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Cornwallis Watershed Water Quality Assessment 2003

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Cornwallis Watershed Water Quality Assessment

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EXECUTIVE SUMMARY

An assessment of surface water quality, based on currently existing data, was carried out for the Cornwallis River watershed. The primary objective of the assessment was to determine the suitability of surface water for agricultural use.

The results of the assessment indicate that the Cornwallis River experiences periods of poor water quality with respect to its use for agricultural purposes. The major problem is high fecal coliform bacteria levels, particularly during the summer when the demand for irrigation water is greatest.

There is also evidence that some trace metals may be present at levels above those considered acceptable for livestock watering, but the available data is very limited, and not recent enough to determine the degree to which this currently poses a threat to livestock.

Recommendations are presented for approaches and studies to determine the sources of fecal coliform bacteria, and for management strategies designed to improve bacterial water quality.

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1.0 Overview of the Cornwallis River

The Cornwallis River is approximately 45 km long. Its originates in the area northwest of the town of Berwick and flows eastward where it discharges into the Minas Basin, the upper region of the Bay of Fundy (Figure 1.1). The lower 15 km portion of the River, beginning just west of the eastern border of Kentville, is tidal. Its watershed occupies an area of about 360 km^2 of which about one third flows into the non-tidal portion of the River through 15 tributary systems. A portion of the lower non-tidal area, located just within the western limits of Kentville, contains a 280 ha freshwater wetland which is an established bird sanctuary managed by the Canadian Wildlife Service. Although there are numerous small wetland and oxbow ponds located within remnant meanders of the River, there are only three lakes within its drainage basin, Silver Lake to the north of the River, and McGee and Tupper Lake to the south of the River. Substrates within the non-tidal portion of the River consist mostly of silts and sands with occasional areas of small short riffles containing gravel and cobble substrates. The River has low relief and little hydropower potential and thus contains no major impoundments. Unlike other rivers in the area, it does not have an aboiteau at its exit into the Minas Basin.

The Cornwallis watershed lies in a valley bounded by the North and South Mountains. The North Mountain bedrock is composed of Triassic basalt, siltstones, and sandstones. The South Mountain is underlain by Palaeozoic granites, slates and quartzites. The valley floor is underlain largely by Triassic Wolfville Formation sandstone. Parent material is of both glacial origin and fluvial origin, and consists of glacial till and glacial outwash sand and gravel deposits with intercalated fluvial and alluvial sediments. The valley soils are composed mostly of sandy-loam material derived from glacial till.

The non-tidal portion of the River receives the effluent from two sewage treatment plants, one located at Berwick and another at Waterville. There are plans to divert effluent from

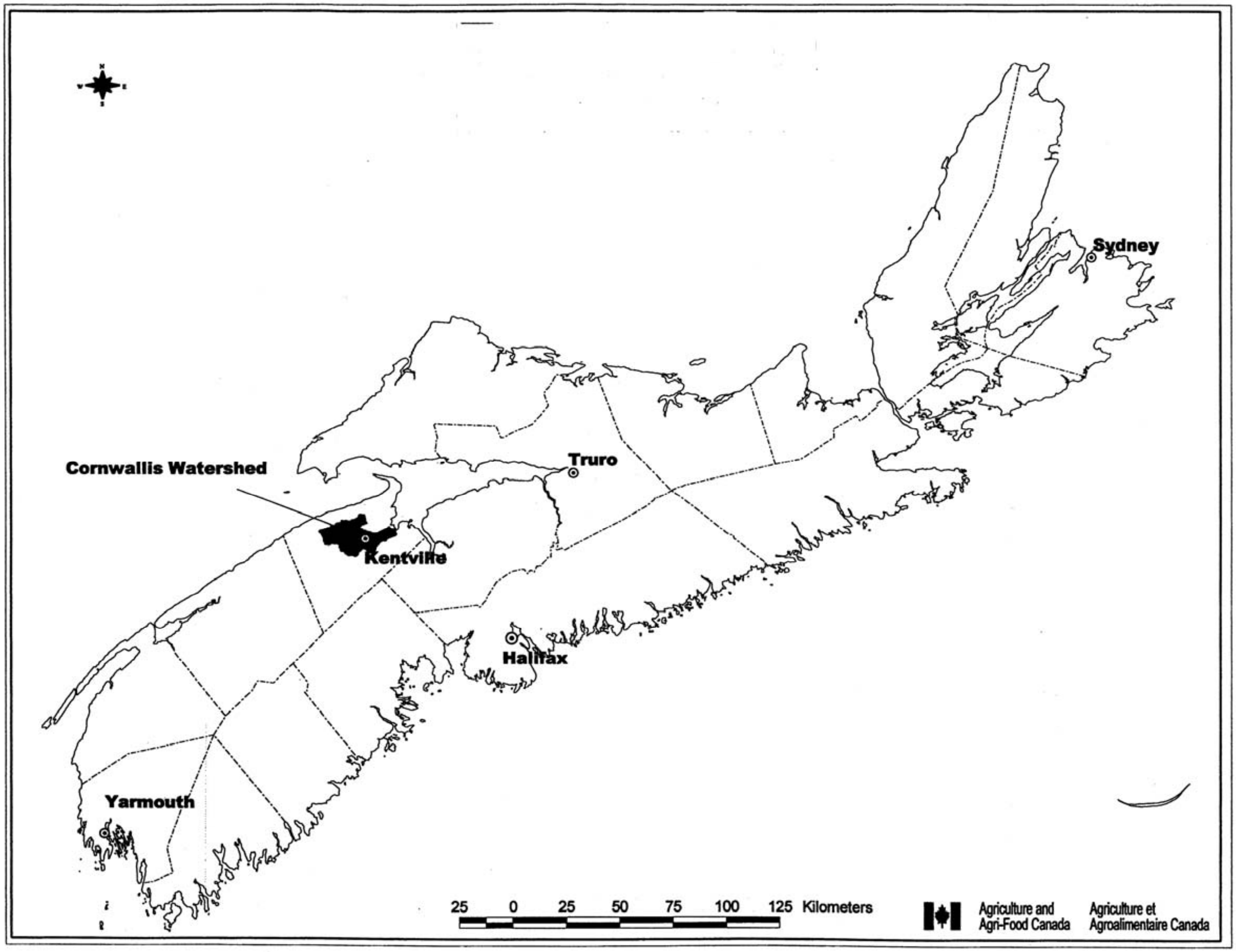

Figure 1.1. Location of study area.

a sewage treatment plant located north of Kentville, which currently discharges into the Canard River, into the Cornwallis River. Two additional sewage treatment plants, one in New Minas and another in Port Williams, discharge into the tidal portion of the River. Although at one time numerous food processing plants discharged untreated waste water into the Cornwallis, almost all of this effluent is now diverted to nearby sewage treatments plants. Exceptions are two apple juice plants, one in Kentville and another in Port Williams.

The River is currently used for agriculture (primarily as a source of irrigation and livestock drinking water), and recreation (including canoeing, sport fishing and, to a limited extent, swimming). With respect to sport fishing it is renowned for its brown trout (*Salmo trutta*). It also contains the occasional Atlantic Salmon (*Salmo salar*), but is not presently considered to be an important salmon river. Other species of fish observed to use the river include brook trout (*Salvelinus fontinalis*), American eel (*Anguilla rostrata*), white sucker (*Catostomus commersoni*), banded killifish (*Fundulus diaphanus*), striped bass (*Morone saxitalus*) and rainbow smelt (*Osmerus mordax*).

2.0 Historical Overview of Water Quality Studies

Water quality studies within the Cornwallis River watershed date back to the late 1950s when Dalziel (1958) responded to reports of fish kills near Berwick in an area of the River receiving effluents from a vegetable cannery plant. Based on measurements of dissolved oxygen levels, it was concluded that water quality in the River was seriously degraded for a distance of about 8 km downstream of the effluent discharge point on the River. The first intensive water quality survey was carried out in 1961 by the Canada Department of National Health and Welfare (Anon 1961). A number of water quality parameters were measured over the period between August 14 and 24 at 17 stations located along the main stem and within tributaries from Berwick to Port Williams. The results indicated the non-tidal portion of the River to be grossly polluted by both sewage and agricultural food processing wastes. The tidal portion, because of its high tidal flushing, was found to have a much greater capacity for the assimilation of waste products and was not as seriously degraded as the non-tidal portion. This is one of the few studies that has addressed water quality within the tidal portion of the River. Both of the above studies occurred prior to the establishment of any waste treatment facilities along the River.

In 1988, the Environmental Protection Service of Environment Canada carried out an intensive study on the pathogenic microbiology of the Cornwallis River (Menon 1988). Water samples were collected from 13 sites along the main stem of the River (Figure 2.1), and from the effluents of seven sewage treatment plants, four fruit and vegetable canneries, a meat packing plant, a poultry processing plant, and a potato processing plant. Samples were collected weekly and during the summer when processing plants were operating. The microbiological analyses included numbers of fecal coliform and fecal streptococci bacteria, *Aeromonas hydrophilia* (a known fish pathogen and suspected human pathogen) and *Salmonella* spp. (a common cause of food poisoning) serotypes. The results indicated very poor bacterial water quality as a whole, especially in the effluents of five of the seven sewage treatment plants and the meat and poultry packing plants. The main River was also found to have high fecal coliform counts and contained five *Salmonella* serotypes. The author concluded that that the discharge of untreated municipal and food processing wastes into the Cornwallis River created a potential health hazard to the recreational uses of the River which also implies that the River was not suitable for domestic or agricultural water use. Because sampling was confined to the summer months when food processing plants were operating, no conclusions could be drawn as to the seasonal nature of bacterial water quality.

At about the same time as Menon's study, the Nova Scotia Department of Health (NSDOH) initiated an intensive water quality sampling program, mostly within the non-tidal portion of the Cornwallis River watershed. This sampling program continued until about 1994 when the responsibilities of the Engineering and Inspection Section of the NSDOH were transferred to the Nova Scotia Department of Environment (NSDOE). At that time the sampling program was, for the most part, discontinued. Unfortunately,

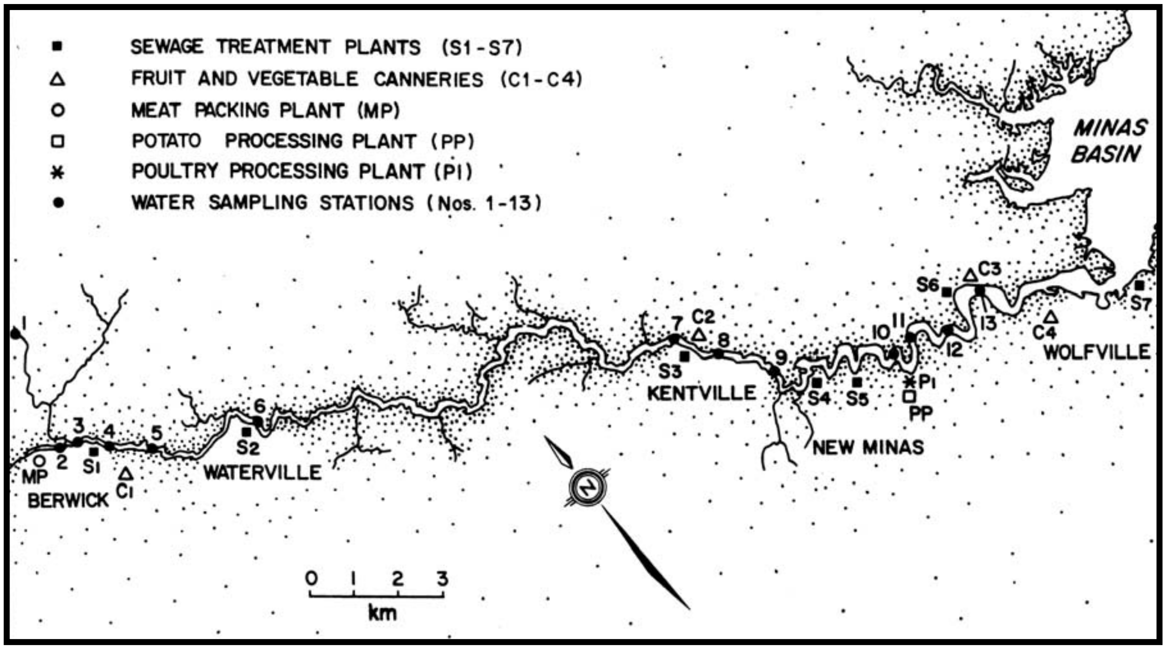

Figure 2.1. Location of sites sampled by Menon (1988)

although a fairly extensive sampling program was carried out by NSDOH, none of the information was summarized in report form and currently exists largely as paper files containing the original data sheets, some of which have been summarized in tabular form.

In 1997, two Honours thesis studies were carried out by students in the Environmental Sciences program at Acadia University (Allen 1998; Nelson 1998). These were relatively intensive studies that focused on coliform bacteria numbers, dissolved oxygen concentrations, levels of biological oxygen demand (BOD) and dissolved nitrate concentrations during the period between 9 July and 26 August. A total of 14 main stem sites and 15 tributaries were surveyed. The results indicated widespread fecal contamination within the main stem of the River from North Berwick to Kentville. Fecal coliform numbers were also found to be high in most of the tributaries, especially those near Berwick and Kentville. Tributaries originating on the north side of the River generally had higher fecal coliform numbers than tributaries originating on the south side of the River. Dissolved oxygen concentrations, however, were quite acceptable except in the area of the River downstream of the Berwick sewage treatment plant, and BOD levels were acceptable in all regions of the River.

Beginning in 1996, and continuing to this day, water quality monitoring programs of varying intensity have been carried out by the Friends of the Cornwallis River Society (FOCS), a non-profit volunteer based community group. This group has concentrated its activities in the non-tidal portion of the River and mainly on assessments of fecal coliform numbers and dissolved oxygen levels. Although a number of reports have been produced by this group, they deal largely with tabulation of the data collected. This is the only data presently available to assess the current water quality status of the Cornwallis River.

Gordon (2002), a research scientist with the Nova Scotia Department of Agriculture and Fisheries (NSDAF), carried out an intensive survey of water quality within the Thomas Brook watershed. Thomas Brook is a small tributary of the Cornwallis River located northwest of the town of Berwick. Agricultural land use within the watershed is diverse and includes dairy and beef operations as well as fruit, vegetable and cereal crop production. It also contains a number of residential areas having on-site septic systems. The main objective of the study was to carry out an intensive water quality survey to determine the potential sources of water quality impairment within the tributary. The results indicated considerable export of fecal coliform bacteria and phosphorous and nitrogen from the subwatershed to the Cornwallis River. Fecal coliform numbers were especially high during summer low-flow conditions and in areas having livestock operations as well as in areas having residences with on-site septic systems. It was also observed that stream sediments appear to serve as 'storage' areas of fecal coliform bacteria which become resuspended during turbulent flow conditions.

There have been very few studies of pollutants other than those related to sewage or food processing wastes within the Cornwallis River or its tributaries. In 1988, the NSDOH surveyed a number of sites, mostly located in the upper reaches of tributaries, for water column trace metal concentrations, but this information does not appear to have ever been reported on. Musial (1974), an MSc student in the Chemistry Department of Acadia University, carried out a study of chlorinated hydrocarbon levels in sediments at several sites within the watershed.

3.0 Objectives of Water Quality Assessment

The primary objective of this study is to evaluate, based on existing data, surface water quality within the Cornwallis River watershed with particular reference to its use for agricultural purposes. Secondary objectives of the study are to:

(1) identify gaps in existing surface water quality data,

(2) make recommendations for management strategies aimed at remediation of areas having poor water quality,

(3) make recommendations for procedures and locations for monitoring surface water quality to evaluate the success of any management strategies implemented, and

(4) determine the suitability of surface water, from the main River as well as tributaries, for impoundment as a source of water for irrigation and livestock watering.

4.0 Development of Database

The database of water quality parameters was developed based on information contained in the existing reports and data files discussed above in Section 2. The majority of data is contained in unpublished reports and files currently held by the Nova Scotia Department of Environment and Labour (NSDEL) and FOCS. For most surveys, the identification of sample locations along the main stem of the River was clearly documented. Within the database, sample locations are listed by name and each is coded to indicate whether it is a site within the main stem of the River or a site within a tributary of the River, and its distance upstream from Kentville. For tributaries, the exact sample location was not usually evident from the information contained in the data files. As a result, the location code refers to the distance upstream from Kentville where the tributary enters the main stem of the River. Each location code consists of letters indicating the site type (M - main River; TS - tributary entering from the south; TN - tributary entering from the north) and a number indicating the distance of the site in km upstream from the Highway 359 Bridge at Kentville. Table 4.1 lists the sites for which at least some water quality data exists. These are also the sites most often referred to in the water quality assessment. The database, however, also includes data collected at sites other than those listed. This is largely older data that was considered of limited use for the assessment of current water quality. The database also includes some data collected at sites in the tidal portion of the River below Kentville.

Figure 4.1 shows the locations of the main stem sampling sites. The sampling locations of the tributary sites are not shown because of uncertainties as to the exact location within the tributary where samples were collected.

The database is constructed in Microsoft© Access and consists of three main files. A single master file contains all of the water quality data. The location of sampling sites is contained in a second file, and the third file contains information on the source of the data. All of the files are related to each other by primary keys. All the information contained in the database files has also been tabulated as Microsoft© Excel files. Appendices IIIA, IIIB and IIIC contain summaries and listings of all the variables and data included in the database, as well as the location and date of each sample collection.

Comments on the quality of data contained in published and unpublished reports and theses are contained in the annotated bibliography (Appendix II). Data obtained from the files of NSDEL and FOCS is considered to be of good quality. Analyses of water samples collected by NSDEL were carried out at certified laboratories (Queen Elizabeth II Environmental Services Laboratory in Halifax, N.S. for chemical parameters and the Valley Regional General Laboratory in Kentville, N.S. for coliform samples).

Table 4.1. Summary of sites for which surface water quality data exists.

Site Code	Site Name	Site Description*
Main Stem Sites:		
M-0.0	Kentville	1-Hwy 359 Bridge at Kentville
M-6.69	Lovette Rd	2-Lovette Road Bridge
M-11.1	Bishop Rd	3-South Bishop Road Bridge
M-14.21	Cambridge Rd	4-Cambridge Station Road Bridge
M-17.50	W'ville STP1	5-Below Waterville STP Effluent
M-17.55	W'ville STP2	6-At Waterville STP Effluent
M-17.59	W'ville STP3	7-Above Waterville STP Effluent
M-18.44	W'ville Rd	8-Waterville Road Bridge
M-20.68	Shaw Rd	9-Shaw Road Bridge
M-21.96	Willow Ave	10-Willow Avenue Bridge
M-23.13	Berwick	11-Hwy 360 Bridge at Berwick
M-24.81	Nth Berwick	12-Hwy 360 Bridge at North Berwick
M-31.11	BlackRock Rd	13-Black Rock Road Bridge
South Tributary Sites:		
TS-3.76	Tupper Bk	East Branch of Tupper/Illsley/Davidson System
TS-11.24	Spidle Bk	Spidle Brook
TS-13.87	Tupper Lake Bk	East Branch of Tupper Lake/Condon/Sharpe Brook System
TS-13.87	Condon Bk	Central Branch of Tupper Lake/Condon/Sharpe Brook System
TS-13.87	Sharpe Bk	West Branch of Tupper Lake/Condon/Sharpe Brook System
TS-17.54	Rochford Bk	Rochford Brook
TS-20.60	Morris Bk(E)	East Branch of Morris Brook
TS-20.60	Morris Bk(C)	Central Branch of Morris Brook
TS-20.60	Morris Bk(W)	West Branch of Morris Brook
North Tributary Sites:		
TN-6.08	Black Bk	Black Brook
TN-6.28	Chute Bk	Chute Brook
TN-7.95	B'ywine Bk	Main Branch of the Brandywine/Illsley/Sweet/Rockwell System
TN-7.95	Lawrence Bk	East Branch of Lawrence/Griffin System
TN-7.95	Griffin Bk	West Branch of Lawrence/Griffin System
TN-7.96	Killam Bk	East Branch of Killam/Ryan/Coleman System
TN-7.96	Ryan Bk	West Branch of Killam/Ryan/Coleman System
TN-7.96	Coleman Bk	Main Branch of Coleman System
TN-17.85	Fishwick Bk	Fishwick Brook
TN-23.63	White Bk	White Brook
TN-23.64	Rand Bk	Rand Brook
TN-24.34	Thomas Bk	Thomas Brook
TN-24.42	Fisher Bk	Fisher Brook

*Number refers to locations identified in Figure 4.1

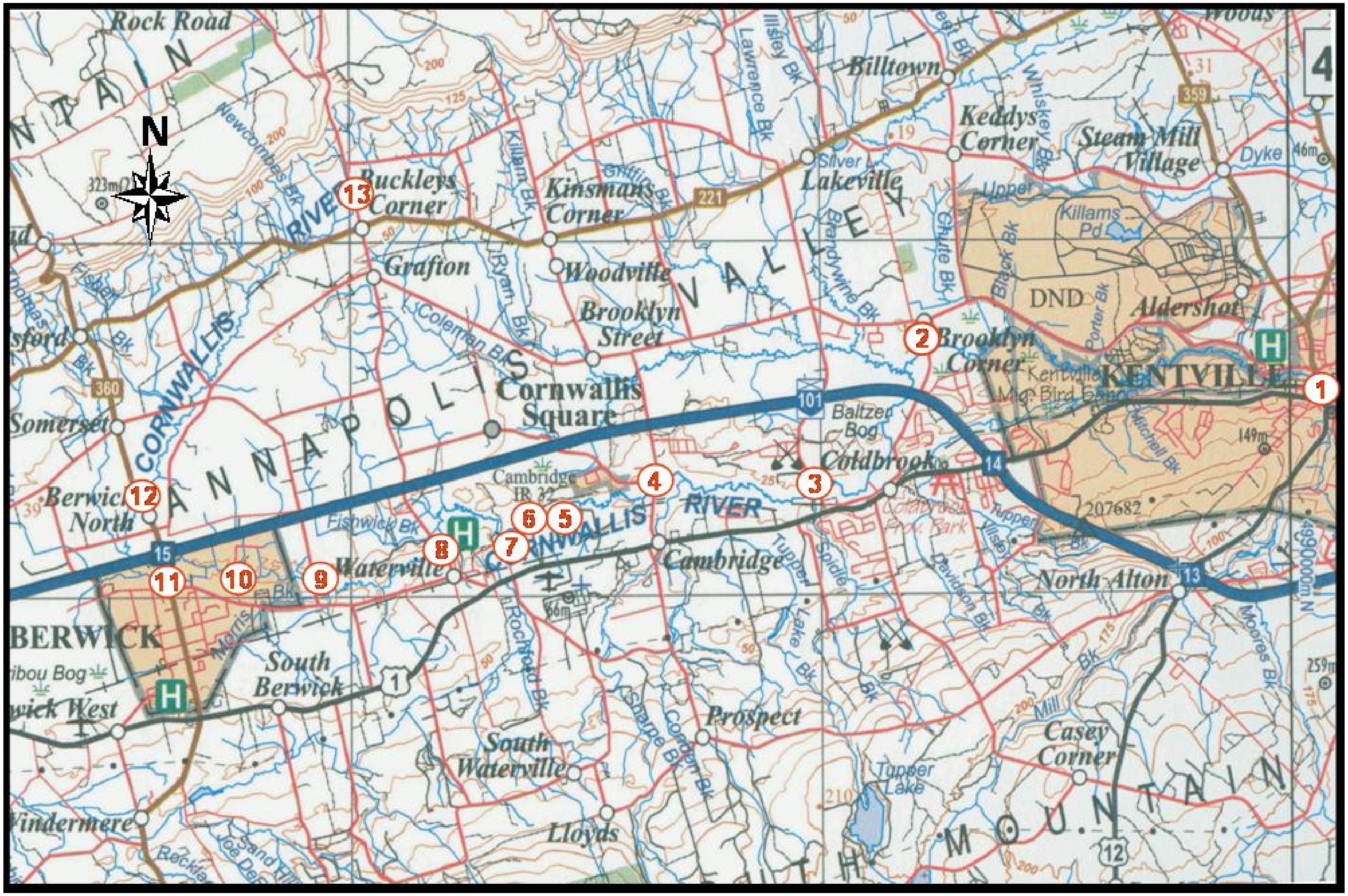

Figure 4.1. Location of main stem sampling sites (numbers refer to sites names listed in Table 4.1).

5.0 Water Quality Assessment

This assessment of water quality is based on the guidelines prepared by the Canadian Council of Ministers of the Environment (CCME 2002). The CCME is an intergovernmental organization comprised of environmental ministers from the federal, provincial and territorial governments of Canada. It has no authority to propose or enforce regulations and each local jurisdiction determines the degree to which the guidelines are adopted. The guidelines are quite comprehensive and cover air quality, water quality for agricultural use, recreation and protection of aquatic life, and soil and sediment quality.

Some of the guidelines specify acceptable values that vary depending on other factors (e.g., the acceptable level of some heavy metals depends on water pH). As a result, when comparisons were made between the CCME acceptable level and the levels reported in the watershed, these factors were considered when relevant.

Water quality can vary considerably from year to year as a result of climatic conditions, especially with respect to precipitation which influences both surface runoff of chemicals and sediments, as well as the degree to which substances entering the River become diluted. Because of this, whenever possible historical comparisons of water quality were made based on values representing more than one year. Most often these comparisons were made between values reported for the periods between 1989-1991 and 2001-2002.

5.1 Overview of Canadian Water Guidelines for Agricultural Water Use and Protection of Aquatic Life

The CCME guidelines for agricultural water use are largely chemical parameters. An exception to this is bacterial concentration, represented as both total and fecal coliform bacteria, the most commonly accepted indicators of the potential presence of pathogenic microorganisms. For irrigation water use, the major groups of chemical factors for which guidelines have been established include trace metals, dissolved salts and toxic organics (mostly halogenated hydrocarbons, benzenes and glycols). The recommended levels that should not be exceeded have been derived to protect sensitive crop species. Guidelines for livestock drinking water are based largely on trace elements, particularly heavy metals, other potentially toxic compounds such as nitrates and pesticides, and pathogenic microorganisms such as bacteria, viruses, protozoans and blue-green algae. The guidelines are designed to protect the health of livestock and do not attempt to define limits that would ensure the safe consumption of livestock products by humans.

The CCME guidelines for protection of aquatic life are quite stringent in that they have been designed to protect all forms of life and consider the most sensitive life stages and the most sensitive species. In some cases, species-specific information is provided. With respect to the parameters considered, most of the chemical parameters established for agricultural water use are also part of those established for the protection of aquatic life. The levels of these substances considered acceptable, however, differ, and are generally more stringent for aquatic life. In addition, the guidelines for aquatic life include a number of parameters that are not considered in the guidelines for agricultural use. Examples are physical factors such as water temperature, total particulate matter (and related parameters such as suspended sediments and turbidity), pH, and dissolved oxygen. The guidelines for aquatic life also contain a greater number of potentially toxic organic compounds.

It should be noted that the CCME guidelines do not consider the potential interactive effects of combinations of substances, which, in some cases, could enhance the negative effect of any one particular substance.

5.2 Physical Characteristics

5.2.1 Water Temperature

With respect to agricultural use, there are no established CCME guidelines on water temperature. With respect to aquatic life, maximum water temperature is the parameter of most interest because of its effect on dissolved oxygen levels and percent dissolved oxygen saturation (see Section 5.3.2). Spatial and seasonal variations in water temperature are used to assess the suitability of a river to support cold-water fish species such as salmonids. It is also important in determining the amount of oxygen dissolved in the water, as well as the rate at which dissolved oxygen is utilized by microorganisms in decomposing organic matter. The capacity of water to dissolve oxygen decreases as water temperature increases, and the metabolic rate of microorganisms increases with temperature. The effects of these two factors are especially important in determining the degree to which a receiving water body can assimilate organic matter. When water temperatures are high, dissolved oxygen concentrations are low. This, combined with the high metabolic rate of microorganisms at high temperatures, can lead to a high biological oxygen demand and result in depressed oxygen levels and the production of toxic by products such as ammonia, hydrogen sulfide and methane, the end products of the anaerobic decomposition of organic matter.

Water temperature is influenced by the source of water and the nature of the riparian zone (the land area adjacent to the river). Water temperatures in spring fed rivers tend to be lower than in rivers fed by surface runoff. The nature and condition of the riparian zone is also important in determining the degree to which solar energy heats the water. A well-vegetated undisturbed riparian zone shades the river and reduces heating of the water.

A relatively comprehensive set of recent water temperature data exists for a number of main stem sites of the Cornwallis River. However, it is largely limited to measurements made during the months from May to August. Figure 5.1 illustrates the spatial and

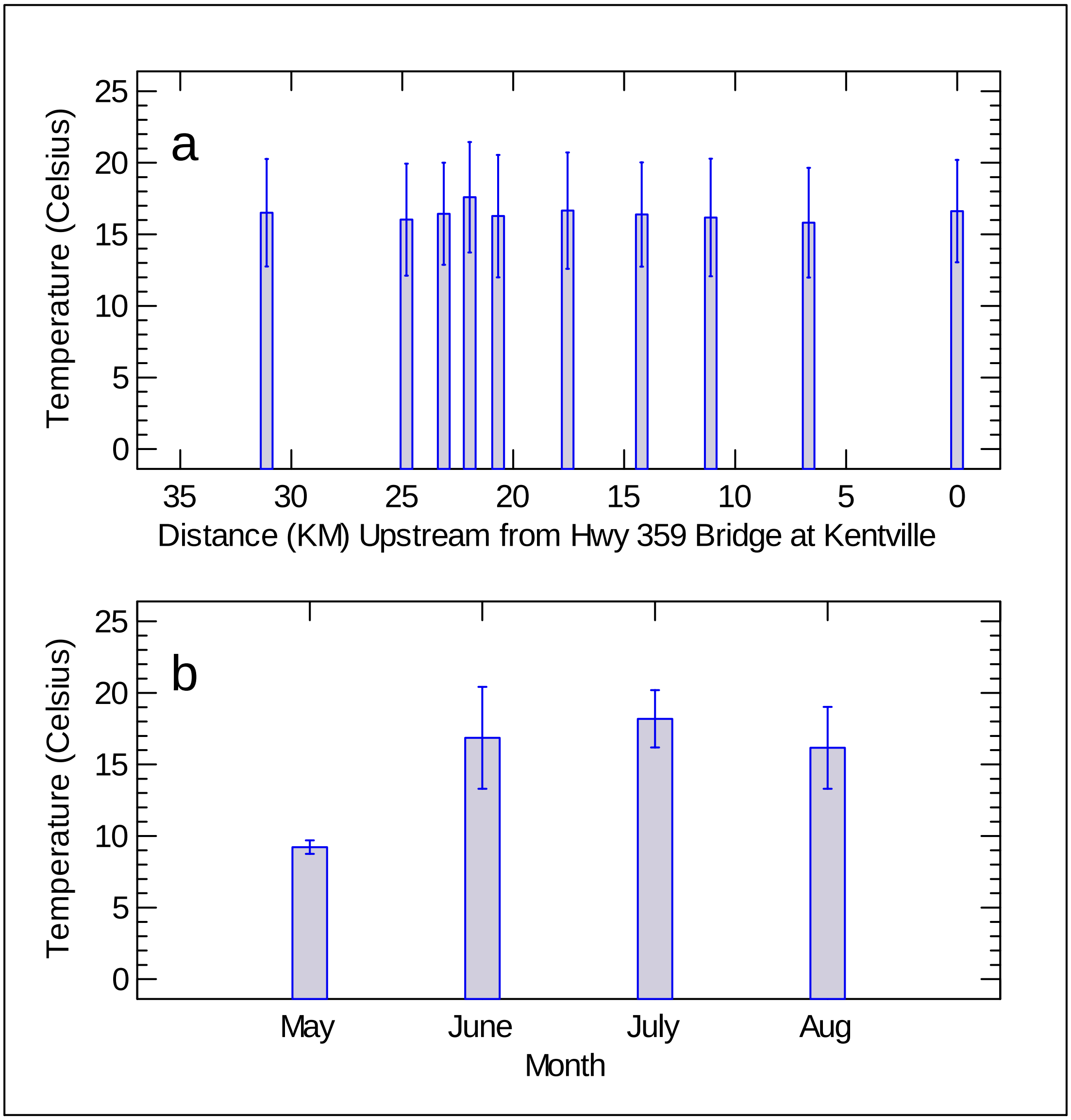

Figure 5.1. Spatial and seasonal variation in average water temperature for main stem sites based on measurements made May through August in 1997, 2000, 2001 and 2002: (a) average temperature vs. distance upstream from Hwy 359 Bridge at Kentville; (b) average seasonal variation for all sites. (Error bars are one standard error of the mean.)

seasonal variation for data collected during 1997, 2000, 2001 and 2002. There appears to be little difference in mean temperature between sites along the River. The seasonal variation, however, is somewhat surprising in that the warmest water temperatures occur in July rather than August. This is probably caused by an increase in the relative proportion of baseline flow originating in cooler groundwater as river water levels decrease during the summer.

Water temperatures seldom exceed 22-23 ºC, the maximum level considered acceptable to sustain salmonids.

Allen (1998) and Nelson (1998) made measurements of water temperature on a number of tributaries within the Cornwallis watershed during August 1997. In general, water temperature in tributaries is considerably lower than at the main stem sites, and tributaries on the south side of the River have lower temperatures than those on the north (Figure 5.2). This is probably largely due to the relatively shorter length and steeper gradient of the north tributaries, which would result in less heating along the course of the tributary before entering the main River.

As part of a survey to identify cold-water fish habitat, the Nova Scotia Department of Agriculture and Fisheries has monitored summer water temperatures at a number of rivers and their tributaries within the Province. During 2001 and 2002, water temperature at 11 sites within the Cornwallis watershed was monitored. The results are listed in Table 5.1. Figure 5.3 shows the location of these sites and the temperature category into which they fall.

Table 5.1. Results of temperature monitoring within the Cornwallis River watershed carried out by Nova Scotia Department of Agriculture and Fisheries (MacMillan 2002).

Location	Dates Monitored	Average Temperature (ºC)	Classification
Cornwallis River 1	13-20 Jul 2001	17.2	intermediate
Cornwallis River 2	27-31 Aug 2001	17.8	intermediate
Tupper Bk	20-27 Jul 2002	17.0	intermediate
Spidle Bk	3-8 Aug 2002	13.4	cool
Sharpe Bk	7-12 Jul 2002	13.1	cool
Rochford Bk	18-27 Aug 2001	13.8	cool
Fisher Bk	10-18 Aug 2002	13.5	cool
Coleman Bk 1	15-21 Jul 2001	17.1	intermediate
Coleman Bk 2	27 Jul-3 Aug 2001	17.2	intermediate
Lawrence Bk	21-29 Jul 2001	16.7	cool
Brandywine Bk	29 Jun-7 Jul 2002	17.3	intermediate

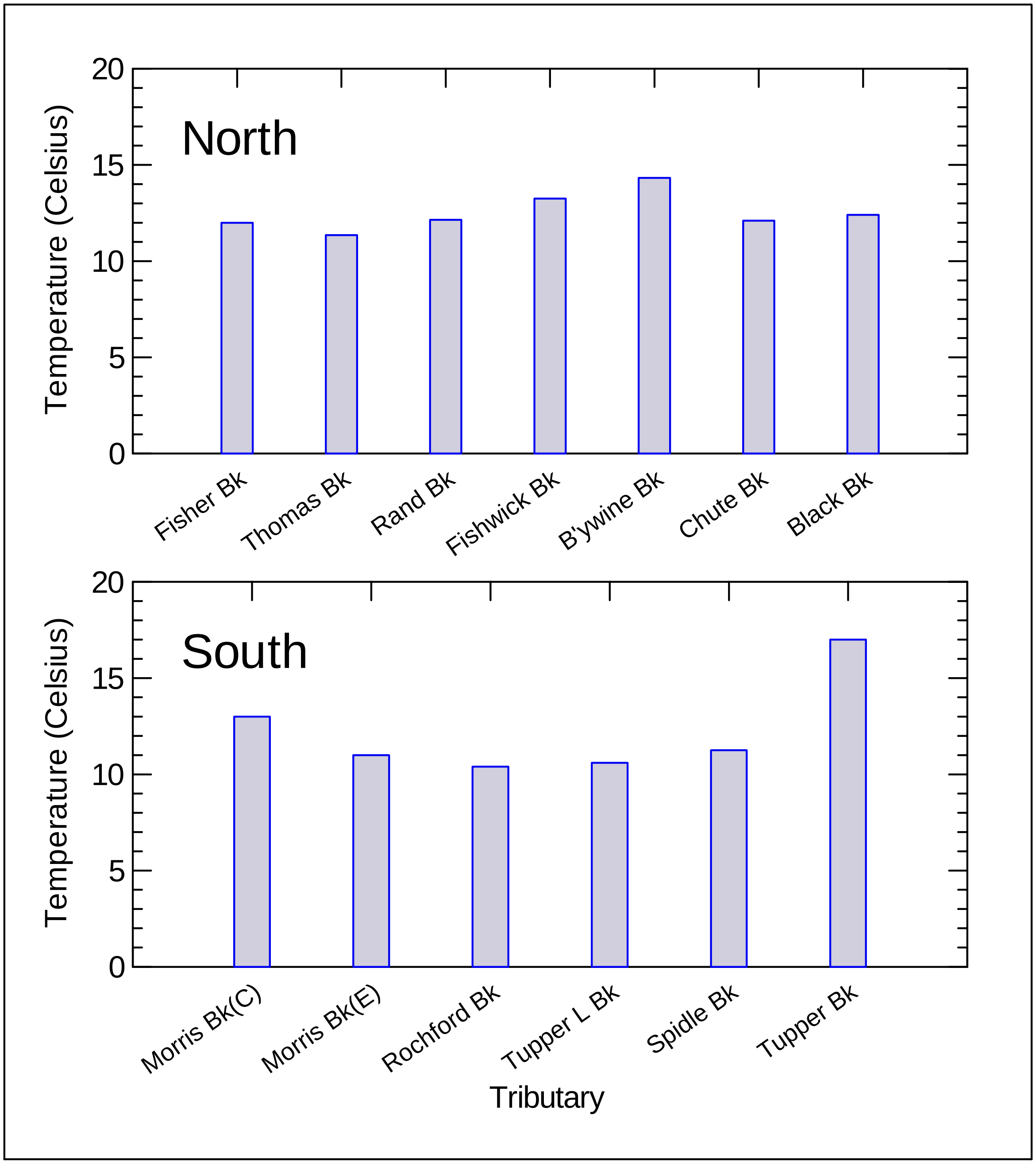

Figure 5.2. Mean water temperatures during August 1997 for selected North and South tributaries entering the main stem of the Cornwallis River (from Nelson 1998 and Allen 1998).

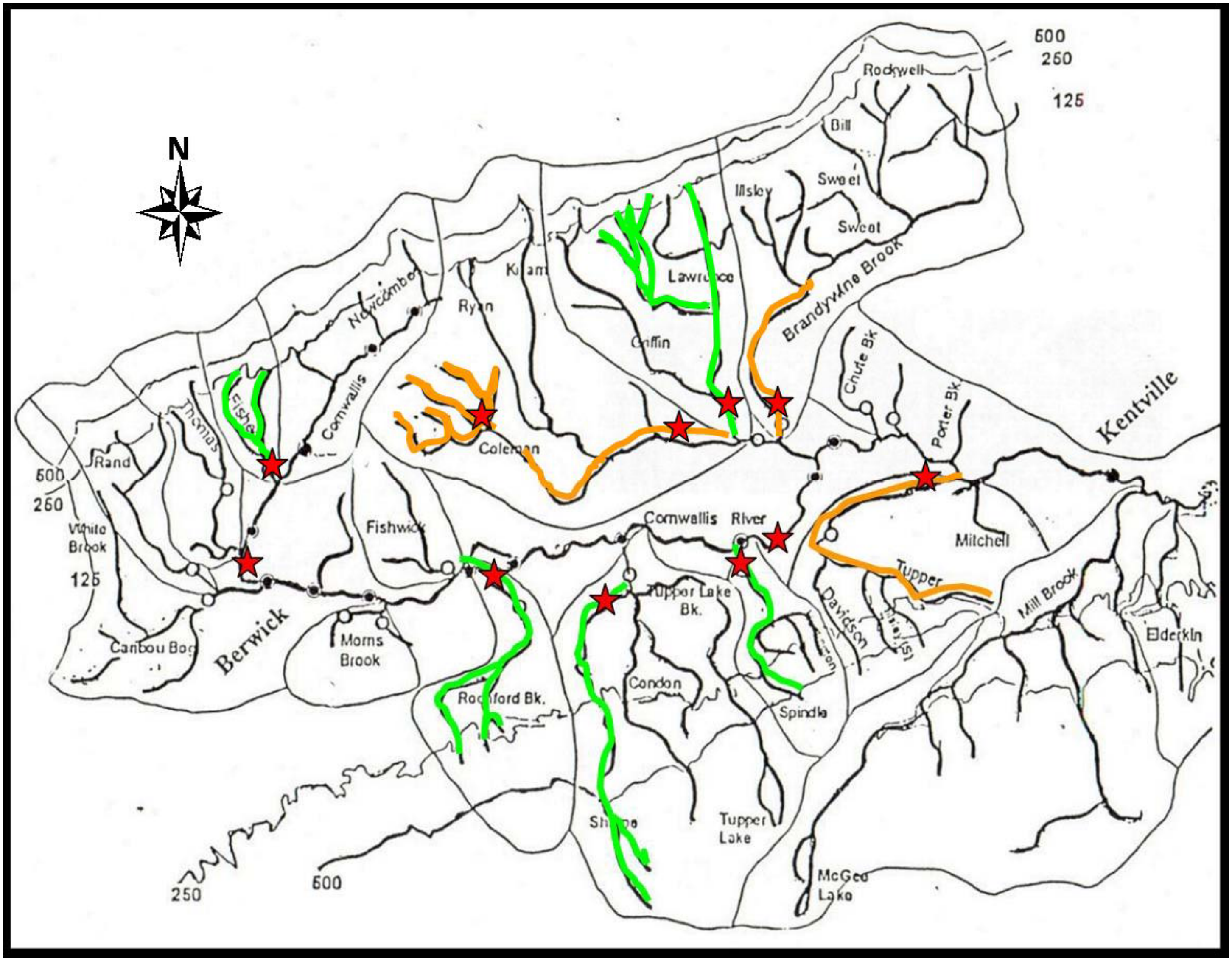

Figure 5.3. Location of sampling sites for water temperature survey carried out by NSDAF during 2001 and 2002 (stars indicate location of temperature loggers; orange tributaries have intermediate water temperatures and green tributaries have cool water temperatures).

5.2.2 Suspended Solids, Turbidity and Colour

Suspended solids (SS) is a measure of the quantity of solids suspended in the water. This parameter is sometimes also referred to as Total Suspended Particulate Matter (TSPM). The solids may be either inorganic or organic and these fractions are usually referred to as Total Particulate Inorganic Matter (TPIM) and Total Particulate Organic Matter (TPOM), respectively.

Turbidity is a related parameter often measured to determine the level of suspended solids in water. Its measurement is based on the degree to which light is scattered by the particles present in the water and is expressed as Nephelometric Turbidity Units (NTUs). Because the amount of light scattered depends on particle size, colour and shape in addition to concentration, it is a much less accurate method of determining the amount of particulate material in a water sample.

High levels of TPIM, or turbidity, indicate the presence of suspended sands, silts or clays which may be caused by land erosion and the natural erosion of stream beds and banks by stream flows. High levels of TPOM typically indicate the presence of high levels of organic materials from biological production within the water column, or organic inputs such as inadequately treated sewage or food processing effluents. TSPM concentrations in natural, undisturbed systems are typically less than 10 mg/L.

There are two types of colour measurement used to characterize water. **Apparent** colour is the colour of water as it appears to the naked eye and is influenced by the colour of particulate matter in the water. **True** color is the colour of water after the particulate matter has been removed by filtration. It is largely caused by materials dissolved in the water.

Suspended solids and other factors that influence taste, odour or colour are not considered to impair the use of water for irrigation nor constitute a major risk to livestock. As a result there are no CCME guidelines for suspended solids, colour or turbidity.

High TPIM values are detrimental to aquatic organisms, particularly for those that require clean, well-aerated gravel for spawning. They can also clog the feeding apparatus of filter feeding organisms and destroy the habitat of benthic macroinvertebrates, thus altering the natural food web of aquatic ecosystems.

The CCME guidelines for suspended solids for protection of aquatic life are complicated and depend on stream flow rates and particle size. Recommended values are not absolute but based on the maximum increase allowed above background conditions.

There are no recent measurements of turbidity and color for the Cornwallis River and the only information available on suspended solids in the Cornwallis River is that reported by Allen (1998). This information is summarized in Figure 5.4. Within the main stem sites, the mean TSPM (i.e., TPIM + TPOM) values are quite low with the highest values near Berwick. At most sites inorganic and organic materials are present in almost equal quantities. The relatively high proportion of inorganic material at Kentville is probably a result of resuspension of river sediments by tidal action.

Tributaries on the north side of the River, which flow mostly through sandy soils, have the highest TSPM values and contain relatively more inorganic materials than tributaries on the south side of the River, which generally flow through much less erodable substrates. Both sides of the River have similar levels of TPOM.

Based on the low TPIM levels measured, it would appear that the Cornwallis River watershed is not subject to much erosion. However, it is important to realize that erosion tends to be an episodic process occurring largely during periods of heavy precipitation. The summer of 1997 was not very typical in that it was characterized by low precipitation. Even during normal weather conditions, it is difficult to accurately monitor the seasonal variation in suspended sediments unless samples are taken very frequently, and especially after significant precipitation events.

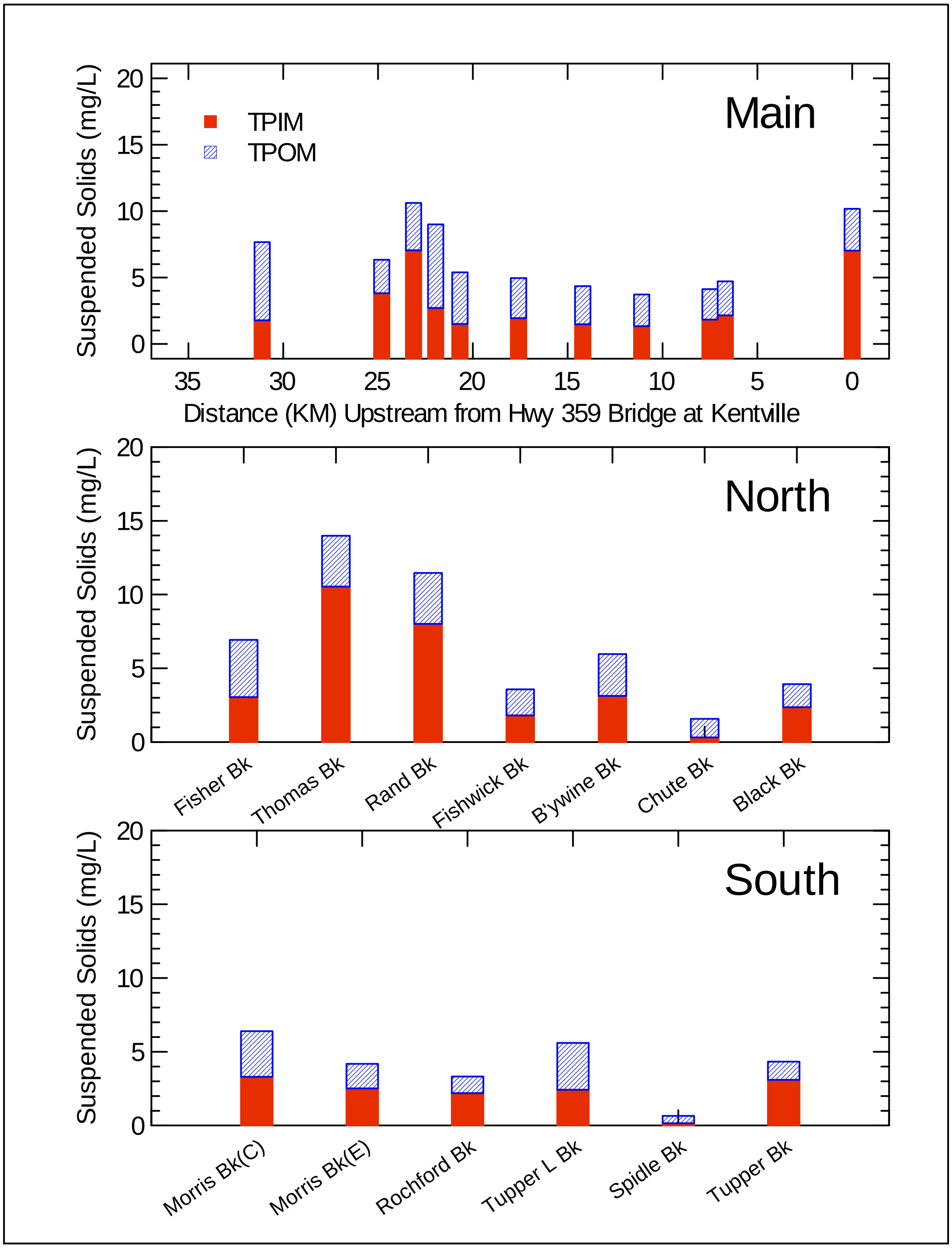

Figure 5.4. Mean suspended solids concentrations for main sites and tributaries based on values measured in 1997 (from Nelson 1998 and Allen 1998). Main site averages are for the period between 26 June and 8 August. Tributary averages are based on measurements made during August. (TPIM - Total Particulate Inorganic Matter; TPOM – Total Particulate Organic Matter)

5.3 Chemical Characteristics

5.3.1 Total Dissolved Solids, Conductivity, Alkalinity pH, Major Ions and Sodium Adsorption Ratio

Total Dissolved Solids (TDS), conductivity, alkalinity and pH are all related in that their values are determined largely by the kinds and quantities of dissolved salts present. High concentrations of dissolved salts typically results in hard water, which is usually characterized by high conductivity, high alkalinity (buffering capacity) and high pH. Regional variations in these parameters most often result from variations in geology. Water bodies located in geological formations that weather slowly, such as granite and basalt, generally contain low levels of dissolved salts. In contrast, water bodies located in geological formations more susceptible to weathering, such as sandstone, typically have high salt contents.

There is very little information on TDS concentrations for the Cornwallis River. There is, however, a great deal of information on conductivity. Although conductivity depends not only on the amount of dissolved salts, but also on the specific kinds of ions present, the ionic composition and relative proportion of ions in any particular water body tends to be constant. As a result, it is possible to establish a relationship between TDS and conductivity for the Cornwallis River based on data containing concurrent measurements of both parameters. This was done using data contained in NSDOE files from measurements made in 1978 and the relationship is illustrated in Figure 5.5. For the Cornwallis River, TDS values are about equal to one-half of the conductivity values.

Also shown in Figure 5.5 is the relationship between conductivity and alkalinity. Although more variable than the relationship with TDS, conductivity is obviously related to alkalinity which suggests that the major ions responsible for TDS are either calcium or magnesium, the two salts most often associated with the carbonates typically responsible for creating alkalinity.

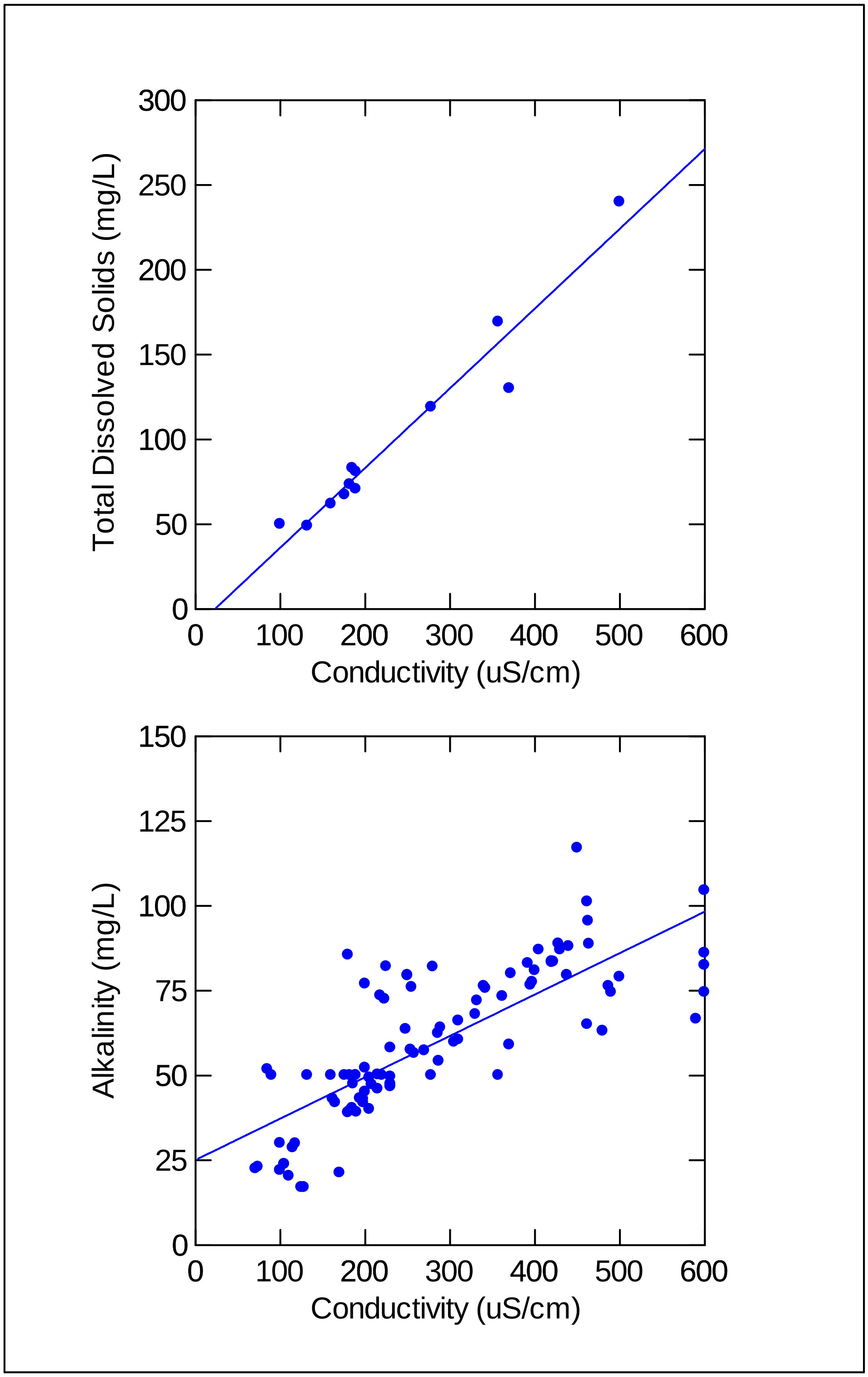

Figure 5.5. Relationship between conductivity and total dissolved solids and conductivity and alkalinity based on data for the Cornwallis River contained in NSDOE files.

Compared to other areas in the Atlantic Maritimes, the Cornwallis River has relativity high salt concentrations. Average values of conductivity at main stem sites range between about 200 and 600 µS/cm (Figure 5.6). It is also relatively well buffered with alkalinity values in the range of 50 to 100 mg/L (Figure 5.7). As a consequence, its pH is very stable with values that seldom fall below 7.0 or above 8.5, and which are well within the guidelines for protection of aquatic life (Table 5.2).

The CCME guidelines for TDS in irrigation water vary depending on the crop being irrigated. Strawberries, raspberries, beans and carrots tend to be sensitive to high salt concentrations and should not be irrigated with water having a TDS concentration greater than 500 mg/L. Other berry and fruit crops are slightly more tolerant and can withstand impacts from irrigation water having TDS values as high as 800 mg/L. Root crops and most forage crops can withstand irrigation with water having TDS values as high as 2500 mg/L, and many grain crops can withstand concentrations of 3500 mg/L. Despite the relatively high conductivities in the Cornwallis River, if it is accepted that conductivity values are about twice the TDS value, these are well below the CCME guidelines for even the most sensitive crops (Table 5.2).

Table 5.2. pH, total dissolved solids and major ions reported for the Cornwallis River (mg/L).

Parameter	CCME Guidelines			Range of Values Reported for Cornwallis River**	
	Irrigation Water	Livestock Water	Aquatic Life	Min	Max
pH	-	-	6.5-9.0	6.1	8.4
Total Dissolved Solids	500-3500*	3000	-	109	1070
Chloride*	100-700	-	-	10.0	19.0
Calcium	-	1000	-	8.9	60.9
Sulphate	-	1000	-	6.6	119.0

*Varies depending on crop being irrigated
** Based on surveys carried out by NSDOE.

Conductivity in the main River generally decreases as one moves downstream along the River. This is also true of the north tributaries. Fisher Brook, which is located at the head of the River, has an exceptionally high conductivity and this may explain some of the spikes seen in conductivity levels downstream in the main stem. This site is the only

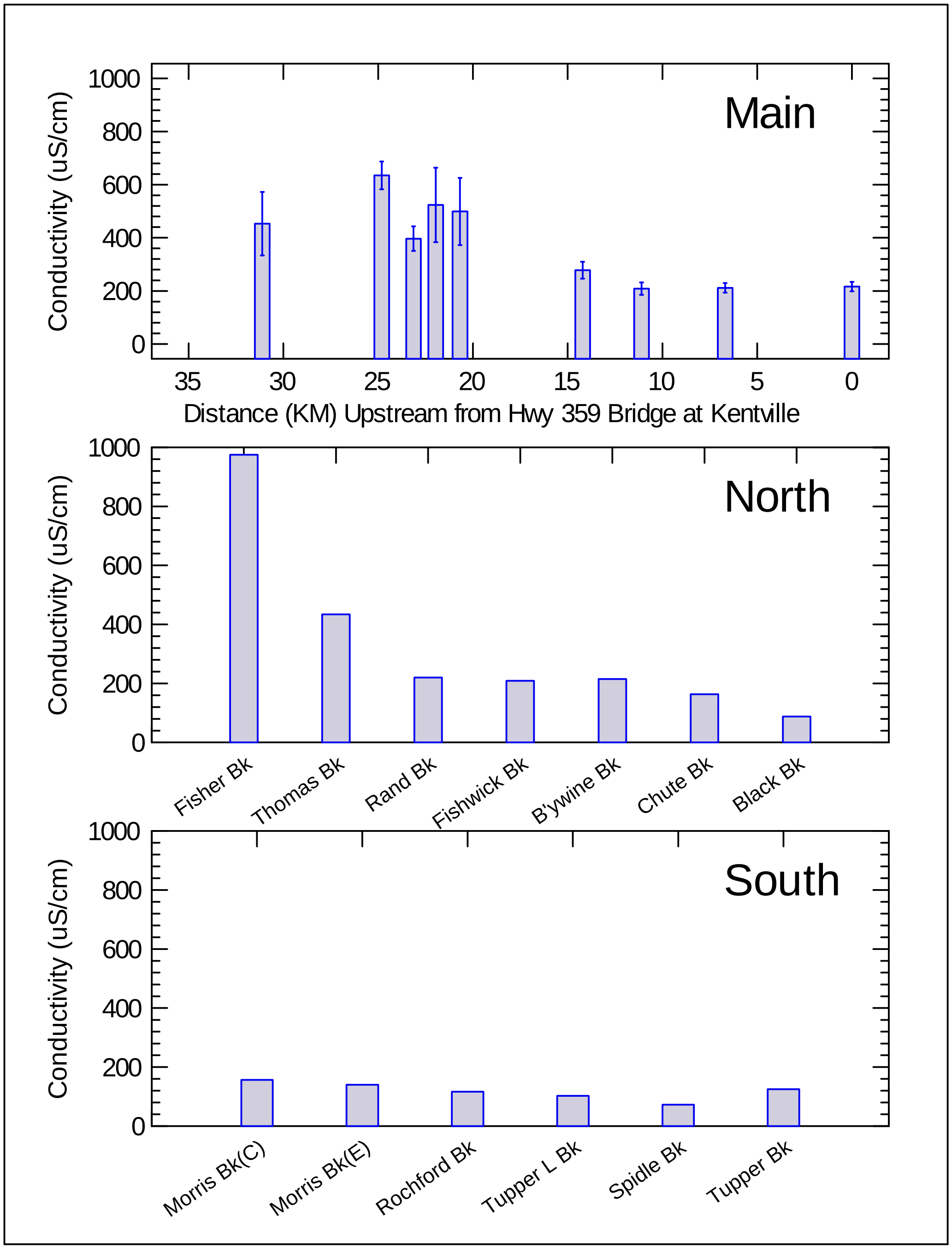

Figure 5.6. Mean conductivity for main sites and tributaries based on values measured in 1997 (from Nelson 1998 and Allen 1998). Main site averages are for the period between 26 June and 8 August (error bars are one standard error of the mean). Tributary averages are based on measurements made during August.

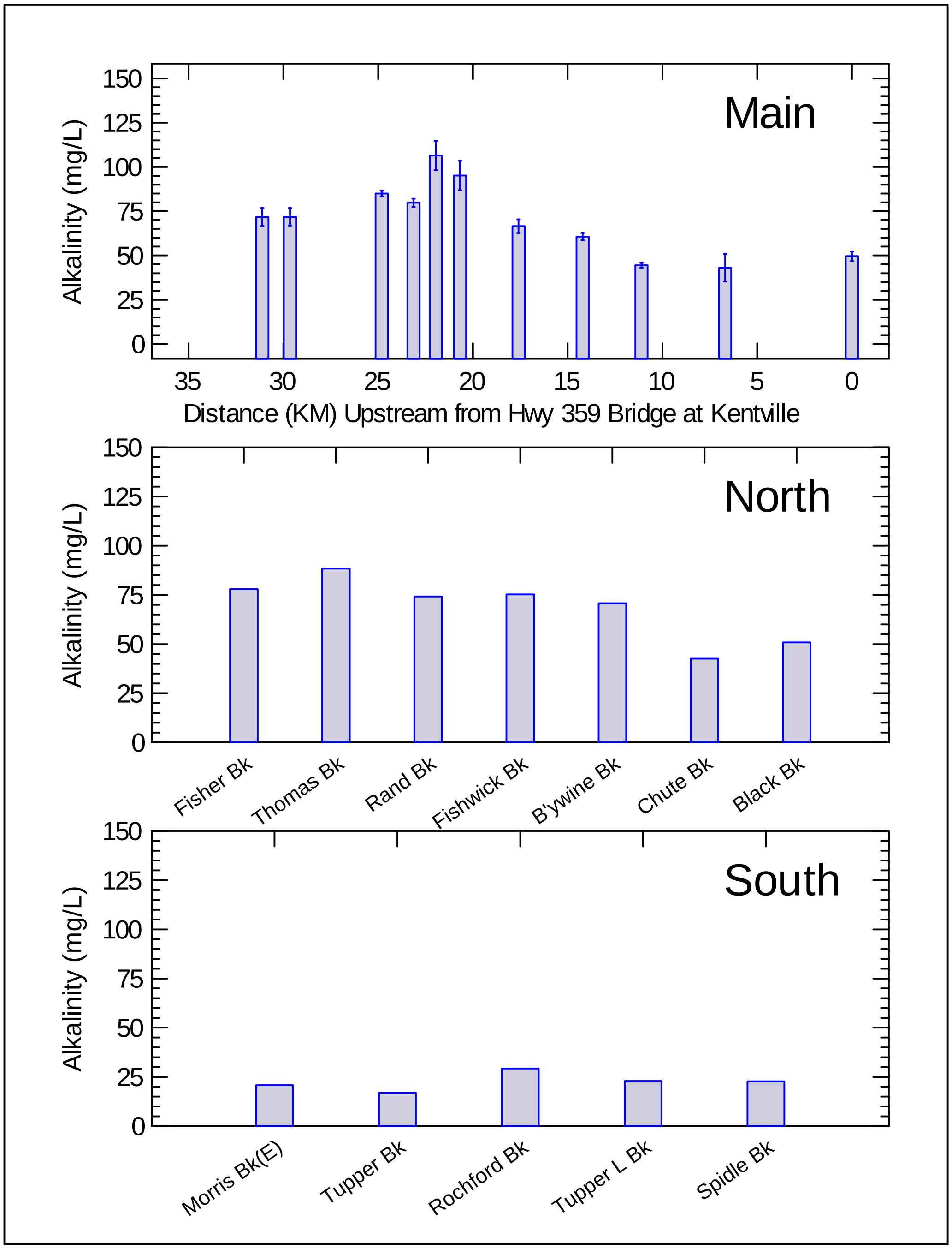

Figure 5.7. Mean alkalinity for main sites and tributaries based on values measured in 1997 (from Nelson 1998 and Allen 1998). Main site averages are for the period between 26 June and 8 August (error bars are one standard error of the mean).

one that exhibited salt concentrations high enough to be damaging to some crops. Conductivity (Figure 5.6), alkalinity (Figure 5.7.) and pH (Figure 5.8) within the north tributaries are very similar to those of the main River. The south tributaries have much lower conductivities and alkalinities, a reflection of their origin in the granitic bedrock of the South Mountain, but still maintain enough buffering capacity to maintain pH values near the neutral range.

Data on the concentration of specific ions is very limited. What little is available is from surveys carried out in 1978 and 1998 by the NSDOE. Those of importance for agricultural use include chloride, calcium, sulphate and sodium (Table 5.3).

Table 5.3. Concentrations of chloride, calcium, sulphate and sodium (mg/L) reported for the Cornwallis watershed based on surveys carried out by NSDOE.

Location	Date	Chloride	Calcium	Sulphate	Sodium
Cambridge Rd	24 Jul 1978	-	8.90	-	-
Bishop Rd	24 Jul 1978	-	42.00	-	-
Shaw Rd	24 Jul 1978	-	17.60	-	-
Willow Ave	24 Jul 1978	-	54.60	-	-
Killam Bk	12 May 1988	10.00	16.20	11.80	6.3
Griffin Bk	12 May 1988	10.00	20.30	21.00	5.2
Coleman Bk	12 May 1988	19.00	24.60	6.60	6.9
Griffin Bk	12 May 1988	10.00	41.10	71.30	5.7
Rand Bk	12 May 1988	19.00	20.70	12.40	8.4
Illsley Bk(N)	12 May 1988	10.00	24.00	11.00	-
Ryan Bk	12 May 1988	10.00	60.90	119.00	6.0
Griffin Bk	12 May 1988	10.00	26.00	21.60	6.2

High concentrations of chloride in irrigation water can cause foliar damage. Sensitive crops (most woody plant species such as stone fruits) should not be irrigated with water having chloride concentrations in excess of 100 mg/L. Tolerant crops (most vegetable, grain, forage and fibre) can be irrigated with water containing chloride concentrations as high as 700 mg/L. All of the values listed in Table 5.3 are less than the recommended limit for both sensitive and tolerant crops.

With respect to livestock watering, high sulphate concentrations have been known to produce gastrointestinal inflammation and diarrhea in young calves and swine. The

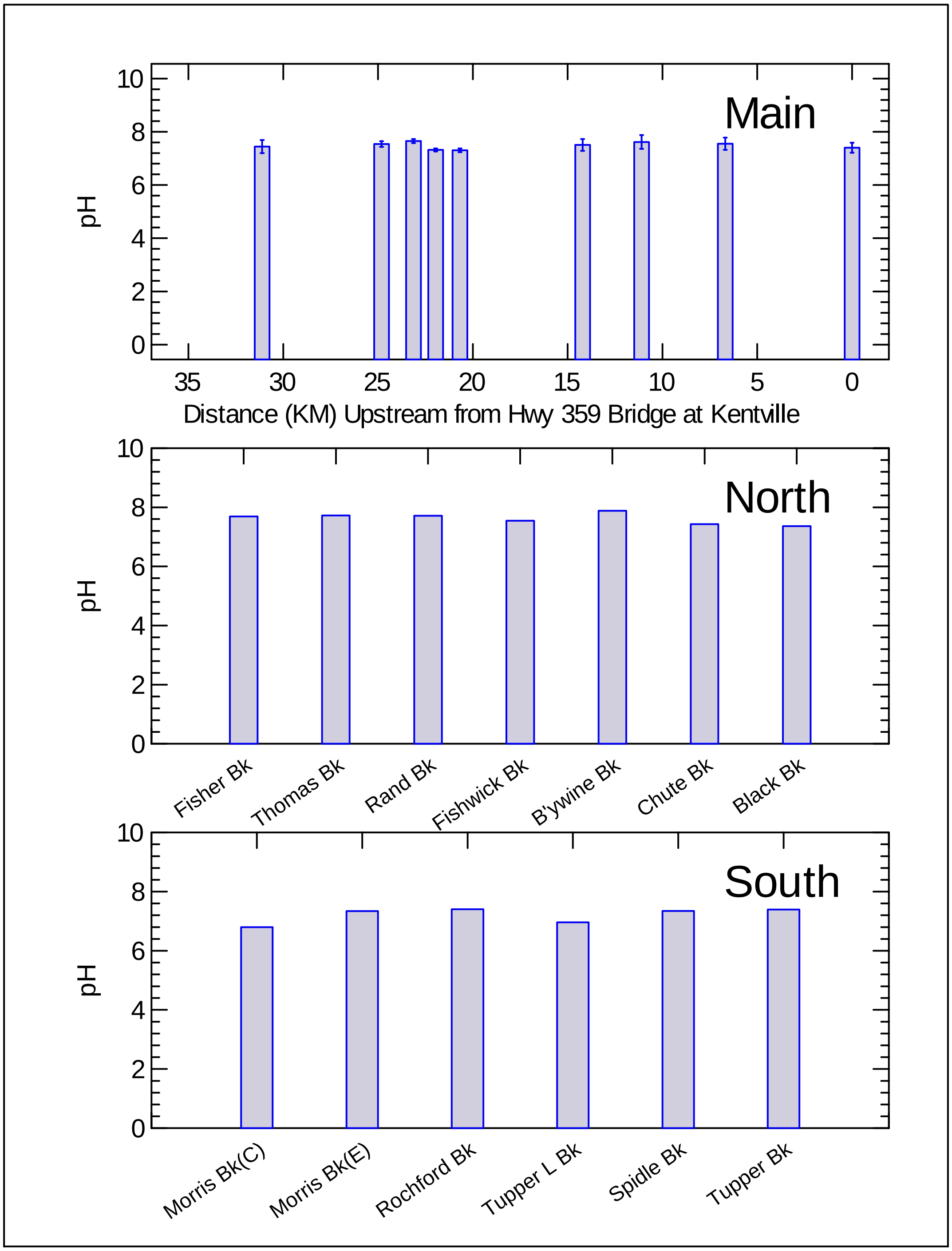

Figure 5.8. Mean pH for main sites and tributaries based on values measured in 1997 (from Nelson 1998 and Allen 1998). Main site averages are for the period between 26 June and 8 August (error bars are one standard error of the mean). Tributary averages are based on measurements made during August.

CCME recommended limit for livestock water is very high, 1000 mg/L, and much greater than the values reported for the Cornwallis River. The same is true for calcium.

Irrigation with water having high concentrations of sodium, relative to calcium and magnesium, can alter the physical properties of soils causing them to become hard, compact and impervious to water when dry. This is especially true of fine textured soils having high clay contents. The potential for this to be a problem can be determined by evaluating the Sodium Adsorption Ratio (SAR), a measure of the relative proportion of sodium cations to the sum of calcium and magnesium cations (concentrations expressed as meq/L). SAR is calculated as follows:

$$SAR = Na / \sqrt{Ca + Mg / 2}$$

CCME guidelines for SAR suggest that values less than 3 will have no harmful effect on soil structure.

The only information available for determination of SAR is from the survey carried out by NSDOE in 1988 at a number of tributary sites (Table 5.4). The calculated SAR values are very low relative to the CCME guideline.

Table 5.4. Concentrations of sodium, calcium and magnesium (meq/L) and the corresponding Sodium Adsorption Ratio based on values reported by NSDOE for samples collected on 12 May 1988.

Location	Sodium	Calcium	Magnesium	SAR
Rand Bk	0.36	1.04	0.28	0.45
Coleman Bk	0.30	1.23	0.18	0.35
Ryan Bk	0.26	3.05	0.34	0.20
Killam Bk	0.27	0.81	0.16	0.39
Griffin Bk	0.22	1.02	0.21	0.29
Griffin Bk	0.27	1.30	0.31	0.30
Griffin Bk	0.25	2.06	0.32	0.24

Based on the limited data available, it does not appear that the levels of sodium, chloride, calcium or sulphate ions in the Cornwallis watershed are of concern with respect to agricultural uses.

5.3.2 Dissolved Oxygen

Dissolved oxygen is essential for most aquatic life. Concentrations below about 5 mg/L are considered stressful. Another indicator of the availability of dissolved oxygen is percent dissolved oxygen saturation, a function of both the absolute amount of dissolved oxygen and water temperature. Most aquatic organisms become stressed when dissolved oxygen saturation levels fall below 50 percent.

The CCME water quality guidelines for protection of aquatic life recommend minimum dissolved oxygen concentrations of 5.5 and 9.5 mg/L for protection of the early life stages of warm and cold water species respectively. The recommended values for other life stages are 6.5 and 9.5 mg/L for warm and cold water species respectively.
There is a great deal of data available on dissolved oxygen levels for the main stem of the Cornwallis River. The lowest dissolved oxygen levels typically occur during the summer when both water temperatures and microbial metabolism are high.

Figures 5.9 and 5.10 show the spatial and seasonal variations in the levels of dissolved oxygen and percent dissolved oxygen saturation, respectively. Both exhibit similar spatial and seasonal trends with lowest levels occurring in the upper regions of the River and during the late summer. The lowest levels occur just downstream of the Berwick sewage treatment plant, which is located about 22 km upstream of Kentville. Table 5.5 illustrates this further. At Willow Avenue, which is located just below the sewage treatment plant, dissolved oxygen levels during May through August were below 50 percent saturation 60 percent of the time.

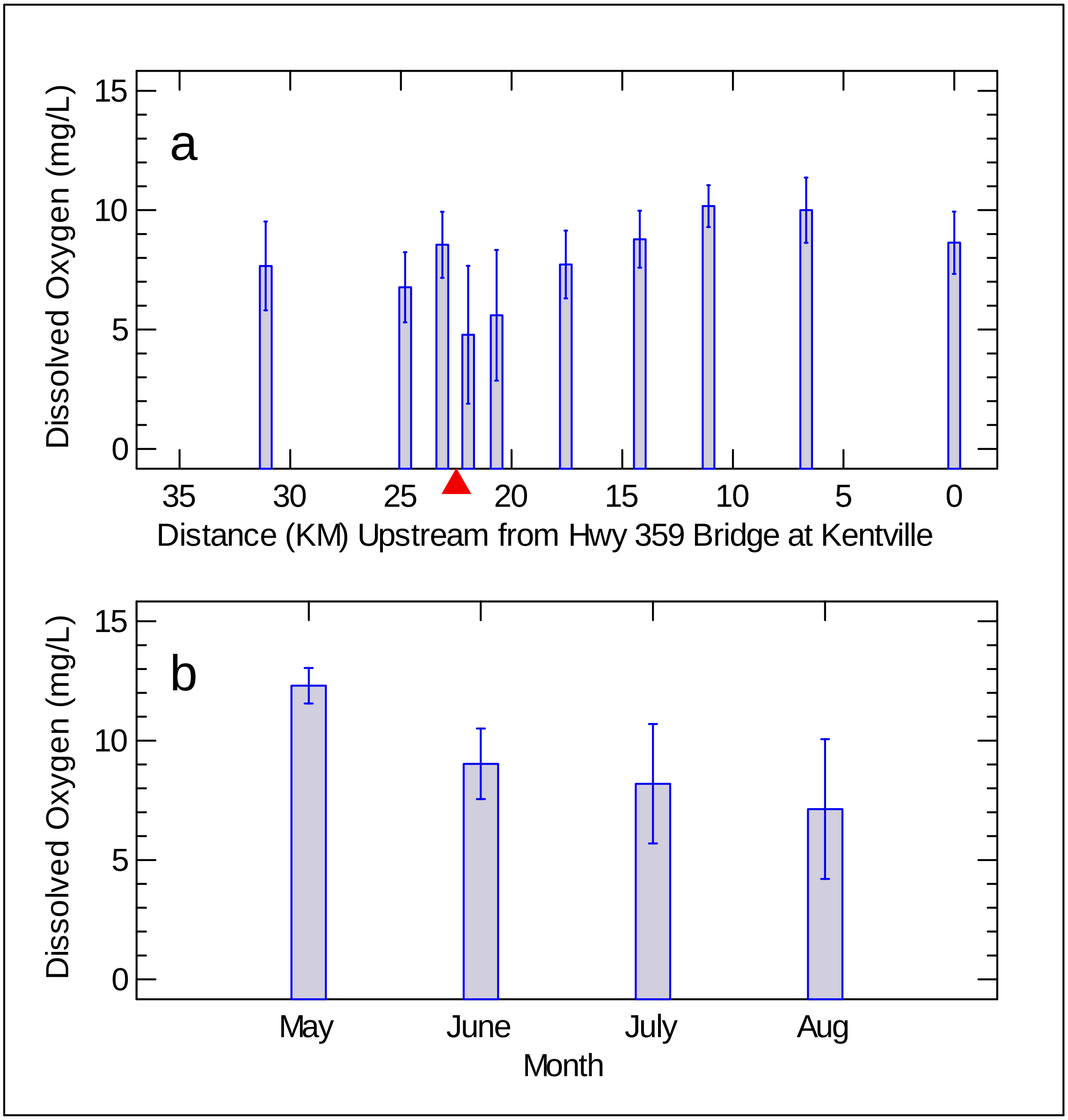

Figure 5.9. Spatial and seasonal variation in average dissolved oxygen concentration for main stem sites based on measurements made May through August in 1997, 2000, 2001 and 2002: (a) average concentration vs. distance upstream from Hwy 359 Bridge at Kentville; (b) average seasonal variation for all sites. (Error bars are one standard error of the mean; ▲ indicates location of Berwick STP.)

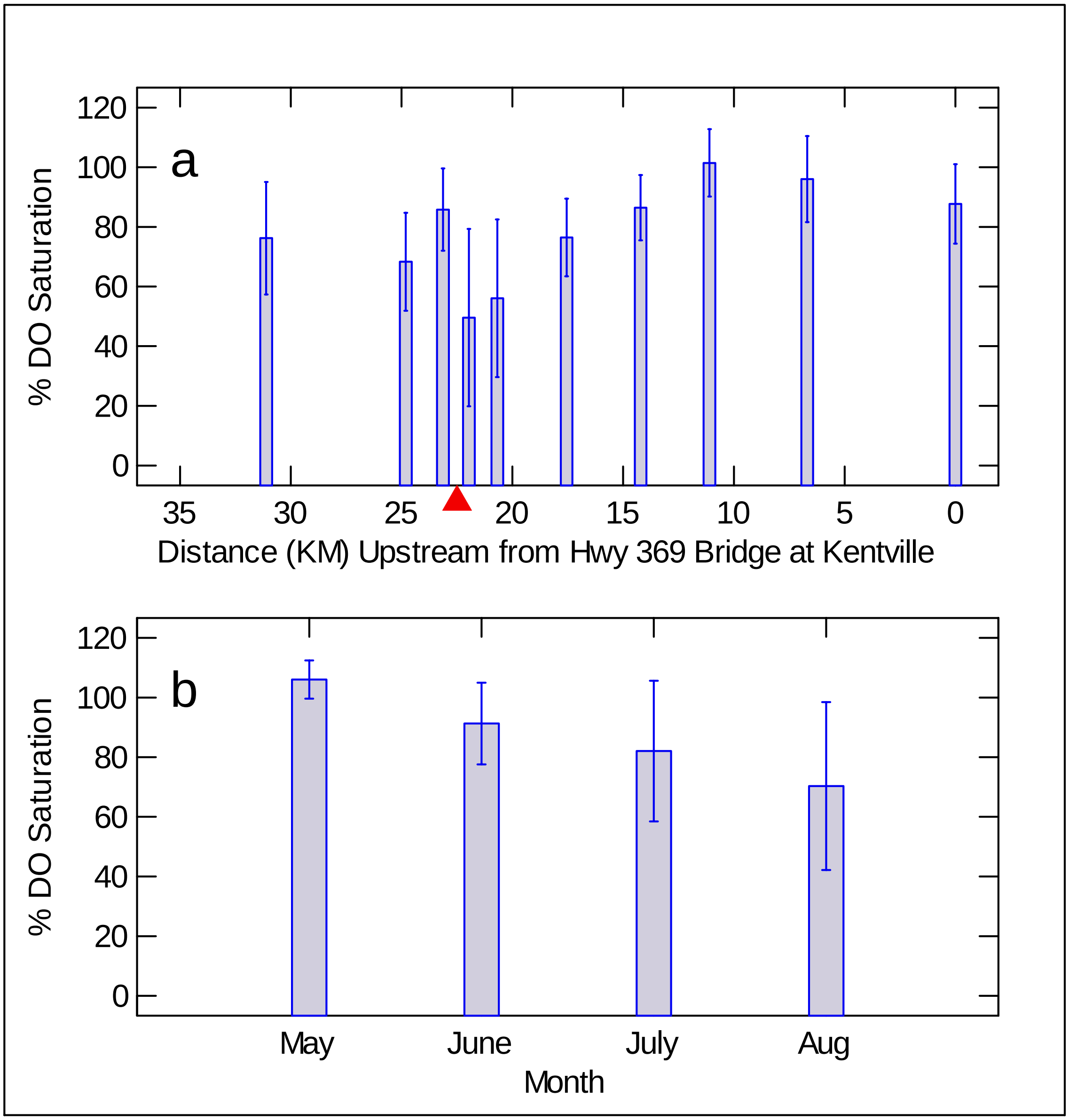

Figure 5.10. Spatial and seasonal variation in percent dissolved oxygen saturation for main stem sites based on measurements made May through August in 1997, 2000, 2001 and 2002: (a) average saturation vs. distance upstream from Hwy 359 Bridge at Kentville; (b) average seasonal variation for all sites. (Error bars are one standard error of the mean; ▲ indicates location of Berwick STP.)

Table 5.5. Percentage of times dissolved oxygen saturation was less than or equal to 50 percent (based on observations made May through August during 1997, 2000, 2001 and 2002).

Location	Total Number of Observations	Range of Values in % Saturation		Percent of Times Below 50 % Saturation
		Min	Max	
Black Rock Rd	48	34.3	126.5	10.4
North Berwick	43	27.9	104.6	11.6
Willow Ave	45	5.5	119.5	60.0
Shaw Rd	64	15.4	103.4	43.7

5.3.3 Biological Oxygen Demand

Biological Oxygen Demand (BOD) is a measure of the amount of oxygen consumed by aerobic microorganisms in decomposing the organic matter contained in a water sample. It is measured as the decrease of dissolved oxygen in water samples incubated at a constant temperature of 20 °C over a set time period, typically five days (in which case it is referred to as BOD_5). Waters containing large amounts of highly degradable organic matter, such as untreated sewage, may have BOD_5 values as high as 100 mg/L. Treated sewage typically has values in the range of 20-60 mg/L (the BOD_5 wastewater discharge limits for the Berwick and Waterville sewage treatment plants has been set at 10 mg/L). Water considered moderately clean has levels in the range of 5-10 mg/L.

Allen (1978) carried out an intensive survey of BOD_5 during the summer of 1977. The results are shown in Figure 5.11. The seasonal and spatial trends are similar, but opposite in magnitude, to that for dissolved oxygen concentrations. The highest values occur in the upper reaches of the River, and are highest just downstream of the Berwick sewage treatment plant, with values increasing over the summer. The levels observed, however, were quite acceptable, ranging between 0.03 and 6.26 mg/L, and indicative of clean to moderately clean water in most areas of the River.

Allen (1978) also measured BOD_5 levels at tributaries on two occasions during August 1977. The levels were highest for tributaries located along the upper reaches of the

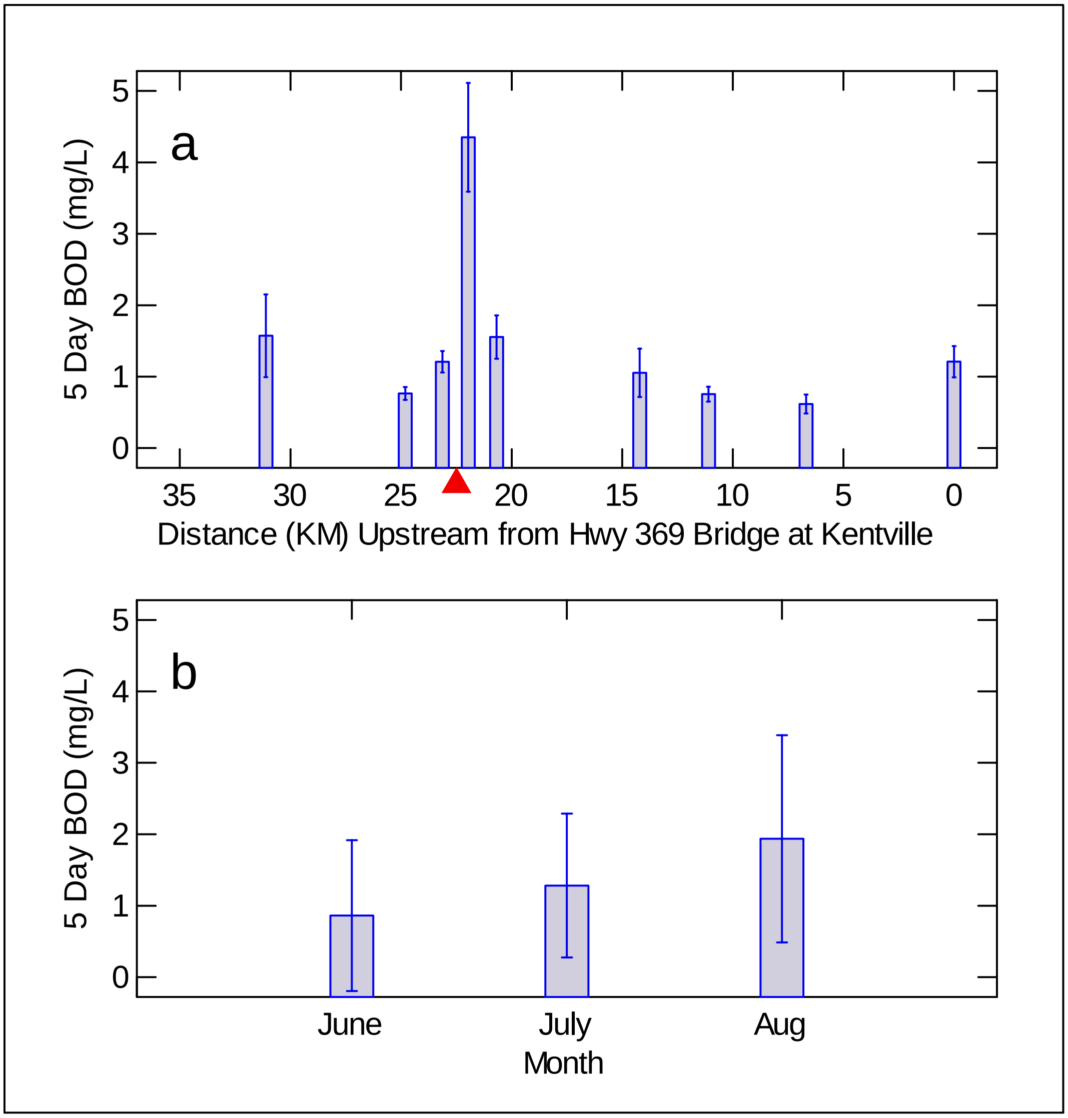

Figure 5.11. Spatial and seasonal variation in BOD_5 for main stem sites based on measurements made June through August 1997. (a) average BOD_5 vs. distance upstream from Hwy 359 Bridge at Kentville; (b) average seasonal variation for all sites. (Error bars are one standard error of the mean; ▲ indicates location of Berwick STP.)

River, but were quite low for all tributaries (Figure 5.12). Values were always less than 1 mg/L except at Fisher Brook and the east and central branches of Morris Brook, but even at these sites the values were only slightly above 1 mg/L.

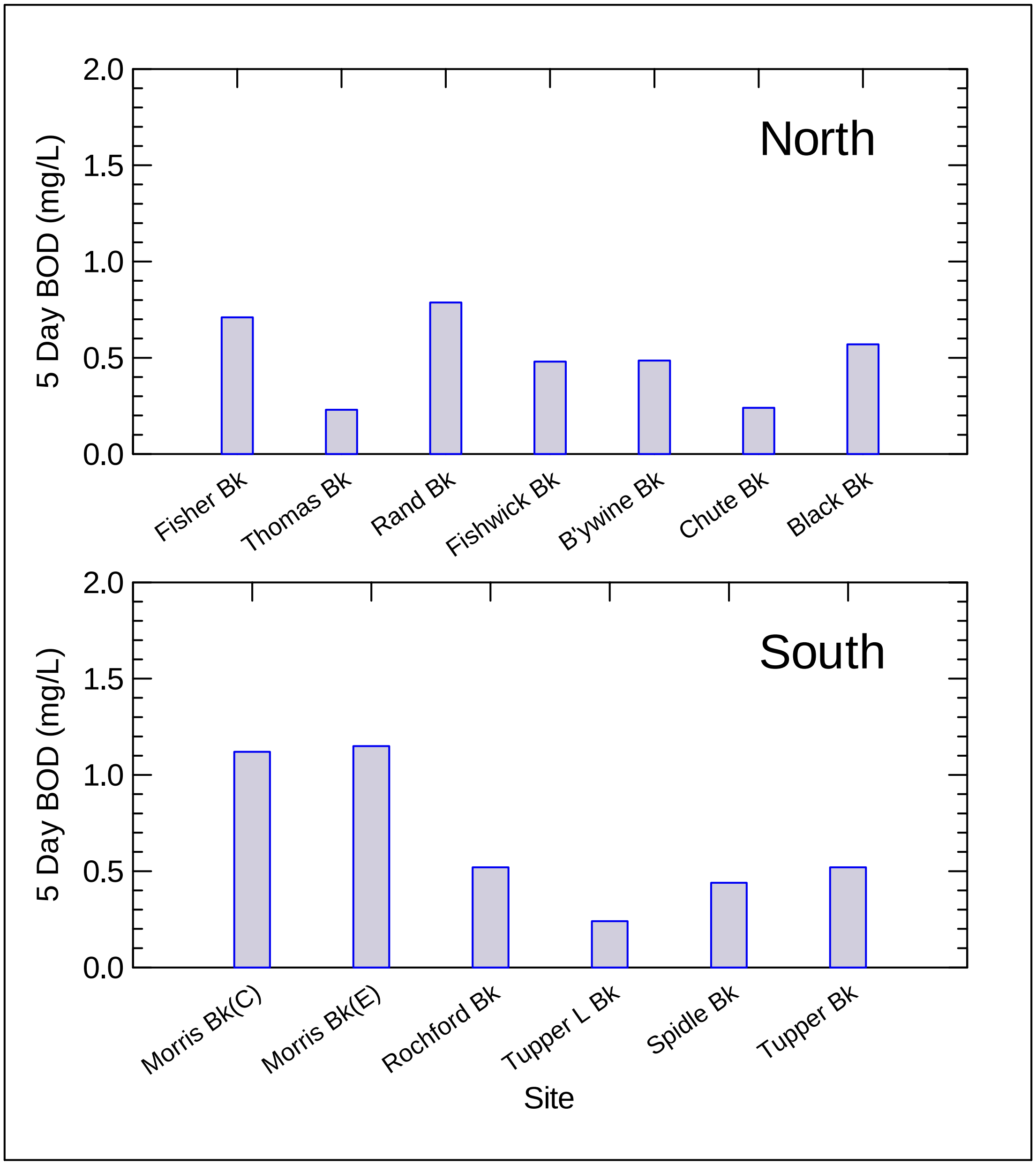

Figure 5.12. Mean BOD_5 values for North and South tributaries during August 1997 (Note: not shown is Morris Bk(W) which had BOD_5 values of 11.2 and 41.8 mg/L).

5.3.4 Micronutrients

Phosphorous and nitrogen are the two most important micronutrients required for the growth of aquatic plants. They are also the nutrients that, when present in high quantities, cause aquatic systems to become eutrophic. The term 'eutrophic' refers to aquatic systems that have excessive plant growth and, consequently, low dissolved oxygen levels as a result of the decomposition of the plant material. Eutrophic systems often also contain high levels of toxic substances such as methane, ammonia and hydrogen sulfide, the end products of organic decomposition under anoxic or anaerobic conditions. Eutrophication is most common in standing water systems such as ponds, lakes and coastal bays. Small rivers and streams are usually well aerated due to the turbulence created by running water and, as a result, seldom become anaerobic. It is generally believed that excessive phosphorous input is the factor responsible for eutrophication of fresh water systems, while excessive nitrogen input is the cause in marine systems. Levels of total phosphorous above about 0.02 mg /L will cause eutrophic conditions in standing water systems. Nitrate-N levels above 2 mg/L are considered high and can also lead to eutrophic conditions.

Ruminants, such as cattle, are highly susceptible to nitrate poisoning (methemoglobinemia). Under the anaerobic conditions within the rumen, nitrate is converted to nitrite which can inhibit the ability of blood to transport oxygen. In pregnant cattle, this may cause the death of unborn calves. The maximum recommended level of nitrate for livestock drinking water is 100 mg/L. Although there are no guidelines for nitrate for protection of aquatic life, nitrate-N levels above about 2 mg/L can led to excessive weed growth and the development of eutrophic conditions (Wetzel 1983).

Other than the study by Gordon (2002), which was confined to the Thomas Brook tributary, there is no recent data available on phosphorous levels in the Cornwallis watershed.

Nitrate concentrations were measured in the main stem of the River Cornwallis watershed by Allen (1998). Samples were collected biweekly between 26 June and 8 August 1997. Nitrate-N values in the main stem average between about 2 and 5 mg/L (Figure 5.13). The highest levels occur just below the Berwick sewage treatment plant.

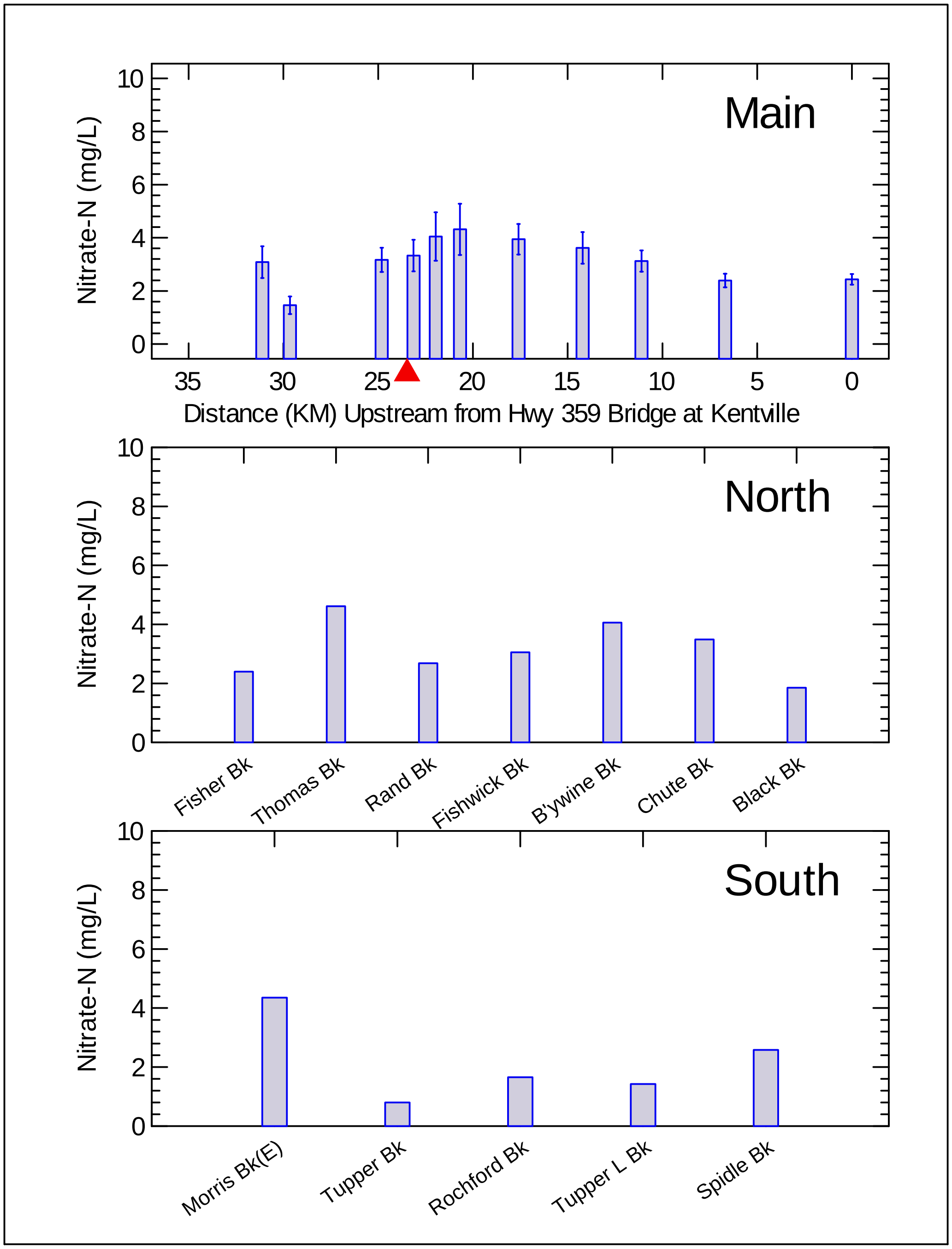

Figure 5.13. Mean nitrate concentrations for main sites and tributaries based on values measured in 1997 (from Nelson 1998 and Allen 1998). Main site averages are for the period between 26 June and 8 August (error bars are one standard error of the mean; ▲ indicates location of Berwick STP). Tributary averages are based on measurements made during August.

Nitrate values in the north tributaries are similar to those in the main stem of the River and, with the exception of the east branch of Morris Brook, nitrate levels are considerably lower in the South tributaries. These differences are possibly related to differences in agricultural activity and nitrate fertilizer use on the north and south side of the River. Gordon measured nitrate levels at five stations located along Thomas Brook. Mean concentrations of nitrate-N measured between May and December 2001 ranged from 0.54 to 2.4 mg/L. The highest concentration were observed furthest downstream and during low-flow periods. The later suggests that groundwater inputs may contain high nitrate levels.

The levels are well below the maximum recommended levels for livestock drinking water, however, most exceed levels considered safe for protection of aquatic life.

5.3.5 Trace Metals

There have been only two surveys to assess the concentrations of water column trace metals in the Cornwallis River watershed. Both were carried by the NSDOE, one in 1978 and one in 1988, and both were quite limited in scope. The 1978 survey was carried out in May and was limited to nine tributary sites. The 1988 survey was carried out at four main stem sites. The locations of the sites sampled during both surveys are shown in Figure 5.14 and the results of the surveys are listed in Table 5.6.

Table 5.7 compares the survey results with the CCME guidelines for agricultural water use and protection of aquatic life. Although the data is quite limited, CCME guidelines were exceeded a number of times, particularly at the main River sites, most of which were located in the upper reach of the River. The guidelines for irrigation water were exceeded for cadmium and zinc at the Willow Avenue and Bishop Road sites, and for lead at the Willow Avenue site. For livestock drinking water, the guideline for arsenic was exceeded at the Cambridge and Bishop Road sites, and for lead at the Willow Avenue site. The guidelines for aquatic life, which are much more stringent, were exceeded for arsenic, copper, iron, lead, mercury and zinc at one or more sites.

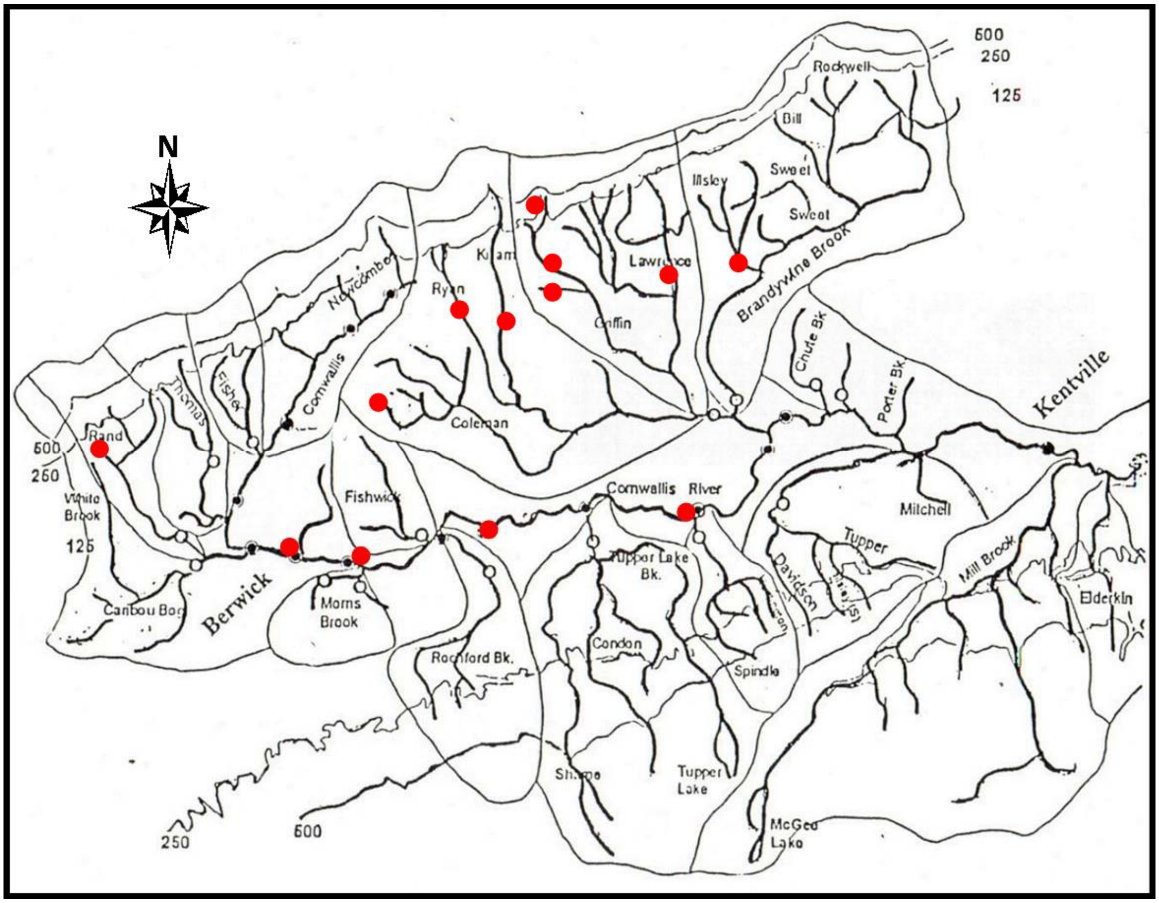

Figure 5.14. Location of sample sites for the trace metal surveys carried out by NSDOE during 1978 and 1988.

Table 5.6 Concentrations of trace metals (mg/L) in Cornwallis River (NSDOE files).

Location	Date	Magnesium	Zinc	Copper	Iron	Manganese	Arsenic	Cadmium	Chromium	Mercury	Lead	Aluminium
Willow Ave	24 July 1978	-	2.10	0.006	0.58	0.090	0.010	0.006	0.009	0.0030	0.22	<0.015
Shaw Rd	24 July 1978	-	0.30	<0.002	0.20	0.030	-	<0.001	0.012	0.0009	0.08	<0.015
Cambridge Rd	24 July 1978	-	0.01	<0.002	0.15	0.006	0.030	<0.001	0.006	0.0009	<0.02	0.040
Bishop Rd	24 July 1978	-	0.62	0.003	0.30	0.360	0.070	0.020	0.010	0.0012	<0.02	0.035
Rand Bk	12 May 1988	3.4	<0.01	<0.002	0.86	0.04	-	-	-	-	-	-
Coleman Bk	12 May 1988	2.2	<0.01	<0002	0.11	<0.01	-	-	-	-	-	-
Ryan Bk	12 May 1988	4.1	<0.01	<0.002	0.11	<0.01	-	-	-	-	-	-
Killam Bk	12 May 1988	2.0	<0.01	<0.002	0.10	<0.01	-	-	-	-	-	-
Griffin Bk (W)	12 May 1988	2.6	<0.01	<0.002	0.24	0.02	-	-	-	-	-	-
Griffin Bk (C)	12 May 1988	3.8	<0.01	<0.002	0.22	0.03	-	-	-	-	-	-
Griffin Bk (E)	12 May 1988	3.9	<0.01	<0.002	0.13	0.04	-	-	-	-	-	-
Lawrence Bk	12 May 1988	3.1	<0.01	<0.002	0.95	0.05	-	-	-	-	-	-
Illsley Bk(N)	12 May 1988	3.1	<0.01	<0.002	0.33	0.04	-	-	-	-	-	-

Table 5.7. CCME guidelines for trace metals and range of values reported for the Cornwallis River (units are mg/L).

Parameter	Irrigation Water	Livestock Water	Aquatic Life	Range of Values Reported for the Cornwallis Watershed	
				Min	Max
Aluminum	5.0	5.0	0.1	<0.015	0.035
Arsenic	0.1	0.025	0.005	0.010	0.070
Boron	0.5-6.0	5.0	-	-	-
Cadmium	0.005	0.080	0.055	<0.001	0.020
Chromium					
Trivalent (Cr(III))	0.049	0.050	8.9	0.010*	0.012*
Hexavalent (Cr(VI))	0.008	0.050	1.0	-	-
Cobalt	0.5	1.0-2.0	-	-	-
Copper:					
Cereals	0.2	5.0	0.002	<0.002	0.006
Tolerant Crops	1.0	5.0			
Fluoride	1.0	15.0	-	-	-
Iron	5.0	-	0.3	0.10	0.58
Lead	0.2	0.1	0.002	<0.02	0.22
Manganese	0.2	-	-	<0.01	0.36
Mercury	-	0.003	0.0001	0.0009	0.0030
Zinc:		50			
soil pH<6.5	1.0		0.03	<0.01	2.10
soil pH>6.5	5.0				

*It is not clear from the data files as to whether this represents the trivalent or hexavalent form.

Because of the limited data, and the long period of time since these measurements were made, it is difficult to assess how much of a concern these results may currently be without further study.

5.3.6 Organochlorines

Musial (1975) studied the occurrence of chlorinated hydrocarbons in sediments at five sites within the Cornwallis River watershed (Table 5.8). Levels of DDT varied seasonally with highest values occurring in spring and fall and lowest values occurring in summer. It was suggested that this variation may be due to surface runoff following periods of precipitation, but no data is presented to support this conclusion. Musial also reported some spatial variation within the River with concentrations increasing downstream.

Table 5.8. Concentrations (µg/kg) of chlorinated hydrocarbons in sediment reported by Musial (1975) at five sites in the Cornwallis River watershed.

Location	Date	Total PCBs	Total DDT	Chlordane	nonachlor	α-endosulfan	β- endosulfan	endosulfan sulphate	Dieldrin
Brandywine Bk	30 Apr 1974	-	33.6	23.3	8.0	3.9	15.6	29.0	15.5
Brandywine Bk	19 July 1974	-	nd**	1.6	1.9	0.6	2.6	-	t*
Brandywine Bk	04 Sep 1974	-	40.7	8.1	2.6	2.8	6.9	9.4	3.7
Brandywine Bk	22 Oct 1974	-	15.1	23.6	8.1	6.3	16.9	18.6	5.1
Brandywine Bk	22 May 1975	-	-	5.8	1.9	1.0	2.5	6.2	0.8
Illsley Bk(N)	30 Apr 1974	-	-	-	-	t*	t*	1.5	t*
Illsley Bk(N)	19 Jul 1974	-	-	-	-	t*	0.5	2.1	0.8
Illsley Bk(N)	04 Sep 1974	-	-	-	-	t*	0.4	2.0	0.5
Illsley Bk(N)	22 Oct 1974	-	-	-	-	t*	0.5	2.1	0.3
Illsley Bk(N)	22 May 1975	-	-	-	-	0.3	t*	1.8	t*
Lovette Rd	30 Apr 1974	31.0	7.4	-	-	0.4	-	-	-
Lovette Rd	19 Jul 1974	15.0	21.2	-	-	t*	t*	1.5	0.7
Lovette Rd	04 Sep 1974	24.3	0.8	-	-	t*	t*	1.4	0.7
Lovette Rd	22 Oct 1974	9.9	t*	-	-	0.3	t*	1.6	0.4
Lovette Rd	22 May 1975	15.2	t*	-	-	-	-	0.5	t*
Cambridge Rd	30 Apr 1974	21.4	6.2	-	-	-	-	t*	2.0
Cambridge Rd	19 Jul 1974	27.7	1.9	-	-	t*	-	4.4	2.3
Cambridge Rd	04 Sep 1974	10.4	3.6	-	-	t*	t*	1.7	t*
Cambridge Rd	22 Oct 1974	2.2	1.4	-	-	-	-	0.6	-
Cambridge Rd	22 May 1974	6.9	1.8	-	-	-	-	0.7	-

*trace
** below limits of detection

There are no CCME guidelines for agricultural water use for the types of organochlorines studied by Musial. For protection of aquatic life there are guidelines for four of the eight compounds measured (Table 5.9). Total PCB levels never exceeded the ISQG guideline, but almost always exceeded the PEL guideline. Total DDT and chlordane levels most often exceeded both guidelines. Dieldrin, in contrast, seldom exceeded either guideline.

As is the case with trace metals, this data is much too limited, and not recent enough to determine with any confidence the potential threat organochlorines may currently have on aquatic life in the Cornwallis watershed.

Table 5.9. CCME freshwater chlorinated hydrocarbon sediment quality guidelines for the protection of aquatic life (units are µg/kg dry sediment).

Parameter	ISQG*	PEL**	Mean and Range of Values Reported for the Cornwallis River		
			mean	min	max
Total PCBs	34.1	2.77	16.4	2.2	31.0
Total DDT	1.19	4.77	9.6	0	40.7
Chlordane	4.50	8.87	12.5	1.6	23.6
Dieldrin	2.85	6.67	1.9	0	15.5

*Interim Sediment Quality Guideline
**Probable Effect Level (Level above which adverse effects are expected to occur frequently.)

5.4 Biological Characteristics

5.4.1 Microbiology

5.4.2 Microbial Pathogens

Aside from the study of Menon (1988), no information exists on the presence of pathogenic microorganisms in the Cornwallis watershed. Although Menon found high numbers of pathogenic microorganisms in the River, his study focused on areas of the River in close proximity to effluents from food processing and sewage treatment plants. All food processing effluents are now diverted to sewage treatments plants, and all of the sewage treatment plants have received substantial upgrades since the time of Menon's study, making it unlikely that his conclusions are relevant to present day conditions.

5.4.3 Fecal Coliform Bacteria

With respect to the use of water for irrigation, the presence of fecal coliform bacteria is of particular concern because it provides an indication of the potential contamination of water by human pathogens. Although most fecal coliform bacteria are not harmful, they are often associated with other bacteria, protozoans and viruses that are pathogenic to humans and other animals.

Coliform bacteria are a group of relatively harmless microorganisms. In the past, total coliform numbers were routinely used to assess the probability of water being contaminated by the feces of humans. Recent studies, however, have shown many types of coliform bacteria to be quite ubiquitous and present in natural systems outside of the body of warm blooded animals. Some are also capable of reproducing in environments having warm temperatures and high organic contents (see Scott et al. 2002 for a recent review). As a result, most microbiologists no longer consider the number of total coliform bacteria to be a reliable indicator of the presence of pathogenic microorganisms and measures of total coliform bacteria numbers are not included in this assessment.[1]

Fecal coliform bacteria are a subgroup of coliform bacteria of which *Eschericia coli* is a major constituent. Most fecal coliform bacteria are harmless, but one recently discovered strain (*E. coli* 0157:H7) can be pathogenic. Fecal coliforms live only in the digestive tract of warm blooded animals making them a much more reliable indicator of fecal contamination by warm-blooded animals. There still exists, however, some problems associated with the use of fecal coliform bacteria as indicators of the presence of human pathogens, largely because they are not unique to humans, and their presence can result

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[1] In most cases, measurements of total coliform numbers in the Cornwallis watershed are above the level (about 3000/100ml) that can be accurately counted using present day techniques.

from fecal contamination by any warm blooded animal, including livestock and wildlife. Waterfowl, in particular, are known for having relatively high concentrations of fecal coliform bacteria in their feces (Valiela et al. 1991).

Despite these problems, fecal coliform bacteria number is currently the only widely used and accepted measure of fecal contamination, and is the only data available for assessing the degree of fecal contamination in the Cornwallis watershed. The CCME guidelines for fecal coliform bacteria levels, as numbers per 100 ml of water, for various water uses are as follows: drinking water - 0; irrigation of produce for human consumption - <100; and contact recreation - <200. There is no specific numeric guideline for livestock drinking water, but it is recommended that only high quality drinking water is provided in high-density livestock operations, and that water supplies for free ranging livestock be monitored and chlorinated if necessary.

5.4.3.1 Current Levels of Fecal Coliform Bacteria

The most recent data on coliform numbers is that collected during 2001 and 2002 by FOCS at ten main stem sites. This data is summarized in Table 5.10 as the percentage of times fecal coliform numbers fell below various levels.[1] Figure 5.15 shows how often fecal coliform numbers fell below 100/100 ml, the level recommended for irrigation water, for both years combined.

Although there is a great deal of variability, both between sites and between years, it is obvious that fecal coliform levels tend to be much higher in the upper regions of the River, and are especially high immediately above, but not below, the Berwick sewage treatment plant. This suggests that the Berwick sewage treatment plant is not the major contributor of fecal coliforms in the upper region of the River. This is also true, but to a lesser degree, for sites upstream and downstream of the Waterville sewage treatment

[1] Because of the small number of samples and the large range of values (0-3000) in fecal coliform numbers, the use of average fecal coliform numbers was not considered to be a useful means of comparing sites.

plant. It is possible that the effluent of both sewage treatment plants often contains cleaner water than exists in the area of the River where the effluent is discharged.

Table 5.10. Percentage of times fecal coliform numbers (as number/100ml) fell below various levels at main stem sites during the months of June July and August during 2001 and 2002 (from FOCS files).

Location	Years	Total Number of Samples	<50	<100	<200	<1000	>1000
Kentville	2001	6	0	0	50.0	83.3	16.6
"	2002	7	0	71.4	71.4	85.7	14.3
Lovette Rd	2001	5	0	0	40.0	100	0
"	2002	7	0	14.3	28.6	100	0
Bishop Rd	2001	5	0	20.0	40.0	80.0	20.0
"	2002	7	0	28.6	28.6	85.7	14.3
Cambridge Rd	2001	10	0	0	10.0	60.0	40.0
"	2002	7	0	14.3	28.6	85.7	14.3
Waterville STP3	2001	5	0	0	20.0	80.0	20.0
"	2002	6	0	0	33.3	66.7	33.3
Shaw Rd	2001	5	0	20.0	80.0	100	0
"	2002	7	14.3	42.8	71.4	100	0
Willow Ave	2001	8	12.5	12.5	50.0	87.5	12.5
"	2002	7	0	0	42.8	100	0
Berwick	2001	5	0	0	0	80.0	20.0
"	2002	7	0	0	0	28.6	71.4
North Berwick	2001	10	0	0	0	60.0	40.0
"	2002	7	0	0	0	57.1	42.9
Black Rock Rd	2001	9	0	22.2	66.7	88.9	11.1
"	2002	7	0	0	0	71.4	28.6

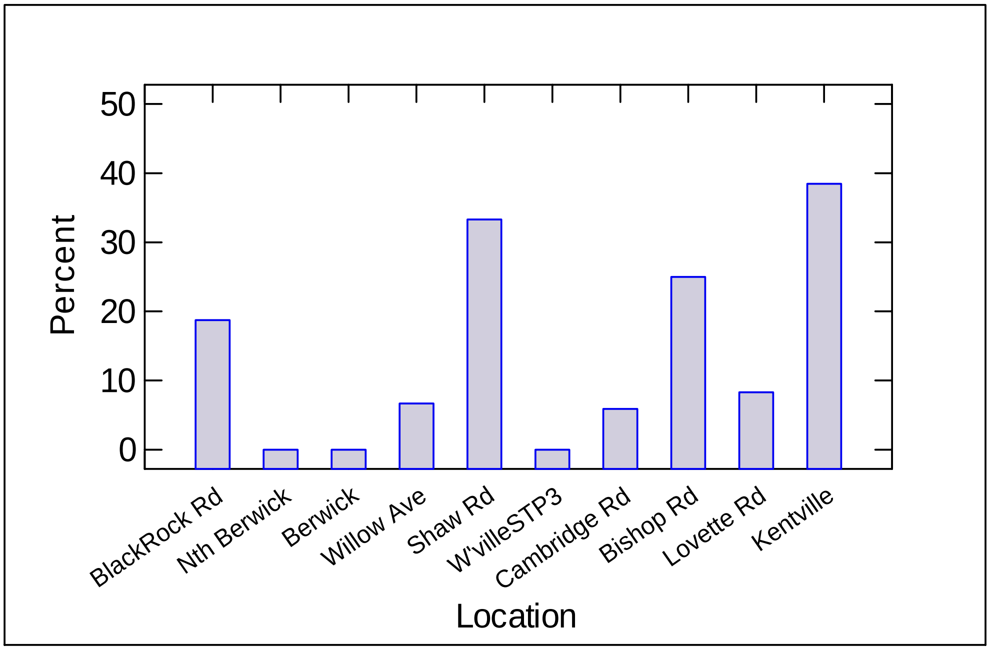

Figure 5.15. Percentage of times fecal coliform numbers fell below 100/100 ml at main stem sites during the months of June July and August in 2001 and 2002.

5.4.3.2 Historical Comparison of Levels of Fecal Coliform Bacteria

In an attempt to assess the degree to which fecal coliform contamination has varied historically, a comparison was made between the most recent data collected by FOCS, and that collected by the NSDOE during a period of relatively intensive surveys carried out between 1989 and 1991. The total number of samples collected during both surveys was 432 and 137, respectively, but of these only 325 and 77 samples, respectively, were collected at locations and times of the year common to both surveys. This information, limited to the six main stem sites monitored by both groups on a consistent basis during the period June through August of the years being compared, is listed and compared in Table 5.11 in terms of the number of times fecal coliform numbers fell below or above various levels. A comparison of the percentage of time fecal coliform numbers are below the level recommended for irrigation water is shown in Figure 5.16.

Table 5.11. Historical comparison of percentage of times fecal coliform numbers (as number/100ml) fell below various levels at main stem sites during the months of June July and August during 1989-1991 and 2001-2002.

Location	Years	Total Number of Samples	<50	<100	<200	<1000	>1000
Lovette Rd	1989-1991	42	26.2	33.3	54.8	92.8	7.2
"	2001-2002	12	0	8.3	33.3	100	0
Bishop Rd	1989-1991	41	24.4	36.6	70.0	85.4	14.6
"	2001-2002	12	0	25.0	33.3	83.3	16.7
Cambridge Rd	1989-1991	42	23.8	38.1	57.1	85.7	14.3
"	2001-2002	17	0	5.9	17.6	70.6	29.4
Shaw Rd	1989-1991	41	34.1	65.9	78.0	90.2	9.8
"	2001-2002	12	8.3	33.3	75.0	100	0
Willow Ave	1989-1991	43	32.6	48.8	70.0	86.0	14.0
"	2001-2002	15	6.7	6.7	46.7	93.3	6.7
Berwick	1989-1991	43	14.0	20.9	30.2	74.4	25.6
"	2001-2002	12	0	0	0	50.0	50.0

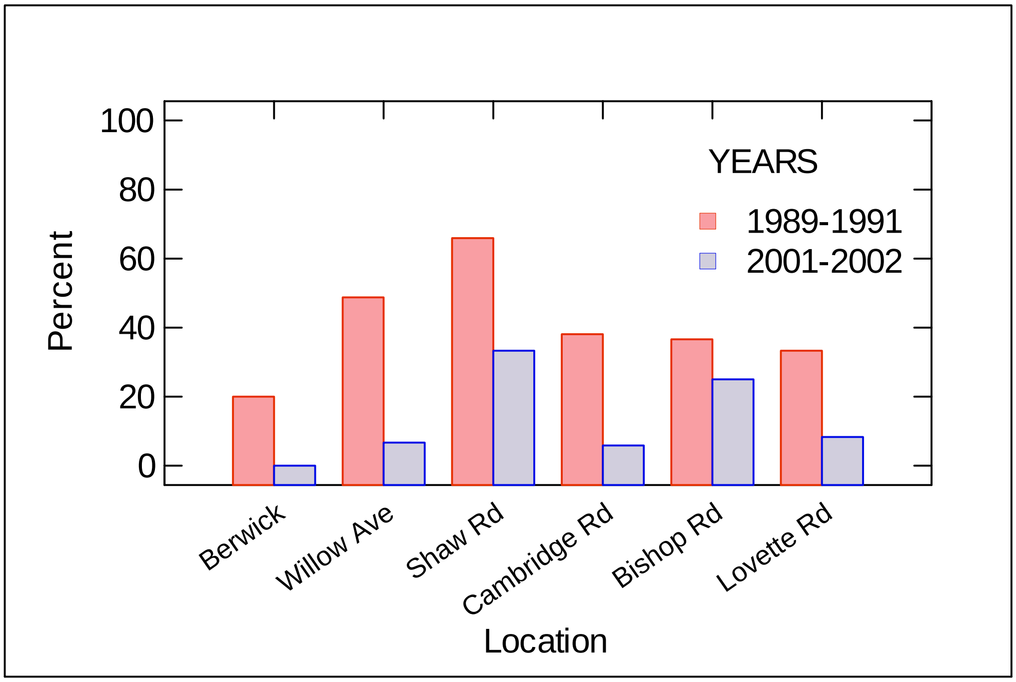

Figure 5.16. Comparison of the percentage of times fecal coliform numbers fell below 100/100 ml at main stem sites during the period between June and August of 1989-1991 and 2001-2002.

With respect to the levels considered acceptable for irrigation water, it is obvious that conditions were better during 1989-1991 than during 2001-2002. At all sites the percentage of times fecal coliform numbers fell below 100/100 ml was less during 2000-2001 than during 1989-1991. With respect to the higher levels, the results are less clear in that some sites show a decrease while others show an increase in extreme values. There is, however, an obvious problem within the area of Berwick upstream of the sewage treatment plant, as well as at the Cambridge Road site which is located downstream of the Waterville sewage treatment plant. At both sites, the percentage of times fecal coliform numbers are greater than 1000/100 ml is about 100 percent greater during 2001-2002 , than during 1989-1991.

In an attempt to determine if this reflects a genuine degradation of bacterial water quality, or is simply a result of differences in the amount of precipitation during the two time periods being compared, the relationship between fecal coliform numbers and precipitation was examined. Total precipitation for each month of the years being compared was plotted against the corresponding mean monthly fecal coliform number. The 2001-2002 time period was considerably drier than the 1981-1991 time period (Figure 17), and there is a strong negative relationship between monthly precipitation and fecal coliform numbers (Figure 5.18). In contrast, there is little relationship between fecal coliform numbers and precipitation during the 1989-1991 time period.

These results suggest that the difference between the time periods being compared is due to differences in precipitation, rather than an increase in the number of fecal coliforms entering the River

Table 5.12. Seasonal variation in percentage of times fecal coliform numbers (as number/100ml) fell below various levels at main stem sites during 1989-1991 and 2001-2002.

Month	Years	Total Number of Samples	<50	<100	<200	<1000	>1000
April	1989-1991	13	100	100	100	100	0
May	"	84	41.7	63.1	82.1	94.0	6.0
June	"	128	13.3	28.2	55.5	87.5	12.5
July	"	120	9.2	14.2	40.0	90.8	9.2
August	"	80	23.8	28.8	37.5	85.0	15.0
June	2001-2002	40	0	22.5	47.5	95.0	5.0
July	"	56	3.6	7.1	23.2	66.1	33.9
August	"	41	2.4	12.2	31.7	80.5	19.5

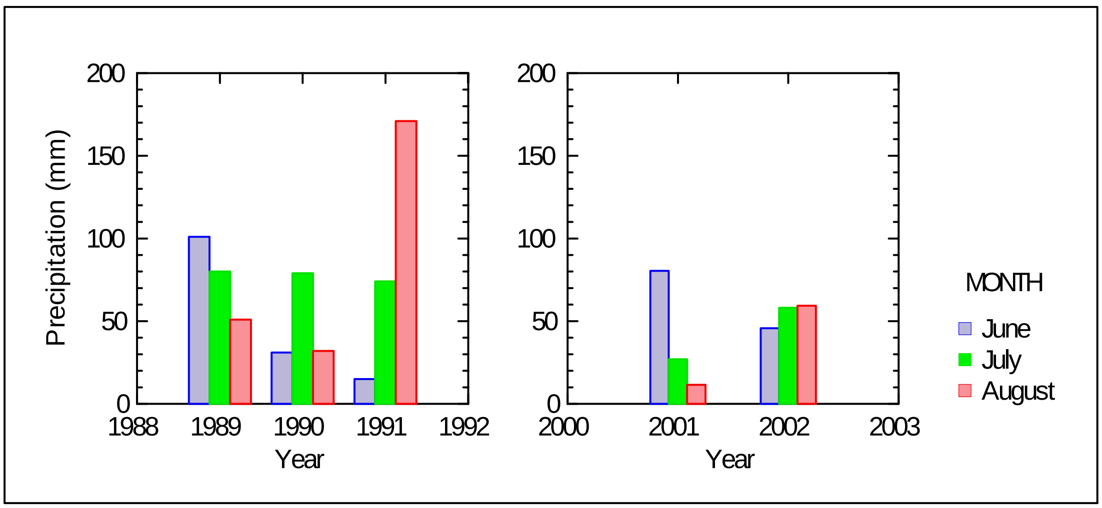

Figure 5.17. Total monthly precipitation for June, July and August during the time periods in which fecal coliform numbers are compared.

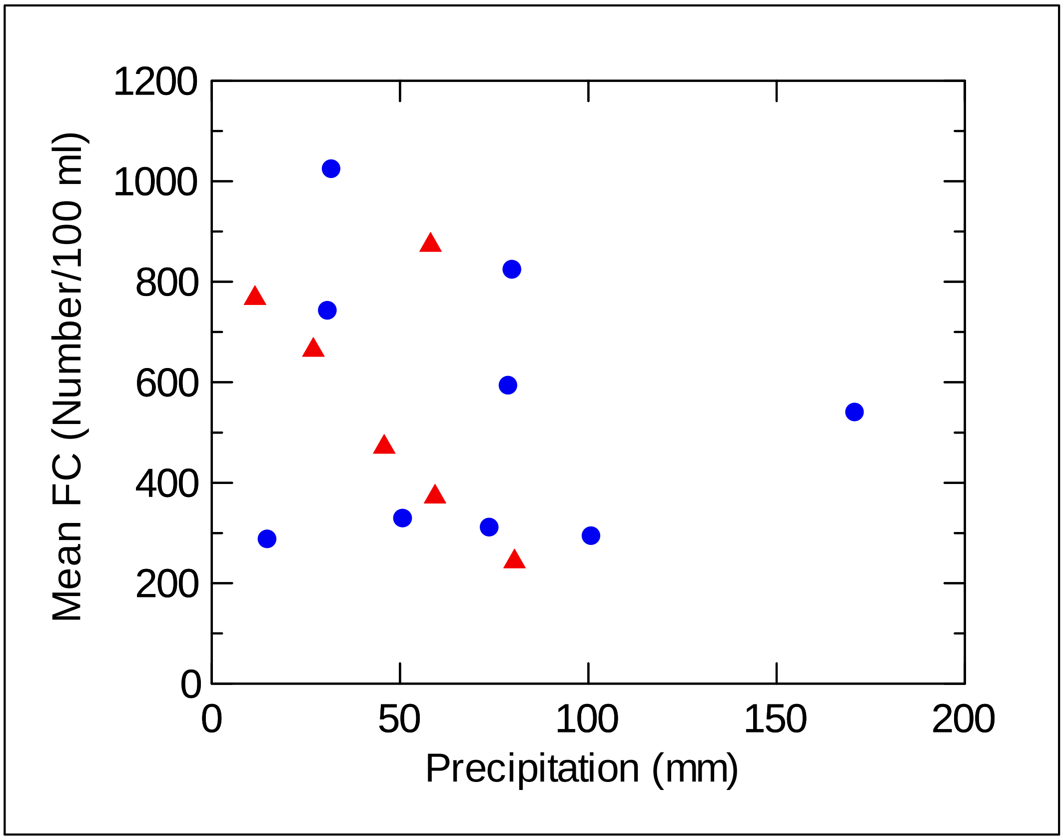

Figure 5.18. Relationship between total monthly precipitation and mean monthly fecal coliform numbers (● – 1989-1991; ▲ – 2001-2002).

5.4.3.3 Seasonal variation in fecal coliform numbers

In order to examine the degree to which fecal coliform numbers vary seasonally, the monthly variation in percentage categories was determined for the 1989-1991 and 2001-2002 data (Table 5.12 and Figure 5.19). The 1989-1991 data shows an obvious trend of lower numbers during the earlier months which is most likely a result of the higher water flows, and resulting dilution, typical of spring when runoff is highest.

5.4.3.4 Fecal Coliform Numbers in Tributaries

Recent data on fecal coliform numbers in tributaries is very limited. Allen (1998) made measurements of fecal coliform numbers at several tributary sites, but these were limited to three dates during August 1977 (Table 5.13). With a few exceptions, all of the tributaries had relatively high fecal coliform numbers, and the numbers were notably higher in tributaries located in the area of Berwick. Of the 29 samples collected, only 6 (21 %) percent, had levels of fecal coliforms acceptable for irrigation water.

Table 5.13. Fecal coliform numbers (as number/ 100 ml) measured at tributaries during August 1997.

Location	12 August	19 August	26 August
North Tributaries			
Black Brook	-	16	0
Chute Brook	-	520	115
Brandywine Brook	-	262	1541
"	-	780	246
Fishwick Brook	-	2800	420
Rand Brook	-	2000	2200
"	-	2300	880
Thomas Brook	-	660	460
Fisher Brook	-	3000	1360
South Tributaries			
Tupper Brook	-	-	115
Spidle Brook	0	-	230
Tupper Lake Brook	115	-	230
Rochford Brook	360	-	700
Morris Brook(E)	440	-	279
Morris Brook(W)	1240	-	980

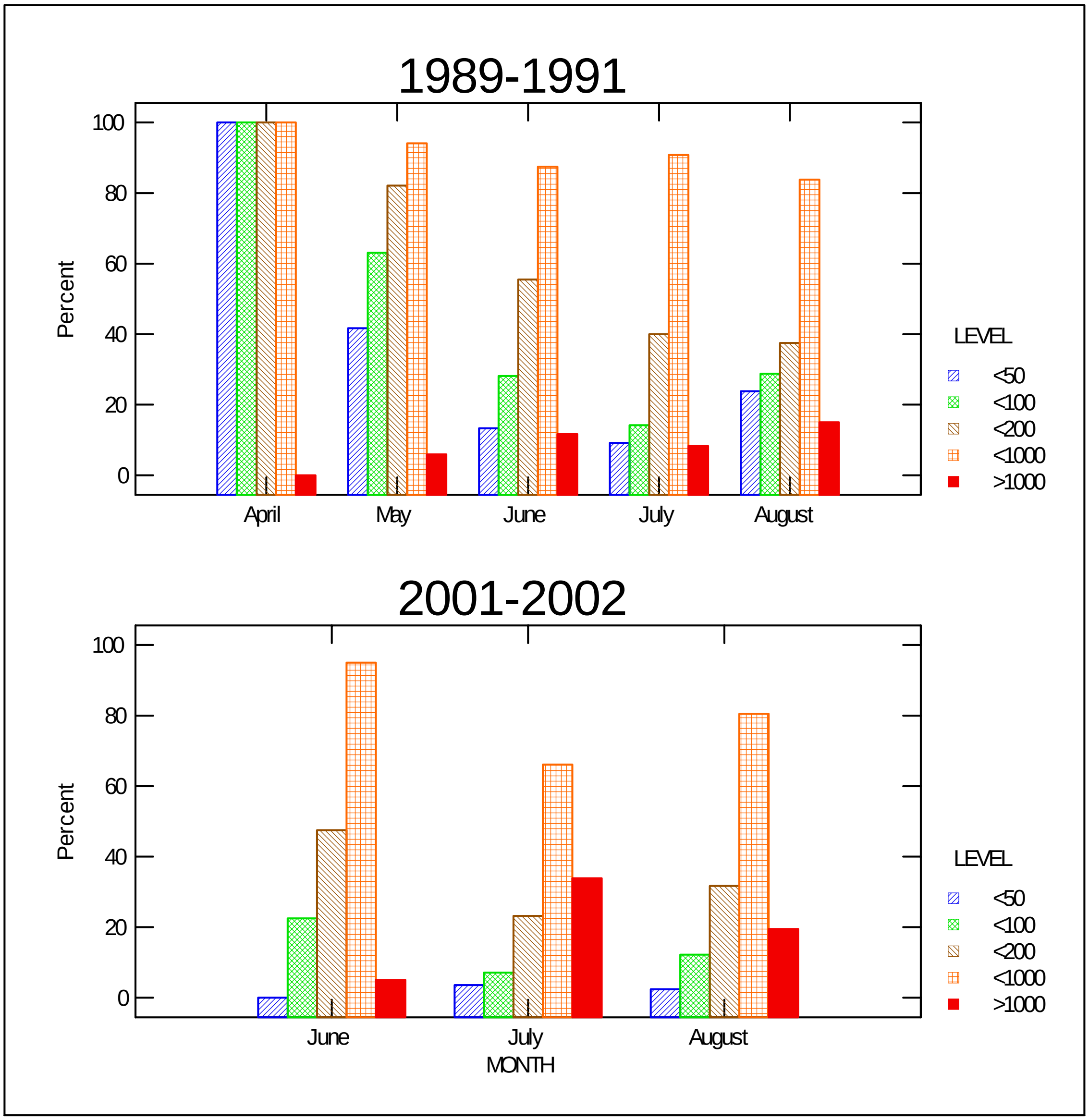

Figure 5.19. Seasonal variation in percentage of times fecal coliform numbers (as number/100ml) fell below various levels at main stem sites during 1989-1991 and 2001-2002.

6.0 Discussion

Although existing information on surface water quality in the Cornwallis watershed is limited, the information that does exist clearly indicates that the Cornwallis River experiences periods of poor water quality with respect to its use for agricultural purposes. There is some evidence that arsenic and lead may be present above levels acceptable for livestock watering. However, the major problem is high fecal coliform numbers, particularly during the summer periods when the demand for irrigation water is greatest. During the months of July and August, fecal coliform levels within the River in 2001 and 2002 were acceptable for irrigation use only 27 percent of the time.

With respect to aquatic life, the major problem is low dissolved oxygen levels during summer, particularly in the upper regions of the River. Both problems are most severe during periods of low flow conditions. The co-occurance of these two problems, both spatially and seasonally, suggests that they are linked to each other. The poor water quality that exists within the upper reaches of the River does not appear to be entirely attributable to the Berwick sewage treatment plant. High coliform numbers and low dissolved oxygen concentration are found upstream of the sewage treatment plant, both within the main stem as well as some of the tributaries. In addition, although dissolved oxygen levels are low below the Berwick sewage treatment plant, BOD_5 levels are not particularly high just downstream of the plant suggesting that the plant's effluent does not contain excessively high levels of organic matter.

Nitrate concentrations are also high in the River, but not to the extent that they impact the agricultural use of the water. The lack of information on the general biology of the River, especially the abundance of aquatic macrophytes, makes it difficult to determine the effect of the high nitrogen levels on aquatic life.

The degree to which trace metals and organic toxins are a problem is difficult to determine based on the information currently available. Existing information is much too limited in scope and not current enough to draw definitive conclusions. However, the fact that the River bottom consists largely of sands and silts makes it susceptible to accumulation of these substances and there is a definite need to carry out additional studies to determine the extent to which these substances may be a problem. The current trend in reduction of forage and cereal crops and increase in vegetable crops raises the likelihood that pesticide residues are or will become more of a problem. A first step would be to determine the degree to which these substances are being concentrated in aquatic organisms through the process of bioaccumulation[1].

The episodic nature of soil erosion events make it difficult to effectively monitor unless suspended sediment concentrations are measured continuously. As a result, the degree to which land erosion and sedimentation presently impair aquatic life is difficult to determine based on the limited amount of data available. The predominance of sandy soils in the watershed, together with agricultural activities and land management practices which may not be suited to the soil type, can increase likelihood of soil erosion. This is especially true in areas where the riparian zone along the main stem and tributaries of the River has been seriously degraded.

Most water quality monitoring efforts in the Cornwallis watershed have focused on abiotic factors. The use of biotic measures of water quality, especially indices of the abundance and diversity of macroinvertebrates (mainly aquatic insects, crustaceans and annelids) has become a popular and valuable tool that provides a direct indication of the health of a water body and this approach should form a part of any future water quality monitoring program.

The lack of data on seasonal variation in micronutrients makes it difficult to determine if storing spring surface runoff water in impoundments for irrigation use in the summer is a viable strategy with respect to water quality issues. Although spring runoff water, which arises largely from snow melt, would be expected to have low coliform and nutrient levels, there is insufficient data available on the impacts of short term storage of water on water quality. Any plans to develop reservoirs for storage of irrigation water must

[1] Bioaccumulation refers to an increase in the concentration of a substance in an organism over time.

include design features and watershed management practices that ensure stored water retains an acceptable level of water quality.

The design of appropriate programs for remediation of water quality problems in any watershed requires identifying the sources of pollution. Unfortunately, this is not often an easy task for watersheds, such as the Cornwallis, in which multiple land use activities occur. It becomes even more difficult when the major water quality problem being addressed is high coliform bacteria levels. The potential sources of fecal coliforms are numerous and involve both point and non-point sources. Although point sources are generally easier to identify, they are not always easy to locate, especially if they involve leaching from farm manure storage systems or on-site septic systems located along portions of tributaries distant from the River. In addition, it is not currently possible to directly determine if fecal coliforms arise from humans or other non-human warm blooded animals, which in turn makes it very difficult to determine if the source is related to agricultural activities, urban development or wildlife.

Most coliform bacteria monitoring in the Cornwallis watershed has been carried out at sites located on the main stem of the River. Although information on main stem sites is useful for determining the status of the River as a whole, it has limited utility in identifying the specific sources of pollution since most River water enters the main stem via tributary systems. Potential point sources of fecal coliform inputs include sewage treatment plants, inadequate or leaking sewage pump stations, faulty on-site septic systems, improperly designed or operated manure and silage storage facilities and direct defecation by livestock at watering areas within the River. Potential non-point sources include runoff from livestock pasture land and agricultural land fertilized with animal manures, and from wildlife, especially aquatic mammals and waterfowl such as beavers and ducks.

From a management point of view, a point source of pollution is easy to deal with once it has been identified. This is the not the case for non-point sources, especially those arising from agricultural activities. Agricultural activities within the Cornwallis watershed that contribute to poor water quality are most likely dispersed throughout the watershed and, although the impact of any one farm may be small, the total impact from all farms is potentially significant. Managing this type of impact requires finding ways to convince farmers to change agricultural practices, which are often rooted deep in tradition, and is a much more difficult task than regulating the outflow from a point source.

It should be noted that many water quality problems result from, or become pronounced, when the riparian zone of a water body becomes degraded. There is a voluminous body of information on the ecological role of riparian zones. In addition to stabilizing shorelines and reducing erosion, they have been shown to significantly reduce surface runoff of sediments, pesticides, nutrients and coliform bacteria. They are also important in providing habitat for both terrestrial and aquatic wildlife. The importance and value of these areas justifies an evaluation of the extent to which they have been degraded within the Cornwallis watershed, and the creation of programs to re-establish riparian areas that have been degraded and protect those that currently exist. This is also true of natural wetlands, which have also been shown to play important roles in water purification as well as moderation of surface runoff during periods of snow melt and high precipitation.

Identifying the activities associated with reducing water quality in the Cornwallis watershed will require studies that focus on identifying sources of pollution. The major objective should be to locate the specific areas, especially within tributaries, that experience poor water quality, and to trace these problem areas to their source. There is also a need to obtain more frequent, year round data on fecal coliform levels, suspended sediment concentrations and dissolved oxygen levels within the main stem of the River to determine how they vary seasonally, and the degree to which they are correlated with precipitation and runoff events. The latter two parameters can be economically and efficiently monitored using continuously recording data loggers.

The lead role in carrying out these monitoring activities should be assumed by the NSDEL since they have the ultimate responsibility for dealing with water quality issues.

It should, however, also utilize the substantial resources of other government agencies such as the NSDAF and, in particular, the numerous governmental and non-governmental local groups that have shown a strong interest in the water resources of the Cornwallis watershed. These include the Friends of the Cornwallis River Society, the Valley Watershed Stewardship Association, the Kings County Wildlife Association, The Growers Water Group of Horticulture Nova Scotia and The Kings County Economic Development Agency. The inclusion of all these groups in the decision making process will ensure a cooperative and holistic watershed approach in the design of monitoring and remediation programs, and that the concerns of all stakeholders will be addressed. It will also ensure that the community becomes an integral part the solution, a component that adds greatly to the success of any program that involves management of a public resource.

7.0 Recommendations

The recommendations that follow are based largely on specific activities required to identify the sources of poor water quality in the Cornwallis watershed. Recommendations for remediation activities once the sources are identified are not addressed since this information is already comprehensively documented as part of programs developed by the Resource Stewardship Branch of the NSDAF.

7.1 Specific recommendations

(1) Carry out an extensive water quality monitoring program designed to determine the sources of pollution. This program should first focus on tributaries with the objective of determining which tributaries contribute the highest pollution loads to the main River. Once this is determined, the focus should shift toward identifying specific pollution sources within those tributaries that are most problematic. The responsibility for carrying out these surveys should be given to the NSDEL, the lead agency responsible for water quality in the Province.

(2) Design and carry out a long-term general water quality monitoring program, focused on the main stem of the River, having the major objectives of (a) determining the status of the River on a yearly basis; and (b) evaluating the success of remediation activities designed to improve water quality.

(3) Employ data loggers to continuously monitor sections of the River for suspended sediment and dissolved oxygen levels to provide a better indication of the seasonal trends in these parameters, how they vary with precipitation events and to determine if they show any relationship to fecal coliform numbers.

(4) Expand the types of monitoring being carried out to include surveys of macroinvertebrate abundance and diversity.

(5) Solicit the aid of local volunteer based community groups to aid in the long-term surveys and provide them with the financial resources and training required to collect, interpret, report and databank water quality information in a reliable manner.

(6) Carry out a general survey of water column and sediment trace metal and organochlorine levels in the main stem of the Cornwallis River to determine if these substances pose a threat to agricultural use of the River or to aquatic life in the River. This should also include studies to assess the degree to which substances may have become concentrated in higher trophic levels organisms through the process of bioaccumulation.

(7) Evaluate the adequacy of the Berwick and Waterville sewage treatment plants by collating existing information on their outflows and determining the degree to which they currently meet their effluent regulations, especially during the summer months when water levels in the receiving River are low.

7.2. General Recommendations

The following recommendations, although related to water quality, are more general than those listed above, and focus on actions important in ensuring that a holistic approach is applied to any restoration activities.

(1) Carry out a survey of the status of the riparian zone along the main stem of the River and its tributaries to locate areas in which riparian zone disturbance may be contributing to water quality problems.

(2) Design and implement a program to restore and manage riparian zones that have been degraded.

(3) Establish regulations, similar to those that exist for forestry activities, to prevent degradation of existing riparian zones.

(3) Carry out a historical survey, using aerial photography and other appropriate resources, to determine the extent to which natural wetlands and groundwater recharge areas have been altered, and determine the potential for restoration of these areas,

(4) Establish and fund a water users group, or solicit and fund existing water user and related environmental groups, having representation from all levels of government and the local community, mandated to produce a long-term vision, strategy and work plan for the Cornwallis watershed in terms of its priority uses and the levels of water quality that should be achieved to meet these uses.

8.0 Conclusions

Although the data is limited, especially for times other than the summer, the information that does exist indicates that water quality in the Cornwallis River is generally poor for both agricultural use and aquatic life.

The major water quality problem for agricultural users is high coliform numbers.

The major problem for support of aquatic life is low dissolved oxygen concentrations.

There is insufficient data to determine if suspended sediments, trace metals or organochlorines are major water quality concerns.

The seasonal and spatial trends in fecal coliform numbers and dissolved oxygen suggest that water quality is poorest in the upper reaches of the River and during the summer months.

It does not appear that either the Berwick or Waterville sewage treatment plants are the major cause of high coliform numbers or low dissolved oxygen levels.

Most of the water quality information currently available is for the main stem of the River, which makes it difficult to precisely determine the sources or activities responsible for poor water quality. This seriously limits the present potential for making recommendations for remediation of poor water quality since these will depend on the nature of the cause.

The first priority in addressing the issue of poor water quality is to determine the sources of pollution.

Regardless of the sources of pollution, riparian zone restoration and management is likely to be one major activity that will produce multiple benefits for both agricultural and non-agricultural activities within the Cornwallis watershed.

9.0 Acknowledgements

Creation of this document was made possible by the Federal Government through financial assistance from the federal drought aid component of the Rural Water Development Program. This assessment would not have been possible without the cooperation of those individuals who kindly and freely shared their information. This is especially true of the NSDEL and FOCS who provided unpublished manuscripts and data files that formed the main part of the water quality database. The Dillon Consulting project team also freely provided data and maps that contributed to the assessment. Dr. Graham Daborn of the Acadia Centre for Estuarine Research of Acadia University critically reviewed portions of the report and provided many useful comments. Dr. A. Mennon of Environment Canada kindly provided permission to reproduce Figure 2.1.

10.0 References

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Appendix I

List of Abbreviations

CCME – Canadian Council of Ministers of the Environment

FOCS – Friends of the Cornwallis River Society

ISQC – Interim Sediment Quality Guideline

NCDAF – Nova Scotia Department of Agriculture and Fisheries

NSDOE – Nova Scotia Department of the Environment

NSDOEL – Nova Scotia Department of Environment and Labour

NSDOH – Nova Scotia Department of Health

PEL – Probable Effect Level

TPIM – Total Particulate Inorganic Matter

TPOM – Total Particulate Organic Matter

TSPM – Total Suspended Particulate Matter

SAR – Sodium Adsorption Ratio

SS – Suspended Solids

STP – Sewage Treatment Plant

Appendix II

Annotated Bibliography of Data Sources

Anonymous, 1961. Aspects of pollution, Cornwallis River, Nova Scotia. Survey Report of the Canada Department of Health and Welfare prepared for Public Health Engineering Division. 45 p.

The earliest comprehensive survey designed to determine the status of water quality in the Cornwallis River. At the time of the study, there was no infrastructure for treatment of effluents entering the River upstream of Kentville. Water quality was measured at 17 stations, nine were on the main River (one of which was in the tidal portion at Port Williams), five were tributaries and three were effluents streams of food processing plants. The parameters measured include colour, turbidity, pH, temperature, dissolved oxygen, BOD5, total coliform bacteria complete chemical analyses from two representative water stations. The survey was carried out over a 10 day period between 14- 23 August 1961. The conclusion reached was that the River has severe pollution problems and that "… any further increase in the volume of contributed pollutants will further intensify the degradation of the Cornwallis River and may possibly result in septic conditions." Although the coliform data was limited to total coliforms, the data collected on most parameters appears to be of high quality considering the methodologies available at the time of the study.

Allen, M. 1998. A survey of biological oxygen demand and dissolved oxygen in the Cornwallis River, Kings County, Nova Scotia. Honours Thesis, Environmental Science Program, Acadia University, Wolfville, Nova Scotia. 47 p.

An Honours thesis assessing biological oxygen demand and dissolved oxygen levels in the main stem and a number of tributaries of tributaries of the Cornwallis River. This study was carried out between 9 July and 6 August 1997. Also includes data on ammonia and nitrate levels. A total of 17 sites were surveyed: 10 main River sites, 5 tributary sites, 2 industrial effluents. The study was carried out under the supervision of Dr. Michael Brylinsky, a research Scientist at the Acadia Centre for Estuarine Research, Acadia University. The data is considered to be of good quality.

Allen, M., A. Nelson and M. Brylinsky.1999. A survey of water quality in the Cornwallis River, Kings County, Nova Scotia, p. 226-239. *In* Partnerships in Water Resource Management: Proceedings of the Canadian Water Resources Association 52nd Annual Conference. Canadian Water Resources Association.

This is basically a summary of the work carried out by Allen (1998) and Nelson (1998) with some additional data collected by the Friends of the Cornwallis River during the summer of 1998.

Brylinsky, M. 2002. Unpublished data files.

Data collected as part of field work by Allen (1998) and Nelson (1998), but not included in the theses. Includes information on suspended solids, water temperature, conductivity, pH and alkalinity.

Dalziel, J.A. 1958. Pollution report: The M.W. Graves Company Limited Fruit and Vegetable Cannery, Cornwallis River, Kings County, Nova Scotia. Unpublished report, NSDOE files. 7 p.

This appears to be the first study of water quality in the Cornwallis River. It was carried out in response to reports of fish kills and foul odours in a section of the River receiving untreated effluents form a vegetable cannery located near Berwick. The survey was carried out from 4-9 August 1958. Water temperature, dissolved oxygen and pH were measured at 14 stations, six within a tributary carrying the waste to the River, and eight at stations located within the main stem of the River. It was concluded that water quality was seriously degraded within the tributary carrying the effluent and for about 8 km downstream of where the tributary entered the main stem of the River.

Gordon, R. 2002. An integrated assessment of water quality in a rural watershed. Final Report submitted to AWARD, Nova Scotia Department of Agriculture and Fisheries.34 p.

This is the only intensive study of a subwatershed within the Cornwallis watershed. Fecal coliform bacteria, phosphorus and nitrogen exports were studied over spatial and seasonal scales from May to December 2001. The results indicated high loading of all three parameters and there is some discussion as to the possible sources. This paper contains high quality data and is an excellent example of the kind of water quality monitoring that should be carried out to better identify pollutant sources.

Mackie, J. 1971. Status of pollution: The Cornwallis River, Kings County, Nova Scotia, Summer 1971. Report to the Federal Opportunities for Youth Program. 37 p.

The objective of this study was to analyse the extent of pollution and type of pollutants discharging into the Cornwallis River. This study was carried out by faculty and students in the Geology Department of Acadia University. A total of 15 stations were sampled during July 1971, two which were located in the tidal portion of the River below Kentville. Water quality parameters measured included total coliform bacteria, pH, and sediment analyses for Cu, Zn, Pb and As. It was concluded that with respect to total coliform bacteria, the River is badly polluted, possibly to a greater extent than reported in the 1961 study by the Canada Department of Public Health and Welfare (Anonymous 1961). There was, however, little indication that River sediments contained concentrations of heavy metal above that found in normal, unpolluted stream sediments. The quality of the data is difficult to assess based on the limited information presented regarding methodologies and it is not clear what the units are for the reported concentrations of trace metals. This report contains no useful data.

McMillan, J. 2003 Temperature mapping project results. Unpublished, Nova Scotia Department of Agriculture and Fisheries files.

This report consists of an Excel spreadsheet containing information on water temperatures in a number of Cornwallis River tributaries. The tributaries are classified with respect to water temperature as being either cold, intermediate or warm.

Menon, A.S. 1985. Salmonellae and pollution indicator bacteria in municipal and food processing effluents and the Cornwallis River. Can. J. Microbiol. 31: 598-603.

This study dealt largely with the pathogenic microbiology of the Cornwallis River. The numbers of fecal coliforms, fecal streptococci, *Aeromonas hyrophilia* (a known fish pathogen and possibly a human pathogen) and *Salmonella* spp were measured in the effluent streams of four fruit and vegetable canneries, one meat packing plant, one poultry processing plant, one potato processing plant, seven sewage treatment plants and at 13 locations along the main River. Samples were collected weekly during the summer months. The results indicated very poor bacterial water quality as a whole, especially with respect to effluents from five of the seven sewage treatment plans and the meat and poultry packing plants. The main River was also found to have high fecal coliform counts and contained five *Salmonella* serotypes. The author concludes that "There is little doubt that the discharge of untreated municipal and food processing wastes in the Cornwallis River seriously affects the water quality and poses a potential health hazard to the recreational uses of the River." This study was carried by highly trained microbiologists and is considered to contain exceptionally good quality data.

Musial, C. 1975. Incidence and distribution of chlorinated hydrocarbons in the Cornwallis River. MSc. Thesis, Acadia University, Wolfville, Nova Scotia.

This study involved a survey chlorinated hydrocarbons in Cornwallis sediments. A total of x sites were investigated.

Nelson, A. 1998. A survey of fecal coliform levels and related water quality parameters in the Cornwallis River, Kings County, Nova Scotia. Honours Thesis, Environmental Science Program, Acadia University, Wolfville, Nova Scotia. 45 p.

An Honours thesis assessing the levels and distribution of fecal coliform bacteria within the main stem of the Cornwallis River and a number of tributaries discharging into the River during the period from 25 June to 6 August 1997. Found fecal contamination to be widespread. Also carried out a historical survey of fecal coliform bacteria collected during 1989 and 1993 and concluded that there has been little change between 1989 and 1997. The analysis of coliform samples was carried out under the supervision of Dr. Colin Bell of the Biology Department, Acadia University. Data is considered to be highly reliable.

Smith, L. 2002. A survey of fecal coliform levels and assessment of local management ability in the Cornwallis River, Nova Scotia. Honours Thesis, Environmental Science Program, Acadia University, Wolfville, Nova Scotia. 35 p.

A survey of 11 sites, 9 main stem and 2 tributary, along the Cornwallis River was carried out biweekly during the period between 9 October and 2 November 2001. The results revealed that fecal contamination was widespread and, in almost all instances, fecal coliform numbers exceeded the levels considered acceptable for use as irrigation water. An attempt was also made to identify the source of fecal coliforms based on an analysis of the relationship between fecal

coliform numbers and land use. It was concluded that runoff from agricultural lands is likely to be a major source of fecal coliforms in the Rivers. The laboratory analysis for fecal coliforms was carried out at Acadia University under the guidance of Dr. Gregory Bezanson, an experienced microbiologist. The data collected is considered to be of high quality.

Appendix III

Database Summary