South Nation Conservation

Water Quality Monitoring Review

Thompson Rosemount Group
The St. Lawrence River Institute of Environmental Sciences

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1.0 Introduction

1.1 Purpose and Objectives

South Nation Conservation (SNC) has embarked on a process to review current water quality monitoring activities. In particular, SNC are particularly interested in addressing the following issues:

- *Is watershed water quality changing over time?*
- *Is the watershed health improving?*
- *Are SNC non-point source abatement programs effective at improving water quality?*

The Thompson Rosemount Group (TRG) in partnership with the St. Lawrence River Institute of Environmental Sciences (SLRIES) was retained by SNC to review and re-focus water quality monitoring activities.

To address these issues, several long-term objectives have been identified by SNC:

- Document watershed health and water quality conditions;
- Provide temporal and spatial trend analysis;
- Develop a plan to document the effectiveness of the SNC water quality initiatives;
- Prioritize and optimize the SNC monitoring strategy for physical, chemical, and biological indicator monitoring in a cost effective manner.

The specific tasks associated with this report are:

- Evaluation of the current flow monitoring plan;
- Review of the Provincial Water Quality Monitoring Network (PWQMN) and Watershed Characterization programs for locations, frequency and parameters;
- An evaluation of volunteer resources;
- Development of bio-monitoring criteria;
- Recommendation of simple techniques to demonstrate water quality changes;
- Recommendations to monitor nutrient levels (eutrophication) and surrogate indicator(s) of phosphorus;
- Incorporate the above into an overall water quality monitoring plan.

To accomplish the specific objectives, and in order to become thoroughly familiar with the characteristics of the watershed, a detailed review and analysis of hydrological, chemical and biological data collected on the South Nation watershed was carried out. Past reports and pertinent scientific literature on the watershed were also reviewed. Discussions with SNC staff responsible for water quality monitoring and some field observations were also conducted. This information was used to provide recommendations for an integrated water quality monitoring plan to address SNC objectives.

2.0 Results and Discussion

2.1 Hydrological Assessment

In order to assess the adequacy of the stream gauge network, it is important to understand the role of hydrology as a master variable in the watershed. A review of the existing stream gauges was undertaken in the context of the water quality component as part of the overall monitoring assessment. In addition to analysis of the temporal and spatial characterization of the flow data, a comparison of the hydrological function of South Nation watershed to other watersheds was also completed.

Based on a review of existing studies, it is evident that land use plays an important role not only in stream flow but also water quality - a term described as its 'hydrologic function' (Watelet and Johnson 1996). The studies that were reviewed include existing work on the South Nation watershed (Wickware 1989, SNRCA 1983) as well as other similar basins (Watelet and Johnson 1996, Richards 1998).

Stream gauge data for the basin was compiled from the Environment Canada water gauges for the South Nation watershed are shown on Figure 1 and listed on Table 1. The data was obtained from Environment Canada (Hydat 1998). This CD-ROM format database contains mean daily and mean monthly flows. This database was used for hydrological assessment. The data record ranges from 80 years (1915 to 1995) for the South Nation at Plantagenet to 16 years (1979 to 1995) for the West Scotch River near St. Isidore. The 4 gauging stations that had discontinuous records or much missing data were not analyzed.

Table 1 - Summary of Stream Gauge Locations and Record Duration

Location	Reference Number	Period of Record	Included in Analysis
South Nation River at Spencerville	02LB007	1948 – 1995	•
South Nation River at Plantagenent Springs	02LB005	1915 – 1995	•
Castor River at Russell	02LB006	1949 – 1995	•
Bear Brook Near Bourget	02LB008	1949 – 1995	•
South Nation River at Chesterville	02LB009	1949 – 1995	•
South Nation River at Lemieux	02LB015	1972 – 1982, 1995	
East Scotch Near St. Isidore	02LB012	1970 – 1995	
West Scotch River Near St. Isidore	02LB018	1979 – 1995	•
South Nation River at Casselman	02LB013	1974 – 1995	•
North Branch South Nation River at Heckston	02LB017	1977 – 1995	•
South Castor at Kenmore	02LB020	1978 – 1995	
Little Castor Near Embrun	02LB016	1978 – 1985	
Payne River Near Berwick	02LB022	1976 – 1995	•

The purpose of the hydrological assessment was to evaluate the monitoring network in relation to the water quality component. Using information from the existing studies (SNRCA 1983), the six major subwatershed boundaries were super-imposed on the watershed map (Figure 2). The gauge locations are also shown. A review of the existing studies shows that the land use is dominated by agriculture (60 % of the 391,000 ha catchment) followed by woodlands (23 %), idle land (9%), wetlands (2 %), and urban and other (6 %). Most of the woodland lies within the northern part of the watershed, north of Casselman while most of the tile-drained land are distributed across the central,

southern parts of the watershed. The stream gauge locations are distributed throughout the watershed and reflect the variability of the land use as discussed in the following sections.

The mean monthly flow data from the 10 watershed gauges was plotted to observe the annual flow distribution (Figures 3 - 12). The East Scotch River gauge was not included in this study since the gauge was reported discontinued in 1991.

The results illustrate that stream flow in the watershed consists of a short-duration, high magnitude spring freshet (March, April, and May) followed by a typically low flow period (June to September). There is a late fall period (November and December) of increased flow but still this is less than the spring freshet. Typically, about 60-80 % of the equivalent annual stream flow is discharged through the spring period.

The flow records from each gauge were normalized by setting the peak flow equal to 100% and plotting on one graph (Figure 13). The results show that for all but the Chesterville gauge, the peak flow occurs in April. This is demonstrative of the snowpack melt in the upper watershed. The Spencerville gauge, located in the upper watershed, also shows high flows in March. These results highlight the importance of characterizing upstream vs. downstream stations as discussed in Section 3.0.

The summer baseflows are grouped closely at 3-7 % of peak flow. The winter baseflow ranges from 5-18 % - the higher results are at Heckston, Payne River, and Spencerville. Figure 13 highlights the seasonality of the hydrologic response which also varies in each subwatershed. Again, the predominance of spring flow and its contribution (between 60-80 %) to the annual flow volume is highlighted.

It is important to understand that seasonal variations in flow are large and that land use plays a key role in this variation. In order to consider the temporal changes in stream flow on a sub-watershed (i.e. spatial) basis, the mean monthly flow data for a period of several years (between 3 to 5) at the beginning and the end of the period of record was analysed. For example, for Plantagenet, the monthly flow data was averaged between 1915 to 1919 (reference level) and compared to the average for 1991 to 1995. Although precipitation and evapotranspiration data analysis for these periods is beyond the scope of this qualitative study, a 5-year averaging period was chosen such that dry and wet years would average out and not influence the flow data. The purpose of this simple technique is to demonstrate the relative difference in flow between January to December and thus highlight any change in hydrological function above a reference level. The results for each gauge are shown on Figures 14 to 22. It is important to note that the graphical results have not been normalized in this case.

Generally the results can be divided into two groups: those with demonstrable flow changes above baseline; and to those not showing demonstrable change between the two periods.

The results provide the following observations:

- The gauges showing hydrologic alterations in decreasing order are: Castor River; Bear Brook; West Scotch River; South Nation at Casselman; South Nation at Chesterville; North Branch near Heckston; and Payne River near Berwick.
- The gauges which are relatively un-affected between these two periods are: South Nation at Plantagenet (although this gauge has the highest flow and least resolution between the curves); and South Nation at Spencerville.
- The Castor River and Bear Brook show about 50-100 % (3-6 m^3/s) additional flow on a year round basis above reference level. The peak flow increased sharply in the Castor River at Russell to about 70 % (11 m^3/s) above reference level. The Bear Brook spring peak was also higher but only about 25 % (6 m^3/s). These shifts suggest that (a) additional precipitation occurred through the 1991-1995 period or (b) that baseflow increased over time perhaps as a result of additional drainage works into bog areas or other undeveloped areas of these subwatersheds. Deepening channels for example would increase the baseflow. An analysis of the net precipitation during these periods as a well as a review of the drainage works should be undertaken to better understand the nature of the hydrological shift. A review of the precipitation record should be undertaken to superimpose its effect on the flow data.
- The west Scotch and the South Nation River at Chesterville and at Casselman display sharp spring peaks exceeding baseflow by as much as 100 %. The flow record for Casselman also highlights the change in summer base flow between the initial and current period of record.

The implication of the spatial and temporal results is that developed areas (e.g. tile drained land) show a distinct hydrologic response. For example, in the Castor River subwatershed where fine-grained soils (e.g. clays) predominate, a summer storm after a dry period produces a rapid hydrologic response including erosion and sediment release into streams. It appears that excessive drying of soils (e.g. tile drainage) results in soil crust formation which exacerbates sheet runoff.

As discussed in the proceeding sections, the proposed water quality monitoring program emphasizes the need to intensify the temporal component of the monitoring program to reflect the various hydrologic regimes (e.g. spring freshet, summer low flow, fall peak, and winter baseflow).

> *The interpretation of flow monitoring must continue at the described stations commensurate with the water quality initiatives described in the proceeding sections. The hydrologic function is an integral aspect of watershed health and water quality.*

2.2 Water Quality

2.2.1 Approach

Review of the water quality monitoring activities, including the Provincial Water Quality Monitoring Network (PWQMN) and other water quality programs was carried through inspection and analysis of the locations, parameters and frequency of the monitoring data obtained to date. The focus was on the most recent data (1990-97) although in many cases data from as far back as 1966 is available. The more recent data reflects the current trends of water quality conditions, as well as the possible results of efforts by SNC to improve water quality.

Water quality has been monitored in the South Nation through various studies. A summary of current and past monitoring efforts is presented in Table 2. The longest water quality records have been collected as part of the PWQMN. The PWQMN includes 8 sites in each of the sub-basins except for Bear Brook. Of the 8 stations, 4 are located in the main reach of the South Nation River. Sampling intensity has varied from year to year, ranging from 1-12 times per year at the 8 stations since 1966.

A second systematic study of the lower watershed was setup under the Cleanup Rural Beaches Program (CURB). Sampling for this program was undertaken with weekly samples from June - August during the period 1992 to 1995. The Watershed Characterization program was initiated at several similar stations with sampling from April through October, 1996-97.

Water quality in individual sub-watersheds has been also studied in recent years through various initiatives including: the Payne River study with weekly sampling for herbicides from 1991 -1992; the Ontario Reference Network with monthly sampling at 2 stations in Bear Brook and Black Creek from 1992 -1994; and the North Castor Study with sampling twice per month from April to October (1994 -1995). These data from studies serve as a useful comparison for the PWQMN studies.

2.2.2 Previous Reports on Water Quality in the South Nation River

It is informative to review previous reports and conclusions regarding water quality of the South Nation River. A thorough summary of most recent reports is presented in Appendix A (Water Quality Program Review by Sandra Porter, SNC) and salient features are discussed here. A report prepared by MacLaren Plansearch Lavalin (1982), hereafter MPL, identified the pivotal impacts of erosion and sedimentation on the water quality of the South Nation River basin. This report estimated that 80% of the total sediment load is transported from the sub-basins in the months of March, April and May. The Castor River, Bear Brook, and Scotch River basins discharge the greatest amounts of sediment. The same group also identified that water quality in the South Nation did not meet provincial water quality objectives for bacteria and total phosphorus (MPL, 1982). Significant phosphorus losses associated with eroded sediment were identified. The main contributors of sediment were found to be mass wasting, open channel drains, and sheet erosion of fields.

The South Nation River Basin Water Management Study (Main Report, 1983) concluded that high total phosphorus (TP), bacteria and turbidity (i.e. sediment load) were the major parameters affecting surface water quality. Reductions in dissolved oxygen levels were noted during periods of low flow. The source of the contaminants was identified as both non-point sources (NPS) as well as point sources (PS).

More recently, a study of water quality for the period of 1980-88 was produced by Wickware & Associates (1989) for the SNC. This report concluded that water quality in the South Nation and the Castor and Scotch tributaries was generally poor, with no evidence found for improvement in water quality over the study period. High phosphorus, turbidity and bacteria concentrations were identified as the major contributors. Nitrate, nitrite and TKN concentrations generally met provincial guidelines, and mean dissolved oxygen values ranged between 9.1 and 11.2 mg/L. Agricultural runoff, livestock activities, and fall discharges from municipal and industrial lagoons were suggested as major contributors to the high TP and bacteria levels. There was evidence for increasing turbidity levels in the Castor and Scotch rivers from 1980-88, perhaps a result of increased tile drainage in these basins. A linear relationship between TP and turbidity ($r^2 = 0.72$) was found for the lower South Nation River supporting the notion that suspended sediments are a key source of phosphorus.

An intensive sampling of the Payne River in 1987-89 was presented in a SNC report (1990). Bacteria and total phosphorus problems were attributed mainly to agricultural sources. It was concluded that biological oxygen demand, however, remained generally within acceptable levels.

Provincial water quality data collected during the period 1967-91 from three stations in the main South Nation River was compared to the Rideau and Mississippi Rivers in a Masters' thesis by Zhu (1993). It was concluded that phosphorus contamination was a more serious problem in the South Nation than the Rideau and Mississippi Rivers. Zhu (1993) also observed higher turbidity in the South Nation (means 6.5-27 FTU) than those in the Mississippi (means 0.8-3.0 FTU) and Rideau (means 2-4 FTU) rivers.

Zhu used a statistical approach called multiple regression to examine trends in water quality data in each of these rivers. An increase in turbidity of 46% in the South Nation for the years 1967-91 was detected by trend analysis. Increase in land drainage and erosion was suggested to be the major cause of the observed increases. It was estimated that total phosphorus levels had decreased by 37% in the main branch of the South Nation River between 1967-91; however, no trends were discernable for fecal coliform data. The decrease in TP was attributed to phosphorus discharge control programs, improved agricultural management practices, and the installation of phosphorus removal facilities. Decreased use of P-rich fertilizers associated with changing crop requirements may also have played a role in this decrease. Zhu (1993) concluded that at the rate of P decline for the South Nation River, between 1980 to 1990, phosphorus concentrations would remain substantially above the provincial guideline (0.03 mg/L) well into the 21st century.

Zhu (1993) examined the data set for possible relationships between individual water chemistry and physical parameters for the South Nation and presented the data in a form called a correlation matrix. Flow correlated significantly ($p > 0.001$) with total phosphorus, total iron, alkalinity, pH, chloride, and turbidity. In addition, total phosphorus correlated significantly ($p > 0.001$, $r^2 = 0.66$) with turbidity. These results were evidence that surface runoff carries phosphorus adsorbed onto soil into the river.

A water quality index was developed by Zhu (1993) to compare the three rivers as shown in Figure 23. The index compares ambient levels of various parameters against the provincial water quality guideline. The index value was derived as a ratio of the mean value for a parameter and the guideline value. A value of 1.0 indicates water equivalent to the provincial water quality guideline. Using this simple approach, Zhu (1993) indicated that the South Nation river exhibited the poorest water quality (average relative index of 1.5) when compared with the Rideau (0.5) and Mississippi (0.3) rivers. Again, non-point sources were identified as the major cause of poor water quality in the South Nation river compared with the other two rivers. In fact, an estimated 93% of phosphorus loads were contributed by non-point sources in the South Nation watershed (Gore and Storrie, 1993).

The Clean Up Rural Beaches (CURB) program was undertaken in 1992-95 with sampling for chemical, physical and bacteria parameters throughout the lower South Nation watershed. These studies supported earlier conclusions that phosphorus, bacteria and turbidity levels commonly exceeded provincial water quality objectives.

In summary, there is general consensus among past reports that high phosphorus, turbidity and bacteria levels are the parameters contributing to poor water quality in the South Nation river and its tributaries.

2.2.3 Water Quality Monitoring Network Review

2.2.3.1 Locations

Current water quality monitoring efforts in the South Nation watershed are based on the PWQMN and the SNC Watershed Characterization programs. Sampling locations for these programs are shown in Figure 2. The PWQMN sampling locations were examined and compared to the stream gauge locations. These locations are important because discharge rates or contaminant loadings from different tributaries are not equal. Water quality in the main stem of the South Nation continues to be largely dependent on major tributaries: Castor, Payne, Bear Brook, and Scotch Rivers which contribute large phosphorus and sediment loads to the main river. For most major tributaries, PWQMN stations are proximate to the stream gauges. One exception is the Payne River which does not have a PWQMN site.

Many of the Watershed Characterization Network locations are complimentary to the PWQMN sites, including a station on the Payne River. These locations are concentrated in the lower basin, reflecting areas where specific NPS programs have been undertaken.

The PWQMN and Watershed Characterization Network sites provide sampling locations throughout the watershed. Such a widespread sampling base is appropriate for a 'snapshot' analysis of the watershed, suitable to characterize the general chemical, biological and physical characteristics of the upper and lower South Nation River and its tributaries. It may also useful to pinpoint any consistent or episodic events.

The major limitation to such widespread sampling locations is that would be prohibitively expensive to carry out analyses at a suitable frequency required for statistical trend analysis to characterize each sampling station throughout the year. To answer questions regarding long-term changes in water quality and watershed health using statistical approaches, it is therefore necessary to chose a smaller number of sites which can be sampled often, integrate all inputs, and as best possible represent the overall water quality of the watershed.

2.3.3.2 Parameters

The suite of parameters that have been used to monitor water quality are typical of the MOE's surface water monitoring suite including temperature, pH, conductivity, major nutrients, cations, anions, trace metals, and turbidity. A review of the PWQMN data for the time period 1990-97 was carried out to augment the selection of parameters for optimizing the SNC water quality monitoring program. This analysis has included a review to identify data where mean levels between 1990-97 (indicating long-term water quality problems) exceed Provincial Water Quality Objectives (PWQO, MOE 1994) and Ontario Drinking Water Objectives (ODWO). Since agricultural use is the major land use in the watershed, Canadian Water Quality Guidelines (CWQG) for livestock watering, and irrigation are also noted. Table 3 outlines water quality parameters which exceeded these guidelines. A brief discussion of the parameters exceeding guidelines and the nature of the exceedences is provided below. These parameters include phosphorus, turbidity, E coli, fecal coliforms, and certain trace metals.

Turbidity (Water Clarity, Suspended Solids)

PWQO for turbidity measurements are defined as a Secchi disk depth not exceeding 10% of the natural Secchi disc depth. A more clearly defined objective for recreational water clarity is defined as a Secchi disk depth of greater than 1.2 m. During this investigation, Secchi disk depths were measured at several locations in the upper Payne River watershed, the North Branch of the South Nation near Inkerman, and the South Nation River at Chesterville. Secchi disk depth was found to range between 40 and 60 cm.

Turbidity in the South Nation river increases from upstream to downstream locations as sediment input from tributaries mixes into the main branch of the South Nation River. Tributaries located in the lower South Nation (Castor, Payne, Scotch, and Bear Brook) carry the highest sediment loads.

Poor water clarity is primarily caused by erosion of fine-textured clay soils as discussed in the previous section. Suspended sediments are sources for nutrient and contaminant transport and can reduce primary productivity. High turbidity is also associated with

poor habitat for most biological species. Highly turbid waters are not conducive to providing good sportfish habitat.

Phosphorus

Total phosphorus levels routinely exceed the PWQO of 0.030 mg/L in all sub-basins of the watershed. It is important to note that phosphorus is not toxic. Guidelines have been developed to limit phosphorus concentrations because it is the nutrient which determines the amount of algal growth in most freshwater systems. Excess phosphorus can lead to eutrophication, where high levels of free-living and attached algae impart a green, slimy characteristic to the water (algal blooms). By mid-summer, warm waters and bacterial decay of dead algae can deplete dissolved oxygen levels in eutrophic waters. In the worst cases, water becomes anaerobic resulting in fish kills and unpleasant odours.

In addition to total phosphorus, filtered reactive phosphorus (FRP) levels in the South Nation and its tributaries are consistently higher than what is normally expected in waters typically in this area. FRP analyses reflect the amount of phosphorus that can be detected in a water sample after the suspended sediment has been removed by filtration. In most freshwaters, filtered reactive phosphorus levels are below analytical detection limits of 0.001 mg/L. However, in the South Nation watershed, filtered reactive phosphorus levels can range as high as 0.10 mg/L. The filtered reactive phosphorus concentration is generally considered to be 100% available to algae. High levels of filtered reactive phosphorus indicate a system in which algae are not consuming phosphorus as expected.

As indicated previously, Secchi disk depth at several stations in the Payne River and the South Nation River at Chesterville ranged between 40 and 60 cm in mid-May 1998. By comparison, Secchi disk depths in the Raisin River are approximately 1m at the same time of year and between 5 - 7m in the relatively transparent St Lawrence River. These Secchi disk measurements, while very preliminary, indicate that algal growth is likely light-limited in the lower South Nation River. Turbulent mixing in small rivers can ensure that algae spend a majority of time at depths in the river where light does not penetrate - simply, plants do not grow in the dark.

In addition, phosphorus discharged into the South Nation River watershed at its characteristic pH of 8.0-8.5 is probably bound to the iron- and aluminum-rich soils and not freely dissolved in the water. This situation occurs in areas that are susceptible to erosion of fine-grained soils. Evidence that this occurs can be found from the good correlations between TP and turbidity measurements. Over the years 1995-98, good correlations are found between these two parameters for data from the Castor and Payne Rivers. Such relationships between TP and turbidity has been noted in earlier reports on water quality in the South Nation river (Wickware & Associates, 1989; Zhu 1993). Phosphorus bound to fine-grained soils is likely not bioavailable and will not sustain algal growth.

The relationship between the levels of algae and total phosphorus in a water body is often illustrated by plotting the log of Chl a (chlorophyll-a is measure of algae levels) vs. log Total Phosphorus data. For most lakes and rivers the plot generally produces a straight line. Basu and Pick (1996) have established that many rivers in eastern Canada obey a [Chl a] and [TP] relationship given by the equation $\text{chl a} = -0.26 + 0.73 \log \text{TP}$. In addition, Chetelat *et al.* (1997) have shown that epilithic periphyton biomass is correlated with total phosphorus in rivers from Southern Ontario and Quebec. A useful characterization of the South Nation system would be to test these relationships for each sub-watershed. It is postulated that in the lower reaches of the South Nation River, as well as the Castor, Bear Brook, Payne and Scotch Rivers sub-watersheds, limited algae growth occurs because light penetration is limited by the high turbidity. Most of the measured phosphorus is likely bound to aluminum- and iron-rich clays and thus not available to algae.

Based on these interpretations, the significance of high phosphorus levels in the lower watershed must be carefully considered. Phosphorus water-quality guidelines have been developed to avoid eutrophication scenarios. While a great deal of effort has been applied to controlling P inputs into the watershed through various activities, much of the P in the South Nation watershed is likely not available because it is sorbed to fine-grained soils and sediment. Most probably, available phosphorus (FRP) remains abundant because algae cannot consume P due to growth limitation caused by sunlight attenuation. As water quality and clarity in the South Nation improve however, algae may become more abundant. Continued monitoring and careful observations of the relationships between water clarity, phosphorus and algae are required in future monitoring programs.

Nitrite

Nitrite levels averaged 0.23 mg/L in the West Scotch but values as high as 8.6 mg/L were measured in this tributary between 1990-97. The nitrite limit in drinking water is 1.0 mg/L. When oxidized, nitrite forms nitrate which, in high concentrations, has been attribited to causing *infantile methemoglobinemia* (CWG 1-9). In accord with PWQO, levels of nitrite should stay below 0.06 mg/L which is the level at which tissue damage may occur in the gills of certain species of fish.

Table 3 - Chemical and Bacteria Parameters of Concern in the South Nation Watershed

Site	Analysis	Mean (mg/L)	Min - Max. (mg/L)	PWQO (mg/L)	Drinking Water guideline (mg/L)	Irrigation guideline (mg/L)	Livestock Watering guideline (mg/L)
SNR, County Rd. 18, Augusta Twp.	TP	0.04	0.02 - 0.05	0.03	--	--	--
Castor, Conc 5, Russell	TP	0.08	0.00 - 0.27	0.03	--	--	--
Twp.	FC	82.74	8 - 91,000	--	0.00	100.0	--
SNR, at Chesterville	Fe	0.60	0.00 - 28.00	0.30	< 0.3	5.0	--
	Pb	0.031	0.00 - 1.69	0.007	0.01	0.2	0.1
	TP	0.022	0.00 - 0.14	0.03	--	--	--
SNR, Upstream Casselman Dam	Fe	0.11	0.00 - 0.61	0.30	< 0.3	5.0	--
	Mn	1.34	0.00 - 26.0	--	< 0.05	0.2	--
	Ni	0.014	0.00 - 0.55	0.15	--	0.01-0.05	0.5
	Pb	0.005	0.00 - 0.14	0.007	0.01	0.2	0.1
	TP	0.032	0.00 - 0.13	0.03	--	--	--
	FC	111	4 - 21,000	--	0.00	100.00	--
W. Scotch, Conc 17, downstream of ST. ISIDORE	Fe	0.63	0.00 - 3.60	0.30	< 0.3	5.0	--
	NO_2	0.23	0.00 - 8.57	0.06	3.2	--	10.0
	TP	0.25	0.00 - 8.40	0.03	--	--	--
	FC	96	50 - 15,000	--	0.00	100.0	--
E. Scotch, Conc 19, up St. ISIDORE	Fe	0.44	0.00 - 1.46	0.30	< 0.3	5.0	--
	TP	0.80	0.00 - 0.64	0.03	--	--	--
	Mn	0.10	0.00 - 0.88	--	< 0.05	0.2	--
	FC	940	4 - 2,800	--	0.00	100	--
SNR, HW 17, Plantagenet	Fe	0.33	0.00 - 3.60	0.30	< 0.3	5.0	--
	TP	0.01	0.00 - 0.24	0.03	--	--	--
	FC	18.28	4 - 2,800	--	0.00	100.0	--

Fe - iron, Mn - manganese, TP - total phosphorus, Pb – lead, Ni – nickel, NO_2 – Nitrite, FC - fecal coliform

Bacteria

Bacterial levels have been monitored using fecal coliforms and *E. coli* levels. *E. coli* is the indicator of choice to determine contamination of water by faeces of warm-blooded animals because levels in surface waters are correlated with frequency of gastrointestinal illnesses. Both forms of bacteria typically exceded PWOQ in all statsions throughout the watershed during the period 1990-97. High bacterial levels are indicators of increased risk of pathogenic infection to humans and livestock. Limiting livestock access to streams for watering is particularly important not only because of the direct introduction of bacteria to the watercourse but the potential health risk to livestock. High bacteria levels often can result in increased costs for veterinary care for livestock.

Trace Metals

Concentrations of iron and manganese exceed PWQO at several stations in the watershed. High values of iron, manganese and as well as other trace metals such as aluminum are necessarily expected since they are abundant in the earth's crust and are therefore associated with suspended sediments and clays. As trace metal analyses were carried out on unfiltered samples, it is difficult to assess whether sources other than suspended sediment rich in clays were the cause of the high values. For example, iron is correlated to flow in the South Nation (Zhu, 1993).

On the other hand, Ni is not highly correlated with flow (Zhu, 1993) which suggests possible point sources of this trace metal. Major anthropogenic sources of nickel are the burning of fossil fuels, smelting, casting, and electroplating activities. Nickel is also reported to be relased from the manufacture of foods, baked goods, soft drinks, flavouring syrups, and ice cream (CWQG, 6-44, 1994). Industrial and wastewater discharges are listed as major point sources of lead to the environment.

> ***An effective water quality monitoring plan will focus on measurement of phosphorus, turbidity, and suspended solids. Monitoring for nitrate, nitrite, bacteria, nickel, and lead should also be continued.***

2.3.3.3 Frequency

Frequency of the current monitoring programs ranges from 1-12 times per year for the PWQMN and at least once per month (May-October) for the Watershed Characterization program. While monthly or bi-monthly grab samples, taken mainly between May-October, at a large number of stations may provide a general characterization of water quality in the watershed, this sampling frequency will miss many events (in particular about 70 % of the annual flow through the basin) and is therefore not sufficient to determine seasonal trends. Unless long-term changes in water quality are of sufficient magnitude (see Zhu 1993), once per month samples cannot distinguish less dramatic changes such as that that may be occur from SNC non-point source abatement programs. Sampling must also be representative of the entire volume of water moving past a particular monitoring point. To date, because of staffing and other logistical reasons, sampling has occurred mainly between May through October. This perod of the year

biasses water quality results based on baseflow characterization. As noted above, between 60-80% of the entire river discharge occurs during the 90-day period between March and May, with another 10-15% of the annual discharge occurring in November and December.

> *In order to observe statistical trends, a greater sampling frequency is required in each of the characteristic seasons of spring freshet, baseflow, and fall periods. The goal of this type of monitoring is to sample sufficient events to adequately characterize temporal water quality changes.*

Statistical Considerations

A statistical analysis of water quality trend analysis requires careful screening of the data and appropriate statistical approaches. Several approaches can be used to identify temporal trends in water quality. Zhu (1993) used a multiple regression approach to identify water quality trends in three main stem stations of the South Nation. Chapter 3 of the Zhu thesis also provides a good description of this approach, the techniques used to inspect the *data* for extremes and for data normalcy. Recently, Richards (1998) presented a time trend analysis of 2 major tributaries of Lake Erie. The approach employed an Analysis of Covariance (ANCOVA) technique in which flow and month (season) were used as covariance with the parameter of interest.

> ***It is recommended that the SNC establish a standard analysis technique that can be consistently applied on a yearly basis to monitor water quality trends. The technique chosen will depend on the available software, end users, and objectives (e.g. using flow-weighted vs. time-weighted results).***

2.3 Volunteer Resources

Volunteers can represent an important resource enabling professional staff to monitor a wider range of parameters over a larger area than would be possible using existing staff. Some programs, for example, the North American Breeding Bird Survey (Droege 1990), have been extremely successful. Indeed, much of our current understanding of the dynamics of breeding bird populations is derived from the analysis of Breeding Bird Survey data collected by volunteers (Robbins et al. 1989, Hagan 1993). In surveys like the Breeding Bird Survey, regional population trends are estimated from the weighted averages of the trends along individual routes. The statistically robust inferences about population trends are possible only if the number of routes is large. The large number of routes is essential because the route (not the individual sampling station) is the sampling unit.

The above assumptions are inherent in the design of many volunteer-based monitoring programs even though they are not explicitly stated. When working at a small geographic scale, sampling protocols must be modified if statistically defensible conclusions are to be drawn. When designing a sampling protocol it is essential to establish how the data will be used before the sample stations are chosen. For example if the goal is to determine whether a particular chemical parameter is always below a

guideline limit, the sampling regime can be quite simple. Samples can be taken at regular intervals from a series of stations that are representative of the watershed. If the guideline is frequently exceeded then the question has been answered and remedial measures are necessary. In this case sampling design is relatively simple and the only considerations are where to put the sampling stations and how often to sample them.

If the purpose of a volunteer-based monitoring program is to test the hypothesis that restoration programs are having a positive effect on water quality the sampling design may be more complicated. The sampling design will depend on the scale at which the question is being asked (i.e., the watershed, river, project site) but in all cases, if statistically sound inferences are to be made, the sample effort must be sufficient to adequately characterize both the mean and the variance around the mean.

There are large numbers of volunteer-based monitoring protocols available and some of them have been integrated into the South Nation's Riverwatch and Bug Watch Programs. The instruction manuals give volunteers detailed instructions on how to conduct water sampling tests and collect aquatic invertebrates. These manuals also caution participants about the importance of sampling consistency. Lacking in both programs is attention to sampling design. Sampling design is rarely discussed in monitoring protocols but is crucial to collecting data in such that statistically sound conclusions can be made.

> *It is recommended that preliminary sample measurements be obtained by volunteers who are willing to collect replicate samples such that 'within' and 'between' sample variation can be determined. These results can then be used to refine the sampling protocol and have a statistically defensible protocol in place by 1999. For some volunteers, obtaining replicate samples may be too much work. These individuals should be encouraged to continue monitoring since these data can still be used as a broad-based screening tool to identify sites that need more detailed investigation by staff. Education programs and monitoring programs related to water quality should be incorporated to the overall strategy.*

2.4 Biological Monitoring–Benthic Invertebrates

Biological monitoring is an important component of any program designed to monitor ecosystem health. An important advantage of biological monitoring is that it can detect environmental impairments resulting from contaminants that are not being measured or that result from the synergistic effects of several contaminants. The synergistic effects of several contaminants acting together can magnify the biological effects of the contaminants by several orders of magnitude.

Benthic invertebrates have been used by several authors to monitor stream health (Griffiths 1993, 1996, Vermeulen 1995, Dickman and Rygiel 1996) and although several techniques have been developed they are based on the same basic assumption that stream invertebrates vary in sensitivity to changes in water quality and can be classified according to their sensitivity to impaired water quality (Griffiths 1993, 1996). Several protocols are available for monitoring benthic invertebrates for example BIOMAP

(Griffiths 1993, 1996), Save Our Streams, Rapid Bioassessment Protocol, etc. and although they differ somewhat in their details they should provide similar results.

Determining the locations and number of invertebrate samples to be taken is more important than which of the many available protocols are used. The appropriate number of samples and sample location will depend on the objective of the evaluation. Most protocols require taking only one or two samples per location. Even when replicates are included they are usually combined during the analysis. This is appropriate if the goal is to obtain a general indication of stream health at one or a series of sampling locations. If, on the other hand, the purpose of monitoring is to compare temporal or spatial invertebrate communities (e.g. before and after a remediation project, or upstream and downstream of a discharge) sufficient replicate samples are necessary to characterize the source(s) of variation.

The CURB Aquatic Invertebrate Report (SNC 1995) illustrates this point. Invertebrates were sampled up- and down-stream of 4 project sites. At one site, where manure and milkhouse waste was entering the South Nation River, water quality, estimated by the abundance and diversity of invertebrates, was impaired downstream of the project site. The lack of replication and habitat disparity up-and down-stream of both a manure storage and a milkhouse facility made it difficult to determine whether the difference in the invertebrate communities were related to the manure or milkhouse waste entering the stream.

This highlights the importance of appropriate levels of replication for statistical inference. Typically, this is achieved when additional sampling effort no longer results in significant changes in the mean and variance of the sample. A variety of methods to determine when this point has been reached have been developed and can be found in most sampling design or quantitative ecology texts. A simple "rule-of-thumb" is to divide the invertebrate data set in half and compare the two halves of the data. If they yield similar results then the level of replication is sufficient. If the results differ then additional replication is required.

> *The benthic invertebrate monitoring using volunteers should be continued and augmented by a pilot study to determine the appropriate level of replication required to make statistical inferences from invertebrate data. The protocol for volunteers to estimate periphyton growth, provided here, can be integrated into the Riverwatch and Bug Watch programs.*

2. 5 Simple Indicators of Water Quality Changes

2.5.1 Water Clarity

Several simple indicators for water quality are currently used in the monitoring programs. The parameter of major concern in the South Nation River is turbidity. Since total phosphorus is often correlated with turbidity in the South Nation and its major tributaries, situations where turbidity is high need to be identified. Presently, volunteers

use a simple optical technique to measure turbidity based on a sample of water. Another simple approach is to monitor water clarity is the Secchi disk. Secchi disk measurements are made by lowering a standardized white and black disk into the water until it is no longer visible. During a preliminary survey of the Payne and South Nation Rivers, a Secchi disk depth of 40 cm was obtained, which is very shallow. PWQO for recreation (swimming) is a Secchi disk depth of no less than 1.2 m. The general PWQO for turbidity is defined in the following manner:

> Suspended matter should not be added to surface water in concentrations that will change the natural Secchi disc reading by more than 10 percent.

It is clear that this definition is more applicable to point source discharges where the natural Secchi disc reading can be readily identified, never-the-less it is possible to establish a characteristic Secchi disk depth for a given sub-basin. There are applications in which this parameter may be used to identify the effectiveness of SNC programs, where inputs of suspended matter are reduced by the implementation of livestock control measures, buffer strips, and other techniques which control erosion.

Another technique which we recommend for investigation by the SNC is to use the presence of epilithic periphyton as an indicator for high loading of bioavailable phosphorus in the South Nation and its tributaries. A recent study be Chetelat *et al.* (1998), which included sites in the South Nation River, has shown that periphyton, in particular *Chladophera,* sampled from rocks in shallow riffle sections of temperate rivers is correlated to total phosphorus levels. *Chladophera* biomass measured as chlorophyll-a correlated particularly well with TP concentrations (r^2=0.53, p>0.001) over the range 0.01-0.08 mg/L. The PWQO of 0.03 mg/L for streams and rivers originated from evidence that this was the level at which periphyton began to accumulate on rocks (pers. commun., F. Pick, University of Ottawa, 1998).

> *It is recommended that secchi disk depth and periphyton biomass density be used to monitor water quality changes in the South Nation River. Areas with high biomass density should indicate local inputs of bio-available phosphorus.*

3.0 Integrated Water Quality Monitoring Plan

This section of the report describes the recommended monitoring program to improve the SNC's ability to detect improvements in water quality that result from restoration activities in the watershed. The proposed monitoring program contains four components:

1) Water Chemistry Monitoring
2) Bio-monitoring
3) Volunteer Monitoring
4) Annual Report Card

A summary of the water quality monitoring program and the goals of each initiative is given in Table 4.

Table 4 – Summary of Water Quality Monitoring and Goals

Components	Goals
Water Chemistry Monitoring	• Data for statistical trend analysis to monitor large-scale changes in water quality
Bio-monitoring	• Ecosystem integrity information using test organisms sensitive to a wide range of environmental/chemical factors
Volunteer Monitoring	• Provide support data for items (1) and (2) possibility for statistical analyses • Supplement data at strategic locations not monitored by professional staff • Generate community interest/responsibility in ecosystem by engaging the community members/stakeholders • Generate useful data through the delivery of SNC education programs
Report Card	• Feedback (review/evaluate/recommend/report)

3.1 Water Chemistry Monitoring

The goal of the water chemistry program is to provide sufficient data to characterize water quality trends in the South Nation watershed throughout the year including statistical trend analysis. Justification for the sampling frequencies, parameters and locations is described in the following sections. The water chemistry monitoring component of the water quality program is summarized in Table 5a and 5b for the tri-weekly and weekly program's respectively.

Frequency

It is difficult to distinguish gradual improvements in water quality in low gradient agro-ecosystems, particularly those dominated by non-point sources (Baker, 1993). The difficulty arises because concentrations of chemicals in such systems are driven by climatic conditions, which can vary widely from year to year. For example, large fluctuations in flow conditions, which characterizes the South Nation watershed as previously illustrated, are accompanied by large changes in sediment and chemical concentrations. Under such circumstances, accurate characterization of water concentration would require an intense sampling effort, i.e. nearly continuous. The current PWQMN program does not accomplish this requirement and it is necessary to supplement it with a sampling strategy that does. It is likely not financially feasible to measure more than a few parameters at few locations. Therefore, sampling frequency is the component of the water quality monitoring plan that greatly influences and limits other components of the plan, i.e. locations and parameters.

The recommended sampling frequencies are given in Table 5. The parameters are divided into two groups: key parameters designated for tri-weekly and weekly sampling frequency. Brief justifications for each parameter are given in Table 5a and b.

Parameters

Key parameters determining water quality in the watershed are suspended solids and total phosphorus. These parameters require collection of a sample for analysis in the laboratory.

It is recommended that daily water samples be collected for these parameters using a composite sampler. Samples should be collected for analysis thrice weekly. Key parameters that can be analyzed in the field with the aid of portable equipment are temperature, pH, conductivity, dissolved oxygen, Secchi disk depth, and turbidity.

Other basic measurements such as true colour, dissolved organic carbon, loss on ignition (LOI), filtered phosphorus, nitrate and nitrite, and ammonia are important components of the water quality monitoring program that are recommended to be analyzed once weekly.

Locations

The recommended stations for long-term monitoring are given in Figure 24. The monitoring activities focus on the PWQMN stations on the main branch of the South Nation River because these sites best reflect the integrated water quality of the watershed since all of the smaller tributaries eventually flow into the South Nation River. In addition, choosing these stations ensures that a long-term record is available at these sampling sites to compare with newly acquired data.

It is recommended that Station 1 at Spencerville be retained because it represents South Nation water that is least affected by point and non-point sources and thereby provides a well-characterized 'control' site for the water quality index determination. Stations 2, 3 and 4 represent water quality in the main reach of the South Nation most likely affected by point and non-point sources. Station 2 at Chesterville represents the influences of the upper South Nation watershed on water quality, Station 3 (at Casselman) integrates the influences of the Payne and Castor watersheds on water quality, and Station 4 (at Plantagenet) also includes the influences of Bear Brook and Scotch watersheds on South Nation water quality. Therefore, sampling these 4 stations at any given time provides a representative indication of water quality in the South Nation watershed.

Sampling stations in individual tributaries of the South Nation river (e.g. the Castor River) are not recommended in this part of the monitoring plan because the ultimate goal of the plan is to provide representative data of the entire watershed that is suitable for statistical trend analysis. The main branch of the river integrates all influences but is not as widely variable in flows and chemical concentrations compared to the smaller tributaries that are more strongly influenced by point and non-point sources as well as flow. While monitoring stations on these tributaries would certainly reflect these

influences, the additional data scatter produced would serve to obscure long-term trends in watershed water quality.

Given that the analyses for the PWQMN are completed by the MOE, it is advised that the PWQMN surveys be continued. The PWQMN program is useful to monitor for specific problem areas that may arise in the sub-watersheds from time to time and will complement the more directed sampling program recommended above.

It is recommended that the watershed characterization program not be continued. SNC objectives will be better met by the proposed water quality monitoring program in the main branch of the river, and by specific monitoring programs designed on a case by case basis by SNC water quality personnel and relating to non-point source control projects.

Table 5 – Summary of Water Chemistry Monitoring

5a – Tri-weekly Sampling

Parameters	Stations	Frequency	Notes
Suspended Solids Total Phosphorus	1, 2, 3, 4 (see map)	2-day composites, Mon, Wed, Fri	• Composite samples to be collected by automated programmable sampler • Parameters for robust statistical trend analysis • SS can be converted to sediment discharge • Are NPS programs reducing sediment loads and improving water clarity ? • Monitor activities that affect sediment loads (*'hydrologic function'*)
<u>Field Data</u> DO Cond pH Temperature Secchi Disk Turbidity	1, 2, 3, 4	Mon, Wed, Fri	• Field data measured by SNC staff • DO, Temp, Cond, pH, Turb determined using calibrated meters • Secchi disk depth affected by colour, colour inputs mainly from wetlands • Surrogate measures of SS

5b – Weekly Sampling

Parameters	Stations	Frequency	Notes
True Colour Turbidity E. *coli* DOC LOI Chlorophyll-a FRP TKN NO_2 NO_3 NH_4^+	1, 2, 3, 4	weekly (Mon) from composite sampler weekly (Mon) duplicate grab samples concurrent with field data sampling in Table (5a)	• Duplicate analyses used to establish whether weekly variations exceed sampling error • E. *coli* provides information relevant to human and animal health; since non-point sources are major sources of E coli, remedial programs should decrease levels and frequency of high values • DOC is a measure of organic inputs to the river, (e.g. milkhouse wastes, wetland drainage) • Chlorophyll-a (1 L sample) measures plankton growth • Filtered reactive P is conservative measure of bioavailable P • N data is important to assess potential algal growth, N-inputs significant in the watershed • un-ionized ammonia is toxic to fish (PWQO 0.02 mg/L)

3.2 Bio-Monitoring

A summary of the bio-monitoring plan is provided in Table 6. The benthic invertebrate monitoring protocol currently used by SNC involves taking two quantitative samples using a Serber sampler and one qualitative sample during which field workers search for invertebrates for a specified time along a predetermined stretch of river. A review of the data collected using these protocols revealed large variation between samples taken at the same site on the same day.

In order to reduce variation among replicates we recommend using Serber or T-samplers when collecting invertebrates from riffle areas.

These quantitative sampling techniques allow absolute estimates of invertebrate densities whereas qualitative techniques permit only relative estimates of abundance. Aquatic invertebrate sampling protocols such as BIOMAP are designed for sampling in fast flowing riffle areas. If invertebrate sampling is required in streams where riffle areas are absent, qualitative sampling techniques such as those already in use can be used.

Table 6 – Summary of Biological Monitoring

Parameters	Stations	Frequency	Notes
Benthic Invertebrates	riffle sections near Stations 1, 2, 3, 4	triplicate sampling, late spring and late summer	• Recommend BIOMAP protocols, which provide density estimates and less subjective than other methods • Parameters to be compared with chemistry data and for the report card on parameters
Epilithic periphyton	riffle sections near Stations 1, 2, 3, 4 and elsewhere	5 samples per site late spring and late summer	• Presence of epilithic periphyton is an indicator of eutrophication in rivers and streams • Methodology fist-sized rocks are randomly sampled, scraped with a wire brush, chlorophyll-a measured. Surface area of rock calculated by wrapping with aluminum foil and weighing foil.

It is also recommended that bio-monitoring include inspections for the presence of epilithic periphyton as an indicator of eutrophication in the river. As a first priority, sampling should be carried out at sites near the four recommended water quality monitoring stations along the South Nation River. At least 3 to 5 replicate samples should be taking at randomly chosen points. Second priority should be given to sampling invertebrates from riffle areas in smaller tributaries. Where invertebrate data are required from sites where shallow riffle areas are absent, qualitative samples can be used but it is important that a single sampling technique be used for all replicates at a site. A protocol for monitoring periphyton is given in Appendix B.

BIOMAP is a method for making inferences about water quality based on invertebrate communities. Although the BIOMAP protocol recommends using T-samplers the BIOMAP technique can be applied to invertebrates regardless of sampling method. The sampling method (T-sampler, Ekman dredge, Ponar sampler, etc.) will depend on the substrata at the sampling location. In areas where T-samplers or Serber samplers are inappropriate, quantitative samples should be obtained using Ekman or Ponar samplers. If quantitative samples cannot be obtained, the current technique for obtaining qualitative samples (i.e., searching among aquatic vegetation along the stream bank) can be used but the area searched and the time spent searching should be recorded. Whichever technique is used, the sampling time and area should be sufficient to yield about 100 invertebrates. Sampling effort (equipment, time, area, number of people, etc.) should be recorded since it will vary from site-to-site. Samples should be stored in ethanol and archived after they are identified. The use of the BIOMAP technique is recommend because it is being used in other areas of Ontario (Griffiths, 1993), however, other techniques (e.g., Rapid Bioassessment Protocol) should yield similar results.

3.3 Volunteer Monitoring

Volunteer monitoring provides supplemental data to the monitoring plan at strategic locations in the watershed not monitored by professional staff. In addition, volunteer

monitoring is a means by which community interest in the health of the watershed can be fostered. Table 7 summarizes the plan recommended for volunteering efforts. Parameters include sampling for benthic invertebrates, periphyton, and turbidity and Secchi disk depth. These parameters are recommended as those which are most likely to provided usable data.

Table 7 - Volunteer Monitoring Summary

Parameters	Stations	Frequency	Notes
Benthic Invertebrates	riffle sections other than near Stations 1-4, sections of main tributaries (e.g. near schools)	triplicate samples	• can be used in education program to demonstrate techniques and to illustrate biological impacts of changing water quality
Periphyton	riffle sections other than near Stations 1, 2, 3, 4 and elsewhere	spring, summer and fall	• simple technique could be developed for volunteers or for class projects, e.g. can use wet weight of periphyton to avoid chlorophyll a estimate
Turbidity Secchi Disk Depth Dissolved Oxygen	Stations 1, 2, 3, 4 and elsewhere	weekly, triplicate	• techniques are simple and can be used by volunteers on a regular basis on a schedule that compliments professional monitoring

The water chemistry component of the volunteer program will require measurement for dissolved oxygen (DO) and turbidity at sites in each major sub-watershed. Measurements should be carried out using calibrated oxygen meters where available or Hach test kits. Turbidity should be measured using both Secchi disk depth (if appropriate) and the currently used test method based on a water sample. It is recommended that all other measurements used in the previous test kit be discontinued.

3.4 South Nation Report Card

It is recommended that an annual report card be produced as part of the Water Quality Monitoring program to provide a means for the public and stakeholders to track changes in watershed health. This includes a comparison of the Spencerville station to the other stations.

The report card would provide:

- a summary of impairments and remedial action initiatives;
- changes in hydrologic function (spatial indication of duration/intensity response of baseflow and stormflow);
- a summary of water chemistry, bio-monitoring, and volunteer monitoring;
- a simple index of watershed health using a technique where key water quality parameters (e.g. total and filtered phosphorus, Secchi disk depth, *E. coli*, dissolved oxygen, TKN, nitrate and nitrite, and ammonia) are compared to provincial water quality objectives and to the control site at Spencerville.

An annual scientific review of the program is also recommended in the initial years to ensure that the recommended program is accomplishing the desired goals and that the parameters chosen to track watershed health remain relevant.

The detailed review of the program should be completed after the first year including:

- Data analysis;
- Monitoring frequency;
- Parameters;
- Locations;
- Statistical interpretation including analysis of water quality trends; and
- Preparation of the Report Card.

The scientific review of the program, in the initial years of the monitoring, is an integral component of the report card's development. The report card will provide a useful tool by which SNC can illustrate in everyday language the positive effects of NPS and other conservation initiatives on the health of the SNC watershed.

4.0 References

Baker, David B. 1993. The Lake Erie Agroecosystem Program: water quality assessments, Agriculture, Ecosystems and Environment, 46: 197-215.

Basu, B., Pick, F.R. 1996. Factors Regulation Phytoplankton and Zooplankton Biomass in Temperate Rivers. Limnol. Oceanogr., 41:1571-1577.

Canadian Water Quality Guidelines. 1995. Canadian Council of Ministers Of The Environment.

Cane, G. and I.D. Clark. 1997. Tracing Groundwater Recharge In An Agricultural Watershed With Isotopes. Ottawa- Carleton Geoscience Centre. Department of Geology. University of Ottawa.

Chetelat, J., Pick, F.R., Morin, A, Hamilton, J.B. 1998. Effects of Nutrients and Water Velocity on Standing Crop and Community Composition of Periphyton in Rivers of Ontario and Quebec. Can. J. Fish. Aquat. Sci. In Press.

Clark, I.D. and P. Fritz. 1997. Environmental Isotopes and Groundwater Geochemistry. CRC Lewis Publishers.

David, S.M., K.M. Somers, R.A. Reid, R.J. Hall, and R.E. Girard. 1996. Sampling Protocols for the Rapid Bioassessment of Streams and Lakes using Benthic Macroinvertebrates. MOEE, Dorset Environmental Centre.

Dickman, M. and G. Rygiel. 1996. Chironomid larval deformity frequencies, mortality, and diversity in heavy-metal contaminated sediments of a Canadian riverine wetland. Environment International 22:693-703.

Droege, S. 1990. The North American Breeding Bird Survey. Pages 1-4 in: J.R. Sauer and S. Droege (eds), Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish and Wildlife Service Biological Report 90 (1), 166 pages.

Drever, J.I. 1997. The Geochemistry of Natural Waters: Surface and Groundwater Environments. 3rd Edition. Prentice-Hall.

Environment Canada. 1997. Surface Water and Sediment Data To 1995. Atmospheric Environment Program. HYDAT CD-ROM Version 4.95.

Gore and Storrie Ltd. 1993. Waste Water Assimilation Study of the South Nation River Watershed, Main Report and Appendices. South Nation River Conservation Authority and Ministry of Environment.

Griffiths, RW. 1993. BioMAP: Concepts, protocols and sampling procedures for the Southwestern Region of Ontario. BioMAP Report SWR-1. 30 pages.

Griffiths, RW. 1996. BioMAP: Biological measures of water quality for creeks, streams and rivers. BioMAP Report SWR-4. 40 pages.

Hagan, J.M. 1993. Decline of the rufous-sided towhees in the eastern United States. Auk 110: 863-874.

Keith, L.H. 1992. Environmental Sampling and Analysis. Lewis Publishers. Chelsea, MI.

MacLaren Plansearch 1982. Water Resources Study Component of the South Nation River Basin.

Municipal Planning Consultants 1981. South Nation River Basin Development Study: Residential, Commercial, Industrial Component.

Ministry of Environment. 1994. Water Mangemnt

Porter, Sandra. 1998. South Nation Conservation Water Quality Program Review. South Nation Conservation.

Proctor and Redfern 1994. South Nation River Conservation Authority Floodline Mapping.

Richards, Peter. 1998. Trends in Nutrient and Suspended Sediment Concentrations in Lake Erie Tributaries, 1975-1990. Water Quality Laboratory.

Robbins, C.S., J.R. Sauer, R.S. Greenberg and S. Droege. 1989. Population declines in North American birds that migrate to the neotropics

South Nation Conservation Authority. 1983. South Nation River Basin Water Management Study, Main Report. South Nation Conservation Authority

South Nation Conservation Authority. 1990. Payne River Report 1987-1989, Draft. South Nation Conservation Authority.

South Nation Conservation Authority. 1995. Clean Up Rural Beaches Program Aquatic Invertebrate Report. South Nation Conservation Authority. 13 Pages.

SPLASH. 1997. A Newsletter of the Canadian Water Resources Association - Ontario Branch. Vol. 2(2) September.

Stumm, W. and J.J. Morgan. 1981. Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibria in Natural Waters. John Wiley & Sons, New York.

Vermeulen, A.C. 1995. Elaborating chironomid deformities as bioindicators of toxic sediment stress: the potential application of mixture toxicity concepts. Ann. Zool. Fenici 32:265-285.

Wren, C.D., C.A. Bishop, D.L. Stewart, and G.C. Barrett. 1997. Wildlife and contaminants in constructed wetlands and stormwater ponds: current state of knowledge and protocols for monitoring contaminant level and effects in wildlife. Technical Report Series No. 269. Canadian Wildlife Service, Ontario, Region.

Watlet and Johnson. 1996. Raisin River Basin Hydrology And Surface Water Quality. Research Paper No. 46. Ecosystem Recovery on the St. Lawrence.

Wickware and Associates. 1989. Water Quality and Land Use Relationships in the South Nation River Basin. Water Quality Branch, Inland Waters Directorate, Environment Canada.

Zhu Y. 1993. Water Quality of the South Nation River, Rideau River, and Mississippi River: A Statistical Survey. Master of Arts Thesis, Department of Geography, Carleton University.

Table 2a - Summary of Water Quality Monitoring Programs

File	Designation	Station	Station I.D.	Date	Analysis
CURB.xls	Clean up Rural Beaches	1	South Nation River at Jessup's Falls	1992, 1993, 1994	Turb., Temp., F.C., E. coli, NH3, Un-NH3, TKN, NO2, NO3, TP, DRP, pH, Cl, Cond.
		2	Scotch R.	1992, 1993, 1994	
		3	East Branch of Scotch R.	1992, 1993	
		4	West Branch of Scotch R.	1992, 1993	
		5	South Nation River at Pendelton	1992, 1993, 1994	
		6	North Indian Creek	1992, 1993	
		7	Bearbrook Upstream of North Indian Creek	1992, 1993	
		8	Bearbrook	1992, 1993, 1994	
		9	South Nation River at Lemiux	1992, 1993, 1994	
		10	Moose Creek	1992, 1993, 1994	
		12	South Nation River at Casselman	1992, 1993, 1994	
		13	Butternut Creek	1992, 1993, 1994	
		14	North Castor River	1992, 1993, 1994	
		15	Middle Castor River	1992, 1993, 1994	
		16	South Castor River	1992, 1993, 1994	
		17	Castor River at Russell	1992, 1993, 1994	
		18	East Castor River	1992, 1993, 1994	
		19	Castor River downstream of Embrun	1992, 1993, 1994	
		20	South Nation R. upstream of Casselman	1992, 1993, 1994	
		21	Payne R.	1992, 1993, 1994	
		22	South Nation R. at Crysler	1992, 1993, 1994	
		23	Cobb's Lake Creek	1992, 1993, 1994	
		24	Little Castor R.	1992, 1993, 1994	
		25	North Castor R. at Greely	1993	
		26	Middle Castor R at Herbert Corners	1993	
		27	South Castor R. at Vernon	1993	
		28	South Nation R. at Plantagenet	1993, 1994	
		29	South Nation R. at Seguin Bridge	1993, 1994	
Dunvegan.xls	Dunvegan Creek	18207008002	Dunvegan Creek 50 ft. Downstream from outfall	1965-1971	Alk., BOD5, Cl, Cond., DO, Fe, Temp., Hard., NH3, NO2, NO3, TKN, pH, PO4, Residue filtered, Residue Particulate, Total Residue, TC, Turb.
		18207007002	Above Confluence of Dunvegan Creek and ditch	1967-1971	
		18207009002	Dunvegan Creek 50 ft. Upstream of outfall	1965-1971 + 1986	Alk., Cd, Cl, Cond., Ambient Cond., Cr, Cu, Fe, pH, K, NH3, NO2, NO3, TKN, Pb, pH, PO4, Turb., Zn, BOD5, DO, Temp., Residue filtered, Residue Particulate, Residue Total, TC

Table 2b - Summary of Water Quality Monitoring Programs

File	Designation	Station	Station I.D.	Date	Analysis
NorthCastor.xls	Castor River	CK63-001	Castor R. County Rd. 3 Russel/Osgoode Twp.	1995	Temp., F.C., E. coli, NH3, Un-NH3, NO3, SO4, DRP, pH, TKN, TP, TSS, Cond., Cr, Ni, Zn, Al, Cd, Pb, Co, Mo, Va, Cl, Si, Fe, Ma, Ca, K, Mg, Na
		CK63-002	Middle Castor R. Cnty Rd 29 Osgoode	1994, 1995	
		CK63-007	Middle Castor R. Cnty Rd. 25 Osgoode	1994, 1995	
		CK63-102	South Castor R. Ray Wilson Rd. Russel Twp.	1994, 1995	
		CK63-108	South Castor R. Hwy 31 Osgoode Twp.	1994, 1995	
		CK63-202	North Castor R. Pana Rd. Osgoode Twp.	1994, 1995	
		CK63-206	North Castor R. Eighth Line Rd. Osgoode	1994, 1995	
		CK63-208	North Castor R. Parkway Rd. Osgoode Twp.	1994, 1995	
		CK63-254	North Castor R. Hwy 31 City of Gloucester	1994, 1995	
		CK63-262	North Castor R. Hwy 31 Osgoode Twp.	1994, 1995	
		18207014002	Castor R. at Conc. 5 Russel Twp.	1980-1997	As above accept for TSS and Si. Plus Alk., As, Ba, Be, BOD5, Cu, DO, Fecal Strep., Hard., NO2, PO4, *P aeruginosa,* Residue filtered, Residue Particulate, Total Residue, Se, St, Ti, Turb.
		18207014502	Castor R. at Conc 3 Russel Twp.	1980-1997	
ORNBearbrook.xls	Bearbrook Creek		3 way Junction of Cnty Rd. 37, 2, and 26 Cumberland Twp.	1990-1994	Colour, Cond., Turb., Li Total and extractable, Be total and extractable, C dissolved Organic, C dissolved Inorganic, TKN, NO2/NO3, NO2, NO3, NH3, Alk., pH, Na, Mg, Al total and extractable, P dissolved and total, SO4, Cl, K, Ca, Va total and extractable, Cr total and extractable, Ma total and extractable, Fe total and extractable, Co total and extractable, Ni total and extractable, Cu total and extractable, Zn total and extractable, St total and extractable, Mo total and extractable, Cd total and extractable, Ba total and extractable, Hg, Pb total and extractable
		18207012002	Hwy 417 South of Carlsbad Springs	1974	Acidity, Alk., Al, BOD5, Ca, Cl, COD, Colour, Cond., Cu, DO, FC, Fe, Fl, Fecal Strep., Temp., Hard, K, Mg, Na, Ni, NH3, NO2, NO3, TKN, pH, phenolics, PO4, Residue filtered, residue particulat, residue total, Si, SO4, TC, Turb., Zn
		18207013002	Bearbrook at Carlsbad Spring	1975-1979	As above plus As, Cyanide, Cd, Co, Cr, Stream flow, Hg, Pb, TC M/F Bkgd.

Table 2c - Summary of Water Quality Monitoring Programs

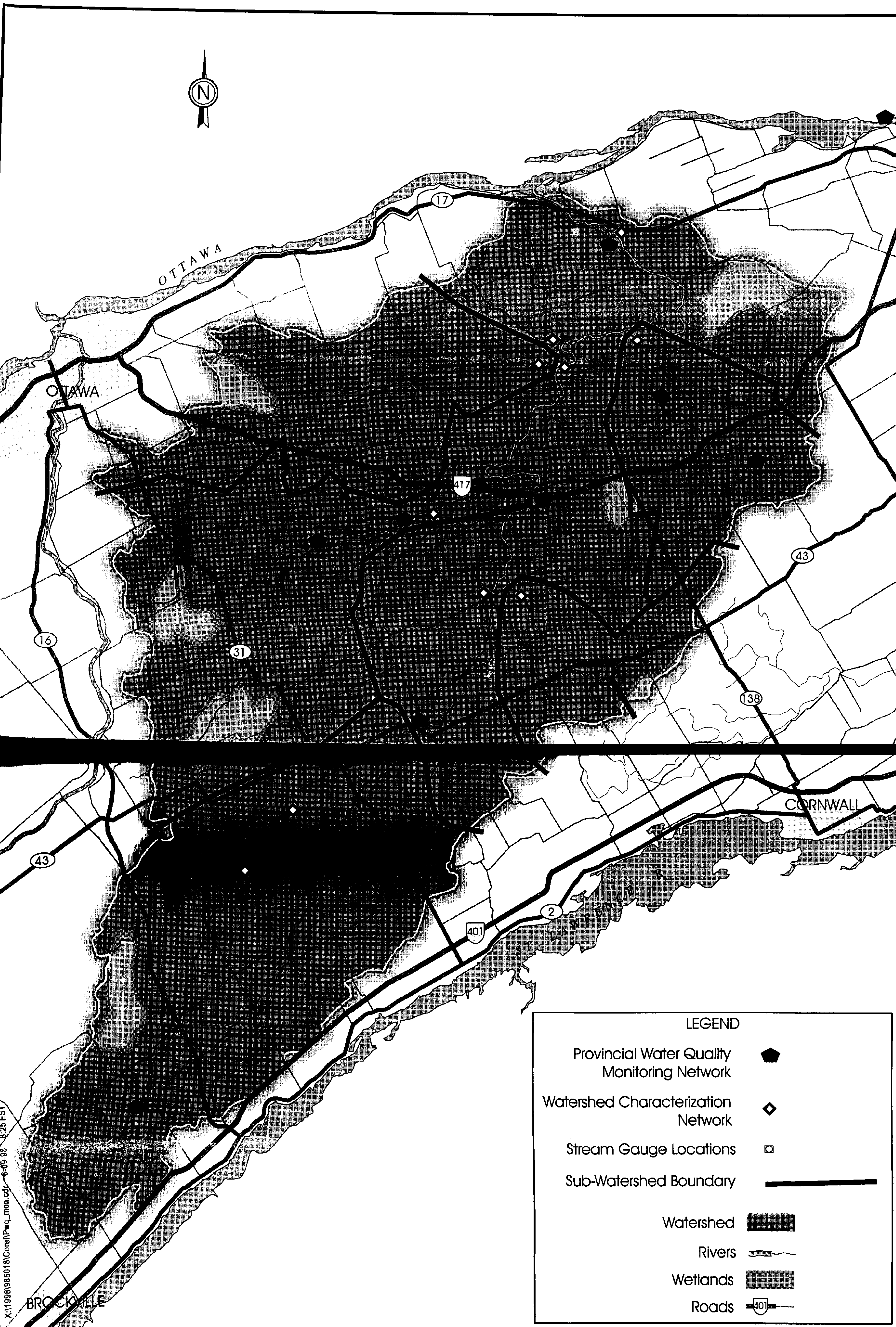
File	Designation	Station	Station I.D.	Date	Analysis
ORNBlackCreek.xls	Black Creek		South of Bourget Cnty Rd. 8 Clarence Twp.	1990-1994	Acidity, Alk., Al, BOD5, Ca, Cl, COD, Colour, Cond., Cu, DO, FC, Fe, Fl, Fecal Strep., Temp., Hard, K, Mg, Na, Ni, NH3, NO2, NO3, TKN, pH, phenolics, PO4, Residue filtered, residue particulat, residue total, Si, SO4, TC, Turb., Zn
PayneRiver.xls	Payne River	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16		1987-1990 1987-1989 1987-1989 1987-1991 1987-1989 1987-1989 1987-1989 1987-1991 1987-1989 1987-1989 1987-1991 1987-1989 1987-1989 1987-1991 1990-1991 1990-1991	BOD5, COD, NH3, TKN, NO2, NO3, TP, DRP, Cond., Cl, pH, Alk, Fe, K, Colour, Turb., SS, Fe, Fecal Strep., Ca, Mg, Hard.
ScotchR.xls	Scotch River	18207005002 18207009502	Scotch R upstream from Dunvegan Creek Scotch R. at Cnty Rd. 9, South of St. Isidore	1967-1971 1965-1967	Alk., BOD5, Cl, Cond., DO, Fe, Temp., Hard., NH3, NO2, NO3, TKN, pH, PO4, Residue Filtered, Residue Particulate, Residue Total, TC, Turb.
		18207004002	West Scotch R. Conc. 17, Downstream from St. Isidore	1965-1990	As above + Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, E. coli, FC, Fe, Fecal Strep., K, Mg, Ma, Mo, Na, Ni, Pb, *P aeruginosa*, Se, St, Ti, Va, Zn
		18207006002	East Scotch R. Conc. 19, Upstream from St. Isidore	1967-1997	
SNRCasselman.xls	South Nation R.	18207010002	South Nation R. Upstream of Casselman Dam	1964-1997	Alk., Al, As, Ba, Be, BOD5, Ca, Cd, Cond., Co, Cr, Cu, DO, FC, Fe, Fecal Strep., Temp., Hard., K, Mg, Mo, Na, Ni, NH3, No2, NO3, TKN, Pb, pH, PO4, *P aeruginosa,* Residue filtered, Residue Particulate, Residue Total, Se, St, Ti, Turb., Va, Zn

Table 2d - Summary of Water Quality Monitoring Programs

File	Designation	Station	Station I.D.	Date	Analysis
SNRChesterville.xls	South Nation R.	18207011002	South Nation R. at Chesterville Dam	1964-1997	Alk., Al, As, Ba, Be, BOD5, Ca, Cd, Cond., Co, Cr, Cu, DO, FC, Fe, Fecal Strep., Temp., Hard., K, Mg, Mo, Na, Ni, NH3, No2, NO3, TKN, Pb, pH, PO4, *P aeruginosa,* Residue filtered, Residue Particulate, Residue Total, Se, St, Ti, Turb., Va, Zn, DOC, E. coli, Ion Balance, Ma, TN, SO4
SNRPlantagenet.xls	South Nation R.	18207002002	South Nation R. Highway 17 Plantagenet	1966-1997	Alk., Al, As, Ba, Be, BOD5, Ca, Cd, Cond., Co, Cr, Cu, DO, FC, Fe, Fecal Strep., Temp., Hard., K, Mg, Mo, Na, Ni, NH3, No2, NO3, TKN, Pb, pH, PO4, *P aeruginosa,* Residue Particulate, Se, St, Ti, Turb., Va, Zn, DOC, E. coli, Ion Balance, Ma, TN, SO4
SNRPlantspring.xls	South Nation R.	18207003002	South Nation R. at CPR Bridge, Plantagenet Springs	1970-1971	Alk., BOD5, Cl, COD, Colour, Cond., DO, Fe, Temp., Hard., NH3, NO2, NO3, TKN, pH, Phenolics, PO4, Residue filtered, Residue filtered ashed, Residue total filtered loss on ignition, Residue Particulate, Residue Particulate Ashed, Residue Particulate Loss on Ignition, Residue total, Residue total ashed, Residue total loss on ignition, SO4, TC, Turb.
SNRRoebuck.xls	South Nation R.	18207015002	South Nation R. County Rd. 18 Roebuck Augusta Twp.	1995-1997	Alk., Al, Ba, Be, BOD5, Ca, Cd, Cl, Cond., Co, Cr, Cu, E. coli, Fe, Fecal Strep., Temp., Hard., K, Mg, Ma, Mo, Na, Ni, NH3, NO2, NO3, TKN, Pb, pH, PO4, *P aeruginosa,* Residue particulate, St, Ti, Turb., Va, Zn
SouthBranch,xls	South Branch R.	1 2 3 4 5	South Branch R. at Oak Valley Rd. South Branch R. at Cnty Rd 2 South Branch R. on Taylor Rd. Conc 6 Lot 25 Matilda Twp. Black Creek at County Road 18 South Branch R. at Cnty Rd. 18 Conc 5/6 Lot 29 Matilda Twp.	1994-1996	1994 = DRP, Cl, Cond., TKN, NO2 1995 = DRP, Cl, Cond., Temp, NH3, Un-Amm., NO3, TP, pH, Turb., DO 1996 = Temp, NH3, Un-Amm., NO3, TP, pH, Turb., DO

Table 2e - Summary of Water Quality Monitoring Programs

File	Designation	Station	Station I.D.	Date	Analysis
Wcharacter.xls	South Nation R. Watershed Characterization	1	South Nation R. at Jessup's Falls Conservation Area	1996-1997	1996 =E. coli, NO2+NO3, TP, Turb. 1997 = E. coli, NO2+NO3, NO2, P, Turb
		2	Mouth of Scotch R.		
		5	South Nation R. at Pendelton		
		8	Mouth of Bear brook		
		11	Little Castor R. at Embrun		
		19	Castor R. Downstream of Embrun		
		21	Mouth of Payne R. at Crysler		
		22	South Nation R. at Crysler		
		23	Cobb's Lake Creek at Pendelton		
		30	North Branch of the South Nation R. at Inkerman		
		31	South Branch of the South Nation R. at South Mountain		
			* Note 1997 data excludes station 19		



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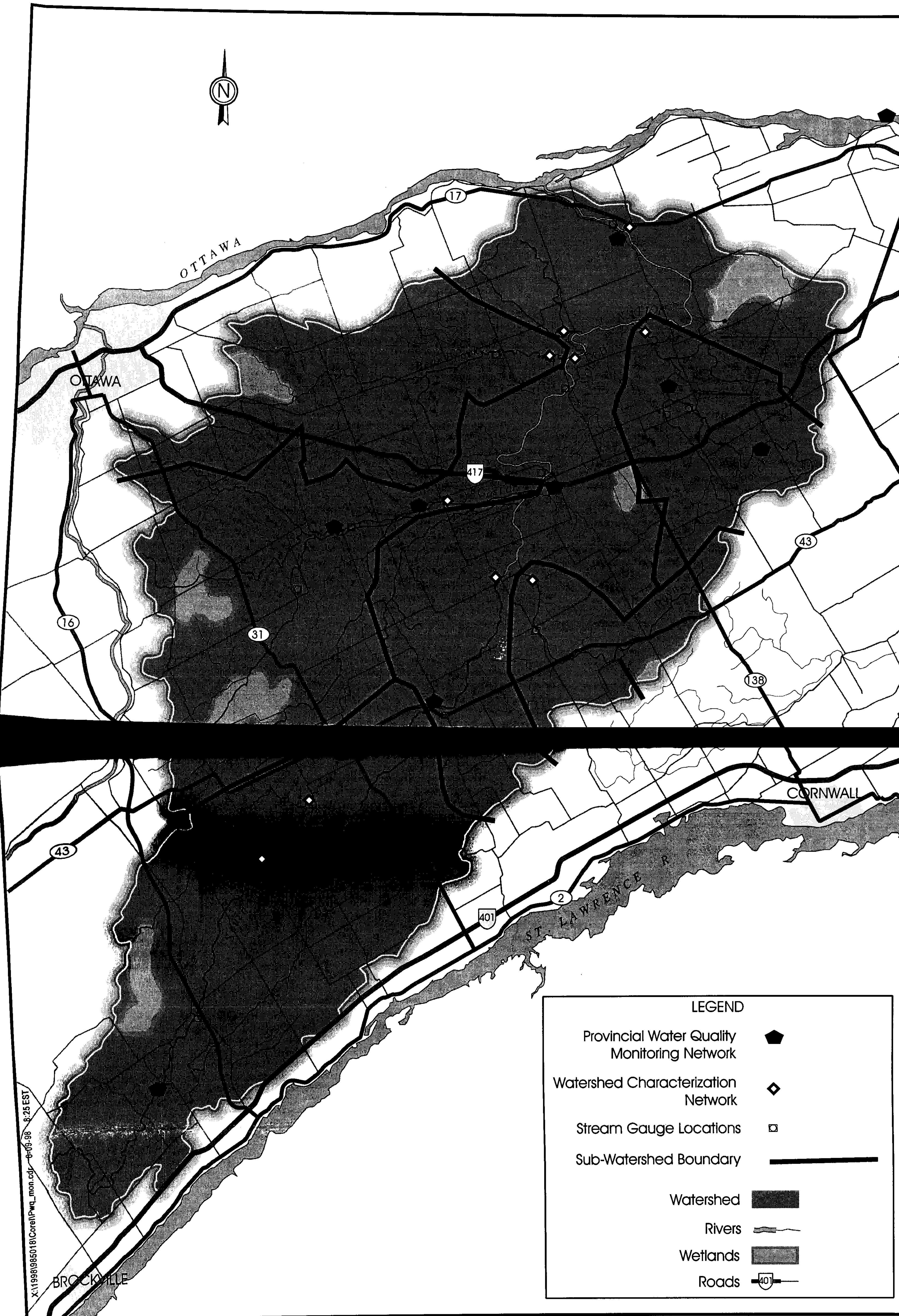
SOUTH NATION CONSERVATION AUTHORITY
WATER QUALITY MONITORING ASSESSMENT

STREAM GUAGE LOCATIONS

scale	NOT TO SCALE
date	JUNE 1998
drawn	DP
job no.	985018
drawing no.	FIGURE 1



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WATER QUALITY MONITORING ASSESSMENT

EXISTING PWQMN STATIONS
AND WATERSHED CHARACTERIZATION

scale	NOT TO SCALE
date	JUNE 1998
drawn	DP
job no.	985018
drawing no.	FIGURE 2

Figure 3 - Mean Monthly Flow
Spencerville (1948-1995)

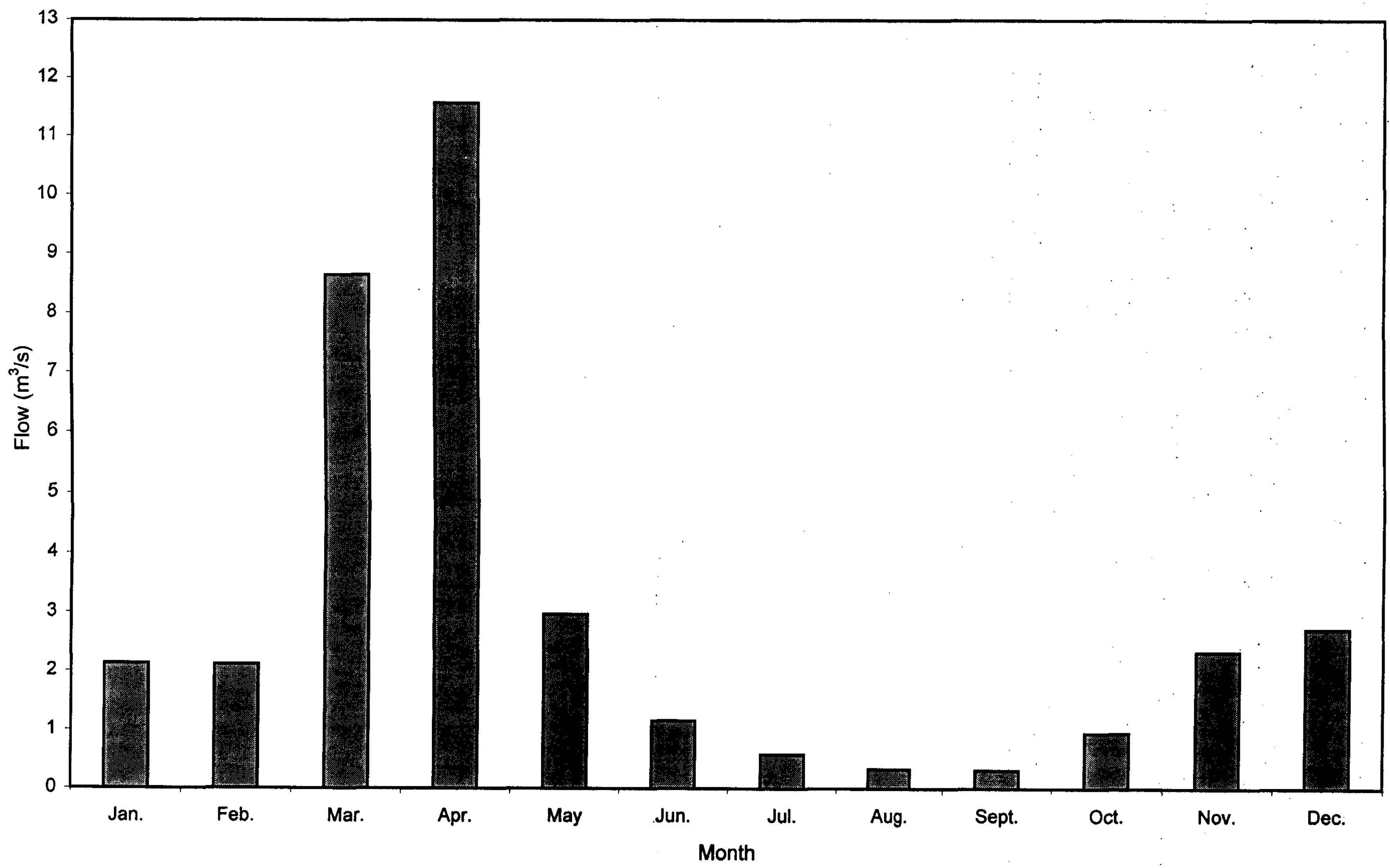


Figure 4 - Mean Monthly Flow
Plantagenent (1915-1995)

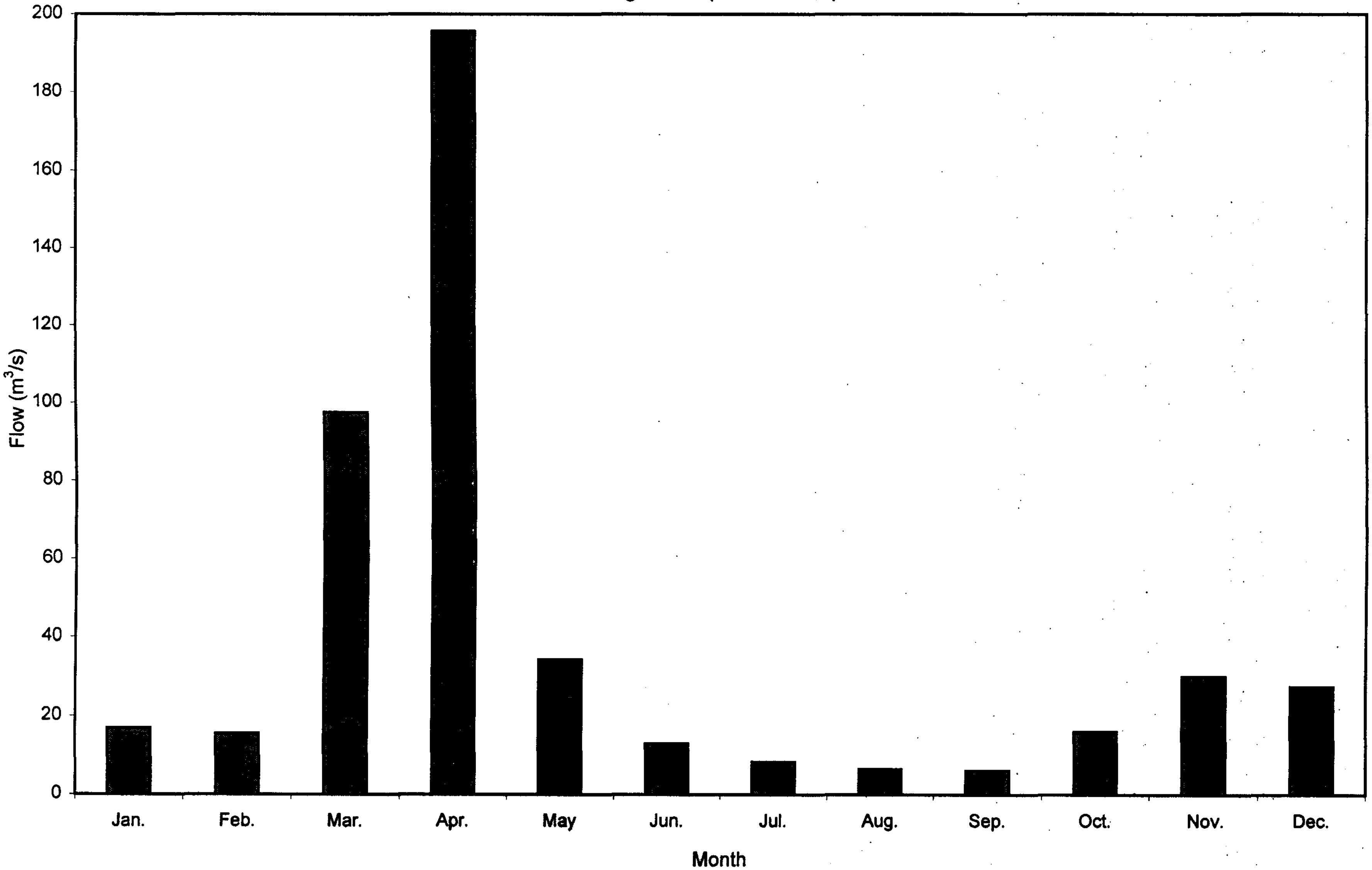


Figure 5 - Mean Monthly Flow
Castor River at Russell (1949-1995)

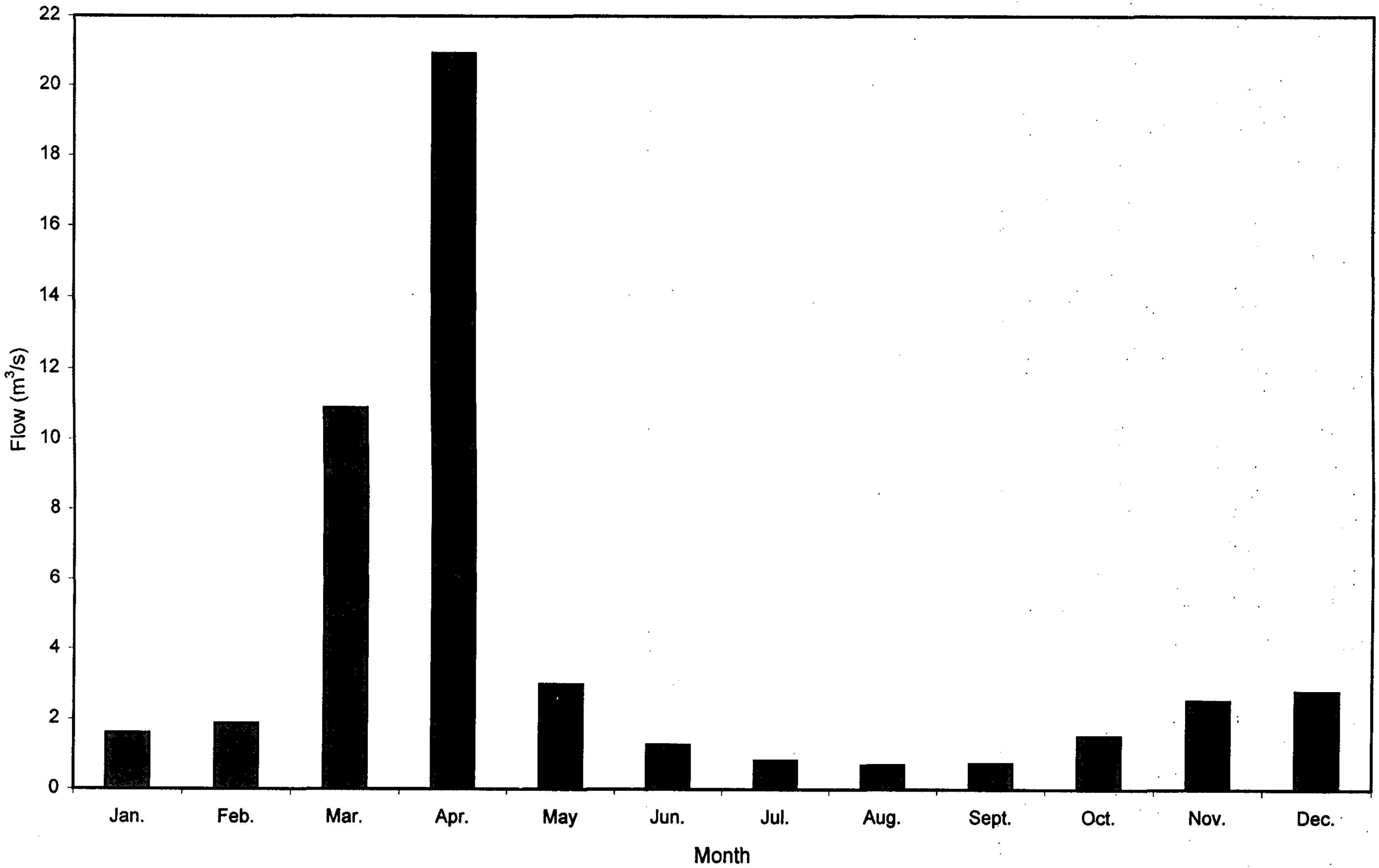


Figure 6 - Mean Monthly Flow
South Nation River at Chesterville (1949-1994)

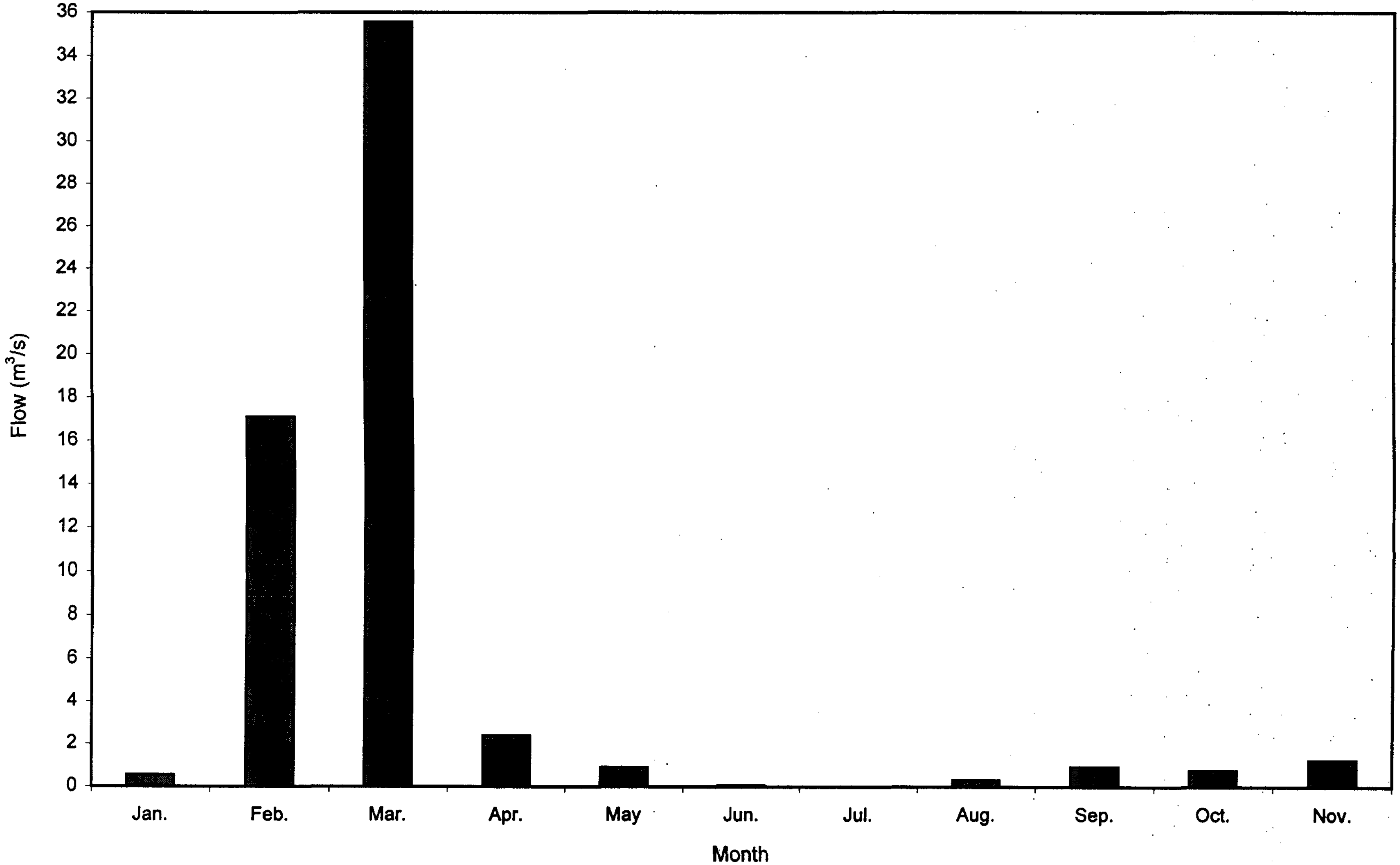
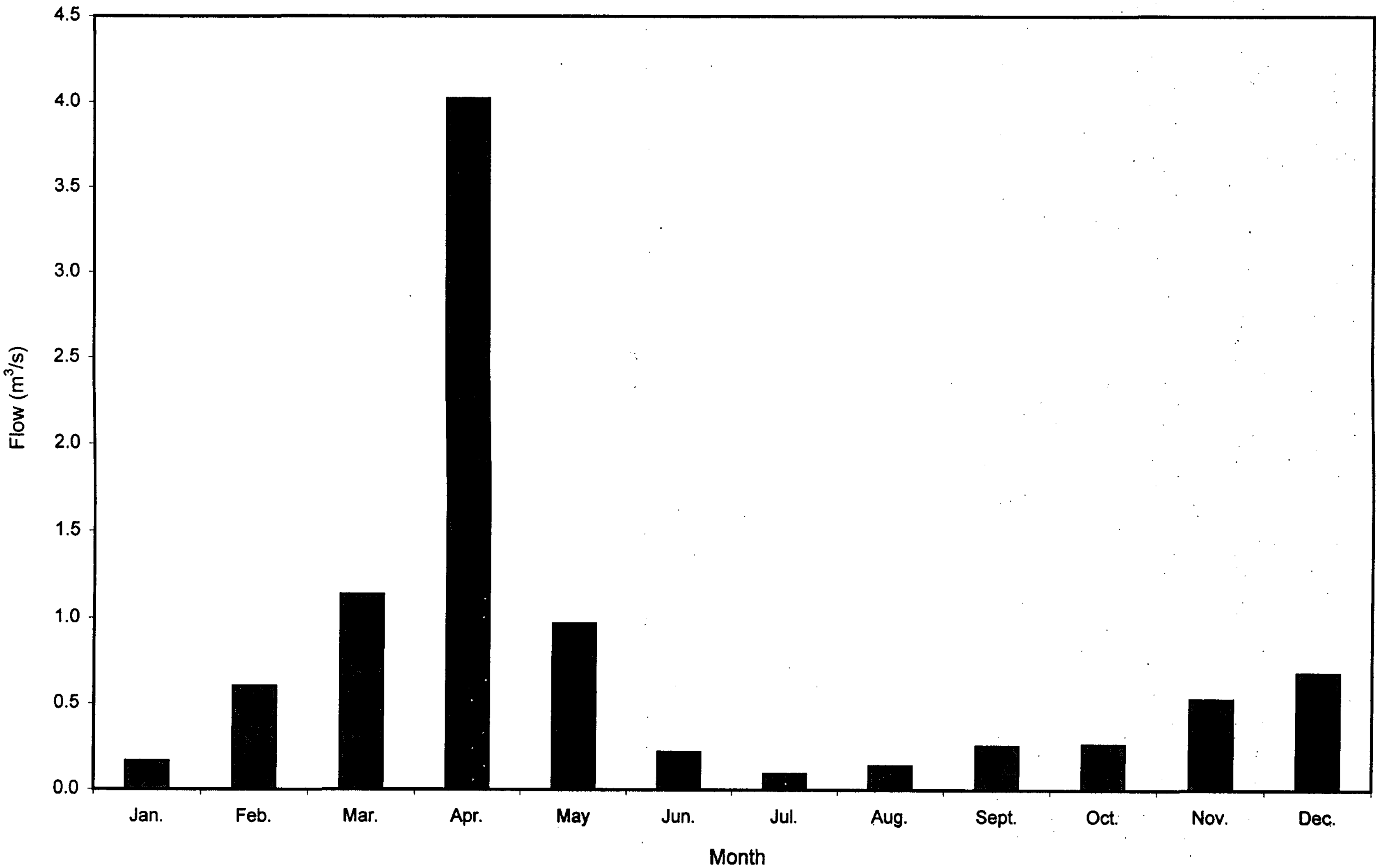


Figure 7 - Mean Monthly Flow
West Scotch River (1979-1995)



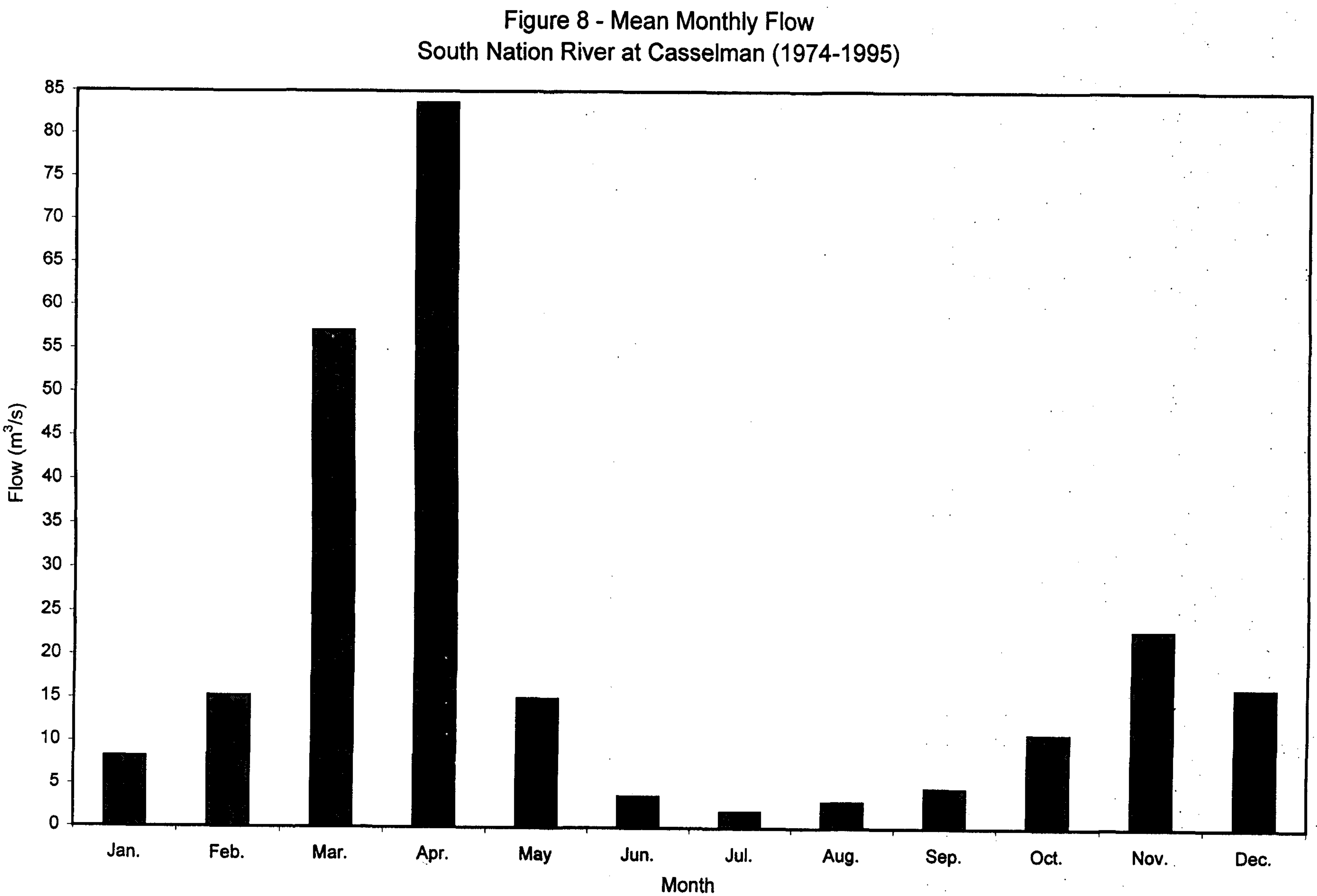
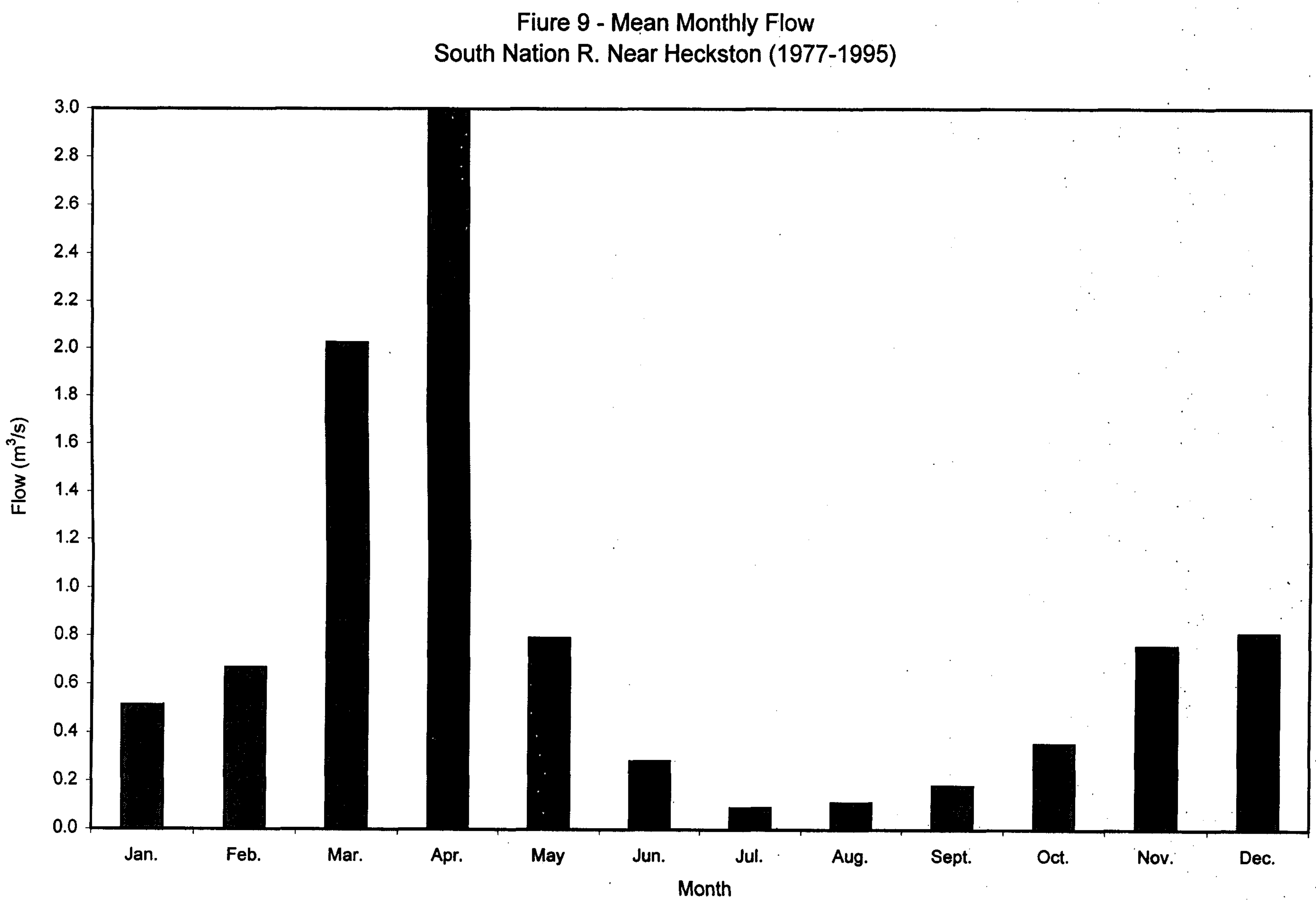


Figure 8 - Mean Monthly Flow
South Nation River at Casselman (1974-1995)
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Flow (m3/s)
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Month



Fiure 9 - Mean Monthly Flow
South Nation R. Near Heckston (1977-1995)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Flow (m^3/s)
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sept.
Oct.
Nov.
Dec.
Month

Figure 10 - Mean Monthly Flow
Payne River (1976-1995)

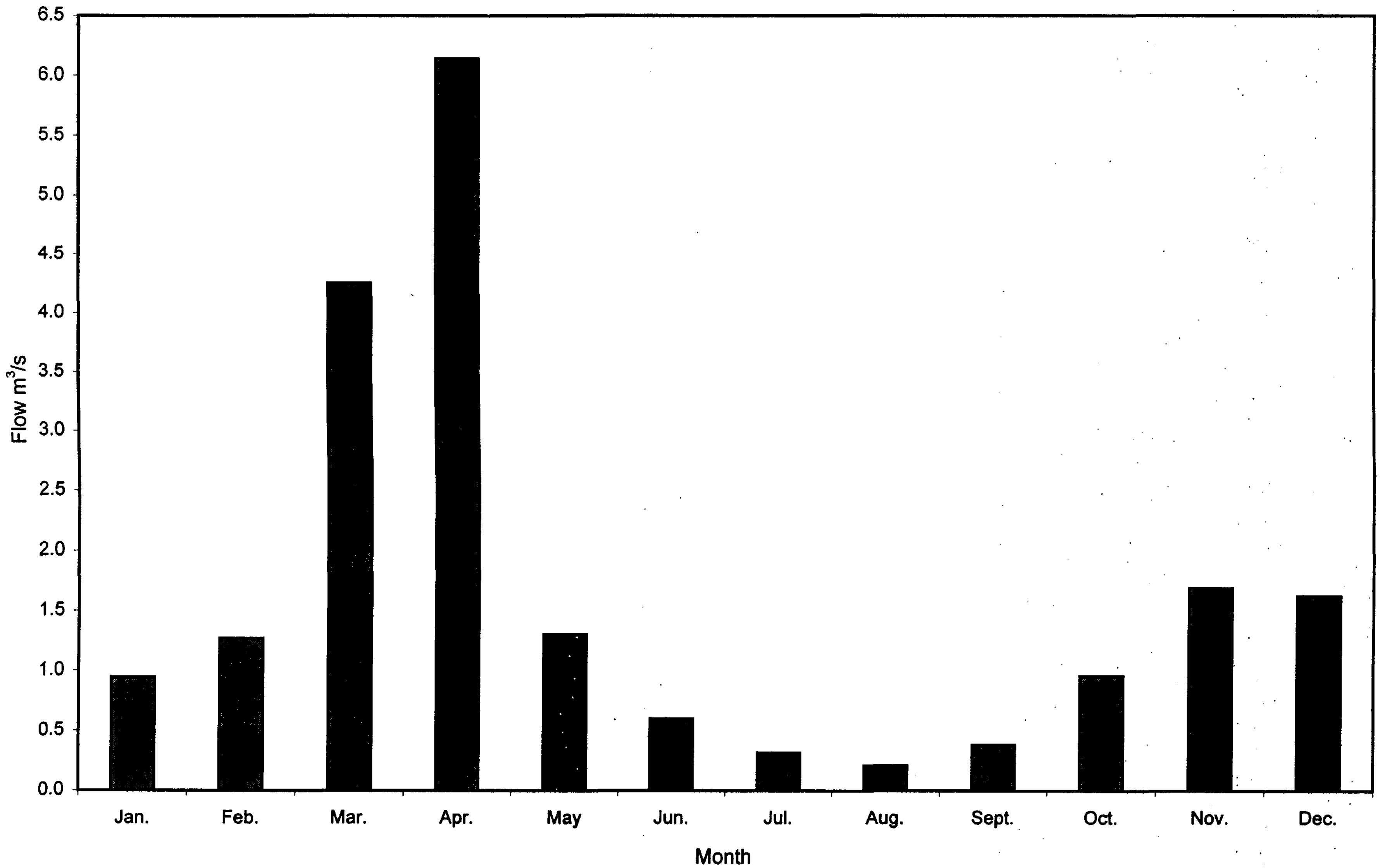


Figure 11 - Mean Monthly Flow
Bear Brook (1949-1995)

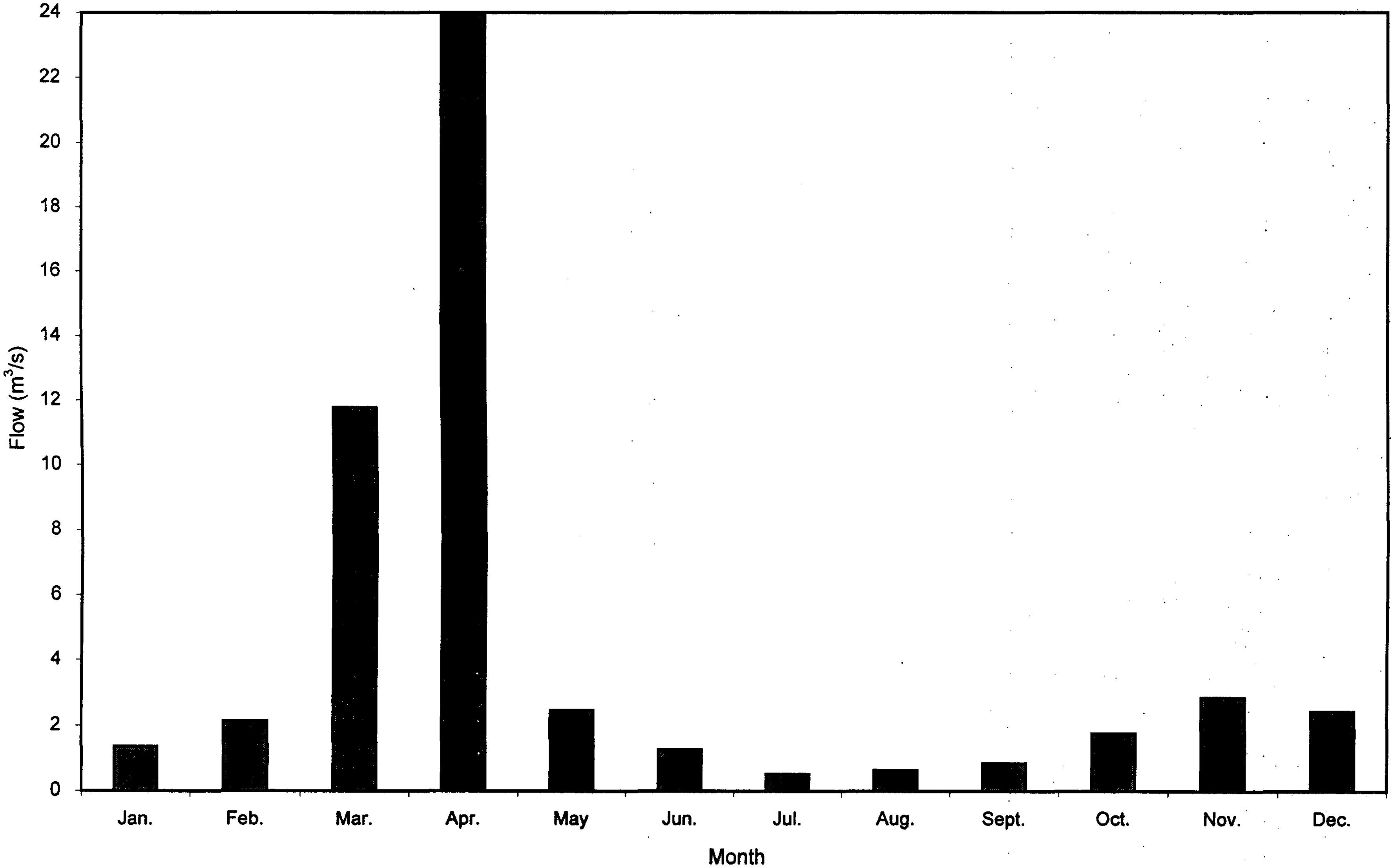


Figure 12 - Mean Monthly Flow
Little Castor River (1978-1983)

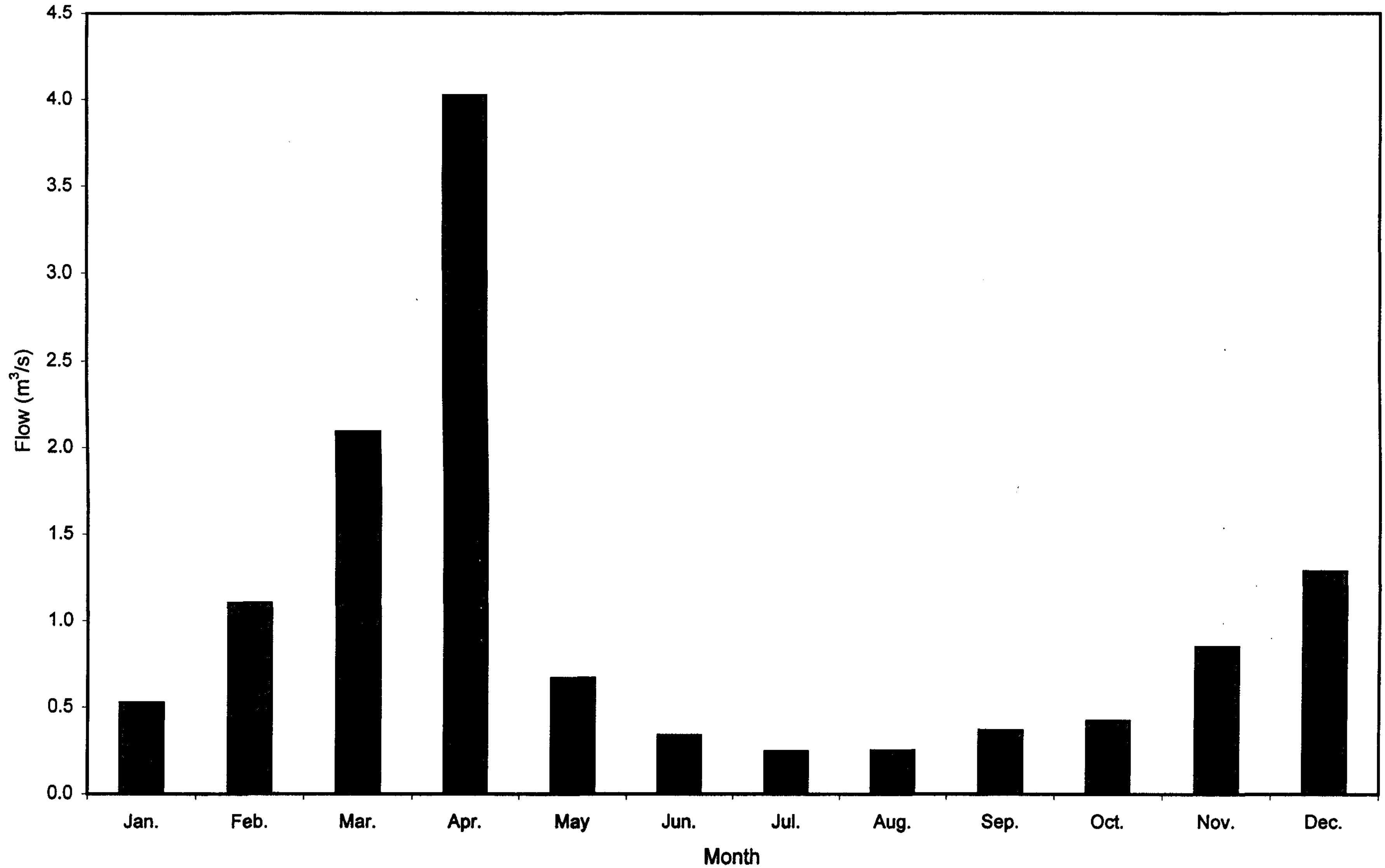


Figure 13 - Percent Monthly Mean

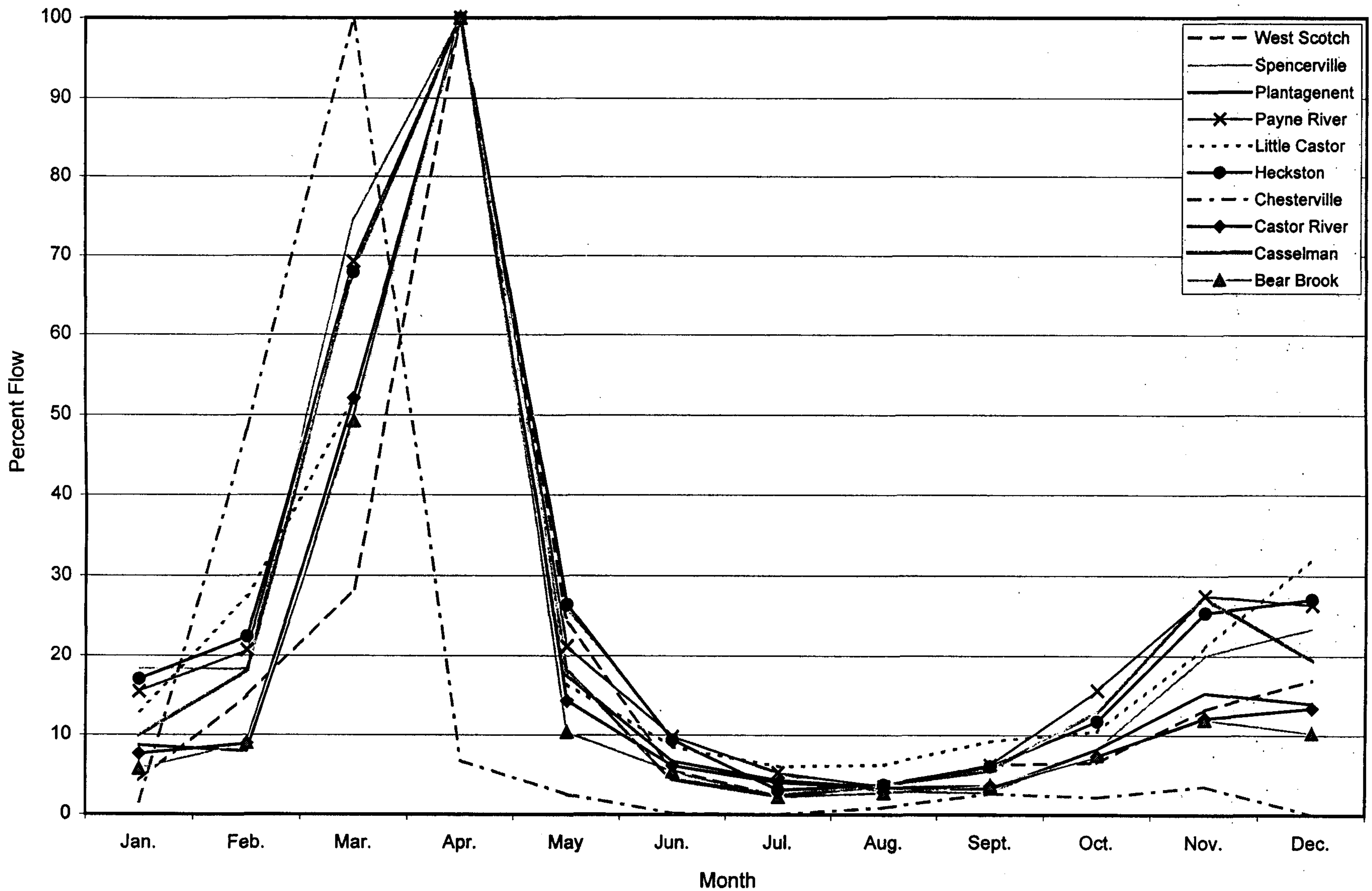


Figure 14 - Monthly Mean Comparison
Castor River At Russell

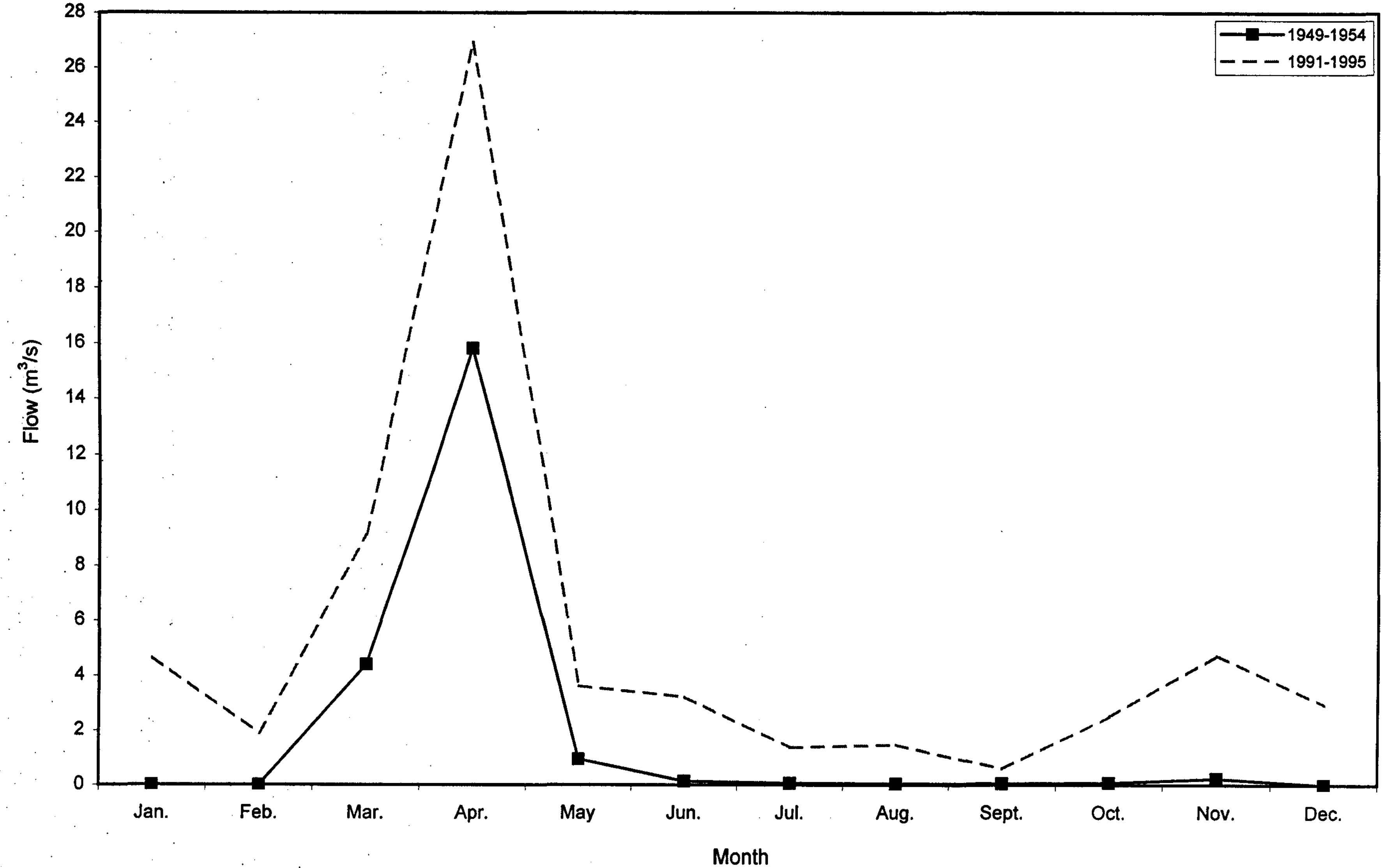


Figure 15 - Monthly Mean Comparison
Bear Brook

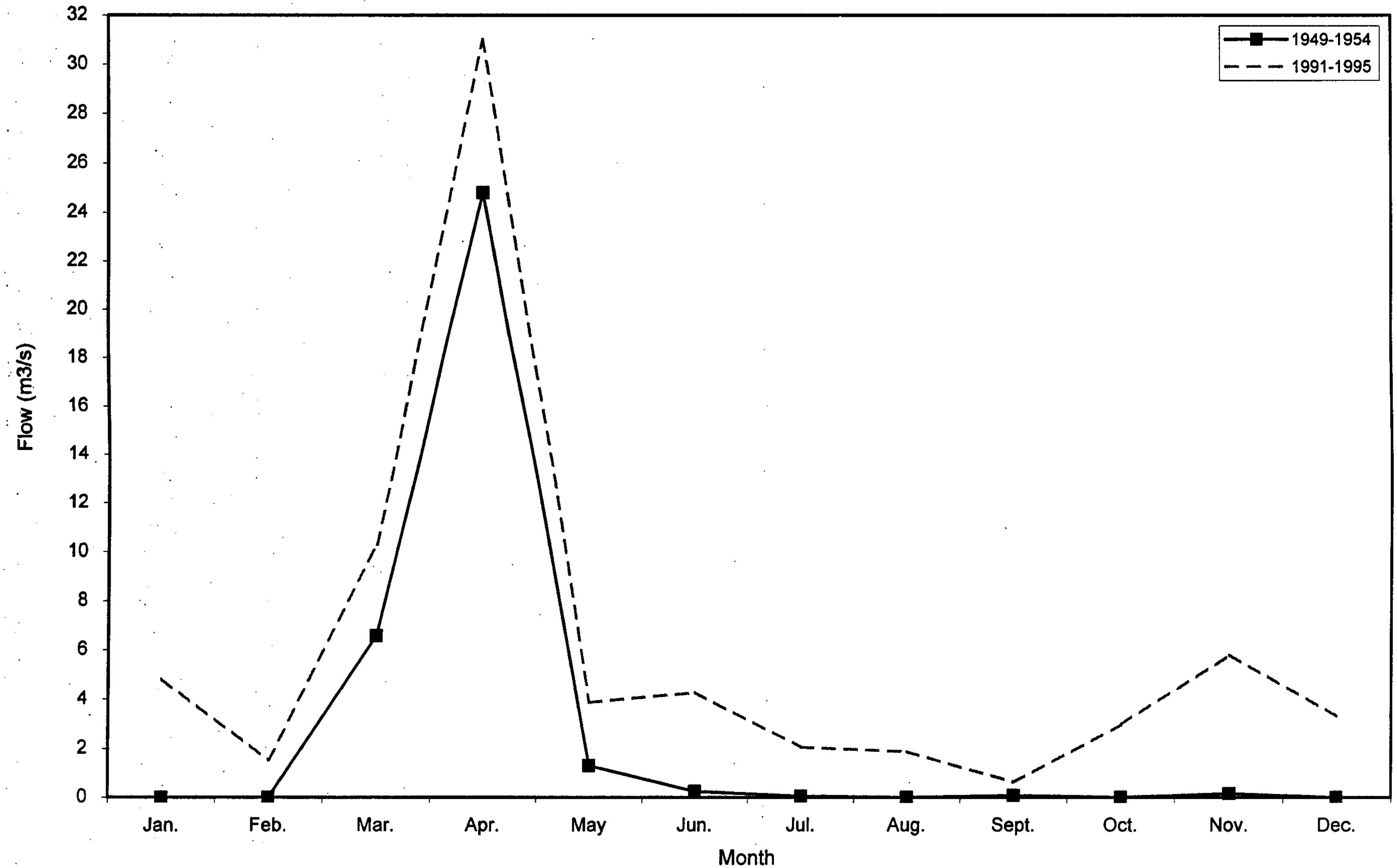


Figure 16 - Monthly Mean Comparison
West Scotch River

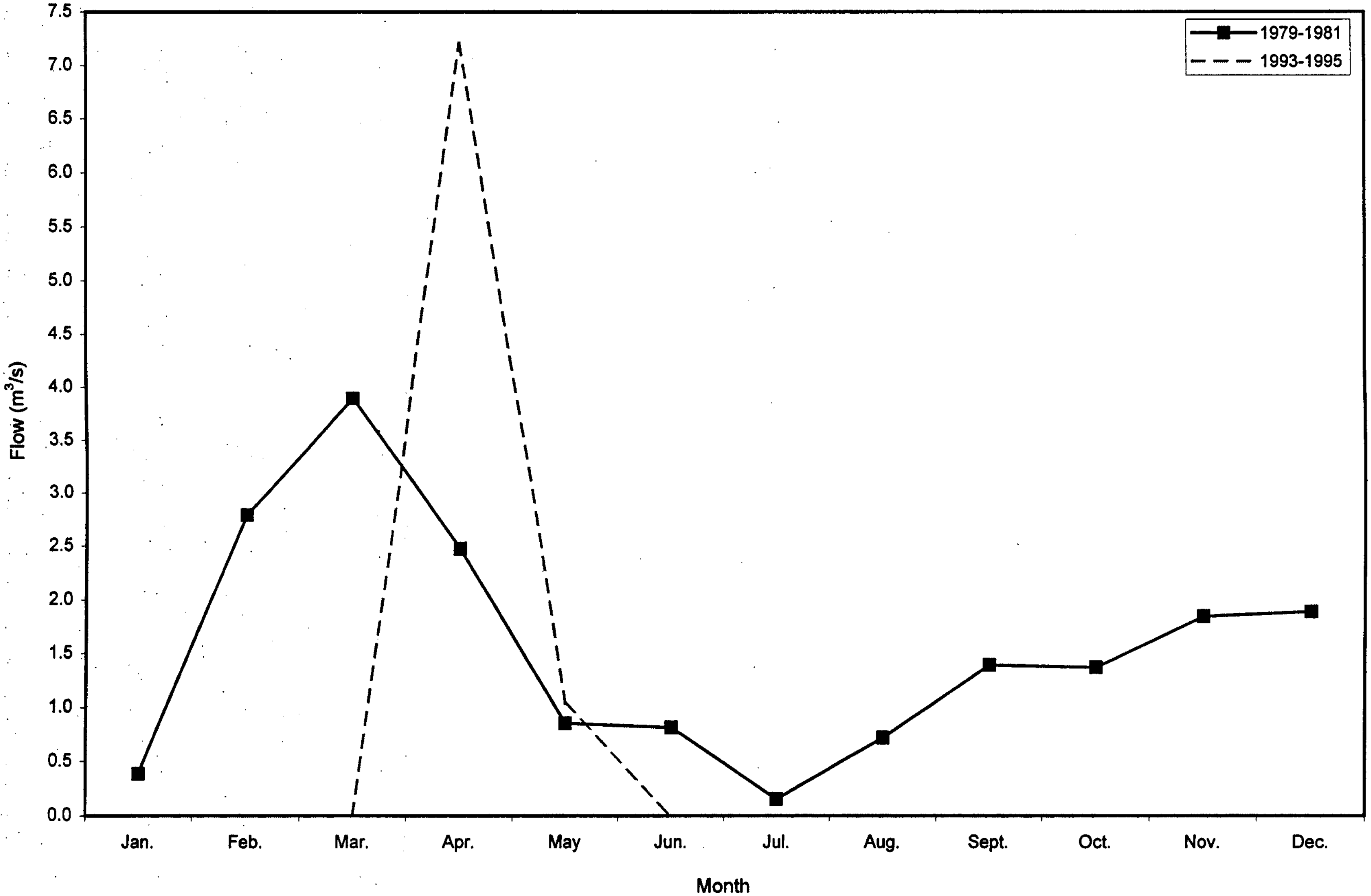


Figure 17 - Monthly Mean Comparison
South Nation River at Casselman

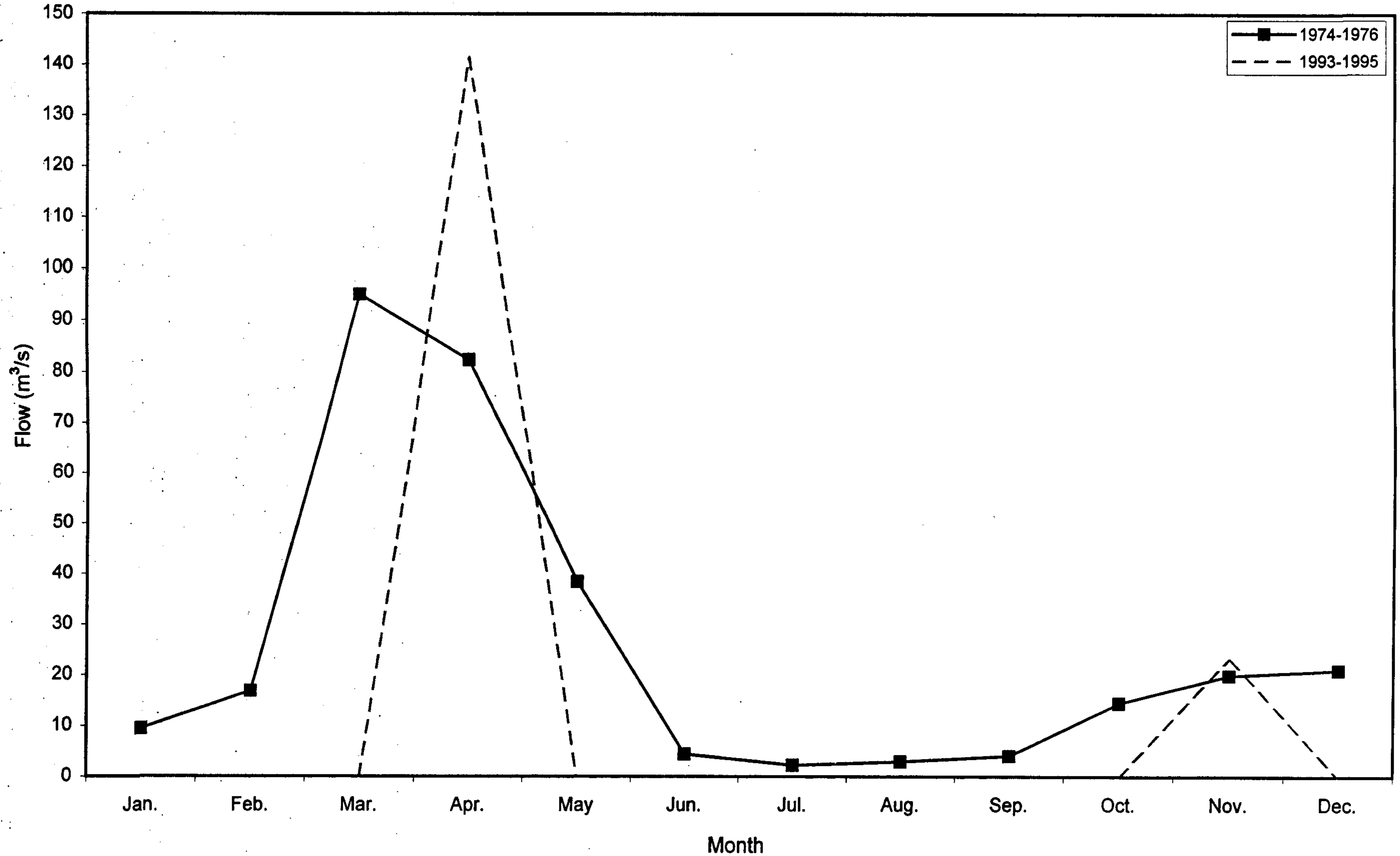


Figure 18 - Mean Monthly Comparison
South Nation River at Chesterville

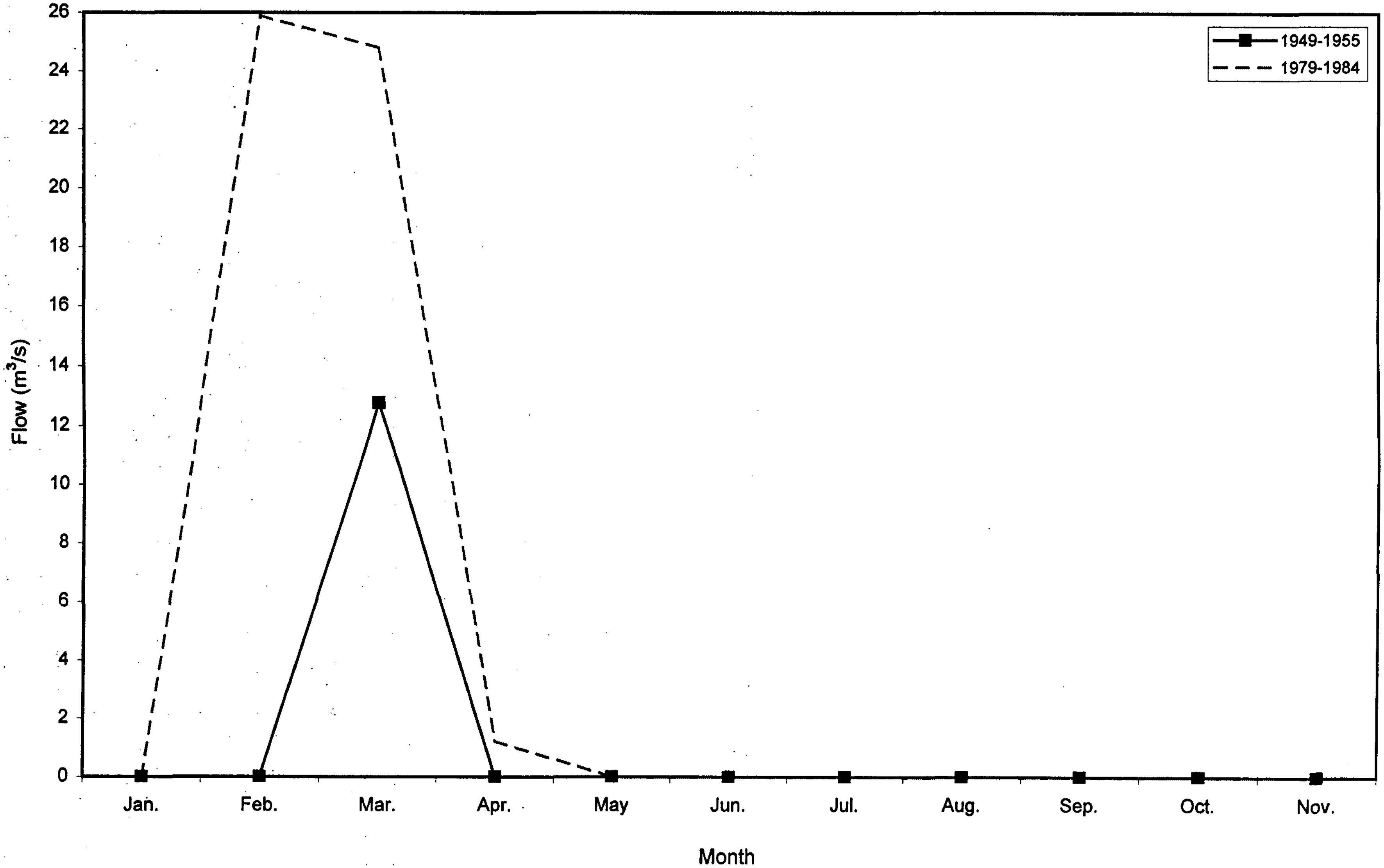


Figure 19 - Monthly Mean Comparison
South Nation River Near Heckston

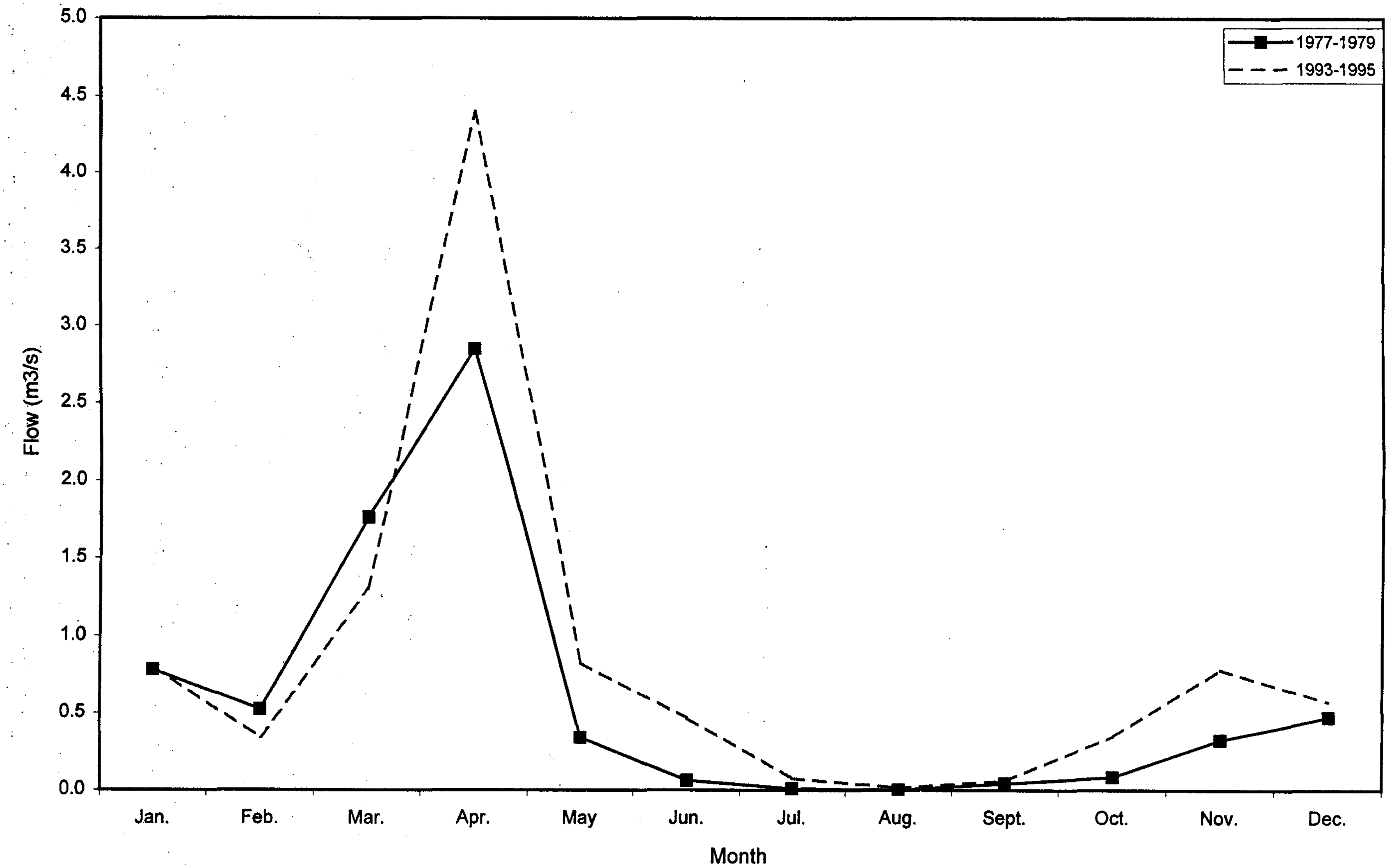
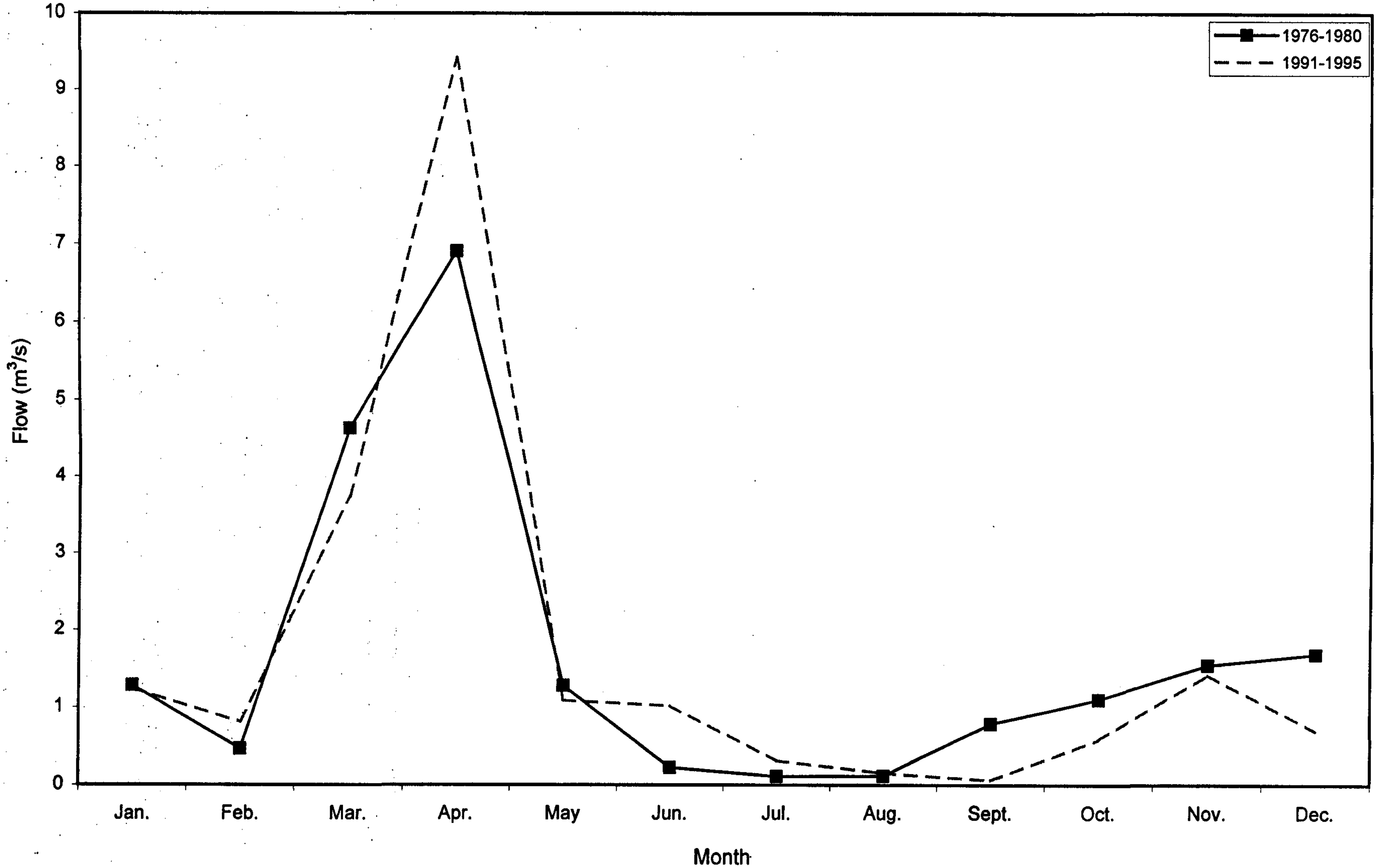


Figure 20 - Mean Monthly Comparison
Payne River Near Berwick



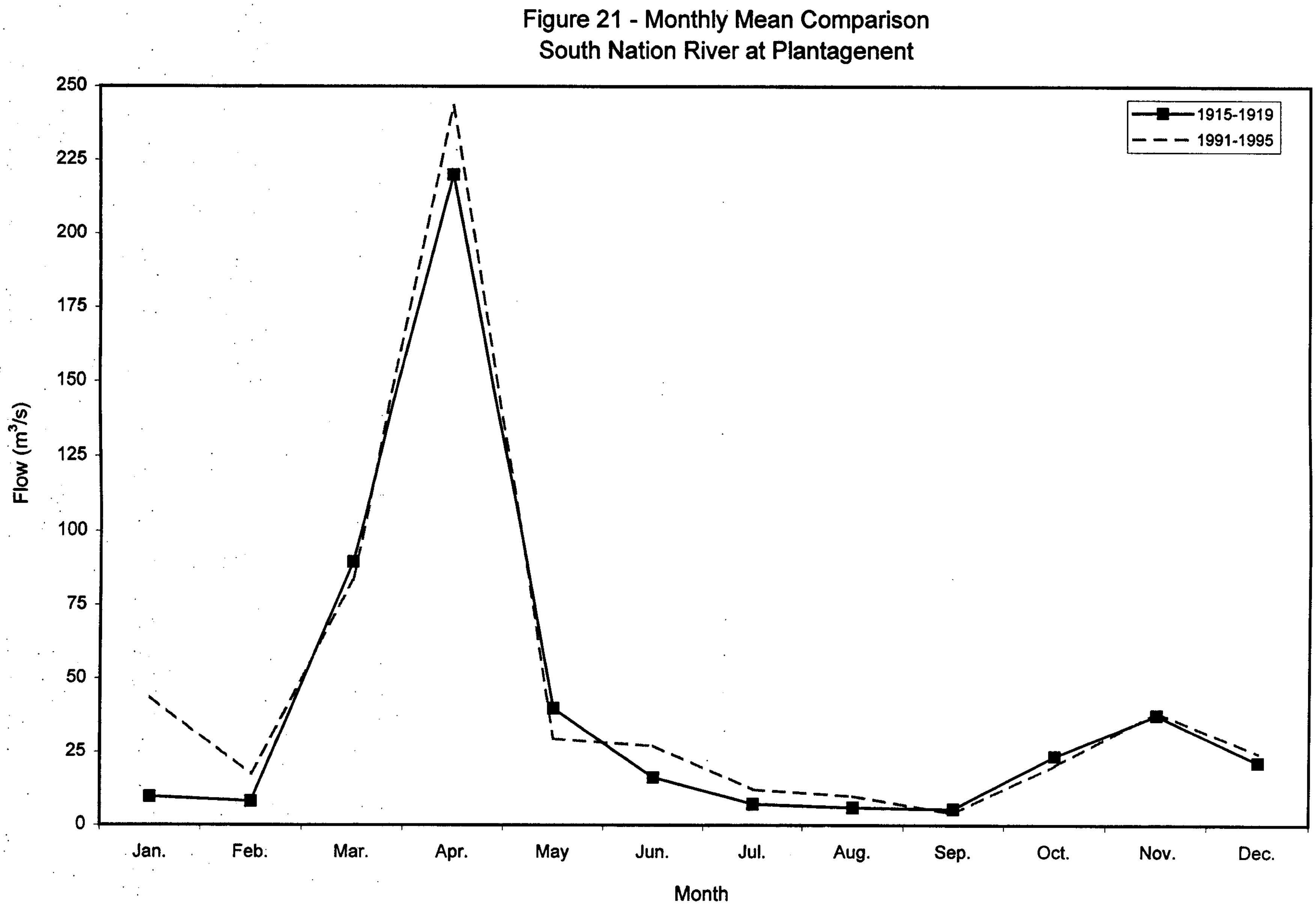


Figure 21 - Monthly Mean Comparison
South Nation River at Plantagenent
Flow (m³/s)
250
225
200
175
150
125
100
75
50
25
0
1915-1919
1991-1995
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Month

Figure 22 - Monthly Mean Comparison
South Nation River at Spencerville

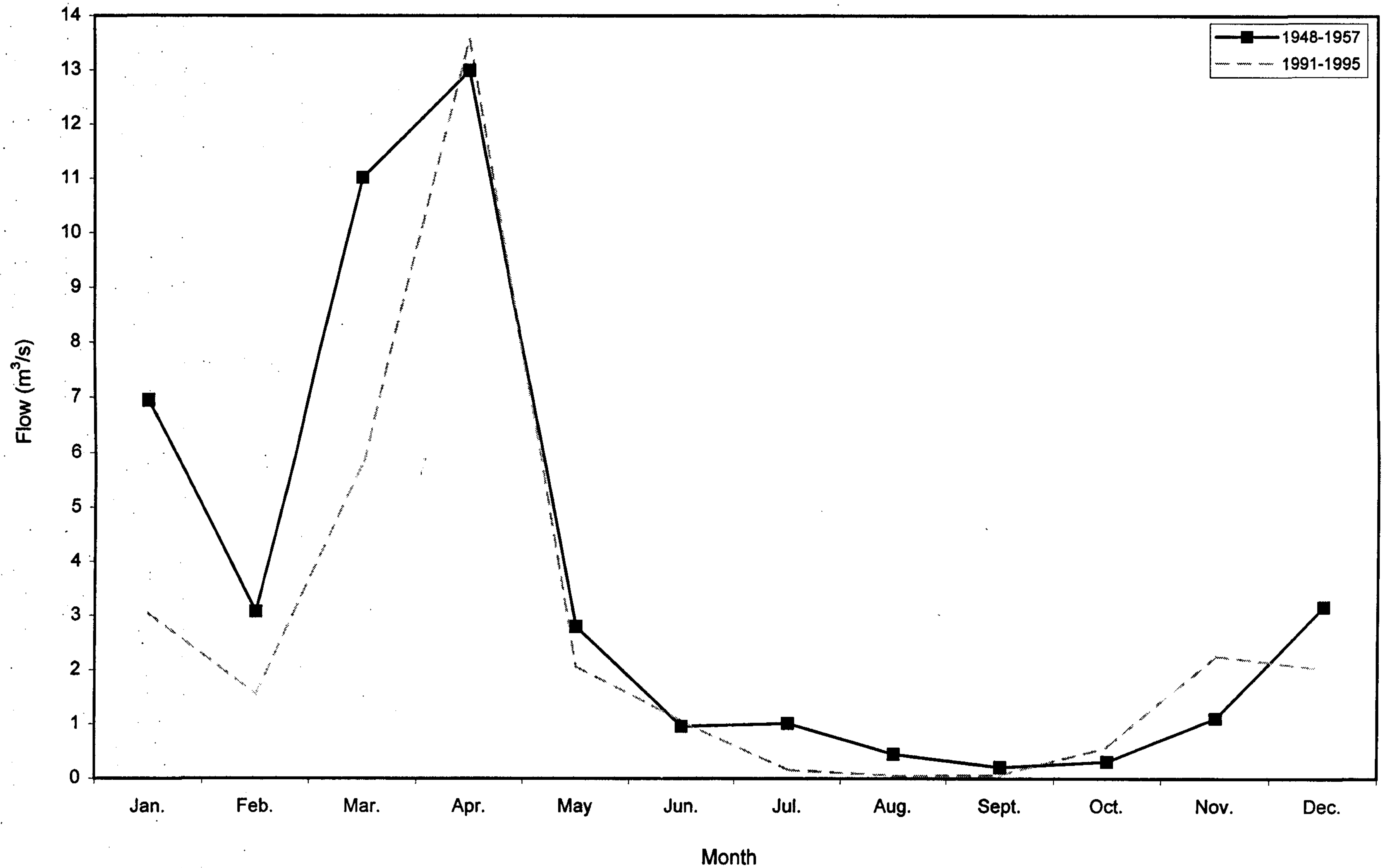
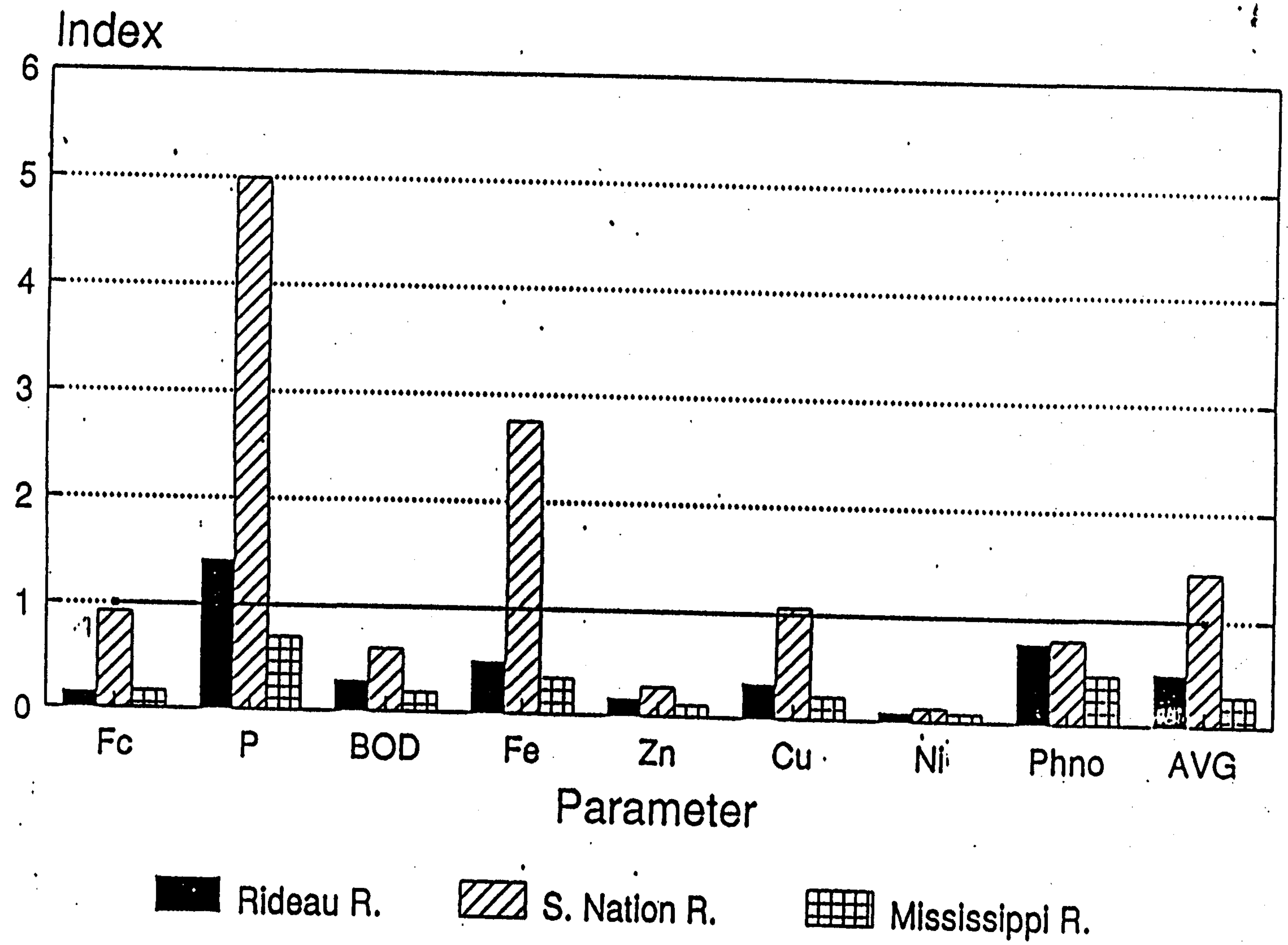
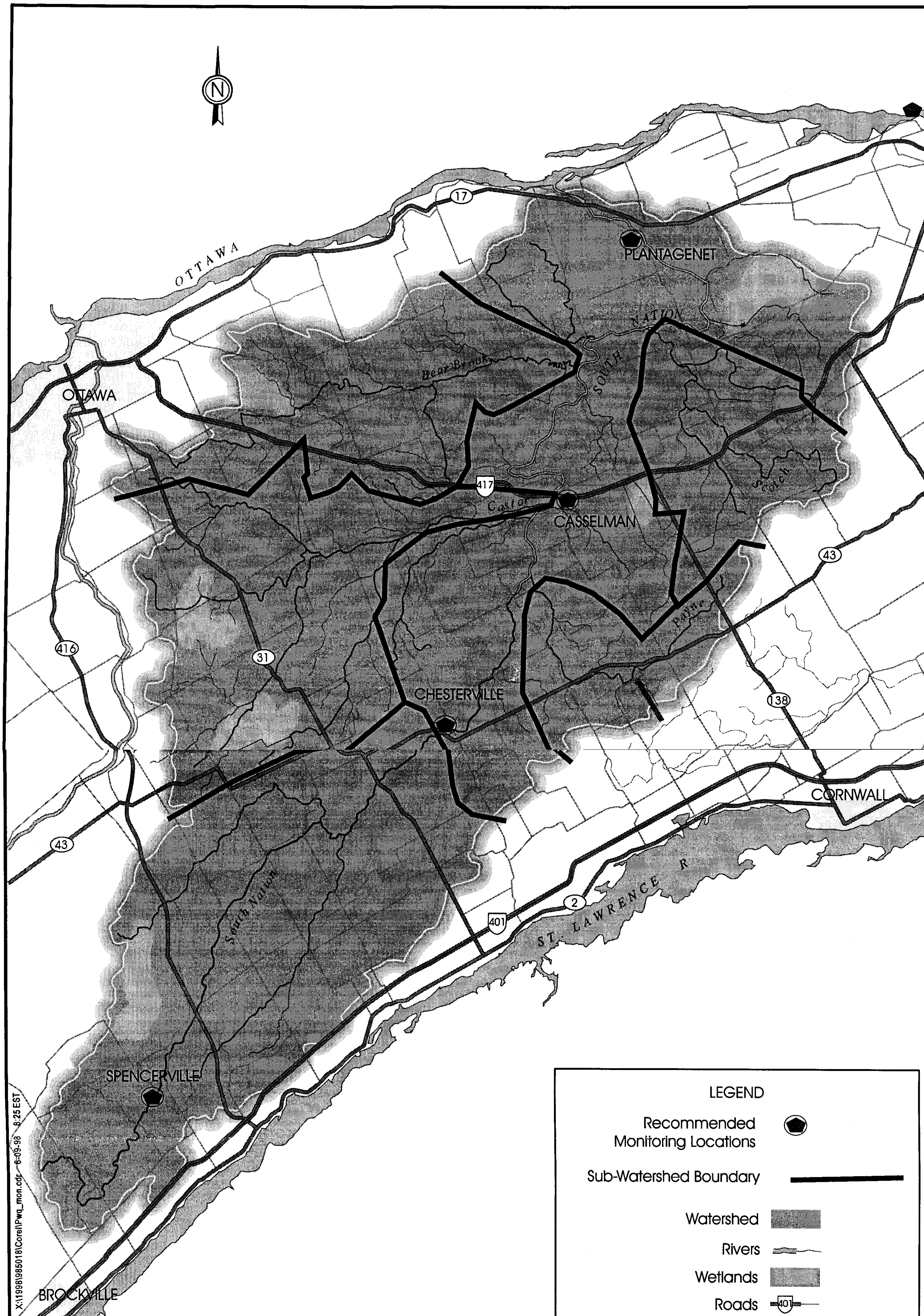


Figure 23 – Overall Water Quality Index





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SOUTH NATION CONSERVATION AUTHORITY
WATER QUALITY MONITORING ASSESSMENT

RECOMMENDED MONITORING STATIONS

scale	NOT TO SCALE
date	AUGUST 1998
drawn	DP
job no.	985018
drawing no.	FIGURE 24

APPENDIX A

South Nation Conservation
Water Quality Program Review

Bibliography

February 4, 1998
Sandra Porter

Water Quality Reports

Fischer, J.D., Apedaile, B.E, and Vanclief, L.K. (1995), "Seasonal Loadings of Atrazine and Metolachlor to a Southeastern Ontario River from Surface Runoff and Groundwater Discharge", Water Quality Resources Journal of Canada, Vol. 30, No. 3, 533-553.

Payne River was continuously sampled during 1991 and 1992. The maximum concentrations for atrazine were 0.83 and 1.20 $\mu g/L$. These values were approximately half the Canadian Water Quality Guideline for the Protection of Freshwater Aquatic Life (2 $\mu g/L$). Maximum concentrations of metolachlor, recorded on the same dates, were 0.43 and 0.26 $\mu g/L$, well below the Canadian Water Quality Guideline of 8 $\mu g/L$ for the Protection of Freshwater Aquatic Life. The presence of these compounds in the river water under dry weather conditions suggests that in addition to surface runoff, groundwater is also a significant source of pesticides to the Payne River.

Gore and Storrie Limited (1993), "Waste Water Assimilation Study of the South Nation River Watershed, Main Report and Appendices", prepared for the South Nation River Conservation Authority and Ministry of Environment.

Water quality in the South Nation River system has been improving during the past 12 years as additional wastewater treatment capability has been installed. However, the background quality in the streams consistently remains above the Provincial Water Quality Guideline for phosphorus. Annual nitrogen and phosphorus loads contributed by non-point sources to the South Nation River are greater than 98 and 93%, respectively.

With present background concentrations of phosphorus in the South Nation River system there is no assimilative capacity for phosphorus. New point sources will have to achieve low effluent total phosphorus (TP) concentrations along with concurrent reductions in non-point sources to return the rivers to a desirable state with respect to this pollutant .

River water quality analyses span from 1966 to 1991. Data from years before 1980 are not as relevant to the analysis for many parameters because waste sources discharging into the river have changed. Many communities did not have any wastewater conveyance or treatment facilities before 1980. River water quality is also highly affected by agricultural practices. More recent quality data would more accurately reflect the results of current agricultural practices in the watershed. During 1986-1991, phosphorus concentrations were almost always higher than the objective concentration. BOD and DO have improved during the same period. This was attributed to the installation of treatment facilities which have replaced malfunctioning septic tank disposal systems and other direct discharge sources. Changes in agricultural practices is another factor.

It is apparent that the total contribution of N and P from all wastewater sources is minimal compared to the nonpoint and other sources; same with BOD_5.

MacLaren Plansearch Lavalin (1982), "Water Resources Study Component of the South Nation River Basin, Executive Summary", prepared for the South Nation River Conservation Authority.

In general, water quality in the South Nation River Basin does not satisfy provincial water quality objectives for bacterial and total phosphorus concentrations. The majority of the phosphorus export emanates from the northern half of the basin which includes the Castor River and the Bear Brook, with unit area losses about twice that of the southern half of the basin. A previous study of the South Nation River Basin concluded that most of the sediment is being produced in the northern half of the basin with the Bear Brook and Castor River systems contributing the most sediment. Phosphorus losses associated with eroded bank material may be a high as 30-50% of the total annual basin phosphorus export. Subsurface drainage, which includes tile drain effluent, inter flow and active groundwater recharge, is estimated to contribute approximately 15% of the phosphorus export. The contribution of phosphorus losses associated with livestock activities is estimated to be between 7 and 35% of the total basin phosphorus export attributable to non-point sources. These studies demonstrate that management of livestock activities is more important in determining nutrient loss rates than animal densities per se, the larger animal inventories in the northern half of the basin may account for some of the higher phosphorus losses found in the north. The available database is insufficient to determine the mechanism by which nutrients attributable to livestock activities reach the streams. Cattle access to streams, feedlot runoff and poor manure management are likely sources and warrant closer examination on a farm by farm basis. Continuous corn cultivation usually results in the greatest unit area phosphorus losses compared to the other agricultural cultivation activities.

Bacteriological objectives are exceeded throughout much of the basin, notably in the northern areas. Fecal contamination is animal in origin....data is insufficient to distinguish the mechanism by which this reaches the stream. Other studies have shown that the level of bacterial contamination cannot be related to livestock density since manure management practices are the controlling factors.

Recommendations include controlling erosion, esp. in the northern half (bank, channel and field erosion sources), buffer strips and grassed waterways, controlled cattle access, improved manure management techniques; evaluate reductions in sediment and nutrient losses associated with no tillage, conservation tillage, and crop rotation systems.

Smith, B.D. (1993), "Summary of Sediment Monitoring of the 1993 South Nation River Lemieux Landslide", Monitoring and Systems Branch, Environment Canada, Ontario Region.

Historic data collected from sediment monitoring on the South Nation River near Plantagenet Springs indicated that the majority of suspended sediment load transported is of the silt-clay size fractions with very little sand. The material that now was deposited in the river from the June 1993 slide included large quantities of sand sized material resulting from the sand lens that were capped by the Leda marine clay. Four sites were sampled for sediment monitoring along the South Nation River (Casselman, Pendleton Bridge, Seguin Bridge, and Plantagenet Springs) 1993 and 1994. Casselman site was sampled previously during the 1971 landslide and up to 1982, a considerable quantity of pre-1993 landslide sediment data was available. All sites monitored below the landslide area show that the majority of suspended sediment loads are fine silt-clay in composition. This will continue to pose problems downstream in terms of water quality parameters, and its effects on fish and wildlife. The upstream site at Casselman will continue to supply a natural suspended sediment load of fine grained material, with the exception of the Bear Creek tributary which contributes the only sand component of pre-landslide sediment loads.

South Nation River Conservation Authority (1983), "South Nation River Basin Water Management Study, Main Report".

Surface water quality in SNRB does not satisfy PWQ objectives for phosphorus and bacteria. Sediment loads are high..mainly associated with spring snowmelt flood and high flows. High phosphorus concentrations result from high sediment loads. Most of the sediment is produced in the northern half of the basin (Bear Brook and Castor River being largest contributors). Three major sediment producing sources identified as: mass wasting, open channel drains, and sheet erosion of fields. Sediment data from 1972 to 1977. Total phosphorus concentrations throughout the basin have frequently been measured at more than twice the PWQG (0.03 mg/L) and are sometimes higher than 10 times. Reference to the Water Resources Background Study states approximately 95% of the phosphorus losses to the stream originate from non-point sources. Nitrate-Nitrogen rarely exceeds PWQG of 10 mg/L level. Runoff from tile drains was of better quality than surface runoff, except for nitrate-nitrogen. Bacteria objectives were exceeded throughout the basin, most notably in northern areas; sources include livestock access and concentrated feedlot runoff. Livestock operations appeared to be the major source of bacterial pollution - in some watersheds bacterial quality was extremely poor even though the livestock density was very low. It would follow that the way livestock operations are managed and not just their size, is also an important consideration. Management options for non-point source pollution problems discussed (manure management, cattle access, crop rotation, conservation tillage, critical area planting, permanent vegetation, field borders).

South Nation River Conservation Authority (1990), "Payne River Report 1987-1989", draft.

Sampling 1987-1989; Payne River discharges into South Nation upstream of the Villages of Casselman and Plantagenet (which draw their drinking water from the river). Fecal Coliform densities indicate contamination throughout the entire Payne River with worst contamination being at uppermost stations. Primary sources of fecal contamination are cattle in the river and runoff from manure piles, barnyards, and pastures; also faulty domestic septic systems. 52 farms were surveyed in 1987 in the upper Payne Basin; 5 out of 40 dairy farms drained their milkhouse waste into an open ditch, potentially causing significant phosphorus loading on the river. Others used weeping tile systems and thus, a malfunctioning weeping tile system will also contribute significantly to phosphorus loading. For two of three years, all of the stations have averaged in excess of 0.03 μg/mL. Poor tillage practices, lack of permanent vegetation in critical areas, and stream bank erosion by animals will all contribute to the problem. There were no incidents of nitrate concentrations over 5 ppm and only isolated incidents of nitrate concentrations over 1 ppm. The amount of BOD is an indicator of the organic pollution in the water (a BOD level of 2 mg/L or less indicates little or no organic pollution in the river). BOD levels over three year study were mostly between 2 and 3 mg/L. There were several elevated readings (between 10 and 70 mg/L); these were limited to headwater stations and were associated with elevated TKN levels, fecal contamination, and excessive phosphorus levels. The sample stations in the upper reaches of the river exhibited excessive turbidity (stations 11, 12, and 13 were all consistently over 100% of natural turbidity level). Pesticide sampling took place for only one year but it is evident that pesticides are moving through drainage water into the river. In terms of agricultural pollution, it is reasonable to assume that the Payne basin is typical within the South Nation River watershed.

South Nation River Conservation Authority (1993), "Rural Beaches Study of the Lower South Nation River Watershed, Year 1 Report".

The South Nation River and its tributaries, downstream of the Village of Crysler were sampled weekly from June 11 to August 26, 1992 (twenty-three stations). E. coli levels exceeded Ministry of Health's objectives of 100 organisms per 100 mL of water for five weeks at Jessup's Falls CA near Plantagenet and for the entire sampling period at High Falls CA in Casselman. Faecal coliform concentrations were similar to E. coli at these stations. Total phosphorus concentrations exceeded the Provincial Water Quality Guideline at all sample stations for the entire sampling period.

South Nation River Conservation Authority (1994), "Lemieux Landslide Impact on Water Quality of the South Nation River, 1993 Interim Report".

Weekly water quality samples were collected between June and August 1992 and 1993. Sites were located at Jessup's Falls CA (north of Plantagenet), Pendleton, and Lemieux (all three downstream from the slide) and Casselman (upstream of slide). Parameters tested included E. coli, faecal coliform, nitrate, total phosphorus, turbidity, and suspended sediment. Casselman was used to determine background water quality. This site exhibited bacteriological levels and total phosphorus levels above PWQO (for recreational use).

An increase in turbidity, suspended sediment, bacteria and nutrient concentrations were noted at other stations as a result of the Lemieux landslide, which had a great impact on water quality of the South Nation River. Water supplies for drinking water, animal consumption and general farm use were impaired downstream of the landslide.

South Nation River Conservation Authority (1995), "Clean Up Rural Beaches (CURB) Program, Aquatic Invertebrate Report".

Four CURB sites were sampled upstream and downstream (control site, manure/milkhouse wash, septic and cattle access) for aquatic invertebrates, bacteria, and nitrogen and phosphorus; each station was only sampled once, during July 1995. Premise that "surface waters of good quality are expected to carry a diversity of aquatic insect species; poor quality waters are expected to contain a higher frequency of pollution-tolerant aquatic insect species". Waters of the South Nation described as "very turbid". Invertebrate data indicated poor water quality at manure/milkhouse site; livestock fencing showed water quality to be excellent upstream and good downstream; good water quality at the septic system site. Septic system site and manure/milkhouse wash site both exhibited higher phosphorus and nitrogen levels downstream; the three non-controls sites showed bacteria levels exceeding Provincial Water Quality Guideline (PWQG) both upstream and downstream.

South Nation River Conservation Authority (1995), "Clean Up Rural Beaches (CURB) Plan for the Lower South Nation River Watershed", prepared for the Ontario Ministry of Environment and Energy.

Twenty eight stations along the South Nation River system downstream of Crysler were sampled on a weekly basis between June and August 1992 and 1993. Both bacteria and nutrient samples were collected from the centre of a bridge spanning the river, where possible. The South Nation River at Jessup's Falls Conservation Area near Plantagenet (Station 1) exhibited occasional values above the PWQO for E. coli during both years of the study. E. coli concentrations were above the Objective (100 counts per 100 mL of water) for a period of five weeks during 1992 and on two occasions in 1993. Excessive bacteria, turbidity and phosphorus concentrations were noted following the Lemieux landslide in June 1993 along the South Nation River and tributary mouth stations downstream of the landslide. High Falls Conservation Area in Casselman consistently exceeded the Objective for E. coli during both the 1992 and 1993 sampling seasons. The Castor River at Russell exhibited E. coli values consistently near the PWQO. All tributaries excluding Castor River and Moose Creek exhibited dry weather E. coli geometric means above the PWQO during both years. Total Phosphorus values were above the PWQ Guideline of 0.03 mg/L for most sample stations throughout the two year sampling period. The prevalent occurrence of elevated total phosphorus concentrations suggests that phosphorus pollution is a widespread problem through the entire study area. Nitrogen parameters were within the acceptable limits at all stations during the two year study interval. Values above 40 FTU for Turbidity were common on the South Nation River downstream of the Village of Lemieux and at sites located on Moose Creek, Bear Brook, Cobb's Lake Creek and the Scotch River. Turbidity values were extremely high at these sites following the landslide in June 1993. Turbidity levels gradually approached pre-slide levels at the end of the 1993 sampling season. Suspended sediment concentrations generally decreased with downstream distance from the slide.

South Nation River Conservation Authority (1995), "Water Quality Analysis of the South Branch South Nation River" (DRAFT).

A two-year channelization project (to widen and deepen the channel) began in the summer of 1992 on the South Branch. Monthly water samples were collected along the South Branch between May and November 1994, four sampling stations on the South Branch and one on Black Creek.

For a better understanding of water quality characteristics and trends in the South Branch, the 1994 water quality data should be compared to pre-channelization data. However, for a number of reasons, no statistical comparison between the 1974, 1978 and 1994 data sets can be conducted. These reasons included the limited amount of data for 1974 and 1978 and sampling and parameter testing methods for 1974 and 1978 are unknown.

The South Branch is impacted to some degree by pollution, indicated by general increasing downstream trends in turbidity, total phosphorus, nitrate and nitrite. Pollution contributors may include stream bank erosion, faulty septic systems, manure runoff, milkhouse waste water, field erosion and commercial fertilizer.

South Nation River Conservation Authority (1995), "Farm Water Supply Testing Downstream of the 1993 Lemieux Landslide".

Water samples taken from the South Nation River after the 1971 slide showed sediment loads downstream of the slide showed sediment loads downstream of the slide to be 10 to 50 times greater than sediment loads upstream of the slide. Increased sediment loads were still experienced 10 years later with loads being 2 to 5 times greater than pre-slide loads. The increase in sediment load had a detrimental effect on the already poor water quality of the South Nation River and negative effects on drinking water, fisheries habitat, crop yields, livestock consumption, recreational use of the South Nation River, and sanitation of dairy farm equipment downstream of the landslide. The water quality standards required for a farm are dictated by the end use of the water. There are three common classifications of farm use water: domestic (drinking water), livestock, and irrigation. Water used for domestic use should meet the "Ontario Drinking Water Objectives" (ODWO). As well, water used in sanitizing milking equipment should meet these objectives.

Water samples were taken from milkhouse taps at 6 farms located along the South Nation downstream of the Lemieux landslide. A minimum of one sample per month was taken from each farm between October 1993 and June 1994. Although most of the farms in the program had water treatment systems that worked with varying degrees of success, none of the systems produced water that consistently met the ODWO. Four farms had total coliform and indicator organism densities that were consistently higher than the Maximum Acceptable Concentration (MAC) from Ontario Drinking Water Objectives (ODWO). Three farms exceeded the Aesthetic Objective (AO), 5 NTU, for turbidity. All farms were well below MAC levels for nitrate.

South Nation River Conservation Authority (1996), "The South Branch of the South Nation River: The Wetland, Woodland, Wildlife Study, 1995 Water Quality Results".

4 stations along the South Branch and 1 on Black Creek - 1995 sampling season, 8 samples collected between April and October. All 5 stations exhibited phosphorus levels five times PWQO (0.03 mg/L). Black Creek station reached levels 23 times higher than PWQO. In 1994-95, mean levels of total phosphorus exceeded the guideline. Phosphorus worsened at three out of 5 sites. Turbidity levels were worse in 1995 at all sites. 1995 received more rain than 1994.

South Nation River Conservation Authority (1996), "Non-Point Source Pollution Study for the South Nation River Watershed".

Landuse is given for six sub-watersheds of the South Nation Basin (Upper South Nation, Castor River, Bear Brook, Payne River, Scotch River, and the Lower South Nation). Typically water quality in the South Nation River and its tributaries is poor throughout the year with high phosphorus, bacteria and sediment concentrations resulting in unpotable water. In the past, water quality in the basin has not satisfied the PWQOs for bacteria and phosphorus. Although there are a number of sources, the high levels of these contaminants have been atttributed to the large percentage of agricultural land. Water and Earth Science Associates Ltd. concluded that most of the sediment is produced in the northern half of the watershed with little contribution from areas upstream of Crysler. They found that the Bear Brook and Castor River systems were producing most of the sediment. Also, an ongoing study of the water quality in the Castor River system incidates that sediment continues to be a problem. Other areas of concern in terms of sediment production included Horse Creek, Caledonia Creek and the Scotch River. The South Nation River Basin Development Study reported three major sediment producers: a) mass wasting; b) open channel drains; and c) sheet erosion of fields; also improperly constructed open channel drains are main contributors of sediment. Erosion from fields is less significant than erosion from open channel drains in terms of sediment production. This is due to the relatively flat topography and diverse cropping pattern within the watershed.

The 1976 MOE nutrient survey of the SNR watershed found that there were elevated levels of phosphorus in the entire watershed, including all major rivers, tributaries and the headwaters (most samples had concentrations were at least twice the guideline (0.03 mg/L). TP levels were slightly lower in the southern portion of the watershed. Between 1980-88, most water quality samples taken in the watershed had total phosphorus concentrations greater than the MOEE guideline. The Scotch River sub-watershed had the highest concentration of total phosphorus. The Castor River also had high concentrations of total phosphorus. The data collected by the

CURB program between 1992 and 1994 is similar to 1980-1988 data. The two sub-watersheds with the highest concentrations of total phosphorus were the Scotch sub-watershed and the Lower South Nation sub-watershed. Cobb's Lake Creek had the highest TP in the South Nation River watershed. High concentrations were attributed to erosion susceptible soils and a high density of agricultural operations. Chan et al. (1980) reported that in the past the objectives for both total and fecal coliform were exceeded throughout much of the watershed. Between 1992 and 1994, there was no bacterial data collected in the Upper South Nation River watershed. Cobb's Lake Creek (located in the Lower South Nation Sub-Watershed) had the worst water quality in terms of bacterial contamination. Other areas of concern were the Scotch and Payne sub-watersheds. The presence of total, fecal and E. coli in the South Nation River system is attributed to both human and animal sources. The primary human source is faulty septic systems. In some test watersheds water quality, in terms of bacteria, was poor although the livestock density was very low, indicating proper management of livestock operations is as important as the size of the operation.

South Nation River Conservation Authority (1996), "South Nation River Clean Up Rural Beaches (CURB) Program, Year II Annual Report, 1995/96", prepared for the Ontario Ministry of Environment and Energy.

Completed CURB projects from 1994 to 1996, dealing with septic systems; livestock access restriction; milkhouse wastewater disposal; and manure storage. Seasonal E. coli geometric means for stations upstream of Casselman were below the PWQO for all years 1992-1995. Total phosphorus levels in the South Nation River and its tributaries exceeded the MOEE guideline of 0.03 mg/l for the protection of aquatic life for most samples collected during the four years of sampling. The prevalence of elevated total phosphorus concentrations suggests that phosphorus is a widespread problem throughout the South Nation River watershed. The "Non-Point Source Pollution Study - Draft Report" also identified phosphorus and sediment as being largely contributed from non-point source pollution in the South Nation River watershed. Values above 35 FTU were common in the South Nation River downstream of the Village of Lemieux and at sites located on Moose Creek, Bear Brook, Cobbs Lake Creek and the Scotch River.

Uutala, A.J., (1995) Personal Correspondence with South Nation River Conservation Authority, regarding: Invertebrate Samples from the South Branch of the South Nation River, 1978 & 1995, Queens University.

Comparison of invertebrate data collected on the South Branch 1978 and 1995. Four sites, one control and three others) were sampled. Data indicates that the sites are probably more polluted than they were in 1978. Productivity levels have gone up and water clarity and oxygen levels have probably declined.

Water and Earth Science Associates Ltd. and McNeely Engineering (1981), "Erosion-Sedimentation Study", prepared for the South Nation River Conservation Authority.

Mass movement, either directly or indirectly, is probably responsible for most of the sediment production in the basin. It is because of deposition into rivers and looseness of material that landslide deposits can be easily eroded by the rivers and why they are so important as a source of sediment. For the 1972-78 period maximum daily loads [sediment] varied from 9260 t/d in 1975 to 157,000 t/d on 20 May 1976. Two events caused very significant increases in total sediment loads, the Lemieux slide in 1971 and an exceptionally rainy and wet year in 1976. Max. daily loads between 21,000 and 38,000 t/d seem to be average during more typical years. In general, very significant variations in suspended sediment loads which vary directly as a function of discharge are typical of the watershed. About 80% of the total sediment load is fluvially transported from the basin in the months of March, April and May. In general, little sediment is being derived from the southern parth of the watershed. Apart from natural channel erosion along the South Nation River, most of the streams south of the mouth of the North Branch South Nation River are indicated as carrying no sediment. Most sediment is derived from sources in the northern part of the basin; little sediment is contributed above Crysler. The basins producing the most sediment are Bear Brook (including the North and South Indian Rivers) and the Castor River Basins, with Horse Creek, Caledonia Creek and Scotch River Basins being significant. Most of the sediment sources appear to be landslides and slumps along the rivers, creeks, and drains and sediment produced from drain construction and maintenance. High intensity summer storms may cause significant erosion, however, the mean monthly discharges during these periods is so low, that the quantity of sediment removed from the basins is probably very low.

Wickware and Associates (1989), "Water Quality and Land Use Relationships in the South Nation River Basin", prepared for Water Quality Branch, Inland Waters Directorate, Environment Canada.

Water Quality data for the SNR basin for the period of 1980-88, at 7 monitoring stations: 2 on Castor River; 2 on Scotch River; one each at Plantagenet, Casselman, and Chesterville. Water quality in the river and its tributaries is typically poor throughout the year with high phosphorus and bacteria concentrations frequently resulting in unpotable water. Runoff from agricultural cropland and livestock activities contribute phosphorus and bacteria that impair water quality. Fall discharges of effluent from municipal and industrial lagoons, as well as sanitary and storm sewage outfalls, also contribute to poor water quality in the main river and its tributaries. The highest concentrations of total P occur in the Scotch sub-basin. The Castor sub-basin also exhibits relatively high concentrations of phosphorus. Trend analysis suggests that TP concentrations have increased in all but the downstream basin of the South Nation River watershed throughout the 1980's. All TKN values are less than the Drinking Water quality Guideline. The highest concentration of turbidity was associated with the Scotch River sub-basin. An increasing trend in turbidity in all of the sub-basins is apparent throughout the 1980's, reflecting the increase in land drainage. Water quality issues such as high phosphorus and turbidity levels remain similar to those identified earlier in the decade. Trends for most parameters examined during the study indicate that water quality in the basin is not improving.

Zhu, Y., (1993), "Water Quality of the South Nation River, Rideau River and Mississippi River: A Statistical Survey", Master of Arts Thesis, Dept. of Geography, Carleton University.

The most prominent surface water problems in the river are excessive bacteria and high nutrient (phosphorus) concentrations. Concentrations of total phosphorus are considered high enough to contribute to excessive aquatic plant growth and nuisance conditions in basin streams. Bacterial contamination is evident throughout much of the basin. Concentration levels are often far in excess of Ontario provincial water quality objectives. These elevated levels have been attributed to the agricultural activities within the watershed. It was estimated that about 95% of phosphorus and nitrates entered the river system as a consequence of massive bank erosion, and from the leaching action of surface water runoff from fertilized fields and from livestock operations, and 5% comes from the industrial and municipal waste lagoons. Bacterial contamination is attributed to both human and animal sources. Past studies determined that the main source of bacteria was animal manure in the river, although the discharge of waste lagoons at low water times of the year also contributed to the problem. The sediment problem had been of concern, both with regard to aesthetics (turbidity) and phosphorus levels.

Trend analysis [of bacterial] showed that in the period of 1970s there was no significant trend except at Casselman and Chesterville in the South Nation River. Comparing the means in the 1970s and the means of recent data, no significant difference was detected by a T-test. Higher fecal coliform means for Casselman could be attributable to large amounts of inputs coming from the Castor River and the Payne River tributaries.

Decreasing trends were found for phosphorus levels, the decline was very slow and phosphorus concentrations were still higher than the guideline. With the present decreasing rate at this location, the phosphorus concentration will not be reduced to 0.03 mg/L until the year 2033. It is evident that controlling point sources only is not enough to reduce the phosphorus content to the objective because a large amount of the phosphorus comes from non-point sources. Only when effective remedial measures are taken to control non-point sources such as milkhouse washwater, fertilizers, soil erosions, etc. can we expect significant improvement of water quality in terms of phosphorus level.

For nitrates, during the period of 1984 to 1991, concentrations fluctuated from year to year but without any trends.

Distinctly higher BOD_5 means and medians were observed in the South Nation River, especially at Casselman. The high BOD_5 contents in the South Nation River are consistent with the overall high nutrient levels in the river. An upward trend of BOD values was found.

An increasing trend for turbidity in the South Nation River. The prevailing increasing trend of turbidity throughout the study period reflects in particular the increase in land drainage as well as a corresponding increase in the erosion problem. Ontario Drinking Water Objectives specifies the maximum acceptable limit is 1 Formazin turbidity unit (FTU), aesthetic objective is 5 NTU.

Additional Unpublished Studies:

Black Creek and Bear Brook were sampled from 1990 to 1994 through the Ontario Reference Network Program (Environment Canada). This is a good comparison between two streams with different landuse impacts. Water quality data, such as turbidity and total phosphorus, indicates that Bear Brook is impacted from agricultural and rural use, much more so than Black Creek which has much less landuse in general.

Water Quality Indicators

Canadian Council of Forest Ministers (1997), "Criteria and Indicators of Sustainable Forest Management in Canada, Technical Report".

When roads are constructed through areas with acidic soil, or when these areas are clearcut, the quality of water decreases in terms of both chemistry and turbidity. The decline is reflected in higher concentrations of dissolved nutrients and organic chemicals and decreased pH levels. These changes are usually small and short-lived. Harvesting of forests leads to an increase in nutrients and organic chemicals in stream water for a period of three to five years.

Stream flows can be impacted dramatically by control structures for hydro power generators, flood control measures, agricultural irrigation and human consumption levels. Increased stream flows can lead to erosion and stream sedimentation, which can in turn lead to reduced water quality and aquatic habitat for fish and other organisms.

Specific impacts from forest harvesting activities include increased water temperatures, eutrophication, siltation of river gravels, and reduced oxygen levels. A few species of aquatic fauna benefit from these changes, but most are negatively impacted. Invertebrate species that form the basis of aquatic food chains are also sensitive to the physical and chemical alterations in streams caused by sedimentation and changes in riparian vegetation. Many fish species have a high tolerance for disturbances and are not always the most sensitive indicators of habitat deterioration. Thus, the damage may be well advanced before symptoms are detected. Biological and chemical monitoring protocols need to be developed that would rely on key indicator organisms and elements, based on the findings obtained at existing research sites.

Firehock, K. (1994), "Save Our Streams, Volunteer Trainer's Handbook", The Izaak Walton League of America, MD, US.

Contains a Stream Insects and Crustacean Index which can be used for an indicator of water quality; Group One - pollution sensitive organisms found in good quality water; Group Two - somewhat pollution tolerant organisms can be good or fair quality water; Group Three - pollution tolerant organisms can be in any quality of water.

Ministry of Agriculture, Food and Rural Affairs (1996), "Agricultural Statistics for Ontario, 1995", Publication 20, prepared by Statistical Services Unit, Policy Analysis Branch.

Ministry of Agriculture, Food and Rural Affairs (1987), "Agricultural Statistics for Ontario, 1986".

Ministry of Agriculture, Food and Rural Affairs (1982), "Agricultural Statistics for Ontario, 1981".

Murdoch, T., Cheo M., and O'Laughlin, K. (1996), "Streamkeeper's Field Guide, Watershed Inventory and Stream Monitoring Methods", 5th Edition, The Adopt-a-Stream Foundation.

Contains a good chapter on "Presenting Your Data" (e.g. charts, diagrams) for different water quality parameters.

Sharpley, A.N. (1997), "Dispelling Common Myths about Phosphorus in Agriculture and the Environment", Technical Paper, Watershed Science Institute, US Dept. of Agriculture, Natural Resources Conservation Service.

A 1972 conference concluded that erosion control is of primary importance to minimizing P export. Livestock operations in the U.S. have increased dramatically producing more P than local crops require. Common myths about P include: ◇ Soils are infinite sinks for P - soils cannot indefinitely fix applied P and increasing amounts will be released to runoff. ◇ Erosion control will stop P losses in runoff - erosion control is not the sole answer to P loss concerns; reduction of P loss in runoff can only be achieved by integrating source and transport measures. ◇ Most BMPs are permanent solutions - the only permanent solution to reducing P losses in most cases is balancing P inputs and outputs. The potential for P loss in runoff and thereby, accelerated eutrophication increases as soil P accumulates. Continual long-term application of fertilizer or manure at levels exceeding crop needs, will increase soil P levels. Amounts of P in "average" dairy manure and poultry litter are considerably greater than is removed in harvested crops; the result is an accumulation of soil P. Conservation tillage can also increase the soil P content of surface soil, if P is broadcast (?) without soil profile inversion by plowing.

P associated with soil particles and organic matter eroded during flow events constitutes the major proportion of P transported from most cultivated land (60-90%). Amounts of P transported from watersheds are tied to watershed hydrology, in terms of when and where surface runoff occurs, soil P content, and amount of P added as fertilizer or manure. P is more susceptible to movement through sandy soils with low P sorption capacities; in waterlogged soils, and soils with preferential flow through macropores. Runoff production is usually generated only from limited source areas within a watershed. As surface runoff is the main mechanism by which P and sediment is exported from most watersheds, it is clear that if surface runoff does not occur, P export is negligible. Several studies have reported that the loss of dissolved P in runoff is dependent on the soil content of surface soil. While dissolved P is an important water quality parameter, it only represents the dissolved portion of runoff P readily available for aquatic plant growth. It does not represent fixed soil P that can become available. Efficient management of P amendment on soils susceptible to P loss involves the subsurface placement of fertilizer and manure, and the periodic plowing of no till soils to redistribute surface P accumulations throughout the root zone. Both practices may indirectly reduce the loss of P decreasing its' exposure to surface runoff and increasing crop uptake of P and yield. Phosphorus loss via erosion and runoff may be reduced by conservation tillage, buffer strips, riparian zones, terracing, contour tillage, cover crops and impoundments or small reservoirs. These strategies will be most effective if sensitive or source areas within a watershed are identified, rather than spreading implementation over the watershed. Future advisory programs should reinforce the fact that all fields do not contribute equally to P export from watersheds. Often most P export comes from a only a small portion of the watershed in relatively few storms.

South Nation River Conservation Authority (1993), "Vision 2020, The South Nation River Conservation Authority's Plan for the 21st Century, Conservation Strategy".

Strategies:

- To reduce the adverse affects of erosion and sediment on water quality
- To favour the use of natural measures over man-made structures in erosion control practices
- To encourage the enforcement of regulations for erosion and sediment control
- To encourage the responsibility of landowners for erosion control and shoreline management
- To reduce the pollution of the River resulting from human, industrial, and rural wastewater management practices
- To improve septic system regulation, installation and management
- To educate residents on the detrimental effects of wastewater on water quality and how they can reduce this impact through good wastewater management
- To improve water quality by encouraging agriculture to follow practices more beneficial to the environment
- To provide support for the implementation of these practices
- To protect water systems from the damaging effects of some drainage practices
- To offer educational information on agriculture's role in improved water quality

Terrell, C.R., Bytnar Perfetti, P. (1996), "Water Quality Indicators Guide Surface Waters", 2nd Edition, Terrene Institute, Washington, D.C., Kendall/Hunt Publishing Company, Iowa.

Contains Beck's Biotic Index for stream macro invertebrates; Class I Organisms (sensitive or intolerant), Class II (facultative); Class III (tolerant). Also has indicators for sediment (e.g. turbidity, bank stability, deposition); nutrients (e.g. aquatic vegetation, water color, fish diversity, behaviour and fish kill); and animal waste (e.g. micro-organisms, organic matter, and nutrients).

Articles Downloaded from Internet Sites:

Spooner, C. (date unknown), "Index of Watershed Indicators", provided by Environmental Protection Agency and Partners"; website: http://www.epa.gov/surf/iwi/intro.html

US Environmental Protection Agency (June 1996), "Environmental Indicators of Water Quality in the United States", EPA 841-R-96-002, Office of Water; website: http://www.epa.gov/OW/indic/

Contains a list of 18 Water Quality Indicators. Some of these include: Population served by community drinking water systems violating health-based requirements; Source water protection (involved with groundwater resource protection); Fish Consumption Advisories; Biological Integrity (fish, macroinvertebrates or plants, including algae); Surface Water Pollutants (dissolved oxygen, dissolved solids, nitrate, total phosphorus, fecal coliform, and suspended sediments); Habitat Assessment (quality of riparian corridor habitat, a stream is compared to a reference condition); Selected Point Source Loadings to Surface Water (sewage treatment plants, industrial facilities, and wet weather sources such as sewer overflows); Sources of Point Source Loadings through Class V Wells to Groundwater (septic systems, cesspools, industrial or commercial wastewater); Nonpoint Source Sediment Loadings from Cropland (cropland and livestock; urban runoff, storm sewers; runoff from roads, construction sites, mining and logging; drainage from waste disposal sites and landfills.

Warner, A., (1996), Developing an Applied System of Ecological Indicators for Measuring Restoration Progress in an Urban Watershed", Metropolitan Washington Council of Governments paper delivered at Watershed 1996; website: http://www.epa.gov/OWOW/watershed/Proceed/warner

Humans have been using ecological indicators for hundreds, if not thousands, of years: an aching joint can suggest rain is on the way, a dead canary means it is time to leave the mine, and a shadow-shy groundhog is a forecast for six more weeks of winter.

The loss of important forest and wetland habitat, alterations of streamflow, increases in nonpoint source pollution, and discharges of combined sewer overflow and industrial waste have all contributed to the decline in the ecological health of the watershed [Anacostia Watershed in Maryland).

The primary focus of the Anacostia indicators has been on direct assessment of the ecosystem; only indicators that are supported by existing data were used. First step involves <u>creating a comprehensive list of possible indicators</u> through a series of brainstorm sessions. Potential indicators included water quality parameters (e.g. temp, DO, total suspended solids, fecal coliform) pollutant loads, fish kills, toxic concentrations in fish tissue, bird counts, wetland acreage, volunteer monitoring, dollars spent on restoration projects. The next step involved <u>assessing data availability</u>, many of the indicators on the comprehensive list were eliminated because they were not supported by existing data. The final step relies heavily on professional judgement and discussion of which indicators, individually and together, will best represent the overall condition of the watershed.

Indicators can be used to track progress and educate general public and public officials. The basic purpose of presenting an environmental indicator is to communicate the condition of an important component of the ecosystem in a summarized form to a given audience. Not all indicators are supported by historical data; some have only one year of data, resulting in a presentation of status rather than a trend over time.

Recommended Levels for Water Quality

Parameter	**Recommended Level**
Turbidity	1 FTU (Drinking Water); 5 NTU (aesthetic)
Phosphorus	0.03 mg/L
Atrazine	2 μg/L
Metolachlor	8 μg/L
Dissolved Oxygen	7 mg/L at 0°C to 4 mg/L at 20°C
Nitrate-Nitrogen	10 mg/L
Biological Oxygen Demand	2 mg/L
Bacteria (E. coli)	< 100 counts per 100 mL

Periphyton biomass can be estimated by collecting 10 fist-sized rocks from transects across riffle sections of the river. The rocks are scraped with a wire brush to remove the attached algae. Any water is removed from the container and the algae are weighed. This is the wet weight of algae and any organic and inorganic material that came from the rocks. It will provide a crude estimate of biomass. A more accurate determination is made by determining the dry weight and the loss on ignition. These measurements are made by drying the material for 24 hours at 60 C. The dry weight is then measured. The dry material is then transferred to a muffle oven and heated at 450 C for 24 hours. The reside is non-organic matter and this weight can be subtracted from the dry weight to yield an estimate of the periphyton biomass. The most accurate measurements of biomass are made by determining chlorophyl a using standard laboratory methods.

Biomass is related to surface area of the rocks. The surface area of the rocks are calculated by wrapping each rock in the appropriate amount of aluminum foil. The pieces are then weighed and the surface area calculated by comparing to the weight of a piece of aluminum foil with a known area. If a balance is not available, the piece of aluminum foil can be flattened and the actual area measured.

APPENDIX C

SOUTH NATION
CONSERVATION
DE LA NATION SUD

March 4, 1998

RE: Request for Proposal to Complete a Review of SNC's Water Quality Monitoring Program

South Nation Conservation (SNC) is preparing a strategic monitoring plan for surface water quality monitoring initiatives. SNC has been involved in non-point source pollution incentive programs for five years through the Clean Water Program. SNC is concerned that the current water quality monitoring does not effectively show changes in watershed water quality. Many questions remain unanswered with the current monitoring program, such as: Is watershed water quality changing over time? Is the health of the watershed improving? Are the SNC non-point source programs effective at improving water quality?

SNC would like to complete a review of the current monitoring plan and re-focus activities for 1998 to meet the following objectives:

- document watershed health and water quality conditions;
- provide spatial and temporal trend analysis in the South Nation watershed;
- develop a plan to document the effectiveness of non-point source programs at reducing contaminant loadings to the watercourse;
- increase the effectiveness of the SNC water quality initiatives;
- optimize the SNC monitoring strategy and balance physical, chemical, biological and indicator monitoring in a cost effective manner.

Your firm is invited to provide a proposal to complete the review of SNC monitoring programs and develop recommendations for future monitoring activities of the SNC. The following information should be included in your quote:

- proposed activities to meet the above objectives;
- outline relevant qualifications and experience of staff to be assigned to the project.

The following tasks are targeted for completion through the Monitoring Program Review (listed in priority order). Additional tasks may be considered and worked into the proposal. SNC is committed to $10,000 to complete this review. Proposals should be based on this amount.

a) Review of current Provincial Water Quality Monitoring Network (PWQMN) and Watershed Characterization locations, frequency, and parameters to develop a minimum requirement for monitoring and recommended changes to the program, keeping MOE requirements in mind. An assessment of the program resource constraints versus needs should be made.

b) Evaluate the best use of volunteer resources available through the Riverwatch and Bugwatch Programs and recommend modifications to locations, parameters, and frequency of sampling to ensure quality data is collected.

15 rue Union Street, Berwick, Ontario K0C 1G0 • Tel.: (613) 984-2948 Fax: (613) 984-2872 • info@nation.on.ca

c) Develop criteria for the SNC bio-monitoring plan and consider various techniques for collection of this data. This will lead to the recommendation of the optimum bio-monitoring strategy for SNC, including station location, frequency, and methodology.
d) Use of simple techniques to demonstrate water quality improvements due to SNC projects will be considered for demonstration and public relations' purposes. Criteria will be developed with the input of SNC staff and optimum methods will be recommended.
e) Evaluate supporting programs to add to the effectiveness of water quality monitoring program i.e. rain gauge and stream gauge network.
f) All of the above methods will be integrated into an overall plan for water quality monitoring and reporting for the SNC watershed.
g) Recommendations will be made for the selection and calibration of an accurate indicator parameter for use as a low-cost means of estimating phosphorus levels in a water body.
h) Since phosphorus is a significant factor in determining the trophic status of a water body, a simple means of classifying the level of eutrophication will be recommended.

Proposals should be submitted to the attention of Leslie Vanclief, Water Quality Coordinator, prior to 4:00 p.m. on Thursday, March 12, 1998.

Sincerely,

Leslie Vanclief

Leslie Vanclief,
Water Quality Coordinator.

Enclosures: South Nation Conservation Water Quality Initiatives 1997
SNC Resume