P.E.I. Water Quality

Interpretive Report

1999

Environment Canada   Environnement Canada

Prince Edward Island
CANADA

Technology and Environment

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Interpretive Report

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Prepared for
Canada - Prince Edward Island
Water Annex
to the
Federal/Provincial Framework Agreement
For Environmental Cooperation In
Atlantic Canada

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Executive Summary

The Province of PEI and Environment Canada cooperatively monitor a long-term network of water quality and quantity stations in a number of PEI watersheds. Currently falling under the auspices of the Canada-PEI Water Annex to the Federal Provincial Framework Agreement For Environmental Cooperation in Atlantic Canada, this work includes monitoring completed under a number of programs, at some locations for as long as thirty years. Last reported on in 1978, this report provides an overview of the current conditions and documents long-term trends in water quality identified by these programs.

The water quality network currently includes stations in five watersheds and incorporates groundwater, fresh surface water and estuarine water. Samples are collected at regular intervals on a year round basis. The watersheds were selected to reflect a range of land-uses from mostly forested to largely agricultural, and a range of stream sizes. The data set utilized for this report comprises samples from the current network but also includes other historic samples contained in the Environment Canada Envirodat database. In some cases, there is a wide variety of parameters analysed for the samples in the data set. For this report, the parameters examined generally included major ions, metals, nutrients, pesticides and faecal bacteria when available.

Generally, the water quality of groundwater samples was found to be excellent. There were only isolated cases where the results exceeded drinking water guidelines. However, nitrogen levels in groundwater continue to be a concern both for drinking water in a low percentage of cases, and to a greater extent for nutrient enrichment of surface water bodies into which the groundwater flows. The metals content of groundwater was largely determined by natural bedrock conditions and almost all fell within drinking water guidelines. Most pesticide results have been published previously in other reports and these are briefly reviewed in this report. A small percentage of the analyses had detectable concentrations and none exceeded drinking water guidelines.

Fresh surface water was found to be influenced by land use activities to varying degrees. Where these influences are not large, the water was generally cool and well oxygenated as is typical for PEI. However, where the influence of land use was more evident, a trend of increasing nitrogen concentrations observed in all three stations with a 20-30 year period of record. Turbidity measurements also underline the connection between water quality and land use with higher values in developed watersheds. Elevated faecal bacterial levels were noted in some locations with the levels for primary contact being exceeded at several sites. Pesticides were commonly detected in concentrations below aquatic life guidelines. For the most part, metals were not observed at levels of concern, however elevated values for some metals have been occasionally recorded at many of the stations.

Estuarine water quality tended to be relatively good with some influences of land use being observed. Low dissolved oxygen levels were observed in several areas and are

likely indicative of excessive nutrient input. Long-term trends in phosphorus suggest that there have been increases. Given that the trophic status of PEI estuaries may be phosphorus limited, this implies a possible increase in productivity, suggesting that eutrophic problems may be worsening.

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1 Introduction

This report is intended to provide an overview of the current state of the Province's groundwater, fresh surface water and estuarine resources, as well as highlight any notable changes in water quality over the available period of record. Although water quality data has been collected in the Province since at least the early 1960's, an interpretive report summarizing the key implications of this data has not been released since 1978, when Environment Canada published the "Water Quality Interpretive Report, Prince Edward Island, 1961-1973 (Inland Waters Directorate, Water Quality Branch, 1978). While the primary focus of this report is on data collected from stations comprising the "Water Quality Network" and its predecessors, data from other sources has been drawn upon selectively, where such information helps provide a more comprehensive setting or context in which to discuss data from the "Network".

In order to adequately assess temporal trends in water quality, this report examines the full period of record available, and thus overlaps with the 1978 Interpretive Report. To avoid unnecessary duplication however, observations that may be pertinent only to the earlier period of record are not discussed.

This chapter provides a brief overview of the framework under which water quality monitoring is currently conducted, a general description of the key water resources issues in the Province, and the intended scope of the report.

1.1 Current Framework for Water Quality Monitoring in P.E.I.

The Province of P.E.I. and Environment Canada have maintained various cooperative agreements for water related environmental monitoring and research over the past several decades. The most recent framework for this activity falls under the umbrella of the Canada-P.E.I. Water Annex to the Federal Provincial Framework Agreement For Environmental Cooperation in Atlantic Canada. This "Water Annex" provides the basic management structure for the oversight of all cooperative water related activities conducted in the Province. Under the Annex, long term water quantity and water quality monitoring are conducted under the Ecosystem Monitoring Program component, while shorter term studies or programs are conducted under the Water Management Initiatives program area.

This division in program areas is intended to reflect the need for far sighted, long term monitoring of basic water data at selected sites on the one hand, while providing sufficient flexibility to address more specific water issues on an as needed basis, and with project structures designed to meet the specific data requirements dictated by the nature of the issue being investigated. Thus the assessment of long term water quality data, such as presented in this report is supported by the existence of the Ecosystem Monitoring program and its preceding equivalents, while more focused work such as the relationship between run-off and pesticide levels in surface waters can be conducted with a unique project design developed to meet specific research needs.

1.2 Water Resources Issues on Prince Edward Island

On a small Island Province, water, like the weather, is never far from one's thoughts, and indeed much of our well-being depends on the status of these renewable, yet finite, resources. Because of the physiography of the Province, large fresh surface water bodies are absent, with few lakes, and rivers which for much of their length are brackish.

While the Island has the luxury of substantial groundwater resources to meet many of our human fresh water needs, the fresh water streams and ponds of our province must still sustain a host of other functions as aquatic habitat and as part of the broader ecosystem that is home to our wildlife. In addition, the same features that explain the abundance of our groundwater resources also render them vulnerable to contamination, and once tainted, remediation is often not possible.

Even in our estuaries, which support such biological abundance and are the backbone of a growing part of our fisheries sector, water quality determines the extent to which this resource contributes to our economy and overall wellbeing. In short, P.E.I. has been well endowed with a resource that can make a substantial contribution to our lives, but water quality issues dictate the limitations to our use of these resources.

Until relatively recently, most water issues tended to be regarded as more or less independent of one another. Today, a more holistic view of the environment prevails, and the interconnections between groundwater, fresh surface water and estuarine environments is better appreciated. With this trend is the growing realization that the cause and solution to many of our more pressing environmental problems cannot be solved in isolation, but must be addressed in a broader context. As an example, the growing incidence of eutrophic conditions in our estuarine waters involves groundwater and surface water quality issues, and ultimately the impact of land use on these resources. This in turn reflects the fact that groundwater discharge accounts for some 60 to 70% of fresh surface water flows on the Island, and at some critical periods is the dominant source of water and thus primary influence on surface water quality. The current water quality network, and its integration with water quantity stations, is a reflection of this interconnectedness, and the need for a broader view of the environment.

Key areas of concern that have persisted over the years include soil erosion, and the resulting siltation of streams and estuaries, elevated nitrate concentrations in groundwater and surface waters, bacterial contamination of shellfish harvesting areas, and the occurrence of pesticide residues in groundwater and surface waters. These water quality issues have been discussed at various lengths in previous publications such as “Cultivating Island Solutions” (Round Table on Resource Land Use and Stewardship, 1997); “Water on Prince Edward Island - Understanding the resource, knowing the issues” (P.E.I. Dept. of Fisheries and Environment and Environment Canada, 1996); and “Evaluation and Planning of Water Related Monitoring Networks on Prince

Edward Island" (Environment Canada - Prince Edward Island Dept. of the Environment, 1991), and are summarized very briefly below.

For several decades, the loss of the Island's soils and the resulting damage to agricultural lands and to aquatic habitat have been recognized as a major problem. While considerable progress has been made in the development techniques to minimize soil erosion by agriculture, forestry and highway construction activities, much work remains to be done, particularly with respect to the wide spread adoption of effective erosion control measures. Long term monitoring of sediment in our aquatic systems may help us measure our progress as these efforts continue, and help focus our efforts on areas of greatest priority.

The occurrence of elevated nitrate levels in groundwater, especially in areas of intensive cultivation, is common in many agricultural areas around the world. While the situation for P.E.I. groundwater appears not to be critical for drinking water purposes, nitrate levels clearly depart from "natural levels" often by as much as 3-4 times assumed background levels, and in some heavily cultivated watersheds nitrate levels in water from as many as 6 to 7% of wells exceeds the recommended guideline level (Somers, 1998; Swain, 1995).

Equally important, is the influence of groundwater quality on the level of nutrients in fresh and estuarine portions of surface water bodies. As noted above, baseflow in Island streams comprises a high proportion of total discharge, and nitrate concentrations well below levels of concern for drinking water quality are of serious concern in estuarine environments, where over-enrichment with nutrients, principally nitrogen and phosphorous, can stimulate excess primary productivity, leading to eutrophic conditions in estuarine environments.

Currently, a significant number of Island estuaries exhibit symptoms of eutrophication that have been linked to land use and nutrient enrichment (Thompson, 1998). Table 1 lists some of the estuaries for which impacts have been reported, and the associated symptoms.

Bacteria associated with runoff from agricultural areas, urban areas and wastewater effluent, while not causing direct environmental problems, have indirect implications for the economy of the Island. The principal impact is felt in the shellfish industry, where excessive levels of faecal coliform bacteria render large portions of the prime shellfish producing areas of the Province unfit for sale directly to the consumer because of the risk to public health. In spite of fairly comprehensive wastewater treatment provisions in the Province, non-point sources of bacteria, particularly impacts of livestock on surface waters, have direct and substantial economic implications for the Province (P. Lane and Associates, 1991).

The presence of pesticides in water have been a particularly controversial environmental issue over the past several decades. Several recent fish kills in the western portion of the Province appear to be related to typical pesticide application. Analyses of water samples from these fresh water systems have indicated the

Table 1 P.E.I. Estuaries with Eutrophic Symptoms

Estuary	Observed Conditions
Barbara Weit River	Anoxic
Boughton River	Depressed oxygen upper estuary
Brackley Bay	Anoxic
Hunter River	Anoxic
Mill River	Anoxic
Morell River	Anoxic
Pinette River	Anoxic
Souris River	Anoxic
Southwest River	Anoxic
Stanley River	Anoxic
Trout River (New London Bay)	Anoxic
Vernon River	Anoxic
Wheatley River	Anoxic

presence of a variety of pest control products, but at levels which would not be expected to be lethal for fish. Nonetheless, it has proved very difficult to collect samples at the critical period immediately preceding a fish kill, and the full severity of pesticide contamination of surface waters is likely to be underestimated by the results from the grab samples collected to date.

The occurrence of pesticides in groundwater has received considerable attention, although generally speaking, these compounds have not been found frequently in groundwater samples. Furthermore, with the exception of cases where the presence of pesticides can be attributed to a spill or other accidental release, when detected, concentrations have been very low, well below drinking water guideline values. While the results of pesticide analyses of groundwaters has generally not shown cause for alarm, at least one compound, hexazinone, is being found with disconcerting frequency in some environments, notably in relation to blueberry cultivation.

Because agriculture plays such a dominant role in the Province's economy and landscape, it also has tended to dominate the agenda in terms of water quality. As a result, other potential contaminants which might be of more interest in more heavily industrialized areas have not been given the same amount of attention. Nonetheless, other anthropogenic activities have left some imprint on water quality, especially in urban areas, where fuel spills, road salting and other commercial activities have impaired natural water quality.

2 Methodology

2.1 History of water quality sampling on P.E.I.

Systematic water quality data collection on P.E.I. began with the establishment of the International Hydrologic Decade (IHD) in the mid 1960's, and has evolved since then through various configurations in response to changing issues, fiscal resources, and general approaches to environmental monitoring. (See Figure 1. Historical Water Quality Stations, 1961-1997.)

Some of this work has been designed as screening surveys with extensive parameters lists, whereas other studies have focused on more in-depth investigations of specific parameters. This data has been used to support various water management needs including "state of the environment reporting", development of national water quality guidelines and priorization of research needs.

Much of the earlier work on water quality was driven by specific issues, and conducted under short term mandates to investigate specific phenomena such as the occurrence and distribution of various organic chemicals, heavy metals, etc. As

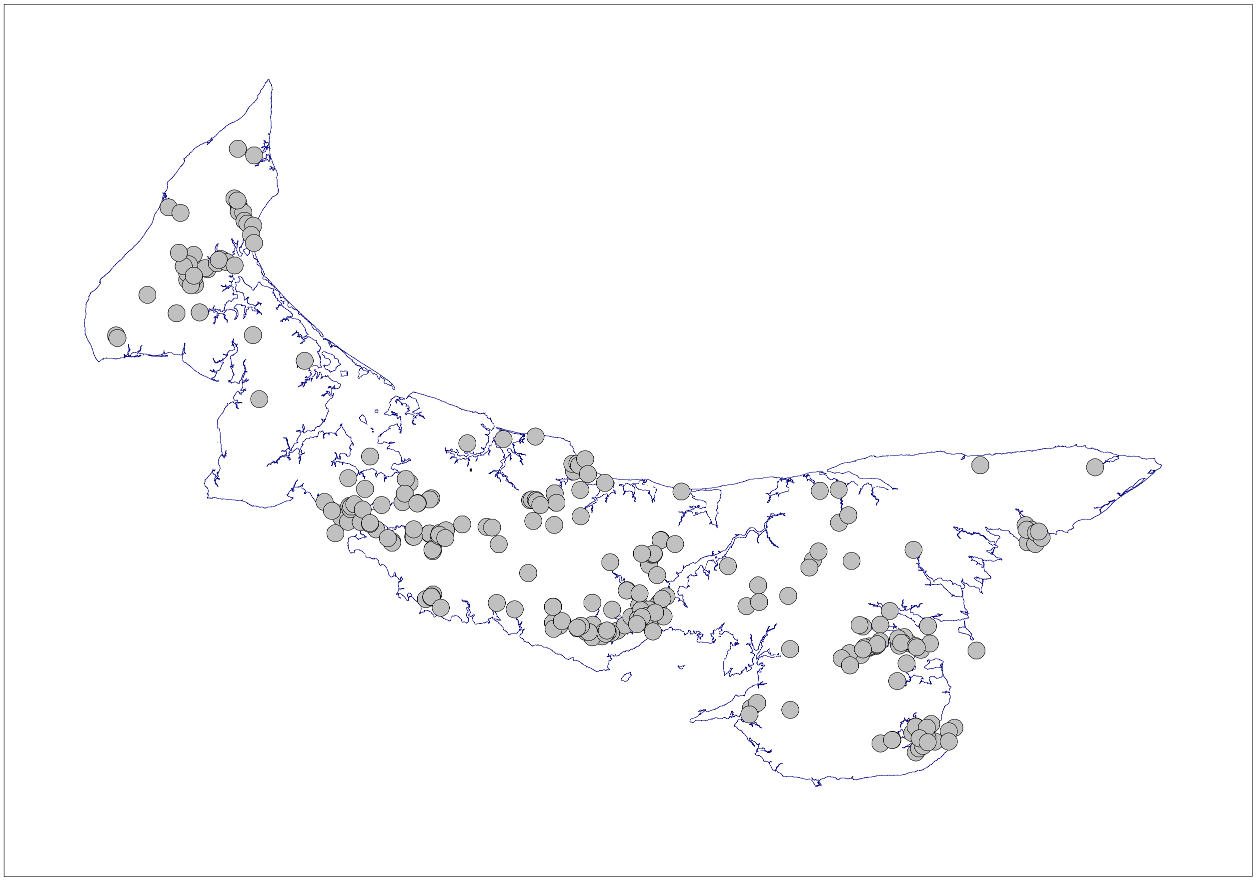

Figure 1 **Historical water quality stations (1961 - 1997).**

a result, the considerable sampling efforts devoted to particular locations or parameters at one time are not necessarily followed up in subsequent periods of record. In assessing the data covered in this report this has been considered, otherwise a somewhat skewed view of overall results would emerge.

For example, while some stations have shown a high frequency of detections for a particular pesticide, these results may reflect the efforts of concentrated sampling over a short period of time, and may not reflect overall water quality conditions at that site over the period of record, or at other stations across the Island. Where possible, an attempt has been made to account for these factors.

While groundwater sampling has been conducted for a good portion of this time, such sampling typically was conducted on an ad hoc, issue driven basis, and as a consequence long term records from individual stations are rare. Only since the adoption of an "index basin approach" developed in the early 1990's, have these activities been integrated with other water quality monitoring efforts.

Established as Canada's contribution to the IHD, the National Water Quality network (1965-1974) saw four stations established on P.E.I. At this time, the network on P.E.I. was based on geographic distribution and proximity to stream gauging stations. The IHD program was established to maintain a water quality and pollution evaluation network.

By the early to mid-1970's the original IHD network evolved into the National Water Quality Monitoring Program. Built on the original IHD network, additional stations were added on an issue driven basis. At the height of activity, 22 sites were in operation representing the major river basins on the Island.

In 1978, as a result of changing Federal mandates, the network was cut to 3 sites on P.E.I., and continued operation under the Atlantic Region Overview/LRTAP Network (1978-1991). Two of these stations; Carruthers Brook on the Mill River system and the Dunk River had been continuously monitored since the IHD program was initiated in 1965, and the third station on the Morrell had been established in 1974.

In 1991 the Federal and Provincial governments undertook a major review of all water related monitoring networks, and proposed for the first time, an integrated approach to the collection and assessment of surface water and groundwater quantity and quality data (Environment Canada / P.E.I. Dept. of the Environment, 1991). Under this basic pattern, with a strong focus on the "watershed" as the principle unit for study, groundwater and surface water quality monitoring continues to the present day. Also at this time, monitoring resumed in estuaries as part of this program. While estuaries were monitored under the IHD program, subsequent monitoring was completed by the province alone until 1991.

At its inception, water quality sampling was conducted under the Canada/P.E.I. Water Quality Monitoring Agreement. In 1995, this agreement and others were replaced by the Canada/P.E.I. Water Annex however the programs differ only in their administrative framework.

Under this arrangement, the Province & Canada jointly maintain a network of watersheds across the Island where long term monitoring of groundwater and surface water quantity and quality are carried out. Although a total of 7 basins around the Island were originally established, rationalization has reduced the scale of the network to five basins; three "index basins" and two "management basins".

2.2 Current Network Design & Operation

The network (Figure 2) now comprises three fully monitored watersheds where groundwater observation wells and stream gauges continuously measure the quantity of water flowing through the watersheds, and groundwater and surface water quality monitoring stations where grab samples are collected on a routine basis. These watersheds have been specifically selected to reflect the range of regional and physiographic characteristics of P.E.I., and are referred to as "Index Basins" (Mill, West and Bear Rivers). In addition, two other watersheds have been equipped with monitoring stations dedicated to more specific, shorter duration research objectives relating to groundwater and surface water quantity and quality, and are designated as "Management Basins" (Dunk/Wilmot and Montague/Valleyfield Rivers). All stations are supported by an

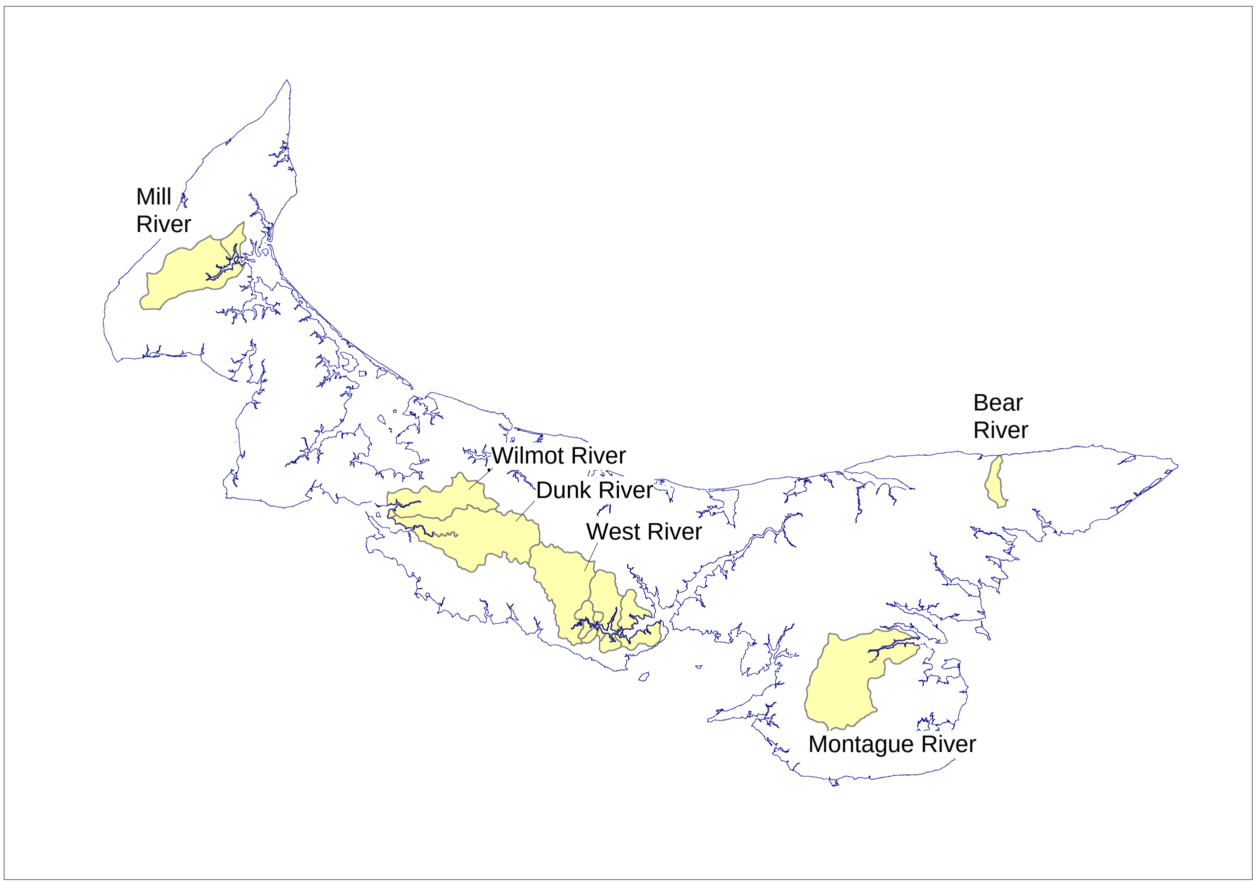

Figure 2 **Monitored watersheds in the current water annex network.**

Island wide network of precipitation stations operated by Environment Canada.

The current agreement includes 23 sampling sites of which 9 are inland streams and rivers, 9 are estuarine sampling stations and 5 are groundwater sites. Figure 3 shows the period of record for the current long term water quality stations. Sampling sites maintained under the Water Annex are sampled from 6 to 8 times per year. Table 2 lists the parameters currently measured at "annex" stations.

2.3 Data Assessment

The data set on which this report is based is a subset of a larger Atlantic region database maintained by Environment Canada called Envirodat. The majority of the analyses in this database have been analysed by Environment Canada or its partners. These analyses were completed using standard methods adopted by Environment Canada and the P.E.I. Dept of Technology and Environment. The data extractions from Envirodat for this report generally selected data collected in P.E.I. that represent ambient environmental conditions. That is, data that were part of experimental manipulations or effluent data or other data not representative of the environment for similar reasons were specifically avoided.

The storage of data on Envirodat is very specific with respect to the naming convention for analyses that are similar but not exactly the same. When ever there is a slight difference in the analytical methodology, a different parameter name is utilized. For this report, it is more

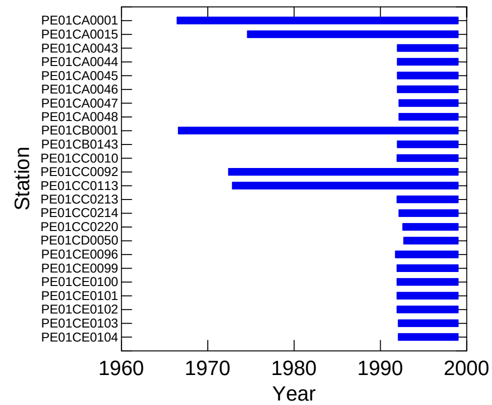

Figure 3 Period of record for stations in the current network.

important to assemble general long-term data sets than to be able to determine minute differences in methods. Whenever possible, parameters of essentially the same analysis were grouped together. As there is some danger in this approach of grouping data together to produce an erroneous conclusion, considerable care was taken to examine the individual parameters separately prior to combining for obvious inconsistencies. The number of raw parameters originally extracted from Envirodat was extensive, exceeding several hundred. Of these, approximately 260 were consolidated to ~90. As the units were sometimes different between parameters, care was taken to convert parameters with differing units to the same units prior to consolidation. A table outlining the actual Envirodat parameters that were combined to form the data set for this report is available from the Dept. of Technology and Environment. There were number of parameters that were not included in the analysis. This was generally because either the parameter had too few values or was not of significant interest on P.E.I.. Also, there were a number of metals that were

Table 2 Parameters Analysed for the Network

Parameter	Groundwater	Fresh surface water	Estuarine water
Aluminum (total)	✔	✔	
Alkalinity (total)	✔	✔	
Ammonium (NH_4+NH_3)		✔	
Arsenic (total)	✔	✔	
Dissolved Organic Carbon	✔	✔	
Calcium (dissolved)	✔	✔	
Cadmium (total)	✔	✔	
Chlorophyll *a*		✔	✔
Chloride (dissolved)	✔	✔	
Cobalt (total)	✔	✔	
Colour	✔	✔	
Chromium (total)	✔	✔	
Copper (total)	✔	✔	
Dissolved oxygen		✔	✔
Iron (total)	✔	✔	
Faecal Coliforms	✔	✔	✔
Lead (total)	✔	✔	
Potassium (dissolved)	✔	✔	
Magnesium (dissolved)	✔	✔	
Manganese (total)	✔	✔	
Nitrogen (total)	✔	✔	
Sodium (dissolved)	✔	✔	
Nickel (total)	✔	✔	
Nitrate+Nitrite Nitrogen	✔	✔	✔
Phosphorous (total)		✔	✔

Table 2 Parameters Analysed for the Network

Parameter	Groundwater	Fresh surface water	Estuarine water
pH	✔	✔	✔
Salinity			✔
Sulphate (dissolved)	✔	✔	
Specific Conductance	✔	✔	✔
Suspended Solids		✔	✔
Temperature		✔	✔
Total Coliforms	✔		
Turbidity	✔	✔	
Zinc (total)	✔	✔	

analysed as both an extractable and a total analysis. With the exception of mercury where a total analysis was not available, only total analyses were selected for this report. This was primarily because the various Canadian Council of Ministers of the Environment (CCME) water quality guidelines reference values for analyses of total metals.

Due to the varying nature of the analytical methods, the detection limits often differed for the various parameters that were combined. To address this problem, for the purposes of calculating statistics, analyses with a result of less than detection limit were converted to zeros. As a result, all average statistics reported in the main body of this report should be considered as slightly conservative. In most circumstances, this conservative tendency is so minor as to be completely negligible. This is not the case for pesticides where the frequency of non-detects is very high. In these cases, in lieu of the average concentration, the frequency of detection is reported as well as the maximum concentration.

Many stations in the data set were sampled on a few occasions and a few stations were sampled hundreds of times. As a result, without weighting the data, average statistics would be heavily weighted towards the water quality at the stations that were sampled more often. In order to properly weight the data when calculating overall averages, averages were first calculated for each station and then the station averages were averaged to determine a global average. Readers should note that when reported, standard deviations thus show the variability of the station averages, not the variability of individual samples. As this methodology does not provide any information on the extremes of the data set, the range reported is the actual minimum and maximum analysis values to impart some information on the outliers in the data set.

A number of the stations that were listed as freshwater were clearly influenced by tidal conditions as indicated by examining the location of the station and the general ionic make-up of the water. These stations were omitted from the calculations for freshwater so as to ensure that the resulting statistics truly represented only freshwater conditions.

Only a few stations had extensive records of analyses that span the several decades included in this report. Because of this simple limitation, much of the long-term trend information reported in the data set originates from these sites. They are the Dunk River (PE01CB0001; 1966 - present), the Carruthers Brook on the Mill River (PE01CA0001; 1966 - present) and the Morell River (PE01CD0003; 1972 - 1995).

There are a number of scatter plots in the report with scatter plot lines displayed on the graph. These lines were generated by Systat 7.0 using the LOWESS option with the tension set to 0.5. The choice of this particular option for this purpose was due to its ability to determine a scatter plot line and not be unduly affected by the odd outlier.

Because virtually all potable water in P.E.I. comes from groundwater sources, groundwater quality has been assessed principally according to the recommendations in the Guidelines for Canadian Drinking Water Quality, published by Health Canada. For surface water stations, the Canadian Environmental Water Quality Guidelines published by CCME with respect to the protection of aquatic life have been used to assess water quality. CCME does not have a large set of guidelines estuarine environments, but where it appears relevant, the equivalent fresh water guideline has been used as a basis for evaluation. In a few cases, other appropriate national guidelines have been utilized which are noted in the text when used. Where a national guideline does not exist and where there are suspected adverse implications associated with the presence of a compound in a particular media, alternate guidelines may be quoted from other jurisdictions.

3 Water Quality Results

The discussion of results for samples collected from the water quality network is organized by the nature of the parameter measured, and for the most part combines results and observations from groundwater, surface water and estuarine sampling stations. This is in recognition that all three media are intimately related on P.E.I. and many of the influences on water quality are common or at least loosely related. While the focus of the report is on results from the network, from time to time reference is made to relevant observations from other work.

This chapter begins with a discussion of physical characteristics of natural waters, followed by a discussion of the major inorganic constituents which determine the overall characteristics of these waters. Additional parameters are discussed under the headings of nutrients, metals, pesticides and other organic chemicals and bacteria.

Although one of the key aims of this report is to examine temporal changes in water quality, the design and changes to the network as it has evolved over the years and the resulting period of record for many stations limits the ability to draw firm conclusions in many of these areas. Where possible, it has been indicated whether the distribution of a particular parameter or group of parameters has remained stable over the period of record or not. Where temporal trends of interest are noted they are discussed more fully in Chapter 4.

3.1 Physical Characteristics

There are a variety of measurements made on water samples that loosely characterize the physical properties of the aquatic environment, or provide indirect information on the chemical composition of these waters. For simplicity, these are collectively grouped here under the category "physical characteristics", recognizing that some of these measures could be more correctly referred to as chemical parameters. Accordingly, the parameters pH, temperature, conductivity, dissolved oxygen, turbidity and total suspended solids are discussed.

3.1.1 pH

The measurement of pH is used to indicate whether a solution is acidic or alkaline. A solution that is considered to be neutral has a pH of 7.0**.** The pH of waters may provide useful clues to the evolutionary history of natural waters, as well as indicating a variety of anthropogenic influences. Over the past few decades, one of the key interests in the pH of natural waters in Atlantic Canada has been the influence of acid precipitation. pH also sheds light on the buffering capacity of soils and aquifer materials and can act as a finger print in distinguishing between relatively new near surface waters and older groundwaters which reflect a longer period of chemical interaction with aquifer materials. Thus, changes in pH can reflect the progressive reactions between groundwater and aquifer materials as it travels throughout the groundwater flow system.

Groundwater samples from the network had a mean pH of 7.7 and all but one sample (representing 0.3% of results) fell within the pH range of 6.5 to 8.5 recommended in the Guidelines for Canadian Drinking Water Quality. Although the period of record for groundwater stations is limited, no temporal trend is indicated by the data. Given the strong buffering capacity of these waters as a result of relatively high alkalinity, it is not surprising that no changes are apparent.

While pH values for fresh surface waters exhibit a slightly greater variability than observed for groundwater sources, they are still relatively uniform across the Province and fall in the same range, with a mean pH of 7.5. The CCME guidelines for the protection of aquatic life suggest a pH range of 6.5-9.0 and only 2.7% fell outside this range, with maximum and minimum values of 9.1 and 4.2 respectively. In the majority of these cases, pH was below 6.5 although in a few cases, pH exceeded 9.0.

The data collected to date indicate a trend of increasing pH values for fresh surface waters, with a gradual increase of approximately 0.2-0.4 pH units over the

25-30 year period of record (Figure 4). The most notable change is in the Dunk River, where pH has increased by approximately 0.4 pH units over the past 30 years . A decrease in the acidity of precipitation and an improvement in precipitation water quality has been noted in the Atlantic Region over the past 20 years (Environment Canada, 1998). The observed increase in pH in Island fresh water bodies may be a reflection of an overall improvement in precipitation quality in the region.

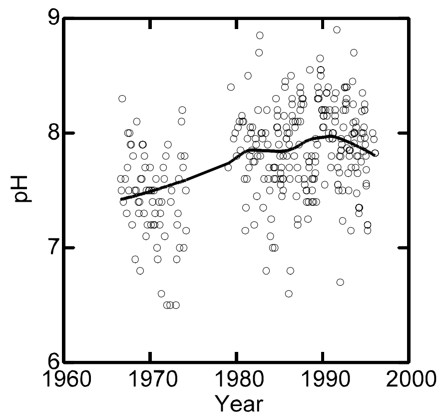

Figure 4 Long term trend in pH in the Dunk River (PE01CB0001)

Estuarine waters have pH values which range from 4.6-9.4 with a mean pH value of 7.7. No long term trends are apparent in data from these stations.

3.1.2 Temperature

Measurements of temperature are routinely taken when samples are collected either as part of the network or for other programs. As it is unclear that the ground water temperature records represent the temperature at depth in the ground as opposed to the temperature in the water distribution system, ground water temperature records have not been assessed in this report.

In the surface water the primary trends of interest are normal seasonal and long-term changes. While factors such as riparian zone cover vegetation, impoundments and long term air temperature trends all could be expected to influence water temperatures, long-term trends are not evident in the data set.

It is not clear that the surface water should mirror the well known increases in air temperature. The variability in temperature between stations due to the influence of other factors such as the prevalence of ponds and springs could obscure any subtle long term changes. The infrequent collection of temperature records could further preclude the detection of any change in the surface water temperature record.

Seasonally however, temperatures vary widely. As would be expected, maximums for fresh and estuarine waters occur in July and August respectively. Average summer and winter freshwater temperatures are approximately 15 and 1°C respectively. Average summer and winter estuarine temperatures are approximately 18 and 0°C respectively.

3.1.3 Conductivity

Conductivity, a measure of the ability of an aqueous solution to carry an electrical charge, provides a useful surrogate for measures of total dissolved solids or salinity, and is a practical field method for preliminary assessment of water quality.

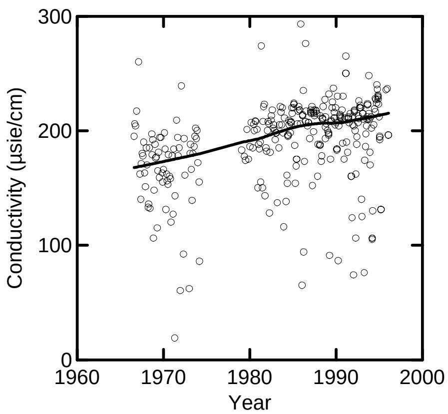

Figure 5 Long term trend in conductivity in the Dunk River (PE01CB0001)

Groundwater samples for the province had a mean specific conductivity of 329 µS/cm while fresh waters had a mean specific conductivity of 200 µS/cm. The higher average values for groundwaters is consistent with the longer residence time for groundwater, (and thus the greater contact time with reactive soil and aquifer materials) as compared with surface water. In fact, the relatively high values for fresh surface waters underline the importance of groundwater discharge in determining surface water quality on P.E.I.

Overall conductivity levels for groundwaters and most fresh surface waters have remained stable over the limited period of record for these stations. An exception to this case is seen for surface water stations on the Dunk River. Conductivity values here have risen by approximately 50 µS/cm over the past 30 years (Figure 5). This increase correlates with an increase in calcium, magnesium and alkalinity, discussed later in Section 3.2 of the report.

3.1.4 Dissolved Oxygen

Dissolved oxygen, while strictly speaking a chemical parameter, is discussed here because it fits the general role as an indicator of a variety of physical, biological and chemical processes in the aquatic environment. The availability of dissolved oxygen is important for most forms of life and the CCME guidelines for the protection of aquatic life recommend oxygen concentrations of at least 9.5 mg/l for the protection of early life stages of aquatic life, based on the premise that this level is set to maintain a level of at least 6.5 mg/l of dissolved oxygen in stream sediments for salmonoid spawning habitat. The guideline for other life stages is 6.5 mg/l.

The mean concentrations of dissolved oxygen observed in freshwater streams is 12.35 mg/l, with nearly 95% of samples meeting or exceeding the 9.5 mg/l guideline for protection of early life stages of aquatic organisms. Forty-two of 748 (5.6%) samples were below the 9.5 mg/l guideline and 2 of 748 (0.3%) were below the 6.5 mg/l guideline for the protection of aquatic life. The minimum level of 2.3 mg/l was recorded on the West Branch of the Morell River at station PE01CD0022.

Dissolved oxygen concentrations for the fresh surface waters have remained relatively stable over the past 25 years however seasonal patterns are typically observed, with decreasing levels occurring throughout the warmer summer months and increased concentrations in the autumn and winter. This seasonal variation is more pronounced in the estuarine data than in the fresh water data (Figures 6 and 7).

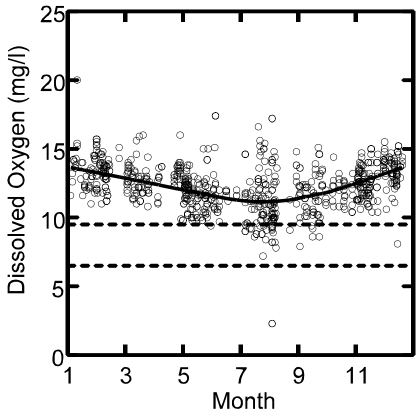

Figure 6 Seasonal dissolved oxygen trends in fresh water. Dashed lines indicate aquatic life guidelines.

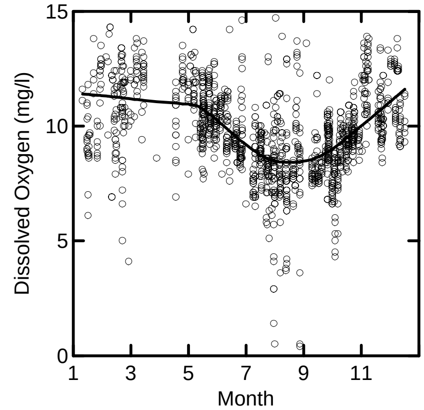

Figure 7 Seasonal dissolved oxygen trends in estuarine water.

The mean dissolved oxygen concentration for estuarine samples is 9.9 mg/l, however low dissolved oxygen concentrations have been recorded for a number of estuaries. Dissolved oxygen values below 3.0 mg/l were recorded for sites PE01CA0004 and PE01CA0005, on the Kildare River Estuary; PE01CA0047 on the Mill River and PE01CA0007 on the Huntley River Estuary, with a minimum value of 0.4 mg/l.

These low concentrations of dissolved oxygen are a serious concern for aquatic life, and point to significant problems in some estuaries of the Province. Although average concentrations of this parameter are generally high and are fairly consistent across the Island most of the time, short term periods of low dissolved oxygen concentrations are sufficient to cause significant damage to aquatic communities. While this data set does not indicate severe problems, other work has demonstrated low dissolved oxygen concentrations in a number of upper estuarine areas on P.E.I.

3.1.5 Turbidity

Turbidity is a measure of water clarity, based on the transmission of light through the water column. While turbidity is an important parameter for drinking water treatment plants exploiting surface water sources, where all potable water comes from groundwater on P.E.I., its prime significance here is the implications for the health of aquatic habitat.

The mean turbidity for fresh surface waters on P.E.I. is 3.0 Jackson Turbidity Unit (JTU), with values ranging up to as much as 700 JTU, recorded at station PE01CB0001 on the Dunk River. Alberta and Saskatchewan have set turbidity guidelines, for the protection of aquatic life, that allow a maximum increase of 25 JTU above background levels. There have been no background levels established for turbidity in P.E.I. streams, and comparison with these recommended levels is not possible at this time. In addition, care must be exercised interpreting this data due to the nature of grab sample measurements. For parameters such as turbidity, it is expected that measurements under dry weather conditions would be much lower than measurements under wet weather conditions in watersheds where there is significant soil erosion as occurs in a number of P.E.I. watersheds. No attempt was made for this report to determine whether wet weather events were adequately monitored in the data set. With this type of program and parameters, the calculated average of a biased data set normally underestimates the true average for the parameter. It is also possible that the maximum measurement does not fairly represent conditions that commonly occur under wet weather conditions.

Turbidity levels show a significant degree of spatial variability across the Island with concentrations generally being correlated to land use practices, and the potential for significant soil losses via erosion. As an example, the mean value of measurements from the Dunk River, in a region of intense cultivation, is 9.7 JTU, while the mean value from the Bear River, a relatively non-impacted area, is 0.56 JTU. Long-term data for turbidity does not indicate any trend over the period of record, and does not appear to show any seasonal variability. Experience has shown that heavy runoff events may occur at any time of the year. In addition, data from grab sampling, may not necessarily reflect the influence of storm events which would be expected to correlate with higher turbidities.

3.1.6 Total Suspended Solids

Total suspended solids are a measurement of all material suspended within the water column, and like turbidity this parameter is generally important in the assessment of the health of aquatic habitat. Soil erosion, and the resulting siltation in Island streams has been identified as one of the most pressing environmental issues on the Island. CCME guidelines for the protection of aquatic life recommend that added suspended solids should not exceed 10 mg/l when background suspended solids concentrations are equal to or less than 100 mg/l, and should not exceed 10% of background levels when background levels exceed 100 mg/l (CCME, 1987).

Mean suspended solids concentrations of 4.5 mg/l were recorded for the surface water stations, with only one sample exceeding 100 mg/l. However, these results are not likely to provide an accurate representation of suspended sediment, as the data is derived from grab samples that may not capture the episodic, short term transport of sediments that one would expect to be associated with heavy runoff events. With the limited amount of data available it can be demonstrated that suspended sediment concentrations follow a seasonal trend (Figure 8). Average concentrations drop from approximately 4

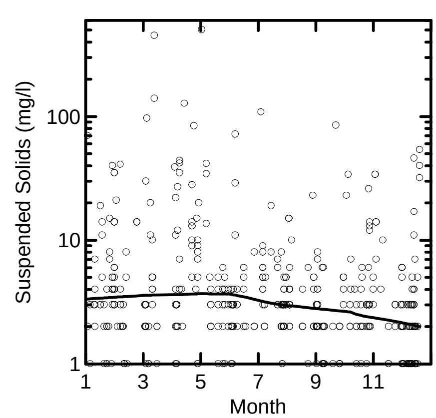

Figure 8 Seasonal suspended solids trends in fresh water.

to 2 mg/l from the summer through the fall.

Data collection for this parameter began in the early 1990s and because the data set contains no long term data upon which to determine background levels for suspended solids, a comparison with these recommendations is not possible at this time.

3.2 Major Ion Chemistry

The general chemical characteristics of most natural waters are determined by the relative and absolute concentrations of the major cations and anions present in solution. These characteristics are in turn determined largely by the “history” of the water, and reflect the nature of precipitation in the area, the materials the water is in contact with and residence time of the water as it flows through the local environment. These major ion characteristics can be used to define general “water types”, and can facilitate discussion of the broad characteristics of natural waters and trends in water quality. Described below are observations on the major ion chemistry of the Province’s fresh and estuarine waters.

Fresh Waters

On P.E.I., groundwaters and fresh surface waters share generally similar major element characteristics, and are of a "calcium - bicarbonate" or "calcium - magnesium - bicarbonate" type, reflecting the influence of carbonate minerals in local soils and bedrock. Generally speaking, waters in the eastern and central portions of the Island are calcium-magnesium bicarbonate waters, resulting from the dissolution of dolomitic cement in soils and bedrock. Further west, calcium - bicarbonate waters dominate, presumably reflecting the importance of calcite as opposed to dolomite as a cementing agent in local bedrock. While the relative abundance of these ions is similar in fresh and groundwater, the latter normally have higher total dissolved solids because of their longer residence time in contact with the soil and bedrock which determines their character. However, because of the significant volumetric contribution of groundwater to surface water systems, the differences in total dissolved solids are not always large. Groundwaters are normally hard to very hard and have neutral to slightly alkaline pH’s. Surface waters are normally somewhat softer and exhibit lower total dissolved solids than groundwaters, although they also exhibit the same neutral to slightly alkaline pH.

Two other water types, both associated with groundwater, are known to occur on P.E.I., but are not represented by any of the sampling stations upon which this report is based. They are mentioned briefly because of their localized importance, although their geographic distribution is limited .

The first are "sodium - chloride" type groundwaters where fresh groundwater is mixed with marine water, with resulting brackish to saline groundwaters occurring locally in some coastal aquifers. The second are sodium bicarbonate waters that are known to occur at depth in some regional flow systems, and more rarely in localized discharge regions of these systems in some areas of the province. Characterized by high sodium and total

Table 3 Major Ion Chemistry of Fresh Waters

Parameter	**Groundwater**			**Surface Water**		
	mean	**std. dev.**	**range**	**mean**	**std. dev.**	**range**
calcium mg/l	37.7	16.2	LD - 137	21.9	10.7	0.5 - 57
magnesium mg/l	12.6	7.9	LD - 72	6.9	4.3	0.5 - 31
sodium mg/l	10.2	8.1	1.4 - 165	6.2	2.7	1 - 32
potassium mg/l	1.7	1.5	0.09 - 14	1.3	0.5	LD - 10
alkalinity* mg/l	128.3	41.7	6.7 - 488	67.9	26.8	3.6 - 203
chloride mg/l	21.9	22.4	0.7 - 711.7	12.1	6.2	0.1 - 62
fluoride mg/l	0.053	0.046	LD - 0.72	0.026	0.025	LD - 0.72
sulphate mg/l	9.0	4.7	LD - 41.7	6.5	4.1	LD - 39.8
conductivity** µS/cm	329	115	30.1 - 1680	200	121	18.8 - 1100

* Alkalinity is generally assumed to reflect the activity of carbonate species in most natural waters and is used as a proxy for bicarbonate concentration in this discussion.

** Conductivity values are used here as a proxy for total dissolved solids.

dissolved solids but low chloride levels and hardness, these waters are often referred to as “naturally softened” waters and their chemical characteristics reflect ion exchange processes between groundwater and clay minerals in the aquifer. Because of the localized nature of these features, and their lack of representation in the data base upon which this work is based, these water types are not discussed further in this report. Table 3 describes the general range of major ion compositions for P.E.I. groundwater and fresh surface waters. The mean values reported are in fact the mean of mean values for individual stations, and standard deviations calculated for these mean station values as well. These are intended to provide an indication of the average characteristics, and variability of fresh water stations across the Island. The range reported reflects the span of all analyses from all stations for that parameter.

With the exception of the calcium: magnesium ratios noted above, the relative abundance of major ions in groundwater samples is relatively consistent across the Province, and the range of absolute concentrations for each of these constituents is likely to reflect residence time of water in the aquifer. This in turn can be expected to vary from site to site as a result of factors such as position within the groundwater flow system and well construction. Although the period of record for groundwater

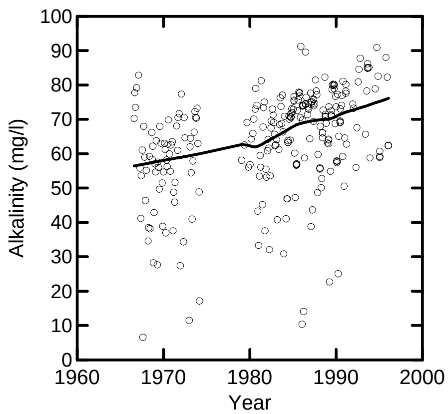

Figure 9 Long term trend in alkalinity in the Dunk River (PE01CB0001).

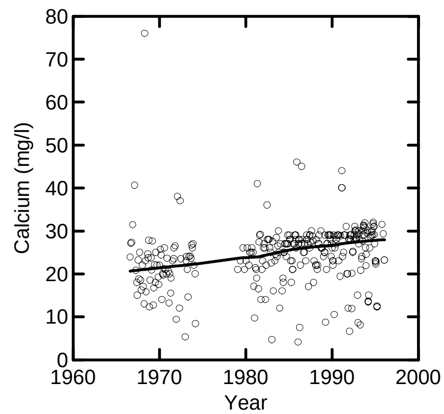

Figure 10 Long term trend in calcium in the Dunk River (PE01CB0001).

samples is considerably shorter than for some surface water stations, no temporal trends are apparent in the major ion composition of groundwaters represented in the data set, and all parameters are well within the range considered acceptable for drinking water quality.

As is illustrated in Table 3, the relative proportions of major ions for fresh surface waters of the Province are generally similar to groundwater, but occur in slightly lower concentrations. Unlike groundwater, however, some temporal trends in surface water quality have been observed at stations with a long term period of record. Samples from the Dunk, Mill and Morell rivers, exhibit a subtle, but significant increase in alkalinity, calcium and magnesium, the ions constituting the bulk of dissolved constituents in these waters. These increases have also been accompanied by similar increases in conductivity in the Dunk River, but have not been observed in the Mill or Morell Rivers. Figures 9 through 11 illustrate these trends in the Dunk River data. No clear explanation of this trend is apparent at this time.

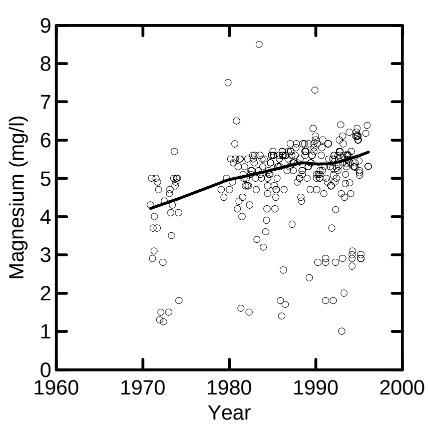

Figure 11 Long term trend in magnesium in the Dunk River (PE01CB0001).

Slight increases in chloride concentrations have also been observed in samples from the Dunk and Morell Rivers, and may be related to road salt application within these watersheds, however the significance of this weak trend is unknown at this point.

Long term surface water data for the Dunk, Mill and Morell River indicate a slight decrease in sulphate levels, and as has been noted earlier, pH values have exhibited a slight increase over the same general period. This apparent decrease in sulphate concentration may be an artifact of changes in analytic

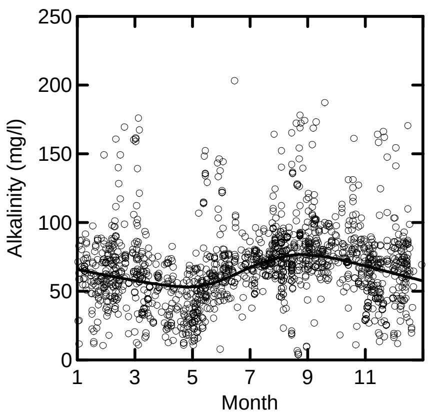

Figure 12 Seasonal trend in freshwater alkalinity.

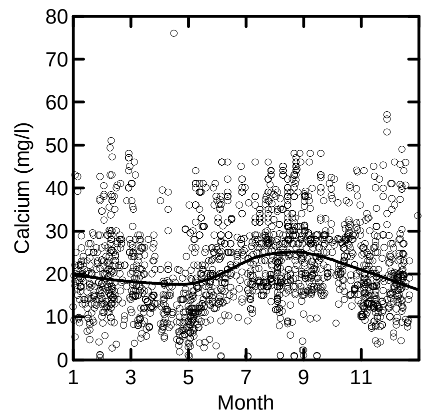

Figure 13 Seasonal trend in freshwater calcium concentrations.

methodology. It may also be related, at least in part, to an overall improvement in the quality of precipitation falling on the region. There has been a 28-40% reduction in precipitation of sulphate in the Atlantic Provinces since 1980 (Environment Canada, 1998).

In addition to long term trends, calcium and alkalinity concentrations in surface waters follow seasonal patterns with maximum concentrations of alkalinity (Figure 12), and calcium (Figure 13) generally occurring during mid summer to early fall, and minimums occurring during the spring. This pattern correlates well with the expected relative distribution of surface run-off and baseflow during the water year, with the highest values for these two dominant inorganic species, coinciding with the period where groundwater discharge, represented as baseflow, comprises the highest proportion of total stream flow.

Estuarine waters

Estuarine waters represent a mixture of fresh and marine waters, and their major ion characteristics reflect the relative proportions of "sodium - chloride type" marine waters, and the fresh waters described above. It is more difficult to make broad generalizations about the major ion content of these waters, even at individual sampling stations, because of the dynamic nature of this mixing process. As a consequence, mean values should be interpreted with caution. They should not be taken to reflect average concentrations for P.E.I. estuaries, but rather are a reflection of the average position of sampling stations within the estuarine environment.

Because of the very high concentration of dissolved solids in marine waters relative to freshwater, water in all but the furthest upstream reaches of the Island's estuaries would be characterized as a sodium chloride type. Table 4 presents mean values and ranges for major ions analysed in estuarine waters on P.E.I.

Sodium and chloride comprise over 85% of the dissolved inorganic constituents in seawater, while their concentrations in fresh water are virtually negligible in comparison. As a result the observed

Table 4 **Major Ion Chemistry of Estuarine Waters**		
Parameter	**Mean**	**Range**
calcium mg/l	247	10.5 - 1050
magnesium mg/l	894	LD - 1600
sodium mg/l	5777	2.5 - 9500
potassium mg/l	304	0.7 - 750
alkalinity* mg/l	99.8	24.9 - 165
chloride mg/l	10768	6.4 - 18500
sulphate mg/l	1658	LD - 2995
salinity ‰	21.6	0.7 - 28.1

* alkalinity used here as a proxy for bicarbonate

range of sodium and chloride concentrations from the estuarine samples can provide a crude estimate of the relative proportions of fresh and marine waters represented at these sites. The results of such a calculation indicate that samples collected range from virtually fresh water to waters comprised of 88% to 95% seawater. Mean sodium and chloride values suggest that on average the samples represent approximately 60% seawater and 40% freshwater.

The major ion chemistry of waters from most estuarine stations have not been examined on a regular basis since the mid 1970's Because of the constancy of the composition of seawater, and the dominant influence it has on the major ion characteristics of estuarine waters, it is not expected that temporal trends would be observed for these elements in the data set representing estuarine sites.

3.3 Nutrients / Chlorophyll

Nutrients are assessed apart from other major ions in this report because of their particular significance in both P.E.I. groundwaters and surface waters, and because unlike the major ions discussed in section 3.2, anthropogenic influences are believed to be the controlling factors in the abundance and distribution of these parameters on P.E.I. Both nitrogen and phosphorous are essential plant nutrients, however over-enrichment of surface waters can have a significant influence on the trophic status of surface water systems. Nitrogen, in the form of nitrite, is also of concern in relation to drinking water supplies. However, it is normally assessed as part of a nitrate analysis and compared to a nitrate guideline formulated with this in mind. Chlorophyll is also discussed in this section as its concentration in phytoplankton is intimately related to nutrient loading and excesses are ultimately the end result of nutrient enrichment.

3.3.1 Nitrogen

Although various nitrogen species are ubiquitous in the environment, background or "natural" levels of nitrogen in groundwater and surface water are relatively low, and not generally of concern. Anthropogenic sources of nitrogen, particularly fertilizers, animal and human wastes and some industrial effluents exert a significant influence on nitrogen levels in the aquatic environment, resulting in observed concentrations several times greater than presumed "background levels". While the movement and fate of nitrogen compounds through the environment involves a single, albeit complex system, its distribution is discussed here under the headings of groundwater, fresh surface water and estuarine waters because of different impacts in each of these respective environments. The interconnection between these environments is important however, particularly the substantial influence groundwater quality is expected to have on surface water quality.

Groundwater

Nitrate, expressed here as mg/l nitrate-nitrogen (NO_3-N) is the most stable, and thus dominant form of nitrogen found in typical, well oxygenated groundwaters on P.E.I. In some rare instances, particularly under highly reducing conditions, ammonia may be detected at levels of significance. For the majority of cases however, nitrate is considered to behave conservatively in groundwater flow systems on P.E.I., and is the only nitrogen species discussed with respect to groundwater quality.

The mean nitrate nitrogen concentrations for all groundwater stations is 2 mg/l, with 3% of the sites having at least one value exceeding the 10 mg/l guideline recommended in the Guidelines for Canadian Drinking Water Quality. This guideline has been developed in response to an association between high nitrate concentrations in drinking water and the occurrence of methemoglobinemia in young infants. None of the current network sites had values exceeding 10 mg/l. Mean concentrations from individual wells range from less than the detection limit to 6.8 mg/l. Generally speaking, seasonal trends for nitrate in P.E.I. groundwater are not readily apparent, except in relatively shallow wells (Somers, 1998). Ammonia was detected in 33 of 86 groundwater samples but at levels below any public health significance. The mean ammonia concentration of groundwater samples was 0.005 mg/l.

Since long-term groundwater quality stations were only established in the early 1990's, the relatively short period of record for these sites does not permit the identification of any trends in groundwater nitrate concentrations. However, evidence from other research does cause some concern both in terms of the current distribution of nitrates in groundwater, and implications for the future.

Previous work by the P.E.I. Department of Fisheries and Environment (Somers, 1998) indicates a strong relationship between land use and groundwater nitrate concentrations, with heavily impacted groundwater, frequently exhibiting nitrate concentrations 3 to 4 times "background levels". Other work has shown that 1-2% of all wells tested on the Island exceed recommended levels (Bukowski, J., Somers, G., and Bryanton, J., 1997) and in some watersheds, water from as many as 6 to 7 % of wells does not meet the 10 mg/l drinking water guideline (Swain, 1995). In addition, there is some evidence to suggest that groundwater nitrate concentrations are increasing in at least some areas of the Island. Although much of the evidence from individual wells is somewhat equivocal, trends from data from other sources appear to correlate with changes in land use (Somers 1998).

Aggregate data from records of the P.E.I. Dept. of Technology and Environment, for the Province as a whole (Somers 1999) shows a slight increase in average nitrate concentrations in private wells from about 3.15 to 3.5 mg/l over the past 10 years. On a more regional basis, more significant increases are seen in western Prince and northeastern Kings Counties, with virtually no change in eastern Prince County. This pattern could be interpreted to indicate that groundwater quality is still responding to changes in land use (moving toward more intensive cultivation) in the north eastern and western portions of the Island, while conditions may have reached some form of steady state or equilibrium between nitrogen inputs and outputs in eastern Prince County, where land use may not have changed much over the past few decades. This "theory" must be viewed with caution however, and needs to be confirmed with more thorough research.

Paradoxically, water quality data from individual wells over approximately the same time, shows no clear trend, with nearly as many wells showing decreases in nitrate concentrations as those showing increases. Furthermore, there is no clear geographic pattern to the data. This phenomena underlines the fact that there is a considerable range of nitrate concentrations observed in any one area, and highlights the uniqueness of results from each individual well.

As will be discussed in more detail below, results from surface water samples lend some support to the suggestion that groundwater nitrate concentrations are increasing in some portions of the Province**.** Given the well established link between land use and nitrate concentrations in groundwater, recent expansion of potato acreage in the Province could be expected to result in an even greater frequency of elevated nitrate levels in domestic water supplies, and as will be discussed, has considerable significance for surface water quality.

Supporting evidence for a trend of increasing nitrate concentrations can be found in surface water data. Because such a high proportion of the water in Island fresh water streams is baseflow from groundwater, surface water samples collected under dry summer conditions can be expected to be fair approximations of "average" groundwater quality in the watershed. Dry weather surface water data from the Dunk, Mill and Morell Rivers all show increasing nitrate concentrations that more or less correspond to the observed "aggregate" groundwater data noted above, including a "levelling off" of nitrate concentrations in the Dunk River, more or less corresponding with the observed lack of change in average groundwater nitrate concentrations in the east Prince area over the past 10 years. Crude mass balance calculations (Somers 1998), assuming approximate distributions of land use and associated nitrate leaching losses, also compare well with observed concentrations in intensively cultivated areas and more undeveloped watersheds respectively, lending some support to the notion that observed concentrations in areas such as the Dunk River may in fact represent "steady state" conditions.

At this point, temporal aspects of the relationship between land use and the link to water quality are not sufficiently well defined to determine if the full extent of the current land management practices on water quality have been witnessed. Among the many confounding factors, are the variable nature of many agricultural practices on nitrate losses, and the variability in transit time for groundwater through different reaches of the groundwater flow system. Further research is needed to address these issues in a quantitative manner.

Fresh Surface Waters

The introduction to section 3.3 raised concerns about the level of nutrients in the Province's surface water systems. The nitrogen content of fresh surface waters is not so much a concern to the fresh water aquatic habitat itself, but to the important role these waters play in the transport of nutrients to estuarine environments, where their contribution to eutrophication can be significant. Nitrogen has been measured at fresh surface water stations as ammonia, nitrate and total nitrogen. As with groundwaters, ammonia is not normally present in significant quantities, and most inorganic nitrogen is found as nitrate-nitrogen. Mean ammonia, nitrate and total nitrogen levels from fresh water stations are 0.02, 1.7 and 2.1 mg/l respectively.

The CCME guideline for total ammonia, for the protection of aquatic life ranges from 1.37 to 2.2 mg/l, depending on pH and temperature. The mean concentration of 0.02 mg/l observed at fresh surface water stations is significantly below this level, and no samples exceeded the recommended level. Data from long term stations reveal declining ammonia concentrations in the Province's fresh waters. No ready explanation for this trend has been identified, although different analytic methods were used over the period of record represented by the data set.

The concentrations of nitrate found in natural waters is well below the levels considered to be toxic for fresh water organisms, and no Canadian guideline level for the protection of aquatic life has been adopted. However as noted above, nitrogen is of concern because of it's role in the stimulation of excessive primary productivity, and both Alberta (1977) and Saskatchewan (1983) have adopted "multi-purpose" water quality objectives for total nitrogen at a level of 1 mg/l. Nitrate and total nitrogen levels observed at fresh water stations on P.E.I. regularly exceed these levels, and even the mean concentrations noted above are considerably in excess of this value.

Overall nitrate concentrations show a muted seasonal trend in the Island's fresh waters (Figure 14), with concentrations rising through the summer months and reaching a peak in August before gradually decreasing during the fall and winter. Seasonal total nitrogen

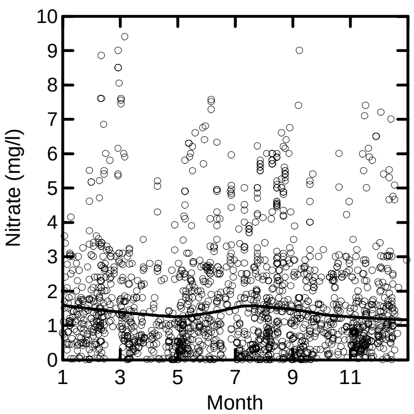

Figure 14 Seasonal freshwater nitrate trends.

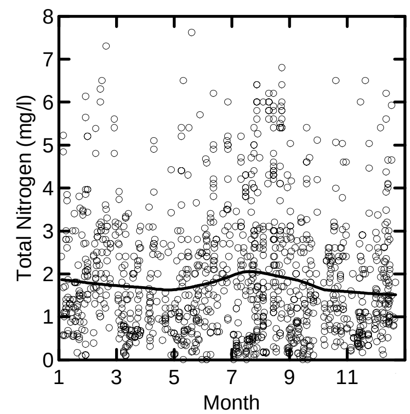

Figure 15 Seasonal trends in freshwater total nitrogen concentration.

concentrations show similar trends to that of nitrate (Figure 15).

As inferred in the preceding discussion of groundwater, data from long term monitoring stations indicate that nitrate and total nitrogen concentrations have been progressively increasing over the period of record. Mean total nitrogen levels in samples from stations on the Dunk River have changed from approximately 2 mg/l increasing to 3 mg/l over the past 18 years (Figure 16). Nitrate levels have doubled in the Mill, Dunk and Morell River over the past 20-30 years (Figure 17).

At other sampling sites, mean total nitrogen concentrations exceeding 4 and 5 mg/l have been observed in some watersheds. The Wilmot River and Wright's Creek have mean nitrate levels of 4.0 mg/l and 6.5 mg/l respectively. Wright's Creek had a maximum nitrate level of 9.0 mg/l. The high nitrate concentrations in Wright's Creek may be

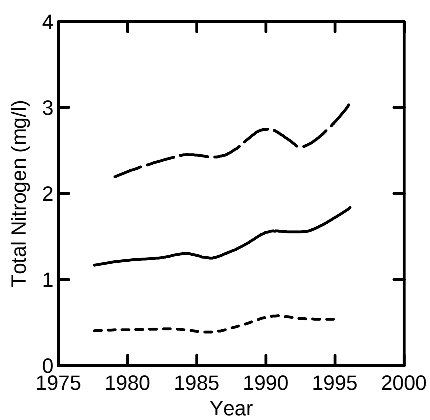

Figure 16 Long term trends in total nitrogen in the Mill, Dunk and Morell Rivers.
Mill River (PE01CA0001) - solid line;
Dunk River (PE01CB0001) - long dashes;
Morell River (PE01CD0003) - short dashes.

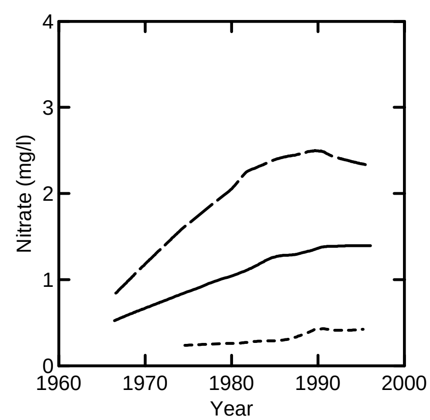

Figure 17 Long term trends in nitrate in the Mill, Dunk and Morell Rivers.
Mill River (PE01CA0001) - solid line;
Dunk River (PE01CB0001) - long dashes;
Morell River (PE01CD0003) - short dashes.

related to runoff from urban and agricultural lands as well as input from runoff of deicing fluid from Charlottetown Airport. In contrast, the mean total nitrogen concentration in the Bear River, a relatively “pristine” or “undeveloped” watershed, is 0.37 mg/l and the maximum observed concentration to date has been 0.71 mg/l.

Estuarine Waters

Nitrogen levels are of prime concern in P.E.I. estuaries, and concentrations as low as 2-4 mg/l in fresh water sources have resulted in estuarine eutrophication, symptoms of anoxia, obnoxious smells, and excessive algal growth. Total Kjeldahl nitrogen plus nitrate levels ($TKN+NO_3$) observed at estuarine sampling stations during the mid 1970's averaged 0.12 mg/l.

Mean nitrate concentrations for sampling stations in mid-estuarine environments of the current index basins are: Mill River 0.27 mg/l(PE01CA0015), West River 0.61 mg/l (PE01CC0113) and Montague River 0.25 mg/l (PE01CE0103).

Because of the dynamic nature of the mixing of fresh and marine waters found in estuaries, differences in nitrogen concentration should be expected in different parts of these water bodies. Furthermore, because a number of other factors play an important role in determining the impact of nitrogen in these waters, direct comparison of the significance of nitrogen levels from estuary to estuary, or between different portions of a single estuary may not be meaningful. As a consequence, an assessment of the significance of any spatial differences in total nitrogen concentrations in estuarine waters is not possible.

As recent data has not been analysed for total nitrogen for the network, long term temporal comparisons are not possible. Nitrate, while it has been measured in both historical and recent estuarine samples, has not been measured at the same long term stations to provide a long-term record at the same location (as has been the case for several fresh water stations). In addition, the relationship of nitrogen to chlorophyll concentrations is also not possible as the chlorophyll analyses date from the 1990's while the $TKN+NO_3$ analyses are from the late 1970's.

3.3.2 Phosphorus

Phosphorus is a nutrient that has come under considerable scrutiny during the last number of decades for its role in causing undesirable eutrophication of lake environments. The paucity of lakes on P.E.I. minimizes its importance on P.E.I.’s freshwater environments but it certainly has considerable influence on water quality in the hundreds of man-made impoundments present on P.E.I. Recently, contrary to conventional wisdom, phosphorus has been determined to be an important limiting nutrient in a P.E.I. estuary (Meeuwig, 1998). While common sources of phosphorus in the past included laundry detergents and other household cleaners, in agricultural areas such as P.E.I., the dominant source is likely the extensive usage of inorganic phosphorus fertilizers.

Groundwater

Phosphorous concentrations in groundwater may reflect natural sources, or anthropogenic influences, particularly on-site sewage disposal and the presence of phosphates in many detergents. Conventional wisdom has normally held that phosphorous is retained by soils, and leaching of significant levels of phosphorous to the water table is not normally anticipated under usual conditions. The mean concentration of total phosphorous in groundwater samples is 0.055 mg/l. At the concentrations normally found in groundwater, phosphorous is not a concern, and there is no drinking water guideline for phosphorous in Canada. The EEC has recommended a maximum admissible concentration of 5 mg/l for total phosphorus for drinking waters.

Fresh Surface Waters

The mean total phosphorous levels for fresh surface waters for the province is 0.049 mg/l and the mean concentration of phosphate is reported as 0.027 mg/l.

For the three stations with long term records, there are several notable trends (Figure 18). Firstly, the general relationship of total phosphorus concentrations between the stations is different than that observed for nitrogen. For nitrogen, the Morell River (PE01CD0003) has the lowest concentrations (Figures 16 and 17). However, for total phosphorus, the concentrations in the Morell River are approximately equal to that of the Dunk River (PE01CB0001).

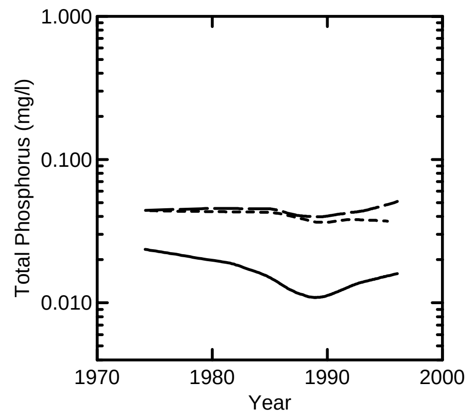

Figure 18 Long term trends in total phosphorus in the Mill, Dunk and Morell Rivers.
Mill River (PE01CA0001) - solid line
Dunk River (PE01CB0001) - long dashes
Morell River (PE01CD0003) - short dashes

Another notable trend in the long term phosphorus record is that for the Mill River location (PE01CA0001), there was a long term decrease until approximately 1989 when concentrations began to increase. Increasing concentrations also appear to have occurred in the Dunk River since 1989.

There are no Canadian fresh water aquatic guidelines for this nutrient but Alberta has a limit of 0.15 mg/l for phosphorus. Thirty-two samples of 1366 (2%) exceed the Alberta guideline level.

A comparison of the long term stations to the Bear River station in a relatively undeveloped watershed is not as dramatic for total phosphorus as it is for nitrogen (see Section 3.3.1). Mean phosphorous concentrations for the Mill, Dunk and Morell Rivers are 0.03 mg/l, 0.06 mg/l, and 0.04 mg/l respectively with maximums of 3.3 mg/l, 0.96 mg/l, and 0.33 mg/l while mean concentrations in the Bear River are 0.028 mg/l with a maximum of 0.039 mg/l.

As noted earlier, phosphorous is normally considered to be well bound to soil particles and the movement of phosphorous in the environment might be expected to show some relationship to movement of sediment. The average and maximum turbidity values for the four stations mentioned above are different from each other but do not mirror the total phosphorus concentrations for these stations.

Phosphorous levels in the full data set were compared with turbidity and suspended sediment concentrations. Regression analysis revealed that there is a weak relationship (R^2 value of 0.320) between suspended sediment concentrations (turbidity) and phosphorous levels in the fresh water rivers and streams. While the relationship is relatively weak, it is also noted that currently available turbidity measurements, based on grab samples may not be a good reflection of overall sediment movement (see discussion in section 3.1). The relationship between turbidity, suspended sediment and phosphorous levels in surface waters is the focus of on-going monitoring.

Seasonally, phosphorous concentrations don't display appreciable variability. It is not clear whether this is due to the influence of groundwater on surface water concentrations, the infrequent appearance of highly turbid samples or some other unknown influence.

Estuarine Waters

The mean total phosphorus levels for estuarine waters is 0.04 mg/l. Using a technique referred to as the "Redfield Ratio" which compares total nitrogen and total phosphorus levels (Redfield, A.C., 1934), it is possible to assess the relative roles of these nutrients as limiting factors in aquatic productivity in estuarine environments. The Redfield Ratio calculated for the estuarine data prior to 1980 is 21:1. This suggests that PEI's estuaries are phosphorus limited which corresponds with a recent assessment of the Mill River Estuary (Meeuwig, 1998). There is insufficient data to determine the ratio in later years. The observation in the Mill River study that the ratio is dropping over time cannot be fully assessed with this data set.

There are no sampling stations that were sampled in both the current network and during the 1970's. However, there were a number of stations that were sampled in the 1970's that were near to some of the present locations in the network. At these sites, there appears to have generally been an increase in the total phosphorus concentrations between the two time frames (Figure 19). The most marked is near the mouth of the West River where

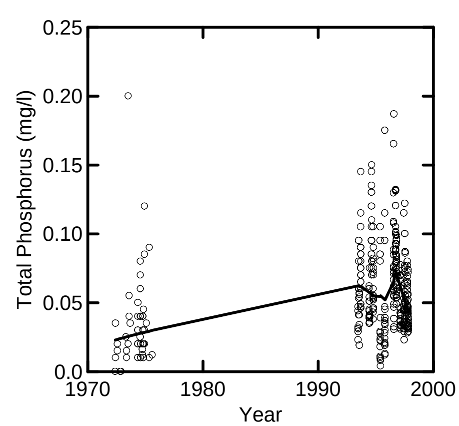

Figure 19 Long term trends in total phosphorus in the Mill, West and Montague River estuaries.

concentrations have increased from ~0.02 to ~0.05 mg/l.

3.3.3 Chlorophyll

The measurement of chlorophyll has, over the last number of decades, become an essential tool in the assessment of trophic status of surface waters. P.E.I. is no exception especially in estuarine water. As chlorophyll has no utility when assessing ground water, it is not analysed in groundwater samples and thus will not be discussed here.

Fresh Surface Waters

The mean chlorophyll concentration for fresh surface waters for the province is 1.6 µg/l. Seasonally, chlorophyll concentrations show a strong trend with the peak normally occurring in July or August with an average of ~2 µg/l (Figure 20). Minimum concentrations tend to occur in February at approximately 0.3 µg/l. The maximum concentration observed was 43.4 at station PE01CC0004 in the lower part of the Winter River. This concentration was highly unusual for this location and would not be suggestive of eutrophic conditions. Nevertheless, on P.E.I., with phosphorus concentrations normally being adequate to support higher trophic levels, it is not uncommon for ponds to exhibit high productivity.

There are no Canadian guidelines for the concentration of chlorophyll, however, such a guideline would normally be applicable to lake systems and might not necessarily be applicable to streams on P.E.I.

Estuarine Waters

Average concentrations of chlorophyll in the network estuarine data is 4.3 µg/l. Chlorophyll has only been measured in the network since 1991 at three stations in each of the Mill, West and Montague Rivers. Seasonally there are strong trends with high concentrations of approximately 5 µg/l during June through September (Figure 21). An annual peak would be expected to occur during a spring bloom however, sampling is not normally possible at this time of year because of ice conditions during the

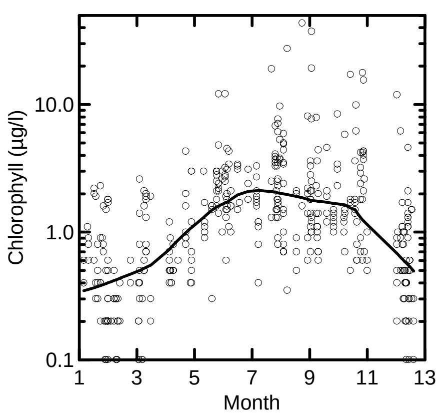

Figure 20 Seasonal trends in freshwater chlorophyll concentrations.

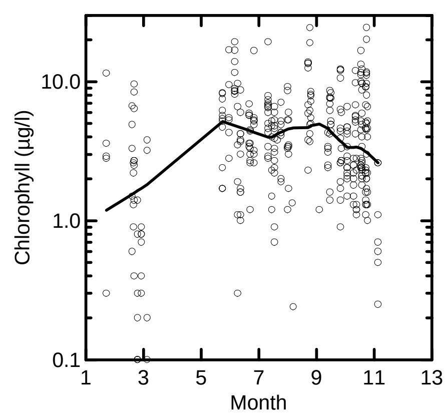

Figure 21 Seasonal trends in estuarine chlorophyll concentrations.

spring break-up.

Of the three estuaries in the network, both the Mill and West Rivers exhibit fall concentrations lower than the summer concentrations. The Montague River, on the other hand, exhibits fall chlorophyll levels that are higher than those in the summer. While there is no ready explanation for this difference, it does suggest that the fall phytoplankton bloom is a strong phenomenon in the Montague River. The highest concentration observed was 24.5 µg/l at station PE01CE0096 in the Montague River. Low concentrations occur during the winter at approximately 1 µg/l.

Overall, concentrations that were observed in the estuaries suggest that each of the estuaries is at a mesotrophic level of primary productivity. This is an important observation as the Mill River has been assessed in a more comprehensive data set as being eutrophic in its upper reaches. The network station on the Mill River that is located in the area of eutrophic conditions has concentrations that are similar to that found in the other study. Indeed, the highest chlorophyll levels at that station tend to have occurred in the last few years of the data set. This is consistent with local observations that the primary productivity and anoxic conditions have been at their worst ever in the last few years in the upper part of the Mill River estuary. The observation of mesotrophic status in the West River is also important as that estuary suffered from eutrophic conditions in the mid-eighties prior to a modification to a causeway in the centre of the river restored natural tidal flushing to the estuary.

Long term trends for chlorophyll are not readily apparent and this may be due to the relatively short time frame of the observations. Nevertheless, the increasing frequency and number of locations that anoxic conditions are observed on P.E.I. suggest that overall, chlorophyll concentrations may be increasing although individual estuaries would of course be exhibiting chlorophyll concentrations reflecting each individual set of watershed inputs.

3.4 Metals

3.4.1 Analytical Results

Analysis of samples collected from the water quality network from groundwater, fresh surface water and estuarine environments includes a suite of 15 metals. Most of these parameters are naturally occurring in the environment at least at low levels, while others are not as commonly found in the environment except through anthropogenic influences.

Tables 5 and 6 summarize the results of metal analyses for groundwater and fresh surface water sampling stations respectively. Short descriptive sections on selected, individual parameters are included later in this section to highlight some of the more important results of the analyses, or to suggest possible sources, or implications of these metals in their respective environments.

Groundwater

The majority of metals analysed in groundwater samples were detected on a frequent basis, although concentrations were low relative to guidelines for drinking water quality, and for the most part, are presumed to reflect background concentrations as a result of natural processes or ambient concentrations in recharging waters. With few exceptions, there appears to be little variation between the metals content of groundwaters across the Island. This relatively uniform distribution could be taken to suggest that the geological rather than anthropogenic factors play the dominant role in metals composition of P.E.I. groundwaters.

Table 5 Metal Concentrations in Groundwater (mg/l)

Parameter (total except where indicated)	Mean "station" concentration	Standard deviation	Maximum concentration (all samples)	Drinking water guideline	% of stations exceeding guideline
aluminum	0.005	0.004	0.057		
arsenic	0.001	0.002	0.026	0.025	2 (1/50)
barium	0.37	0.27	1.13	1	5 (1/19)
beryllium	0.002	0.005	0.06		
cadmium	0.00001	0.00001	0.0014	0.005	0
chromium	0.0006	0.0005	0.013	0.05	0
cobalt	0.0001	0.0001	0.0004		
copper	0.005	0.004	0.060	1*	0
iron	0.012	0.008	0.427	0.3*	6 (1/18)
lead	0.0004	0.0007	0.054	0.01	10 (2/20)
lithium	0.003	0.003	0.016		
manganese	0.0005	0.0005	0.038	0.05*	0
mercury (extractable)	0.000002	0.000011	0.00007	0.001	
molybdenum	0.00002	0.00003	0.0017		
nickel	0.00003	0.00007	0.007		
selenium	0.0001	0.0001	0.0022	0.1	0
strontium	0.14	0.17	0.799		
vanadium	0.005	0.004	0.015		
zinc	0.024	0.024	0.415	5*	0

* guideline based on aesthetic considerations

Table 6 Metal Concentrations in Fresh Surface Water (mg/l)

Parameter (total except where indicated)	Mean "station" concentration	Standard deviation	Maximum concentration (all samples)	Fresh water aquatic life guideline	% of stations exceeding guideline
aluminum	0.150	0.20701	4.68	0.1	81 (22/27)
arsenic	0.0014	0.00295	0.016	0.05	0
barium	0.10387	0.05702	0.446	5*	0
beryllium	0.00316	0.00985	0.05	n/a	n/a
cadmium	0.00002	0.00002	0.0004	0.0008	0
chromium	0.00036	0.00020	0.0074	0.02-0.002**	22 (6/27)
cobalt	0.00014	0.00007	0.0017	n/a	n/a
copper	0.00071	0.00044	0.0134	0.002	59 (16/27)
iron	0.25710	0.25493	5.74	0.3	67 (18/27)
lead	0.00014	0.00018	0.0056	0.002	15 (4/27)
lithium	0.00112	0.00052	0.00750	n/a	n/a
manganese	0.02826	0.01764	0.238	0.1-1.0*	22 (6/27)
mercury (extractable)	0.0000595	0.0006656	0.0034	0.0001	64 (14/22)
molybdenum	0.00003	0.00007	0.00036	n/a	n/a
nickel	0.00011	0.00014	0.0032	0.065	0
selenium	0.00008	0.00005	0.00016	0.001	0
strontium	0.04270	0.02612	0.08927	n/a	n/a
vanadium	0.00291	0.00241	0.01021	n/a	n/a
zinc	0.00194	0.00283	0.313	0.03	7 (2/27)

* B.C. Guideline

** 0.02 for fish, 0.002 for zooplankton and phytoplankton

Three parameters, arsenic, barium and lead were detected at concentrations above their respective health based drinking water guideline, although in each case more than 99% of samples were in compliance with recommended levels.

Results of surface water sampling show

more variability, possibly as a result of the greater number of potential influences on surface water quality and also because of the much longer period of record. Whereas groundwaters may be expected to be influenced by the quality of precipitation, local aquifer materials and only very local anthropogenic influences, in addition to these factors surface waters are also influenced by a host of constituents that may be present in direct runoff.

A number of metals (including aluminum, cadmium, copper, iron, lead, manganese and mercury) have been detected at levels exceeding values recommended for the protection of aquatic life on a relatively frequent basis. In at least some of these cases however, analyses are for total or extractable metal concentrations, and may reflect the presence of these metals in association with sediment rather than dissolved species in the water column. In these cases, it is questionable what implications these values have for the health of aquatic ecosystems. Prime examples of this are aluminum, iron and manganese. The occurrence and implications of these metals are addressed further under the respective sections on individual parameters.

Very few analyses for metals in estuarine waters have been conducted and the available data are insufficient to draw any meaningful conclusions for metals in this environment. Furthermore, guidelines against which to evaluate the significance of metals concentrations in this environment are not readily available. As a consequence, no discussion of metals from estuarine sampling stations are included in this report.

3.4.2 Comments on the occurrence of selected metals

Aluminum

Aluminum is one of the most abundant elements on earth, but because of its limited solubility, concentrations of dissolved species in natural waters are generally not high. In the absence of anthropogenic sources, most aluminum is derived from the natural weathering of rock materials, and may be present in clays, complexes or free (dissolved) aluminum.

In drinking water, elevated levels of dissolved aluminum are often associated with water treatment processes, and there has been considerable discussion about possible association between aluminum in drinking water and Alzheimer’s disease, but no causal association has been established. While no drinking water guideline has been established in Canada at this point, the EEC has established a guideline of 0.05 mg/l for this metal. However drinking water on P.E.I. is derived from groundwater sources and is not treated with coagulants, and the mean concentration for total aluminum was only 0.005 mg/l.

Aluminum concentrations can also be of concern for freshwater aquatic habitat and may pose health risks to a number of fish species, with possible impacts on the early developmental stages of salmonids, the sac fry of lake trout, as well as the cleavage embryos of rainbow trout (Gunn and Keller, 1984). The CCME guideline for total aluminum ranges from 0.005 to 0.1 mg/l depending upon pH, Ca ion concentrations, and DOC content.

Data from fresh surface water stations show aluminum levels frequently exceeding even the higher end of this range with mean concentrations of 0.150 mg/l. Indeed, 26% of the fresh water samples exceed 0.1 mg/l.

It is notable that a reasonably close correlation exists between aluminum levels and turbidity, suggesting that much of the observed aluminum may be associated with sediment in some bound form. If this is the case, and dissolved aluminum levels are in fact low, the bio-availability of aluminum, and its significance to aquatic habitat in this environment, may be of limited importance.

Mean concentrations for the Dunk, Mill and Morell Rivers, are 0.133 mg/l, 0.158 mg/l, and 0.051 mg/l respectively. Sample site PE01CC0042 (Winter River) has high total aluminum concentrations with a mean of 0.25 mg/l. In contrast, aluminum levels in the Bear River, a relatively undeveloped area of the Province are much lower, with an average total aluminum concentration of 0.054 mg/l. It is interesting to note that turbidity levels in the Bear River are also an order of magnitude lower than the Dunk River. This association would tend to lend support to the suggestion that much of the observed distribution of aluminum relates to suspended sediment in the water column.

Arsenic

Arsenic is widely distributed in geological materials, however generally, significant contributions of arsenic to natural waters are normally associated with environments where significant weathering or leaching of arsenic bearing sulphide minerals is occurring. Arsenic has also been widely used in a number of commercial and industrial applications, including in some pesticide products. The geologic environment in P.E.I. is not consistent with significant natural sources of arsenic, and anthropogenic influences may determine any occurrence of elevated levels of arsenic in Island groundwater and surface waters. Mean arsenic levels in Island groundwater and surface waters are 0.001 and 0.0014 mg/l respectively, well below levels of concern. 2% of groundwater samples (from a single station) exceeded the recommended drinking water guideline of 0.025 mg/l with a maximum concentration of 0.026 mg/l. Given the relative uniformity of other groundwater results (standard deviation from mean of 0.002) the minor exceedance of the guideline is considered as a spurious result.

Barium

Barium is a naturally occurring component of many minerals, normally occurring in trace levels in feldspars and clays and levels are often higher in groundwaters than surface waters. The average barium concentration observed in groundwaters was 0.37 mg/l and all of the 280 groundwater samples tested for barium had detectable concentrations of this metal. Higher barium concentrations were found at two locations in Western P.E.I. At Bloomfield Elementary School (PE01CA0045) the mean concentration was 0.87 mg/l and Hernwood Junior High School (PE01CA0046) a mean concentration of 0.43 mg/l was observed. Only one sample, collected at Bloomfield

Elementary School at 1.13 mg/l, exceeded the drinking water guideline of 1.0 mg/l. Based on the limited number of groundwater stations, it is difficult to determine whether these are anomalous concentrations or not, however it is probable that they reflect local geological conditions.

There are no Canadian guidelines for the protection of aquatic life for barium although the Province of British Columbia has established an MAC for the protection of fresh water aquatic life at 5.0 mg/l barium. The mean concentration of this metal in fresh surface waters observed on P.E.I. is 0.10 mg/l, with a maximum of 0.44 mg/l.

Cadmium

Although cadmium occurs naturally in some minerals, major sources of cadmium in the environment are from anthropogenic activities including mining, manufacturing and agricultural use of sludges, fertilizers and pesticides containing cadmium, and the burning of fossil fuels (CCME, 1987). Cadmium was detected in 4% of 308 groundwater samples, with a maximum concentration of 0.0014 mg/l. The maximum acceptable concentration (MAC) recommended in the Guidelines for Canadian Drinking Water Quality is 0.005 mg/l.

For the protection of aquatic life, the CCME recommends cadmium concentrations should be below the range of 0.0002-0.0018 mg/l depending on water hardness. For typical P.E.I. surface waters, the appropriate value is 0.0008 mg/l. Mean cadmium concentrations for fresh surface waters is 0.00002 mg/l, with a maximum value of 0.0004 mg/l

Chromium

Although chromium may enter the aquatic environment from the weathering of chromium bearing minerals or from anthropogenic sources, given the geology of the Island it is likely that anthropogenic activities would be the dominant influence on its distribution in waters on P.E.I.

Chromium was detected in 86% of groundwater samples, although levels were low with a mean concentration of 0.0006 mg/l and a maximum concentration of 0.013 mg/l. The Guidelines for Canadian Drinking Water Quality recommend chromium levels do not exceed 0.05 mg/l.

Chromium was also detected in fresh surface water stations, albeit generally at very low levels with a mean concentration of 0.00036 mg/l. The CCME has established a guideline of 0.02 mg/l for the protection of fish and 0.002 mg/l for the protection of aquatic life (i.e. zooplankton and phytoplankton) (CCME, 1987). 1.4% of stream water samples exceed the 0.002 mg/l guideline for aquatic life with a maximum concentration of 0.0074 mg/l recorded for the Dunk River. Chromium concentrations for the fresh surface waters tend to be site specific and do not appear to show regional or temporal trends. Values in excess of the recommended levels were recorded at 6 of 27 stations (PE01CA0001, PE01CA0044, PE01CB0001, PE01CB0141, PE01CC0010, and PE01CC021).

Chromium has not been measured at estuarine stations in the network.

Copper

Copper may be released to the aquatic environment from the weathering of a variety of minerals, or through a variety of anthropogenic activities. Copper at the concentrations commonly found in drinking water is not a health concern, but elevated levels may cause staining of fixtures, enhanced corrosion of other metals, and impart an unpleasant taste to water. Based on these aesthetic considerations, the Guidelines for Canadian Drinking Water Quality recommend that copper concentrations do not exceed 1 mg/l. The mean concentration of extractable copper observed at groundwater stations is 0.005 mg/l, and no samples exceeded the 1.0 mg/l aesthetic objective for drinking water.

Elevated copper concentrations pose a risk to trout, as well as to several species of invertebrates and aquatic plants (CCME, 1987). The guideline for copper in surface waters, is dependant on water hardness, and for P.E.I. conditions, a concentration of 0.002 mg/l would be considered protective of aquatic life. The mean value for copper in fresh surface waters was 0.00071 mg/l. Data from fresh water stations indicate mean total copper concentrations for individual rivers ranging from 0.0007 mg/l to 0.001 mg/l. Approximately 13% of samples exceeded the recommended level with a maximum concentration of 0.0134 mg/l being recorded.

Iron

Iron is an abundant naturally occurring component of soils and rocks, and its occurrence in natural waters in association with sediment is not uncommon, however dissolved iron species are only sparingly soluble except under oxygen deficient conditions. Iron at elevated levels is undesirable in potable water supplies because of aesthetic considerations and is also undesirable in the aquatic environment. The guideline values for the protection of aquatic life as well as for drinking water supplies is 0.3 mg/l. Iron concentrations in all but one sample from the groundwater stations were below this level.

The average concentration of total iron in the streams and ponds of the province is 0.012, with a maximum concentration of 0.427 mg/l being observed. As with aluminum, it is possible that much of the iron observed in surface waters is associated with sediment, and may have limited environmental significance. Iron concentrations appear to be closely related to turbidity and a regression analysis between iron concentrations and turbidity reveals a strong relationship with an R^2 value of 0.756 (Figure 22).

Iron concentrations are variable across the island but tend to be slightly higher in areas of intense agricultural production such as the Dunk River and Bradshaw Rivers, again suggesting a relationship with higher concentrations of suspended sediments in these streams. Total iron concentrations observed in the relatively pristine Bear River are 0.11 mg/l, while concentrations for the Dunk River are 0.22 mg/l. Long-term data for iron shows no change in the fresh surface waters

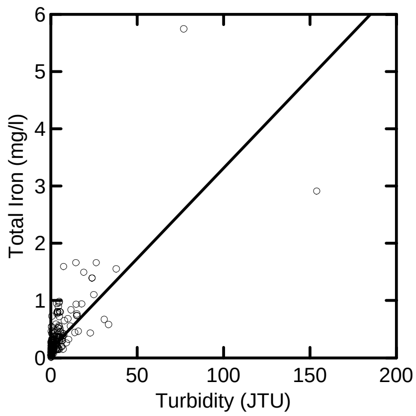

Figure 22 Relationship between total iron and turbidity. The line shown is a linear regression between total iron and turbidity.

over the past 30 years.

Lead

Elevated concentrations of lead are of concern in drinking water and in the aquatic environment. While the natural occurrence of lead in groundwater is low, elevated lead levels in drinking water supplies are normally attributed to the leaching of lead from plumbing fixtures. The mean lead concentration observed in samples from the groundwater stations was 0.0004 mg/l, below the 0.01 mg/l maximum acceptable concentrations (MAC) in the Guidelines for Canadian Drinking Water Quality. Only 0.7% of samples exceeded the guideline, with a maximum concentration of 0.054 mg/l.

High concentrations of lead in the surface waters pose risk to benthic bacteria, freshwater plants, invertebrates and fish as lead can be bio-accumulated by these aquatic organisms (CCME, 1987). Lead guidelines for the protection of aquatic life depend on water hardness and for typical P.E.I. surface waters the appropriate value would be 0.002 mg/l. The mean concentration of lead for stream waters is 0.00014 with a maximum concentration of 0.0056 mg/l being observed. Lead values above the recommended level were observed at 15% of surface water stations, although no spatial or temporal trends are apparent in the data.

Manganese

Manganese exhibits similar geochemical characteristics as iron, and while abundant in rocks and soils, dissolved manganese is normally found principally in oxygen deficient waters. Although there is a drinking water guideline for manganese of 0.05 mg/l, based on aesthetic considerations the mean groundwater concentration was 0.0005 mg/l and no samples exceeded recommended levels.

The concentration of manganese in the surface waters of the province is somewhat higher than for groundwater, with a mean value of 0.028 mg/l. While there are no Canadian guidelines manganese in the aquatic environment, British Columbia, has set a guideline of 0.1-1.0 mg/l total manganese for the protection of fresh water fish. Mean manganese concentrations fall below these guidelines, but 4.6% of samples, representing 22% of stations, had observations that exceeded the 0.1 mg/l guideline, with a maximum concentration of 0.238 mg/l.

The manganese concentrations observed in P.E.I. surface waters are in line with those recorded for the Atlantic provinces (CCME, 1987), and have remained fairly static over the past 30 years.

Mercury

The drinking water guideline for mercury is 0.001 mg/l, and mean groundwater levels were 0.000002 mg/l, with a maximum concentration of 0.00007 mg/l being reported. The mean concentration of extractable mercury in fresh surface waters was slightly higher at 0.0000595 mg/l, however 7.5% of samples did exceed the 0.0001 mg/l guideline level set for the protection of aquatic life (CCME, 1987). The maximum concentration observed was 0.0034 mg/l.

Zinc

Although there is a drinking water guideline for zinc of 5 mg/l based on aesthetic considerations, observed groundwater concentrations were all more than an order of magnitude below this level. Guidelines for the protection of aquatic life are more stringent with maximum allowable concentrations of 0.03 mg/l (CCME, 1987). Mean zinc levels for fresh surface waters are 0.0019. Only 1.7% of samples exceeded aquatic life guidelines, and the maximum concentration observed was 0.313 mg/l.

3.5 Pesticides and selected other organic chemicals

Over the life of the water quality network a variety of organic compounds have been examined, and given the prominence of agriculture in the Island's economy and the absence of significant industrial activity, attention has focused primarily on pesticides. Most work on other organic compounds has been limited to groundwater samples, normally from municipal drinking water supplies.

Much of the work conducted on pesticides has been the result of specifically focused projects rather than general surveillance from Island wide networks. As a consequence, it is difficult in many cases to draw broad generalizations about the occurrence of pesticides in Island waters, and still place these conclusions in the context they belong. The varying sampling program designs can be expected to have a strong bearing on the significance of individual sampling results. Fortunately, the results of the bulk of this work has already been published previously. For these reasons, brief descriptions of the more significant works on pesticides are described individually.

3.5.1 Review of Envirodat Data Base

A summary of some of the results contained in the Envirodat data base is provided in Table 7. Results from programs that focused on highly site specific phenomena, or for which no information on sample sites were available, have been excluded from the table. Only very limited commentary is offered for the data presented in Table 7, and the reader is directed to the brief summaries of individual studies presented below, or to the original works. The reader should note however, that in some cases the data described in the descriptions below is not represented in the results included in Table 7.

In total, the table represents data from 8196 analyses, and reports some 296 pesticide detections (3.6% of analyses).

Table 7 **Envirodat results for pesticide analyses in groundwater, fresh surface water and estuarine waters.**

Pesticide	Detection Limit (µg/l)	Groundwater		Freshwater		Estuarine Water	
		Percent Detected	Max. Conc. (µg/l)	Percent Detected	Max. Conc. (µg/l)	Percent Detected	Max. Conc. (µg/l)
Aldicarb	0.001	8% (n=421)	4.200	0% (n=27)			
Aldrin	0.001	1% (n=174)	0.001	0% (n=42)		0% (n=138)	
Atrazine	0.0006	71% (n=21)	0.033	63% (n=43)	0.032		
Azinphosmethyl	0.1	1% (n=184)	0.001	4% (n=24)	0.091		
Carbaryl	0.001	0% (n=151)		0% (n=33)			
Carbofuran	0.001	0% (n=135)		0% (n=32)		0% (n=3)	
Carbophenothion		11% (n=166)	0.019				
Chlordane	0.005	0% (n=174)		0% (n=42)		0% (n=134)	
Chlorfenvinphos	0.1			0% (n=29)			
Chlorothalonil	0.001			4% (n=108)	0.311		
Crufomate		0% (n=184)					
2,4 D				0% (n=31)		0% (n=127)	
P,P DDD	0.001	0% (n=174)		5% (n=42)	0.002	0% (n=134)	
P,P DDE	0.001	0% (n=174)		8% (n=39)	0.001	0% (n=133)	
DDT	0.001	0% (n=174)		19% (n=42)	0.003	2% (n=134)	0.052
Diazinon		9% (n=176)	0.001	0% (n=24)			
Dieldrin	0.005	0% (n=174)		0% (n=42)		0% (n=134)	
Dimethoate				15% (n=20)	0.033		
Disulfoton	0.1	3% (n=172)	0.008	0% (n=38)			
Endosulfan	0.005	0% (n=174)		2% (n=48)	0.008	0% (n=124)	

Table 7 Envirodat results for pesticide analyses in groundwater, fresh surface water and estuarine waters

Pesticide	Detection Limit (µg/l)	Groundwater		Freshwater		Estuarine Water	
		Percent Detected	Max. Conc. (µg/l)	Percent Detected	Max. Conc. (µg/l)	Percent Detected	Max. Conc. (µg/l)
Ethion		0% (n=183)					
Fenchlorphos		0% (n=183)					
Fenitrothion		0% (n=183)					
Heptachlor	0.001	3% (n=174)	0.002	14% (n=42)	0.001	0% (n=134)	
Hexachloro benzene	0.002	0% (n=195)		0% (n=9)		4% (n=24)	0.0005
Imidan		5% (n=174)	0.0000 09				
Imidicloprid				0% (n=12)			
Lindane	0.001	2% (n=174)	0.011	17% (n=42)	0.002	51% (n=135)	0.018
Linuron				0% (n=14)			
Malathion		0% (n=184)		0% (n=29)			
Metalaxyl		10% (n=84)	13.75	43% (n=14)	0.075		
Methamidophos				14% (n=7)	0.007		
Methidathion				0% (n=29)			
Methoxychlor	0.01	0% (n=174)		2% (n=42)	0.01	0% (n=134)	
Metribuzin	0.001	24% (n=21)	0.010	6% (n=52)	0.005		
Mirex	0.001	0% (n=173)		41% (n=29)	0.006		
Parathion		1% (n=184)	0.007				
Phorate		1% (n=183)	0.001	0% (n=43)			
Simazine	0.001	52% (n=21)	0.154	0% (n=14)			

Just under 5300 of the analyses (32 parameters), are from groundwater samples, with about 2.5% of analyses reporting detectable concentrations. Surface water sampling includes 1157 analyses (34 parameters) with about 7.7% of analyses reporting detectable concentrations. Estuarine water samples were only analysed for 15 compounds and account for the remaining 1747 analyses. Slightly over 4% of estuarine samples analysed had detectable concentrations of pesticides.

In general, all detections were at low levels, and only two products were observed to exceed published Canadian water quality guidelines. These two cases, both for surface water samples were for DDT, and Endrin, and of the two, only DDT was detected with any frequency (19% of 42 samples collected).

The most commonly detected pesticides overall were the triazines; atrazine, metribuzin and simazine. Atrazine was detected in 42 of 64 analyses, more or less evenly distributed between groundwater and fresh surface water samples. For metribuzin 8 of 73 analyses reported detections, mostly from groundwater samples and for simazine, 11 of 35 analyses, all from groundwater samples reported detections. What is perhaps most notable about these figures is the relatively high detection rate for these compounds in spite of the fact the triazines are not particularly high use pesticides on P.E.I. Further comment on specific studies of the triazines is noted later in the report. It is worth noting however that this data comes from a very limited number of stations (4 groundwater and 4 surface water stations) and as such may not be very representative of Island-wide conditions.

Aldicarb (Temik™), an insecticide used extensively in the past in potato production was also found on a relatively frequent basis in groundwater samples in the late 1980's, although the product is no longer in use. Lindane and DDT residues were both detectable in a reasonable number of fresh water samples and estuarine samples, with Lindane being more commonly detected in estuarine samples and DDT being reported more frequently in fresh water samples. Other compounds detected on a less frequent, but not insignificant frequency in late 1980's samples include carbophenothion, diazinon, disulfoton, heptachlor and imidan in groundwaters, and heptachlor and mirex in surface waters.

As noted above, it is difficult to discuss these results further in a meaningful way, without also addressing the context in which sampling programs have been designed and executed. Furthermore, the sampling efforts represented in Table 7 cover a significant period of time, and cannot easily be used to assess current conditions. It is beyond the scope of a general report such as this to go into detail on the many projects represented by the data presented above, and a brief summary of some of the key findings of a number of these projects are presented below. In addition, certain other works, not represented in the Envirodat data base are included, where it is felt they will contribute to the general understanding of pesticide occurrences in P.E.I. waters. The reader is directed to the original works for more details on specific studies.

3.5.2 Summary of selected projects / reports on pesticide or other organic compounds in P.E.I. Waters

1983-1992 Aldicarb studies

During the mid to late 1980's and early 1990's several studies were conducted on the occurrence and environmental fate of the highly toxic, and relatively soluble carbamate insecticide Aldicarb (Temik) (Matheson et al., 1987; Priddle et al.1987, Mutch et al. 1992). A farm well survey conducted in 1983/1984 showed Aldicarb, to be present in 18% of high risk wells around potato fields. Subsequent field studies suggested that the persistence of aldicarb was related to cool soil temperatures at the time of traditional application, combined with inhibition of product breakdown as a result of the oxidation of ammonia-based fertilizers. The research resulted in recommendations for product application aimed at reducing the persistence of aldicarb, however by the early 1990's, Temik had been withdrawn from the market.

An Assessment of Atlantic Region Water Quality Branch Toxic Chemical Data 1980-1987 IW/L-AR-WQB-88-140 - **O'Neill, 1988**

This report synthesizes the results of analyses conducted by the Environment Canada's Water Quality Branch's work on toxic chemicals in the Atlantic region between 1980 and 1988 and deals principally with surface water samples. The report comments on results for five chemical groups frequently reported in Atlantic region surface waters as well as other less common parameters. Included in the report are data for: organochlorine insecticides including polychlorinated biphenyls (18 analytes), polynuclear aromatic hydrocarbons (6), phthalic acid esters (14), organophosphorous pesticides (17), carbamate compounds (6), chlorinated benzenes (11), chlorophenoxy acid herbicides (3), triazine herbicides (3) and tri-aryl-phosphates (4). Organochlorine insecticides and PCB's received particular attention because of their previous widespread use. The bulk of samples collected from P.E.I. waters are from sub basin CB including principally the Dunk and Wilmot River systems.

Of the organochlorine insecticides quantified, only alpha-BHC and lindane (gamma-BHC) were observed in surface waters at trace levels. DDT and its isomers were the most commonly found OC compound in lake (pond) sediments and was detected in stations from sub basin CB. Of the polynuclear aromatic hydrocarbons (PAH's) only fluoranthene was detected in surface waters, although all 6 PAH's quantified were detected in sediment samples. PCB's were not detected in any Island waters.

Of the triazine herbicides, only atrazine is reported. It was observed in areas of extensive agriculture, at levels comparable to those seen in some streams in Southern Ontario and Quebec. Carbamate pesticides were not detected in surface water samples, although the report notes that aldicarb and its metabolites have been detected in groundwater on P.E.I.

Detection of chlorophenols, chlorinated benzenes, chlorophenoxy acids and tri-aryl-phosphates are not indicated for P.E.I. waters, although reference is made to infrequent observations of several organophosphorous pesticides in surface waters of the Atlantic region as a whole, albeit at levels at or slightly above detection limits. The detection of OP pesticides in groundwater is also noted, but is discussed in another report (see Atlantic Region Federal-Provincial Toxic Chemical Survey of Municipal Drinking Water Sources 1985-1988 below).

Atlantic Region Federal-Provincial Toxic Chemical Survey of Municipal Drinking Water Sources, Data Summary Report, Province of Prince Edward Island, 1985-1988 - (Environment Canada, 1989)

The purpose of this survey was to describe the current state of drinking water sources serving Atlantic Canadian Municipalities, and included an examination of over 150 parameters. Parameters included various in-use and past-use pesticides, synthetic organic chemicals, volatile organic materials, metals, major ions, and physical parameters. Thirty municipal water supply sources were sampled on Prince Edward Island. Highlights of the survey are summarized below.

The study examined fifteen organophosphorous compounds with carbophenothion, phorate, disulfoton and methyl parathion being reported at detection limit concentrations in some samples. Similar results were found for samples in other provinces and were attributed to sample contamination or analytic interference.

Fourteen chlorinated phenols were quantified with only a few individual observations of pentachlorophenol being reported. The observations were not matched in duplicate samples and all but one were at the detection limit. The maximum concentration reported was 0.007 µg/l. The maximum acceptable concentration in drinking water is 60 µg/l.

Five carbamate pesticides were quantified with aldicarb and one of its metabolites being reported from several wells. All observations were below the 9 µg/l MAC for aldicarb. Seventeen organochlorine compounds were quantified. Traces of heptachlor were observed on three occasions and traces of lindane in a single sample.

With the exception of a single sample, polychlorinated biphenyls (PCB's) were below the detection limit of 0.005 µg/l. The exception was a single sample from St. Eleanor's well #2 at a level of 0.063 µg/l. Subsequent sampling of this well did not confirm this result. Samples from this same well also contained low levels of PAH's and CFC's. It should be noted that this well is not normally connected to the distribution system, and is maintained only for back-up purposes.

Eleven chlorinated benzenes were examined, but all results reported were less than the respective detection limits. Six PAH's were quantified, with low levels of fluoranthene being detected in nearly all samples at ranges from 0.001 to 0.004 µg/l. Similar results were seen in other Atlantic Provinces. Four other PAH's were reported at detection limit values in a single sample from St. Eleanor's Well #2 as noted above, but were not reported from a duplicate sample.

Over fifty volatile organic materials (VOM's) were also quantified in the survey. Several VOM's were detected at trace levels, although some of the same compounds are also reported in blanks at comparable concentrations. Trihalomethanes (THM's) were observed either at levels close to the minimum quantitation limit (0.5 µg/l) or at trace levels at the 9 sites having treatment (chlorination). Trichloroethene (TCE) and tetrachloroethene (PCE) and 1,21,2 - trifluorotrichloroethene (CFC-113) were detected at low levels (maximum concentrations of 1.6, 3.87 and 7.7 µg/l respectively from a back-up well to the Charlottetown water supply). Results for well #7 in Summerside reported a maximum level of 4.8 µg/l tetrachloroethene (PCE), and St. Eleanor's well #2 reported 2.0 µg/l trichlorofluoromethane (CFC-11). All results for VOC's were below respective drinking water guideline levels.

Canada - P.E.I. Water Management Agreement Pesticide Sampling Project 1988-1991

Between 1988 and 1991, groundwater samples were collected from "high risk" wells in areas of active pesticide use. The surveys were conducted in two phases, the first examining the products phorate, disulfoton, metribuzin and atrazine (Dinoseb analyses are also reported, but relate to investigation of a specific pesticide spill) and included samples from 149 wells located within 300 metres of treated fields. All four pesticides were detected in the survey, with frequencies of detection ranging from 2.7% for phorate and disulfoton to 11.7% for metribuzin. Atrazine, although only examined at 9 sites due to its limited use on the Island, was detected in 4 wells.

The second phase of the project was more limited in scope and reported on results of 74 analyses from 43 wells for atrazine, mancozeb, chlorothalonil and metribuzin. Each pesticide were detected, with 13 samples reporting the presence of one or more pesticide residues. The frequency of detection for this second phase of the project ranged from 33% for atrazine to 8% for chlorothalonil. Metribuzin was only examined on 3 occasions but was detected in 2 of these samples. As in the previous phase, all values were well below respective health based drinking water guideline values.

A Screening Survey for Chlorothalonil Residues in Waters Proximal to Areas of Intensive Agriculture - (O'Neill et al., 1992)

This study was conducted in New Brunswick and P.E.I., and included surface water and groundwater samples as well as precipitation and tile field samples. Only the tile drain work and surface water samples were conducted in P.E.I., with a "once only" sampling run including 11 surface water stations in eastern Prince County, primarily in the Dunk River and Wilmot River areas. Sampling was conducted during the peak growth and spray season and the sample sites were selected on the basis of more than 50% the surrounding land use being agricultural. Of eleven stations sampled, Chlorothalonil was detected only twice, once on a tributary to the Dunk river and once on the Wilmot river (0.006 and 0.01 µg/l respectively). The report notes that the concentrations reported are in the same order of magnitude as those reported in precipitation collectors, and the role of long range transport of contaminants is discussed briefly.

A Review of Triazine Herbicide Occurrence in Agricultural Watersheds of Maritime Canada 1983-1989 - (O'Neill and Doull, 1992)

In 1992, O'Neill and Doull reviewed he results from various toxic chemical studies, providing a synthesis of data for triazine herbicides in agricultural watersheds of Maritime Canada up until early 1989.

The data include results from a study conducted in the Dunk River and Southwest River watersheds, both areas of intensive potato production. Both atrazine and metribuzin were included on the parameter list. Metribuzin was not detected in any of the 29 samples, however atrazine concentrations ranging from 0.011 to 0.017 µg/l were observed in 13 samples. The authors noted that atrazine was only detected in July, August and October samples, consistent with the use pattern anticipated in the area.

In an 1986 survey in the Wilmot Valley 12 surface water samples were all observed to contain atrazine at concentrations between 0.016 and 0.032 µg/l.

Metalaxyl Contamination of Ground Water and Tile Drainage Water in Atlantic Canada - (Léger, D., 1996)

Selected farm wells in New Brunswick and P.E.I. were sampled four times between 1994 and 1995 as part of a broader study examining potential contamination of groundwater and tile drainage water by the systemic fungicide metalaxyl. Samples were collected from wells within 100 metres of fields that had been treated with metalaxyl either in the current year or in preceding years. Two of the 21 P.E.I. wells consistently had positive metalaxyl concentrations: one in the range of 0.07 to 0.25 ppb; the other in the range of 10 to 25 ppb. The latter well was used for pesticide mixing and in all likelihood contamination was due to accidental release, but this was not confirmed. All values were well below the recommended drinking water guideline of 500 ppb.

Pesticide Residues in Sediment and Water from Two Watersheds in Prince Edward Island, 1996 and 1997 - (Savard et al., 1999)

Several fish kills have occurred in western Prince Edward Island in the last five years in an area of intensive potato production. Although the cause of one fish kill has been attributed to a spill of pesticides, the causes of the remaining fish kills has not been positively determined. In all but the spill case, these fish kills had been preceded by heavy rainfall events. Sampling on the Big Pierre Jacques and Long Rivers was conducted in 1996 and 1997 to determine if pesticides were entering these systems at concentrations that could present a risk to aquatic life.

Analytes included in the program included Chlorothalonil, Metribuzin, Dimethoate, Metalaxyl, Endosulfan, Azinphosmethyl and Linuron. All of the analytes examined were detected, with frequencies of detection varying both by product and by rainfall amounts immediately preceding individual sampling runs. The highest percentage of positive detections was 23% which was from the sampling run conducted during the highest rainfall event of the sampling program, although no consistent correlation was found between precipitation and the frequency or magnitude of pesticide detections. Metalaxyl and metribuzin had the highest percentage of positive detection at 23%, followed by chlorothalonil at 21%. Endosulfan was detected in 17% of samples, with the three remaining pesticides being detected in 8% of samples. On only one occasion was a pesticide (chlorothalonil) detected at levels in excess of published guidelines for the protection of aquatic life.

Pesticides in Groundwater survey 1996-1998 - **(Mutch, in preparation)**

Over the period 1996 -1998 the P.E.I. Department of Technology & Environment conducted a multi-faceted survey of pesticide occurrence in groundwater (Mutch, in preparation). As an initial step, a comprehensive list of high and moderate use pesticides were screened according to their chemical properties and leaching potential, toxicity and use characteristics to prioritise ten compounds for field study. Sampling sites included 30 "high risk" wells in an intensive potato producing region and 30 wells distributed across the Province, with emphasis on high capacity wells servicing significant portions of the population. In addition sites were targeted for sampling for specific compounds, with 10 sites in the vicinity of fields treated with a new insecticide imidicloprid (Admire) and 10 wells in the vicinity of blueberry fields were sampled for Hexazinone (Velpar) and Atrazine (Aatrax.). "High risk" wells in potato producing areas were sampled twice a year over the three year period, with the remaining sites being sampled once per year.

With the exception of hexazinone, the results of the survey were very encouraging, with none of samples collected from the 30 "high risk" sites or the 30 "Island-wide" sites having detectable levels of any the 10 pesticides selected via the screening process. Imidicloprid was detected at trace levels in only one of the thirty samples collected for this product. In contrast, hexazinone in 14 of the 41 samples collected in blueberry growing areas. Seven of these detections were at trace levels between 0.05 and 0.5 ppb, while the remaining seven detections ranged from 0.63 to 8.10 ppb. All values were well below the 210 ppb life time health advisory level recommended by the U.S. EPA.

A Survey of the Quality of Municipal Supplies of Drinking Water from Groundwater Sources in Prince Edward Island - (Blundell and Harman, in preparation)

The Sierra Club of Eastern Canada and the University of Waterloo jointly conducted a survey of municipal water supply wells on Prince Edward Island during the summer of 1998. The survey included 18 sampling sites from 12 water utilities across the Province. The study was designed to provide a one time set of analytic results from municipal wells across Canada. The analytic results are to be used to assess the quality of groundwater sources used for municipal drinking water supply and to provide a baseline data base for water quality for subsequent work. Two hundred and seventeen parameters were examined, including standard inorganic chemistry, metals, V.O.C.s and pesticides. The presence of agricultural activity in the vicinity of some well fields made pesticides an important parameter in the survey, and pesticides comprised 114 of the analytes examined in the survey.

In spite of the extensive list of analytes, not a single pesticide or metabolite was detected in any sample analysed. V.O.C. analyses detected a number of trihalomethanes (THM's) in treated water supplies, although at very low levels (maximum concentrations in the range of 0.0002 to 0.0006 mg/l for individual THM's), and trace levels of the THM chloroform was detected in raw water samples from nine other wells. All detections were well below the current drinking water guideline value of 0.1 mg/l.

In addition to THM's, a single detection of trace concentrations (0.004 mg/l) of tetrachloroethene (PCE) was made in a sample from one well in the City of Summerside. Similar results have been reported in previous surveys at this well, and all values have fallen well below the 0.03 mg/l maximum acceptable concentration recommended in the Guidelines for Canadian Drinking Water Quality .

3.6 Faecal Coliform Bacteria

While the microbiological quality of water is of interest principally for reasons of public health, the focus of this section is on microbiological quality of surface waters and the associated constraints on commercial shellfish harvesting and recreational uses. While the microbiological quality of drinking water is of obvious importance, on P.E.I., all potable water supplies draw water from groundwater sources. In these cases bacterial quality relates more to the integrity of the well or distribution system rather than to the state of groundwater quality as a whole. Because of the nature of the sampling points and the density of this water quality network, an adequate assessment of the integrity of water supply systems from public health perspective is not possible. As a consequence, the bacterial quality of groundwater is not discussed further in this report.

Faecal coliform bacteria are a group of bacteria associated primarily with faeces of warm blooded animals and are used to indicate the possible presence of pathogenic organisms which are harmful to human health. Faecal coliform bacteria are used as an indicator by the Canadian Shellfish Sanitation Program (CSSP) for the determination of shellfish closure areas. Faecal coliform contamination is a serious problem for the waterways and estuaries of the Province and approximately 83 shellfish growing areas are closed to harvesting due to faecal coliform contamination.

Results for faecal coliform in freshwater sites are outlined in Table 8. The overall geometric mean coliform concentration for the freshwater sites was 25 MPN/100ml. The worst location, the Clyde River, is located in the middle of a cattle pasture.

There are no criteria for freshwater that ensure that the estuarine area into which it discharges won't be closed for shellfish harvesting. However, freshwater concentrations do provide insight as to the sources of the faecal coliform concentration in the estuary. For those freshwater sites that are close to estuarine waters, the geometric mean of ranges from 9 to 141 MPN/100ml. The percentage greater than 43 ranges from 0 to 73% of samples. While these streams don't represent all of the contribution to the growing area, in the estuary below each of site, the estuarine area has a shellfish closure with the exception of the Bear River which discharges directly to the Gulf of St. Lawrence and has not been assessed by the CSSP. In each of the three estuaries that are monitored in the annex network, there are shellfish closures. The

Table 8 Faecal Coliform Concentrations At Fresh Water Stations.

Sample Location	River	# samples	Geometric Mean (MPN /100ml)	% > 43	% > 260	% > 400
PE01CA0001	Mill (Carruthers Bk)	30	31	43%	17%	13%
PE01CA0042	Miminegash	25	49	52%	36%	24%
PE01CA0043	Cains Brook	27	14	26%	11%	7%
PE01CB0001	Dunk	24	35	50%	4%	0%
PE01CB0005	Dunk (Breadalbane)	25	139	76%	24%	24%
PE01CB0141	Bradshaw	24	10	25%	4%	0%
PE01CB0143	Wilmot	25	42	56%	0%	0%
PE01CC0004	Winter	23	37	48%	13%	13%
PE01CC0010	Clyde	30	129	73%	37%	33%
PE01CC0213	West	28	60	57%	7%	7%
PE01CC0218	Hunter	23	24	43%	4%	0%
PE01CD0003	Morell	23	9	0%	0%	0%
PE01CD0050	Bear	22	23	18%	14%	5%
PE01CE0099	Montague	29	15	24%	0%	0%
PE01CE0101	Montague (Oceanview)	19	2	0%	0%	0%
PE01CE0100	Valleyfield	30	5	3%	0%	0%

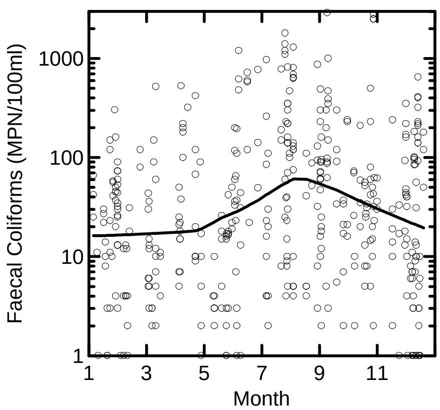

Figure 23 Seasonal trends in freshwater faecal coliform concentrations.

freshwater stations in the network closest to these three estuaries have geometric means ranging from 14 to 141 MPN/100ml. The percentage greater than 43 for each of these sites ranges from 24 to 73%.

Guidelines for recreational purposes (i.e. swimming, boating, etc.) are a geometric mean of 200 MPN/100ml for the site with no sample exceeding 400 (CCME, 1995). Thirty-four samples (8%) exceeded the 400 MPN/100ml component of the guideline.

Faecal coliform counts are generally low during the winter months then increase during the spring to peak during late summer (Figure 23). Bacteria counts then decrease throughout the autumn.

Estuarine sites where the median or geometric mean concentration of faecal coliforms exceeds 14 MPN/100ml (MPN-Most Probable Number) or where more than 10% of the samples exceed 43 MPN/100ml for faecal coliforms are considered unsafe for the harvest and direct consumption of shellfish. Faecal counts in the estuarine waters of the province are much lower than that of the rivers and streams (Table 9). The geometric mean faecal coliform concentration for the estuaries is 6 MPN/100ml. There are only 192 records in the network for this parameter for estuarine waters, with 6% exceeding 43 MPN/100ml, 1% exceeding 260 MPN/100ml and 0% exceeding 400 MPN/100ml. The upper estuarine station in both the Mill and Montague Rivers exceed shellfish growing criteria and match the closed classification for the area in which they are located.

This is not the case for the upper estuarine station for the West River where the area is classified closed but the network data meet the shellfish growing area criteria. This is likely due to the nature of the regular sampling methodology of the network.

It is important to again review the importance of rainfall events on the results obtained in the network data set due to the nature of bacterial contamination. It is often observed that bacterial concentrations increase in areas subject to non-point sources of faecal coliforms during and after rainfall events. Because the network sampling is completed utilizing a regular schedule of approximately six week intervals, the network data set will probably underestimate the worst conditions observed in an estuary and its watershed. Normally, when shellfish closure decisions are made under the auspices of the CSSP by Environment Canada, care is taken to ensure that the data set includes adequate amounts of wet weather data. Readers should note that as this data will not be utilized for the location of shellfish closures, this check has not been completed for this report.

Seasonal trends in faecal coliform concentrations are also prominent in estuarine samples (Figure 24). As in freshwater samples, there is a prominent peak in the middle of the year albeit a month later in September. Unlike the freshwater samples, there is also a prominent peak in the winter under the ice. This is likely due to the influence of stratification with fresher water occurring immediately under the ice where the faecal coliform samples are collected. In this fresher water, the concentration of faecal coliforms will more resemble the higher concentrations found in freshwater than the lower ones in estuarine water.

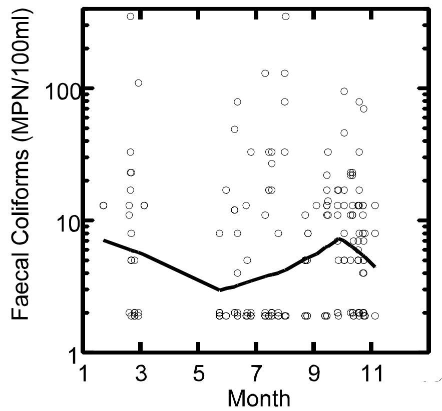

Figure 24 Seasonal trends in estuarine faecal coliform concentrations.

Table 9 Faecal Coliform Concentrations At Estuarine Water Stations.

Sample Location	River	# Samples	Geometric Mean (MPN /100ml)	% > 43	% > 260	% > 400
PE01CA0047	Mill - upper	30	10	13%	3%	0%
PE01CA0015	Mill - mid	22	3	0%	0%	0%
PE01CA0048	Mill - lower	22	2	0%	0%	0%
PE01CC0214	West - upper	18	10	6%	0%	0%
PE01CC0113	West - mid	14	9	7%	7%	0%
PE01CC0092	West - lower	13	5	0%	0%	0%
PE01CE0105	Montague - upper	5	24	20%	0%	0%
PE01CE0103	Montague - mid	36	7	3%	0%	0%
PE01CE0104	Montague - lower	30	3	0%	0%	0%

4 Discussion and Recommendations

4.1 Key Findings

The water quality results discussed in this report indicate that the quality of the groundwater supplies, fresh surface waters, and estuarine waters of the province is generally high, however, there are a number of areas of concern, which highlight the need for further research and attention.

Groundwater

With few exceptions, groundwater quality, as judged by the data presented in this report has generally been excellent. The data examined for this report contains only a small number of cases of a parameter being measured at levels that exceed those recommended in the Guidelines for Canadian Drinking Water Quality.

A review of the major ion chemistry, shows the water to be relatively consistent in composition across the Island, and while it would be considered to be relatively hard, it is generally free of any characteristics that would render it unusable for most domestic, industrial or commercial purposes.

The presence of elevated sodium and chloride levels, often accompanied by excessive hardness is perhaps the one most notable departure from this generalization. While in some cases the presence of these salts is likely to be a reflection of marine influences on groundwater quality, it is equally likely that a large number of these cases are a result of the storage and use of salt for road deicing.

Nitrate levels in groundwater are a source of concern. Although a relatively small number of sampling stations (3%) reported results exceeding safe drinking water levels, data from other sources indicate that up to 7% of domestic wells in some agricultural areas of the Province do not meet the 10 mg/l nitrate-nitrogen standard. Furthermore, because of groundwater's substantial contribution, via baseflow to Island streams and rivers, the nitrate content of groundwater can be expected to play a significant role in the nutrient levels in surface water bodies. Unfortunately, nitrate levels that may be low enough to be of no consequence from a drinking water perspective may be high enough to still have a detrimental impact on surface water quality.

The metals content of P.E.I. groundwaters appears for the most part to be determined by the native geology of the Province, and while all parameters measured were reported at detectable levels, almost all fell well within health based drinking water guidelines. Typically, iron and manganese are the two metals most commonly found at elevated levels on P.E.I., although the data base reviewed here shows that the aesthetic objectives were only rarely exceeded, and not by a large margin.

Barium levels on the Island appear to be relatively high, a feature that is attributed to geological controls, although in all but a single instance, health based guideline values were met.

Anthropogenic influences are suspected

with respect to the occasional values of lead in excess of recommended levels (leaching from plumbing fixtures). Anthropogenic sources are postulated also for arsenic, although in this case, this conclusion is based more on the apparent absence of natural sources, rather than conclusive evidence of any specific man-made influence.

The contamination of groundwater by organic chemicals, and in particular pesticides, is one of the more commonly voiced environmental concerns, and groundwater analyses account for nearly 65% of the pesticide data examined. The results confirm the fact that some pesticide compounds do leach to the water table, but at the same time indicate that this is a relatively uncommon occurrence, with only 2.5% of the 5300 groundwater pesticide analyses reporting detectable concentrations. None of the analyses in the database exceeded recommended maximum concentrations for drinking water.

One notable feature of the groundwater pesticide data is the disproportionate occurrence of specific compounds such as the aldicarb or the triazine herbicides. For the triazines this is even more remarkable considering the small number of analyses conducted (21). While the past detection of aldicarb is now no longer an issue, it also serves to underline the potential for highly leachable compounds to impair groundwater quality. Analyses of other organic compounds were rarely included in the data base, however work published elsewhere (particularly surveys of municipal drinking water supplies) indicates few influences of anthropogenic activity on natural water quality. Nonetheless, the detection of some organochlorine compounds in some wells underscores the potential impact of land use on groundwater quality.

Fresh Surface Waters

Natural surface water quality on P.E.I. is generally excellent, and the generally cool, well oxygenated surface waters of the province supports a rich and diverse set of ecosystems. However the surface waters of the province, by their very nature, are subject to more diverse influences and uses than groundwaters, and this is reflected in the number of water quality issues associated with Island streams, rivers and estuaries. For the most part these influences tend to be from non-point sources, making the development of remedial strategies more difficult.

Soil erosion, and the accompanying siltation of surface water bodies continues to be one of the prime environmental issues facing the Province. Turbidity and suspended solids data generally fall within acceptable limits, however it is unlikely that this data, collected largely by grab sampling, adequately represents the movement of sediment within the surface water environment. This is perhaps best illustrated by the apparent absence in the data, of evidence for seasonal variation in sediment loads, when anecdotal evidence indicates that a substantial portion of sediment movement may occur over relatively short “events”. As a consequence, the data reported here could be expected to seriously underestimate the extent of the problem. The data do indicate a strong association between sediment loads and adjacent land use, consistent with conventional wisdom on the topic.

Nutrient enrichment of P.E.I. estuarine environments is a growing problem, and too often has implications for dissolved oxygen levels as well. While much of the attention has been given to the role of nitrogen in the development of eutrophic conditions in Island estuaries, there is evidence that phosphorous levels may also be significant, perhaps even limiting factors in many of these cases (Meeuwig, 1998).

The problem is complex, not only because of the dynamic character of estuarine waters, but also because different pathways may dominate the movement of nitrogen and phosphorous, even though the source of the nutrients may be similar. In the case of nitrogen, it is likely that the discharge of groundwater containing elevated levels of nitrate comprises a substantial, if not dominant, source of nitrogen to surface water bodies. In contrast, phosphorous, which is held well by the soil profile, may reach surface water bodies in association with sediment rich run-off.

Results of pesticide analyses suggest that low levels of these compounds are commonly detected in surface waters, however the concentrations reported are normally well below the levels which would be expected to exert a significant negative impact on aquatic life. Nonetheless the mid to late 1990's have seen several fish kills, particularly associated with intense rain fall events in the western part of the Province. While these events have not been conclusively linked to the use of pesticides, the evidence does suggest that pesticides are implicated in some way. If so, it also suggests that pesticides are entering surface water systems at concentrations considerably higher than reported in the data presented here, and that they are reaching these waters as a result of normal pesticide application practices.

The fact that apparently “lethal” levels of these compounds are not reported in surface waters may relate to the difficulty of capturing short term excursions in water quality via the collection of grab samples, in much the same way that it may also be difficult to get truly representative indicators of sediment movement.

Bacterial contamination of surface waters also remains a concern, with a significant portion of the Province’s shellfish growing areas closed to direct harvesting. As with nutrient enrichment and siltation, non-point sources are believed to be significant contributors to the problem, hampering efforts to improve microbiological quality of these waters.

While some metals have been observed exceeding fresh water guidelines at a number of stations, the frequency of exceedance at each station is very low and not considered to be a concern.

4.2 Temporal Trends in Water Quality

It is the aim of this report to comment both on the current quality of the Province’s water resources, and on notable changes in water quality. With the distribution and abundance of many waterborne constituents being controlled by natural processes, only a few parameters are expected to exhibit significant shifts over the short time frame of available data. Influences that are most likely to be reflected in changes in the environment are most likely to be man-made. It is not surprising therefore that most of the data examined shows little temporal variation, and that where changes are seen , such as for the nitrogen data, they are associated with widespread anthropogenic activities. It is also noted however, that the period of record for many parameters is not particularly great, and subsequent investigations may detect trends not clearly apparent in the existing data.

The data do suggest a subtle decrease in sulphate and marginal increase in pH in fresh surface waters of the Province. This may indicate an overall improvement of precipitation water quality for the Province and may be an indicator of an overall decrease in acid rain. In some watersheds, slight increases in total dissolved solids, mostly calcium, magnesium and bicarbonate (bicarbonate estimated from alkalinity data), have accompanied the increase in pH, however no explanation for this trend has offered itself at this time.

A comparable trend is not readily evident in groundwater, however given residence times that are likely to range from years to several decades, and the dominating influence of geology on major ion chemistry, it would not be expected to observe such changes over the period of record.

The most striking trend in the data however is for nitrogen in surface waters. As section 3.3 indicates, surface water analyses clearly exhibit substantial changes in nitrogen concentrations, with nitrate levels doubling in some rivers over the past two decades. Data from the Mill River, Dunk River, and Morell River, while exhibiting differing absolute concentrations, each show increases in nitrate over time. Unfortunately, data from existing groundwater stations is not particularly useful in further illuminating these trends, although examination of aggregate groundwater data from a variety of sources tends to support the association of elevated nitrate concentrations with land use, and the increase in nitrate levels over time. The predominance of site specific factors, including well construction, position in the watershed, and in many cases very local land use, is responsible for these short comings.

Interestingly, the Dunk River data exhibits a slight levelling off of nitrate levels, starting about the mid 1980's. It is tempting to speculate on the significance of this apparent change in trend, however, there is insufficient information at this time to draw firm conclusions. One possibility is that nitrate inputs relating to land use, and nitrogen outputs as observed in surface water, have reached some sort of steady state in this watershed. There are many uncertainties however, particularly relating to the residence time of nitrogen in the groundwater portion of the system. Until these questions are resolved, it is difficult to predict what future nitrogen levels might be in the Island's groundwater and surface water systems. These trends have important implications both for the availability of safe drinking water, and for the health of aquatic ecosystems across the Province.

While the change in nitrogen concentration in the three long-term freshwater sites is the most well grounded in a continuous collection of samples, the apparent increase in estuarine phosphorus concentrations is also disturbing. Nevertheless, it would be expected that if freshwater nitrogen loading to the estuaries is increasing, that phosphorus loading would also be increasing. While the freshwater sample collection methods do not permit this trend to be observed, it is likely that an increase in freshwater phosphorus loading to the estuary must have occurred to result in an increase in concentration in the estuary. The implication for resolving eutrophication problems in P.E.I. estuaries is large. It is not likely that reduction of either nitrogen loading nor phosphorus loading alone would be an appropriate approach for remediation. In fact it may well be that both might have to be reduced so as to not alter the ratio of phosphorus and nitrogen in the estuary. As the primary form of nitrogen loading, nitrate, is soluble in water and phosphorus is largely bound to sediment, methods to reduce them may not be the same.

The nature of the existing data on pesticides, and other organic compounds, do not readily allow interpretation of temporal trends. The relatively low frequency of detection, the dependance of results on the nature and intent of individual sampling programs, and the varying emphasis over time on particular parameters, make it difficult to compare results over significant periods of time. However, in-use pesticides can be commonly detected at low levels. The occurrence in the mid to late 1990's of fish kills related to pesticide residues in surface water are of major concern, but at this point in our understanding of the problem, conclusions on further trends with respect to water quality cannot be drawn.

Soil erosion has long been recognized as perhaps the most serious environmental problem on P.E.I., a point reinforced most recently by the report of the Round Table on Resource Land use, however the data from the current network do not illustrate a significant trend over time. This may simply be an indication that soil losses comparable to those seen today have persisted over the available period of record, or just as likely may be a function of limitations in the manner in which data has been collected.

4.3 Limitations of existing data collection network and recommendations for further work

This report is based on data collected from a variety of sources, over a considerable period of time, and provides a useful review of water quality trends and issues for the Province. The mechanisms in place for the collection of this data have evolved considerably over time, and have developed into a well integrated monitoring system for key elements of aquatic ecosystems on Prince Edward Island.

Much of this “re-alignment” took place in the early 1990's through efforts such as the “Evaluation and Planning of Water Related Networks on Prince Edward Island” (Environment Canada - P.E.I. Dept. Of Environment, 1991), and the subsequent refinements to ecosystem monitoring. In particular, the availability of data from all relevant media within individual systems, such as those represented by the index basins and management basins of the current network, provide much more meaningful information than could be collected from individual “stand alone” stations. As the complexity of issues examined increases, it will be even more important to be able to integrate information from several media within individual systems, if we are to understand the linkages and relationships between different portions of the environment. The current “alignment” of water quality stations, should also greatly improve the ability to evaluate water quality data over time, providing a comprehensive, long term network of stations, that will facilitate subsequent comparative studies. Key to the ability to track long term trends is the need to monitor the same parameters at the same location for decades. At this time, only two active stations have records in excess of ten years. Careful consideration must be made to the re-activation of historical stations to aid in determining long term trends.

Nonetheless, this review of data also highlights the limitations of this approach to data collection. It was noted in section 3.3 that groundwater data for nitrogen, as collected from a limited number of stations, was of limited value in illuminating trends over time. Similarly, the evaluation of pesticides in groundwater or surface water, because of their low frequency of detection, and in the case of surface water samples, highly “event specific” nature is difficult to accomplish with a limited number of “sentinel” type sampling stations. In some cases, modifying the monitoring program to utilize continuous monitoring by probes will assist with this limitation. In other cases it may be best to focus attention on periodic, specific research projects, which may examine certain phenomena in greater detail, or in the case of groundwater, may involve comprehensive surveys of much larger numbers of wells than the current network can provide. Toward this end, the “Water Management Initiatives” portion of the current Federal - Provincial Water Annex, has played a vital role, providing under this umbrella, the flexibility and resources needed to address specific research requirements.

The accumulated data also suggests that differing time frames could be employed for different environments. Current sampling involves collection of groundwater and surface water samples on approximately 6 week intervals. Given the relatively long residence time of groundwater, the frequency of collection at groundwater stations could be reduced substantially, without jeopardising the value of the data.

Semi-annual sampling, particularly if timed with recharge and recession periods of the hydrologic year, would provide more than adequate tracking of most trends that might be expected, and could conceivably free up resources that could be used to advantage by an expanded parameter list, or a larger number of sampling stations. For example, recurring surveys of municipal water supply wells for an extensive list of parameters may provide more useful information than the collection of up to 8 samples per year from a limited number of wells.

Special challenges for future sampling are posed by the need to more fully understand the timing and magnitude of pesticide residues and sediment entering waterways. In both cases, evidence suggests that the most significant inputs are closely related to weather events, and in some cases, probably only isolated geographic regions. Continued work will be required to address these needs.

Finally, the period of record represented in this review has seen many shifts in emphasis with respect to parameters of concern. While many of the parameters currently being reported are likely to be of issue for the foreseeable future, other parameters such as a number of metals may no longer be of the same significance as when they were initially proposed. For this reason, it may be timely to review data needs in light of current issues, and issues we can anticipate to be of importance in the future. While agricultural issues are likely to dominate the water quality agenda for some period of time, it might be opportune to examine, as an example, the growing field of climate change research, and determine if changes to the current suite of parameters could assist in evaluating this or other up-coming issues.

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Appendix 1 Annex Water Quality Stations

Station	Name	Latitude	Longitude
PE01CA0001	Mill River at Wsc Gauge in Bloomfield Park	46.744167	-64.181667
PE01CA0015	Mill River Estuary About 5 km SW of Alberton	46.770278	-64.114167
PE01CA0041	Mill River 600 M E of Hwy 12 Bridge	46.775278	-64.110000
PE01CA0042	Miminegash River Near St. Lawrence	46.849167	-64.196667
PE01CA0043	Cains Brook Near Bloomfield Corner	46.754444	-64.181667
PE01CA0044	Bloomfield Mall Washroom From Washroom Sink	46.768333	-64.177222
PE01CA0045	Bloomfield Elementary School From Water Tank	46.765556	-64.189444
PE01CA0046	Hernewood Junior High School	46.735556	-64.173333
PE01CA0047	Mill River Estuary at Mill R. Provincial Park Dock	46.750556	-64.166389
PE01CA0048	Mill River Estuary Near Fox Point	46.766667	-64.073889
PE01CB0001	Dunk River at Waugh Road	46.345556	-63.632778
PE01CB0005	Dunk River at Hwy 231 Bridge, Breadalbane	46.356111	-63.502500
PE01CB0115	Summerside Town Well 7	46.415833	-63.778056
PE01CB0141	Bradshaw River at Central Bedeque	46.331389	-63.716944
PE01CB0142	Bedeque Senior Citizens Home From Laundry Room Tap	46.338333	-63.726389
PE01CB0143	Wilmot River Near Kelvin Grove	46.393333	-63.658611
PE01CB0144	Well at Gary Woodworth'S House, Stanchel, PEI	46.328889	-63.474722
PE01CC0004	Winter River Near Pleasant Grove	46.335833	-63.106667
PE01CC0010	Clyde R. About 1.5 km North of Clyde R. (Hwy 247)	46.236944	-63.262500
PE01CC0042	Winter River South Branch at Union Road Culvert	46.312500	-63.128056
PE01CC0059	Charlottetown - Union A	46.314167	-63.123889
PE01CC0092	Charlottetown Hbr--West River Estuary	46.210833	-63.159444
PE01CC0113	West (Eliot) River 770 M East of Dickieson'S Pt.	46.190278	-63.227778
PE01CC0180	Charlottetown Water Supply - Brackley Well #9	46.314167	-63.150000
PE01CC0213	West River at Riverdale	46.230833	-63.351389
PE01CC0214	West River at Dunedin	46.198056	-63.296667
PE01CC0218	Hunter River Below Bell Pond at Bridge	46.394167	-63.343889
PE01CC0220	Cornwall Well (G. Somers)	46.226111	-63.217778
PE01CD0003	Morell River From Road Bridge	46.362778	-62.703056
PE01CD0047	Morell Senior Citizens Home Unit B	46.414722	-62.703889
PE01CD0048	Compton Farms Near Bangor	46.374444	-62.681944
PE01CD0049	North Lake Creek Near Lakeville	46.449722	-62.122222
PE01CD0050	Bear River at St. Margarets	46.453056	-62.382500
PE01CE0096	Montague River Near Robertson	46.176389	-62.610000
PE01CE0099	Montague River Above Knox Pond	46.149722	-62.696944
PE01CE0100	Valleyfield River Near Kilmuir	46.138611	-62.678056
PE01CE0101	Montague River at Ocean View	46.068611	-62.813333
PE01CE0102	Montague Senior Citizens Home Unit G	46.166944	-62.644722
PE01CE0103	Montague River Estuary Near Dewars Point	46.171667	-62.616389
PE01CE0104	Montague River Estuary Near Lower Montague	46.174167	-62.561944
PE01CE0105	Montague River Estuary Near Montague	46.163889	-62.648611

Appendix 2 Historical Water Quality Stations

Station No	Station Name	Lat	Lon
PE01CA0002	Carruthers Brook (Mill River) at Hwy 143 Bridge	46.720556	-64.271667
PE01CA0003	Profitts Pond at Outlet	46.783333	-64.166667
PE01CA0004	Kildare River Estuary in Centre of Channel	46.866389	-64.066667
PE01CA0005	Kildare River Estuary in Centre of Channel	46.863056	-64.065278
PE01CA0006	Kildare River Estuary in Narrowest Channel	46.856944	-64.063611
PE01CA0007	Huntley River Estuary in Centre of Channel	46.851111	-64.064722
PE01CA0008	Kildare River Estuary in Centre of Channel	46.849722	-64.054167
PE01CA0009	Kildare River Estuary in Centre of Channel	46.836944	-64.051667
PE01CA0010	Kildare River Estuary in Centre of Channel	46.832500	-64.045000
PE01CA0011	Kildare River Estuary in Channel, SE of Causeway	46.829167	-64.031667
PE01CA0013	Kildare River Estuary in East Shore Channel	46.814722	-64.036667
PE01CA0016	Tignish River Estuary From Hwy 135 Bridge, Tignish	46.939444	-64.029722
PE01CA0017	Miminegash River Estuary From Hwy 14 Bridge	46.858056	-64.223889
PE01CA0018	Trout River at Carleton From Hwy 2 Bridge	46.693056	-64.153056
PE01CA0020	Mill River Below Hwy 12 Bridge, Center of Estuary	46.776944	-64.105278
PE01CA0022	Gulf of St. Lawrence ~ 300 M SE of Kildare Point	46.801944	-64.030000
PE01CA0024	Smelt Creek Estuary at Confluence of Bideford R.	46.616944	-63.915000
PE01CA0026	Kildare River Estuary in Centre of Channel	46.871944	-64.074444
PE01CA0027	Kildare River Estuary in Centre of Channel	46.868611	-64.067778
PE01CA0034	Arsenaults Pond	46.950000	-64.066667
PE01CA0035	Leards Pond at Trout River	46.691667	-64.205556
PE01CA0036	Mill River at Mill River Provincial Park	46.736389	-64.163611
PE01CA0037	Mill River Near Bloomfield Corner	46.747778	-64.165000
PE01CA0038	Mill River at Fortune Cove	46.760833	-64.135278
PE01CA0039	Mill River at Mill River East	46.762500	-64.140556
PE01CA0040	Mill River Near Cascumpec	46.771944	-64.091667
PE01CA0049	Big Pierre Jacques River, Upper	46.656944	-64.342500
PE01CA0050	Big Pierre Jacques River, Middle	46.656111	-64.342222
PE01CA0051	Big Pierre Jacques River at Bridge	46.652778	-64.339722
PE01CA0052	Drainage Ditch Near Miscouche	46.556667	-64.018056
PE01CA0053	Unnamed Brook	46.657222	-64.032222
PE01CA0054	Long Creek	46.786667	-64.200278
PE01CB0002	Scales Pond 100 M Above Dam \Center	46.346389	-63.608611
PE01CB0003	Summerside Hbr., Bedeque Bay, West of Indian Head	46.370556	-63.831944
PE01CB0004	Paynters Pond at Outlet.	46.487500	-63.545833
PE01CB0006	Dunk River 1.6 km West of Breadalbane	46.355000	-63.490000
PE01CB0007	Summerside Harbour, Bedeque Bay	46.364167	-63.816944
PE01CB0008	Summerside Harbour About 198m North of Indian Head	46.388889	-63.813889
PE01CB0009	Summerside Harbour,Bedeque Bay, WNW of Grahams Pt.	46.346111	-63.845556
PE01CB0010	Summerside Harbour, Miscouche Cove	46.395278	-63.870000
PE01CB0011	Summerside Harbour Estuary of Dunk River	46.363611	-63.787778
PE01CB0012	Summerside Harbour Estuary of Dunk River	46.352222	-63.753056
PE01CB0013	Summerside Harbour Estuary of Dunk River	46.360556	-63.766944
PE01CB0014	Scales Pond at Unnamed Tributiary	46.340000	-63.605278
PE01CB0015	Scales Pond 600 M Above Dam at Center	46.345556	-63.604167
PE01CB0016	Scales Pond Above Dam	46.350833	-63.594722
PE01CB0017	North Brook (Lloyds Brook) South of South Freetown	46.345833	-63.631944
PE01CB0018	Wilmot River Near Wilmot Valley	46.393333	-63.658611
PE01CB0019	Dunk River at Lower Bedeque	46.340556	-63.668889
PE01CB0020	De Sable River Ne of Hampton	46.226667	-63.438889

Station No	Station Name	Lat	Lon
PE01CB0023	Westmorland River East of Crapaud at Hwy 13 Bridge	46.236667	-63.479444
PE01CB0025	Unnamed River North of Augustine Cove Below Dam	46.229167	-63.606389
PE01CB0026	Unnamed R. at Road Bridge 100m N of Cape Traverse	46.242778	-63.640000
PE01CB0030	Barbara Weit River at Hwy 2 Bridge	46.425278	-63.677222
PE01CB0038	Summerside Harbour Estuary of Dunk & Wilmot Rivers	46.391667	-63.802222
PE01CB0040	Dunk River Below Scales Pond at Hwy. 109	46.341667	-63.610556
PE01CB0041	Southwest Brook 50 M Above Middleton Pond	46.317778	-63.624722
PE01CB0042	Southwest Brook at Outfall of Middleton Pond	46.321944	-63.623889
PE01CB0043	Wilmot River at Outfall of Ducks Unlimited Pond	46.401111	-63.628056
PE01CB0044	Wilmot River 350 M Below Hwy 109	46.399167	-63.631667
PE01CB0045	Upstream Background Site: Pestfund 1988	46.250000	-63.623889
PE01CB0046	Inlet To Pond Pestfund Project 1988	46.246667	-63.626944
PE01CB0047	Outlet From Pond 25 M Downstream:Pestfund 1988	46.245833	-63.628333
PE01CB0048	Dunk River at Outflow of Scales Pond	46.343611	-63.609444
PE01CB0050	Pond Pestfund 1988 Study Site Unnamed	46.246389	-63.627778
PE01CB0053	Marchbanks Pond On The Wilmont River	46.395000	-63.693056
PE01CB0060	Summerside Hbr., Bedeque Bay, South of Phelan Pt.	46.381389	-63.853056
PE01CB0067	Summerside Harbour Estuary of Dunk & Wilmot Rivers	46.384167	-63.811389
PE01CB0069	Summerside Harbour Estuary of Dunk & Wilmot Rivers	46.388056	-63.809444
PE01CB0074	Middleton Pond at Depression, 200 M Above Dam	46.320000	-63.625556
PE01CB0075	Malpeque Bay 1850m.S.61 W.From Boat Launching Site	46.466667	-63.766667
PE01CB0080	Summerside Harbour at Wilmot River Estuary	46.390556	-63.740556
PE01CB0082	Summerside Harbour	46.383333	-63.783333
PE01CB0084	New London Bay 1200 M E of McEwens Island	46.494167	-63.464167
PE01CB0102	Barbara Weit River Estuary From Road Bridge	46.431389	-63.685833
PE01CB0108	Dunk River Estuary at Hwy 110 Bridge	46.340556	-63.667778
PE01CB0112	Summerside Harbour, Colville Bay	46.362222	-63.766944
PE01CB0135	Pond On Property of L. Huestis, Hwy 107	46.408333	-63.688056
PE01CB0136	Wilmot River at Hwy 110 Adjacent To Wsc Gauge	46.393611	-63.659167
PE01CB0137	Emerald Brook Near Emerald	46.360000	-63.557500
PE01CB0138	Elmo River 1 km West of Newton On Route 111	46.338611	-63.596389
PE01CB0139	Unnamed Stream 1.22 km South of Lower Freetown	46.352222	-63.667778
PE01CB0140	Wrights Pond	46.333333	-63.716667
PE01CB0188	Wilmot River	46.393056	-63.659722
PE01CC0002	North (Yorke) River at Hwy 258 Bridge	46.300556	-63.221944
PE01CC0006	O'Keefe Lake (Boat Launching Site) at Hwy 5	46.247778	-62.818333
PE01CC0007	Moss Lake	46.231667	-62.913056
PE01CC0008	Weisner'S Pond	46.264167	-62.886389
PE01CC0009	Glenfinnan Lake at South Shore of Lake	46.294444	-62.955000
PE01CC0011	Hardys Pond (Winter River#Near Boat Ramp)	46.335278	-63.107778
PE01CC0016	Winter (Chapel) Creek From Hwy 6 Bridge	46.414167	-63.290000
PE01CC0017	Clyde River 1070 M North of Clyde River Mouth	46.202500	-63.261667
PE01CC0027	West River 1.3 km East of Tch. Bridge, Bonshaw	46.200833	-63.336944
PE01CC0029	West (Eliot) River 320 M SW of Dickieson'S Point	46.187500	-63.240000
PE01CC0032	Hunter River Estuary in Channel Centre	46.443056	-63.303889
PE01CC0033	Hunter River Estuary 1080 M West of Lighthouse	46.455000	-63.308056
PE01CC0034	Hunter River Estuary 270 M West of Lighthouse	46.455556	-63.296389
PE01CC0035	Hunter River Estuary About 225 M SW of Lighthouse	46.452778	-63.292778
PE01CC0036	West (Eliot) River From Hwy 13 Culvert, Brookvale	46.283611	-63.408056
PE01CC0037	West (Eliot) River at Crosbys Mill	46.205556	-63.351944
PE01CC0038	Lake of Shining Waters Outlet From Hwy Bridge	46.498056	-63.391667
PE01CC0039	Winter River @ Bridge Behind Union Pumping Station	46.313889	-63.123333
PE01CC0040	Wrights Creek 500m Above Andrews Pond	46.280278	-63.115556

Station No	Station Name	Lat	Lon
PE01CC0041	Charlottetown Hbr 175 M South of PEI.	46.226667	-63.126667
PE01CC0044	Unnamed Tributary	46.312778	-63.123889
PE01CC0045	Hunter River at Outfall of Bagnalls Pond	46.359167	-63.348889
PE01CC0046	Hunter River at Outfall of Bells Pond	46.394167	-63.344444
PE01CC0047	West (Eliot) River Estuary at Hwy 1 Bridge	46.196111	-63.350556
PE01CC0048	Charlottetown Hbr 710 M NW of Battery Point	46.211667	-63.136389
PE01CC0055	West River at Center at Confluence of Ferguson Ck.	46.201389	-63.188889
PE01CC0056	North River at Center 100 M Above Cable Crossing	46.233611	-63.156111
PE01CC0062	Gulf of St. Lawrence About 1440 M NE of Lighthouse	46.462500	-63.279167
PE01CC0064	Charlottetown Harbour at Hillsborough River	46.246944	-63.094444
PE01CC0068	Charlottetown Hbr-Hillsborough Estuary	46.236389	-63.111667
PE01CC0074	Charlottetown Hbr 150 M East of Texaco Terminal	46.230556	-63.119167
PE01CC0075	Lake Verde 150 M From South End of Lake	46.238056	-62.884444
PE01CC0076	Charlottetown Hbr. About 1350 M W of Ferry Point	46.225278	-63.124444
PE01CC0079	Charlottetown Harbour	46.216667	-63.116667
PE01CC0082	Charlottetown Hbr. About 1800 M W of Ferry Point	46.226389	-63.135000
PE01CC0086	Charlottetown Hbr-North River Estuary	46.225556	-63.152778
PE01CC0087	Charlottetown Hbr.,North R. Estuary (Hwy 1 Bridge)	46.256667	-63.183889
PE01CC0090	Charlottetown Hbr--West River Estuary	46.193611	-63.205000
PE01CC0095	Hatchery Pond Near Outlet Southport Prov. Park	46.215556	-63.101111
PE01CC0096	Charlottetown Hbr. About 0.80 km N of Alchorn Pt.	46.203611	-63.133889
PE01CC0100	Charlottetown Hbr. 1350 M South of Old Battery Pt.	46.216111	-63.139722
PE01CC0102	Mackinnons Pond at Left Bank Near Outfall	46.412778	-62.746667
PE01CC0104	West (Eliot) River 1080 M East of Causeway	46.189167	-63.220278
PE01CC0108	West (Eliot) River 240 M East of Causeway	46.191389	-63.230278
PE01CC0110	West (Eliot) River 220 M East of Causeway	46.191389	-63.236667
PE01CC0112	West (Eliot) River 760 M South of Dickieson'S Pt.	46.184167	-63.240556
PE01CC0119	Long Creek 550 M South of Long Creek Mouth	46.182778	-63.262778
PE01CC0120	West (Eliot) River 1.2km SE of Bridge, Dunedin	46.191667	-63.277778
PE01CC0123	West (Eliot) River 140m West of Bridge	46.200278	-63.288889
PE01CC0125	West (Eliot) River 750m West of Bridge	46.196667	-63.296389
PE01CC0127	West(Eliot)River 1610m West of Bridge, Dunedin	46.190833	-63.270556
PE01CC0130	West River 4 km East of Tch. Bridge,Bonshaw	46.208056	-63.331667
PE01CC0144	Rustico Bay in Centre of Channel	46.439167	-63.272500
PE01CC0145	Rustico Bay About 720 M Ne of Grand Pere Point	46.425278	-63.234167
PE01CC0148	Hillsborough River Estuary 72 M NE of Oil Tanks	46.243056	-63.103889
PE01CC0151	Hunter River Estuary From Hwy 224 Bridge	46.408889	-63.348056
PE01CC0155	Charlottetown Harbour 325 M WNWof Rosebank Point	46.221667	-63.120278
PE01CC0158	Charlottetown Harbour at North Creek	46.251667	-63.155556
PE01CC0159	Charlottetown Harbour Centre	46.214722	-63.150278
PE01CC0162	Charlottetown Harbour Mouth	46.191944	-63.125278
PE01CC0166	Wheatley River Estuary From Hwy 224 Bridge	46.372778	-63.288889
PE01CC0168	North (Yorke) River Estuary From Causeway Gates	46.256111	-63.184722
PE01CC0206	Officers Pond	46.329167	-63.075000
PE01CC0207	West River at St. Catherines	46.200000	-63.288611
PE01CC0208	West River at Dunedin	46.200556	-63.288611
PE01CC0209	West River Near Meadowbank	46.188333	-63.232500
PE01CC0210	West River at Meadowbank	46.193333	-63.229722
PE01CC0211	West River Near Rocky Point	46.203333	-63.161389
PE01CC0212	West River Near York Point	46.215000	-63.174167
PE01CC0219	S.B. Winter River Near Charlottetown Airport	46.296389	-63.133611
PE01CC0221	Clarks Pond, Natural Seepage Inlet Area	46.397778	-63.403889
PE01CC0222	Clarks Pond, Middle	46.398889	-63.400000

Station No	Station Name	Lat	Lon
PE01CC0223	Clarks Pond Near Outlet	46.365556	-63.396667
PE01CC0224	Lake of Shinning Waters Outlet	46.398611	-63.390556
PE01CC0225	Lake of Shinning Waters	46.396389	-63.388333
PE01CC0226	Green Gables Pond	46.390278	-63.380556
PE01CC0227	Campbells Pond Outer Basin	46.411667	-63.060556
PE01CC0228	West River	46.230556	-63.351944
PE01CD0007	Souris River 260 M Nnw of Hwy 2 Bridge	46.358889	-62.279722
PE01CD0008	Colville Bay Entrance 470 M Se of Souris Head	46.331944	-62.275278
PE01CD0015	Morell River, East Branch From Road Bridge	46.302778	-62.674722
PE01CD0018	Boughton River From Road Bridge	46.320000	-62.534167
PE01CD0022	West Branch Morell River at Hwy 320 Bridge	46.303611	-62.762222
PE01CD0023	Colville Bay About 75 M SW of Knight Point, Souris	46.345833	-62.248333
PE01CD0025	Colville Bay About 110 M SE of Breakwater Beacon	46.347222	-62.254167
PE01CD0028	Colville Bay About 7 km NE of Lobster Pt., Souris	46.351667	-62.266667
PE01CD0033	Colville Bay About 450 M NW of Lobster Pt., Souris	46.351667	-62.277500
PE01CD0034	Mooneys Pond at Outlet	46.292222	-62.770278
PE01CD0037	Colville Bay About 2 km SE of Souris Head	46.329167	-62.257778
PE01CD0039	Colville Bay About 30 M West of Breakwater Beacon	46.346944	-62.256667
PE01CD0040	Colville Bay Entrance 420 M SE of Swanton Point	46.338889	-62.243889
PE01CD0041	Souris Harbour Inside Fisherman's Wharf	46.348889	-62.250278
PE01CD0051	Morell River	46.317500	-62.749444
PE01CE0001	Brudenell River 1km Below Hwy 4 Bridge (Wsc Gauge)	46.199722	-62.648889
PE01CE0002	Knox Pond On The Montague River	46.157500	-62.679444
PE01CE0003	Cardigan Bay Estuary of Cardigan River	46.224167	-62.588056
PE01CE0004	Orwell River at Uigg	46.164167	-62.813889
PE01CE0005	Cardigan Bay,Georgetown Hbr. 530m NE of Aitken Pt.	46.173056	-62.543611
PE01CE0012	Murray Harbour About 350 M Ne of McInnis Point	46.042778	-62.529167
PE01CE0015	Sturgeon R. Above McKinnon Pond at Hwy 317 Bridge	46.113889	-62.570833
PE01CE0021	Pinette River Estuary Centre Fork	46.071944	-62.902500
PE01CE0022	Pinette River Estuary 800 M Below Dam	46.079444	-62.888611
PE01CE0023	Cardigan Bay Estuary of Montague River	46.168611	-62.620278
PE01CE0024	Montague River Estuary From Hwy 4 Bridge	46.163889	-62.648056
PE01CE0025	Cardigan Bay Estuary, Georgetown Harbour	46.163056	-62.517222
PE01CE0027	Cardigan Bay at Mouth of Brudenell River	46.183056	-62.555278
PE01CE0028	Cardigan Bay at Mouth of Montague River	46.174722	-62.559444
PE01CE0029	Murray River 320 M NNE of Hwy 4 Bridge	46.016111	-62.609167
PE01CE0030	Murray River 2.2 km NNE of Hwy 4 Bridge	46.021667	-62.581667
PE01CE0031	Murray River 420 M South of Fairchild Point	46.032778	-62.536389
PE01CE0032	Murray Harbour at Greek River 670m W of Indian Pt.	46.042222	-62.529167
PE01CE0033	Murray Harbour 950 M E of N Tip of Reynolds Island	46.040556	-62.503056
PE01CE0034	Murray Harbour 360 M NE of Sharams Point	46.024167	-62.520278
PE01CE0035	Murray Hbr Estuary of Fox River	46.020000	-62.520556
PE01CE0036	Murray Hbr Estuary of South River	46.008056	-62.521667
PE01CE0037	Murray Harbour Estuary of South River	46.018333	-62.502778
PE01CE0038	Murray Harbour (Poverty Beach)	46.019167	-62.485556
PE01CE0039	Northumberland Strait 2.6 km NNE of Murray Head	46.040556	-62.441389
PE01CE0040	Valleyfield River Estuary From Hwy 326 Bridge	46.155000	-62.653611
PE01CE0042	Murray Hbr Estuary 2 km ENE of Indian Point	46.046389	-62.493889
PE01CE0043	Murray Hbr Estuary In Channel	46.025556	-62.502778
PE01CE0044	Northumberland Strait off Cardigan Bay	46.161944	-62.391389
PE01CE0047	Cardigan Bay Estuary of Brudenell River	46.202500	-62.609722
PE01CE0048	Northumberland Strait About 2 km N of Murray Head	46.035278	-62.454167
PE01CE0053	Montague River Above Hwy 320 Bridge	46.157778	-62.679444

Station No	Station Name	Lat	Lon
PE01CE0054	Stewarts Pond at Outlet	46.141667	-62.550000
PE01CE0055	Cardigan Bay, Cardigan River Mouth	46.200278	-62.501389
PE01CE0058	Cardigan Bay 30 M South of Cardigan Point	46.173056	-62.496667
PE01CE0061	Georgetown Harbour About 495m N of St. Andrews Pt.	46.168611	-62.529167
PE01CE0067	Murray R. Estuary About 2.6 km Below Hwy 4 Bridge	46.021389	-62.582778
PE01CE0069	Murray River Estuary About 1.1km E of Pleasant Pt.	46.032222	-62.536944
PE01CE0071	Murray Harbour About 700 M North of Cherry Island	46.040833	-62.503889
PE01CE0072	South River Estuary In Centre of Channel	46.001944	-62.528611
PE01CE0076	South River Estuary In Centre of Channel	46.012222	-62.512778
PE01CE0078	Murray Harbour Channel About 165m S of South Point	46.018889	-62.454444
PE01CE0079	Murray Harbour About 315 M NE of Sharams Point	46.024167	-62.520278
PE01CE0080	Pinette River Estuary 75 M Above Tch. Causeway	46.061667	-62.906389
PE01CE0084	Cardigan Bay Estuary of Montague River	46.166389	-62.634722
PE01CE0086	Georgetown Harbour In Center of Channel	46.166944	-62.526944
PE01CE0091	Murray Harbour About 400 M East of Machon Point	46.017778	-62.501944
PE01CE0093	Montague River at Montague - 400 M E of Wharf	46.166111	-62.640000
PE01CE0094	Montague River at Montague - 850 M NE of Wharf	46.168333	-62.634722
PE01CE0095	Montague River at Dewar Point	46.170556	-62.616667
PE01CE0097	Montague River at Lower Montague	46.169722	-62.566667
PE01CE0098	Montague River Near Brudenell	46.181111	-62.569167
PE01CE0106	Brudenell River	46.201944	-62.656389