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Prepared by:
Michael Allen, Alanna Nelson, Michael Brylinsky

Acadia Centre for Estuarine Research,
Acadia University, Wolfville, Nova Scotia BOP 1X0
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A SURVEY OF WATER QUALITY IN THE CORNWALLIS RIVER, KINGS COUNTY, NOVA SCOTIA

Michael Allen[1], Alanna Nelson[2], Michael Brylinsky[3]

ABSTRACT

The Cornwallis River, Kings County, Nova Scotia, is one of the most seriously degraded rivers in the province. Surveys conducted in 1997 and 1998, and historical data dating back nearly forty years, were analyzed to determine current and historical trends in water quality within the river. Biological oxygen demand and ammonia levels are high in the upper parts of the river and tend to decrease down river. Dissolved oxygen concentrations are inversely correlated to biological oxygen demand and are often below fifty-percent saturation. Coliform numbers are high throughout the river, exceeding acceptable levels for drinking, recreation, and most agricultural uses. Despite the current poor water quality, analysis of historical data revealed that biological oxygen demand and dissolved oxygen levels have improved over the last several decades. An analysis of the relationship between land use patterns and coliform levels suggests that agricultural activities are important contributors to the high coliform numbers observed.

RÉSUMÉ

On peut soutenir que la rivière Cornwallis, dans le comté de Kings en Nouvelle-Écosse est l'une des rivières les plus gravement dégradées de la Nouvelle-Écosse. Des enquêtes menées en 1997 et en 1998 et des données historiques qui remontent à près de quarante ans ont fait l'objet d'analyses pour déterminer les tendances actuelles et historiques de la qualité de l'eau dans la rivière. Les taux de demande en oxygène biologique sont élevés dans les parties supérieures de la rivière et tendent à décroître vers le bas de la rivière. Les taux d'ammoniac présentent la même tendance. Les taux d'oxygène dissous sont inversement corrélés à la demande en oxygène biologique et sont souvent en-deça d'une saturation de cinquante pour cent. Le nombre des coliformes est élevé dans toute la rivière et il dépasse les niveaux acceptables pour l'eau potable et pour les usages récréatifs et agricoles (irrigation et abreuvement du bétail). En dépit de la piètre qualité de l'eau actuelle, une analyse de données historiques remontant à 1961 a révélé que la demande en oxygène biologique et les taux d'oxygène dissous se sont améliorés. Une analyse de relation entre les modèles d'utilisation des sols et les taux de coliforme indique que les activités agricoles sont d'importants facteurs contribuant au nombre élevé de coliformes ayant été observé.

INTRODUCTION

Background

Kings County lies in the heart of the fertile Annapolis Valley, Nova Scotia. It is a scenic and prosperous area, heavily dependent on agriculture. Bounded by the North and South Mountains, the valley provides an ideal catchment area for several rivers which flow to and along its floor. One of the more prominent river systems is the Cornwallis River, Kings County, which is approximately 50 km long and has a

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[1] Friends of Cornwallis River Society, PO Box 470, Port Williams, Nova Scotia B0P 1T0, [2] Environmental Science Program, Acadia University, Wolfville, Nova Scotia B0P 1X0, [3] Acadia Center for Estuarine Research, Acadia University, Wolfville, Nova Scotia B0P 1X0.

drainage basin covering about 400 km^2. Because of the excellent underlying aquifers (the Wolfville and Blomidon formations), the river is fed by groundwater springs as well as overland flow. The Cornwallis River is a valuable community resource used by wildlife (habitat), agriculture (irrigation and livestock watering), industrial sectors (wastestream), and recreationalists (sportfishing).

Historically, the Cornwallis River system has suffered from poor water quality. Fish kills were reported in August 1968, 1973, 1985, 1988 (Coleman 1997) and August 26, 1997 (Personal Communication, Bob Petry, N.S. Department of the Environment). The 1988 incident resulted in closure of the river for swimming, irrigation, and livestock watering. On June 23, 1989, the Nova Scotia Department of Health and Fitness deemed water in the river unfit for the irrigation of certain food crops (Corriveau, 1989). Such incidents have a negative impact on all uses of the resource and reflect badly on the biological integrity of the entire Cornwallis River system. Many factors, such as agricultural practices, sewage treatment facilities, and faulty on-site sewage disposal systems, have been blamed for pollution of the river.

Documentation of pollution problems in the Cornwallis River dates back to the 1960's (Department of National Health and Welfare, 1961) when the biological condition of the Cornwallis River was stated as being "bad" or "doubtful" over its entire length with no self-contained means for adequate remediation. In 1971, a project sponsored by the Federal Opportunities for Youth Program concluded that the river "...is still badly polluted, possibly to a greater extent than in 1961 - a negative indication in itself." A 1978 study (Environment Canada: Conservation and Protection Division) concluded that organic nutrient pollution was occurring within the entire river at varying degrees and was probably due to agricultural land drainage and the dumping of industrial and/or municipal wastes.

Objectives

The major objective of this study was to analyze both recent and historical water quality data from the Cornwallis River in order to determine current and past trends, and to use these trends as a tool for identifying critical problem areas and the probable pollution sources. This was accomplished largely through the investigation of fecal coliform bacteria counts, biological oxygen demand levels, and dissolved oxygen concentrations, which are the most serious degraded water quality parameters in the river. Ammonia levels were also examined as an indication of the presence of sewage inputs. Furthermore, these are some of the most critical factors concerning the biological health of the system and use of the river by both wildlife (habitat) and humans (natural resource).

Fecal coliforms are a group of non-pathogenic bacteria used to detect contamination of water by the feces of warm-blooded animals (Valiela et al., 1991). Fecal coliform levels are of great concern because fecal pollution can adversely affect human health. Guidelines for use of water with respect to fecal coliform levels prepared by the Canadian Water Quality Guidelines (1990) are: 0 per 100 ml for drinking water; less than 200 per 100 ml for recreational activities and; less than 100 per 100 ml for irrigating crops and watering livestock.

Biological oxygen demand (BOD) levels indicate the amount of biodegradable organic material in an aquatic ecosystem. When aerobic bacteria metabolize dissolved organics, oxygen is consumed in the process. High BOD levels can result in the depletion of dissolved oxygen. BOD levels greater than 4 - 5 mg/l are considered an indication of excessive organic input.

Dissolved oxygen (DO) is a critical factor concerning the health of many aquatic organisms. High levels are favorable for healthy conditions. As previously mentioned, it is affected by organic pollution, but also by water temperature and the occurrence of re-aeration zones in a river system.

When nitrogenous organic matter is aerobically decomposed, it results in production of ammonia (NH_3). According to the Guidelines for Canadian Drinking Water Quality (1993), the presence of NH_3 at concentrations above 0.2 mg/l is an indication of excessive contamination.

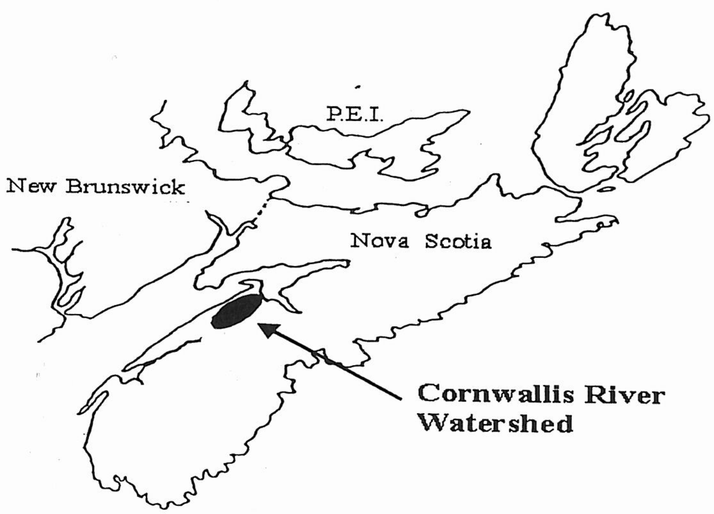

Figure 1. Map showing location of the Cornwallis River Watershed

METHODS

Fecal coliform, BOD, DO, and NH_3 data from the Cornwallis River collected over nearly forty years was analyzed to determine current and historical trends in water quality. This data came from studies during the summers of 1998 (Allen, 1999) on behalf of the Friends of the Cornwallis River, 1997 (Allen, 1998) and Nelson (1998), 1993 and 1989 (Nova Scotia Department of the Environment Files), 1978 (Environment Canada: Conservation and Protection Division, 1978), and 1961 (Department of National Health and Welfare, 1962). It should be added that not all studies covered every water quality parameter.

Land use data from 1997 (Allen, 1998; Nelson ,1998) and rainfall data provided by the Kentville Agricultural Research Station was analyzed to aid in identifying current pollution sources. Further, data from an impact analysis of the Berwick sewage treatment plant (Berwick STP) on behalf of the Friends of the Cornwallis River Society (FOCRS) during the summer of 1998 (Allen, 1999), was examined to determine the effect of this facility on the river.

Main stem sampling stations common to the majority of studies were used in this survey. This included those from Kentville to north of Berwick. The area below Kentville was not included as this part of the river is subject to heavy tidal flushing. In addition, tributary sampling stations from the 1997 survey (Allen, 1998) and Nelson (1998), and main stem stations from the Berwick STP impact analysis (Allen, 1999), were used in this investigation.

Table 1. Sampling stations on the main stem and tributaries of the Cornwallis River and distance (km) upriver from Kentville Bridge

Main Stem Stations		Tributary Stations	
Name	Distance (km)	Name	Distance (km)
Kentville Bridge	0.00	Tupper Brook	4.85
Lovett Bridge	10.28	Black Brook	7.20
South Bishop Bridge	14.58	Chute Brook	8.20
Cambridge (Woodville Rd.)	18.69	Coleman Brook	10.85
Waterville (Correctional Center)	21.85	Brandywine Brook	10.85
Black Rock Road	25.50	Spidle Brook	14.32
Shaw Road	28.94	Tupper Lake Brook	17.81
Willow Avenue	30.78	Fishwick Brook	25.10
Commercial Street (Berwick)	32.20	Rochford Brook	25.15
Berwick North	34.22	Morris Brook (1)	27.12
Shaw Bridge	36.30	Morris Brook (2)	28.31
		White Brook	32.21
		Rand Brook	32.21
		Thomas Brook	34.00
		Fisher Brook	36.10

Table 2. Stations sampled on August 28, 1998 for an impact analysis of the Berwick STP and distance (km) upriver from Kentville Bridge

Station Name	Distance (km)
Shaw Road	28.94
Willow Avenue	30.78
Downriver STP (Below Berwick STP)	31.38
Berwick STP (Outfall)	31.78
Commercial Street (Berwick)	32.20

RESULTS

Biological Oxygen Demand and Dissolved Oxygen In the Cornwallis River

1961 and 1978 Data: Studies performed under the direction of the Department of National Health and Welfare (1961) and Environment Canada: Conservation and Protection Division (1978) were used in this assessment. In 1961, a significant rise in BOD_5 (>15 mg/l) was noted below Morris Brook(s) approx-iamately 26 km upriver of the Kentville Bridge as shown in Figure 2. The BOD_5 was also high at Shaw Rd. (28.94 km). As expected, % DO saturation levels were negatively correlated with BOD_5. The BOD_5 level was extremely high (276-329 mg/l) in Morris Brook 2 (28.31 km), in the vicinity of the high river values, and the % DO saturation level in this tributary was corresondingly low (Figure 2). At the time, raw effluent was entering Morris Brook 2 via a fruit and vegetable processing plant.

Only the DO data from 1978 could be analyzed. Percent DO saturation levels (Figure 3) were low overall and there was a profound decrease in the area of Shaw Rd. and Willow Ave. (30.78 km). The Berwick STP would have been established at the time, and its effluent would have entered the river above these sites.

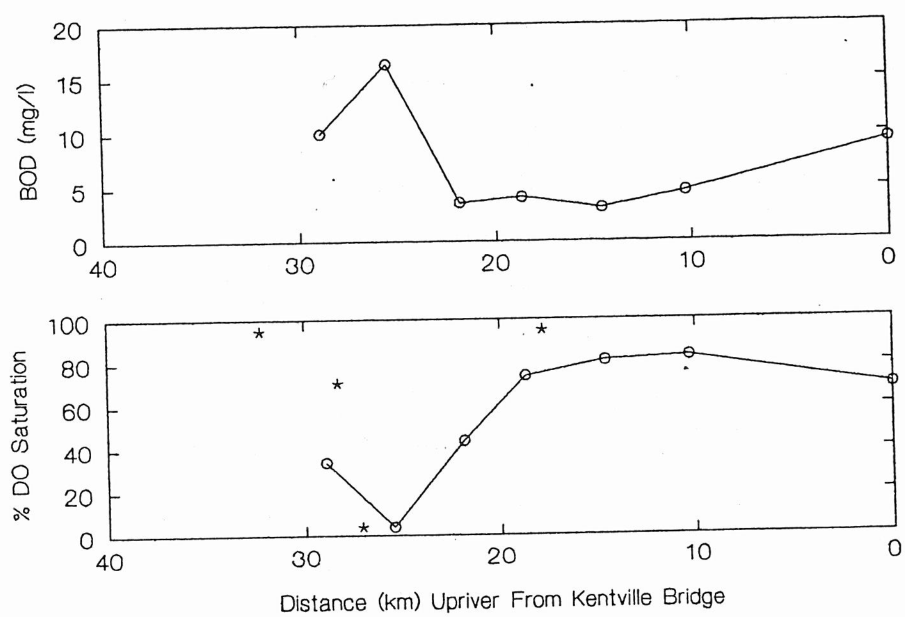

Figure 2. Average BOD_5 and % DO saturation profiles for the Cornwallis River and selected tributary values (*) during summer 1961

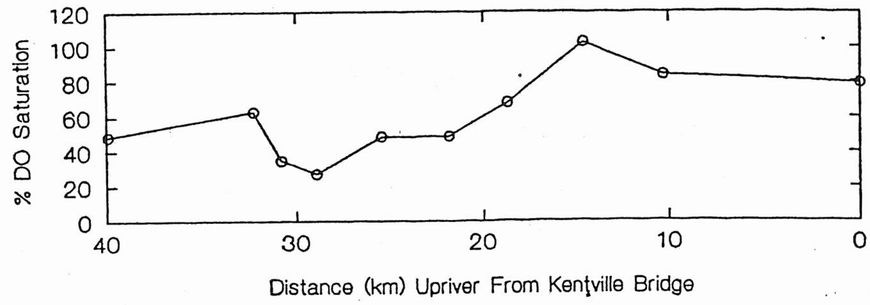

Figure 3. Average % DO saturation profile for the Cornwallis River during summer 1978

1997 and 1998 Data: Studies conducted by Allen and Nelson (1998) and FOCRS (Allen, 1999) were analyzed to reveal the following. BOD_5 and % DO saturation profiles were mainly consistent between the summers of 1997 and 1998 (Figure 4). DO concentrations exhibited a strong negative correlation to BOD_5 levels. In each case, conditions were satisfactory in the lower reaches of the sampled river section. However, at Shaw Rd. (28.94 km) and Willow Ave. (30.78 km), BOD_5 levels were high enough to seriously deplete DO. NH_3 concentration showed a positive correlation to BOD_5 levels in this same area during 1997, and levels were high enough to indicate contamination (> 0.9 mg/l) as shown in Figure 5. Although the BOD_5 levels were not overly high at Berwick North (34.22 km) and Shaw Bridge (36.30 km), DO concentration was lower here as well (Figure 4). Overall water quality with regards to BOD and DO levels were poorer during the summer of 1998 than the summer of 1997.

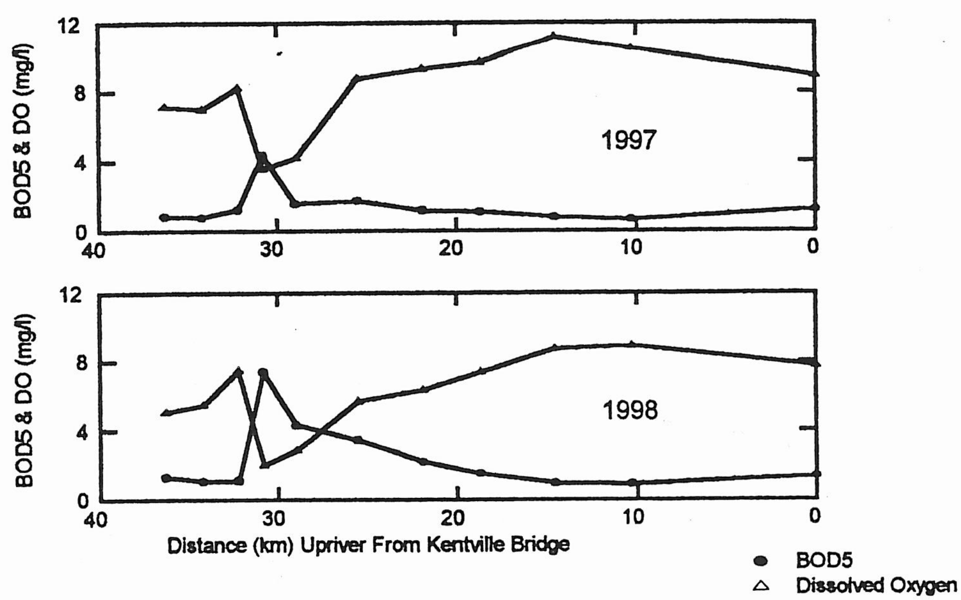

Figure 4. Average BOD_5 versus DO profiles for the Cornwallis River during summers 1997 and 1998

The Berwick STP was the probable source of the DO depletion problem at Willow Ave. and Shaw Rd. during the summer of 1997 survey. This was proven to be the case with an impact analysis of the facility on August 28, 1998. As shown in Figure 6, the BOD_5 value at Commercial St. was low (1.00 mg/l) relative to that which was coming out of the outfall pipe (23.60 mg/l). In response, levels in the river below the outfall were much higher (12.98 mg/l) and decreased downriver. The true impact of this organic effluent is illustrated in the DO histogram in Figure 6. Although the DO of the effluent was higher than the river above, the level decreased as a result of BOD once it entered the river. The DO did not start to recover until Shaw Rd., nearly 3 km downriver of this input. Also, on August 28,1998, river flow was measured at Commercial St. for comparison with the effluent volume at the Berwick STP. The average river flow was 12 m^3/sec. For the month of August, the effluent volume was estimated at 600,000 gpd or 0.032 m^3/sec (Personal Communication, Vic Spencer, Regional Plant in New Minas). Therefore, the effluent was at least 25 percent of the river volume above. It is clear that this was above the assimilative capacity of the river in this area.

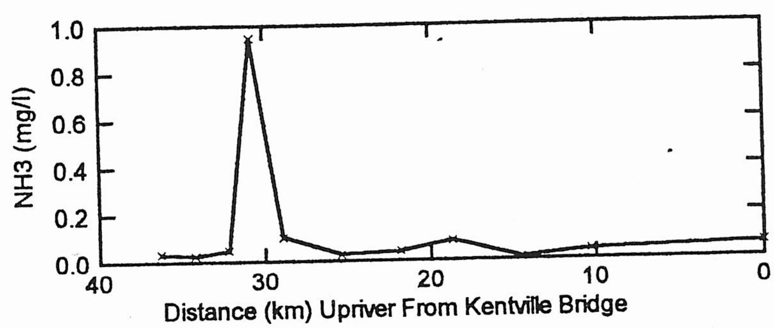

Figure 5. Average NH_3 profile for the Cornwallis River during summer 1997

On August 20, 1998 and August 6, 1997, the highest BOD_5 levels were observed at Waterville (21.85 km) and Black Rock Rd. (25.50 km) as opposed to Shaw Rd. and Willow Ave. Coincidentally, the most substantial rainfalls of the summer occurred in the three day period before these dates (Table 3).

Table 3. Amount of rainfall recorded in the three days prior to each sampling day and data for past rainfall levels (provided by the Kentville Agricultural Research Station)

Date	Prior 3-day Rainfall (mm)	Total Rainfall for August (mm)	5 year average for August (mm)	37 year average for August (mm)
August 6, 1997.	21.7	54.7	55.1	92.7
August 20, 1998.	24.5	51.3	-	91.5

Fecal Coliform Bacteria in the Cornwallis River

1997 and 1998 Data: Studies conducted by Nelson (1998) and the Friends of the Cornwallis River Society (Allen, 1999) were analyzed. The Cornwallis River was sampled only once (July 30th) during the summer of 1998 for fecal coliforms. There were high levels overall (Figure 7) with two peaks at Cambridge (18.69 km) and Commercial St. (32.20 km). A sharp decline in fecal coliform levels was noted at Willow Ave. (30.78 km). Lower concentrations were also noted at Shaw Bridge (36.30 km) and Kentville Bridge (0 km). Levels on July 30, 1998 ranged from 180 to 2295 fecal coliforms per 100 ml and the average count was 748 per 100 ml.

Fecal Coliform levels in the main river during the summer of 1997 were very similar to the July 30, 1998 profile except at Kentville Bridge (Figure 7). Both exhibited rises at Commercial St. and in the area of Black Rock Rd. (25.50 km) to Cambridge and a sharp decine at Willow Ave. (below Berwick STP). The 1997 results however, displayed a tremendous rise in fecal coliforms at Kentville Bridge. The average concentration at this site was 21,000 per 100 ml. Most sites in 1997 had values which exceeded 200 fecal coliforms per 100 ml, the allowable limit for recreational and agricultural uses.

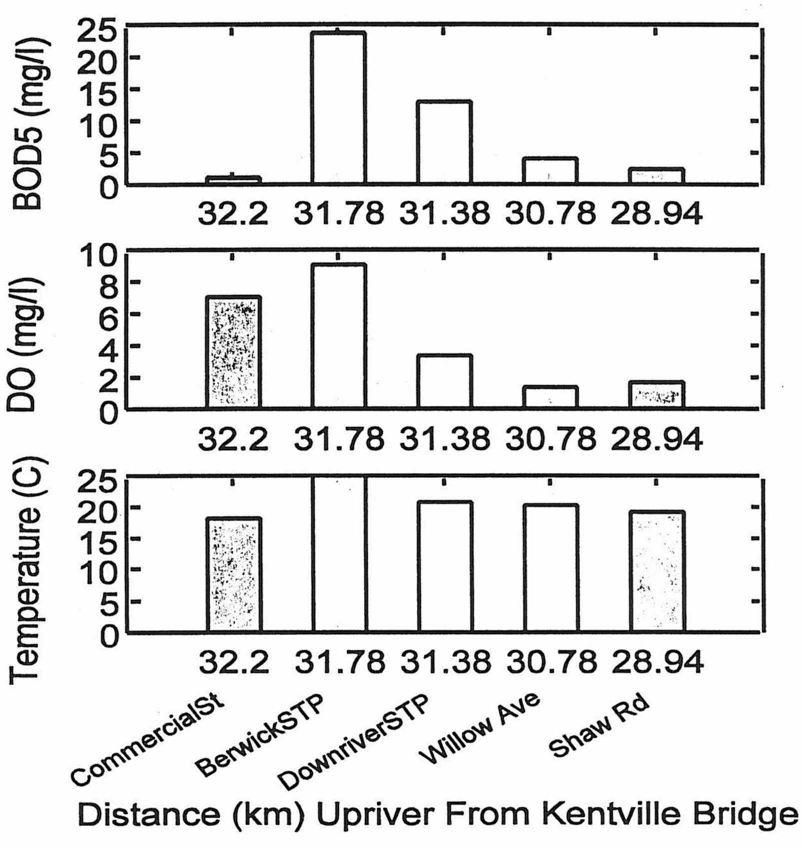

Figure 6. BOD_5, DO, and temperature levels at the Berwick sewage treatment facility outfall and in the Cornwallis River above and below this point on August 28, 1998.

The Berwick STP outfall (31.78 km) appears to be beneficial in lowering the fecal coliform levels in the river. Although the fecal coliform concentrations below this input were not at acceptable levels, they were lower than at the sites above. This could be due to fecal coliform concentrations in the effluent being lower than in the river in this area.

Fecal coliform bacteria levels were high in tributaries of the mid to upper portion of the sampled area of the Cornwallis River watershed (Figure 8). White Brook (32.21 km) and Fisher Brook (36.10 km) exhibited the the highest concentrations at over 2000 per 100 ml. Tributaries in the Berwick area had much higher levels than those near Kentville. For the most part, fecal coliform levels were higher in tributaries flowing from the north than those flowing from the south (Figure 8).

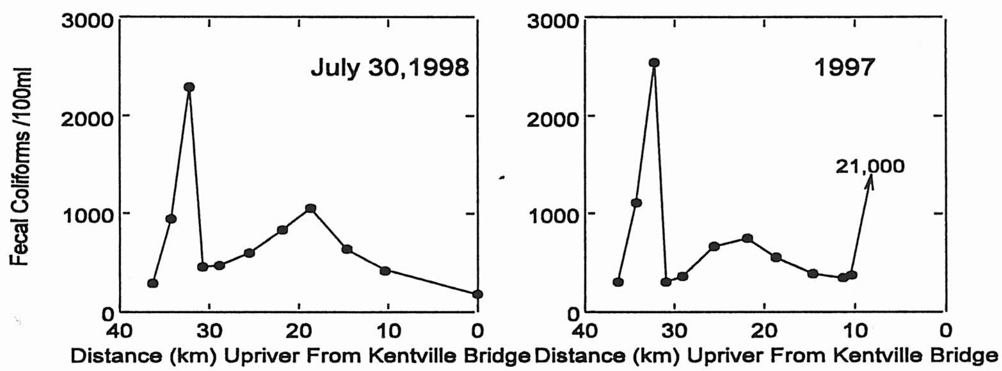

Figure 7. Fecal coliform profile for the Cornwallis River on July 30, 1998 and the average profile for summer 1997 (21,000 refers to average concentration at Kentville Bridge)

High fecal colifom counts in northern Berwick during the past two summers, especially at Commercial St., could be due to agricultural practices. Tributaries in this area (White and Rand Brooks, for example) exhibited the highest fecal coliform concentrations (1300-2200/ 100 ml) and their watersheds are comprised of 40-60 % agricultural land use (Figure 9). Fishwick Brook had high fecal coliform levels as well, and a watershed comprised of nearly 40 % agricultural land. This may also explain why north tributaries had higher levels than south tributaries as shown in Figure 8. There is more intense agricultural activity on the north side of the Annapolis Valley due to the better drainage and soils. However, due to low runoff, a point source such as a faulty on-site waste disposal system could also have played a role.

1989 and 1993 Data: Profiles for fecal coliform bacteria levels in the Cornwallis River in 1989 and 1993 were produced from historical fecal coliform data provided by the Nova Scotia Department of the Environment. The 1989 profile (Figure 10) exhibited lower levels than in 1997 and 1998. However, the

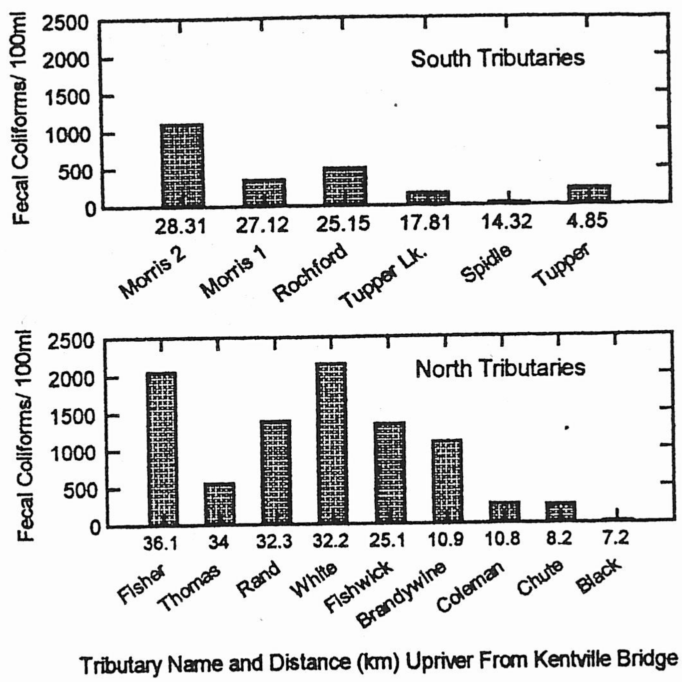

Figure 8. Average fecal coliform levels for each of the tributaries sampled during summer 1997

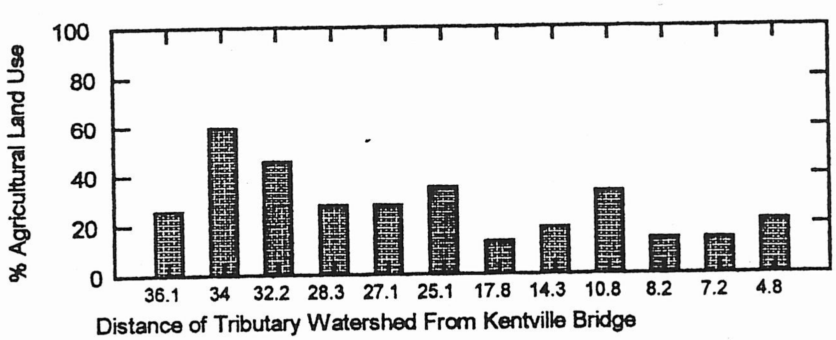

Figure 9. Percent agricultural land use for each tributary watershed sampled during summer 1997

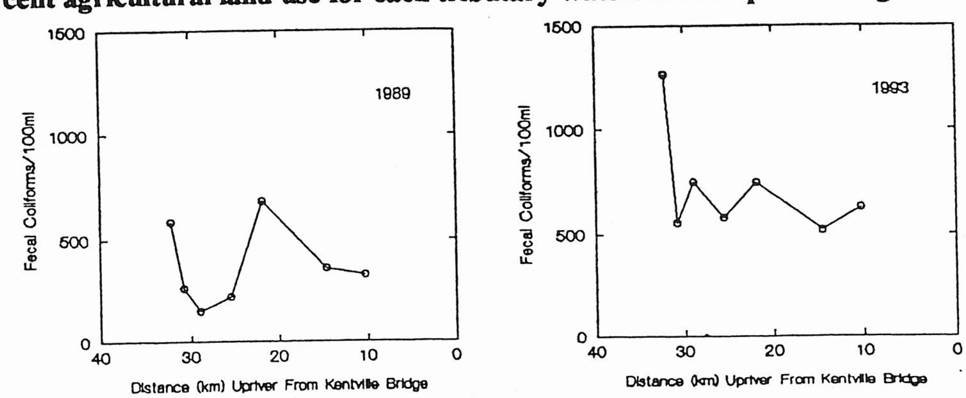

Figure 10. Average fecal coliform profiles for the Cornwallis River for summers 1989 and 1993

profile itself was essentially the same with peaks at Waterville (21.85 km) and Commercial St. (32.20 km) and a sharp decline at Willow Ave. (30.78). The 1993 profile (Figure 10) exhibited poorer conditions with all values in the river exceeding 500 fecal coliforms per 100 ml. Again, this profile showed peaks at Commercial St. and Waterville, but differed with a rise at Shaw Rd. (28.94 km).

DISCUSSION AND CONCLUSIONS

Current Trends in Water Quality in the Cornwallis River

BOD_5 levels in the Cornwallis River during the past two summers (1997 and 1998) have been satisfactory except at Willow Ave. and Shaw Rd. for most dates sampled, and at Black Rock Rd. and Waterville on August 6, 1997 and August 20, 1998. The BOD_5 levels occurring at these sites were high enough to deplete DO concentrations to seriously low levels. Although BOD_5 levels were not overly high north of Berwick (Berwick North and Shaw Bridge), DO concentrations were low there as well.

The most likely cause of the degraded conditions at Willow Ave. and Shaw Rd. is the Berwick STP outfall. This input, in combination with dry, hot weather and continuous withdrawal of water for irrigation, can have a severe impact on the Cornwallis River in this area. These conditions hamper the river's assimilative capacity and it is unable to handle the pollution load. Currently (1999), the Berwick STP is undergoing an upgrade to improve the quality of its effluent with regards to BOD_5, suspended solids, and bacteria (i.e. coliforms). This will involve implementing both filtering and disinfection units at the facility (Personal Communication, Sandy Dewar, Hiltz and Seamone Co. Ltd.).

In the three days prior to August 6, 1997 and August 20, 1998, when elevated BOD_5 levels occurred at Black Rock Rd. and Waterville, Kings County recieved the largest rainfall of the summer. During both summers, due to drought conditions and irrigation, there were extremely low flows and stagnant stillwater conditions at Willow Ave. and Shaw Rd. The rainfall may have caused a flushing of degraded water present at these sites downstream to the vicinity of Black Rock Rd. and Waterville. Another possibility is that the rainfall caused some overland flow and non-point source pollution from adjacent lands, some of which is agricultural. Thirdly, Black Rock Rd. is downriver from the Morris Brook system on which there is a lift station that pumps waste from a vegetable processing plant to the Bewick sewage treatment facility. Malfunctions due to the rain event may have occurred allowing some overflow. However, on the basis of just these two events, no solid conclusion can be made as to the cause of the elevated BOD_5 at these sites except that it was associated with rainfall. It is suggested that under wet, rainy conditions, there may be a substantial organic pollution source in this area of the watershed.

Fecal pollution is currently a major problem in the entire Cornwallis River watershed but especially in the Berwick area. There are direct recreational, social, and economical impacts associated with this contamination. Potential pollution sources include agricultural acivities (cattle watering and manure spreading) and faulty on-site waste disposal systems. In many areas of the Cornwallis River, cattle frequent the riparian areas and enter the river and brooks. In a summary of studies by Baxter-Potter and Gilliland (1988), the presence of cattle was shown to directly affect the concentration of fecal coliforms in streams. Fecal coliform levels often increase rapidly when cattle are introduced and continue to be high until cattle are removed (Baxter-Potter and Gilliland, 1988).

In 1997, the Kentville Bridge site exhibited extremely high fecal coliform counts (21,000/ 100 ml on average) which was not seen in 1998 (one sample set). Between the two sampling periods, work was done to correct a problem of sewage entering a storm drain system which flows into the river beneath the old railway bridge in Kentville (above Kentville sampling site) (Personal Communication, Bob Rowe, N.S. Department of the Environment). It is probable that this may have remediated the immense fecal contamination problem at the Kentville Bridge and resulted in the low level found here on July 30, 1998.

Historical Trends in Water Quality in the Cornwallis River

Comparison of results of studies carried out over the last several decades shows that, generally, water quality in the Cornwallis River is improving with respect to BOD and DO. However, there appears to be a worsening of conditions during the summer of 1998 (Table 4). It is felt that this decline in water quality was due to extensive drought conditions and water extraction practices, which rendered water levels extremely low and decreased the river's assimilative capacity.

Improvement in water quality can be attributed to the fact that over the past forty years, treatment facilities have been constructed and upgraded to handle both industrial and municipal wastes. Past studies such as that of 1962 (Department National Health and Welfare) helped establish the need for wastewater treatment facilities. Biological conditions in the Cornwallis River should keep improving with such measures as the current upgrade at the Berwick sewage treatment facility.

Table 4. Average BOD_5 and % DO saturation in the Cornwallis River during summers 1961, 1978, 1997, and 1998

Year	Average BOD_5 (mg/l)	Average % DO Saturation
1998	2.38	64.4
1997	1.53	82.1
1978	-	60.4
1961	7.30	55.6

With respect to fecal coliform levels, the trend is not so optomistic. Despite increasing awareness of this problem, it appears that there has been no overall improvement in the past ten years, as shown in Table 5.

Table 5. Average fecal coliform levels in the Cornwallis River for 1989, 1993, 1997, and 1998.

Year	Period Sampled	Average Fecal Coliforms/ 100ml
1998	30th July	747
1997	June 25th to August 6th	755
1993	May 26th to August 24th	739
1989	April 25th to August 29th	388

The only discernable difference in fecal coliform numbers was in 1989, the oldest survey analyzed for this parameter. High counts in 1997 and 1998 are indicative of extremely dry weather conditions. Year to year variations in fecal coliform levels may depend on precipitation, time of year sampled, unidentified factors, and combinations of the aforementioned. As it stands, fecal pollution is a serious problem for the entire Cornwallis River watershed.

The Cornwallis River has been sampled regularly only during the summer months. Because of this, one is left with an incomplete picture of its seasonal cycles. Current studies are mainly indicative of extremely dry conditions when low rainfalls and substantial amounts of the river's water was being extracted for irrigation. similar studies under more normal conditions are required to determine if similar trends are typical.

ACKNOWLEDGEMENTS

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