally reflective of similar programs across North America. Lists of these variables are provided in a variety of PPWB publications and will not be presented here.

Objectives are not required for some variables (e.g., discharge), of the variables currently measured in the PPWB Monitoring Program. However, approximately 50% of the currently measured variables are not associated with any objective. Of those that are associated with an objective, some (e.g., some nutrient measures) have objectives that are ultimately based on guidelines developed for other regions and may not be appropriate for prairie rivers. The lack of such objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Current PPWB variables should be reviewed on a reach-specific basis (such a review is currently underway for nutrients) and objectives developed for those variables that currently lack them.

Although in many cases objectives or guidelines designed to protect one component of the ecosystem (e.g., human populations) already exist the current objective may not address the most sensitive use (e.g., protection of aquatic life) and there will be a need to interpret monitoring data at a variety of different levels and for a variety of different purposes. It may be thus necessary to modify current objectives or to establish multiple objectives for a single variable, depending on use (e.g., protection of aquatic life *versus* irrigation) and/or season (e.g., low discharge *versus* high discharge). If a single objective is to be used it should be that associated with the most sensitive use (in most cases this will be the protection of aquatic life).

The development of site-specific objectives for all PPWB measurements at all monitoring sites represents a major commitment of time and effort but such a commitment is needed to realize the maximum benefit from the monitoring effort. Not all objectives need have the rigor of legislated guidelines, rather, they should be developed as aids to the interpretation of monitoring data and as indicators of adequate ecological function. Moreover, the suite of objectives employed should be flexible enough to accommodate changes in methodology, detection limits and our understanding of ecological function within the river reach.

3.3 Ecological Relevance And The Choice Of Measurement Endpoints

Ideally, all of the specific parameters chosen for a given reach should be directly and predictively related to ecological processes such as primary productivity, nutrient dynamics, and the health and survival of biota (including human populations) dependent on the river reach. However, while measures of water chemistry may greatly influence biotic structure and process, it is not usually possible to assess the health of biota solely on the basis of such measures. Given that the PPWB is mandated to take an ecosystem approach and that one objective of the COWQ Monitoring Program is to "describe the quality of the aquatic ecosystems at the interprovincial boundary" it will thus be necessary to add monitoring techniques that more directly describe biotic components of aquatic ecosystems. These may involve employing ecological endpoints (e.g., benthic community structure, primary production), a change in the medium in which some parameters are measured (e.g., metal concentrations in sediment or biota *versus* the water column), or the elimination of parameters deemed not relevant.

A characterization of this type is also useful in so far as it identifies (and in some cases quantifies) what it is the monitoring program is attempting to protect or restore. It also serves to provide a context in which the consequences of changing water quality can be assessed.

In recent years the PPWB has begun to collect data on fish health and community structure and to compare directly that data with contaminant measures in fish tissue. The use of such endpoints provides greater insight into ecological structure and function and allows for a direct assessment of the impact of water quality on biota. An assessment of benthic community structure (using rapid assessment techniques) and direct measures of primary productivity could also serve as valuable additions to the Water Quality Monitoring Program.

Benthic macroinvertebrates are more commonly used in the assessment and monitoring of aquatic ecosystems than are any other group of organisms (Resh *et al*. 1995). The advantages of using benthic macroinvertebrates have been well documented (see summaries in Plafkin *et al*. 1989; Rosenberg and Resh 1993) and include the fact that: (i) they are a diverse and widely distributed group that can be found in virtually all aquatic ecosystems; (ii) because they are relatively sessile, they integrate, and are representative of, conditions present in the area in which they are sampled; (iii) they are sensitive toa wide variety of environmental stresses (both natural and anthropogenic) and show a wide variety of responses to such stress; (iv) with some notable exceptions (e.g., Chironomidae, Oligochaeta) the taxonomy of benthic macroinvertebrates is generally well understood.

Critics of the use of benthic macroinvertebrates to assess aquatic ecosystems have pointed out: (i) the considerable cost associated with collection and sample analysis, (ii the inability of traditional methods to supply results in a timely fashion, and (iii) the difficulties in controlling for the (often tremendous) natural variation observed in these communities.

The rapid bioassessment approach to monitoring is characterized by a more qualitative approach to the assessment of environmental condition and relies on a series of individual measures or metrics that are eventually summarized in a single score or index. As the name suggests, a major objective of the rapid bioassessment approach is to provide useful information in a timely and cost effective manner (Resh *et al*. 1995). This is accomplished by: (i) reducing the number of habitats sampled and by reducing (or pooling) the number of replicates taken within each habitat; (ii) eliminating measures of absolute density, thus allowing for the use of easier to use, more rapid sampling techniques such as kick nets; (iii) enumerating some subset of the animals collected rather than counting the entire sample; (iv) employing the coarsest taxonomic resolution (i.e., family level or higher) that satisfies the pre-defined program objectives (Resh and Jackson 1993).

The rapid bioassessment approach has been most fully developed by the US EPA (Plafkin *et al*. 1989) and is now the primary biomonitoring tool used in many American states for environmental assessment in streams and rivers. This approach relies on detailed habitat characterization of a site over time or on a similar characterization of matched impact and reference sites. The characterization recognizes the importance of habitat characteristics in determining benthic community structure and helps to "tease" apart natural and anthropogenically induced variation in benthic community structure. Once habitat characterization is complete a variety of measures or metrics (usually eight) are taken on the benthic macroinvertebrate community, changes in the index value over time are suggestive of changes in community structure.

This approach has the advantage of being relatively rapid (i.e., usually capable of providing information on the order of weeks), inexpensive (i.e., requires little time or training to sample or sort invertebrates) and provides managers with simple, readily understood measures of the environment (i.e., "biological condition"). However, the use of ratios and indices are integral to this approach and have been severely criticized by a number of researchers. Of particular concern is the fact that the use of some ratios and indices may provide little biological insight and are often not amenable to statistical investigation (Green 1979; Norris and Georges 1993). Despite these limitations, use of rapid bioassessment techniques has been shown to be a valuable monitoring tool in a variety of locations (Resh *et al*. 1995).

In previous discussions, the COWQ has several times considered the value of measuring benthic community structure but has typically rejected investing in this parameter because of the costs involved, the lack of timely results, and the fact that benthos was deemed to be a low priority relative to measures of chemical concentrations in the water column and in fish tissues. Rapid bioassessment, as described here, is a inexpensive way to measure benthic macroinvertebrate communities within monitoring reaches. While it may provide less detail than more traditional methods it is probably adequate to generally characterize the benthic community and monitor trends within that community.

Measures of benthic community structure should be standardized for season and, ideally, would be collected every year. If yearly sampling was not deemed feasible, sampling every other year would still allow for trend assessment but any trends would obviously be more difficult to detect. As with the collection of water quality data, any program designed to assess benthic community structure should, in so far as possible, co-ordinate activities with those provinces undertaking similar programs (e.g., Manitoba (Manitoba Environment 1997)).

Finally, measures of primary productivity (measured in the water column or periphyton), though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota. A PPWB supported investigation exploring the relationship between ambient nutrient levels, discharge, and primary productivity is currently being conducted by Dr. Patricia Chambers of Environment Canada.

3.4 Additional Endpoints

A major challenge facing any monitoring program is to ensure, in so far as possible, that all variables likely to affect ecosystem quality at a given site are adequately measured. As stated above, the "core" suite of parameters currently monitored by the PPWB provide a general description of water quality at a given site. This general description, has at various time, been augmented by directed measures of toxics (e.g., chlorinated organics) known to be an issue within the system but it is not possible to monitor all variables of potential concern at all times.

A feasible alternative to targeting a small, and expensive to measure, subset of toxicants may be to perform a broad spectrum analysis (BSA) which considers the full spectrum of contaminants present in a sample. The BSA approach makes use of gas chromatographs and mass spectrometers to identify types, or families, of chemicals present in a sample. The approach does not provide a detailed analysis of any particular compound but can be used as a screening process to identify those compounds, or groups of compounds, that warrant further investigation. As with measures of contaminants in fish it would not be necessary to perform BSA on each reach in each year. Rather the PPWB could establish a rotating schedule in which a BSA is performed at each monitoring site every three to five years.

Sediments, both bottom and suspended can be an important sink for both toxins and nutrients. Sediments are an important component of the aquatic ecosystem and can exert strong effects on overall aquatic quality or health. The importance of sediment quality has been recognized by the PPWB but unfortunately the costs associated with monitoring those sediments has been considered prohibitive. Although perhaps not practical in all reaches, an assessment of sediment quality where possible would provide a significant contribution to the overall evaluation of ecosystem condition within monitoring reaches and is consistent with the ecosystem approach adopted by the PPWB.

It is also important for the Monitoring Program to maintain flexibility as to the suite of variables measured at any site. A concerted effort should be made to identify and evaluate new and emerging issues (e.g., changes in agricultural practice or land use) and where appropriate address those issues by adapting the monitoring program in a timely fashion. Similarly, variables deemed to be no longer of immediate concern should be eliminated. The PPWB has adopted a flexible strategy throughout its monitoring history and has recognized the need for the monitoring plans, variables and objectives to be assessed on an ongoing basis.

3.5 Reporting of Monitoring Results

An integral part of any monitoring program is the reporting of results to both managers and the general public. This posses a particular problem in the case of water quality monitoring because of the complexity associated with analyzing a large number of measured variables. The traditional approach to this problem has been to produce large reports describing trends and excursions on a variable by variable bases. The advantage of this approach is that it provides a wealth of data and information but in many cases managers and the general public have neither the inclination nor the training to study these reports in detail. Rather, they require statements concerning the general health of the system.

One possible solution to this problem is to reduce the multivariate nature of water quality data by employing an index that will combine all water quality measures and provide a general, and readily understood description of water quality on a use by use basis. Although there have been a variety of attempts to create such a water quality index the most successful Canadian attempt to date appears to be the index developed by the British Columbia Ministry of Environment, Lands and Parks (British Columbia Water Quality Status Report, 1996).

The index is based on a combination of three factors:

1. $\mathbf{F_1}$, the number of excursions to the objectives
2. $\mathbf{F_2}$, the frequency of excursions to the objectives
3. $\mathbf{F_3}$, the magnitude of the excursions.

that are combined to produce a single value (between 1 and 100) that describes water quality.

In January 1997 the Canadian Council of Ministers of the Environment (CCME) Water Quality Task Group, in cooperation with the CCME State of the Environment Task

Group undertook to examine and, if necessary, modify the BC index with a view to creating a national water quality index that could be adopted by all provinces and territories. That work is currently underway and is making use of some PPWB data in testing modified versions of the index. A variation of the BC index has already been employed by the Province of Manitoba in its State of the Environment Report (Manitoba Environment 1997) and it is currently being tested in both Saskatchewan and Alberta.

Unlike some earlier indices, the basic BC formulation captures all key components of water quality, is easily calculated, and is sufficiently flexible that it can be applied in a variety of situations. The index can be very useful in tracking water quality changes at a given site over time. However, because both the variables and objectives that feed into the index will vary across sites, it is not an appropriate tool for comparing among sites, except in so far as comparing their ability to meet a defined use (e.g., recreation, irrigation, protection of aquatic life, etc.).

The water quality index is a simple and powerful way to draw general conclusions concerning water quality and could greatly enhance the PPWBs ability to communicate its results to both managers and the general public. Use of this index in the Prairie provinces as well as other Canadian jurisdictions would also serve to standardize the way in which the results of water quality monitoring could be communicated.

It must be stressed however, that the index is a technique used to report on water quality analyses and does not replace the need to analyze individual variables and trends. Any use of the index should be accompanied by narrative descriptions explaining the underlying causes of the calculated index values. It should also be noted that because the index is based on only those variables for which objectives exist, its utility to the PPWB will be largely constrained by the availability and appropriateness of such objectives.

4.0 STATISTICAL ISSUES

4.1 Introduction

An important component of the PPWB Water Quality Monitoring Program is trend analysis. The PPWB currently analyses trends in water quality variables on an approximately five year cycle (Dunn 1995a,b) using a combination of parametric and non-parametric approaches recommended to the PPWB by El-Shaarawi (1991). The issues surrounding trend analysis are complex and stem largely from five factors: (1) Water quality data tend to be significantly non-normal, thus many traditional parametric approaches may be inappropriate. (2) The data are often serially correlated or autocorrelated. In other words observations near one another in time are not statistically independent. Correlations of this type present problems for time series analyses. (3) The ability to detect annual trends may be obscured by seasonal changes. (4) Observed values for a given variable may covary with other variables not be accounted for. (5) many variables are subject to significant natural variation, making identification of trends difficult. These issues are in no way unique to the PPWB dataset and are faced by all monitoring programs.

4.2 Parametric *Versus* Non-Parametric Trend Analysis

As described above, the PPWB currently employs a combination of parametric and non-parametric analyses. Parametric analyses focus largely on linear regression on the entire data set (e.g., Figure 2.). These data presentations provide a useful visual summary of the data but may be of little value in quantitatively assessing trends. Relative to non-parametric approaches, linear regression is not robust to non-normal data and is more sensitive to missing values and outliers. Even when linear regression does produce significant effects, such as those given in Figure 2, the associated coefficient of determination (r^2) are typically very low (0.021 in this example). Given that r^2 values less than 0.6 are thought to have little predictive power, linear regression is not likely to prove a useful tool in analyzing trends in these data. Data transformations and stratification of data by month or season will reduce some of the variation and increase r^2 values (Figure 3) but in a survey of data from the Qu'Appelle and North Saskatchewan rivers few benefits were apparent by using this approach. It should be noted that linear regressions plotted in the PPWB Trend Reports (Dunn1995a,b) appear to be plotted correctly but are associated with incorrect equations.

A superior and more widely used approach is the use of non-parametric techniques, primarily the Kendall Tau and Seasonal Kendall Tau. These approaches are the ones most relied on by the PPWB (Dunn1995a,b) and have the advantage of being less sensitive to underlying distributions of data, missing data and outliers (Ward *et al*. 1988). As with parametric analyses non-parametric techniques are sensitive to serial correlation however these problems can be largely overcome by dividing the data into discrete (usually monthly) periods as is done by the PPWB. An alternative to analyzing on a monthly basis is to analyze seasonal averages. This approach involves fewer analyses, and because it makes use of an average (calculated over three to four months) is less sensitive to missing or extreme values

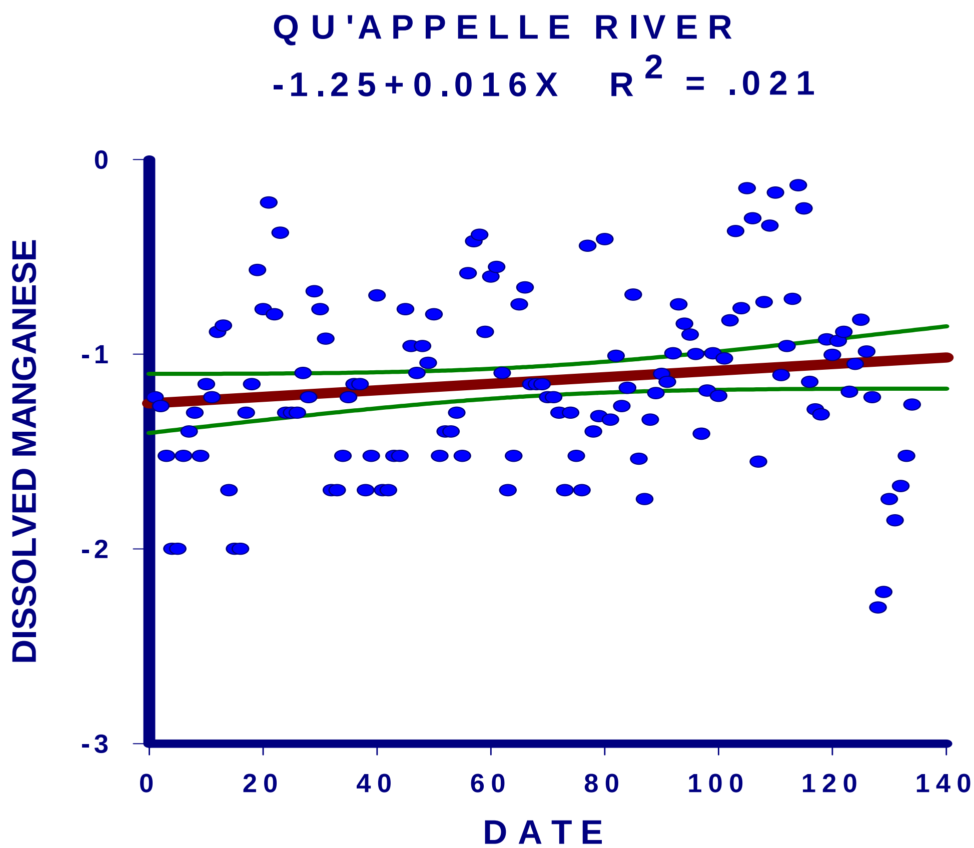

Figure 2. Concentrations of dissolved Manganese (mg/L - log transformed) over time in the Qu'Appelle River.

4.3 Other Approaches to Trend Analysis

In addition to the techniques described above Florence and Nguyen (1995) attempted to estimate time series sample sizes and sampling frequencies required for the PPWB data collected at the North Saskatchewan River site. More specifically, they looked at the sampling frequency and duration required to detect a 10% change in the mean concentration with a power of 85% and an alpha of 10%. The authors treated each variable independently and owing to serial correlation and natural variation found that the number of independent variables samples a year (assuming 12 samples/year) ranged from 1 to 12 and that the sampling period required to detect a 10% change in mean concentration ranged from 1 to 8815 years. Although the authors demonstrated that in some cases bimonthly or quarterly sampling provided as much information as monthly sampling, the duration of sampling required to detect a change remained unacceptably high for most variables except pH.

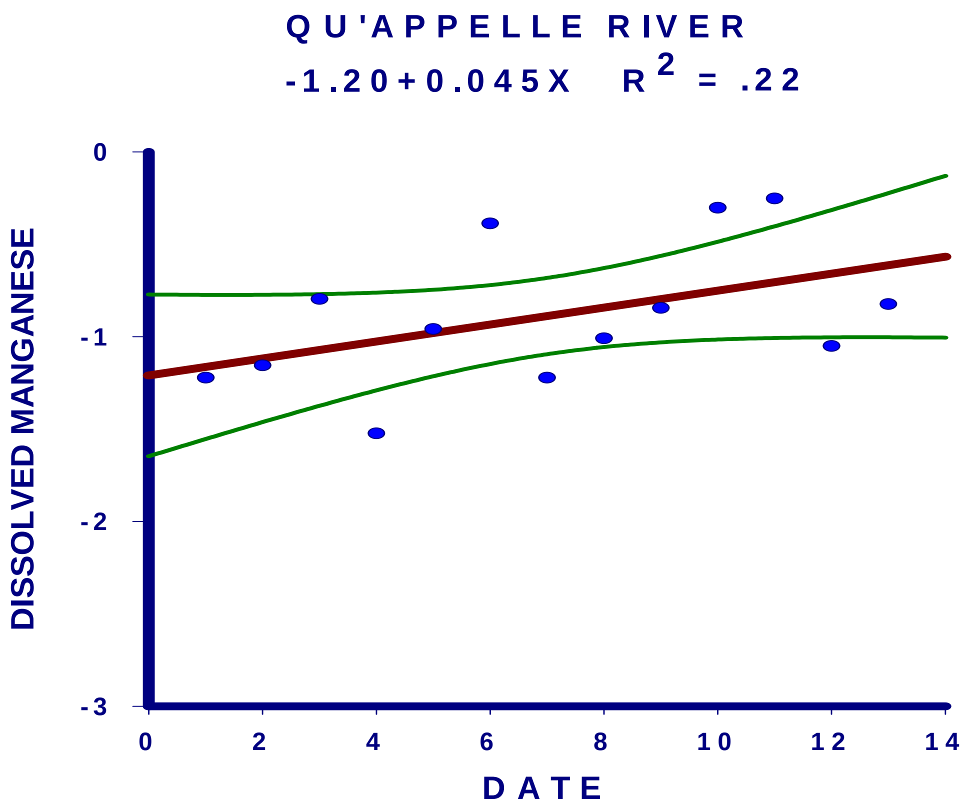

Figure 3. June concentrations of dissolved Manganese (mg/L - log transformed) over time in the Qu'Appelle River.

Vecchia *et al*. (in press) have also attempted to take a parametric approach to time series model designed to detect trends in surface water quality and have tested their model in the Souris River. Their model claims to effectively handle serial correlations, cross-correlations, missing data and variable sampling frequencies and also allows for the analysis of trends using generalized least squares regression. Unfortunately, the sampling frequency required (every 10 days) is beyond the resources available to the PPWB and is thus of little utility to the Water Quality Monitoring Program.

At present, how to best analyze water quality trends is the subject of numerous ongoing investigations and new and better techniques will no doubt become available. The increasing availability of commercially available software, such as SAS and WQHYDRO, facilitates the analysis of data in a variety of ways and should encourage those tasked with analysis to view their data using different techniques. Despite the need to be aware of and incorporate new developments in analysis, the techniques currently employed by the PPWB for trend analysis are widely used, well understood and most appropriate for the issues at hand.

4.4 Additional Considerations

As discussed above, the majority of variables are analyzed as if they were independent of one another. However, we know there some variables (e.g., discharge) may strongly influence others, and that a consideration of these relationships may be important in setting objectives and determining trends. There are a variety of techniques available to deal with these covariates (ANCOVA, regression techniques, simple correction factors) but the most appropriate technique will vary as a function of the nature of the relationship among/between the variables in question.

In a related sense, it may be possible to use multivariate techniques to describe trends in groups of variables such as nutrients or metals rather than analyzing the data on a variable by variable basis. Multivariate trend analyses are not currently widely employed but that may change as new techniques become available.

Ecological knowledge, and a clear understanding of why a particular variable is measured can also help to reduce measured variation and serial correlation by allowing for a focused collection of data in a period when the variable is known to be an issue. For example, in many of the PPWB reaches dissolved oxygen only becomes an issue during late winter when ice-cover prevents aeration of the river. By focusing data collection during that period it may be possible to reduce variation and simplify analysis and at the same time collect more relevant data. Similarly, if nutrient contribution to nuisance weeds is the issue then monitoring could be focused on the period when macrophytes are known to respond most strongly to nutrient additions.

4.5 Ecological Interpretation

Although statistical analyses provide essential insight into trends within these ecosystems, ecological interpretation must consider additional elements. For example, certain trends may be statistically valid but of little immediate ecological interest. In the case of the North Saskatchewan River boron concentrations were found to be increasing. However, concentrations remain well below the objective and even if they continue to increase at the current rate, they will not approach the objective for many years. In this case, a statistically significant positive trend may not require action. Conversely, a variable for which no trend is apparent but which is consistently measured at or near its objective may be deserving of more detailed trend analysis.

Ecological interpretation is further complicated by the nature of ecological endpoints. Unlike many of the more traditional chemically based endpoints, ecological endpoints are generally not amenable to the development of precise quantitative objectives or guidelines. For example, there is no single level of primary productivity or benthic community structure that is considered ideal for aquatic ecosystems. Rather, appropriate levels of productivity and community structure will vary both within and among ecosystems as a function of local environmental factors. While the lack of objectives does not preclude the analysis of trends in biological indicators, analyzing trends in a multidimensional context can be complicated. Alternatively the analysis can be simplified greatly if the number of analyzed dimensions is reduced through the calculation of an index.

Regardless of whether measures are univariate or multivariate, associated with an objective or not, it has become generally recognized that monitoring data should be evaluated and acted upon using a weight of evidence approach to environmental assessment. This approach does not rely exclusively on a strict interpretation of regulatory guidelines and/or statistical output as an indicator of environmental quality but adopts a more dynamic and flexible approach that simultaneously considers a variety of quantitative and qualitative measures of ecosystem structure and function. The implementation of such an approach thus requires a more exhaustive consideration of monitoring results and the ability to directly relate such results to the unique issues present in each ecosystem.

5.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE QU'APPLE RIVER

5.1 Overview

The Qu'Appelle river flows approximately 290 km from its headwaters at Lake Diefenbaker to its confluence with the Assiniboine River. The Qu'Appelle River Basin drains an area of 50,000 km^2, most of which has been developed for agricultural purposes. Principal water uses include water supplies for towns, cities, industries, irrigation, recreation and habitat for fish and wildlife (see Dunn 1995b for a more detailed description of the river basin). The PPWB Water Quality Monitoring site on the Qu'Appelle River is located at Welby, Saskatchewan.

An analysis of long-term trends in water quality in the Qu'Appelle River suggests that the majority of measured variables show few systematic trends over time. Parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that ten water quality variables significantly decreased over the period of measurement. These variables included: boron, nitrate plus nitrite, total nitrogen, magnesium, total phosphorus, dissolved phosphorus, alpha BHC, potassium, zinc, and daily discharge. Changes in daily discharge were thought to be responsible for some reductions in measured concentrations (Dunn1995 b). The same statistical trend analysis revealed that three variables, manganese, alkalinity and fecal coliforms increased over the same period. Trends in alkalinity and fecal coliforms were not considered to represent a concern. However, given its positive trend and the fact that measured values often exceed the PPWB guideline (0.05mg/L) it was concluded that manganese had the potential to adversely affect downstream users.

In addition, to the variables described above, sodium, total phosphorus and chloride levels were identified as deserving special attention in several PPWB Excursion Reports. Although no trend is apparent, for sodium or chloride, most measures of sodium are well above the PPWB guideline of 100 mg/L, while chloride approaches or exceeds the PPWB guideline of 100 mg/L in at least one month in most years. Similarly, although total phosphorus levels are decreasing, measured concentrations typically exceed the PPWB guideline of 0.05 mg/L. Water column concentrations of mercury occasionally exceed the PPWB objective of 0.006 μg/L however, such concentrations are difficult to interpret and mercury is probably more appropriately measured in sediment or biota.

In some cases, the excursions described above may be attributable to inappropriate objectives (e.g., those for total phosphorus and sodium) that fail to account for the natural geochemistry of the area. Saskatchewan Environment and Resource Management (SERM) has undertaken a review of water quality data collected throughout the Qu'Appelle River Basin in an effort to identify the underlying causes of the excursions and the results of that review will assist in the evaluation of objectives.

5.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report. Any changes to the monitoring program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

5.2.1 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured in the Qu'Appelle River and that, where objectives are needed, they be developed.** As discussed above, the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

5.2.2 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives.** Such a consideration may necessitate the control of certain covariates in trend analysis or the development of a number of condition-dependent objectives for some variables.

5.2.3 **It is recommended that the PPWB continue monitoring fish condition and tissue contaminant levels in the Qu'Appelle River on a five year cycle**. Fish collected for contaminant analysis should also be assessed for general condition. Fish captured, but not collected for contaminant analysis, should also be assessed for general condition prior to release. Fish should be collected in Round Lake only if conditions in the lake adequately represent those observed in the mainstem.

5.2.4 **It is recommended that the PPWB evaluate the benthic macroinvertebrate community present at the Qu'Appelle River monitoring site on annual basis using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

5.2.5 **It is recommended that the PPWB examine the feasibility of measuring primary productivity (periphyton and/or epiphyton) measured at the Qu'Appelle River monitoring site.** Measures of primary productivity, though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota.

5.2.6 **It is recommended that the PPWB explore the possibility of performing a broad spectrum analysis (BSA) on water samples from the Qu'Appelle**

River. The results of such an analysis should be used to identify classes of contaminants not currently measured but of potential concern. Such analyses would be conducted on a three to five year cycle.

5.2.7 It is recommended that the PPWB explore the possibility of measuring sediment quality within the Qu'Appelle River monitoring site. Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

5.2.8 It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the Qu'Appelle River monitoring site. Trend analysis is essential to the monitoring program but given the data already collected an analysis every five years should be sufficient to detect changes in trends and identify potential concerns.

5.2.9 It is recommended that the PPWB collect water samples from the Qu'Appelle River on a monthly basis every other year and quarterly in intervening years. Such a change in sampling frequency will not significantly alter the ability to analyze trends or detect excursions.

5.2.10 It is recommended that, contingent upon the data review currently underway by SERM, the PPWB monitor major ions at the Qu'Appelle River monitoring site on a quarterly basis only. Current evidence suggests that while some major ions consistently exceed objectives, high levels may be a natural consequence of underlying geochemistry and need not be measured monthly.

5.2.11 It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for prairie rivers. The importance of nutrient levels in determining ecological function in these systems has long been recognized by the PPWB, as has the possible inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study conducted by Dr. P. Chambers (DOE) and sponsored, in part, by the PPWB.

5.2.2 It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the Qu'Appelle River monitoring site. Statistical analyses do not suggest any trend in dissolved oxygen concentrations and exceedences of the PPWB guideline (6.0 mg/L) are very rare. More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to

5.2.3 It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the Qu'Appelle River site. Mercury and chromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

5.2.4 It is recommended that the PPWB cease monitoring dissolved boron at the Qu'Appelle River site. Long-term trend analysis fails to suggest any trend in boron concentration and the fact that concentrations have never approached the PPWB objective (2.0 mg/L) suggest there is little value in continuing to monitor boron.

5.2.5 It is recommended that the PPWB cease monitoring total coliforms in favour of monitoring fecal coliforms and *Escherichia coli*. Because total coliforms is a poor indicator of sewage contamination it has been replaced in many jurisdictions by fecal coliforms. *E. coli* possess the added advantage of being a superior indicator of gastrointestinal illness. A shift toward monitoring fecal coliforms and *E. coli* would also make PPWB data more comparable to that collected downstream in Manitoba.

5.2.6 It is recommended that the PPWB adopt the water quality index currently being developed by the CCME as a means by which the results of water quality assessments can be communicated to managers and the general public. As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

6.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE NORTH SASKATCHEWAN RIVER

6.1 Overview

The North Saskatchewan River originates in the mountains of western Alberta and flows eastward through Alberta and Saskatchewan until it meets with the South Saskatchewan River near Prince Albert, Saskatchewan and forms the Saskatchewan River. The river has a drainage area of 57,088 km^2, which is home to a variety of economic activities including, manufacturing, oil and gas development, mining (coal and potash) and agriculture. The basin is also densely populated (relative to other parts of the prairies) and the North Saskatchewan River flows through Alberta's second largest city, Edmonton. Principal water uses include water supplies for towns, cities, industries, irrigation, recreation and habitat for fish and wildlife (see Dunn 1995b for a more detailed description of the river basin). Analysis of water quality data collected over the last 25 years and an assessment of current development levels suggest that, of all streams monitored by the PPWB, the North Saskatchewan has the greatest potential to cause interprovincial concerns (Dunn1995b).

An analysis of long-term trends in water quality in the North Saskatchewan River suggests that the majority of measure variables show few significant trends over time. However, parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that eight variables significantly increased in concentration over the measurement period. These variables included: conductivity, turbidity, boron, pH, NFR, total phosphorus, lindane and total coliforms. At the same time, other variables such as, TDS, sodium, chloride, magnesium, Alpha BHC, potassium, calcium and zinc were observed to decrease significantly. Of those variables with a significant positive trend only total phosphorus was identified as having the potential to adversely affect downstream users. There is no PPWB objective for total phosphorus in the North Saskatchewan but, as with other rivers in the PPWB Monitoring Program, the interpretation of nutrient data and the appropriateness of suggest objectives are unclear.

In addition, to the variables described above, recent (i.e., 1993-1995) PPWB Excursion Reports have identified potential issues associated with total cooper, fecal coliform, lead, and zinc. While cooper shows no significant trend over the long-term the PPWB objective of 0.004 mg/L was exceed six times between 1993 and 1995 (n = 32 samples). Over the same period the Alberta guideline for cooper in surface waters (0.007 mg/L, see Shaw 1996) was exceeded twice. Although no overall trend is apparent, the frequency with which cooper meets or exceeds its objectives is of concern and is deserving of ongoing monitoring. As with cooper fecal coliform counts show no trend but have historically met or exceed the PPWB guideline of 100 counts/100 ml. However in the period from 1993 to 1995 the PPWB objective was only exceeded twice and both exceedances occurred outside the summer months (i.e., March and October, 1994), when irrigation/recreation uses are highest. Lead and zinc have both exceeded PPWB objectives (0.007 mg/L and 0.03 mg/l, respectively) in the past but neither variable has recorded an excursion since before 1993 suggesting that the potential for concern associate with these variables has lessened.

6.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report. Any changes to the monitoring program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

6.2.1 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured in the North Saskatchewan River and that, where objectives are needed, they be developed.** As discussed above, the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

6.2.2 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives at the North Saskatchewan River monitoring site.** Such a consideration may necessitate the control of certain covariates in the trend analysis or in the development of a number of condition-dependent (over a certain range of water hardness) objectives for some variables.

6.2.3 **It is recommended that the PPWB continue monitoring fish condition and tissue contaminant levels in the North Saskatchewan River on a five year cycle**. Fish collected for contaminant analysis should also be assessed for general condition. Fish captured, but not collected for contaminant analysis, should also be assessed for general condition prior to release.

6.2.4 **It is recommended that the PPWB evaluate the benthic macroinvertebrate community present at the North Saskatchewan River monitoring site on an annual basis using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

6.2.5 **It is recommended that the PPWB examine the feasibility of measuring primary productivity (periphyton and/or epiphyton) measured at the North Saskatchewan River monitoring site.** Measures of primary productivity, though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota.

6.2.6 **It is recommended that the PPWB explore the possibility of performing a broad spectrum analysis (BSA) on water samples from the North Saskatchewan River monitoring site**. The results of such an analysis should be used to identify classes of contaminants not currently measured but of potential concern.

6.2.7 **It is recommended that the PPWB explore the possibility of measuring sediment quality within the North Saskatchewan River monitoring site.** Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

6.2.8 **It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the North Saskatchewan River monitoring site.** Trend analysis is essential to the monitoring program but given the data already collected an analysis every five years should be sufficient to detect changes in trends and identify potential concerns.

6.2.9 **It is recommended that the PPWB collect water samples from the North Saskatchewan River monitoring site on a monthly basis every other year and quarterly in intervening years.** Such a change in sampling frequency will not significantly alter the ability to analyze long-term trends or detect excursions. Mercury and dissolved metals would be temporarily excluded from this change. These variables are of current concern to AEP and could be monitored monthly until those concerns are addressed.

6.2.10 **It is recommended that the PPWB monitor major ions at the North Saskatchewan River monitoring site on a quarterly basis only.** Current evidence suggests that while some major ions exceed objectives, high levels may be a natural consequence of underlying geochemistry and need not be measured monthly.

6.2.11 **It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for prairie rivers.** The importance of nutrient levels in determining ecological function in these systems has been recognized by the PPWB, as has inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study sponsored, in part, by the PPWB.

6.2.12 **It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the North Saskatchewan River monitoring site.** Statistical analyses do not suggest any trend in dissolved oxygen concentrations and exceedences of the PPWB guideline (6.0 mg/L) are very rare. More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to characterize the variation.

6.2.13 **It is recommended that the PPWB cease monitoring chromium in the water column at the North Saskatchewan River monitoring site. C**hromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

6.2.14 **It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the North Saskatchewan River monitoring site within three years.** Mercury levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue). Mercury is of concern to AEP however, the techniques currently employed by the PPWB to measure mercury are not adequate to address those concerns. Continuing to monitor mercury over the short-term may be helpful to immediate PPWB concerns but continued long-term monitoring using current techniques is inappropriate.

6.2.15 **It is recommended that the PPWB cease monitoring dissolved boron at the North Saskatchewan River monitoring site.** Long-term trend analysis suggests a trend of increasing boron concentration in the North Saskatchewan River. However, the fact that concentrations have never approached the PPWB objective (5.0 mg/L) suggest there is little value in continuing to monitor boron.

6.2.16 **It is recommended that the PPWB cease monitoring total coliforms in favour of monitoring fecal coliforms and *Escherichia coli*.** Because total coliforms is a poor indicator of sewage contamination it has been replaced in many jurisdictions by fecal coliforms. *E. coli* possess the added advantage of being a superior indicator of gastrointestinal illness. A shift toward monitoring fecal coliforms and *E. coli* would also make PPWB data more comparable to that collected downstream in Manitoba.

6.2.17 **It is recommended that the PPWB adopt the water quality index currently being developed by the CCME as a means by which the results of water quality assessments can be communicated to managers and the general public.** As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

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